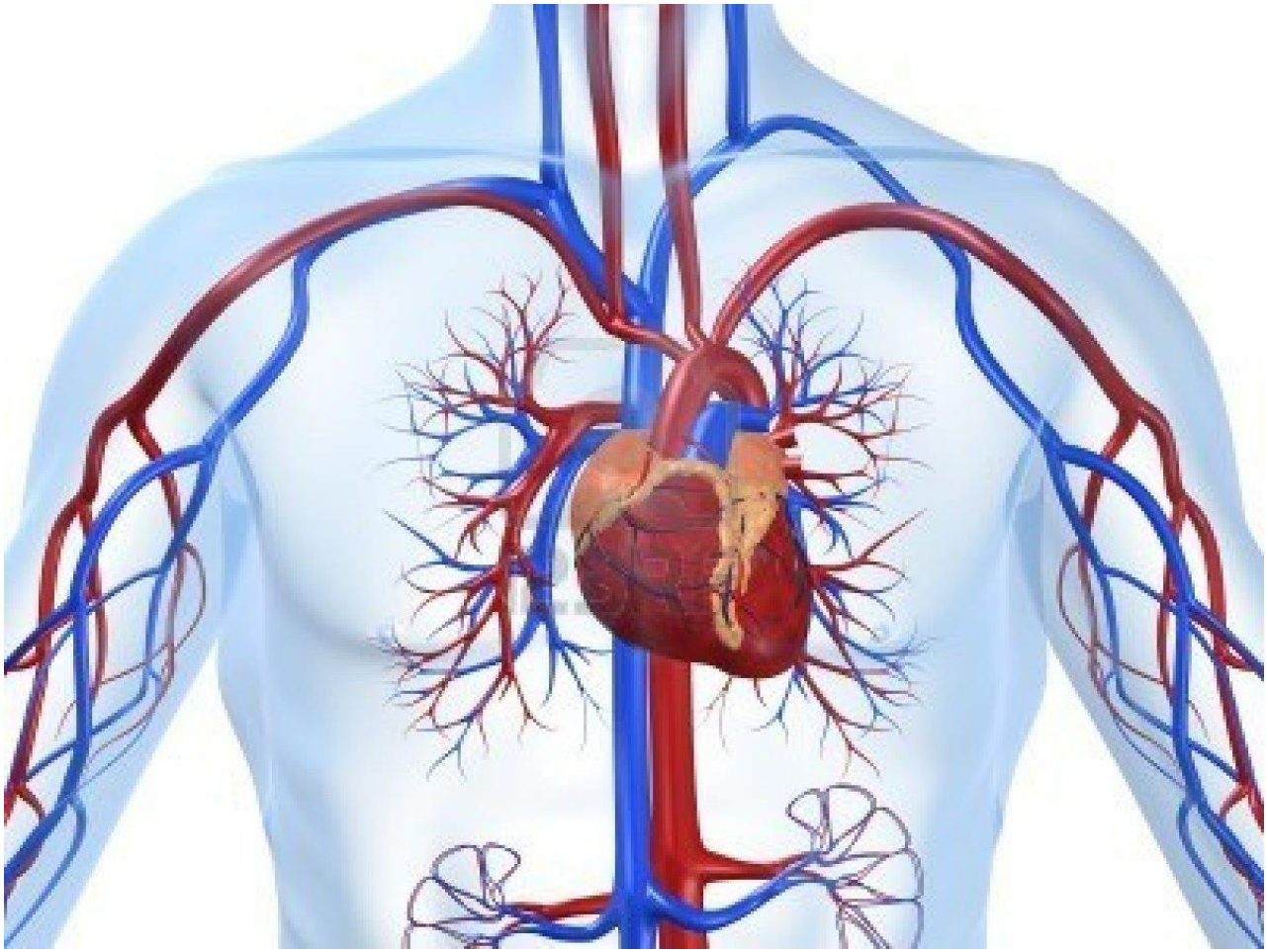
КАЗАНСКИЙ (ПРИВОЛЖСКИЙ) ФЕДЕРАЛЬНЫЙ УНИВЕРСИТЕТ

The cardiovascular system

Components of the Cardiovascular system

- **Heart**
- **Vessels:**
  - Arteries
  - Capillaries
  - Veins



Functions of CVS:

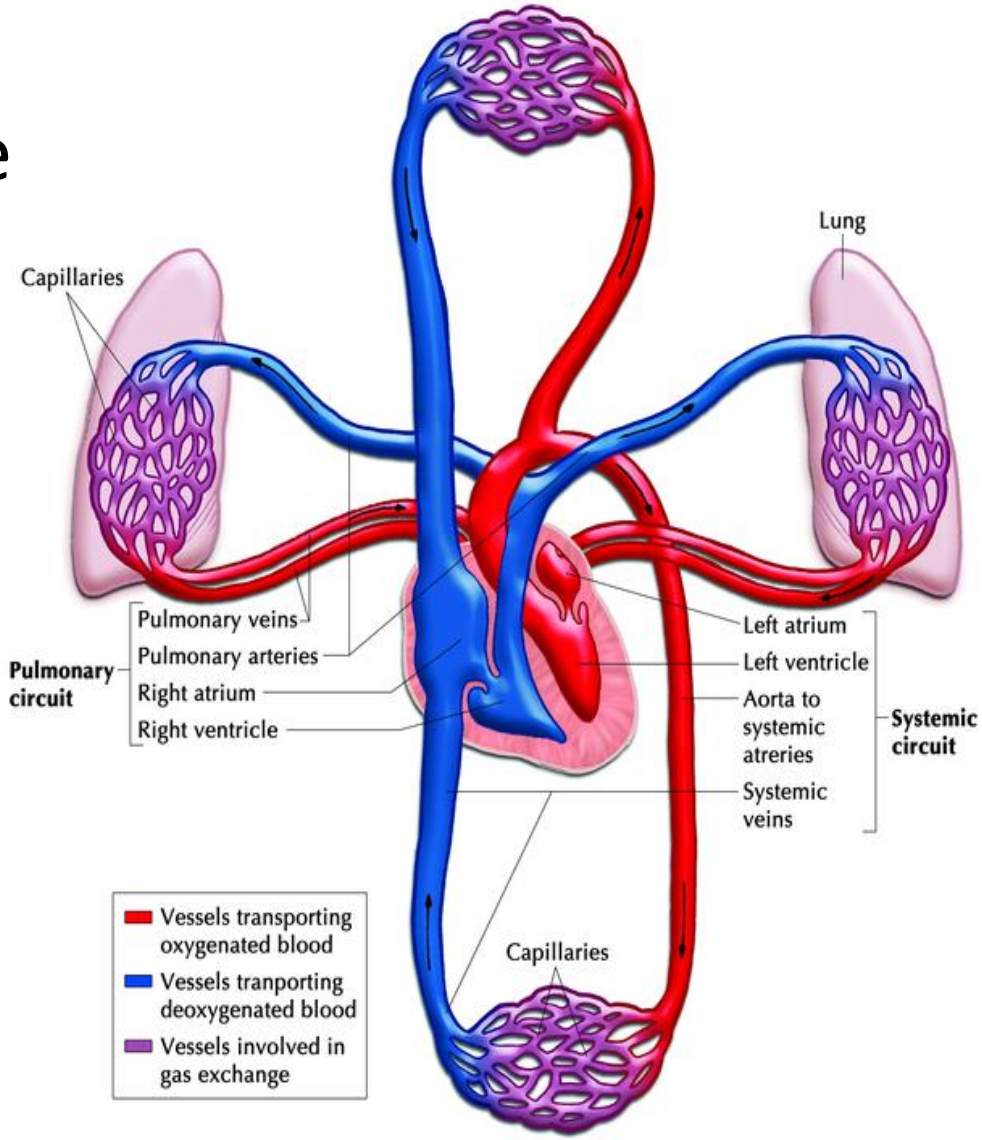
- Transportation system where blood is the transporting vehicle
- Carries oxygen, nutrients, hormones, cell wastes to and from the cells to provide body homeostasis
- Provides forces to move the blood around the body (heart)

Two blood circuits

- Two circuits distribute blood in the body:

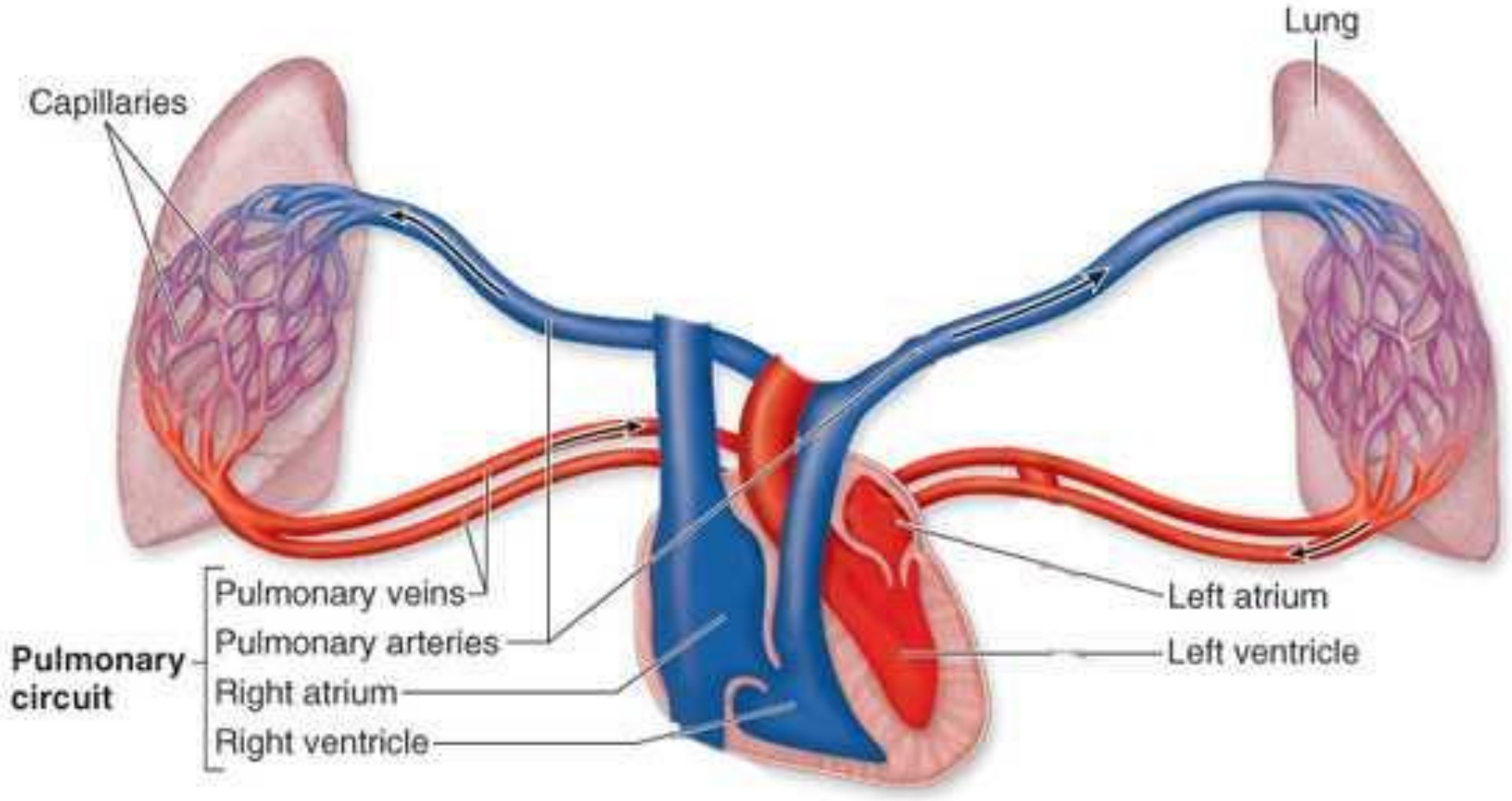
➢ **the pulmonary circulation**

➢ **the systemic circulation**



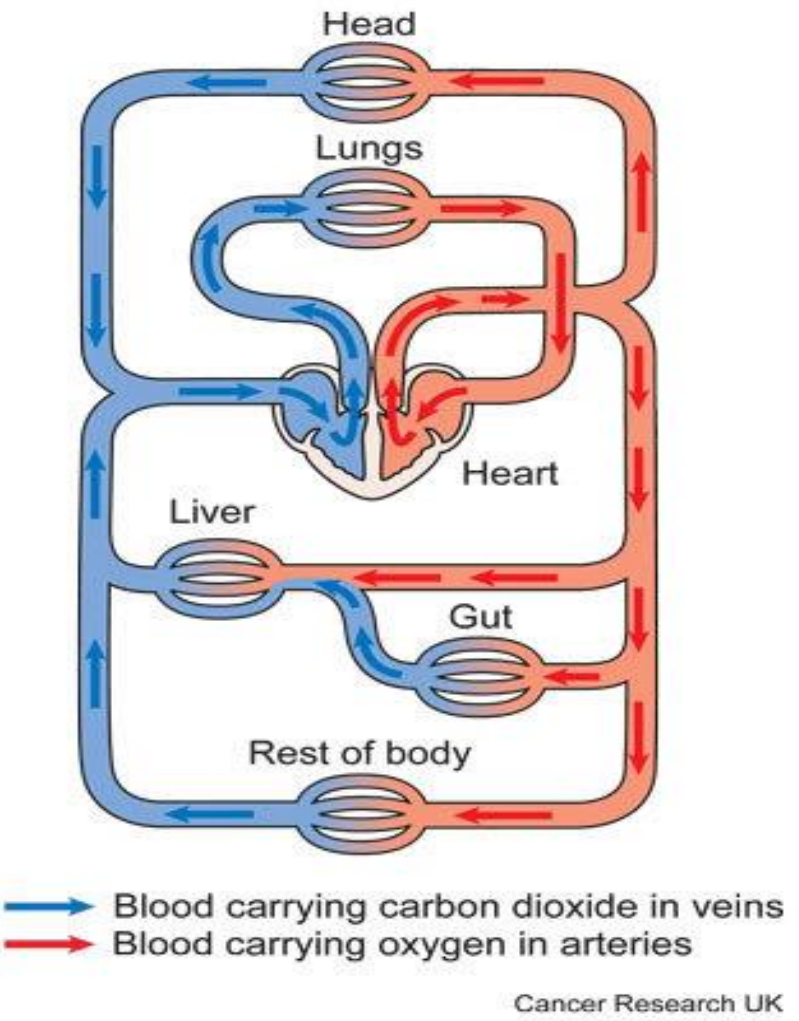
Pulmonary circulation

- Left and right Pulmonary arteries carry deoxygenated blood (right ventricle) away from the heart to the lungs
- Gas exchange in the lungs (the blood-air barrier)
- Return of oxygenated blood back to the heart (left atrium)



Systemic circulation

- Carries oxygenated blood away from the heart (left ventricle)
- Supply of all cells of the body
- Return of deoxygenated blood to the heart (right atrium)



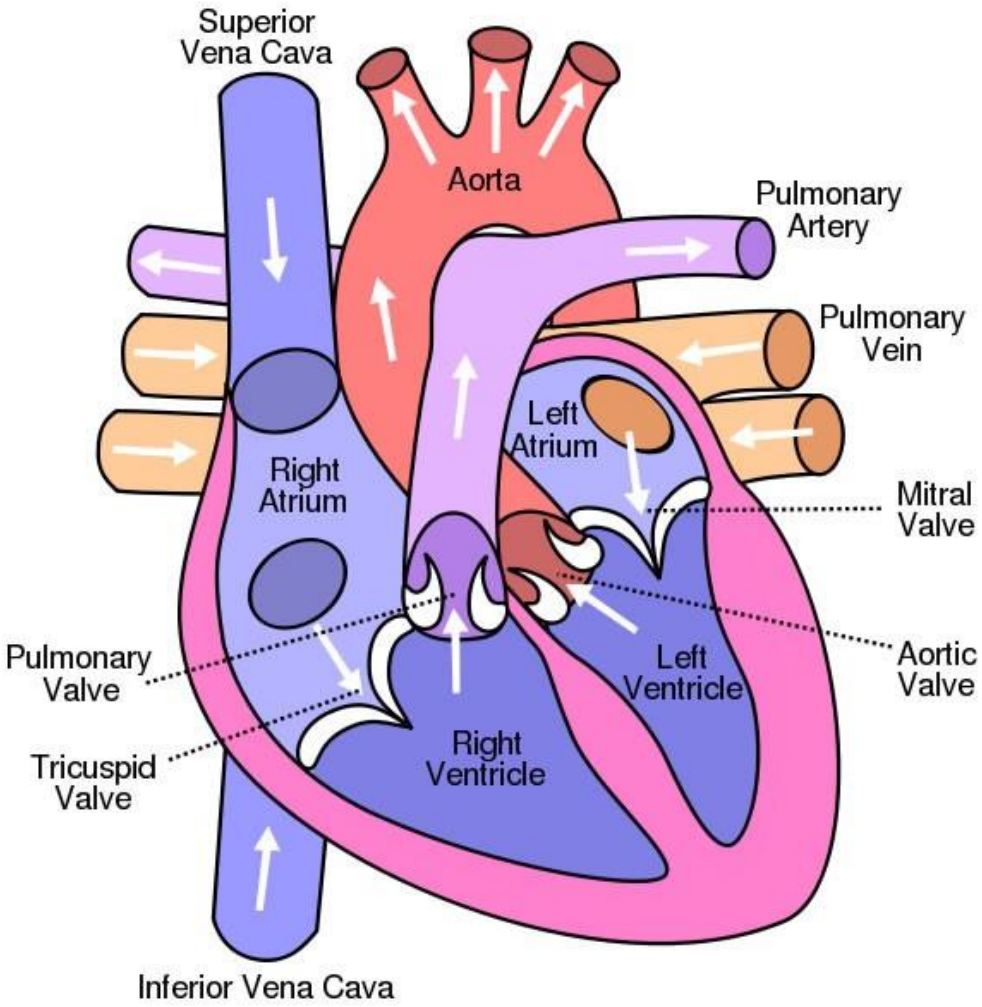
Structure of the heart

- 4 chambers:
  - Left atrium
  - Right atrium
  - Left ventricle
  - Right ventricle
- Tricuspid valve
- Mitral valve

Between atrium and ventricle

- Pulmonary valve
- Aortic valve

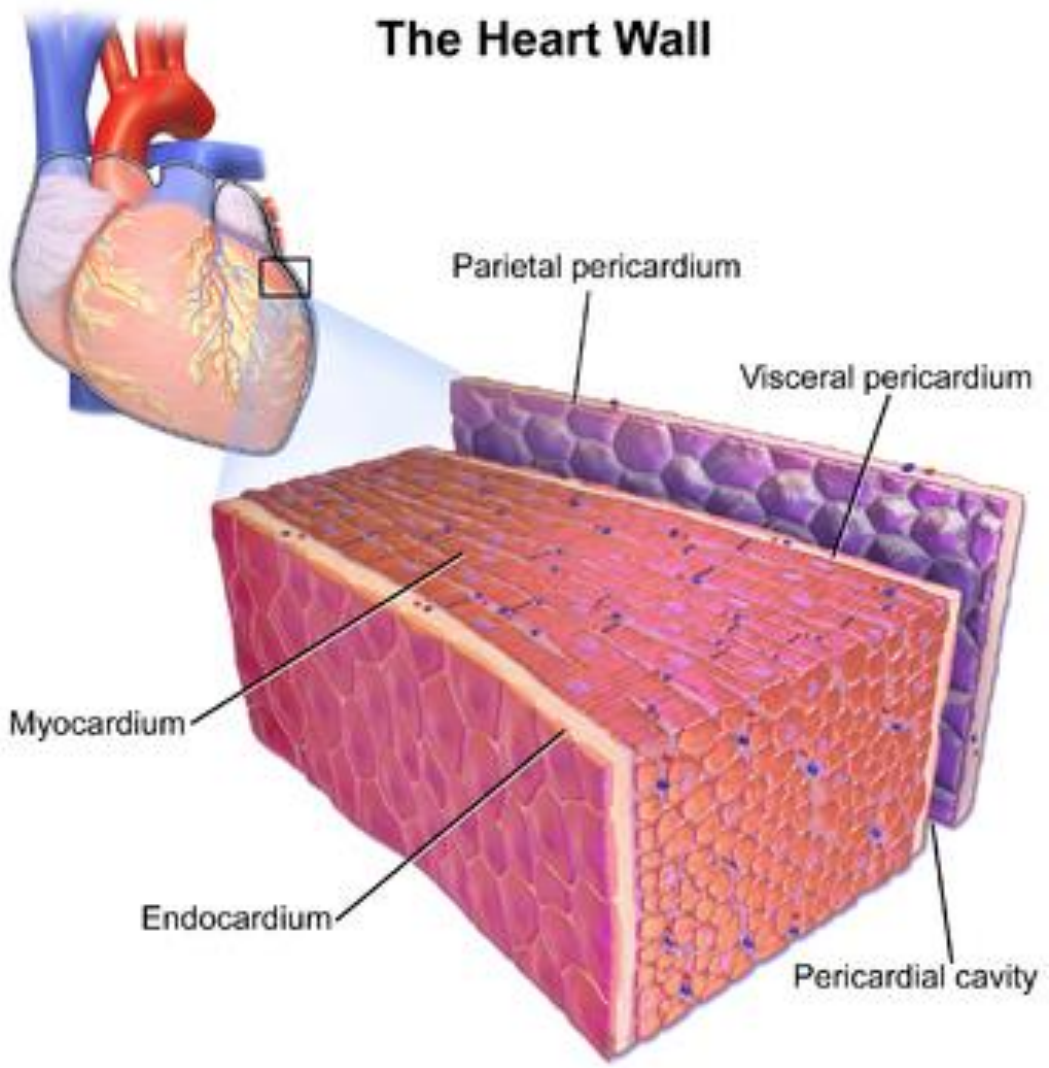
Between ventricle and major vessels



Structure of the heart

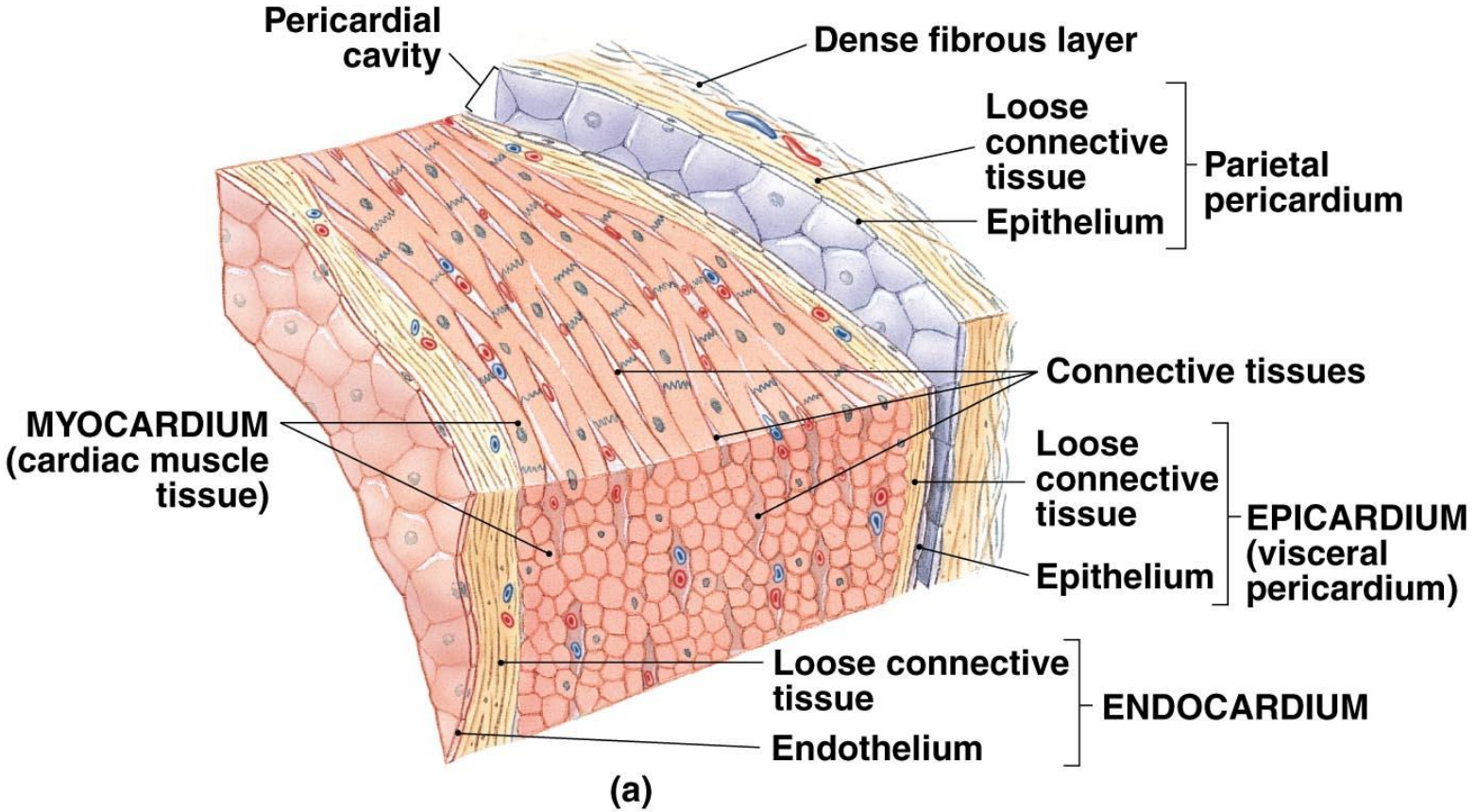
- The wall of the heart is composed of three layers:

1. **The epicardium** also known as the visceral layer of serous pericardium
2. **The myocardium** consisting of cardiac muscle
3. **The endocardium** – epithelium + connective tissue

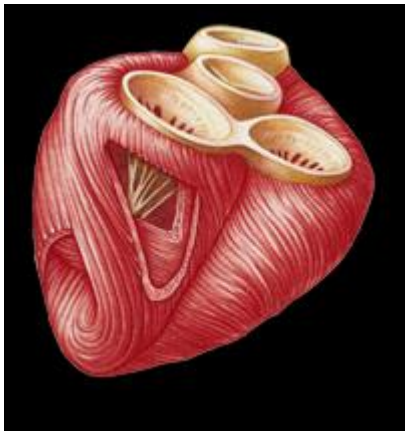


The epicardium

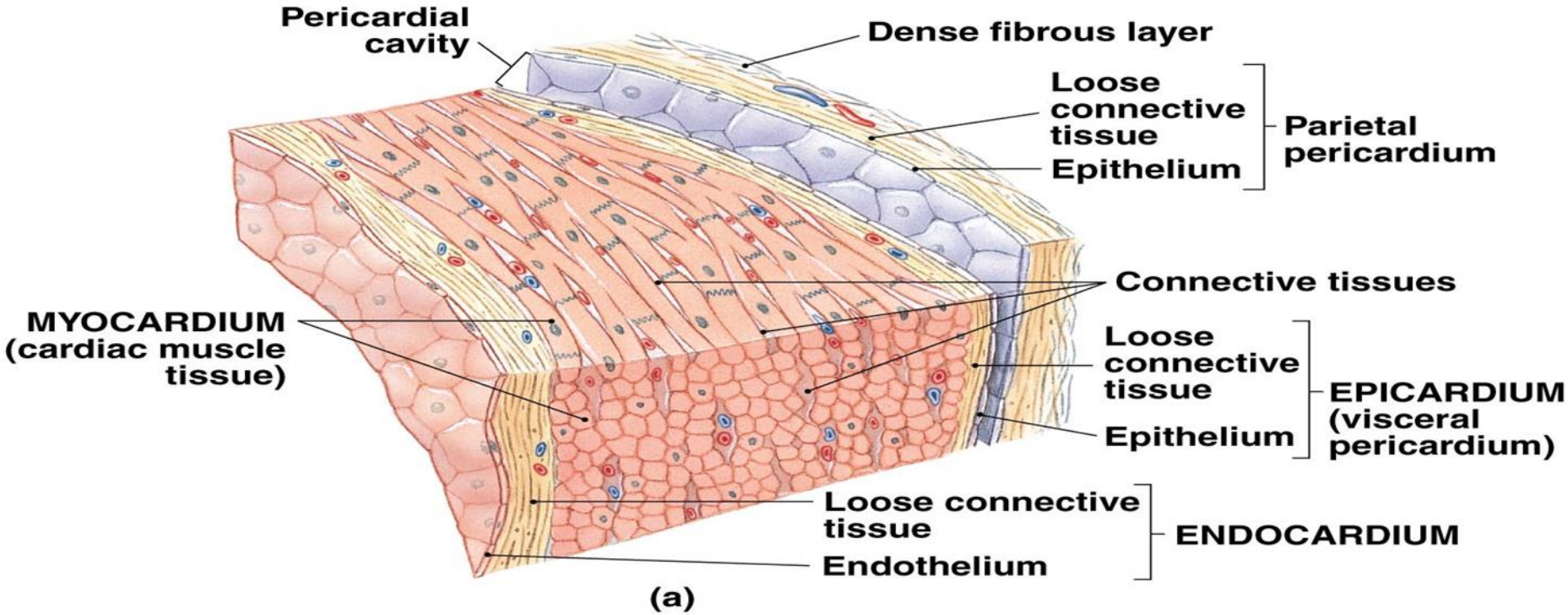
- Covers the outer surface of the heart
- Mesothelium (simple squamous epithelium) and an underlying layer of connective tissue



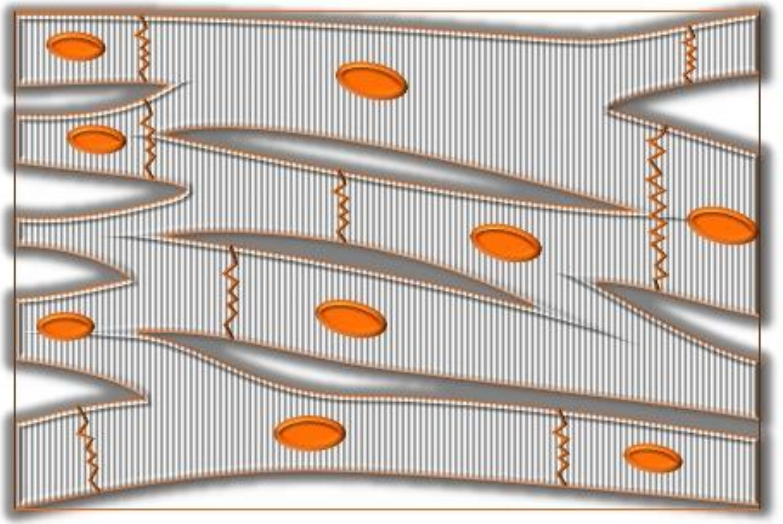
Myocardium



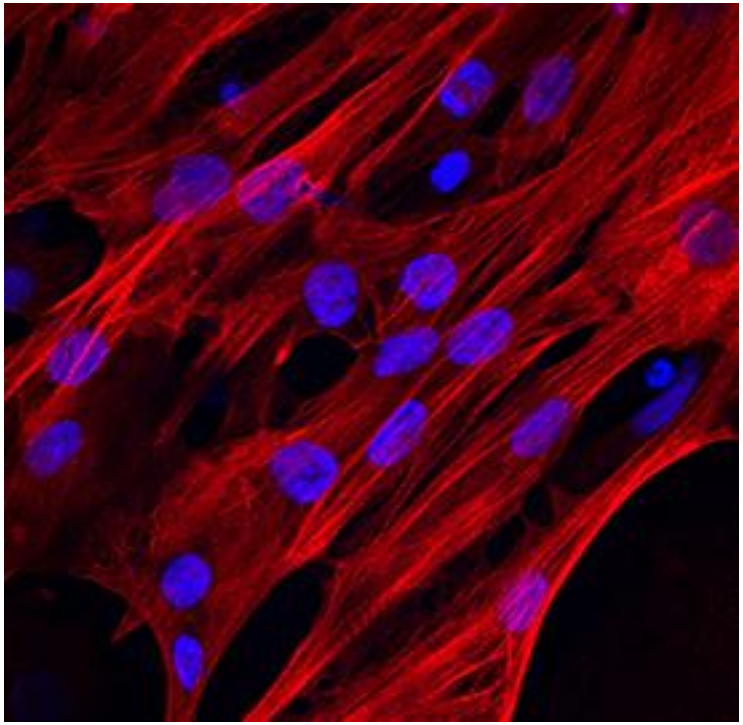
- Consist of cardiomyocytes
- Striated
- Involuntary
- Conducting system



Cardiomyocytes



- Branched cells
- One central nucleus
- **Intercalated disc** – connections of cardiomyocytes allowing rapid transmission of impulses



Three types of cardiomyocytes

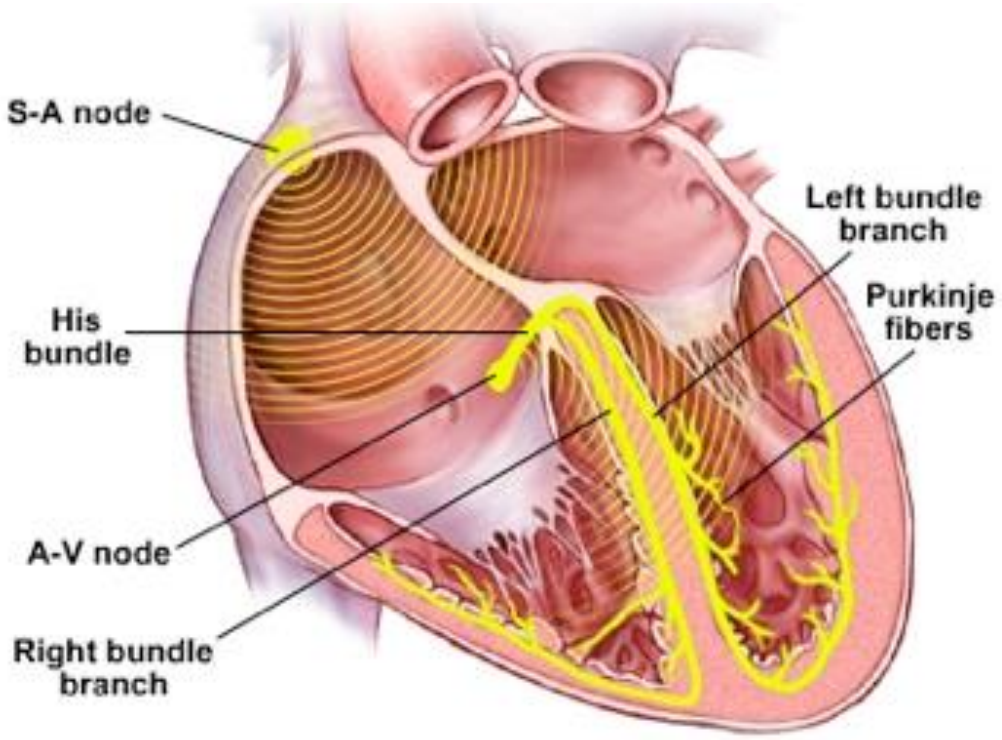
- Typical cardiomyocytes – predominant type, function - contraction
- Atypical cardiomyocytes – less myofibrils, function – impulse **generation** and conduction
- Secretory cardiomyocytes – located in right atrium, secrete hormone atrial natriuretic factor, which causes sodium and water loss, reducing blood pressure

Contraction impulse is generated and conducted by specialized cardiac cells

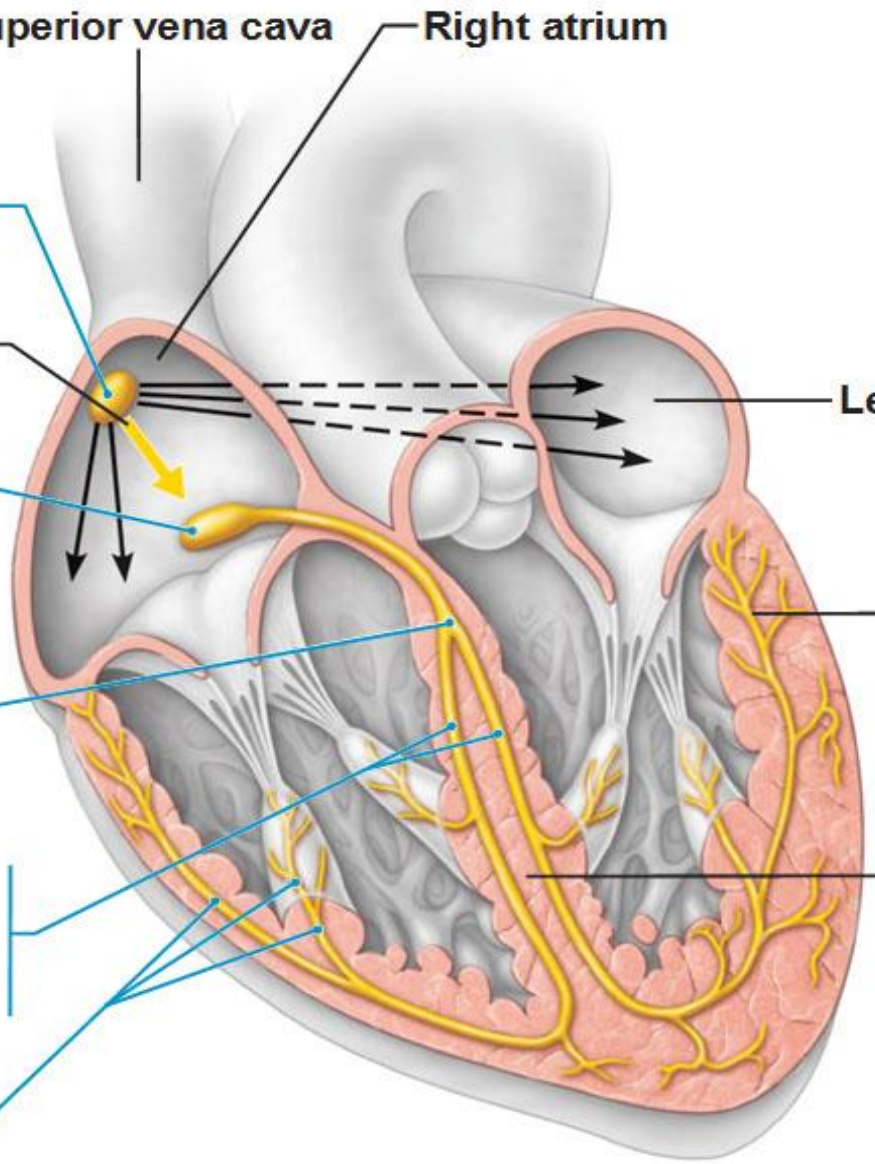
- **Sinoatrial node**
- **Atrioventricular node**

and conduction fibers

- **Bundle of Hiss**
- **Purkinje fibers**



Conducting System, a series of Specialized Cardiac Muscle Cells



(1) The **sinoatrial (SA) node** (pacemaker) generates 70-80 impulses per minute; atria contract.

(2) The impulses pause (0.1 sec) at the **AV node so ventricles have time to fill.**

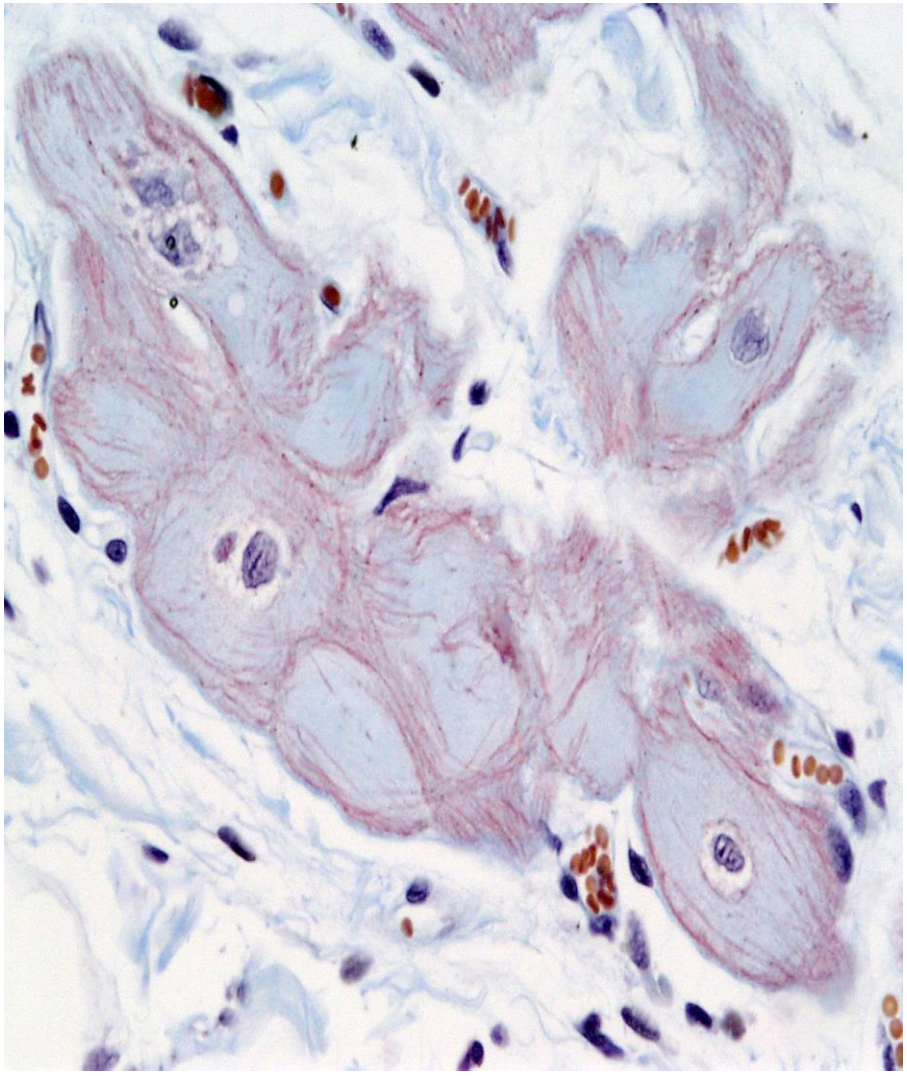
(3) The **atrioventricular (AV) bundle** connects the atria to the ventricles.

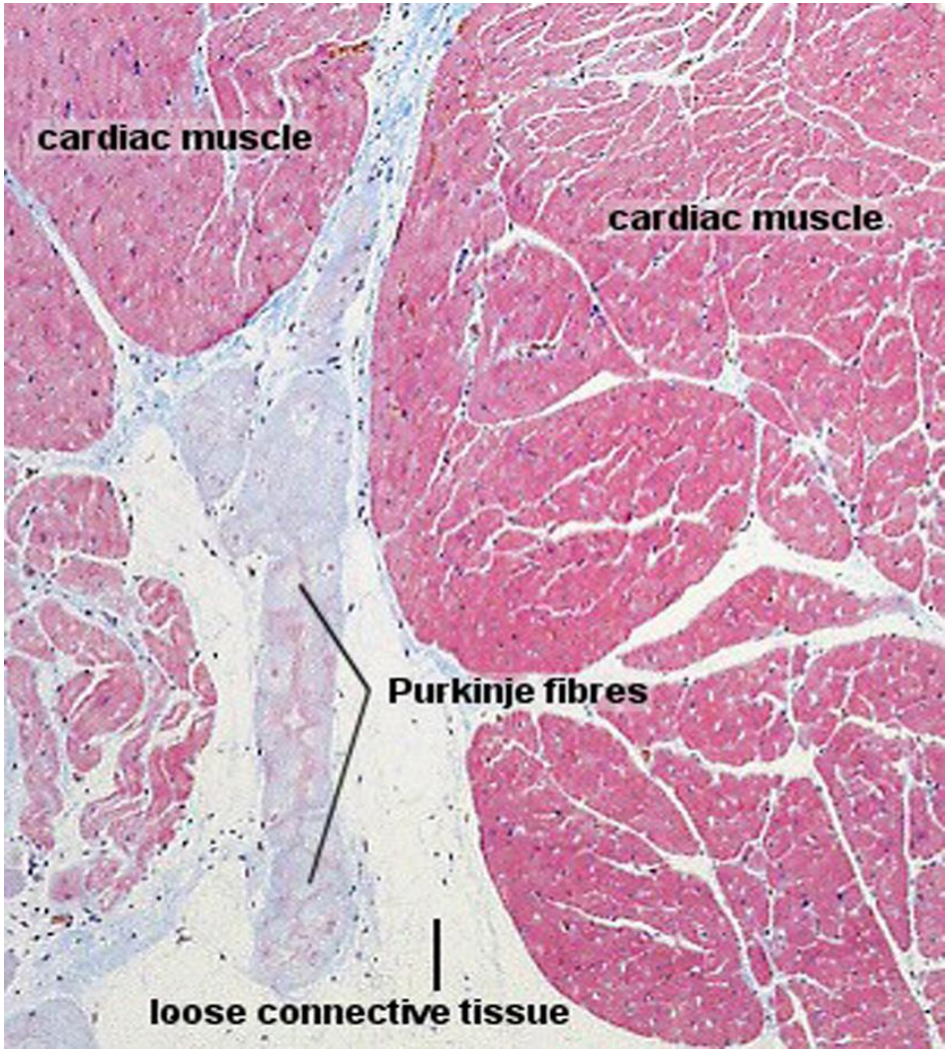
(4) The AV bundle branches conduct the impulses through the interventricular septum.

(5) The **Purkinje fibers** stimulate the contractile cells of both ventricles, starting at apex and moving superiorly.

Purkinje fibers

can be distinguished by their location (along the interventricular septum), large size and light cytoplasmic staining (glycogen)

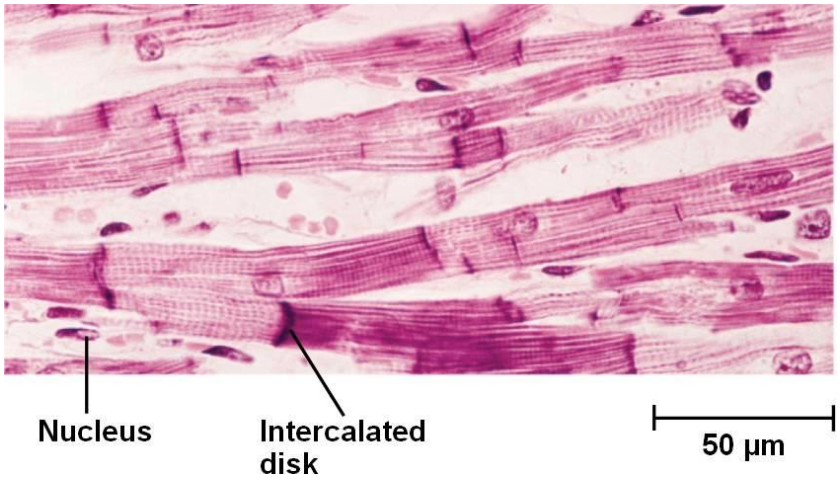


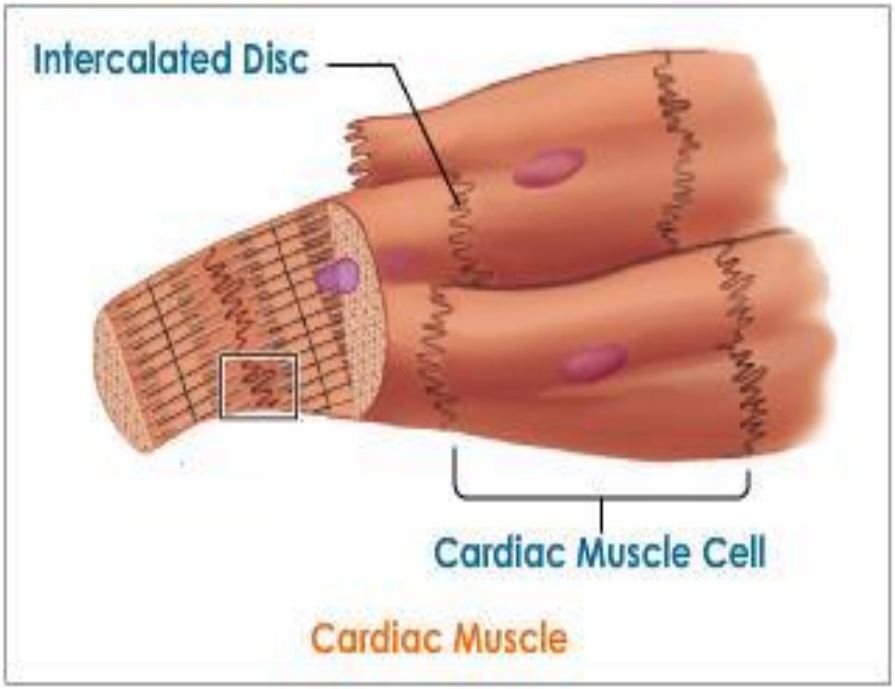


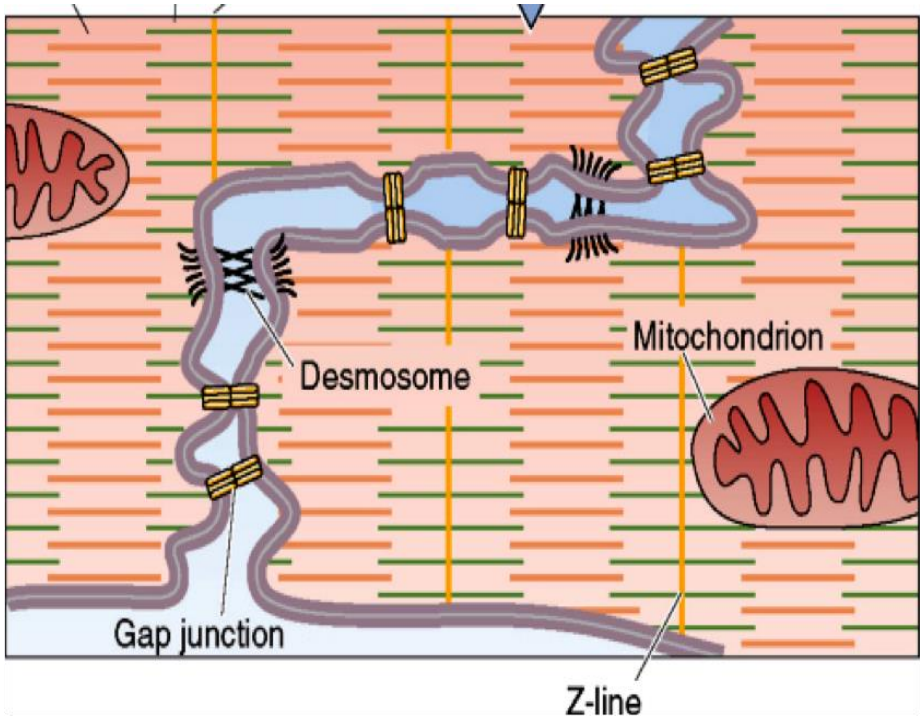
Intercalated discs

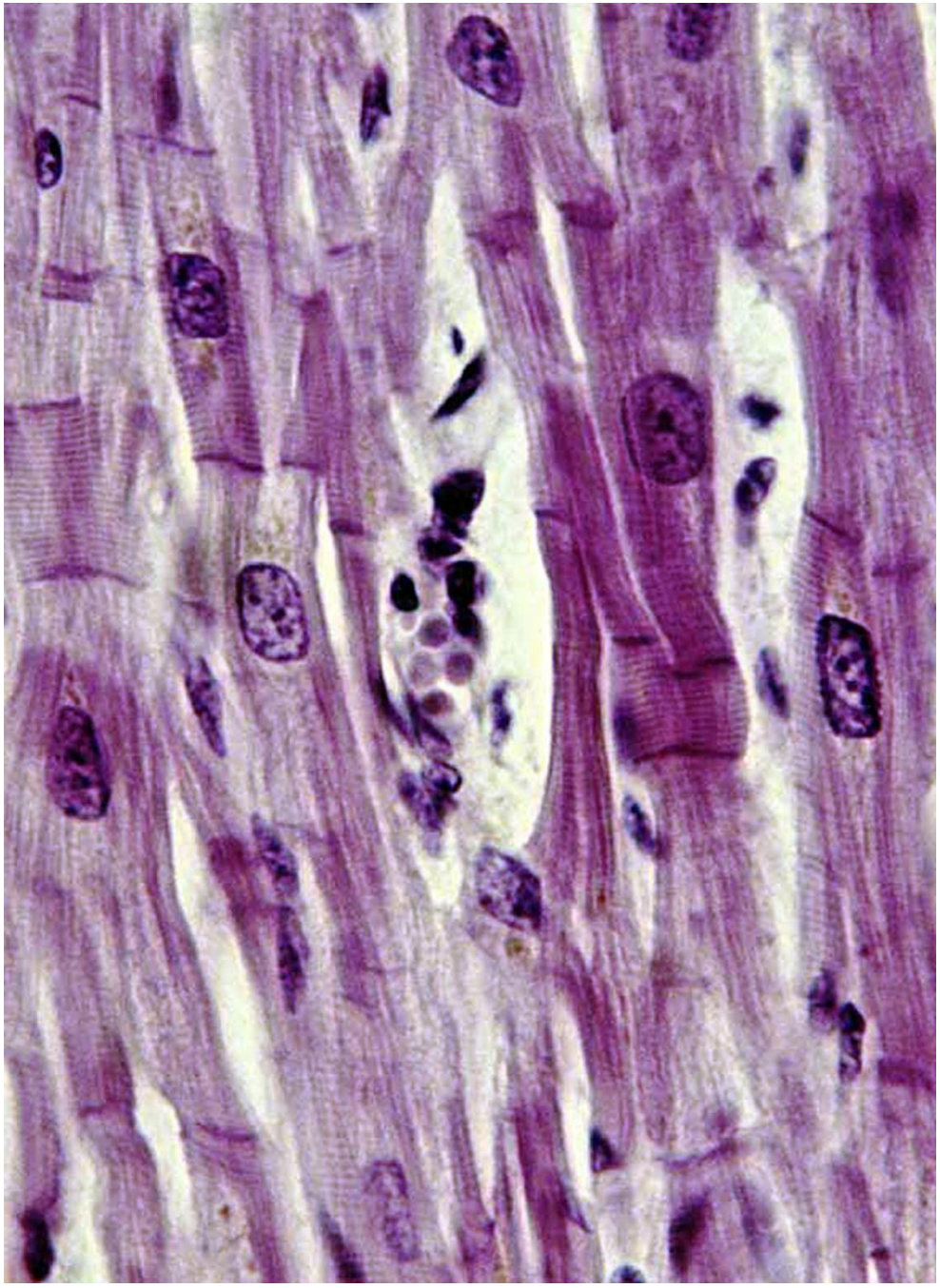
• Specialized junctional complexes to transmit generated impulses to the typical cardiomyocytes

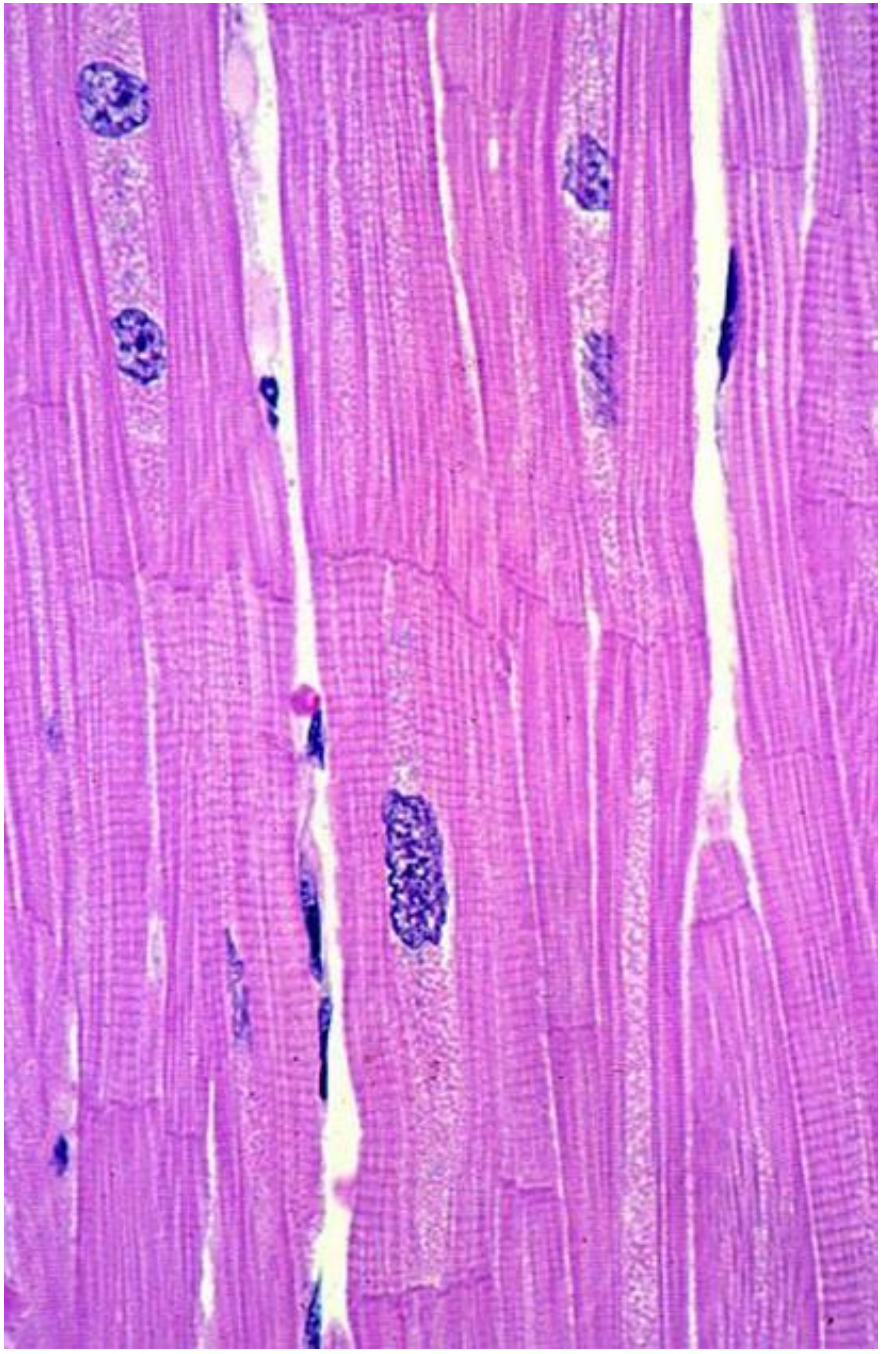
•Consist of:
- desmosomes
- gap junctions





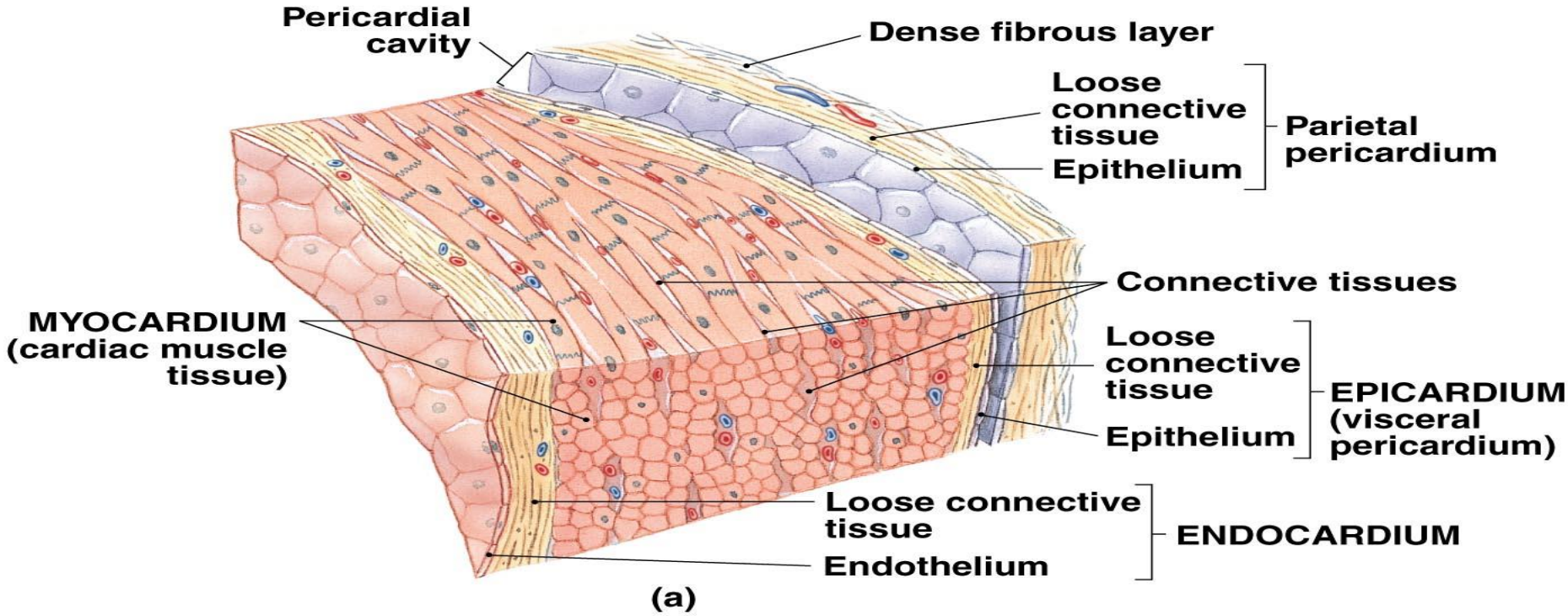






The endocardium

- Endothelium (simple squamous epithelium) and underlining connective tissue membrane
- Lines the inner surface of the heart chambers and valves



Components of the Cardiovascular system

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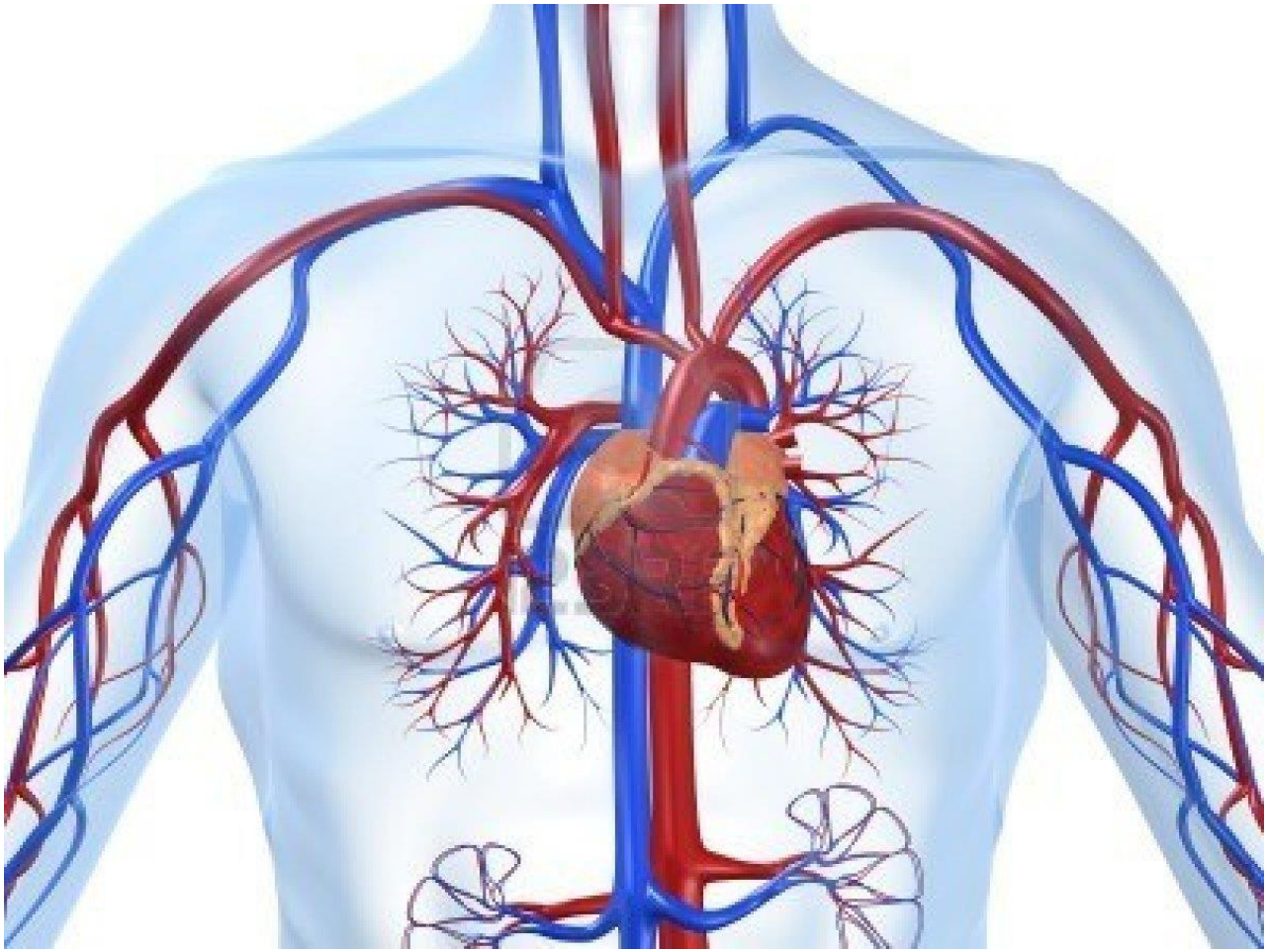
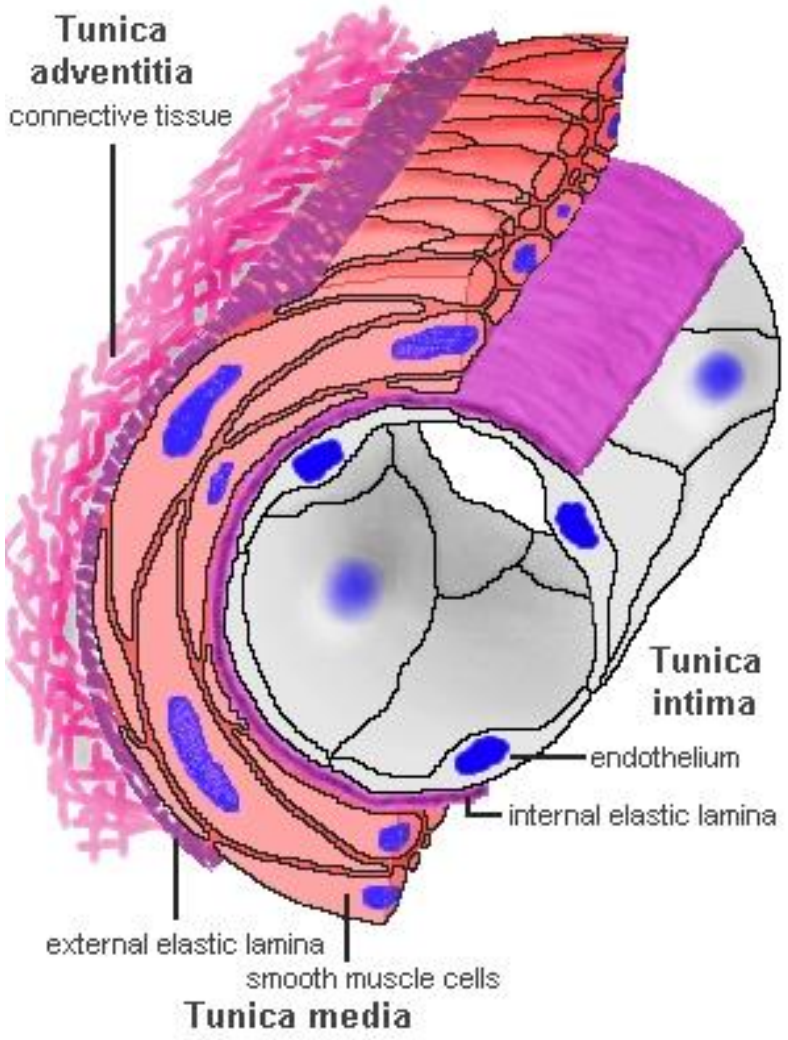
- **Vessels:**
  - Arteries
  - Capillaries
  - Veins



General structure of the blood vessels

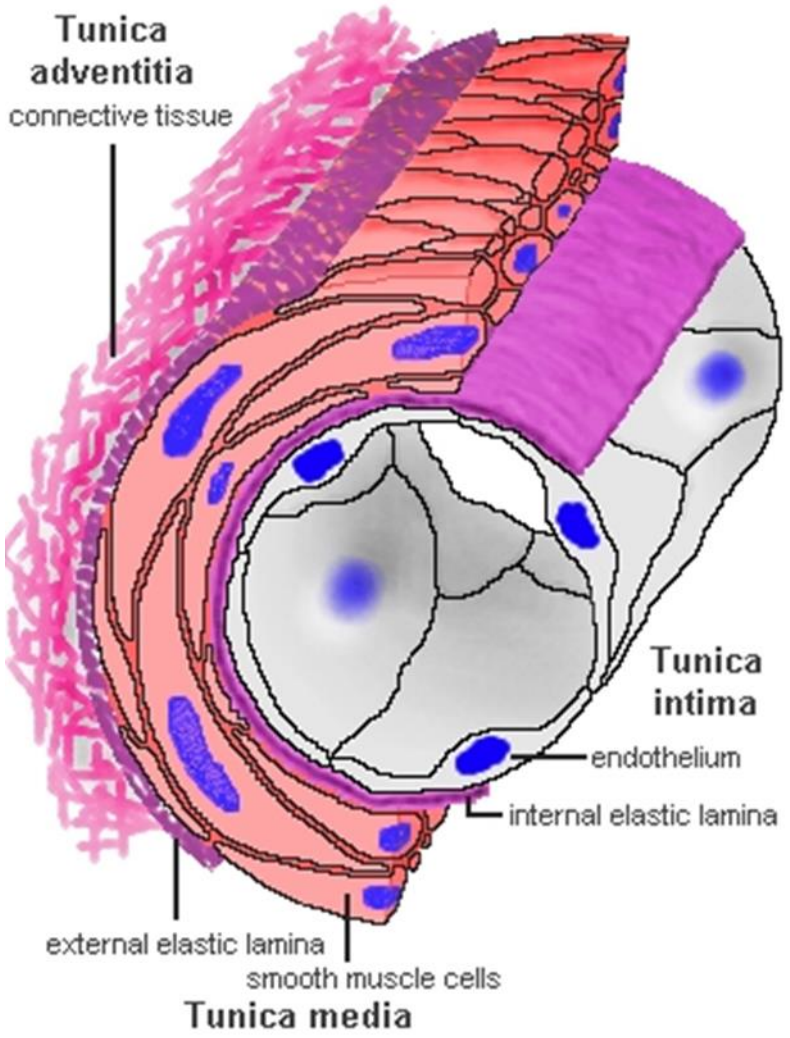
- Most vessels consist of three layers or tunics:
  - Tunica Intima
  - Tunica media
  - Tunica adventitia



The tunica intima

- **The tunica intima**, the innermost layer of the vessel, consists of three components:

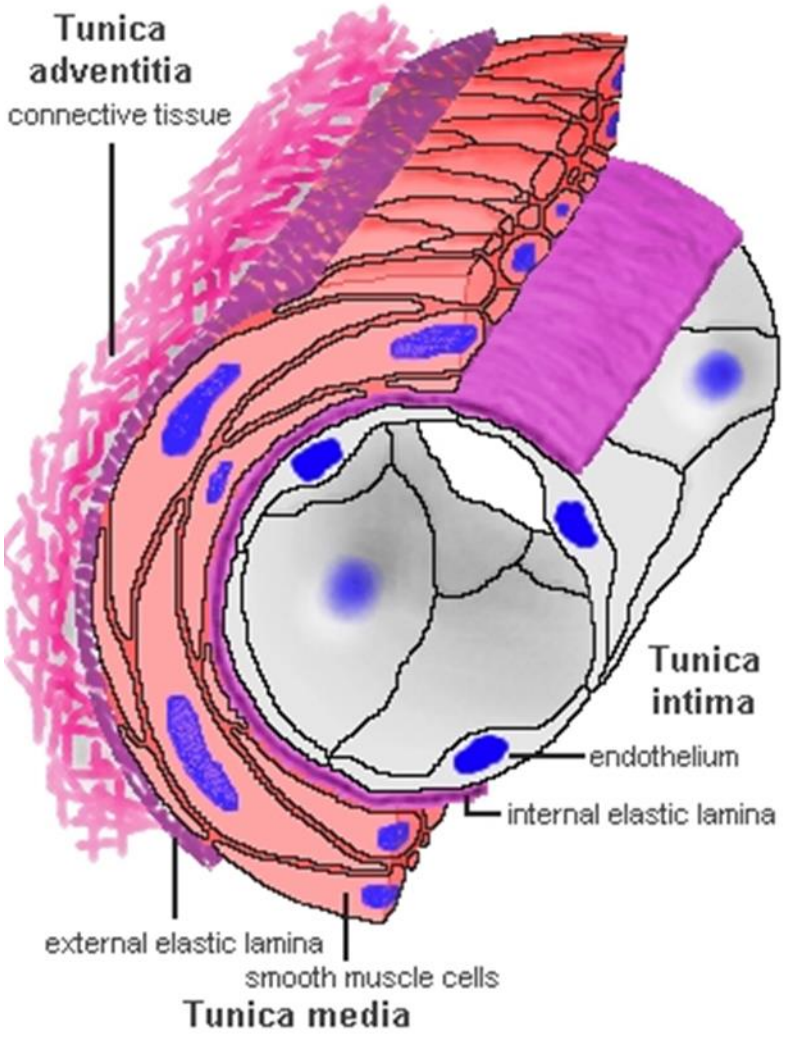
1. **The endothelium -** a single layer of squamous epithelial cells
2. **The subendothelial layer** - loose connective tissue
3. **The internal elastic lamina**, which delimits the tunica intima from tunica media



The tunica media

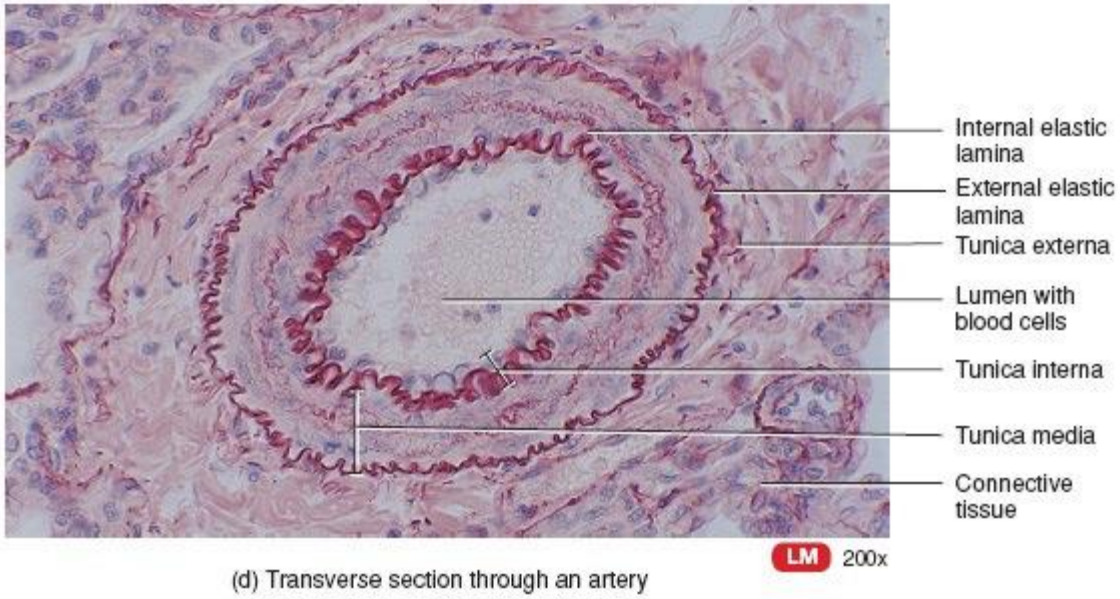
- **Circumferential smooth muscle** layers and variable amounts of **connective tissue**

- **The external elastic lamina** - delimits tunica media from tunica adventicia

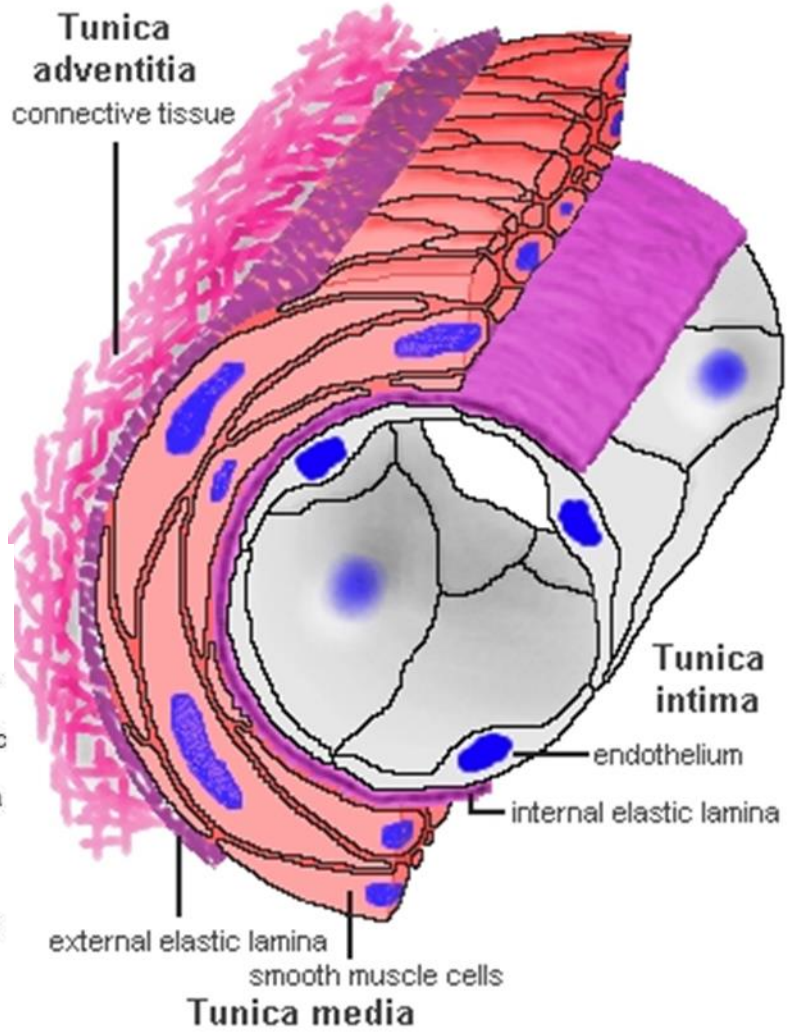


The tunica adventitia

- **Connective tissue fibres** surrounding the vessel from the outside
- The tunica adventitia blends with the connective tissue surrounding the vessel

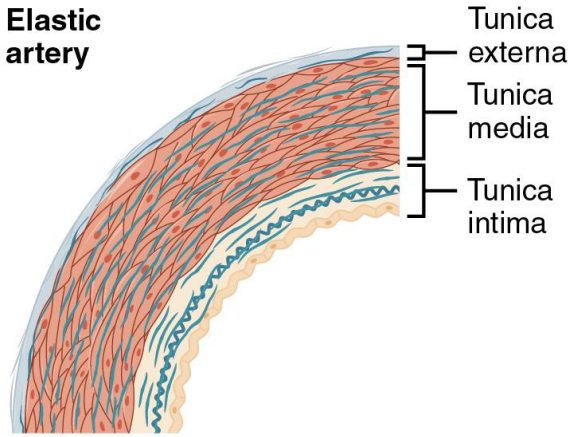


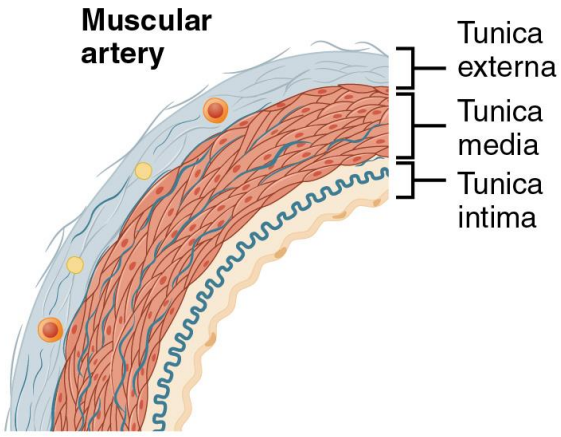
(d) Transverse section through an artery

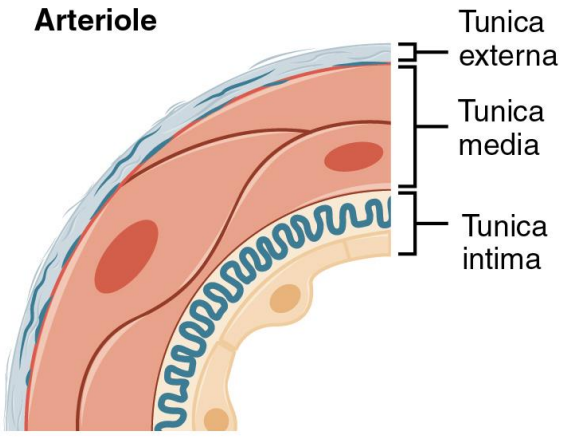


Types of arteries

1. **Elastic arteries** or **conducting arteries** - large vessels with diameters up to 2,5 cm (the aorta and pulmonary arteries)
2. **Muscular arteries** or **distributing arteries –** transport blood to the skeletal muscles and internal organs (most of the "named" arteries of the body)
3. **Arterioles –** smaller than muscular arteries, average diameter about 0.1 - 0.5 mm

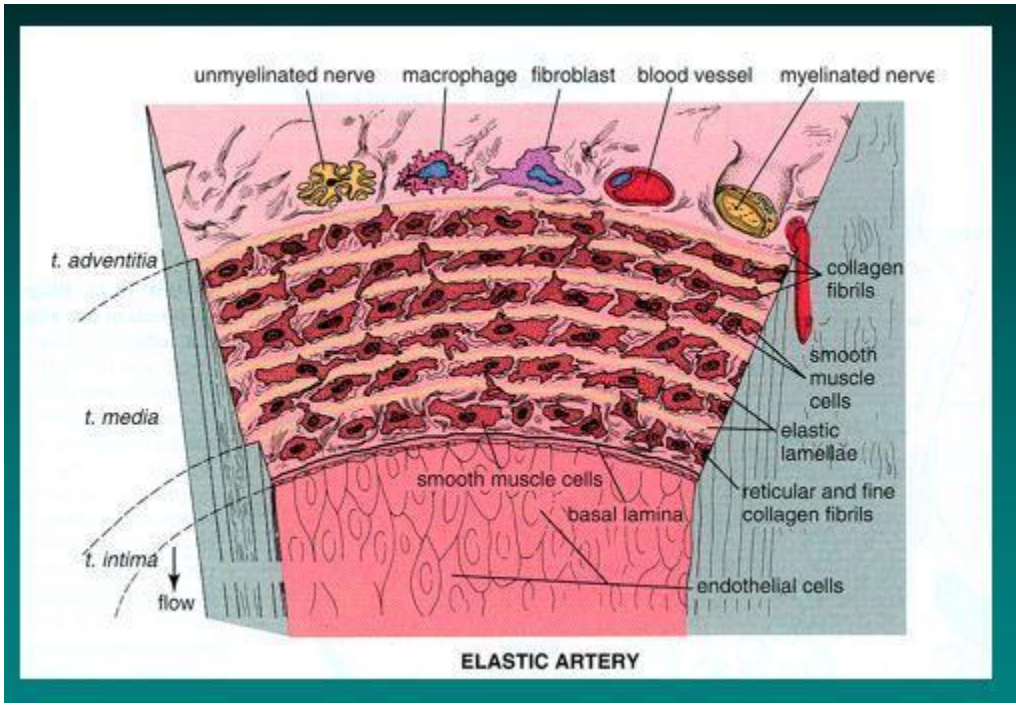


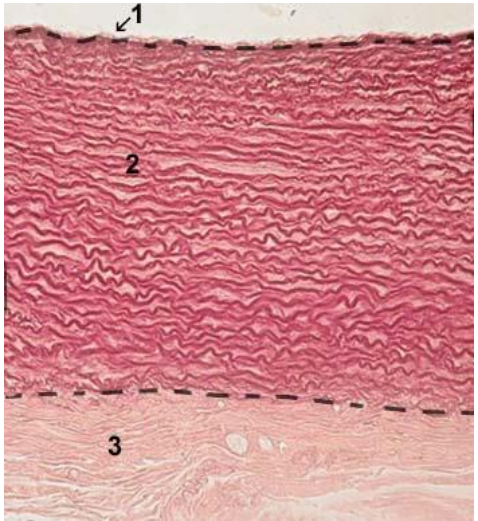




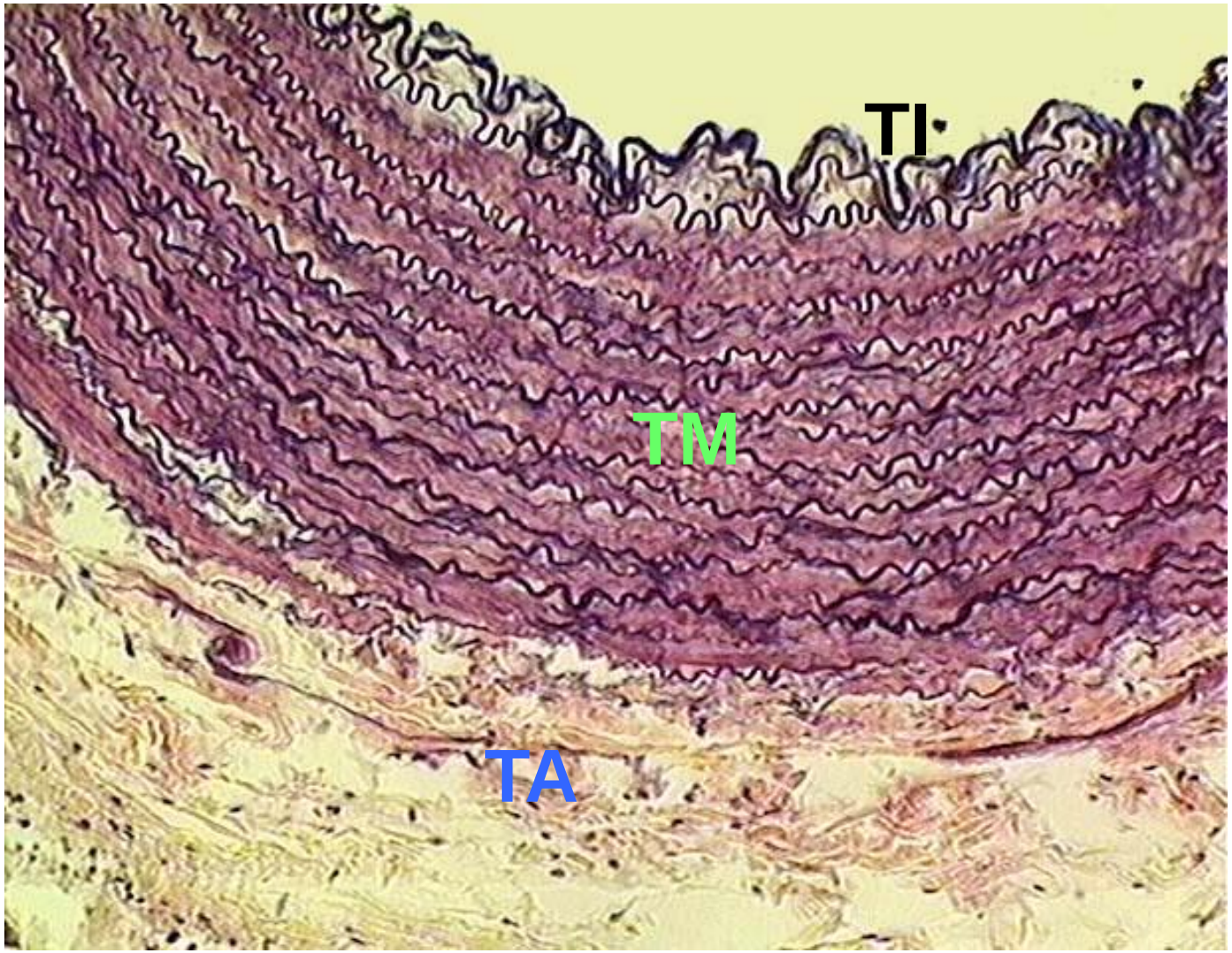
Elastic arteries

- The tunica media consists of multiple layers of smooth muscle cells separated by **elastic lamellae**
- Resist high pressure
- The external elastic lamina is difficult to discern from other layers of elastic fibers in the tunica media.
- *Vasa vasorum* – vessels that supply external layers of elastic arteries.





Wall of the Elastic Artery

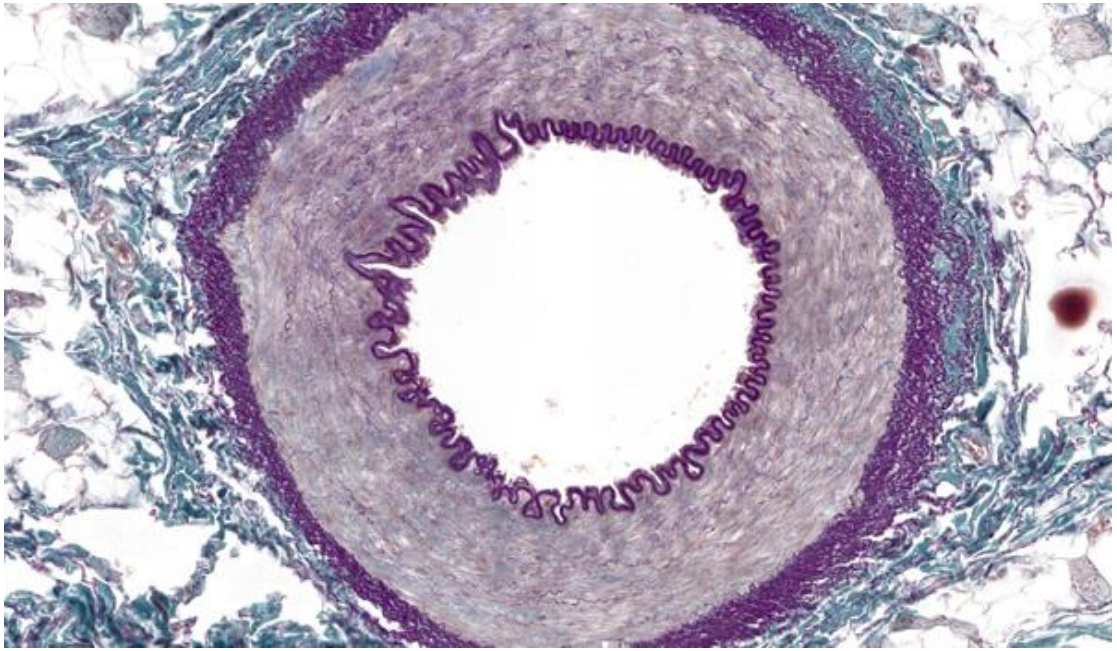


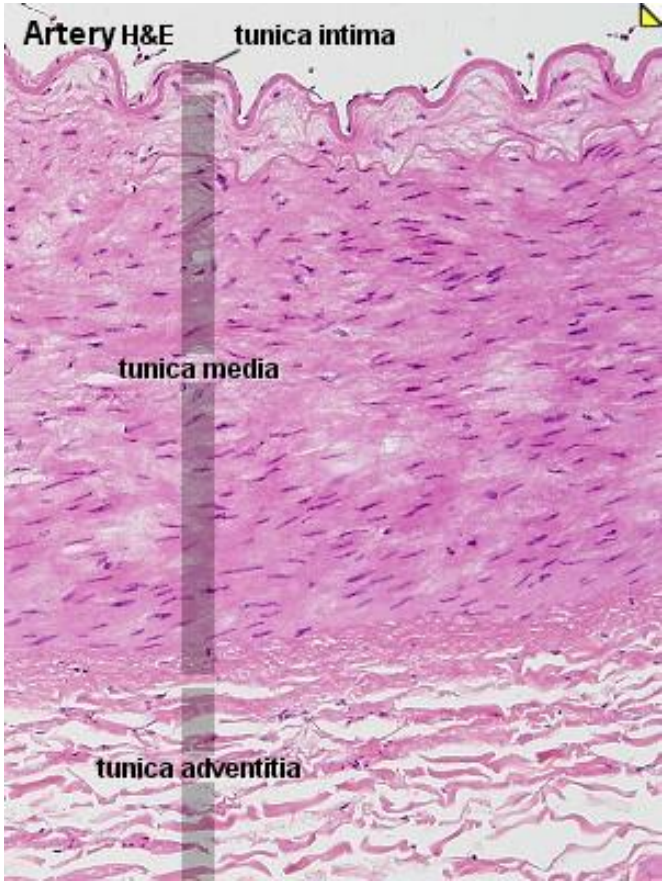
TI = T. Intima; TM = T. media; TA = T. adventitia

Muscular arteries

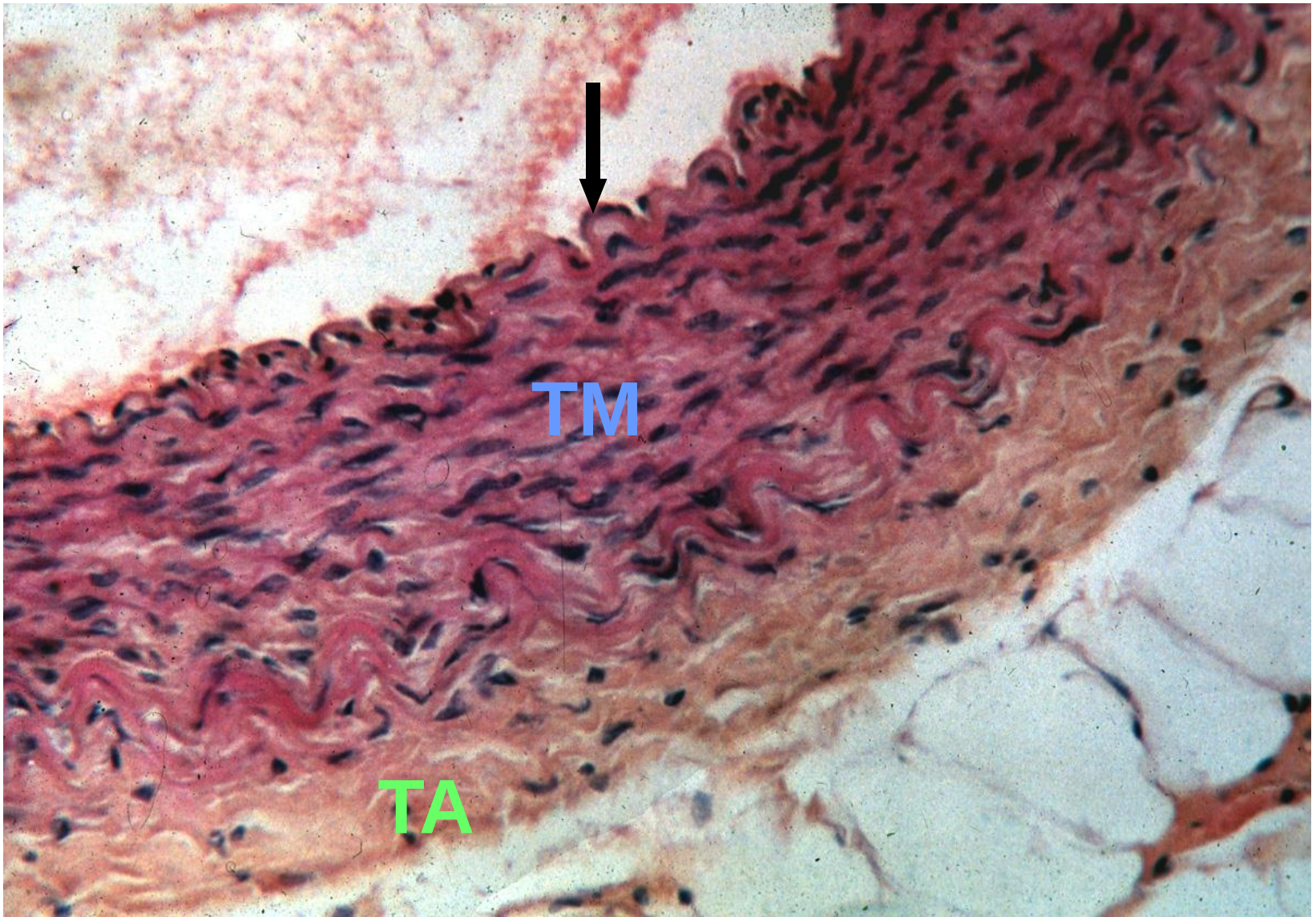
- The tunica media of muscular arteries is composed almost entirely of smooth muscle, with little elastic material

- Can regulate the blood flow due to the abundant smooth muscle cells



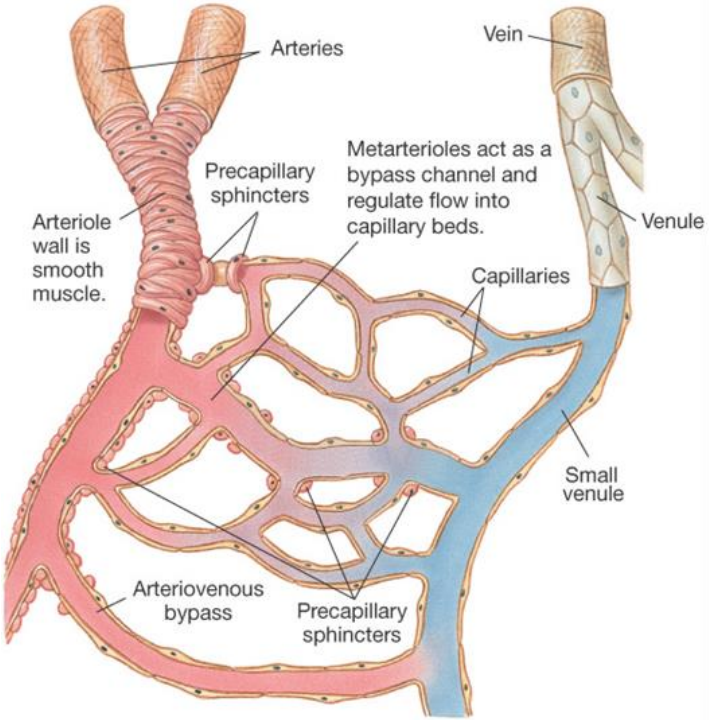


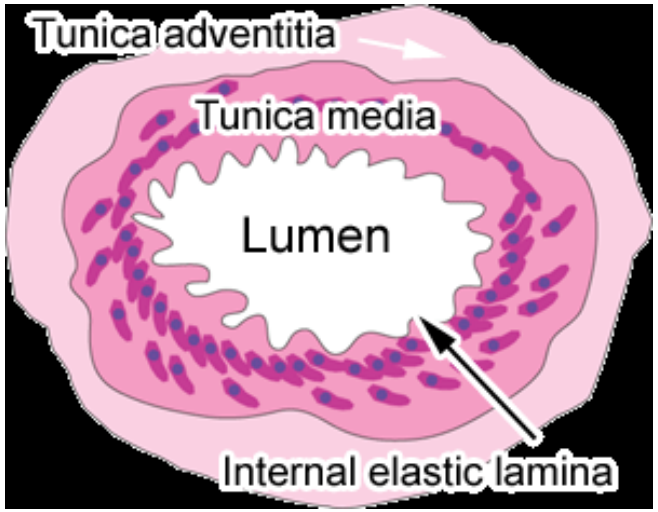
Wall of the Muscular Artery Arrow = T. Intima; TM = T. media; TA = T. adventitia



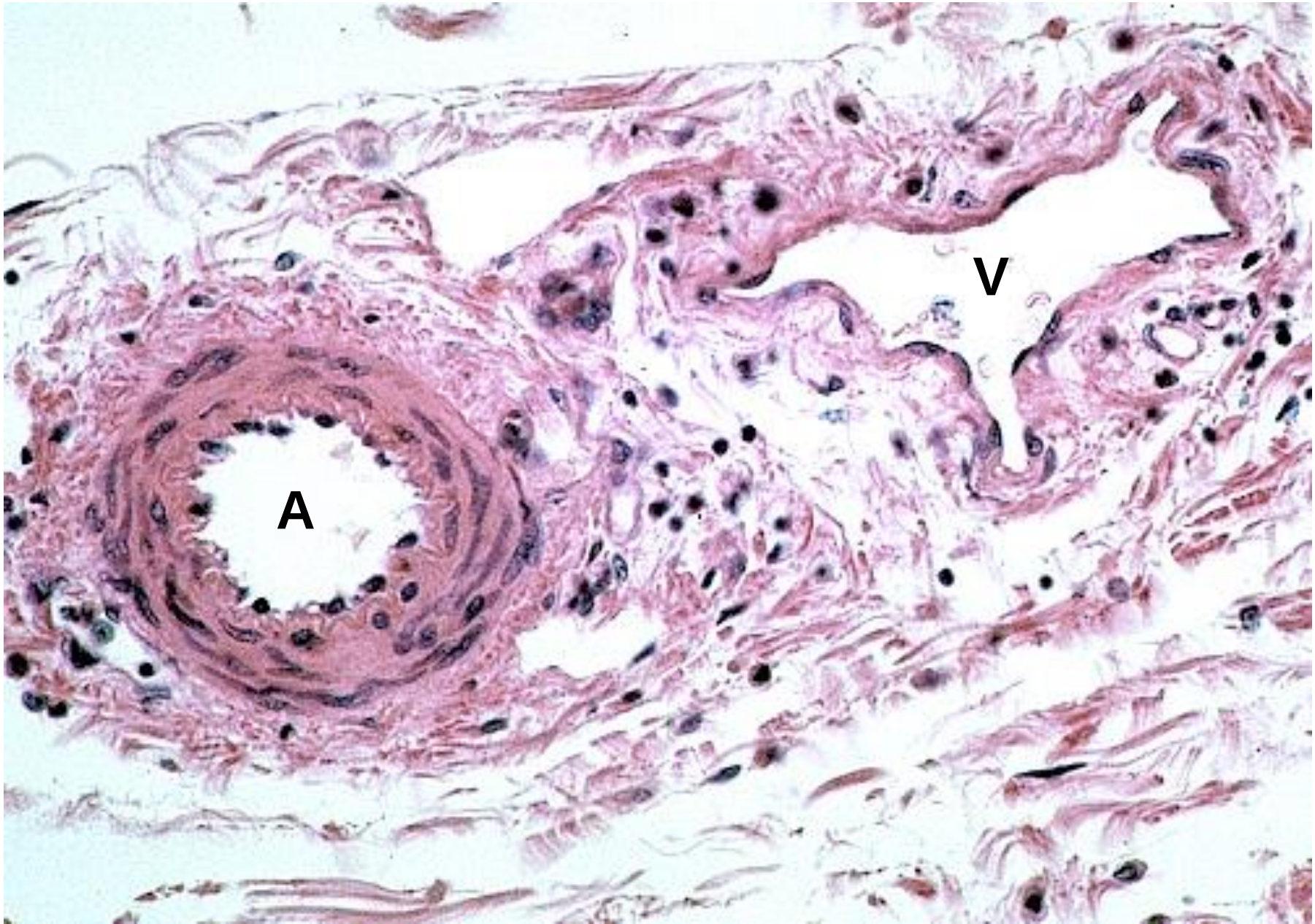
Arterioles

- Small arteries and arterioles are **distinguished** from one another **by the number of smooth muscle cell layers** in the tunica media.
- Arterioles control blood flow to capillary networks by contraction of the smooth muscle cells.

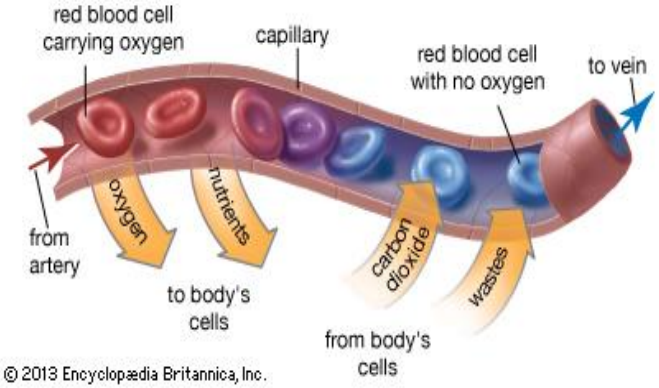




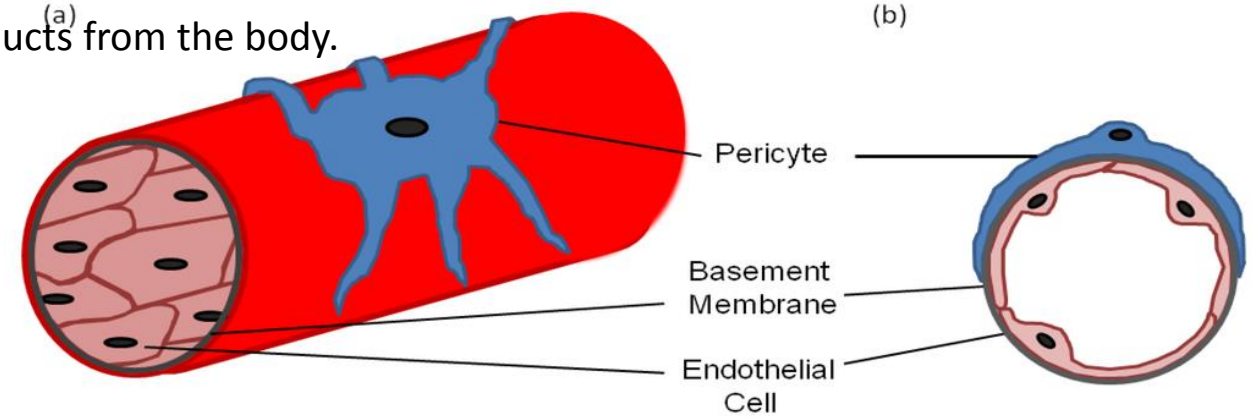
Arteriole (A) and Vein (V)



Capillaries

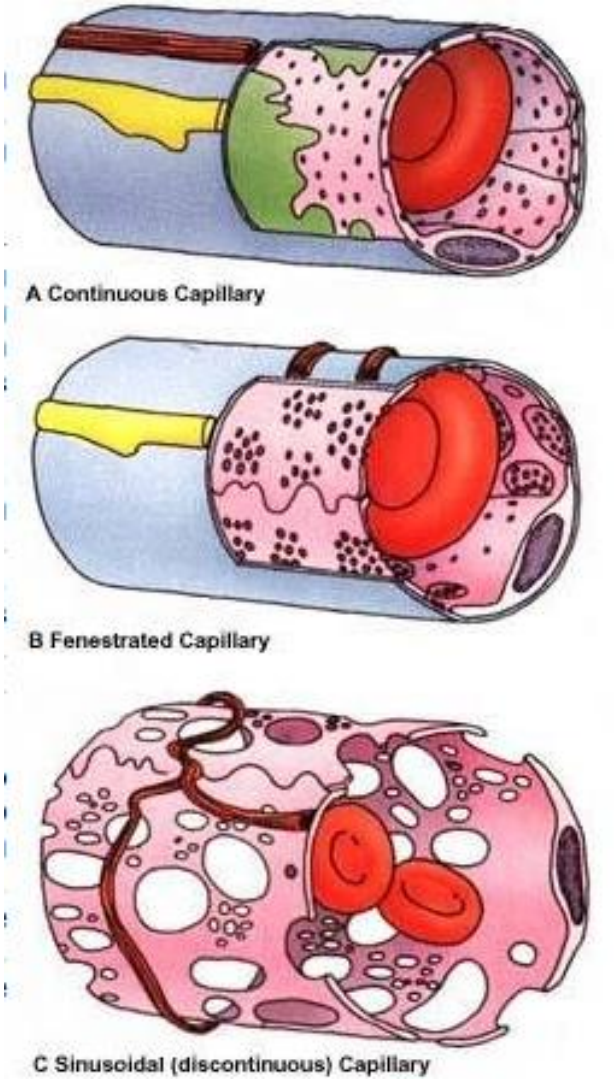


- Very small vessels, diameter ranges from 4-15µm
- *Only the tunica intima is present*:
  - endothelium
  - basal lamina
  - *pericytes* - cells surrounding the capillary
- **Pericytes** have contractile properties and can regulate blood flow in capillaries, they can also differentiate into endothelial and smooth muscle cells.
- The low rate of blood flow and large surface area facilitate the functions of capillaries in
  - providing nutrients and oxygen to the surrounding tissue, in
  - the absorption of nutrients, waste products and carbon dioxide, and in
  - the excretion of waste products from the body.



Types of Capillaries

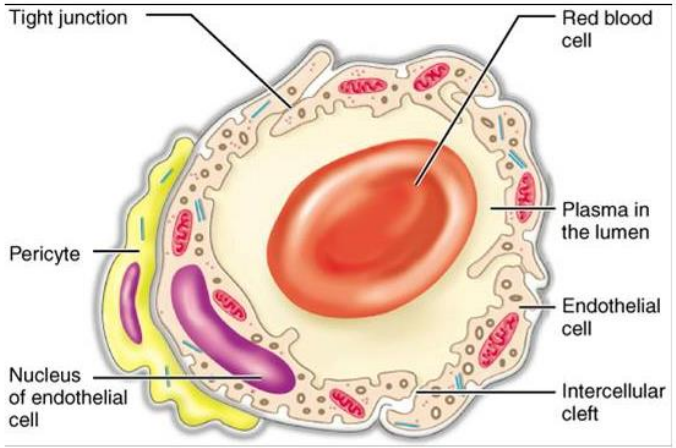
- *Three types of capillaries can be distinguished based on features of the endothelium.*:
  - **continuous capillaries**
  - **fenestrated capillaries**
  - **discontinuous capillaries**

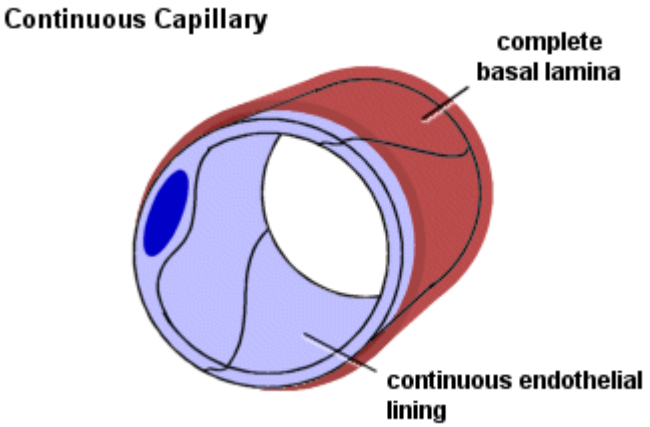


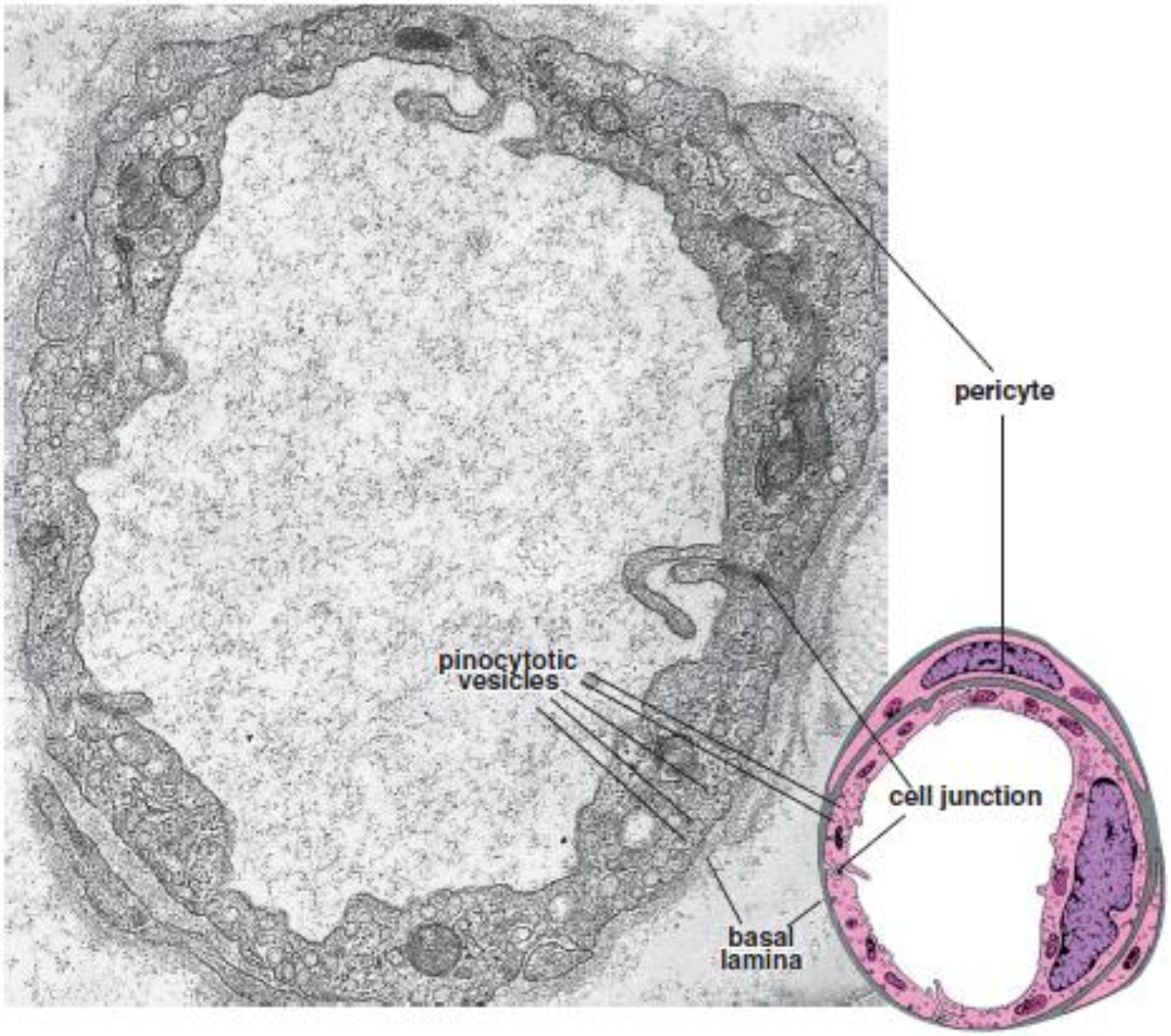
Continuous capillaries

- The endothelial cell and the basal lamina do not form openings, which would allow substances to pass the capillary wall without passing through both the endothelial cell and the basal lamina

- Continuous capillaries are typically found in muscle, lung, and the CNS

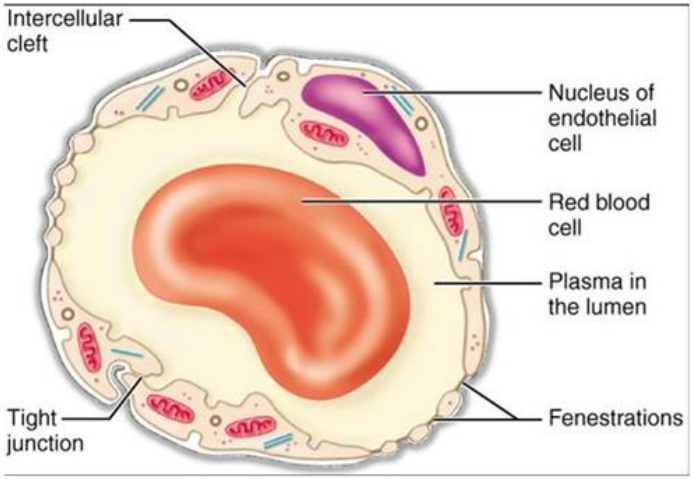





pericyte
pinocytotic vesicles
cell junction
basal lamina

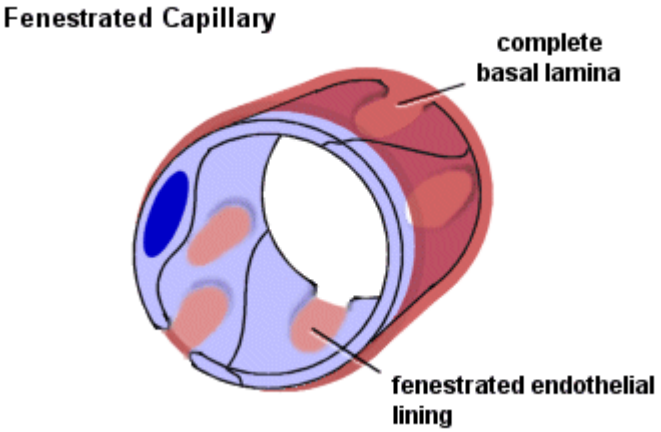
Fenestrated capillaries

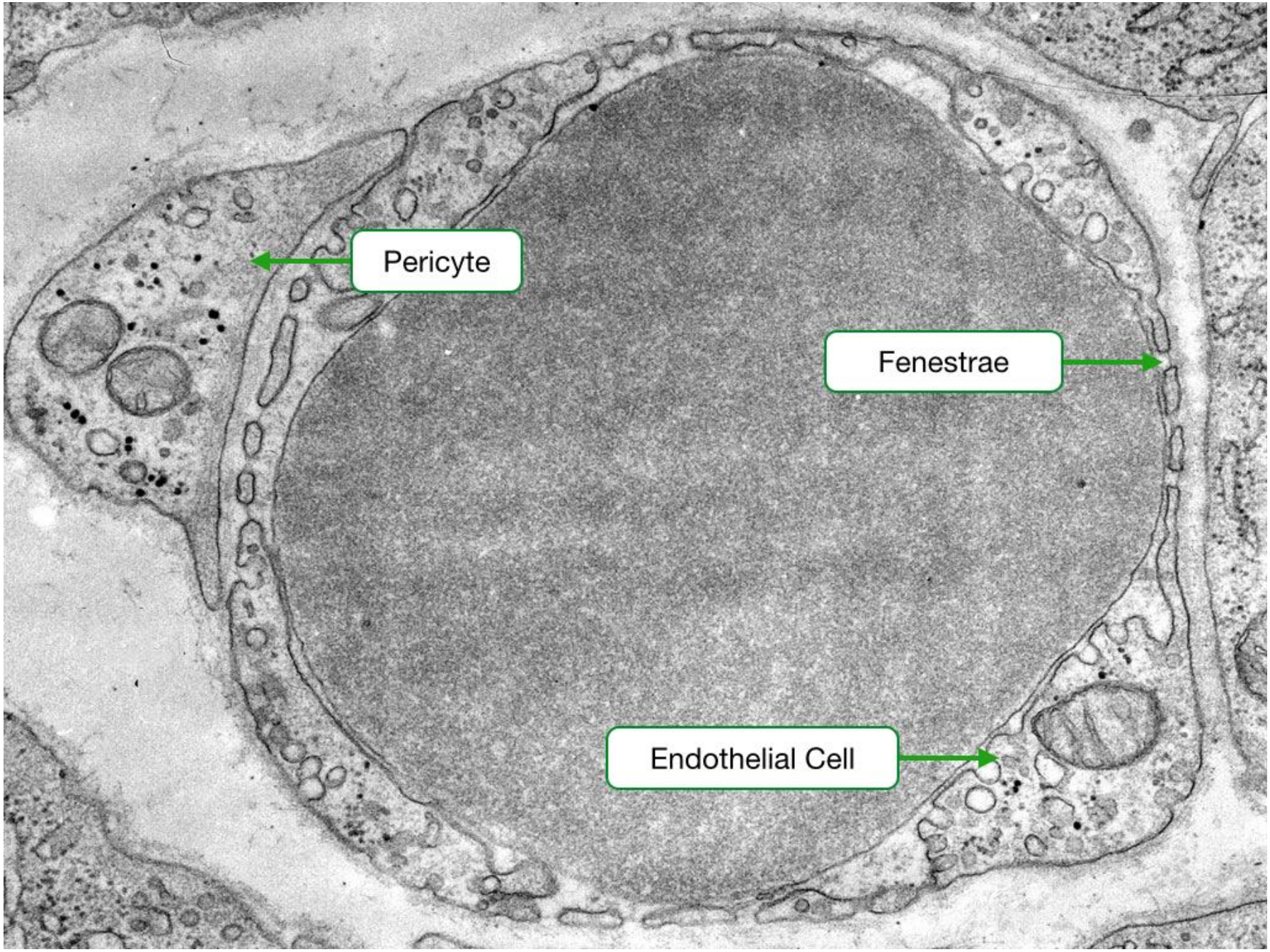
- The endothelial cell body forms small openings called *fenestrations,* which allow components of the blood and interstitial fluid to bypass the endothelial cells on their way to or from the tissue surrounding the capillary.



- The endothelial cells are surrounded by a continuous basal lamina, which can act as a selective filter.

- Typically found in endocrine glands and sites of fluid and metabolite absorption such as the kidney

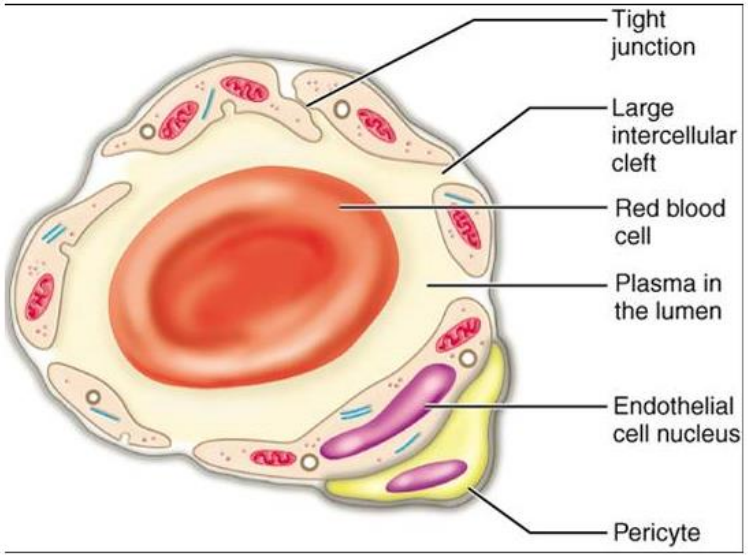


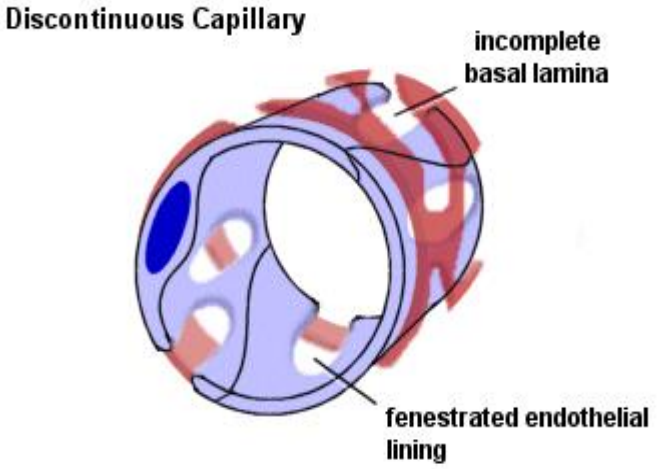

Pericyte
Fenestrae
Endothelial Cell

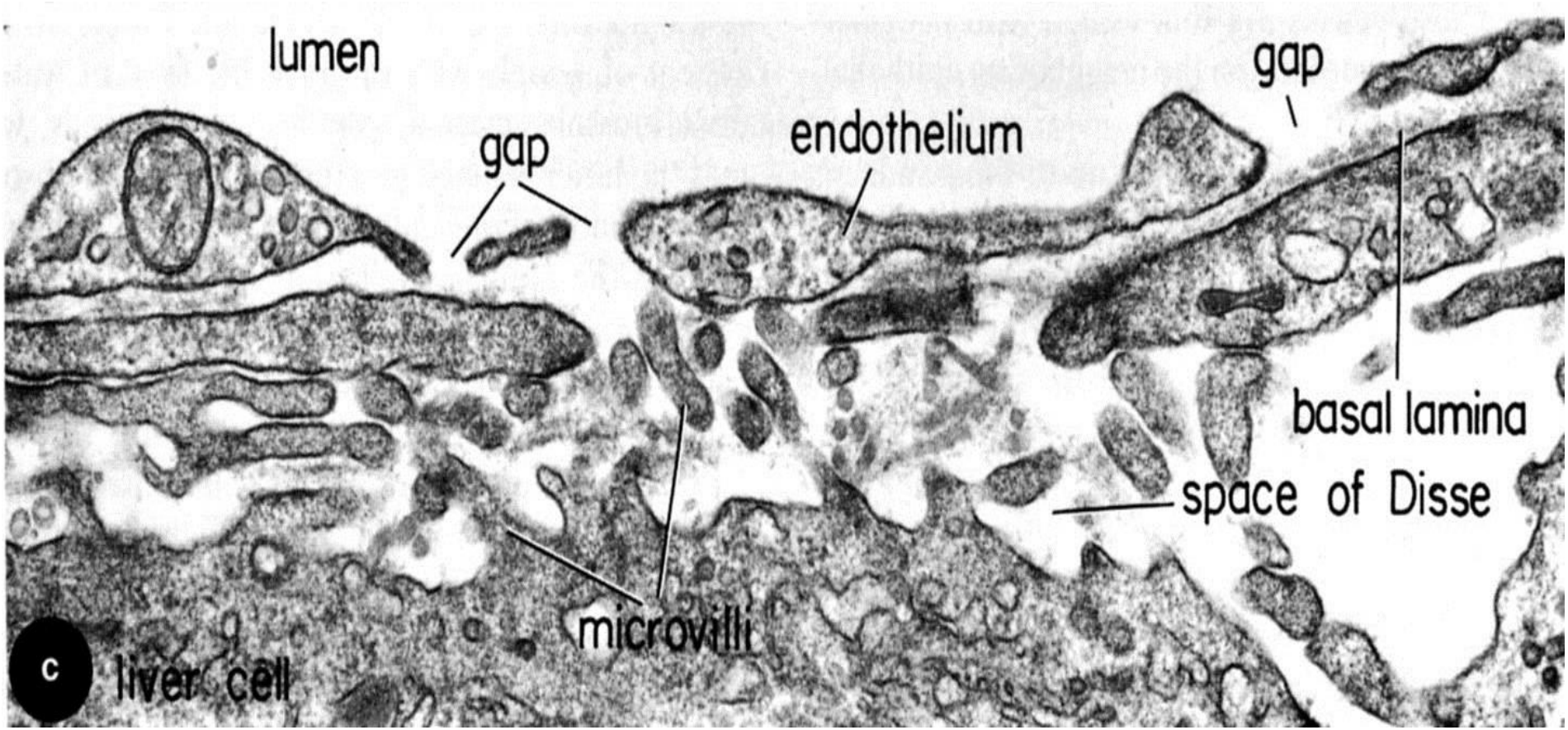
Discontinuous capillaries

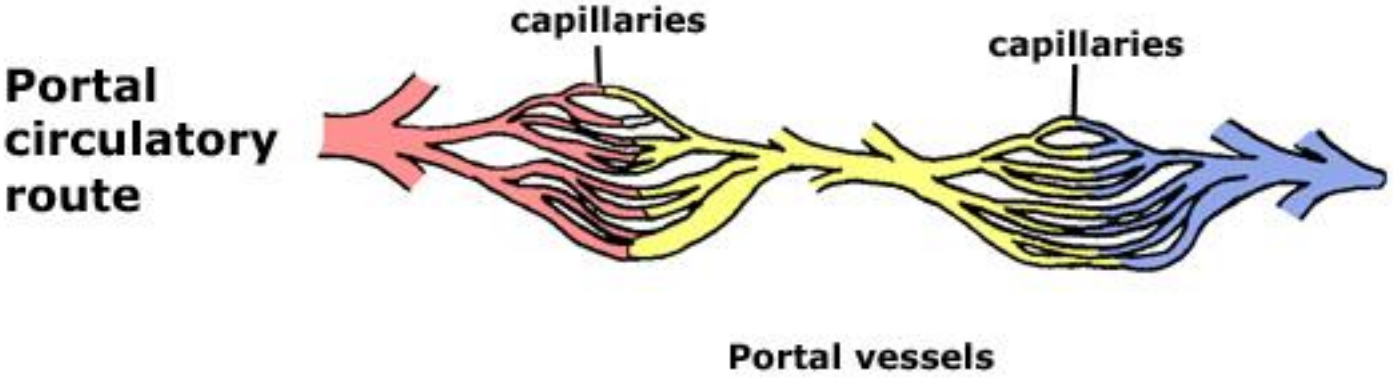
Sinusoidal capillaries or Sinusoids

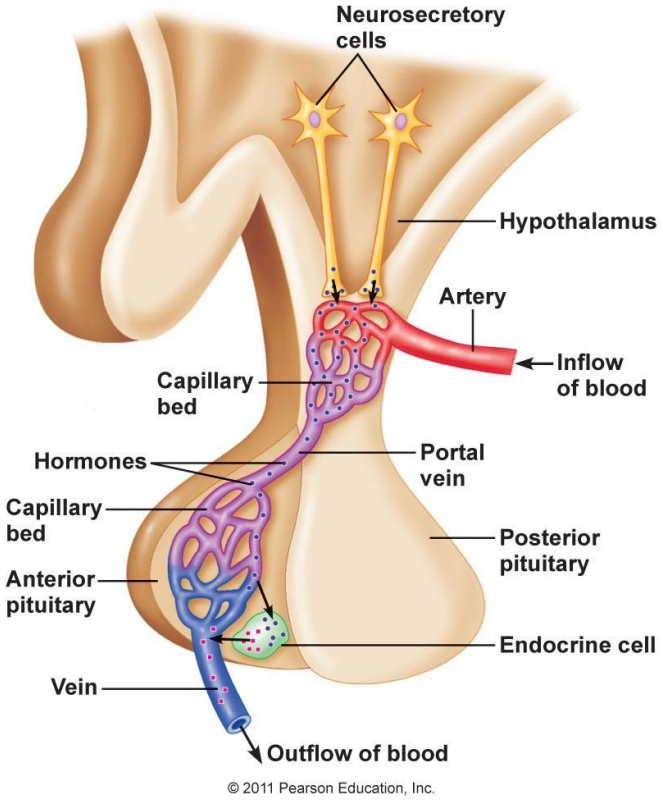
- Have gaps between endothelial cells allowing cells to pass
- Have many fenestrations
- Have discontinuous basal lamina
- Typically found in the liver, spleen, and bone marrow.

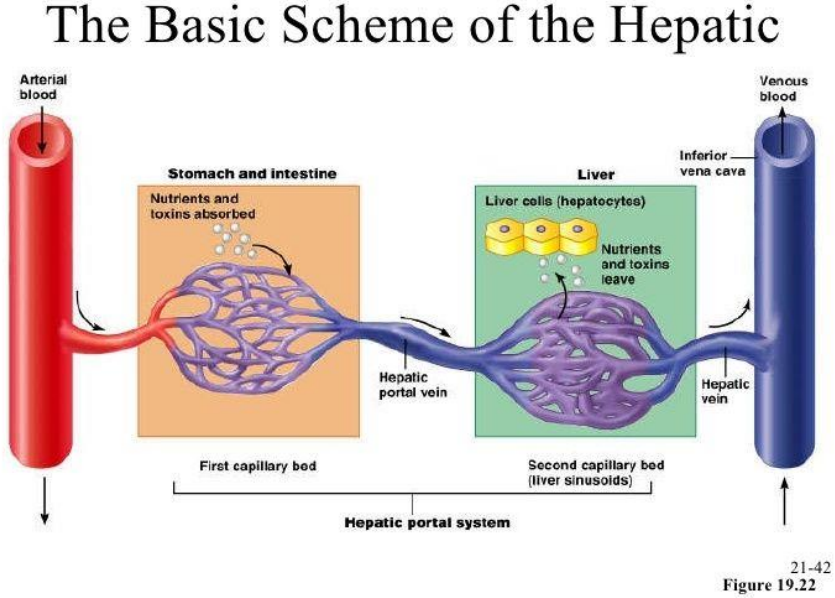





lumen
gap
endothelium
gap
basal lamina
space of Disse
microvilli
c
liver cell

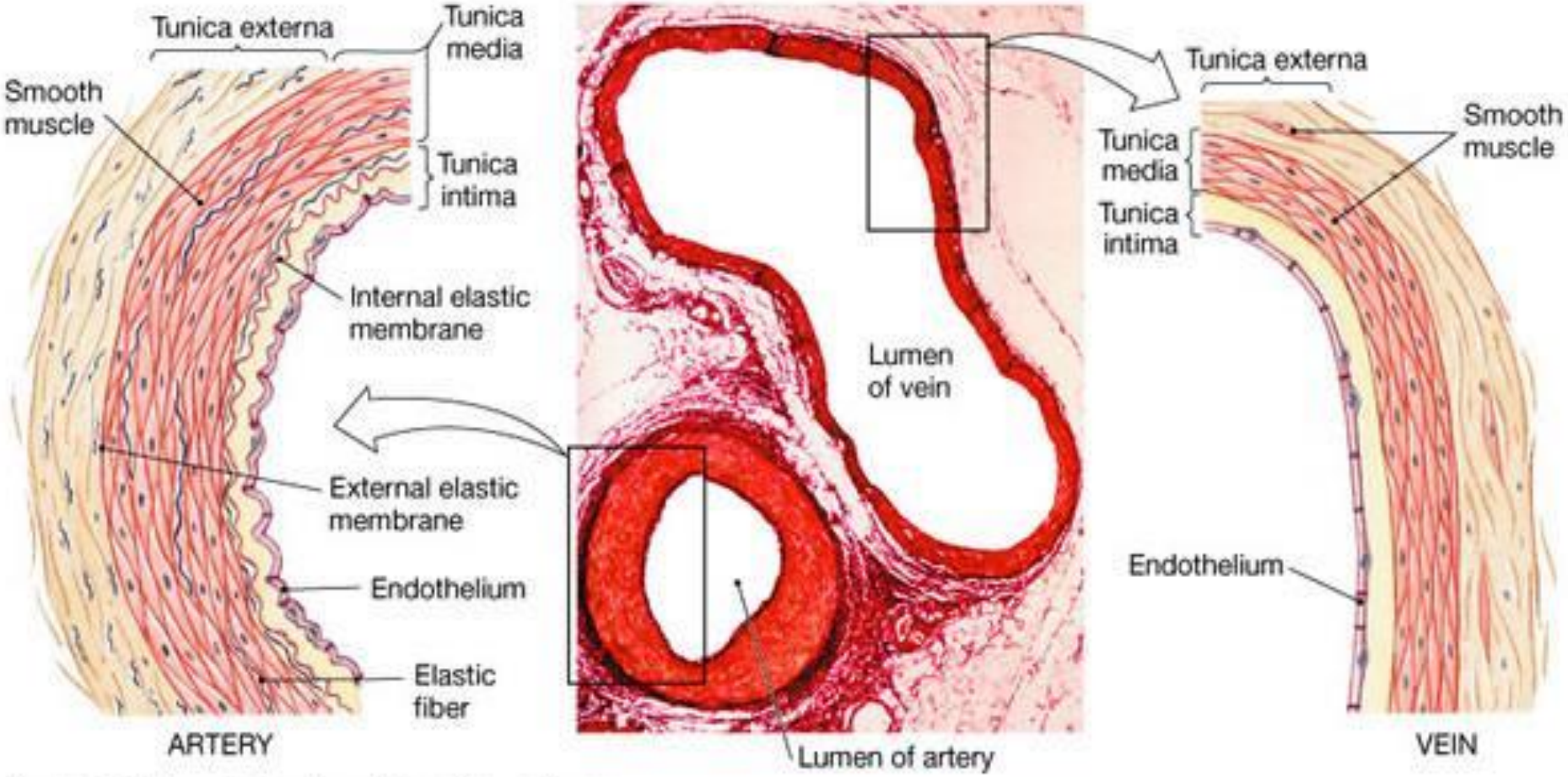






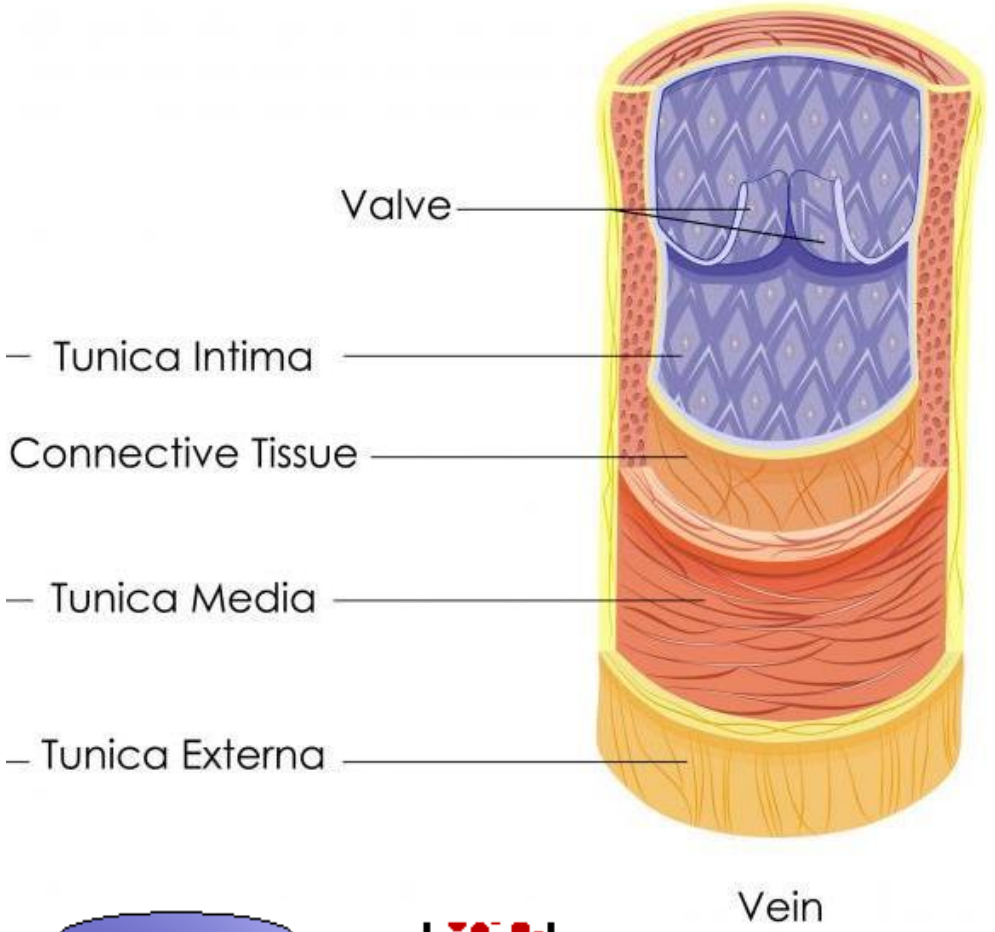
21-42
Figure 19.22

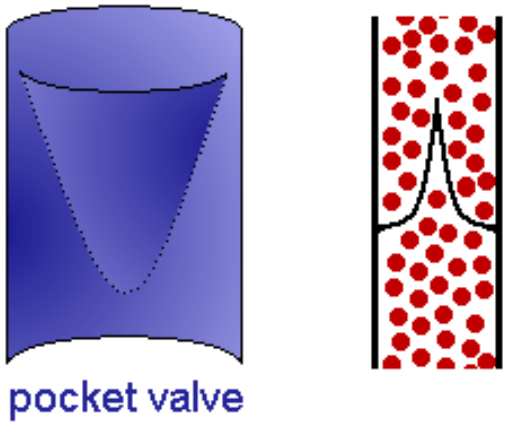
Arteries vs Veins



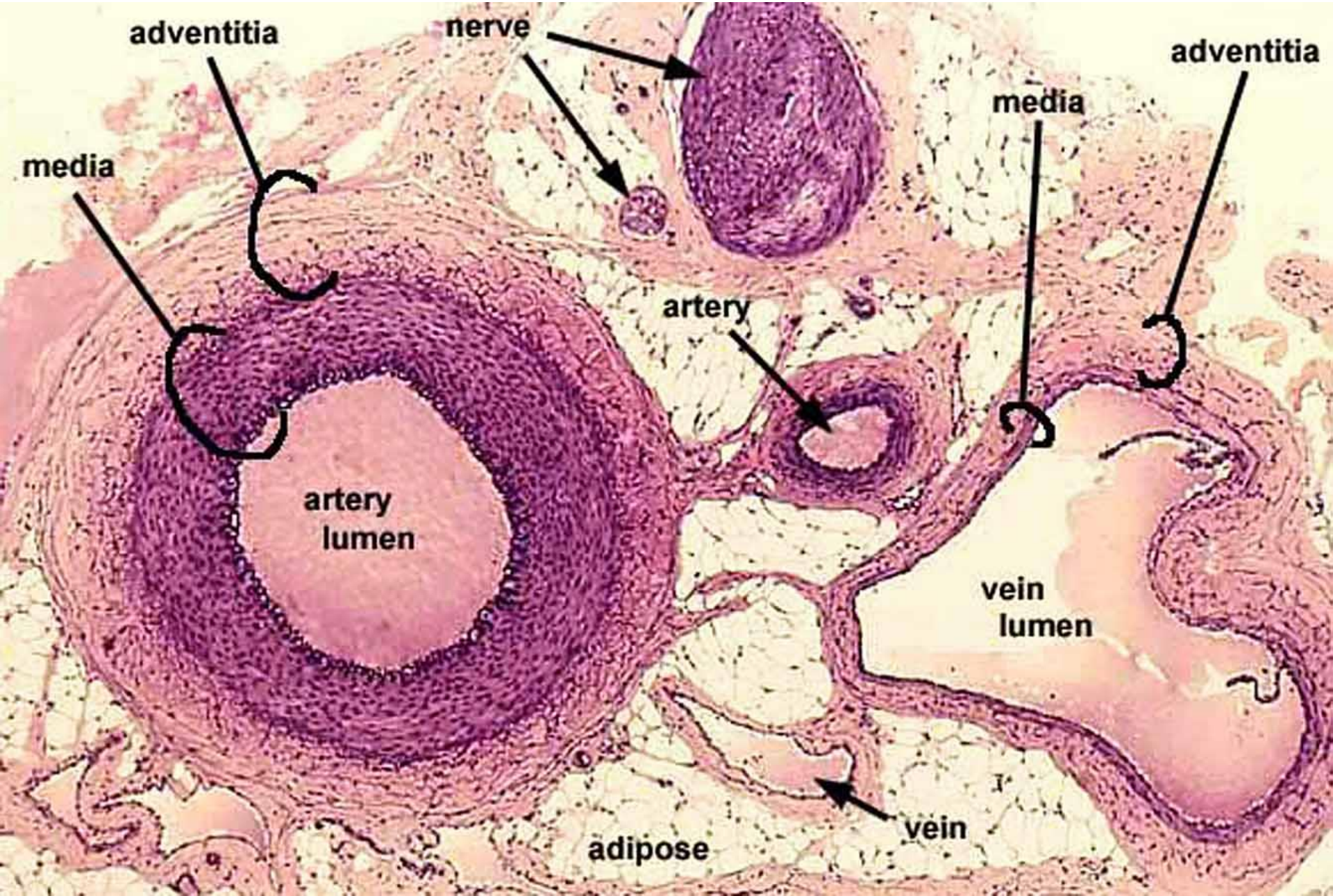
Veins

- Walls are thinner than the walls of arteries, while their diameter is larger
- The layering in the wall of veins is not very distinct
- The tunica intima is very thin
- *Internal and external elastic laminae are absent or very thin*
- The tunica media appears thinner than the tunica adventitia, and the two layers tend to blend into each other
- Valves are present



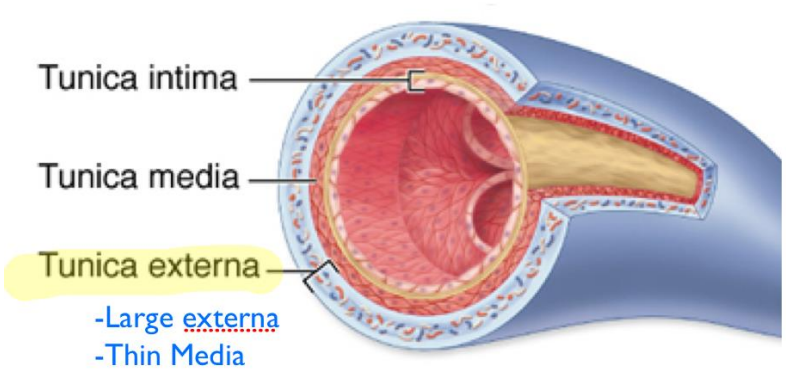


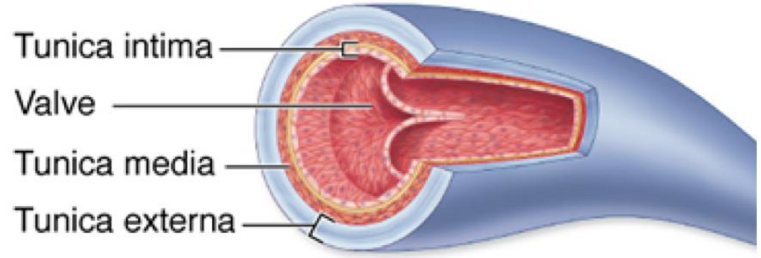
Muscular artery and large vein

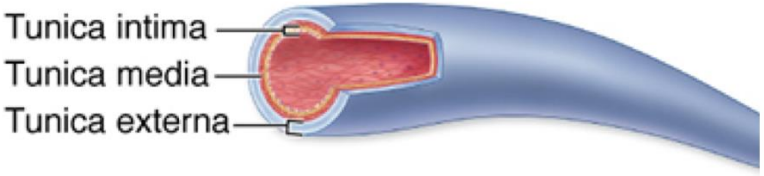


Types of veins

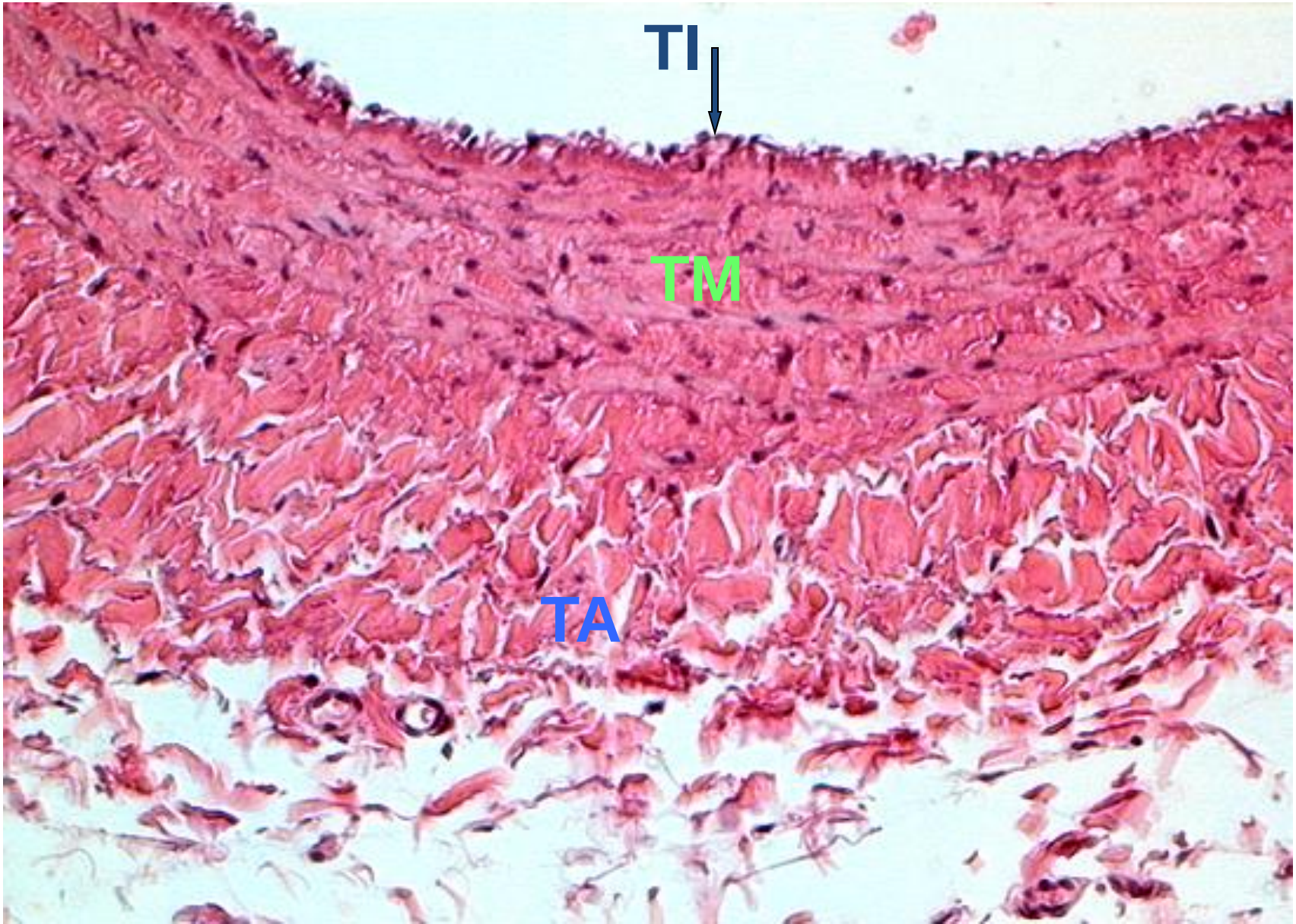
- **Venules** - receive blood from capillaries and have a diameter as small as 0.1 mm.
- **Small to Medium veins -** represent most of the named veins, usually are accompanied by arteries and have valves (except veins of head and neck)
- **Large veins -** tunica adventitia is very wide, contains bundles of *longitudinal* smooth muscle. Examples of such veins include the superior and inferior vena cava and hepatic portal vein



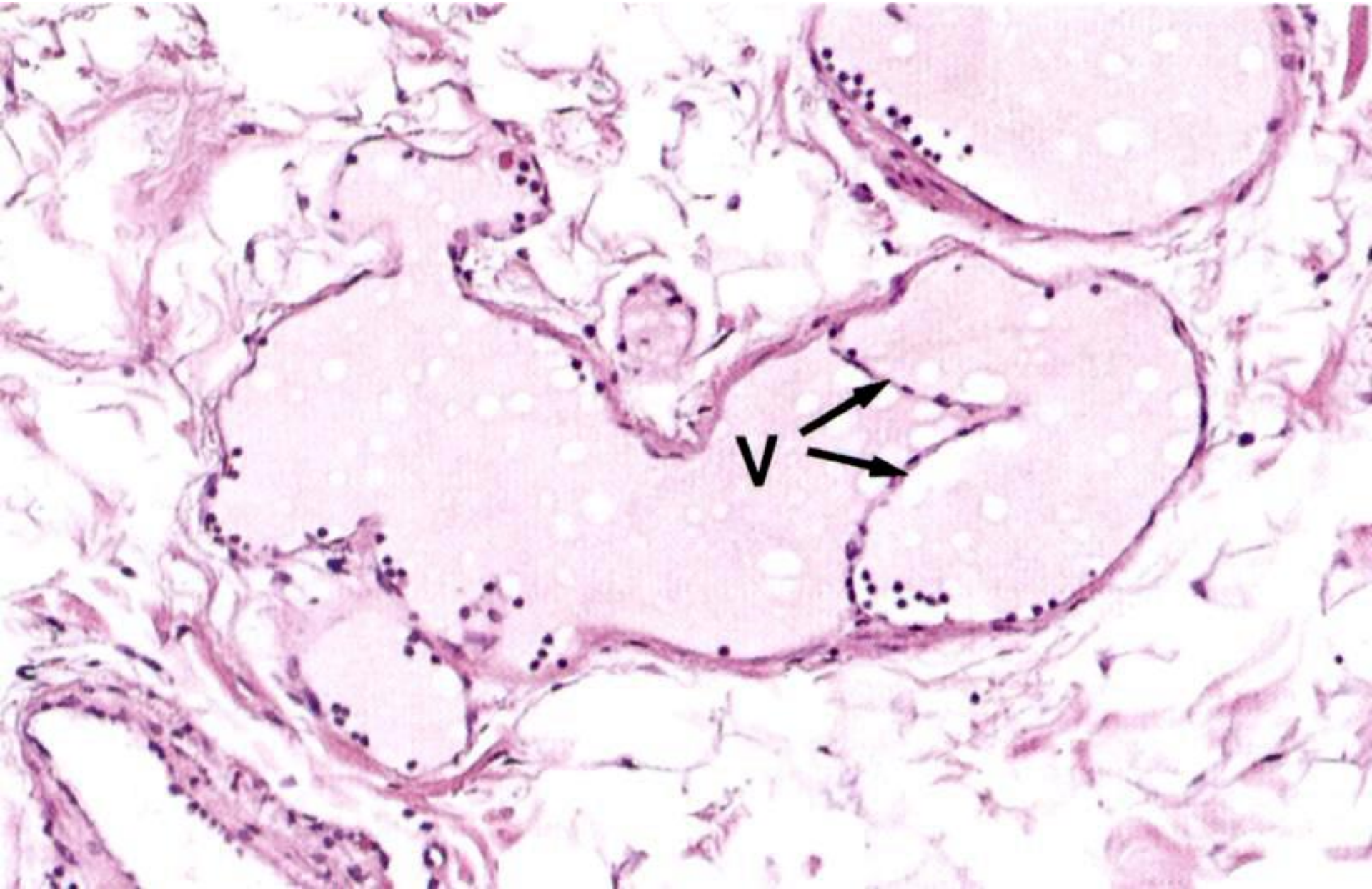


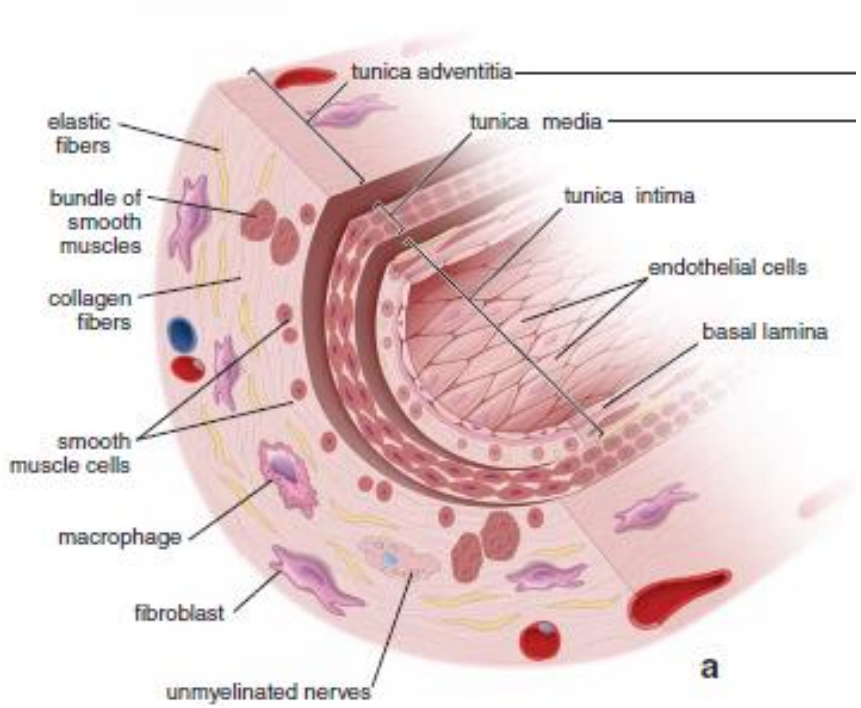


Wall of a vein – TI = T. Intima; TM = T. Media; TA = T. Adventitia

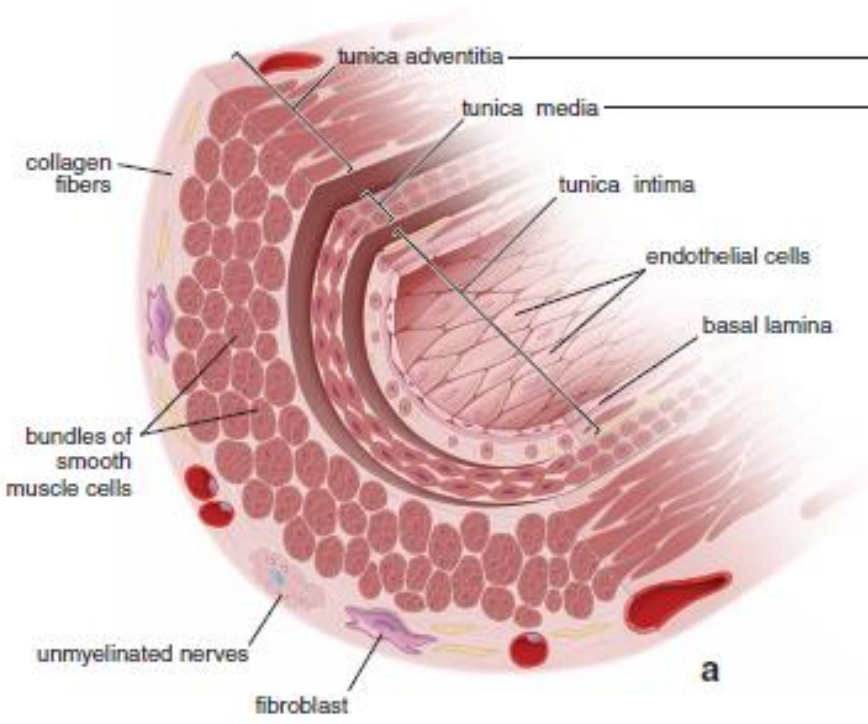


Vein with infoldings of the T. Intima = valves (V)





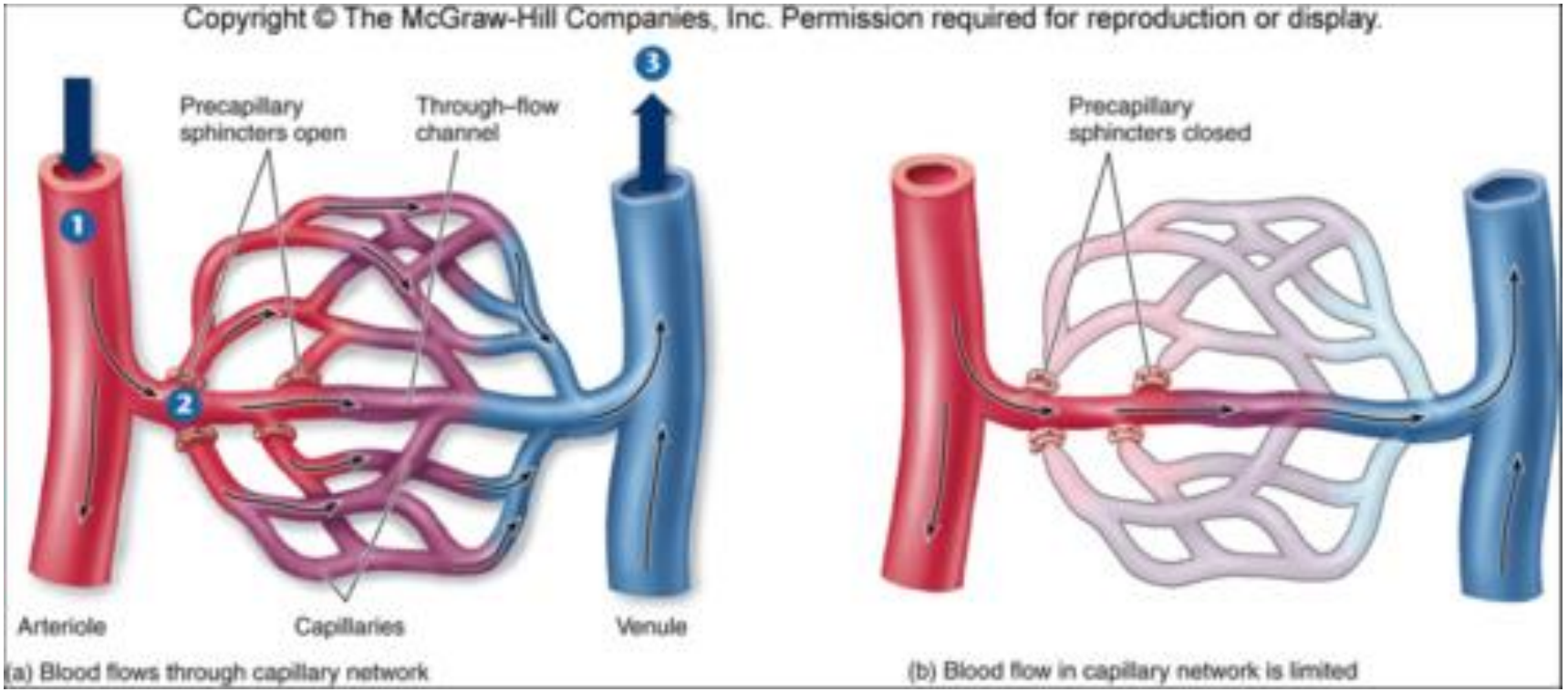
MEDIUM-SIZED VEIN



LARGE VEIN

	Arteries	Capillaries	Veins
Function	Carry blood **away** from the heart at **high** pressure	-Supply all cells with their **requirements** -Take away **waste** products	**Return** blood to the heart at **low** pressure
Structure of wall	-**Thick**, strong -Contain **muscles**, **elastic** fibres and **fibrous** tissue	**Very thin**, only one cell thick	-**Thin** -Mainly **fibrous** tissue -Contain far **less muscle** and **elastic** tissue than arteries
Lumen	-**Narrow** -Varies with heartbeat (increases as a pulse of blood passes through)	-**Very narrow** -Just wide enough for a red blood cell to pass through	**Wide**
Valves	(-)	(-)	(+) Prevent backflow
How structure fits function	-Strength and elasticity needed to withstand the pulsing of the blood, prevent bursting and maintain pressure wave -Helps to maintain **high blood pressure**, preventing blood flowing backwards	- No need for strong walls, as most of the blood pressure has been lost -Thin walls and narrow lumen bring blood into close contact with body tissue, allowing **diffusion** of materials between capillary and surrounding tissues. -White blood cells can squeeze between cells of the wall	- No need for strong walls, as most of the blood pressure has been lost - Wide lumen offers **less resistance** to blood flow

Arteriovenous Anastomoses



- Direct connections between arteries and veins
- Regulate blood flow by smooth muscle contraction
- Examples: stress, temperature changes, heavy exertion

Lymphatic vessels

Lymphatic vessels convey fluids from the tissues to the venous system

Lymphatic capillaries

↓

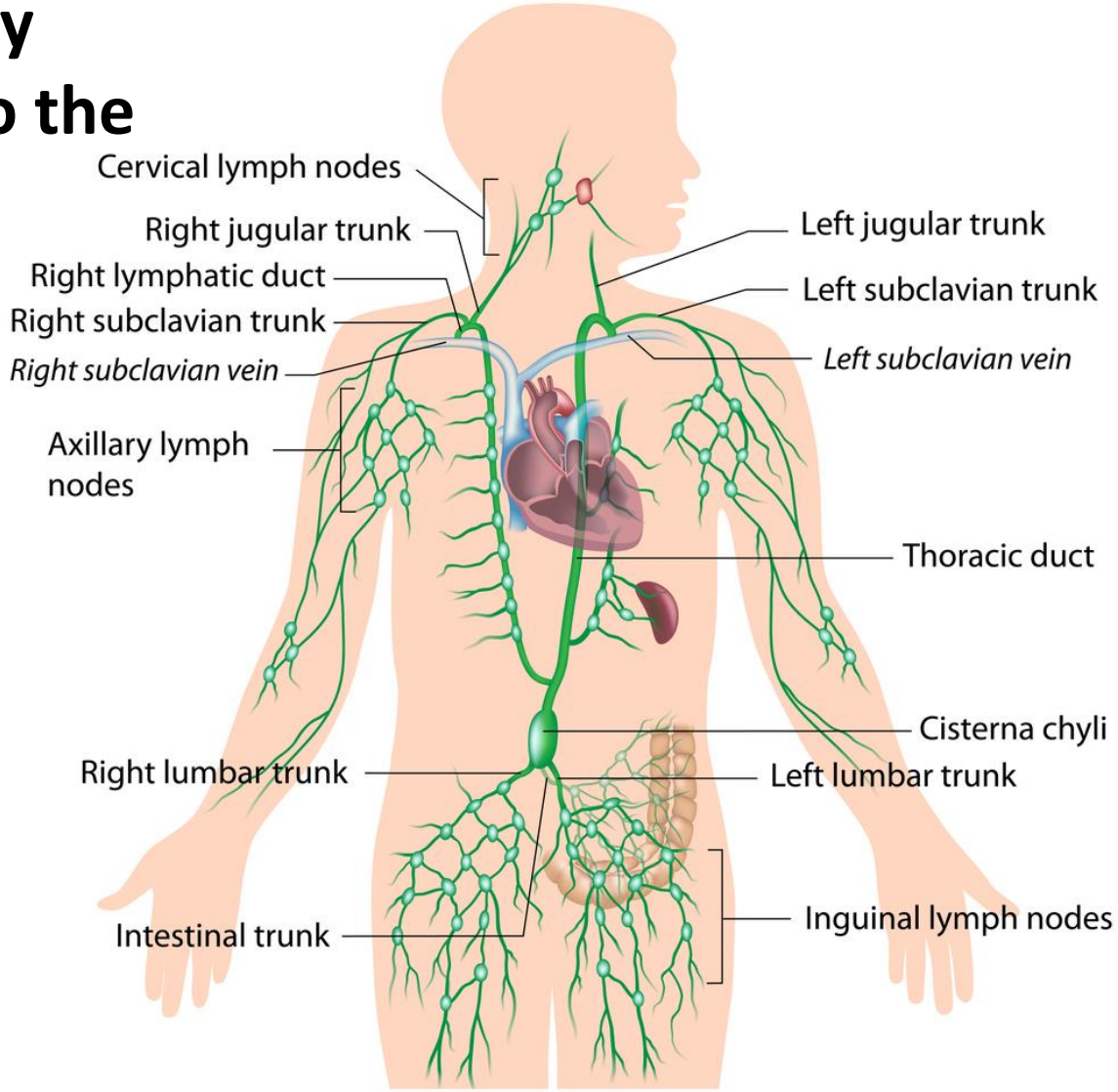
Lymphatic vessels

↓

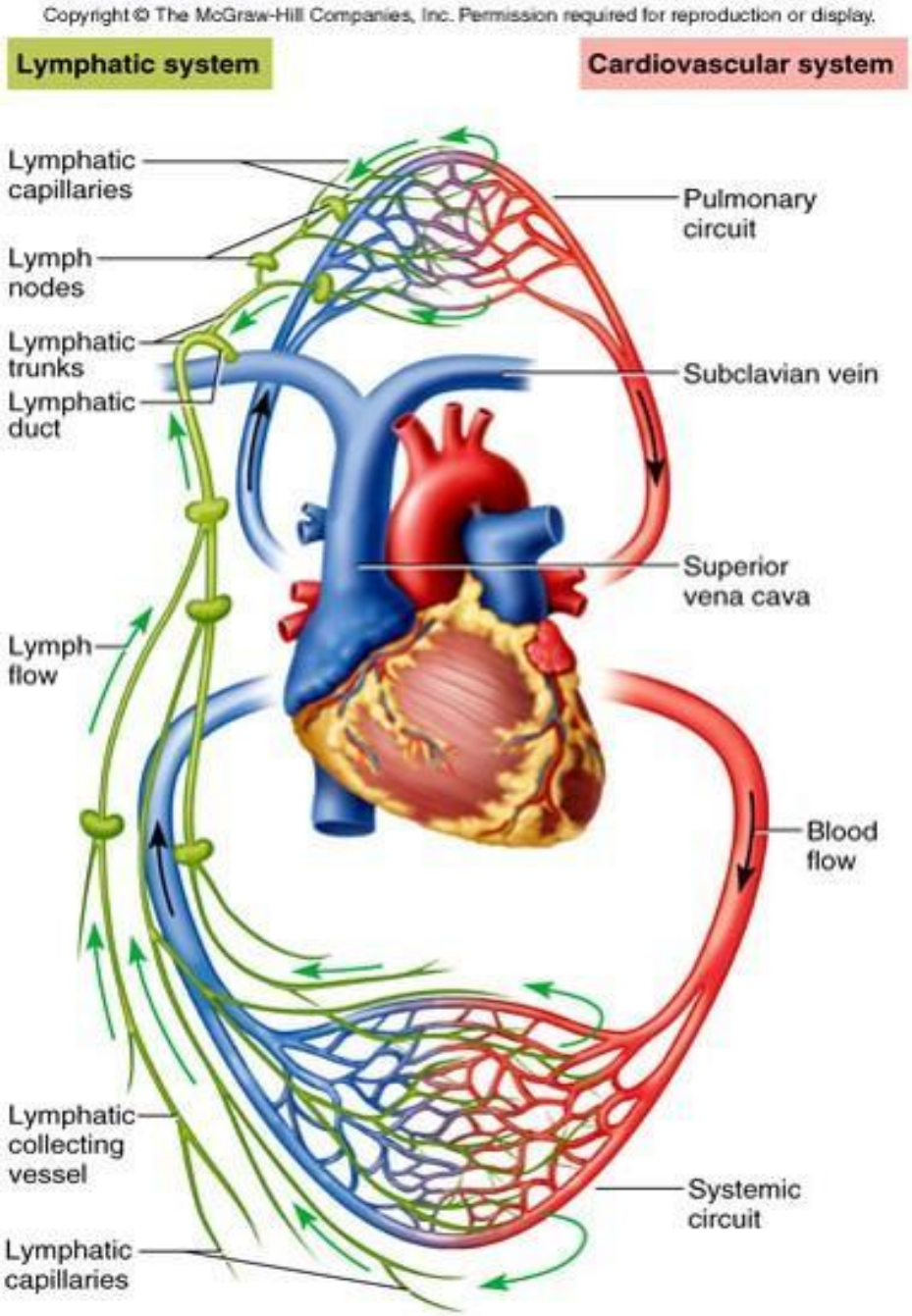
Lymphatic ducts

↓

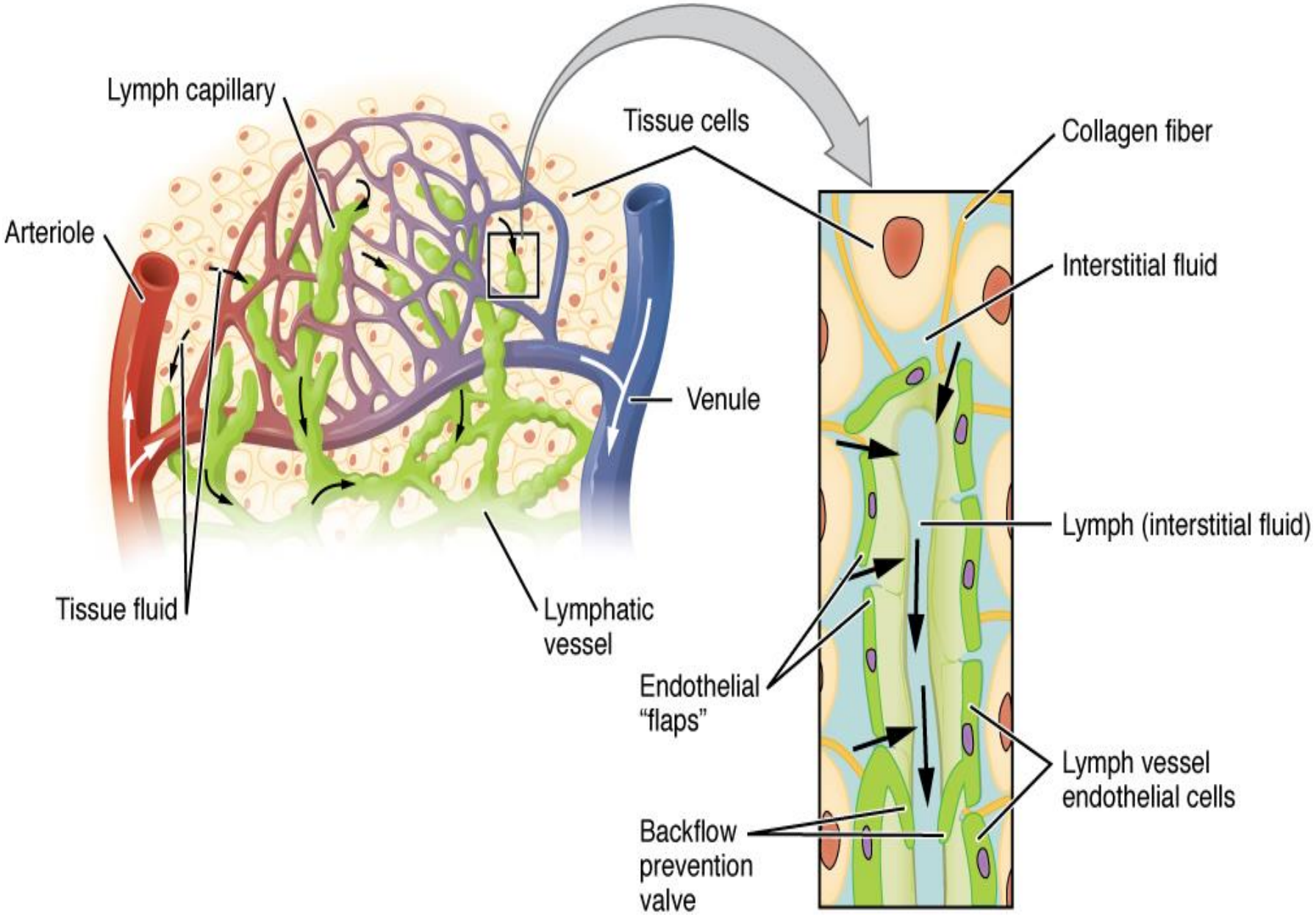
Lymphatic tracts



- **Lymphatic capillaries are more permeable than blood capillaries and collect excess protein-rich tissue fluid**
- Once the collected fluid enters the lymphatic vessel, it is called lymph
- Before lymph is returned to the blood, it passes through lymph nodes, where it is exposed to the cells of the immune system.

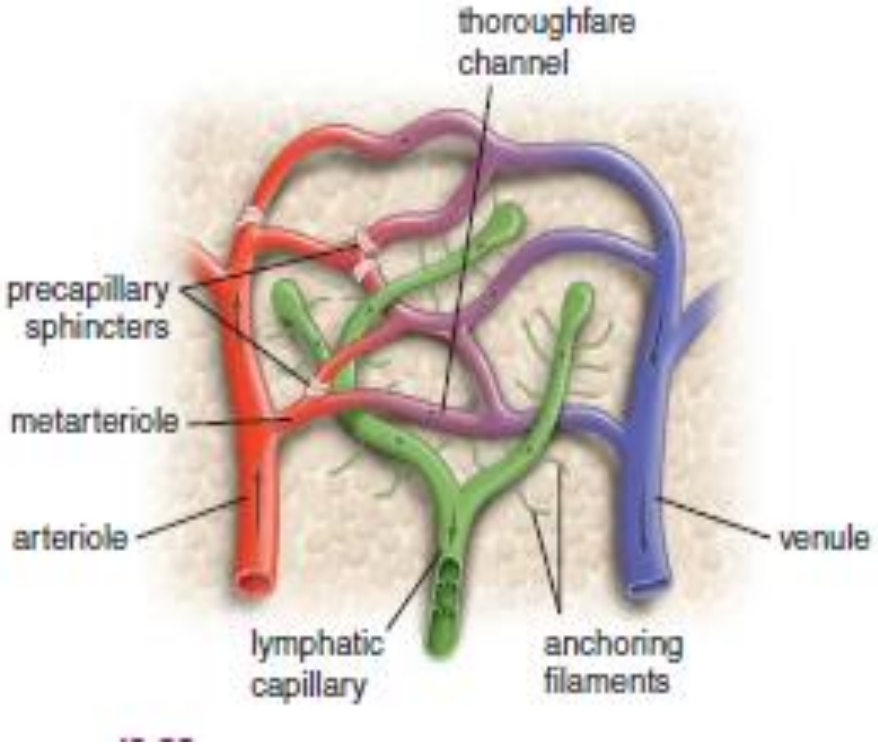


Lymph capillaries in the tissue spaces



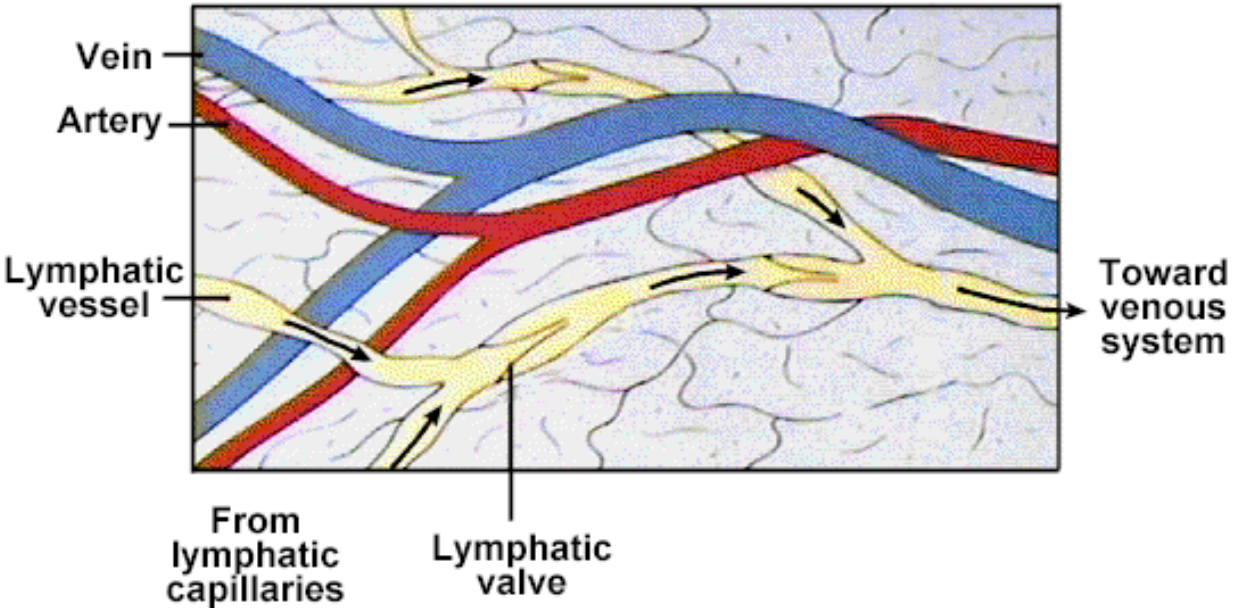
Lymphatic capillaries

- Begin as “blind” tubes in the capillary beds
- Lined by simple squamous epithelium
- Discontinuous basal lamina
- Have greater diameter than blood capillaries



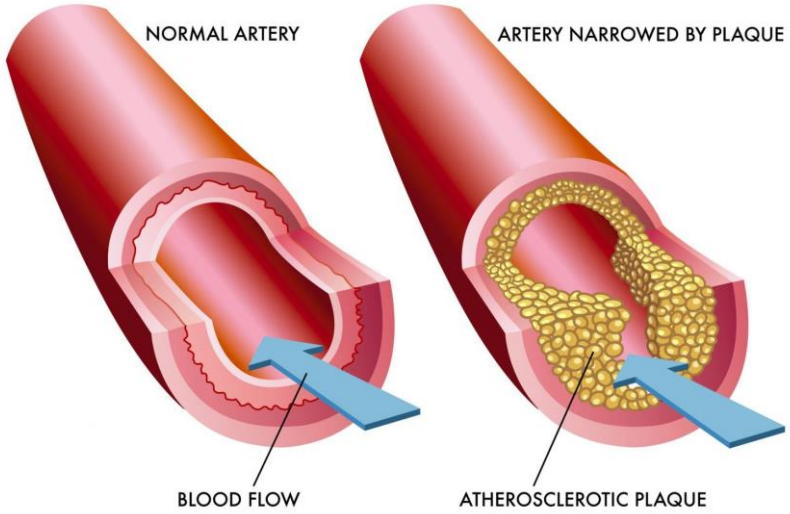
Lymphatic vessels and ducts

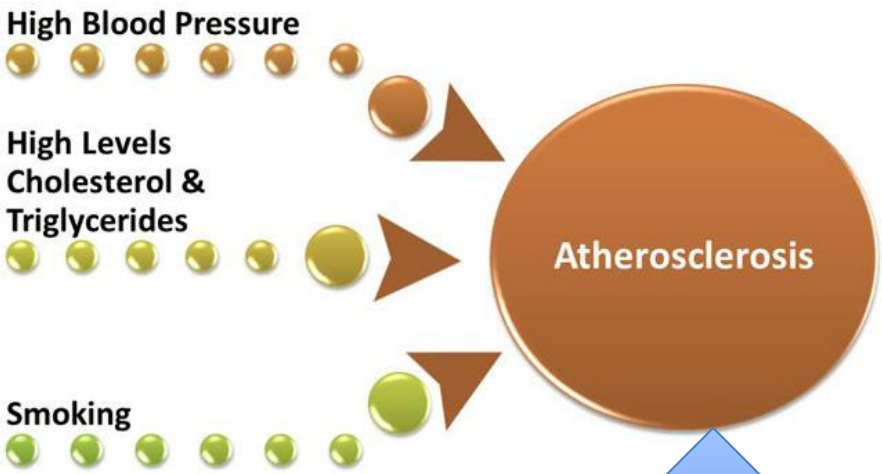
- Resemble veins in structure
- Have beaded appearance
- Possess valves that prevent backflow of the lymph
- Simple squamous epithelium
- Tunica media with predominant longitudinal muscle fiber
- Thin adventitia



Atherosclerosis

- hardening and loss of elasticity of the arteries due to the formation of plaques



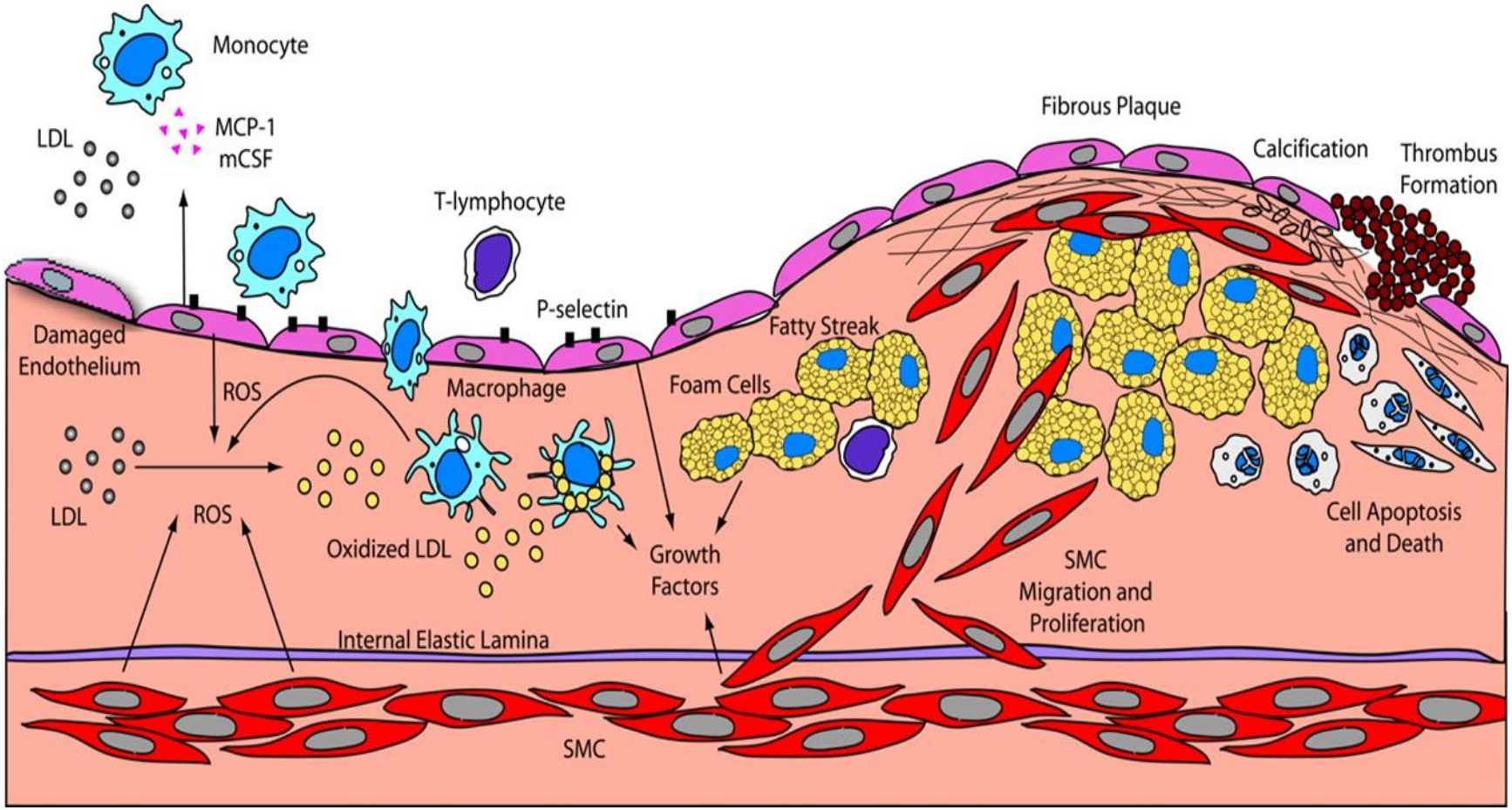


Causes

Results

Heart	• Coronary artery disaese(CAD) • Anging(Chest pain which become worse with physical actvity) • Arrythmia(irregular heart beats) • Heart attack
Brain	• Carotid artery disease(numbness, fatigue, dizzness, and headaches) • Stroke
Arms &Legs	• Peripherial arterial disease(numbness and serious infections) • Intermittent claudication(leg pain on walking)

Formation of atherosclerotic plaque



Types of cholesterol

HDL

GOOD CHOLESTEROL!
High Density Lipoprotein

Good cholesterol (High Density Lipoprotein), carries excess cholesterol in your blood back to your liver where it's broken down and removed from your body. This means a high level of good HDL cholesterol can maintain your heart health.

LDL

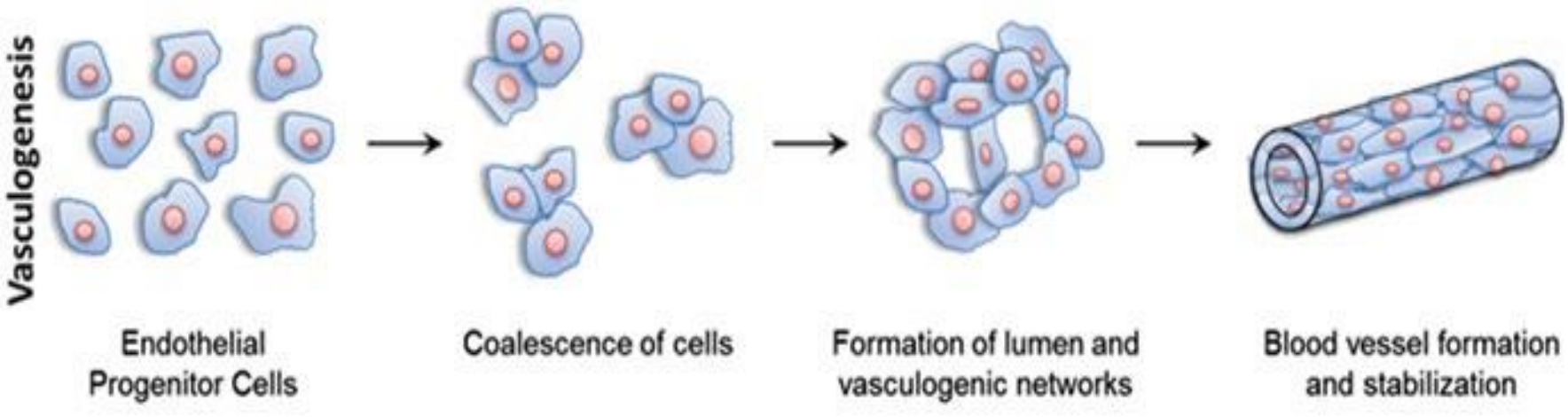
BAD CHOLESTEROL!
Low Density Lipoprotein

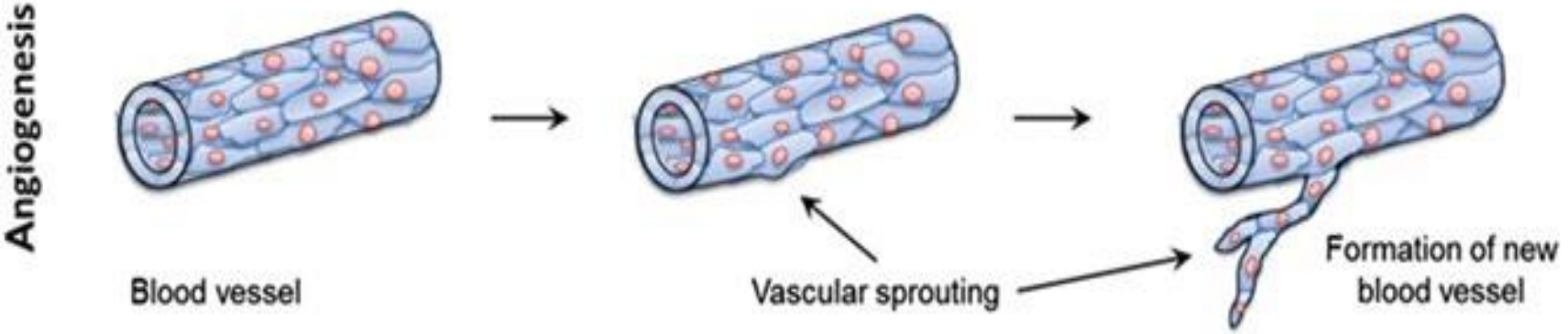
Bad cholesterol (Low Density Lipoprotein) carries cholesterol to your cells. But when you have too much LDL it can build up in your artery walls, causing them to narrow. This reduces blood flow, which can be bad for your heart health.

Your total cholesterol level is made up of **both LDL and HDL cholesterol**. When you get your cholesterol checked make sure you find out both these levels.

Vasculogenesis - is the process of blood vessel formation from endothelial progenitor cells occurring in embryogenesis.

Angiogenesis - formation of new blood vessels from pre-existing ones.





Thank you for attention