Histology Lab – CARDIOVASCULR SYSTEM

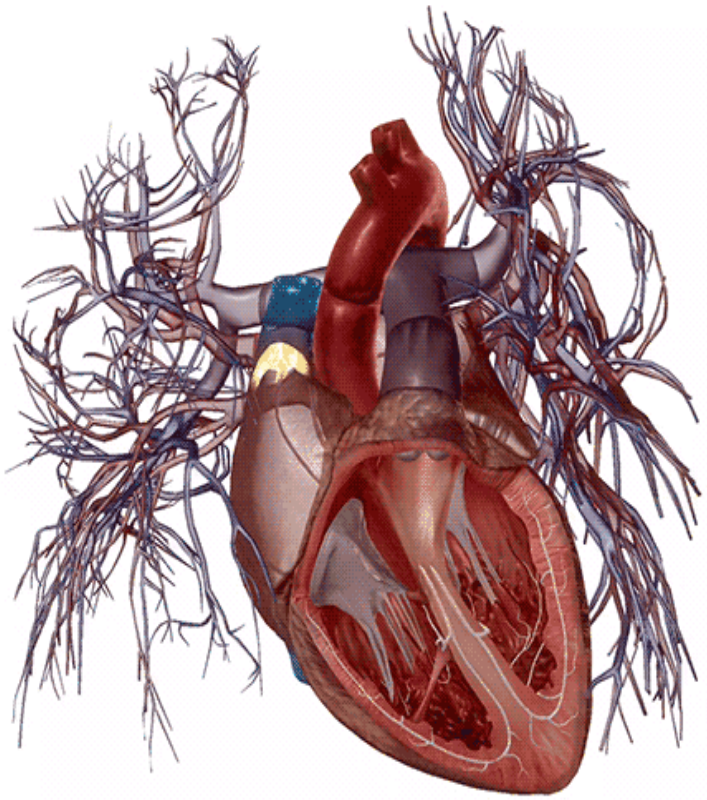
Cardiovascular system

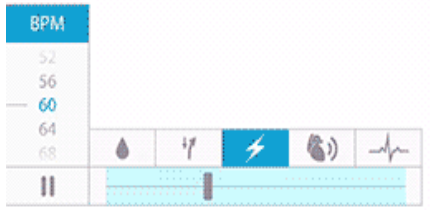
1- Components of cardiovascular system.

2- Structure of the heart.

3- Differences between cardiac muscles& skeletal muscles.

4- Growth & regeneration of the cardiac muscles.



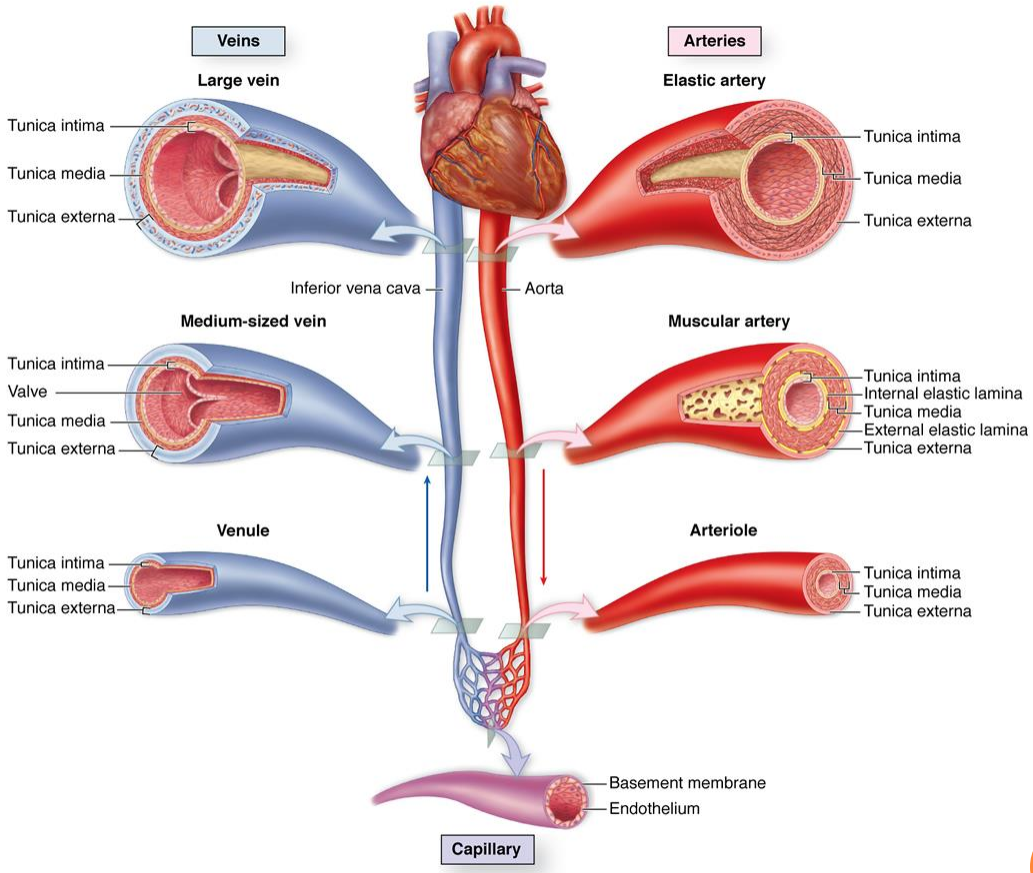


Circulatory system

- **It consists of:**

1- Vascular system: heart, arteries, capillaries & veins.

2- Lymphatic system.



Heart

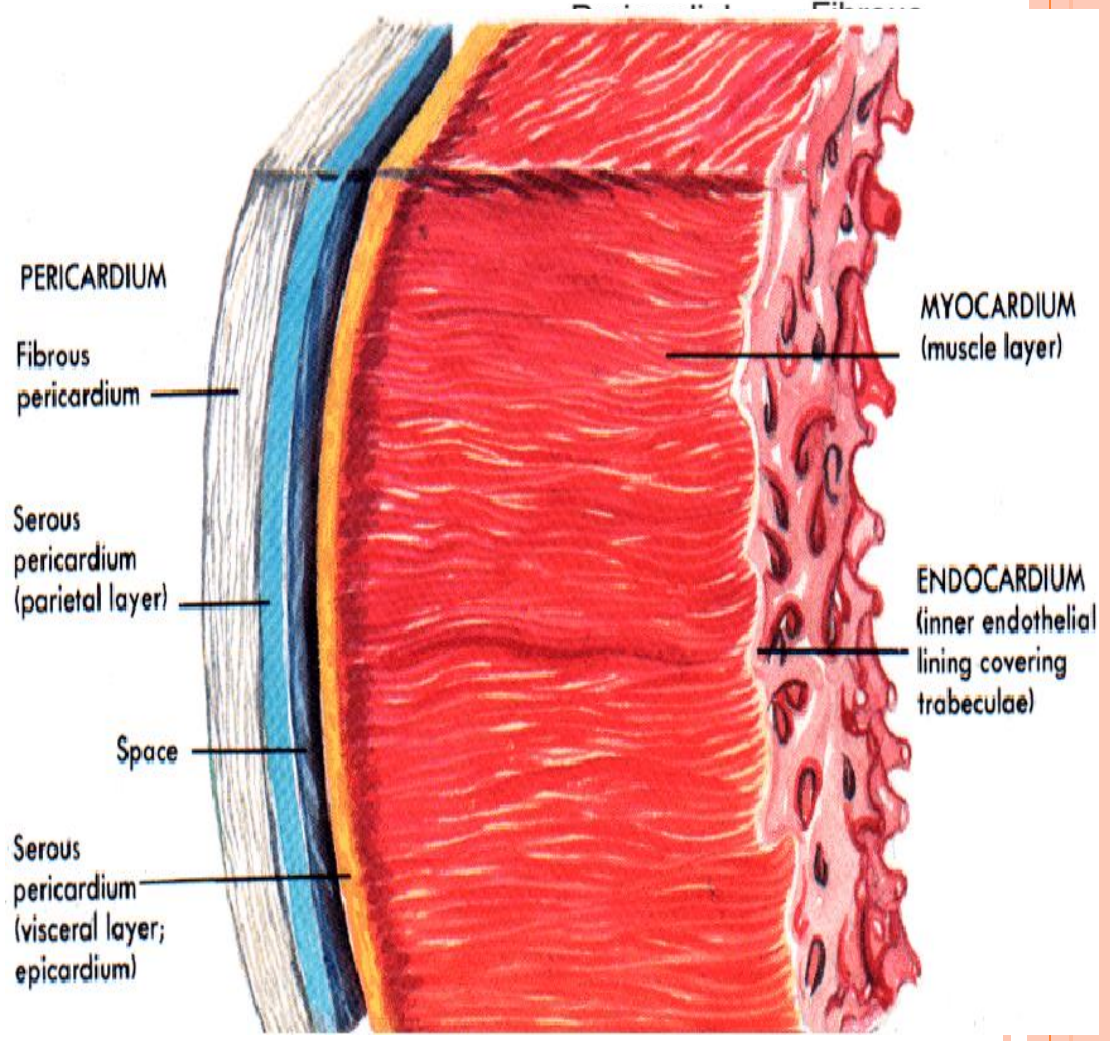
HEART

- The wall of the heart consists of three layers:

1- *Endocardium:* inner layer.

2- *Myocardium:* middle muscular layer.

3- *Epicardium:* outer layer.



HEART

1- Endocardium: consists of:

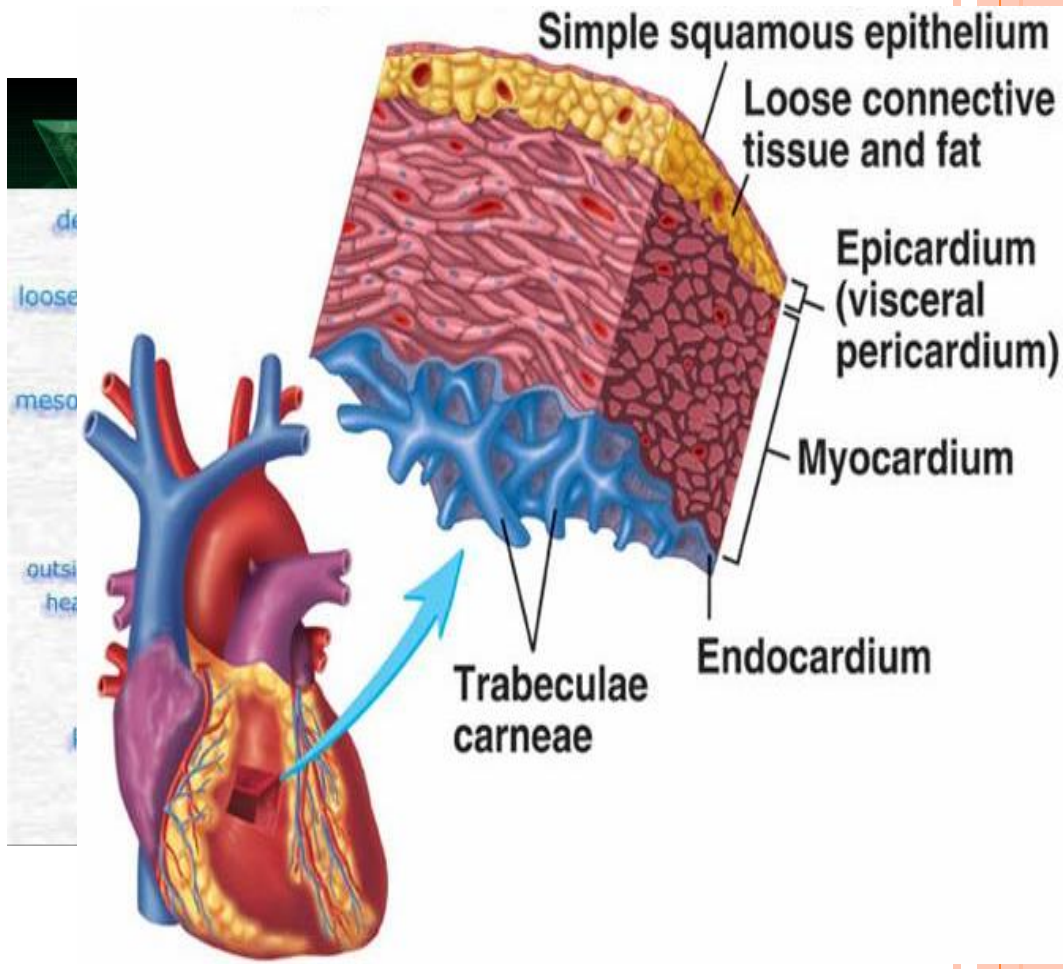
- *Endothelium:* simple squamous epithelium.
- *Subendothelial connective tissue:* which is continuous with that of the blood vessels entering and exiting from the heart.
- *The subendocardium:* a layer of connective tissue where branches of the conducting system are located.

2- Myocardium:

- It is the thickest coat.
- It is composed of *cardiac muscle fibers* bound together by connective tissue.

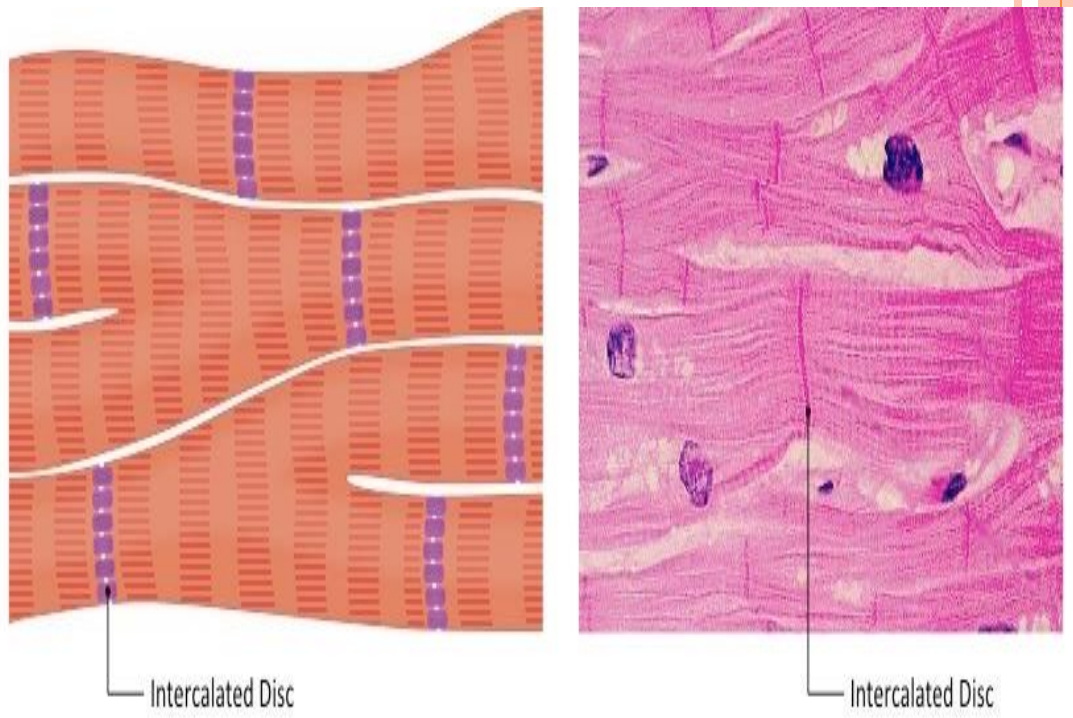
3- Epicardium:

- It is the visceral layer of the pericardium.
- It consists of a simple squamous *mesothelium*, supported by loose connective tissue containing the coronary vessels, nerves, and adipose tissue.



Cardiac muscle

- It is striated & involuntary.
- Its contraction is initiated by the spontaneous depolarization of pacemaker cells.

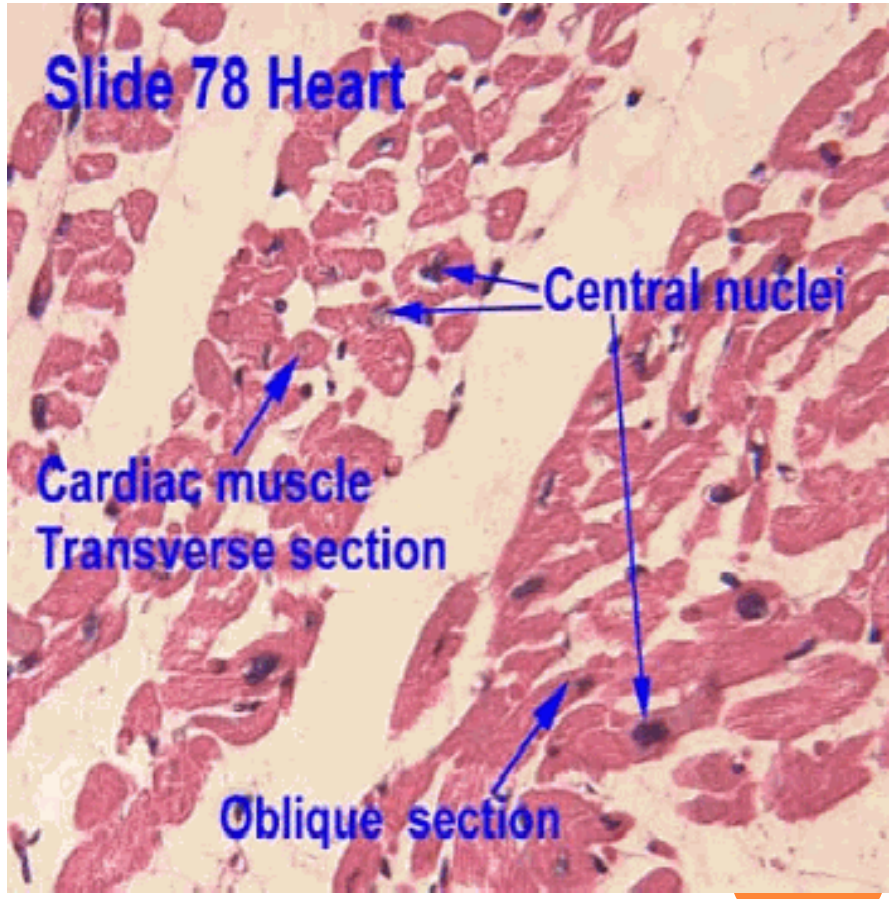


Structure of cardiac muscle
LM
1- Connective tissue

- It consists of:

1- Perimysium: highly vascularized, formed of collagen and elastic fibers, which are present between the bundles of cardiac muscle fibers.

2- Endomysium: a network of reticular fibers surrounds each muscle fiber.



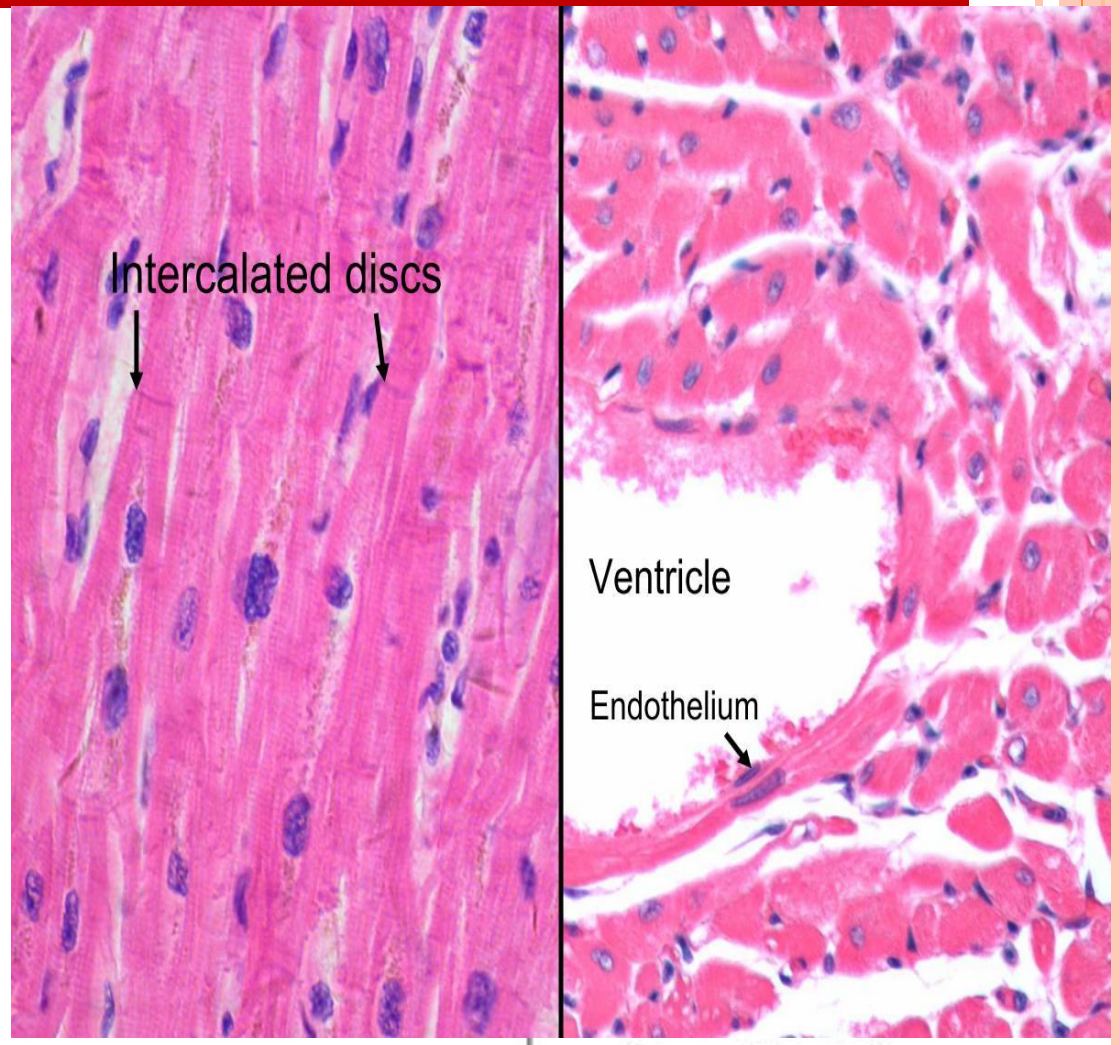
Structure of cardiac muscle
LM
2- Cardiac muscle fibers

1- They are long cylindrical fibers which *branch and anastomose* leaving slit-like spaces between them. Thus, in the same section, different cuts in cardiac muscle fibers could be seen (longitudinal, transverse&oblique).

2- The fibers show *fainter striations* than those seen in skeletal muscle fibers.

3- Each cardiac muscle fiber consists of short columnar cells called *cardiomyocytes* joined by the *intercalated discs* that run transversely across the fiber.

4- Each cardiomyocyte has a single, central & oval *nucleus*.



Structure of cardiac muscle
LM
2- Cardiac muscle fibers

Structure of cardiac muscle
EM
1- Myofibrils

1- The myofibrils branch and anastomose thus they are *not perfectly in register* with one another.

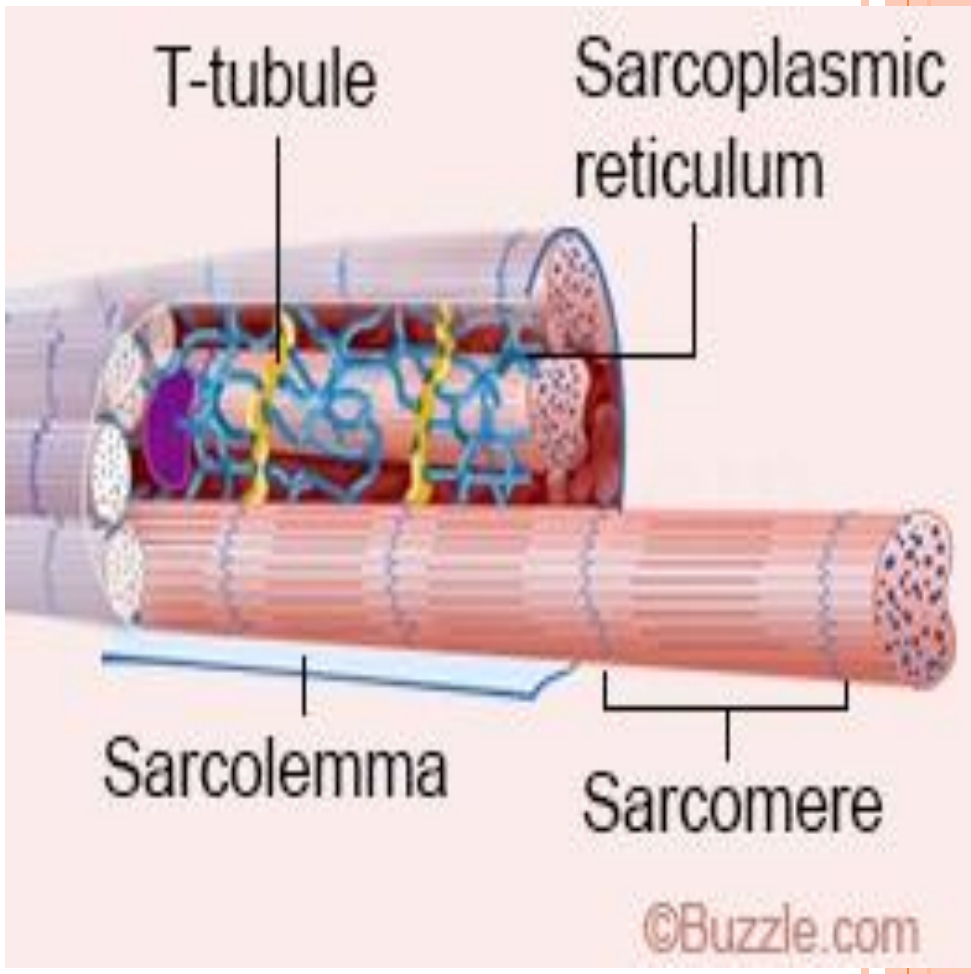
2- The pattern of cross striations are identical to that of skeletal muscle.

3- The myofibrils diverge around the nucleus leaving the sarcoplasm at the nuclear poles containing various organelles & inclusions (numerous mitochondria, glycogen granules and *lipofuscin pigments*).

Why do the cardiac muscle fibers show fainter striations?

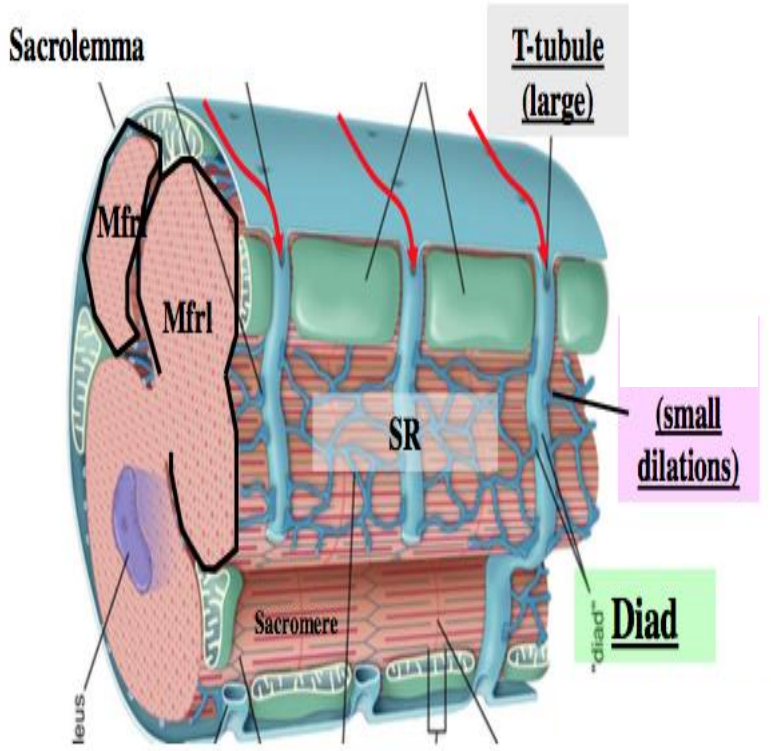
Structure of cardiac muscle
EM
2- T tubules

- **Definition:** inward extensions of the extracellular space at the sarcolemma.
- **Characteristic features:** large & numerous.
- **Site:** at the Z line.
- **Function:**
  - Excitation-contraction coupling.
  - Provide additional surface area for exchange of metabolites between cardiac muscle fibers and the extracellular space.



Structure of cardiac muscle EM
3- Sarcoplasmic reticulum

- It is less organized than the skeletal muscle.
- It consists of narrow anastomosing sarcotubules *without the continuous terminal cisternae* that encircle the whole myofibrils, instead, scattered small expansions of sarcotubules are in close apposition with the T tubules forming *diads*.



Structure of cardiac muscle
EM
4- Intercalated discs

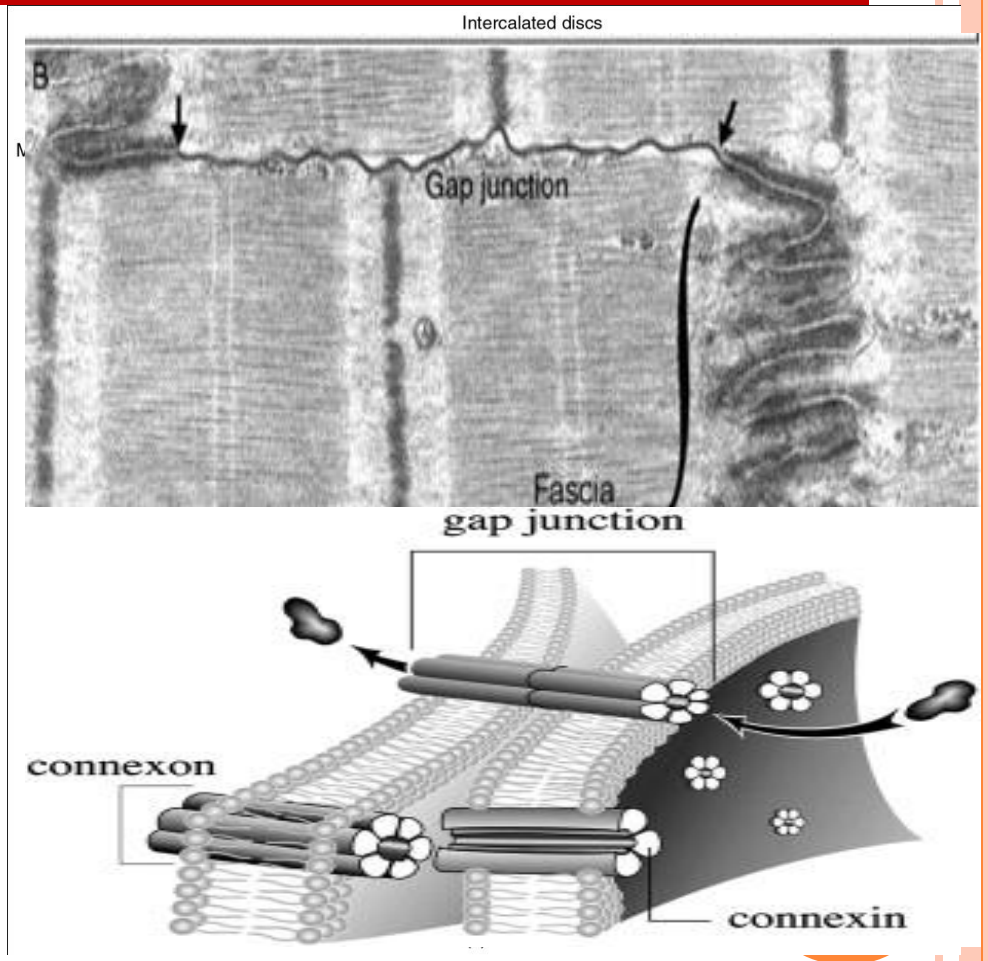
- **Definition:** specialized junctions of cell membranes of adjacent cardiomyocytes.
- **Site:** extend across the fiber at the level of the Z lines.
- **Shape:** stepwise.
- **Structure:**

1- Transverse portion:

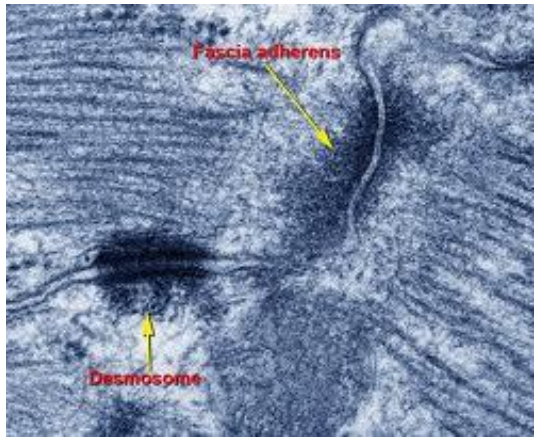
- Site: runs across the fibers perpendicular to the myofilaments at the level of the Z line.
- Structure: It is formed of fascia (zonula adherens)and macula adherens (desmosomes attached to desmin)
- Function: provide strong adhesion between the adjacent cardiomyocytes.

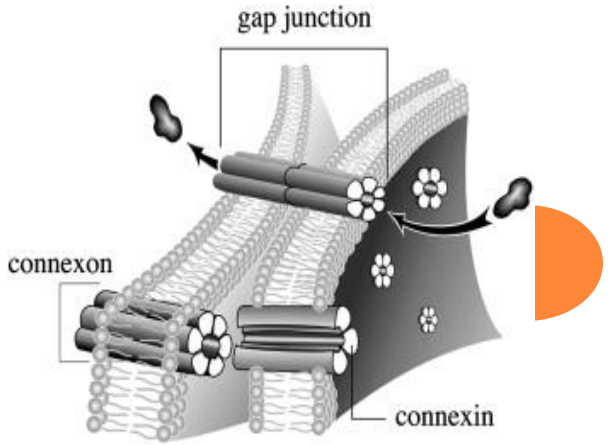
2- Longitudinal portion:

- Site: runs parallel to the myofilaments
- Structure: many gap junctions.
- Function: allow rapid spread of excitation between the adjacent cardiomyocytes.



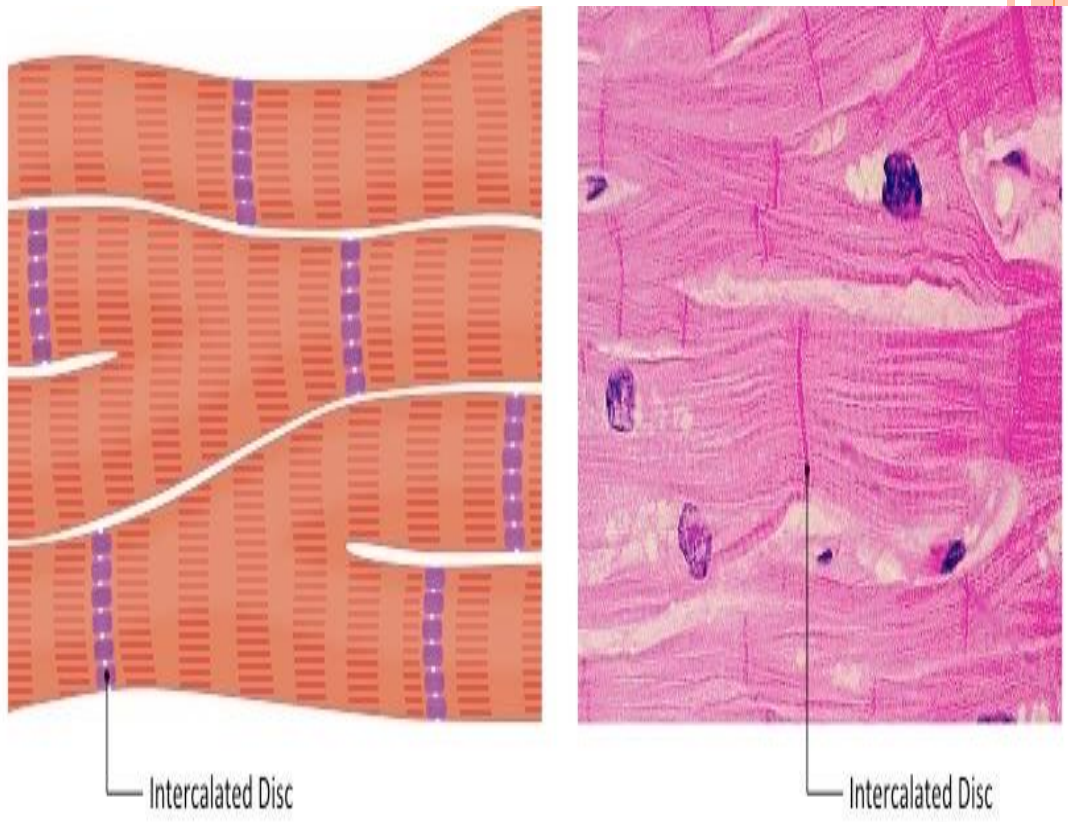
Intercalated discs	Transverse portion	Longitudinal portion
Site	Perpendicular to myofilaments, at the level of Z line.	Parallel to myofilaments.
Stress of contraction	↑↑	↓
Structure	1- fascia adherence 2- macula adherence	Gap junctions
Function	Strong adhesion between the cells during contraction	Rapid spread of excitation from one cell to the other





Types of cardiomyocytes
1- Contractile cardiomyocytes

- **Definition:** They are the ordinary cardiomyocytes that form the majority of the myocardium of the atria and ventricles.
- **Function:** contraction.



Types of cardiomyocytes
2- Endocrine cardiomyocytes

- **Definition:** They are cardiomyocytes which have an endocrine function.
- **Site:** in the atria, especially the right atrium.
- **Structure:** *They differ from contractile cardiomyocytes in:*

1- They have fewer myofibrils.

2- They have numerous electron dense secretory granules containing *the atrial natriuretic factor* which has a role in control of blood pressure and electrolyte balance.

Atrial endocrine cardiomyocytes

Types of cardiomyocytes
3-Cardiomyocytes of the conduction system

- **Definition:** modified cardiomyocytes that are specialized in the initiation and propagation of depolarization through the myocardium faster than the contractile cardiac muscle fibers.
- **Types:**

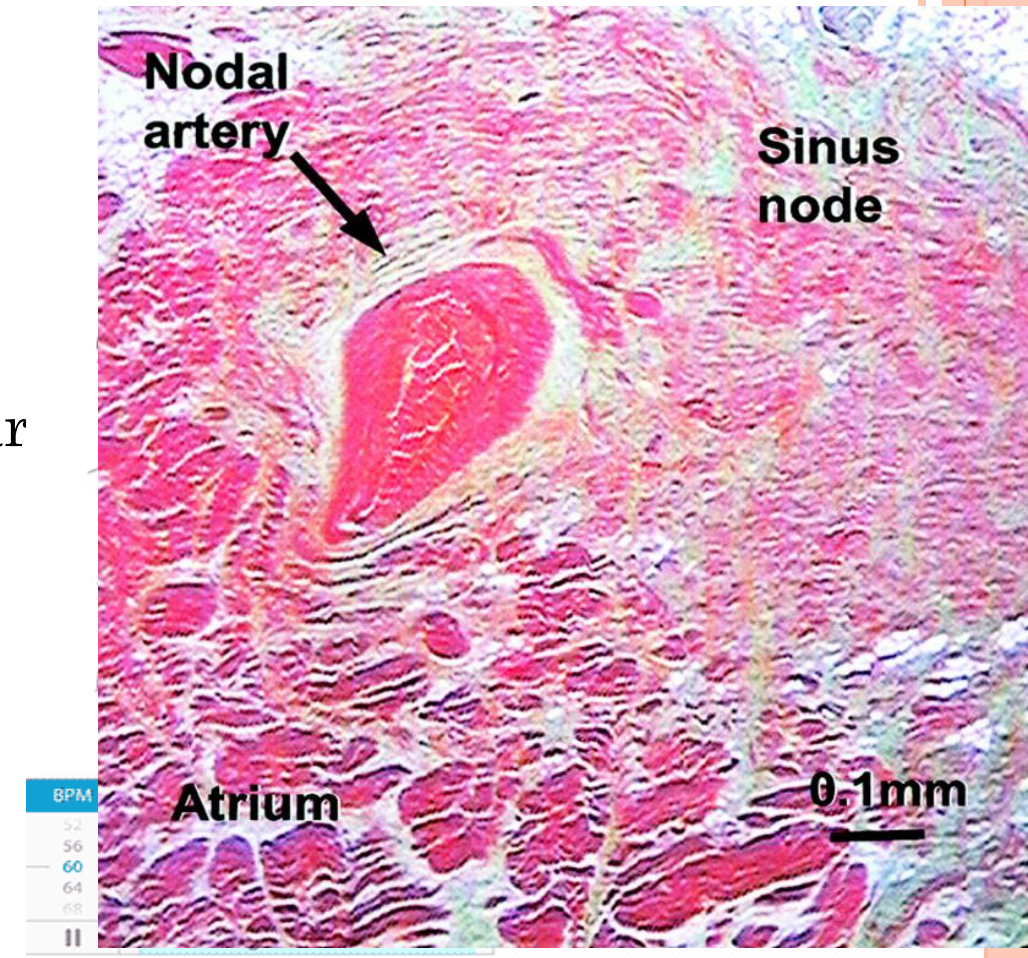
a) Nodal cells:

- Site: in the sinoatrial node, the atrio-ventricular node and the trunk of the bundle of His.
- Structure:

1-They are smaller than the surrounding atrial muscle fibers.

2- Contain fewer myofibrils.

3- Lack typical intercalated discs.



Types of cardiomyocytes
3-Cardiomyocytes of the conduction system

b) Purkinje fibers:

- Site: in the myocardium of the ventricles.
- Structure:

1- They are present *in groups* of two or more.

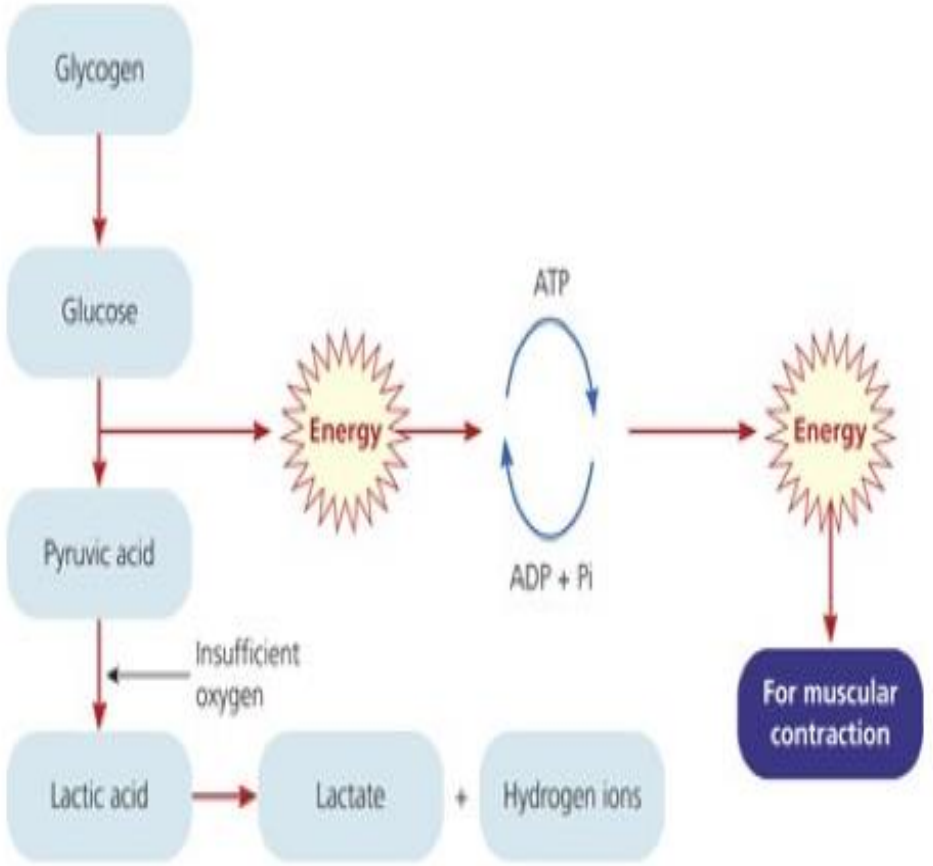
2- They are often *binucleated*.

3- They are *larger* than the ventricular muscle fibers

4- They contain *fewer myofibrils* which are located peripherally.

5- Their cytoplasm is rich in mitochondria and *glycogen*, so they are pale in H&E sections.

5- They do not contain typical intercalated discs, although, they contain many *gap junctions* more than in contractile cardiomyocytes.



Because of the large amounts of stored glycogen,
Purkinje fibers are more resistant to hypoxia than contractile cardiac muscle fibers.

Cardiomyocytes of the conduction system	Nodal cells	Purkinje fibers
Sites	SAN, AVN& trunk of bundle of His.	Myocardium of ventricles.
Function	Generation& conduction of excitation.	Transmission of impulses 4.5 times faster than the contractile cardiomyoctes.
Structure	•Smaller than contractile atrial myocytes. •Few myofibrils. •lack typical intercalated discs.	•Larger, in groups, binucleated. •Few myofibrils. •lack typical intercalated discs. •↑glycogen,mitochondria. •↑gap junctions.

Growth & regeneration of the cardiac muscle fibers

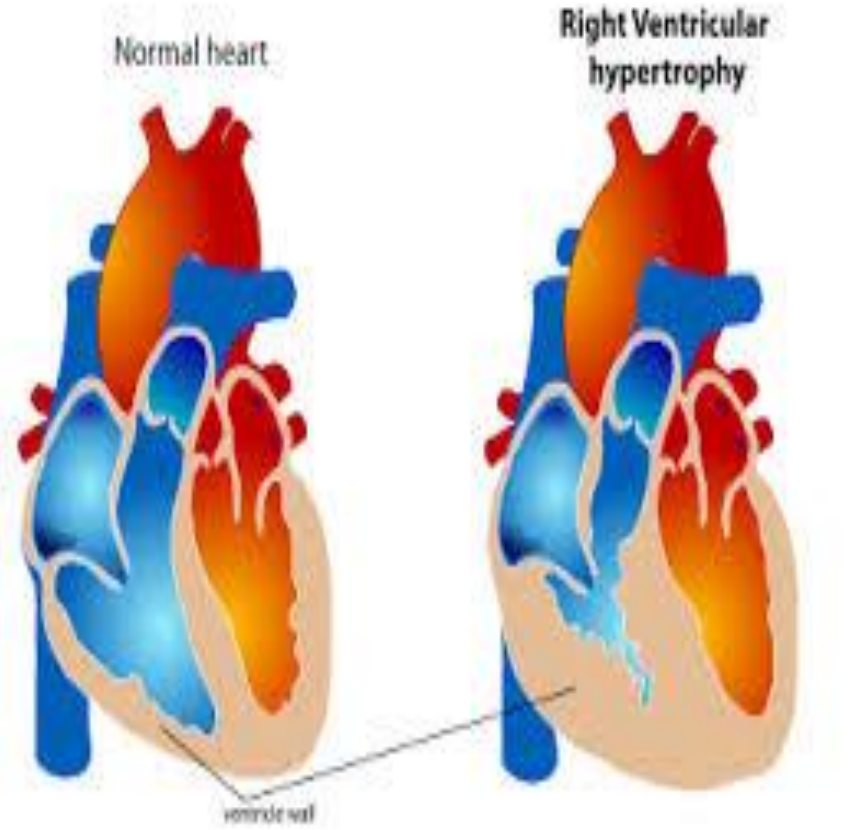
- The cardiac muscle fibers *have no ability for regeneration*, because:

1-They are static cell population

(can not divide by mitosis).

2- Satellite cells are absent.

- The injured cardiac fibers are replaced by fibrous tissue.
- The heart muscle responds to increased functional demands by *compensatory hypertrophy*.



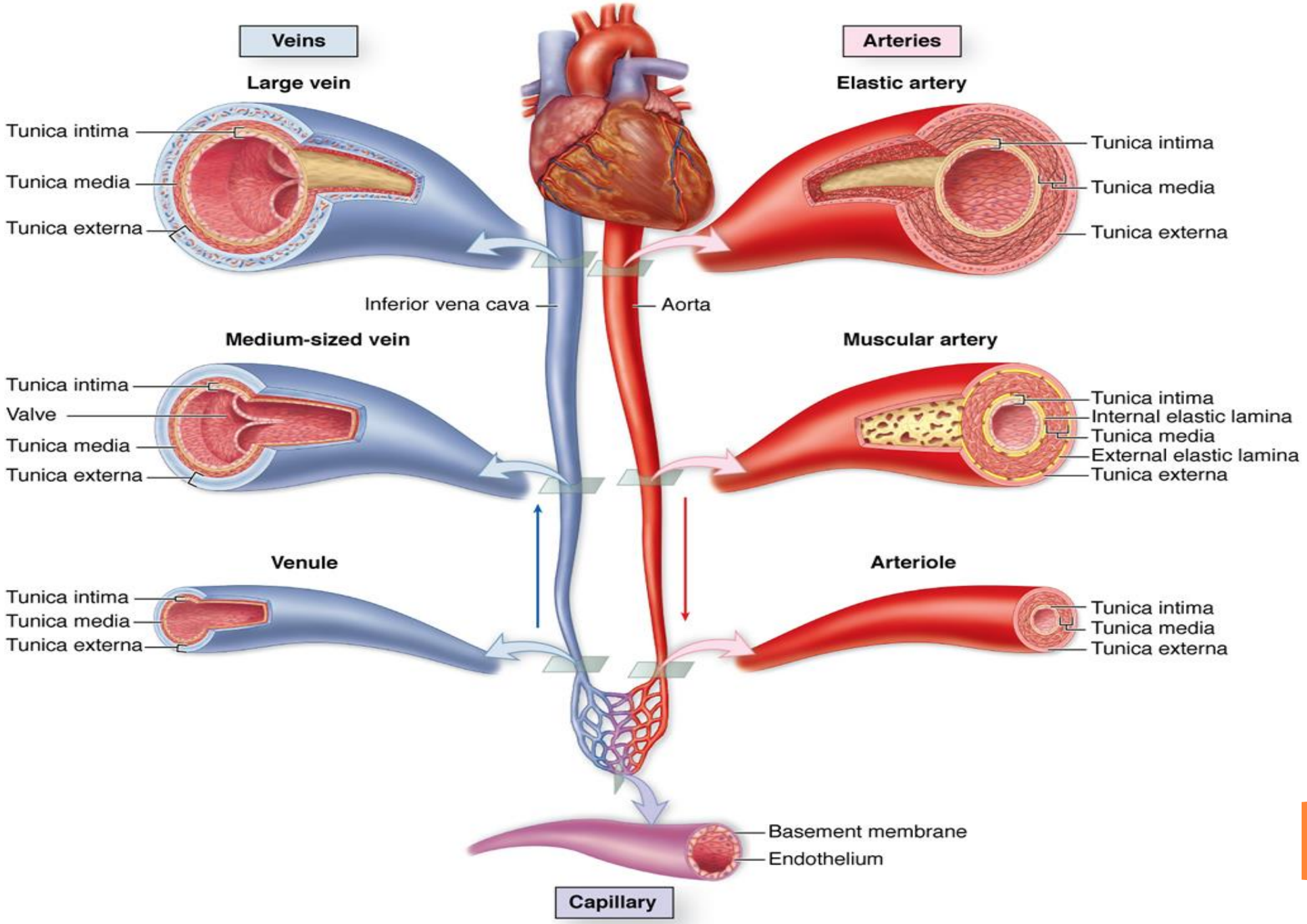
Blood Vessels

Blood vessels

1- Structure of Blood vessels.

2- Types & structure of the arteries.

3- Types & structures of veins.


Veins
Large vein
Tunica intima
Tunica media
Tunica externa
Arteries
Elastic artery
Tunica intima
Tunica media
Tunica externa
Inferior vena cava
Aorta
Medium-sized vein
Tunica intima
Valve
Tunica media
Tunica externa
Muscular artery
Tunica intima
Internal elastic lamina
Tunica media
External elastic lamina
Tunica externa
Venule
Tunica intima
Tunica media
Tunica externa
Arteriole
Tunica intima
Tunica media
Tunica externa
Basement membrane
Endothelium
Capillary

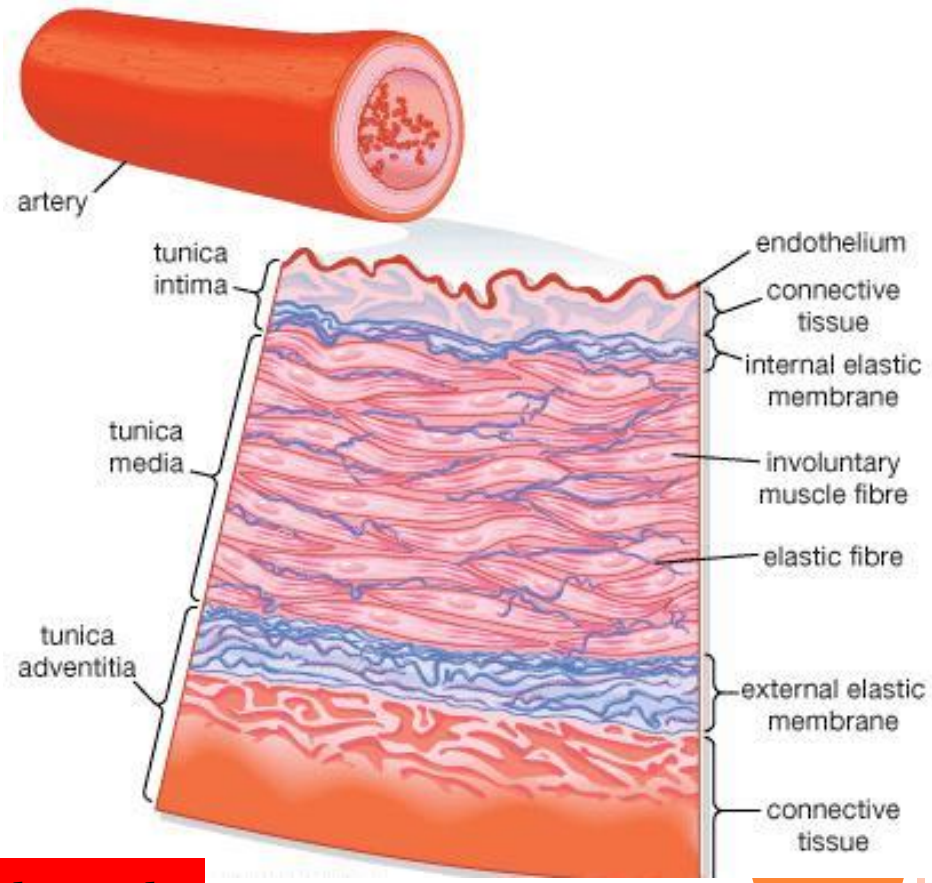
BLOOD VESSELS

- The wall of any blood vessel, *except* capillaries is formed of three layers:

1- Tunica intima: the inner layer.

2- Tunica media: the middle layer, its structure is related directly to the function of the vessel.

3- Tunica adventitia: the outer layer.



Do not forget: Internal & external elastic laminae

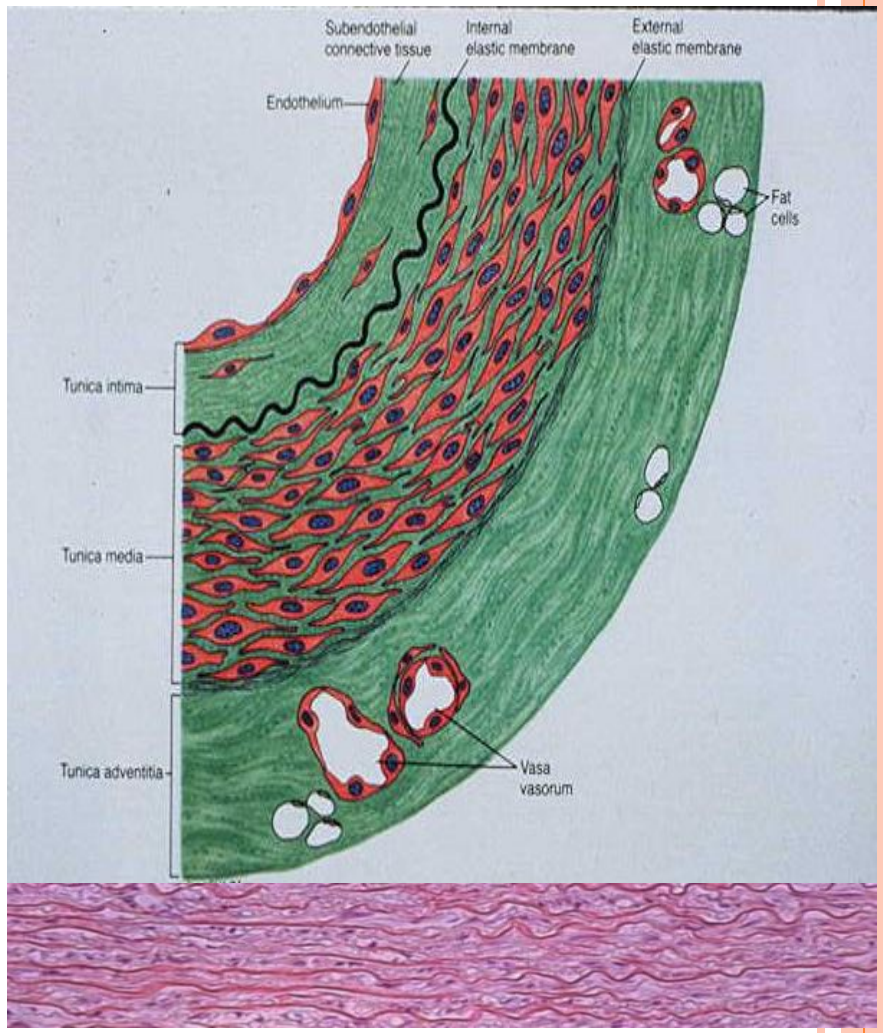
I-TUNICA INTIMA

1- Endothelium:

- Simple squamous epithelium.
- Resting on a basement membrane.
- The cells are joined together by *occluding junctions.*

2- Subendothelium: loose fibro-elastic connective tissue.

- In many arteries: the elastic fibers become condensed externally forming *the internal elastic lamina* which is fenestrated to allow diffusion of substances to nourish the deeper part of the vessel wall.



II- TUNICA MEDIA

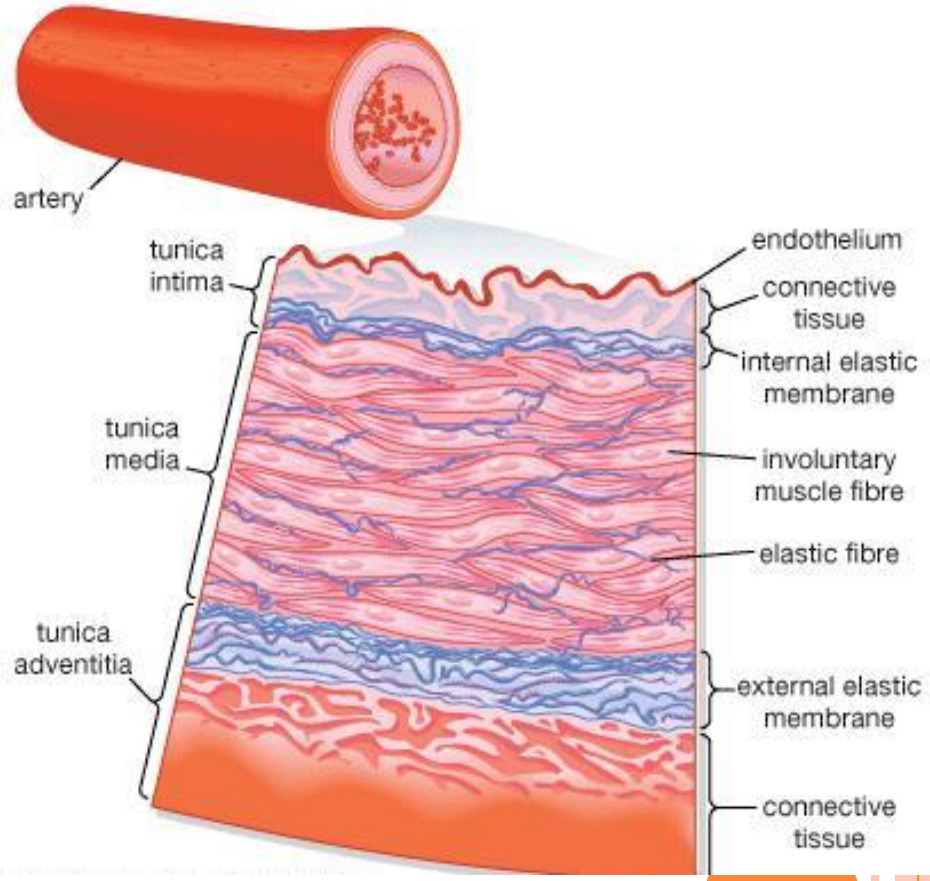
1- Concentric layers of spirally arranged *smooth muscle fibers*.

2- Elastic fibers.

3- Collagen fibers.

4-Extracellular matrix of proteoglycans.

- In many arteries: elastic fibers may form *the external elastic lamina* separating the media from the adventitia.



The fibers & the matrix are produced by smooth muscle cells.

III-Tunica adventitia

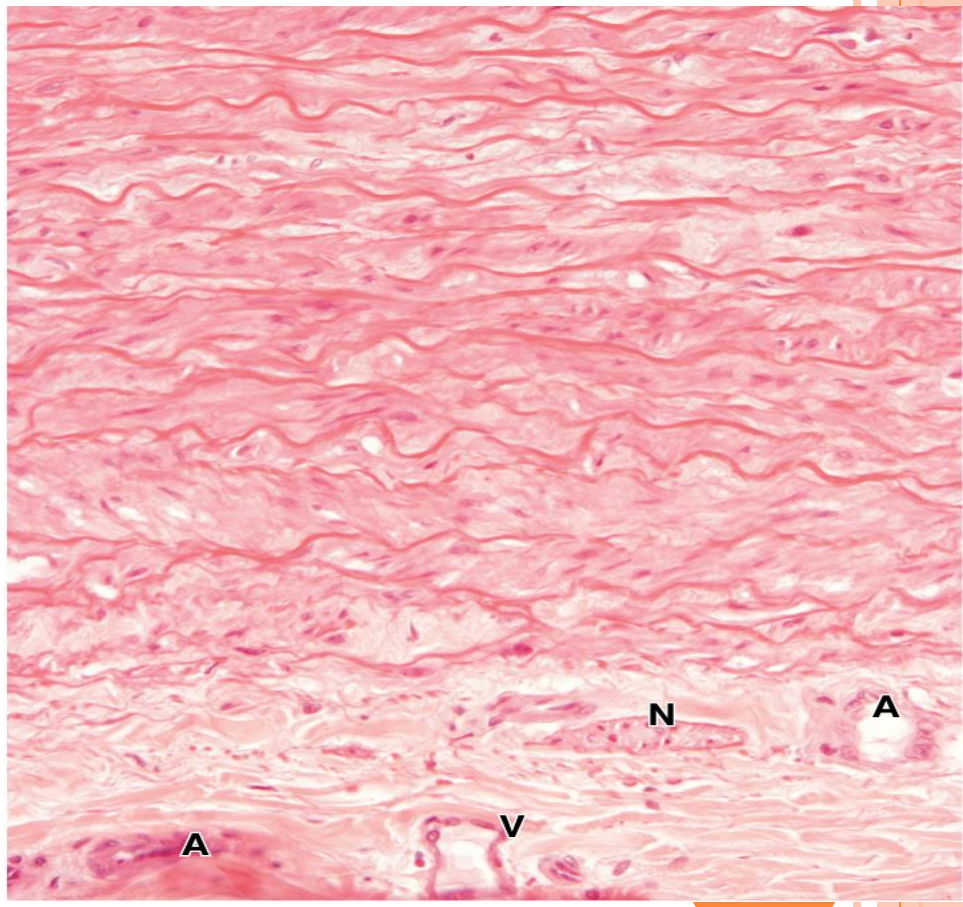
1- Fibroelastic: *Collagen and elastic fibers*: arranged longitudinally.

2- *Fibroblasts*.

3- *Vasa vasorum:* small blood vessels which provide nutrition to the vessel wall

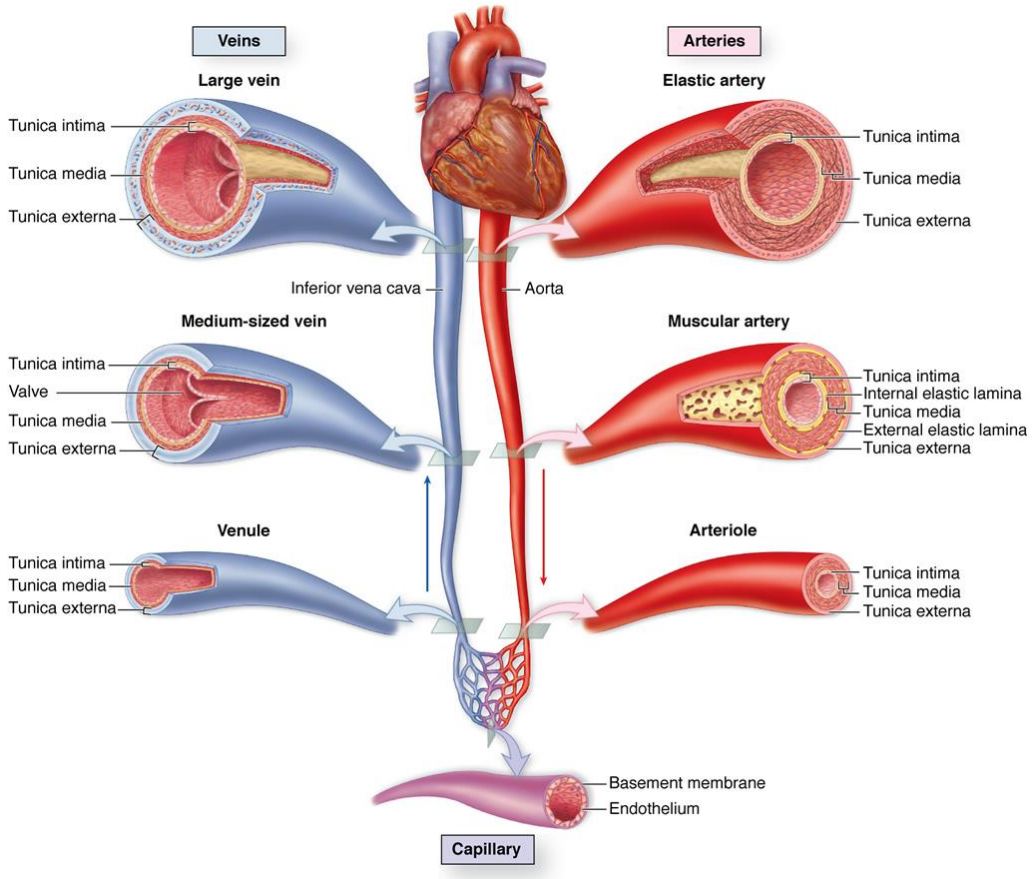
(especially the large sized arteries& veins).

4- *Nervi vasorum:* the vasomotor autonomic nerves.



A-Arteries

- Arteries are classified according to their size into large elastic arteries, medium-sized arteries and arterioles.



I-Large arteries= Elastic arteries=Conducting arteries

- These include aorta and its large branches.
- These arteries have the general structure +

1- Tunica intima:

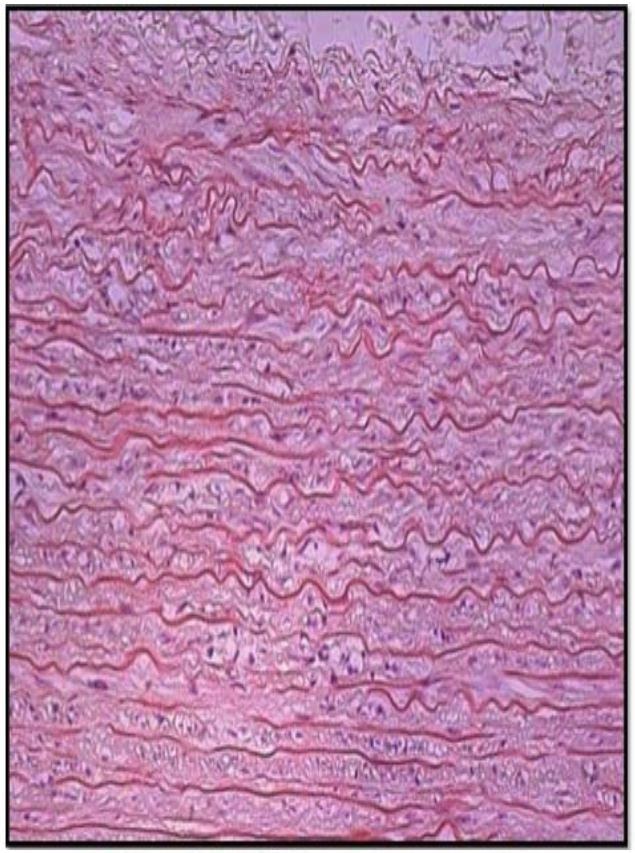
- Forms *10%* of the wall.
- The subendothelium contains also few smooth muscle fibers & macrophages.

2- Tunica media:

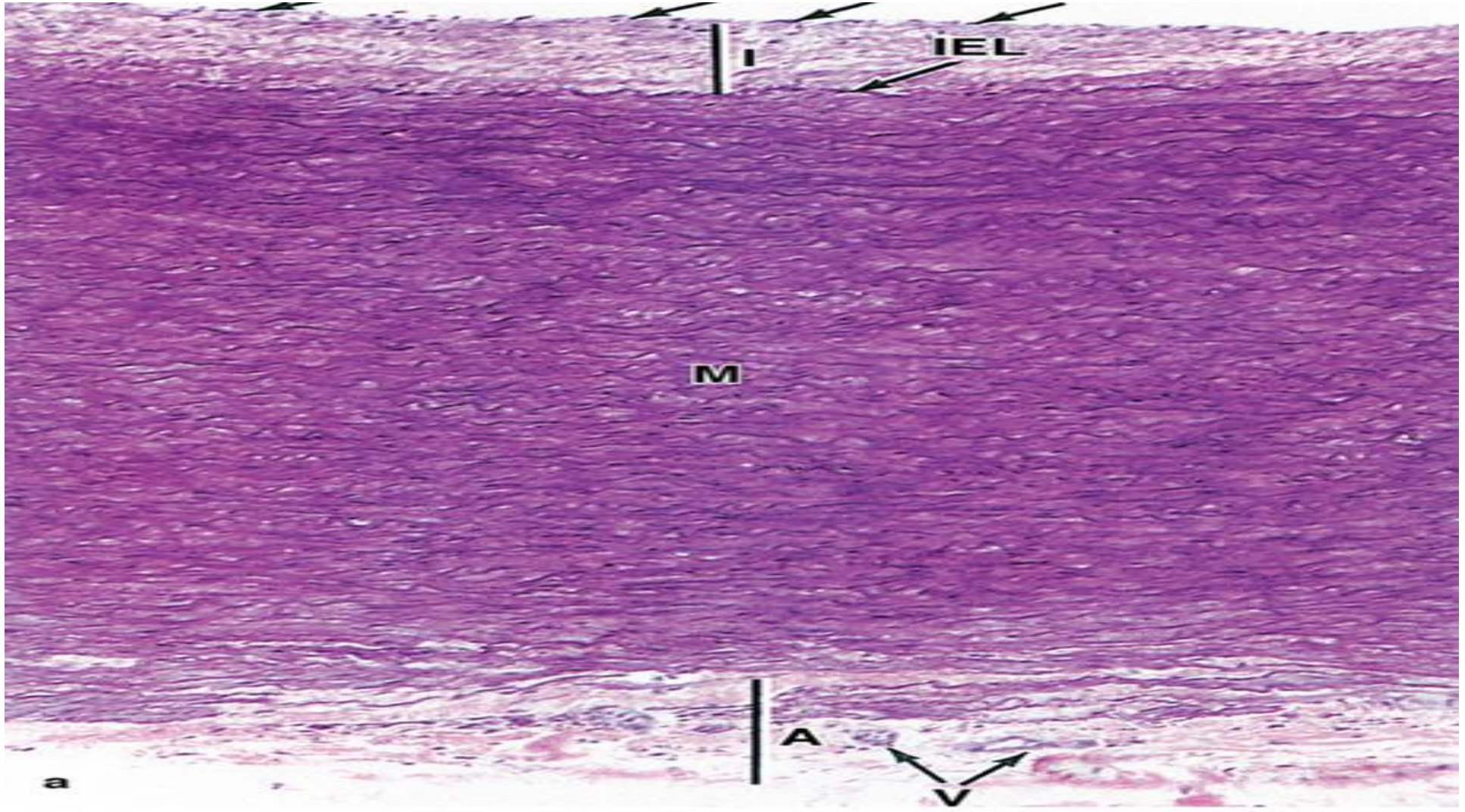
- *70%* of the wall.
- Consists mainly of *fenestrated elastic lamellae* (membranes),the numbe and thickness of these lamellae are related to blood pressure and age.
- The internal and external elastic laminae are present but *not prominen* they cannot be distinguished from the elastic membranes in the tunica media.

3- Tunica adventitia:

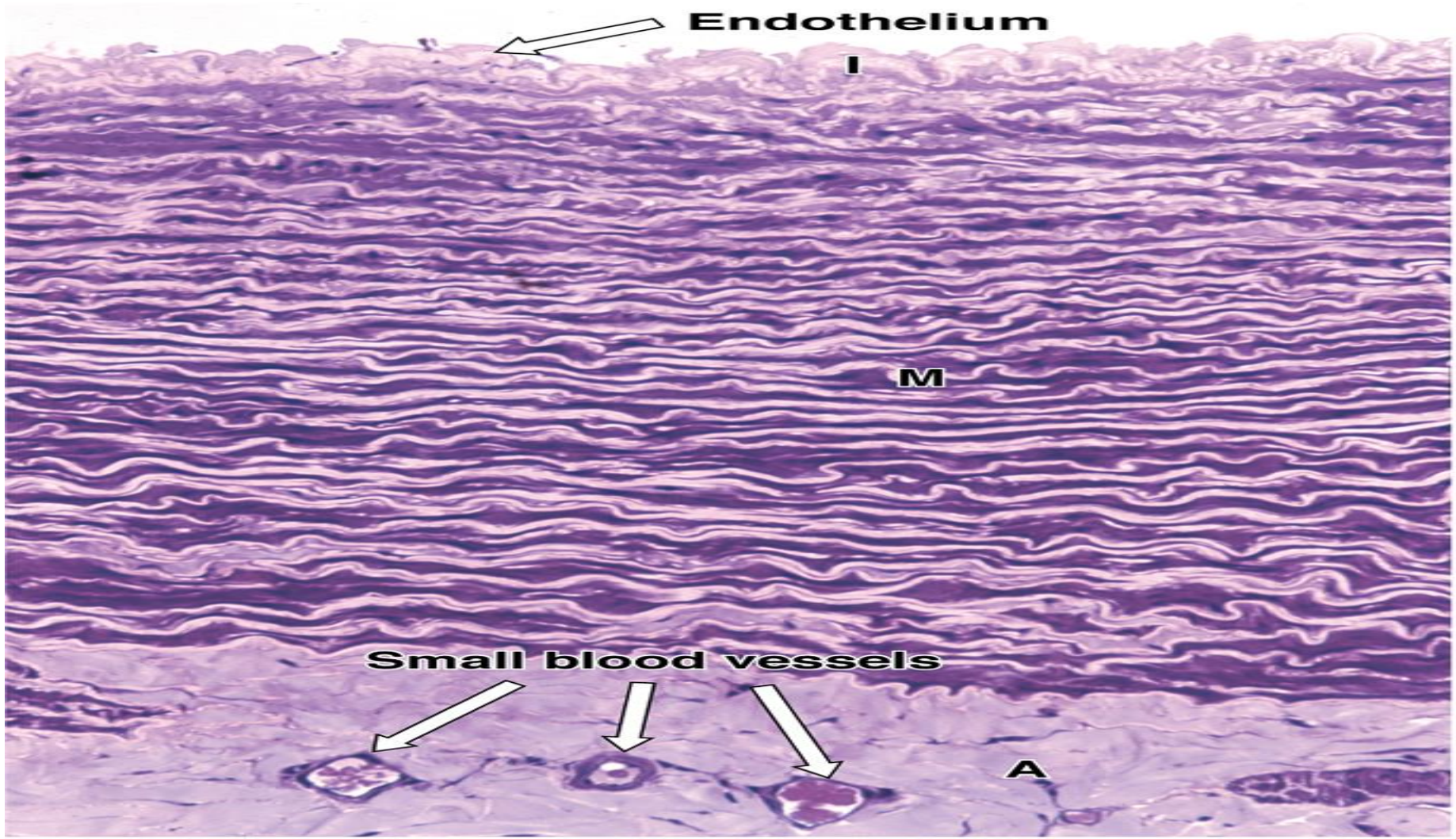
- *20%* of the wall.
- Vasa vasorum: *numerous* to provide nutrition to the adventitia and outc part of the media since the wall is too thick to be nourished by diffusion from the lumen.



I-Large elastic arteries= conducting arteries



I-Large elastic arteries= conducting arteries



II-Medium-sized arteries=muscular or distributing arteries

- These include femoral, radial and most of the named arteries.
- They have the general structure of a blood vessel +:

1- Tunica intima:

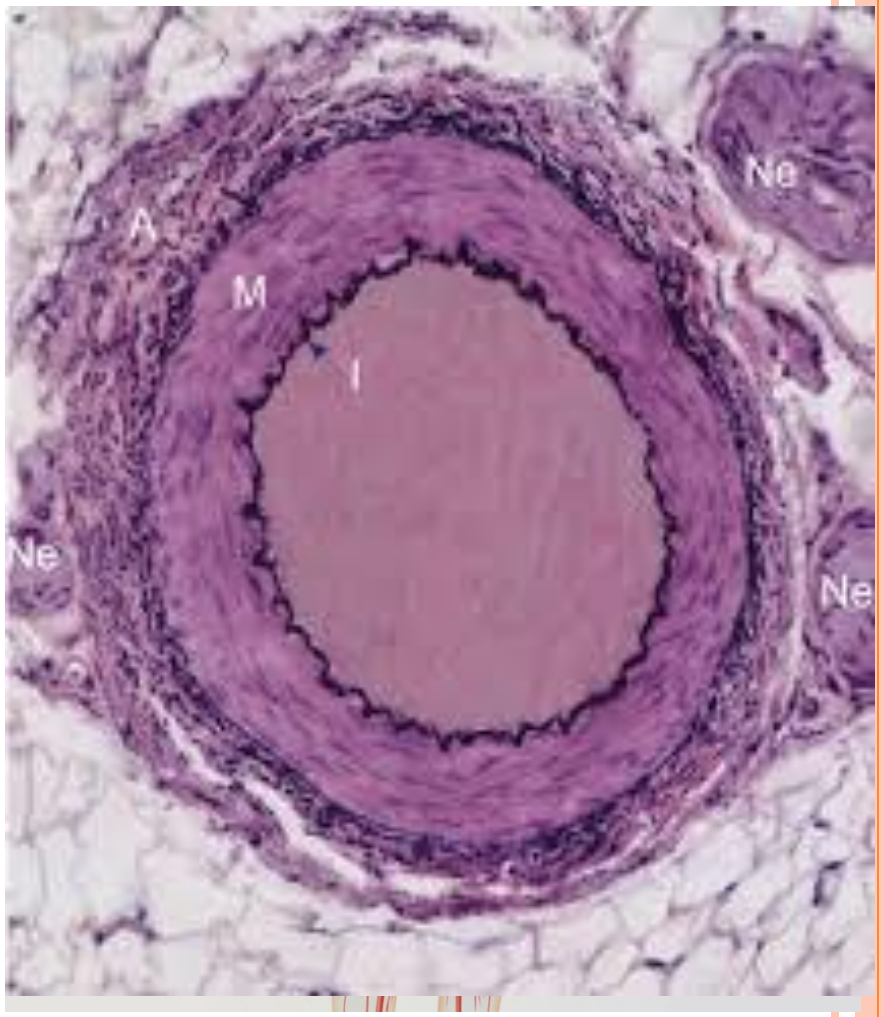
- It is a relatively thin layer.
- *Prominent internal elastic lamina* , which is thrown into folds due to post mortem contraction of the smooth muscle fibers in the tunica media.

2- Tunica media:

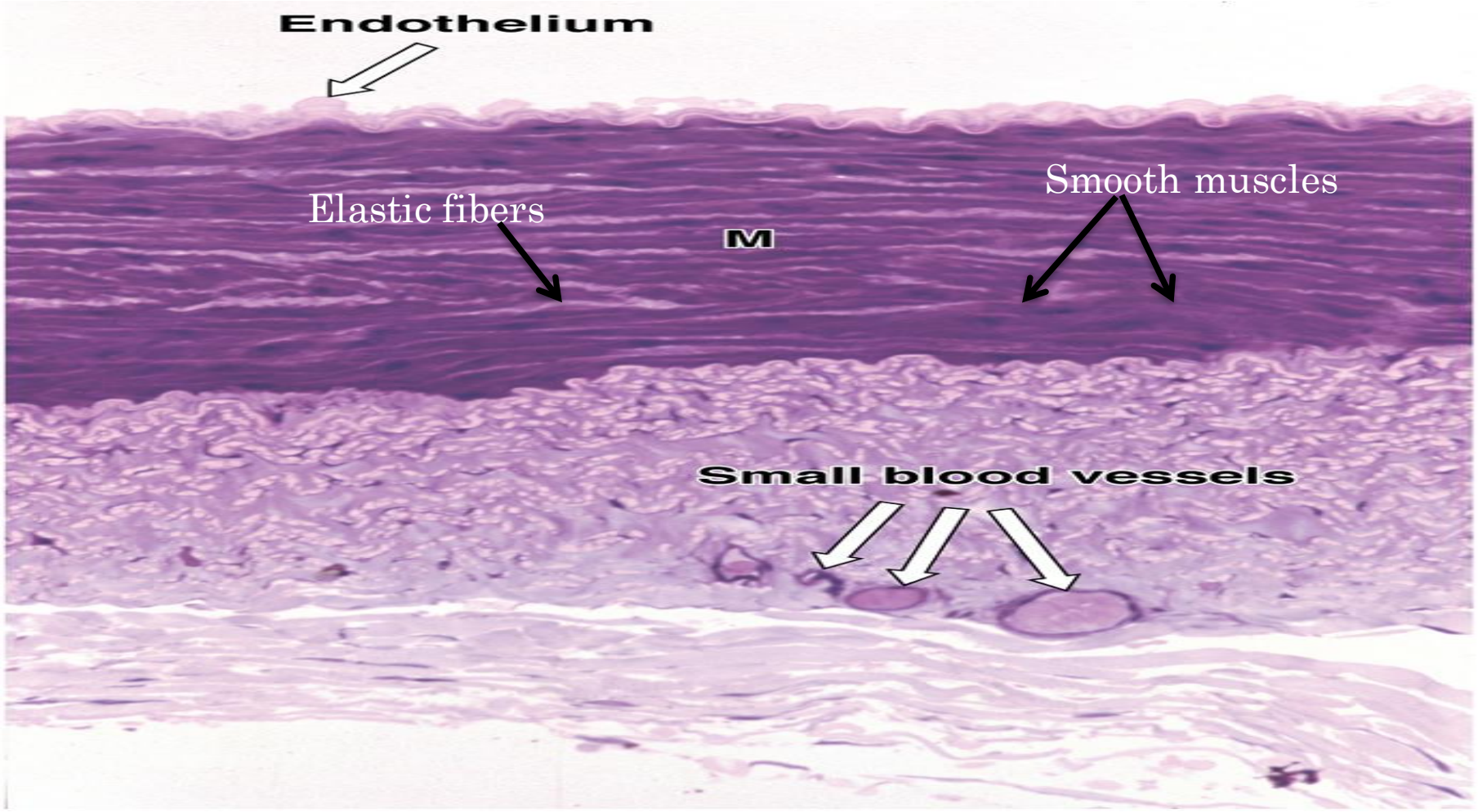
- *50%* of the wall.
- It consists mainly of several concentric layers of *smooth muscle fibers.*
- The external elastic lamina is present.

3- Tunica adventitia:

- *50%* of the wall.
- Vasa vasorum: *few*.



II-Medium-sized arteries=muscular or distributing arteries

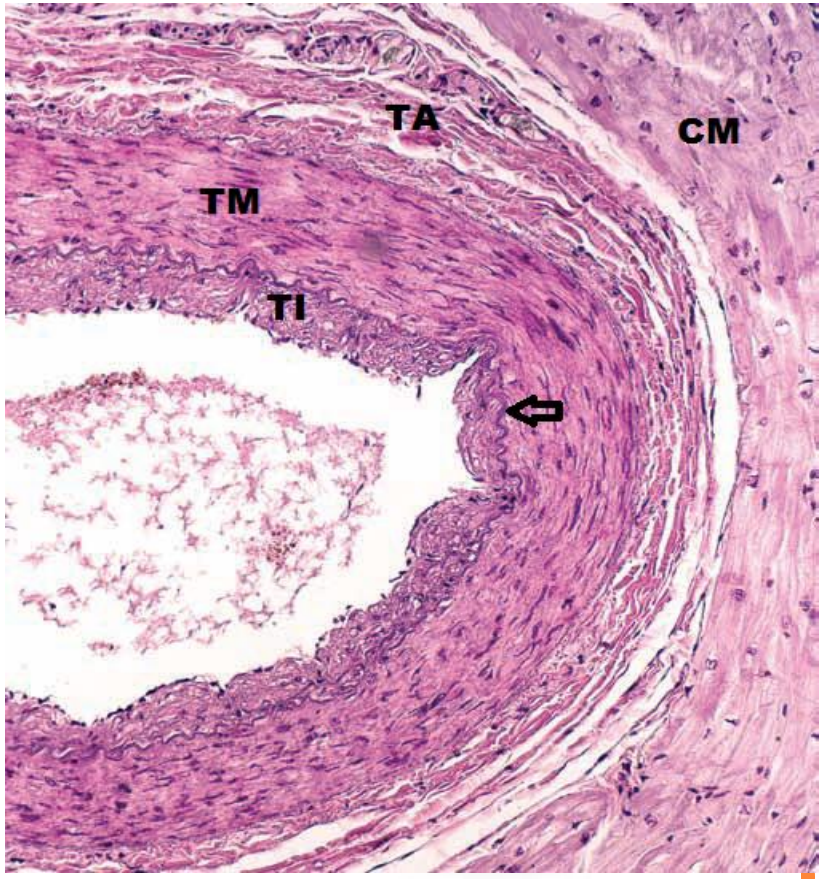


Special types of arteries
Coronary artery

1- Tunica intima: it shows normal, *musculo-elastic thickenings*, that may contribute to development of atherosclerosis.

2- Tunica media: is *thicker* compared to that of muscular arteries of the same size.

3- Tunica adventitia: is unique in its *high collagen-to-elastic fiber ratio*, which reflects high tensile strength and relatively low stretchability.



Subjected to high pressure, bending course, directly exposed to systole & diastole of the he

III-Arterioles

- **Function:** the peripheral resistance. They control blood flow into the capillaries.

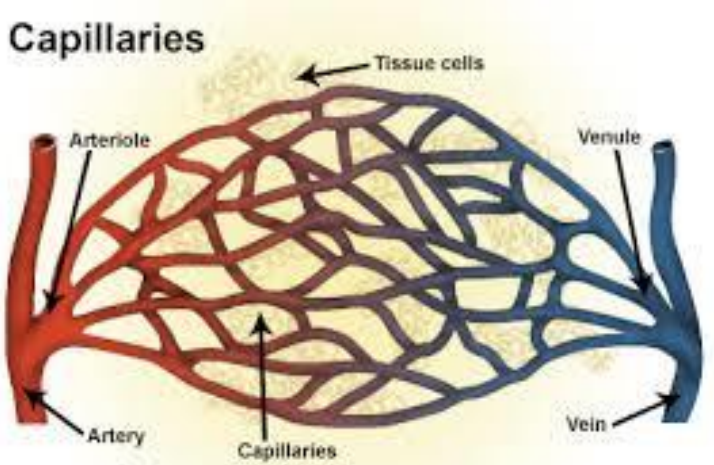
1-They have a *relatively thick wall* compared to their *narrow lumen*.

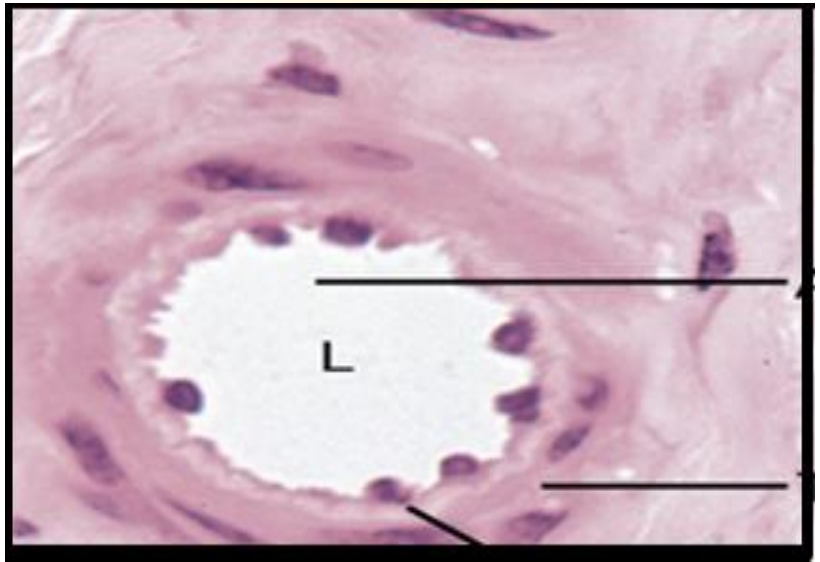
2- The intima: has thin internal elastic lamina is which disappears when the arteriole is smaller in diameter.

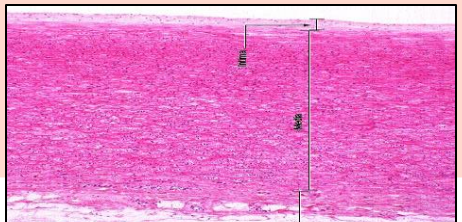
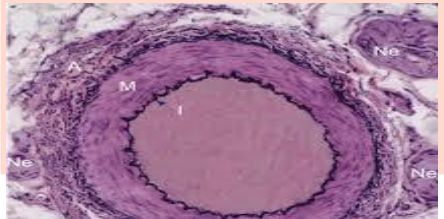
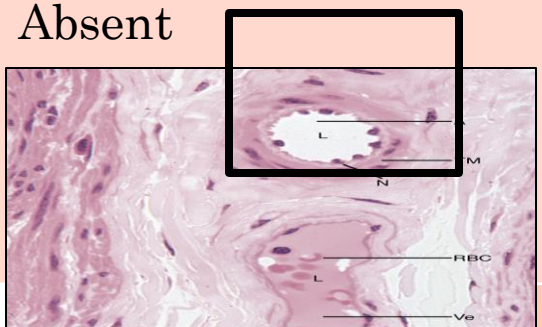
3- The media: is formed of one to two layers of *smooth muscle fibers*.

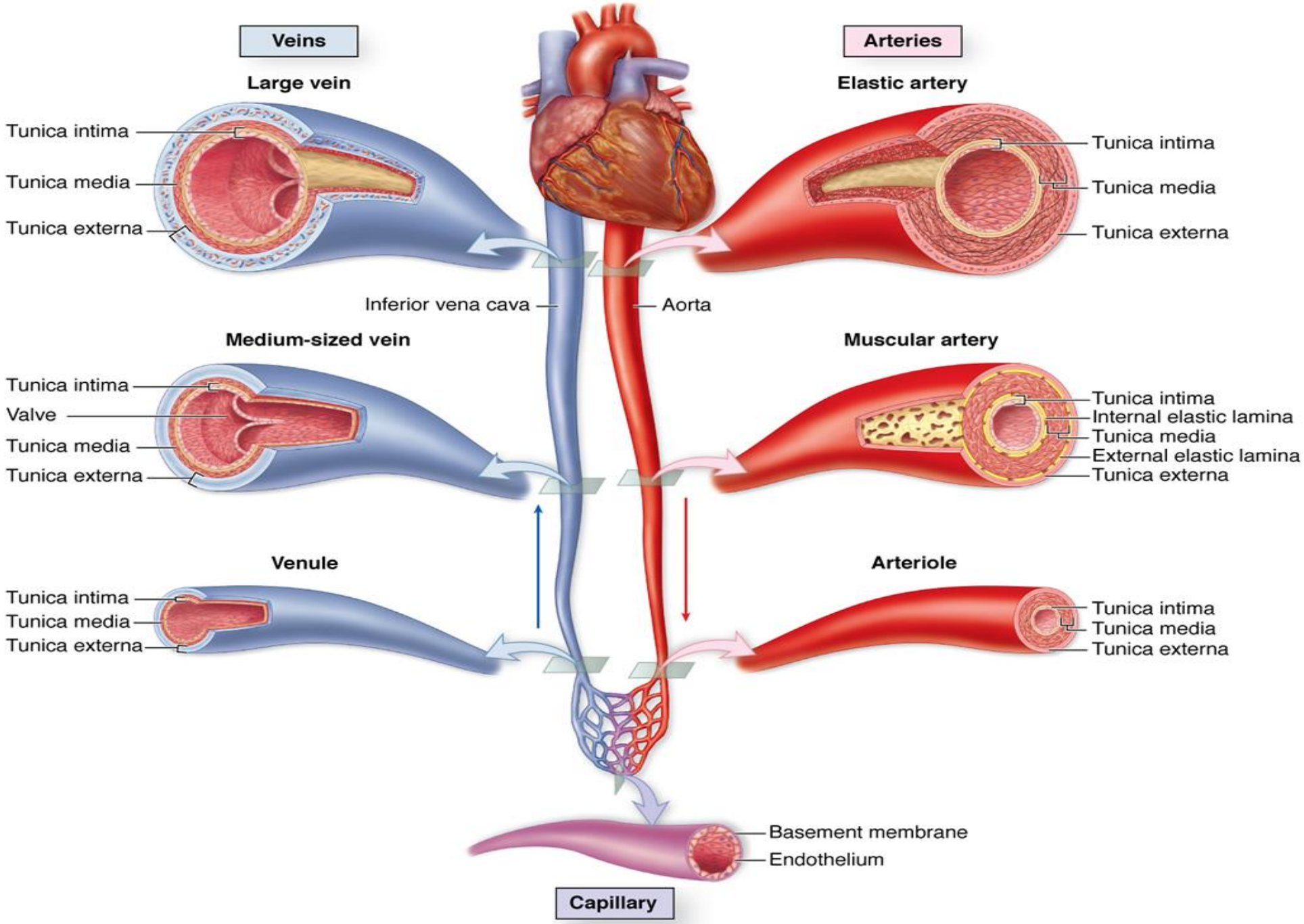
- No external elastic lamina.

4- The adventitia: thin.





	Large artery (Elastic, conducting)	Med sized artery (Muscular,distributing)	Arteriole
T. Intima •Endoth •Subendoth •***Int elastic lamina***	10% Not evident	 evident	 Thin….absent(60μ)
T.Media •***Ext elastic lamina***	70% Fenestrated elastic lamellae(distension&elastic recoil) Not evident	50% Smooth m(distributing; constant change in diameter, control regional blood flow) evident	1-2 layers of smooth m fibers (regulation of blood flow to cap & peripheral resistance+ thick wall) Absent
T.Adventitia •Vasa vasorum	20% Prominent 	50% Not prominent 	Thin Absent 


Veins
Large vein
Tunica intima
Tunica media
Tunica externa
Arteries
Elastic artery
Tunica intima
Tunica media
Tunica externa
Inferior vena cava
Aorta
Medium-sized vein
Tunica intima
Valve
Tunica media
Tunica externa
Muscular artery
Tunica intima
Internal elastic lamina
Tunica media
External elastic lamina
Tunica externa
Venule
Tunica intima
Tunica media
Tunica externa
Arteriole
Tunica intima
Tunica media
Tunica externa
Basement membrane
Endothelium
Capillary

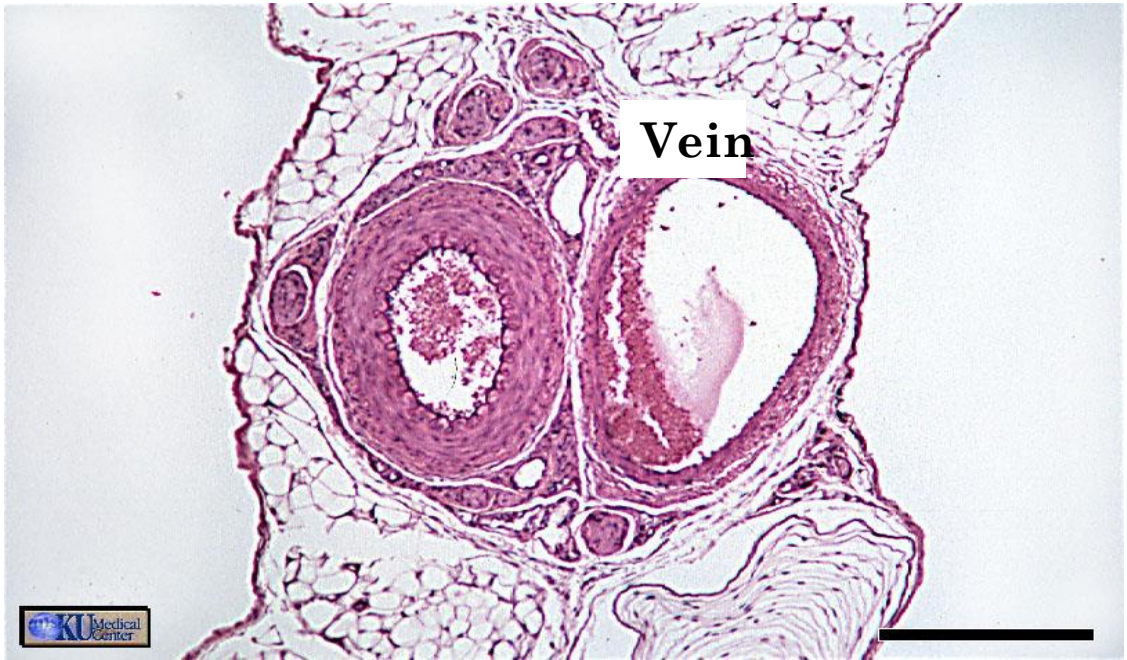
VEINS

Poorly developed smooth muscles+ minimum elastic fibers

Thin wall (thin media) + wide lumen

Low pressure

Drainage system



B-Veins
I-Large veins

- They include the venae cavae, subclavian and portal veins.
- They have the general structure with relatively wide lumen +

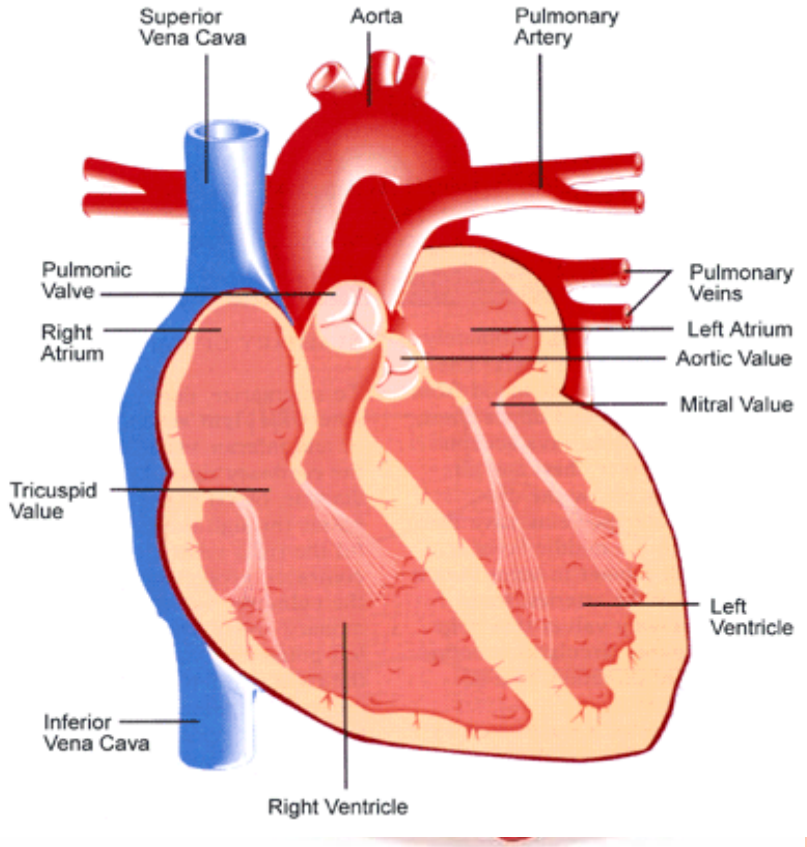
1- Tunica intima: thin with *no internal elastic lamina*.

2- Tunica media:

- *30%*of the wall.
- Consists mainly of *concentric layers of smooth muscle fibers* with collagen fibers.
- *No external elastic lamina*.

3- Tunica adventitia:

- *70%* of the wall.
- It consists of dense fibro elastic CT with *longitudinal arranged smooth muscle fibers* which strengthen the wall and prevent distention of the vessel.
- Near their entry to the heart, venae cavae and pulmonary trunk have extensions of *atrial cardiac muscle fibers* in their adventitia.
- Vasa vasorum: *nu*



The circular and longitudinal arrangement of smooth muscle fibers provides a peristaltic pumping of the blood to the heart.

II-Medium-sized veins

- They include most named veins that accompany their medium-sized arteries.
- They have the general structure of the vessel wall with wide ,collapsed lumen & thin wall due to reduced amount of muscular and elastic components.

1- Tunica intima:

- It contains *valves:* intimal folds projecting into the lumen to prevent backflow of the blood, they are abundant in veins of the lower and upper limbs.

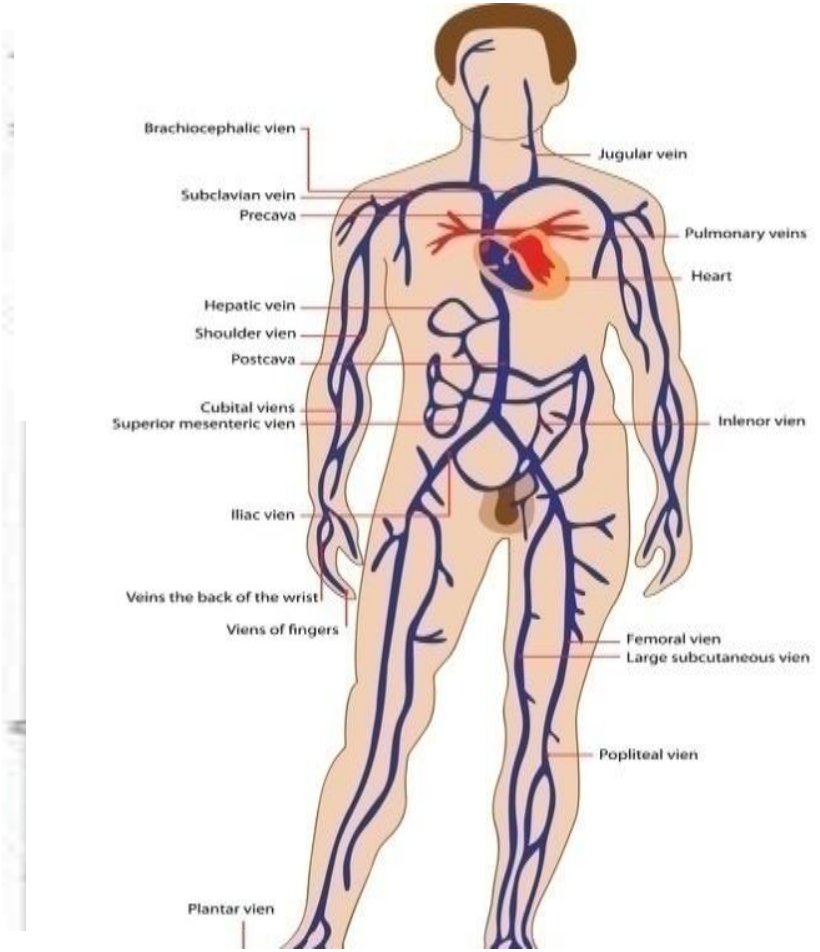
2- Tunica media:

- *30%* of the wall.
- It consists mainly of concentric layers of *smooth muscle fibers* with little collagen and *elastic fibers*.

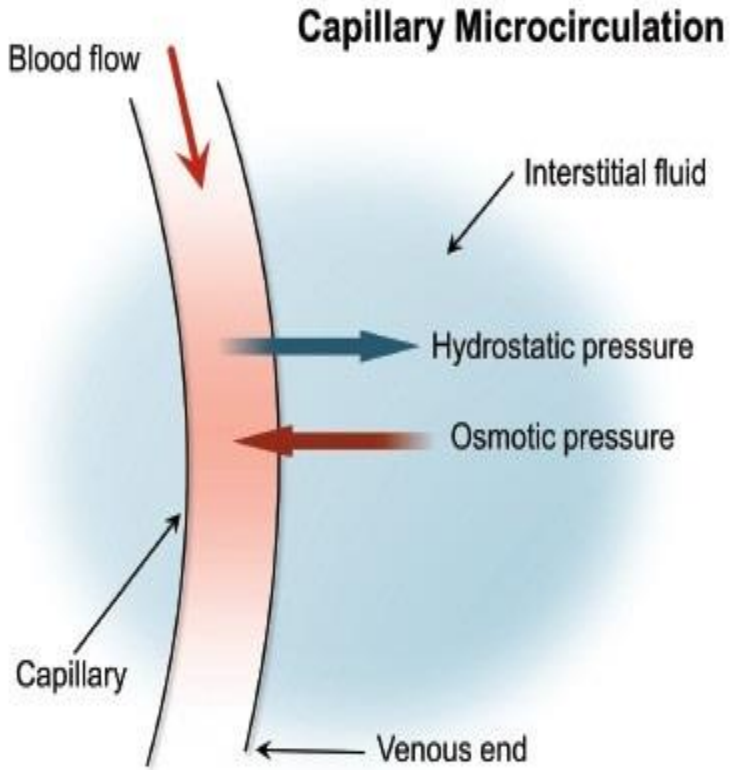
3- Tunica adventitia:

- *70%* of the wall.
- It consists of of dense fibro-elastic connective tissue *with longitudinally-arranged collagen* and little elastic fibers.
- Vasa vasorum*: numerous* as luminal blood has low oxygen content and less nutrients.

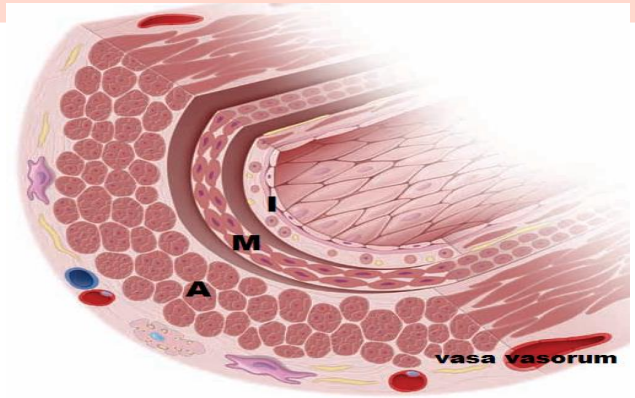
No internal or external elastic laminae

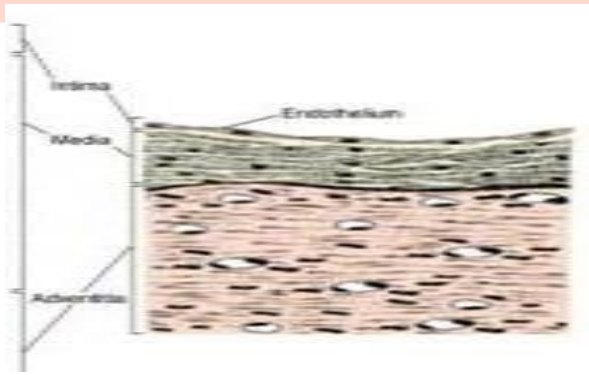


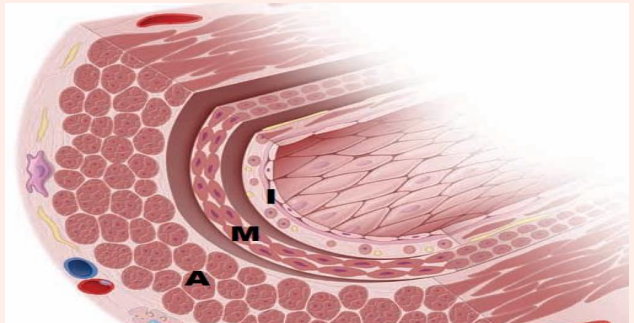
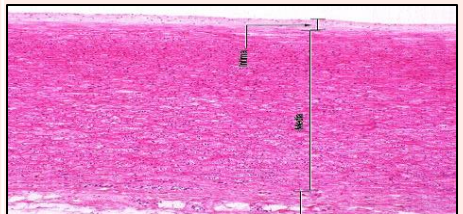
II-Medium-sized veins



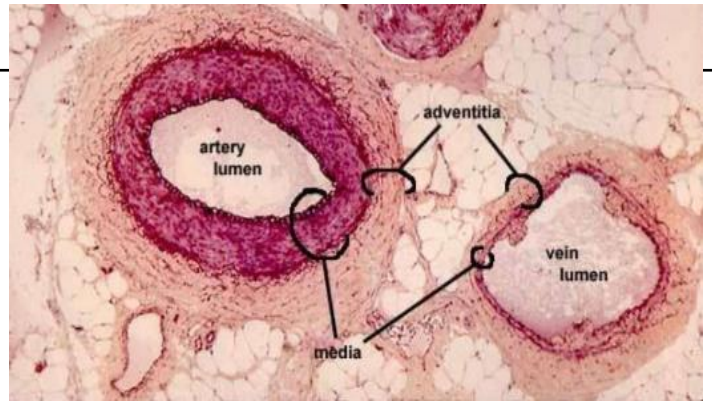
	Large veins	Medium sized veins
T. intima	Thin.	Thin **Valves esp in UL& LL.**
T. media 30%	Conc. Smooth m+ collagen.	The same+ **elastic fibers**.
T. Adv 70%	•Fibroelastic,little elastic. **•Longitudinal smooth muscles** (strength the wall & prevent distension by the effect of gravity+peristalisis) **•Cardiac muscles at the site of entry into the heart.** •Vasa vasorum are prominent.	•Fiboelastic,little elastic. •Vasa vasorum are prominent.

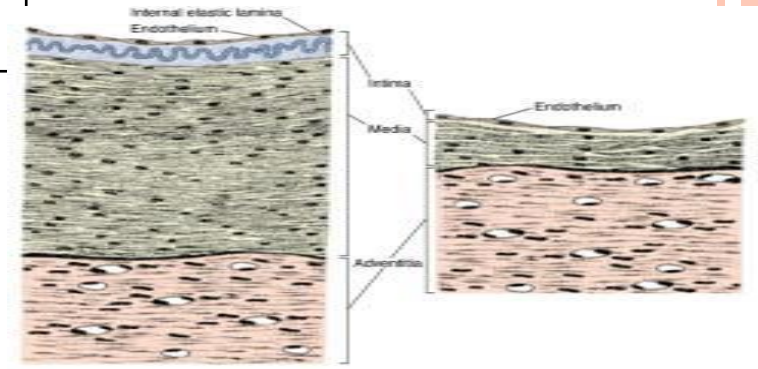




	Large veins	Large arteries
T. intima	Thin.	Relatively thick. 10%
T. media	30% Concentric Smooth m+ collagen.	70% 1-Fenestrated elastic lamellae. 2- Smooth muscles.
T. Adv	•70 % •Fibroelastic, little elastic. •**Longitudinal smooth muscles** (strength the wall & prevent distension by the effect of gravity+peristalisis) •Vasa vasorum are prominent.	•20% •Vasa vasorum are prominent.
Internal,external elastic laminae	•Absent 	•Present but not distinguished from elastic membranes of media. 

	Medium sized artery	Medium sized vein
Wall	Thicker	Thinner
Lumen	Narrow lumen, circular, empty	Lumen wide, collapsed, may contain RBCs
Valves	Absent	Present
Tunica Intima	Relatively thin	Thin
External & internal elastic lamina	Well developed.	No internal or external elastic lamina
Tunica Media	Thick, about 50% formed of mainly muscle tissue with elastic fibers	Thin,(30%), formed of muscle fibers +few elastic fibers.
Tunica Adventitia	It is thick layer (50%), contains elastic and collagen fibers.	Much thicker than the media (70%), with collagen&little elastic fibers.
Vasa vasora	May contain vasa vasora	Contains more vasa vasora.





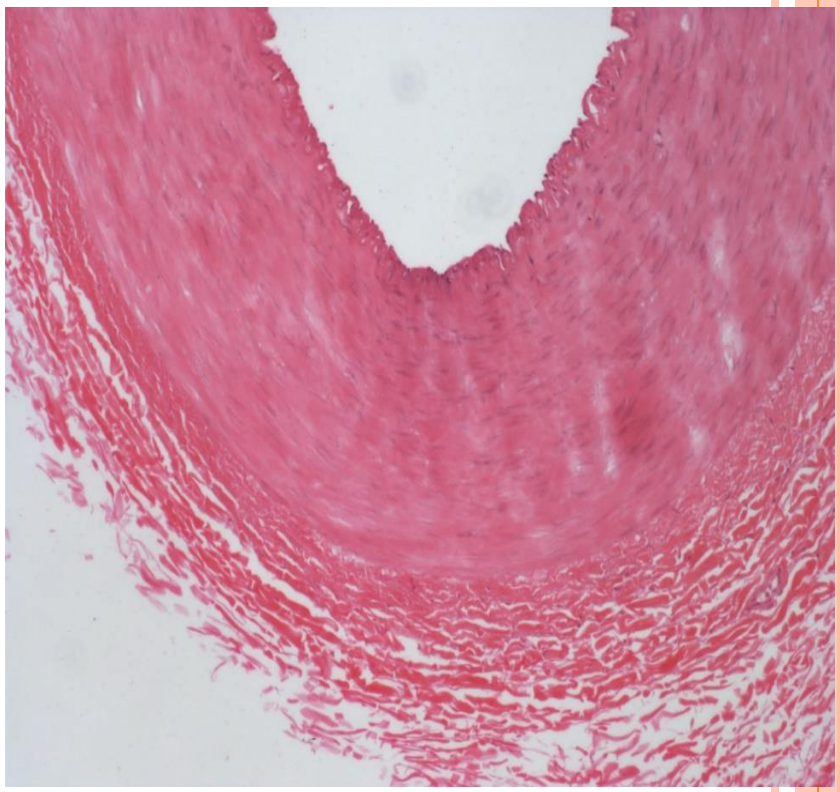
Special types of vein
Great saphenous vein

1- The intima:

- Subendothelium: contains numerous *longitudinal smooth muscle fibers.*
- Thin internal elastic lamina.

2- The media: has an unusual thick *smooth muscle fibers*.

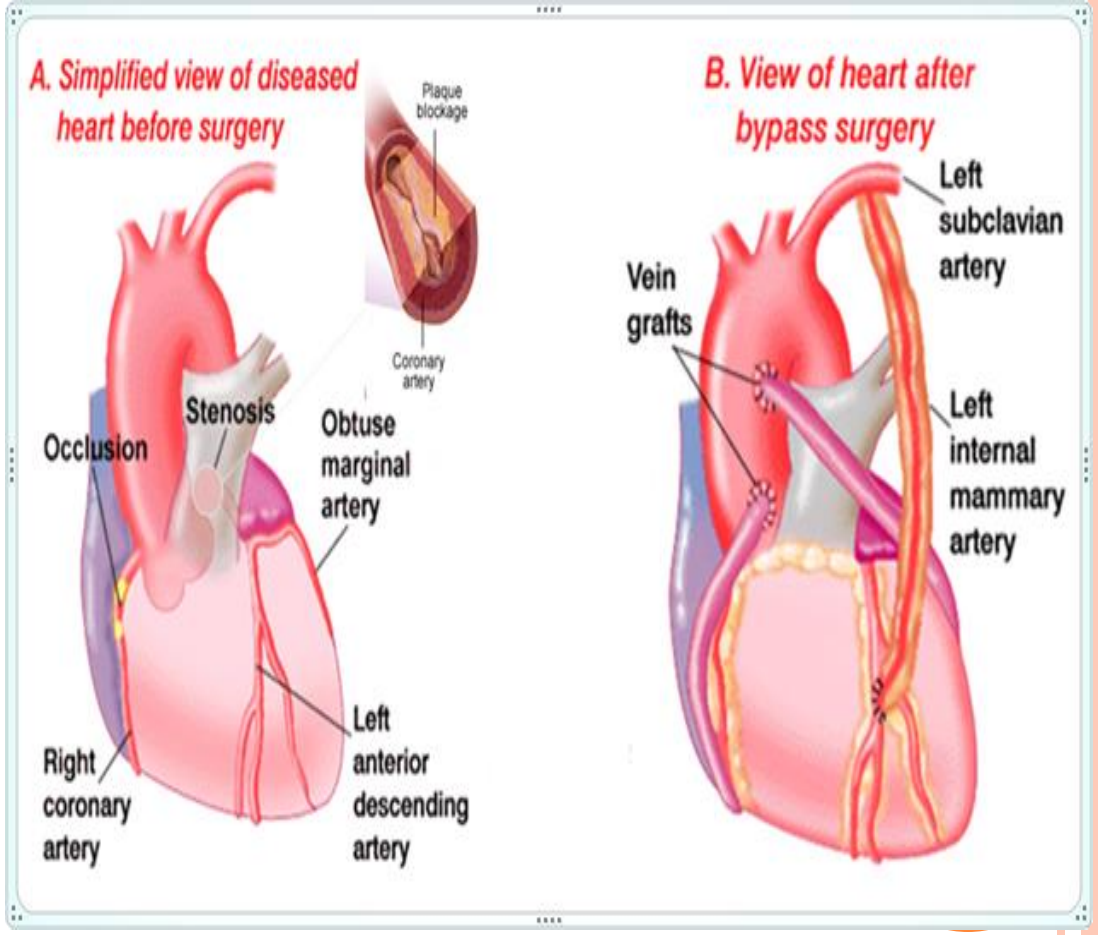
3- The adventitia: has numerous *longitudinal smooth muscle fibers*.



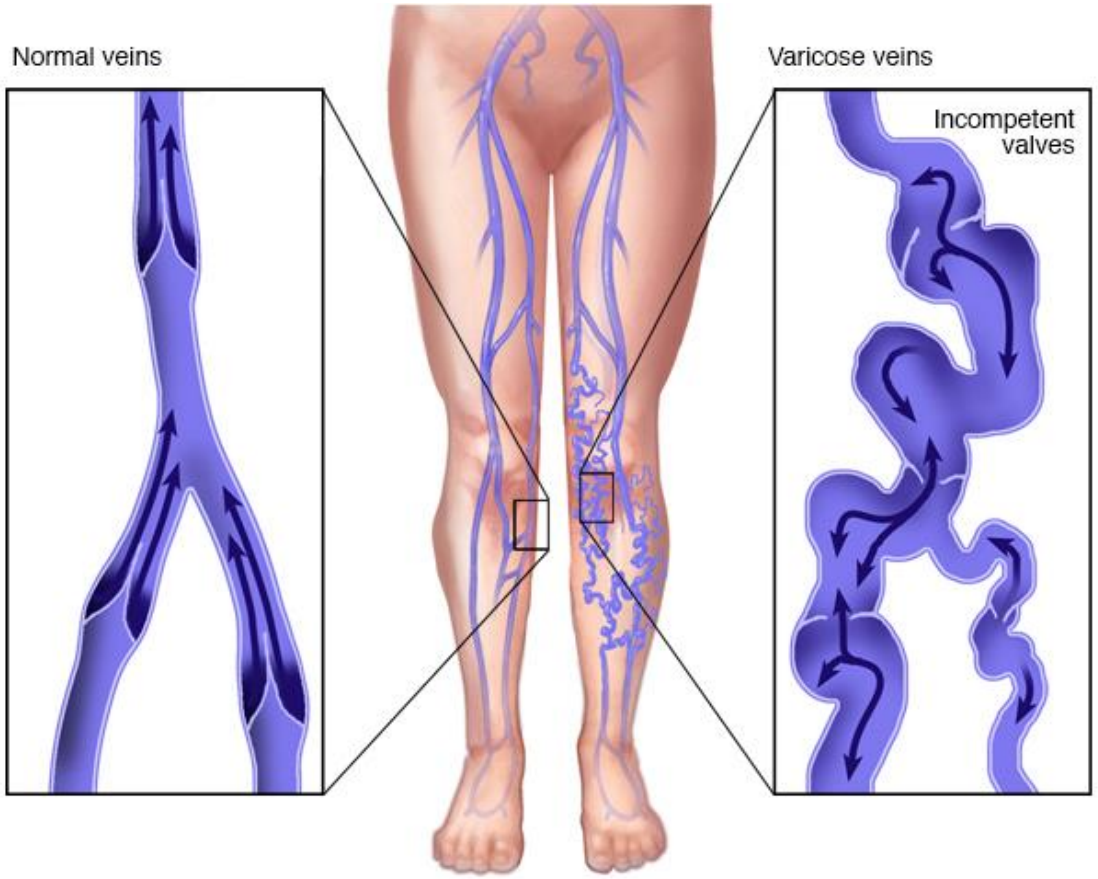
Very long& superficial in position

Special types of vein
Great saphenous vein

- The great saphenous vein is used for auto transplantation in ***coronary artery bypass graft*** surgery when arterial grafts (usually taken from the internal thoracic artery) are not available or many grafts are required for multiple-bypass anastomoses.



VARICOSE VEINS



III-VENULES

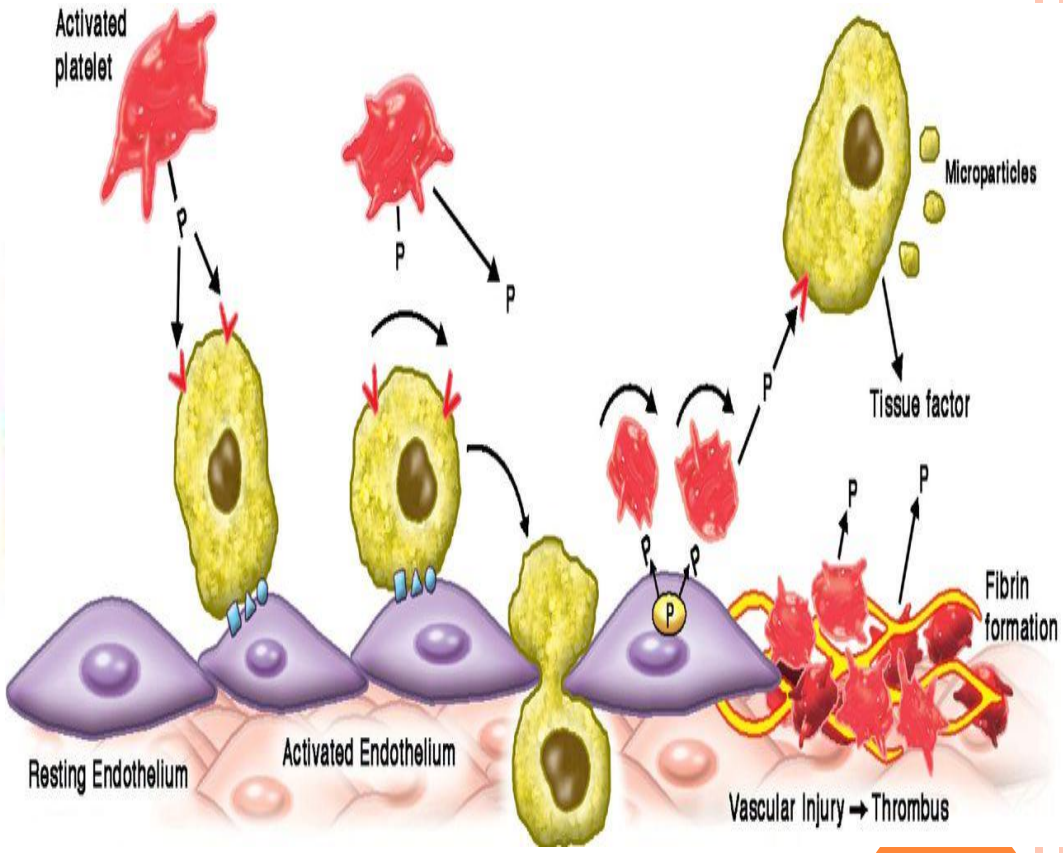
- They are classified into:

1- Post-capillary venules:

- Diameter: 15-30 µm.
- Structure: a single layer of endothelial cells resting on basal lamina surrounded by pericytes.
- Function: They are the site of trans-migration of WBCs during inflammation.

2- Muscular venules:

- The media: is formed of one to two layers of smooth muscle fibers.
- The adventitia: thin.



Peripheral circulation

Peripheral circulation

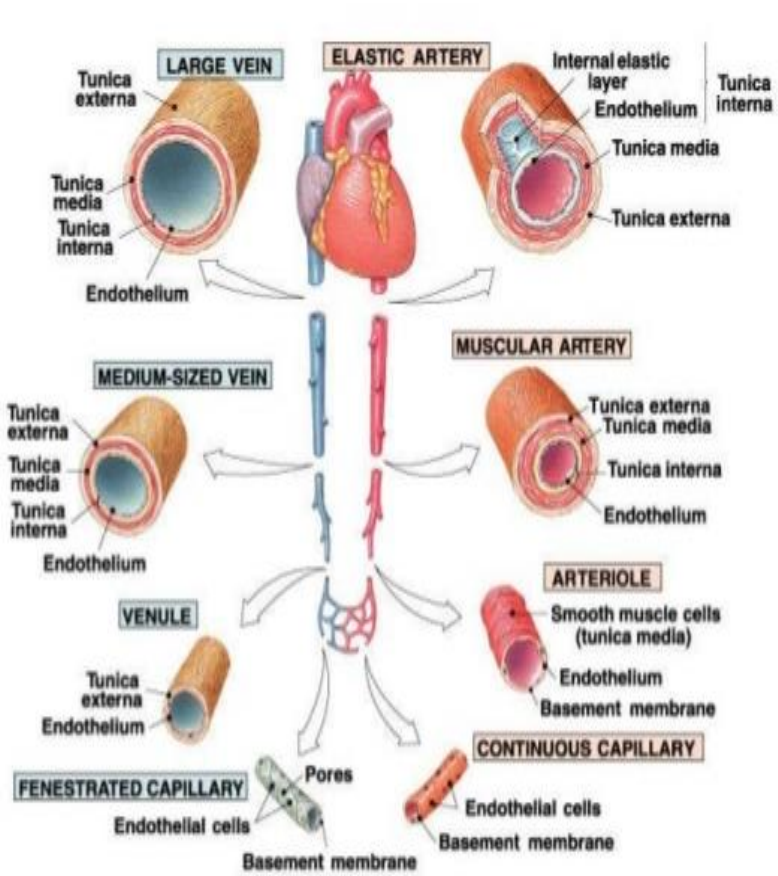
1- Definition of peripheral circulation.

2- Structure& types of capillaries.

3- The lymph system: Function & structure.

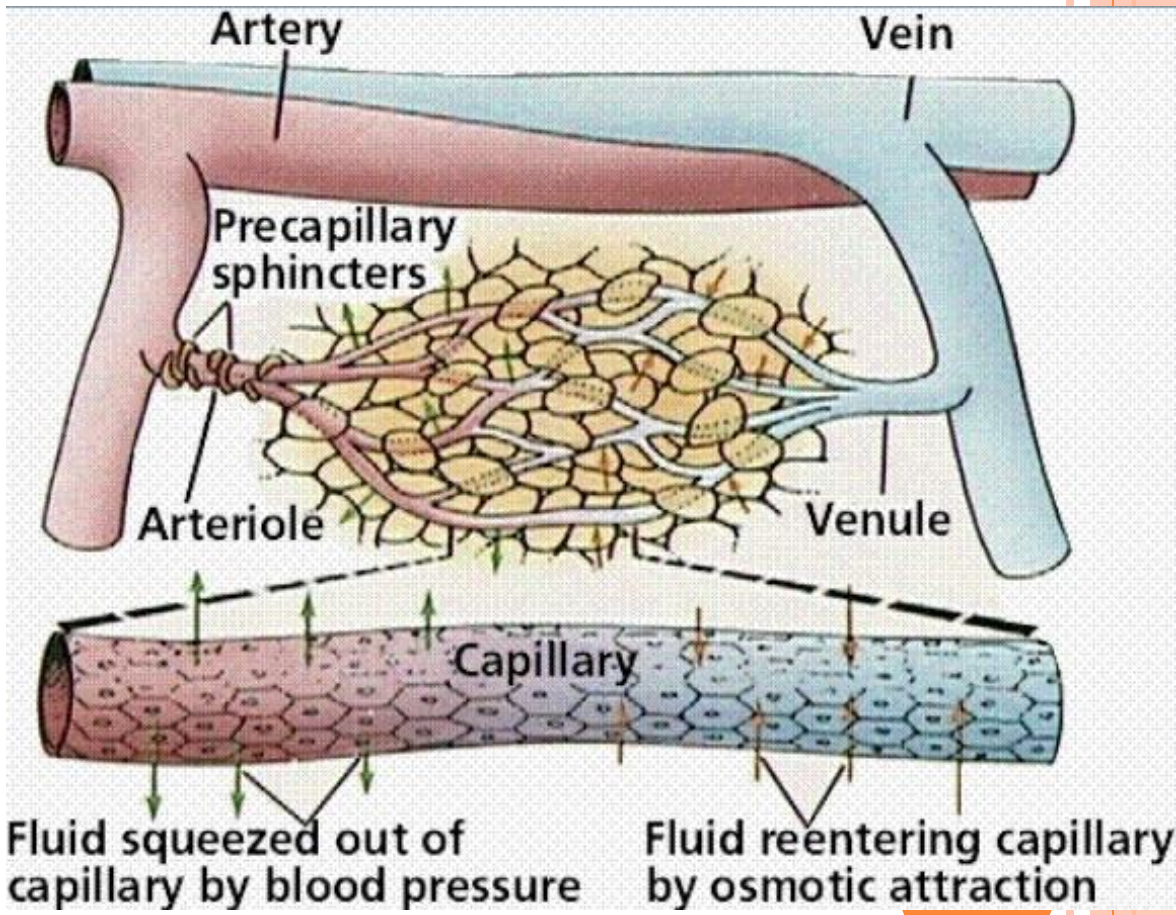
Peripheral circulation

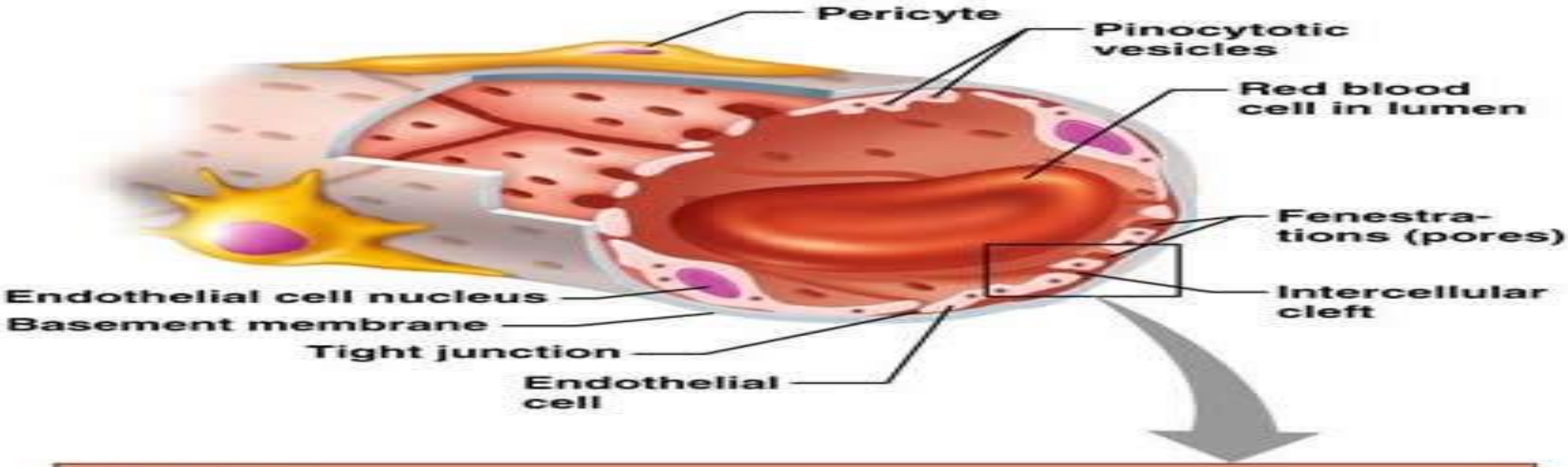
- **Definition:** It is the connection between arteries and veins.
- It includes capillaries and arteriovenous shunts.

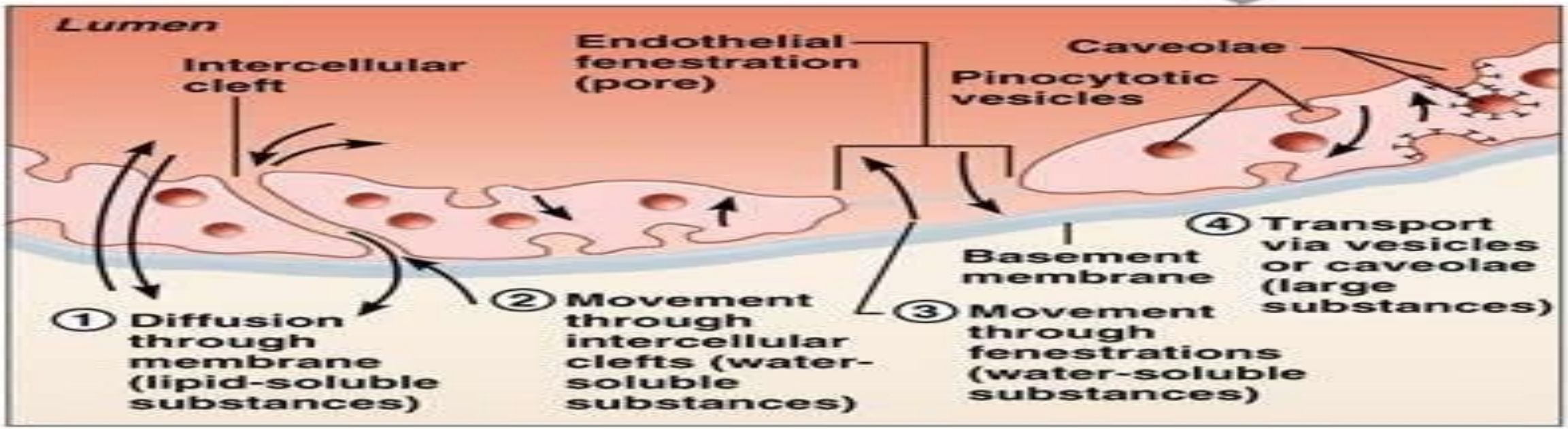


I- Capillaries

- **Definition:** the smallest diameter blood vessels that conduct blood from arterioles to the post-capillary venules.
- Capillaries make up 90% of the body vasculature as they forming the capillary bed.
- **Function:** exchange of gases and metabolites between the blood and tissues.



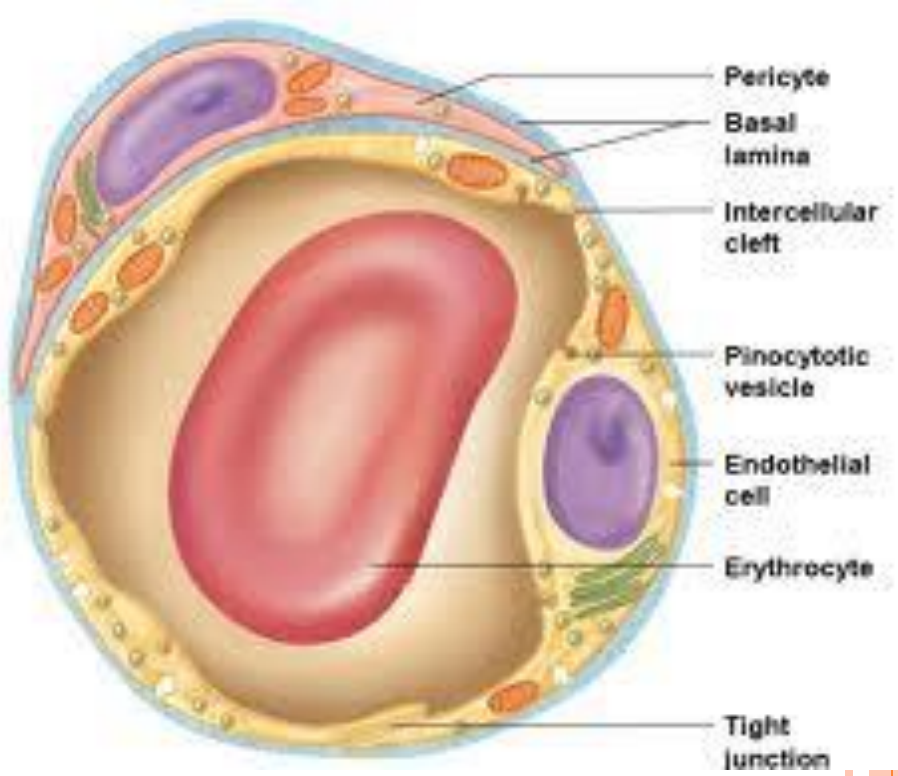

Pericyte
Pinocytotic vesicles
Red blood cell in lumen
Fenestra-tions (pores)
Intercellular cleft
Endothelial cell nucleus
Basement membrane
Tight junction
Endothelial cell


Lumen
Intercellular cleft
Endothelial fenestration (pore)
Caveolae
Pinocytotic vesicles
Basement membrane
④ Transport via vesicles or caveolae (large substances)
① Diffusion through membrane (lipid-soluble substances)
② Movement through intercellular clefts (water-soluble substances)
③ Movement through fenestrations (water-soluble substances)

Structure of the blood capillaries
How do the capillaries adapt to its function?

- Single layer of *endothelial cells* resting on a *basal lamina*, which is splitted to enclose the *pericytes*.
- The endothelial cells are joined together by occluding junctions.
- The diameter of a capillary is 9-12 µm

(large enough to allow passage of RBCs one at a time).



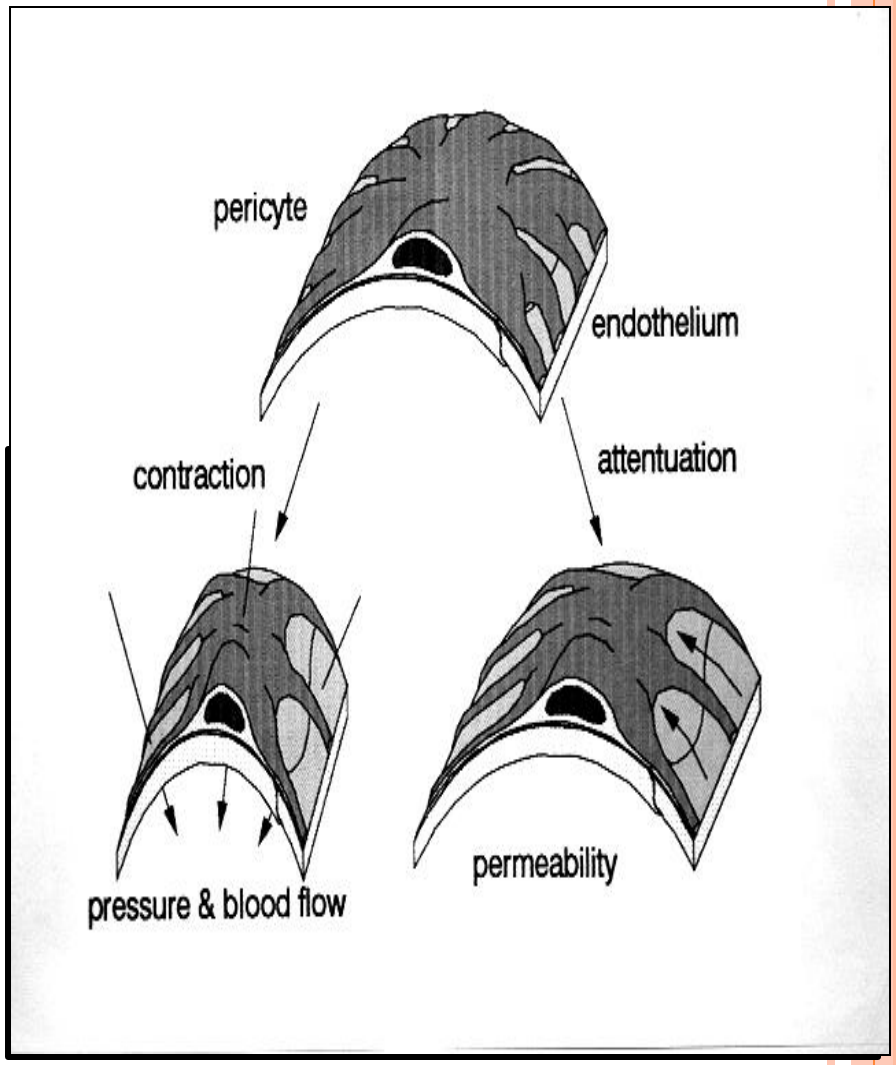
THE PERICYTES

- **Definition:** Perivascular mesenchymal cells.
- **Structure:** They are branching cells with many processes, they are enclosed in the basal lamina of the endothelial cells.
- **Site:** They partially surround the endothelial cells of capillaries and post- capillary venules.
- **Functions:**

1- *Support* of capillaries and post- capillary venules.

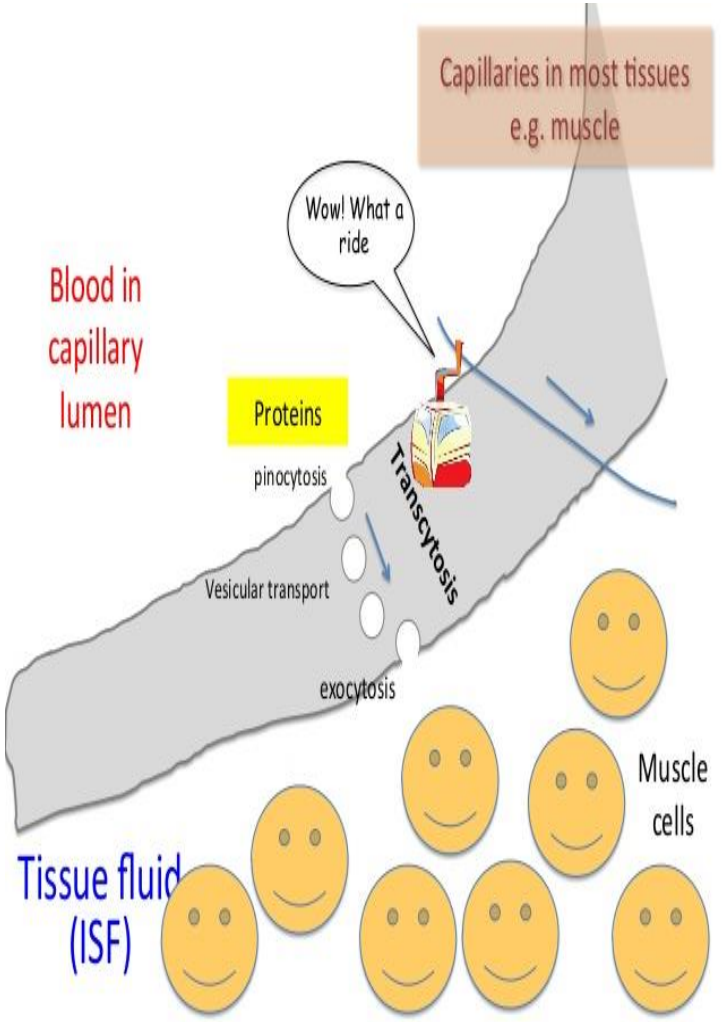
2- *Contractile function*: have actin filaments in their cytoplasm.

3- *Stem cells*: pericytes can proliferate and differentiate to form new endothelial and smooth muscle cells, following tissue injury, thus help in the repair process.

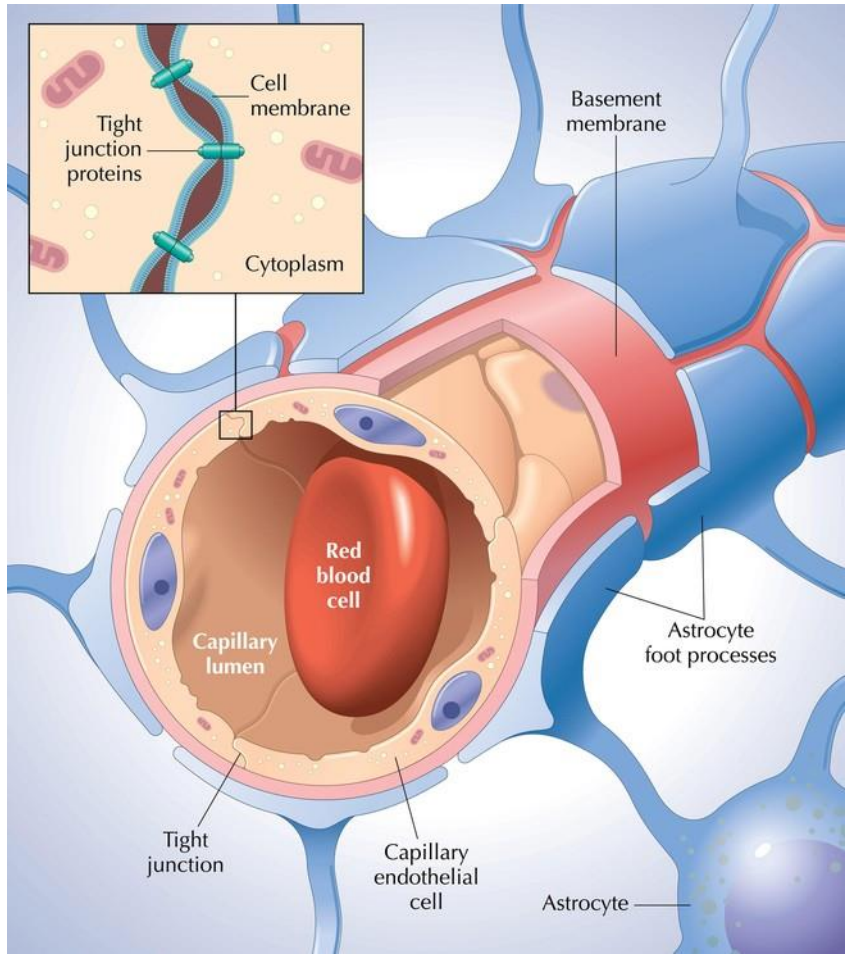


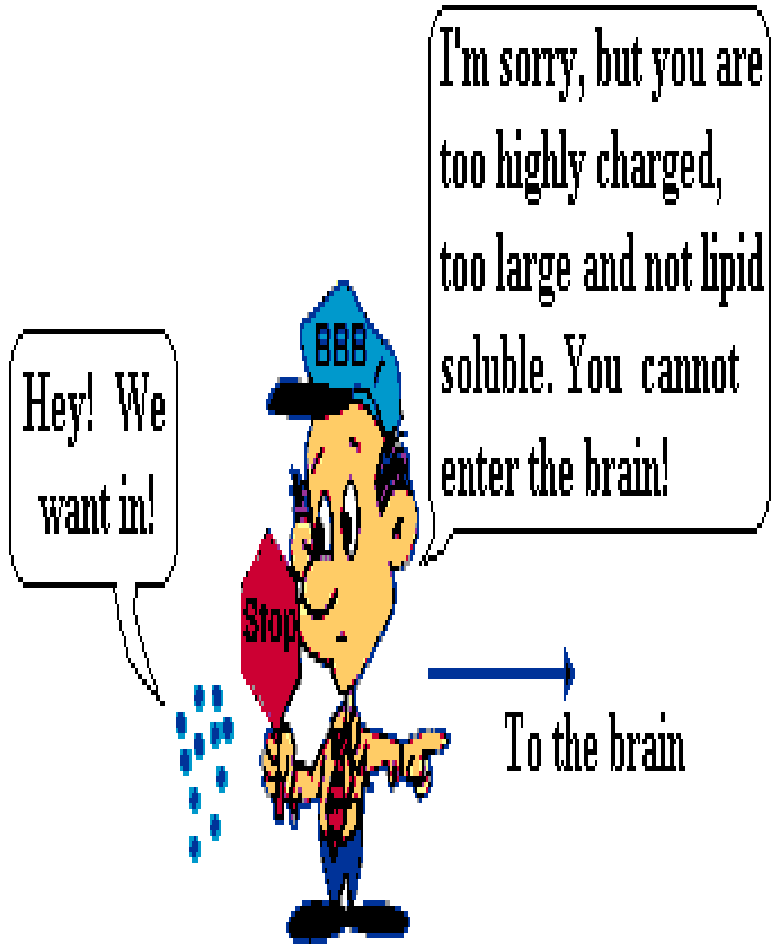
Types of capillaries
1-Continuous capillaries =muscular type

- **Structure:**
  - The wall of these capillaries has *no fenestrations*.
  - The basal lamina is *continuous* .
  - The endothelial cells are held together by *occluding junctions* with overlapping marginal folds.
  - The cytoplasm contains many *pinocytotic vesicles*.
- **Function:** provides metabolic exchange and thus share in the formation of different *blood barriers* (blood brain barrier, blood air barrier and blood thymus barrier).
- **Sites:** This is *the most common* type of capillaries and is found in muscular tissue, lung, skin and nervous tissue.



Blood brain barrier





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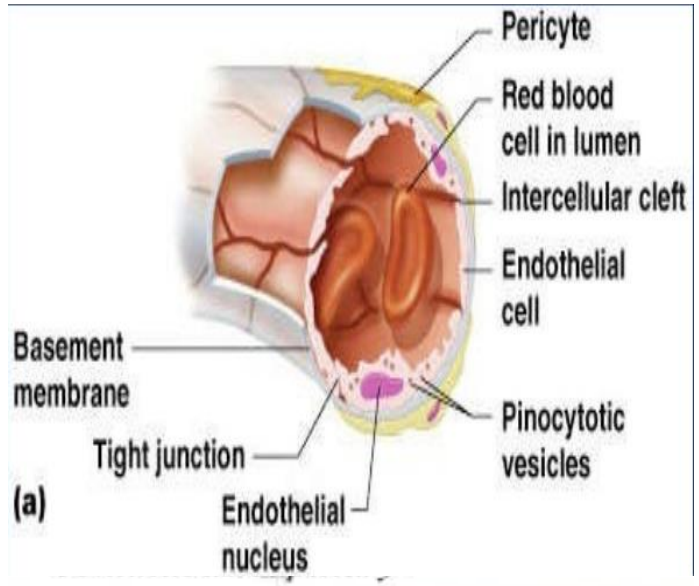
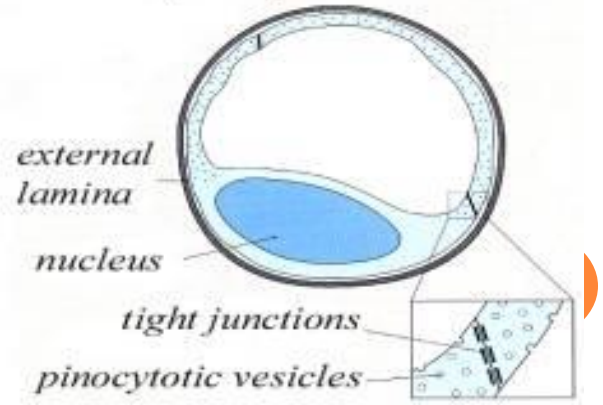
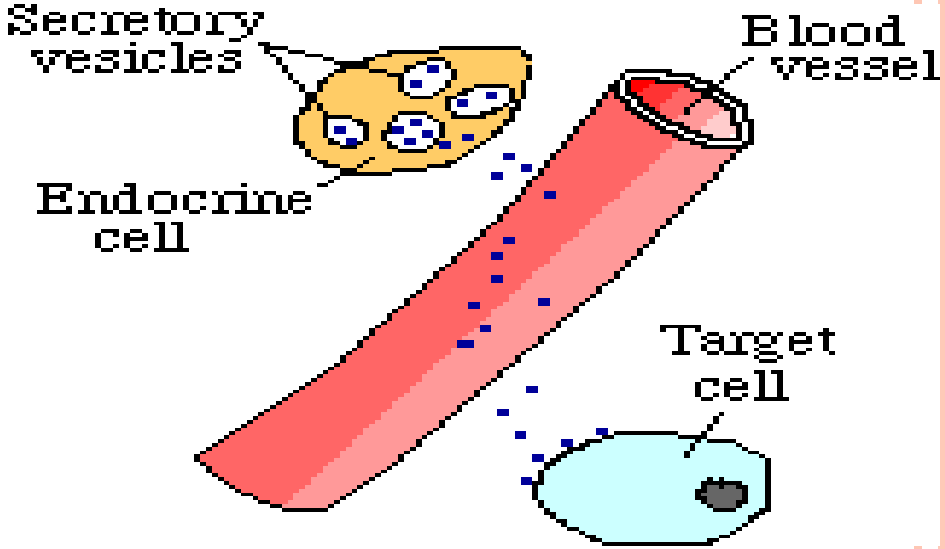
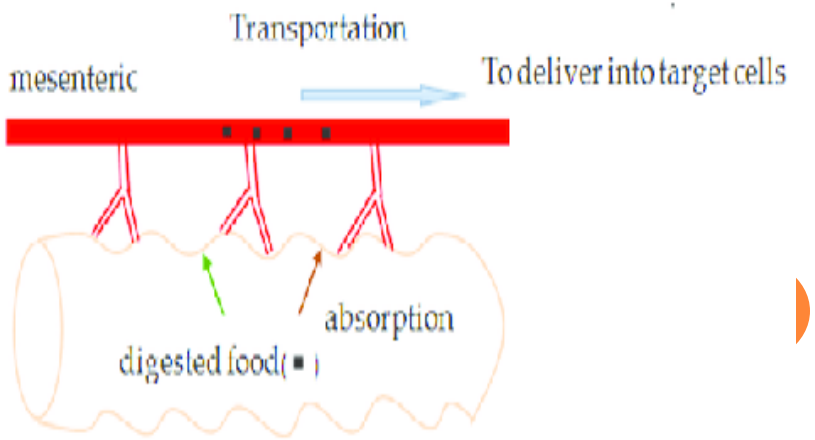




Types of capillaries
2-Fenestrated capillaries =visceral type

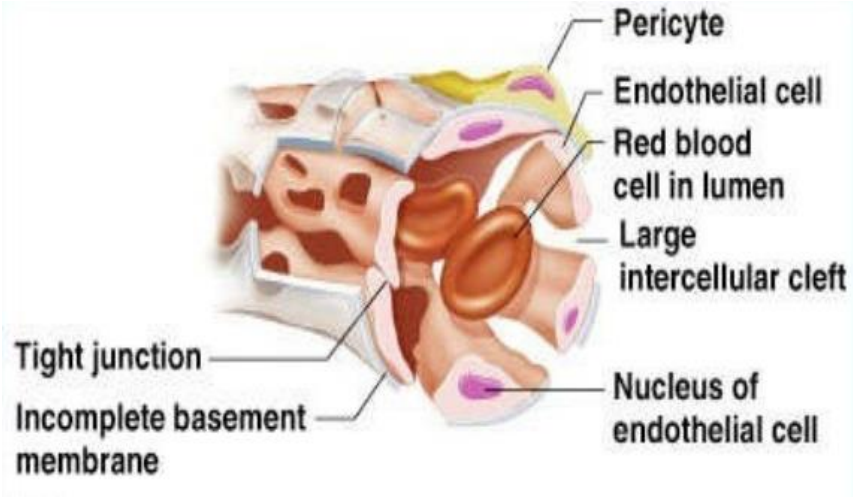
- **Structure:**
  - The endothelial cells have *numerous fenestrations.*
  - The basal lamina is *continuous*.
  - These fenestrations are closed by a thin non-membranous *diaphragm*, derived from the glycocalyx of the cell membrane (WHY).
  - The endothelial cells have numerous *pinocytotic vesicles*.
- **Function**: allows *more molecular exchange* between tissues and blood.
- **Sites:** endocrine glands (secretion) and small intestine (absorption).

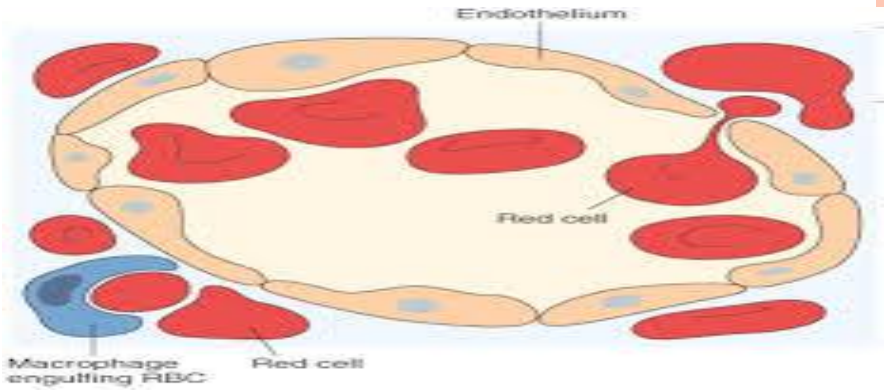




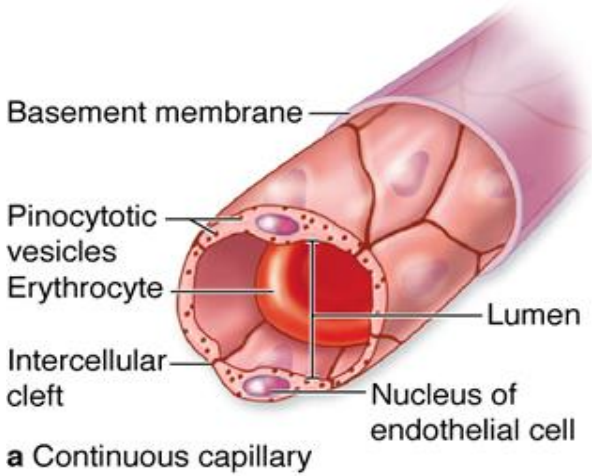
Types of capillaries
3- Sinusoids = sinusoidal capillaries

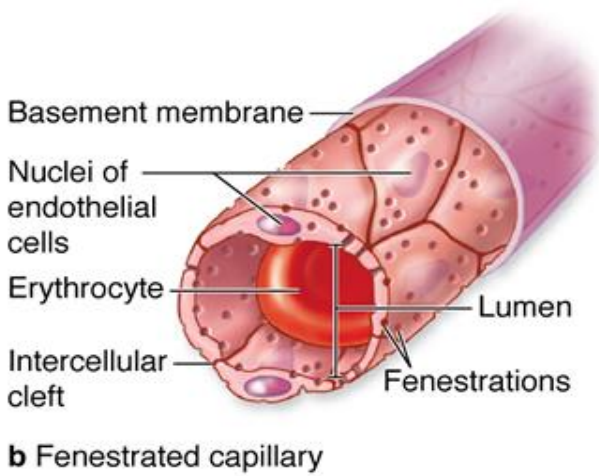
- **Structure:**
  - Vascular channels with a relatively *large diameter* (30-40µm).
  - The outline is *irregular*.
  - The endothelial cells have *large fenestrations without diaphragms* and are separated by wide *intercellular gaps*.
  - The basal lamina is *discontinuous* and supported by reticular fibers.
  - *Macrophages* are usually associated either within or around the sinusoids.
- **Function:** allows *maximal exchange* and *movement of cells* between tissues and blood.
- **Sites:** Liver, bone marrow &spleen.

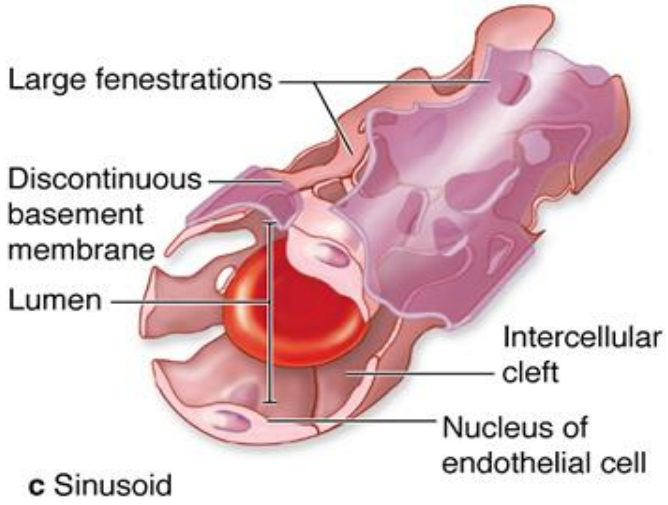




Types	Capillaries	Sinusoidal capillaries
Lumen	Narrow	Wide
Outline	Regular	Irregular
Type	Continuous; fenestrated	Always fenestrated
Intercellular gap ; cleft	Very narrow	Wide
Basal lamina	Continuous	Discontinuous
Associated cell	Pericyte	Macrophage
Sites	Everywhere in the body	Certain sites as liver, spleen &bone marrow.







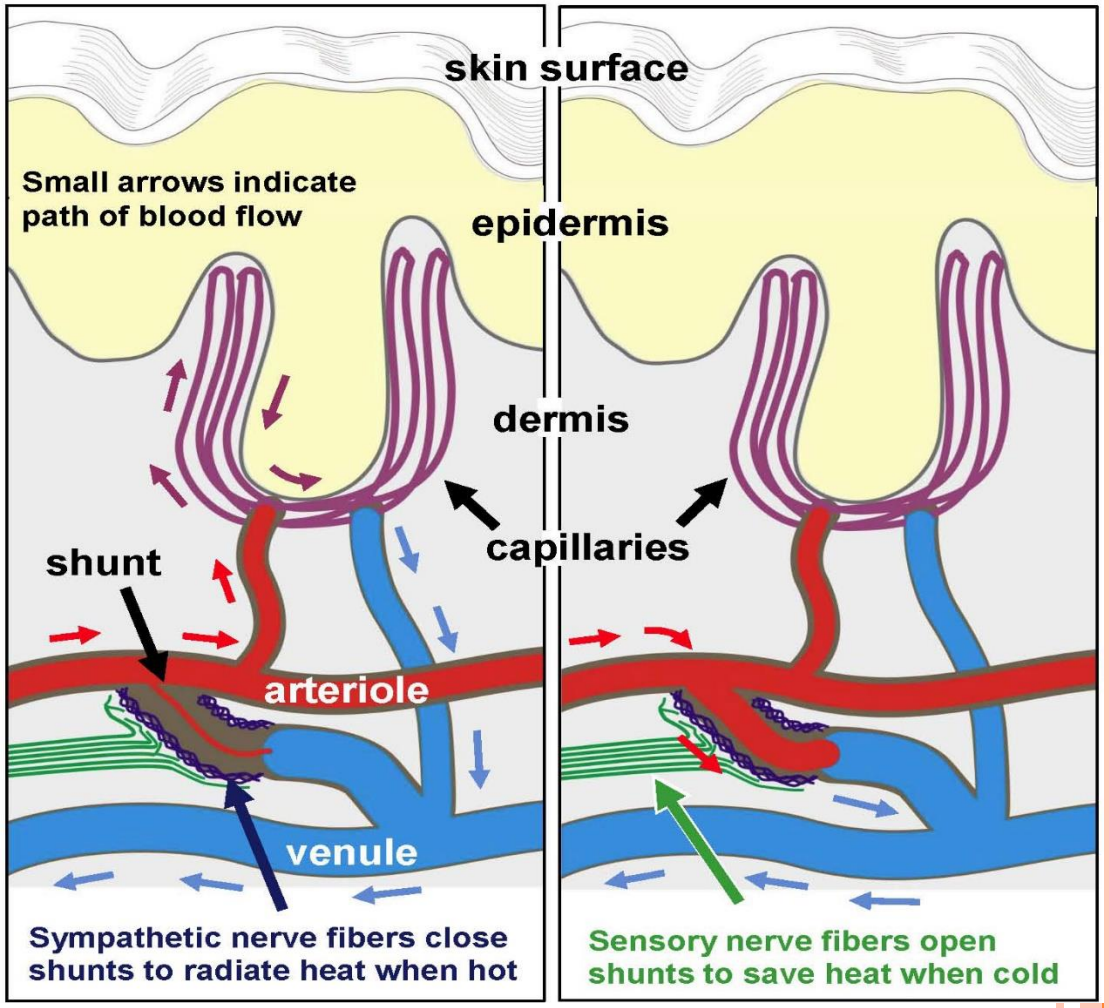
II- Arteriovenous anastomoses=A-V shunts

- **Definition:** a direct connection between an arteriole and a venule without passing in the capillary bed.
- **Structure:** it arises as a side branch from terminal arteriole and runs directly to small venule. The arteriole of the A-V shunt has a relatively thick smooth muscle layer and is richly innervated.
- **Function:**

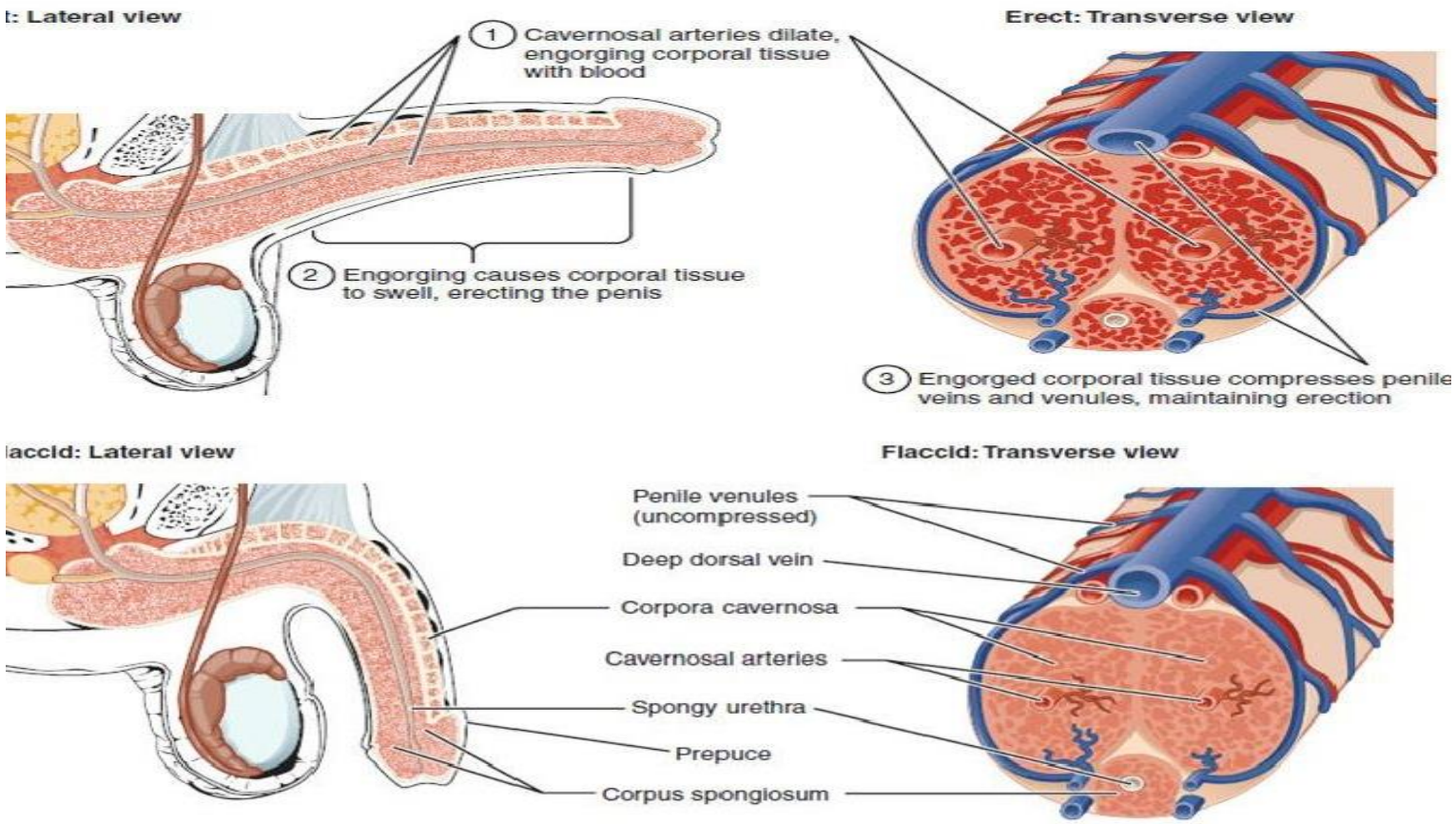
➢ Contraction of the smooth muscle at arteriolar side of the A-V shunt → close the shunt → sends blood to the capillary bed.

➢ Relaxation of arteriolar smooth muscles → open the shunt → sends a considerable volume of blood directly into the venule, bypassing the capillary bed.

- **Sites:** skin of palm & sole, nose, lip and erectile tissue of penis.



II- Arteriovenous anastomoses=A-V shunts



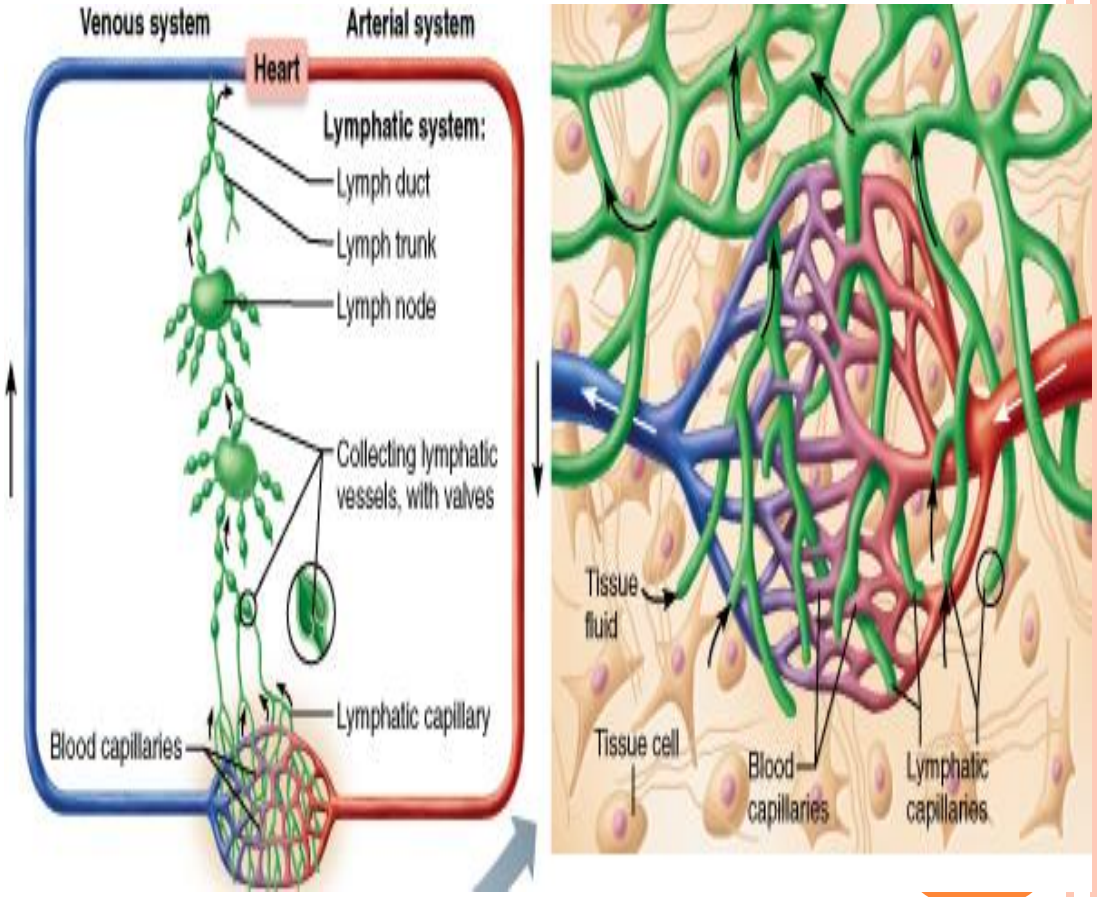
THE LYMPHATIC SYSTEM

- **Definition**: It is a drainage system that collects the excess interstitial fluid in the form of lymph and returns it to the blood.
- **It consists of:** the lymph, lymph vessels and lymphoid tissue.
- **The lymph:** a viscid substance formed of:

1- *Protein-rich fluid:* removed from the intercellular spaces.

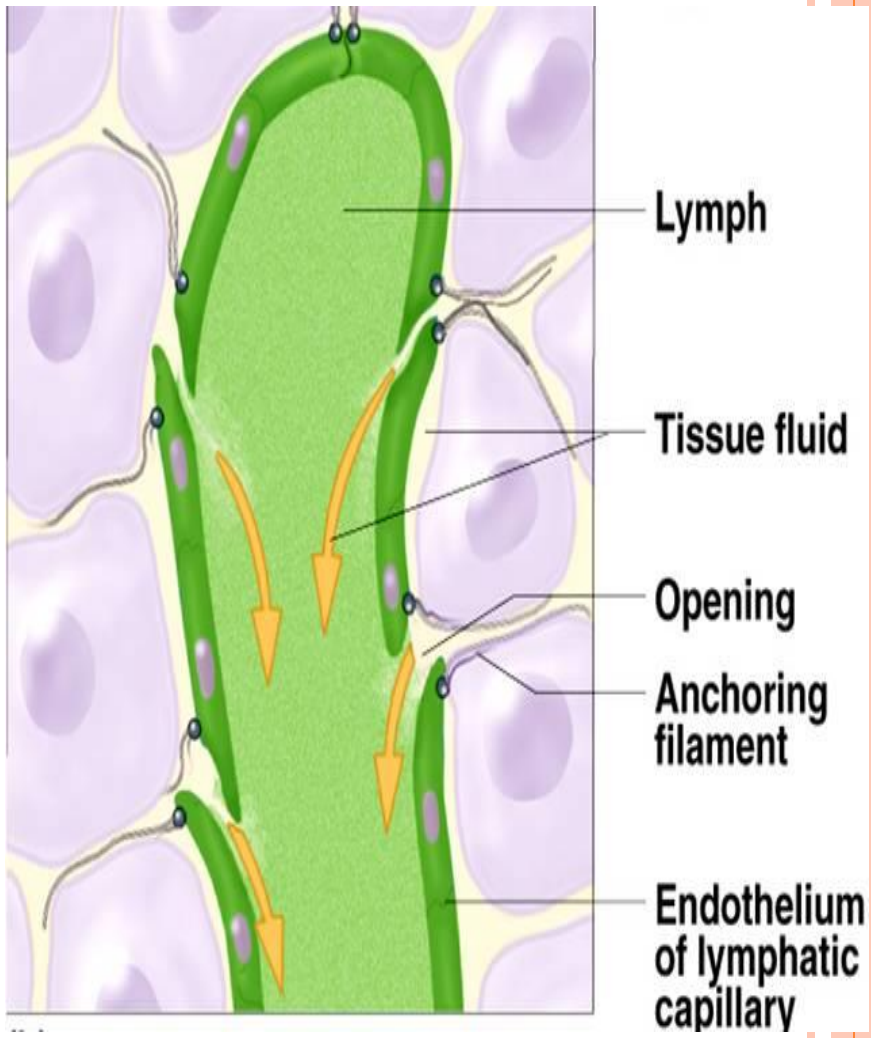
2- *Lipids:* that are too large to cross the fenestrations of the intestinal capillaries.

- Both components cannot be reabsorbed by the venous side of the blood circulation due to their large molecular size.



The lymph vessels
1- Lymphatic capillaries

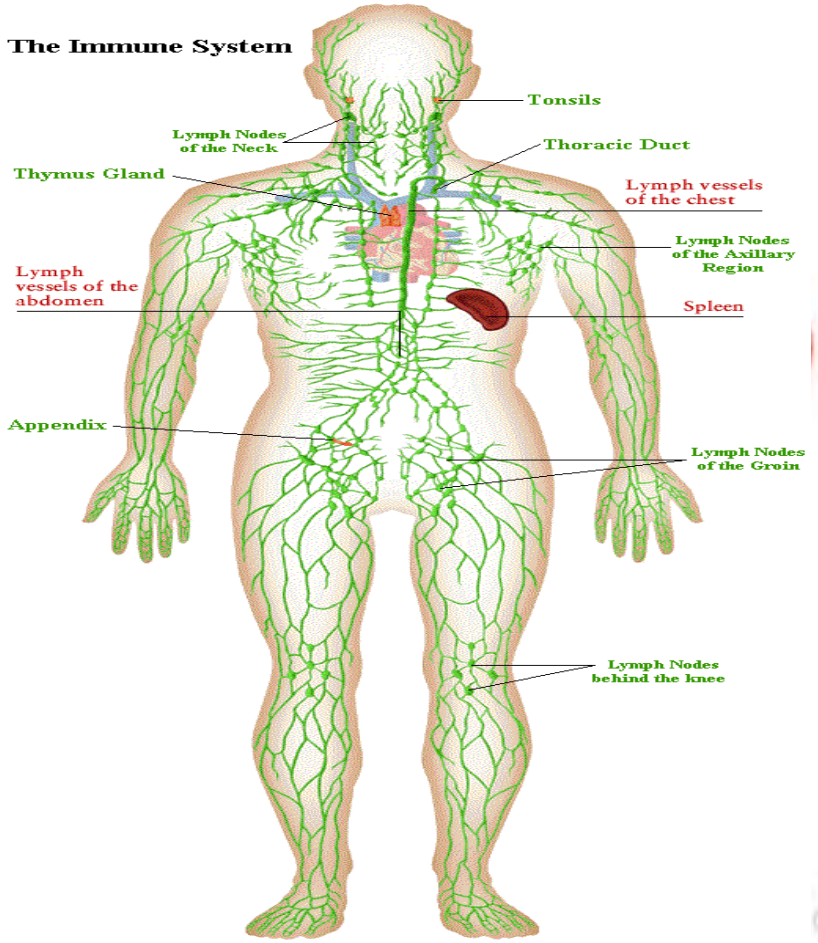
- **Structure:**
  - *Blind ended* channels.
  - *Irregular* in shape.
  - Lined by endothelial cells resting on an *incomplete* basal lamina.
  - *Openings* between endothelial cells are kept open by *anchoring filaments* that bind to surrounding connective tissue.

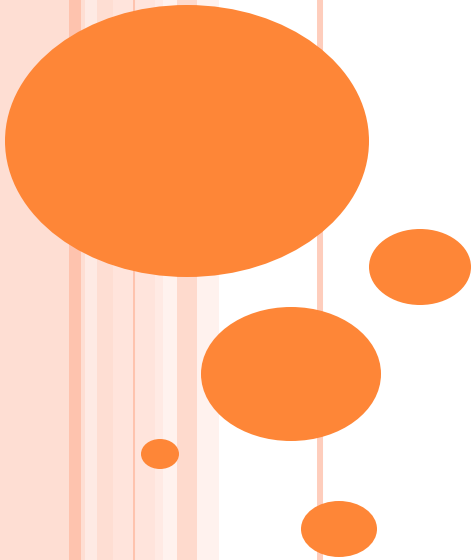


	Lymph capillaries	Blood capillaries
1- Connections	Blind ended connected to larger lymphatic vessels	Open at both ends, connected to venules and arterioles
2- Lumen	Wide lumen	Narrow and usually rounded
3- Shape	Irregular in shape	Regular
4- Basal lamina	Discontinuous basal lamina, and have anchoring filaments to the surrounding collagen.	Have basal lamina and pericytes
5- Content	Carry lymph	Carry blood

The lymph vessels
2- Large lymphatic vessels

- **Structure:**
  - Similar to that of veins, having *valves* to keep the lymph flow unidirectional.
  - But, they have *thinner walls* and *without a clear separation* between layers (intima, media and adventitia).
- Lymphatic vessels converge to form the thoracic duct and the right lymphatic duct which empty lymph back into the blood.





Thank You