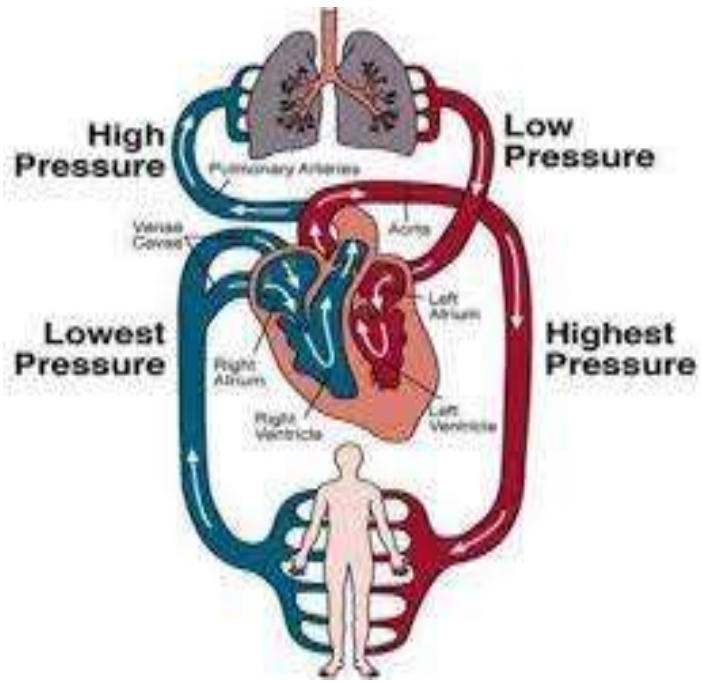
Circulatory system

Function :

Transporting gases, nutrients, hormones and wastes

Circulatory systems generally have **three main features:**

- A heart to pump the fluid through the vessels
- Fluid (blood or hemolymph) that transports materials
- System of vessels (blood, Lymph)
  - Blood = CVS
  - Lymph = Lymphatic vascular system



Major Blood Circulatory Routes

- **Pulmonary**

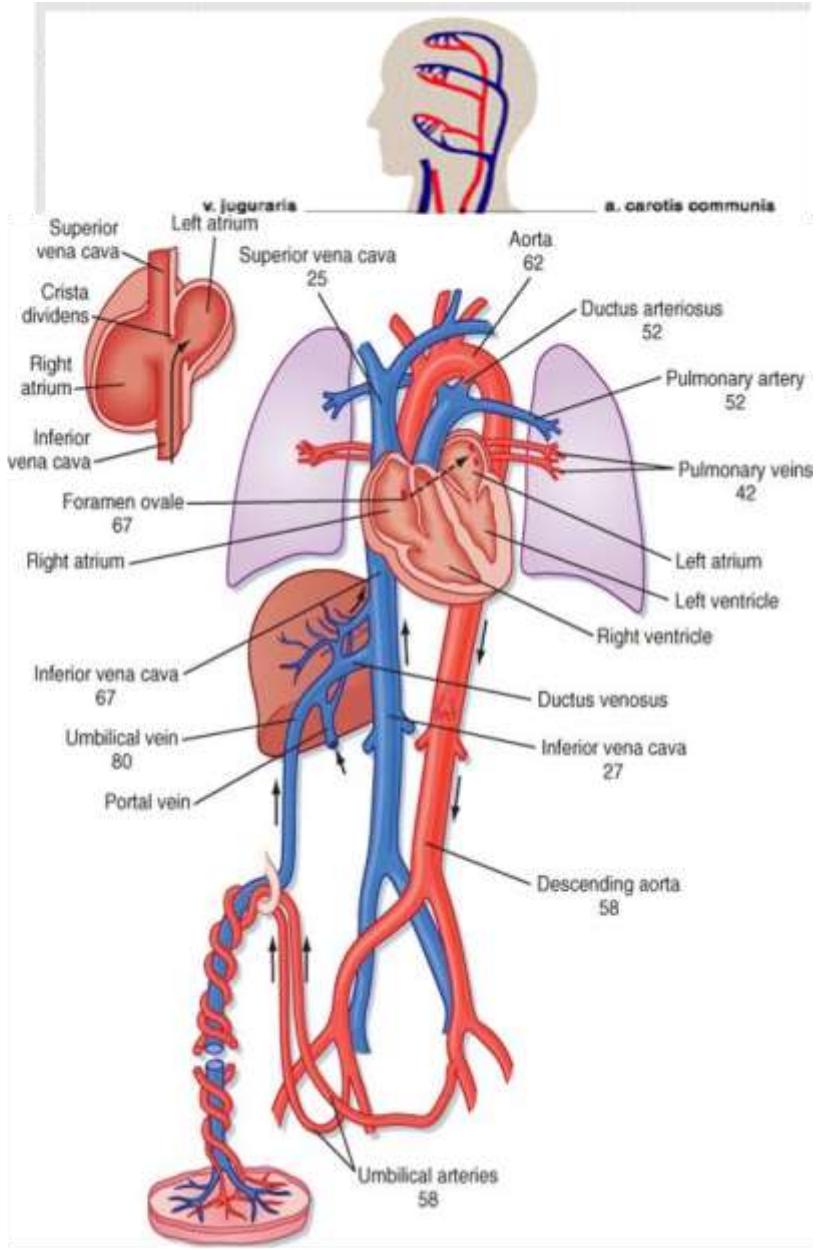
-Rt Ventricle-Pulmonary Artery

-Lungs-Pulmonary Vein -LT. Atrium

- **Systemic**

-Lt Ventricle-Aorta-Arteries-Arterioles-Capillaries-Venules-Veins-Vena Cava

- Cerebral------brain
- Coronary----myocardium of heart
- Hepatic------liver , intestines
- Fetal------ temporary route between fetus & mother



THE HEART

- **The Endocardium** - lines the chambers of the heart. **In the chambers it** consists of a **simple squamous endothelium** overlying a delicate layer of **loose connective tissue**.

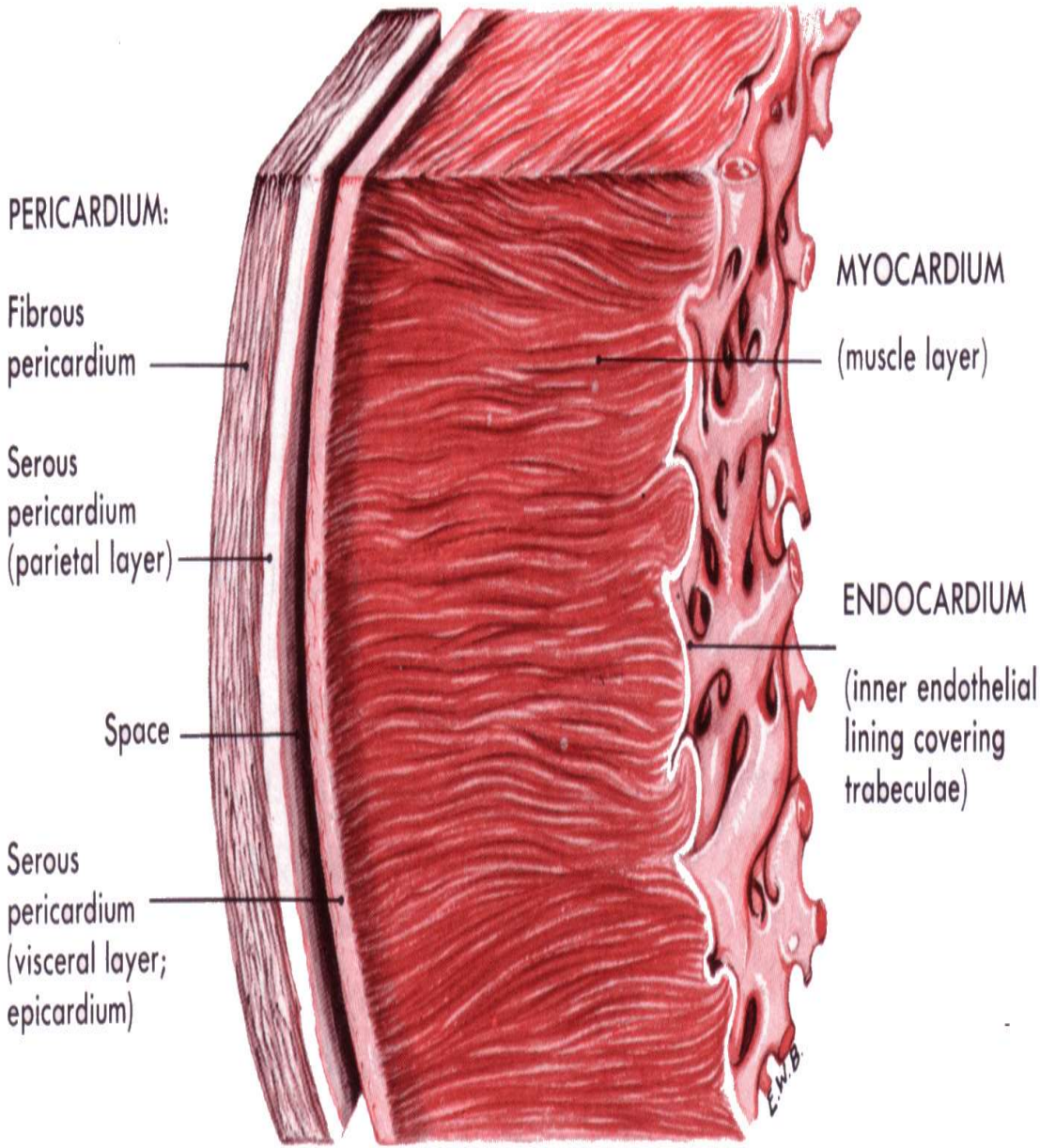
It lines the dense connective tissue of the cusps of the A-V valves.
It is **continuous** with the endothelium of the blood vessels.

- **The Myocardium** - the **muscular wall** of the heart composed of **cardiac muscle** and a reinforcing internal network of **fibrous connective tissue** called

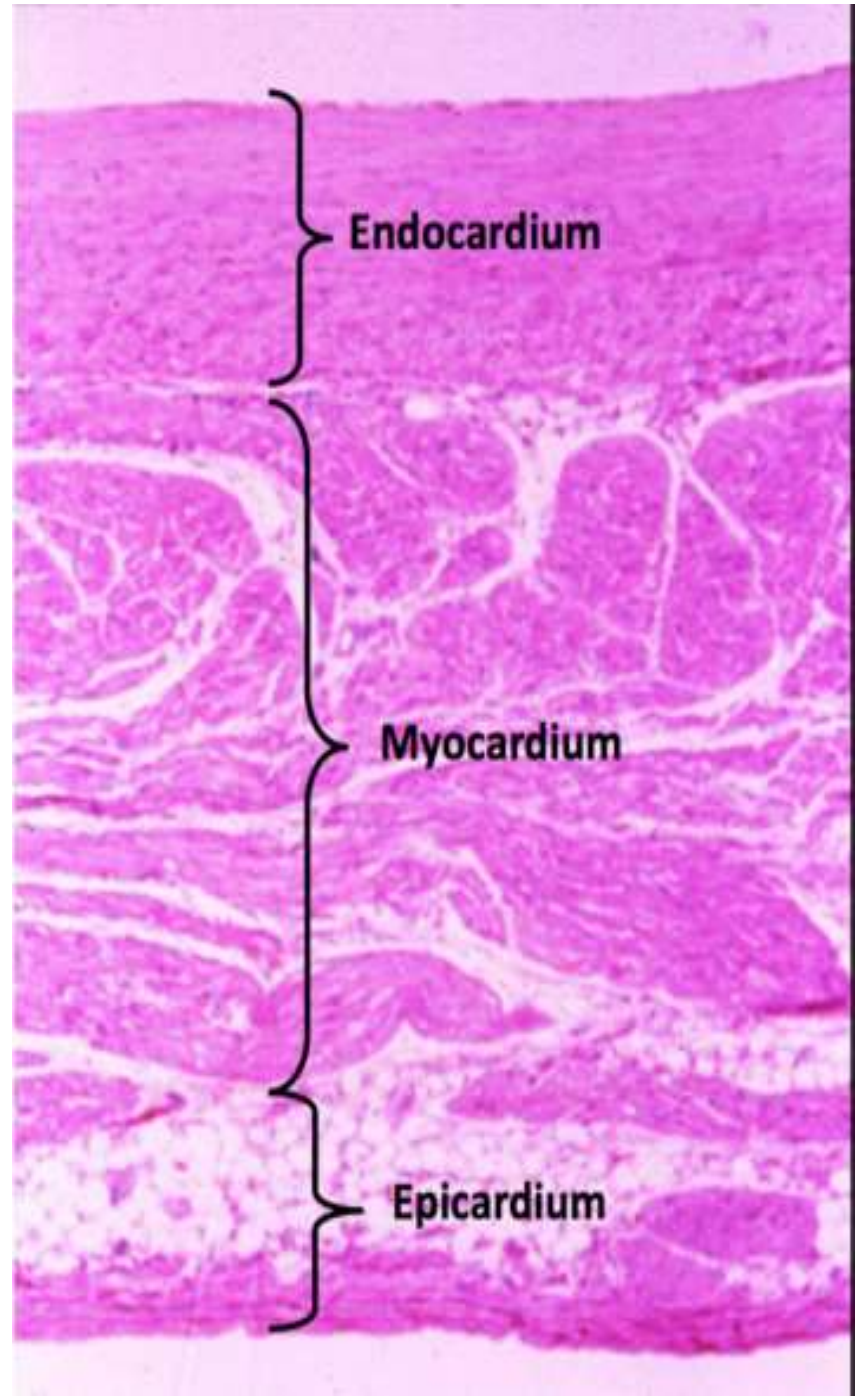
the "**skeleton of the heart**". This connective tissue serves two primary functions:

1. It provides **anchorage** for the cardiac muscle and the atrioventricular valves. The portion of the skeleton anchoring the A-V valves is called the **coronary trigone.**
2. The **elastic** component of the skeleton provides the **recoil** that assists in filling the chambers following systole.

- **Pericardium** - The outer coverings of the heart is a **double** sac of serous membrane surrounding the heart



Section of the heart wall showing the components of the outer pericardium (heart sac), muscle layer (myocardium), and inner lining (endocardium).



The Endocardium

lines the chambers of the heart. In the chambers it consists of a **simple squamous epithelium = endothelium** overlying a delicate layer of **loose connective tissue**.

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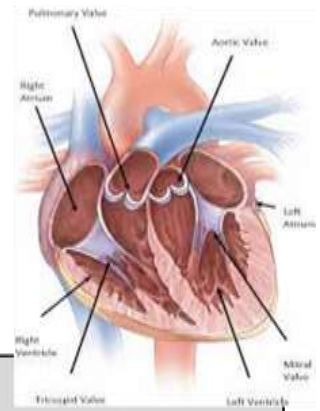
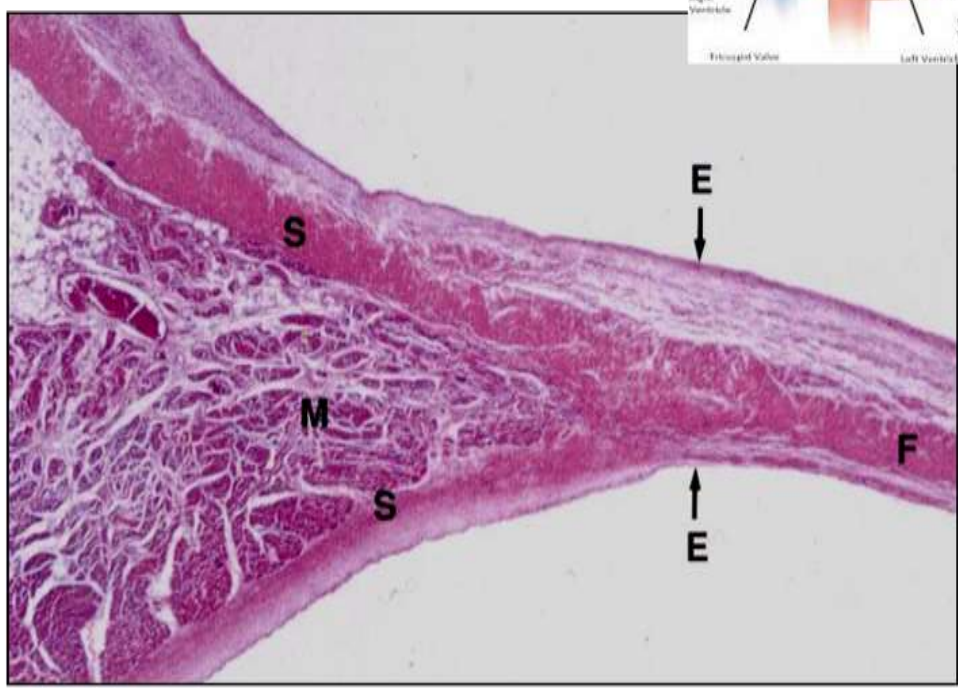


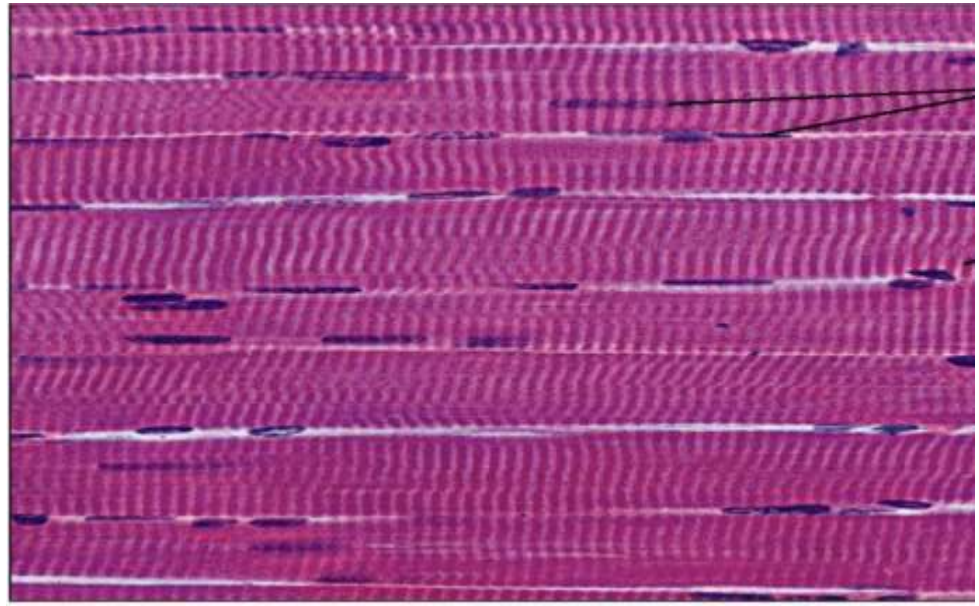
Cardiac Valves

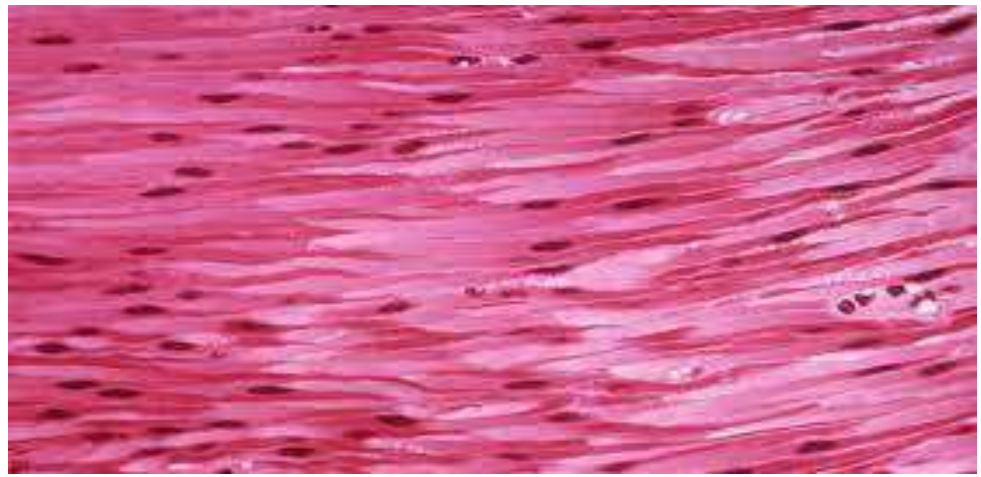
- All insert into fibrous **trigone**
- Connective tissue
- central **collagen** fibers sheet rich
- with **elastic** fibers

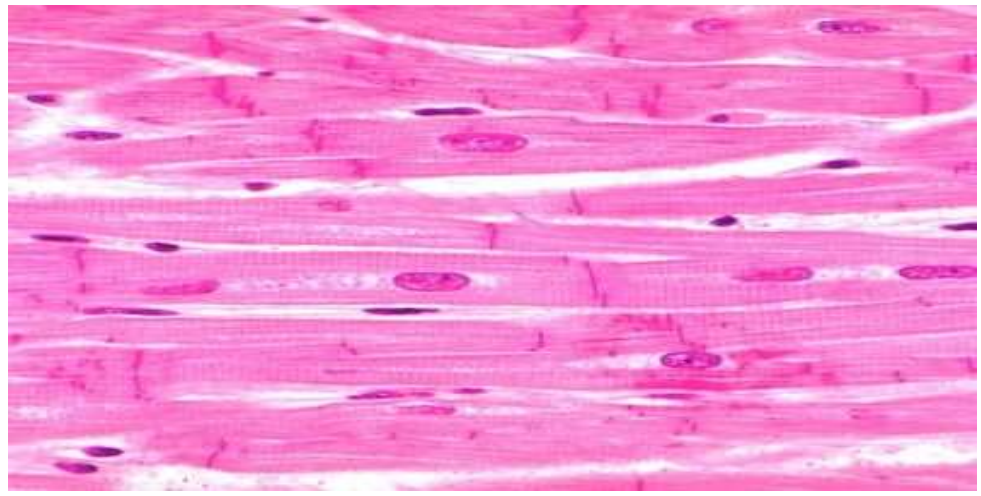
surrounded by **endothelium**



	Main features
Skeletal muscle	- Fibers : striated, tubular and multi nucleated - Voluntary - Usually attached to skeleton
Smooth muscle	- Fibers : non-striated, spindle-shaped, and uninucleated. - Involuntary - Usually covering wall of internal organs.
Cardiac muscle	- Fibers : striated, branched and uninucleated. - Involuntary - Only covering walls of the heart.







Myocardium

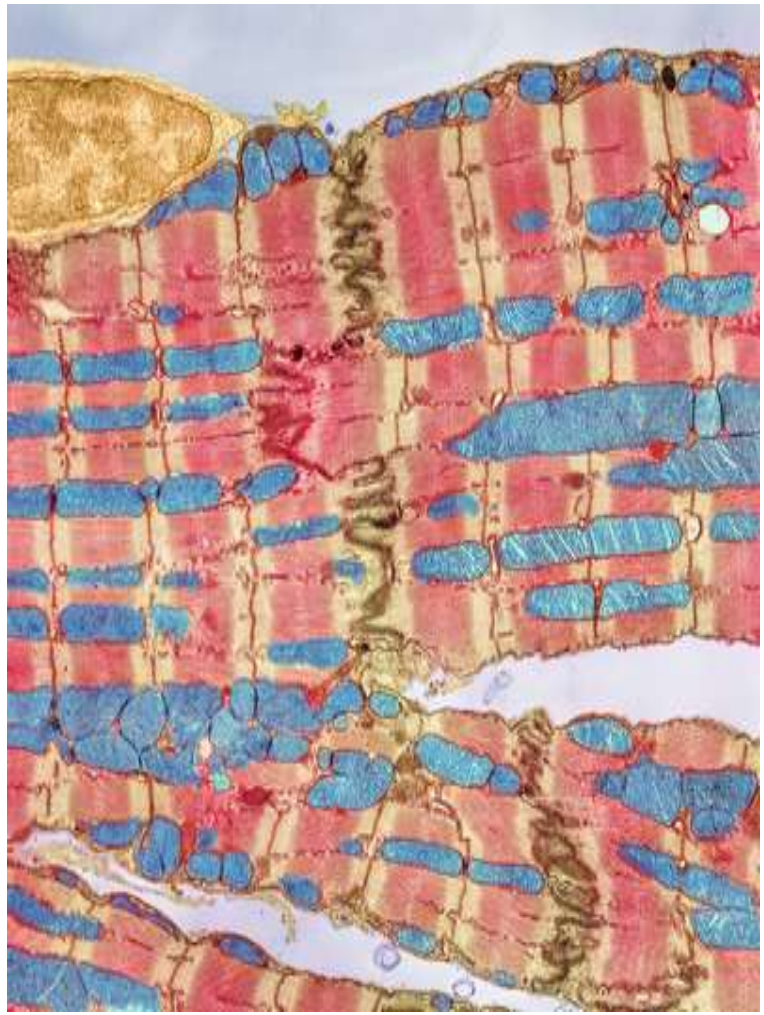
LM:

- Shorter than skeletal muscle
- Cylindrical in shape
- Branched.
- Striated.
- Has one nucleus in the center of the cell.
- Adjacent cells are interconnected end–to- end by **intercalated discs**.

Myocardium

EM of cardiac muscle :

- Striated, Branched.
- Rich in mitochondria
- interconnected end–to- end by **intercalated discs**.
- **Intercalated discs**



➢ Transverse Part:

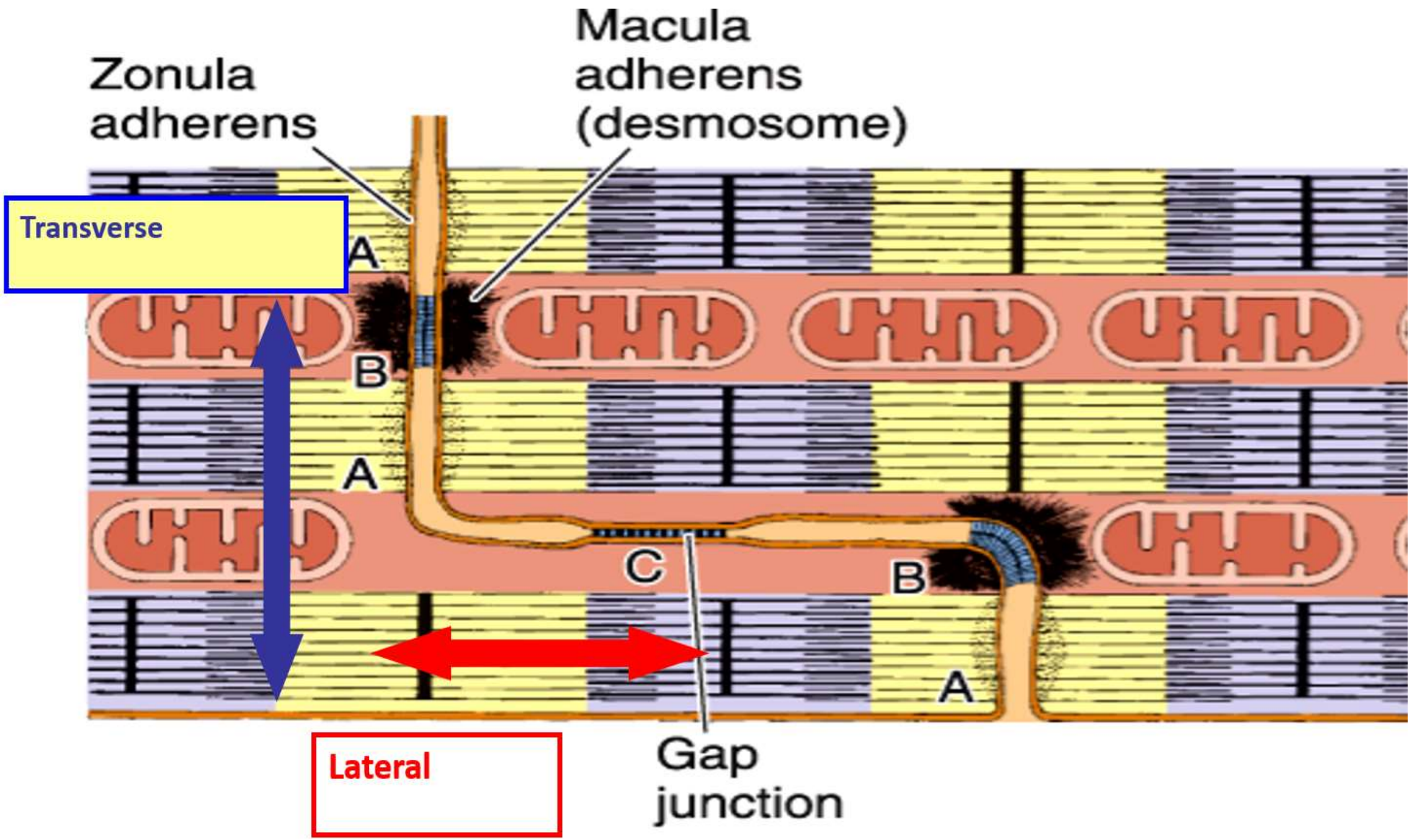
- **zonula (fasciae) adherents**
- **desmosomes (macula adherentes)** to **prevent the cells from pulling apart** under the strain of contraction

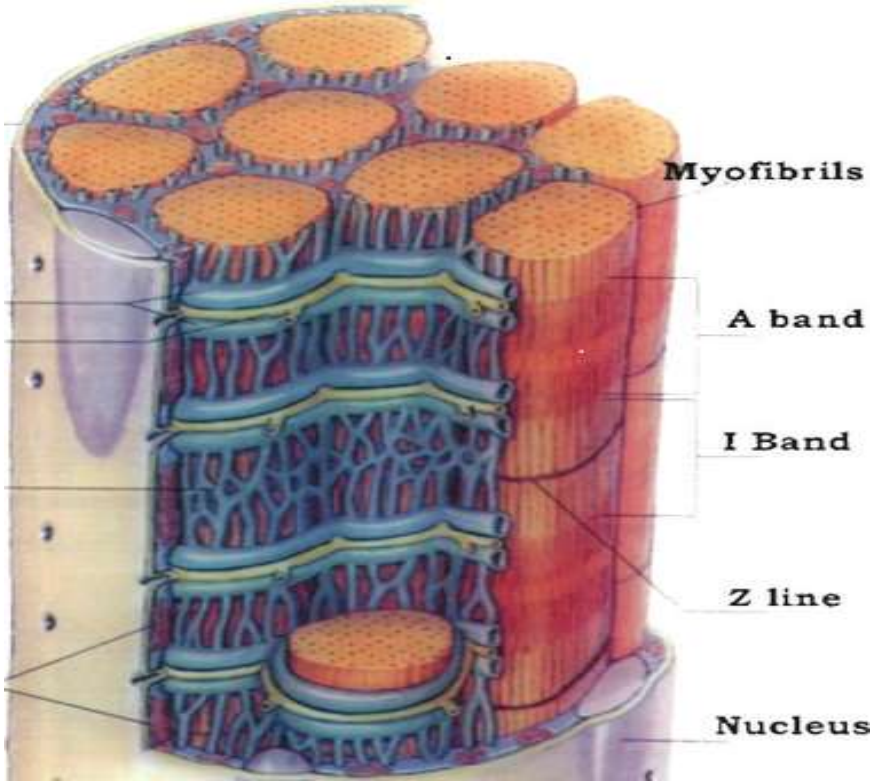
➢ Lateral Part:

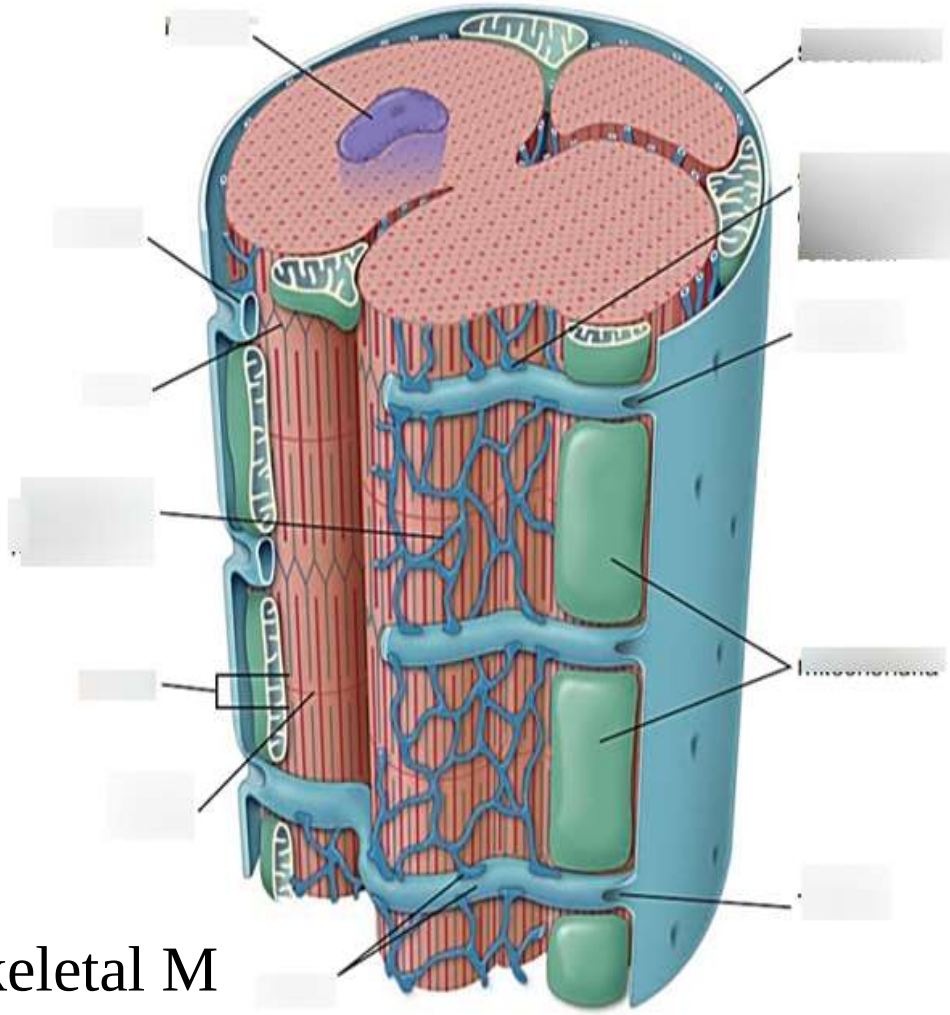
- **Gap junctions (nexus)** - for **impulse transfer** providing ionic continuity between adjacent myocytes (**electrical commtiunicaon** between cardiac muscle cells)

- **T – Tubules**
- **Sarcoplasmic reticulum**
- Others (glycogen , Lipid, Pigment)

Intercalated discs







❑ T- tubules :

- Larger than those in skeletal m
- At Z –line instead of A-I Junction in skeletal M
- Only one T- tubule per sarcomer , 2 in skeletal m

❑ Sarcoplasmic reticulum :

- Not well developed as in skeletal m
- Irregular and narrow with no terminal cisternae this arrangement is known as **diads in skeletal m called triad**

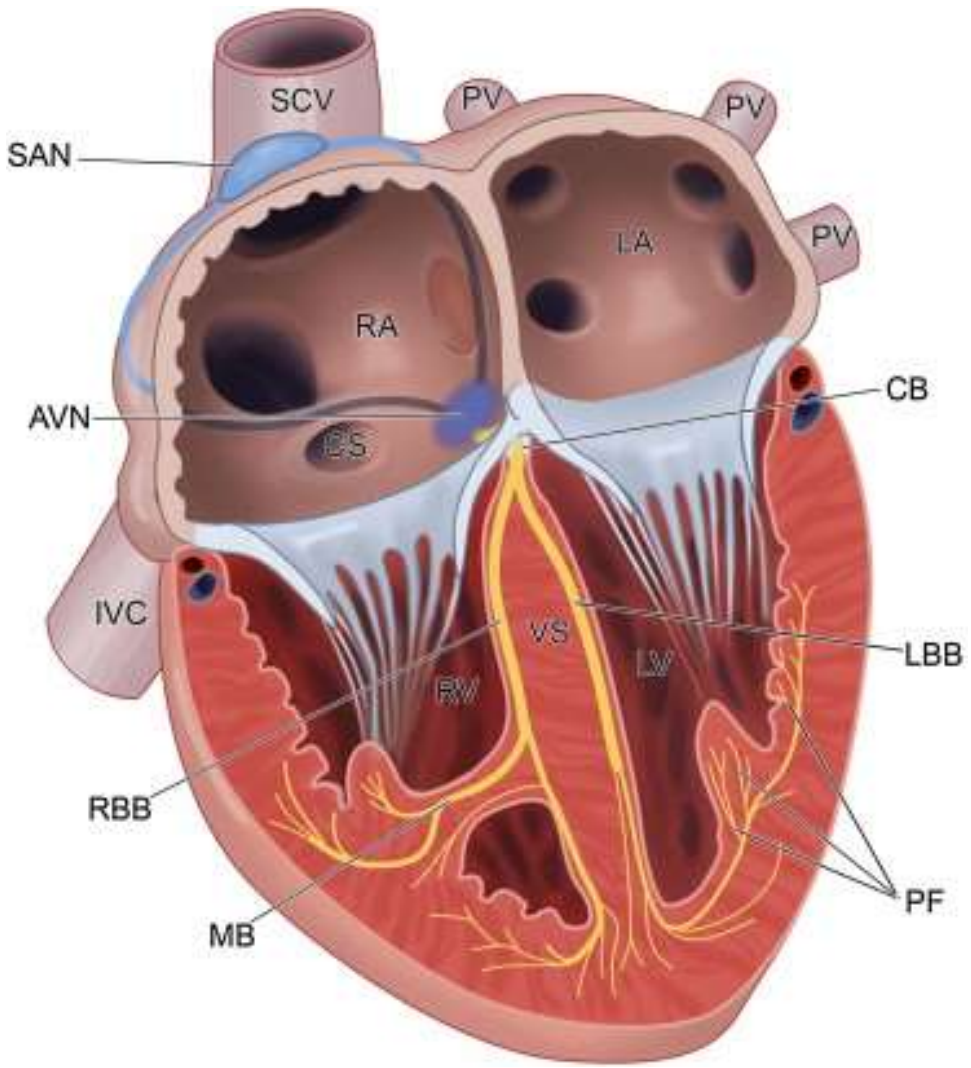
Types of cardiac muscle

Three main types :

- **Contractile**
- **Endocrine (ANF) = modified cardiac in Rt atrium**
- **Myocardium of conduction system**
  - **Sinoatrial (SA) node** located near the junction of the superior vena cava and the right atrium which **initiates** the beating action (called the **pacemaker**). SA node initiates an impulse that spread along the cardiac muscle fibers of the atria and along internodal pathways

Internodal pathways (tracts) form the communication between SA and AV nodes.

  - **Atrioventricular (AV) node** it electrically connects atrial and ventricular chambers, once the impulse reaches the AV node it is conducted across the fibrous skeleton to the ventricles by the
  - **Bundle of His (AV bundle)** which then divided into smaller
  - **Rt & Lt bundle branches** descending into interventricular septum.
  - **Purkinje fibers** stimulation of Purkinje fibers cause both ventricles to contract simultaneously.


SCV
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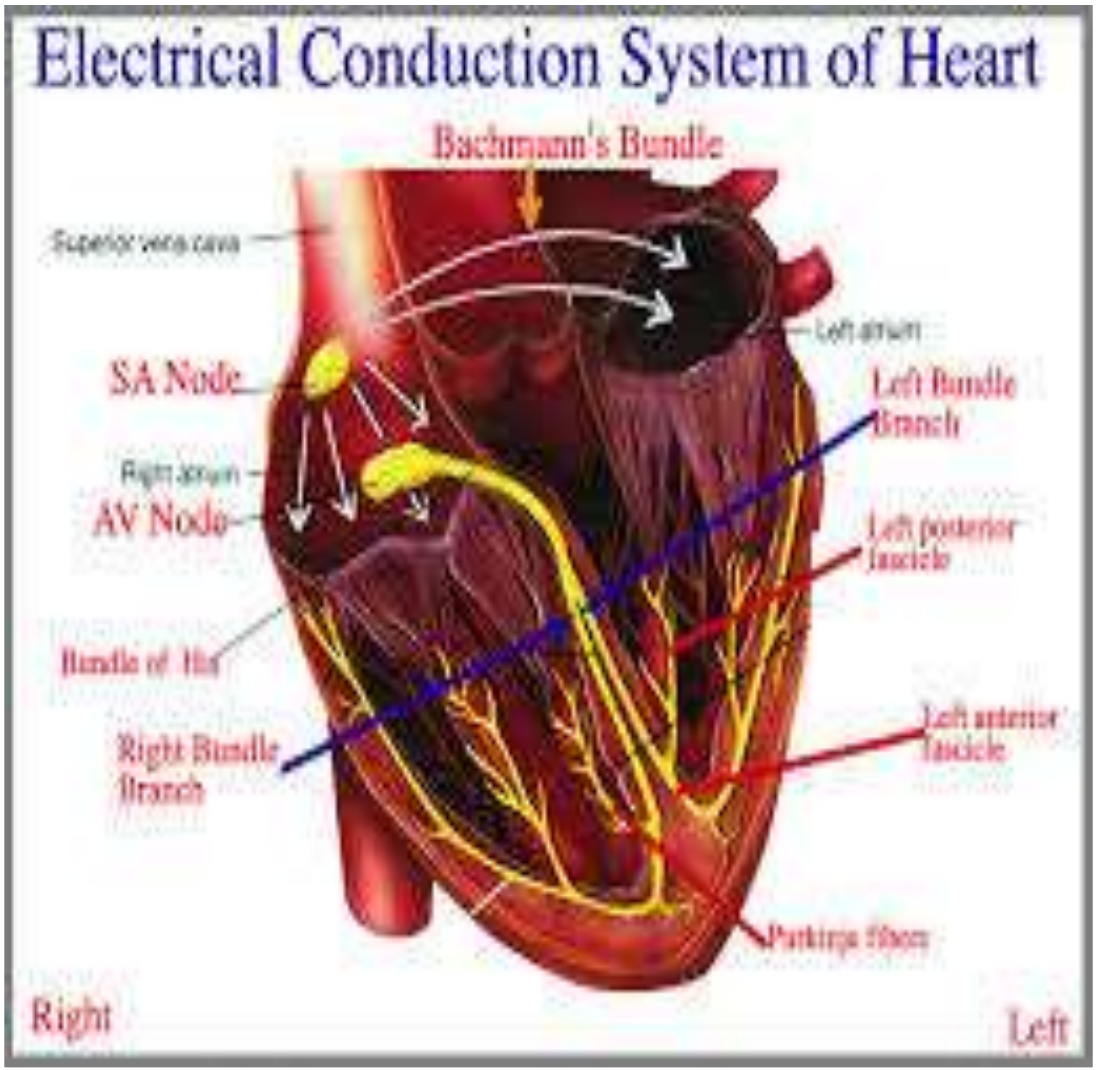
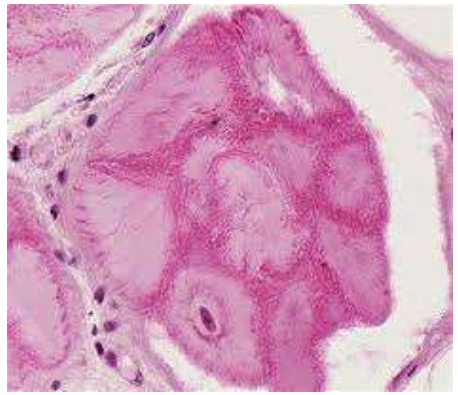

Electrical Conduction System of Heart
Bachmann's Bundle
SA Node
Left Bundle Branch
AV Node
Left posterior fascicle
Bundle of His
Right Bundle Branch
Left anterior fascicle
Purkinje fibers
Right
Left

Purkinje fibers

Site :

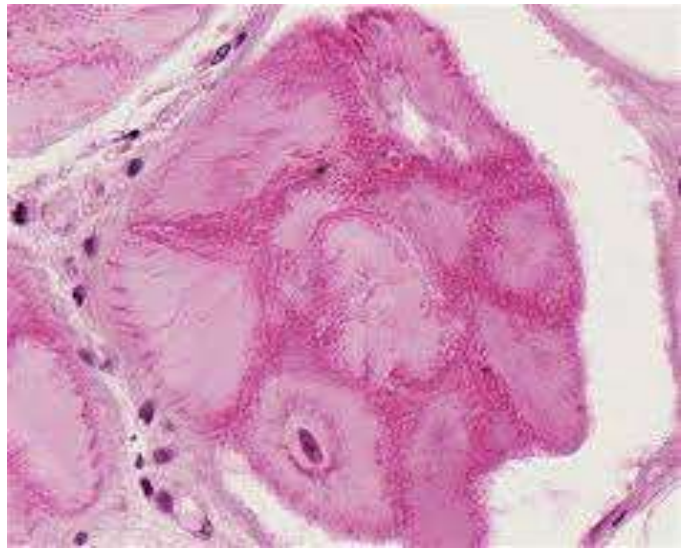
- **subendocardial branches**) are located in the inner ventricular walls of the heart just beneath the endocardium in a space called the **subendocardium**.

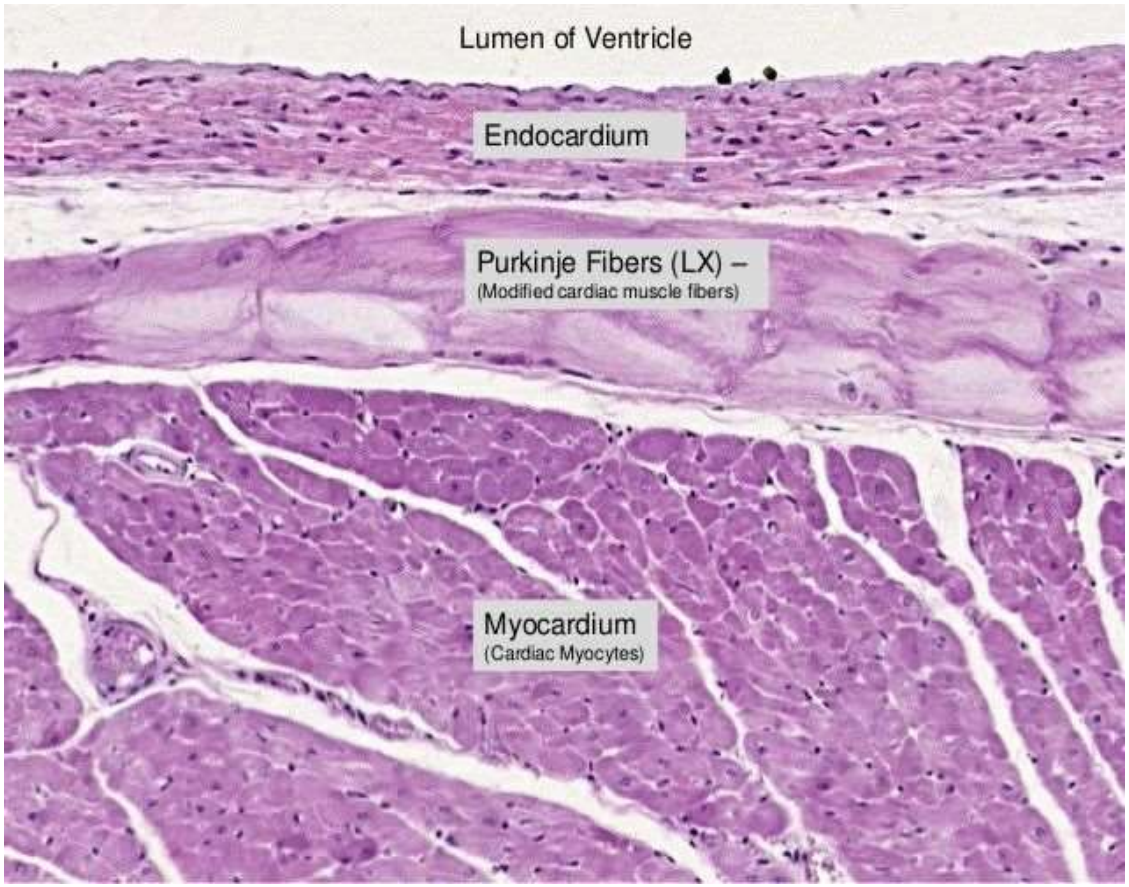


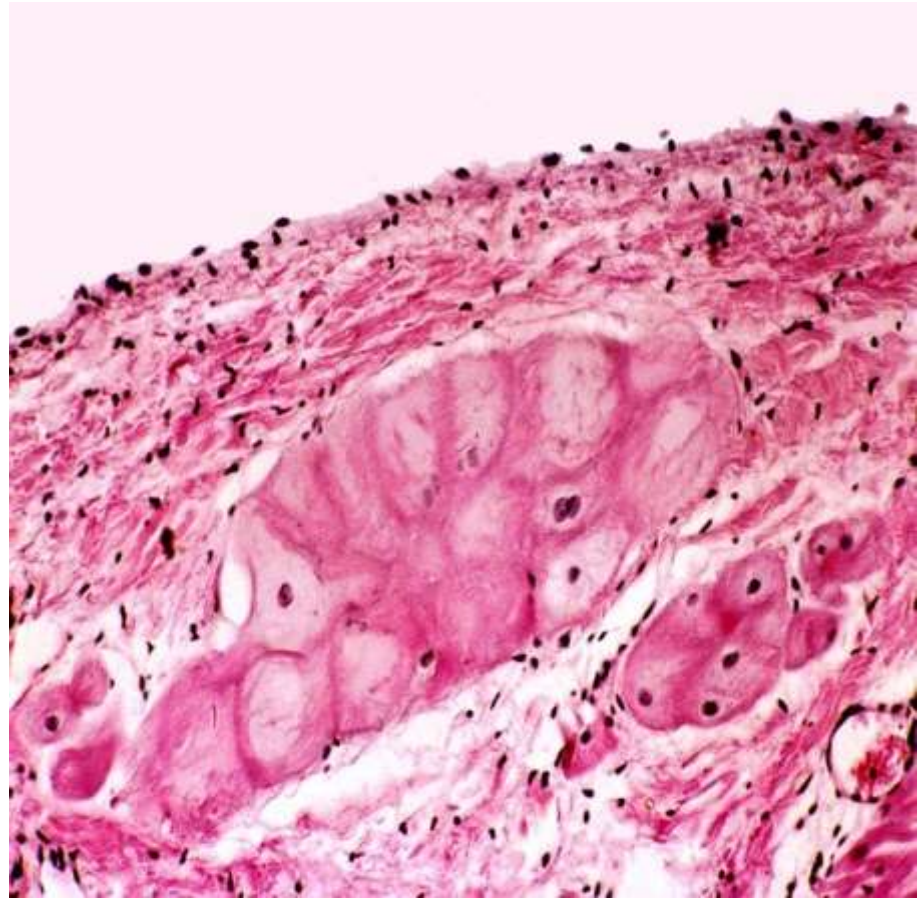
- Present in group **2 or more**
- They are often binucleated cells.
- Purkinje fibers are shorter, larger, **pale** .
- They are **larger** than cardiomyocytes with **fewer myofibrils** at the periphery and many mitochondria.
- Purkinje fibers take up stain differently from the surrounding muscle cells because of having relatively **fewer myofibrils** than other cardiac cells.
- The presence of **glycogen** around the nucleus causes
- **Not** contain T- tubules or **intercalated discs**

Function :

- They conduct cardiac action potentials **more quickly** than any other cells in the heart.

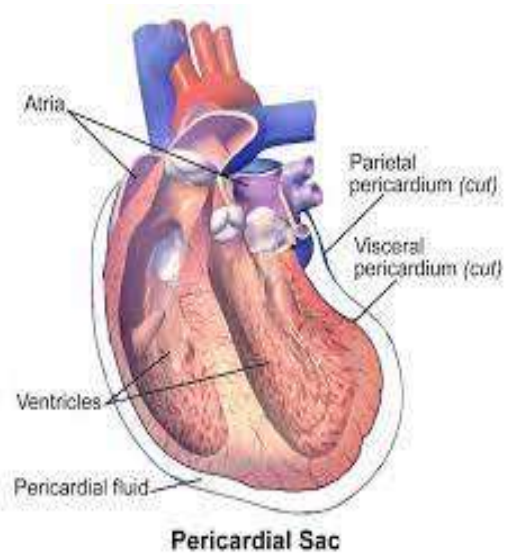



Lumen of Ventricle
Endocardium
Purkinje Fibers (LX) –
(Modified cardiac muscle fibers)
Myocardium
(Cardiac Myocytes)



Pericardium

The outer coverings of the heart is **the** a **double** sac of serous membrane surrounding the heart



Pericardial Sac

- **Visceral pericardium**
  - This layer is also called the **epicardium**.
  - It is well integrated with the muscular wall of the heart.
  - Its largest constituent is **connective tissue**

functions as a protective layer.

- **Parietal pericardium**

a loose fitting **outer membrane** consisting of two layers:

1. The **fibrous layer** - composed of **tough, white fibrous** tissue covering the heart .
2. a thin inner membrane composed of **a thin fibrous layer** on top of a **mesothelium**. This layer folds back over and adheres to the heart forming the **visceral pericardium**. **Mesothelium** is a simple squamous epithelial tissue, not only of the pericardial cavity but also peritoneal and pleural cavities (all major body cavities).

❑Growth and regeneration

- ❑A **satellite cell** help to repair skeletal muscle cells.
- ❑A **satellite cell** are located outside the sarcolemma .
- ❑If a cell is damaged to a greater extent than can be repaired by satellite cells, the muscle fibers are replaced by scar tissue in a process called **fibrosis**.
- ❑Smooth muscle tissue can regenerate from a type of stem cell called **a pericyte**
- ❑Pericytes allow smooth muscle cells to regenerate and repair much more readily than skeletal and cardiac muscle tissue.
- ❑cardiac muscle does **not regenerate to a great extent**. Dead cardiac muscle tissue is replaced by scar tissue, which cannot contract. As scar tissue accumulates, the heart loses its ability to pump because of the loss of contractile power. However, some minor regeneration may occur due to stem cells found in the blood that occasionally enter cardiac tissue.

Pericardial cavity

- is **a fluid-filled cavity** located between the parietal and visceral membranes contain **pericardial fluid**.
- This fluid **prevents the heart and lungs from rubbing against each other during their actions.**
- **Pericarditis** is an inflammation of the pericardium.

It can produce painful adhesions between the membranes.

- **Endocarditis.**

is an inflammation of the endocardium

Growth and regeneration of cardiac muscle

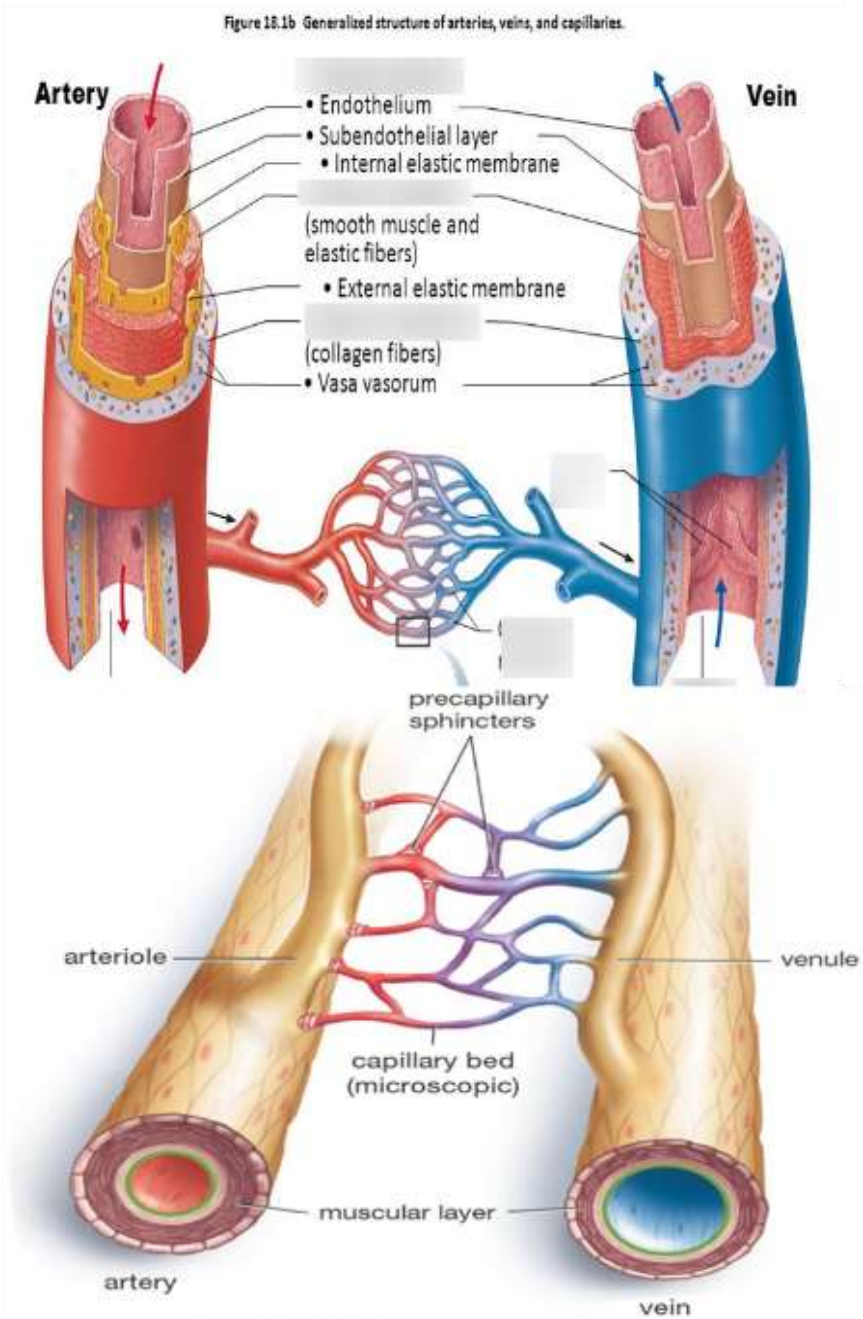
- Increase function demand by hypertrophy
- Satellite cells are absent
- No capacity to mitosis
- Injury of cardiac muscle replaced by fibrous scar

BLOOD VESSELS

- There are five main types of blood vessels; **arteries, arterioles, capillaries, venules** and **veins.**

General Structure of Blood Vessels:

- The arteries and veins have the same basic structure. Like the heart
- wall of the blood vessels consists of **three major layers or tunics**, while the capillaries have only one thick cell layer
- From inside to outside, the wall of the blood vessels consist of
  - **Tunica intima (the thinnest layer):** corresponds to and continuous with the endocardium of the heart
    - a single layer of simple squamous endothelial cells
    - Endothelial cells line the lumen of all the vessels of the blood vascular and lymphatic vascular systems.
  - subendothelial connective tissue
  - Internal elastic lamina elastic bands which delimits the intima.



❑ Tunica media (the thickest layer):

the **most variable** layer both in **size** and **structure** depending on the function of the vessel**.**

It is represented in the heart by the **myocardium**

Formed by a layer of **circumferential smooth muscle** and variable amounts of connective tissue.

A second layer of elastic fibers, **the external elastic lamina**, is located beneath the smooth muscle. It delimits the tunica media from outer layer

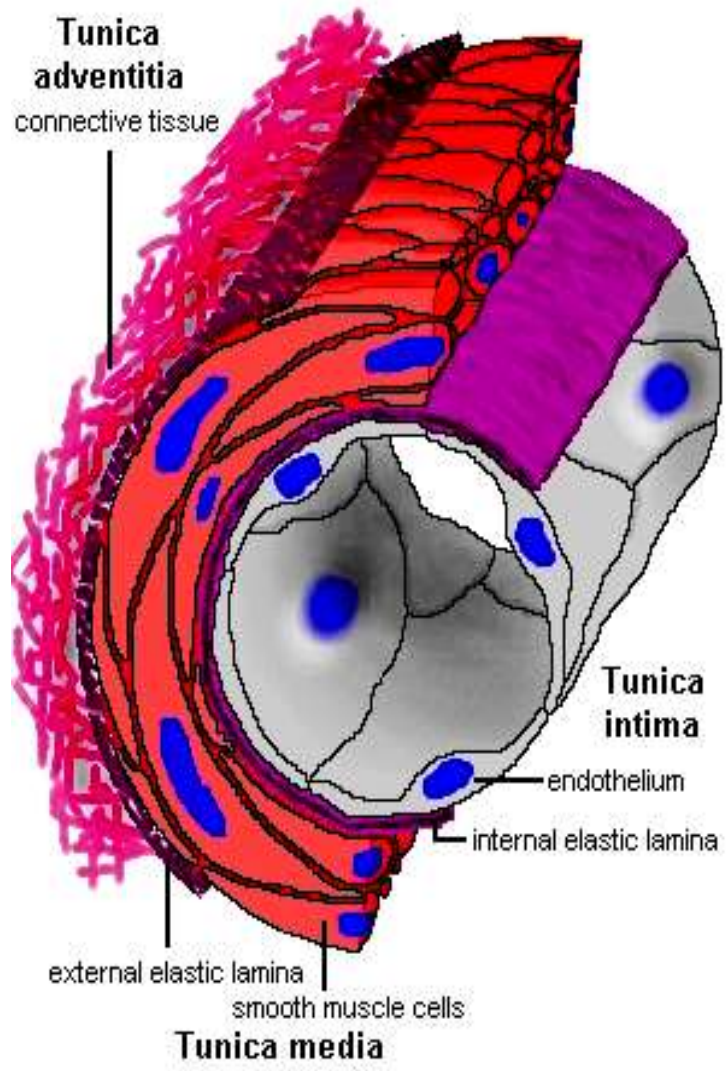
❑ Tunica adventitia,

also variable in thickness in different vessels, corresponding to the **epicardium** of the heart

❑ entirely made of **connective tissue**.

❑ It also contains **nerves** that supply the muscular layer,

❑ nutrient capillaries (**vasa vasorum**)in the larger blood vessels



ARTERIES

- Blood vessels that conduct blood away from the heart to organs and tissues, they branch along their course forming arteries progressively smaller diameter.

Arteries are classified into:

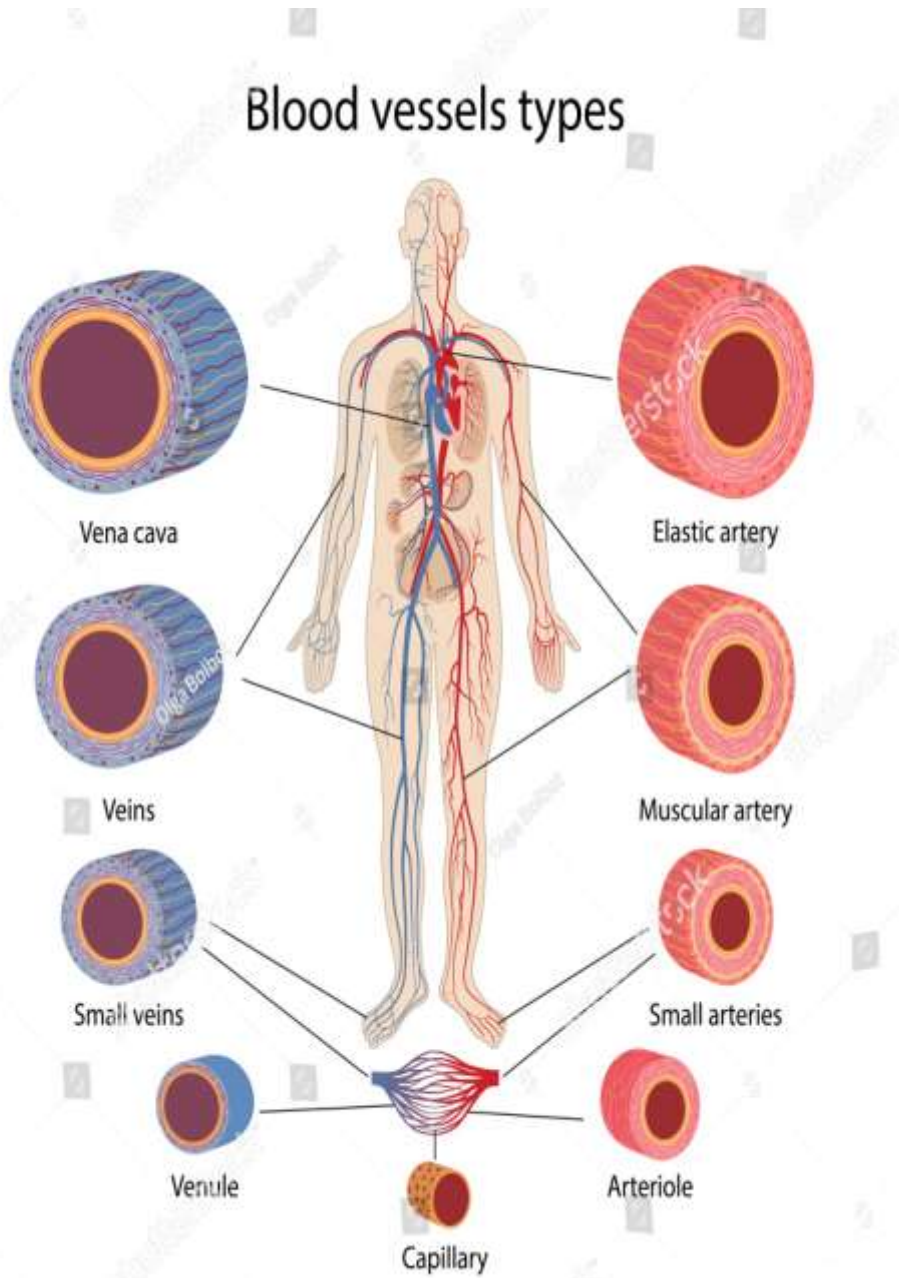
❑ **Conducting or Elastic Arteries**

= (large arteries)

Distributing or Muscular Arteries

=named = (medium arteries)

❑ **Arterioles (small arteries)**



Conducting or Elastic Arteries (large arteries)

- Elastic arteries are those nearest to the heart and because of the large content of elastic tissue they are **EXPANSIBLE.** As blood is pumped from the heart during contraction the walls of the elastic arteries expand; when the heart relaxes the **elastic recoil** of these vessels force the blood onward at the time when no pumping force is exerted by the heart.
- These are large arteries closest to the heart with very high blood pressure **e.g.** aorta, pulmonary, branches of the aorta.

Tunica intima 10 % of elastic arteries is **thicker** than in other arteries

- **Endothelium** with **Weibel-Palade** bodies **rod-like** inclusions that have a dense elements containing glycoprotein **von Willebrand factor** (facilitate platelets **coagulation, (carry factor VIII**), stored **only** in arteries and manufactured by most **endothelial** cells
- **Subendothelial CT**
- **Internal elastic** lamina is **less prominent**

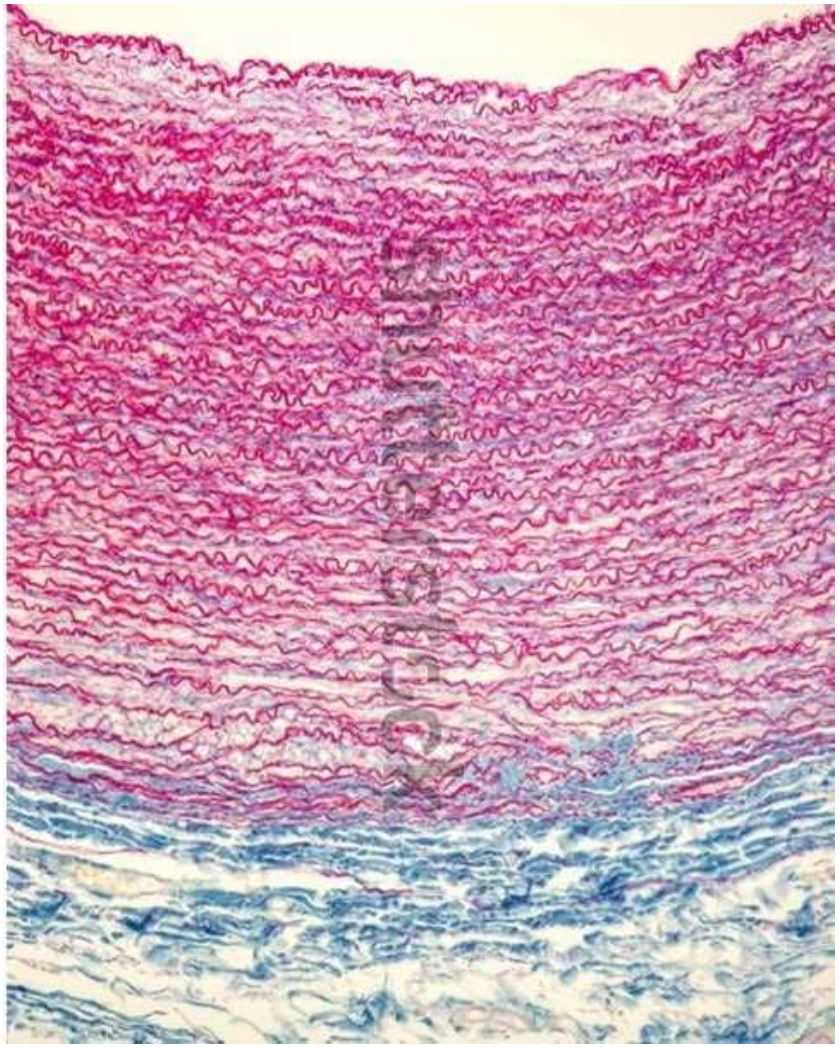
Tunica media 70 % which constitutes most of the wall.

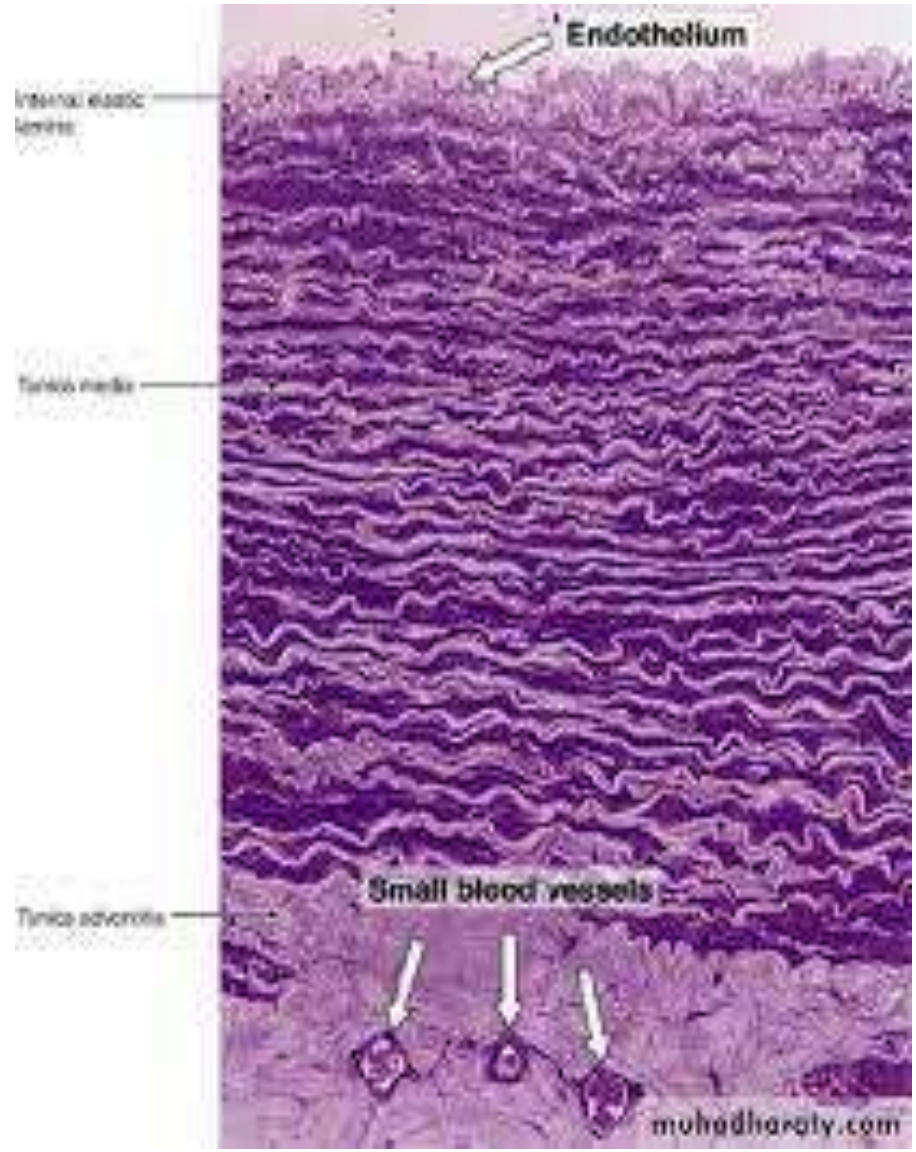
- ❖Distension (with the increase in **systolic blood** pressure) of the walls is facilitated by **concentric fenestrated lamellae of elastic fibers** in a thick tunica media (about 50 elastic lamellae).
- ❖**Smooth muscle** cells and **collagen fibers** (collagen **type III**) are present between the layers of elastic fibres.
- ❖**Indistinct external elastic lamina**

Tunica adventitia 20 % composed of elastic and collagen fibres and is provided with **vasa vasorum** and lymphatics

- The walls of these large arteries are so thick that their peripheral parts cannot derive enough oxygen and nutrients from the blood of the vessel that they form. Larger vessels are therefore accompanied by smaller blood vessels which supply the tunica adventitia and, in the largest vessels, the outer part of the tunica media of the vessel wall. These blood vessels are called **vasa vasorum**.

Conducting or Elastic Arteries





Distributing or Muscular Arteries (medium arteries)

- These are smaller diameter arteries with a slower blood flow.

Tunica intima is **thinner** than in elastic arteries **with endothelium** and **Weibel-Palade** bodies

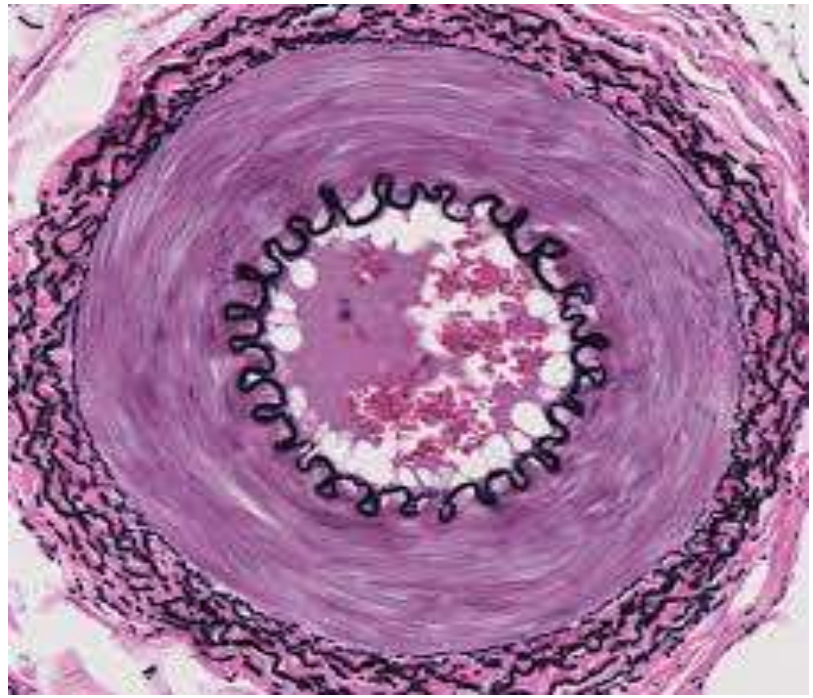
- The **internal elastic lamina** forms a **well defined layer** appears as a refractile wavy pink line

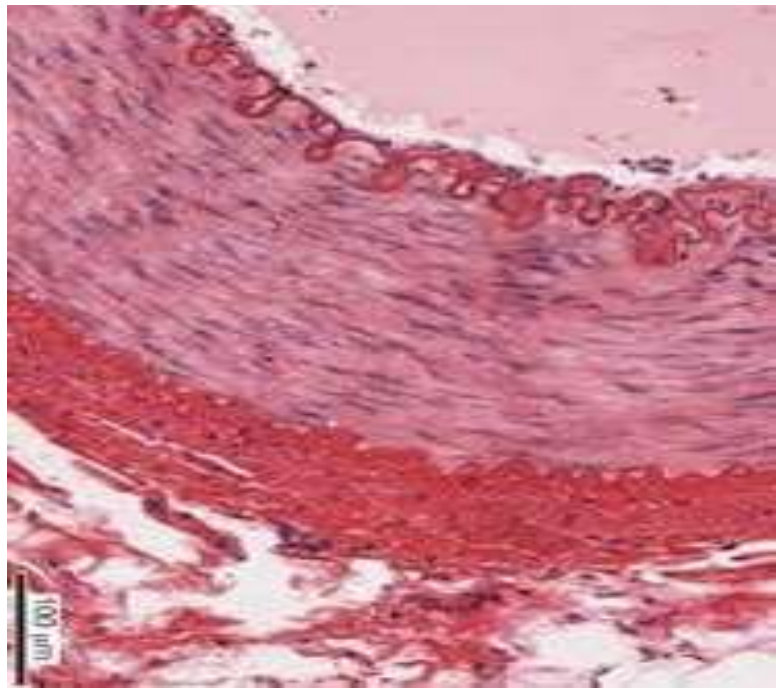
Tunica media 50% is dominated by **numerous concentric layers** of smooth muscle cells. **Fine** elastic fibres and a **few** collagen fibres

- The **external elastic** lamina can be **clearly distinguished** although it may be **incomplete** in places

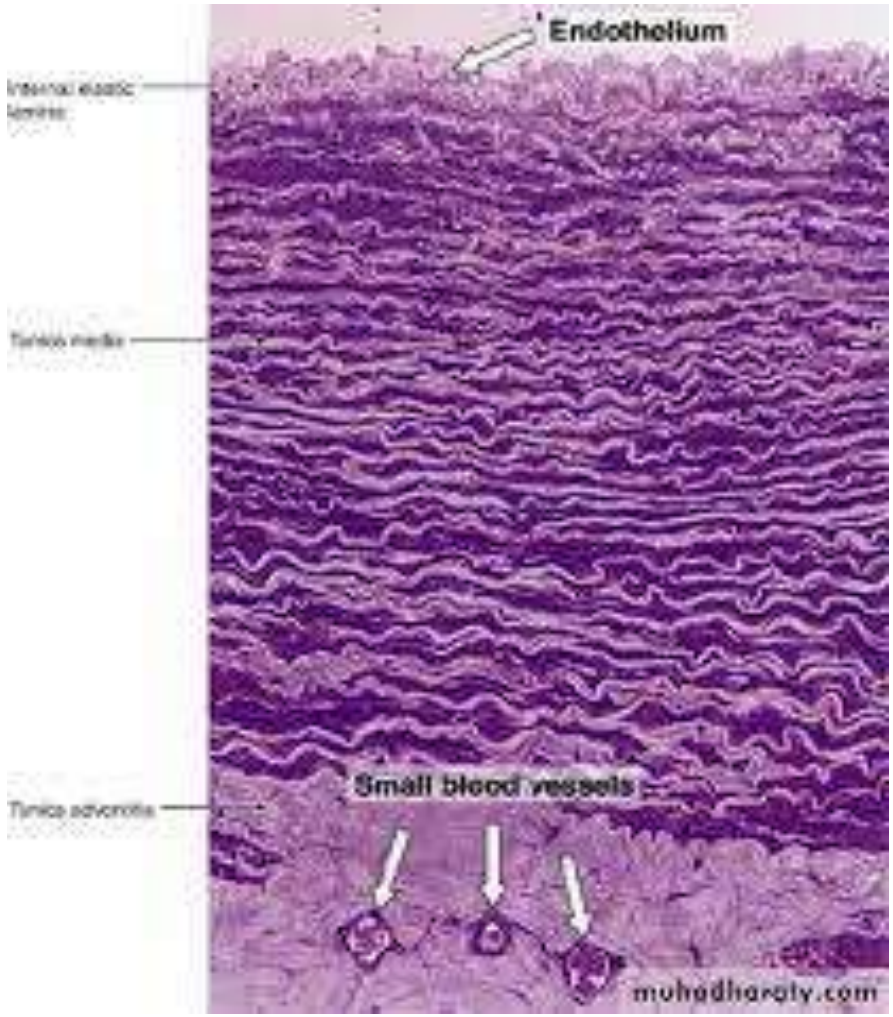
Tunica adventitia 50% The thickness and appearance of the is **variable**.

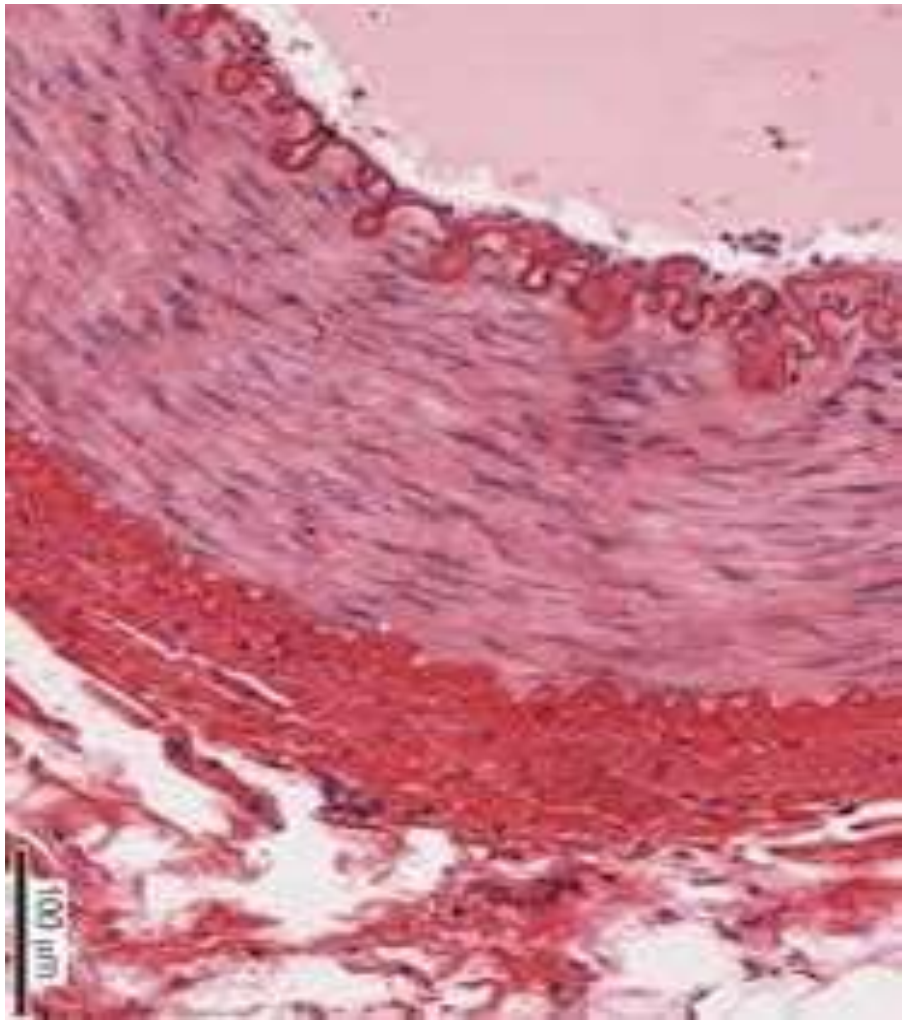
- Example: radial artery, splenic artery, brachial artery and femoral artery





Large & medium size arteries





	Large elastic artery	Medium size artery
Tunica intima	Thick layer , **10%** of the wall	Relatively thin layer
Subendothelium	Contain elastic , collagen and some smooth muscle	Contain elastic , collagen and No smooth muscle
Internal elastic lamina	Present but not evident	Well – developed and evident
Tunica media	**70 %** well developed fenestrated elastic laminae , smooth muscle , collagen fibers	**50%** well developed smooth muscle , little elastic and collagen fibers
External elastic lamina	Present but not evident	Well defined
Tunica adventitia	Thin coat **20%**	Thick coat **50%**
Vasa vasora	Numerous	Less

Modified medium sized arteries

1. Coronary artery

- Intima is **thickened** by musclo- elastic thickening in the subendothelium
- Internal elastic lamina is **fenestrated** to withstand internal pressure and external force
- Media is **thicker**

1. Pulmonary artery

- Contain **less** muscle & elastic fibers due to low blood pressure
- Cardiac muscle extend short distance in the artery

1. Cerebral artery

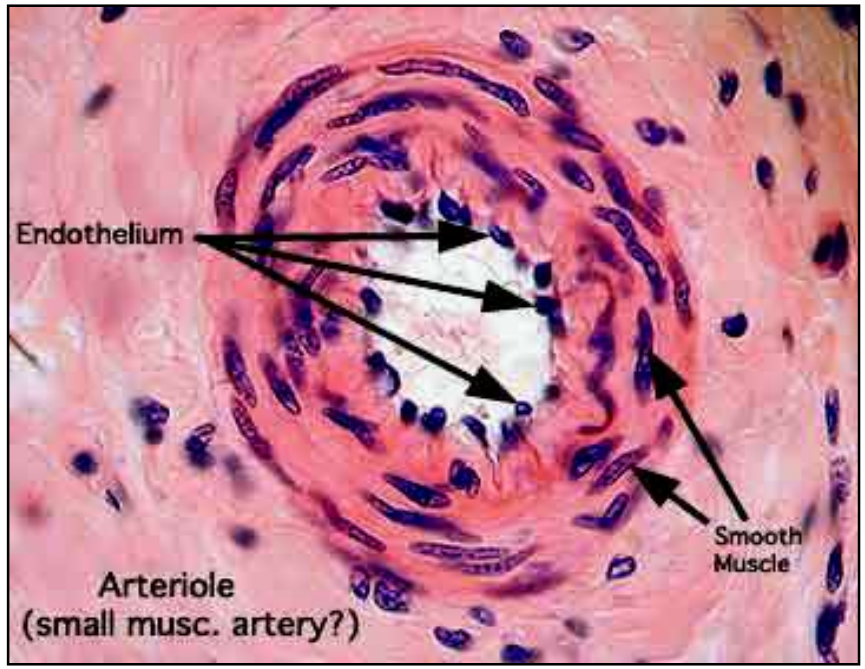
- Artery but similar to vein with wide lumen & thin wall
- Tunica media is **thin** with less elastic fibers
- Internal elastic lamina Well developed
- Tunica adventitia **Absent** becouse the artery well protected in the skull

Blood portal systems

- **In typical configurations**, an artery or arteriole carrying oxygenated blood enters the capillary bed, where there is exchange of oxygen and metabolites, and the vessel exiting the capillary bed is a venule or vein with deoxygenated blood.
- **Portal systems** describe situations where the blood vessel leaving the capillary bed is of the same category as the blood vessel entering the capillary bed. (vein - capillary bed - vein // artery - capillary bed - artery).
- In a **venous portal system** (such as in the liver) a vein (hepatic portal vein) enters the capillary bed and a vein (hepatic vein) exits the capillary bed.
- A similar portal system is found in the hypothalmus-hypophysis.
- An example of an **arterial portal system** is found in the renal cortex. Afferent arterioles break up into the capillary bed of the glomerular tufts of the renal corpuscle and the blood exits in efferent arterioles.

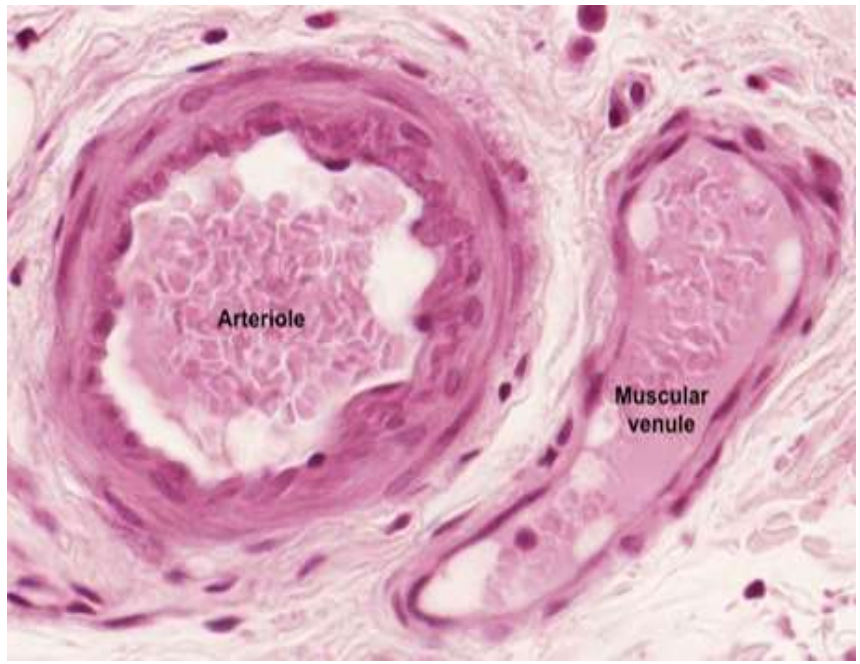
Arterioles (small arteries)

- Arterioles are the **major resistance vessels.** Since the artery, while reaching its target tissue, branches into several arterioles with diameters small enough to offer considerable resistance to flow



Tunica intima is smaller with **endothelium** and internal elastic lamina which may be **incomplete** and which is not always well-defined (absent in small and terminal arteriole but present in large arterioles)

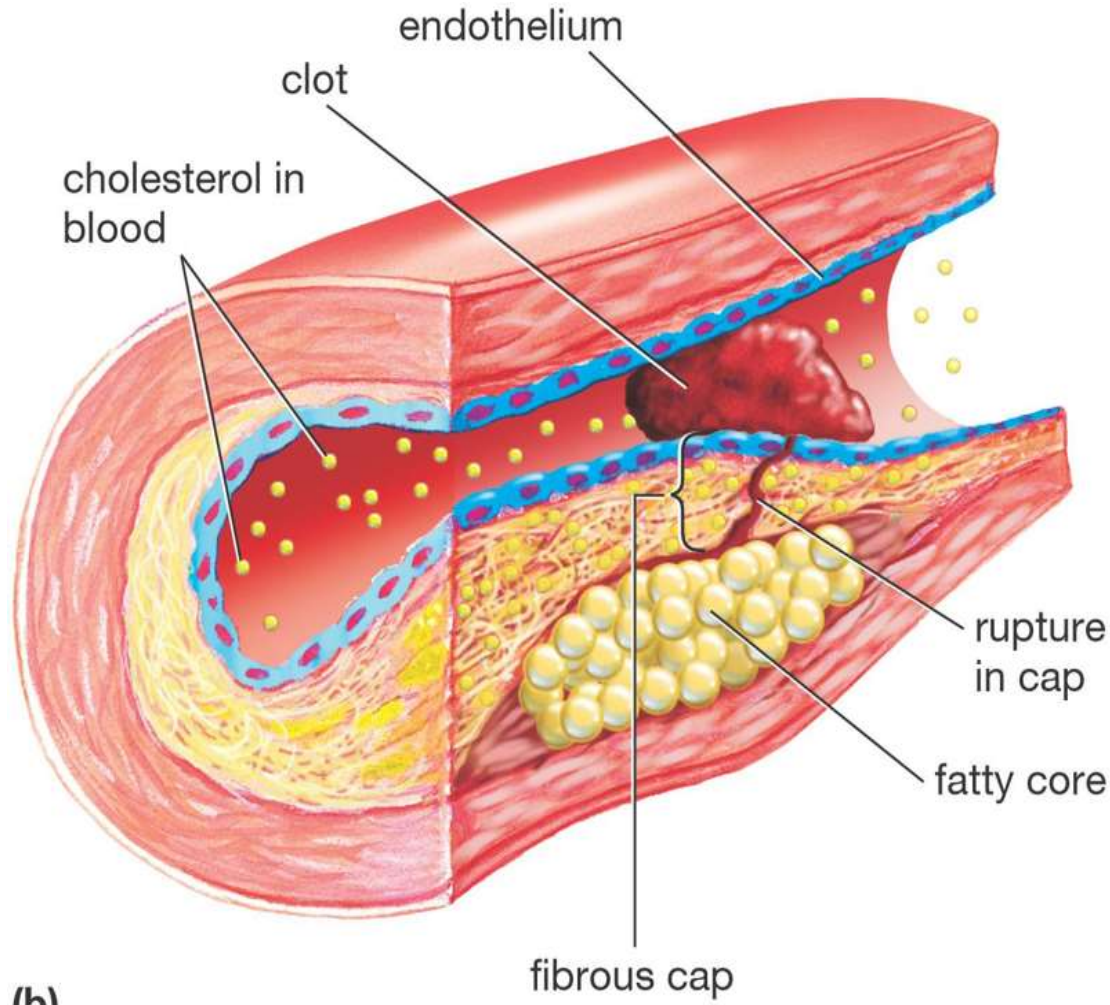
Tunica media is made up of **circular smooth muscles** i.e. single smooth muscle layer in small arterioles; **2-4 layers in large arterioles**



Tunica adventitia posses **autonomic** nerve fibres to control the size of the lumen which is responsible **peripheral resistance** necessary to control arterial **blood pressure**

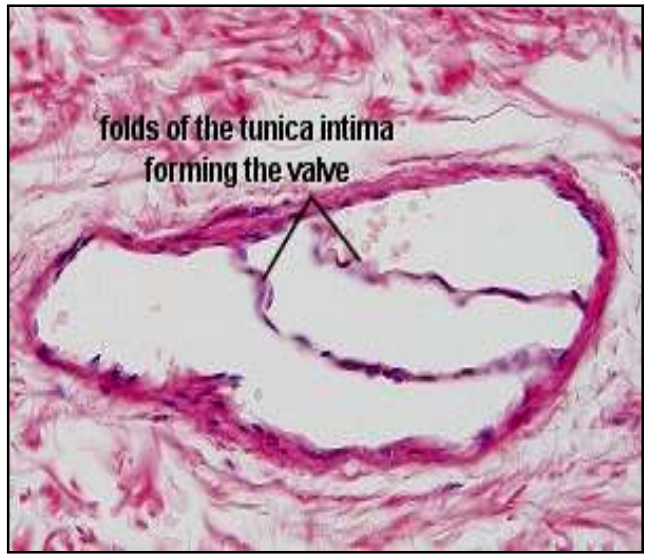
Atherosclerosis

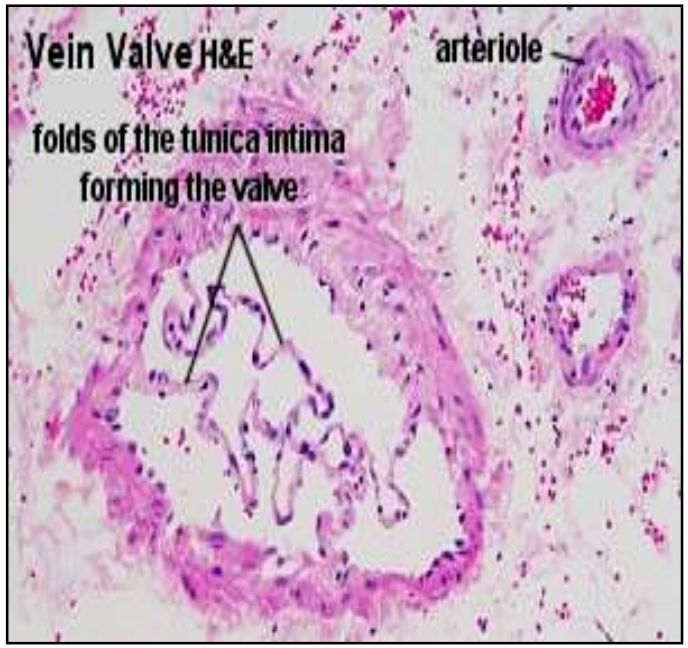
- LDL cholesterol forms plaques in arteries, triggering inflammation.
- The immune system forms a hard cap over the plaque, partially blocking the artery. Caps can rupture, creating clots that can close off an artery.



VEINS

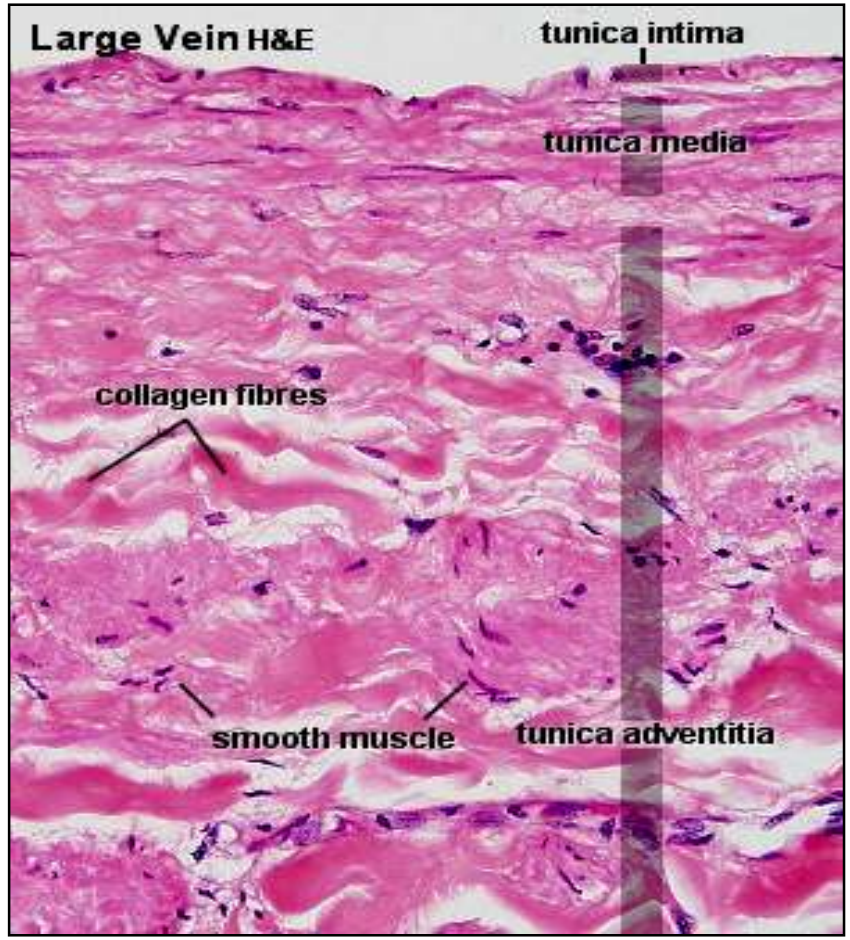
- Veins are subjected to more **variation** than arteries
- Veins are classified as **large**, **medium** or **small veins** (**venules**)
- Characteristics of veins:
  - more **numerous** than arteries
  - diameter of vessels is **larger** than that of adjacent arteries
- walls of veins are **thinner** and **less elastic** i.e. **little elastic recoil** (As a result in histological preparations the lumen often appears **collapsed** or **irregular**)
  - veins are highly **stretchabl**e (**less resistance**)
  - the relative numbers of **vasa vasorum** are **greater** in the veins (necessary as the vessels have much **less oxygenated** blood)
  - **valves** are found in veins.
  - Veins have **less** smooth muscles than arteries





Large veins

- The tunica media is relatively **thin**, and the tunic adventitia is relatively **thick**
- **Tunica intima** consists of **endothelium** with its **basal lamina** and a small amount of **subendothelial** connective tissue. Often the boundaries with tunica media is **not** clear
- **Tunica media** is relatively thin and contains **smooth muscle** cells, collagen fibers .
- **Tunica adventitia** is the **thickest** layer it has bundles of **longitudinal** smooth muscle cells, collagen and elastic fibers.



Medium veins

The **three tunics** of the wall are most evident in medium sized vein

- **Tunica intima** consists of **endothelium** with its **basal lamina**
- **Tunica media** is much **thinner** than in medium-sized arteries with circularly arranged smooth muscles
- **Valves** formed by loose, pocket-shaped folds of the **tunica intima**, which extend into the lumen of the vein, formed by **endothelium** lining covering a core of **elastic fibres** from both sides. The valves **prevent the backflow** of blood. Weakness in the walls of veins can result in **varicose veins** and improper closure of the valve
- **Tunica adventitia** is usually **thicker** than the tunica media and have **longitudinal** bundles of smooth muscles, collagen and elastic fibres

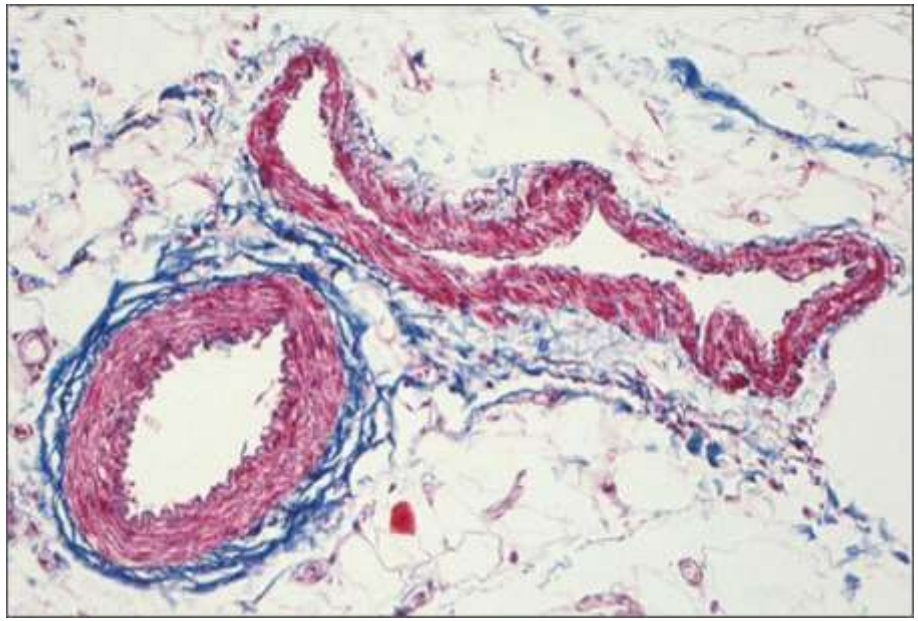
Venules:

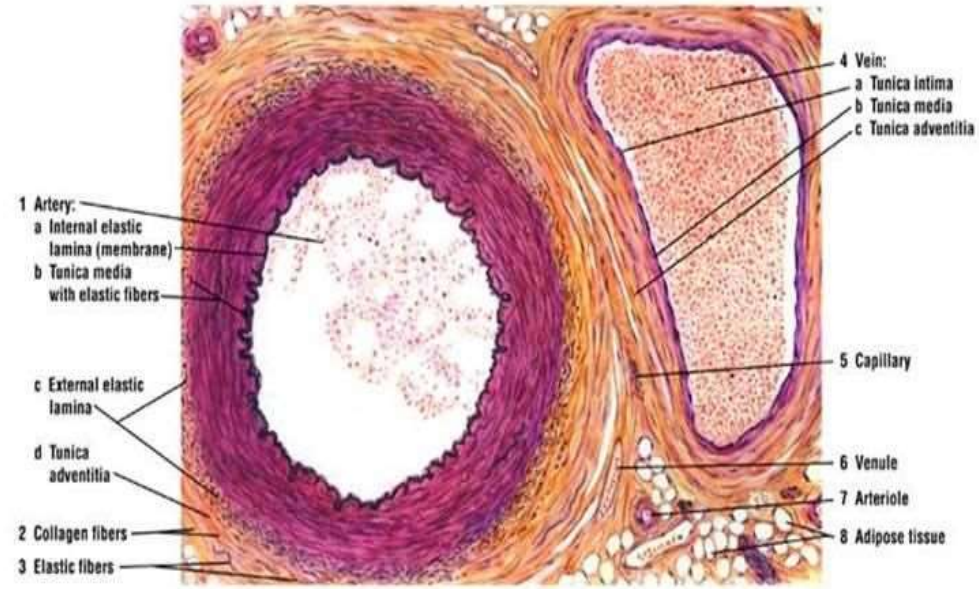
❑**Postcapillary venules and muscular venules**

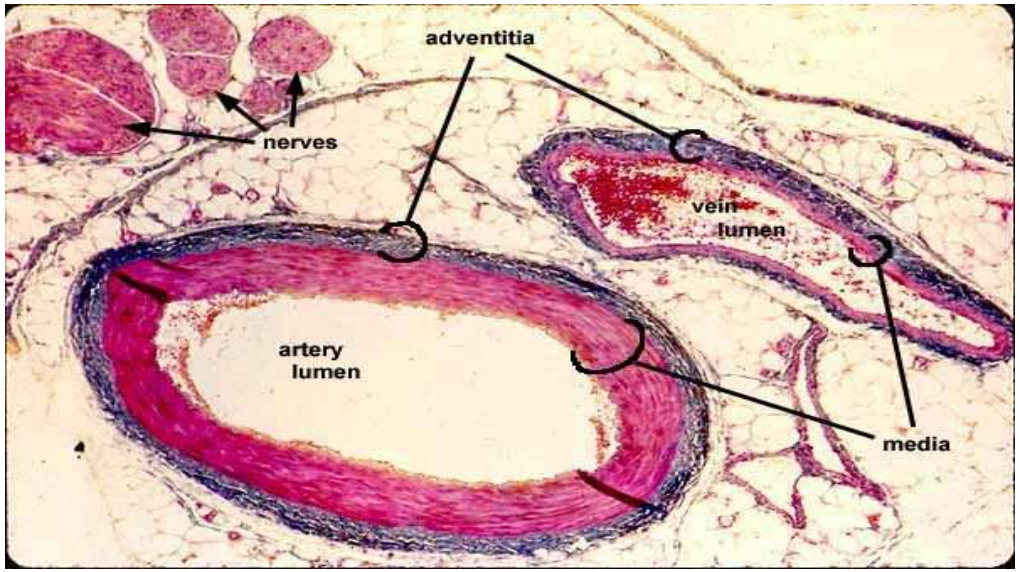
Postcapillary venules receive blood from capillaries and possess an **endothelial lining** with its **basal lamina** and **Pericytes**. They are larger than capillaries

❑**Collecting venules**

❑**Muscular venules** are distinguished from postcapillary venules by the presence of a **tunica media** (which is **present in muscular venules**)




1 Artery:
a Internal elastic lamina (membrane)
b Tunica media with elastic fibers
c External elastic lamina
d Tunica adventitia
2 Collagen fibers
3 Elastic fibers
4 Vein:
a Tunica intima
b Tunica media
c Tunica adventitia
5 Capillary
6 Venule
7 Arteriole
8 Adipose tissue


adventitia
nerves
vein lumen
artery lumen
media


Artery
Nerve
Vein

	Medium – sized artery	Medium – sized vein
Wall	Thicker	Thinner
Lumen	Narrow , circular , empty	Wider , collapsed, contain RBCs
Valves	Not present	Present
Tunica intima	Well – developed	Poorly – developed
Internal & external elastic laminae	Both are well developed	Both are absent
Tunica media	Thick 50% smooth muscle and elastic fibers	Thin 30% few smooth muscle no elastic fibers
Tunica adventitia	50% elastic and collagen fibers	Thicker 70% collagen fibers , no elastic fibers
Vasa vasora	May contain vasa vasora	More vasa vasora

Microvascular bed = peripheral circulation

composed of arterioles, capillaries and venules in the following arrangement:

- **Metarterioles** are small vessels provide direct communication between arterioles and venules and are important in bypassing the blood flow through the capillaries (form the proximal part of thoroughfare channel). True capillaries branch mainly from metarterioles and provide exchange between cells and the circulation. **Precapillary sphincters** are rings of smooth muscles at the origin of true capillaries that regulate blood flow into true capillaries and thus control blood flow through a tissue

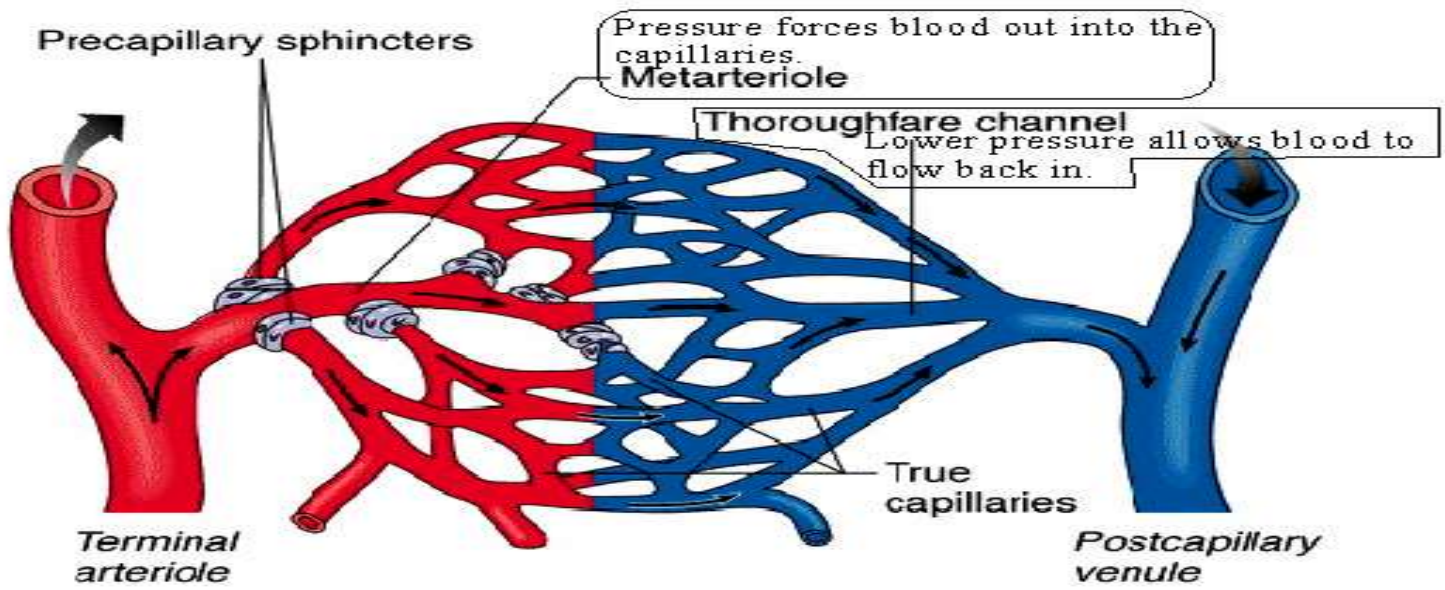
- The **thoroughfare channel** a structure so named because it is **without** precapillary sphincter. These channels drain the capillary bed and empty blood into small venules

- **Arterio-venous anastomosis (arterio-venous shunt)**

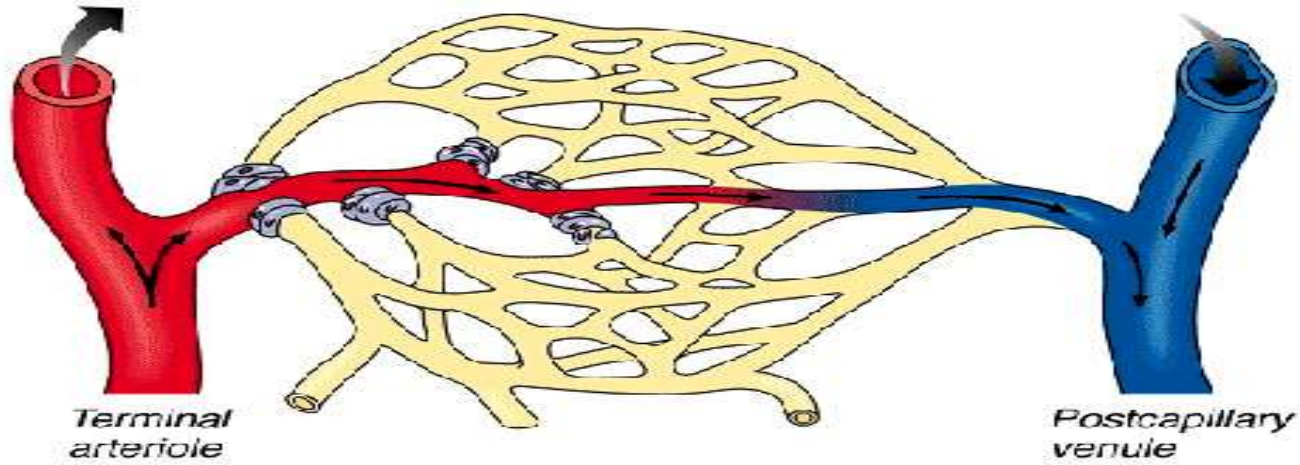
- These represent **direct connections** between arterioles and venules allow blood to bypass the capillary bed very common in the dermis of the **skin, lips, nose** and **GIT**

- **Functions** as **backup routes** for blood to flow if one link is blocked**, control blood flow** and **assist in temperature regulation**

Arteriovenous Anastomosis



(a) Sphincters open



(b) Sphincters closed

CAPILLARIES

Only the **tunica intima**

-endothelium, its **basal lamina** and the **pericytes (perivascular cells)**.

Function : -contractile --repairing -phagocytic

-Three different types of capillaries

-Continuous capillaries
-Fenestrated capillaries
-Sinusoids (discontinuous capillaries)

Continuous capillaries

continuous endothelium lining, continuous basal lamina

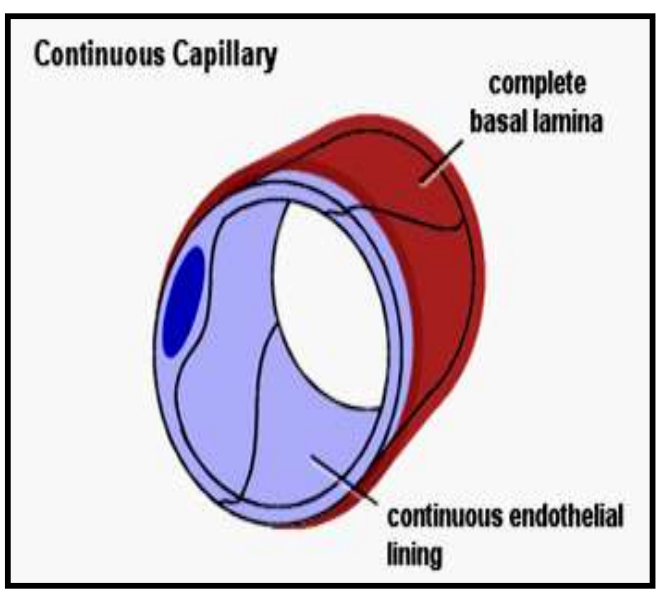
Site : blood-brain-barrier“, "**blood-thymus barrier**, **muscle** and **connective tissue**

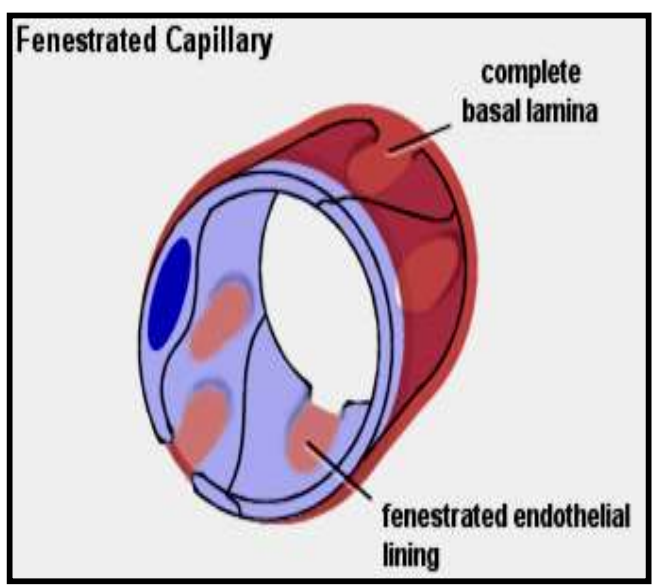
Fenestrated capillaries there are a **tiny pores (fenestrae)**

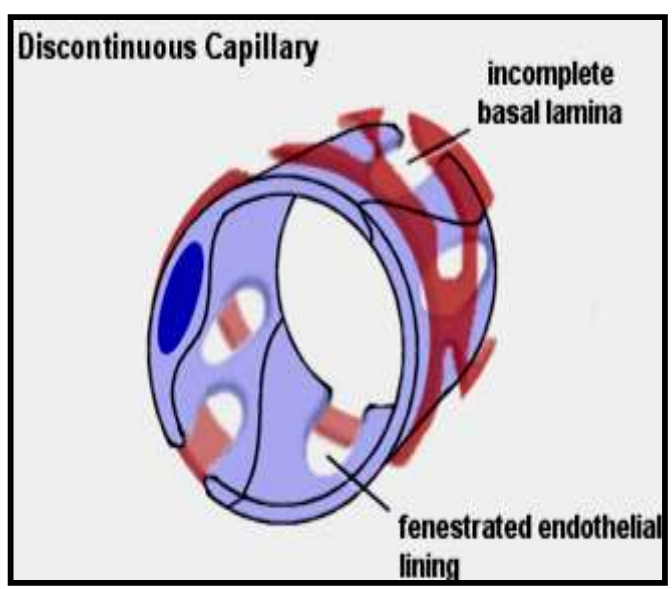
Site : e.g. the **endocrine glands**, **renal glomeruli** , **intestinal villi**

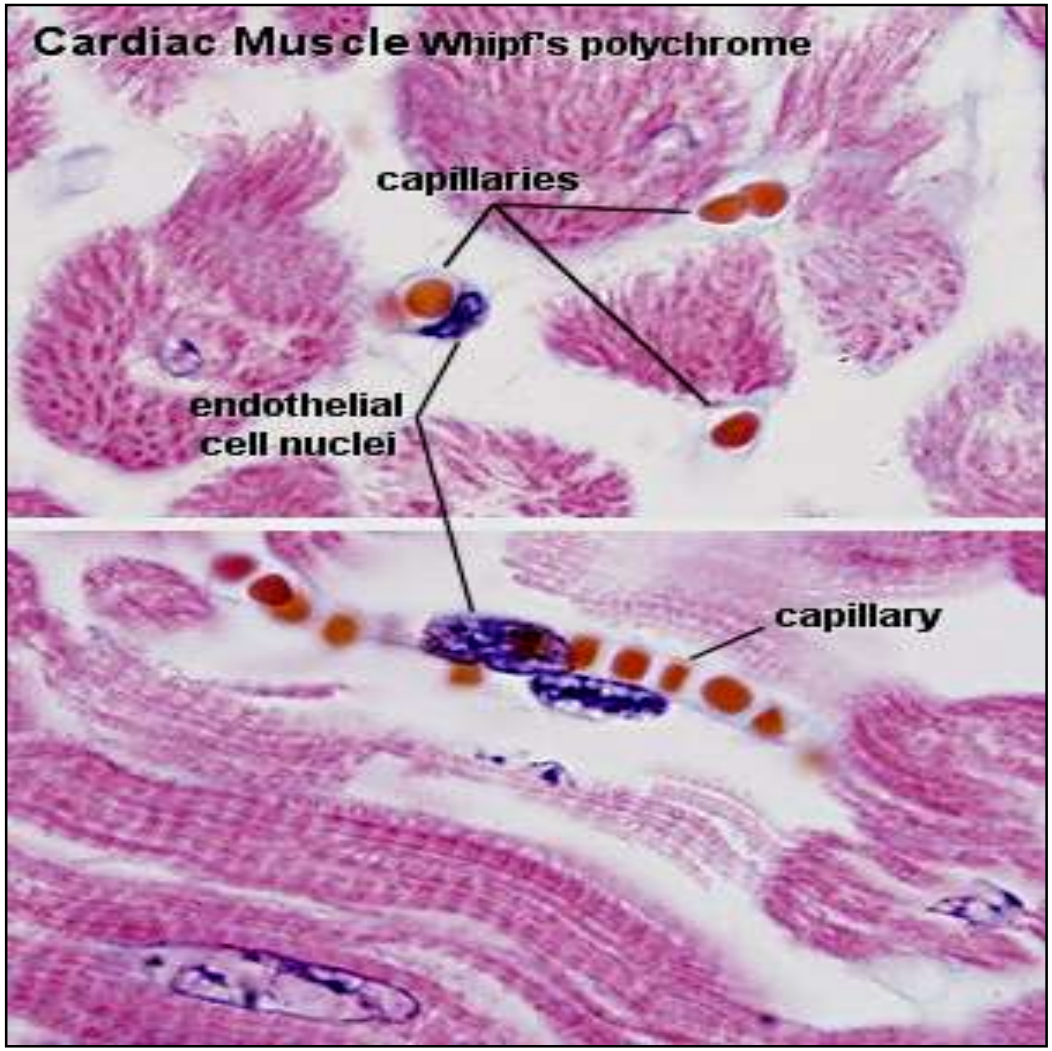
Discontinuous capillaries (Sinusoid)

- **irregular vessels** with large diameters
- endothelium with **gaps** and **discontinuous** basal lamina
- found where a very **free exchange** of substances e.g.
  - **-liver**
  - **-hematopoietic** organs (**bone marrow, spleen)**
  - **-endocrine glands**








Cardiac Muscle Whipf's polychrome
capillaries
endothelial
cell nuclei
capillary

	Blood capillary	Blood sinusoid
Lumen	Narrow lumen 9- 12 microns	Wide lumen 30 or more microns
Outline	Regular	Irregular
Types	Continuous , fenestrated	Always fenestrated
Basal lamina	Well developed basal lamina	Incomplete basal lamina
Associated cell	Pericytes	Macrophages
Site	Present every where	Bone marrow, liver , spleen, endocrine glands
Connection	Connect artery with veins	Connect vessels of the same kind usually veins

Lymphatic Vessels

Lymphatic Vessels

unidirectional flow, the lymph.

Three types

Lymph capillaries

larger than blood capillaries and **irregularly**

absent basal lamina

no tight junctions **entry of liquids** into the lymph capillary

temporary openings **larger particles** (lipid droplet) e.g. villi of the ileum and jejunum

Lymph collecting vessels

similar to lymph capillaries but **larger** and with **valves**

empty into **lymph nodes**

The lymph is moved by the **compression** of the lymph vessels by **surrounding tissues**

Lymph ducts

smooth muscle cells

They also form **valves** which may give **a beaded appearance** to the lymph

the right lymphatic duct and the **thoracic duct** **subclavian veins**

	Lymphatic capillary	**Blood capillary**
Connection	Blind end	Open at both end
Lumen	Wide	Narrow
Shape	Irregular and easy collapsed	Regular and rounded
Basal lamina	Lack continuous basal lamina	Have basal lamina and pericytes
Content	Carry lymph	Carry blood