Histology of the Circulatory System

Dr Shahab
Asstt Professor
Anatomy Dept. KGMC

Learning objectives

- Closed and open circulatory systems
- Histology of blood vessel wall (artery &vein)
- Classification of arteries
- Capillaries and its types
- Veins and its types

Closed circulatory system

Vertebrates, and a few invertebrates, have a closed circulatory system. Closed circulatory systems have the blood closed at all times within vessels of different size and wall thickness.

In this type of system, blood is pumped by a heart through vessels, and does not normally fill body cavities.

1. It provides more power in the form of pressure.
2. It has a lymphatic system that works separately.
3. Complex needs more energy.
4. It is efficient in delivering oxygen throughout an organism.

Open circulatory system

The open circulatory system is common to molluscs and arthropods. Open circulatory systems (evolved in crustaceans, insects, mollusks and other invertebrates) pump blood into a hemocoel with the blood diffusing back to the circulatory system between cells.

Blood is pumped by a heart into the body cavities, where tissues are surrounded by the blood.

Organisms utilizing open circulatory systems are much less vulnerable to pressure changes due to their circulation not being under pressure. They have no blood pressure as such, and so are able to survive in high and low pressure environments.

Open circulatory systems allow organisms to regulate temperate more rapidly, using the large body cavities to sink and absorb heat.

Three principal categories of blood vessels:

1. Arteries: efferent vessels
2. Capillaries:
3. Veins: afferent vessels

Vessel wall of arteries / veins

Three layers

1. Tunica intima
2. Tunica media
3. Tunica adventitia

1. Tunica interna/ Intima

Innermost layer

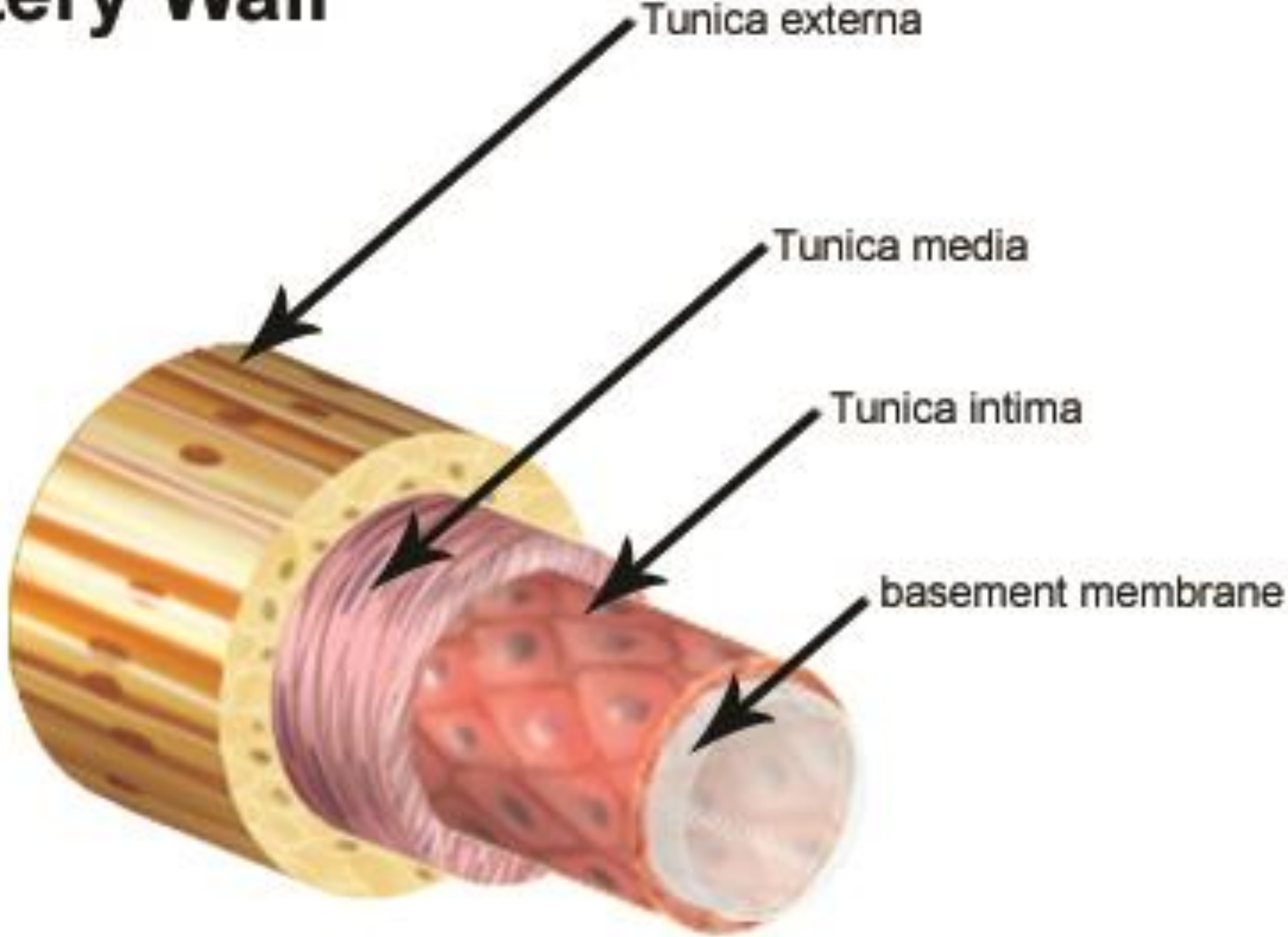
A. Structures: lines the inside of the vessel and is exposed to the blood; consists of--

- Endothelial cells
- Basement membrane
- Connective tissue (sparse)

B. Functions of the endothelial cells

- Selectively permeable barrier
- Secrets chemicals
- Repels blood cells and platelets

Artery Wall


Tunica externa
Tunica media
Tunica intima
basement membrane

2. Middle layer (tunica media)

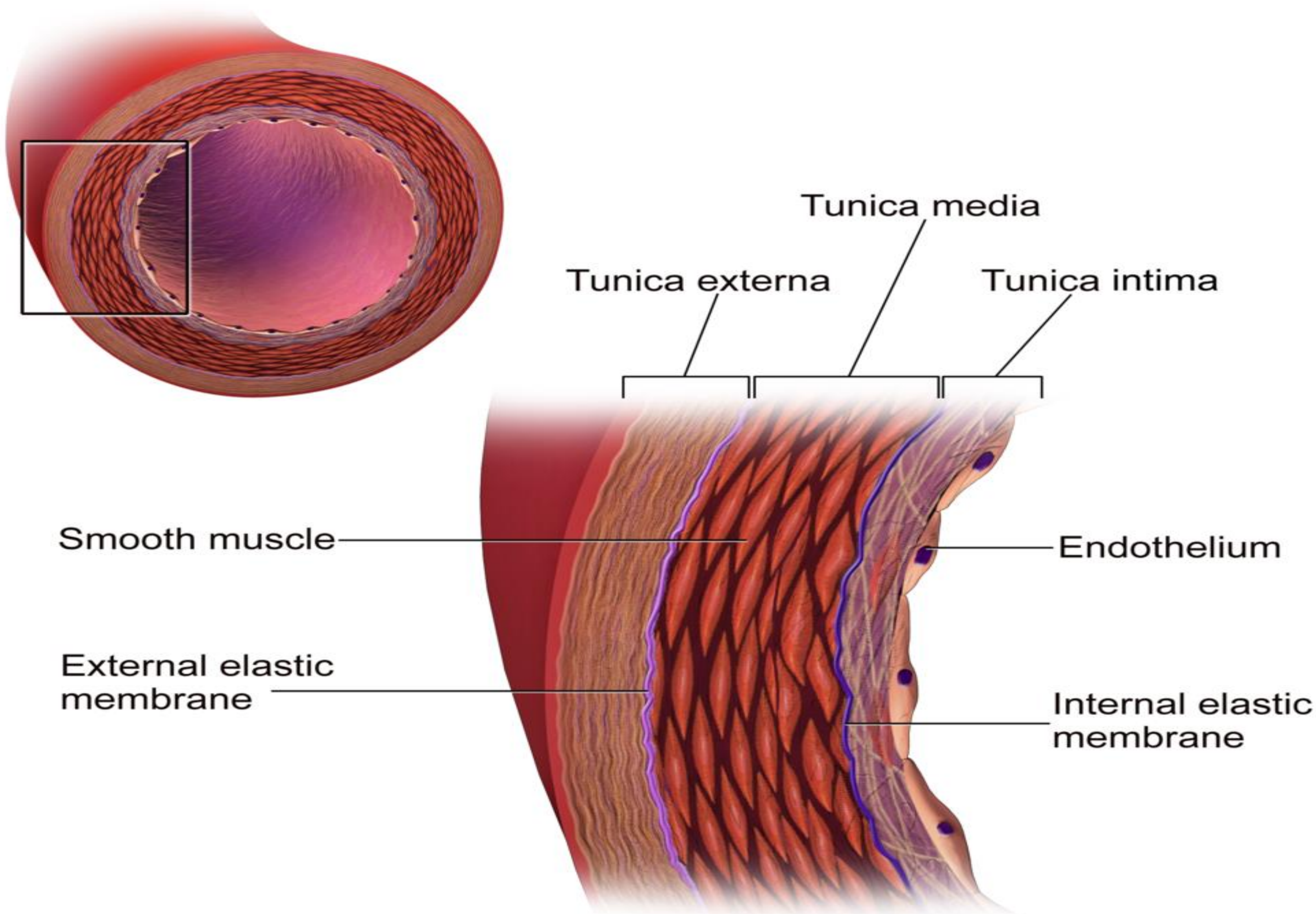
Thickest layer

A. Structures:

- Smooth muscle cells--
- Collagen fibers
- Elastic fibers (in arteries)

B. Functions of this layer:

- Strengthen the vessel
- Provide vasomotion--



Tunica media
Tunica externa
Tunica intima
Smooth muscle
Endothelium
External elastic membrane
Internal elastic membrane

3. Outermost layer (tunica externa or adventitia)

A. Structures:

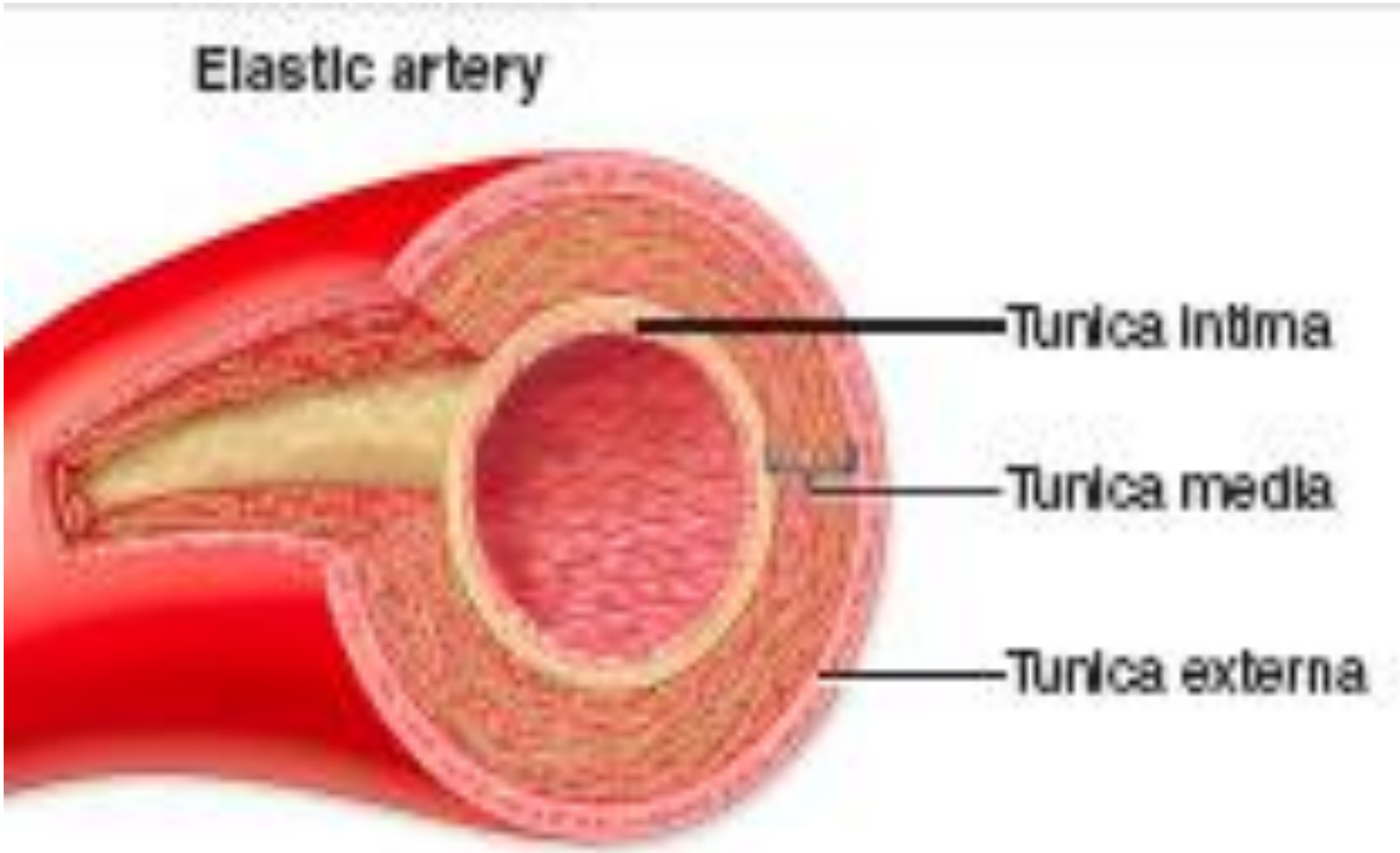
– Largely loose connective tissue (collagen fibers)

B. Functions:

– Protection & anchoring

– Provide passage for--

- Vasa vasorum— vessels of the vessels


Elastic artery
Tunica intima
Tunica media
Tunica externa

Arteries

1. More muscular
2. Able to resist high blood pressure
   - Thus called resistance vessels
3. Retain their round shape even when empty
4. Divided into three categories by size. according to their microscopic structure.

1. large/elastic/conducting arteries

- Are the thick-walled arteries near the heart ,
- i.e. the aorta and its major branches.
- These arteries are the largest in diameter, ranging from 2.5 cm to 1 cm, and the most elastic.
- Because their large lumen make them low-resistance pathways that conduct blood from the heart to medium-sized arteries, they are sometimes referred to as conducting arteries.

Conducting (elastic/large) arteries

Structure

- tunica media-- 40-70 layers of smooth muscle alternating with elastic tissue
- Internal/external elastic lamina— not obvious
- tunica externa– vasa vasorum

Function-

- Able to expand/recoil--
- But not so in atherosclerosis– aneurysms and rupture .

- They contain more elastin than any other vessel type.
- The elastic arteries expand and recoil passively to accommodate changes in blood volume.
- Consequently, blood flows fairly continuously rather than starting and stopping with the pulsating rhythm of the heartbeat.
- Aorta, Brachiocephalic, common carotid, Subclavian, Vertebral, Pulmonary, and Common iliac arteries are the elastic arteries.

2. Medium-sized/ Muscular/ Distributing arteries

- lie distal to the elastic arteries.
- Constituting most of the named arteries seen in the anatomy lab, muscular arteries supply groups of organs, individual organs, and parts of organs, (hence the name distributing).
- Ex. Brachial, Femoral, Renal, and Splenic arteries etc.
- Their internal diameter ranges from that of a little finger (1cm) to that of a pencil lead (about 0.3 mm).

Structure-

- tunica media– up to 40 layers of smooth muscle
- Internal/external elastic lamina— conspicuous/not conspicuous (circle one)

They are called muscular because they have very high amount of smooth muscle fibers in the tunica media of their walls.

By actively altering the diameter of the artery, this muscular layer regulates the amount of blood flowing to the organ supplied according to the specific needs of that organ.

3. Resistance (small) arteries

- Up to 25 layers of smooth muscle
- Elastic tissue little

Arterioles:

- Are the smallest form of arteries (almost microscopic arteries).
- Arterioles have a lumen diameter from 0.3 to 10 µm.
- 1-3 smooth m. layers
- Larger arterioles have all three tunics, but their tunica media is chiefly smooth muscle with a few scattered elastic fibers.
- Smaller arterioles which lead to the capillary beds, are little more than a single layer of smooth muscle cells spiraling around the endothelial lining.
- Under the influence of autonomic nervous system (sympathetic and parasympathetic) they play a key role in regulating peripheral blood pressure.

Veins

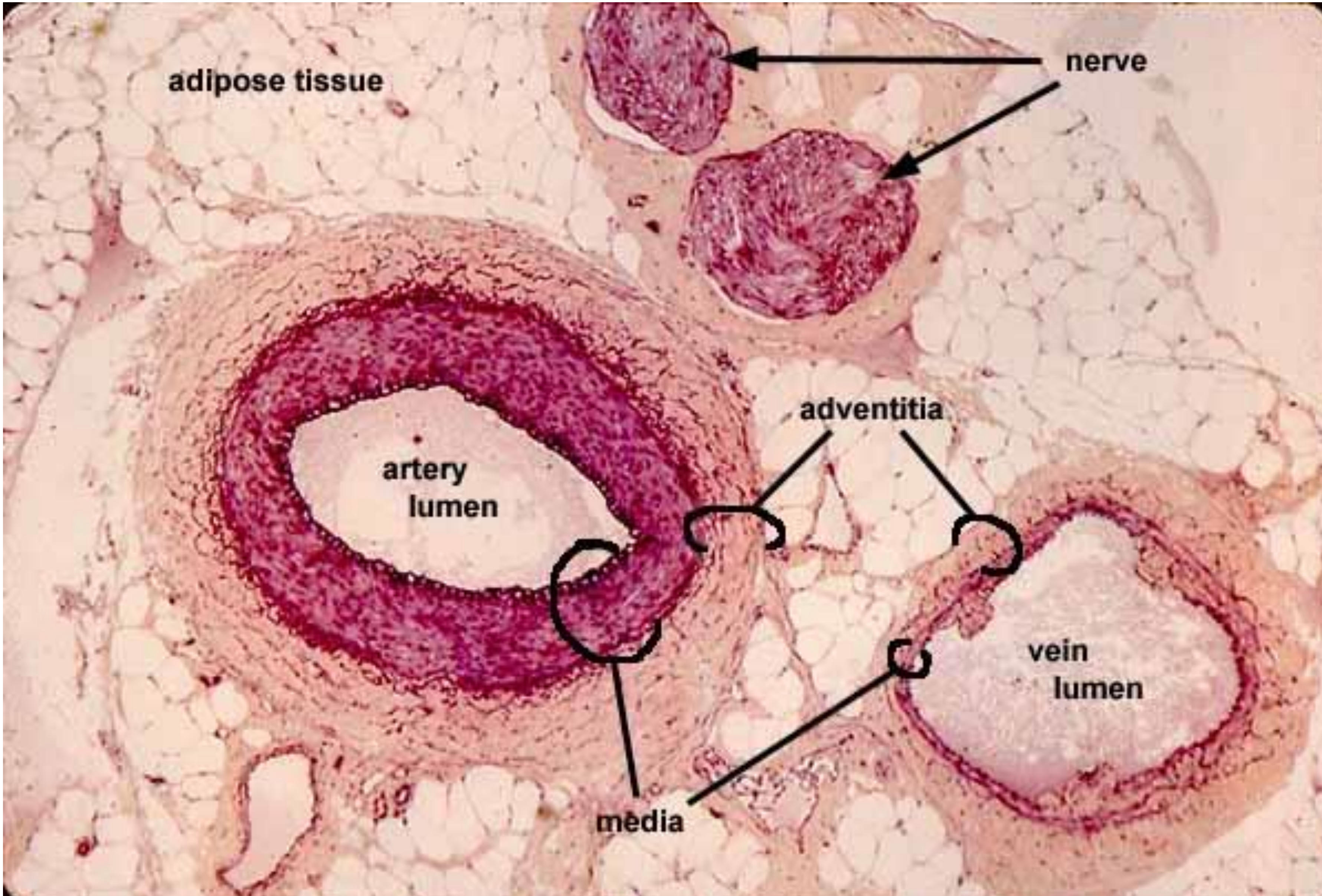
- Post capillary blood flows into *venules* and then into progressively larger veins.
- Compared to arteries, veins have larger diameters and thinner walls. They therefore have larger lumens and contribute capacitance to the circulation, holding approximately two thirds of all circulating blood.
- The intima and adventitia are similar in structure and function to arteries but the media is much thinner due to significantly less smooth muscle and elastic tissue.

- Veins therefore do not have the same capacity for elastic recoil and vasoconstriction as arteries.

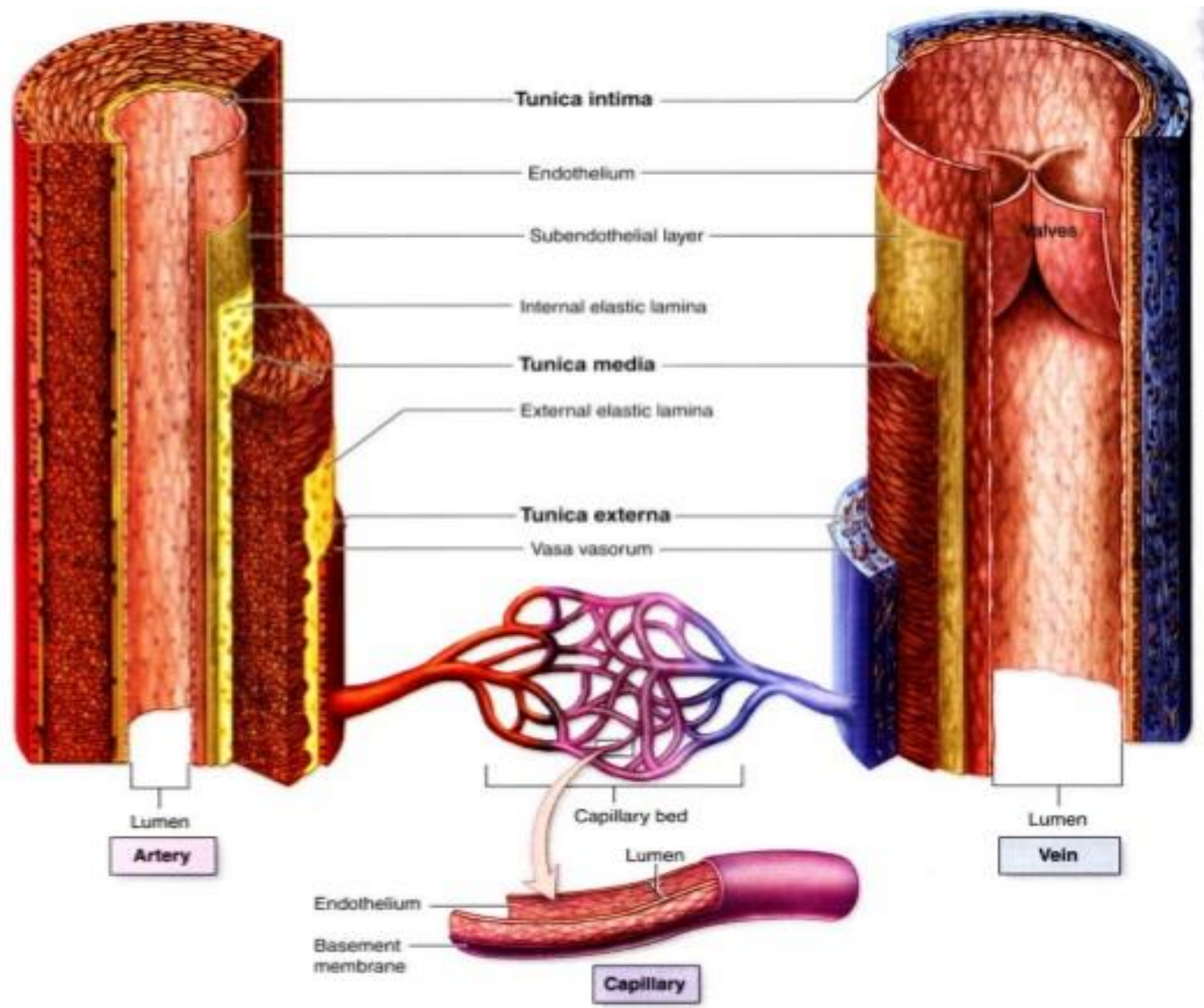
- Blood is propelled forward by contraction of surrounding muscles and pressure gradients created during inspiration and expiration. Reverse flow is prevented by the presence of venous valves.

- Valves are thin folds of intima projecting well into he lumen .

- The flaccid walls of veins predispose them to compression and penetration by tumors and inflammatory processes.

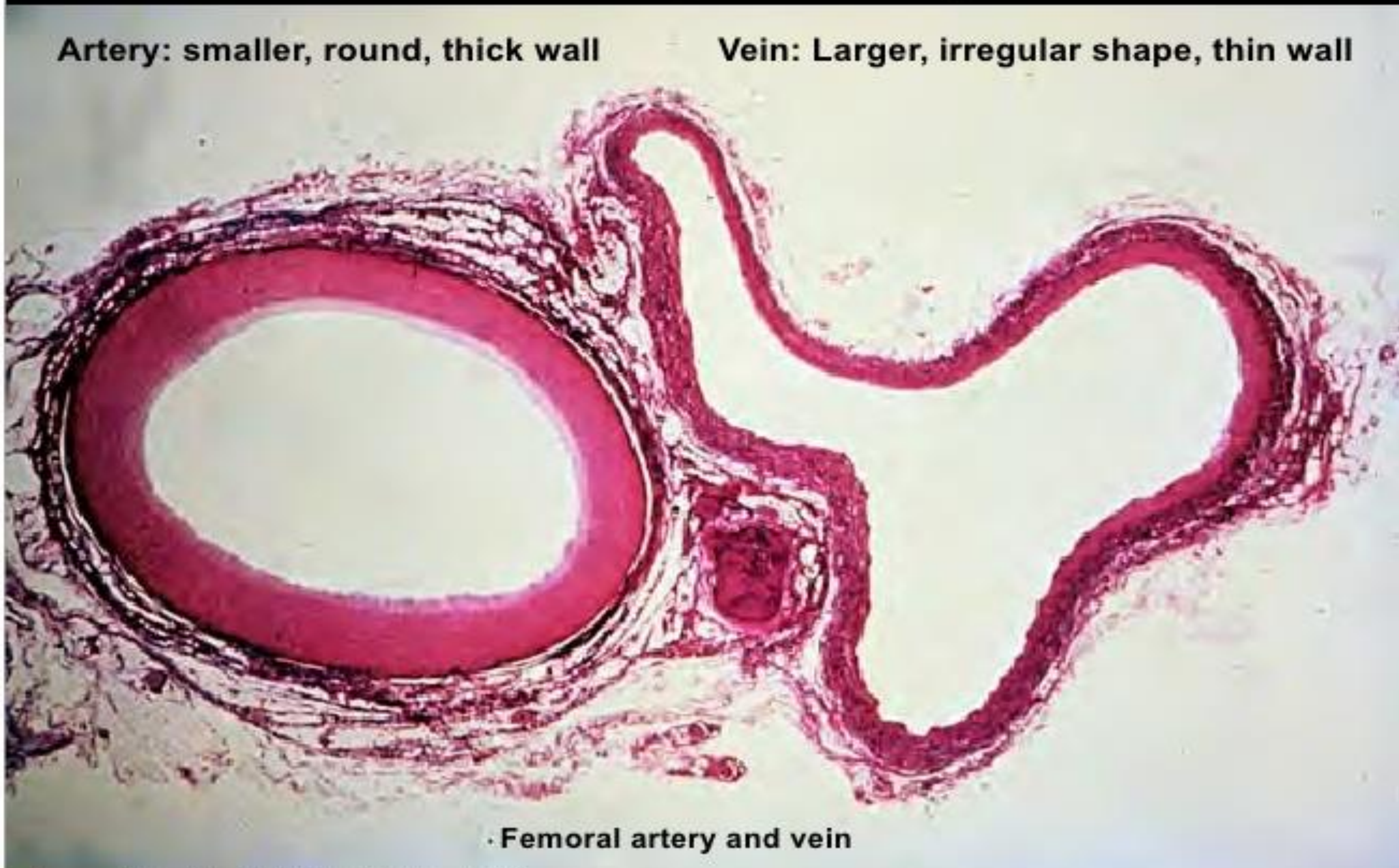

adipose tissue
nerve
adventitia
artery lumen
vein lumen
media

STRUCTURE OF VESSELS



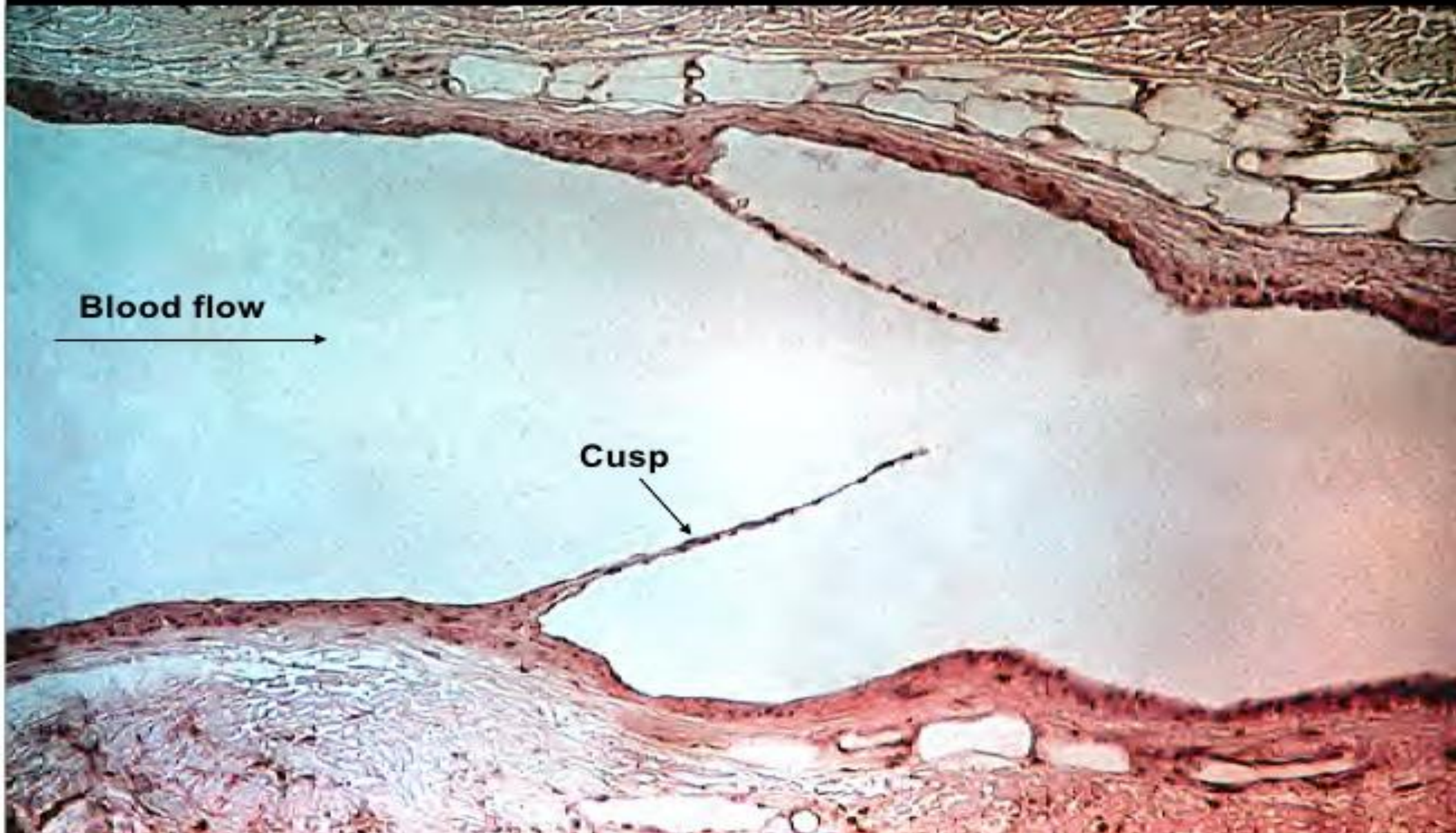

muscular
artery
nerve
vein

Comparison of companion artery and vein

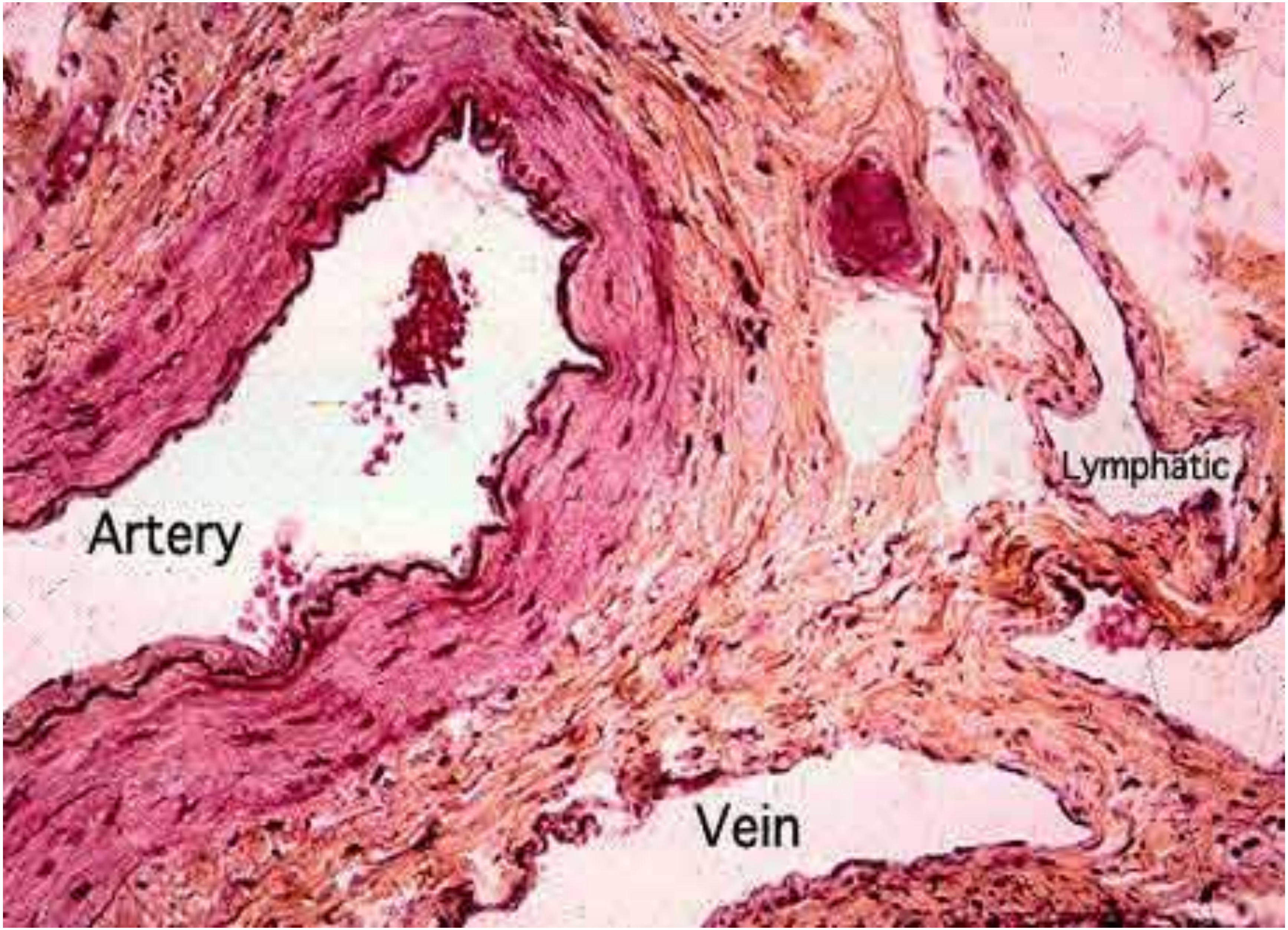


Humio Mizoguti, Kobe Univ Sch Med, slide 235

Valve in a vein, longitudinal section, LM



Hadley Kirkman, Stanford (originally from Columbia P&S)


Lymphatic
Artery
Vein

Capillaries

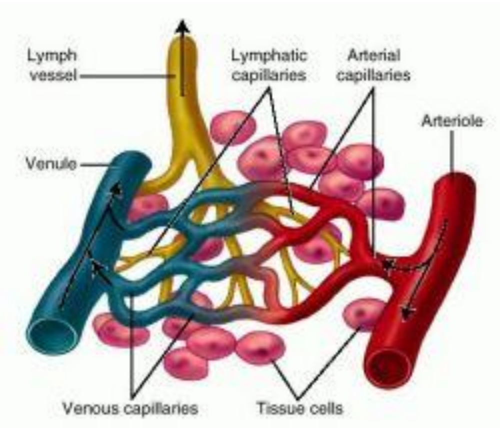
- Capillaries connect arterioles with venules.
- They consist only of a single layer of endothelial cells on a basement membrane.
- There is no media or adventitia.
- The diameter is just wide enough for passage of a red blood cell, therefore flow is very slow.
- These features facilitate exchange of oxygen, nutrients and other substances between blood and tissues.

- Their diameter ranges from 4-15 µm.
- The wall of a segment of capillary may be formed by a single endothelial cell. This results in a very large surface to volume ratio.
- The low rate of blood flow and large surface area facilitate the functions of capillaries in

1. providing nutrients and oxygen to the surrounding tissue, in
2. the absorption of nutrients, waste products and carbon dioxide, and in
3. the excretion of waste products from the body.

- These functions are also facilitated by a very simple organization of the wall of capillaries.
- *Only the tunica intima is present*, which typically only consists of the endothelium, its basal lamina and an incomplete layer of cells surrounding the capillary, the *pericytes*.
- Pericytes have contractile properties and can regulate blood flow in capillaries.
- In the course of vascular remodeling and repair, they can also differentiate into endothelial and smooth muscle cells.

- Scarce in: tendons, ligaments, & cartilage
- Absent from (3 locations)

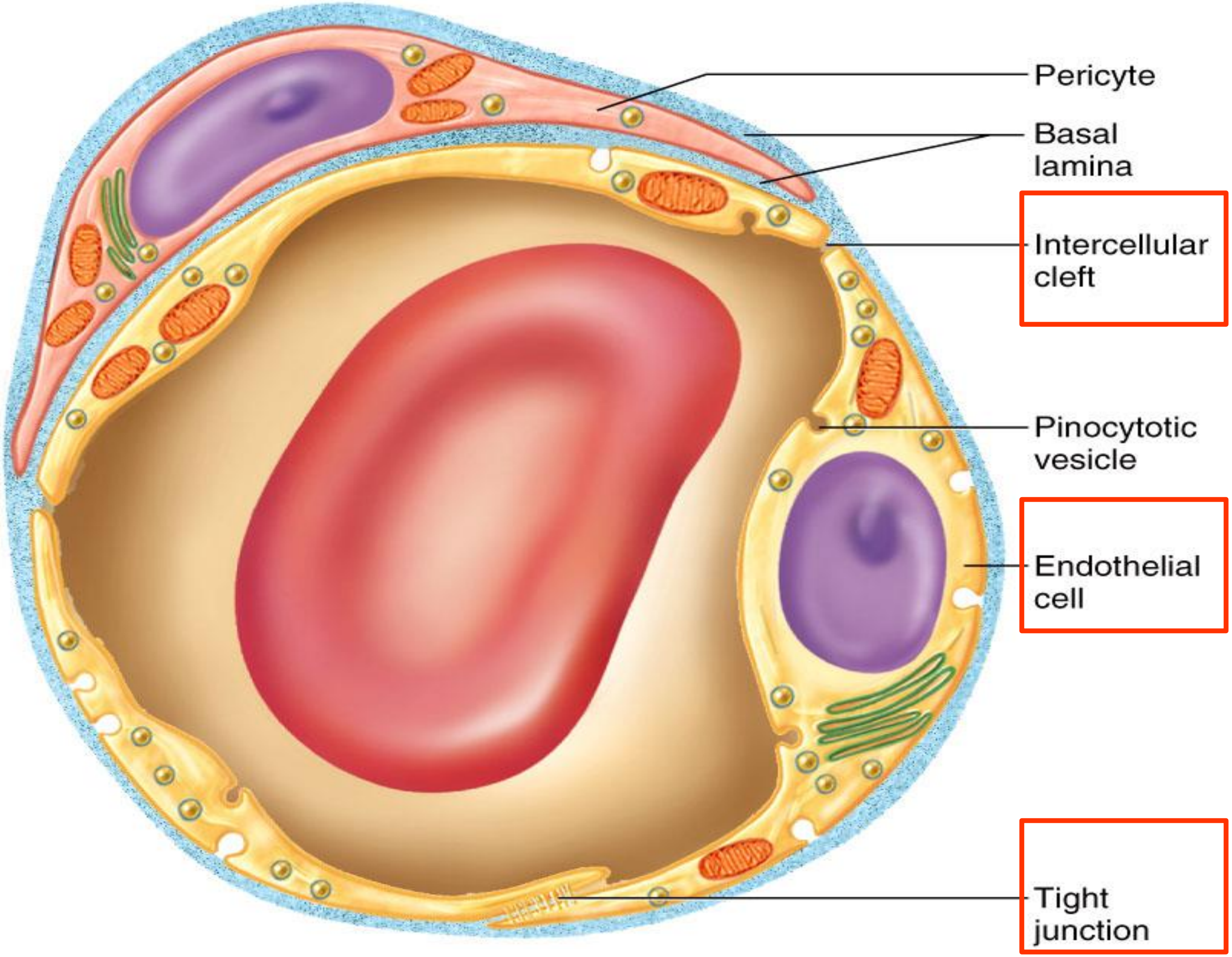


1. Continuous capillaries

occur in most tissues, ex. Skeletal muscle

- endothelial cells have tight junctions with intercellular clefts (allow passage of solutes)
- Both endothelial cells and the basal lamina can act as selective filters in continuous capillaries.
- What molecules can pass– ex. glucose
- What molecules can not– protein, formed elements of the blood

Continuous capillary

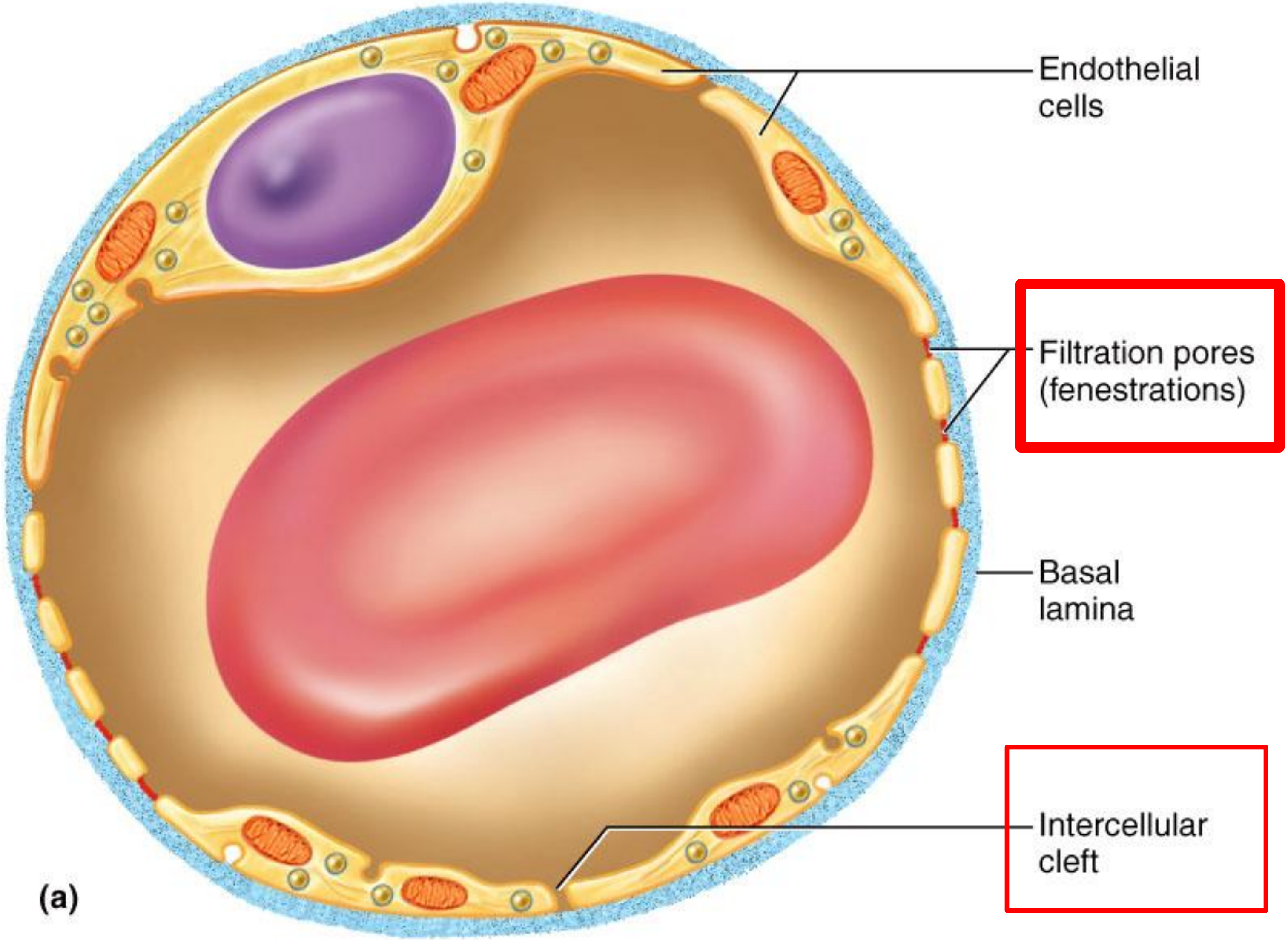


2.Fenestrated capillaries

- The endothelial cell body forms small openings called *fenestrations,* which allow components of the blood and interstitial fluid to bypass the endothelial cells on their way to or from the tissue surrounding the capillary.
- The fenestrations may represent or arise from pinocytic vesicles which open onto both the luminal and basal surfaces of the cell.
- The extent of the fenestration may depend on the physiological state of the surrounding tissue, i.e. fenestration may increase or decrease as a function of the need to absorb or secrete.

- The endothelial cells are surrounded by a continuous basal lamina, which can act as a selective filter.
- Locations .organs that require rapid absorption or filtration - kidneys, small intestine etc.

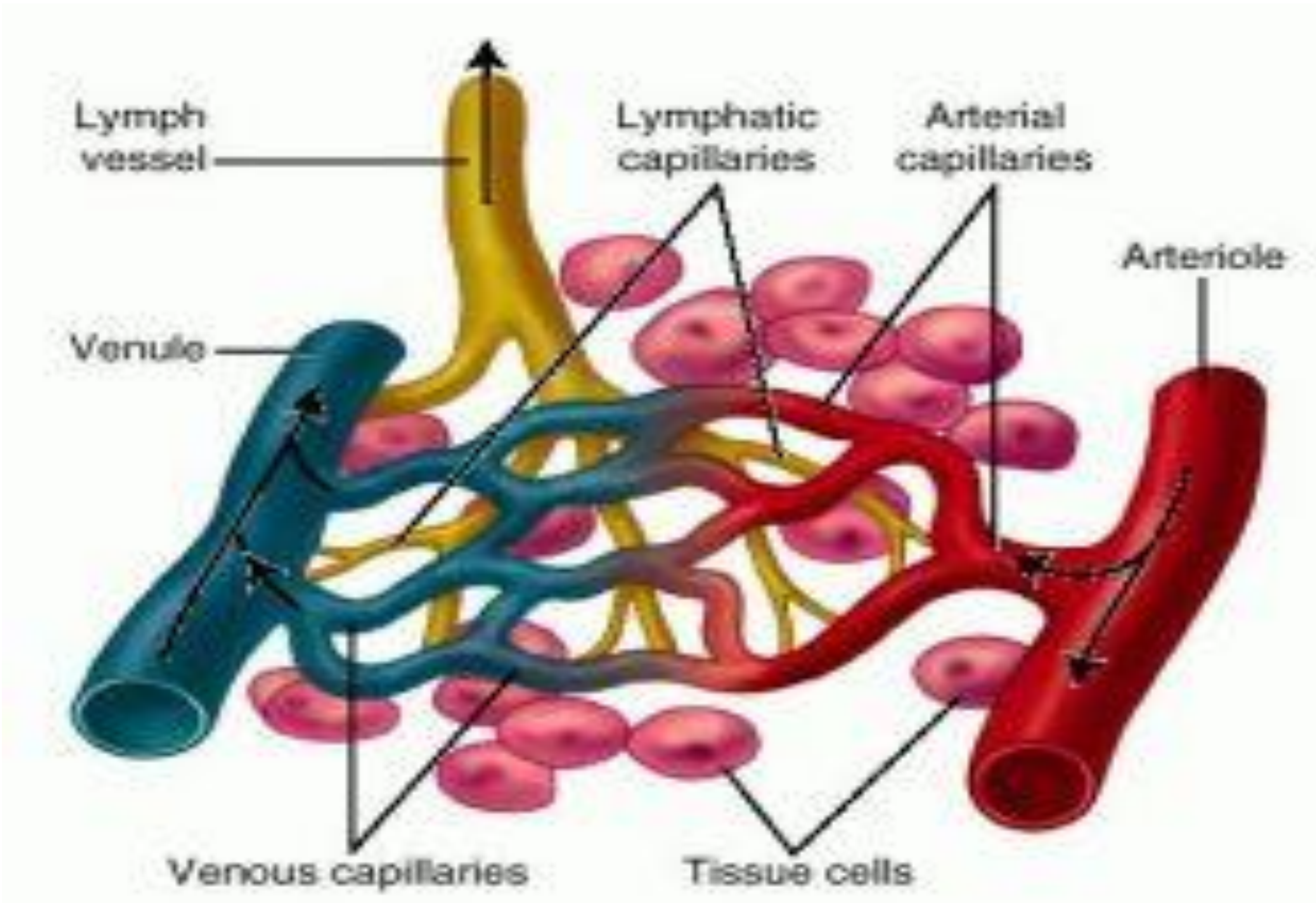
Fenestrated Capillary

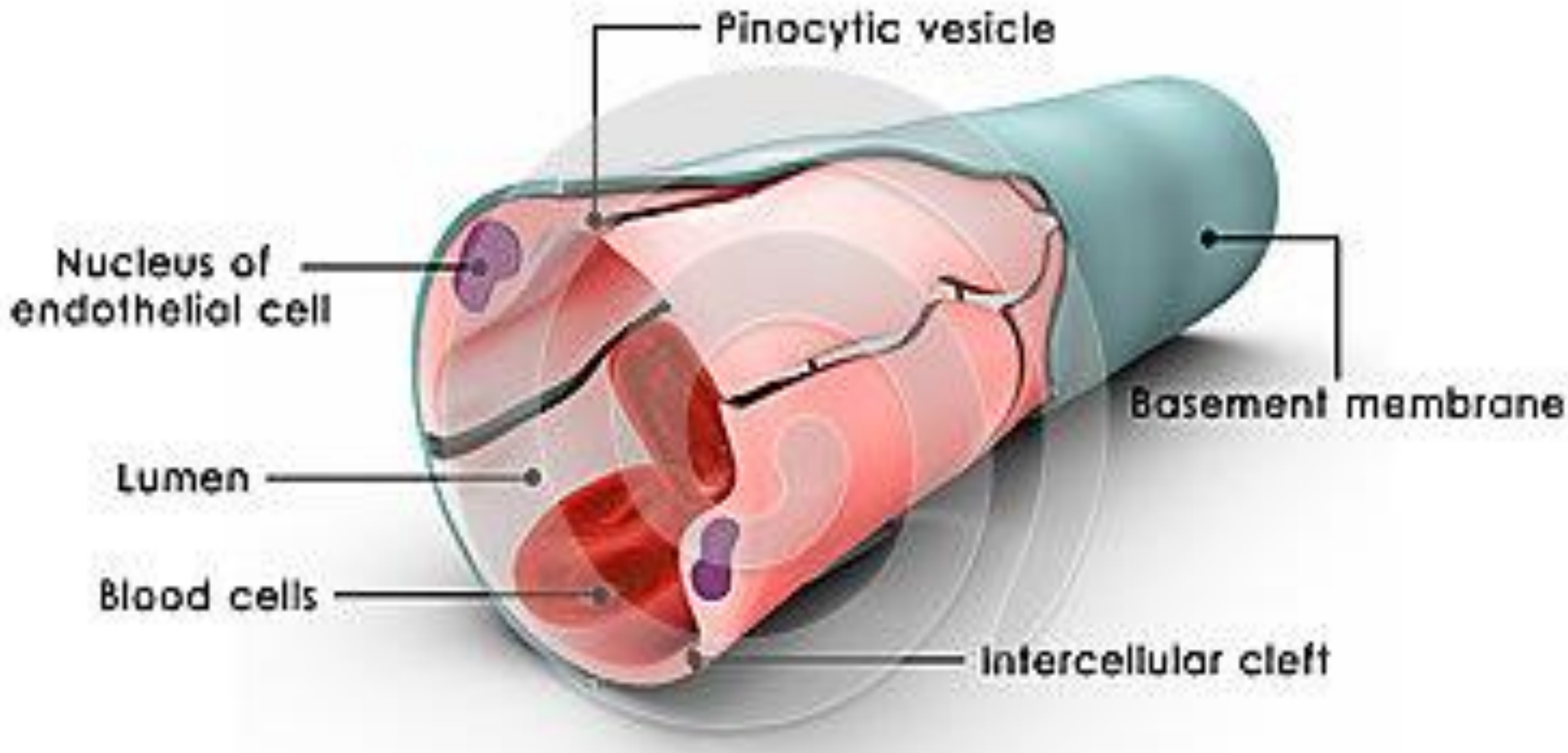


(a)

3.Sinusoids (discontinuous) capillaries

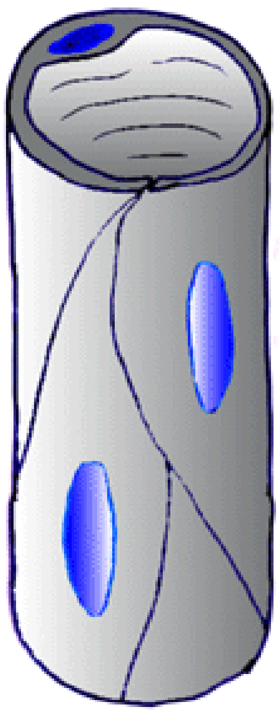
- are formed by fenestrated endothelial cells, which may not even form a complete layer of cells.
- The basal lamina is also incomplete.
- Discontinuous capillaries form large irregularly shaped vessels, *sinusoids* or *sinusoid capillaries*.
- They are found where a very free exchange of substances or even cells between bloodstream and organ is advantageous (e.g. in the liver, spleen, and red bone marrow).


Lymph vessel
Lymphatic capillaries
Arterial capillaries
Arteriole
Venule
Venous capillaries
Tissue cells


Pinocytic vesicle
Nucleus of
endothelial cell
Basement membrane
Lumen
Blood cells
Intercellular cleft

CAPILLARY TYPES

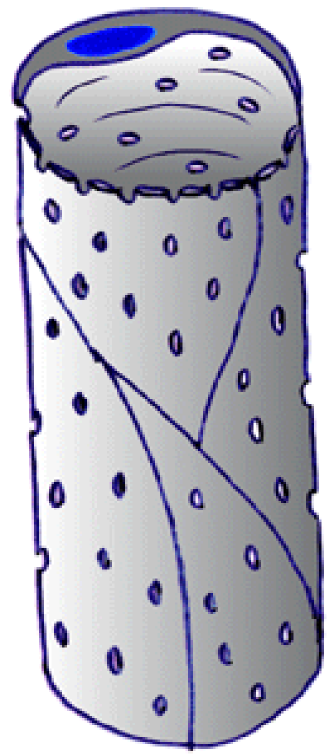
Continuous Capillary



Typical Locations

fat
muscle
nervous system

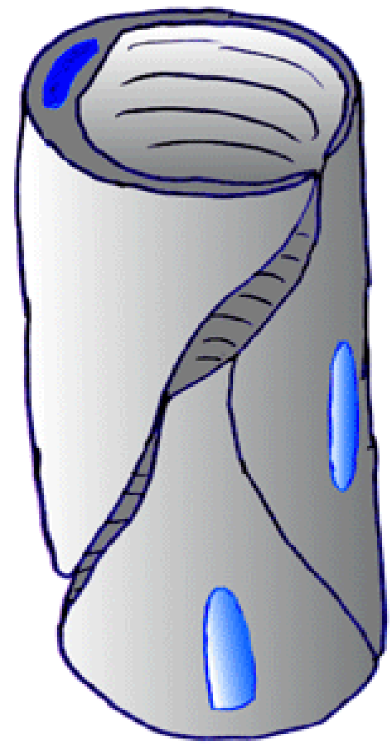
Fenestrated Capillary



Typical Locations

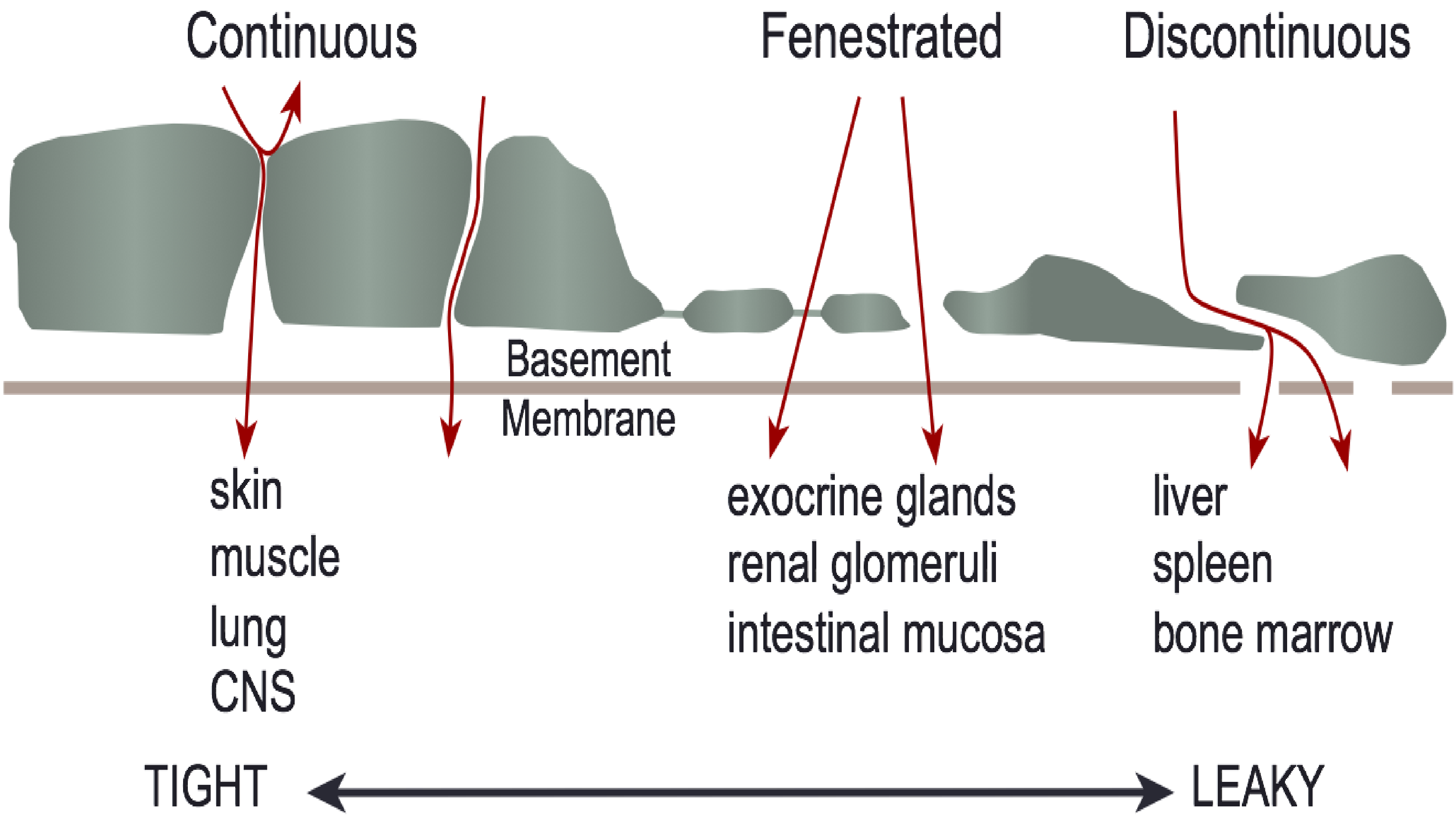
intestinal villi
endocrine glands
kidney glomeruli

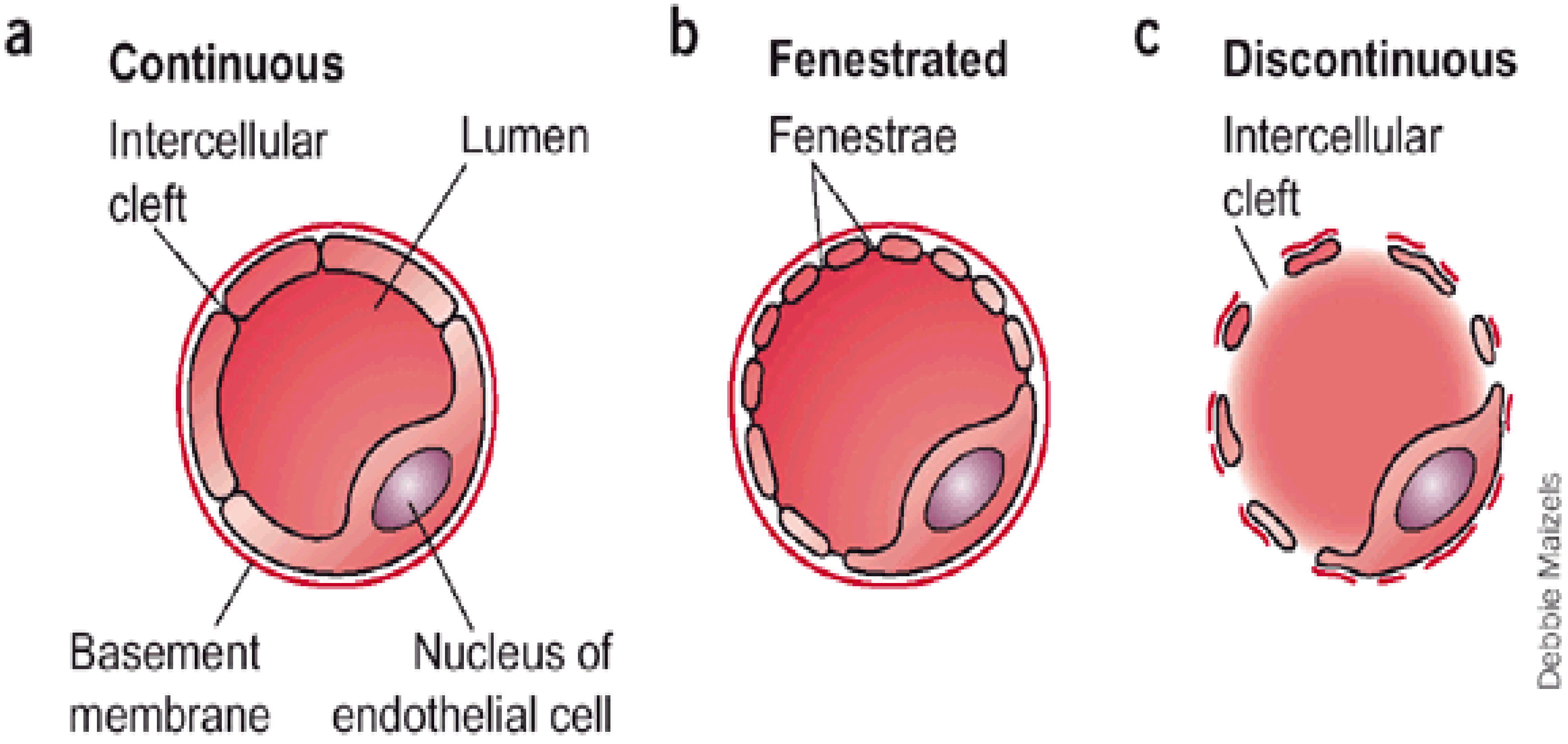
Discontinuous Capillary



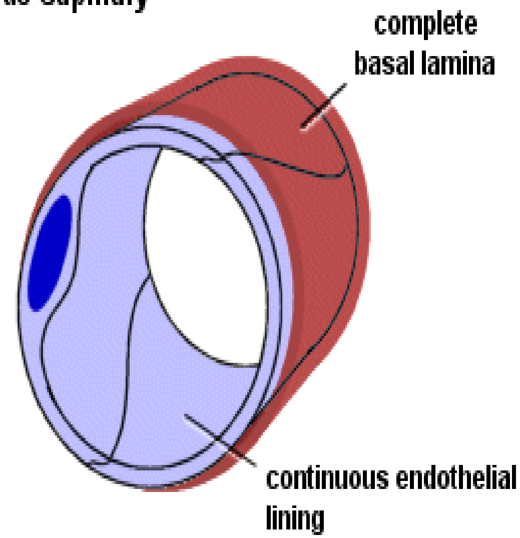
Typical Locations

liver
bone marrow
spleen

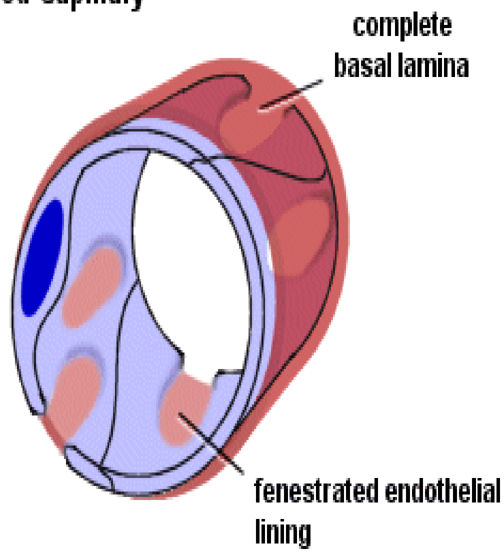

Continuous
Fenestrated
Discontinuous
Basement
Membrane
skin
muscle
lung
CNS
exocrine glands
renal glomeruli
intestinal mucosa
liver
spleen
bone marrow
TIGHT
LEAKY


a
Continuous
Intercellular cleft
Lumen
Basement membrane
Nucleus of endothelial cell
b
Fenestrated
Fenestrae
c
Discontinuous
Intercellular cleft
Debbie Maizels

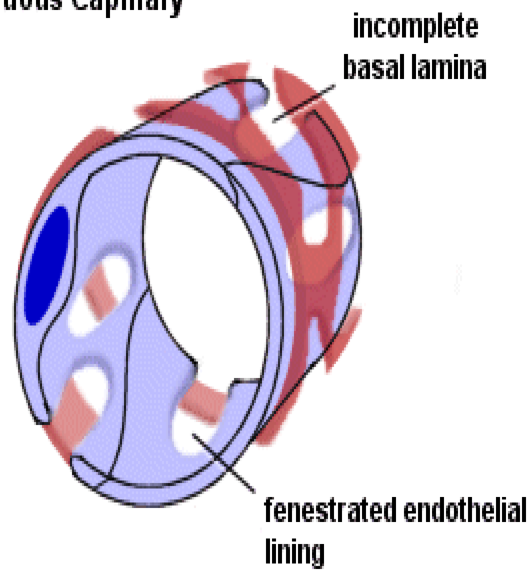
Continuous Capillary



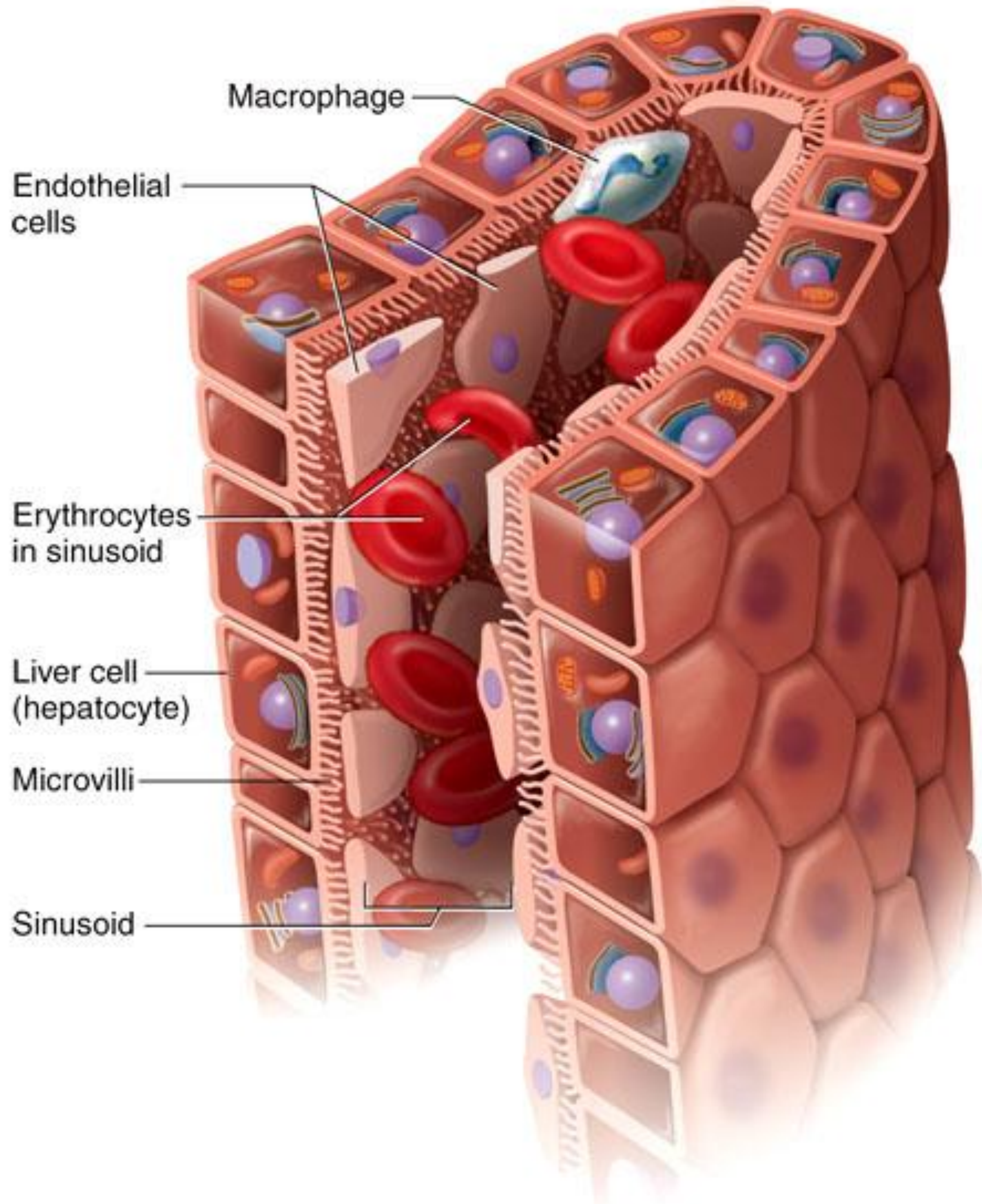
Fenestrated Capillary



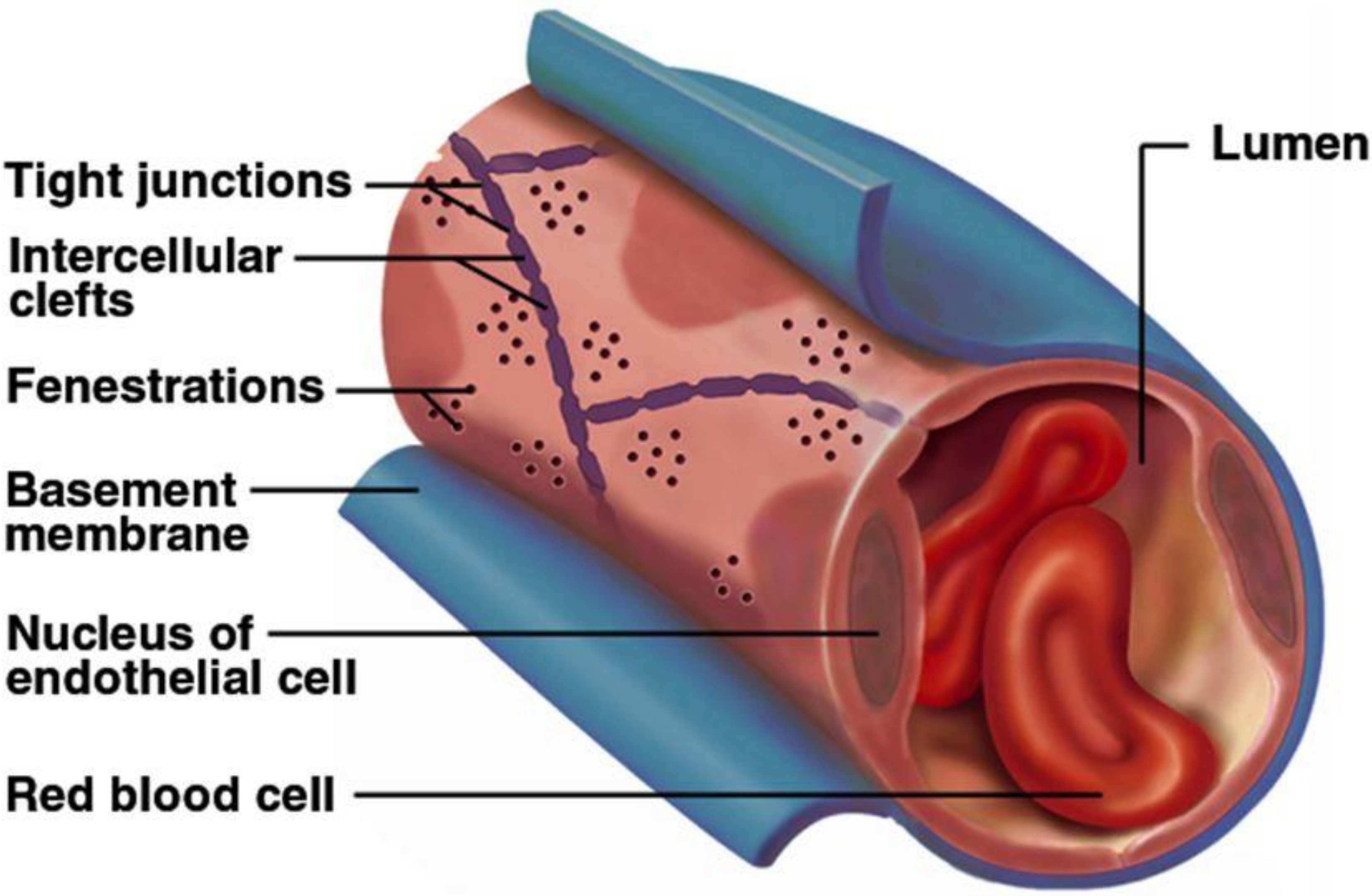
Discontinuous Capillary



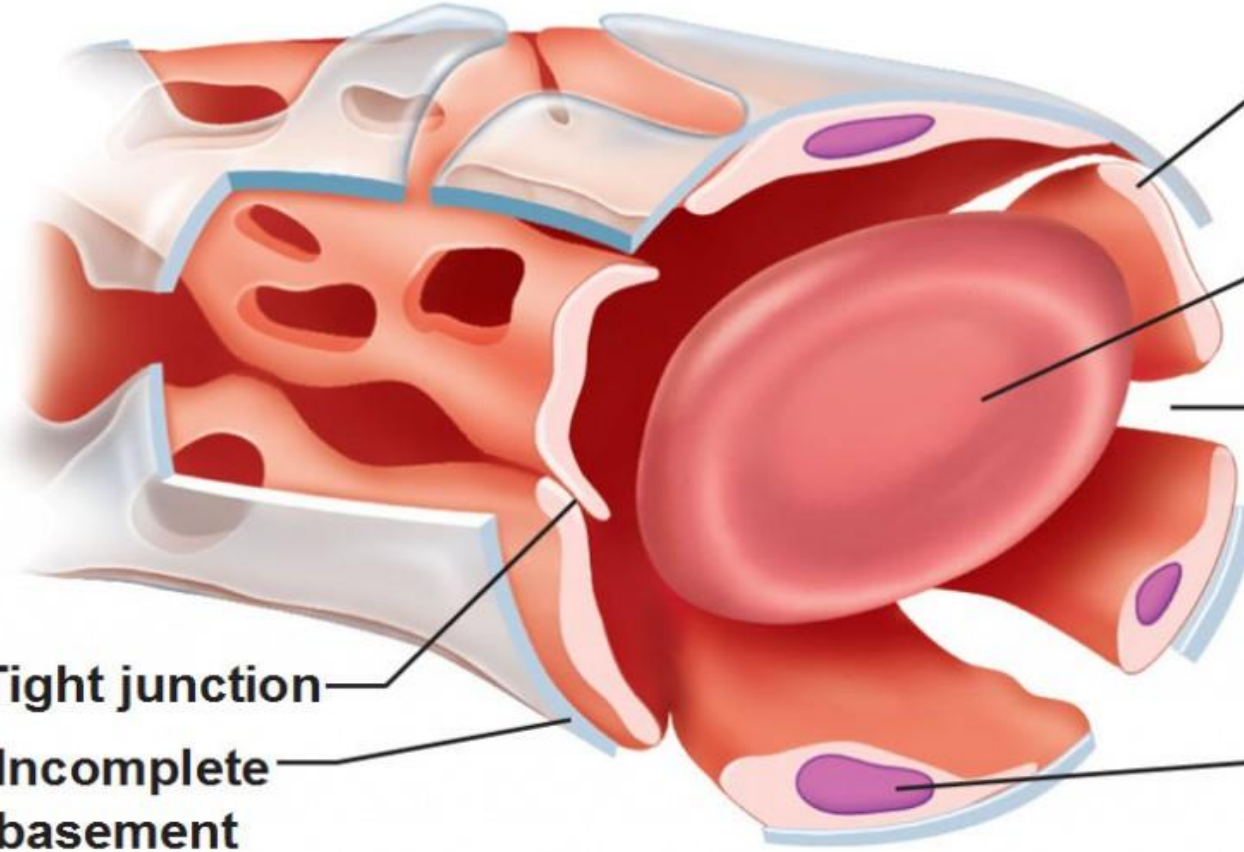
Sinusoid in Liver



Fenestrated Capillary



Structure of Capillaries:Sinusoids have big fenestrations, few tight junctions, and wide intercellular clefts, as well as incomplete basement membranes, allowing for *exchange of large molecules (whole cells)*



(c) Sinusoidal capillary. Most permeable. Occurs in special locations (e.g., liver, bone marrow, spleen).