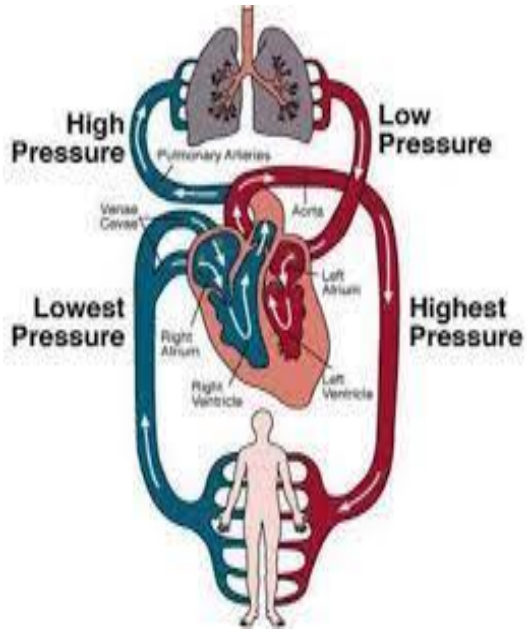
Circulatory system

Function :

The main job of the cardiovascular system is to transport (and exchange) nutrients , gases , hormones, body fluids, heat , waste material around the body.

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

- A heart to pump the fluid through the vessels
- Fluid (blood or hemolymph) that transports materials
- System of vessels (blood vessels , Lymph vessels)



- Lymph = Lymphatic vascular system
- Blood = CVS

The cardiovascular system is basically a closed system blood circulates through (blood vessels) and is propelled by a pump (the heart).

Major Blood Circulatory system

- **Pulmonary**

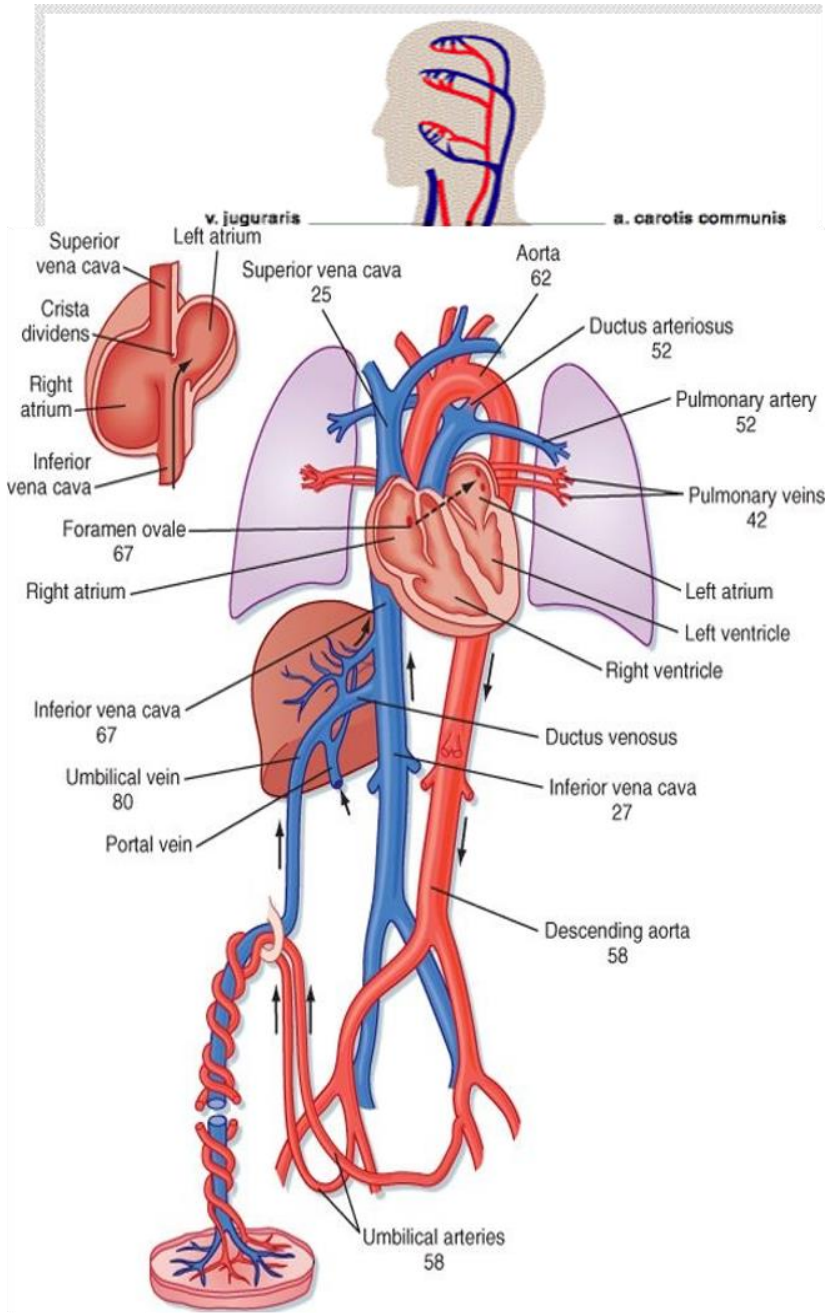
-Rt Ventricle-Pulmonary Artery

-Lungs-Pulmonary Vein -LT. Atrium

- **Systemic**

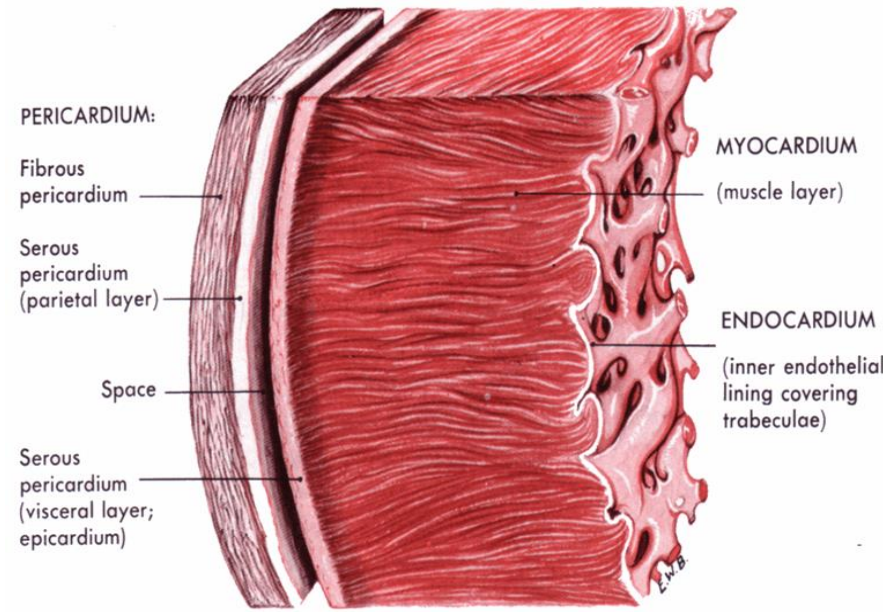
-Lt Ventricle-Aorta-Arteries-Arterioles-Capillaries-Venules-Veins-Vena Cava

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

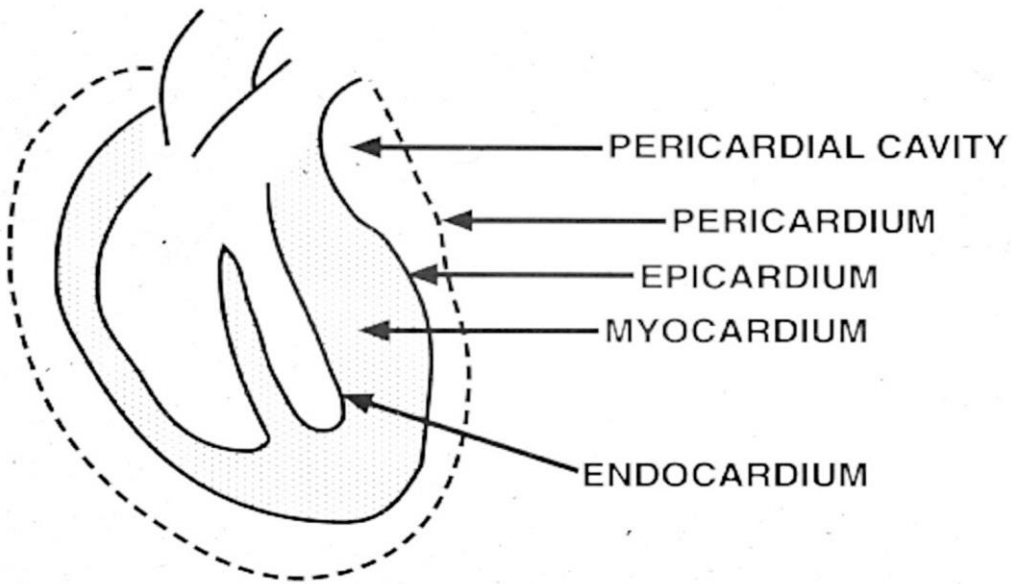


THE HEART

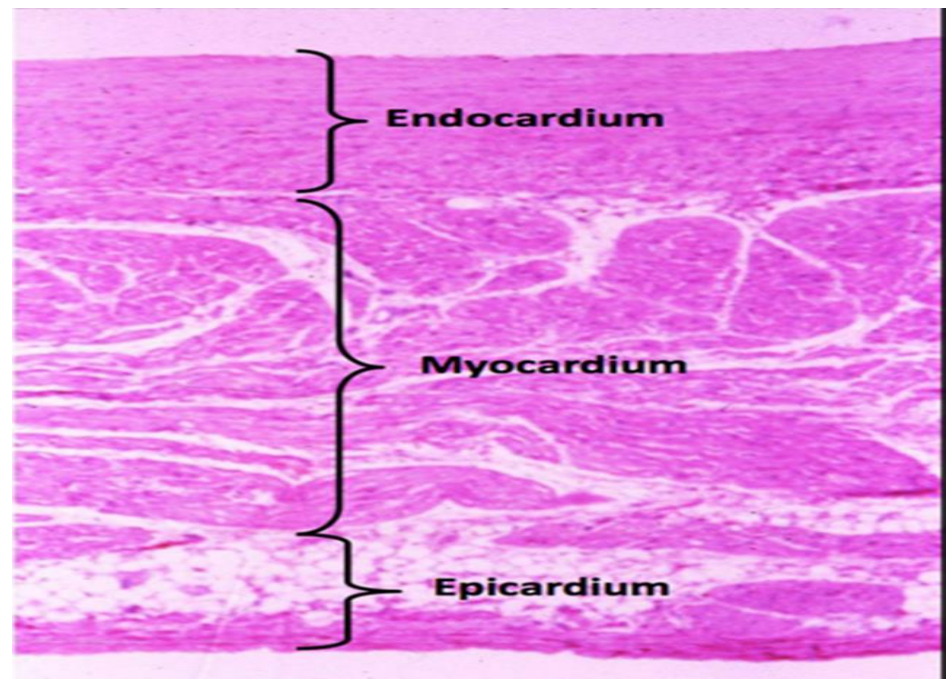
The heart is a muscular pump that propels blood at high pressure round the body through the blood vessels.
the heart has three layers:
endocardium (tunica intima)
myocardium (tunica media)
epicardium (tunica adventitia)



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

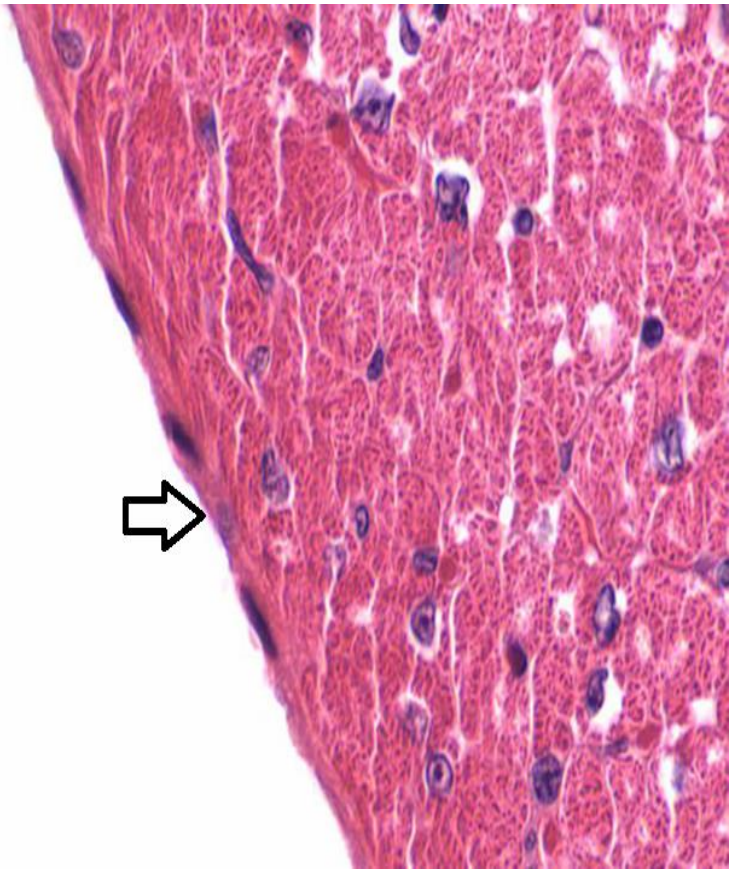


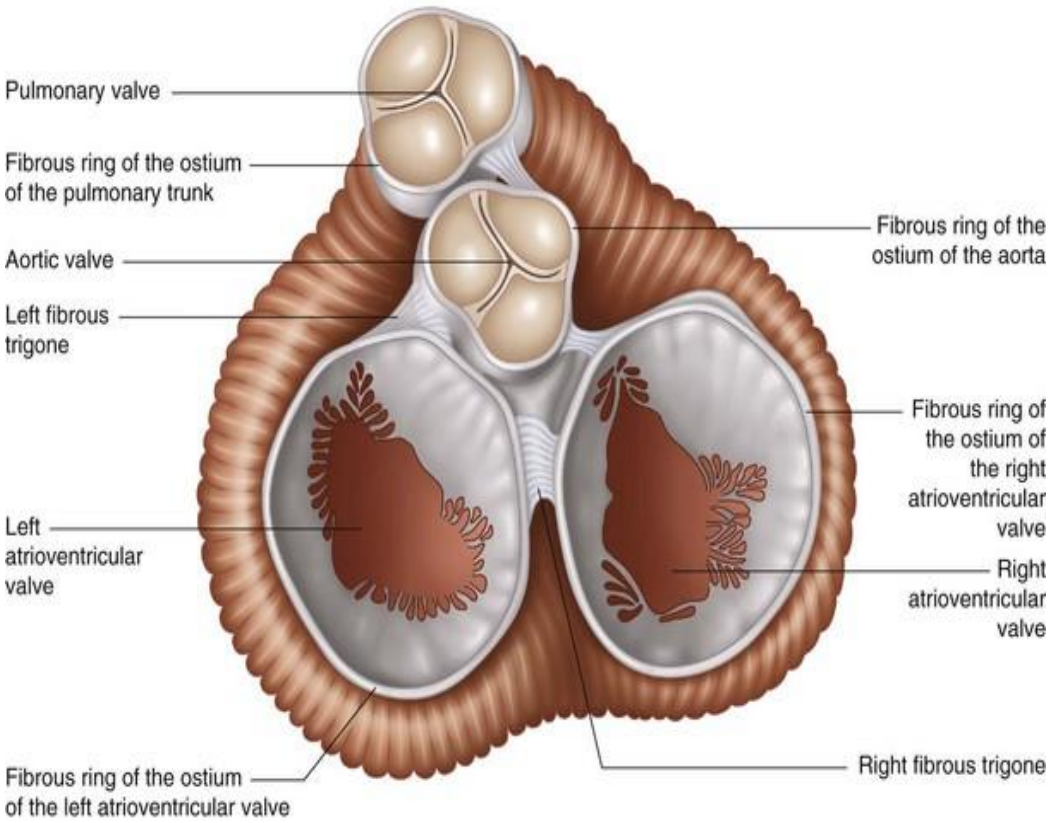
The heart is composed of three layers and surrounded by a pericardial cavity

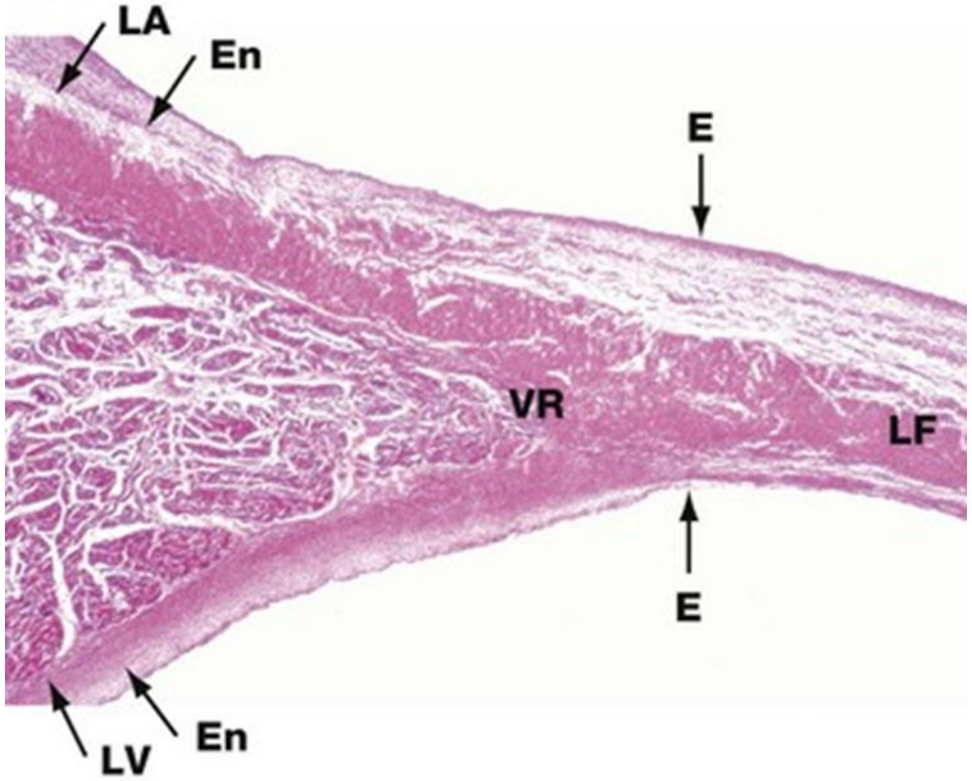


Endocardium

- Inner layer of heart
- Consists of endothelium and basal lamina resting on a thin layer of connective tissue.
- Sub- endocardium is a layer of loose connective tissue between endocardium and myocardium. It contains nerves, blood vessels, and **branches of the conducting system** of the heart in the ventricles .
- **Valves** are considered part of the endocardium.
- The rings of the fibrous skeleton are composed of dense, fibrous connective tissue that encircle the orifices of the heart valves. These fibrous rings are interconnected by connective tissue called the right and left trigones and form the structural support for the heart on which the valvular leaflets and cardiac muscle fibers are anchored.




Pulmonary valve
Fibrous ring of the ostium of the pulmonary trunk
Aortic valve
Left fibrous trigone
Left atrioventricular valve
Fibrous ring of the ostium of the left atrioventricular valve
Fibrous ring of the ostium of the aorta
Fibrous ring of the ostium of the right atrioventricular valve
Right atrioventricular valve
Right fibrous trigone


LA
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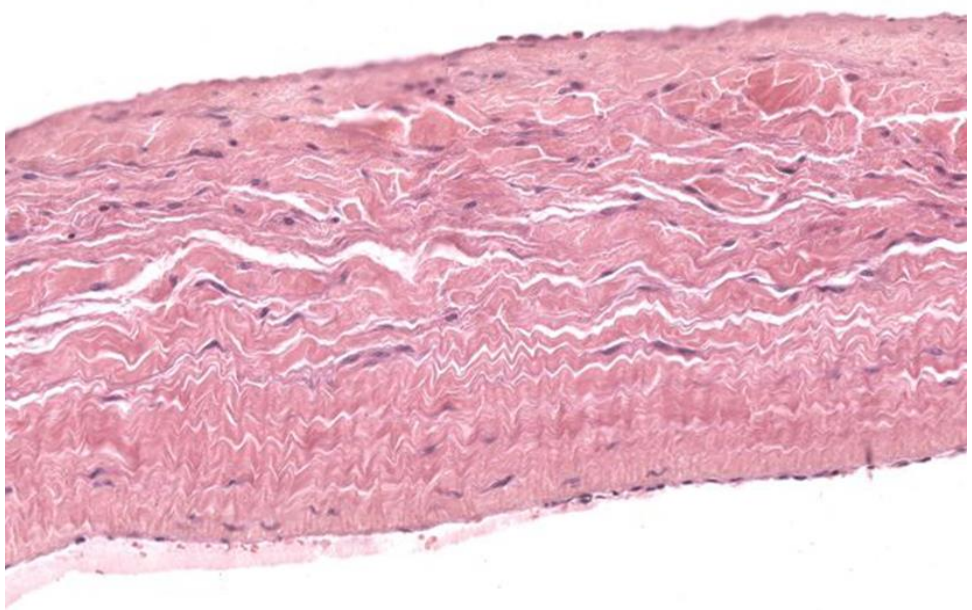
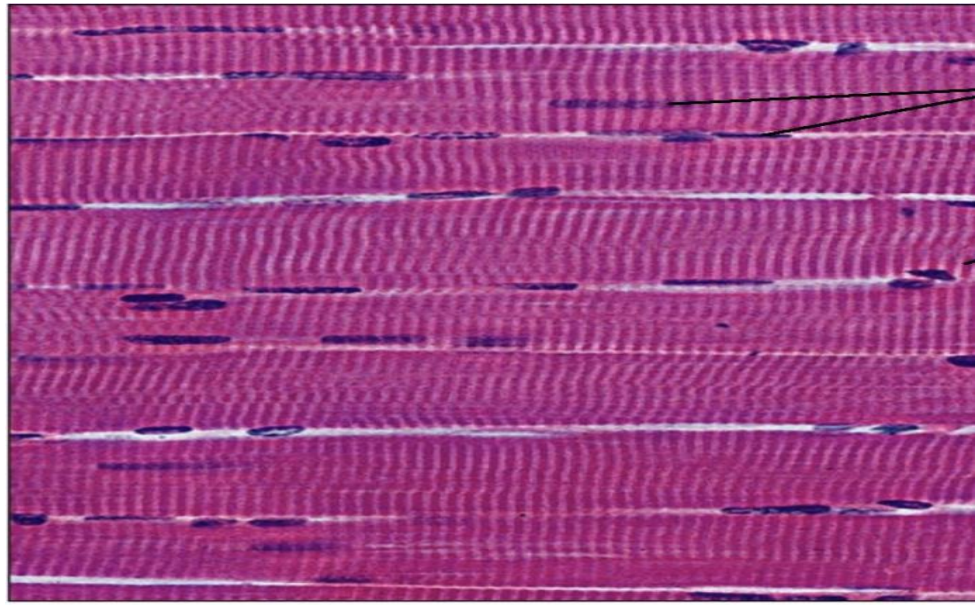
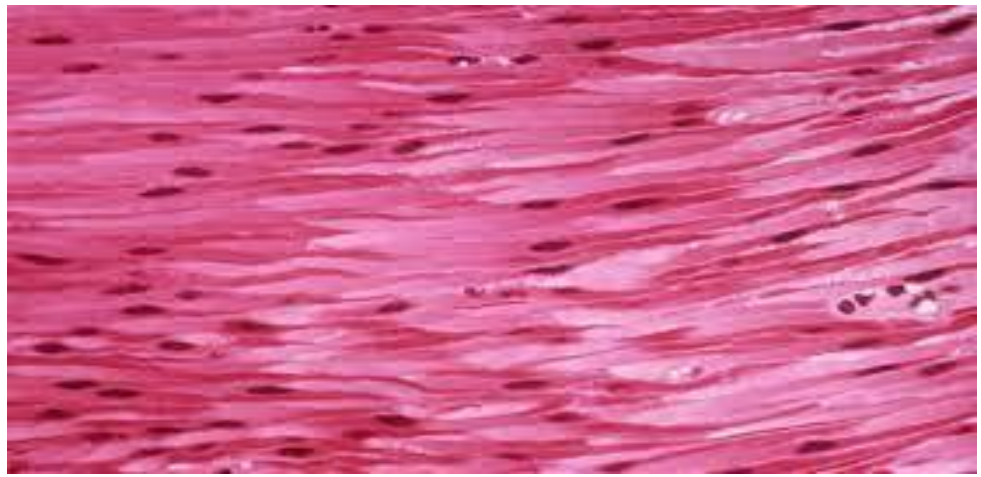
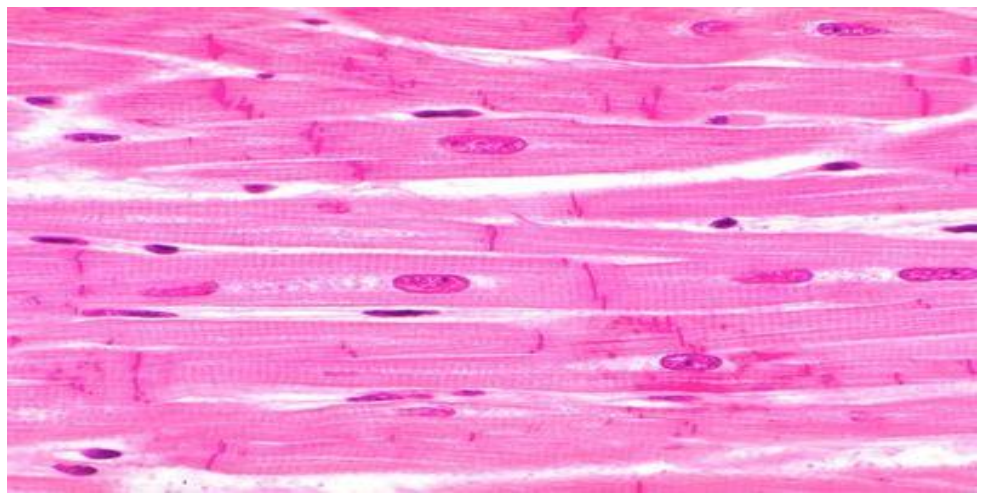


	Main features
Skeletal muscle	- Fibers : striated, tubular and multi nucleated - Voluntary - Usually attached to skeleton
Smooth muscle	- Fibers : non-striated, spindle-shaped, and uninucleated. - Involuntary - Usually covering wall of internal organs.
Cardiac muscle	- Fibers : striated, branched and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







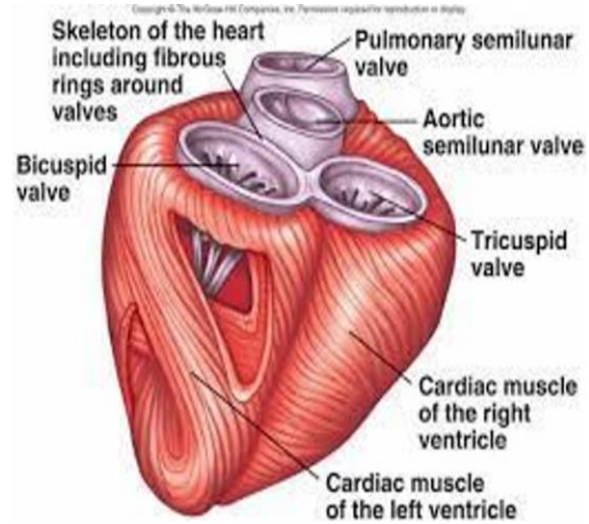
Myocardium

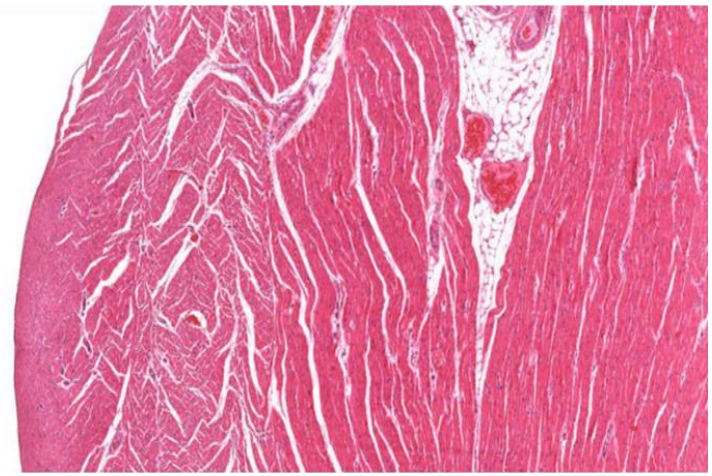
- Muscle fibers are arranged in a spiral pattern around the chambers of the heart.

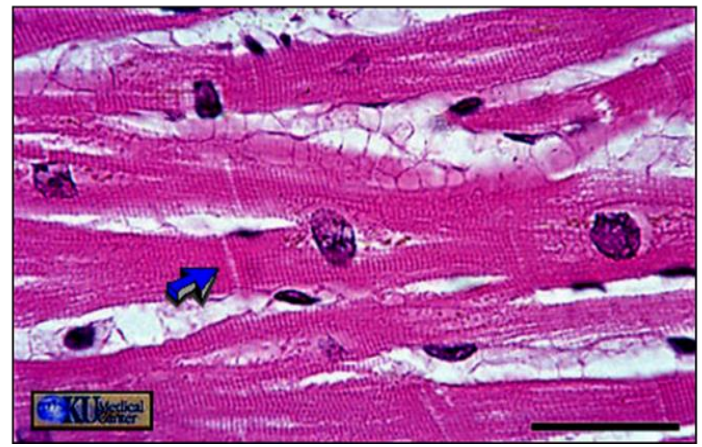
- Cardiac muscle fibers are inserted into a dense fibrous connective tissue skeleton of the heart.

LM:

- ❑Shorter than skeletal muscle
- ❑Cylindrical in shape
- ❑Branched.
- ❑Striated.
- ❑Has one nucleus in the center
- ❑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**

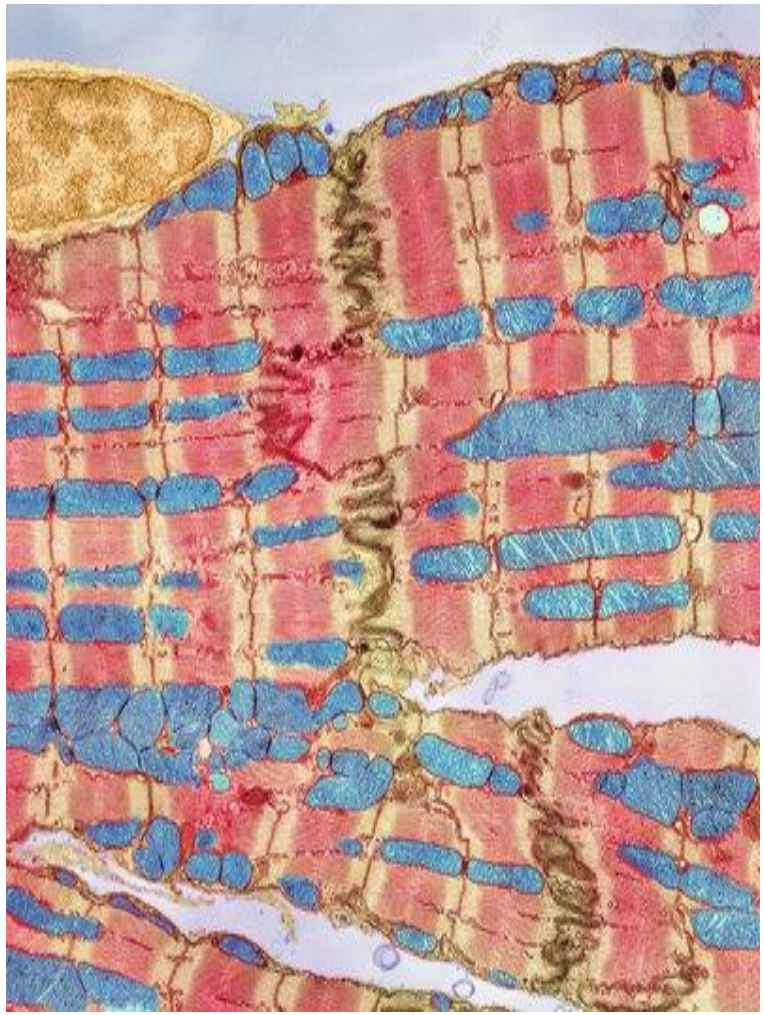
➢ **Transverse Part:**

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

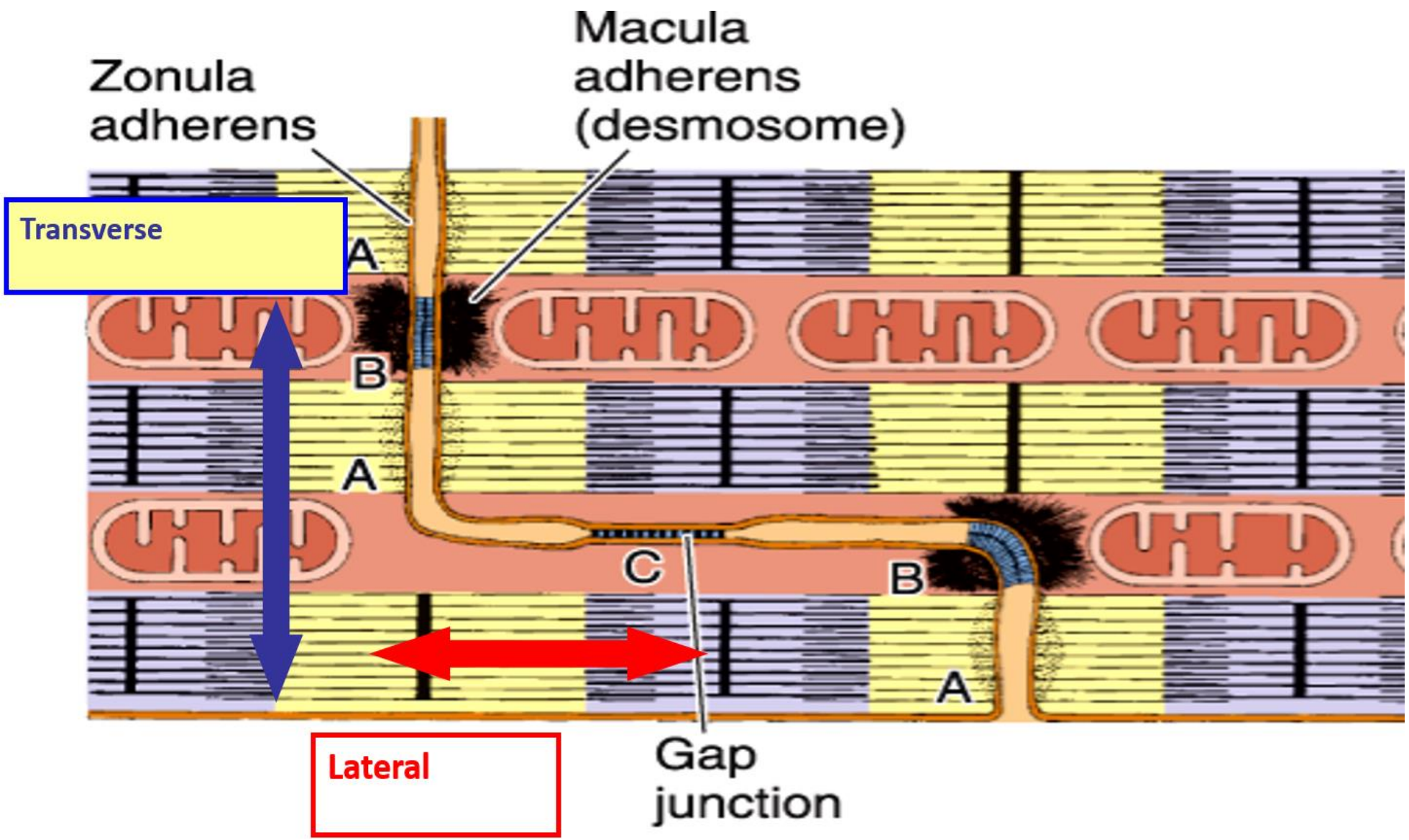
➢ **Lateral Part:**

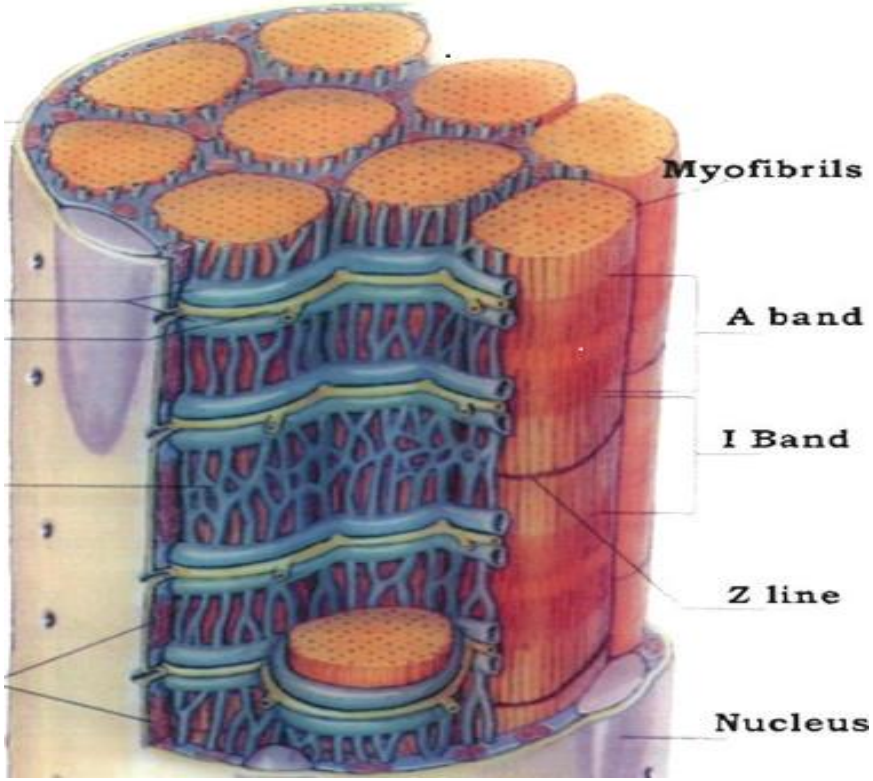
- **Gap junctions (nexus) -** for **impulse transfer** providing ionic continuity between adjacent myocytes (**electrical commtiunicaon** between cardiac muscle cells)

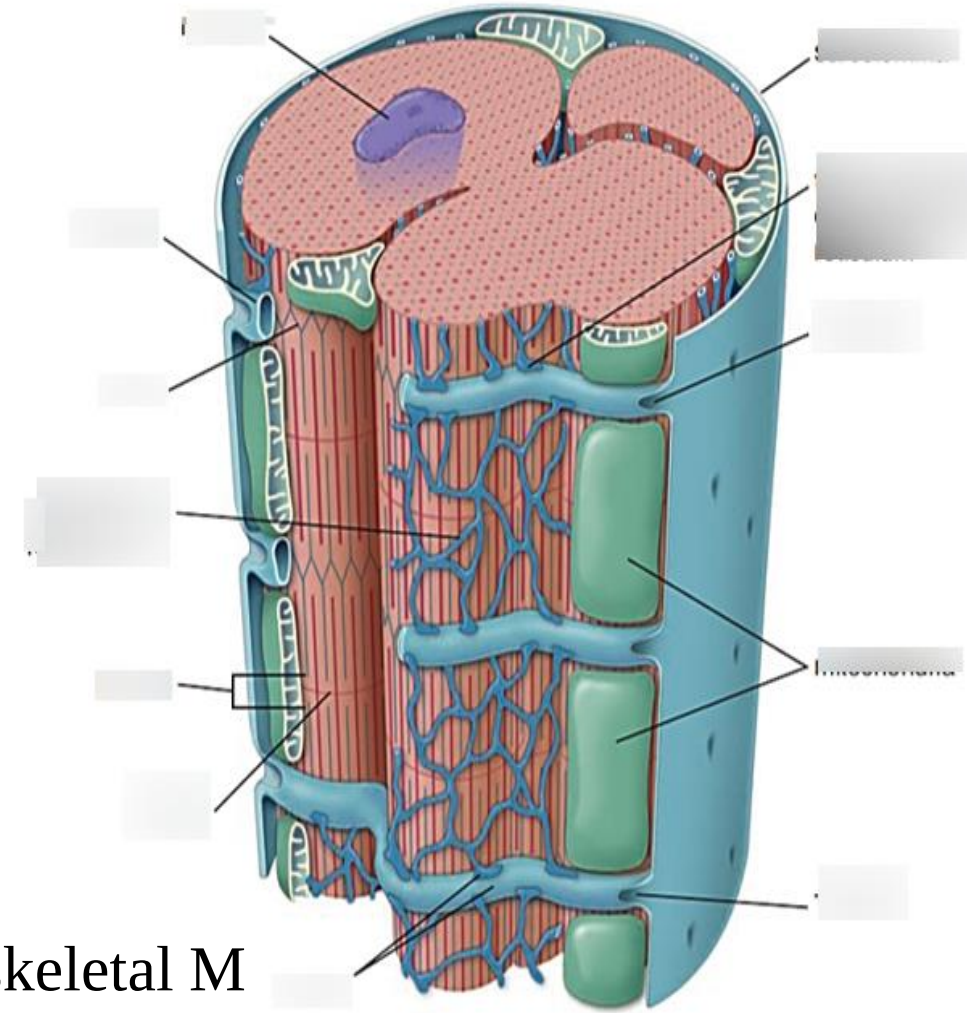
- **T – Tubules**
- **Sarcoplasmic reticulum**
- Others (glycogen , Lipid , Pigment)



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**

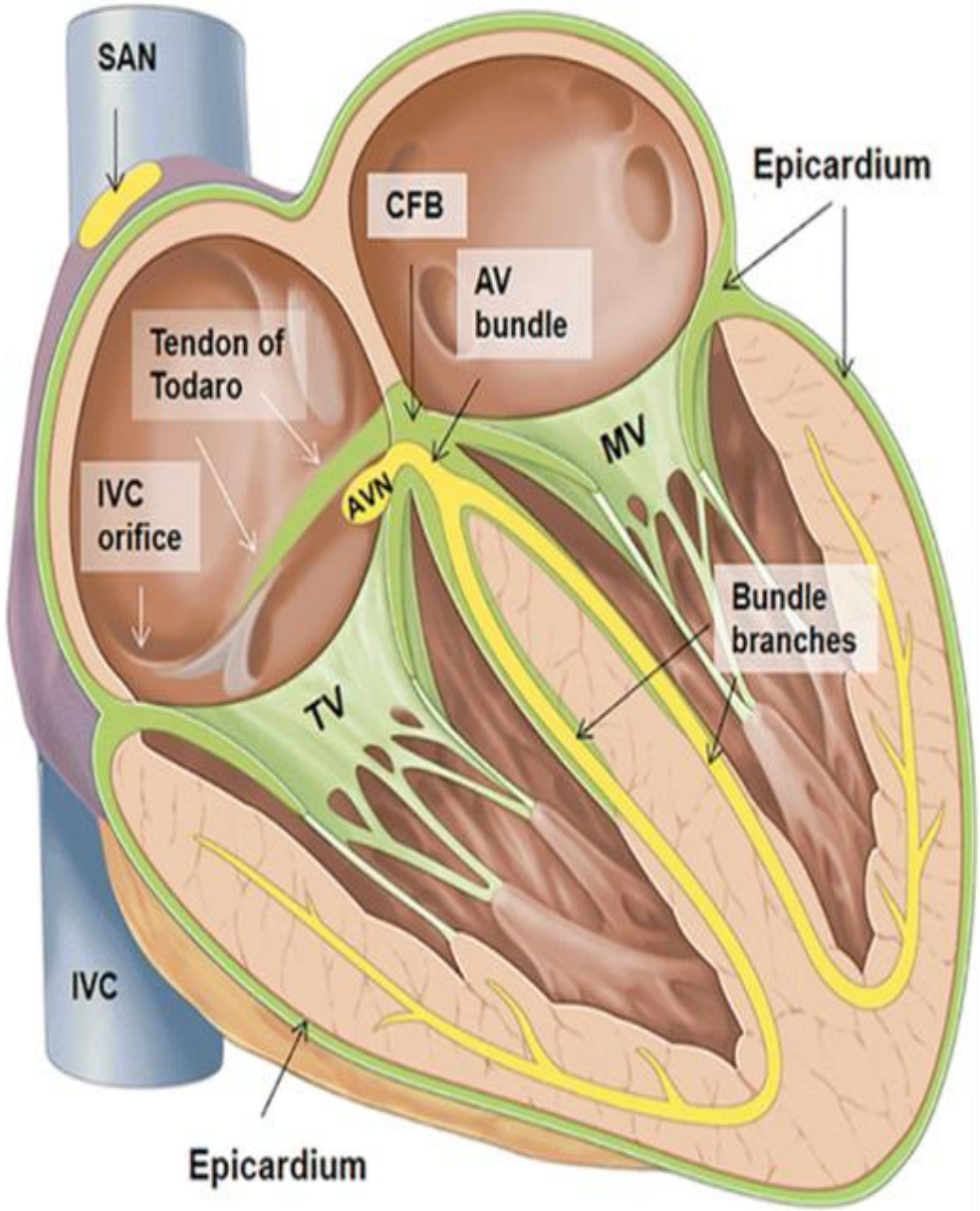
Types of cardiac muscle

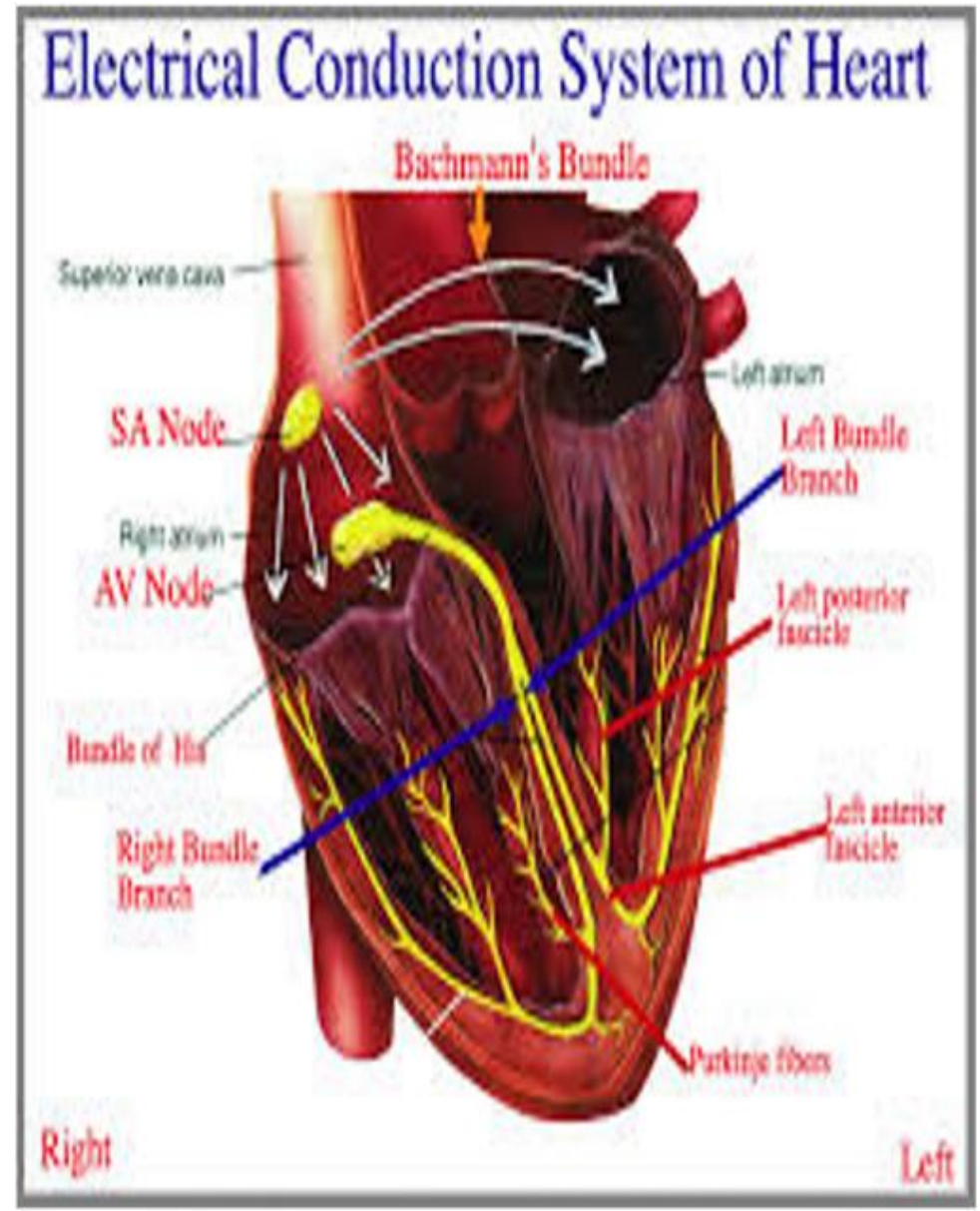
Three main types :

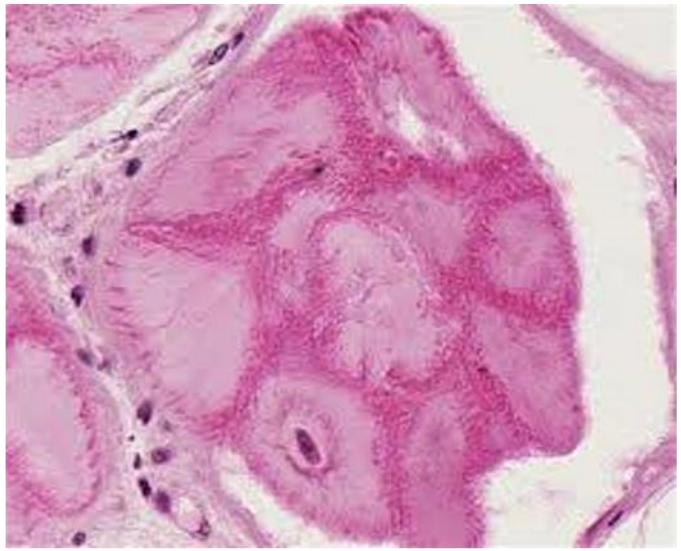
- Contractile
- Endocrine (ANF) = modified cardiac muscle in the Rt atrium
- Myocardium of conduction system
  - Sinoatrial (SA) node located near the junction of the superior vena cava and the right atrium which initiates the beating action (called the pacemaker). SA node initiates an impulse that spread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

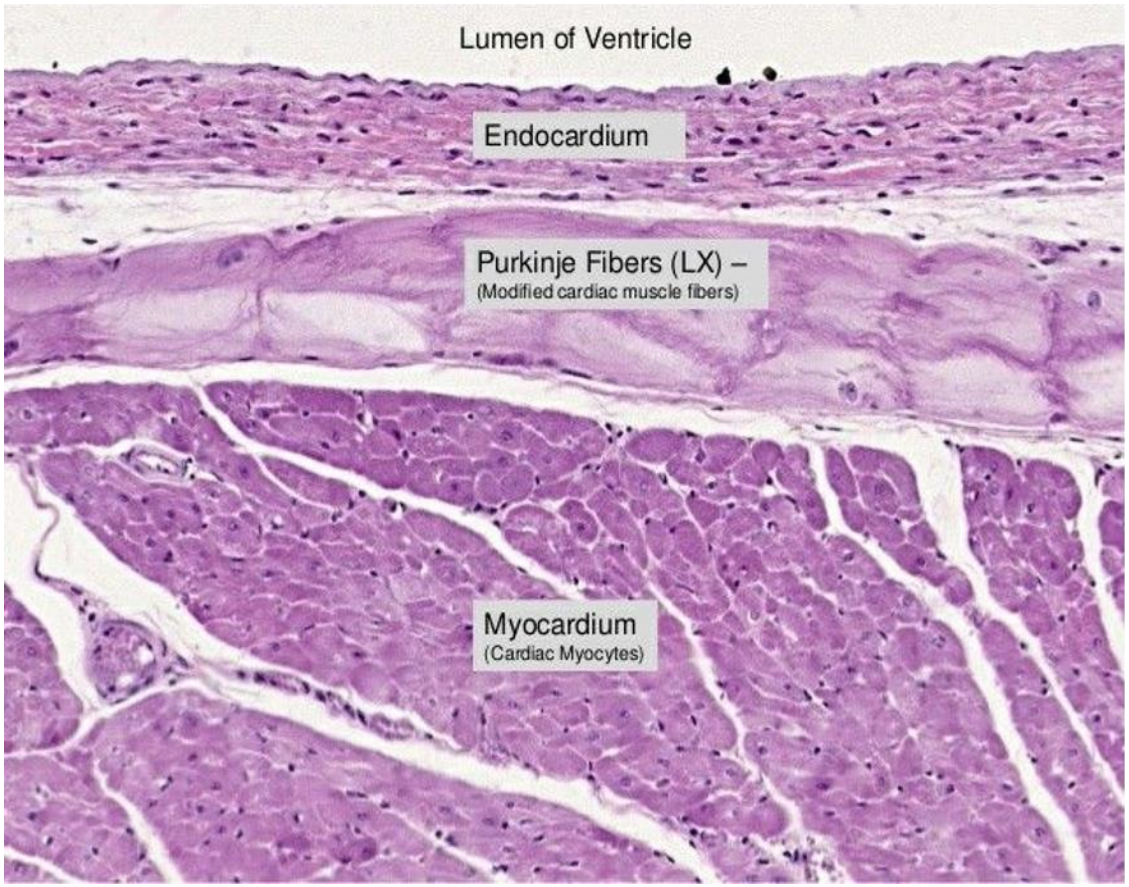
Internodal pathways (tracts) form the communication between SA and AV nodes.

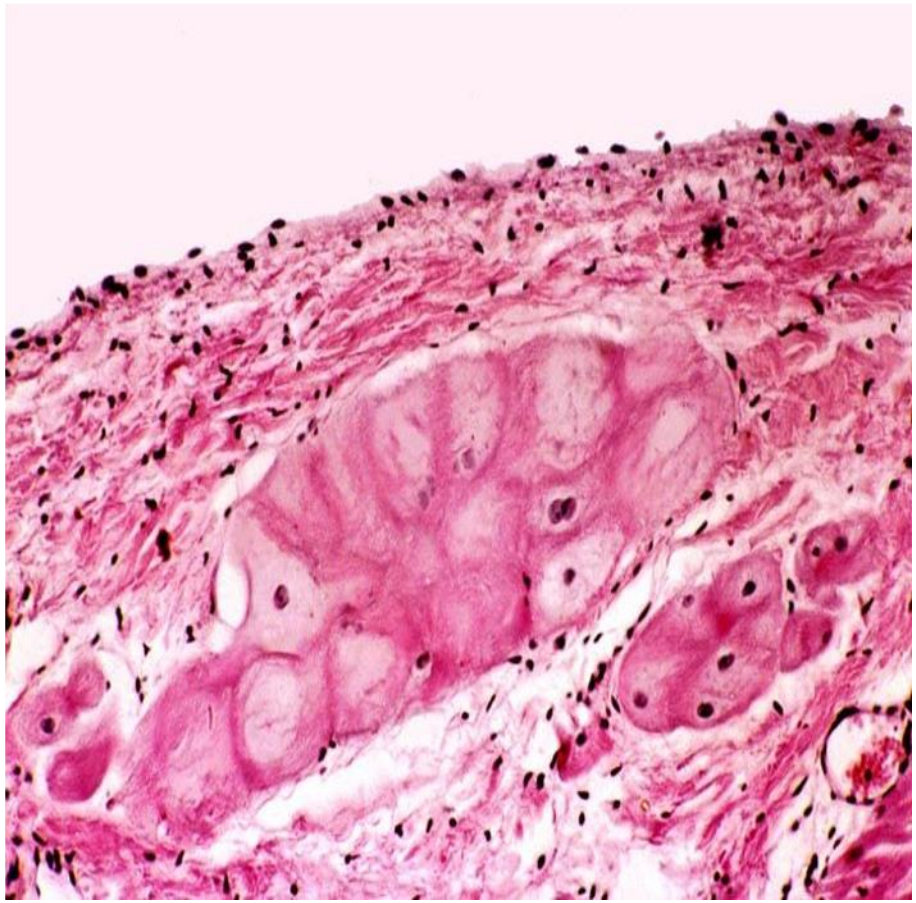
  - Atrioventricular (AV) node it electrically connects atrial and ventricular chambers, once the impulse reaches the AV node it is conducted across the fibrous skeleton to the ventricles by the
  - Bundle of His (AV bundle) which then divided into smaller
  - Rt & Lt bundle branches descending into interventricular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


SAN
CFB
Epicardium
AV bundle
Tendon of Todaro
IVC orifice
AVN
MV
Bundle branches
TV
IVC
Epicardium


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




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



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**.

- Purkinje fibers are shorter, larger, **pale** .
- Present in group **2 or more**
- They are often binucleated cells.
- 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
- **Not** contain T- tubules or **intercalated discs**

Function :

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

Pericardium

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

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

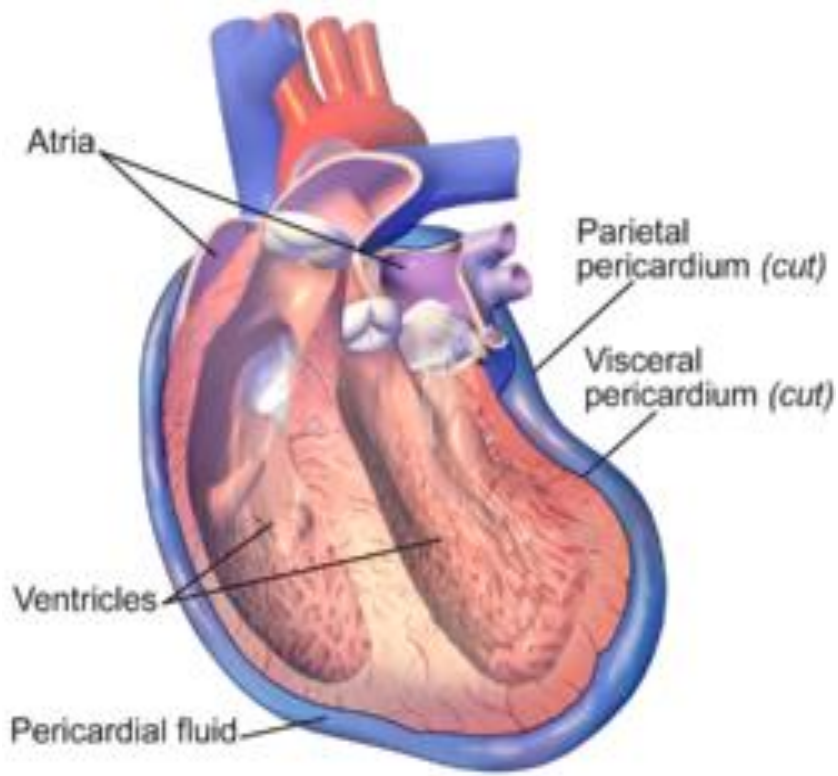
Functions as a protective layer.

- **Parietal pericardium**

a loose fitting **outer membrane**

- **Mesothelium** is a simple squamous epithelial tissue, not only of the pericardial cavity but also peritoneal and pleural cavities

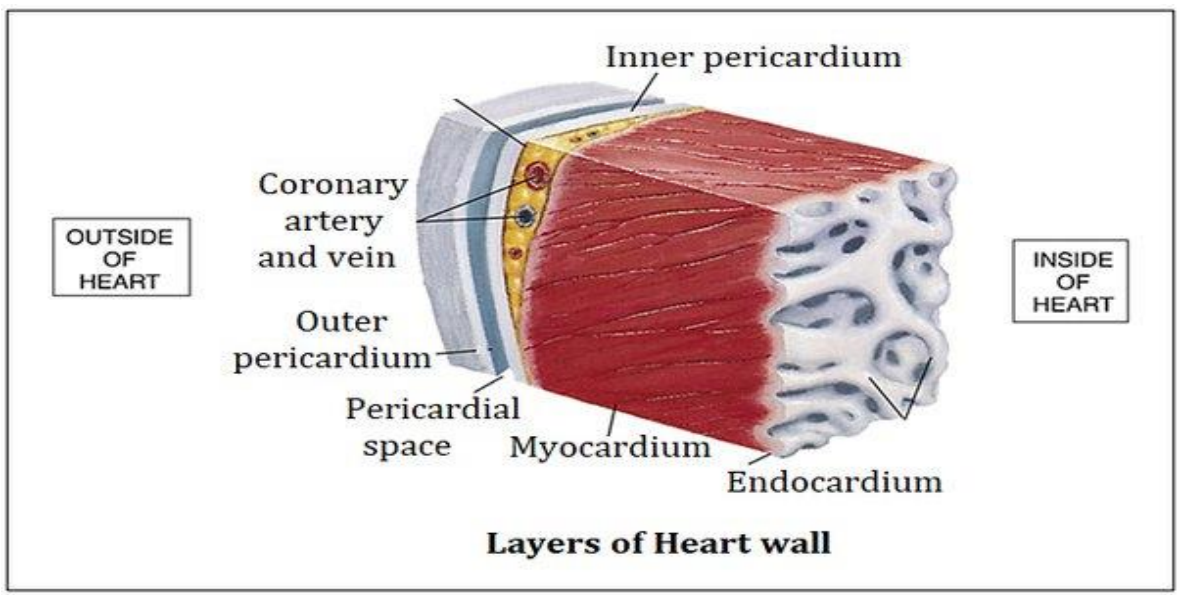
(all major body cavities).



Pericardial Sac

Epicardium

- Outer layer of the heart.
- Consists of a surface of mesothelium (simple squamous epithelium) supported by a thin layer of connectivet issue.
- Epicardium contains loose connective tissue, large amounts of adipose tissue, nerves, and blood vessels, including the coronary vessels.



Epicardium

Growth and regeneration

- A **satellite cell** are located outside the sarcolemma .

help to repair skeletal muscle cells.

- 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 pericytes which 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.

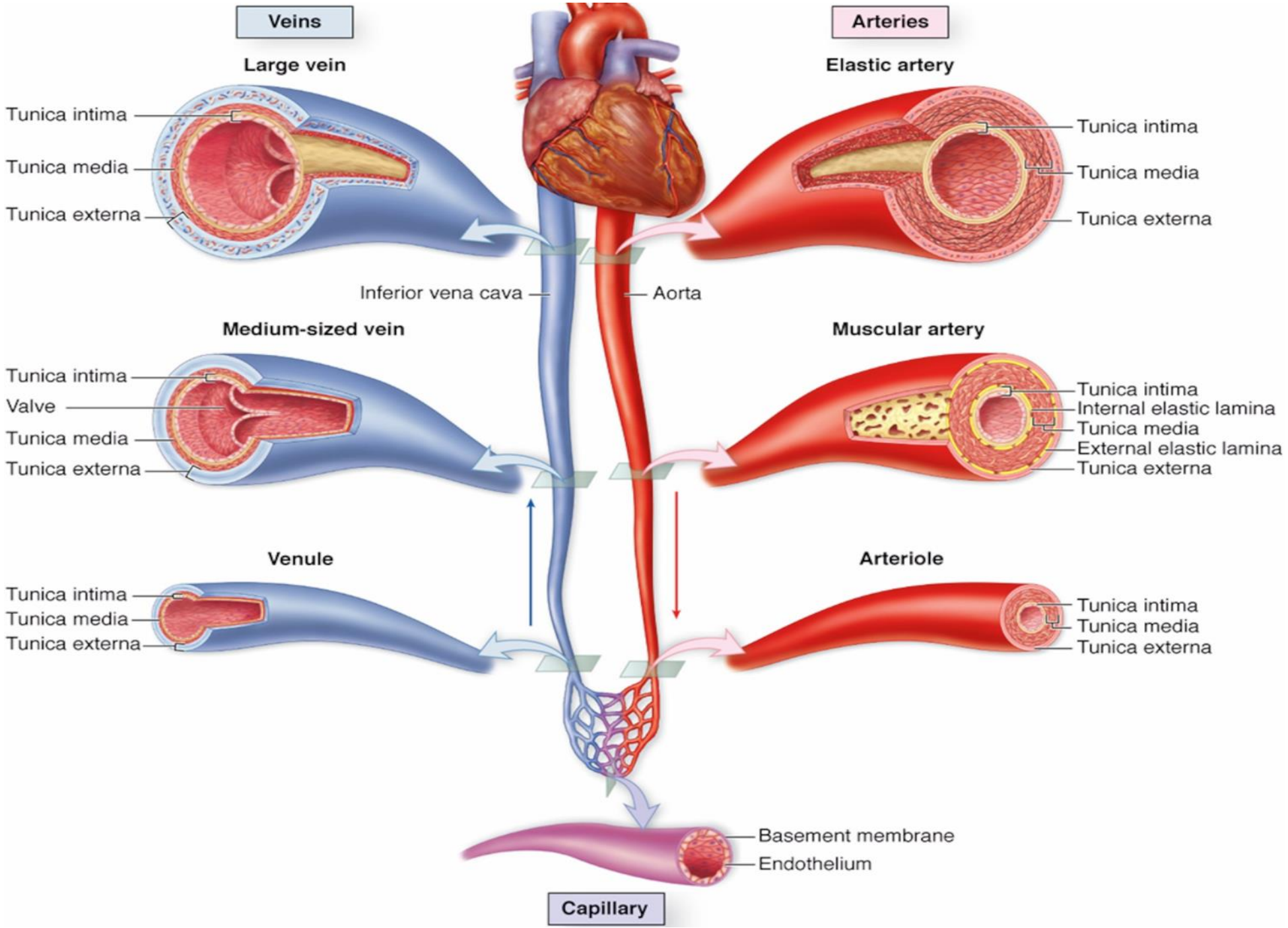
- Endocarditis.

is an inflammation of the endocardium

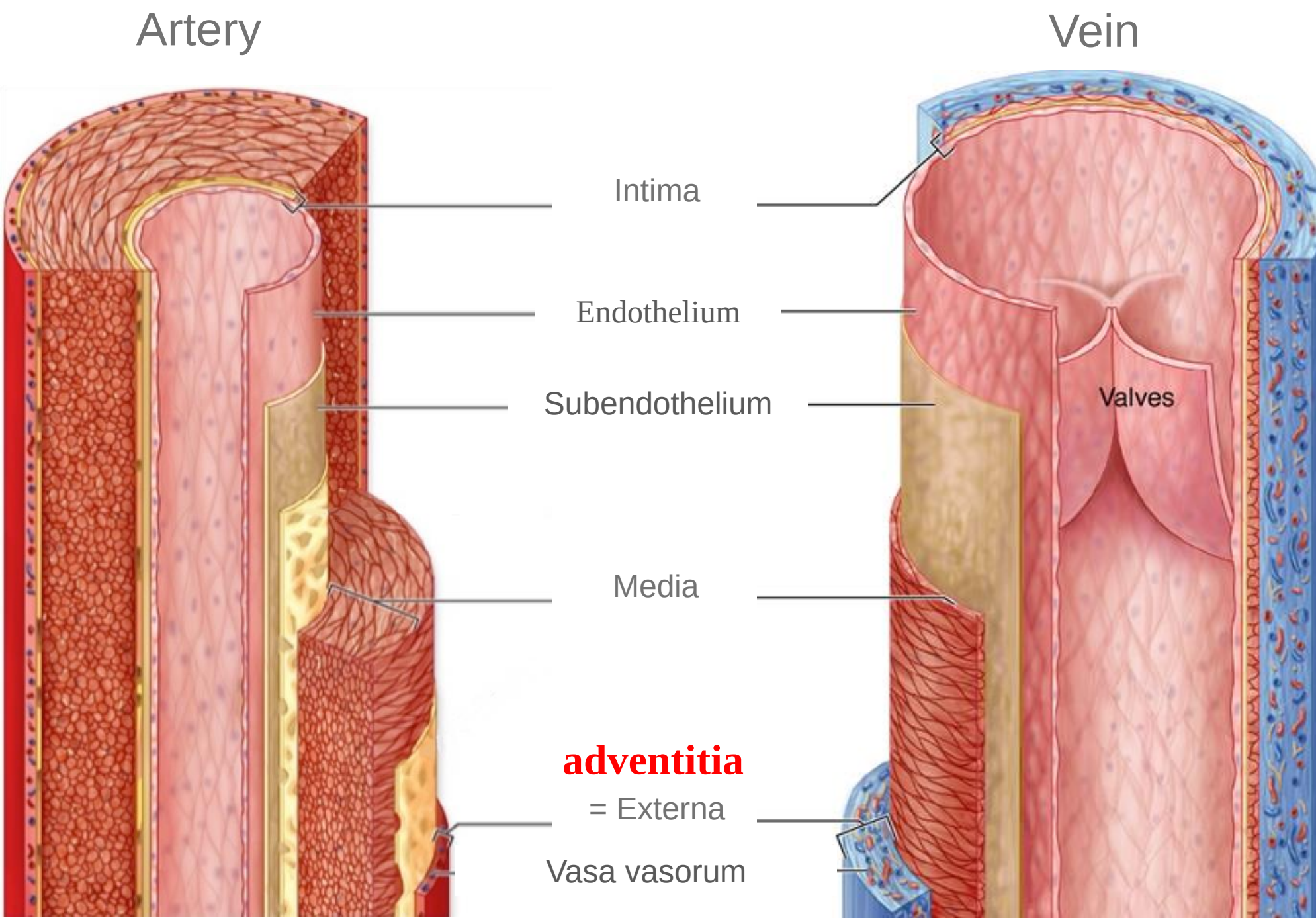
Growth and regeneration of cardiac muscle

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

Vessels of the cardiovascular system



The Three Layers (Tunics) of Blood Vessels

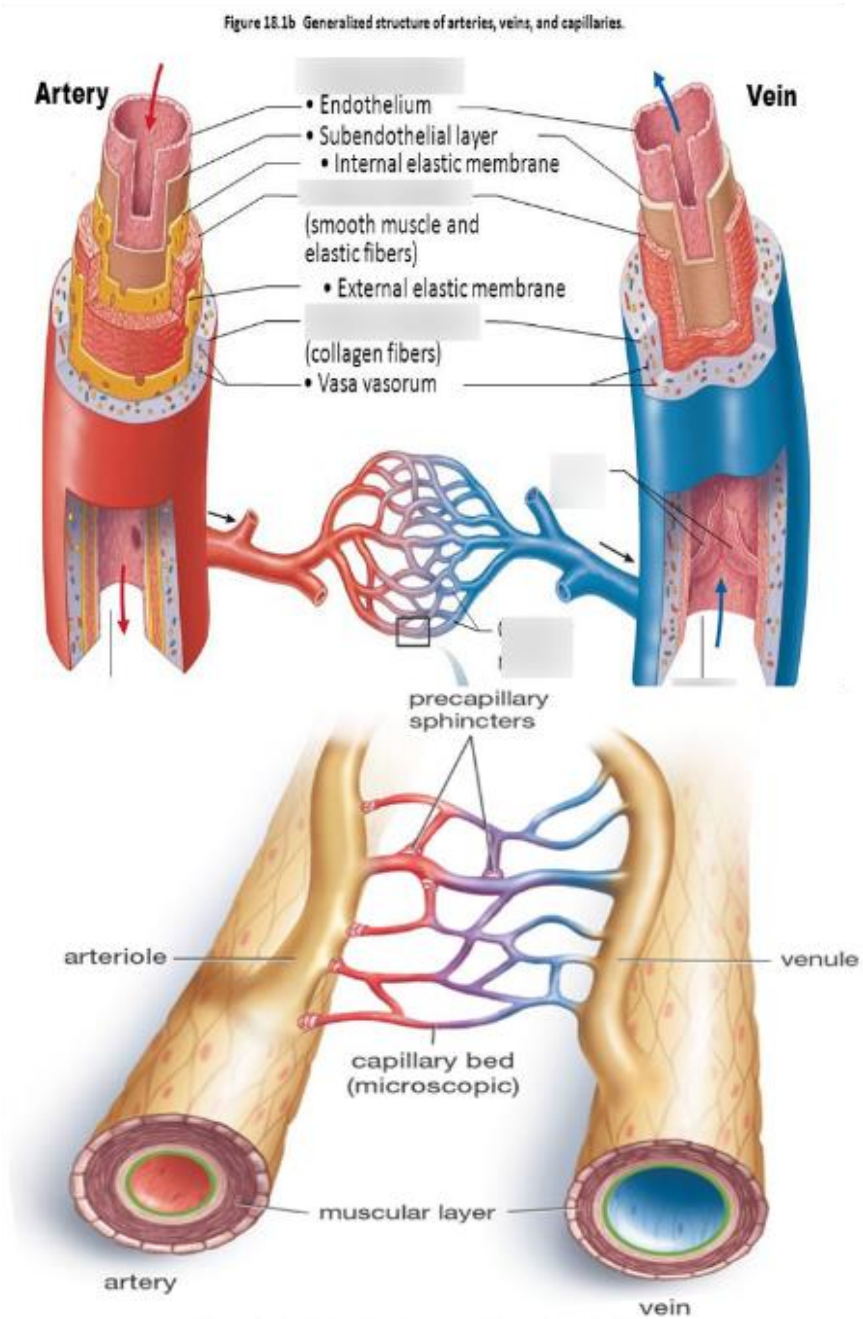


BLOOD VESSELS

- 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

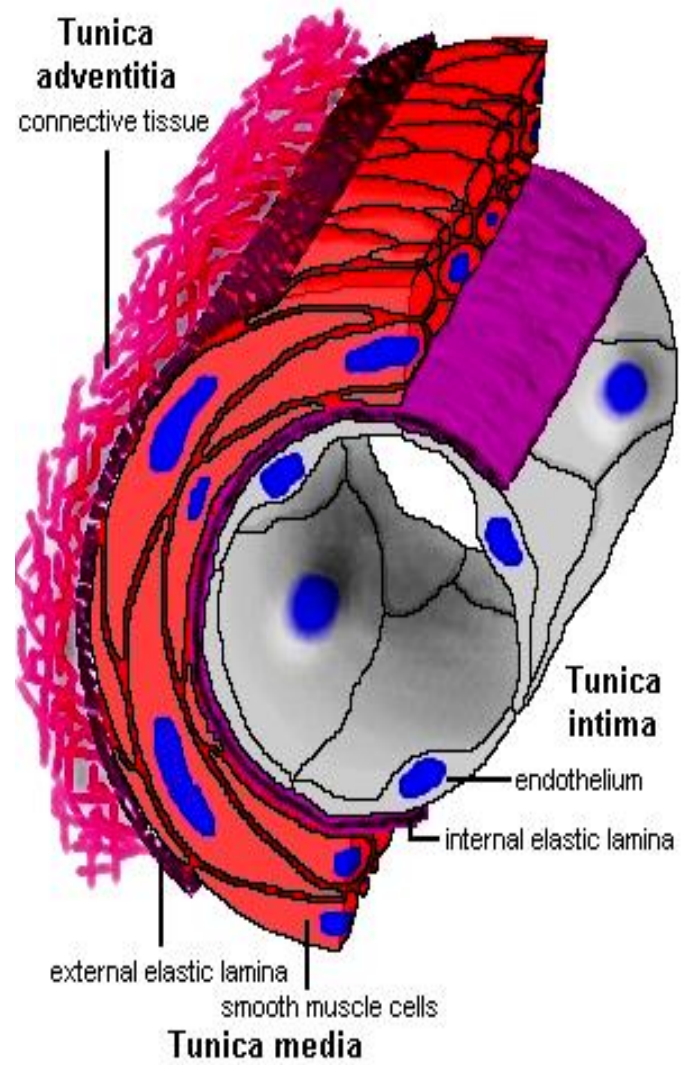
❑ Tunica adventitia,

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:

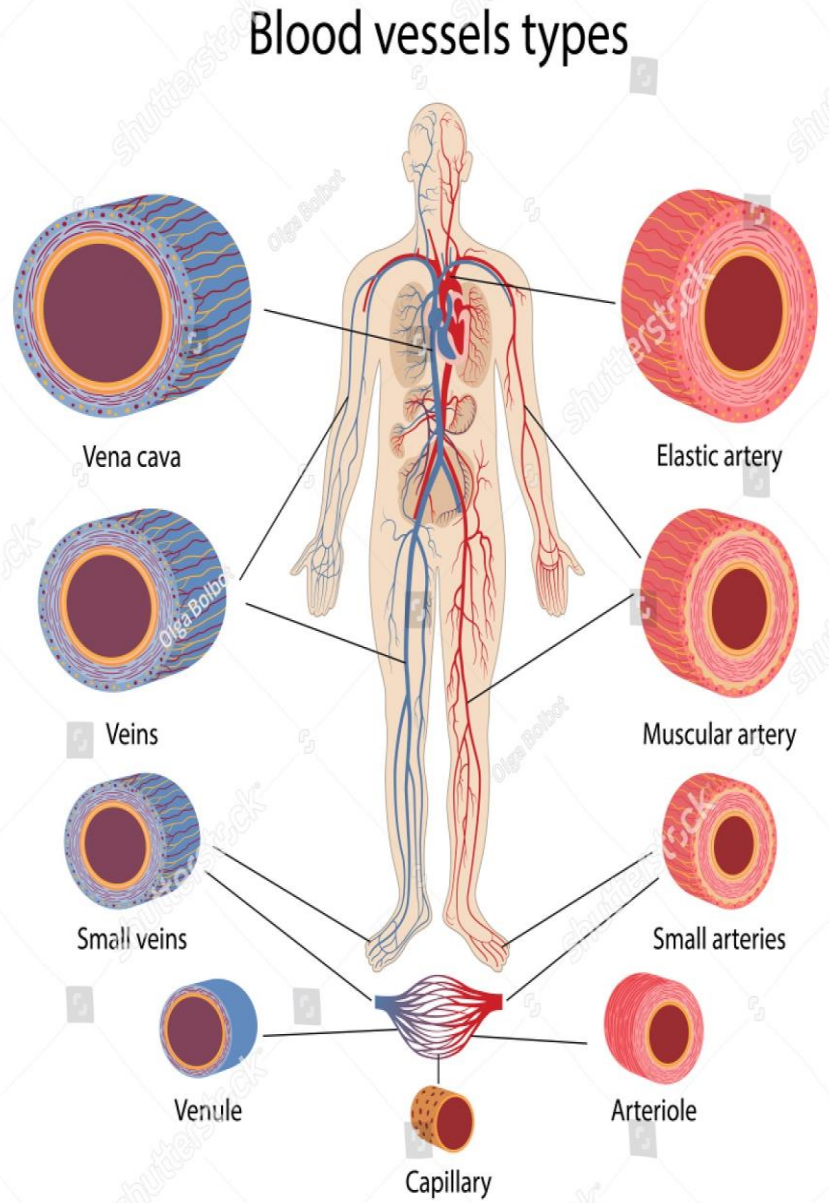
❑ **Conducting or Elastic Arteries**

= (large arteries)

Distributing or Muscular Arteries

=named = (medium arteries)

❑ **Arterioles (small arteries)**



Conducting or Elastic Arteries (large arteries)

- These are large arteries closest to the heart with very high blood pressure **e.g.** aorta, pulmonary, branches of the aorta.
- 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.

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

- **Endothelium** with **Weibel-Palade** bodies **rod-like** inclusions that have a 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**

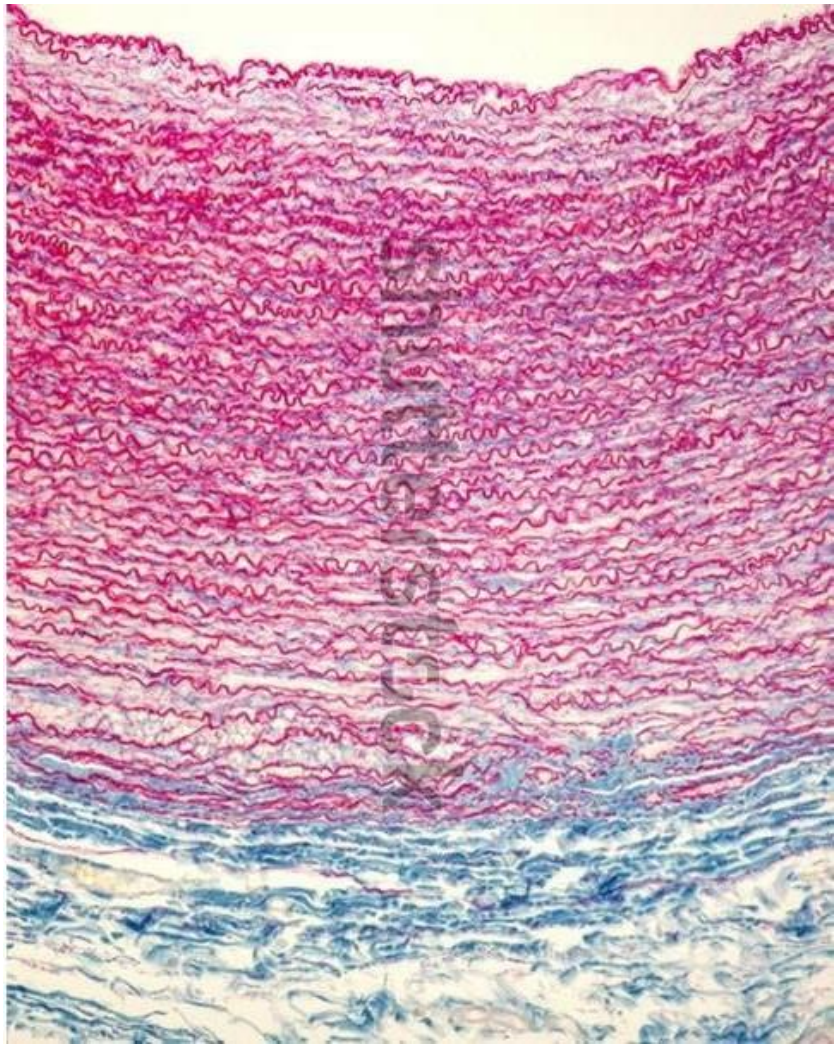
Tunica media 70 % which constitutes most of the wall.

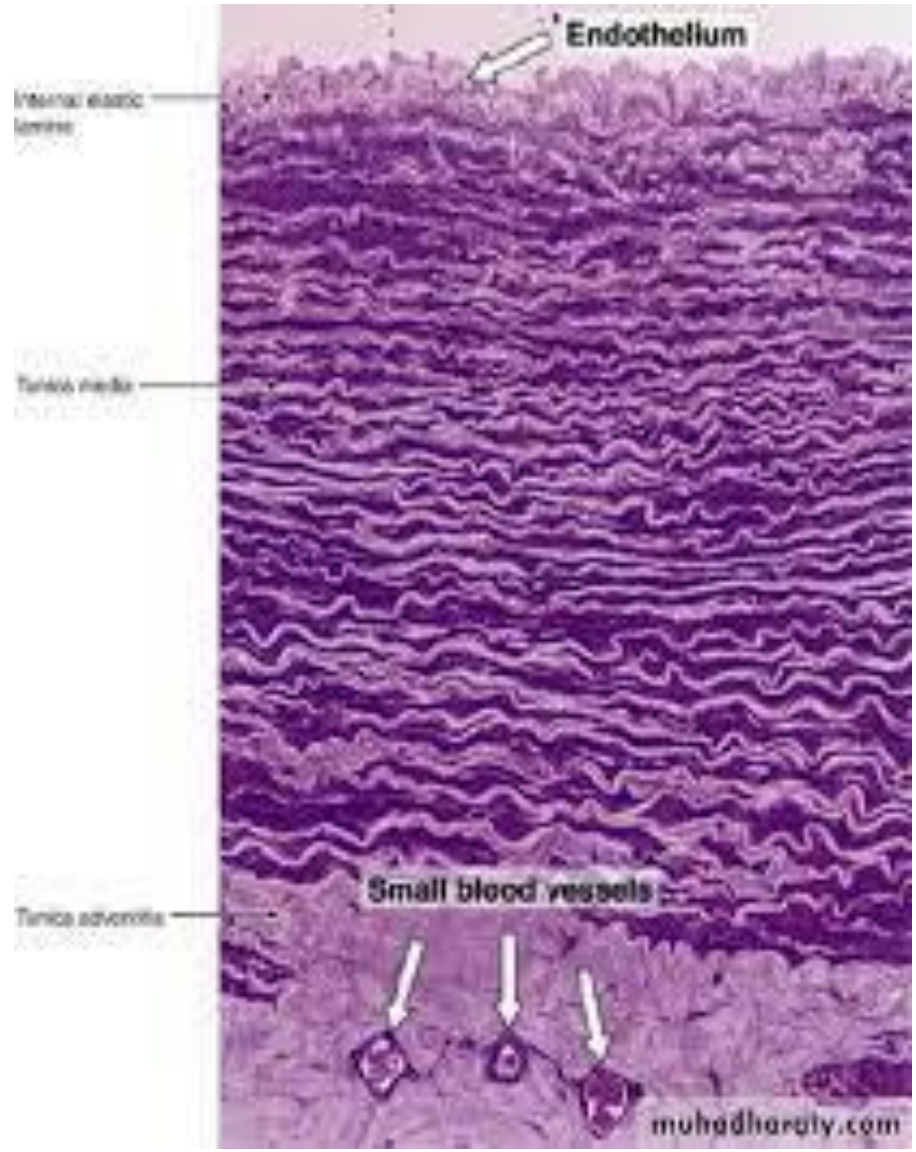
- ❖Distension (with the increase in **systolic blood** pressure) of the walls is facilitated by **concentric fenestrated lamellae of elastic fibers** in a thick tunica media
- ❖**Smooth muscle** cells and **collagen fibers** (collagen **type III**) are present between the layers of elastic fibers.
-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

Tunica adventitia 20 % composed of elastic and collagen fibers 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. 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 = Muscular = medium size = named 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

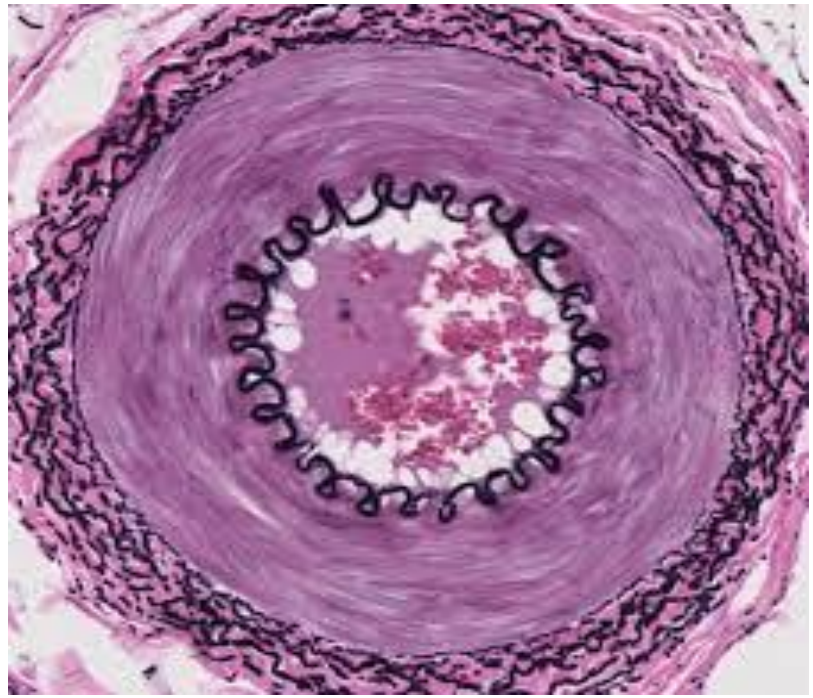
- The **internal elastic lamina** forms a **well defined layer** appears as a refractile wavy pink line

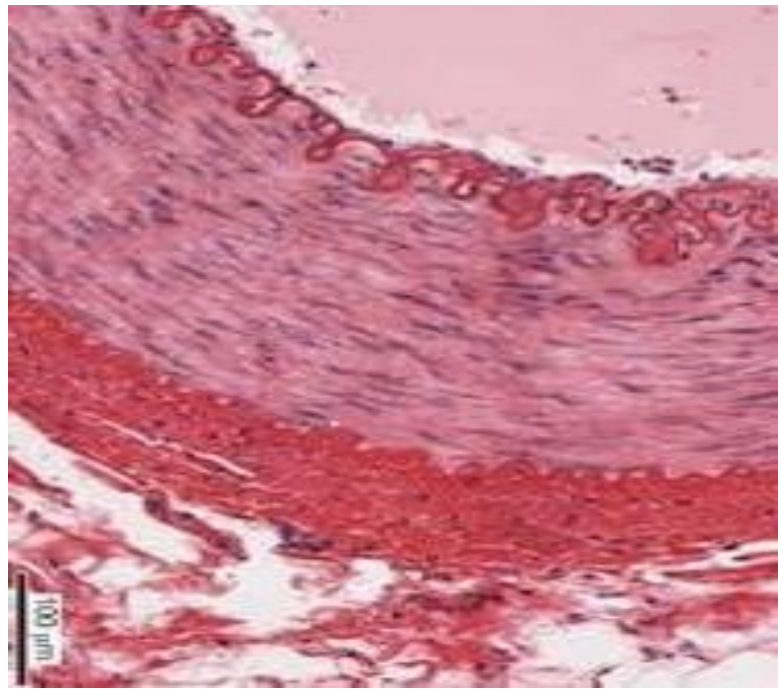
Tunica media 50% is dominated by **numerous concentric layers** of smooth muscle cells. **Fine** elastic fibres and a **few** collagen fibres

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

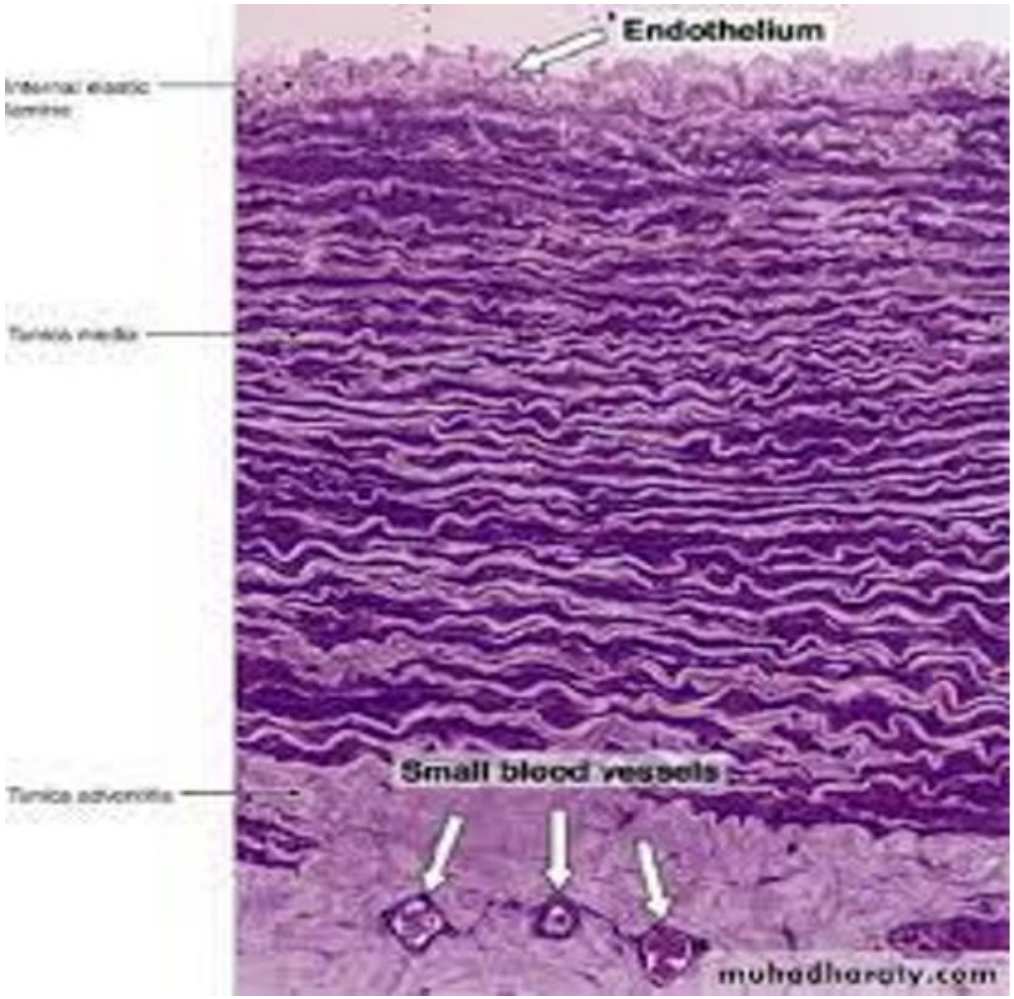
Tunica adventitia 50% The thickness and appearance of the is **variable**.

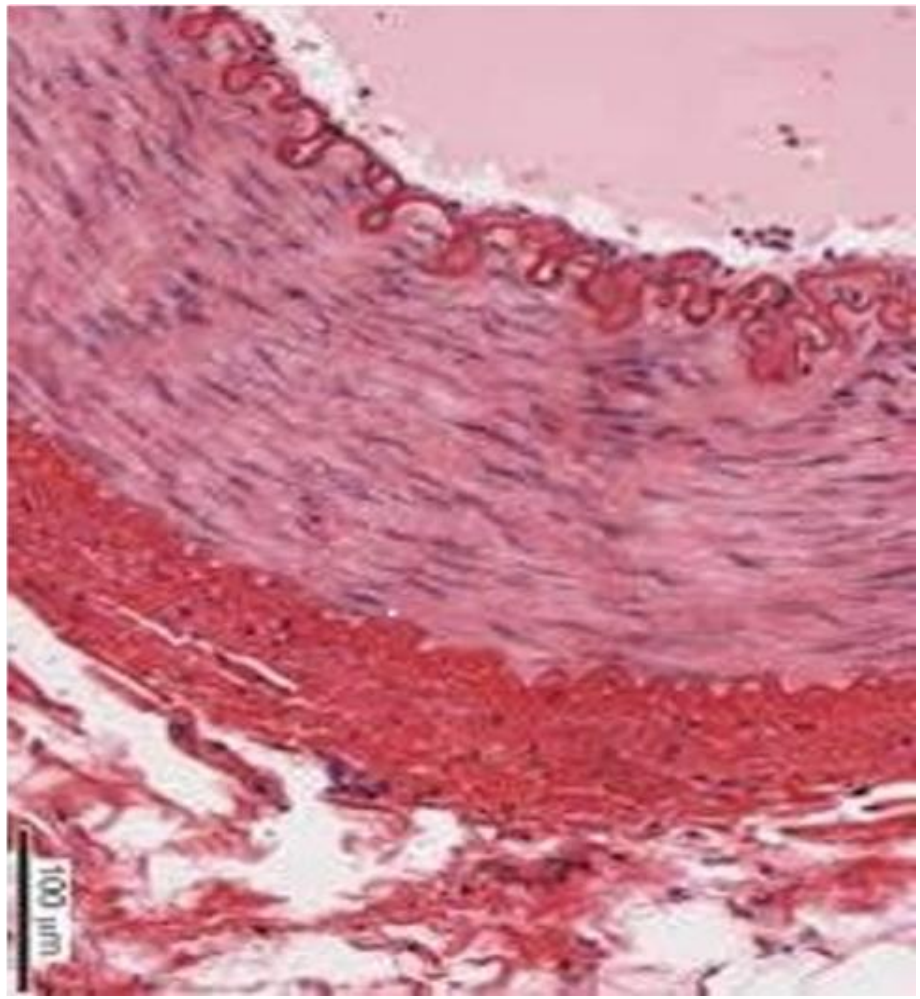
- Example: radial artery, splenic artery, brachial artery and femoral artery





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**

2. Pulmonary artery

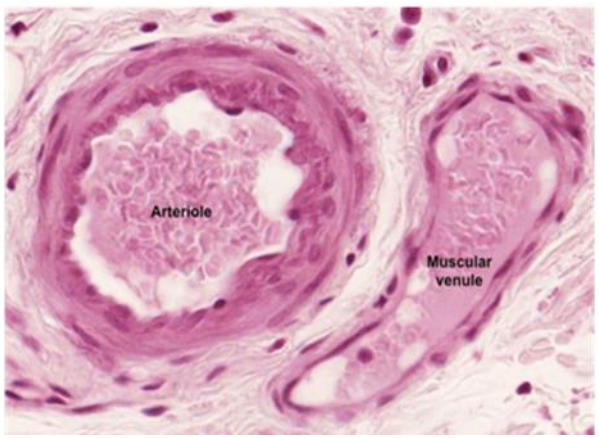
- Contain **less** muscle & elastic fibers due to low blood pressure
- Cardiac muscle extend short distance in the artery

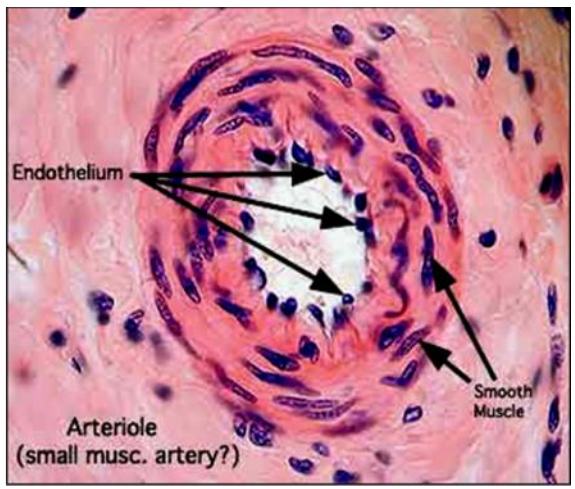
3. Cerebral artery

- 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** because the artery well protected in the skull

Arteriole

- Smallest branches of the arterial system.
- Deliver blood to the smallest blood vessels, the capillaries.
- Diameter - less than 100 Micron m
- Terminal Arterioles: less than 50 Micron m
- Serve as a transition vessel between muscular arteries and capillaries.





Three coats are present

T Intima: Endothelium + NO subendothelial layer thin or absent IEL.

T Media: 1-5 layers of circularly arranged smooth muscle cells.

T Adventitia: thin and poorly developed. Made up of a thin network of collagen fibers.

Venous System

- Veins are thin walled
- Carry blood from capillaries to heart
- Large veins are formed by the union of smaller vein
- Often provided with valves
- Valves serve to prevent reflux of blood.

Types of Veins

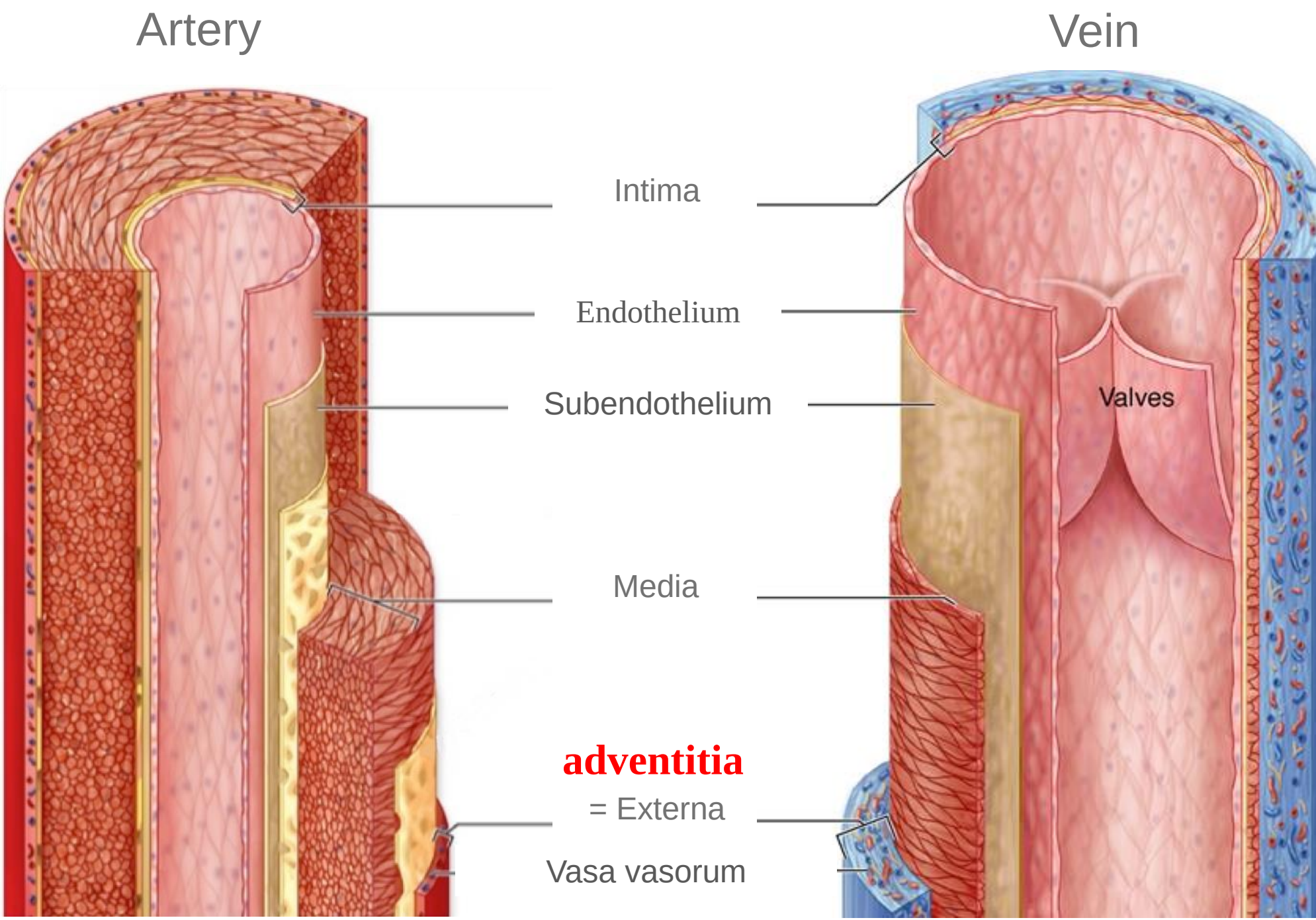
- Large sized Veins
- Medium sized veins
- Venules

A clear distinction between T intima, media and adventitia cannot be made out in small veins as all the layers consist predominantly of fibrous tissue

Same 3 layered organization as arterial system.

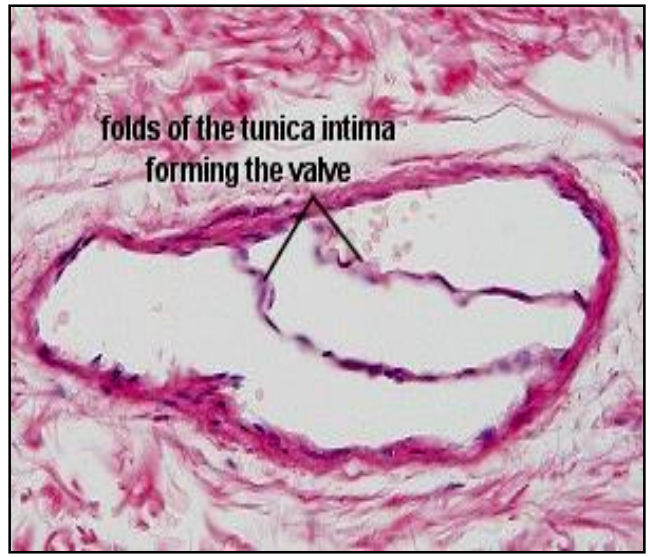
- **T intima**
- **T media**
- **T adventitia**

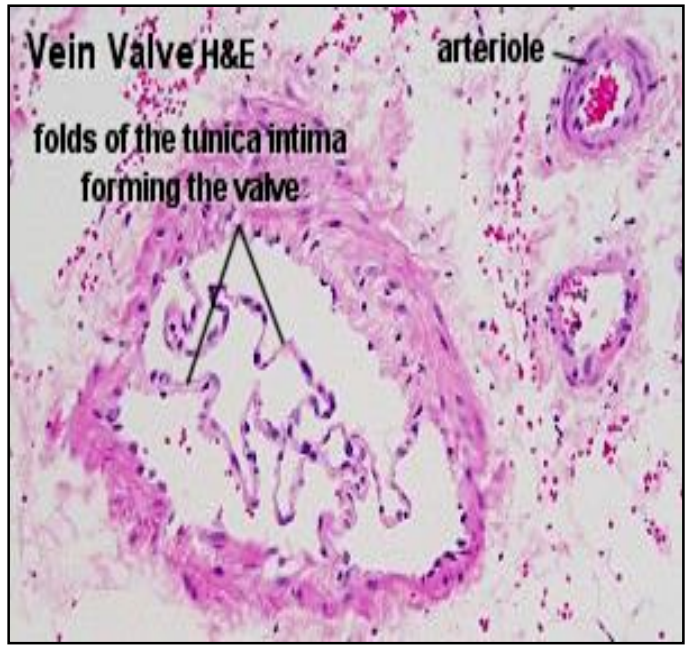
The Three Layers (Tunics) of Blood Vessels



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
  - 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

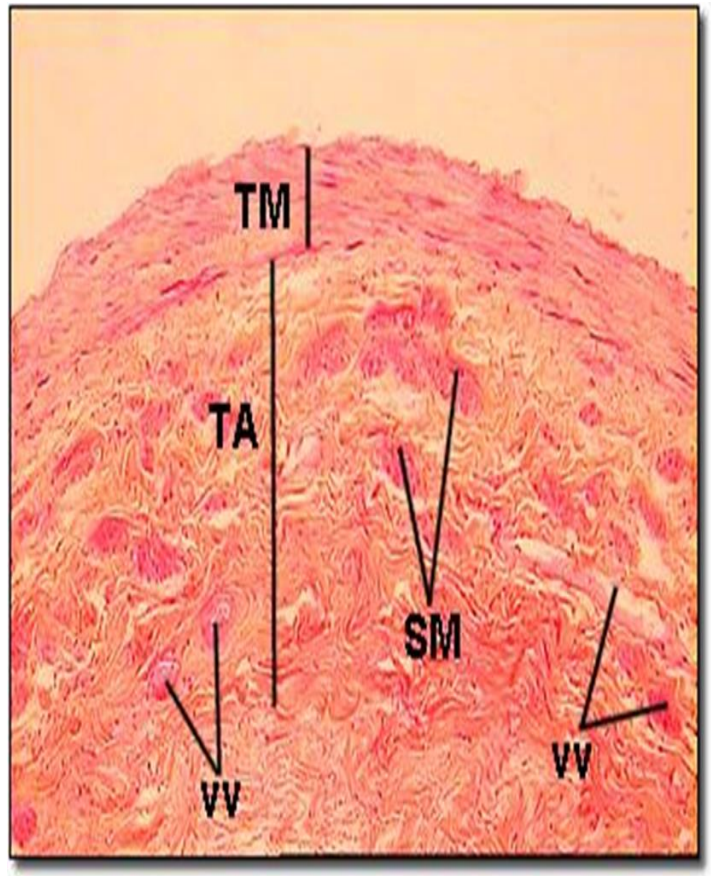




Large Veins

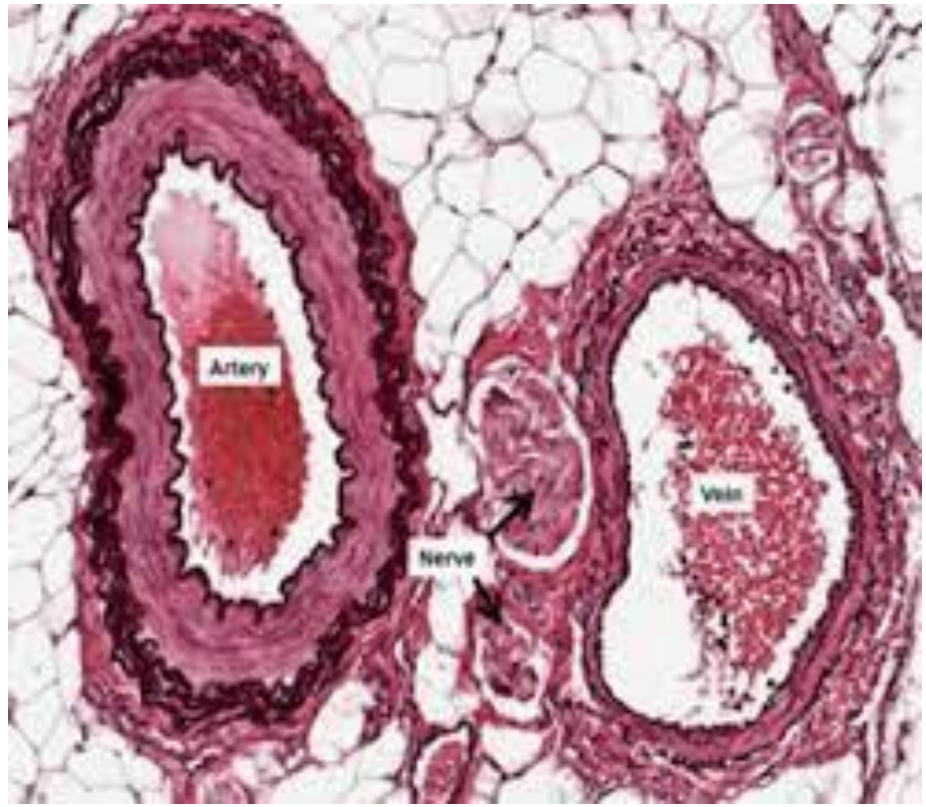
Examples: SVC and IVC

- T intima: well developed, endothelium and subendothelial C T +
- T media 30%: thin circularly arranged smooth muscle fibers
- T adventitia 70%: well developed, thickest coat, many longitudinal bundles of smooth muscle fibers are embedded in C T.
- Longitudinal bundles facilitate shortening and elongation of the vena cava with respiration.



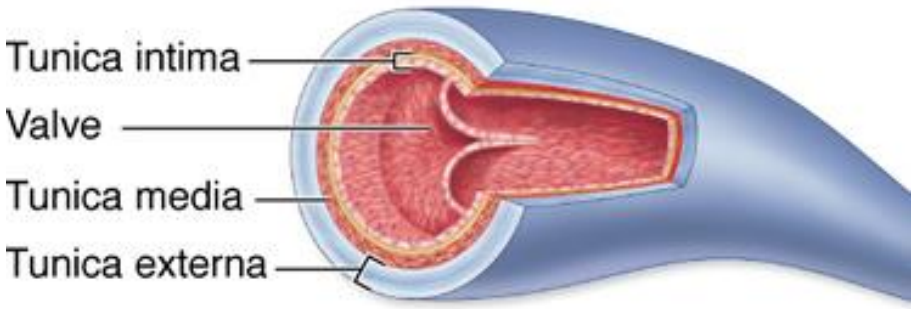
Medium sized Vein

- **T intima**: endothelium & thin layer of subendothelium
- **T media**: Few circularly arranged smooth muscle fibers embedded in C T having predominantly collagen fibers, less elastic fibers.
- **T adventitia**: loose fibero-elastic C T with vasa vasorum and nerve fiberes.



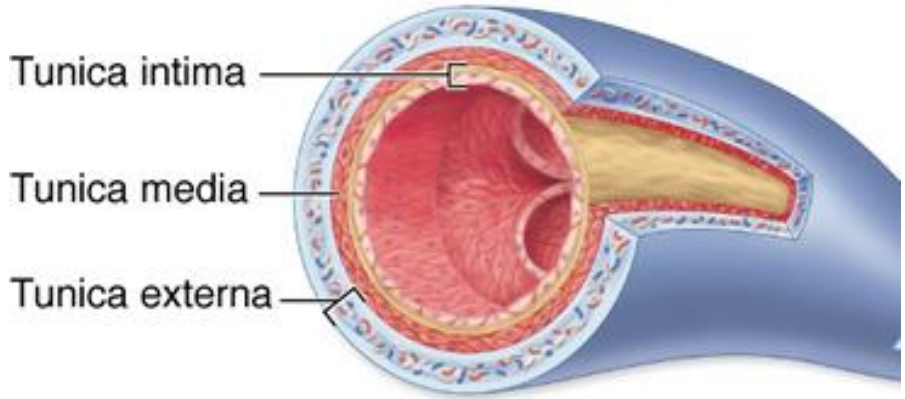
Veins

Medium-sized vein



- Thin intima, may have valves.
- Thin media composed of a few elastic fibers and smooth muscle cells.
- Relatively thick externa composed of longitudinal collagen and elastic fibers .

Large vein



- Thin intima, may have valves.
- Thin media, like medium-sized veins.
- Relatively thick externa composed of longitudinal collagen fibers, elastic fibers, and smooth muscle cells. Also has Vasa vasorum.
- “Named” veins (e.g., portal vein) are usually large veins.

	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

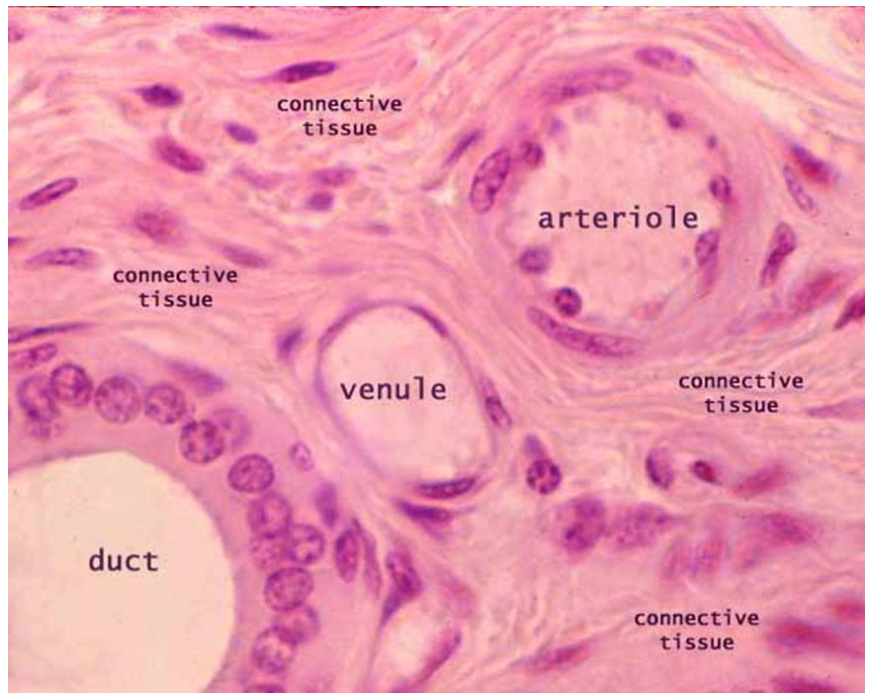
Venules

- Receive blood from capillaries
- Have a larger diameter than arterioles
- Small venules (post capillary venules) take part in exchange of metabolites between blood and tissue
- Also permit leucocytes migration as do capillaries.

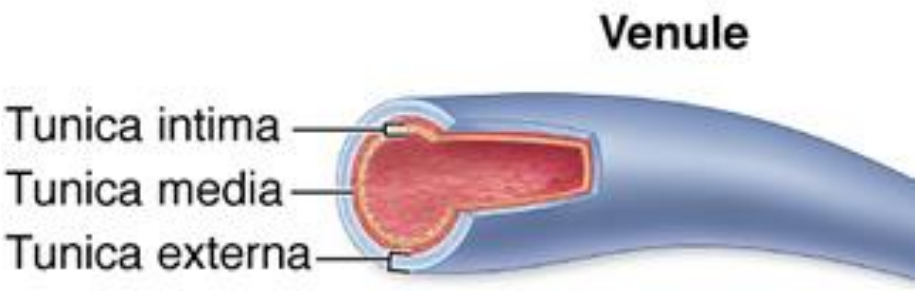
Three layers of Venules

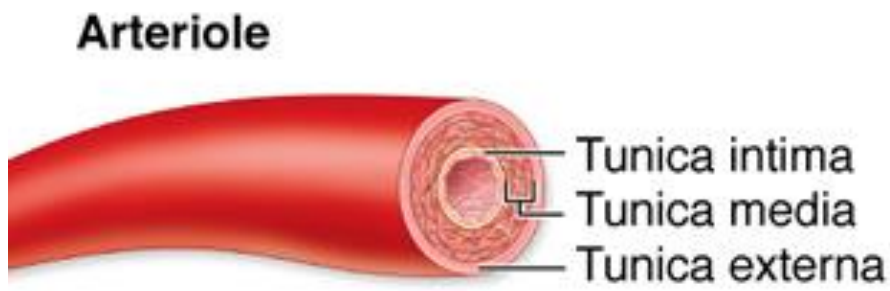
- Wall is thin
- Large collapsed lumen
- T intima: endothelium
- T media: 1-2 layers of smooth muscle fibers.
- T adventitia: thick and composed of connective tissue rich in collagen fibers.

- The post capillary venules in mucosa associated lymphoid tissue(MALT) are lined by tall cuboidal endothelial cells and are called high endothelial venules (HEV)



Venules and Arterioles





- Relatively thin wall and large lumen.
- Media has just a few smooth muscle cells here and there.

- Relatively thick wall and small lumen.
- Media has 1-5 layers of smooth muscle cells.

Microvascular bed = peripheral circulation

composed of arterioles, capillaries and arterio - venous shunt in the following arrangement:

❑ A **metarteriole** is a short microvessel in the microcirculation that links arterioles and capillaries.

- Instead of a continuous tunica media, they have individual smooth muscle cells placed a short distance apart, each forming a precapillary sphincter that encircles the entrance to that capillary bed.
- Constriction of these sphincters reduces or shuts off blood flow through their respective capillary beds. This allows the blood to be diverted to elsewhere in the body.

- **Capillary**

❑ **Arterio-venous shunt**

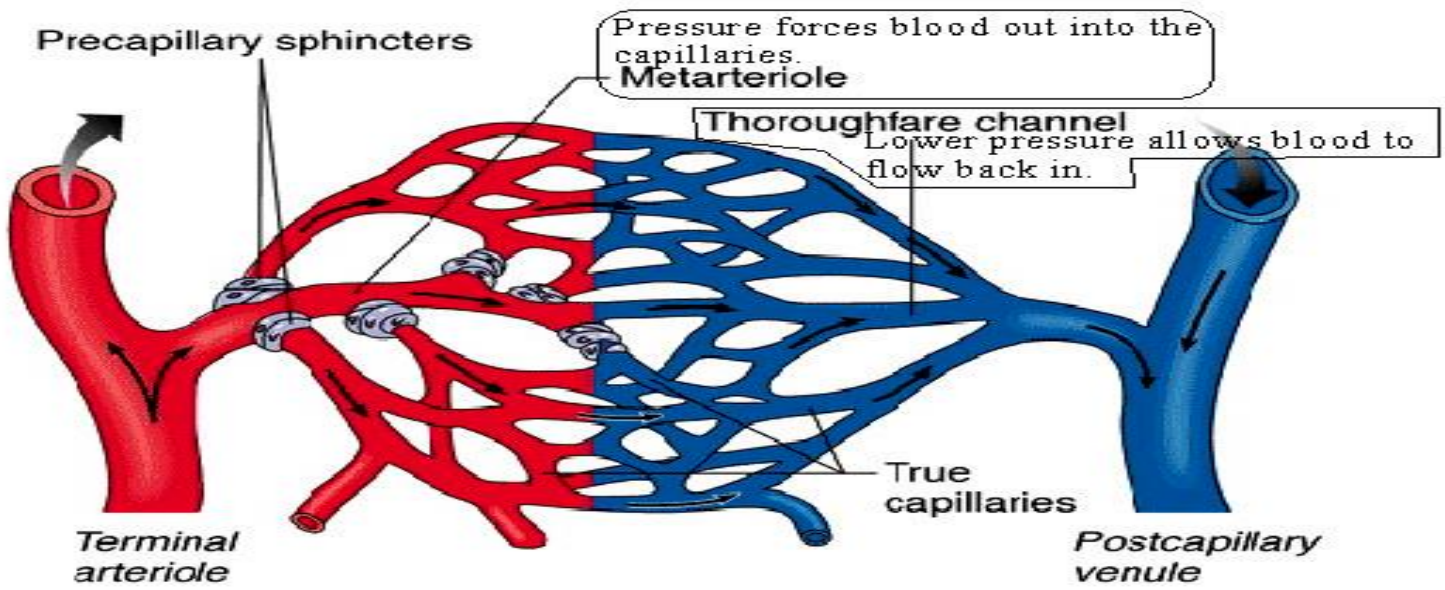
These represent **direct connections** between arterioles and venules allow blood to bypass the capillary bed very common in the dermis of the **skin, lips, nose** and **GIT**

Functions:

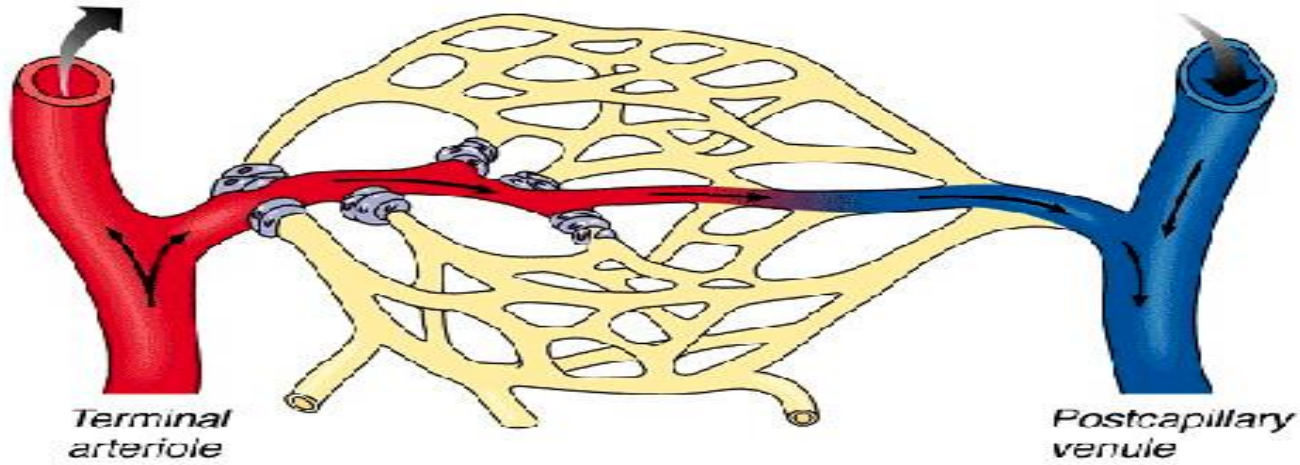
➢ **backup routes** for blood to flow if one link is blocked

➢ **control blood flow** and **assist in temperature regulation**

Arteriovenous Anastomosis



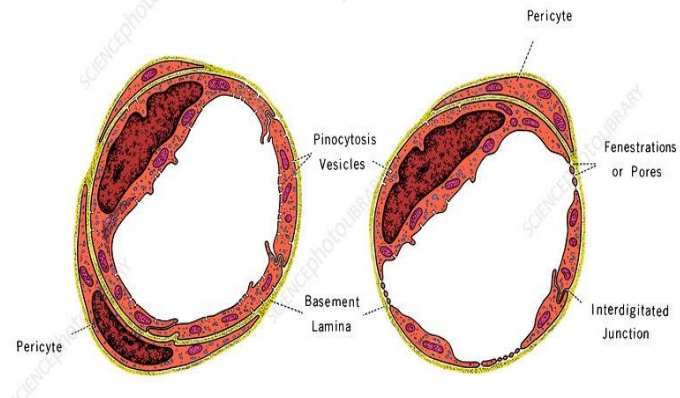
(a) Sphincters open



(b) Sphincters closed

Capillary

- Arterioles break up into small blood vessels, the capillaries.
- Often referred to as **Exchange vessels** as they are involved in the exchange of gases, nutrients and metabolities between blood and tissue.
- Tissues with high metabolic rate have abundant capillary network. Example: kidney, liver and cardiac muscle.
- Diameter (7-9 micron m) equal to the size of an erythrocyte.
- Wall has only one layer-the Intima-Consists of 1-3 circimferentially arranged endothelial cells
- Underlying basal lamina
- Few randomly scattered Pericytes, branching perivascular cells.
- Lacks T Media and therefore no smooth muscle cells
- Pericytes or Adventitial cells contain contractile filaments in the cytoplasm and can transform into other cells



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

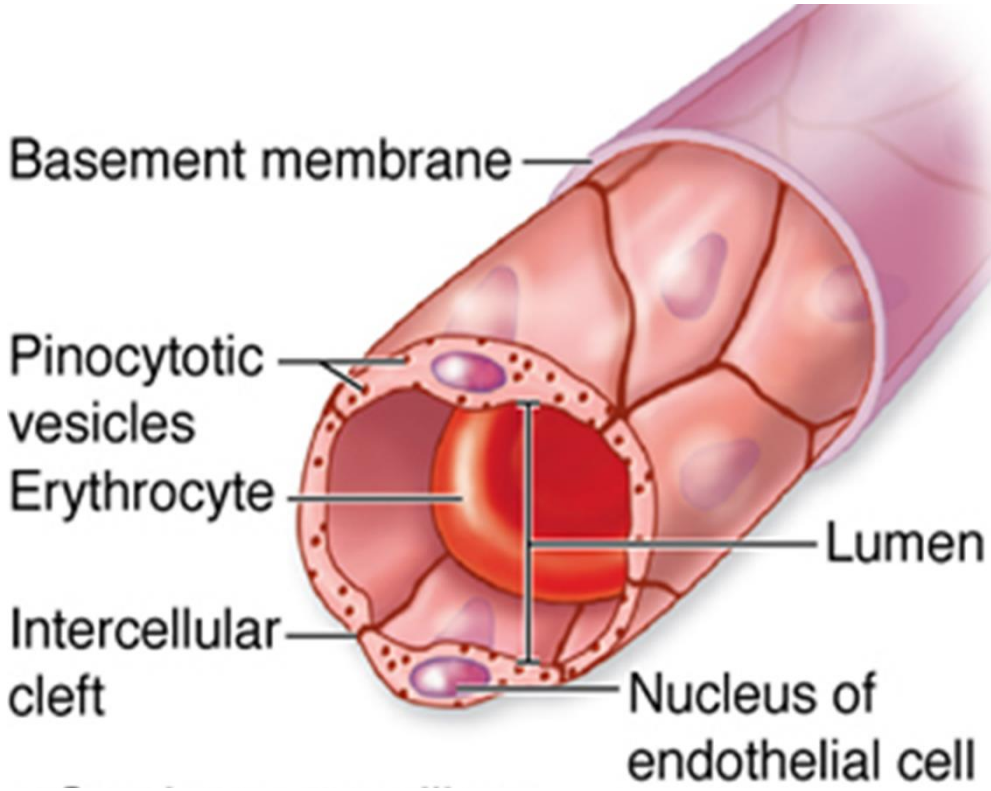
Function :

1. **-contractile (cytoplasm contain actin & myosin)**
2. **-repairing**
3. **-phagocytic**

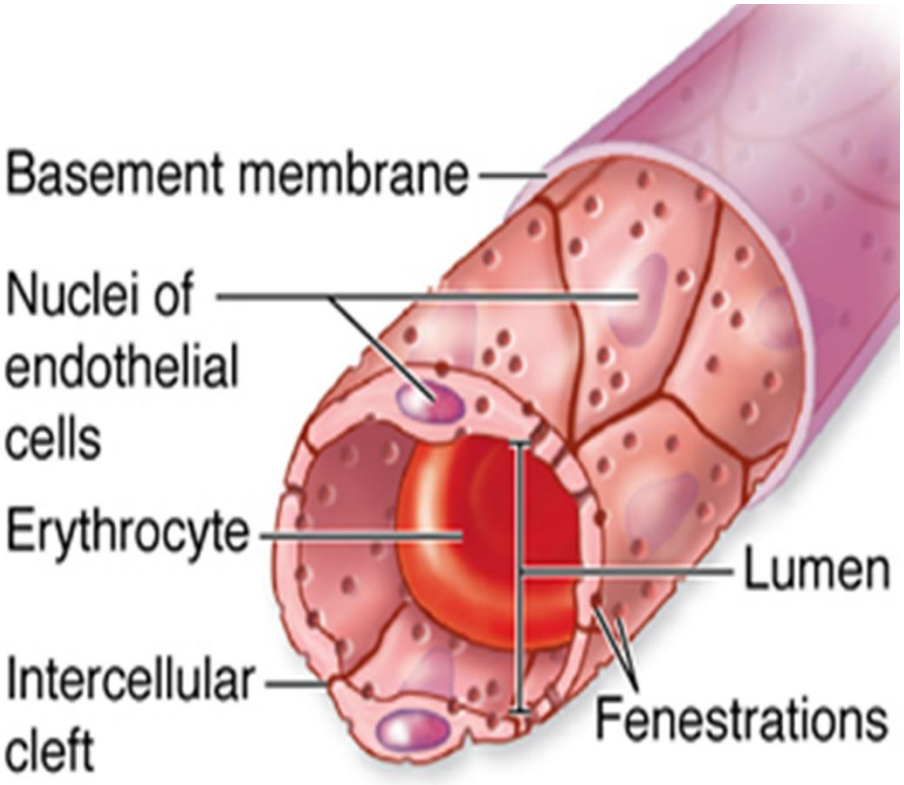
Types of Capillaries

Continuous or Somatic

- Commonest type
- Present in connective tissue, muscle, brain, lung etc
- Endothelial cells form the continuous lining of the capillary.
- Tight junctions, desmosomes and gap junctions are seen.



Fenestrated or visceral



- Endothelial cells are perforated with small fenestrations (holes).
- Tiny pores(openings , fenestrations) are present in the cytoplasm of endothelial cells.
- Pores are so designed for rapid exchange of molecules between blood and tissue(greater permeability)
- Basement membrane is intact
- Found in places where substances need to move quickly between tissues and blood (e.g. kidney, intestine, and endocrine organs).

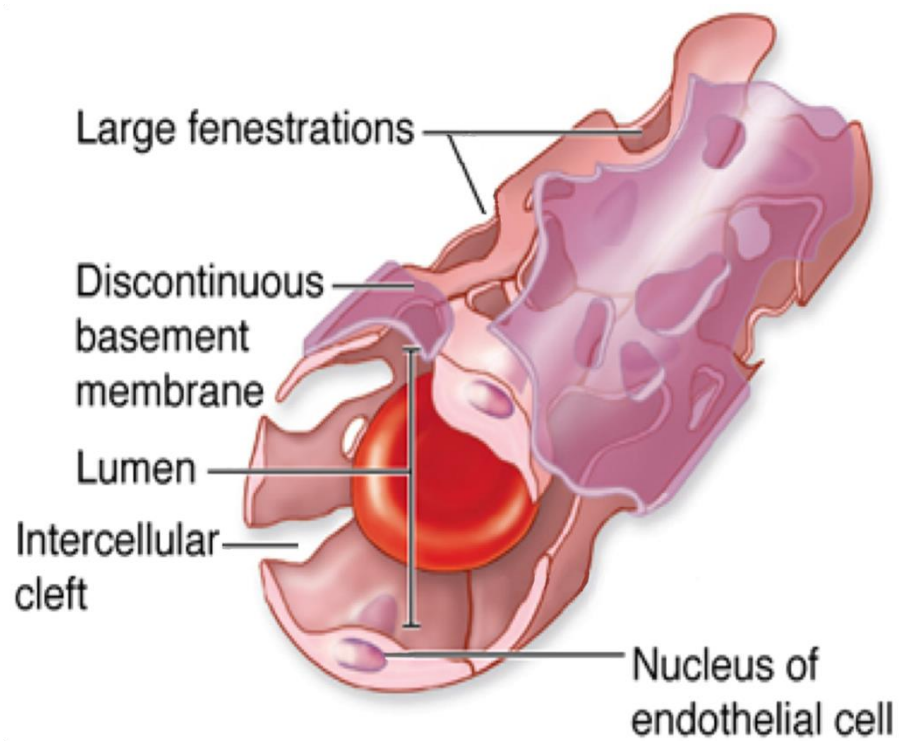
Sinusoidal Capillaries (Sinusoids)

- Also called Discontinuous capillaries because basal lamina is not continuous(Lumen is lined by discontinuous endothelium)
- Thin walled, irregular and tortuous
- Have much wider irregular lumen (30-40 micron m)

- Endothelial cells have big fenestrations and gaps (clefts) between cells.

- Basal lamina is discontinuous.
- These two facts permit passage of blood cells and macromolecules.

- Most permeable of all three capillary types.
- Phagocytic cells may be seen in its wall
- Found in liver and haemopoietic organs like red bone marrow and spleen.



	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

Blood portal systems

- **In typical configurations**, 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 veinule 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 (portal vein) enters the capillary bed and a vein (hepatic vein) exits the capillary bed.
- 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.
- A similar portal system is found in the hypothalmus-hypophysis.

Lymphatic Vessels

- Lymphatic system collects interstitial fluid (lymph) that leaks from blood vessels into connective tissue, and return it to blood

- Flow is unidirectional

- **Lymphatic capillaries** **larger** than blood capillaries consist of one layer of endothelial cells and a discontinous basal lamina

- Lymphatic capillaries merge, forming lymphatic vessels (with very thin walls)

similar to lymph capillaries but **larger** and with **valves empty** into **lymph nodes**

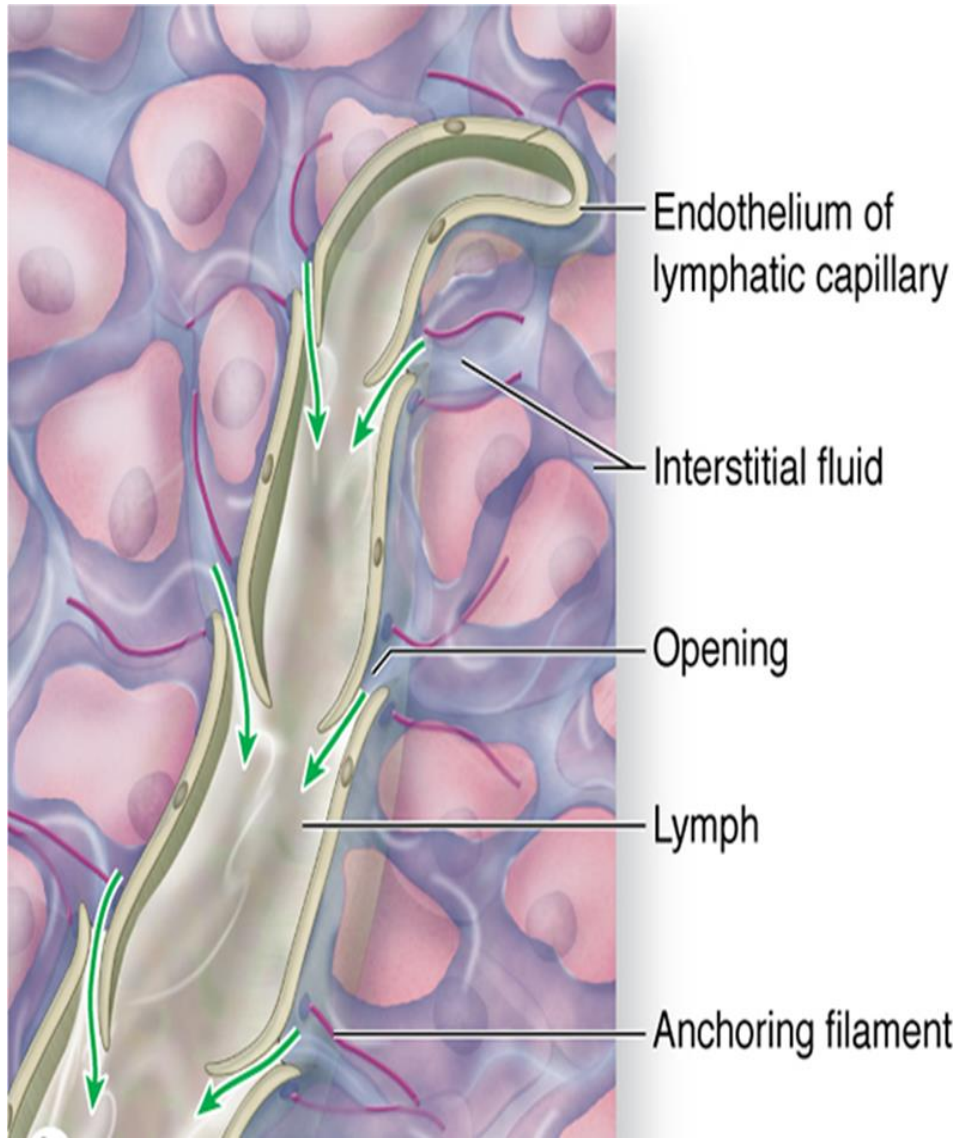
The lymph is moved by the **compression** of the lymph vessels by **surrounding tissues**

- **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

	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