Chapter# 11

Human Circulatory Systems

Humans have two primary systems for the transport of materials throughout the body:

1) **The blood circulatory system**
2) **the lymphatic system.**

The **closed blood circulatory system** consists of **blood**, the **heart**, and **blood vessels** (which include **arteries**, **capillaries**, and **veins**).

Recalling: Blood is the medium in which dissolved nutrients, gases, hormones, and wastes are transported throughout the body. It is composed of two main components (i) plasma and (ii) cells or cell-like bodies (white blood cells, red blood cells, platelets). In a healthy person, plasma constitutes about 55% by volume of the blood, and cells or cell-like bodies about 45% by volume of the blood.

11.1 - Structure and Functioning of the Heart

The human heart is a **hard-working pump** that circulates blood throughout the body.

Position of heart in body

It is located in the **middle of the chest cavity**, between the lungs. The **back surface** of the heart is near the **vertebral column**, while the **front surface** is behind the **sternum** and **rib cartilages**.

Structure of heart

Pericardium

The heart is enclosed in a protective sac known as the **pericardium** (see Figure 11.1). The pericardium serves to separate the heart from surrounding organs. It is made up of two layers:

The heart is usually felt to be on the left side because the left side of heart is stronger and larger, since it pumps to all body parts. Because the heart is between the lungs, the left lung is smaller than the right lung and has a cardiac notch in its border to accommodate the heart.

- **Outer Layer** **(Fibrous Pericardium):** This layer is composed of **strong connective tissue**, providing protection to the heart against external pressure and shocks. It also prevents excessive dilation of the heart.

- **Inner Layer** **(Serous Pericardium):** This sac is composed of two layers:

- **Outer Parietal Pericardium:** Positioned beneath the fibrous pericardium.
- **Inner Visceral Pericardium (Epicardium):** This layer is tightly attached to the underlying heart.

Pericardial cavity: The space between the parietal and visceral pericardium is called the **pericardial cavity**, which contains up to **50 mL of pericardial fluid**. This fluid acts as a lubricant and helps protect the heart from infections.

Wall of the Heart

The wall of the heart consists of **three layers**:

1. **Epicardium:** The outer lining of the heart wall, derived from the inner layer of the pericardium (serous pericardium).
2. **Myocardium:** The thickest layer, located beneath the epicardium. It is made up of **cardiac muscle** tissue and is responsible for the contraction of the heart.
3. **Endocardium:** This layer lies beneath the myocardium and is composed of a single layer of **epithelial cells**, which form the inner lining of the heart chambers.

Chambers and Valves of the Heart

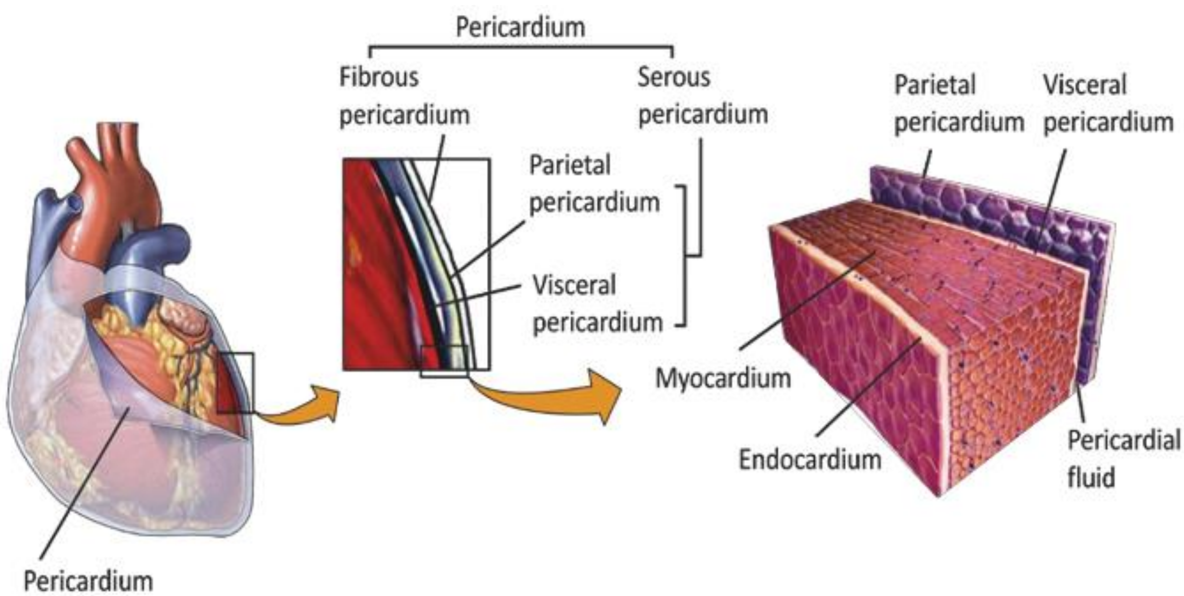

Figure 11.1: Pericardium and heart wall

The heart contains **four chambers**:

- **Two upper chambers**: **Atria** (thin-walled)
- **Two lower chambers**: **Ventricles** (thick-walled)

The **atria** receive blood from the body and pass it into the ventricles, which then distribute the blood throughout the body.

Septa (Separation of Chambers)

- The **atria** and **ventricles** are separated by the **atrioventricular septum**.
- The **left** and **right atria** are separated by the **interatrial septum**.
- The **left** and **right ventricles** are separated by the **interventricular septum**, which is much thicker than the interatrial septum.

Atrioventricular and Semilunar Valves

At the entrances to the ventricles (in the atrioventricular septum), there are two **atrioventricular valves**:

- **Tricuspid Valve:** This valve, made of **three cusps**, is located between the **right atrium** and **right ventricle**.
- **Bicuspid (Mitral) Valve:** This valve, made of **two cusps**, is found between the **left atrium** and **left ventricle**.

Function: These valves prevent the backflow of blood when the ventricles contract.

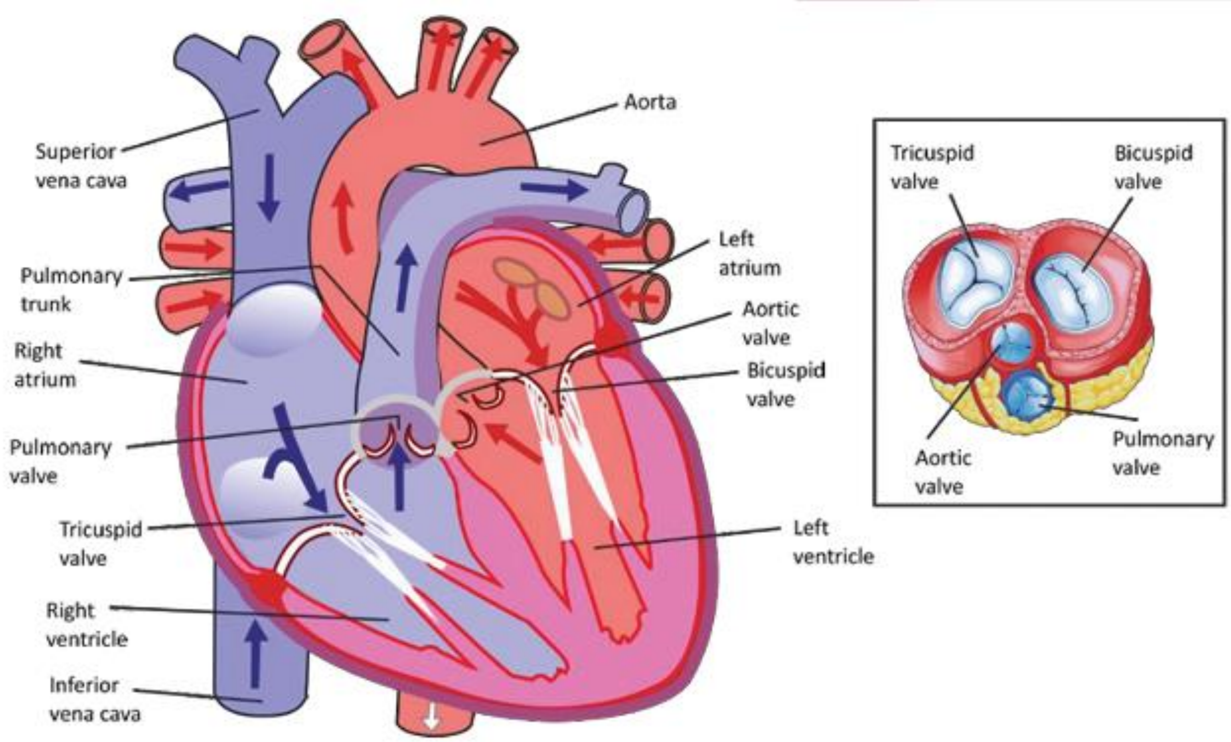

Figure 11.2: Human Heart and valves

At the exit points of the ventricles, there are two **semilunar valves** (shaped like half-moons):

- **<u>Pulmonary Valve</u>**: Located at the base of the **pulmonary artery**.
- **<u>Aortic Valve</u>**: Found at the base of the **aorta**.

<u>Function:</u> When the ventricles relax, both the pulmonary and aortic valves close, preventing the backflow of blood from the pulmonary artery and aorta into the ventricles.

Advantage of the heart structure

This structure and functioning of the heart is essential for maintaining **efficient blood circulation** throughout the body, ensuring that oxygen and nutrients are delivered to tissues and waste products are removed.

Lesson 2

Circulation of Blood through the Heart

Overview of Heart's Function

The **human heart** functions as a **double pump**. It is responsible for two main circulations:

1. **Pulmonary circulation** - the supply of blood to the **lungs**.
2. **Systemic circulation** - the supply of blood to all organs of the body, except the lungs.

Complete separation of **deoxygenated** blood (on the right side) and **oxygenated** blood (on the left side) is maintained within the heart.

Right Side of the Heart (Deoxygenated Blood Flow)

- **Right Atrium** receives **deoxygenated blood** from the body via the **superior vena cava** and **inferior vena cava**.
- The **right atrium** passes this blood to the **right ventricle** via the **tricuspid valve**.
- When the **right ventricle** contracts, deoxygenated blood is passed to the **pulmonary trunk** via the **semilunar pulmonary valve**.
- The pulmonary trunk divides into the **left and right pulmonary arteries**, which carry the blood to the **lungs** for oxygenation.

Left Side of the Heart (Oxygenated Blood Flow)

- The **oxygenated blood** from the lungs is brought to the **left atrium** by the **pulmonary veins**.
- The **left atrium** passes this blood to the **left ventricle** via the **bicuspid (mitral) valve**.
- When the **left ventricle** contracts, oxygenated blood is passed to the **aorta** via the **semilunar aortic valve**.
- The **aorta** carries this blood to all parts of the body (except the lungs).

Function of heart (physiology)

Cardiac Cycle: The Heartbeat

Phases of the Cardiac Cycle

The heart works in continuous cycles, with alternating **relaxation** and **contraction** of its chambers. These cycles are collectively known as the **cardiac cycle**, or one **heartbeat**.

1. **Diastole (Relaxation)**
   - During **diastole**, both **atria** and **ventricles** are relaxed, allowing blood to flow in and fill them.
2. **Atrial Systole (Atria Contraction)**
   - As blood accumulates in the **atria**, their **blood pressure** rises, and they contract. This is called **atrial systole**.
   - Blood is pushed through the **tricuspid** and **bicuspid valves** into the relaxed **ventricles**.
3. **Ventricular Systole (Ventricles Contraction)**
   - When the **ventricles** contract (**ventricular systole**), blood is pumped into the **pulmonary arteries** and **aorta**.
   - During this phase, the **tricuspid** and **bicuspid valves** close, while the **pulmonary** and **aortic valves** open.

Duration of the Cardiac Cycle

- **Diastole** lasts about **0.4 seconds**.
- **Atrial systole** takes about **0.1 seconds**.

- **<u>Ventricular systole</u>** lasts about **0.3 seconds**.

In a human lifetime, the heart beats approximately **2.5 billion times** without stopping.

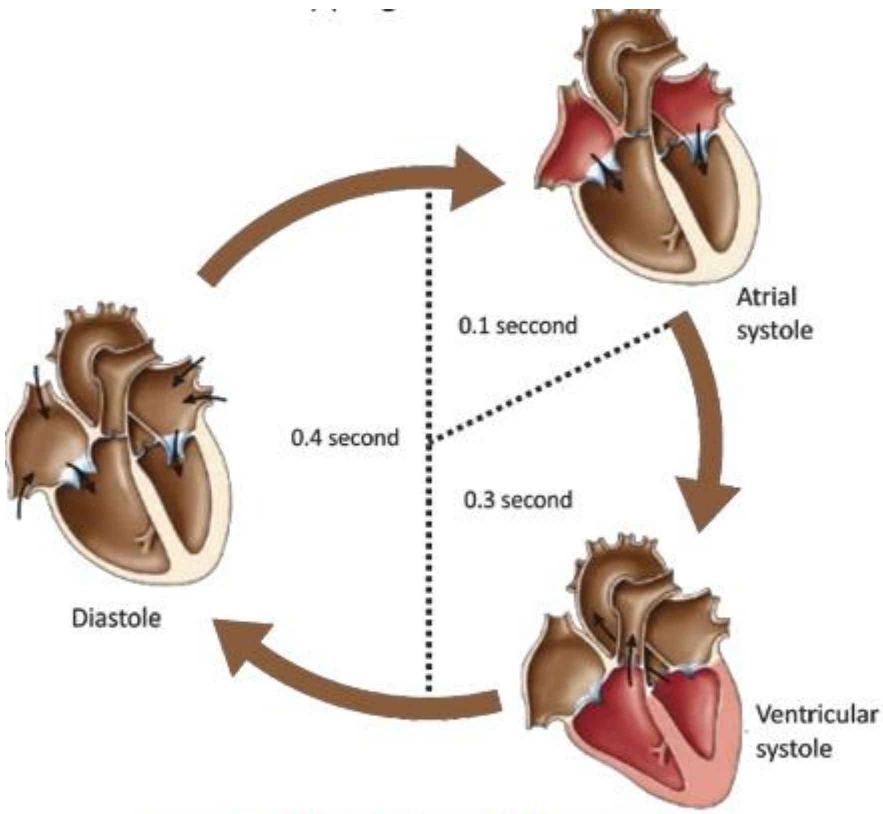

Figure 11.3: Cardiac cycle (one heartbeat)

Sounds of a Heartbeat

The sounds of a heartbeat are produced by the closing of the **heart valves** during the cardiac cycle.

- **"<u>Lubb" Sound</u>**: Produced when both ventricles contract and the **tricuspid** and **bicuspid valves** close.
- **"<u>Dubb" Sound</u>**: Produced when the ventricles relax and the **pulmonary** and **aortic semilunar valves** close.

Most cases of heart murmurs are not serious, and those that prove serious can be corrected by replacing the damaged valves with artificial ones or with valves taken from an organ donor.

These sounds, commonly referred to as **"Lub-dub"**, can be heard with the help of a **stethoscope**.

Heart Murmurs

- If the valves do not close fully or open narrowly, **turbulence** is created within the heart, which can be heard as a **heart murmur**.
- A murmur typically sounds like a **hiss**.

Control of Heartbeat: Heart Excitation and Contraction

Initiation of Heartbeat

The pumping action of the heart is initiated by the **Sinoatrial Node (SA node)**, also known as the **pacemaker**. The SA node is a small cluster of cardiac muscle cells embedded in the upper wall of the **right atrium**.

- The SA node sends **electrical impulses** to the walls of the **atria**, causing both **atria** to contract simultaneously.

Transmission of Impulses

- The impulses from the SA node travel to the **Atrioventricular Node (AV node)**, which is a cluster of cardiac muscle cells located at the lower portion of the **interatrial septum**.
- From the AV node, the impulses travel to the **Atrioventricular Bundle (Bundle of His)**, a network of fibers present in the **interventricular septum**.
- The AV bundle divides into the **left and right branches**, which end at the **Purkinje fibers** in the walls of the **ventricles**.
- The stimulation of these fibers causes the **ventricles** to contract almost simultaneously.

Delay for Proper Timing

There is a delay of about **0.15 seconds** in the conduction of impulses from the **SA node** to the **AV node**. This delay allows **atrial systole** to be completed before **ventricular systole** begins.

Artificial Pacemakers

If there is a blockage in the flow of electrical impulses or if the impulses from the **SA node** are weak, it can disrupt the rhythmicity of the heartbeat or even stop it completely.

- In such cases, an **artificial pacemaker** may be used. This is a **battery-operated** device that is surgically implanted near the **AV node**.
- The pacemaker emits **electrical signals** to trigger normal heartbeats.

This organization of the material with headings and subheadings should make it easier to read, study, and memorize the content. The main wording has been kept intact, but the systematic flow and structured layout will enhance understanding and retention.

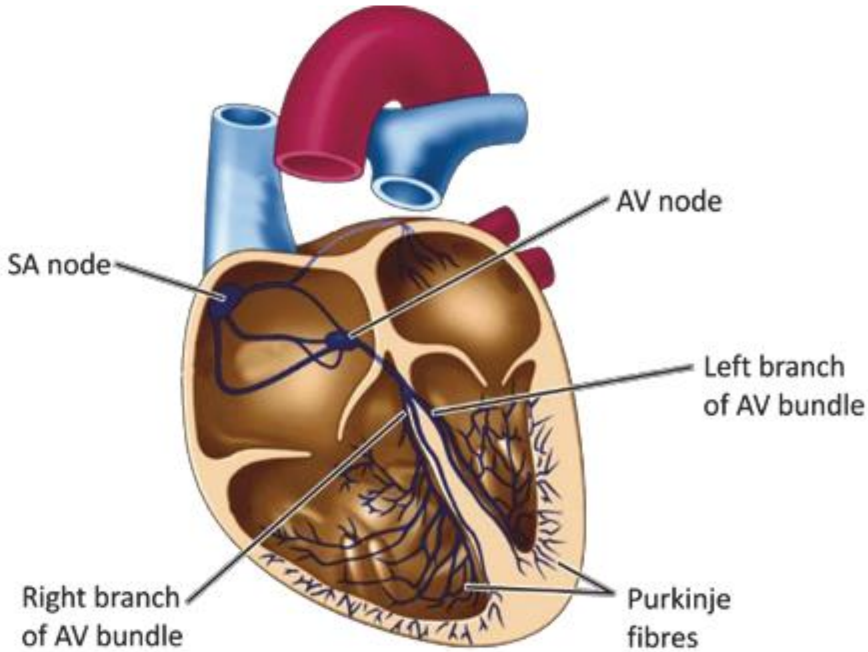

Figure 11.4: Pacemaker and its connections

Lesson 3

Rate of Heartbeat

The **heart** of an average adult beats about **70 times per minute**. It pumps the entire blood volume (about **5 litres**) every minute. The normal speed of the heartbeat is controlled and maintained by the **pacemaker** and **AV node**.

In an adult, about 8,000 litres of blood move through 96,000 km of blood vessels every day.

Influence of the Brain on Heart Rate

The **brain** also exerts some influence on the heart rate. For instance:

- During **fever** or **exercise**, the brain's control center sends nerve signals to both the **pacemaker** and **AV node**, causing them to increase the heart rate. This is to cope with the situation.
- Conversely, when we are **asleep** or at **rest**, the brain's control center slows down the activity of the **pacemaker** and **AV node**.

Electrocardiogram (ECG)

An **electrocardiogram (ECG)** is the recording of electrical potentials generated by the currents of cardiac impulses.

Generation of Electrical Currents in the Heart

When the cardiac impulse passes over the surface of the heart, a **minute electrical current** is generated. This current spreads into the tissues surrounding the heart and travels to the surface of the body.

In an ECG, these electrical potentials are measured and recorded by **electrodes** placed on the skin on the opposite sides of the heart. The electrodes are attached to a machine called an **electrocardiograph**, which records the electrical potentials.

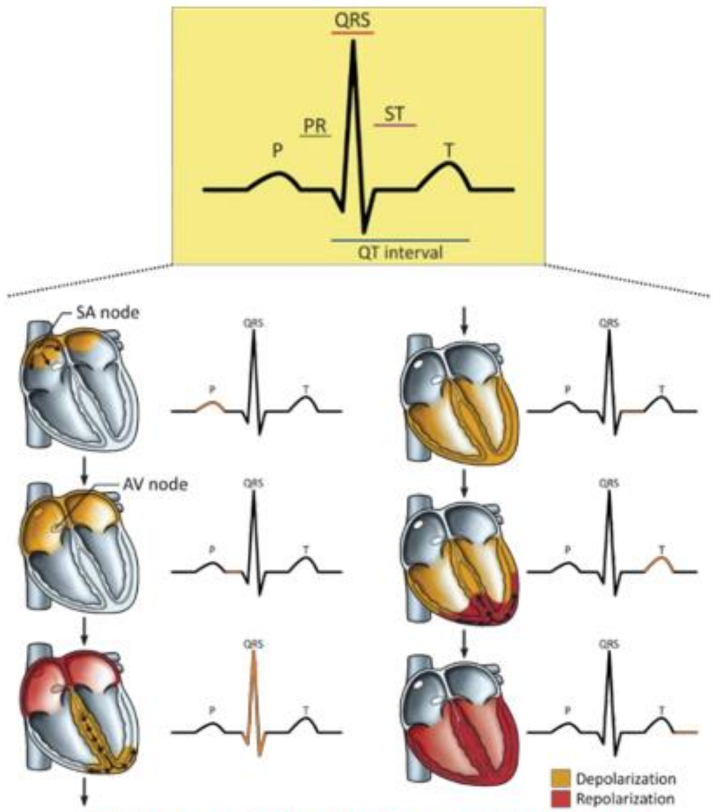

Figure 11.5: ECG reading of a single heartbeat

Purpose of ECG

The **ECG** is used to diagnose abnormalities in the conduction system of the heart.

ECG Waves and Their Significance

An ECG shows several **waves** that correspond to specific events in the **cardiac cycle**:

1. P Wave

- The **P wave** represents the beginning of **atrial depolarization**, initiated by the **SA node**.
- This causes **atrial contraction**.
- **Irregular** or **absent P waves** may indicate **arrhythmia** (lack of rhythmicity).

2. PR Segment

- The **PR segment** shows the completion of **atrial depolarization**.
- It typically lasts between **0.12 to 0.20 seconds**.

- A **prolonged PR segment** indicates a **first-degree heart block**.

3. QRS Complex

- The **QRS complex** shows the beginning of **ventricular depolarization**.
- During this phase, **atrial repolarization** also occurs.
- Abnormalities in the **QRS complex** may indicate conditions such as **bundle branch block**, **ventricular tachycardia**, or other **ventricular abnormalities**.

4. ST Segment

- The **ST segment** shows the completion of **ventricular depolarization**.
- It may be **depressed** in cases of **ischemia** (decreased blood and oxygen flow to the heart) and **elevated** in cases of **myocardial infarction**.
- This segment usually lasts about **0.08 seconds**.

5. T Wave

- The **T wave** represents the beginning of **ventricular repolarization**.
- Abnormalities in the **T wave** may indicate **electrolyte disturbances**.
- The **hyper-acute T wave** is an early indicator of **acute myocardial infarction**.

6. QT Interval

- The **QT interval** spans from the beginning of the **QRS complex** to the end of the **T wave**.
- A normal **QT interval** is about **0.40 seconds**.

11.2 - Blood Vessels

The **human circulatory system** consists of three main types of blood vessels: **arteries**, **veins**, and **capillaries**. These vessels work together to transport blood throughout the body, ensuring the delivery of oxygen and nutrients to tissues and the removal of waste products.

1. Arteries

Arteries are the blood vessels that carry **blood away from the heart** to different parts of the body. **All arteries** carry **oxygenated blood**, except for the **pulmonary arteries**.

Structure of Arteries

- The central core of an artery is known as the **lumen**.
- The walls of arteries are made up of three layers:
  - **Outer Layer (Tunica Externa or Adventitia)**: This is made of **connective** and **elastic tissue**.
  - **Middle Layer (Tunica Media)**: Composed of **thick muscular tissue** and **elastic fibers**, this layer can withstand the higher **blood pressure** during **ventricular systole**.
  - **Inner Layer (Tunica Intima)**: Made up of a **thin layer of endothelial cells**.

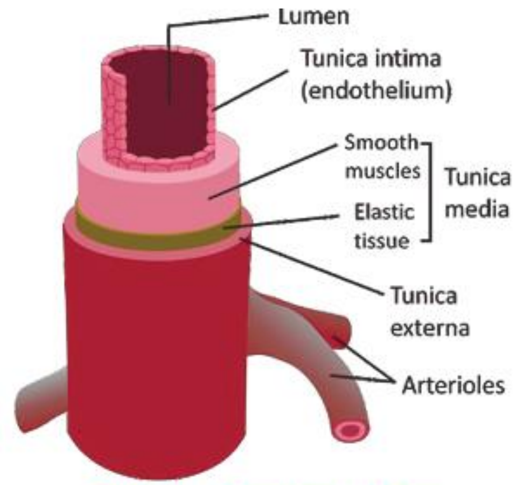

Figure 11.6: Structure of artery

Arterioles

- Arteries divide into smaller vessels called **arterioles**.
- Arterioles then divide repeatedly, forming a **dense network of fine branches**, which are the **capillaries**.

2. Capillaries

Capillaries are formed by the division of **arterioles**. These tiny vessels join together to form **venules**.

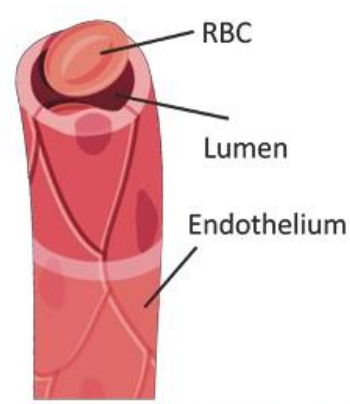

Figure 11.7: Structure of capillary

Structure and Function of Capillaries

- Capillaries penetrate all tissues and reach the **cellular level**, allowing for the exchange of materials between the blood and body tissues.

- The walls of capillaries are made up of a **single layer of endothelial cells**.
- The **internal diameter** of a capillary is about **8 micrometers**.

Exchange of Materials

- **Diffusion** and **active transport** are the primary mechanisms for the exchange of materials across capillary walls.
- **Water** and **diffusible substances** can pass through the capillary walls.
- Materials can move either through the **endothelial cells** or through the **intercellular spaces** of the capillary walls.
- Some materials are taken up by the capillary wall cells through **endocytosis**, and these materials are then transferred to the other side by **exocytosis**.

No cell of the body is more than 100 micrometres away from a capillary. Capillaries are so narrow that RBCs must pass through them in single line. It is estimated that the total length of capillaries in an adult human is over 80, 600 kilometres, enough to encircle the globe twice!

Interstitial Fluid

- The pressure within capillaries causes a **continuous leakage of fluid** from the blood plasma into the surrounding tissues.
- This fluid, called **interstitial fluid**, consists of water, dissolved **nutrients**, **hormones**, **gases**, **wastes**, and **small proteins**.
- **Large proteins**, **RBCs**, and **platelets** remain within capillaries, but some **WBCs** can squeeze out through the **intercellular spaces** of the capillary wall.

3. Veins

Veins are blood vessels that carry **blood towards the heart**. **All veins** carry **deoxygenated blood**, except for the **pulmonary veins**.

Structure of Veins

- The walls of veins also consist of the same three layers as arteries:
  - **Outer Layer (Tunica Externa or Adventitia)**: Made of **connective** and **elastic tissue**.
  - **Middle Layer (Tunica Media)**: This layer is relatively **thin** and contains only a few **muscular** and **elastic fibers**.

- **Inner Layer (Tunica Intima)**: Made up of a **thin layer of endothelial cells**.

Comparison to Arteries

- The middle layer of veins is **thinner** than that of arteries because veins do not need to withstand high blood pressure.
- An **empty artery** remains a hollow tube, whereas an **empty vein** collapses like an **empty balloon**.

Semilunar Valves

- Veins contain **semilunar valves** to prevent the **backflow of blood**, ensuring it moves towards the heart.
- The **pressure** generated by the **contraction of surrounding muscles** helps press veins and assists in the return of blood towards the heart.

Formation of Larger Veins

- Smaller veins join together to form larger veins, which eventually merge to form the **vena cavae** (superior and inferior vena cavae).
- The vena cavae empty blood into the **right atrium** of the heart.
- The **pulmonary veins** from the lungs empty into the **left atrium**.

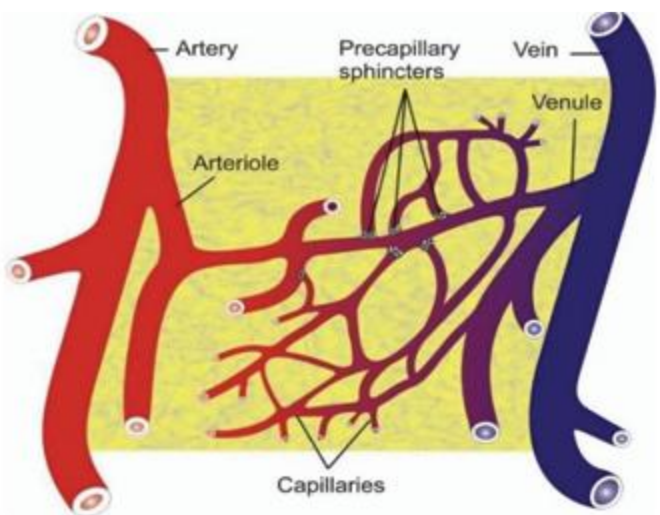

Figure 11.9: Relationship of arterioles, capillaries & venules

Lesson 4

Regulation of Blood Flow

Regulation of Blood Flow in Capillaries

The **amount of blood flowing in capillaries** is regulated by constricting or dilating the capillaries. **Nervous stimulation** can constrict the capillaries, while chemicals like **histamine** can cause dilation. Some capillaries are connected to **arterioles** and **venules** through loops of other capillaries. The entry to each loop is controlled by a ring of muscles called the **pre-capillary sphincter**, which regulates the blood flow through capillaries.

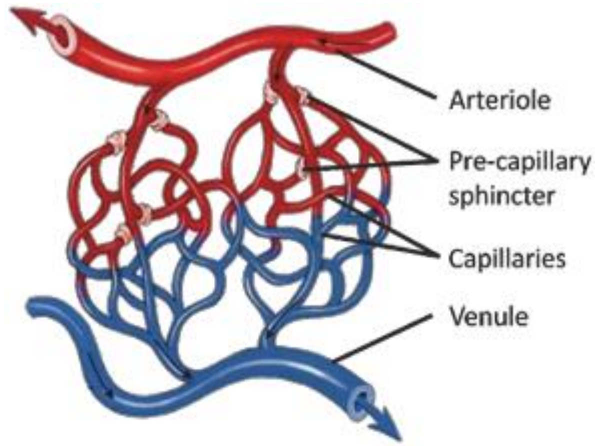

Figure 11.10: Pre-capillary sphincters

Vasoconstriction and Vasodilation in Arterioles

The walls of **arterioles** contain more **circular muscles** than **elastic tissue**. These muscles are under the control of the **nervous** and **endocrine systems**. When these muscles contract, **vasoconstriction** occurs, which reduces blood flow. When the muscles relax, **vasodilation** occurs, increasing blood flow.

Vasoconstriction: Reduced Blood Flow

Vasoconstriction is the process of contraction of arteriolar muscles, which reduces the blood flow through the arterioles. This occurs in response to various factors, including reduced metabolic activity in tissues.

Vasodilation: Increased Blood Flow

Vasodilation happens when the arteriolar muscles relax, which increases blood flow to tissues. This process is commonly triggered by **increased metabolic activity**, leading to decreased oxygen levels and increased carbon dioxide levels in tissues.

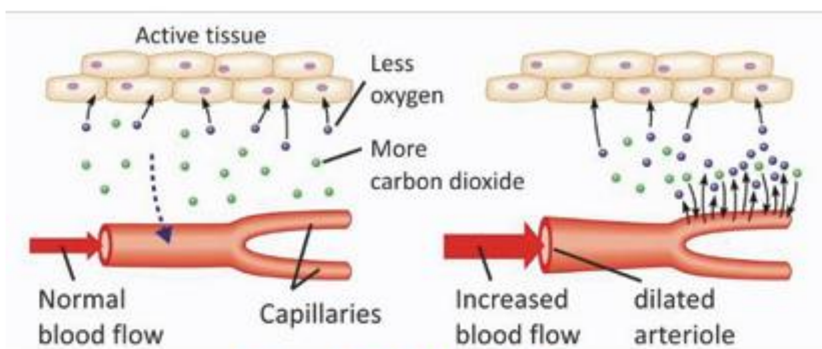

Figure 11.11: Vasodilation

The Role of Blood Flow Regulation in Metabolic Activity

Changes in **metabolic activity** directly influence blood flow. When metabolic activity in tissues rises, oxygen levels decrease, and carbon dioxide increases in the **interstitial**

fluid. This signals the relaxation of the circular muscles in arterioles, leading to **vasodilation** and increased blood flow to meet the oxygen demand. Conversely, when metabolic activity decreases, **vasoconstriction** takes place.

Velocity of Blood Flow

The **velocity of blood flow** varies throughout the circulatory system, being highest in the **aorta** (450-500 mm/sec) and lowest in **capillaries** (0.1 mm/sec). Blood flow velocity increases again in **venules**, **veins**, and **vena cavae** (250-300 mm/sec). These variations are caused by changes in the **total cross-sectional area** of the vessel system.

High Velocity in the Aorta

In the **aorta**, the blood flows at a velocity of 450-500 mm/sec, which is the highest in the circulatory system.

Low Velocity in Capillaries

The velocity drops significantly in the **capillaries** to about 0.1 mm/sec, as the total cross-sectional area increases. This allows for efficient exchange of gases and nutrients.

Return to Higher Velocity in Venules and Veins

Blood flow velocity increases in **venules**, **veins**, and the **vena cavae**, where the total cross-sectional area decreases again.

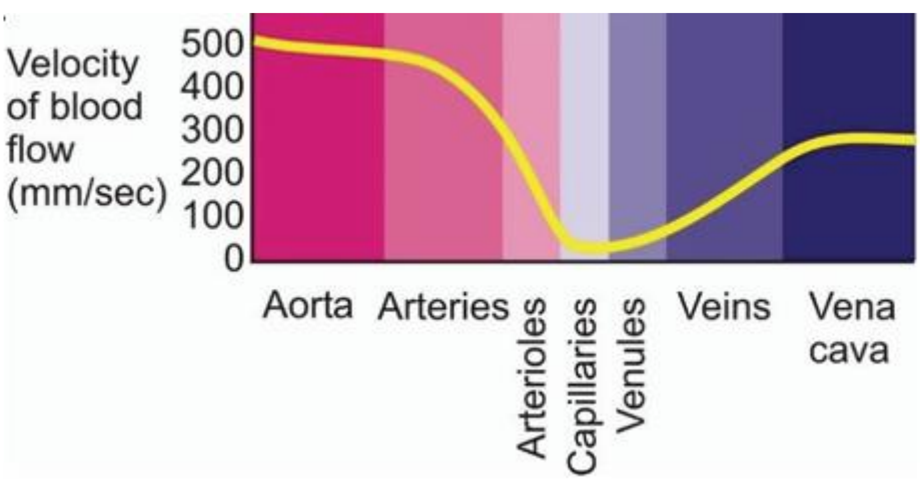

Figure 11.12: Velocity of blood, moving in different vessels

Circulatory Pathways in Humans

In humans (and other mammals and birds), blood circulates in two main pathways: **pulmonary circulation** and **systemic circulation**.

1) Pulmonary Circulation: To and From the Lungs

The **pulmonary circulation** is responsible for supplying **deoxygenated blood** to the lungs and returning **oxygenated blood** to the heart.

- **Pulmonary trunk** carries deoxygenated blood from the **right ventricle**.
- The trunk splits into the **right** and **left pulmonary arteries**, carrying blood to the lungs.
- Inside the lungs, the arteries divide into **pulmonary arterioles** and **lung capillaries**, where blood is oxygenated.
- Oxygenated blood returns through **pulmonary venules**, eventually forming **pulmonary veins**, which open into the **left atrium**.

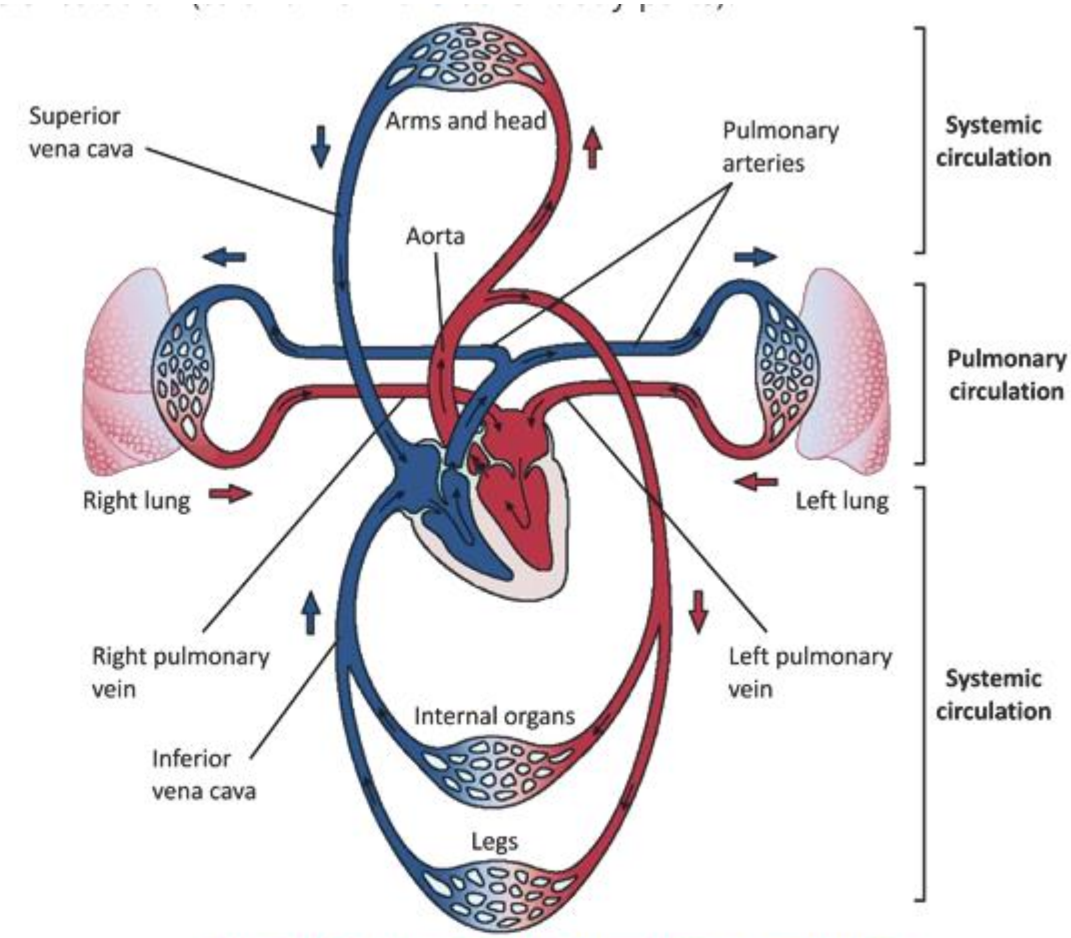

Figure 11.13: Pulmonary and systemic circulations

2) Systemic Circulation: To and From the Body

The **systemic circulation** delivers oxygenated blood to all body tissues and returns deoxygenated blood to the heart. It consists of several components.

Coronary Circulation: Blood Flow to the Heart

The **coronary circulation** supplies blood to the heart muscle. It begins with the **right** and **left coronary arteries** that arise from the aorta.

- These arteries branch into smaller arteries, **arterioles**, and **capillaries**.
- After supplying oxygen to the heart muscle, the capillaries merge into **venules**, which form **coronary veins**.
- These veins join to form the **coronary sinus**, which drains into the **right atrium**.

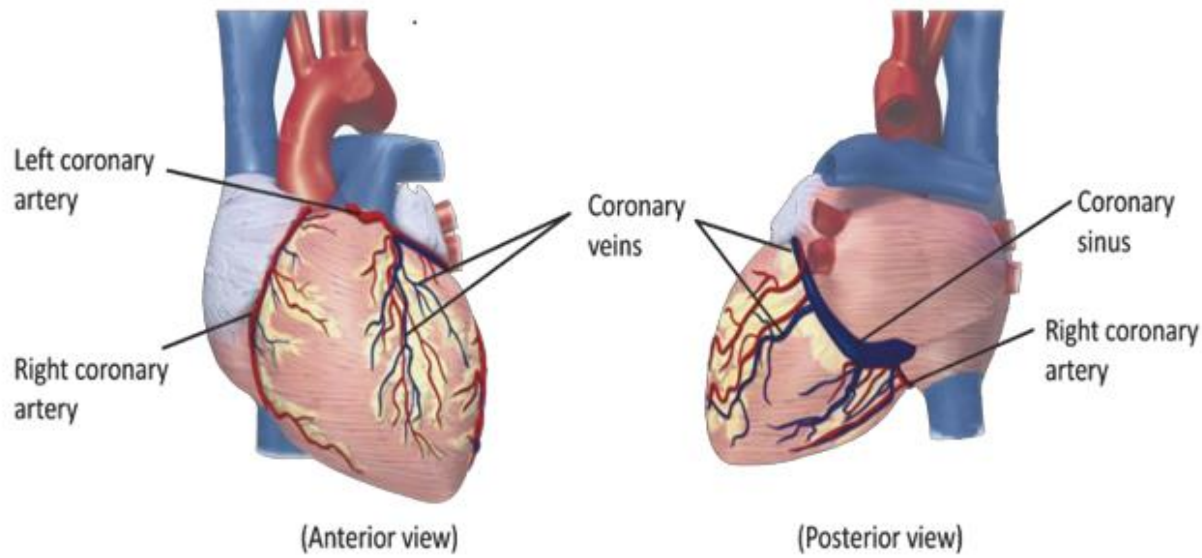

Figure 11.14: Coronary circulation

Hepatic Portal Circulation: Blood Flow to the Liver

The **hepatic portal system** is a specialized circulatory pathway where veins end in capillaries.

- The **hepatic portal vein** collects blood from the **spleen** and **alimentary canal** and transports it to the liver.
- The liver processes the absorbed substances, removing harmful substances and storing nutrients before sending the blood to the heart.
- Blood from the liver is returned to the heart through **hepatic veins**.

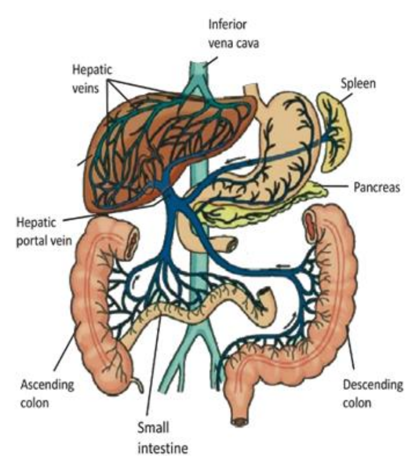

Figure 11.15: Hepatic portal system

This portal system extends from the **lower esophagus** to the **upper anal canal**.

Renal Circulation: **Blood Flow to the Kidneys**

Renal circulation provides blood to the kidneys for filtration.

- **Renal arteries** carry oxygenated blood to the kidneys.
- The arteries divide into smaller branches, eventually forming **afferent arterioles** that supply blood to the **nephrons**.
- The capillaries of the **glomeruli** merge to form the **efferent arteriole**, which divides into two sets of capillaries:
    1. **Peri-tubular capillaries** (around nephron tubules in the kidney cortex).
    2. **Vasa recta** (around nephron tubules in the kidney medulla).
- These capillaries unite to form **venules**, which converge into larger veins, eventually forming the **renal vein** that returns blood to the heart.

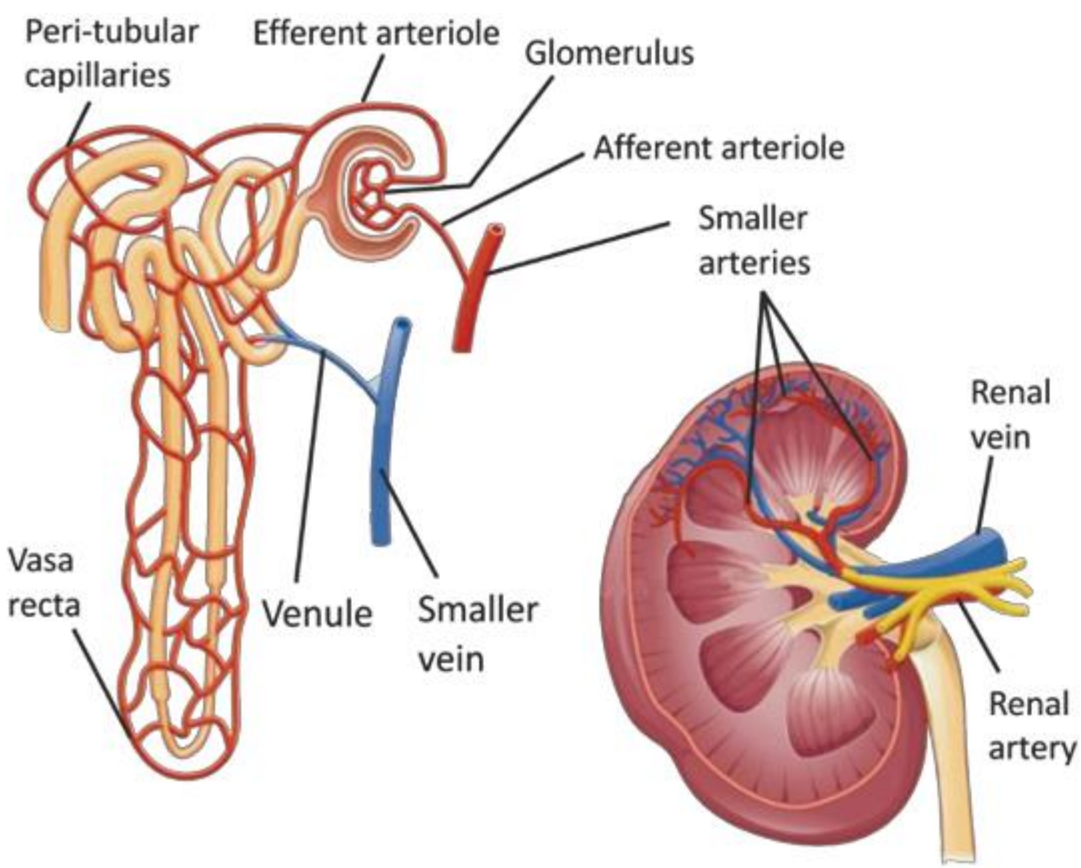

Figure 11.16: Renal portal system

Lesson 5

11.3 - BLOOD PRESSURE

Definition of Blood Pressure

Blood pressure is the **measure of force** exerted by **blood against the inner walls of blood vessels**. This **force keeps blood flowing** from heart to the entire capillary network in the body. Although such a pressure occurs throughout the vascular system, the term **blood pressure** most commonly refers to **systemic arterial blood pressure**.

Blood Pressure in Different Vessels

Blood pressure is **highest in the aorta** and then **gradually reduces** in systemic arteries. The **walls of arteries are elastic**. The flow of blood creates **rhythmical throbbing of arteries**, which is called **pulse**.

Changes in Blood Pressure During Cardiac Cycle

Arterial blood pressure rises and falls corresponding to the **phases of cardiac cycle**.

Systolic Pressure

When **ventricles contract** (*ventricular systole*), the heart forces blood into **pulmonary arteries and aorta**. As a result, the **pressure in these arteries rises sharply**. The **maximum pressure** during **ventricular systole** is called **systolic pressure**. **Systolic pressure** in a **normal young adult** is **120 mm Hg**.

Diastolic Pressure

When **ventricles relax** (*diastole*), the **arterial pressure drops**. The **lowest pressure** that remains in arteries before the next ventricular contraction is called **diastolic pressure**. **Diastolic pressure** in a **normal young adult** is **75-85 mm Hg**.

Conventionally, the **readings of blood pressure** are expressed as **120/80**. The instrument **sphygmomanometer** is used for the **manual measurement of systolic and diastolic blood pressures**. In this instrument, **rise and fall in mercury column** shows the **readings of blood pressure**.

Regulation of Blood Pressure

Role of Baroreceptors

Pressure receptors, known as **baroreceptors**, are present in:

- **Carotid arteries** (arteries that supply blood to the head region and brain)

- **Aortic arch** (portion of artery that bends between the ascending and descending aorta)

When **blood pressure falls**, baroreceptors **activate sensory neurons** that **send information to brain**.

The **control centre in brain** reacts by:

- **Increasing the rate and force of contraction of heart**
- **Causing vasoconstriction in arterioles**

Both these changes **restore blood pressure to normal**.

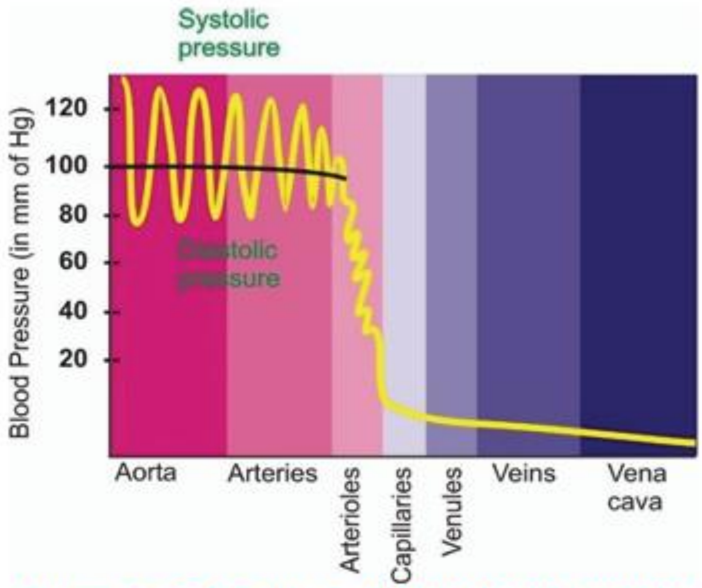

Figure 11.17: Systolic & diastolic blood pressures

Role of Hormones in Long-Term Regulation

The long-term regulation of blood pressure is done through **hormones**. Certain hormones **regulate the volume of blood** by affecting the **reabsorption of water and salt in kidneys**.

Role of ADH (Antidiuretic Hormone)

When there is a **decrease in blood volume and blood pressure**, special receptors in the **brain create thirst**. They also **stimulate posterior pituitary gland** to secrete **antidiuretic hormone (ADH)**.

- **ADH stimulates kidneys** to **retain more water in blood**, excreting **less in urine**.
- It **restores the blood volume** and **ultimately blood pressure**.
- **ADH also constricts arterioles**, which **raises arterial blood pressure**.

Role of ANH (Atrial Natriuretic Hormone)

The **walls of right atrium** contain **endocrine cells** that secrete **atrial natriuretic hormone (ANH)**. When there is **stretching of the atrium** by an **increased blood volume**, the **right atrium secretes ANH**.

- It **speeds up the excretion of salts and water through urine**, which **lowers the blood volume and pressure**.

11.4 - CARDIOVASCULAR DISORDERS

Introduction

Cardiovascular disorders are the **leading cause of death** in developed and developing countries. These involve the **disorders of blood vessels and heart**. **Atherosclerosis** and **arteriosclerosis** are the **major contributors** to cardiovascular disorders.

Atherosclerosis

Definition

Atherosclerosis means **"deposition within arteries"**.

Contributing Materials

Various materials may **accumulate in arteries**, e.g.:

- **Fatty materials**
- **Abnormal amounts of smooth muscle cells**
- **Cholesterol**
- **Fibrin**
- **Cellular debris of various kinds**

All these build-ups **impair the proper functioning of arteries**.

Role of Cholesterol

The **accumulation of cholesterol** is thought to be the **prime contributor to atherosclerosis**.

Effects

Atherosclerosis can lead to heart attacks, because it:

- **Causes narrowing of arteries**
- **Increases the risk of the formation of thrombus**

Arteriosclerosis

Definition

Arteriosclerosis means **"hardening of arterial walls"**.

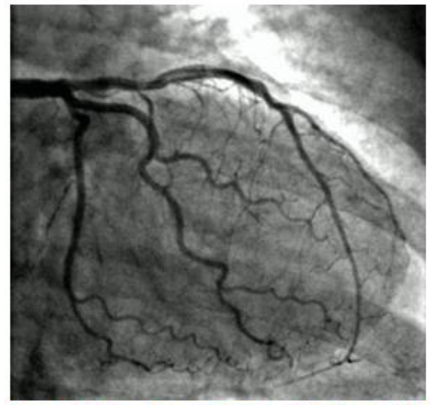

Figure 11.18: An angiogram, showing blood flow in coronary arteries

Causes and Effects

It occurs when **calcium is deposited in arterial walls**.

- The **blood flow through these arteries is restricted**.
- The **arteries cannot expand normally**.
- This forces the **heart to work harder**.
- **Severe atherosclerosis usually leads to arteriosclerosis**.

Diagnostic Tests

Purpose

Various **diagnostic tests** are performed on **cardiovascular patients** to:

- **Locate the exact problem**
- **Measure the severity of disease**

Important Tests

The **important tests** are:

- **ECG**
- **Angiography**

You have learnt about the **readings of ECG**, and here you would go through the **basic learning of angiography**.

Angiography

Definition and Purpose

Coronary angiography is an **X-ray examination** of blood vessels or chambers of the heart.

Procedure

In order to create the X-ray pictures, a physician guides a small **tube-like device called catheter** through the large arteries of the body. When the tip of **catheter** reaches the opening of **coronary arteries**, a **special fluid** (called a **contrast medium** or **dye**) is injected into the catheter. This fluid is **visible in X-ray machine**.

Observation of Coronary Arteries

Pictures (angiograms) of fluid in the **coronary artery** are obtained. If **clots are present** in the lumen of a coronary artery, the **artery appears narrow**.

Use of Diagnostic and Guiding Catheters

By changing the **diagnostic catheter** to a **guiding catheter**, physicians can also pass an **instrument into coronary artery** through the catheter.

The most commonly used instruments are:

- **Guide wires**
- **Balloon dilation catheters** (see angioplasty)

Lesson 6

Thrombosis

Definition

Thrombosis is the **formation of thrombus**. A **thrombus** is a **solid mass or plug of blood constituents (clot)** in a **blood vessel**.

Blockage by Thrombus

This **mass may block** (wholly or only in part) the **vessel**.

Causes of Thrombus Formation

Thrombus formation may be due to:

1. **Irritation or infection** of the **lining of blood vessels**
2. **Reduced rate of blood flow**, due to **long periods of inactivity**
3. Diseases such as **pneumonia, tuberculosis, emphysema**, etc.

Effects of Thrombosis

Thrombosis blocks the **blood flow to organs**.

- A **thrombosis in coronary arteries** causes **heart attack**.
- A **thrombus in the vessels of brain** causes **stroke**.

A **thrombus** may be **dislodged** and carried to **some other locations** in the **circulatory system**. Such a **thrombus is called embolus**.

Heart Problems and Treatments

Role of Coronary Arteries

We know that **coronary arteries** supply **oxygen and nutrients** to **cardiac muscles**.

Consequences of Blocked Blood Flow

If **blood flow is blocked** in coronary arteries, it results in **insufficient supply of blood** to one or more parts of **cardiac muscle**. If **heart muscles die** due to **no supply of oxygen and nutrients**, the condition is known as **myocardial infarction (heart attack)**.

Causes of Coronary Artery Blockage

Blockage of coronary arteries is usually due to **gradual build-up of lipids (especially cholesterol)** in the **inner wall of coronary artery**.

Chest Pain and Warning Signs

If such conditions persist, **chest pain**, called **angina pectoris**, can result during periods of **stress or physical exertion**. **Angina indicates** that **oxygen demands are greater than its delivery** and a **heart attack may occur in future**.

Surgical and Non-Surgical Treatments

If **lifestyle changes and medication** haven't relieved the symptoms or if the **narrowed coronary arteries** are at **imminent risk of a heart attack**, **coronary bypass surgery or angioplasty** is performed.

Coronary Bypass Surgery

Purpose

It is one of the **most common and effective procedures** to **compensate the blockage of blood** to **cardiac muscles**.

Procedure

In this surgery, a surgeon takes a **healthy blood vessel** from **leg, arm, chest or abdomen** of the patient.
He **attaches the ends** of the **blood vessel above and below the blocked coronary artery**.
So, **blood is bypassed** around the **damaged or blocked area**.

Limitations

Coronary bypass surgery doesn't cure the underlying disease process, i.e.,

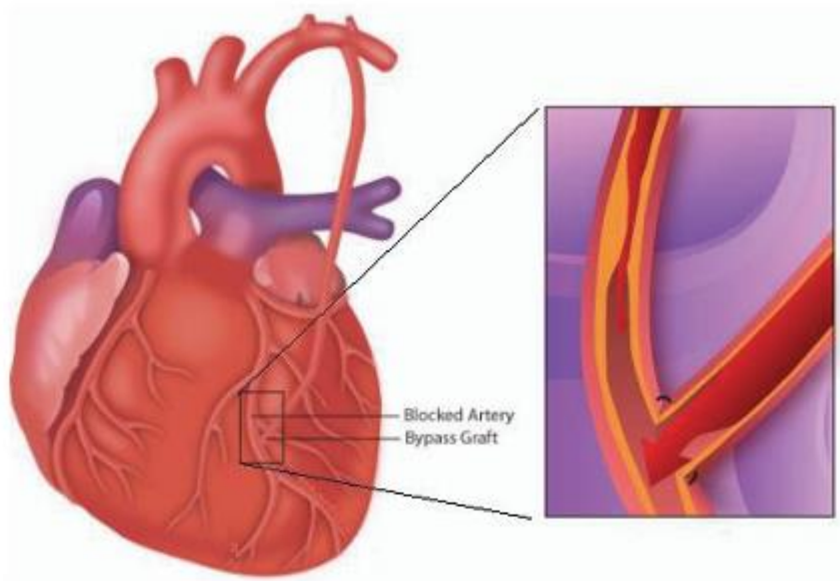

Figure 11.19: Coronary bypass

atherosclerosis or coronary artery disease.

Importance of Lifestyle Changes After Surgery

Lifestyle changes — especially **smoking cessation** — are **crucial** to reduce the chance of **future blockages and heart attacks**, even after **successful bypass surgery**.

In addition, patients need to make other lifestyle changes, such as:

- **Reducing certain types of fat in diet**
- **Increasing physical activity**
- **Controlling high blood pressure, diabetes**, and other **risk factors for heart disease**

Angioplasty and Stenting

Angioplasty

Angioplasty is a procedure that **opens a blocked or narrowed artery**.

Procedure

During an angioplasty:

- A **small wire** called a **catheter**, under **x-ray guidance**, is **passed through the narrowed coronary artery**.
- A **small sausage-shaped balloon** is then **advanced over the wire** into the **narrowed section of artery**.
- The **balloon is then inflated** to **dilate the narrowed section** of the artery.
- Once the artery is dilated, a **small amount of dye is injected** to confirm the **successful dilatation**.

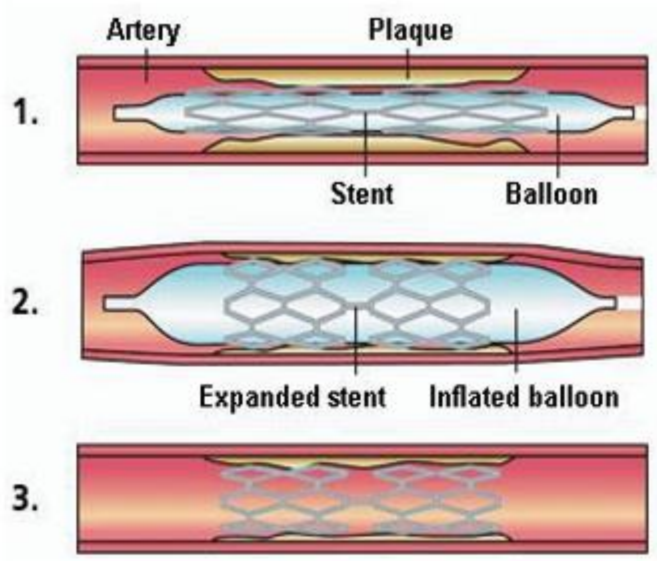

Figure 11.20: Angioplasty and stenting

Stenting

Stenting may also be done during **angioplasty**.

Definition and Function

A **stent** is an **expandable stainless steel mesh tube**, **mounted on a balloon catheter**.

Procedure

- When the **stent/balloon** is positioned within the **narrowed artery**, the **balloon is inflated**.
- The **inflated balloon expands** the **stent and the artery**.
- The **balloon is removed** and the **stent remains in place**.
- The **stent supports the artery walls** and keeps the **artery open and dilated**.

Lesson 7

Hypertension and Its Effects

Definition of Hypertension

A **chronic (long-lasting) elevation in blood pressure** is called **hypertension**. It occurs when **blood pressure consistently remains above 140/90**.

Causes of Hypertension

Any **abnormality in nervous or hormonal mechanisms** of **blood pressure regulation** may cause **hypertension**. Other causes of **hypertension** include:

- **Stress**
- **Obesity**
- **High salt intake**
- **Smoking**

There may also be **hereditary reasons** of hypertension.

Complications Due to Elevated Blood Pressure

Risk of Blood Vessel Rupture

Whenever **blood pressure is chronically elevated**, there is an **increased chance of the rupture of blood vessels**. When this occurs in **brain**, it is called **brain haemorrhage**. It **damages the delicate structure of brain**.

Effects on the Heart

Hypertension also weakens cardiac muscles. If **hypertension is prolonged**, **heart is unable to pump effectively** and **blood flow cannot be maintained** to meet needs of tissues. In such conditions, **blood may be retained in heart and lungs**. It is called **congestive heart failure**.

Effects on the Kidneys

Hypertension can also damage the nephrons of kidneys. It leads to further **retention of salts and water** in blood and therefore **further hypertension**.

Lymphatic System of Humans

Introduction

In human, in addition to the **blood circulatory system**, there is another system responsible for the **transport of materials**. It also **returns the materials from tissues to blood**. This system is called the **lymphatic system**.

Components of the Lymphatic System

The **lymphatic system** consists of:

- **Lymph vessels**
- **Lymphoid masses**
- **Lymph nodes**
- **Lymph** – the **fluid** which flows in the system

Lymph Vessels and Lymph

Lymph Capillaries

The **lymphatic system begins** with **small vessels** called **lymph capillaries**, which have **blind endings in extracellular fluid (interstitial fluid)**. **Pressure of the interstitial fluid forces it to enter into lymph capillaries**. **Lymph capillaries are more permeable than blood capillaries**, so **larger molecules can also enter**

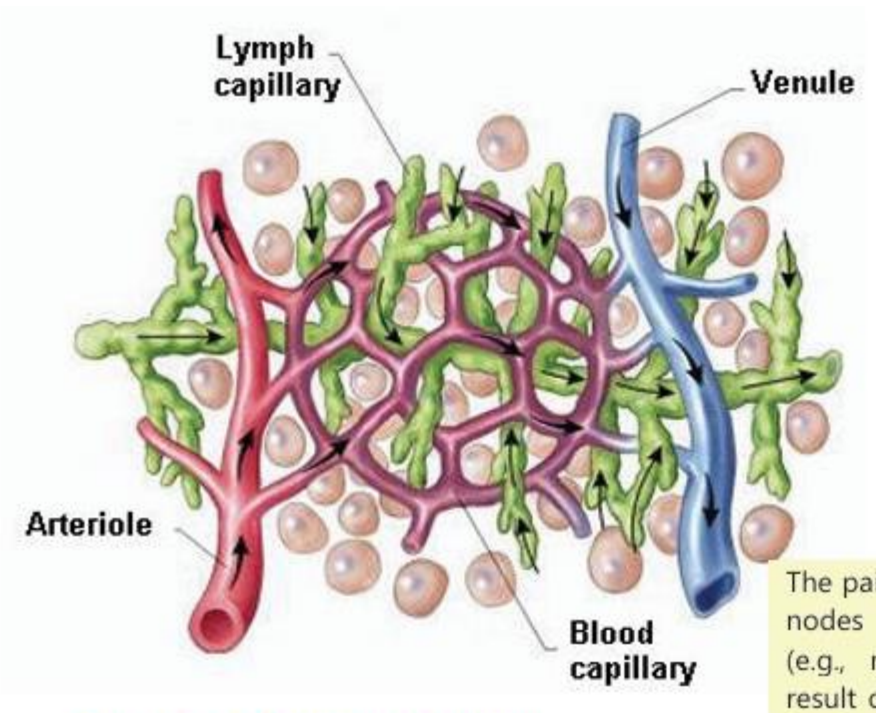

Figure 11.21: Formation of lymph

The painful swelling of lymph nodes in certain diseases (e.g., mumps) is largely a result of the accumulation of dead lymphocytes and macrophages.

lymph capillaries. When **interstitial fluid enters lymph capillaries**, it is called **lymph**.

Larger Lymph Vessels and Ducts

Lymph capillaries join to form **larger lymphatic vessels** (or **lymphatics** or **lymph vessels**). **Lymph vessels join** to form **larger lymph ducts**. There are **two main lymph ducts**:

- **Right lymphatic duct**
- **Thoracic duct**

These vessels **open into right and left subclavian veins** (veins that drain blood from the arms and shoulders to the heart), respectively.

Direction and Maintenance of Lymph Flow

The **flow of lymph is always from body tissues towards thoracic duct**. It is maintained by:

- **Activity of skeletal muscles**
- **Movement of viscera**
- **Breathing movements**

The **valves present in lymph vessels prevent the back flow of lymph**.

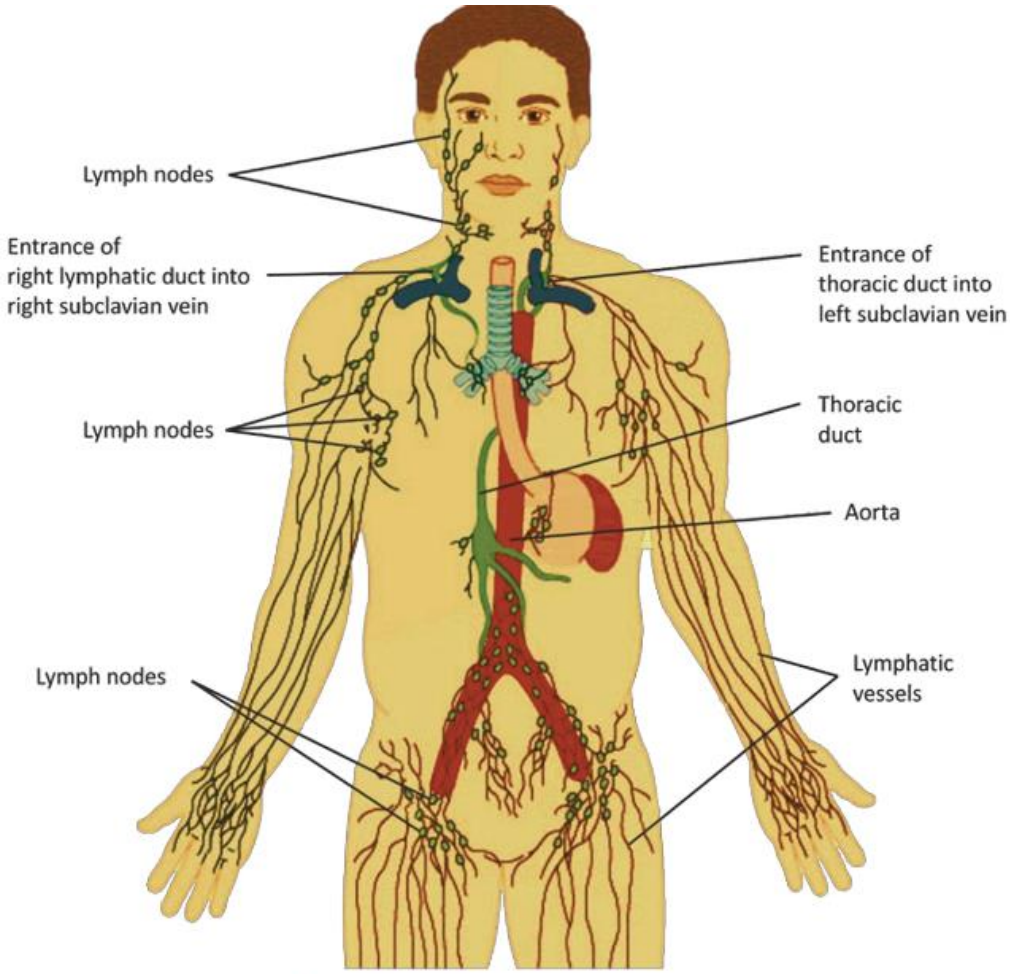

Figure 11.22: Human lymphatic system

Functions of the Lymphatic System

Fluid Return to Blood

The **lymphatic system returns the excess fluid** and **dissolved proteins and other substances to blood**. In an **average person**, about **three litres more fluid leaves blood capillaries daily**. But it is **absorbed by lymphatic capillaries and returned to bloodstream**, before the blood enters heart.

Defense Against Foreign Invaders

The **lymphatic system also helps to defend body against foreign invaders**.

Role of Lymph Nodes

- Lymph nodes filter lymph.

They have: 1) **Lymphocytes, 2)Macrophages.**

- These **destroy bacteria and viruses present in lymph**.

Role of the Spleen

Spleen filters blood through its **macrophages and lymphocytes** that **destroy foreign particles and aged RBCs**.

Spleen also functions to store RBCs.

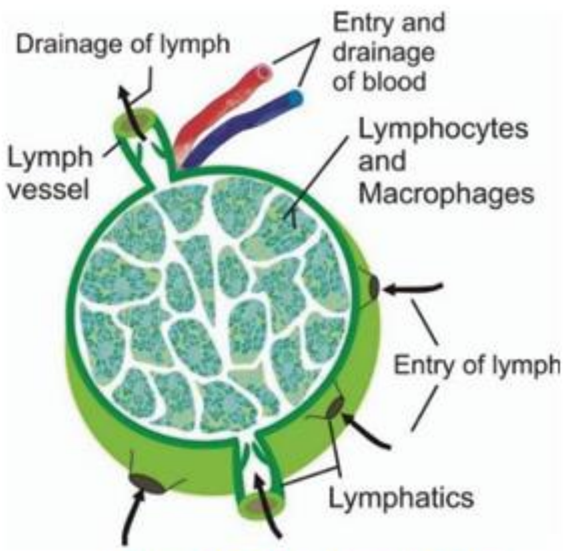

Figure 11.23: A lymph node