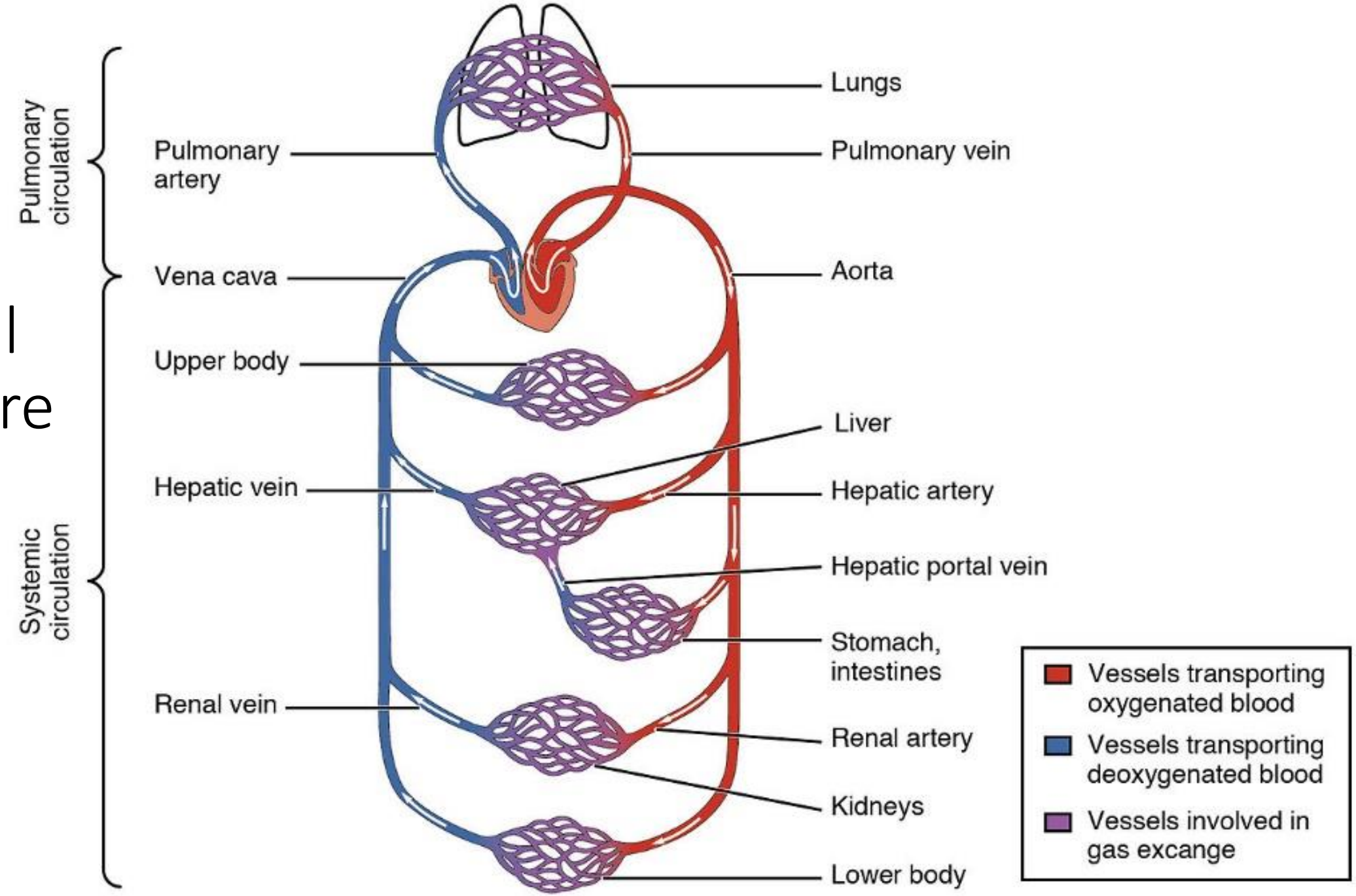
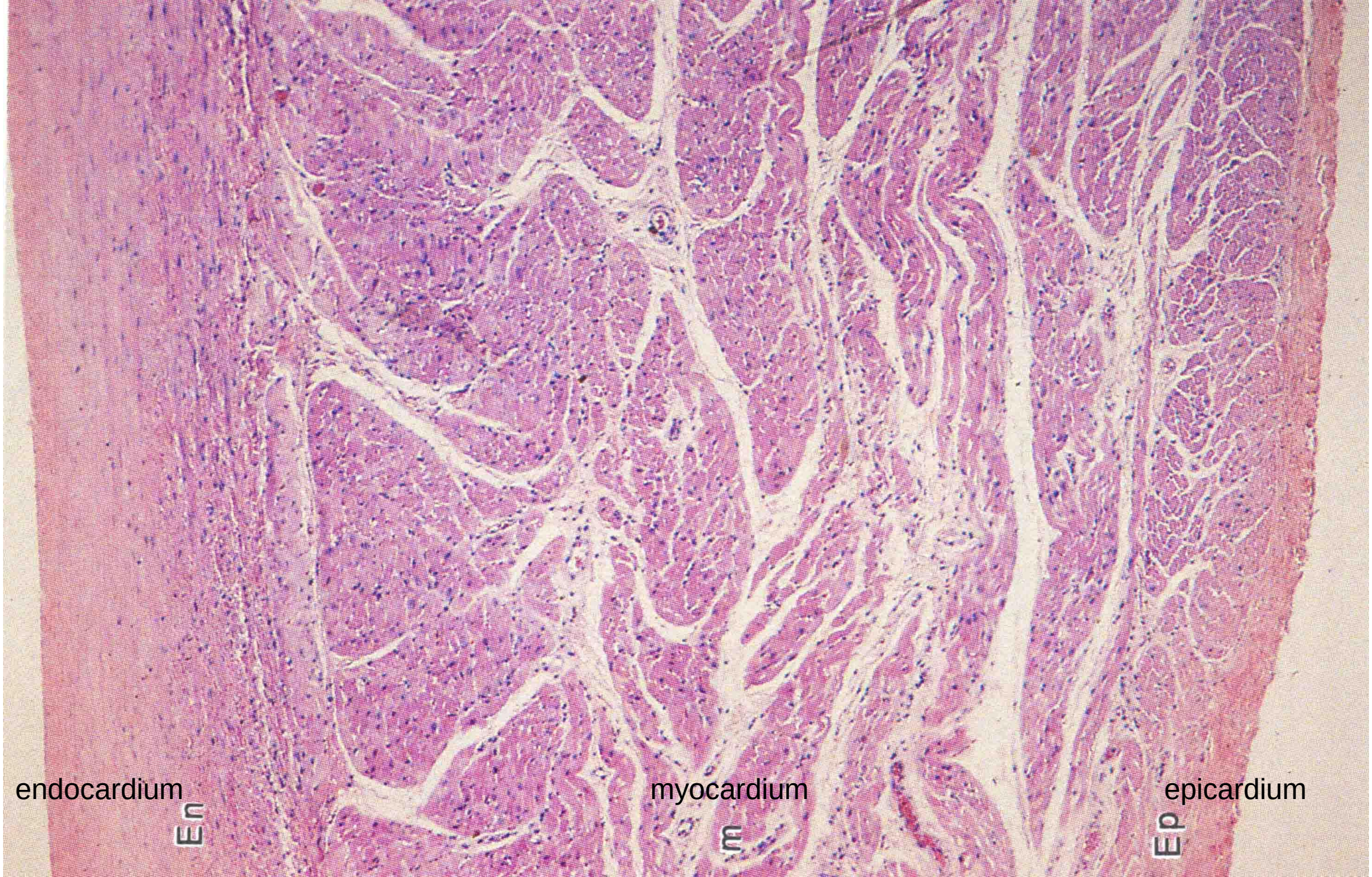
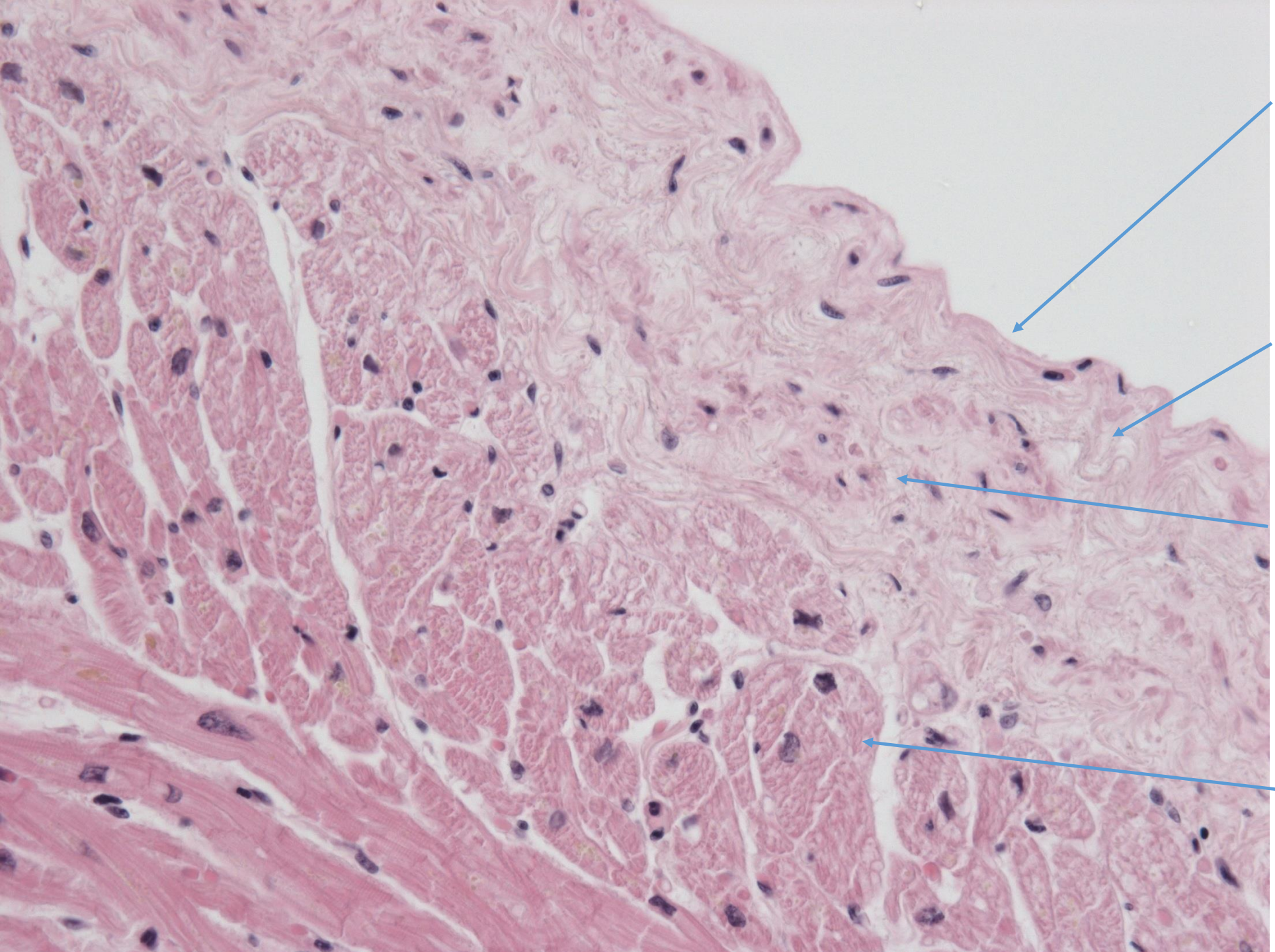
Cardiovascular system

MUDr. Pavel Roštok

General structure




endocardium
myocardium
epicardium
En
M
Ep



Endothelium

- Flat epithelium

Subendothelial layer

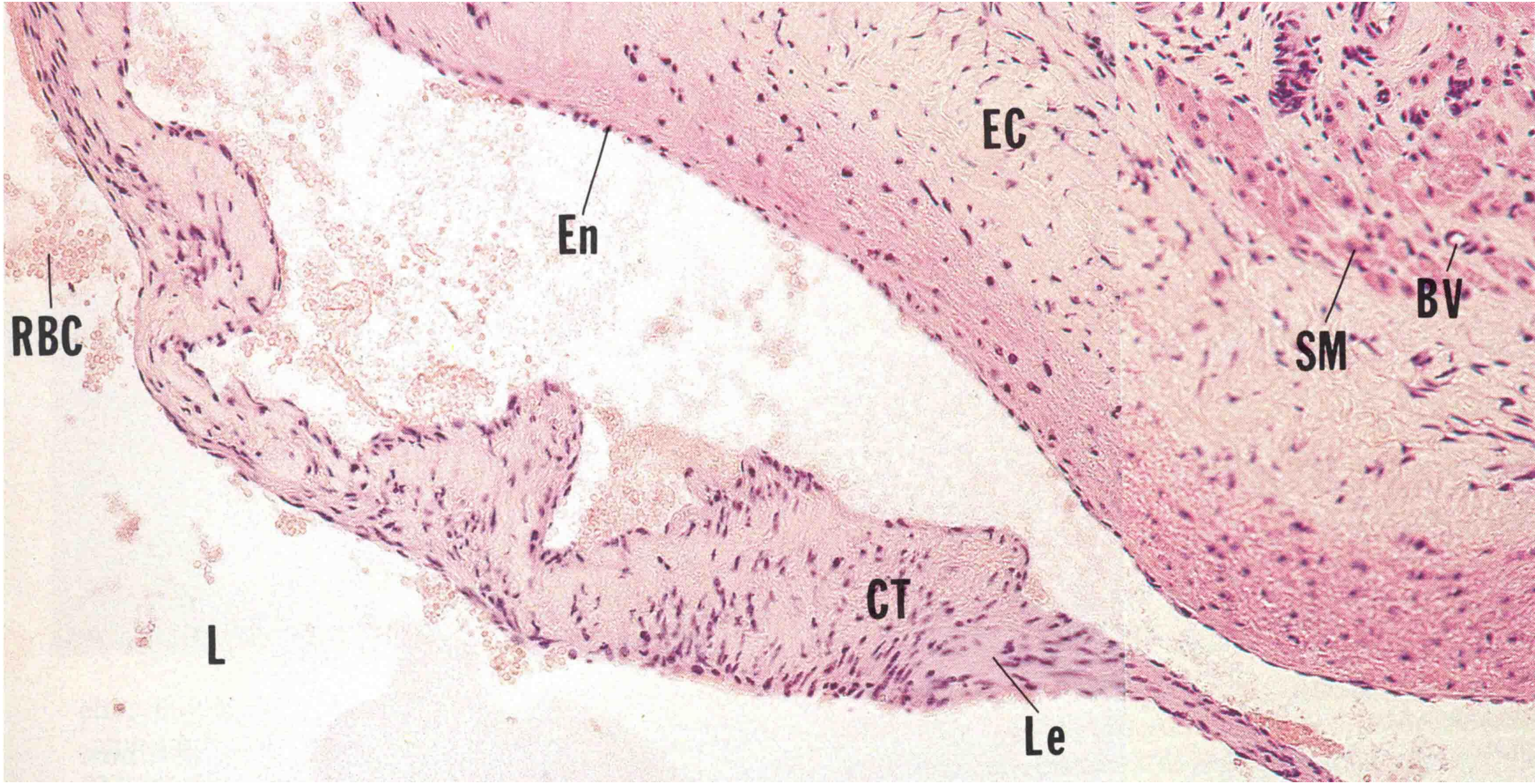
- Supporting loose CT

Myoelastic layer

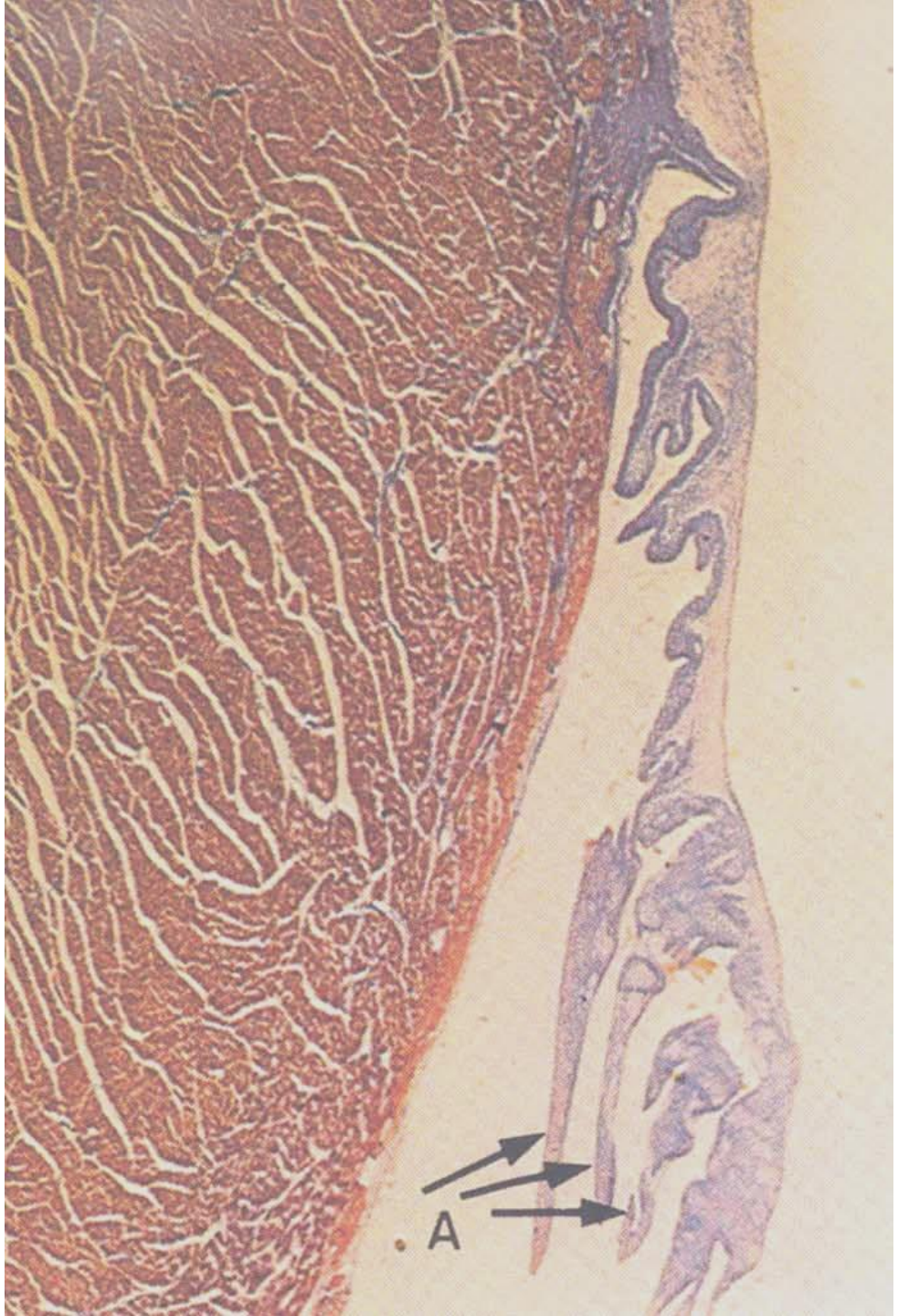
- CT with a lot of elastic fibers and SM cells

Subendocardial layer

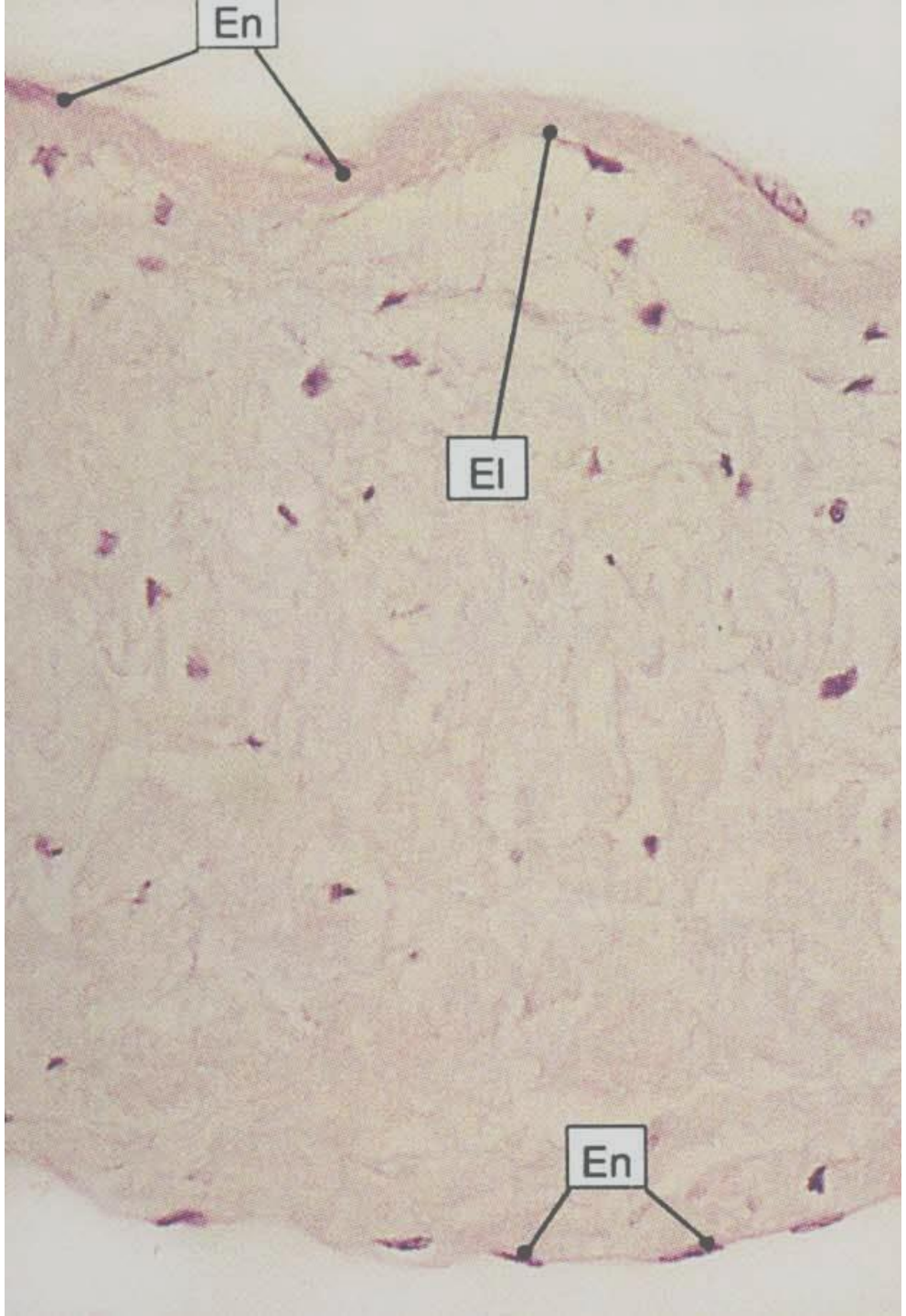
- Specialized cardiomyocytes


EC
En
RBC
SM
BV
CT
L
Le

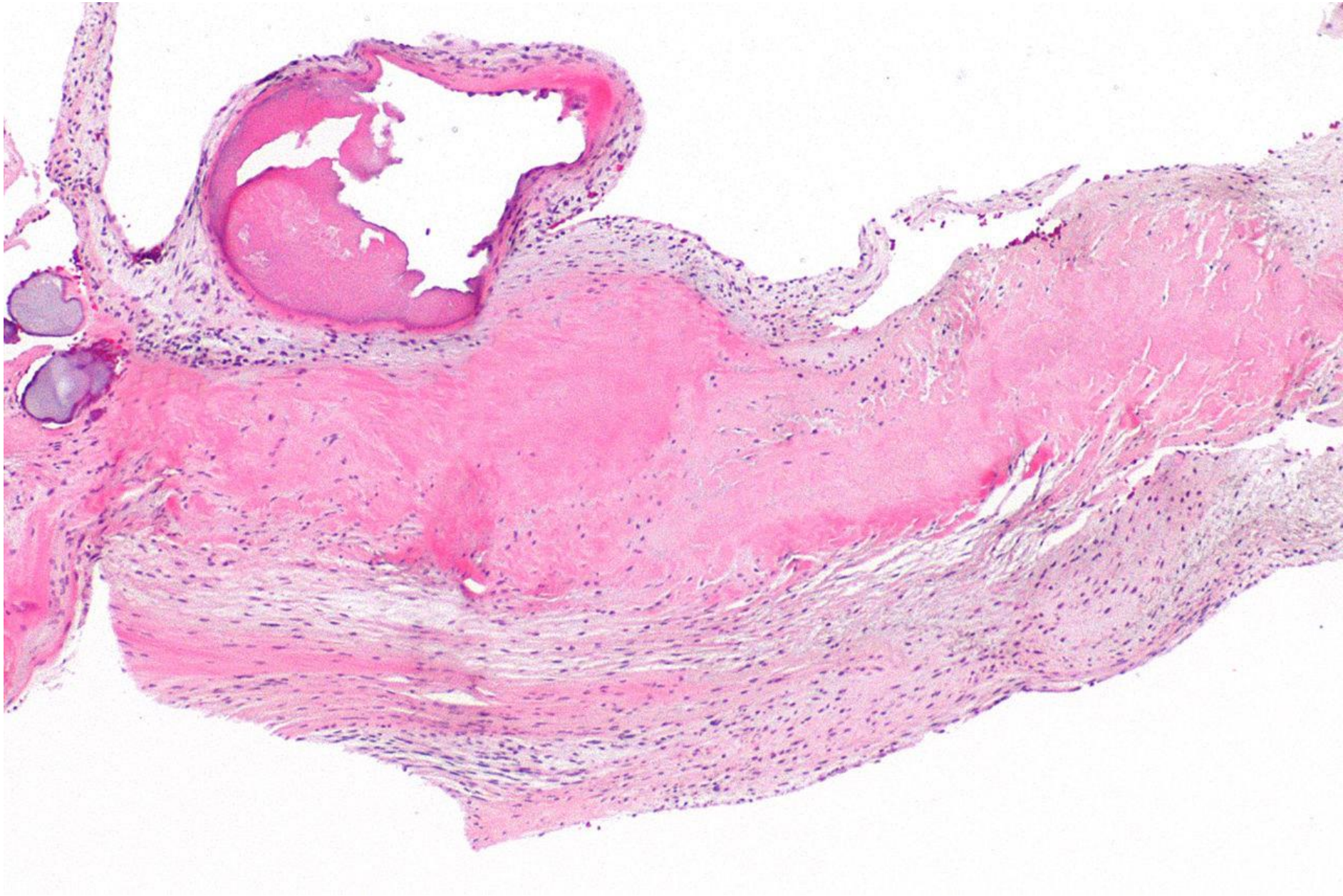
AV valves (tricuspid, mitral) are flaps of connective tissue covered by endothelium. They are connected to the dense CT of the cardiac skeleton. Chordae tendinae are connective tissue cords that extend to the papillary muscles. You can see cords‘ attachment to the cusps.



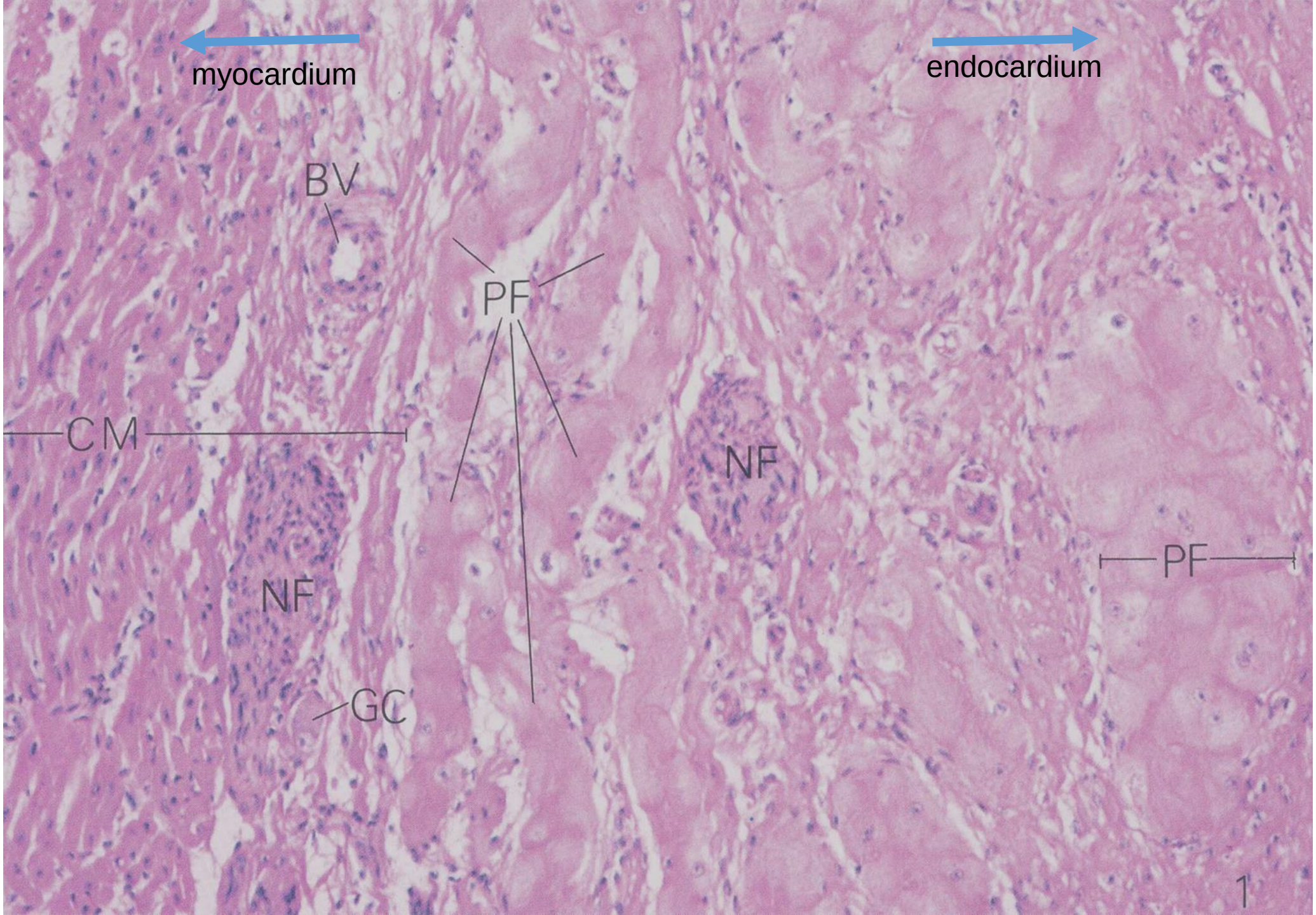
Semilunar valves have layers similar to the AV valves. They do not have cords. Elastic fibers are labeled in the picture. Vasculature is notably absent.



Valvular diseases can severely alter cardiac function. Here you can see slide from a pacient with aortic stenosis. Aortic valve contains fibrin, which becomes calcified. This causes thickening of the valve, which also becomes stiff. Thus, the aortic valve cannot open sufficiently during systole.

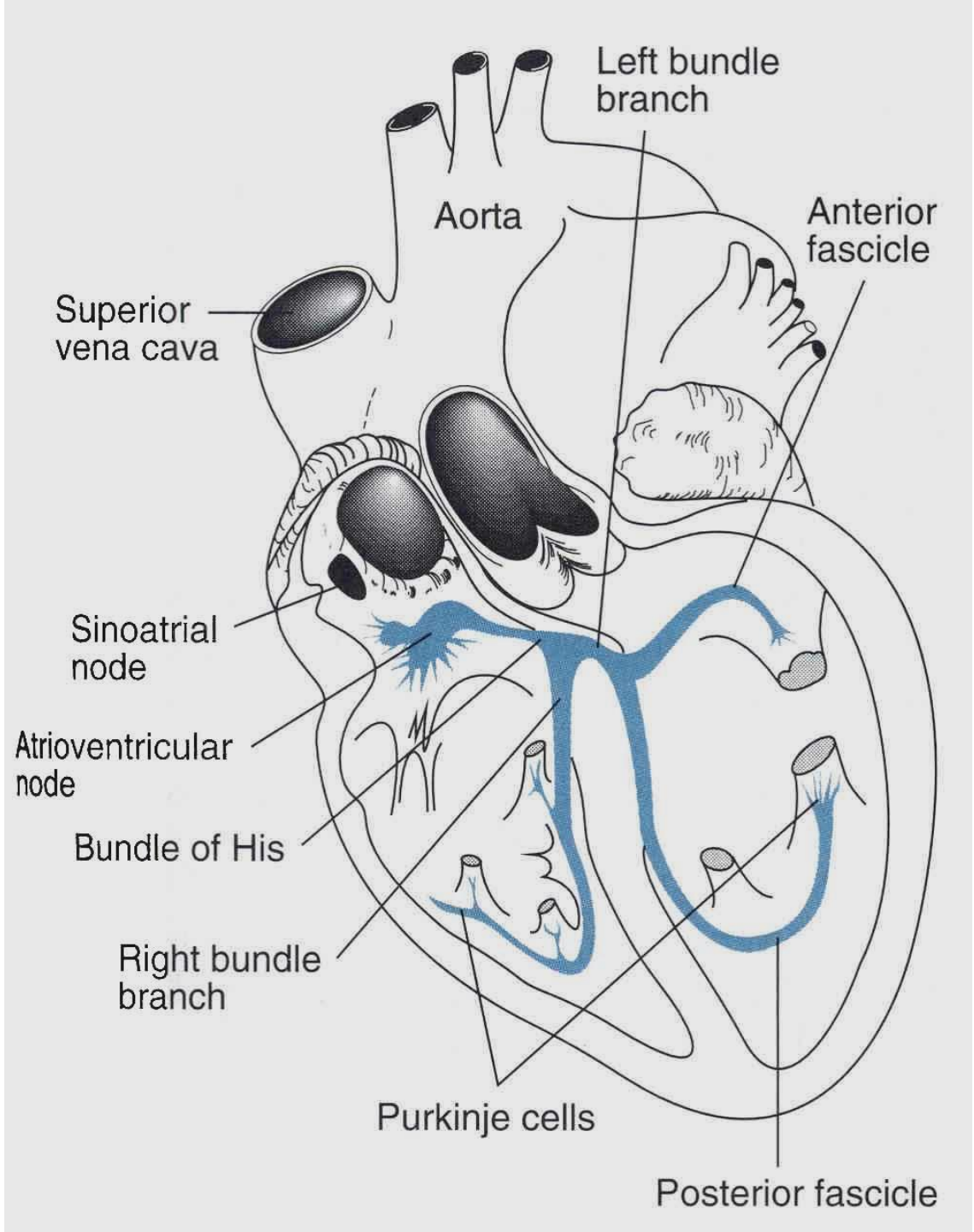


Subendocardial layer with Purkinje fibers. PF are a part of the heart‘s conducting system. You can also see nerves.

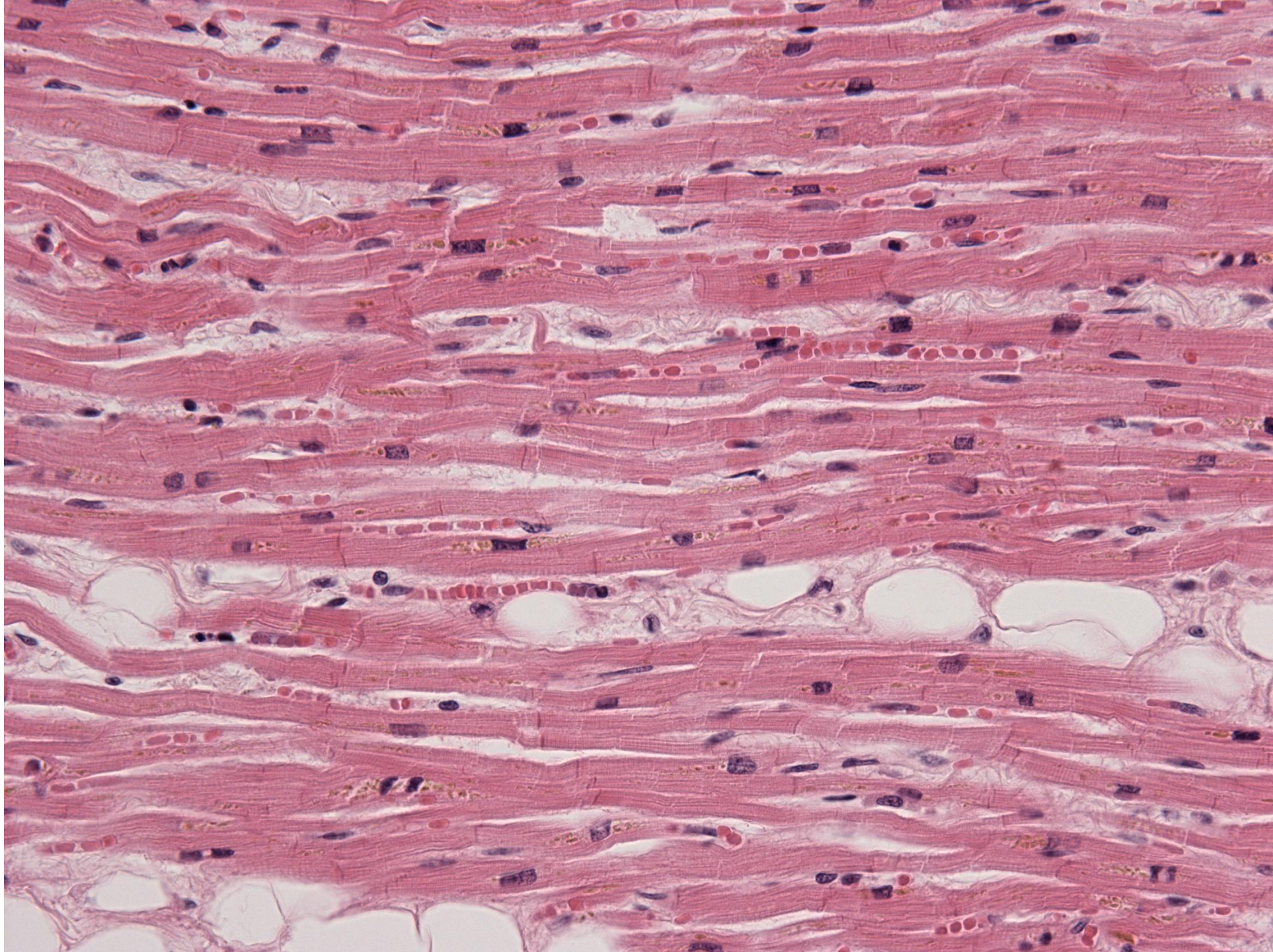


Purkinje fiber

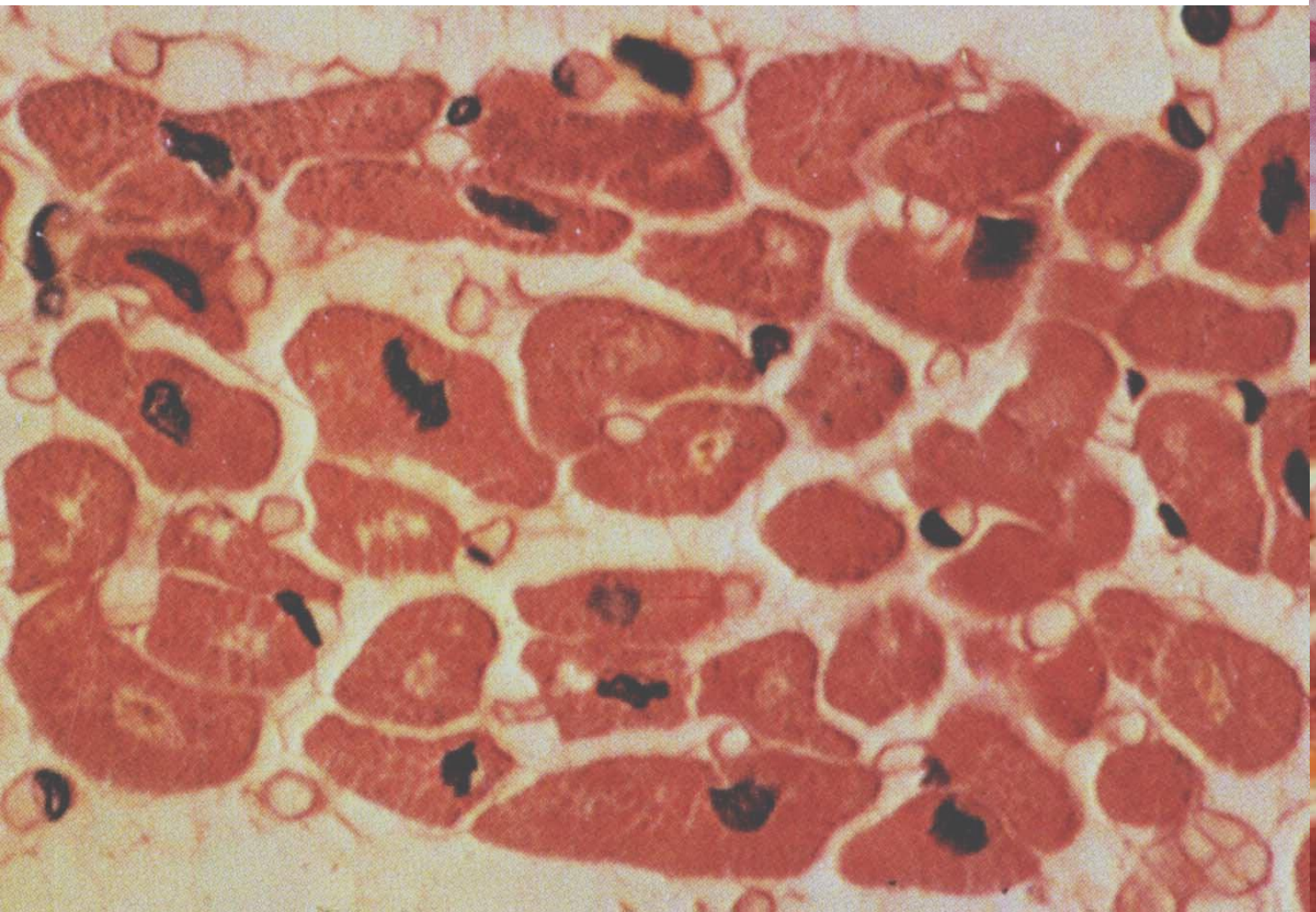
Cardiomyocytes in PF are larger and stain paler than other cardiomyocytes (glycogen inclusions). Myofibrils are in the perifery.

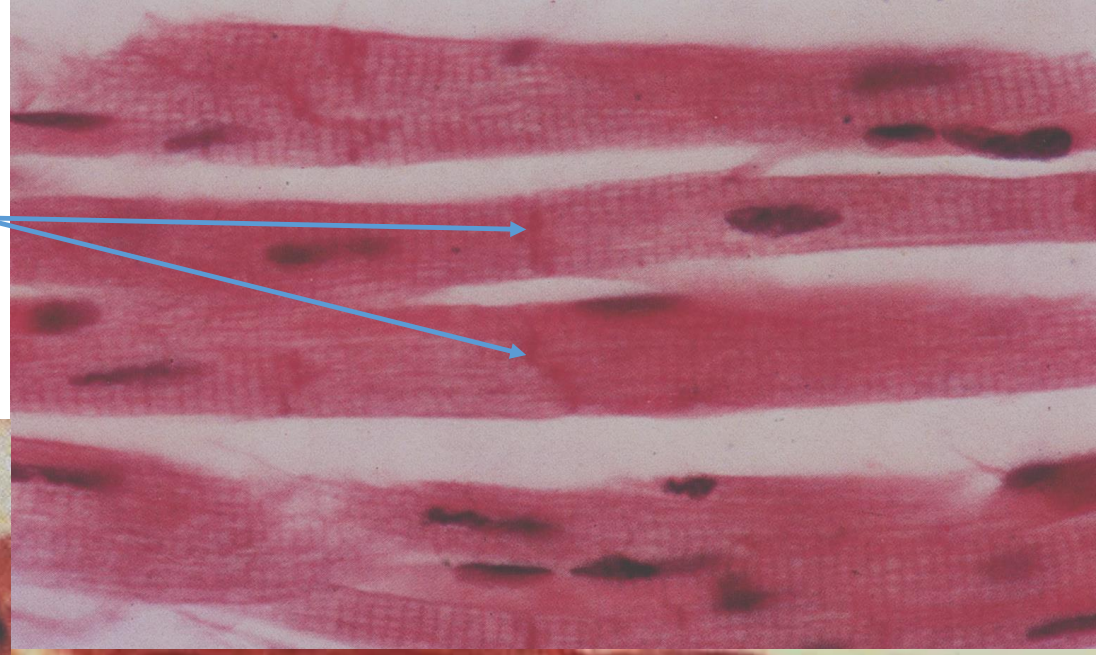

Left bundle branch
Aorta
Anterior fascicle
Superior vena cava
Sinoatrial node
Atrioventricular node
Bundle of His
Right bundle branch
Purkinje cells
Posterior fascicle

Myocardium has been already described in a previous lecture (muscle tissue). Note abundant capillaries.

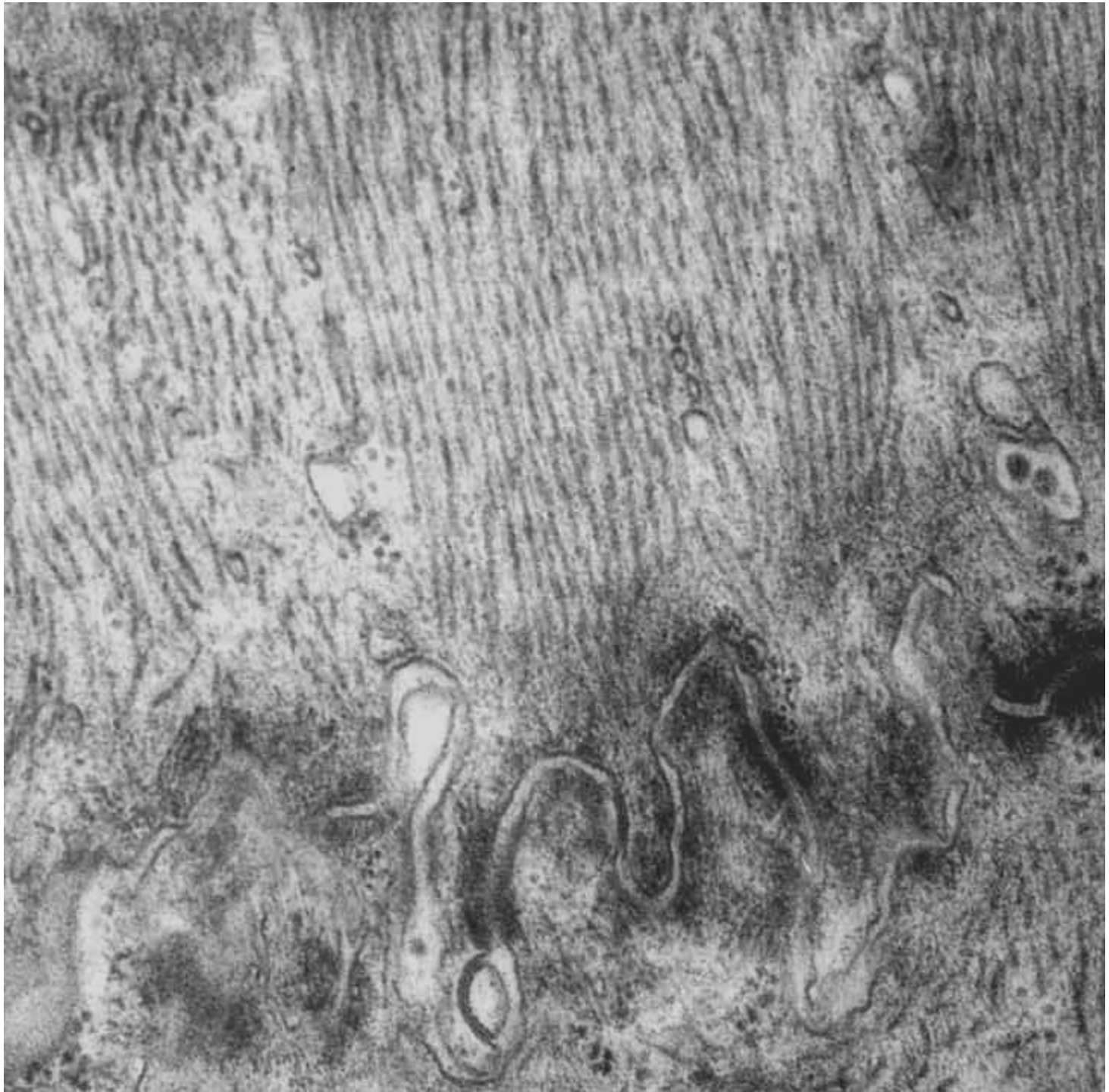


Longitudinal sections showing striations, in cross-section they are not apparent. Cardiomyocytes are connected through intercalated discs (mechanically as well as electrochemically).

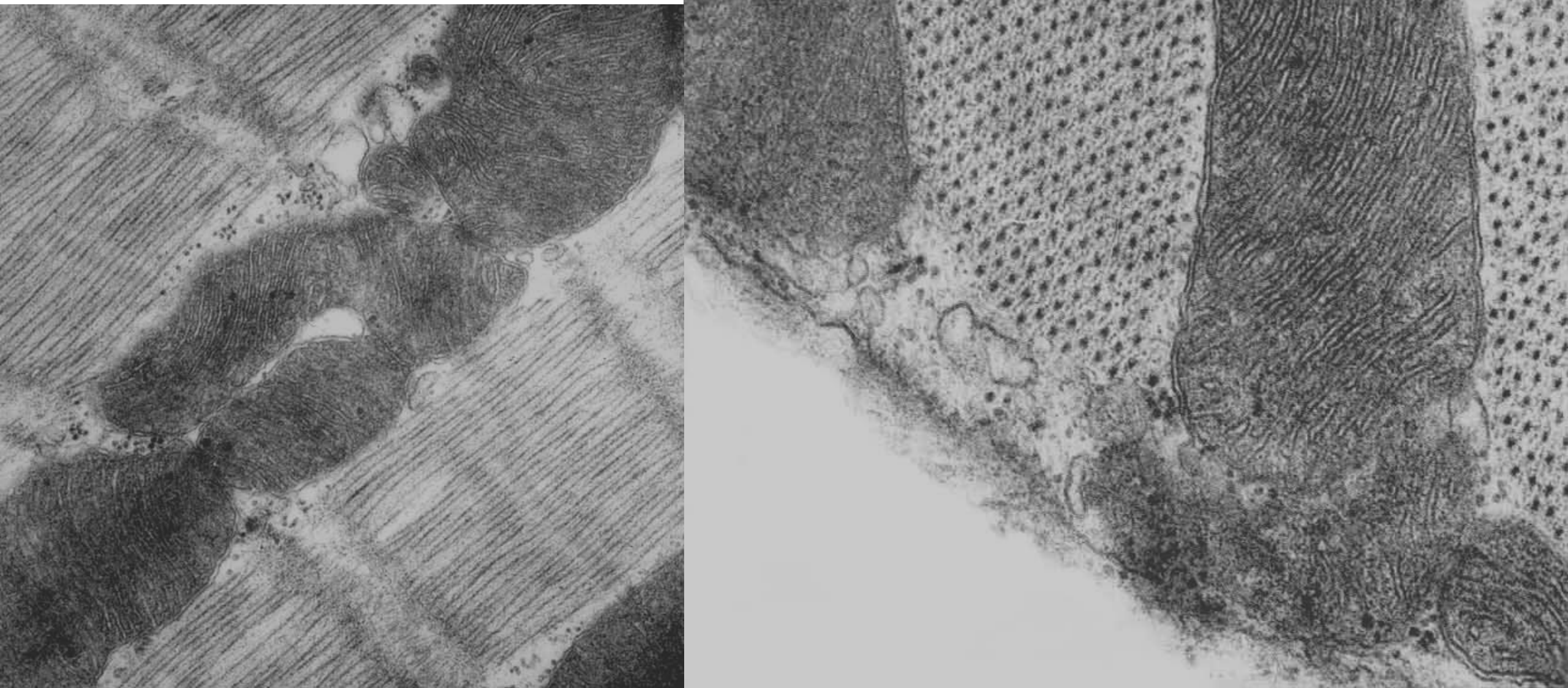




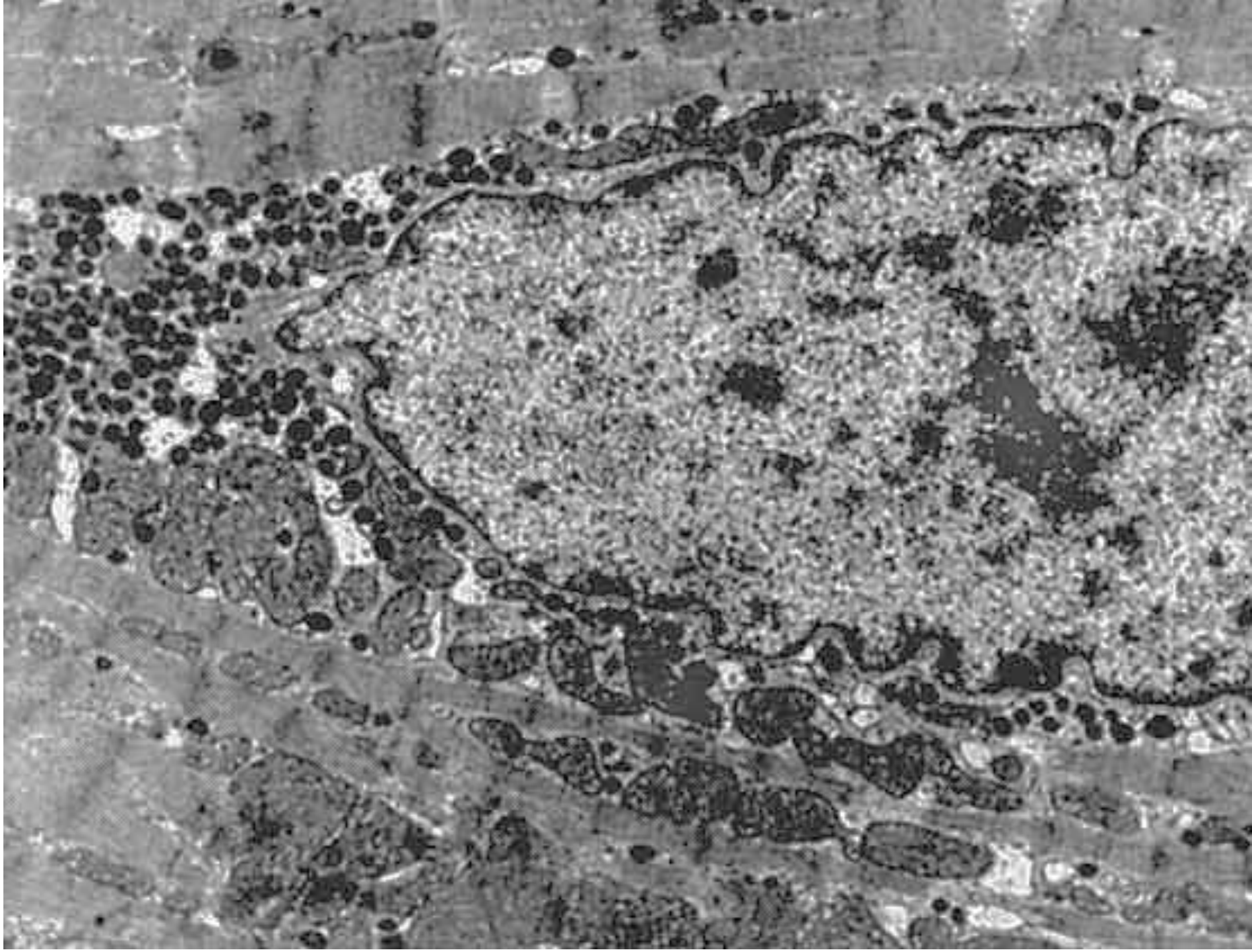
Intercalated disc



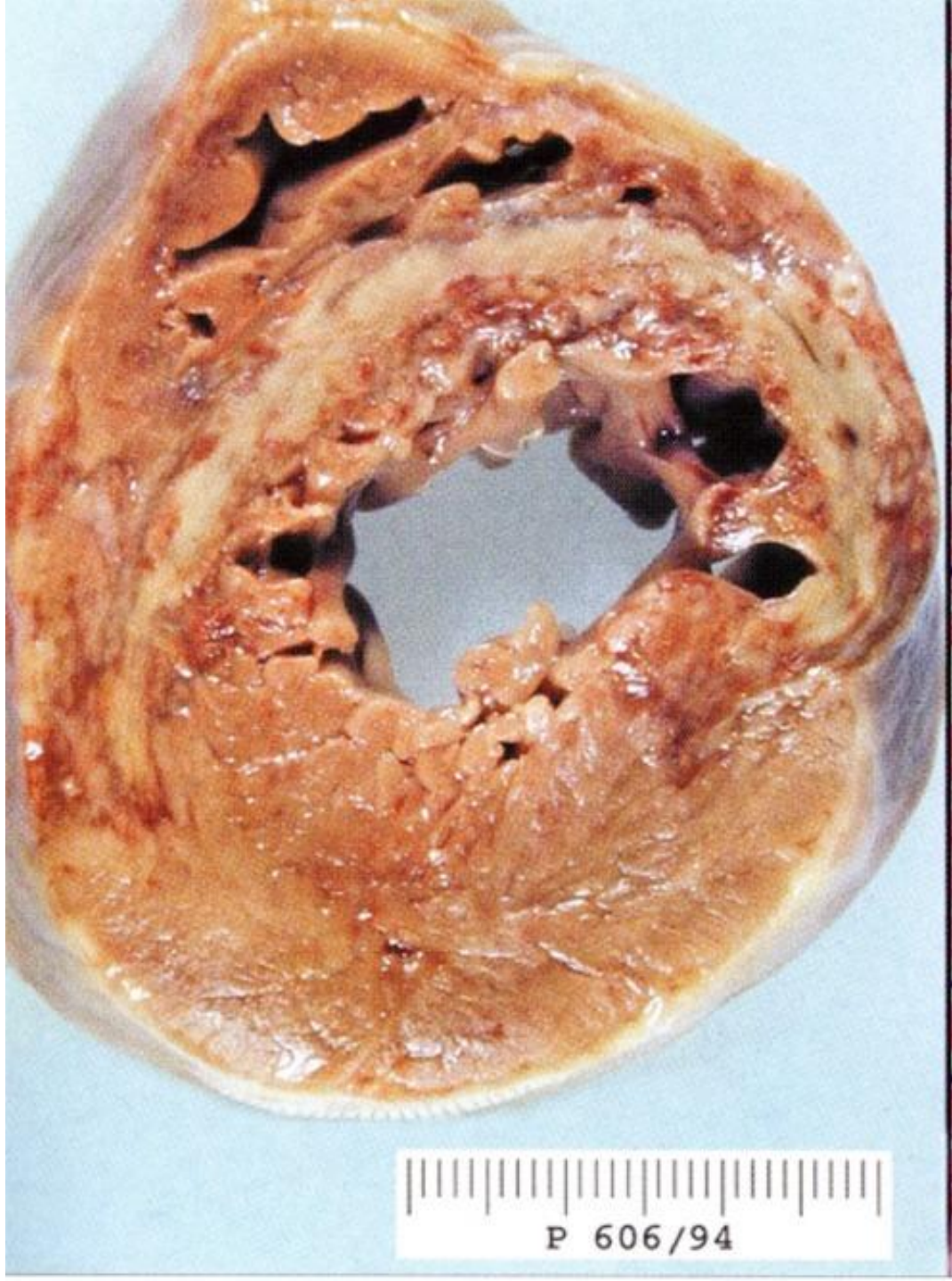
Myofibrils in longitudinal section (left) and cross-section (right). Abundant mitochondria constantly supply energy using aerobic metabolism.

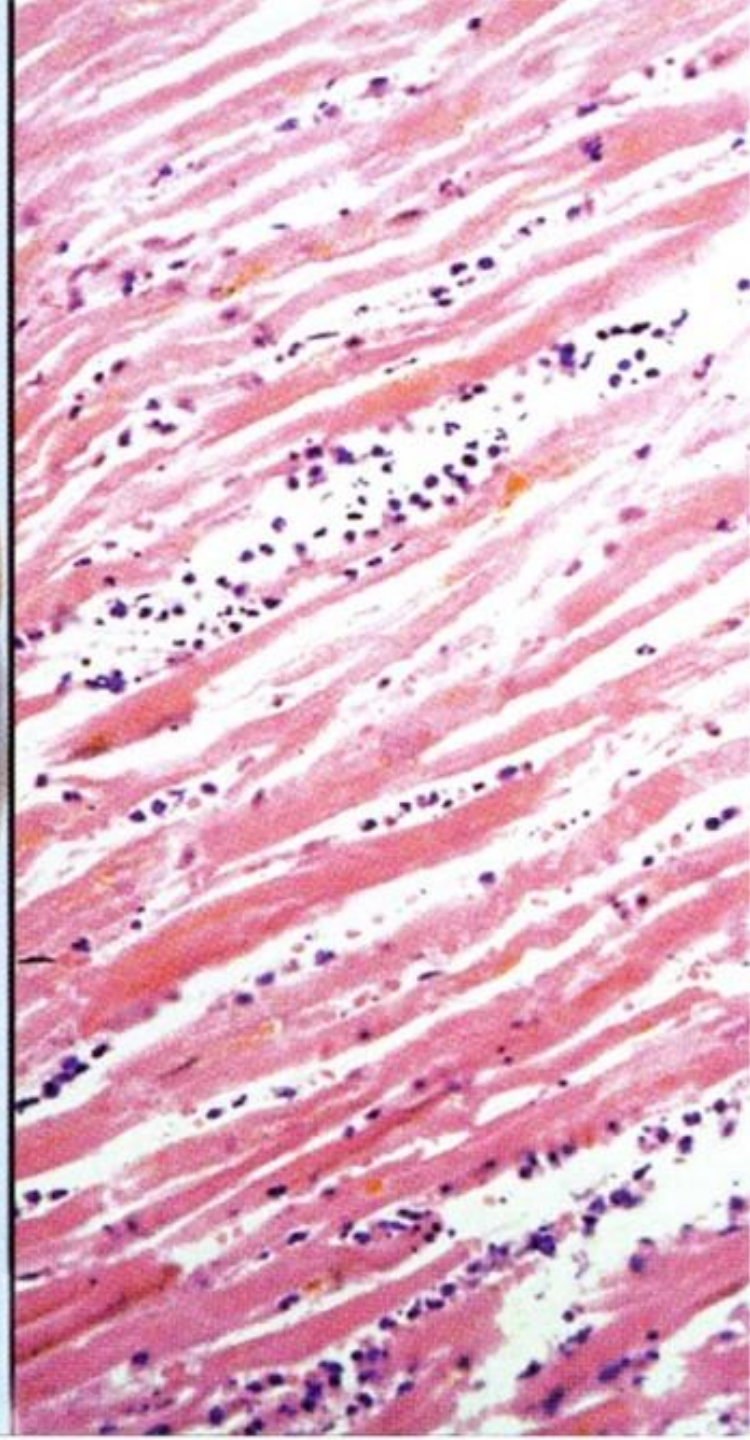


ANP containing granules are present in the juxtanuclear space of this atrial cardiomyocyte. ANP (atrial natriuretic peptide) is a peptidic hormone secreted by atria in response to high blood pressure. ANP lowers the blood pressure and causes natriuresis and diuresis in the kidney. In the ventricles, a structural and functional analogue BNP (brain natriuretic peptide) is produced.

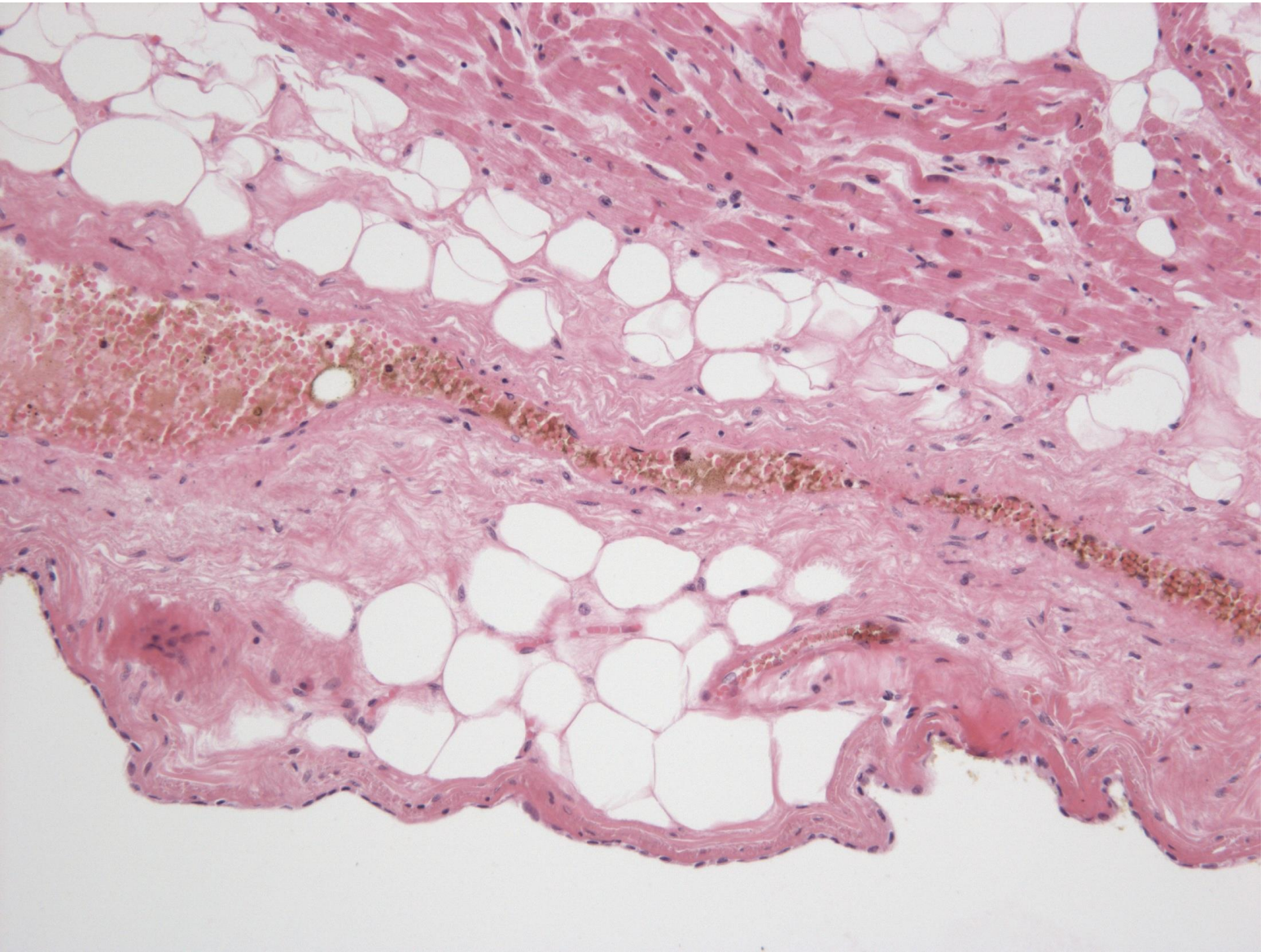


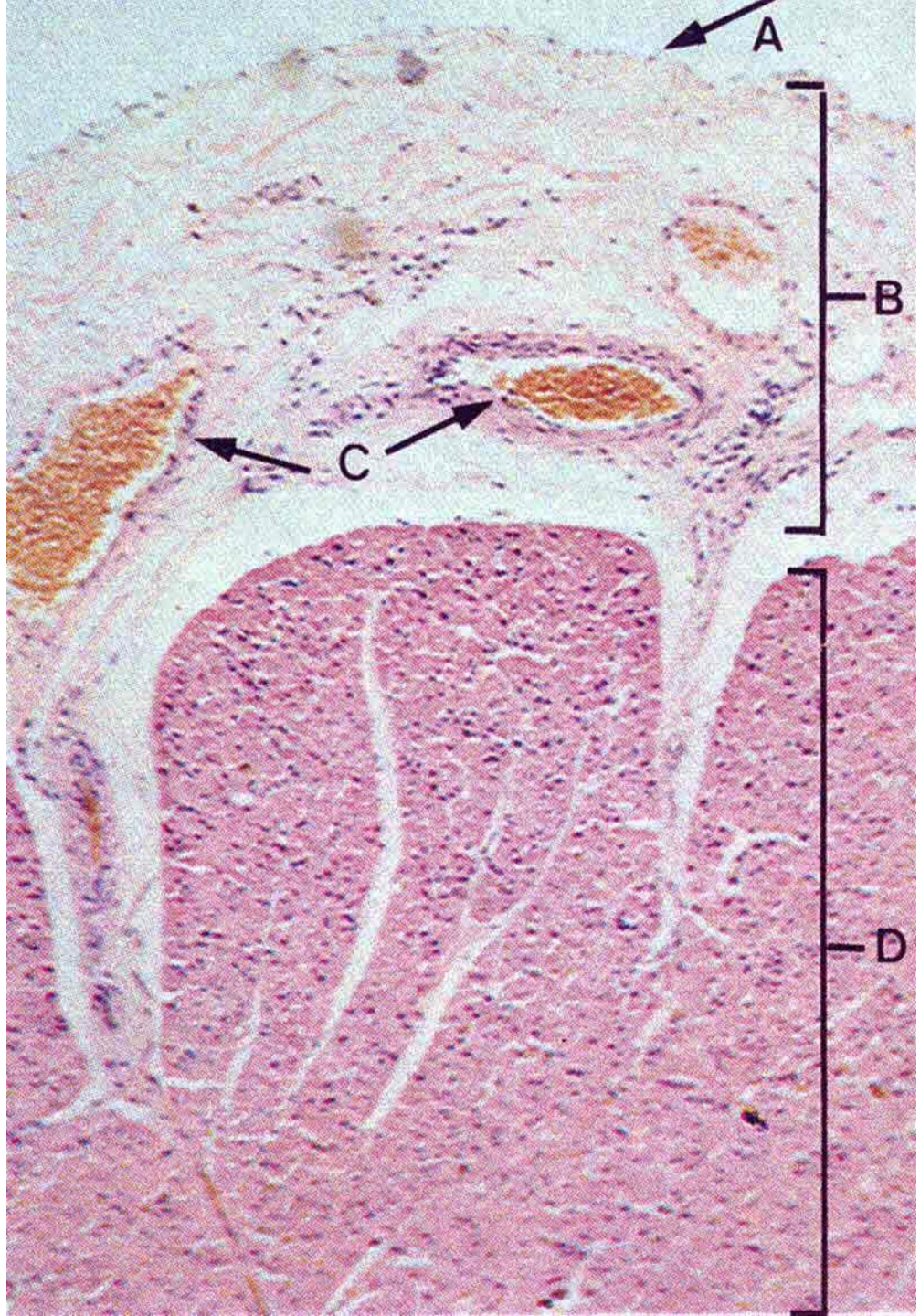
Myocardial infarction of the septum and a part of the posterior wall of the LV. Gradually histological changes develop as a result of necrosis (right). In later stages, the lesion is macroscopically visible. The lesion cannot be fully regenerated, instead connective tissue replaces the necrotic tissue (scar).





Epicardium is a visceral layer of pericardium. Under simple squamous mesothelium there is a layer of loose CT. Abundant vessels. Adipocytes are typical.



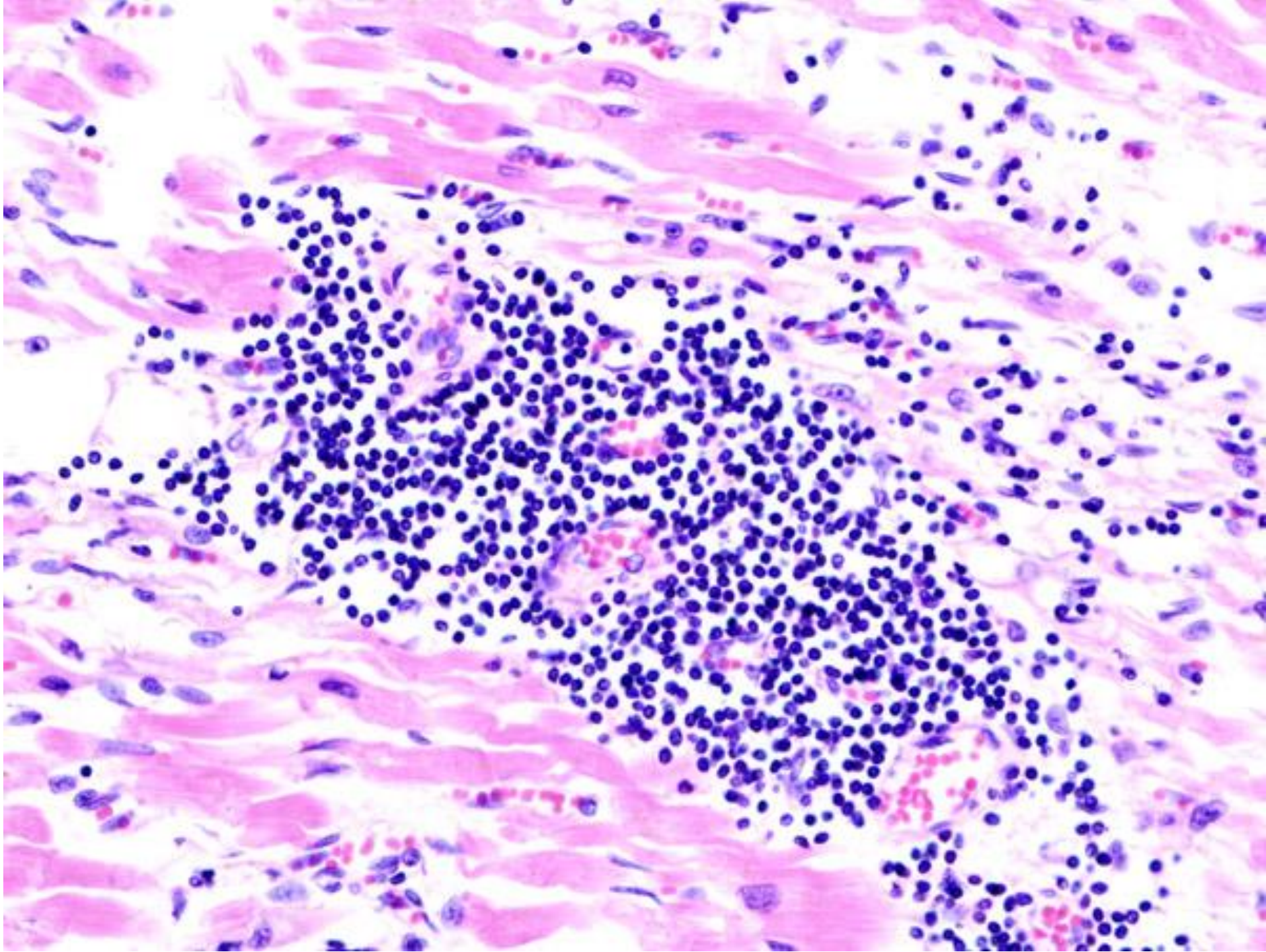


Question time - heart

1. Which biochemical marker would you use for assessment of the myocardial damage? In which pathological states these markers would be elevated?

2. Can you describe the relation of the autonomous nervous system to the heart conducting system?

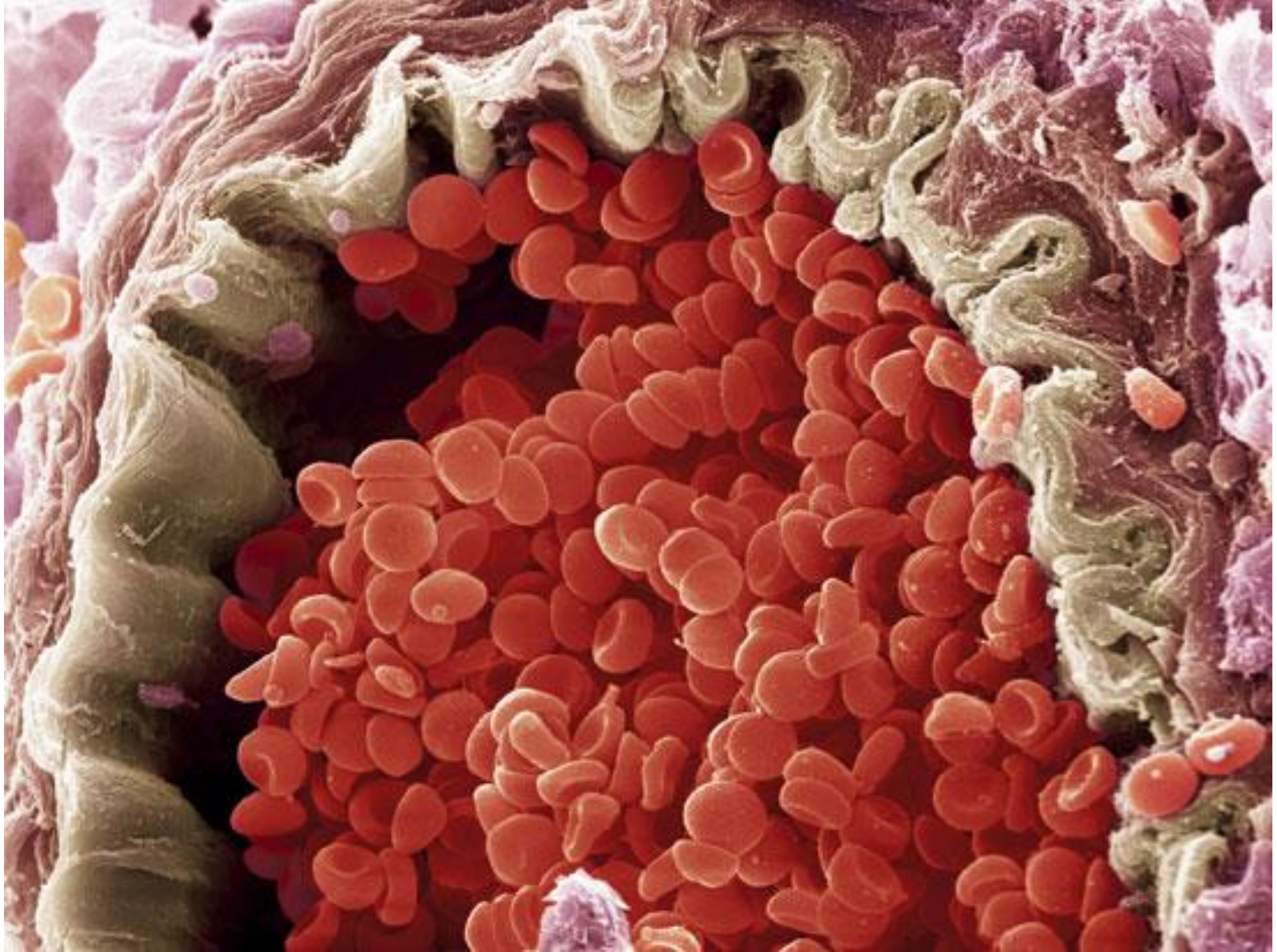
Myocarditis is an inflamatory disorder that can result from viral infections. Lymphocytes are present in the myocardium.



Heart

- 3 layers
  - Endocardium (4 sublayers)
    - Endothelium
    - Subendothelial
    - Myoelastic
    - Subendocardial
  - Myocardium
  - Epicardium (2 sublayers)
    - Mesothelium
    - Loose CT

- 2 types of valves (AV, semilunar)
- 2 types of epithelium (mesothelium, endothelium)
- 2 types of cardiomyocytes (conducting system, work cells)
- 2 similar hormones (ANP, BNP)



Vessel structure

Tunica intima

Endothelium (simple squamous to cuboidal)

Subendothelial layer (loose CT)

Tunica media

Membrana elastica interna*

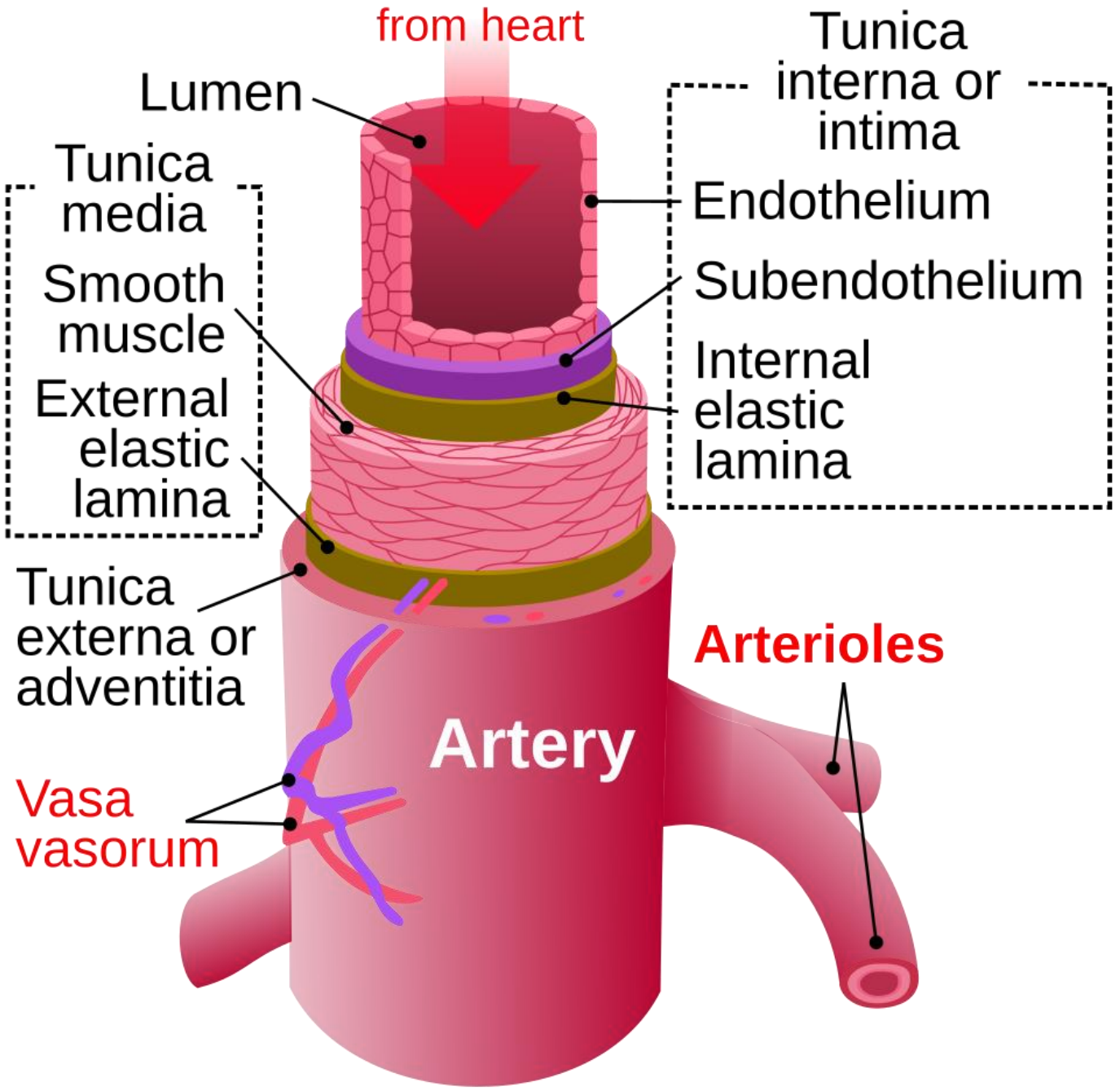
Smooth muscle

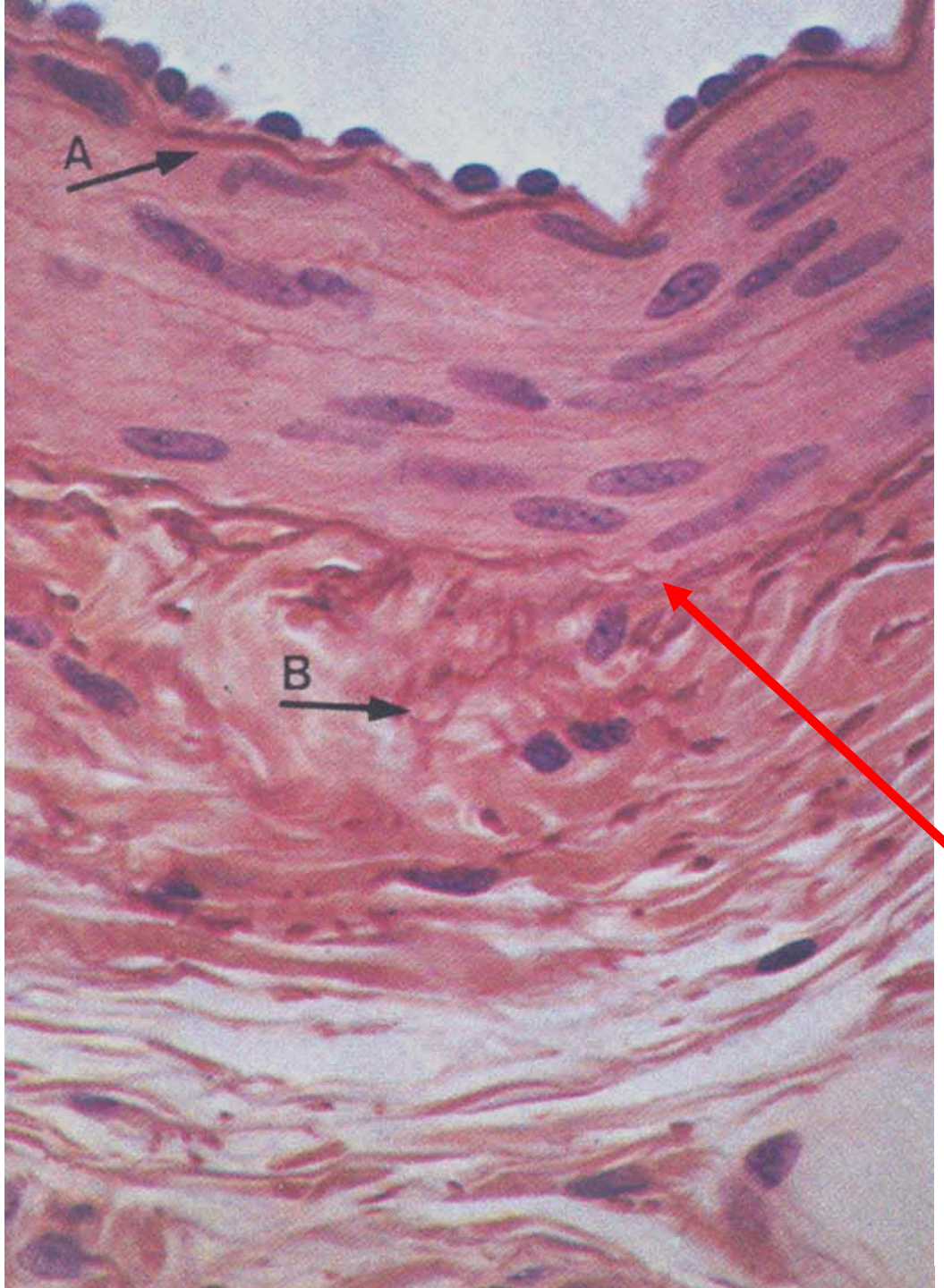
Membrana elastica externa*

Tunica adventitia

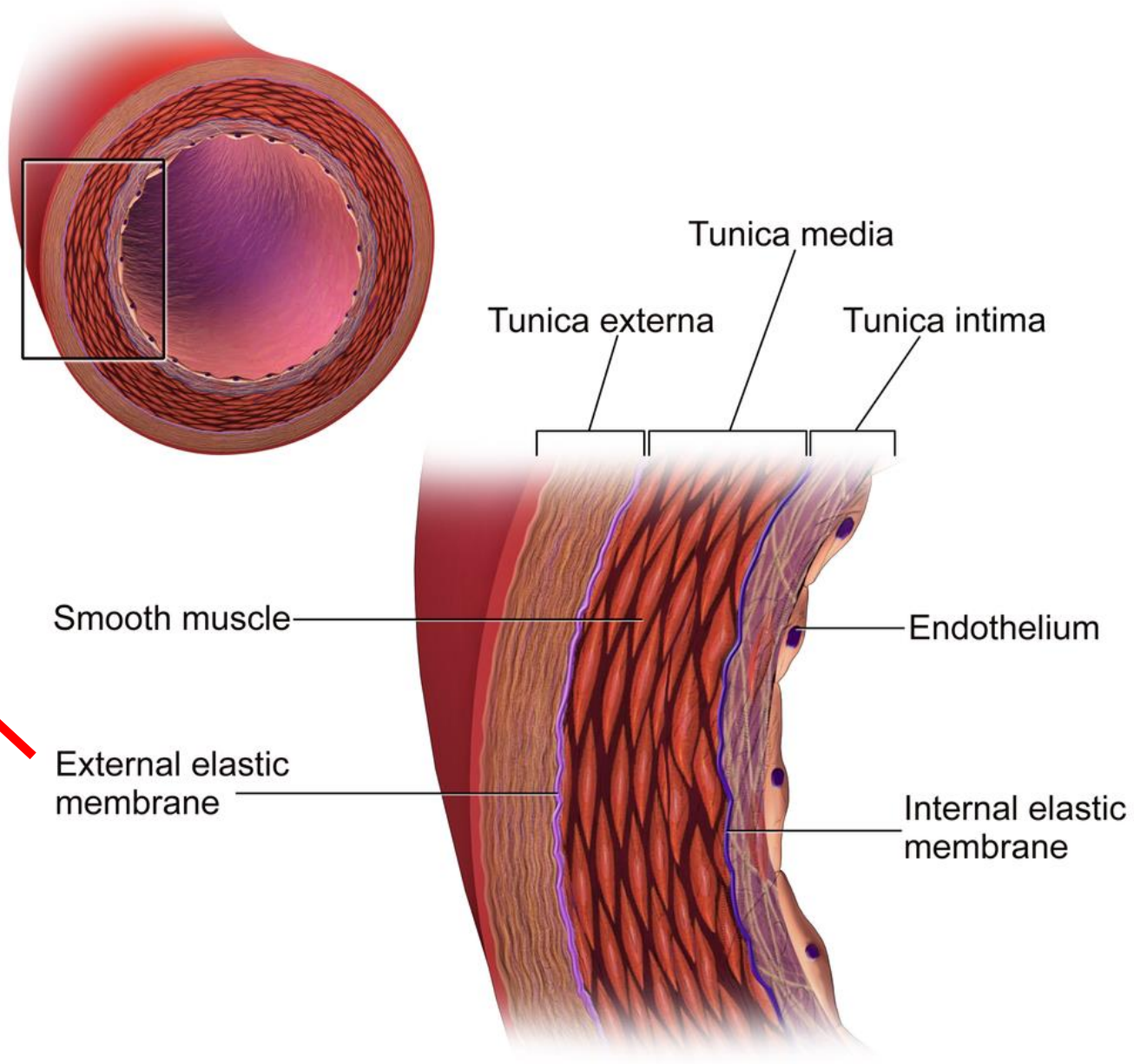
CT, possibly with some SM cells

*poorly developed in veins



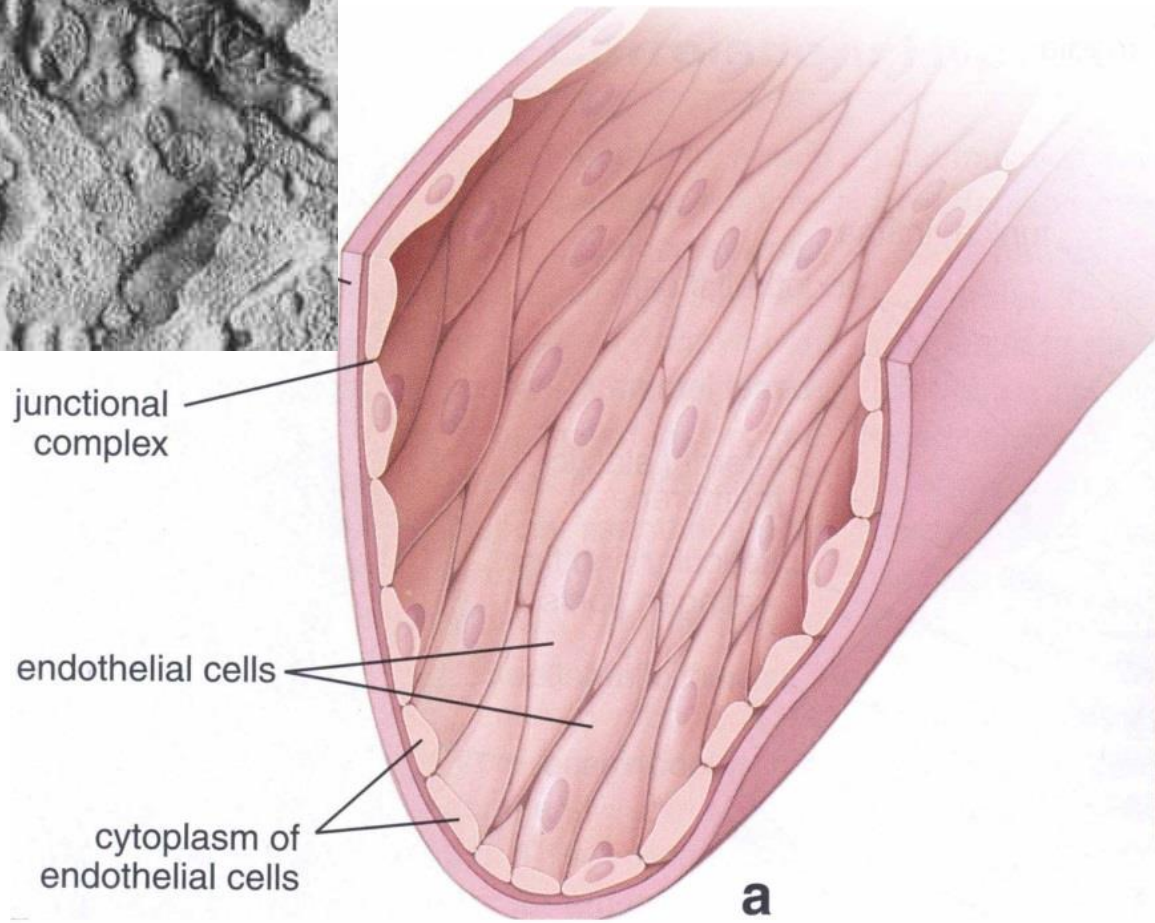


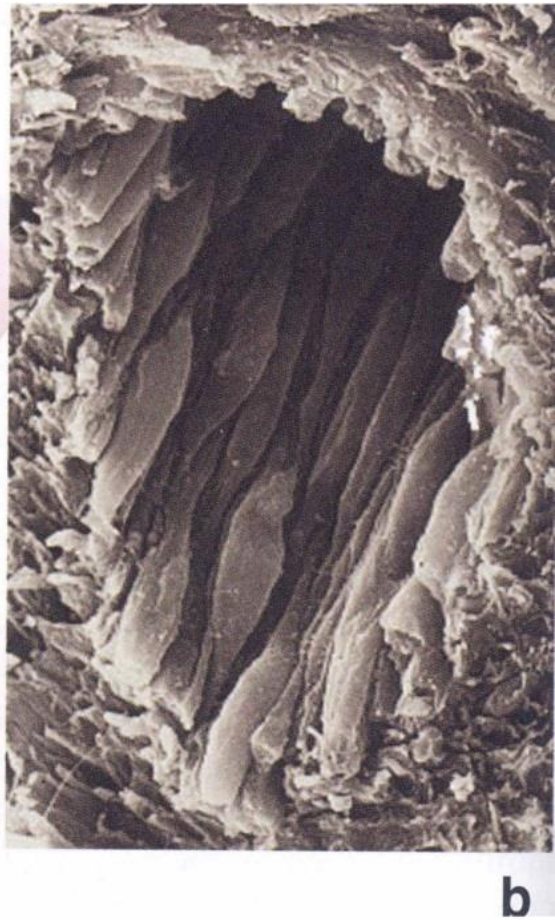
The Structure of an Artery Wall



Endothelial cells are flat cells elongated in the direction of blood flow. They provide nonthrombogenic surface to the vessel wall.

Endothelium forms a barrier between the vessel wall and the blood. Occluding junction (seen on the upper picture) makes this possible.





Other functions of endothelium

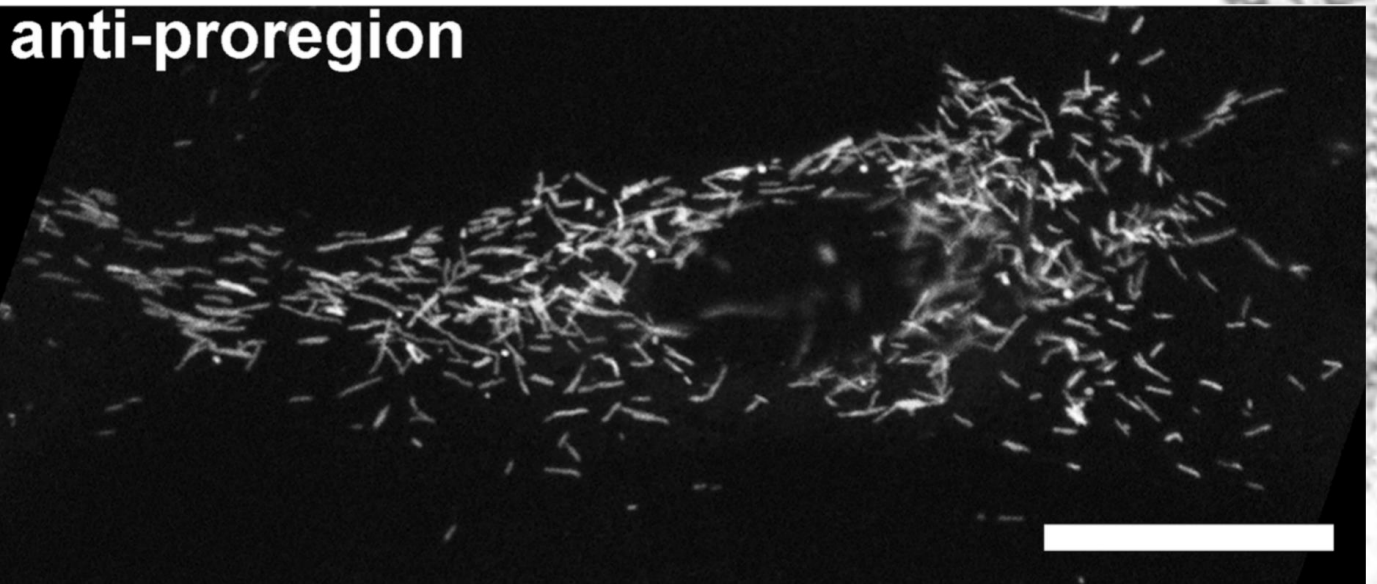
- In fact, endothelium performs a wide spectrum of functions:
- Cell adhesion via CD31 (PECAM), CD34, and CD106 (VCAM-1)
- lipolysis
- angiotensin I to II conversion
- **inactivation** of bradykinin, thrombin, prostaglandin, noradrenalin, serotonin
- **production** of endothelin, NO, von Willebrand factor, prostacyclin, thrombomodulin
- They can also produce ECM (collagen, biglycan, versican)

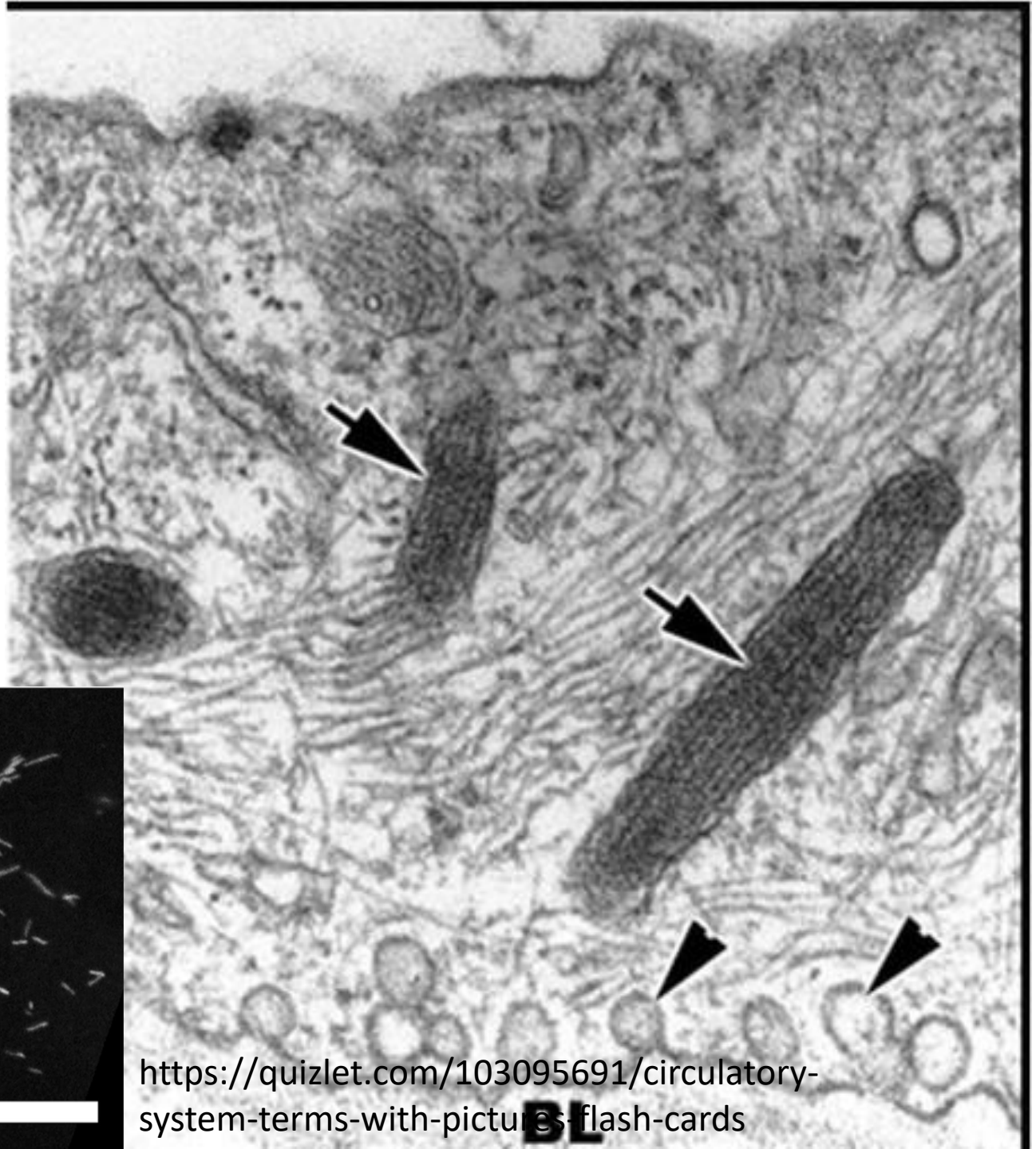
Selected important molecules

Blood pressure
coagulation

- Cell adhesion via CD31 (PECAM), CD34, and CD106 (VCAM-1)
- lipolysis
- angiotensin I to II conversion
- **inactivation** of bradykinin, thrombin, prostaglandin, noradrenalin, serotonin
- **production** of endothelin, NO, von Willebrand factor, prostacyclin, thrombomodulin
- They can also produce ECM (collagen, biglycan, versican)

Weibel-Palade granules containing vWF

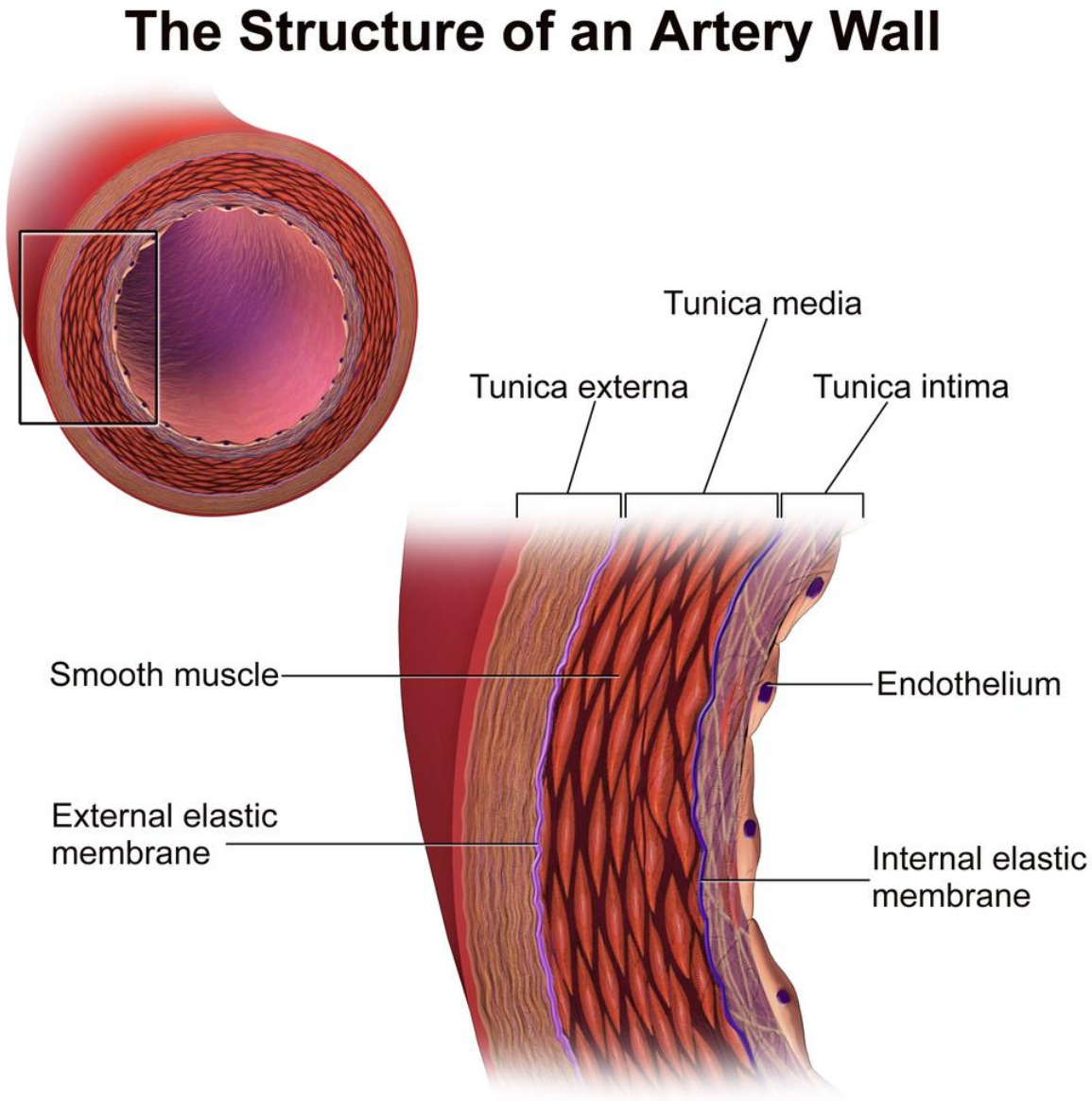




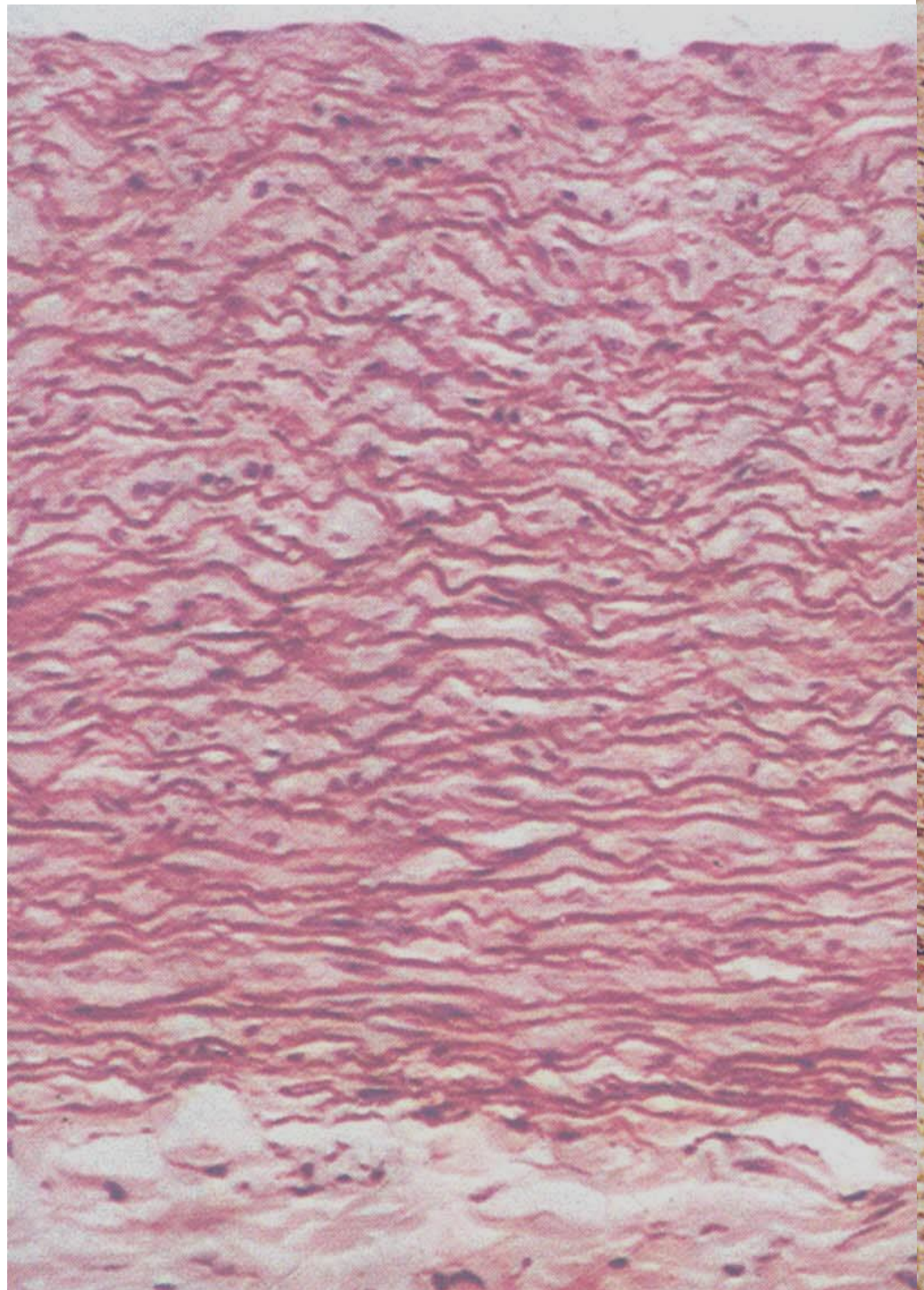
https://quizlet.com/103095691/circulatory-system-terms-with-pictures-flash-cards

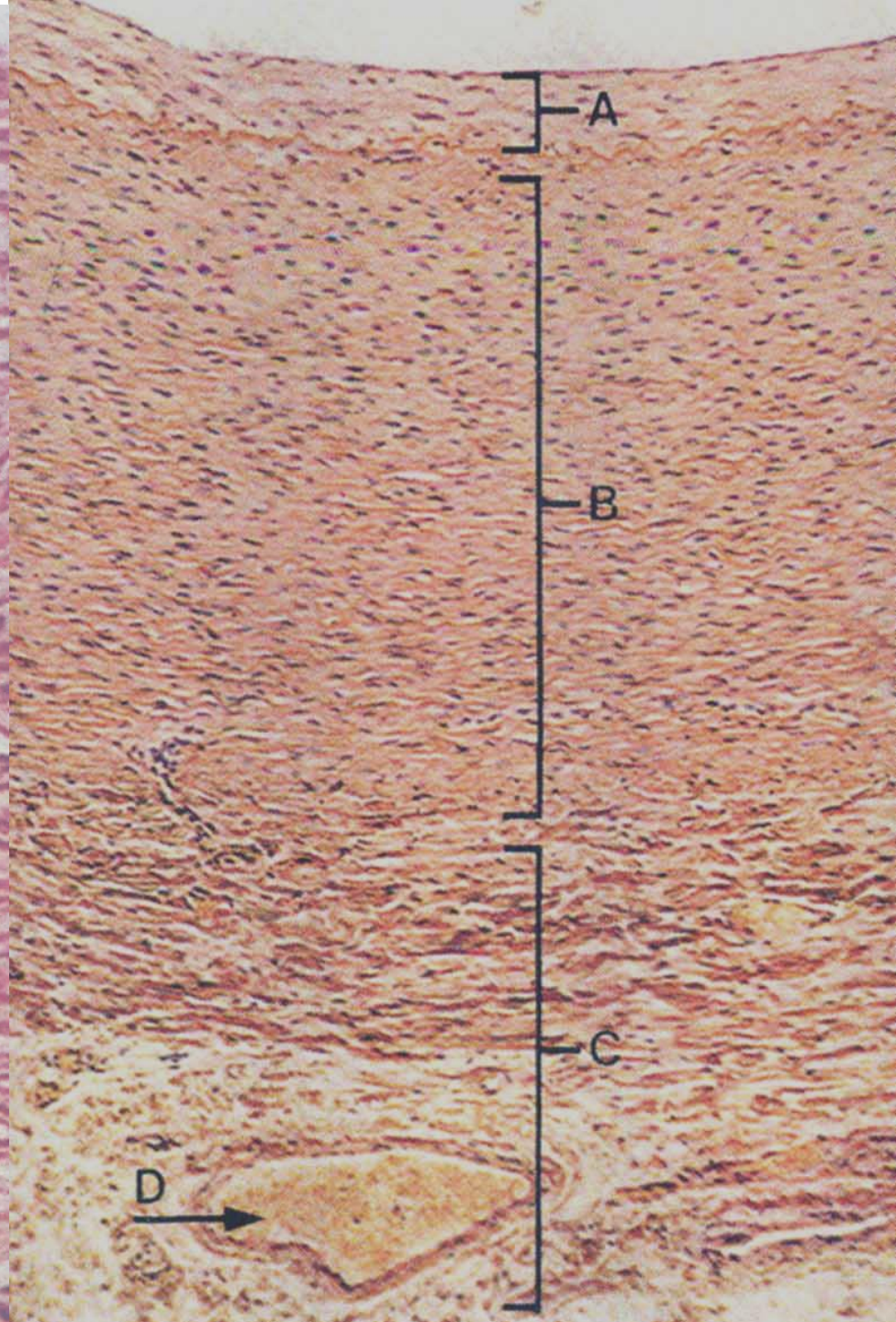
Arteries

- Elastic arteries
  - Aorta and large arteries over 1 cm
- Muscular arteries
  - 0,5 mm to 10 mm
- Arterioles
  - Less than 500 μm
  - Metaarterioles smaller than 40 μm

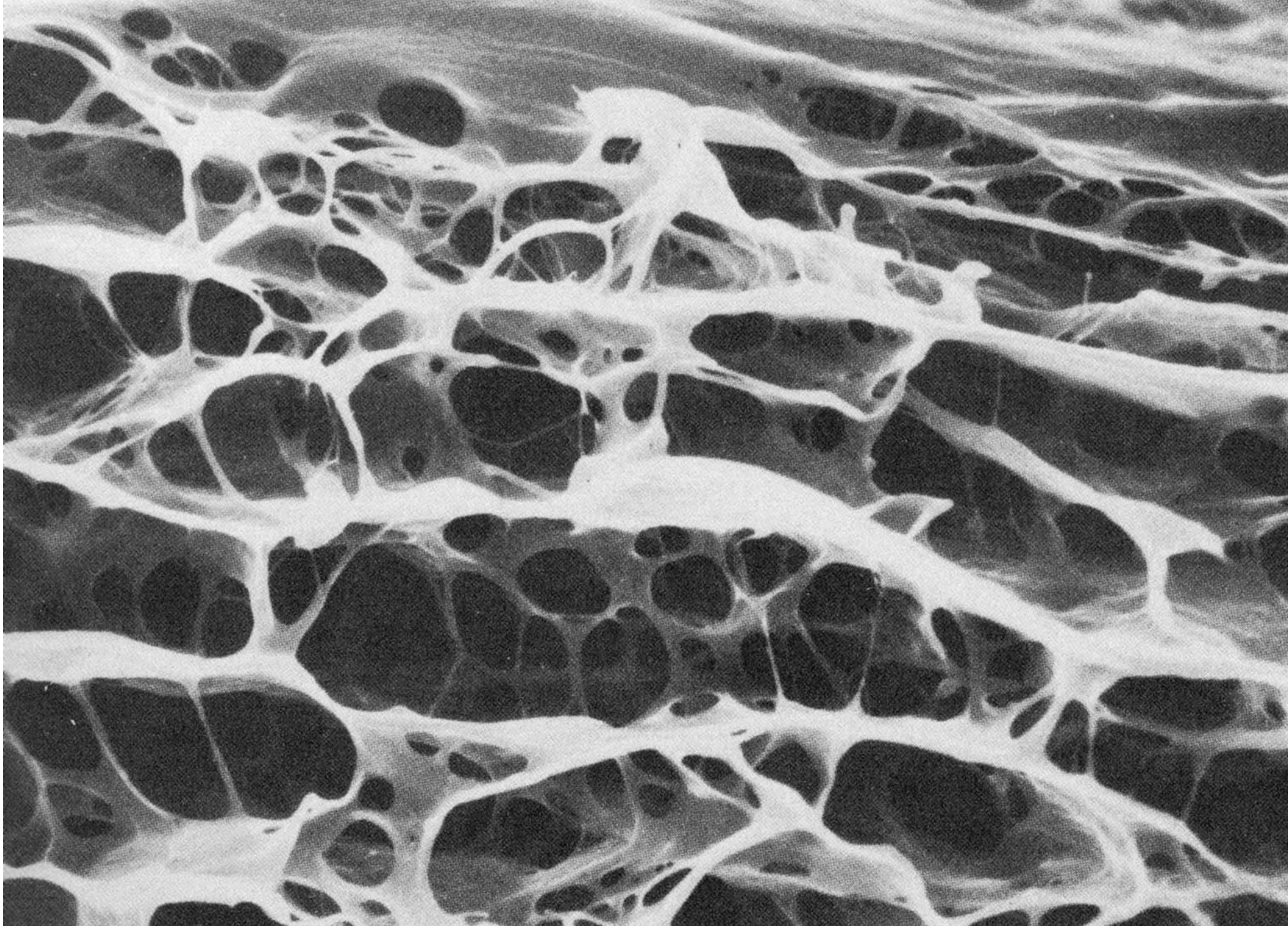


Elastic artery wall contains many elastic membranes – membranae fenestratae. Elastic fibers stretch during systole storing energy. During diastole the tension in the vessel wall helping to maintain blood pressure.

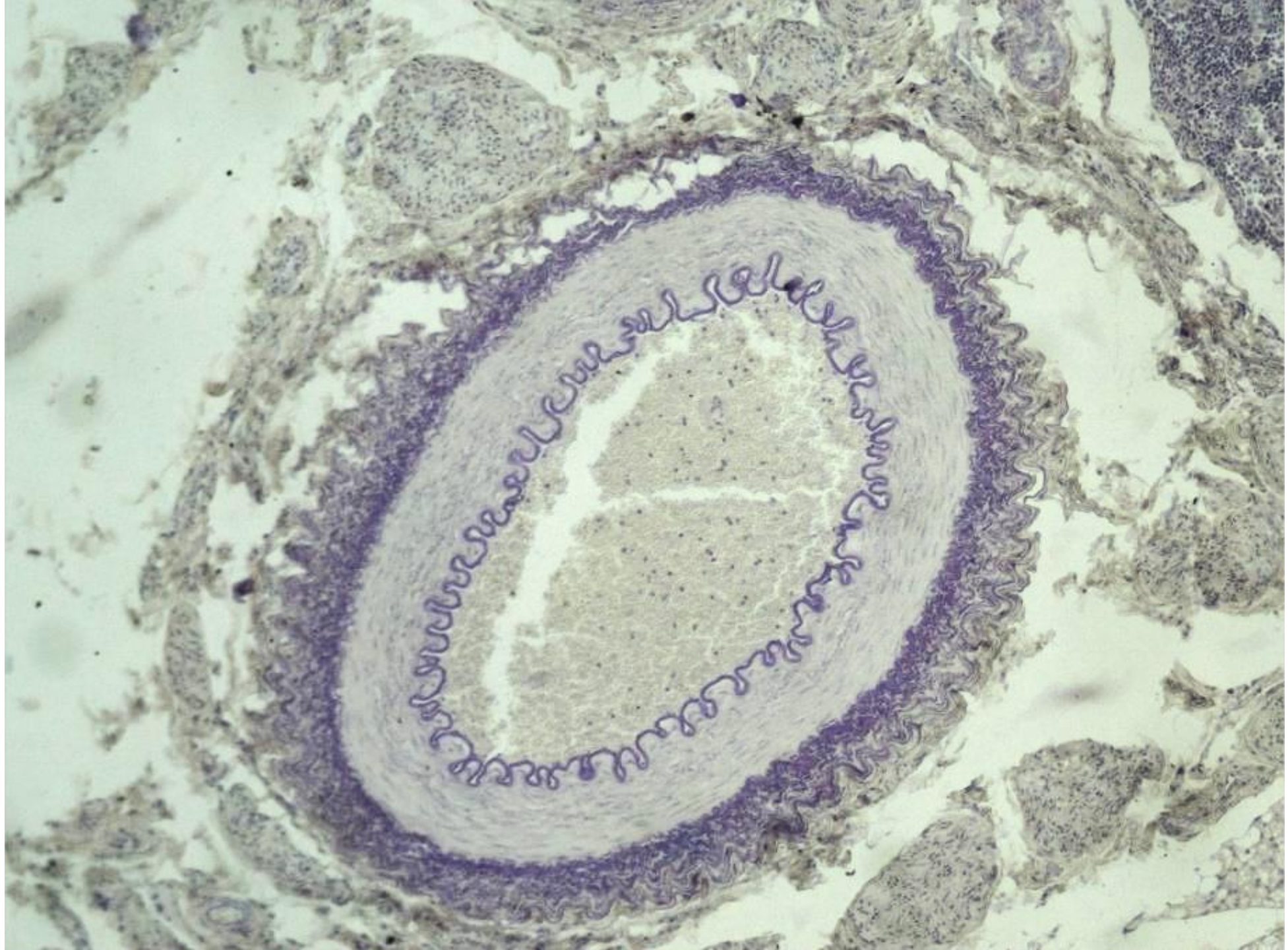




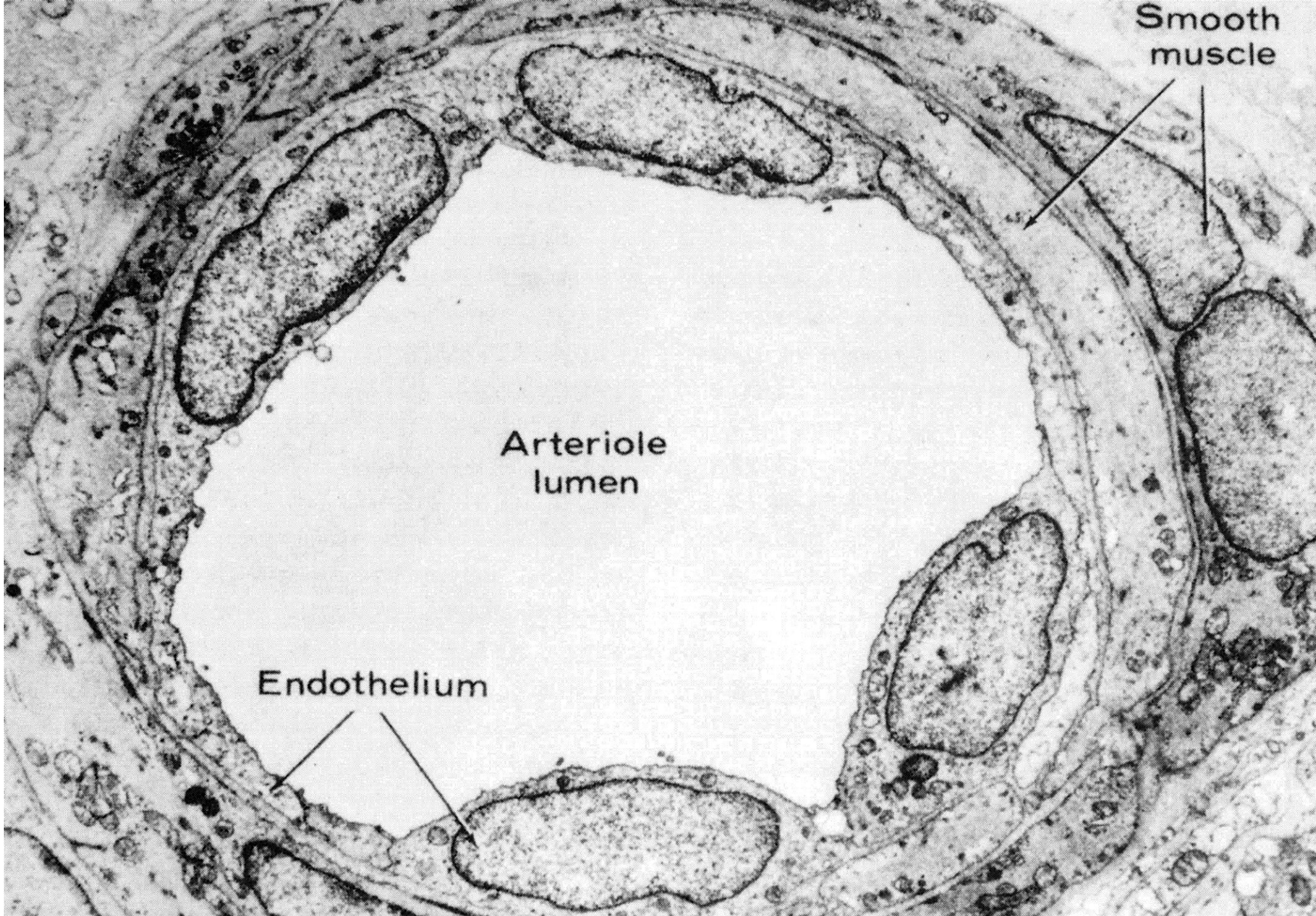
Discontinuous membranae fenestratae allow for passage of nutrients and metabolites through the vessel wall while at the same time mechanically supporting large vessels against the pulsatile changes in the blood pressure.

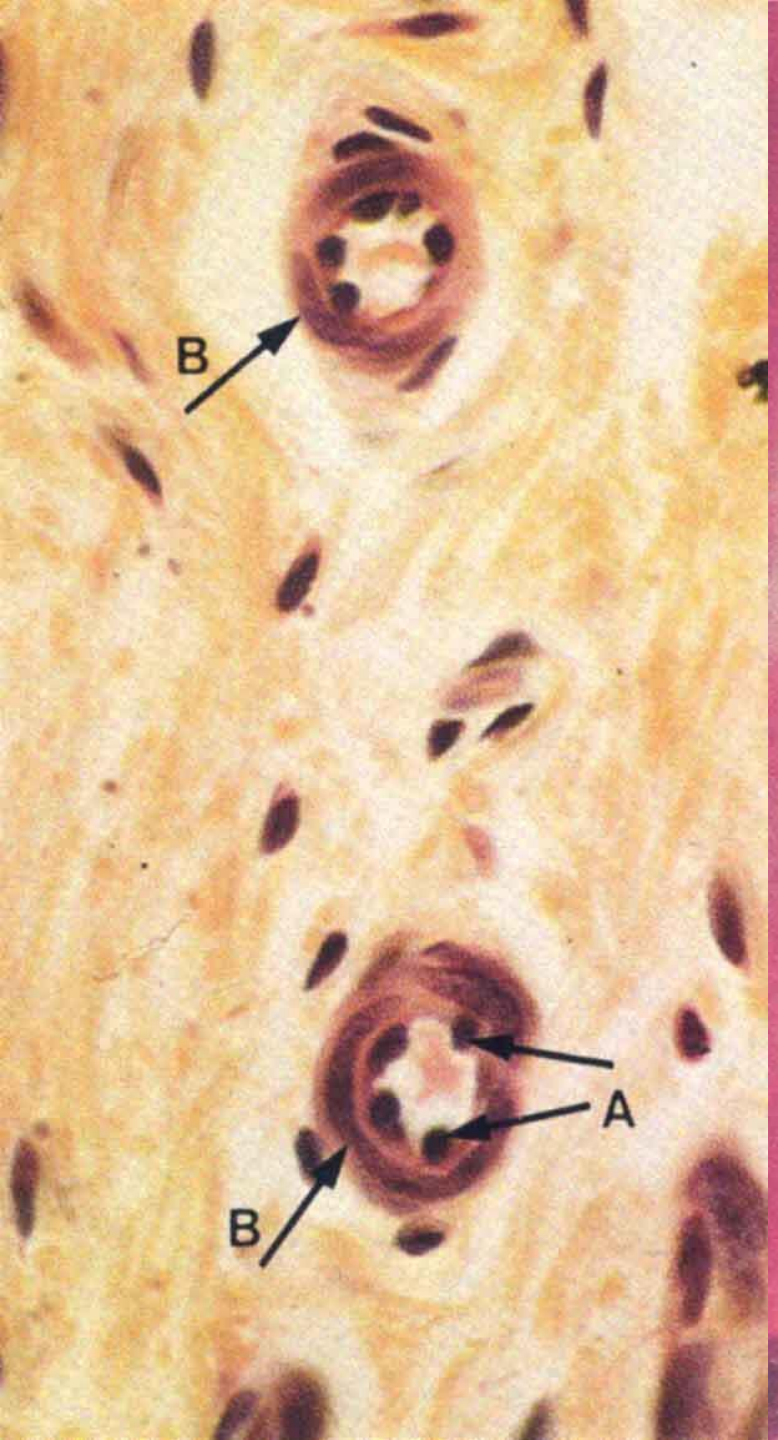


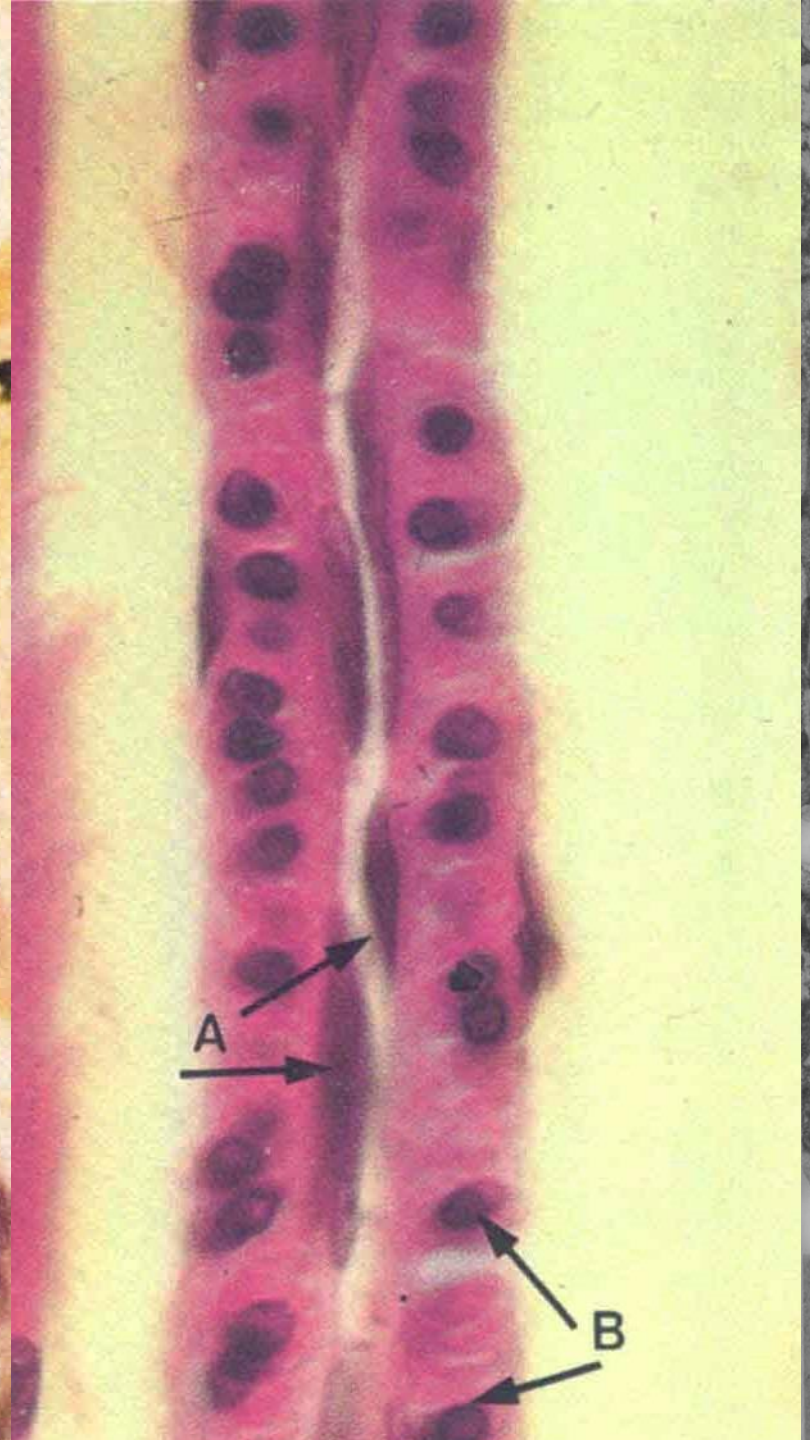
Muscular arteries have dominant media with SM cells

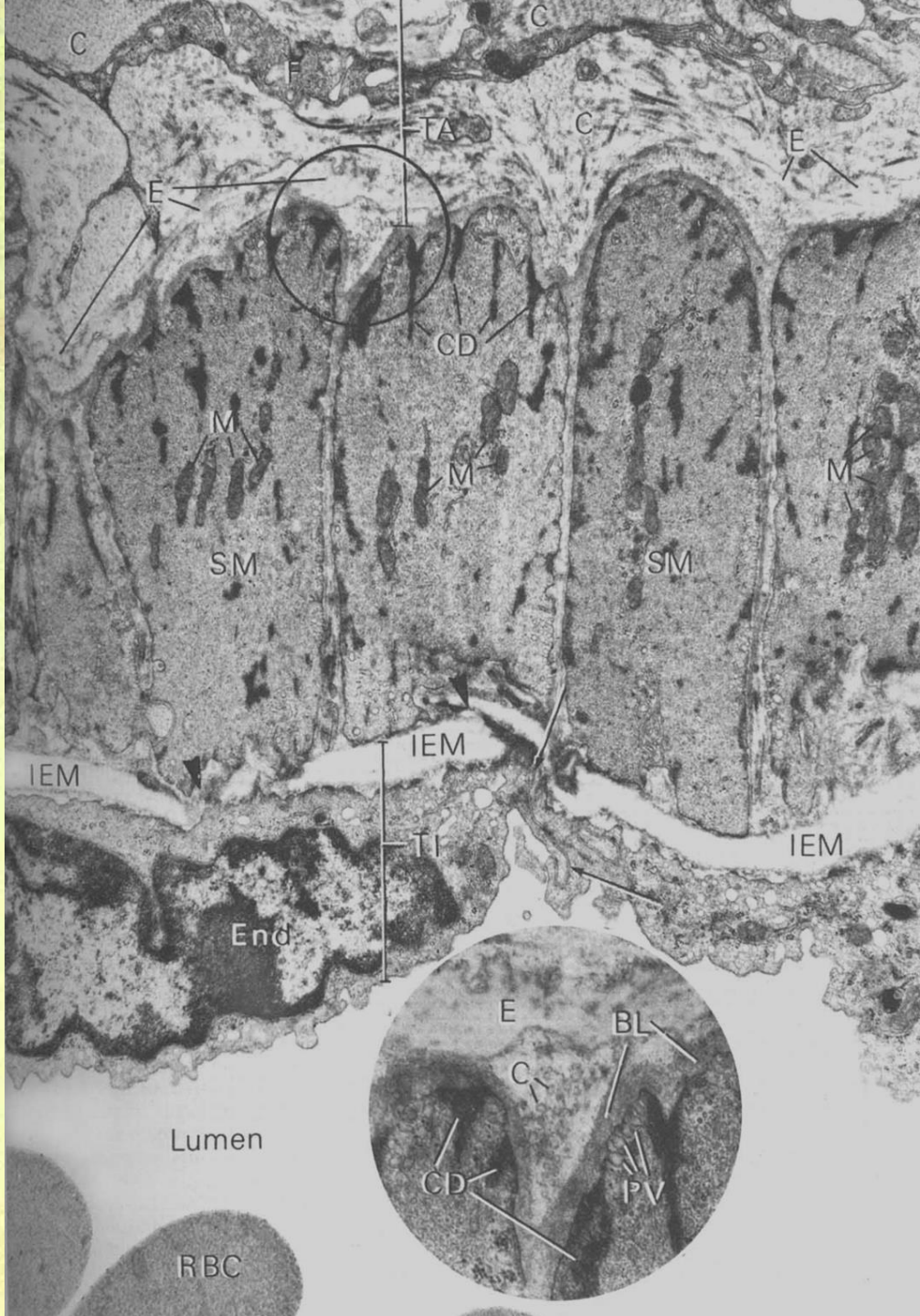


An arteriole has one or two layers of SM. The elastic laminae are absent. The subendothelial layer and adventitia are absent.



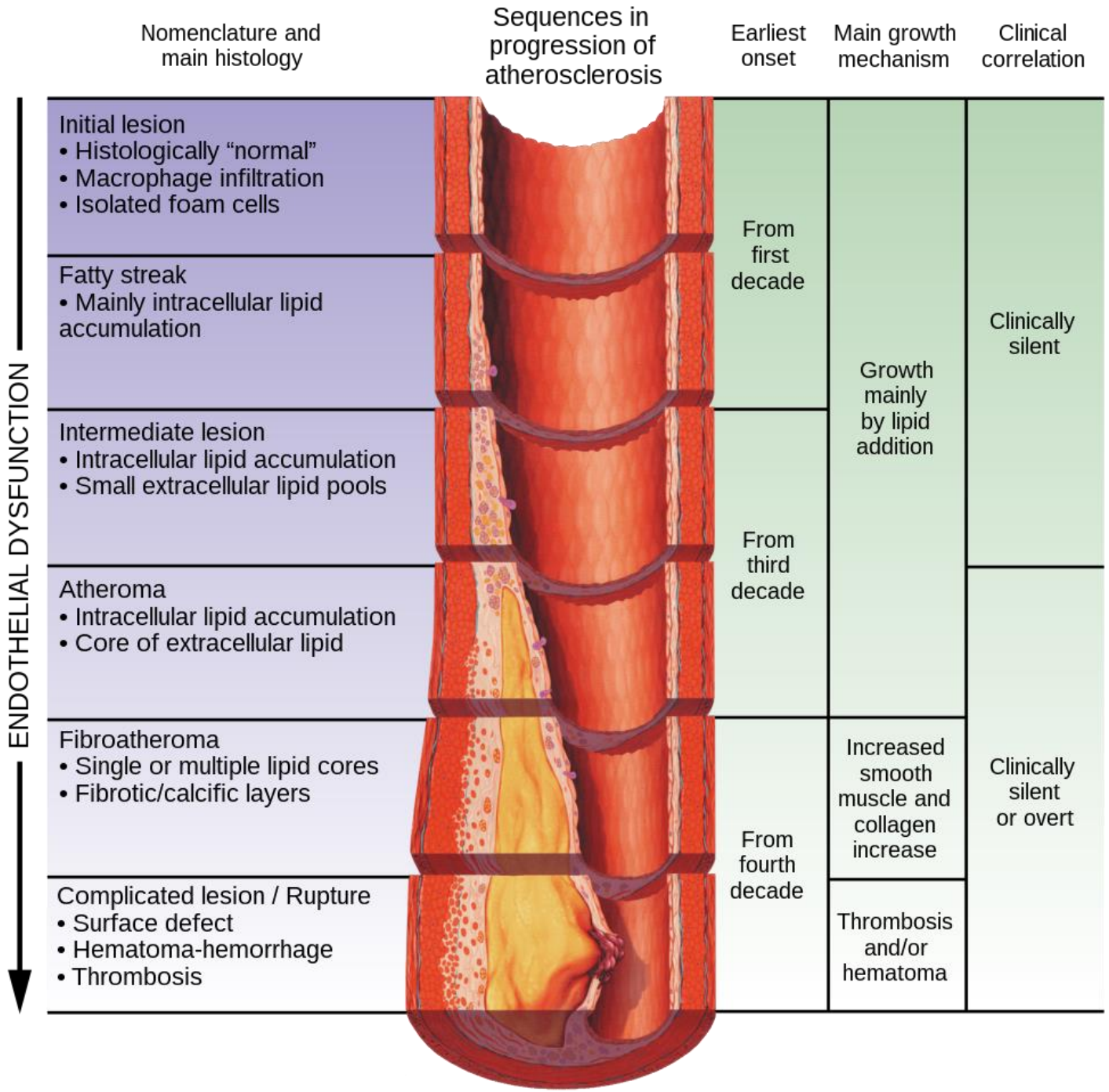

B
A
B


A
B

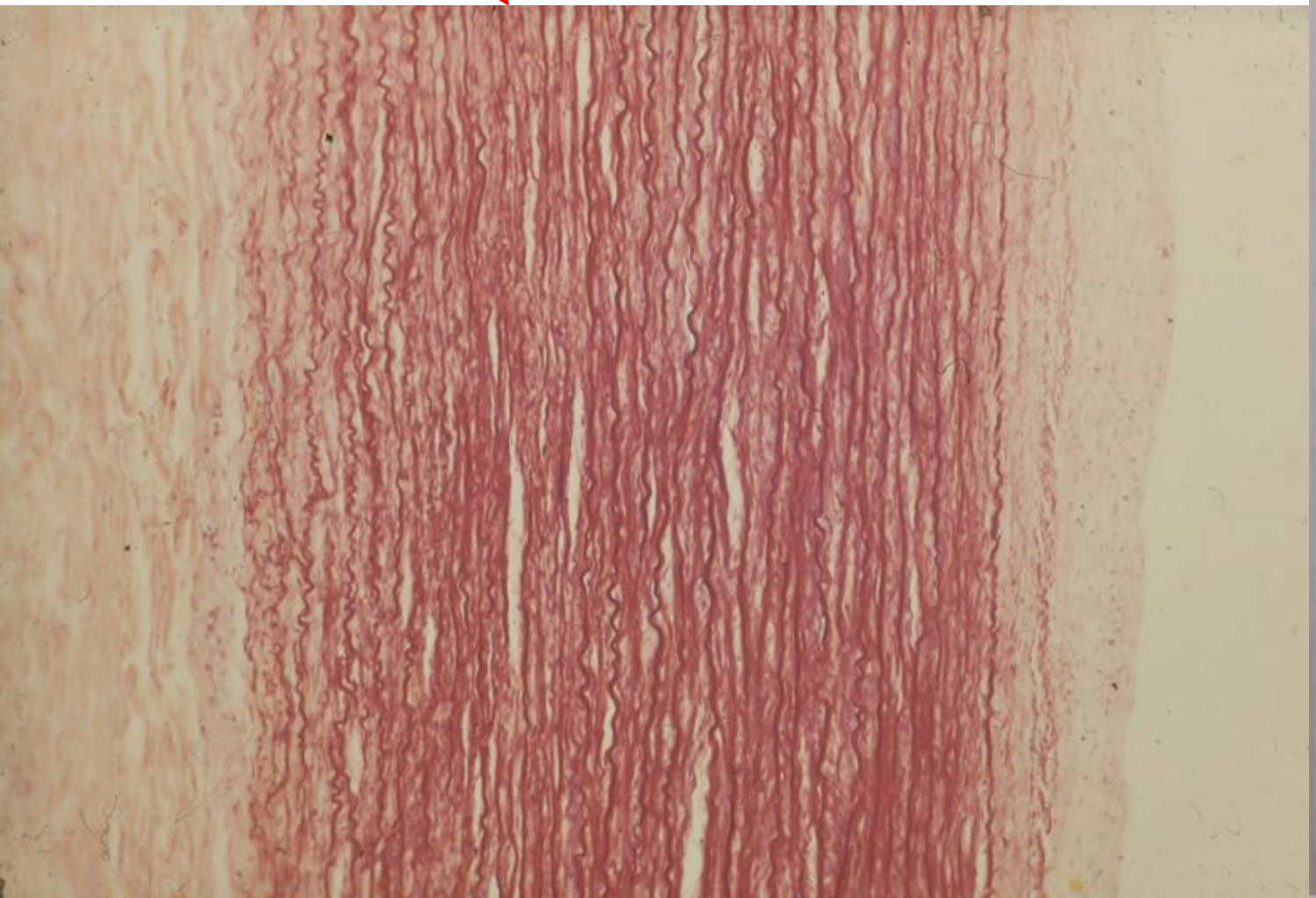

C
F
C
TA
C
E
E
CD
M
M
M
SM
SM
IEM
IEM
IEM
TI
End
E
BL
C
Lumen
CD
PV
RBC

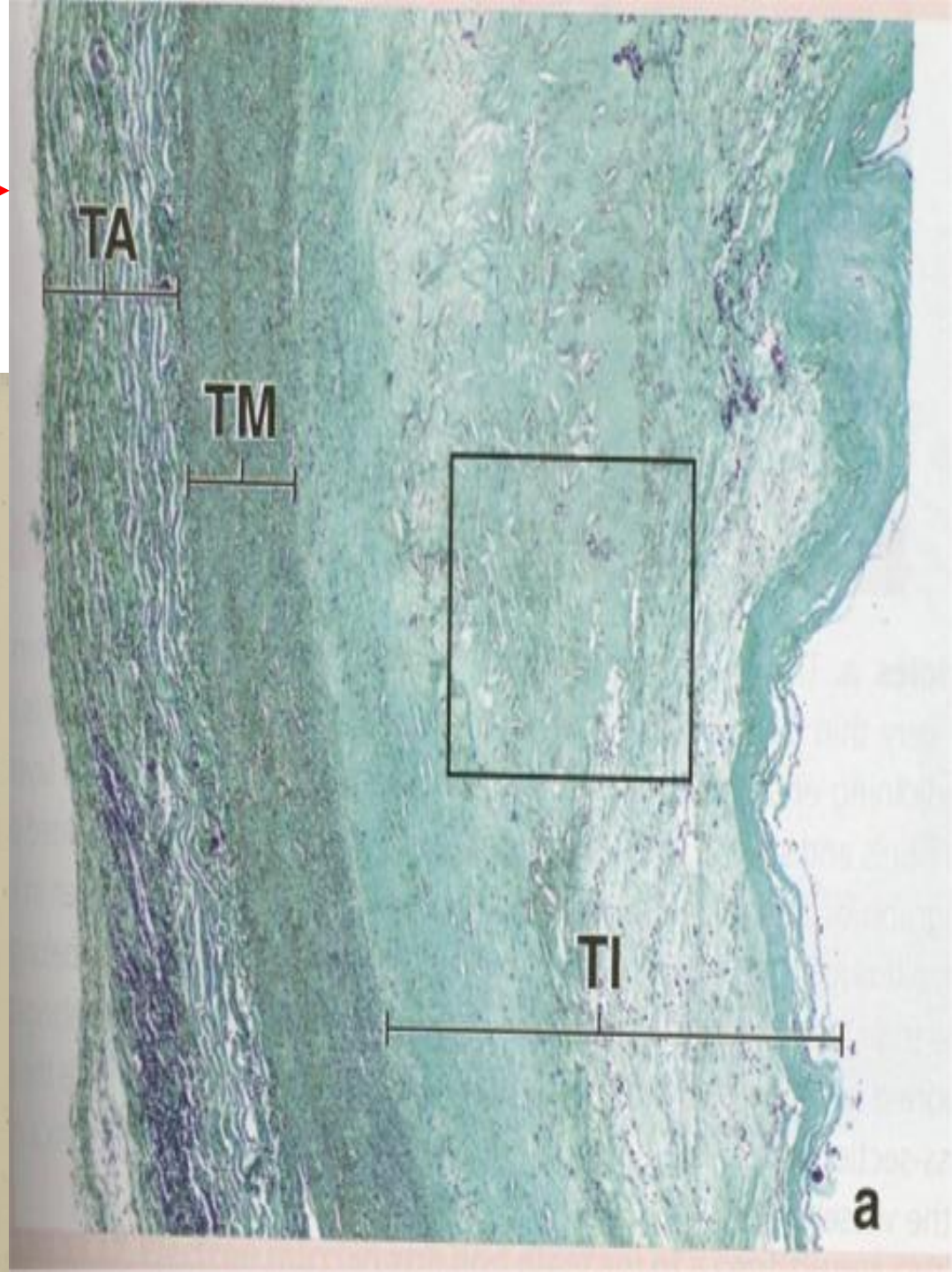
In atherosclerosis, lipids build up in the intima, especially inside macrophages (foam cells). Inflamation further damages the intima, leading to formation of necrotic calcified fibroatheroma. High levels of LDL (a type of cholesterol transporting particle) and diabetes are among the factors accelerating this proces.

Thickening of the intima can obliterate the vessel lumen. The blood flow becomes turbulent, further straining the endothelium and exacerbating the condition. Rupture of the plate causes thrombosis.



Normal vs. atheroma

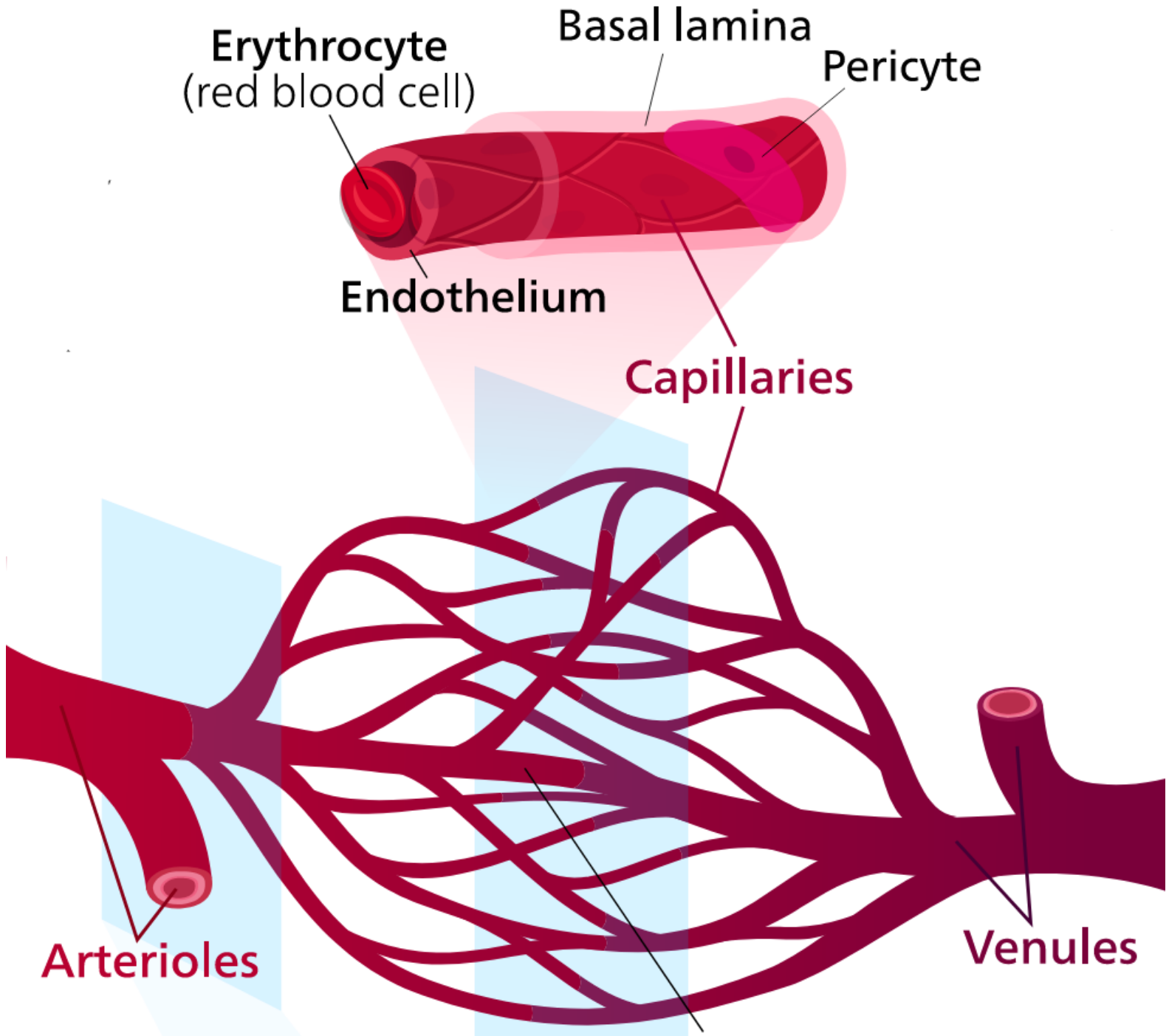




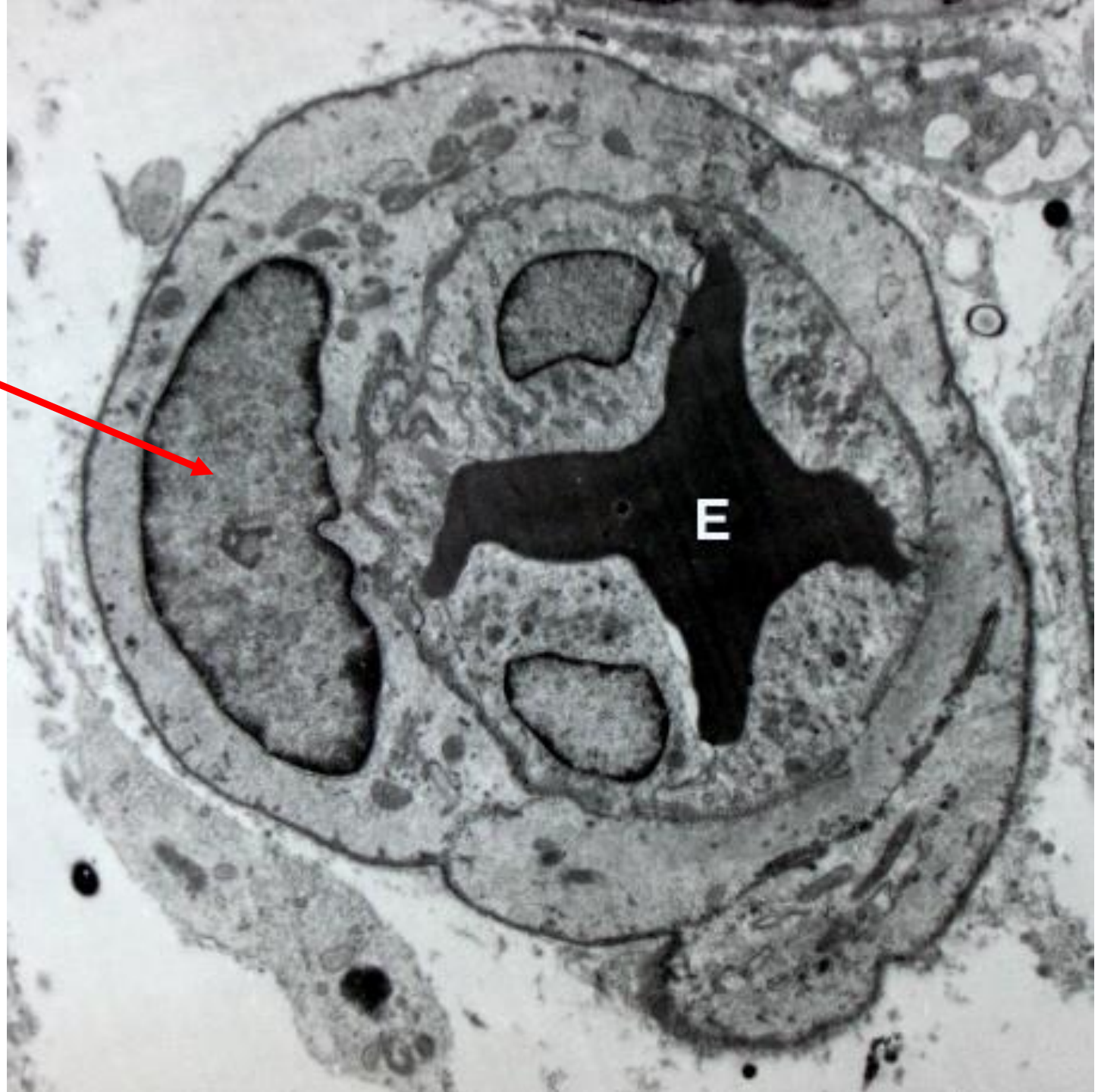
Atherosclerosis and disease

1. Can you name some diseases caused by atherosclerosis? Which vessel type is affected?

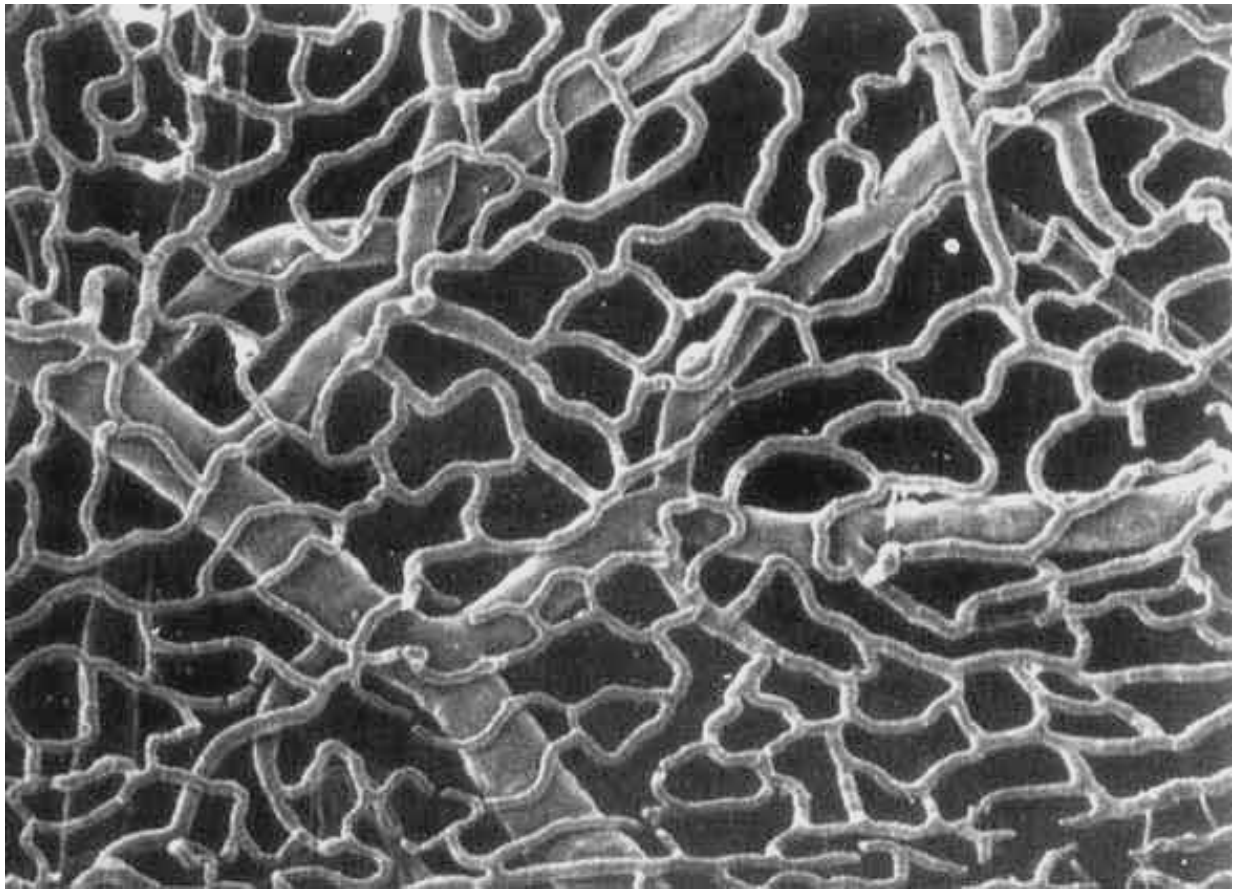
2. How can we prevent atherosclerosis?

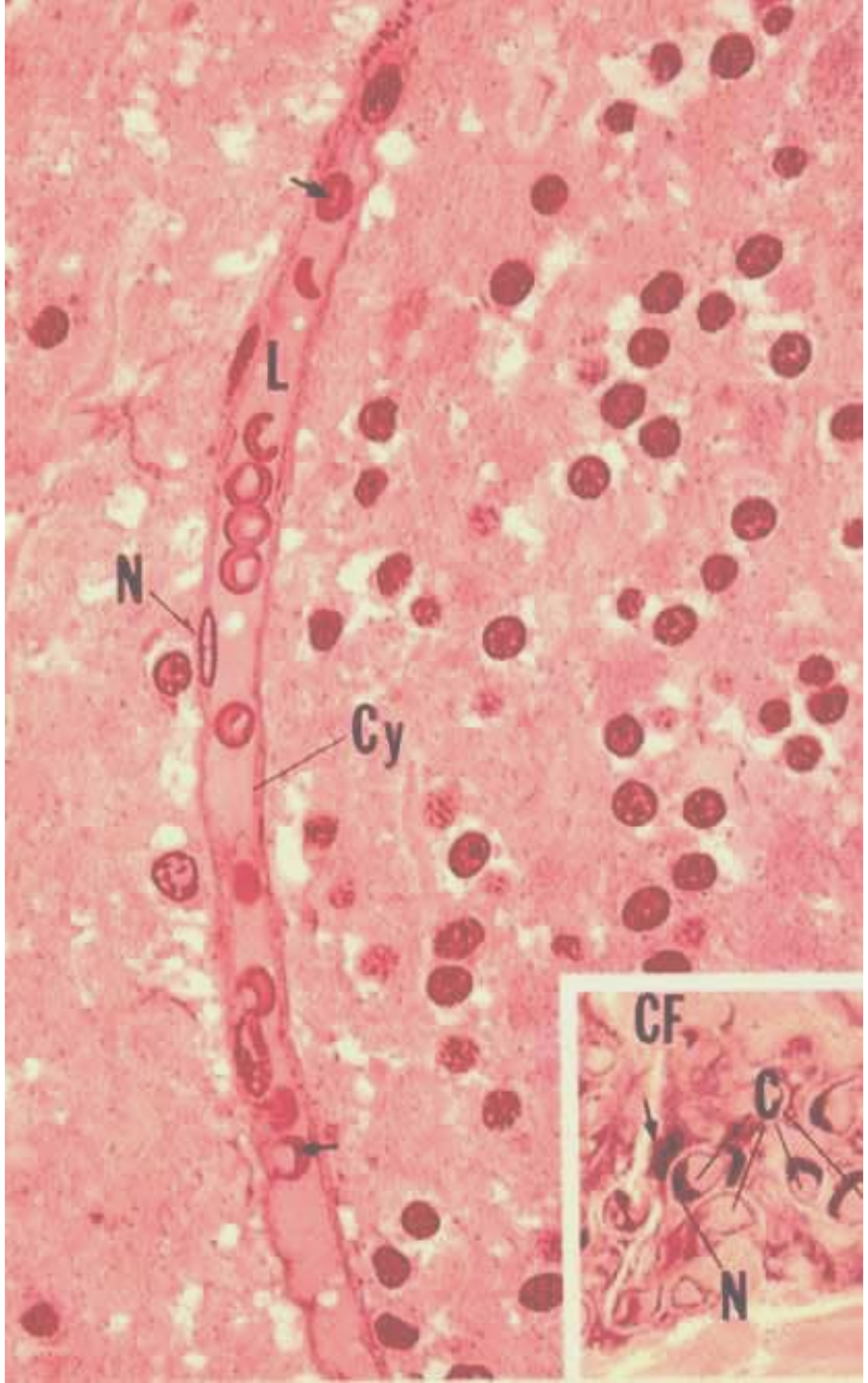

Erythrocyte
(red blood cell)
Basal lamina
Pericyte
Endothelium
Capillaries
Arterioles
Venules

Sometimes the capillary is found to be surrounded by a pericyte. Pericytes contain contractile apparatus similar to SM cells. They also play a role in tissue regeneration.

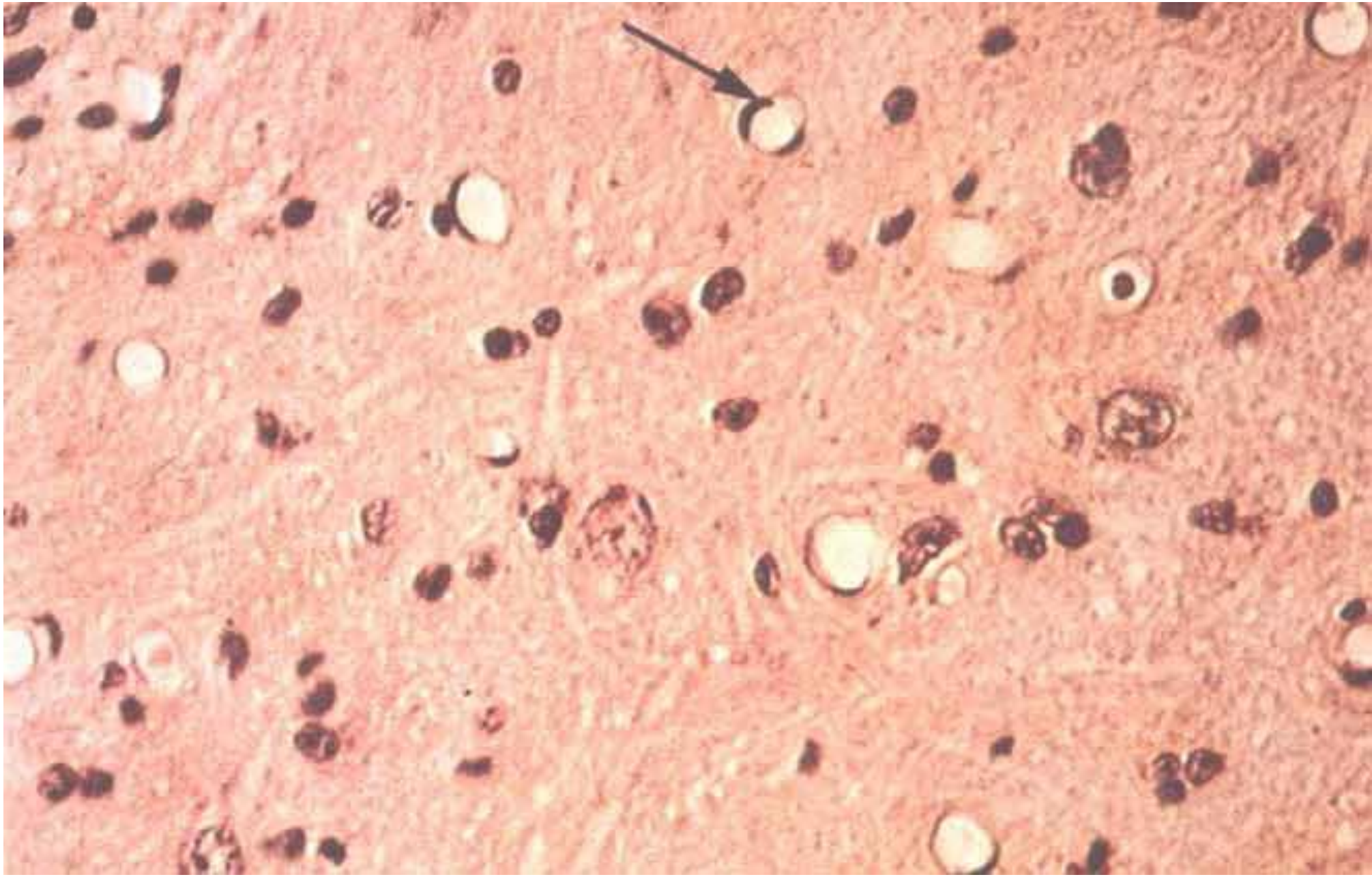


Capillaries in numbers: diameter 4 – 10 micrometers, total length 100000 km, total area 5000 square meters



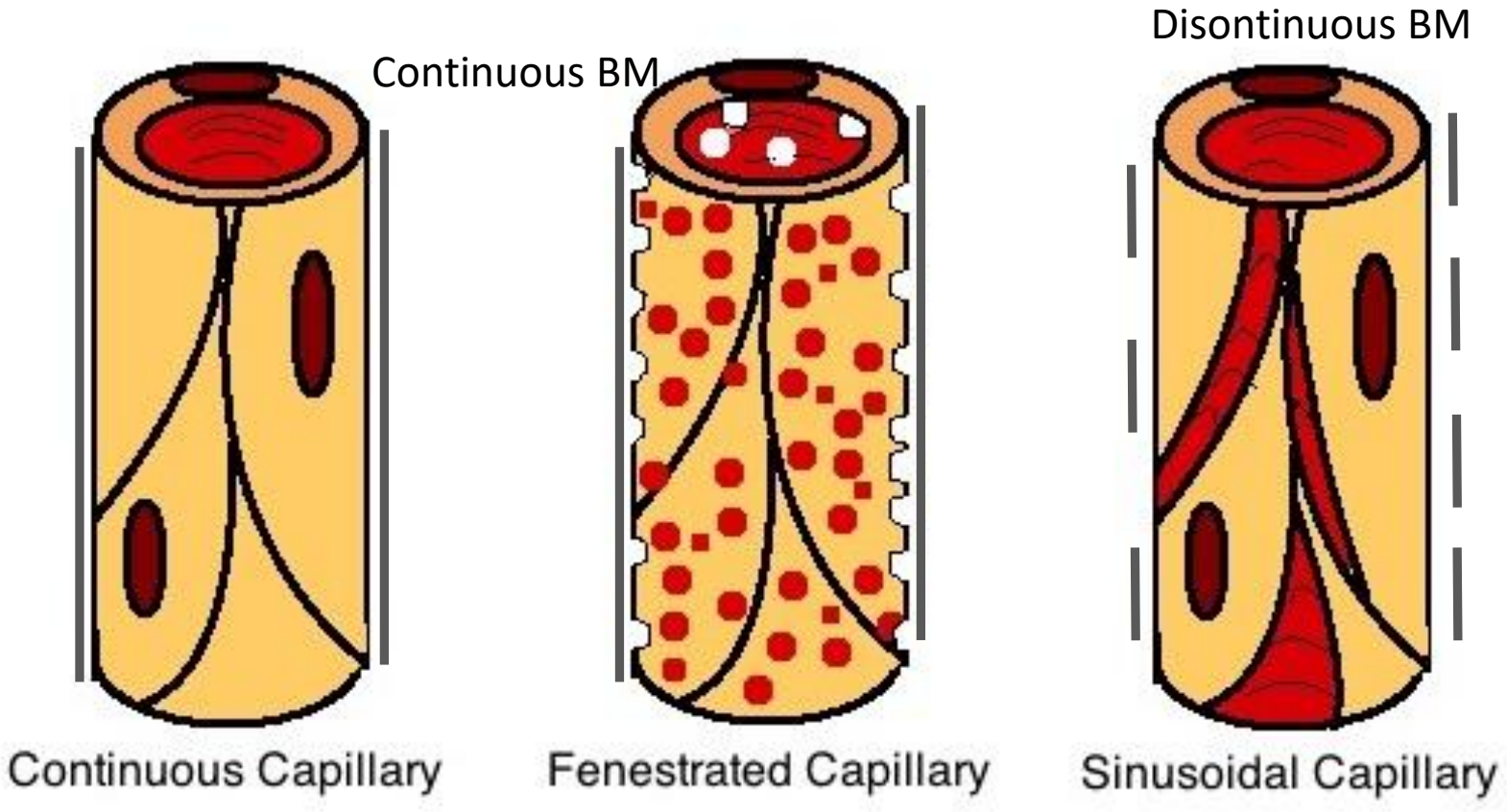


Cross-section through capillaries. Ring-like appearance with flat curved nuclei of endothelial cells.

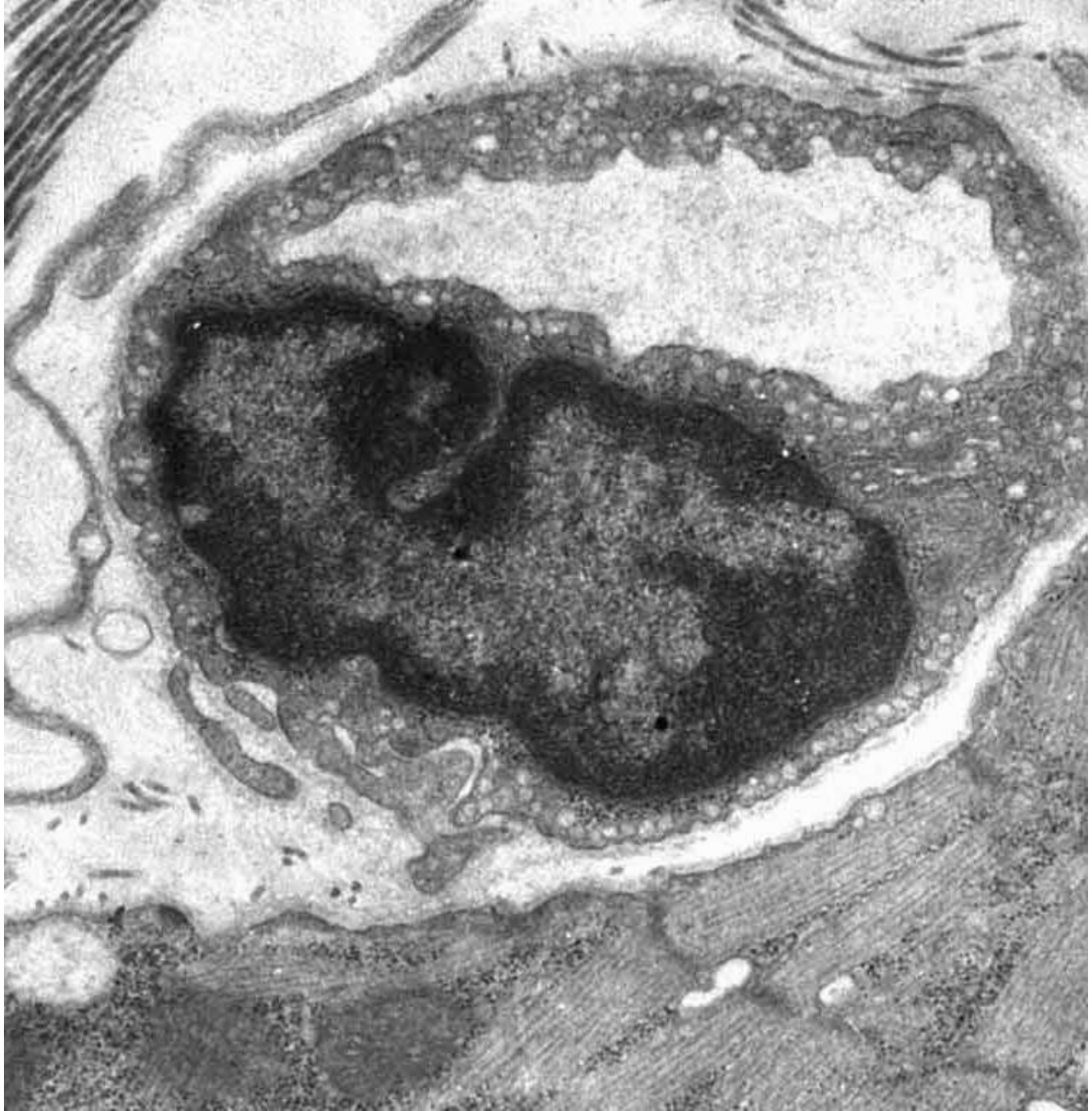


Capillary types

- Continuous
  - Muscle, nervous tissue
- Fenestrated
  - Fenestrations with diaphragm
  - Intestine, endocrine glands
- Capillaries with pores
  - No diaphragm, in glomeruli in kidney
- Sinusoids
  - Both endothelia and BM discontinuous, large diameter
  - Spleen, liver, bone marrow

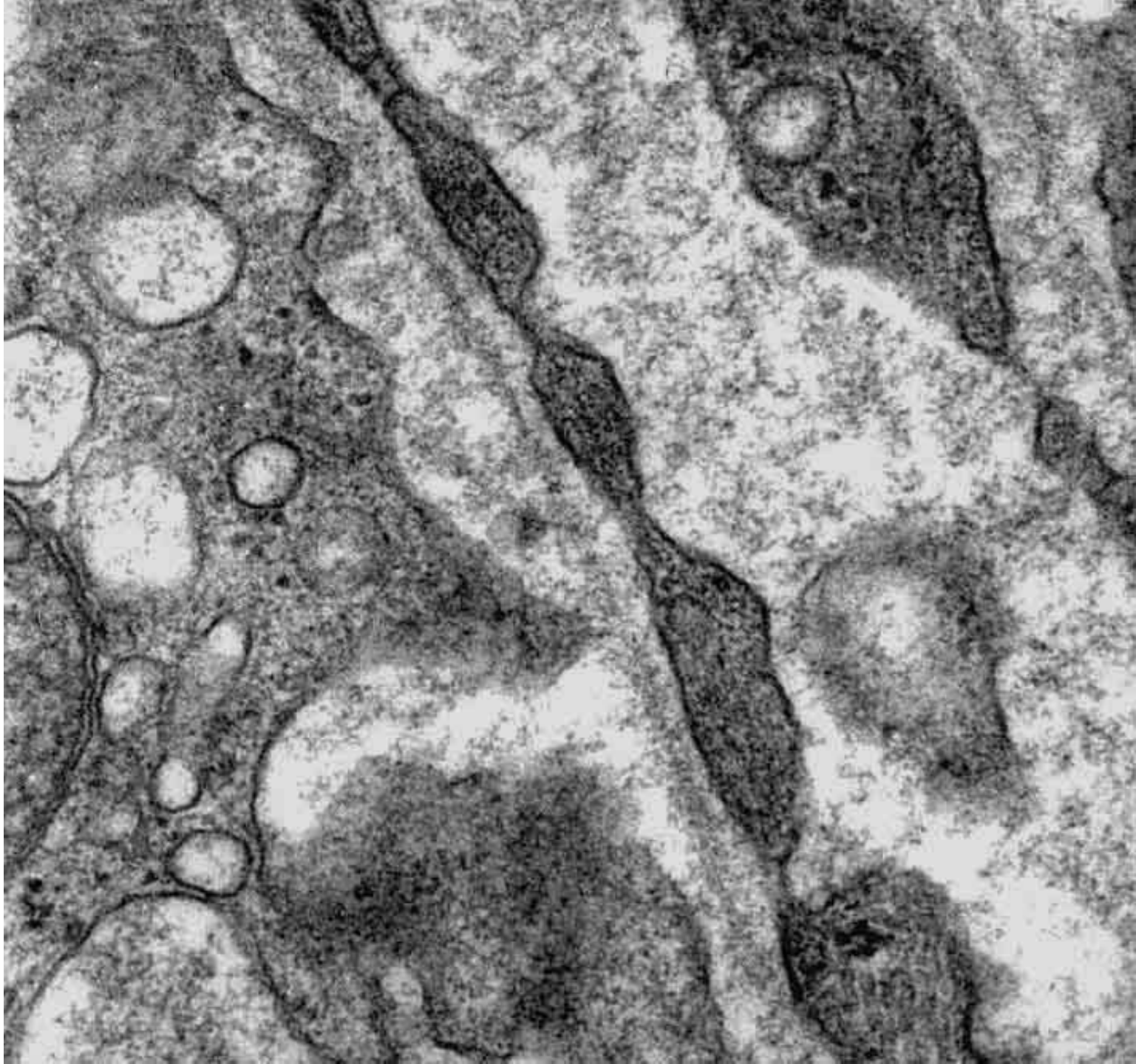


Continuous capillary in muscle. The endothelial cell is continuous. In the surrounding region you can see collagen fibrils and myofibrils.

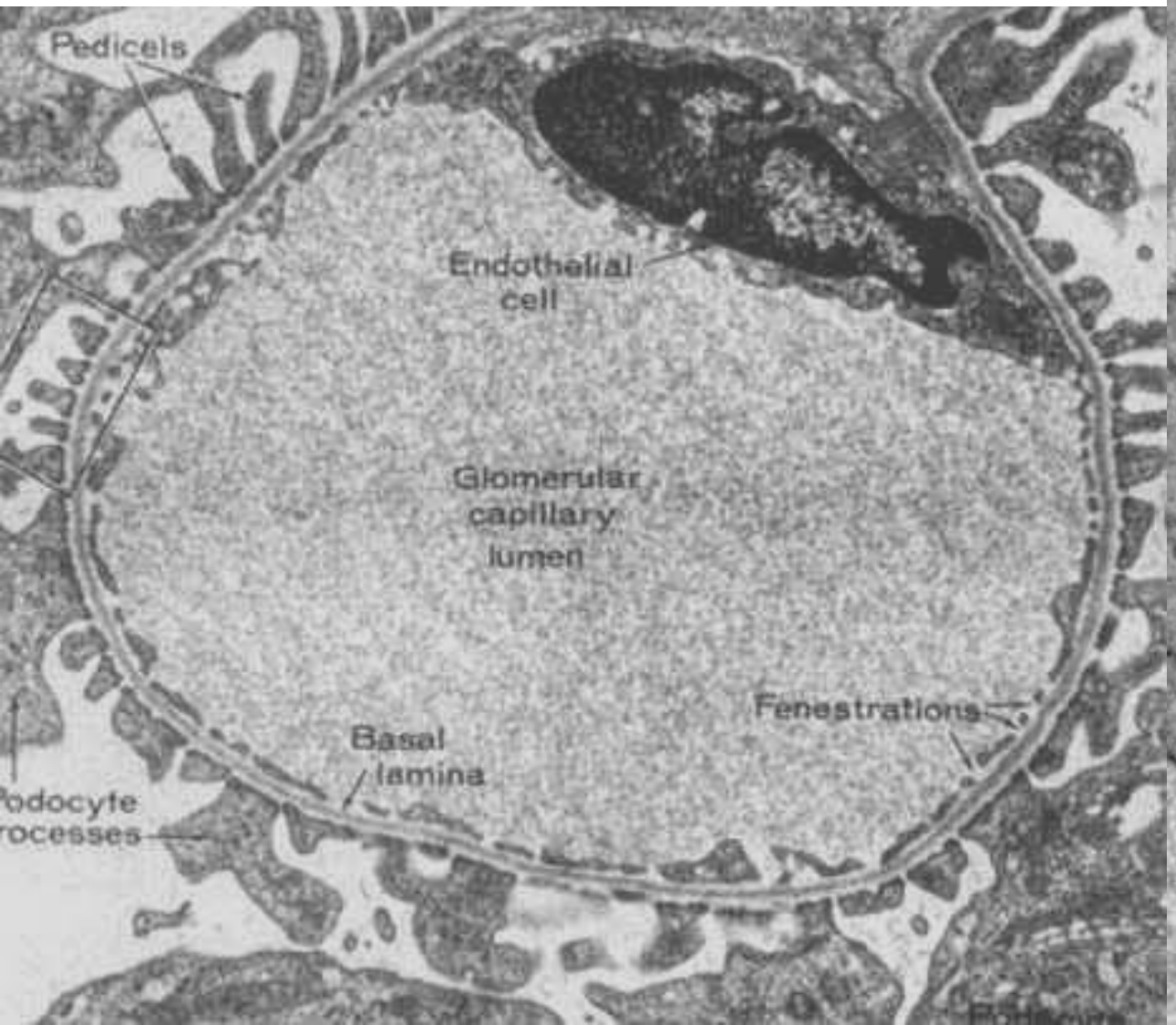


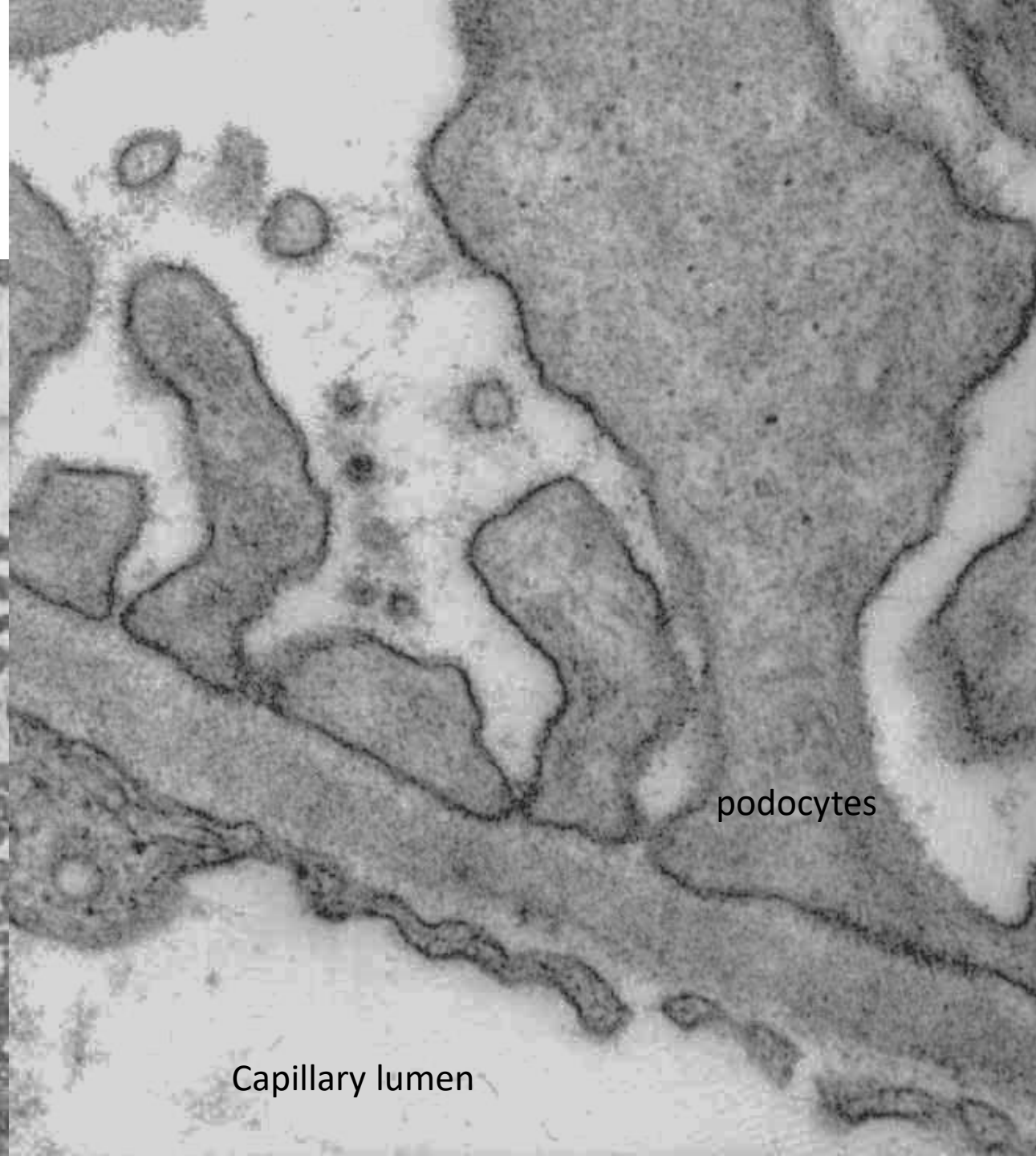
Capillary in the pancreatic tissue. Note numerous fenestrations and vesicles. Basement lamina and collagen fibrils of reticular lamina visible just outside of epithelial cells. The erythrocyte in the vessel has typical high electron density. Surrounding pancreatic acinar cells have abundant RER.

Fenestrations

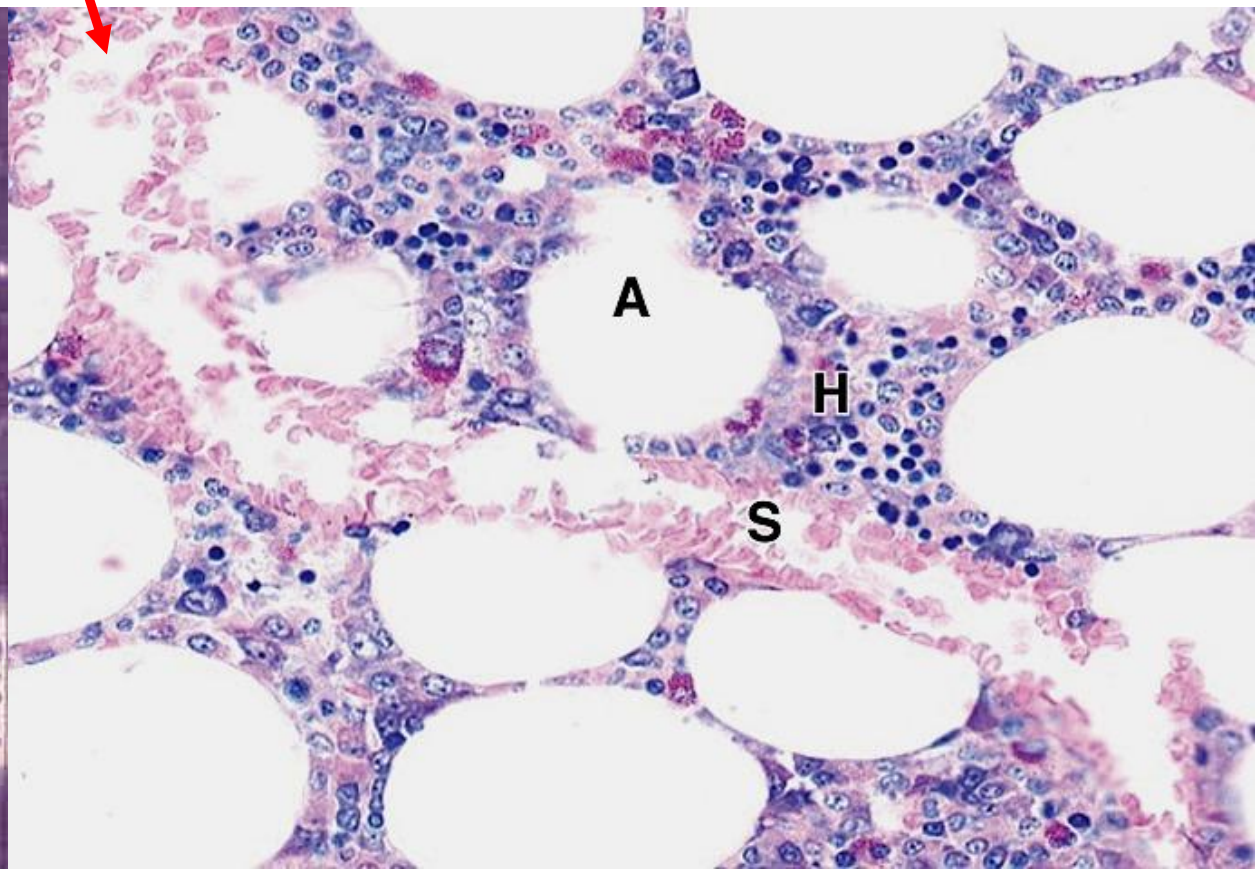


In glomerular capillaries in kidney, there are pores. Permeability is influenced by surrounding special cells (podocytes).

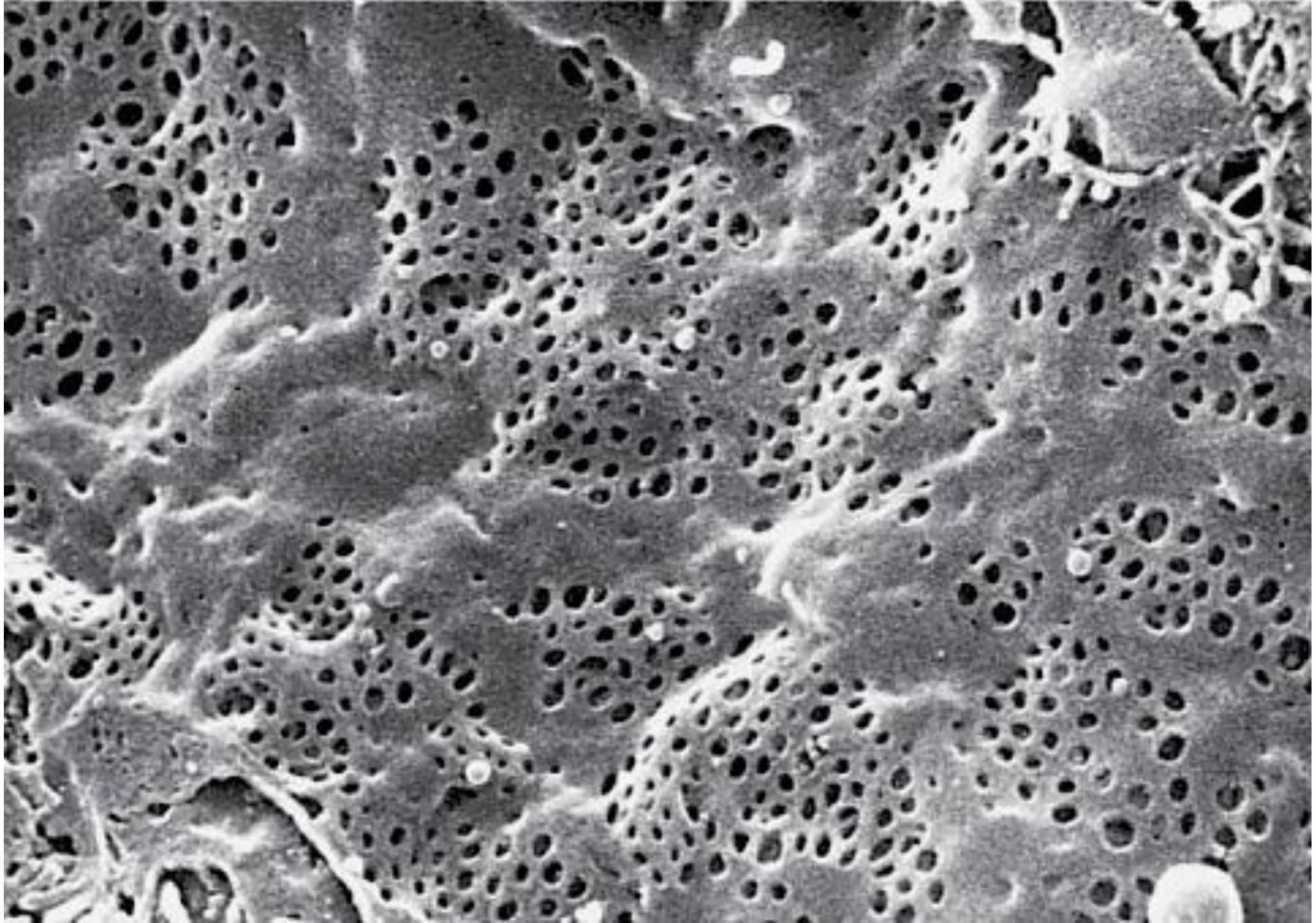




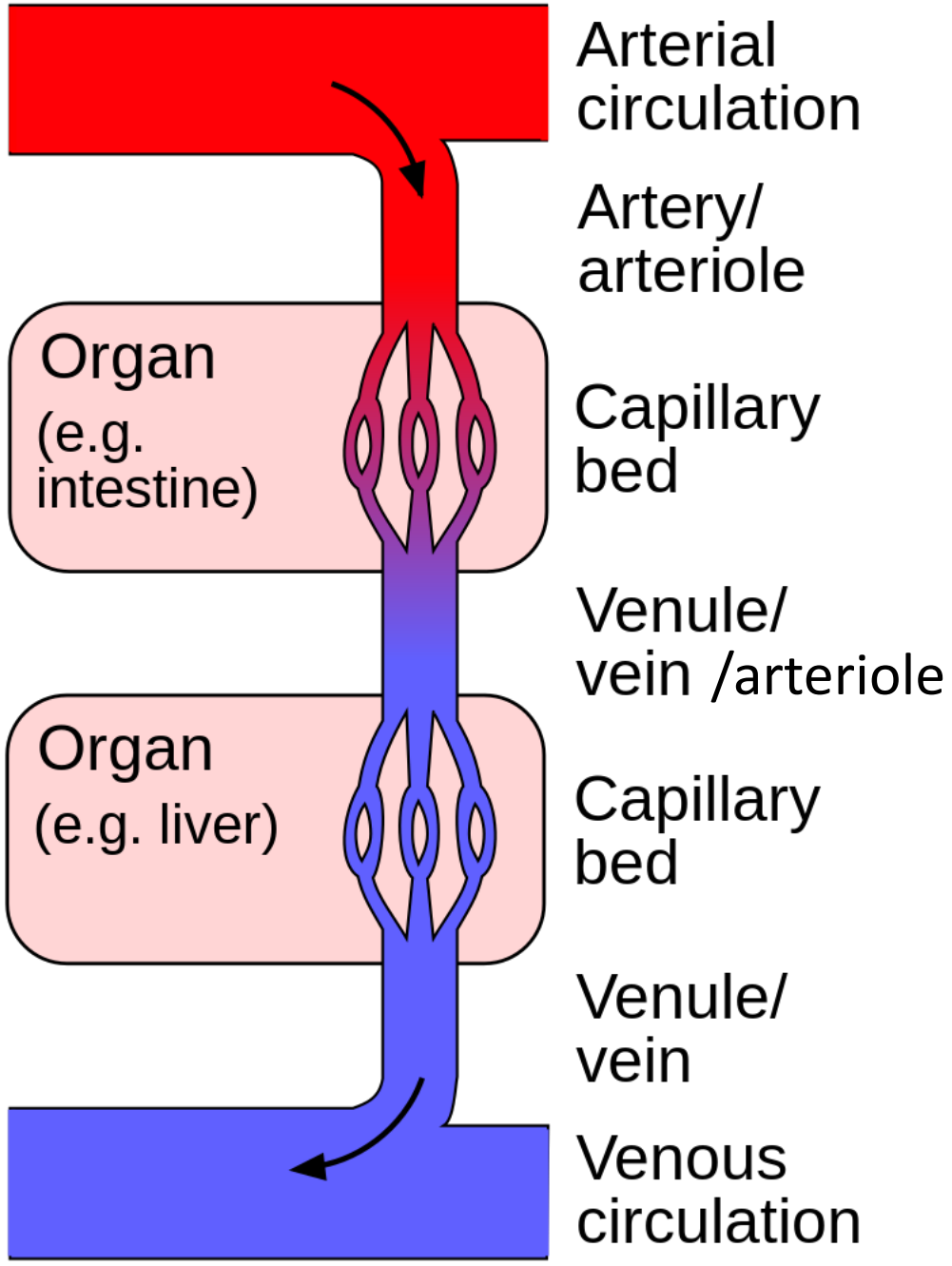
Large diameter of the sinusoids apparent in the liver and bone marrow.



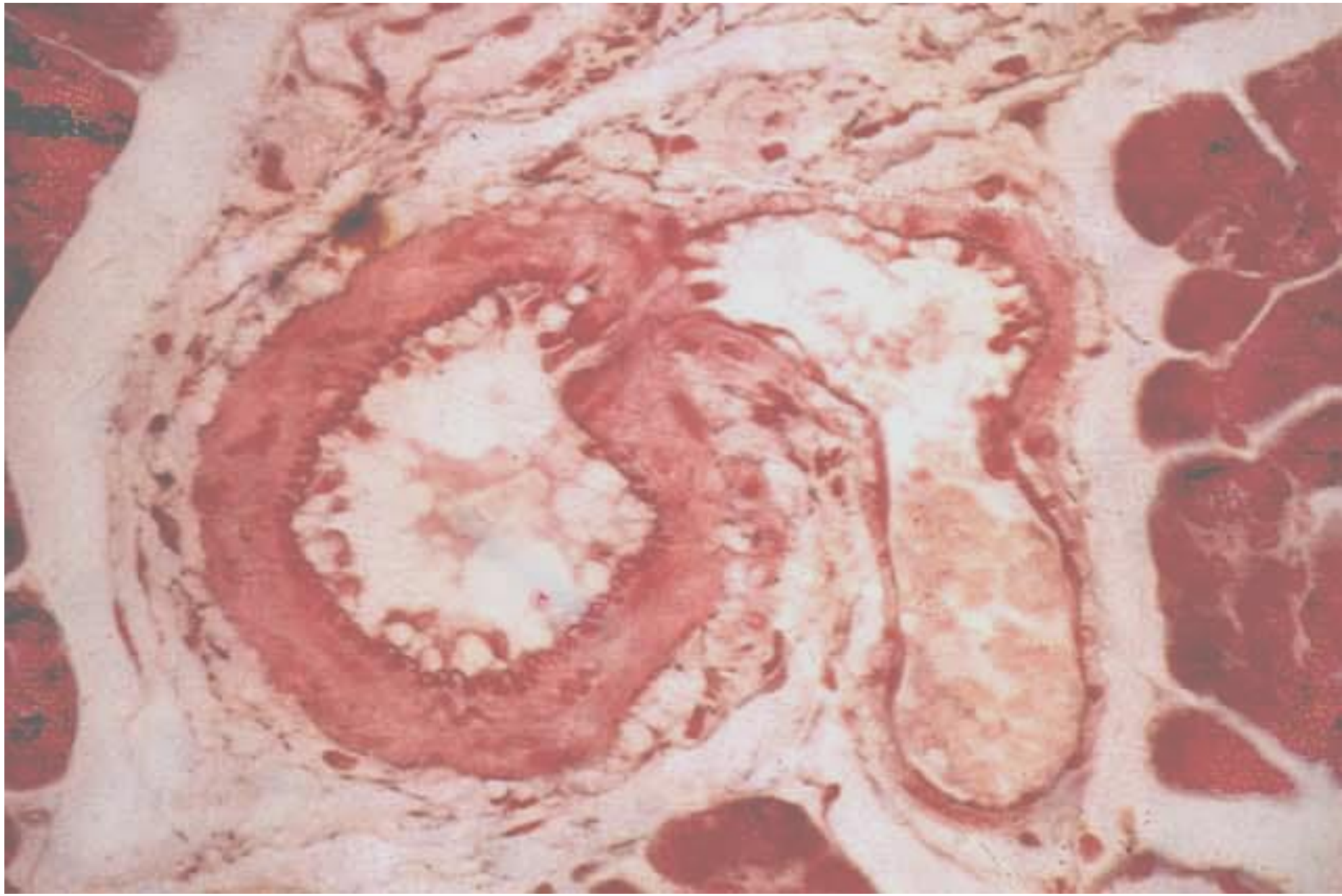
Porous endothelia of a sinusoid.



Portal system is characterized two capillary beds in a series. Portal venous system (picture) connects these two capillary beds with a vein (found in the **pituitary** and the **liver**). In portal arterial system, the capillary beds are connected by an arteriole (found in **kidney**).



AV anastomosis allows blood passage directly from an artery to a vein, bypassing the capillaries.



In diabetes capillaries are damaged among other mechanisms by the build-up of AGEs (advanced glycation end-products). This is manifested as a thickening of the basement membrane.

Normal capillary

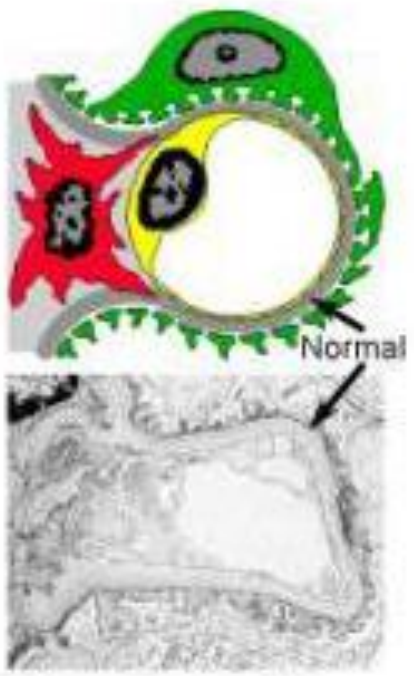
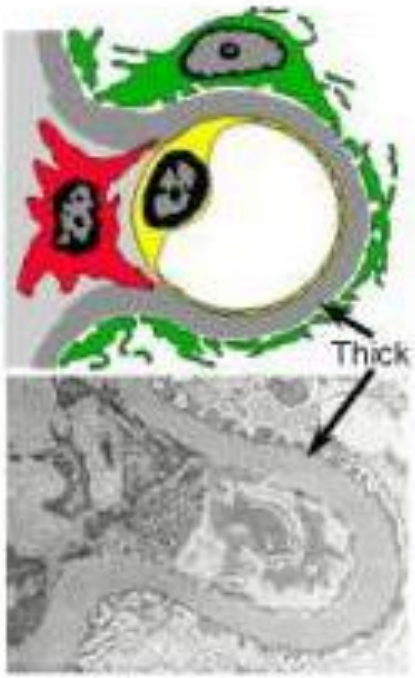


Diagram and electron microscopic photograph of a cross section of a normal glomerular capillary. The basement membrane is normal.

Diabetic capillary

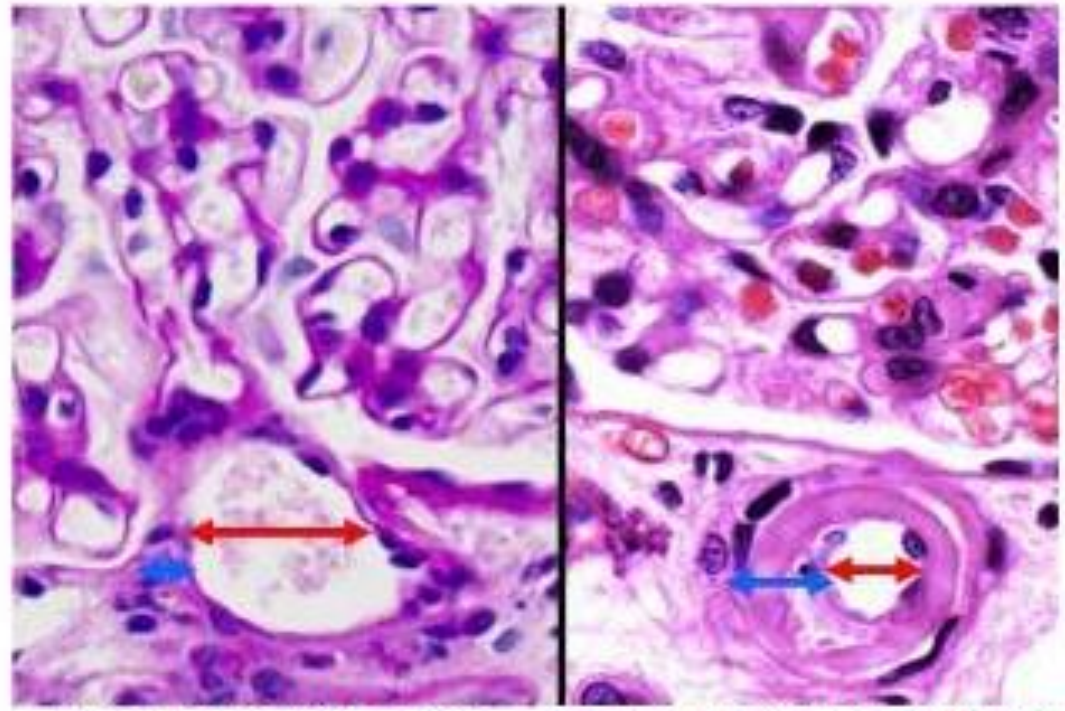


Cross section of a glomerular capillary injured by diabetes in a kidney biopsy specimen. The basement membrane is abnormally thick compared to normal.

https://unckidneycenter.org/kidneyhealthlibrary/glomerular-disease/diabetes/

Normal arteriole

Diabetic arteriole



Thin wall & wide lumen

Micoscopic photograph of a cross section of a normal arteriole next to a glomerulus. The lumen is wide open to allow normal flow of blood.

Thick wall & narrow lumen

Microscopic photograph of a cross section of an arteriole with diabetic arteriolosclerosis. The lumen is narrowed by the thick wall thus reducing flow of blood.

https://unckidneycenter.org/kidneyhealthlibrary/glomerular-disease/diabetes/

Question time - capillaries

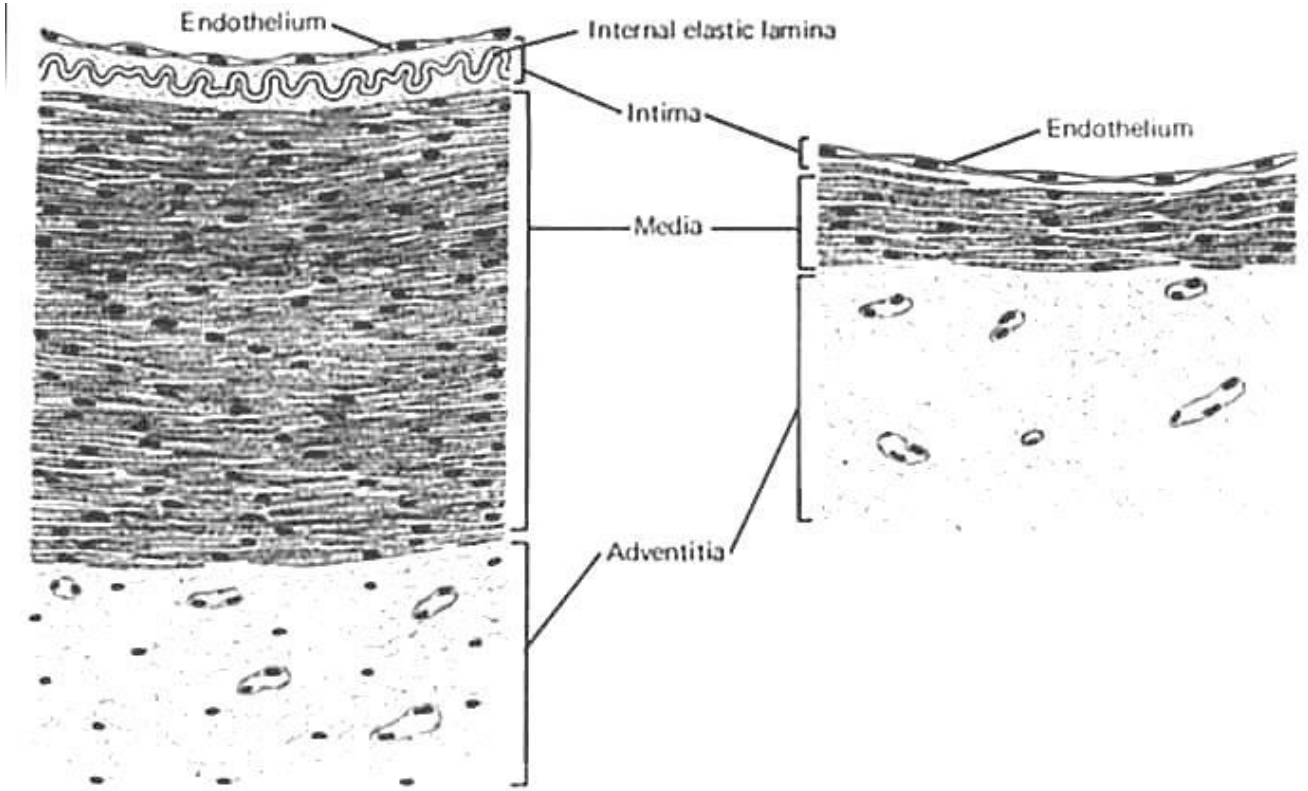
1. Describe the factors influencing the transport of metabolites and water across the capillary wall.

2. Do you know which vascular structure in the skin is important for thermoregulation?

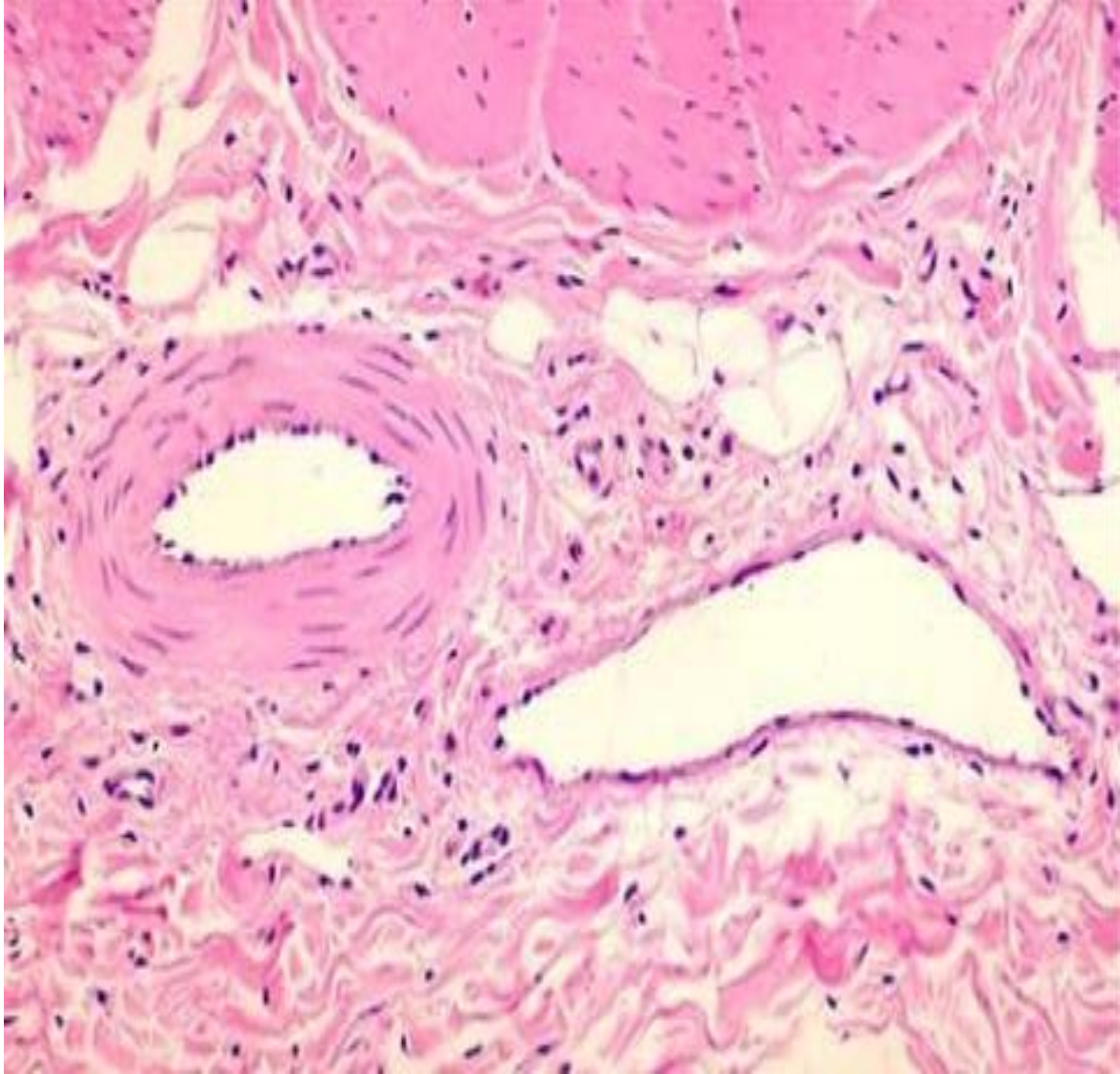
3. VEGF is a factor (signalling protein) promoting new vessel development. Do you know which diseases are dependant on formation of new vessels and thus treatable by VEGF inhibitors?

Veins

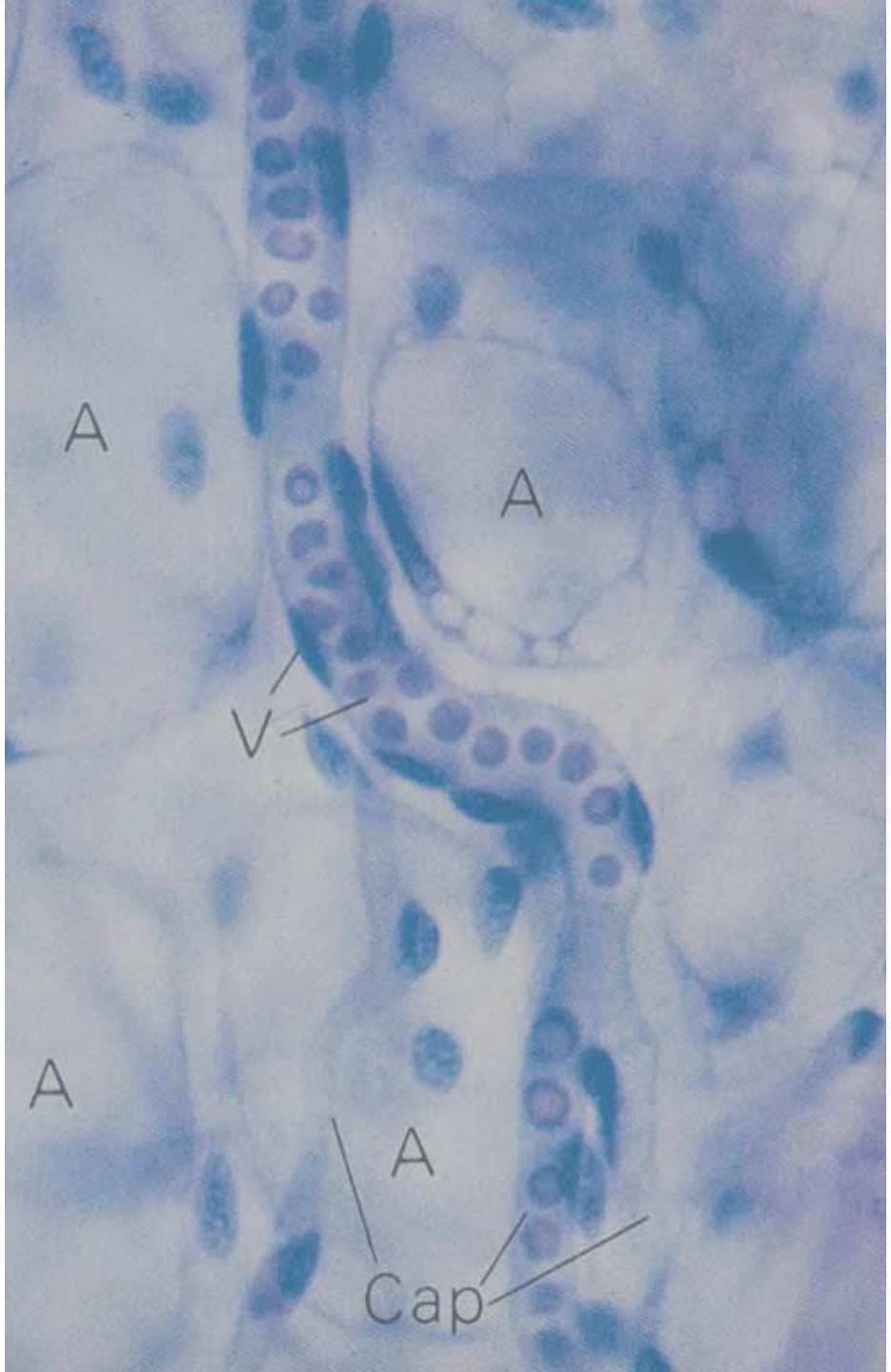
- Venules
  - Postcapillary less than 50 μm, pericytes
  - Collecting 50 - 100 μm, more contractile cells
  - Muscular up to 200 μm, distinct media with SM
- Veins
  - Small and medium under 10 mm, adventitia is the thickest
  - Large more than 1 cm, intima also produces valves



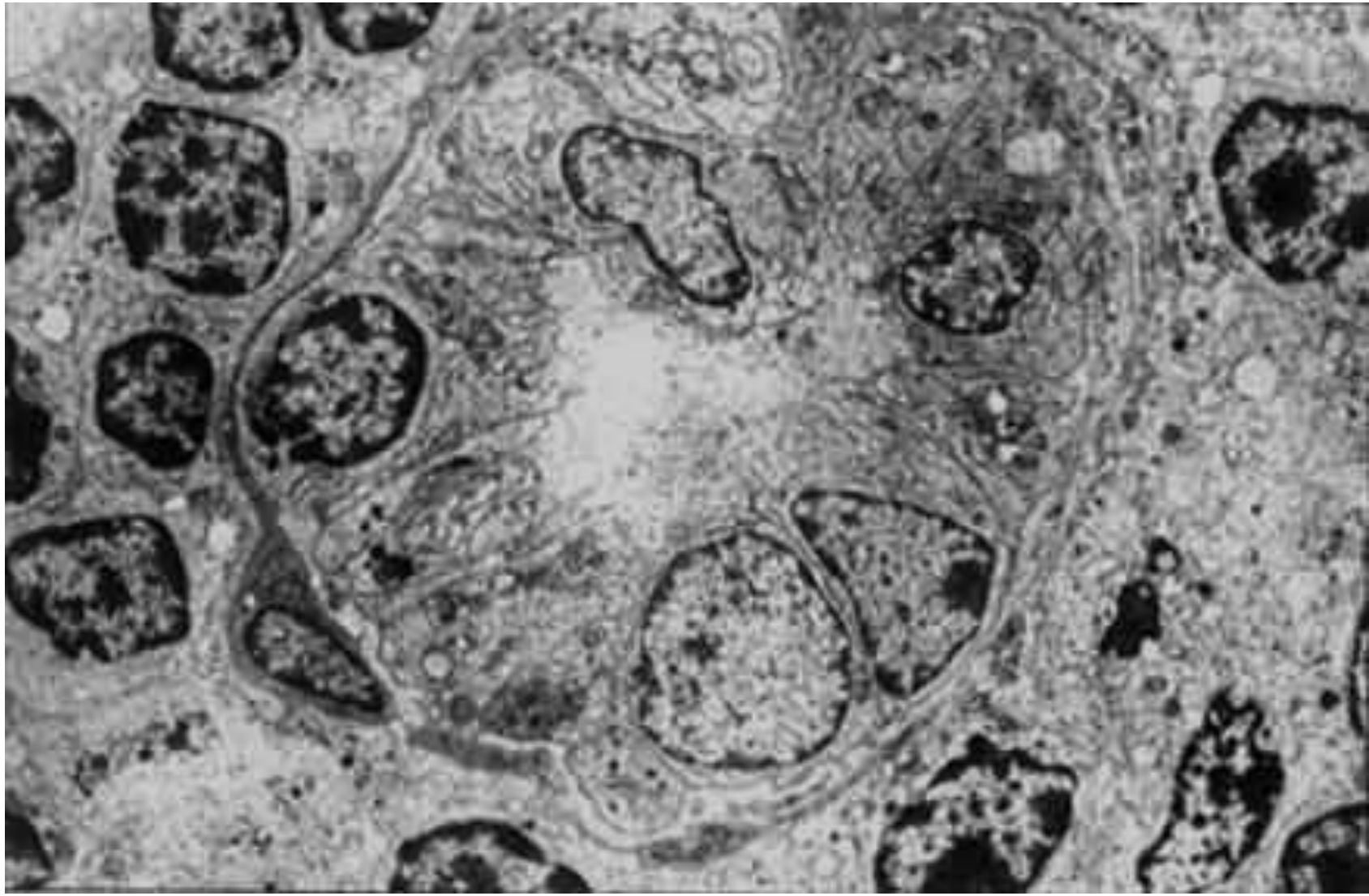
Arteriole x venule



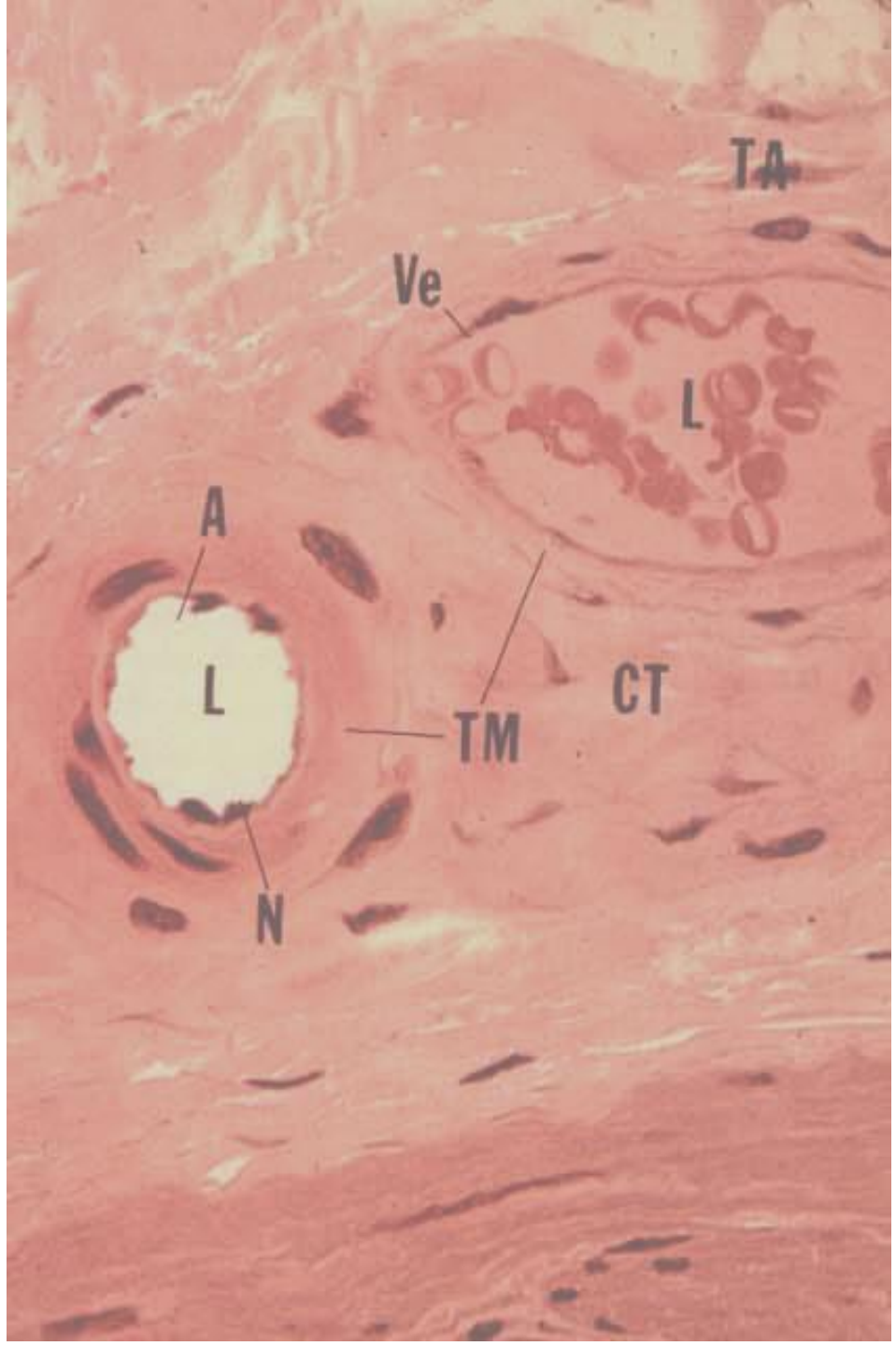
Postcapillary venule. Larger diameter than arteriole. More peircytes.



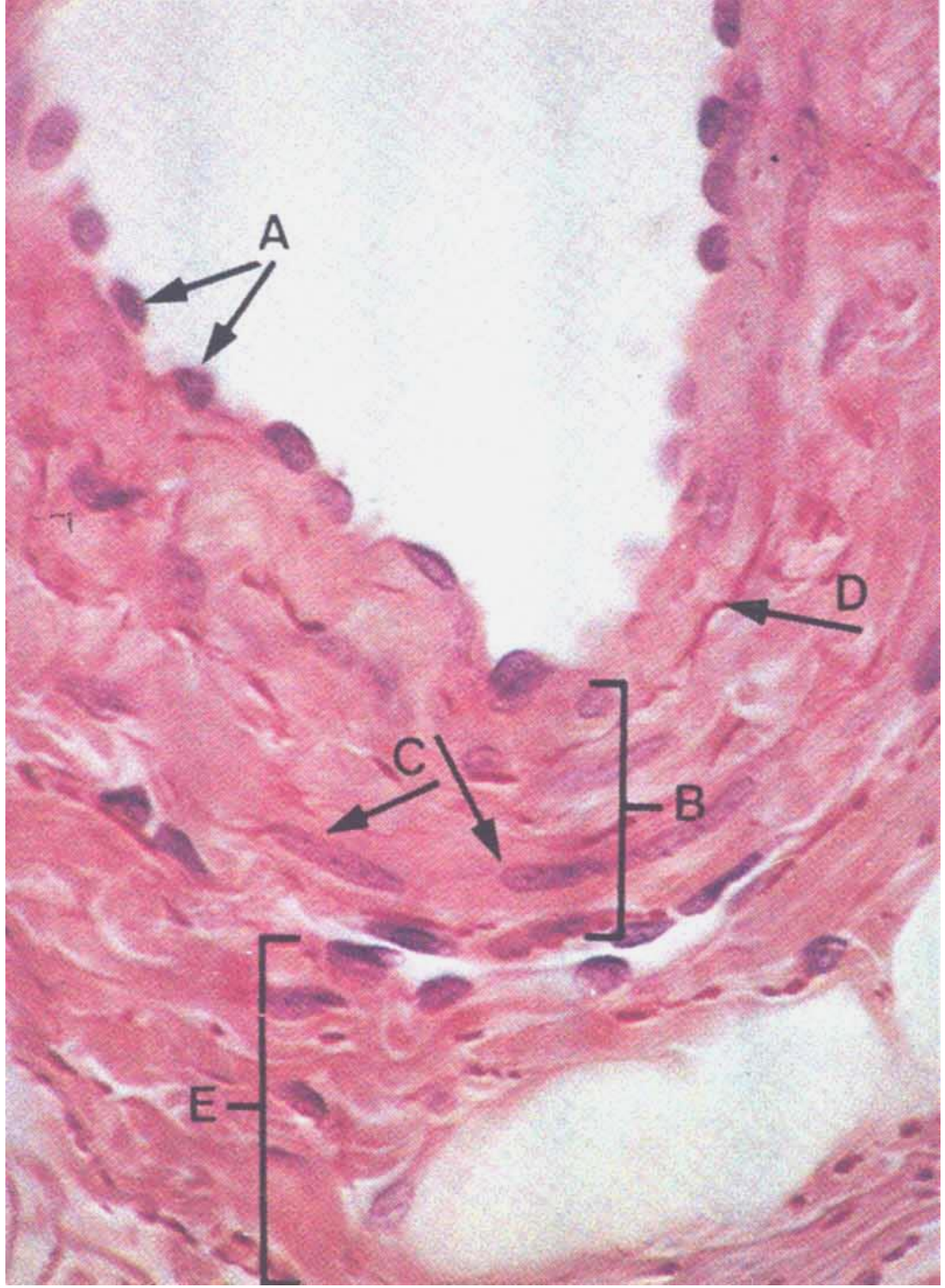
High endothelial postcapillary venule is found in organs of the lymphatic system (thymus). It allows movement of lymphocytes between the tissue and the blood.



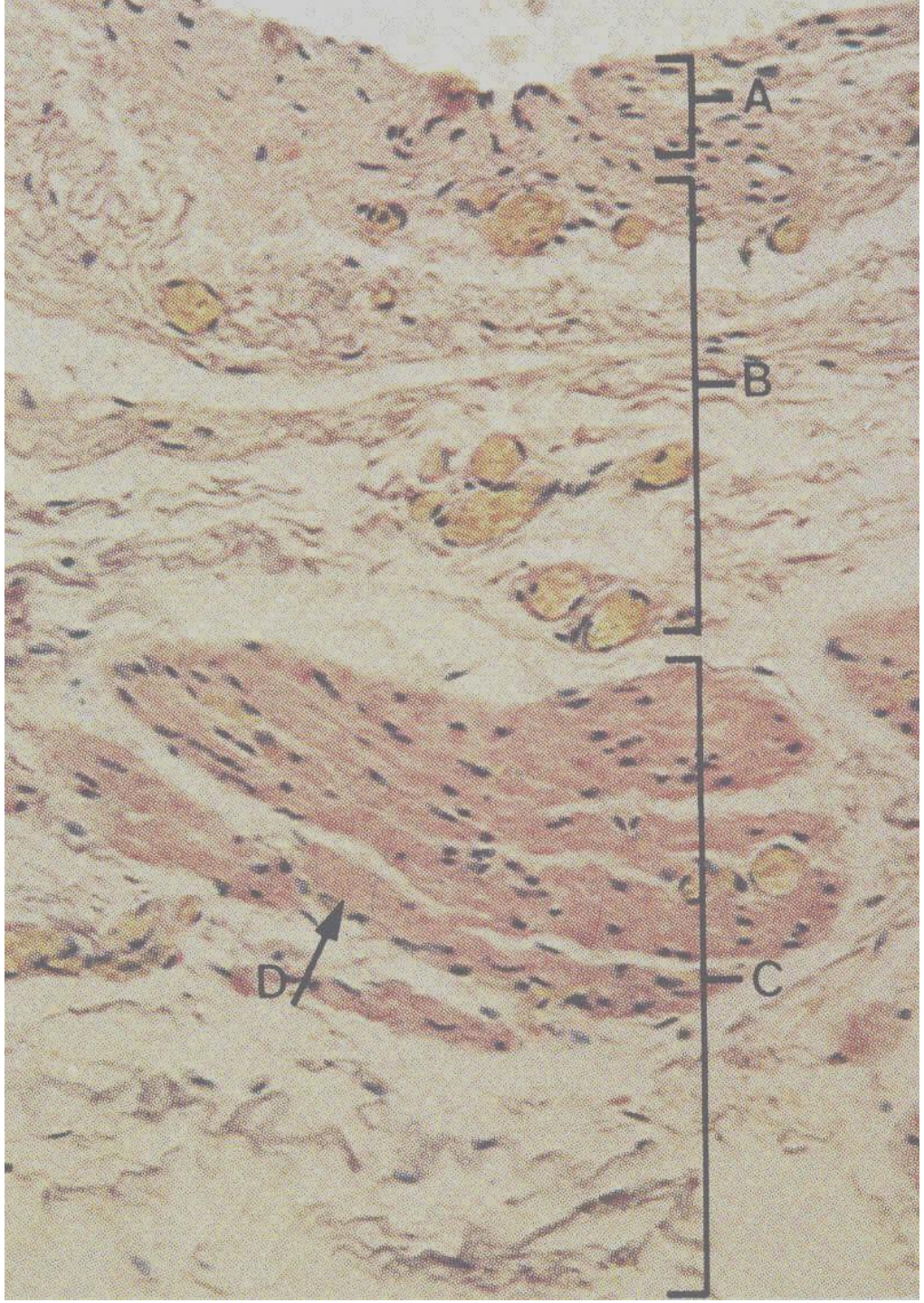
Collecting venule

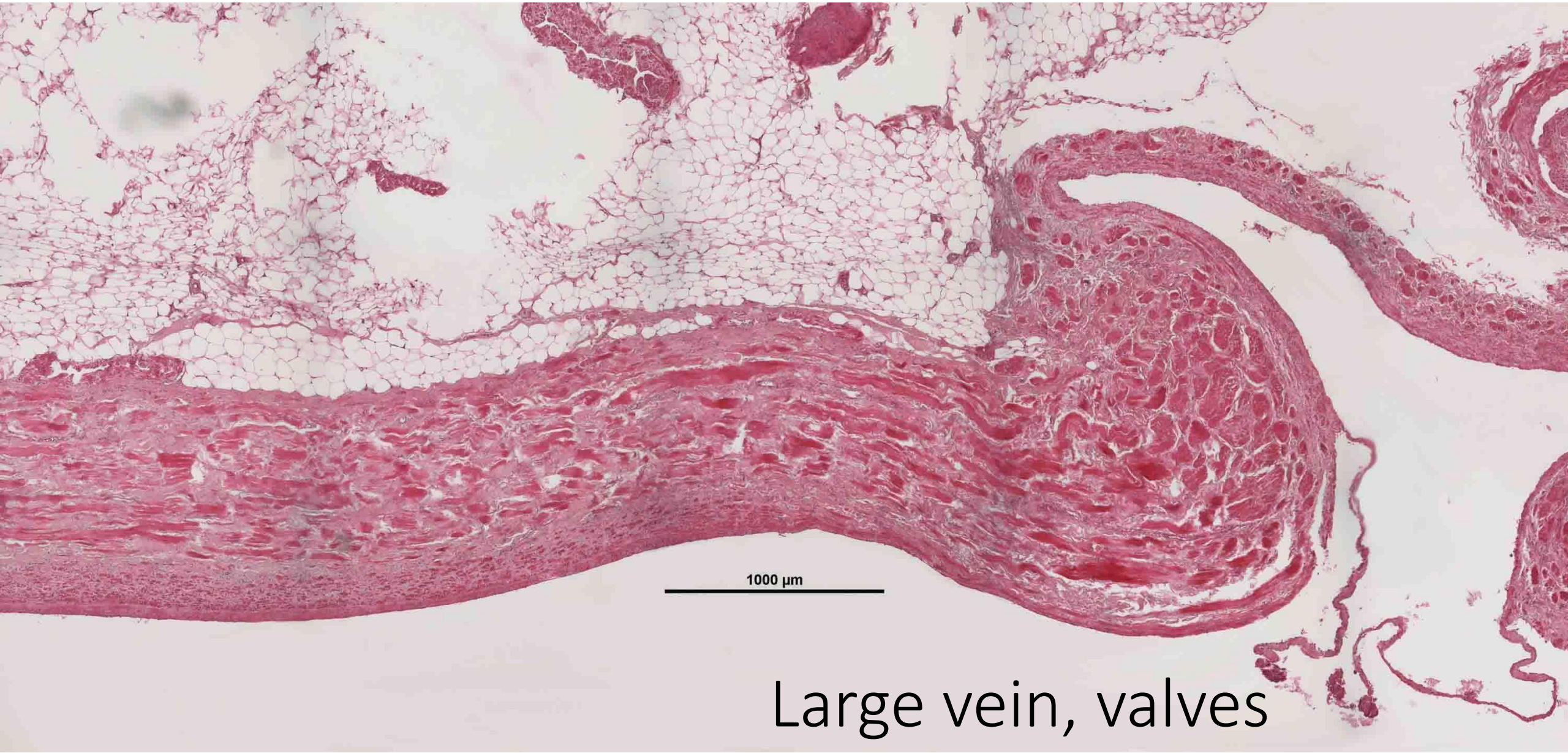


Small vein, B – media, E - adventitia



Large vein





Large vein, valves


valve

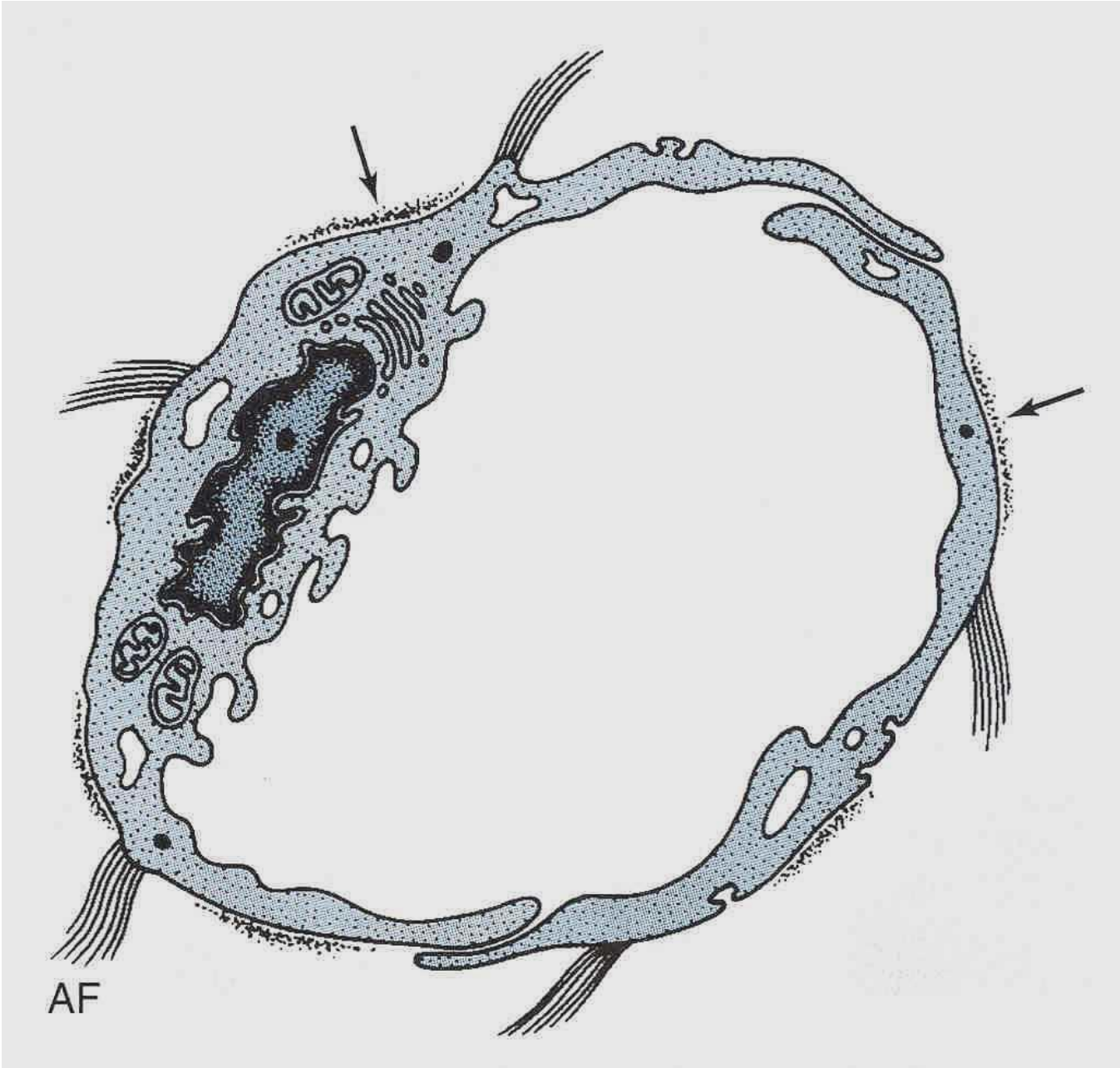
Question time - veins

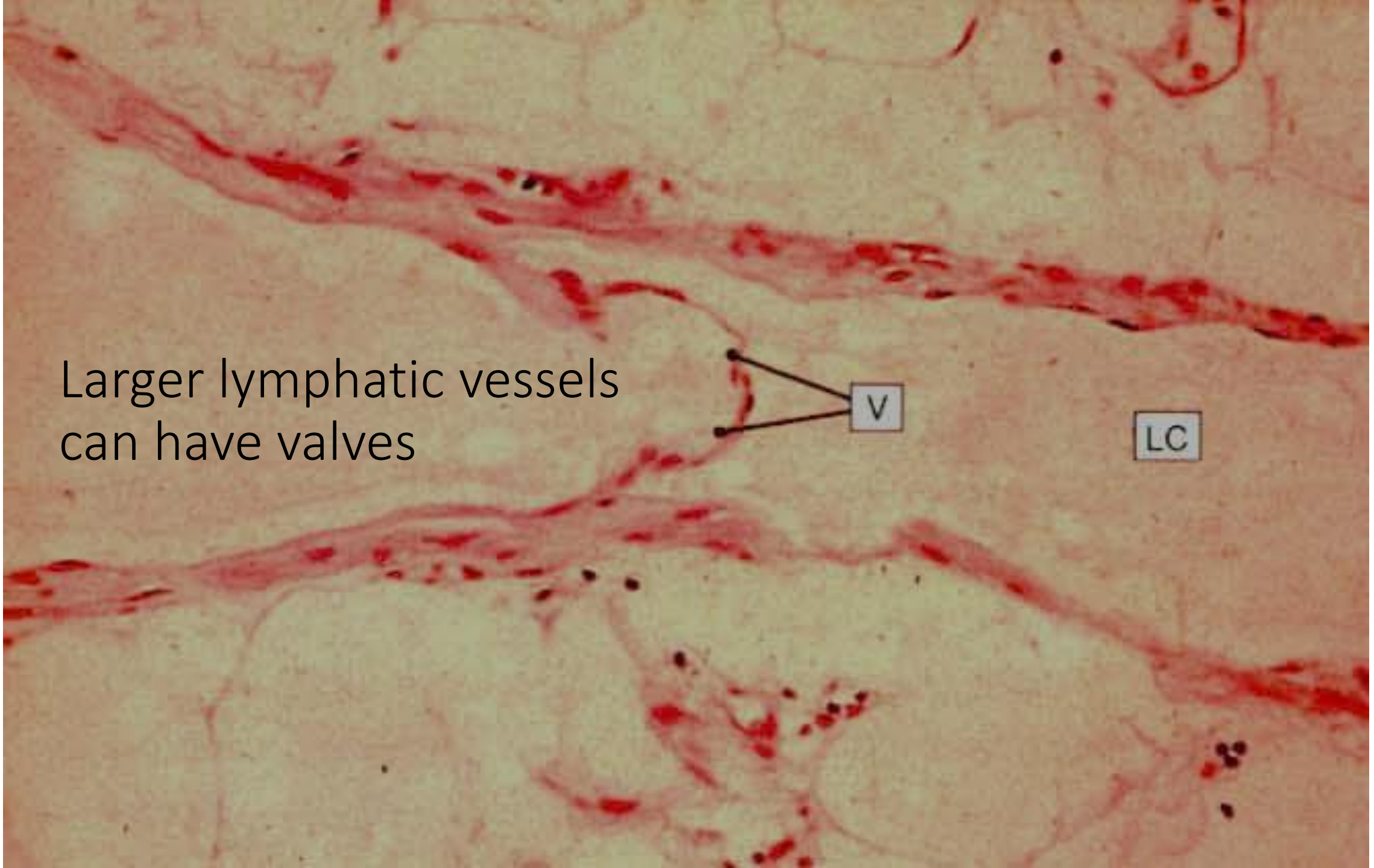
1. What mechanisms help to pump blood from the legs to the heart?

2. What is the largest vein in the human body? Does it have valves?

3. What is the most common site of deep vein thrombosis? What is the life threatening complication?

Lymphatic capillary




Larger lymphatic vessels
can have valves
V
LC

Lymphedema is caused by insufficient lymphatic drainage. Do you know any of its causes?