Circulatory System Overview

- The circulatory system consists of
  - **Blood**
  - **Blood vessels**
  - **The Heart**
  - **Lymphatic vessels**

- It works together with other systems in maintaining Homeostasis
  - **Respiratory**
  - **Urinary**
  - **Digestive**
  - **Endocrine, and**
  - **Integumentary systems**

Function of The Circulatory System

- **Transportation** – transport substances essential for cellular metabolism

  These substances can be categorized as follows:
  - ***Respiratory*** – Oxygen (RBC), Carbon dioxide (blood)
  - ***Nutritive*** - absorbed products of digestion (blood, lymphatics)
  - ***Excretory*** - Metabolic wastes (such as urea), excess water and ions, etc. (blood into kidneys = urine)

- **Regulation** - contributes to both hormonal and temperature regulation
  - ***Hormonal*** – hormones (blood)
  - ***Temperature*** - diversion of blood from deeper to more superficial cutaneous vessels or vice versa

Function Cont'd...

- **Protection** – protects against blood loss from injury and against pathogens, including foreign microbes and toxins introduced into the body.

  These substances can be categorized as follows:

  - ***Clotting***– prevents blood loss when blood vessels are damaged
  - ***Immune function*** - protect against many disease-causing agents (pathogens). Performed by *leukocytes (white blood cells).*

Major Components of the Circulatory System

- The circulatory system is divided into two major subdivisions:
  - **The Cardiovascular system** and the **Lymphatic system**

❑Cardiovascular system consist of:

- **Heart**
- **Blood vessels:** form a tubular network that permits the flow of blood
  - Arteries, arterioles, veins, capillaries

❑Lymphatic system consists of:

- **Lymphatic vessels**
- **Lymphoid tissues**
  - Found in the spleen, thymus, tonsil and lymph nodes

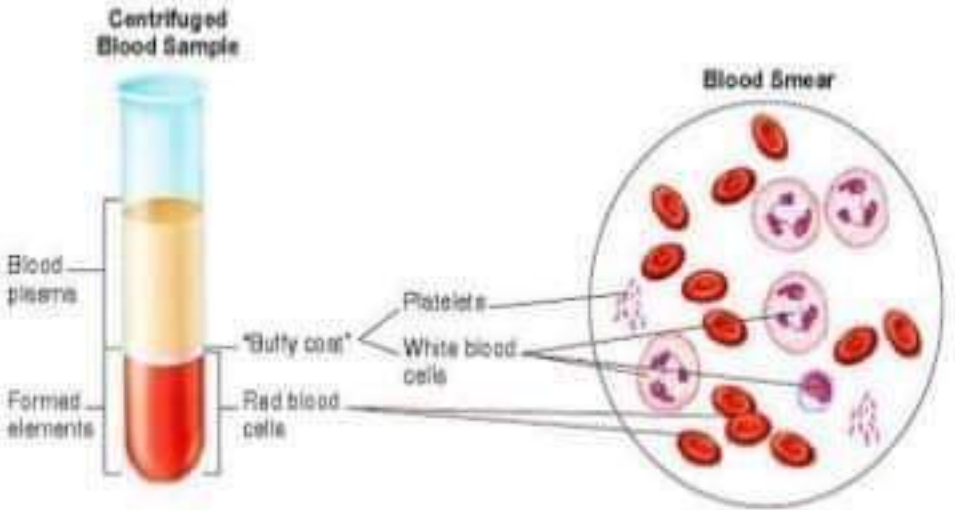
Composition of the Blood

- It consist of formed elements that are suspended and carried in fluid know as plasma

- The formed element of the blood consist of:
  - **Erythrocyte (RBC)**
  - **Leukocyte (WBC)**
  - **Platelets**

- Hematopoiesis is the formation of blood cells
- Hematopoietic stem cells

The Constituents of Blood



- **Figure 1.1 The constituents of blood.** Blood cells become packed at the bottom of the test tube when whole blood is centrifuged, leaving the fluid plasma at the top of the tube.

Blood Composition Cont'd...

- **Erythropoiesis** refers to the formation of erythrocytes
- **Leukopoesis** refers to the formation of leukocytes
- These processes occur in two classes of tissues after birth
- Myeloid and lymphoid

The Heart Structure

- Located in the thoracic cavity in the mediastinum, between the lungs and deep to the sternum

- Contains four chamber
- Its about the size of a fist, the hollow, cone-shaped

- There is a layer of dense connective tissues b/t the atria and ventricle

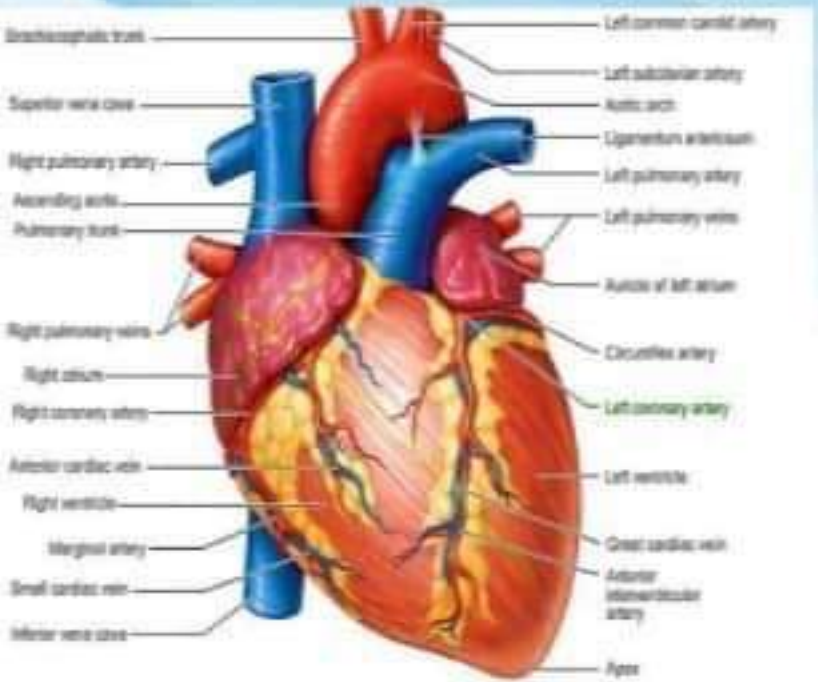


Figure 1.5. The Structure of the Heart

Blood Circulation

- Movement of blood through the vessels of the body that is induced by the pumping action of the heart and serves to distribute oxygen to and remove wasted products from all parts of the body

- Two (2) types:
  - **Pulmonary circulation**
  - **Systemic circulation**

Blood Circulation Cont'd...

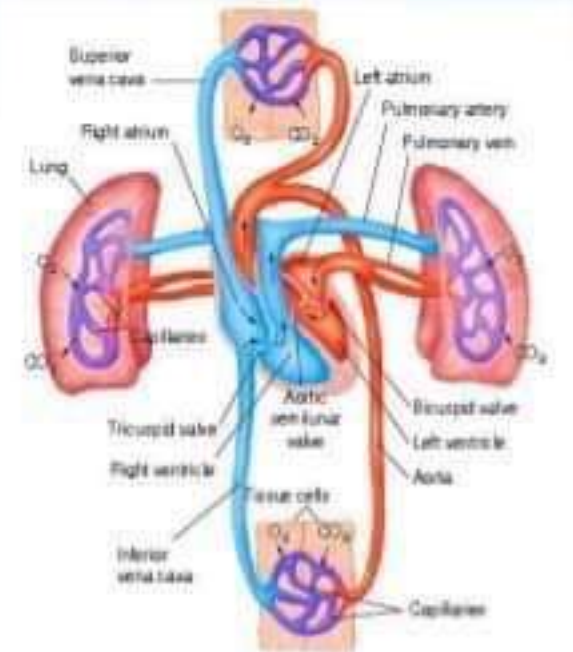


Figure 1.6 A Diagram of the circulatory system.

- **Pulmonary circuit** carries deoxygenated blood away from the heart to the lungs and returns oxygenated blood to the heart
- **Systemic circuit** carries oxygenated blood away from the heart to body system and returns deoxygenated blood to the heart
- Pulmonary circuit begins in the right ventricle and ends in the left atrium
- Systemic circuit beings in the left ventricle and ends in the right atrium

Valves of the Heart

- Two (2) main types:
  - **Atrioventricular Valves**
  - **Semilunar Valves**

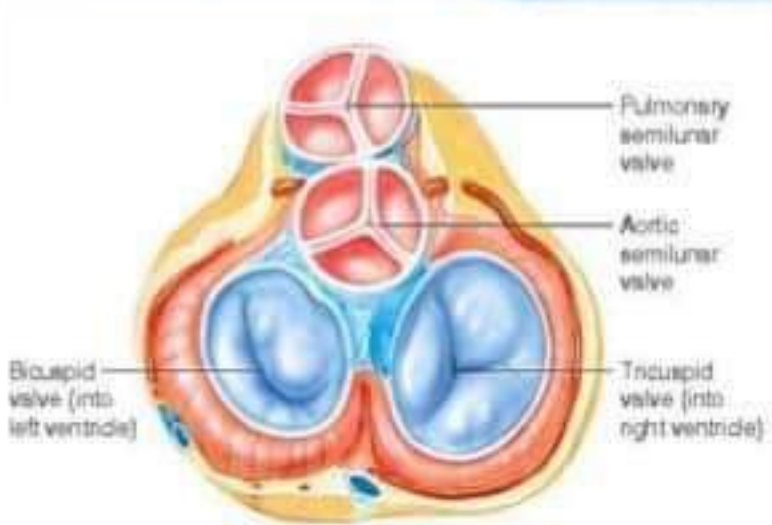
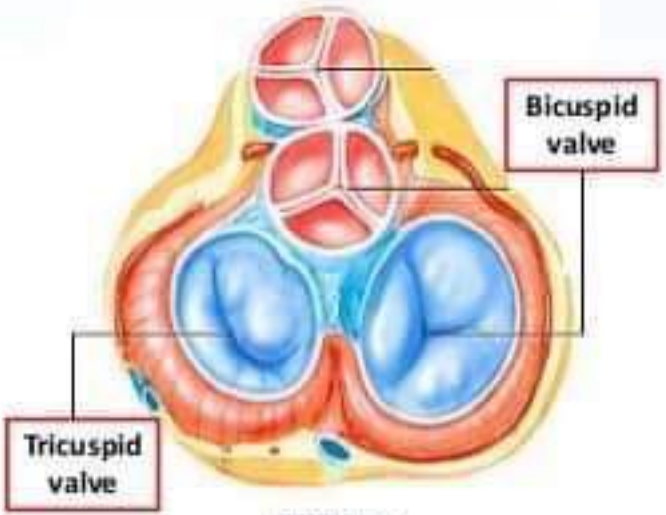


Figure 1.7 The heart valves

Valves of the Heart: Atrioventricular Valves



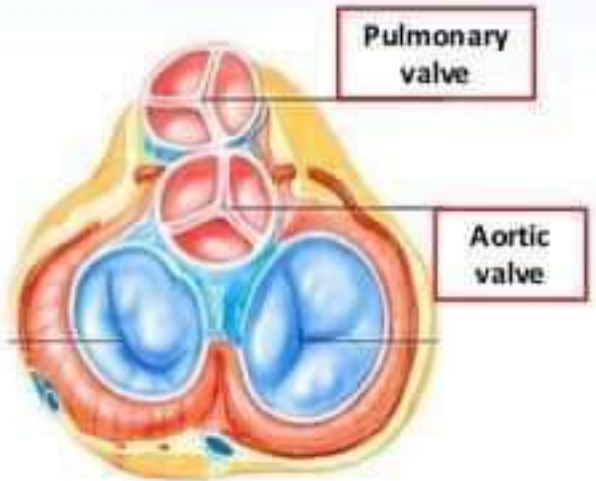
AV Valves

- Found between the atria and ventricles
- Constitutes;
  - **Tricuspid valve**
  - **Bicuspid valve**

- **Tricuspid valve:** right AV valve that prevents blood from flowing back into the right atrium when the right ventricle contract. It has three flaps of tissues

- **Bicuspid valves:** left AV valve that prevents blood from flowing back into the left atrium when the left ventricle contract.

Valves of the Heart: Semilunar Valves

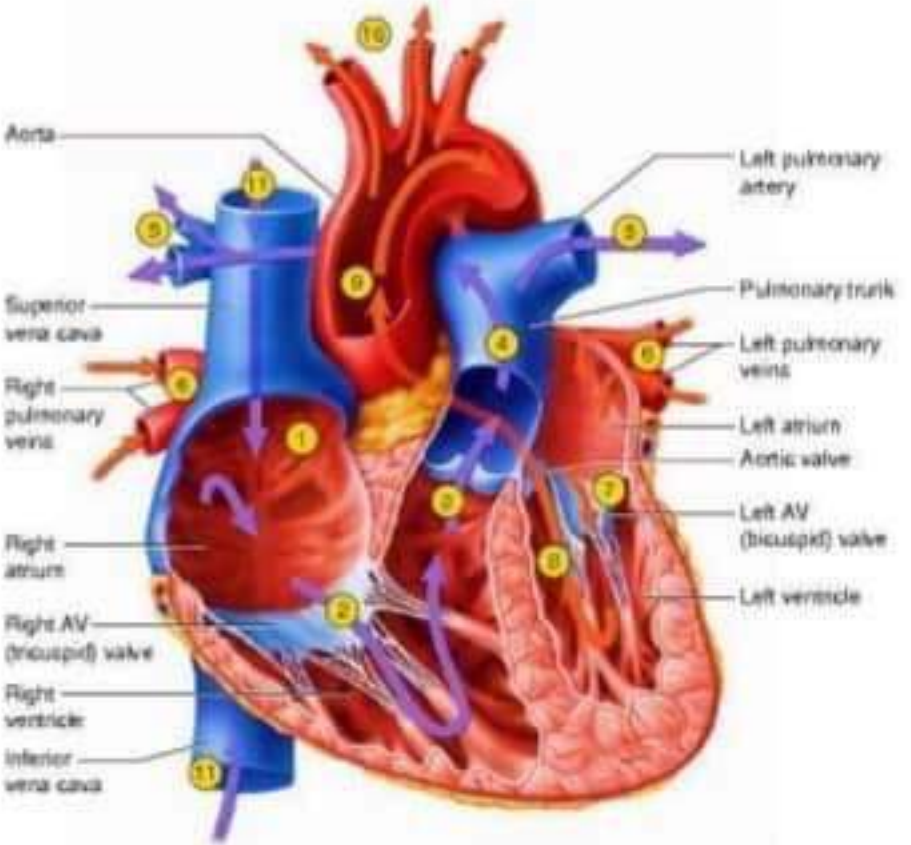


- Shaped like half moons
- Constitutes;
  - **Pulmonary valve**
  - **Aortic valve**

- **Pulmonary valve:** beginning of the pulmonary truck. Prevents blood from flowing back into the right ventricle

- **Aortic valve:** beginning of the aorta. Prevents blood from flowing back into the left ventricle

Pathway of Blood Flow Through the Heart



The Cardiac Cycle

- Cardiac cycle refers to the repeating patterns of contraction and relaxation of the heart. The phase of contraction is called **systole**, and the phase of relaxation is called **diastole**
- **One heartbeat = one cardiac cycle**
  - Atria contract and relax
  - Ventricles contract and relax

- **Right atrium contracts** (1st Diastole)
  - Tricuspid valve opens
  - Blood fills right ventricle
- **Right ventricle contracts** (1st Systole)
  - Tricuspid valve closes
  - Pulmonary semilunar valve opens
  - Blood flows into pulmonary artery

- **Left atrium contracts** (2nd Diastole)
  - Bicuspid valve opens
  - Blood fills left ventricle
- **Left ventricle contracts** (2nd Systole)
  - Bicuspid valve closes
  - Aortic semilunar valve opens
  - Blood pushed into aorta

Cardiac cycle

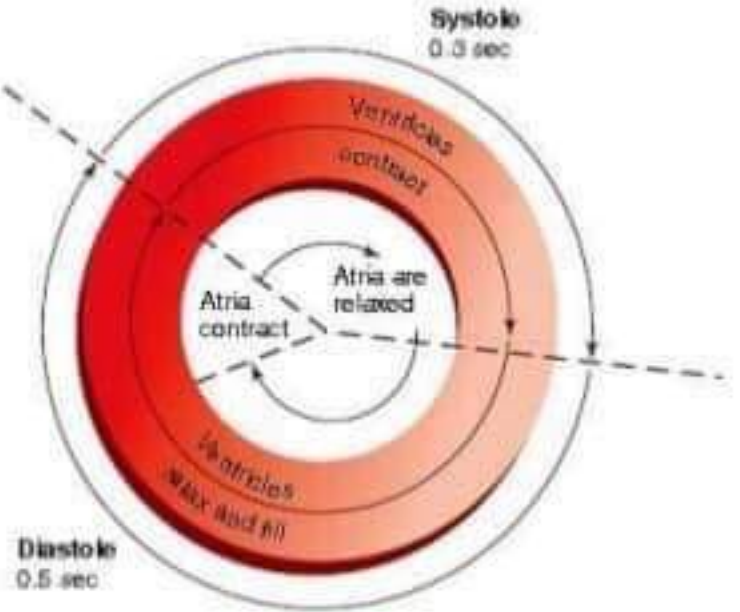


Figure 1.9 The cardiac cycle of ventricular systole and diastole. Contraction of the atria occurs in the last 0.1 second of ventricular diastole. Relaxation of the atria occurs during ventricular systole. The durations given for systole and diastole relate to a cardiac rate of 75 beats per minute.

Cardiac Output

- Defined as the amount of blood each ventricle pumps out per minute.
- Determined by:
  - **Stroke volume** – amount of blood that each ventricle pumps out per beat
  - **Heart rate** – number of times the heart beats in one minute
- **Cardiac Output** = Heart rate **X** Stroke volume

Cardiac Output Cont'd...

- Normal resting stroke volume = **70 mL of blood**

- Normal resting heart rate = **70-72 beats per minute**
  - **When one factor changes, the body regulates the other factor to enhance the cardiac output.**

- Normal cardiac output = **4.9-5.4 L/min** (based on the body size of an individual)
- Normal physiological Resting Cardiac Output – **5 L/min**

- When the body begins to move, the cardiac output increases so as to enhance blood flow to the muscles.

Heart Sounds

- There are 4 heart sounds, 3 normal, 2 of which are easily heard
- The 4th heart sound may normally be heard in a young child, but is abnormal in adults
- The 1st and 2nd heart sounds are associated with the closure of valves

Heart Sound Cont'd...

- **1st Heart Sound (Lubb)**
  - When the ventricle contract, the tricuspid and bicuspid valves snap shut

- **2nd Heart Sound (Dubb)**
  - When the atria contract and the pulmonary and aortic valves snap shut

The Heart: Cardiac Conduction System

- Group of structures that send electrical impulses through the heart

- ***Sinoatrial node*** (SA node)
  - Wall of right atrium
  - Generates impulse
  - Natural pacemaker
  - Sends impulse to AV node

- ***Atrioventricular node*** (AV node)
  - Between atria just above ventricles
  - Atria contract
  - Sends impulse to the bundle of His

- ***Bundle of His***
  - Between ventricles
  - Two branches
  - Sends impulse to Purkinje fibers

- ***Purkinje fibers***
  - Lateral walls of ventricles
  - Ventricles contract

Cardiac Conduction System

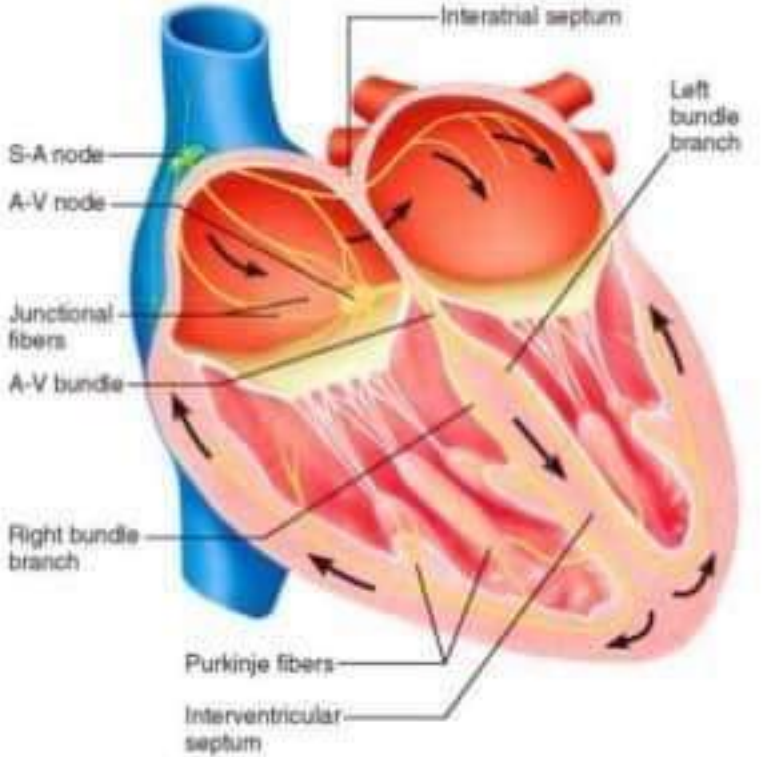


Figure 1.10 **The conduction system of the heart.** The conduction system consists of specialized myocardial cells that rapidly conduct the impulses from the atria into the ventricles.

Blood Vessels

- Blood vessels form a tubular network throughout the body that permits blood to flow from the heart to all the living cells of the body and then back to the heart

- Blood leaving the heart passes through vessels of progressively smaller diameters, referred to as ***arteries***, ***arterioles***, and ***capillaries***

- Blood returning to the heart from the capillaries passes through vessels of progressively larger diameters, called *venules* and *veins*.

Blood Vessels: *Arteries and Arterioles*

- Strongest of the blood vessels
- Carry blood away from the heart
- Under high pressure
  - Vasoconstriction
  - Vasodilation
- **Arterioles**
  - Small branches of arteries
- **Aorta**
  - Takes blood from the heart to the body
- **Coronary arteries**
  - Supply blood to heart muscle

The Microcirculation

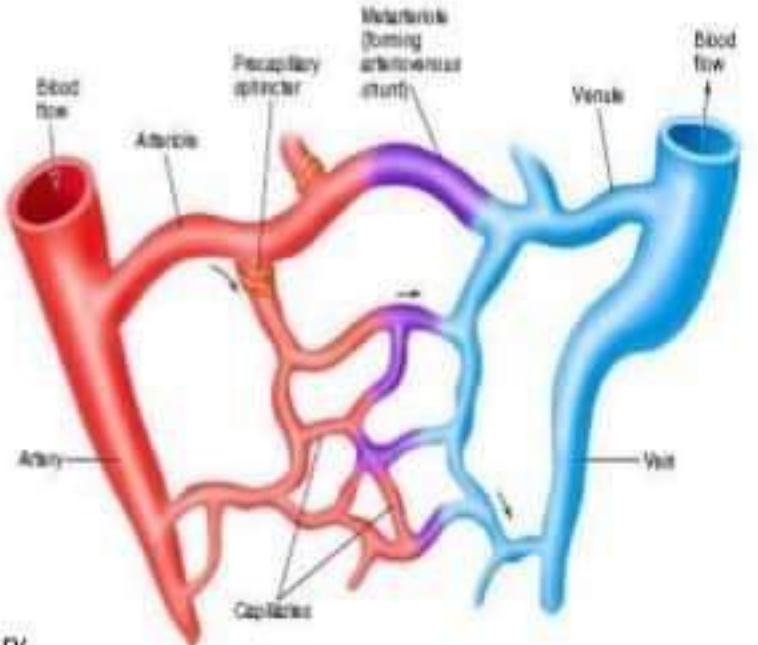


Figure 1.12 **The microcirculation.** Metarterioles (arteriovenous anastomoses) provide a path of least resistance between arterioles and venules. Precapillary sphincter muscles regulate the flow of blood through the capillaries.

Blood Vessels: *Capillaries*

- The arterial system branches extensively to deliver blood to over 40 billion capillaries in the body.
- The tiny capillaries provide a total surface area of 1,000 square miles for exchanges between blood and tissue fluid.
- The amount of blood flowing through a particular capillary bed depends primarily on the resistance to blood flow in the small arteries and arterioles that supply blood to that capillary bed.
- Vasoconstriction in these vessels thus decreases blood flow to the capillary bed, whereas vasodilation increases blood flow

Types of Capillaries

- In terms of their endothelial lining, these capillary types include those that are ***continuous***, those that are ***fenestrated***, and those that are ***discontinuous***.

- **Continuous capillaries** are those in which adjacent endothelial cells are closely joined together. These are found in muscles, lungs, adipose tissue, and the central nervous system.

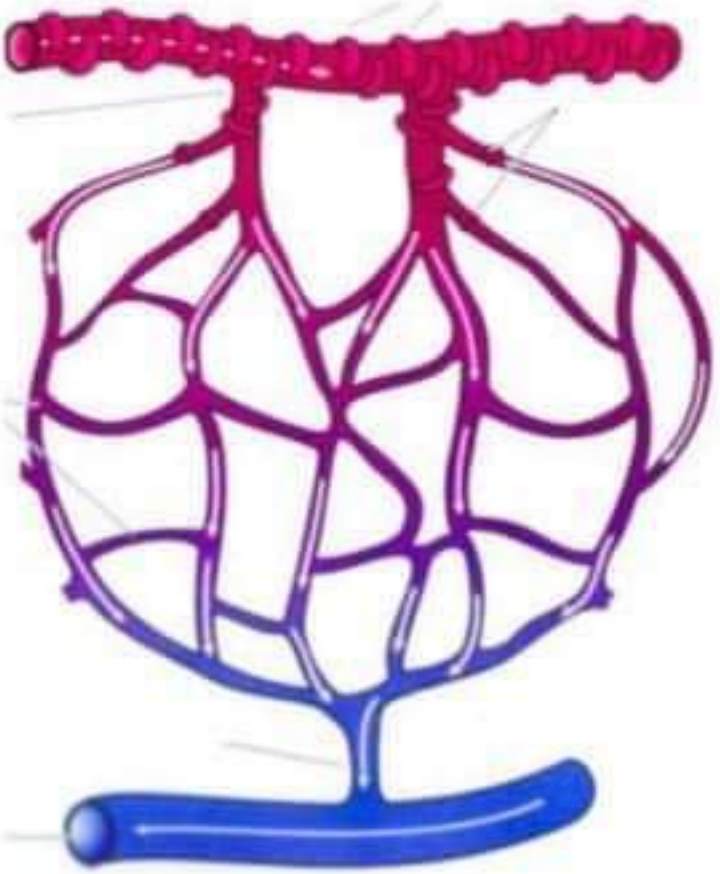
- **Fenestrated capillaries** occur in the kidneys, endocrine glands, and intestines. They are characterized by wide intercellular pores that are covered by a layer of mucoprotein, which serves as a basement membrane over the capillary endothelium

- **Discontinuous capillaries** are found in the bone marrow, liver, and spleen

Capillaries

Capillaries

- Smallest blood vessels
- Average diameter – **8 µm**
- Thin-walled & form plexus which spread throughout the tissue & continuous with
  - Smallest arteriole at one end
  - Smallest venules at other end
- **Site of exchange of gases, nutrients and metabolic wastes**
- Abundant in tissue with high metabolic rate like
  - Kidney, liver and cardiac muscle

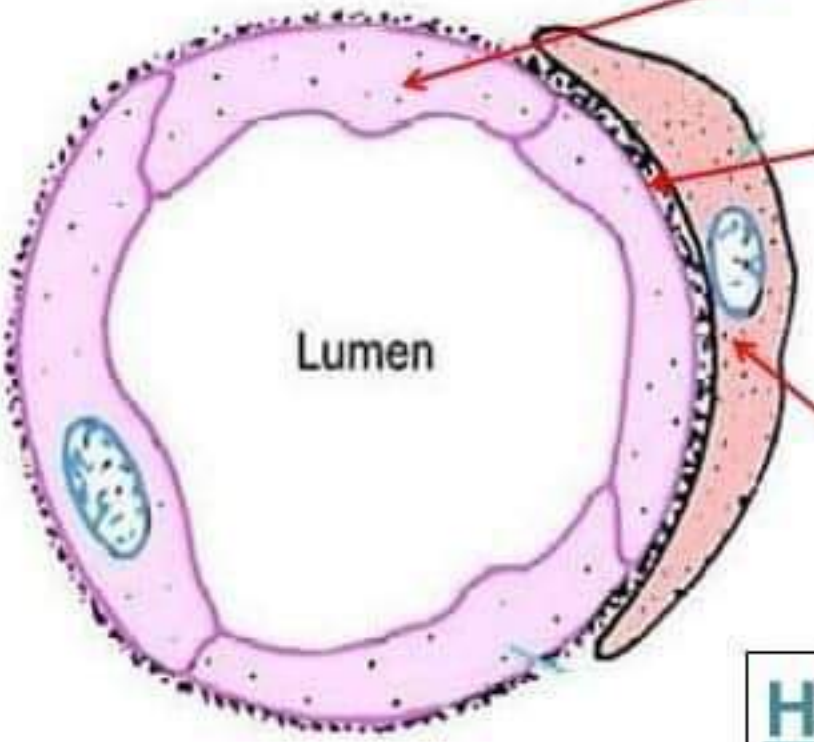


Structure of Capillaries

The capillary wall is formed by

Single layer of endothelial cells

Glycoprotein layer of Basal lamina



Out side the basal lamina- **Contractile cells** wrapped around the capillaries

Pericytes

Has only Tunica Intima

Lacks T Media and therefore no smooth muscle cells

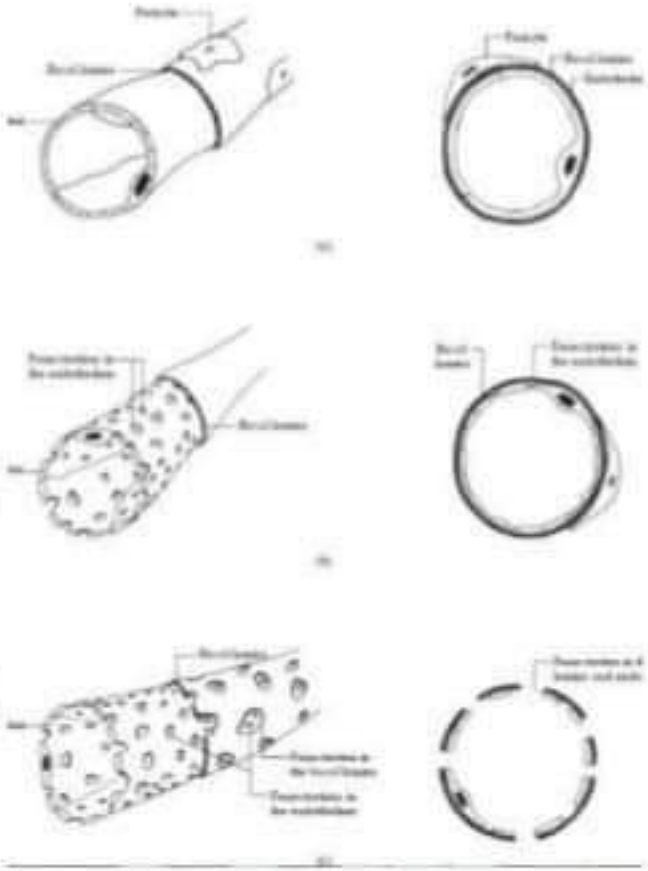
Types of Capillaries

- According to the appearance under the electron microscope, there are **3 types of capillaries**:

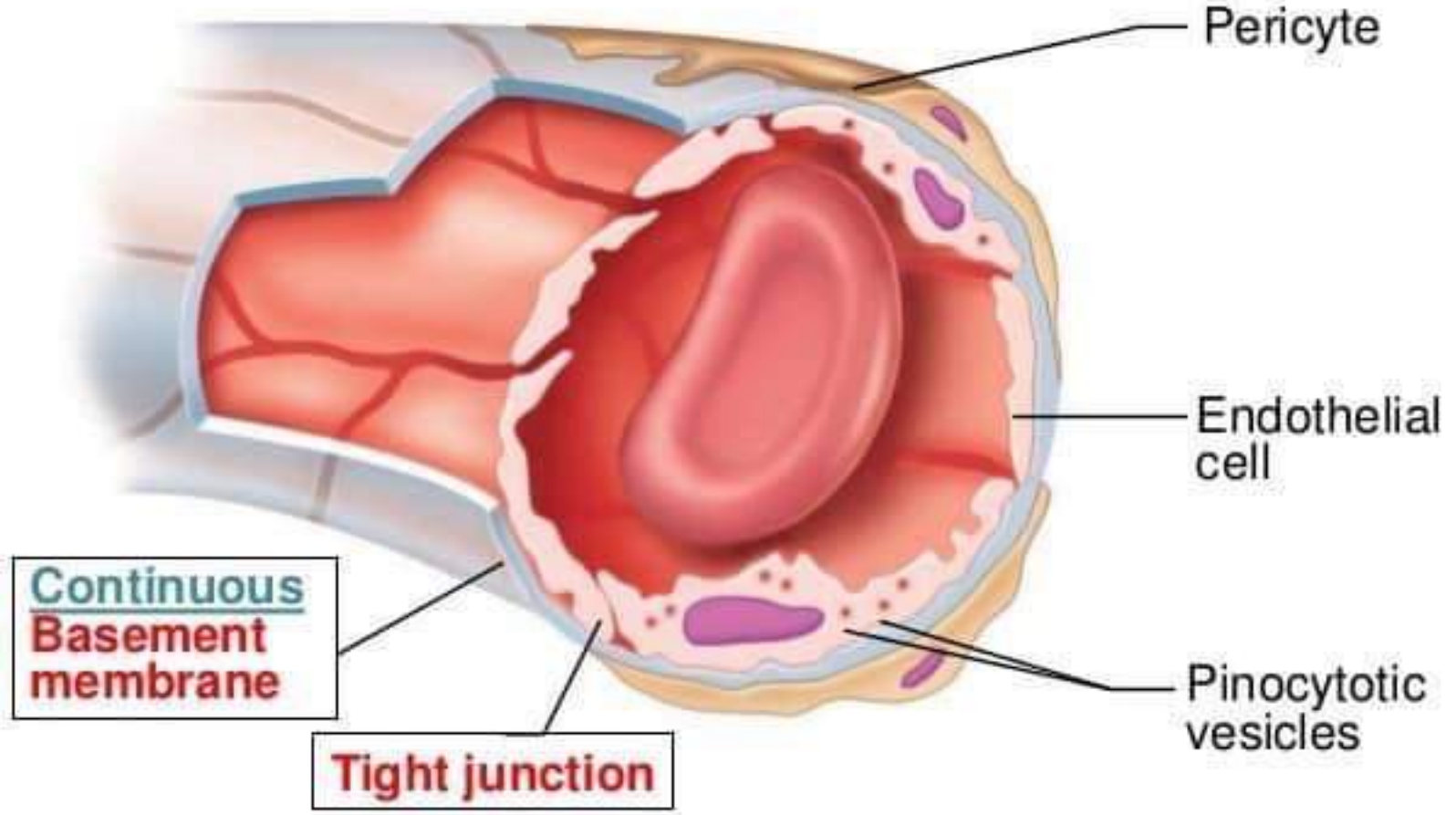
1. Continuous
2. Fenestrated

} **6-10 µm D**

3. Sinusoidal – **30-40 µm D**



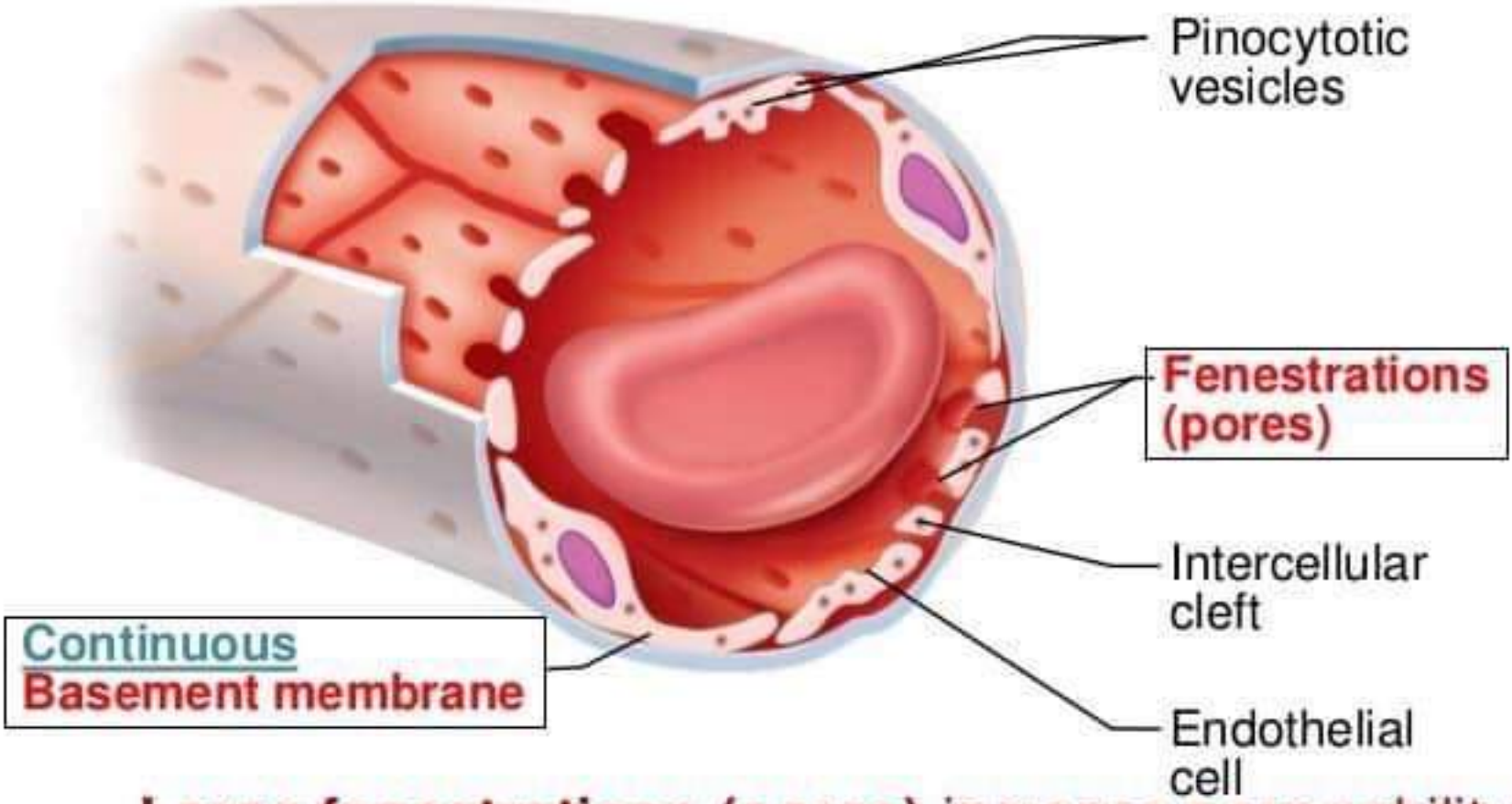
Continuous Capillaries



(a) **Least permeable, and most common**

E.G., skin, muscle, nervous tissues, etc…

Fenestrated Capillaries

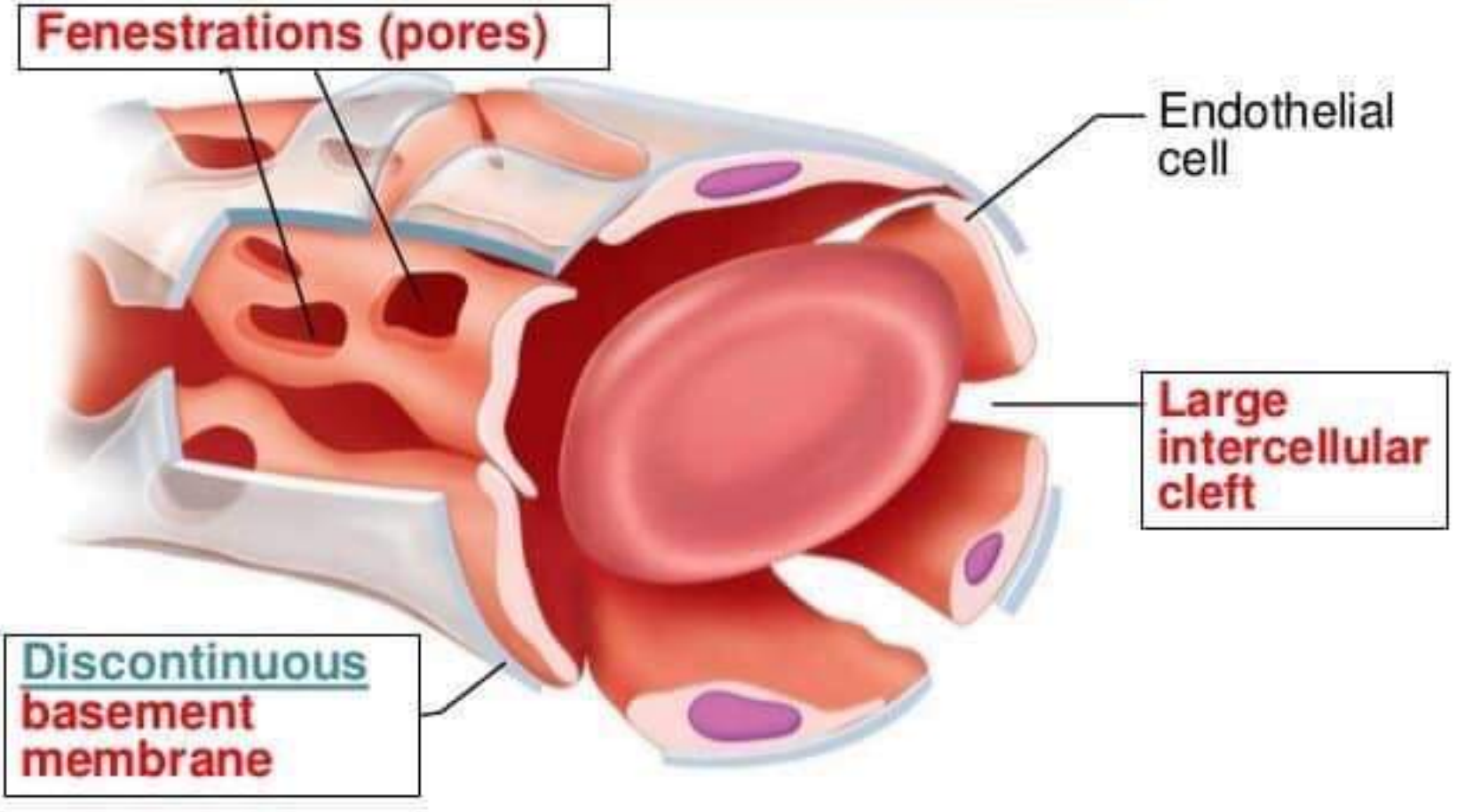


Large fenestrations (pores) increase permeability

(b) Occurs in areas of active absorption or filtration

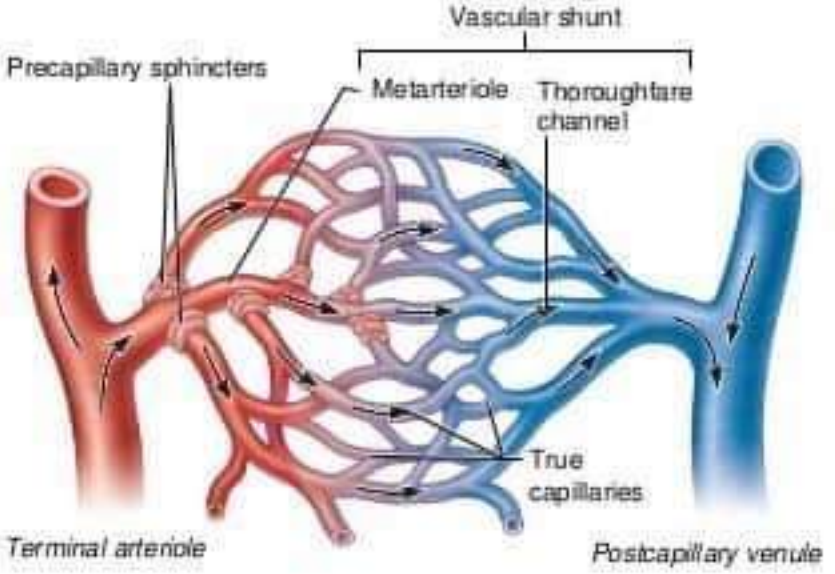
E.G., kidney, small intestine, endocrine glands etc…

Sinusoidal Capillaries



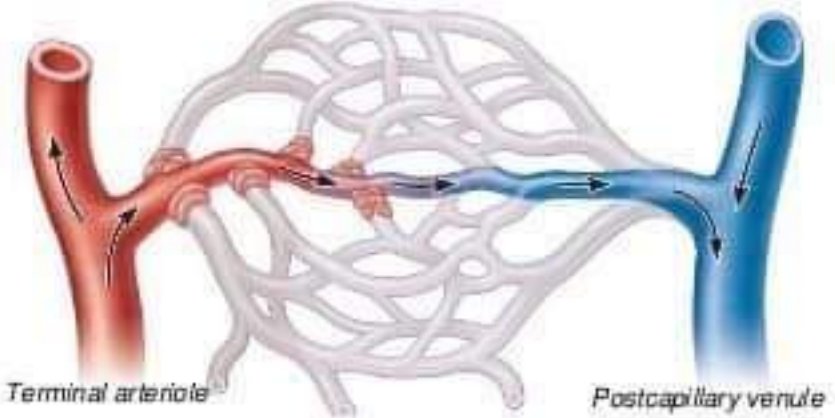
(c) **Most permeable. Occurs in special locations**

E.G., liver, bone marrow, spleen



Active

Sphincters open—blood flows through true capillaries



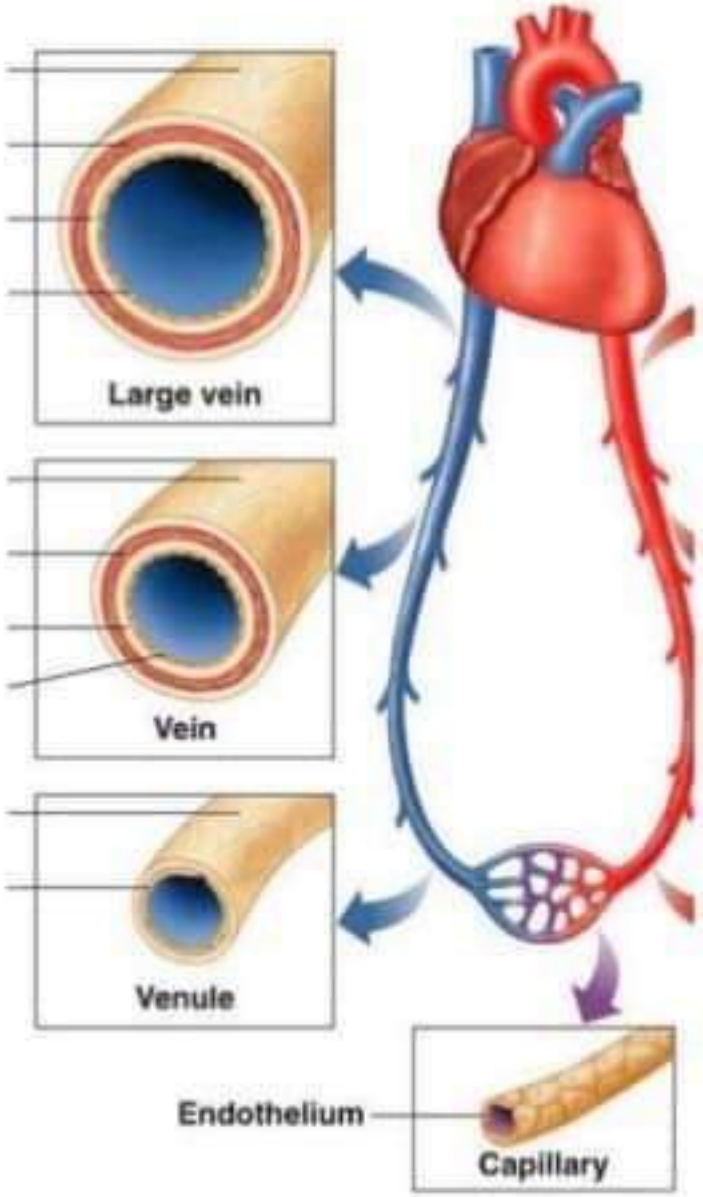
Rest

Sphincters closed—blood flows through metarteriole – thoroughfare channel and bypasses true capillaries.

Venous System

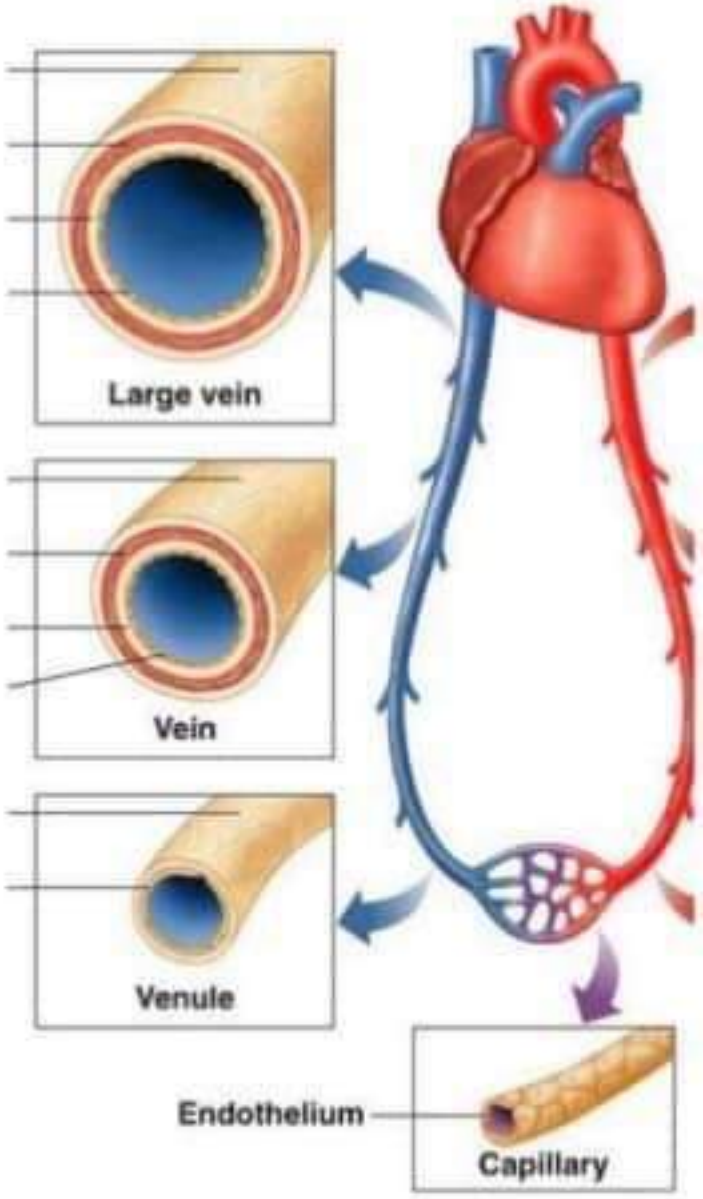
Venous System

- Veins are thin walled
- Carry blood from capillaries to heart
- Large veins are formed by the union of smaller vein like **tributary of a river**
- Often provided with valves
  - Prevent reflux of blood
  - Maintain unidirectional flow of blood



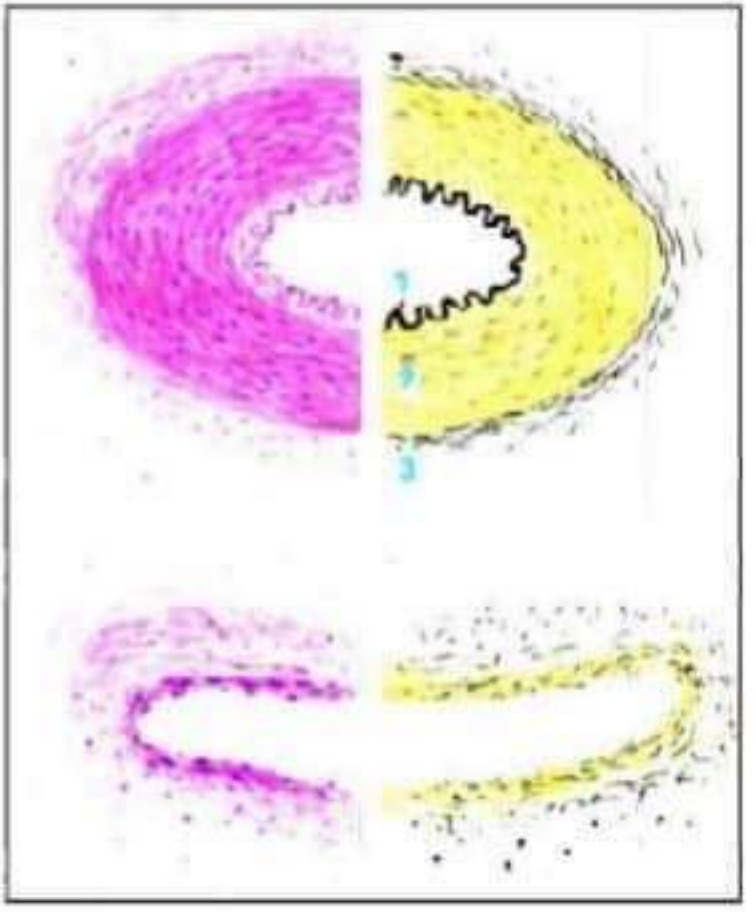
Types of Veins

- **3 types**:
  - Large sized Veins
  - Medium sized veins
  - Venules
- Same 3 layered organisation as arterial system
  - **Tunica intima**
  - **Tunica media**
  - **Tunica adventitia**



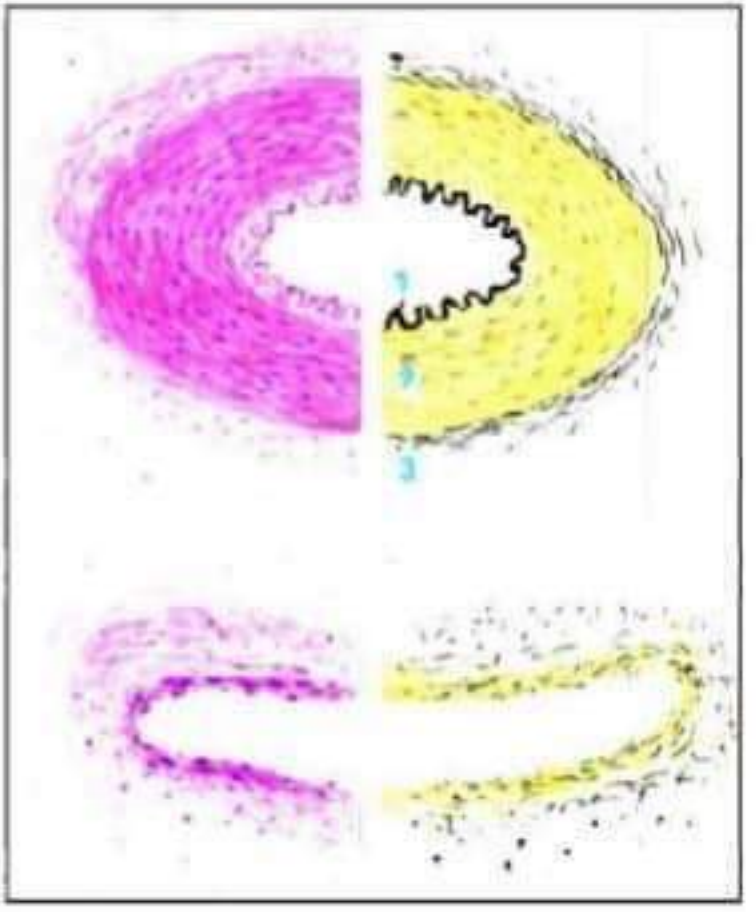
Difference in Structure of Veins from the Arteries

- **Wall thickness to lumen diameter ratio is less**
  - Wall of a vein is distinctly thinner than that of same sized artery
- **Tunica Media** is **thin** and **poorly developed**
  - Contain **more collagen** &
  - **Less elastic tissue**
  - Veins are usually **collapsed after death**



Difference in Structure of Veins from the Arteries

- **Tunica Intima & adventitia** are **more prominent**
  - **Adventitia** of veins is **thicker** than **media**
- **Internal and external elastic lamina** are **difficult to distinguish (Mainly in small veins)**
  - No clear distinction between the tunica intima, media and adventitia



Large Veins

≥1 cm in diameter

Examples:

SVC and IVC

Endothelium & Sub-endothelial CT

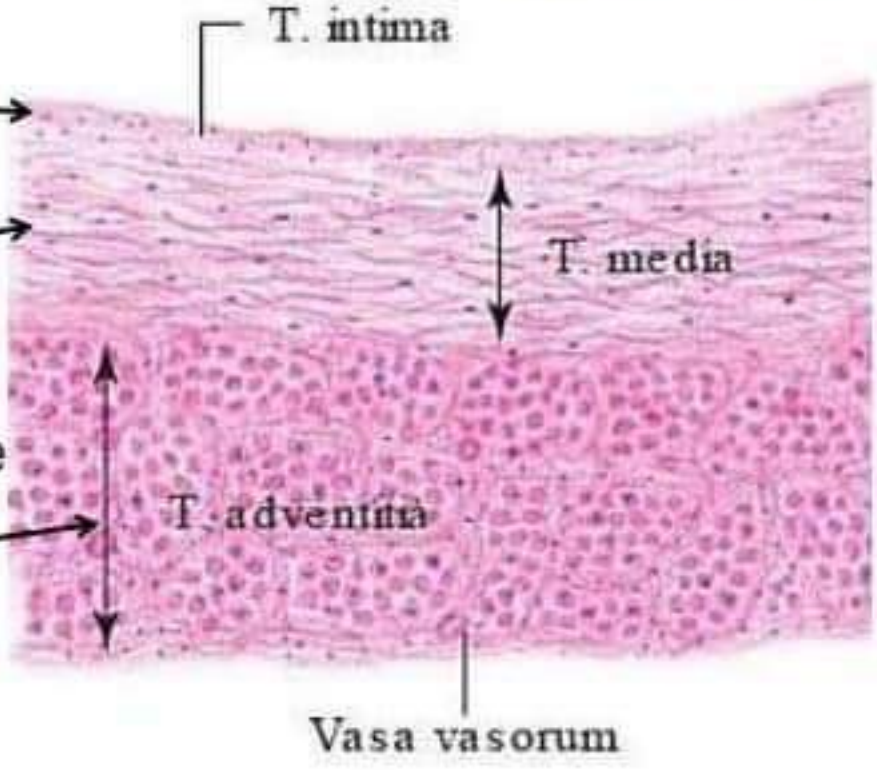
Tunica Intima - **Well developed**

Tunica Media - **Thin**

Less smooth muscle & elastic fibers & **more** connective tissue

Tunica Adventitia

Well developed & thicker than the media



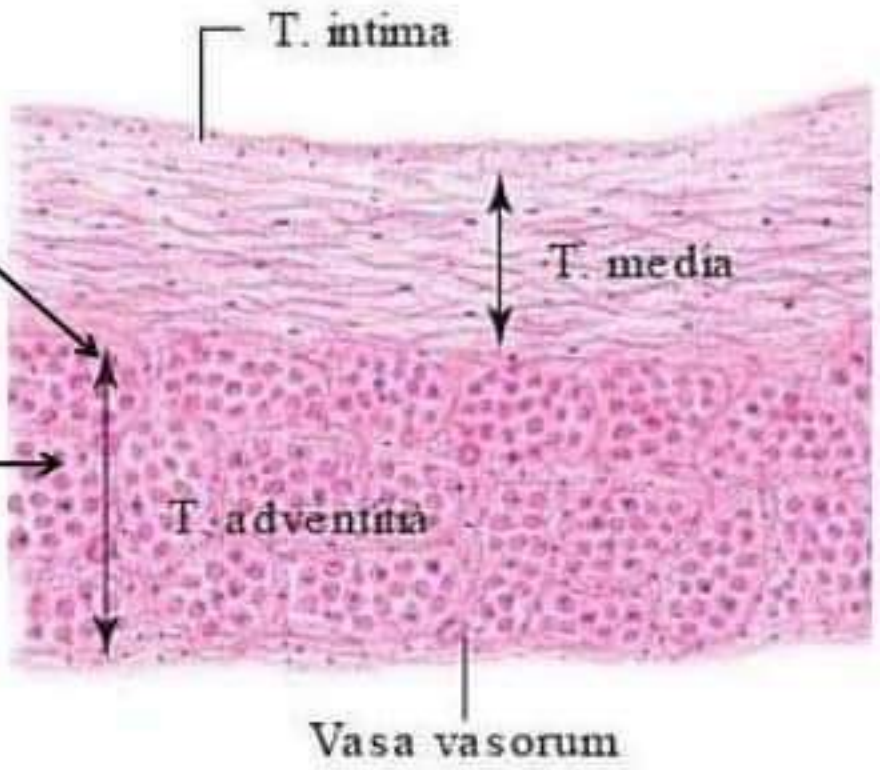
Both internal & external elastic lamina are poorly defined

Large Veins ≥1 cm in diameter

Tunica Adventitia

Longitudinal bundles of smooth muscle

Facilitate shortening & elongation of vena cava with respiration

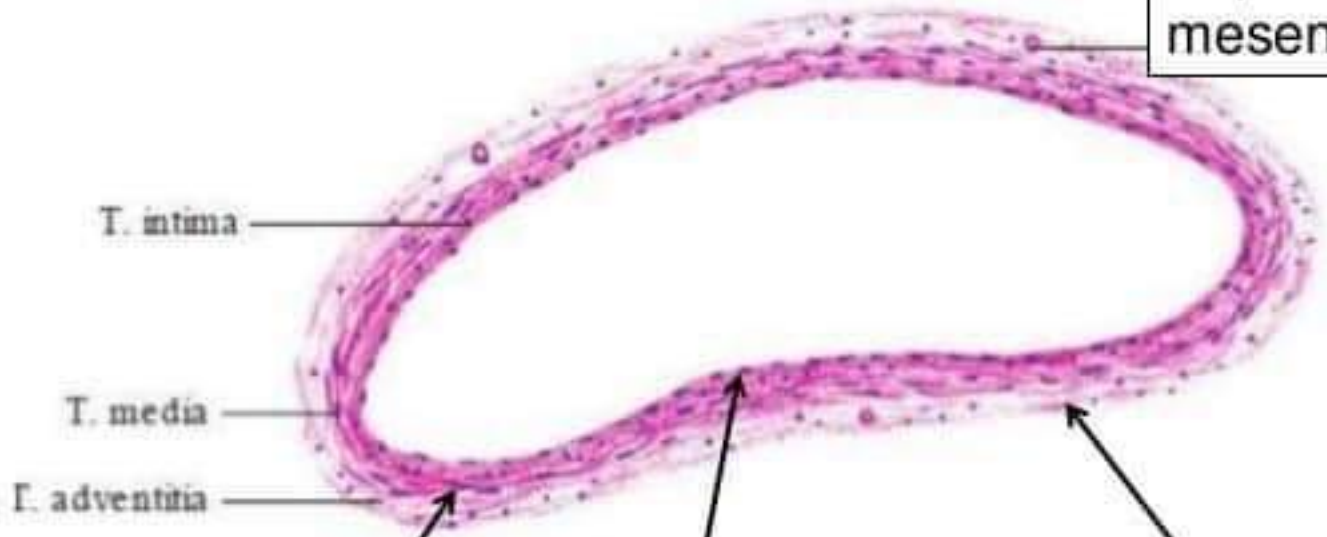


Medium - Sized Veins

1–10 mm in diameter

All layers are thinner than large vein

Femoral vein & Superior mesenteric vein



Tunica Intima
Very thin

Endothelium & Thin Sub-endothelial CT

Tunica Media
Less muscular

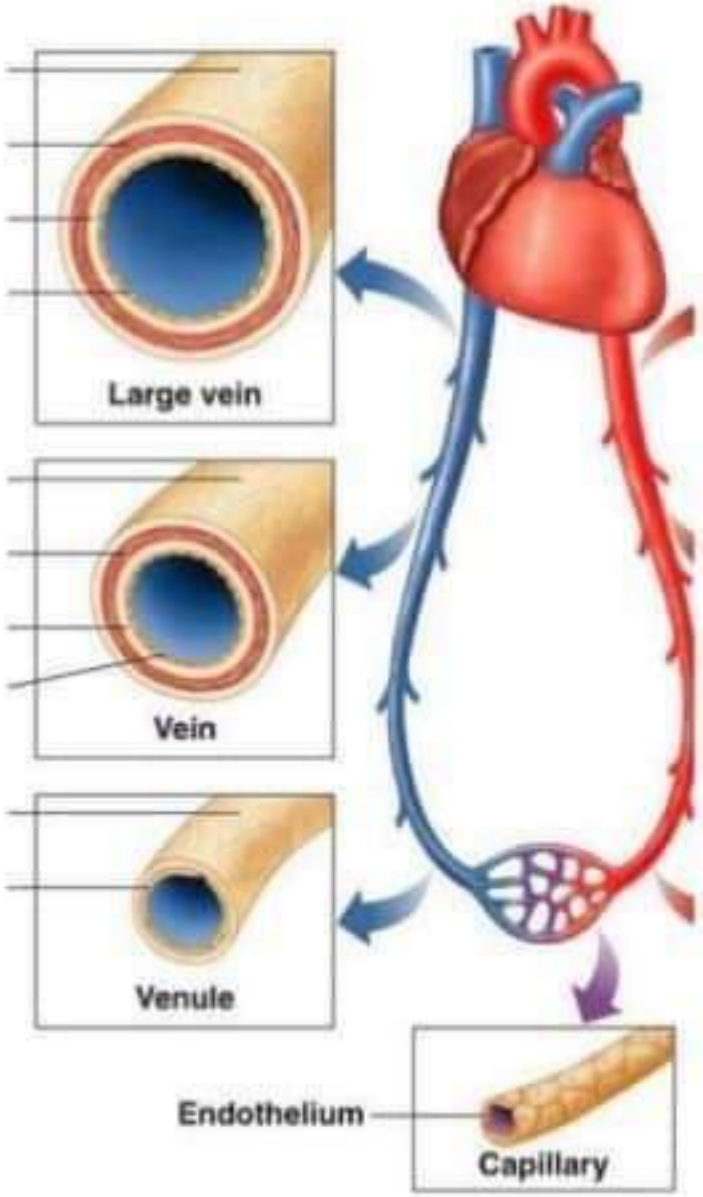
Few smooth muscle fibers

Tunica Adventitia

Well developed & thicker than the media

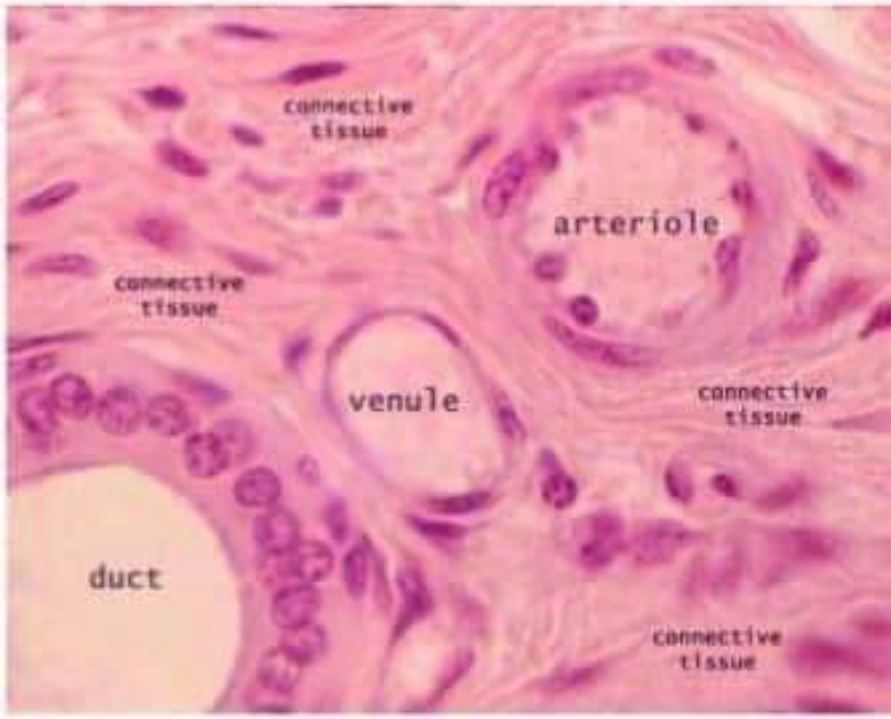
Venules

- Smallest Veins
- Capillaries drain into **post-capillary venules** (**10–40 µm** in diameter)
- Post-capillary venules drain into **large muscular venules** (**40–100 µm** in diameter)
- Important sites or exchange of metabolites



Venules

- Wall is thin
- Large collapsed lumen
- **T intima**: endothelium
- **T media**: 1-2 layers of smooth muscle fibers
- **T adventitia**: thick and composed of connective tissue rich in collagen fibres



Valves of Veins

- Valve of a vein is composed of 2 leaflets
- Each leaflet has a thin fold of the Tunica Intima
- **Components**: Endothelium + Core of C.T.
- Maintain unidirectional flow of blood towards the heart