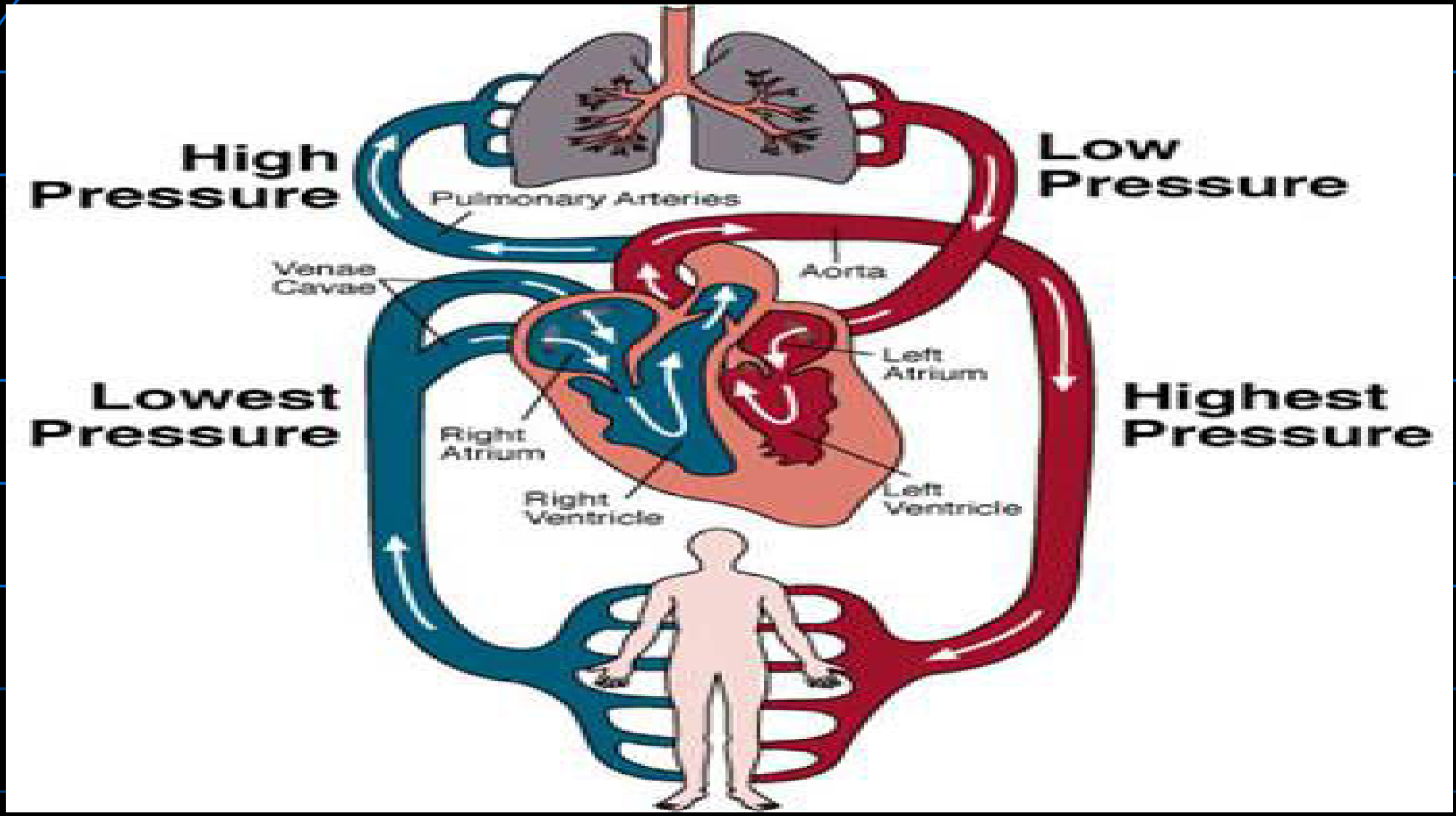
بسم الله الرحمن الرحيم

Circulatory system



1. The Cardiovascular System
2. The Lymphatic system

The Cardiovascular System

Heart: serves as pumping unit of blood

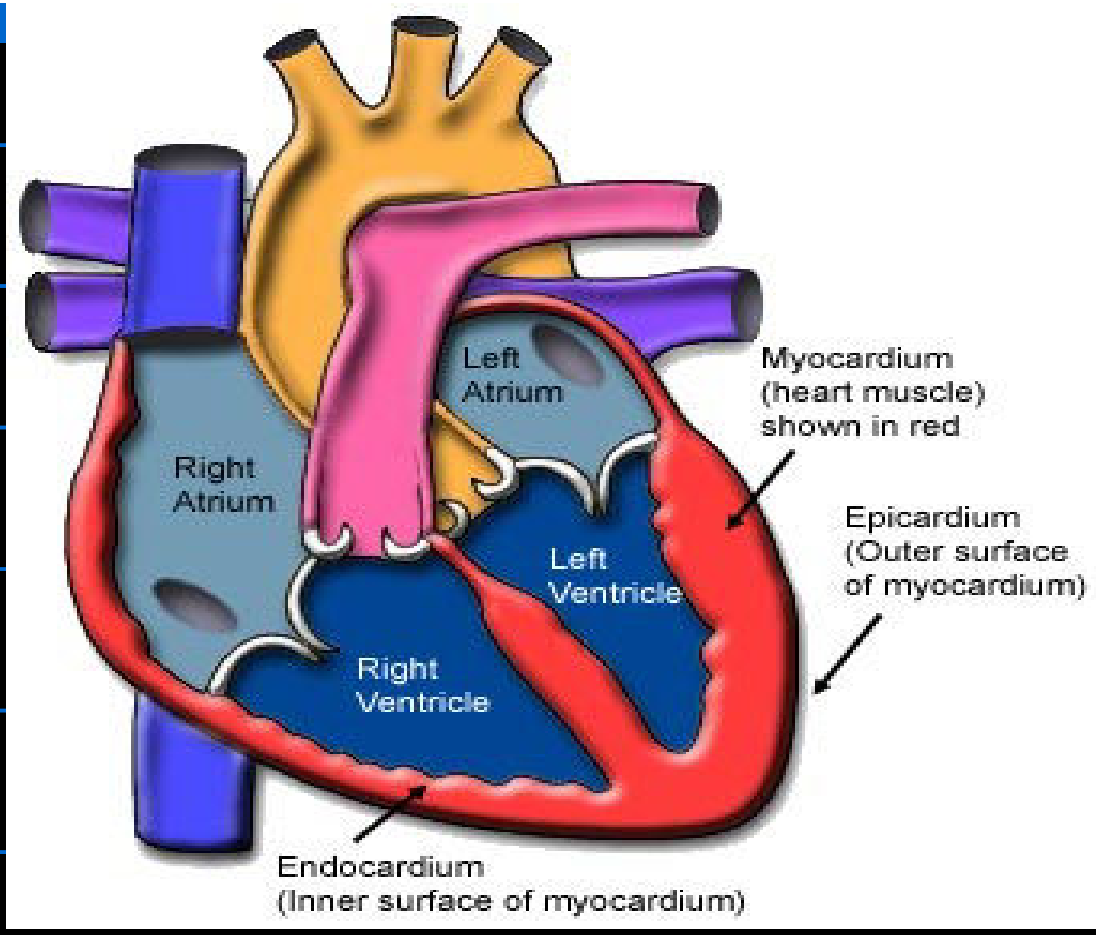
Arteries: Transport bl. from heart to peripheral tissues.

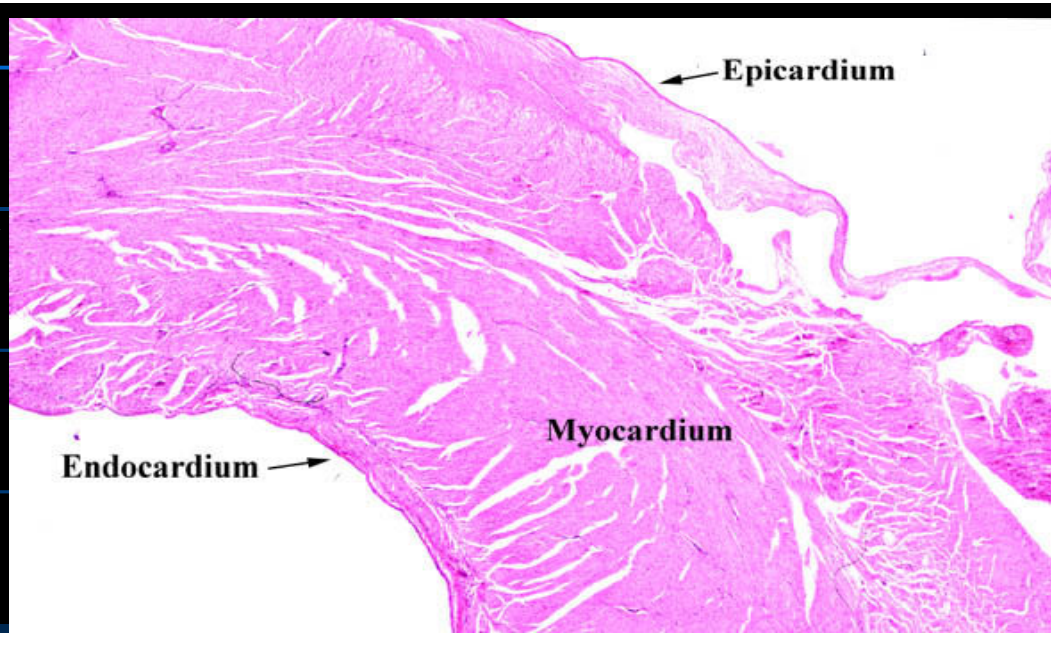
Capillaries: where exchange of materials occurs.

Veins: return blood back to heart

The Heart

- Heart is muscular organ consists of four chambers.
- Wall of the heart is formed of three coats: endocardial, myocardial and pericardial layer





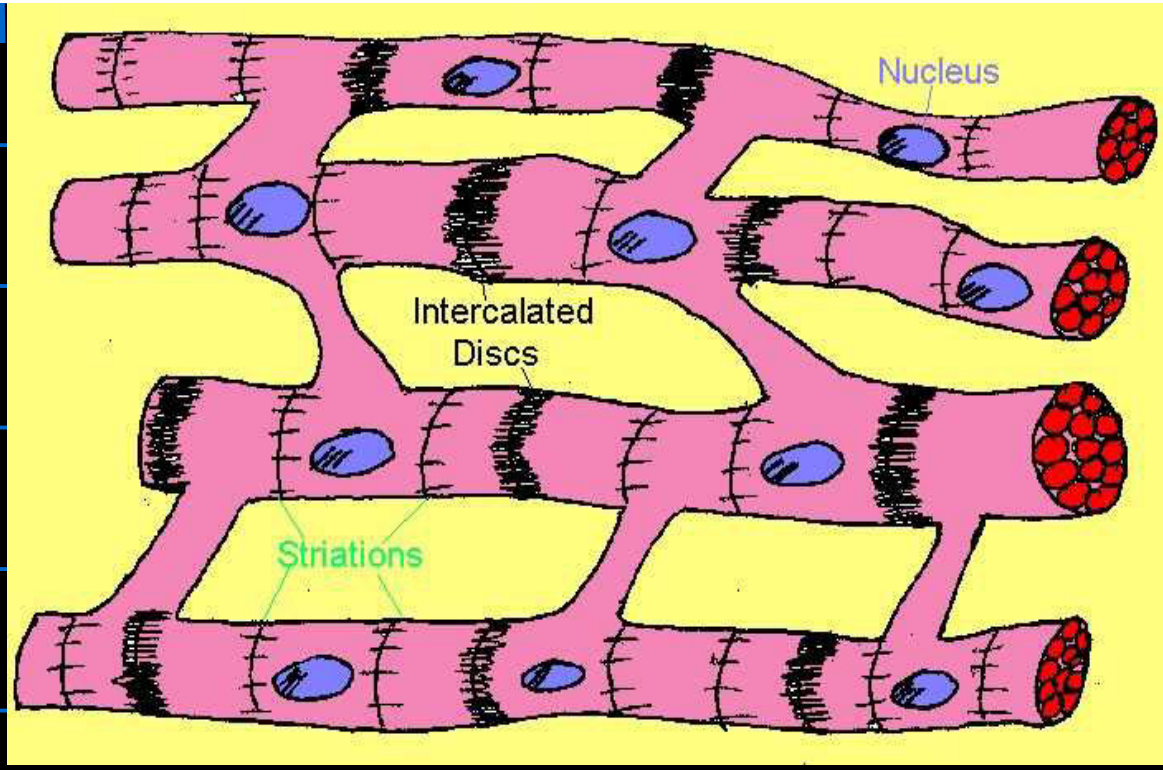
Microscopic structure of heart wall

1- Endocardium: inner lining layer, formed of:

Endothelium: **simple squamous layer.**

Subendothelial C.T.: **loose C.T., contains elastic and collagen fibers.**

2- Myocardium



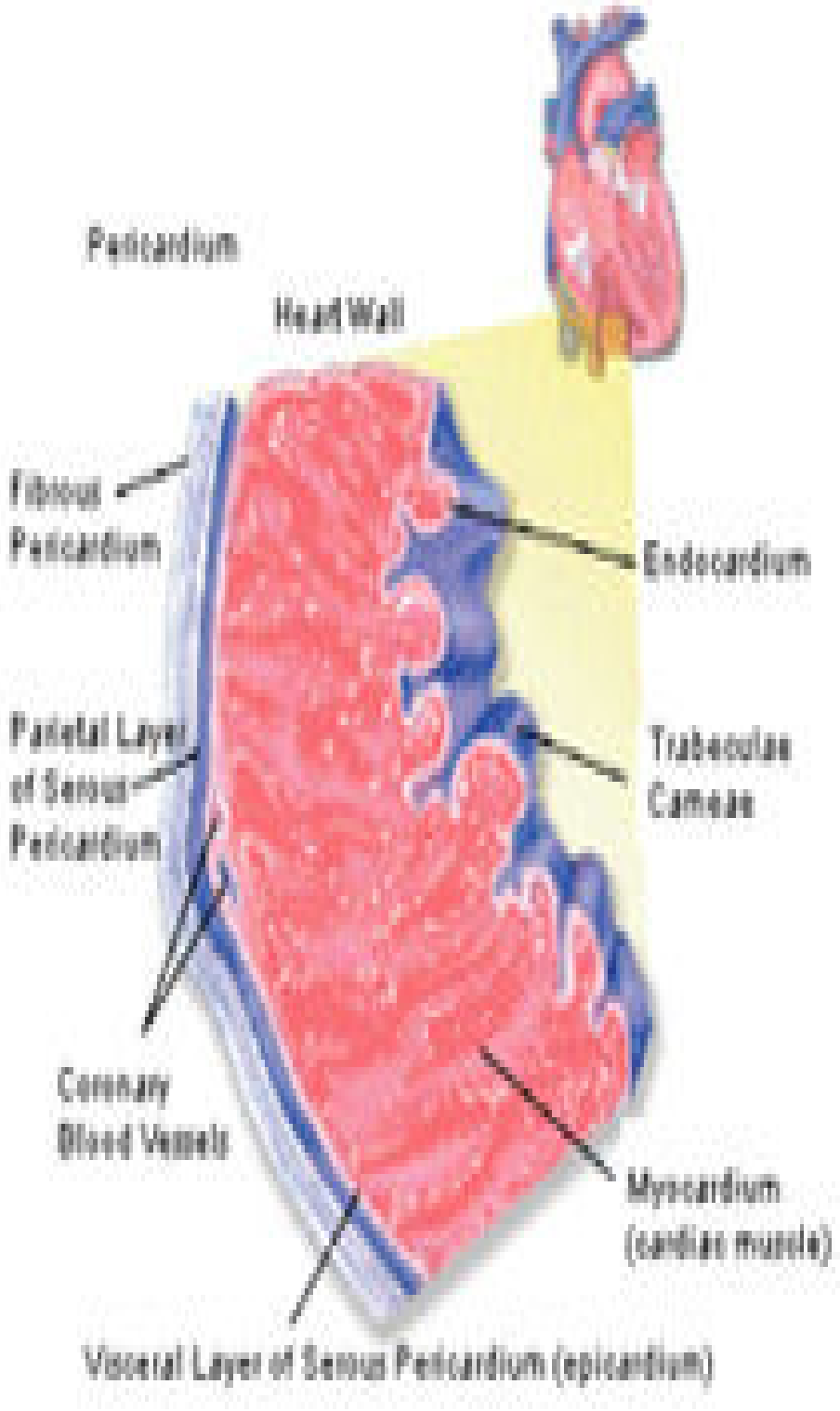
- Forms main the of cardiac wall.
- Formed of network of cardiac muscle fibers that are thinner in atria than ventricle. It spirals in layers around heart. It contains in-between rich capillary network.

3- Epicardium:

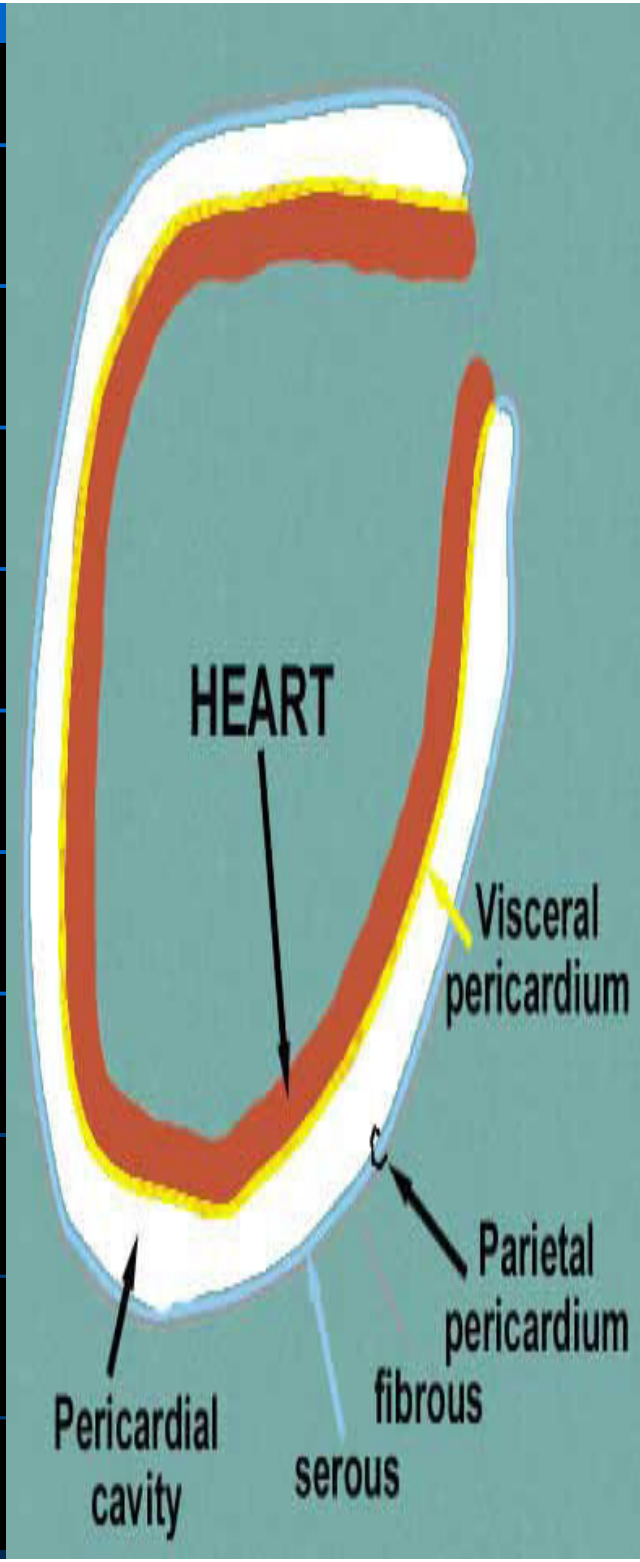
Represents visceral layer of pericardium (serous membrane)

Covers outer surface.

Rests on loose C.T. which contains fat cells and coronary blood vessels.

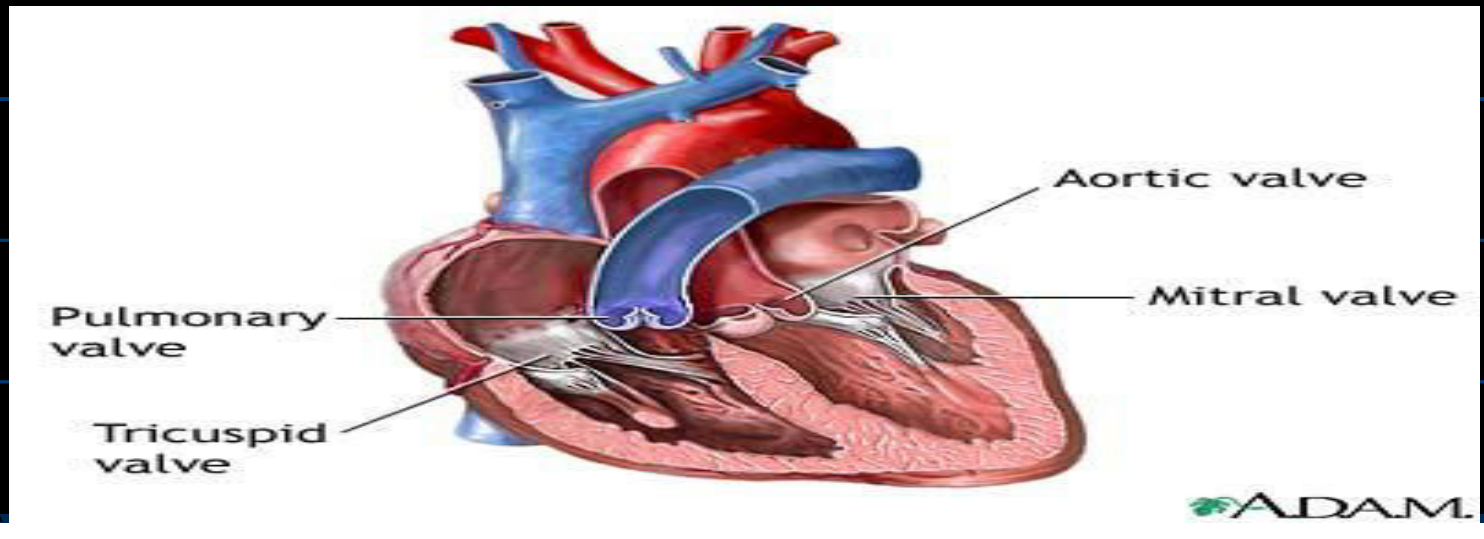


- Pericardium has visceral layer (epicardium) and parietal layer. Latter has two inseparable parts, outer fibrous and inner smooth serous parts. Serous fluid is present between two layers. This allows these layers to slide over each other during contraction and relaxation of the heart.



Valves of the heart:

- They are folds of endocadium, covered with endothelium from both sides, with middle supporting plate of dense fibrous C.T. and elastic fibers.
- They are present between atria and ventricles, at openings of pulmonary artery and aorta. They are similar in structure.



The Blood Vessels

They include:

- **Arteries:** Large arteries, medium sized arteries & arterioles.
- **Veins:** Large veins, medium sized veins & venules.
- **Arterio-venous connections:** Blood capillaries, sinusoids & arterio-venous anastomosis.

General structure of blood vessels

1-Tunica Intima:

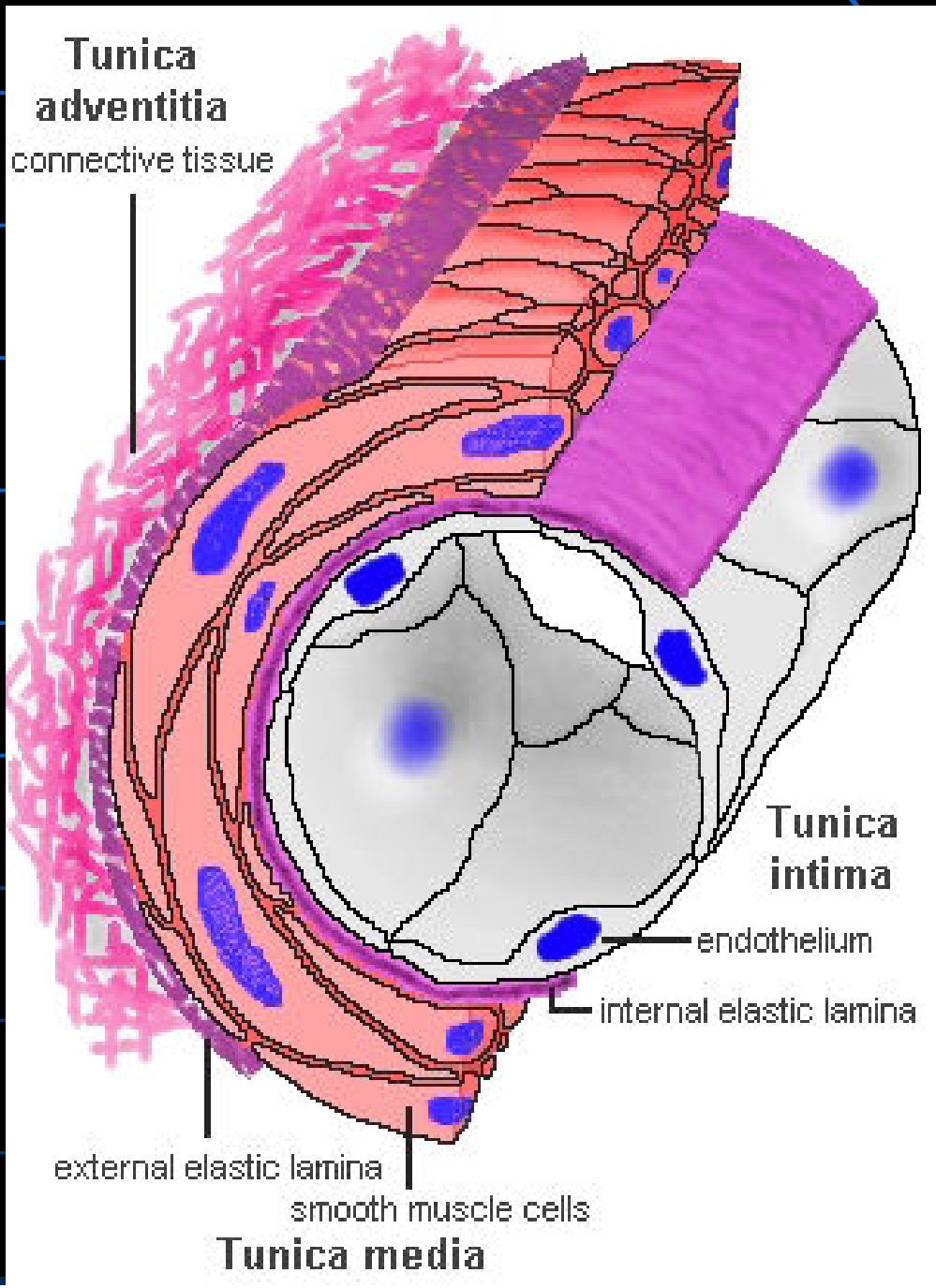
Innermost layer, contact with blood.

2- Tunica Media:

The middle layer of blood vessels.

3- Tunica Adventitia:

The outermost layer.



1- Tunica Intima: formed of

a- Endothelium:

Simple squamous epithelium, lies on basal lamina. It provides a smooth surface for blood flow,,secrets collagen II,IV,V& endothelin.

B- highly differentiated basal lamina to mediate easy exchange of molicules.

c- Subendothelium:

Loose areolar C.T. to support the endothelium

c- Internal elastic lamina:

Present in arteries. Made of dense elastic fibers(elastin) with opinings allow diffusion of substances to nourish the deeper parts of vessel wall . Well developed in muscular arteries

2- Tunica Media: formed of:

- Concentric layers ofsmooth muscle f arrenged hellically.
- elastic fibers,Fine collagen fibers (III), reticular f.,&proteoglycans.
- Ground substance in between.
- Its outer layer is limited with elastic membrane in some arteries, which forms (External elastic lamina).
- Regulates blood flow by contraction of its smooth m.

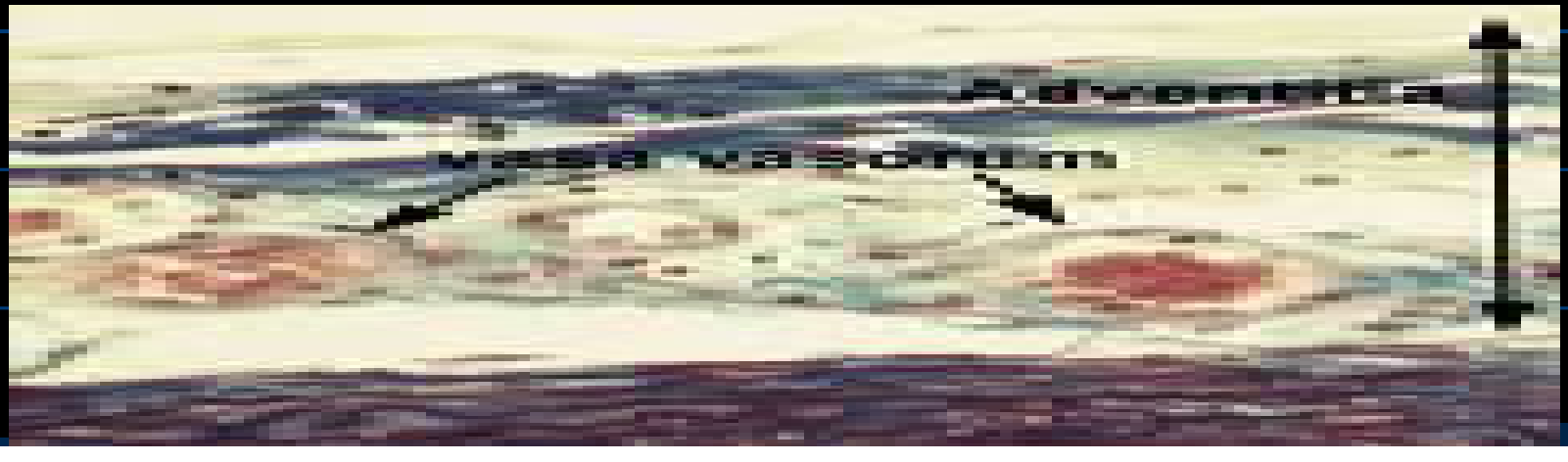
3- Tunica Adventitia:

- Formed of loose C.T. in which collagen f (I). are predominant, with some elastic f. and some C.T. cells.
- Contains nerves, lymphatics and vasa vasorum to nourish deep layer of vessel wall (more in veins) .
- It connects blood vessels to the surrounding tissues

- **Vasa Vasorum:**

(blood vessel of the blood vessel).

- **Small arteries that branch in adventitia and outer part of media, in large vessels to nourish them.**



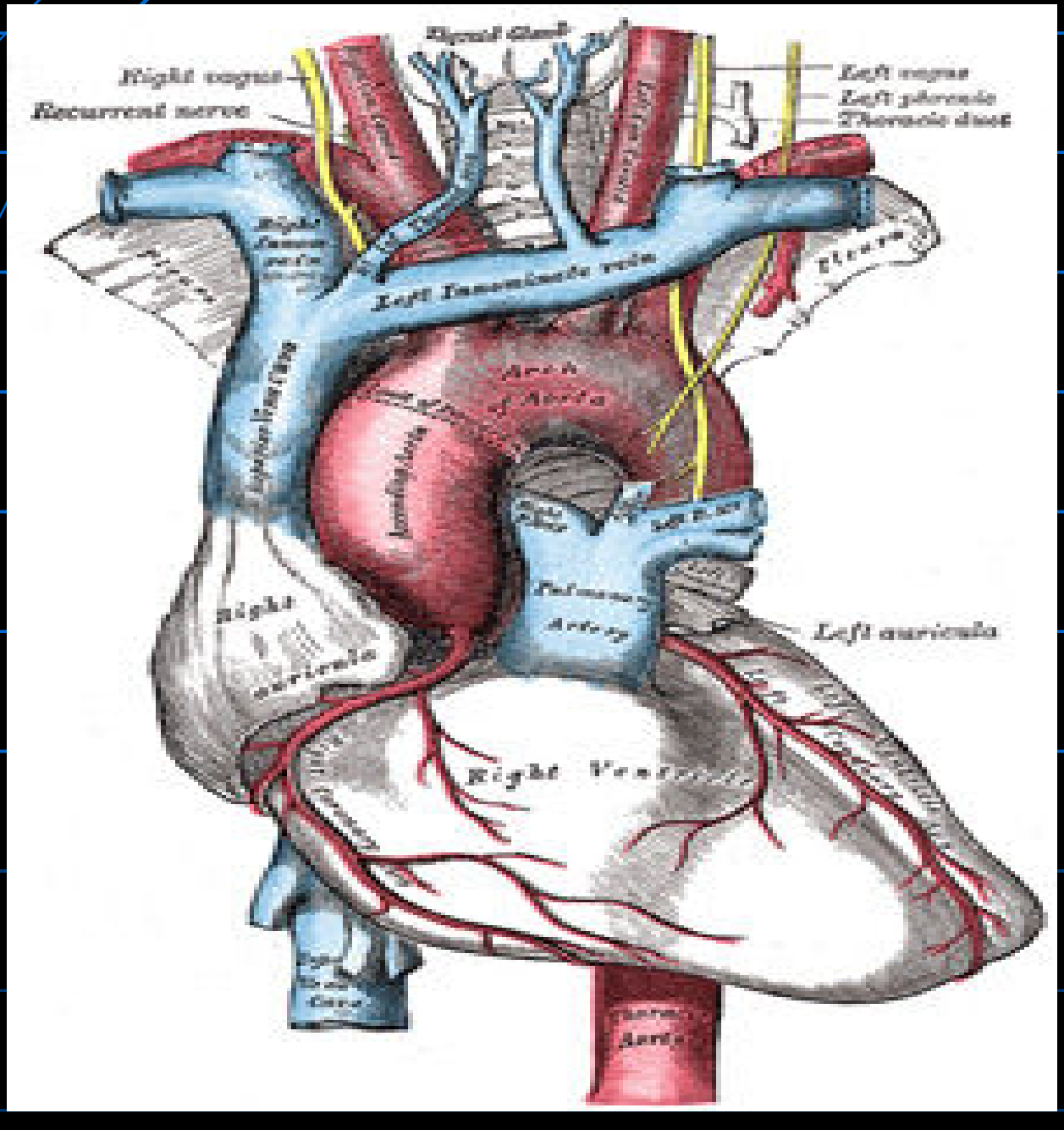
Arteries

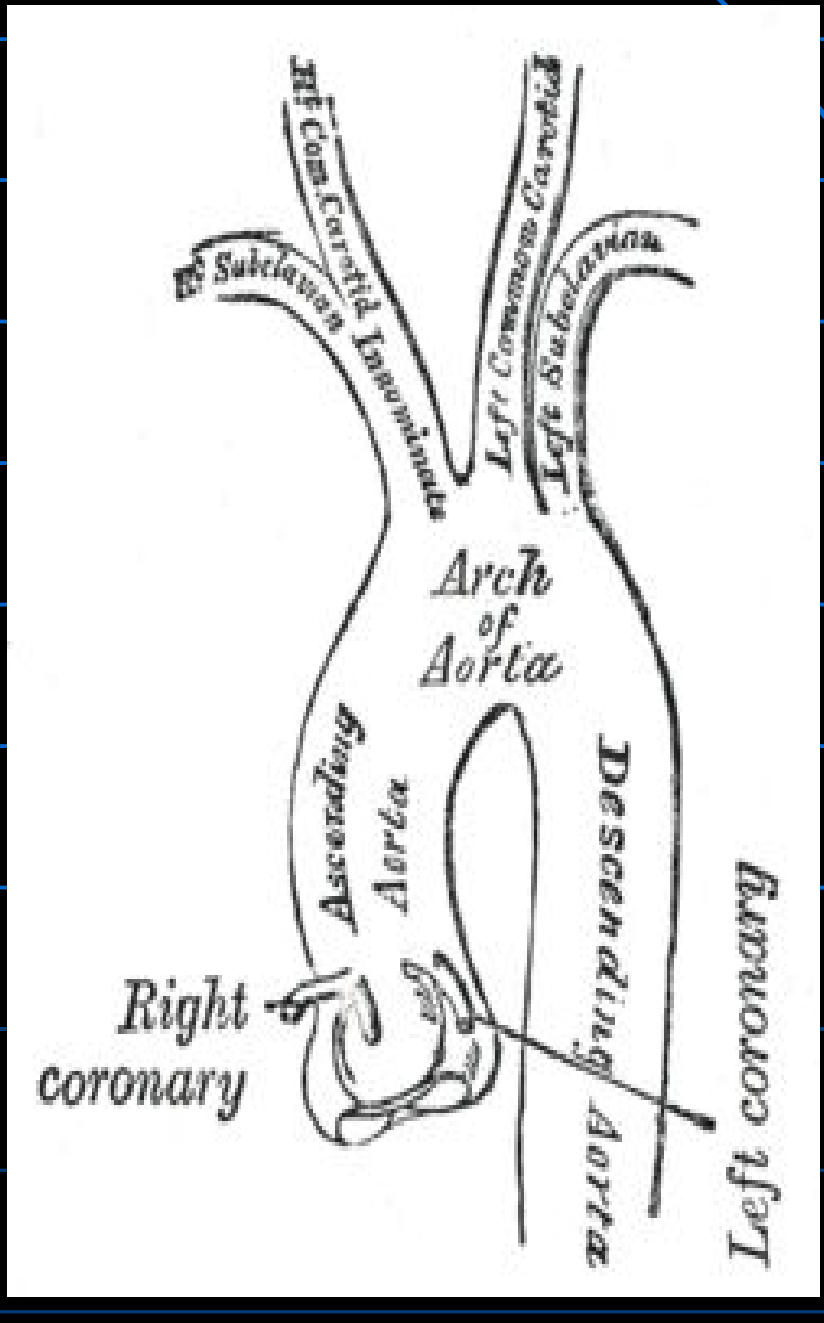
- Classified according to their size & main tissue in their media into:

1- **Large elastic arteries:** which carry blood from the heart.

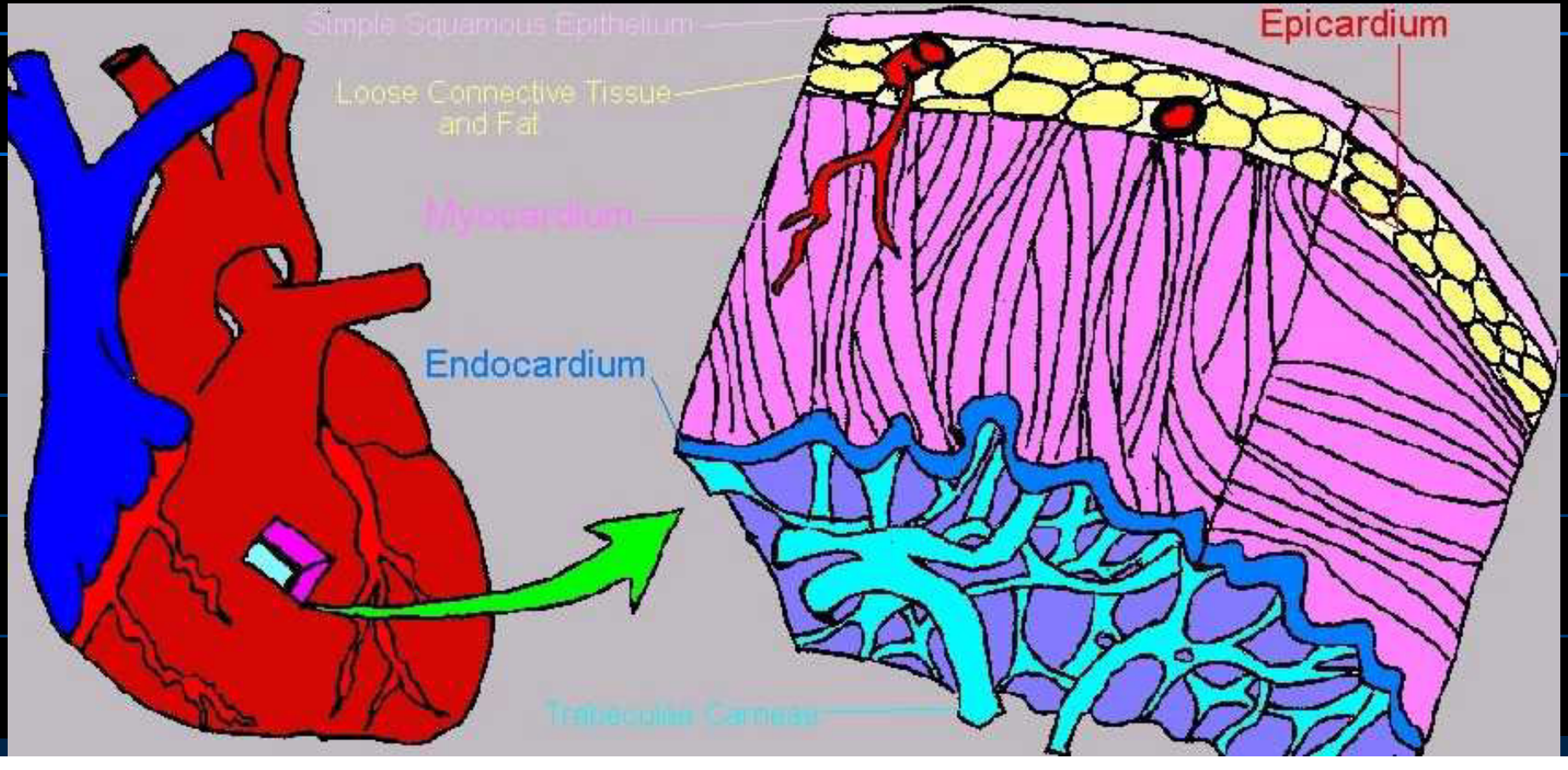
2- **Medium-sized muscular arteries:** distribute blood to organs.

3- **Small arteries (arterioles):** regulate blood flow to capillaries


Right vagus
Recurrent nerve
Left vagus
Left phrenic
Thoracic duct
Left innominate vein
Arch of Aorta
Left auricula
Right ventricle


Right Com. Carotid
Left Innominate
Left Common Carotid
Left Subclavian
Arch of Aorta
Ascending Aorta
Descending Aorta
Right coronary
Left coronary

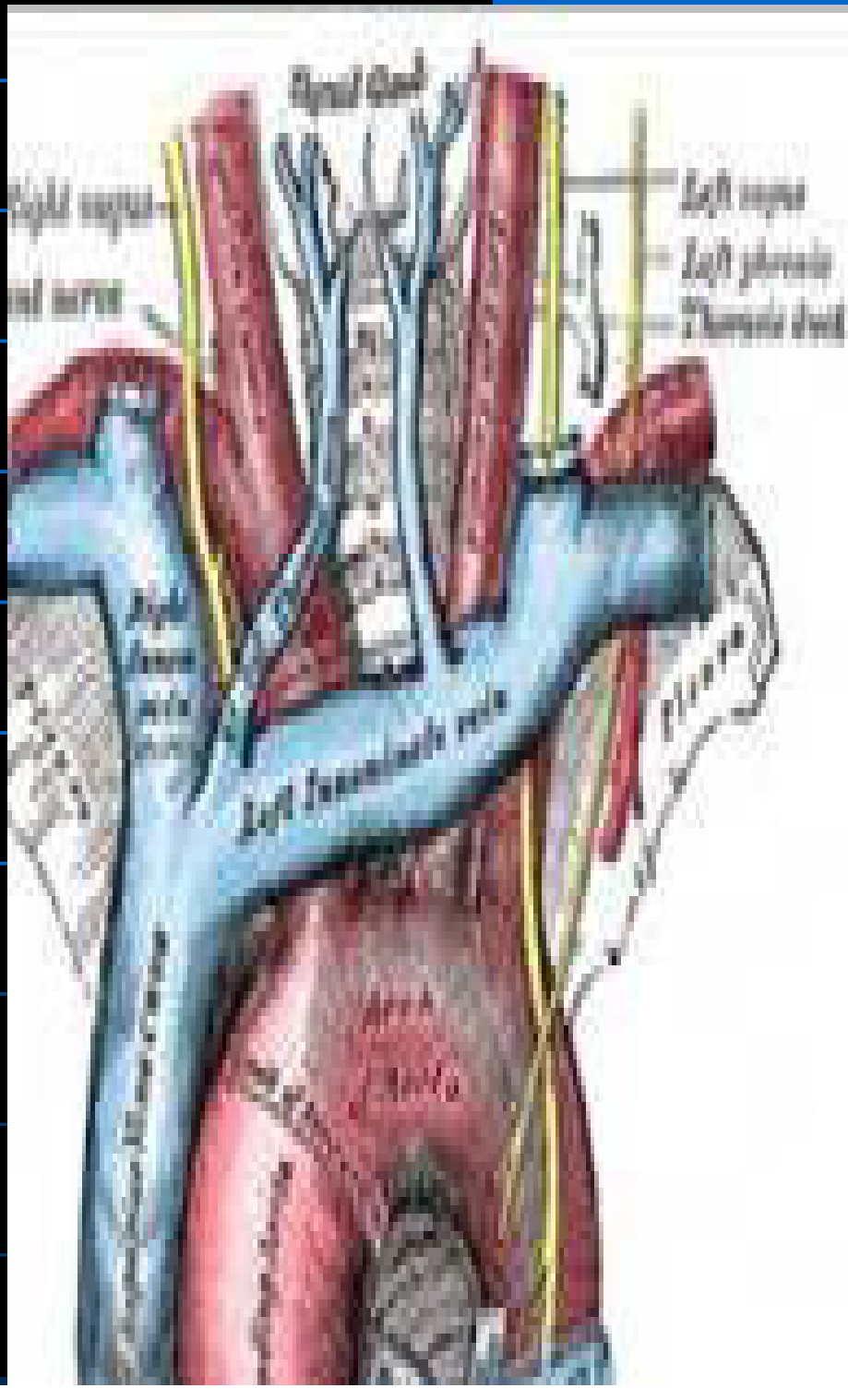
The basic structure of arteries is similar in having the three concentric layers.



I- Large Elastic Arteries:

- Resist changes in blood pressure in their initial parts by their elastic recoil.
- They have thick walls which appear yellowish in fresh conditions as they are mainly formed of elastic f. They also have very wide lumina.

The large elastic arteries in the body are: pulmonary, aorta and its large branches (left common carotid, left subclavian and innominate arteries). Aorta will be studied as an example.



The Aorta

1- Tunica Intima:

a. Endothelium: simple sq. epithelium

b. Subendothelium: thick loose C.T. rich in elastic fibers, collagen fibers which are longitudinally arranged.

c. Internal elastic lamina: non-clear, as it is similar to the underlying elastic laminae of the media.

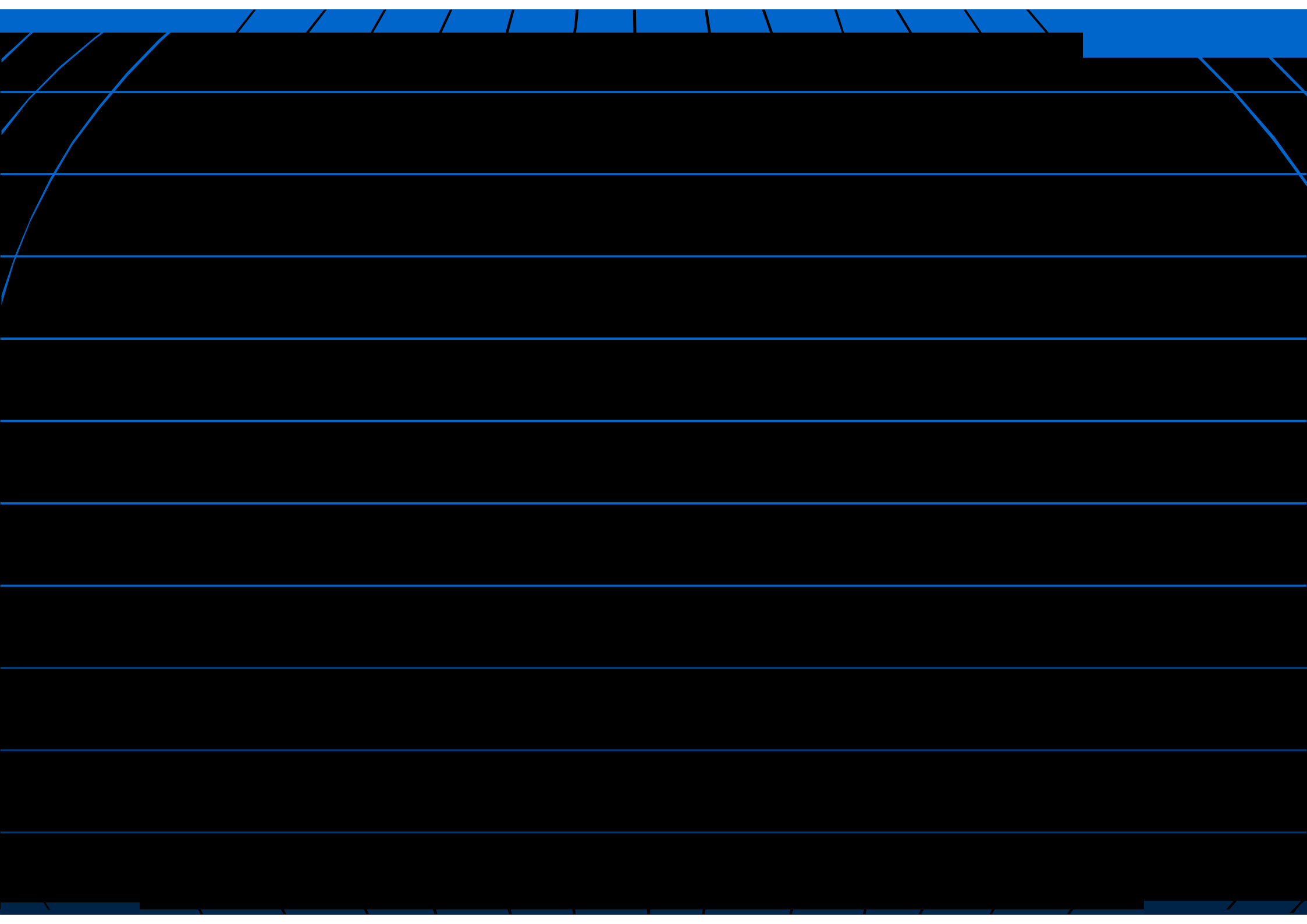
2- Tunica Media:

The thickest layer, (70% of the wall), made of:

- Concentrically arranged fenestrated elastic membranes, increase with age

N.B.: the fenestrae in the elastic laminae are important to facilitate the diffusion of substances through the arterial wall.

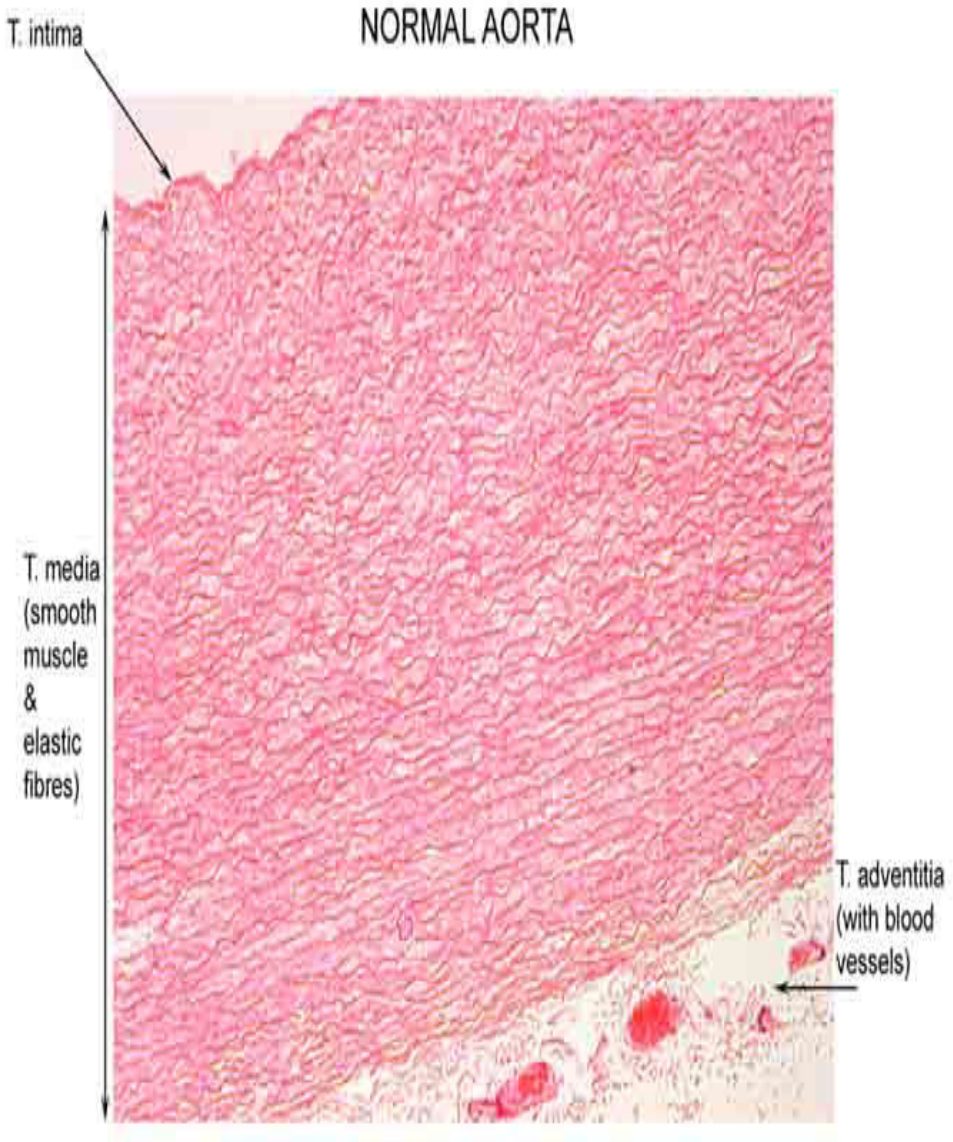
- Smooth muscle fibers, alternating with the elastic membranes (which is responsible for production of elastic f. and ground substance
- Collagen fibers are found between elastic f.
- External elastic lamina cannot be differentiated from those of the media



3-Tunica Adventitia:

Thin coat, formed of loose C.T., in which:

- longitudinally arranged Collagen & elastic f. are found,
- Containing vasa v.
- Lymphatics and nerves are present.



II-Medium-Sized (Muscular) Arteries:

- The most common type
- Their wall is formed mainly of smooth muscles regulate blood flow to organs.
- Transition from elastic to muscular arteries is not abrupt; there is gradual reduction in elastic f. and increase in smooth muscles.

1-Tunica Intima:

thinner than in elastic arteries.

a. **Endothelium.**

b. **Subendothelium:** thin layer of C.T., may contain smooth muscle fib.

c. **Internal elastic lamina:** is very prominent, well developed and appears as a wavy pink line in H & E sections.

2- Tunica Media:

- Thick layer of concentrically arranged smooth muscle fibers (from 4 layers in small arteries, up to 40 layers in large muscular arteries).
- Elastic and fine collagen fibers (reticular) are found scattered between the muscle fibers.

- **External elastic lamina:**

Present in large muscular arteries between media and adventitia as condensed elastic fibers.

3- Tunica Adventitia:

- **Its thickness is less than the media.**
- **Formed of longitudinal collagen and elastic fibers and fibroblasts.**
- **Nerves, lymphatic and vasa vasorum in large ones.**

Type	Large Elastic Arteries	Medium-Sized arteries
site	Aorta & its large branches, pulmonary, yellowish colour	Most muscular and organ arteries.
Tunica intima	Thicker.IEL is not prominent	Thinner. Prominent IEL.

Tunica intima	Endothelial cells are joined by occluding junctions. & contain weibel bodies(von willebrand factor) Subenotheliu m rich in elasic f IEL: non clear	Subenotheliu m yhin layer of Ctcontain few smooth muscle f

Tunica media	Thickest ,70 layers of elastic mm. Smooth muscle. Ill defined external elastic lamina	40layer circular smooth M. Elastic and collagen(III) fibers in-between. External elastic lamina is prominent.

- **Tunica adventitia thin coat of loose fibroelastic CT in which collagen f elastic f. ,nerves, lymphatics and vasa vasorum may be found in elastic arteries.**

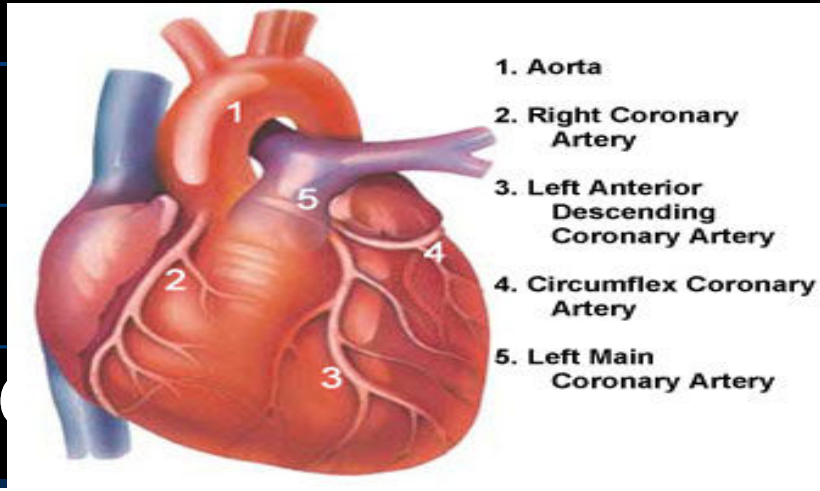
Specialized types of medium sized arteries

1. Cerebral arteries (Basilar artery):

- As these arteries protected within skull, they have thin walls and wide lumens, like veins.
- They have prominent thick internal elastic lamina.
- Tunica media: thin, poor in elastic f.
- Tunica adventitia is thin

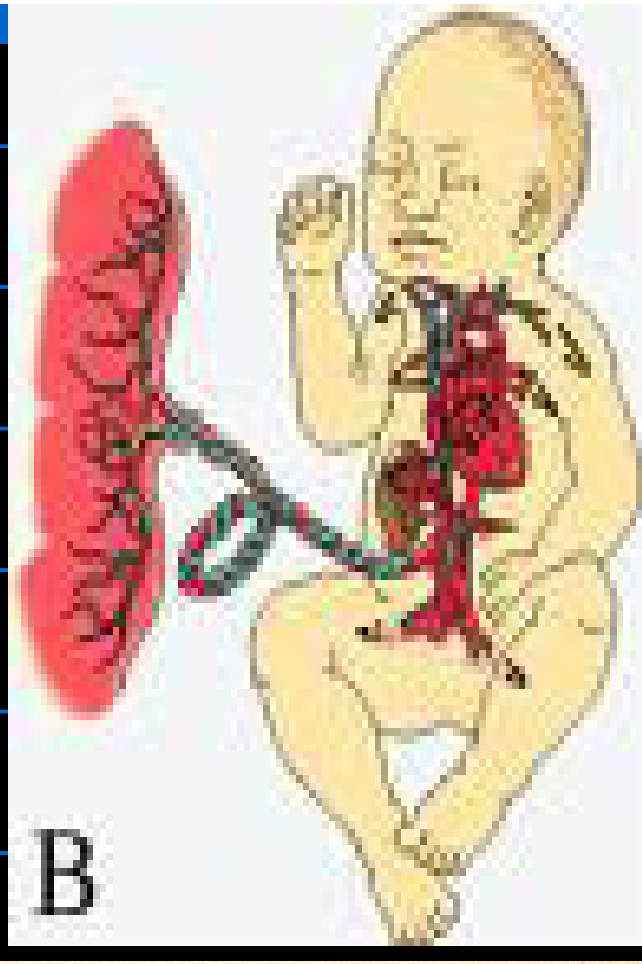
2. Coronary arteries:

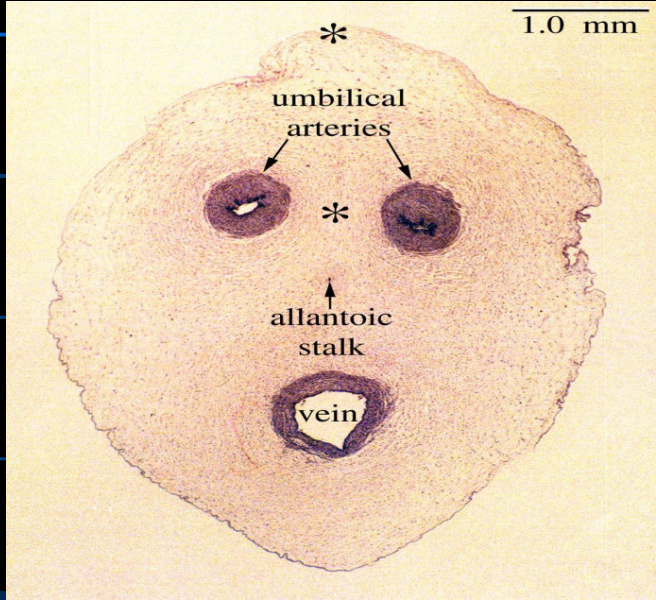
- T. intima: thick, has longitudinal smooth m. & elastic f. in subendothelium, ground substance and fat droplets.
- Tunica media: thick if compared to muscular arteries of the same size.
- They have well developed internal & external elastic lamina



3.Umbilical arteries:

- Tunica intima lacks internal elastic lamina
- Tunica media has smooth m., inner longitudinal and outer circular.
- Tunica adventitia is formed of mucoid C.T.
- This arrangement makes umbilical arteries occlude after birth.



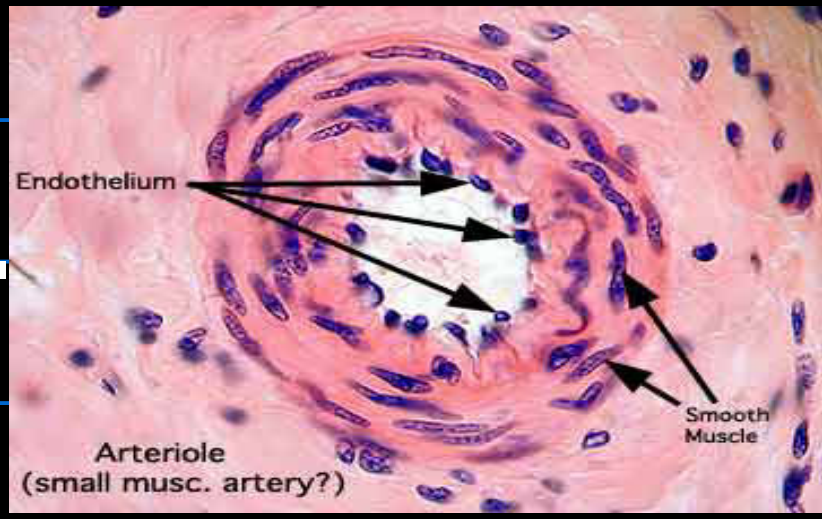


III- Small Arteries (Arterioles):

- Are responsible for the peripheral resistance of b.v., they control blood flow into capill.
- They are the smallest branches of muscular arteries, which decrease in diameter gradually, and their walls also decrease in thickness.

1- T. Intima:

- Endothelium rest on thin basal lamina and very thin subendothelial l.
- IEL is thin, gradually disappears in smaller ones.



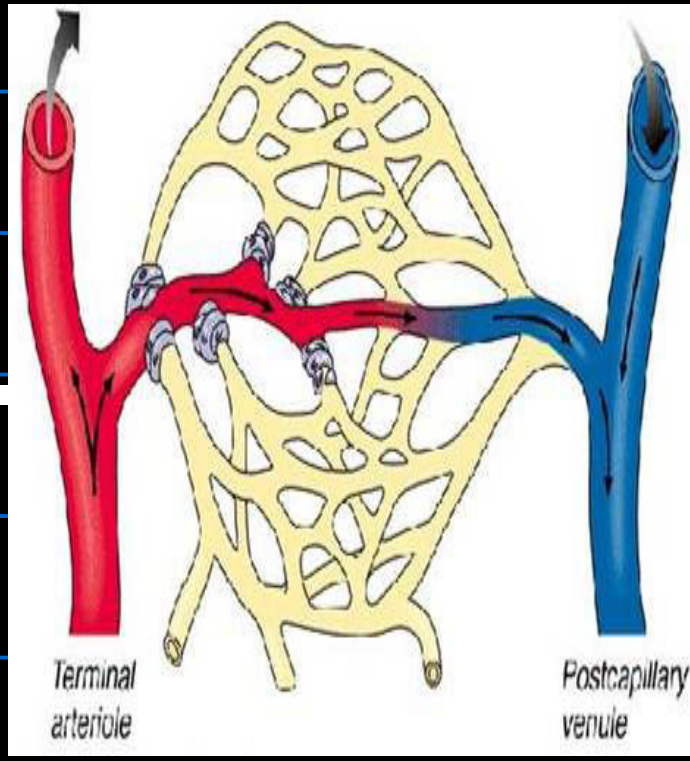
2- T. Media:

one or two layers of smooth muscles, which gradually disappear, and replaced by pericytes in small arterioles.

3- T. Adventitia: very thin.

Metarterioles:

- lateral branches of terminal arterioles, and the connection between arterioles and capillaries.
- At their initial segments, they are surrounded by rings of smooth m. cells that act as sphincters to control blood flow to cap.



Veins

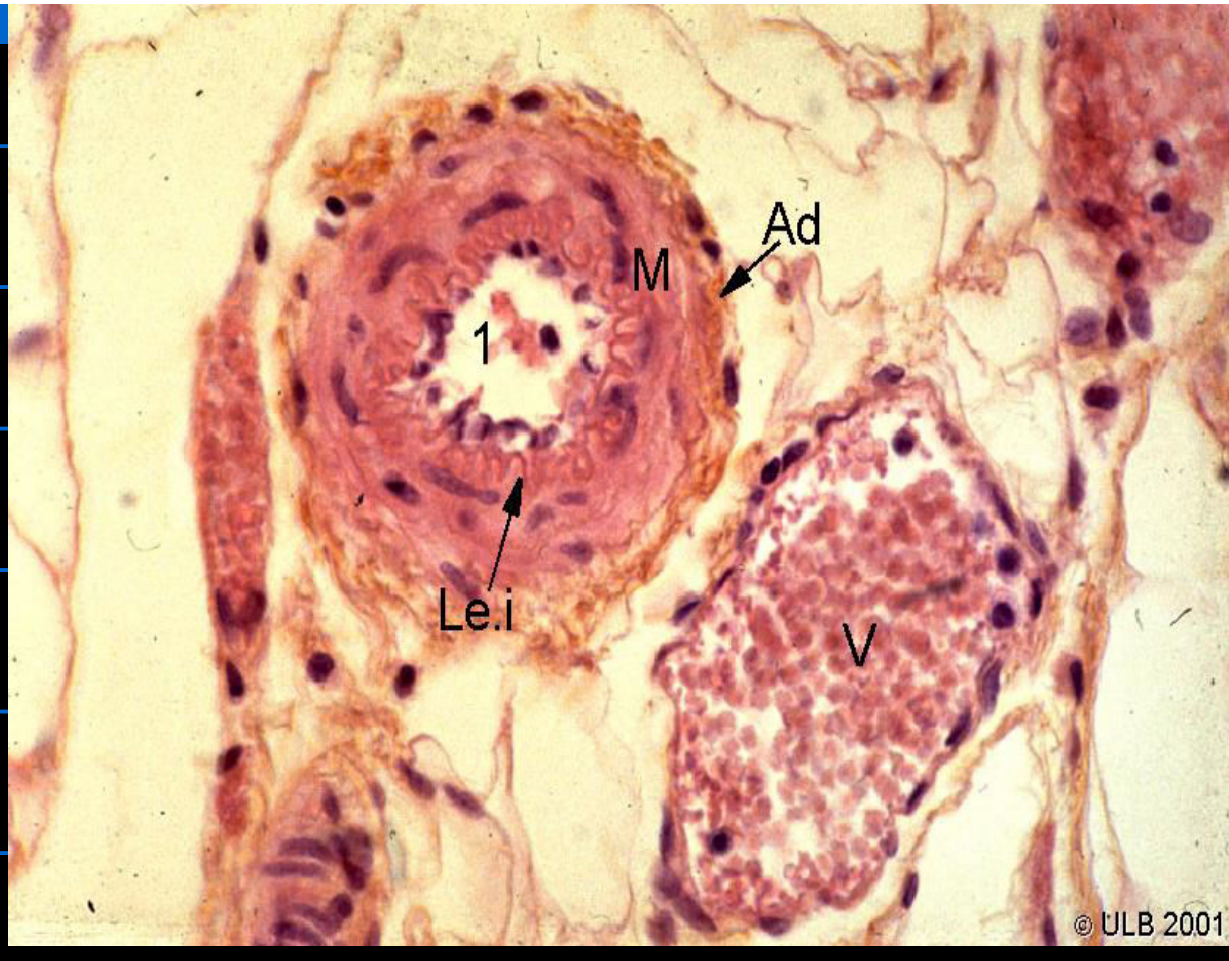
- Carry bl. from tissues and return it to heart.
- Veins start as post capillary venules, muscular, then large veins.

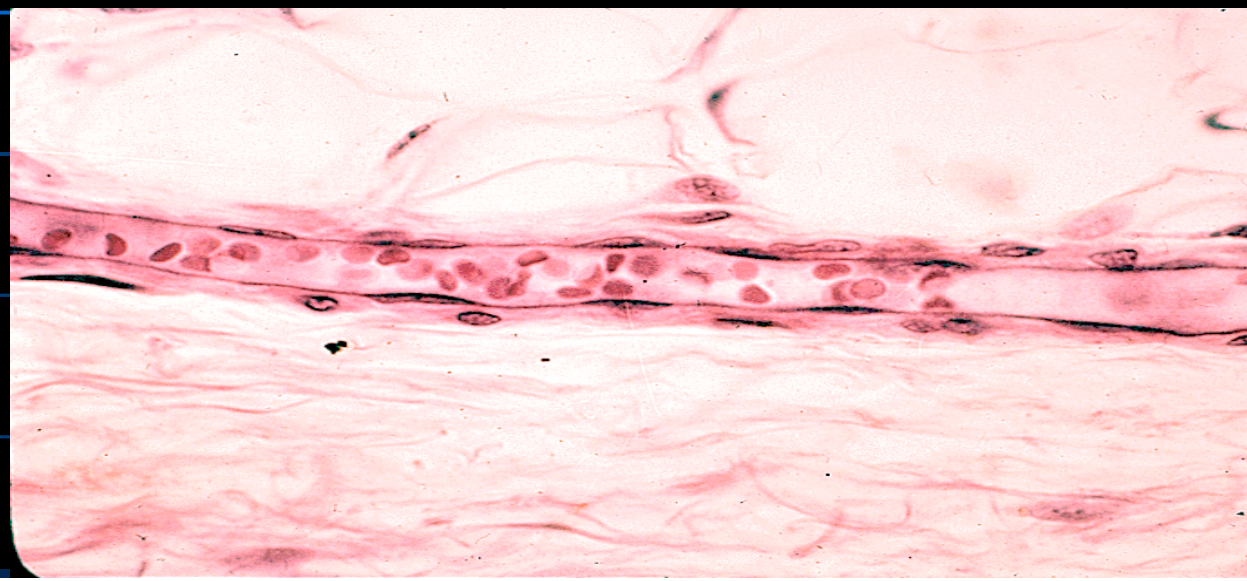
1- Small veins (venules): Smallest veins into which capillaries drain

- They have very thin walls.
- **T. Intima:** endothelium rich in actin filaments, rests on thin basal lamina
- **T. Media:** contains pericytes and reticular fibres. Few smooth m. differentiate from pericytes start to appear as diameter increases, then called muscular venules.

- **T. Adventitia:** relatively thick

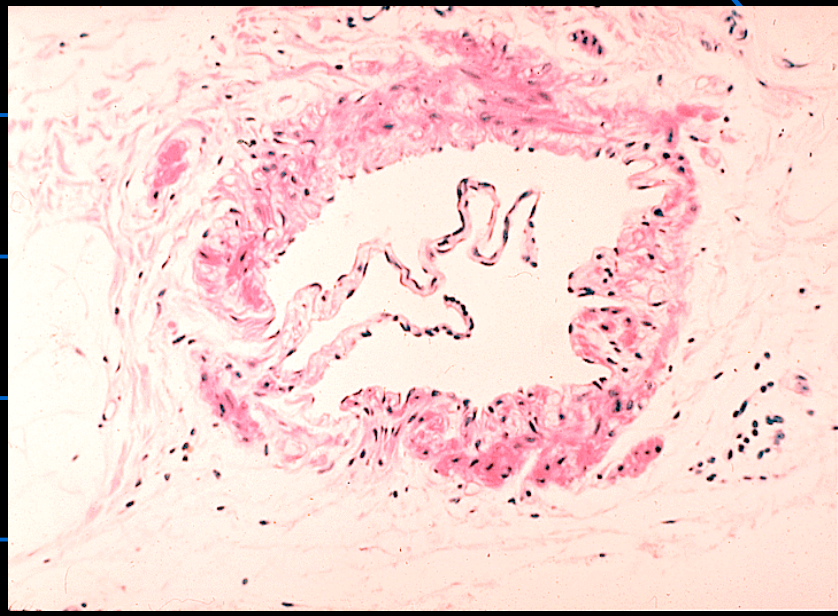
N.B. Exchange of materials between blood and tissues occurs in capillaries and in postcapillary venules





2- Medium-sized (muscular) veins:

T. Intima:



- Endothelium.
- Thin subendothelium:

C.T. with no elastic fibers.

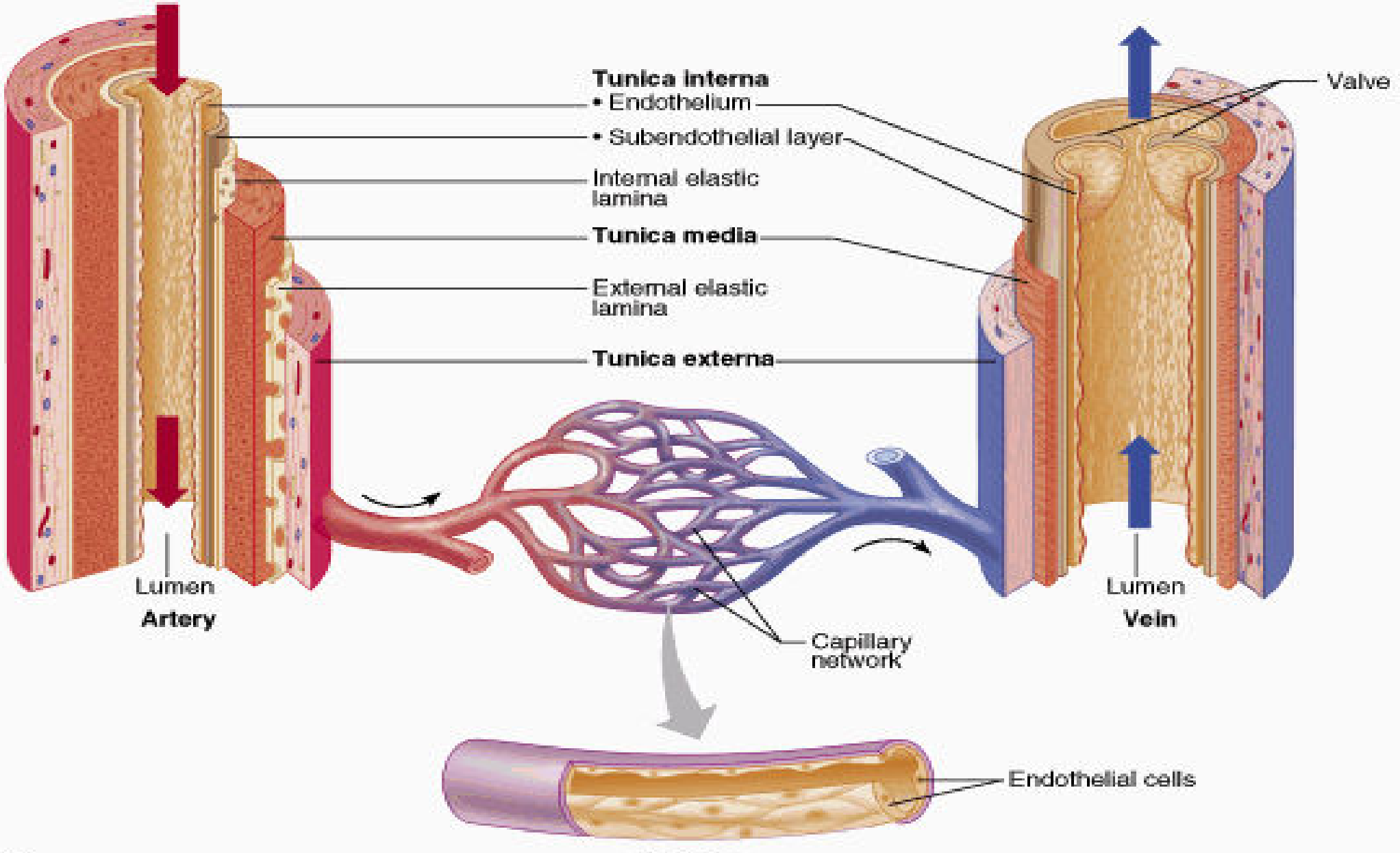
- Endothelium projects into the lumina to form valves. Valves are semilunar folds that project from the intima into the lumina, lined from both sides by endothelium. Their core is formed of elastic tissue.

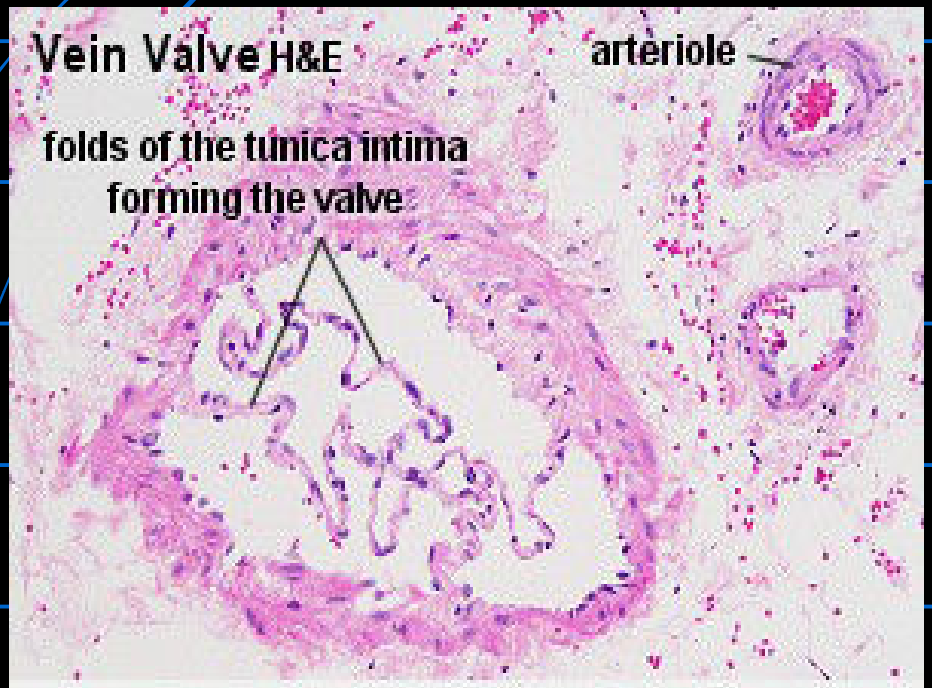
- Valves are absent in small veins, and large veins.
- **T. Media:** Thin, formed mainly of small bundles of smooth muscles, circularly arranged, separated by longitudinally arranged collagen fibers and fibroblast in-between, but poor in elastic fibers.

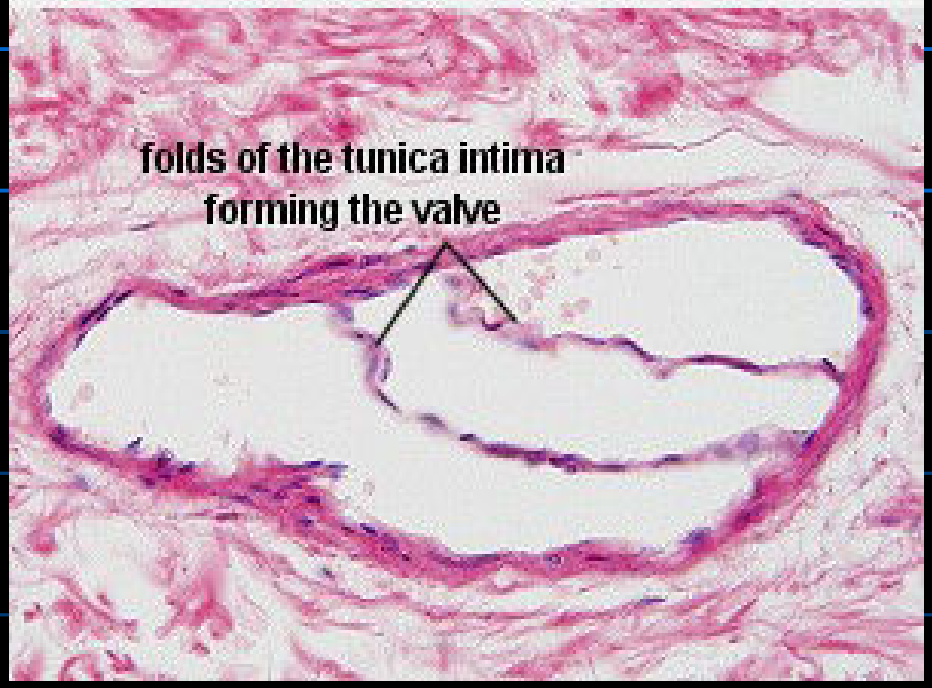
T. Adventitia: the thickest layer, loose C.T., rich in collagen fibers which are mostly longitudinally arranged. In large ones vasa vasorum are found, as the blood passing in these veins has a low O2 tension.

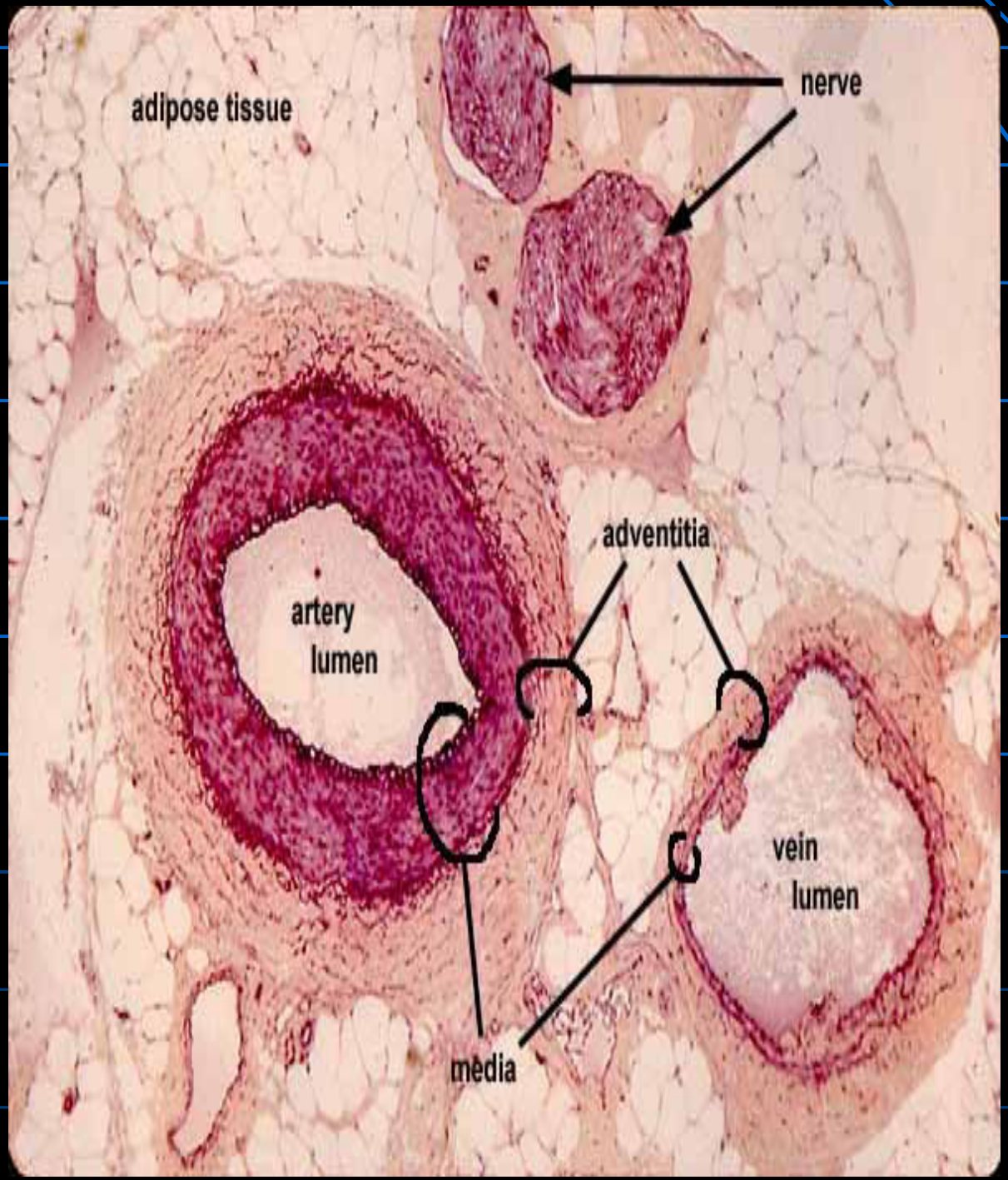
Medium-sized Artery	Medium-sized Vein
T. Media is thick, made of smooth muscles and elastic fibers	T. media is thin, made of smooth muscles poor in elastic fibers
External elastic lamina may be present in between the media & adventitia or absent	It has no external elastic lamina
T. Adventitia is thin, rich in elastic fiber	T. Adventitia is thick, rich in collagen fibers
It has a rapid flow of arterial blood	It has a slow flow of venous blood

Medium-sized Artery	Medium-sized Vein
Thick wall and narrow lu	Thin wall and wide L
The lumen is rounded, doesn't collapse (patent)	The lumen collapses after death
It has no valves	It has valves
The lumen contains no blood after death	The lumen contains blood after death
T. Intima is thick, folded, rich in elastic fibers, has a clear internal elastic l.	thin, not folded, poor in elastic fibers, has no internal elastic lamina




Vein Valve H&E
arteriole
folds of the tunica intima
forming the valve


folds of the tunica intima
forming the valve

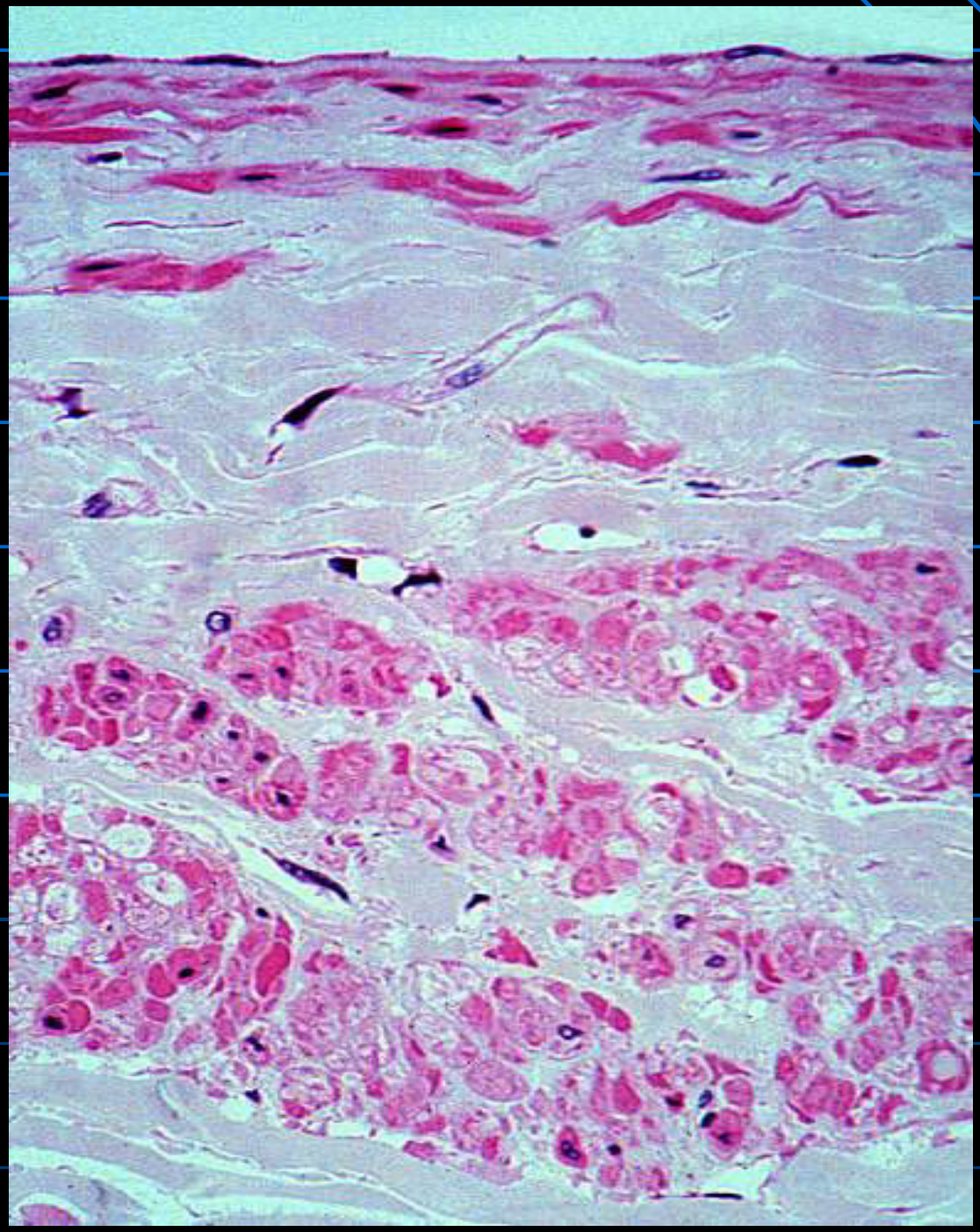

adipose tissue
nerve
adventitia
artery
lumen
vein
lumen
media

3- Large veins

Has a thick wall and a wide lumen. Inferior vena cava is the best example.

- **T. Intima:** well developed, no IEL, no valves
- **T. Media:** thinner than arteries, few smooth m. and abundant C.T., poor in elastic fibers.

T. Adventitia: thickest layer, it is formed of loose C.T. that contains longitudinal bundles of smooth muscle fibers and elastic fibers. These fibers facilitate elongation and shortening of the vena cava with respiration.



Peripheral Circulation (Arterio-Venous Connections)

I- Blood Capillaries:

- Terminal arterioles are continued into plexuses of thin vessels called capillary bed, which supply the tissues.
- They have variations in arrangement and density in tissues to adapt variable metabolic activities between blood & tissues, e.g. more denser around lung alveoli, for gas exchange and around intestinal villi for absorption.

Structure of Capillaries:

- They are formed of single layer of endothelial cells, held together by occluding junctions, that roll to produce a narrow tube, the external surface of endothelial cells rests on a basal lamina. The basement membrane splits to enclose small cells called pericytes.
- **Diameter:** 7-9 µm(very narrow, regular and complete lumen).
- **Length:** 0.25-1 mm.
- **Origin:** mesenchymal (UMCs).

Pericytes

-They are perivascular undifferentiated mesenchymal cells, enclosed in the basement membrane of the capillary endothelial cells.

–Their cytoplasm contains actin, myosin and tropomyosin filaments, giving them contractile ability to regulates the blood flow.

-They are considered the media of capillaries.

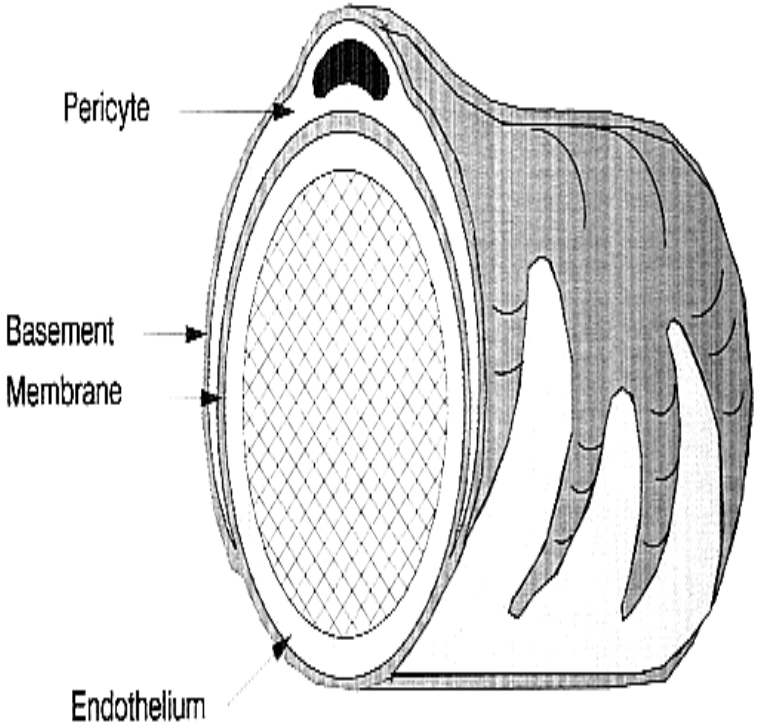
– Their processes wrap around capill. or venule

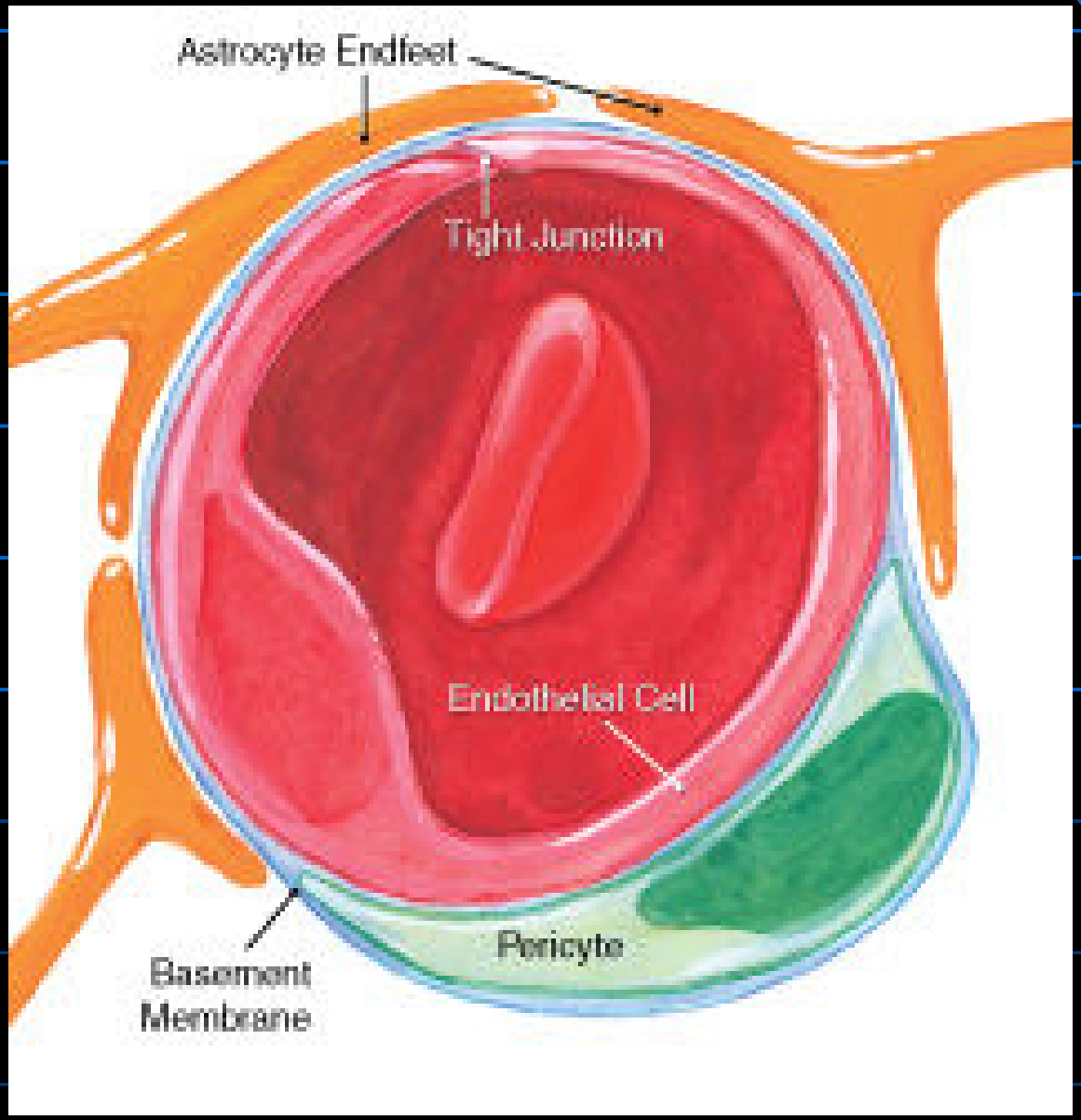
–They can differentiate into endothelial cells, fibroblasts & smooth m. in response to injury

Types of Capillaries

1- Continuous (somatic): Most common type, no pores in their walls.

- **Sites:** found allover the body; e.g.: C.T., skeletal m., bone, skin, brain (modified capillaries
- **Structure:** Endothelium forms a continuous layer, resting on continuous basement m.
- Pinocytic vesicles in their cytplasm for transport of substances to & from capillaries.


Pericyte
Basement
Membrane
Endothelium


Astrocyte Endfeet
Tight Junction
Endothelial Cell
Pericyte
Basement
Membrane

2- Fenestrated (visceral):

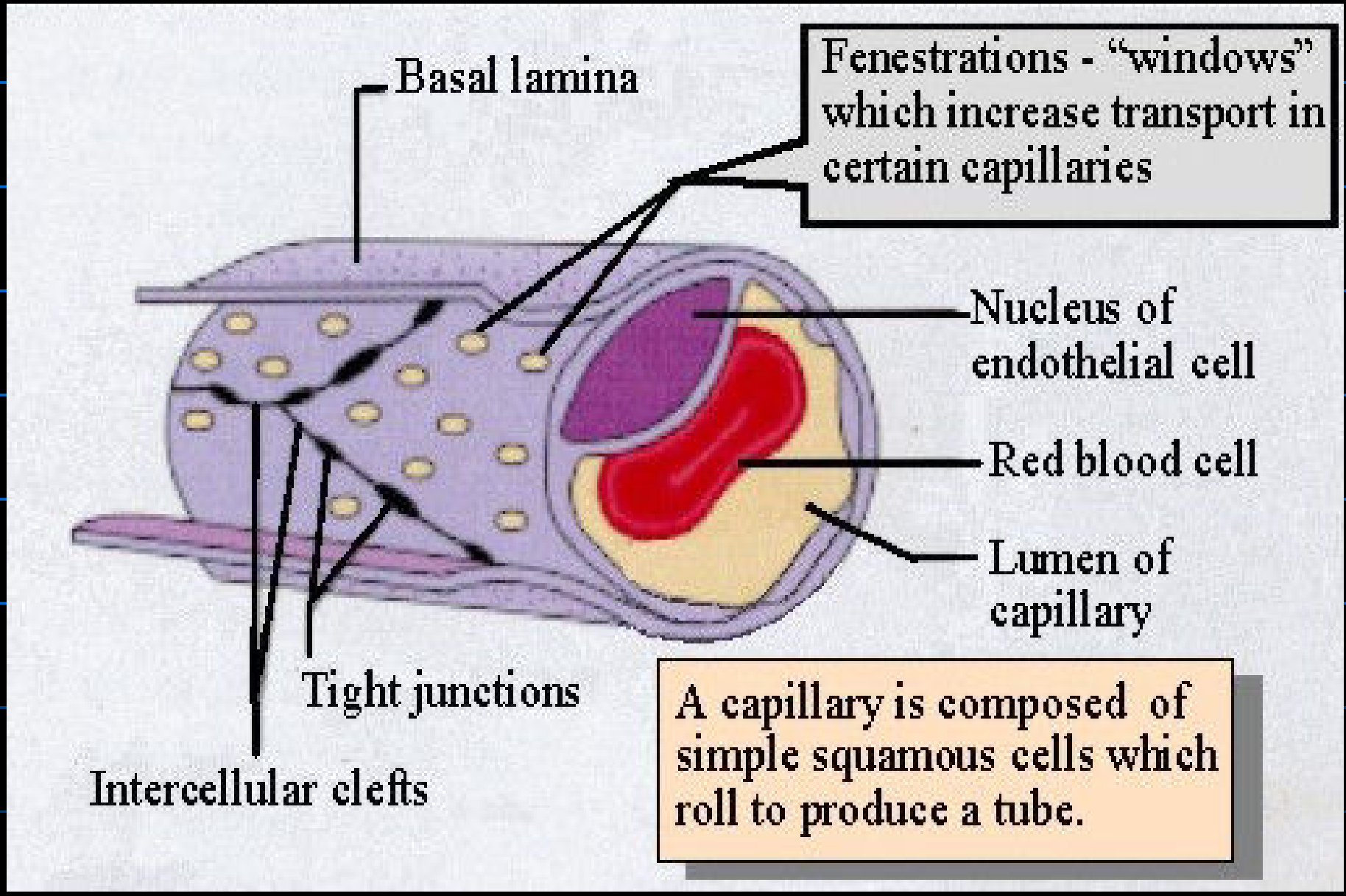
- **Structure:** endothelial cells contain pores, which are discontinuation of cell memb., they rest on thin continuous basement membrane. Fenestrae are covered by thin diaphragms, which are thinner than cell membrane.
- **Sites:** They are found at sites where rapid exchange is needed; e.g:

-Endocrine glands (transport hormones to bl.)

-Kidney glomeruli (for blood filtration).

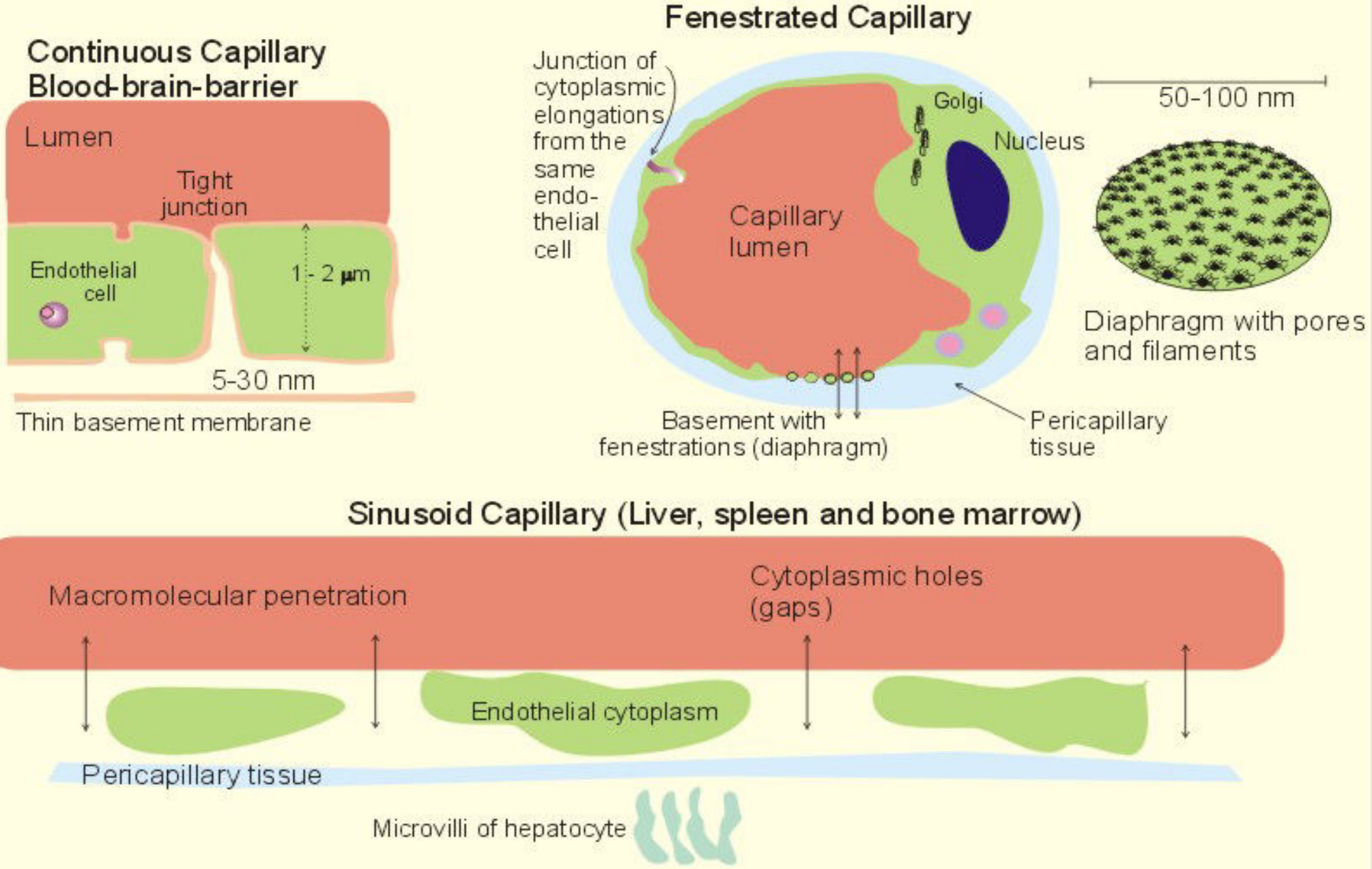
-Intestine (for absorption).

- N.B.: renal capillaries have no diaphragms.


Basal lamina
Fenestrations - "windows" which increase transport in certain capillaries
Nucleus of endothelial cell
Red blood cell
Lumen of capillary
Tight junctions
Intercellular clefts
A capillary is composed of simple squamous cells which roll to produce a tube.

3- Sinusoidal capillaries (Blood sinusoids)

- **Structure:** - Tortuous dilated capillaries; have irregular wide lumens up to 40 µm in diameter. This leads to slowing of circulation.
- **Enothelium:** have multiple fenestrae without diaphragms, cells are separated by large gaps and rest on discontinuous basal L.
- **Macrophages** are found in sinusoidal wall, extend their pseudopodia into sinusoidal bl. to phagocytose foreign bodies.
- The wall is supported by reticular f.


Continuous Capillary
Blood-brain-barrier
Lumen
Tight junction
Endothelial cell
1 - 2 µm
5-30 nm
Thin basement membrane
Fenestrated Capillary
Junction of cytoplasmic elongations from the same endo-thelial cell
Golgi
Nucleus
Capillary lumen
50-100 nm
Diaphragm with pores and filaments
Basement with fenestrations (diaphragm)
Pericapillary tissue
Sinusoid Capillary (Liver, spleen and bone marrow)
Macromolecular penetration
Cytoplasmic holes (gaps)
Endothelial cytoplasm
Pericapillary tissue
Microvilli of hepatocyte
Fig. 8-11
Kmc

Blood capillary	Blood sinusoid
Narrow regular lumen (7-9 µm)	Wide irregular lumen (5-40 µm)
Uniform diameter	Variable diameters & tortuous
Complete basal lamina	Incomplete basal lam.
Continuous or fenestrated	Always fenestrated
Surrounded with Pericytes	Surrounded with macrophages
Present in all tissues	Present in certain sites

II. Arterio-Venous Anastomoses

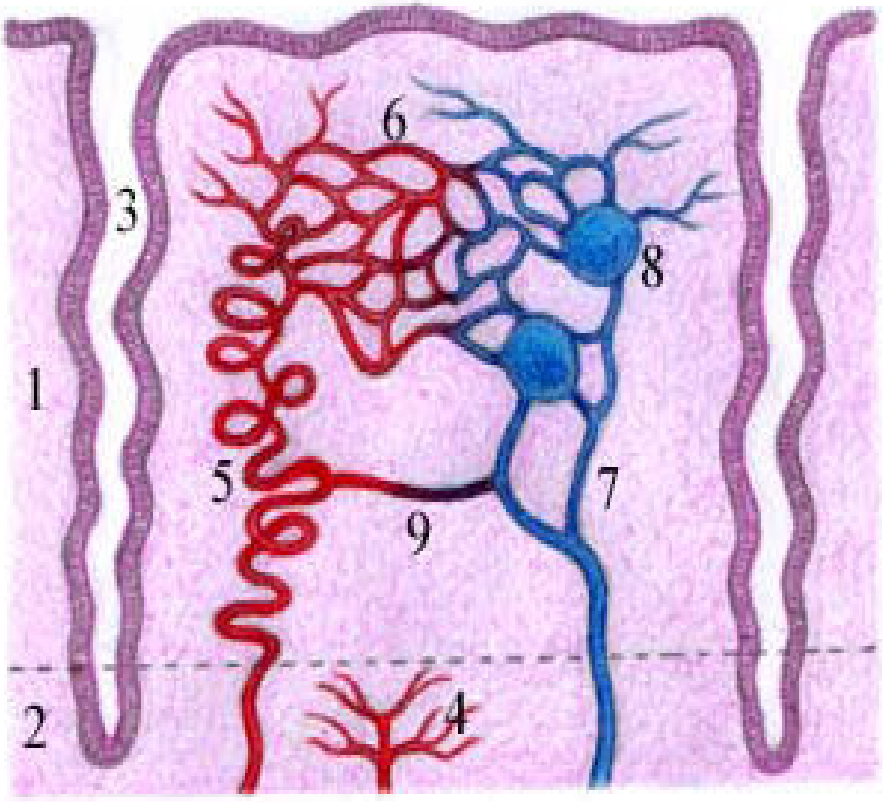
- They are direct connections between arteries and veins without passing through the capillary bed.
- They arise as side branches from arterioles to venules, without passing through capill.
- They allow a short and rapid circulation of blood to certain areas of the body.

Sites:

- They are present in exposed parts as:

Tips of fingers, external ears, tip of nose, lips

- In some internal organs as: stomach, placenta, penis, endometrium of uterus and thyroid glands



1. Endometrial Functional Layer
2. Endometrial Basal Layer
3. Endometrial Gland
4. Straight Artery
5. Spiral Artery
6. Capillary Plexus
7. Veins
8. Venous Lake
9. Arteriovenous Anastomosis

Structure: **1. Direct connections:**

side branches between arterioles and venules. The wall of connecting segment has similar structure to arteriole at arterial side and similar structure to venule at venous side.

When AVAs is closed blood passes through the capillary bed .

When they open, alarge amount of bl. Bypass the capillary bed and flows through AVAs resulting in short and rapid circulation of blood.

Functions of A-V anastomoses

1- Regulate body temperature, they dilate in cold weather, so blood is shunted away from the skin to conserve heat, and constrict in hot to release heat to the environment.

2- Regulate venous return.

3- regulate flow in the uterus during menstrual cycle.

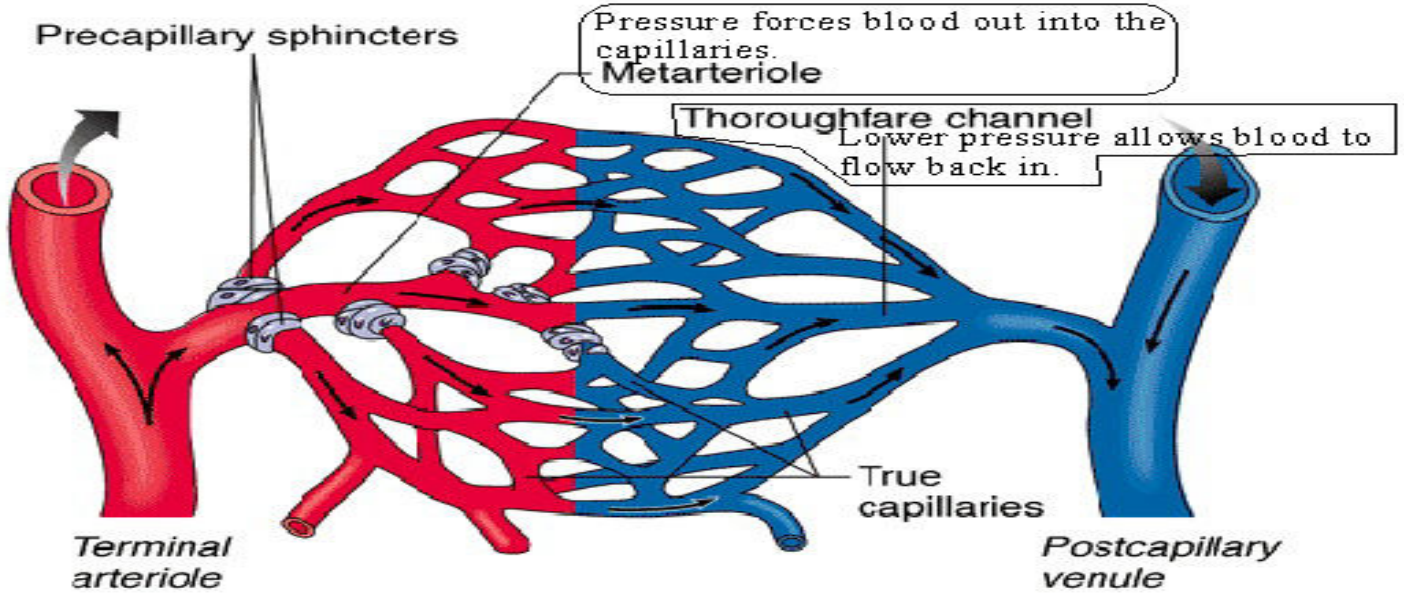
3- Regulate blood flow to organs during digestion, absorption, secretion....

Indirect connections (Glomus):

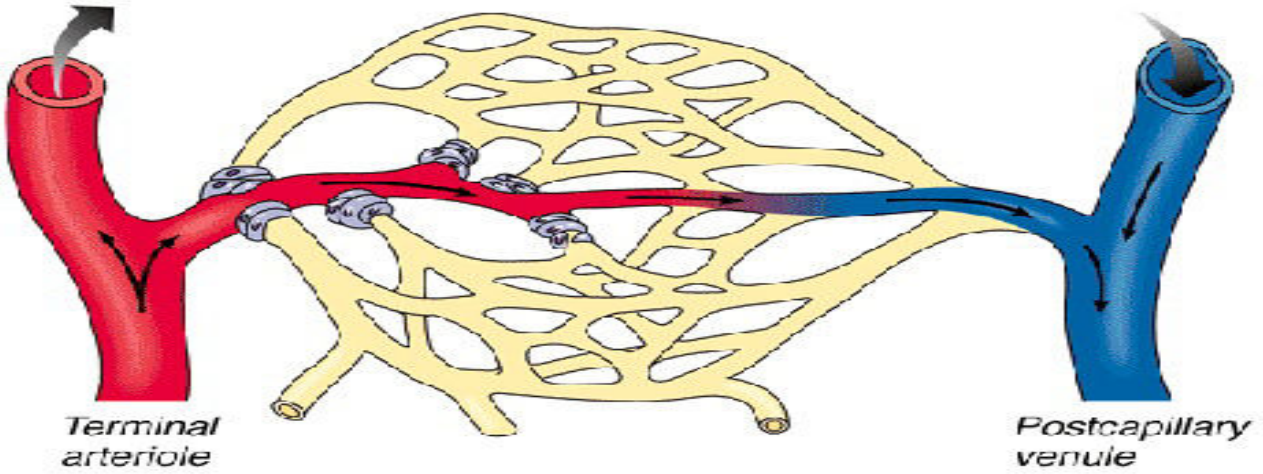
an organized complicated side branch. Arterial branch becomes convoluted, IEL is lost, elastic tissue is decreasing, muscle fibers are replaced by myoepithelial cells which are supplied with sympathetic and parasympathetic nerve endings.

Sites: genital organs, nailbed and lobule of ear

Arteriovenous Anastomosis



(a) Sphincters open



(b) Sphincters closed