HISTOLOGY OF THE CVS

Mr. BABATUNDE. D. E.

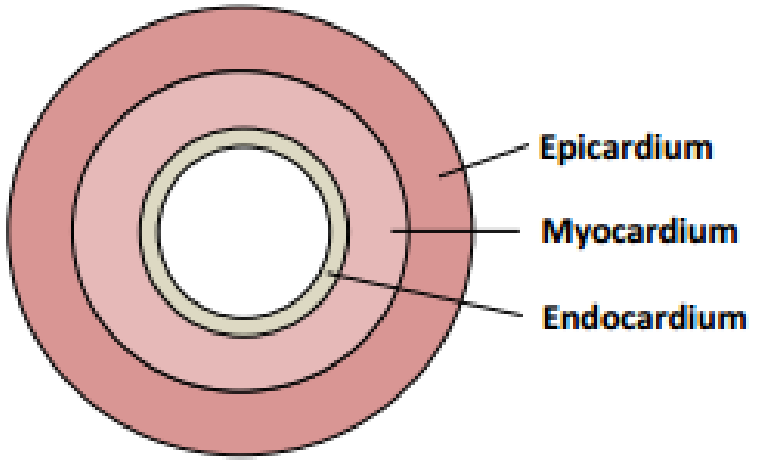
FUNCTIONS OF THE CIRCULATORY SYSTEM

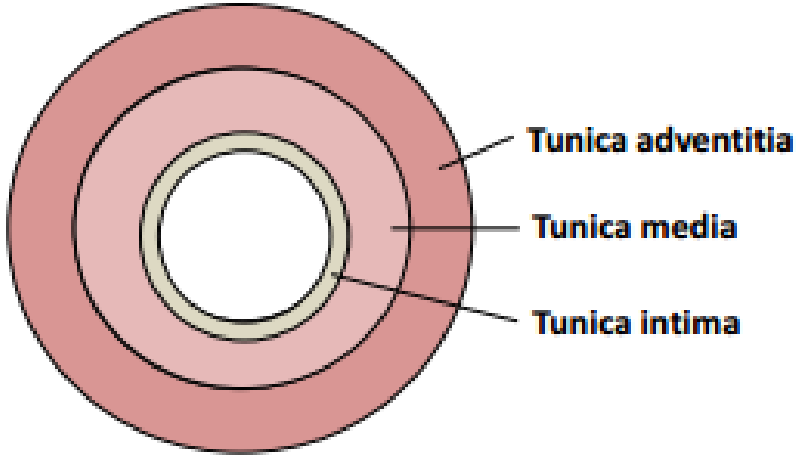
- Transport of blood
- Regulation of blood pressure
- Transport of hormones
- Transport of components of the immune system, coagulation molecules and enzymes
- Exchange of nutrients, waste products, and gases

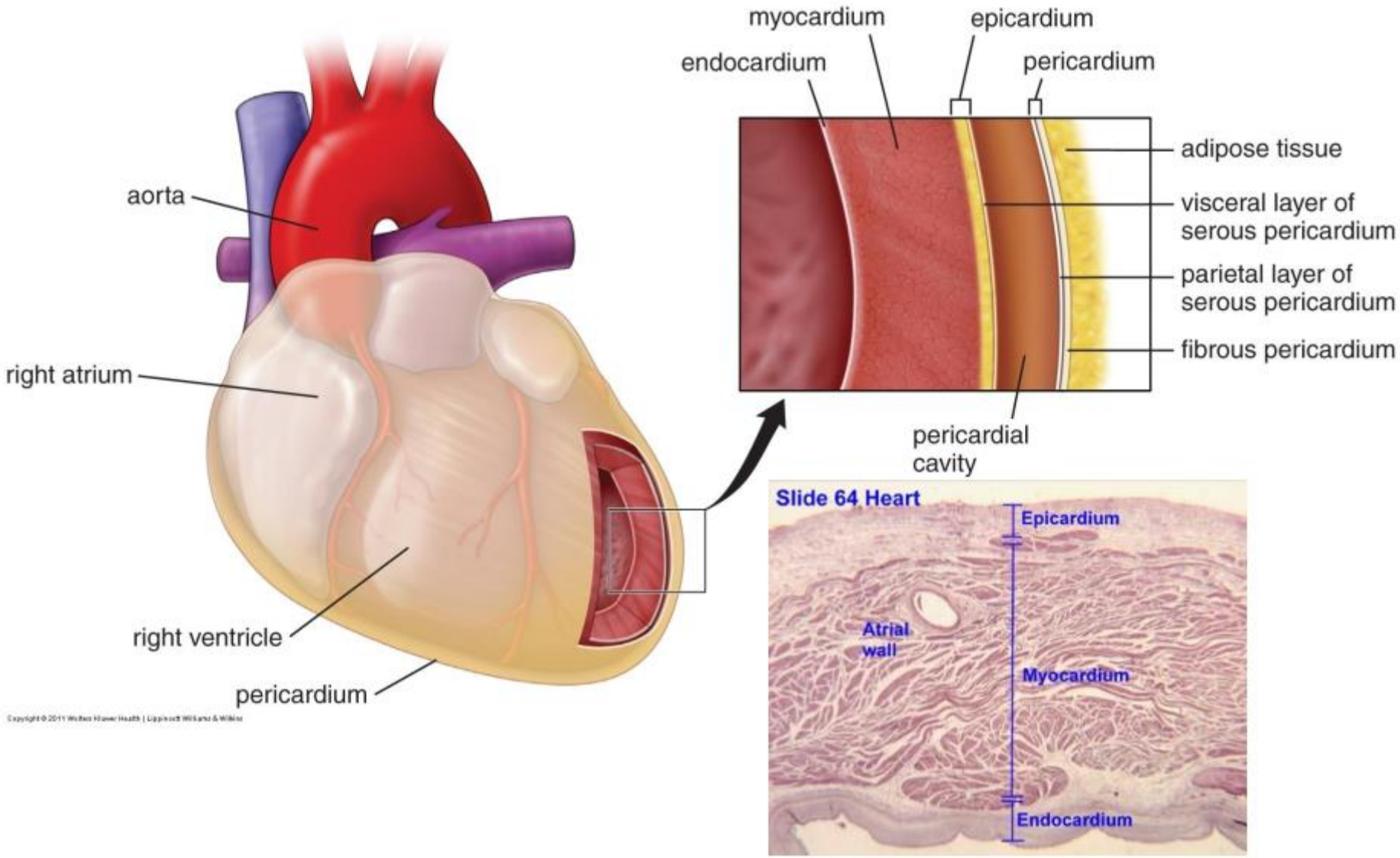
ORGANIZATION OF THE HEART AND BLOOD VESSELS

- Heart wall has three layers
  - Endocardium – inner layer
  - Myocardium – middle layer
  - Pericardium (epicardium) – outer layer

- Blood and lymphatic vessel walls (except for capillaries) have three layers
  - Tunica intima – inner layer
  - Tunica media – middle layer
  - Tunica adventitia – outer layer

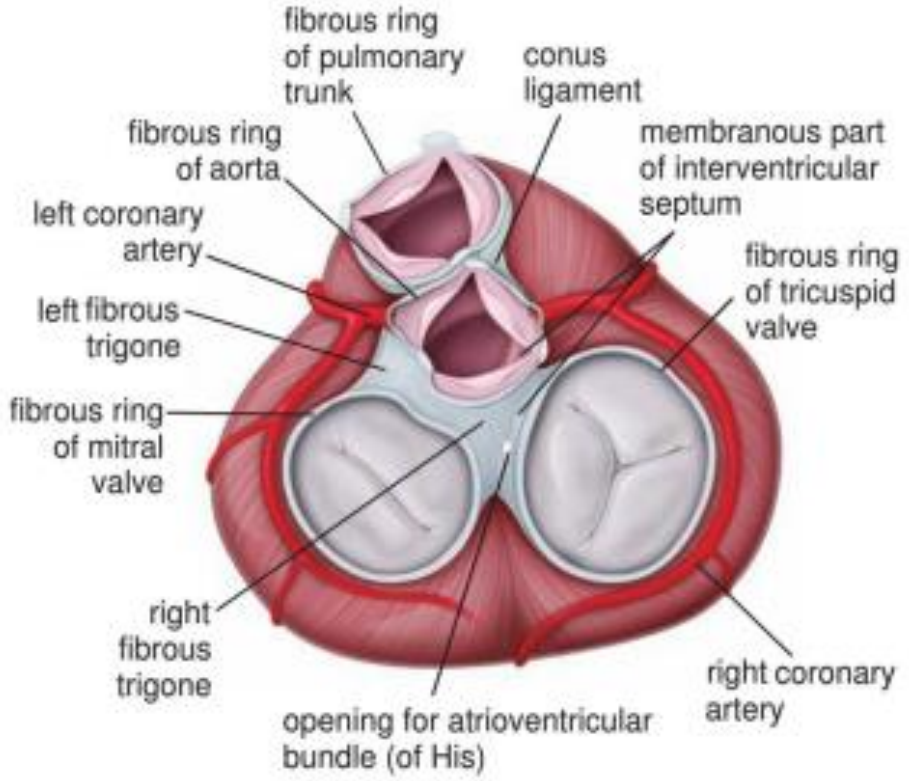





aorta
right atrium
right ventricle
pericardium
myocardium
epicardium
endocardium
pericardium
adipose tissue
visceral layer of serous pericardium
parietal layer of serous pericardium
fibrous pericardium
pericardial cavity
Slide 64 Heart
Epicardium
Atrial wall
Myocardium
Endocardium

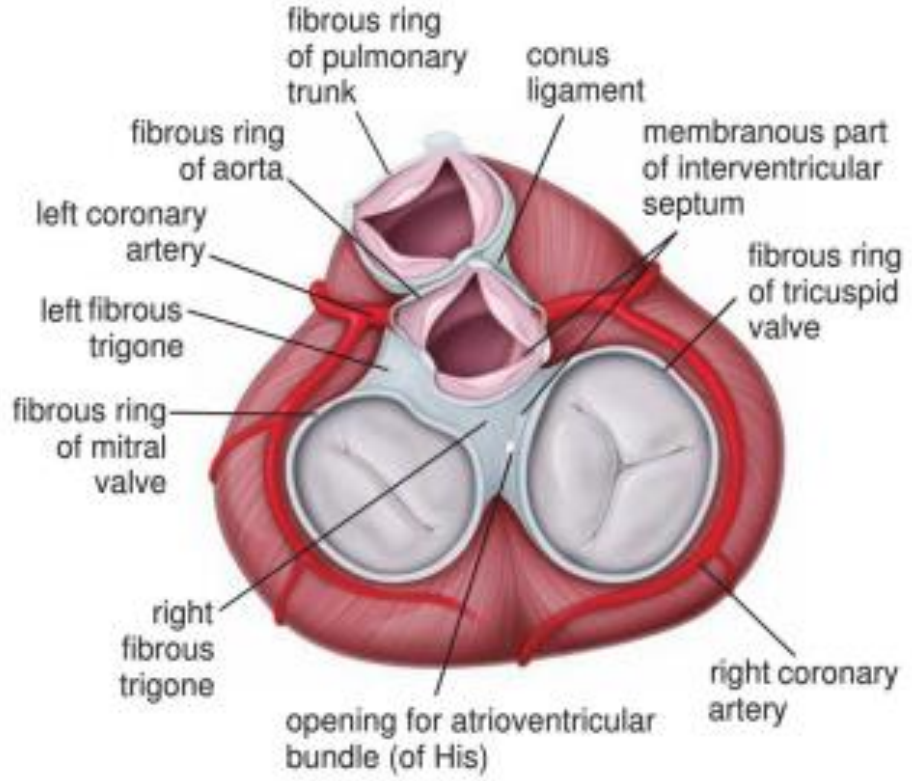
HISTOLOGY OF THE HEART

- The heart contains the following:
  - Cardiac muscle – for contraction to propel blood
  - A fibrous skeleton that consists of four rings surrounding the valve orifices
    - The fibrous rings are composed of dense irregular connective tissue
    - The fibrous rings encircle the base of the two arteries, leaving the heart (aorta and pulmonary trunk) and the openings between the atria and the ventricles (right and left atrioventricular orifices)



HISTOLOGY OF THE HEART

- The functions of the fibrous skeleton are:
  - Provision of attachment site for the valve leaflets
  - Provision of attachment points for the atrial and ventricular myocardium
  - Provision of the base of attachment for major arteries (pulmonary artery, ascending aorta)
  - It acts as electrical insulator between the atria and ventricles
- Please note that the atrial myocardium is not in contact with the ventricular myocardium. This will be explained later in the slides



HISTOLOGY OF THE HEART

- ENDOCARDIUM
  - It consists of an inner layer of endothelium, basal lamina and subendothelial connective tissue
  - It consists of a middle layer of connective tissue and smooth muscle cells
  - It consists of an outer layer of subendocardial connective tissue, which is continuous with the connective tissue of the myocardium
  - Small blood vessels and nerves are present in the endocardium

DIAGRAM HERE

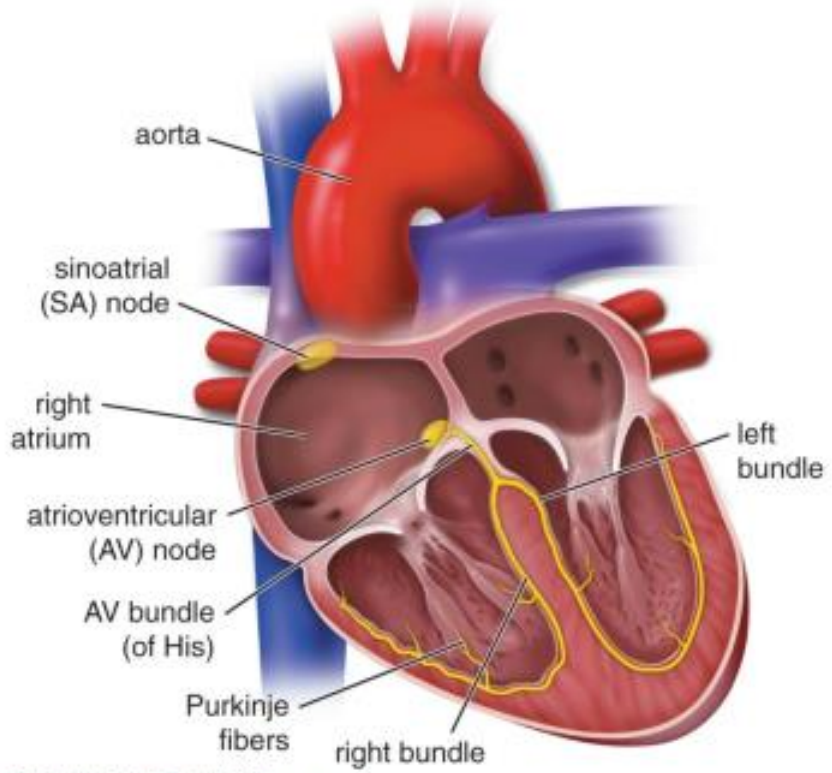
HISTOLOGY OF THE HEART

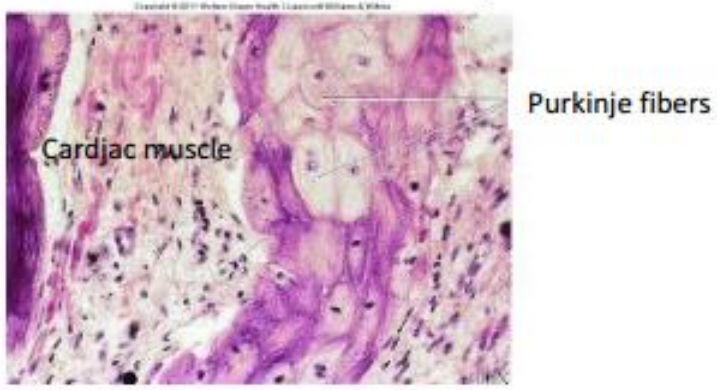
- MYOCARDIUM
  - It consists of cardiac muscle
  - It is the principal component of the heart
  - It can be classified into two broad divisions
    - General myocardium – this is mostly concerned with atrial and ventricular contractility
    - Specialized myocardium – this is further divided into two
      - Those with specialized electrical properties (pacemaker and conduction pathways)
      - Myocardial endocrine cells – these myocardial cells produce hormones, the most important of which is atrial natriuretic peptide (ANP) – ANP regulates blood volume and cardiac output

DIAGRAM HERE

CONDUCTING SYSTEM OF THE HEART

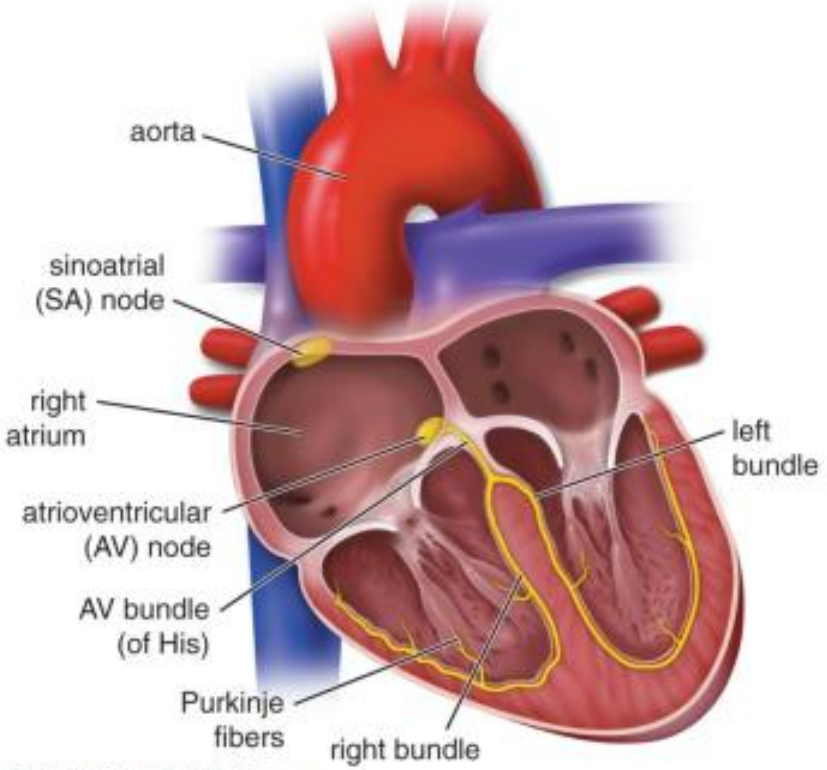
- It is composed of specialized myocardial tissue which can transmit electrical impulses
- The myocardial cells are specialized for initiating impulses and conducting them rapidly through the hear
- It is made up of three main components
  - The sinoatrial (SA) node
  - Atrioventricular (AV) node
  - Atrioventricular Bundle of His

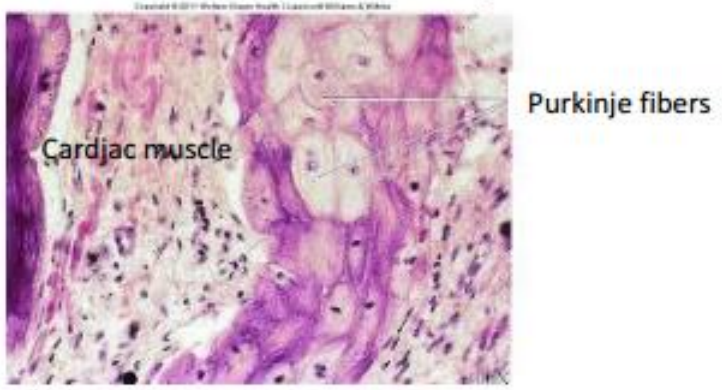




CONDUCTING SYSTEM OF THE HEART

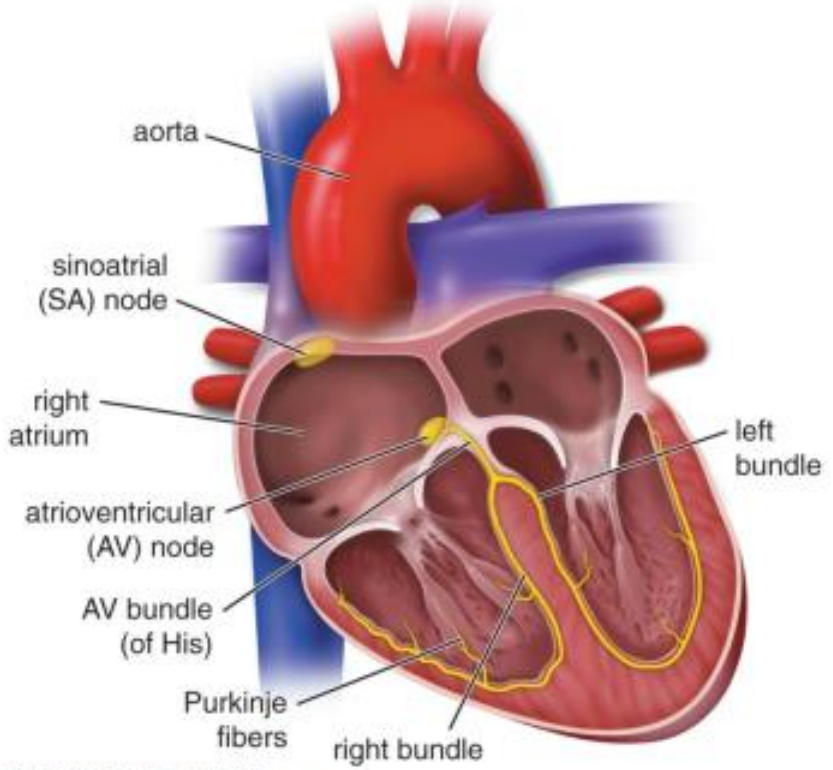
- SINOATRIAL (SA) NODE
  - It is located in the right atrium
  - Electrical impulses are generated here
  - It can act independently of the nervous system (it displays automaticity)
  - Impulses are transmitted to the left atrium via the a group of myocardial cells called Bachman bundle
  - Specialized myocardial cells also transmit impulses from the SA node to the AV node via anterior and posterior internodal pathways
  - Impulses coming from the SA node to the AV node are delayed for a few milliseconds before passing it to the ventricles, this is done to avoid excitation of the atria and ventricles at the same time

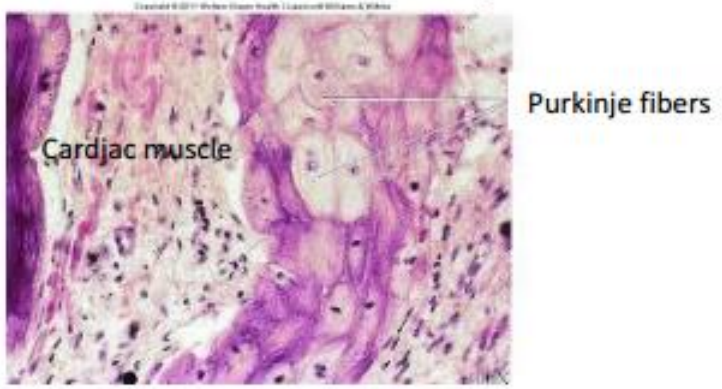




CONDUCTING SYSTEM OF THE HEART

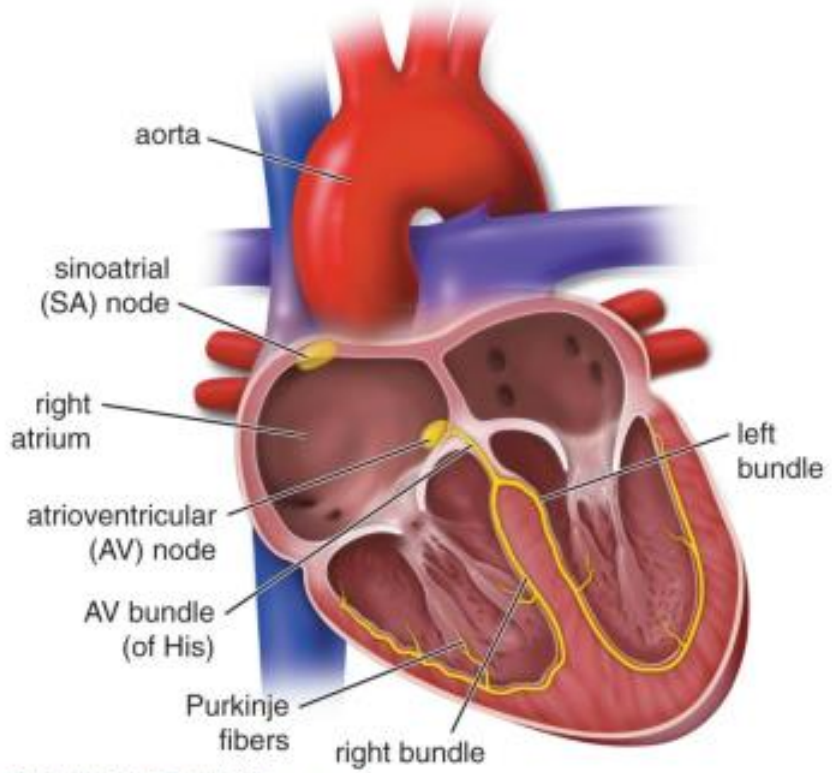
- SINOATRIAL (SA) NODE
  - The reason why the myocardial tissues of the atria and ventricles are not in contact is because there is need for spacing of their excitations and consequent contractility
  - The atria have to be filled and contract before the ventricles fill and contract
  - The only excitatory link between the atria and ventricles is the AV node, which is why it delays the electrical impulse so as to allow the entire atria to be stimulated before it passes the impulse to the ventricles which will thereafter become stimulated too
  - Any medical condition that distorts this mode of operation can cause dysrhythmia and consequent death of the individual

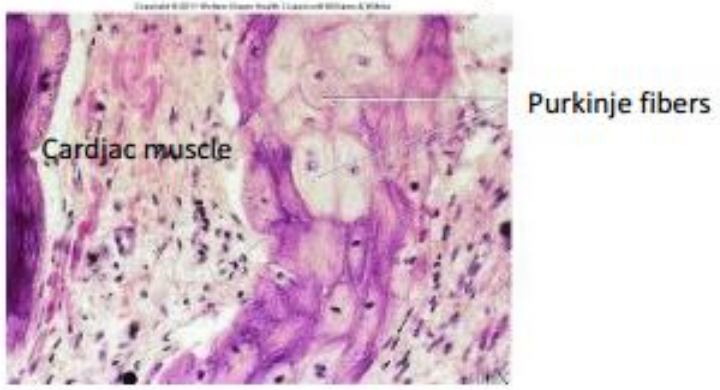




CONDUCTING SYSTEM OF THE HEART

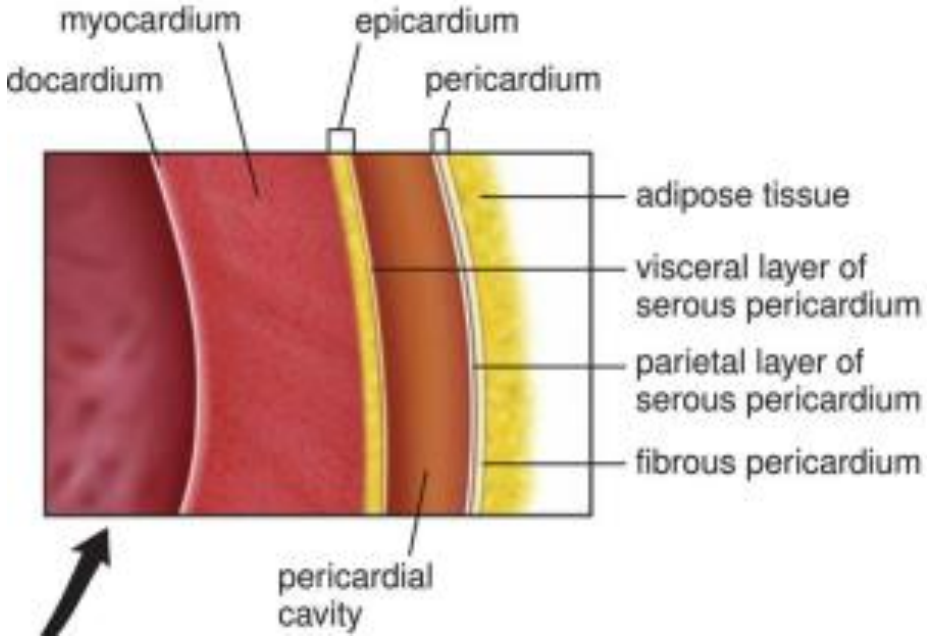
- ATRIOVENTRICULAR (AV) NODE
  - It has specialized myocardial cells which slows down conduction
  - Thereafter it permits impulses to flow to the ventricles via the Bundle of His
- Bundle of His
  - It is made up of specialized myocardial cells known as Purkinje cells
  - The Purkinje cells course on the sides of the ventricles
  - Purkinje cells send Purkinje fibres to the general myocardium, which then facilitates contraction of the ventricles





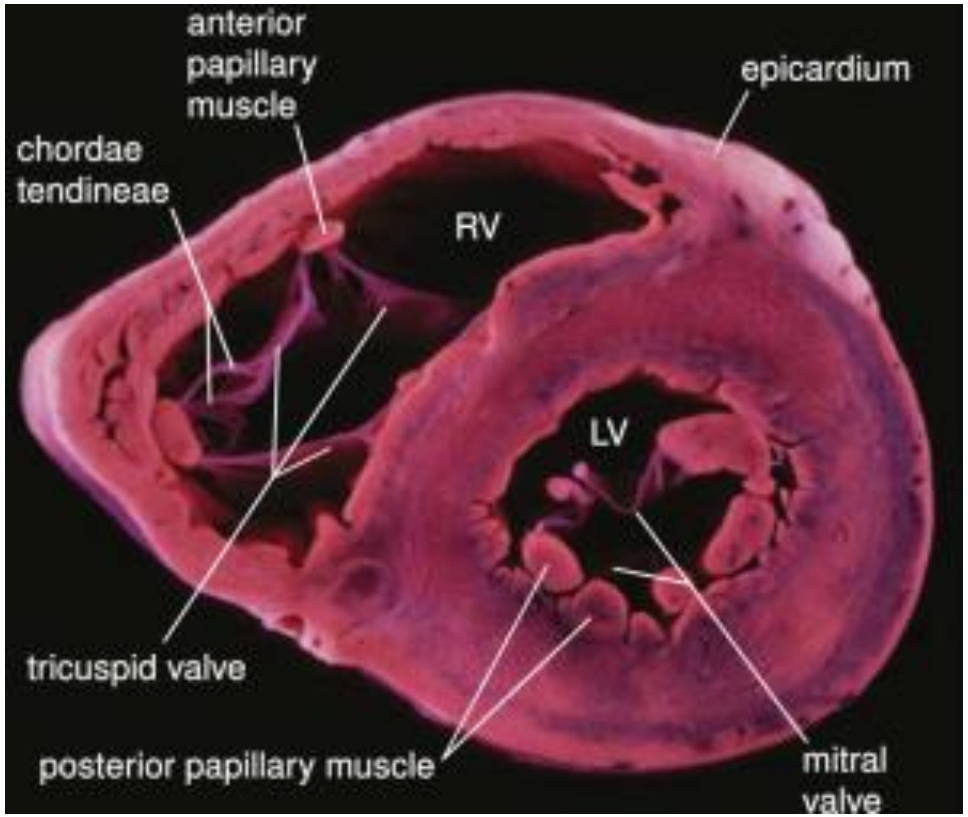
HISTOLOGY OF THE HEART

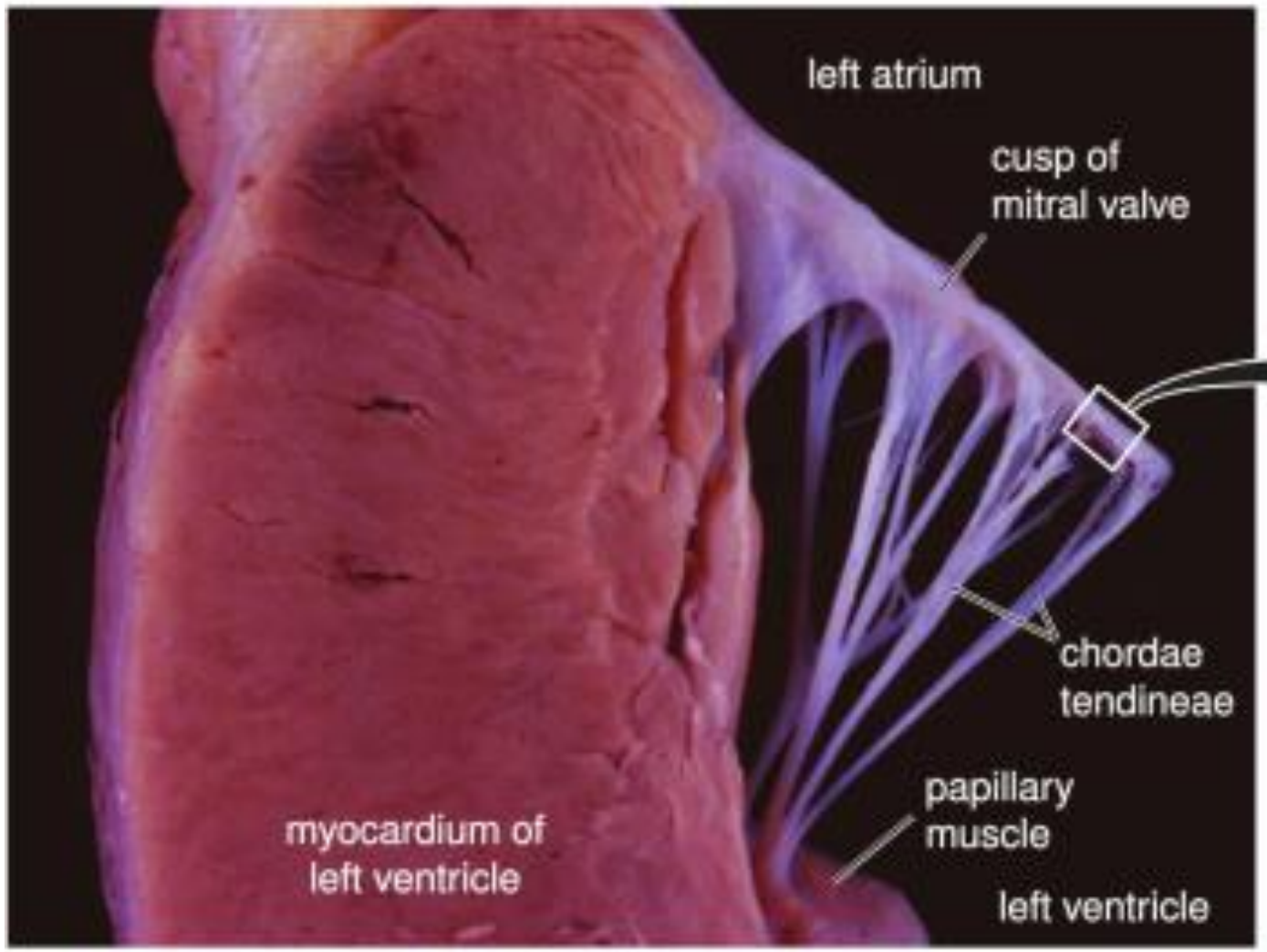
- EPICARDIUM
  - The outer most layer of the heart is the pericardium. It is divided into two – the visceral pericardium and the parietal pericardium
  - The epicardium is another name for the visceral pericardium
  - The epicardium consists of a single layer of mesothelial cells and underlying connective tissue and adipose tissue
  - Blood vessels and nerves that supply the heart lie in the epicardium and are surrounded by adipose tissue



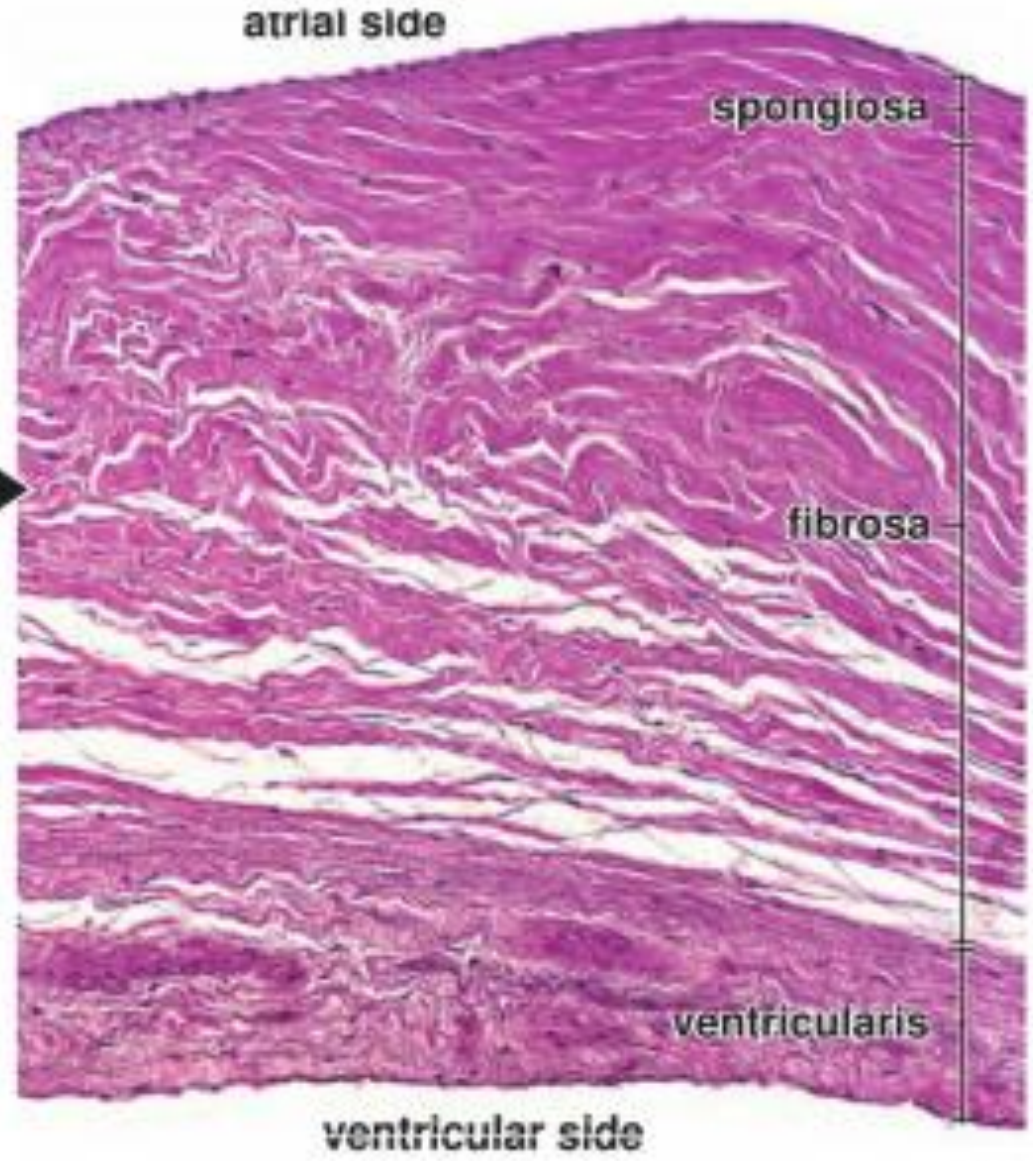
HEART VALVES

- The heart valves attach to the dense irregular connective tissue that forms the fibrous skeleton of the heart
- Each valve is composed of three layers:
  - Fibrosa – it forms the core of the valve and contains fibrous extensions from the dense irregular connective tissue of the skeletal rings of the heart. It is made of connective tissue proper
  - Spongiosa – it is made of loose connective tissue, collagen, elastic fibres interspersed with proteoglycans
    - It is located on the atrial side of each valve




left atrium
cusp of
mitral valve
chordae
tendineae
papillary
muscle
myocardium of
left ventricle
left ventricle

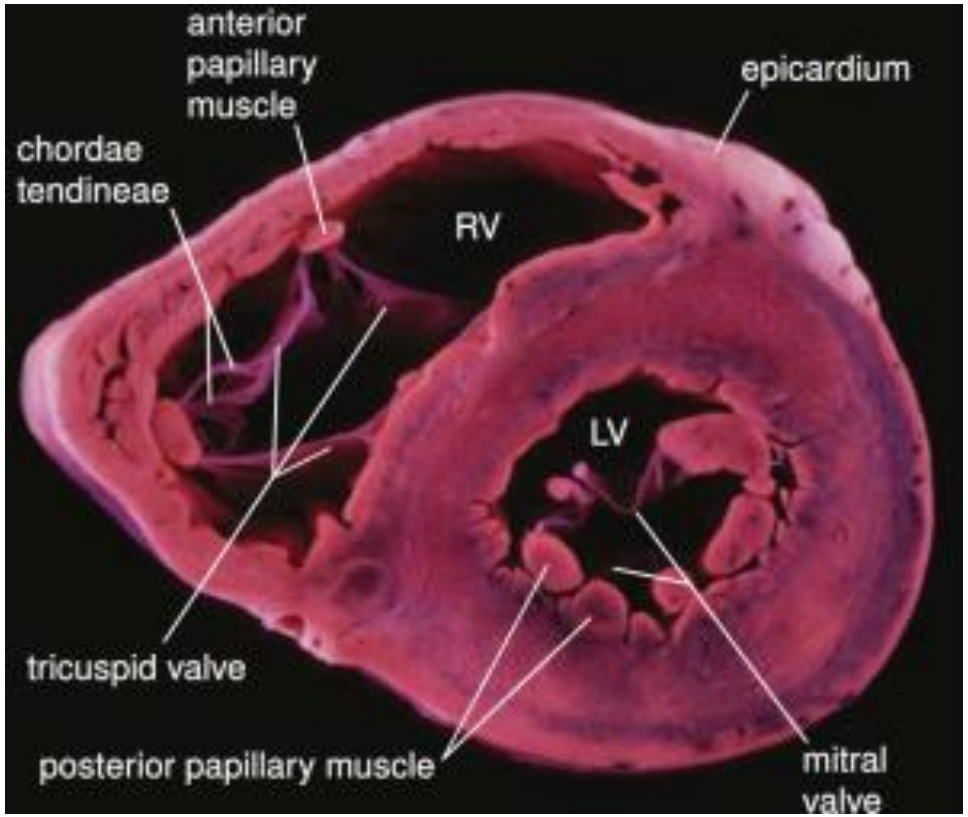
a


atrial side
spongiosa
fibrosa
ventricularis
ventricular side

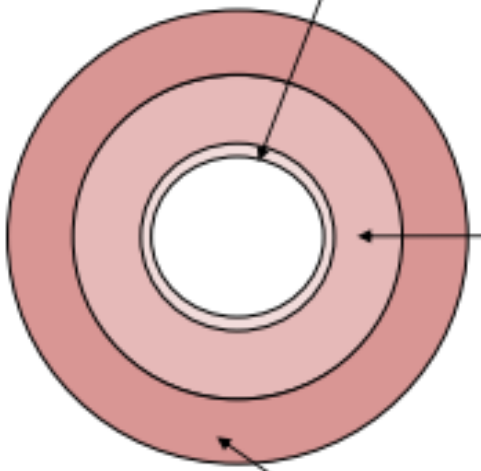
b

HEART VALVES

- The mitral and tricuspid (AV) valves are thin and not so strong
- When the ventricles contract, the aortic and pulmonary valves open, and the mitral and tricuspid valves close
  - This is to prevent backflow of blood into the atria
- The ventricular pressure when pumping out blood is very high, it has the tendency to push the AV valves into the atria and thus send blood back into them.
  - This situation is prevented by the attachment of tendinous cords (chordae tendineae) which are held firmly to the ventricular walls by the papillary muscles. Thus preventing the valves from everting into the atria



BLOOD VESSEL WALL HAS THREE LAYERS



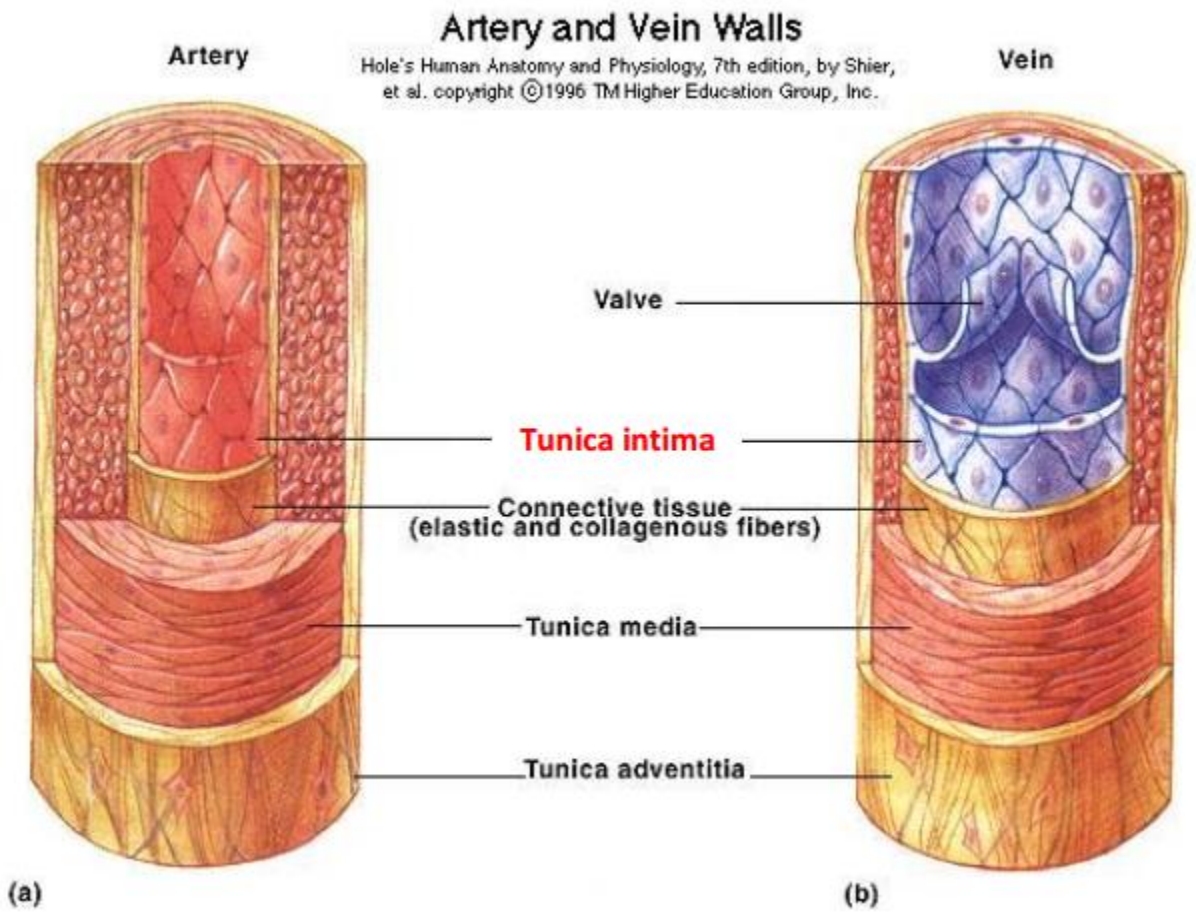
Tunica intima
1. Endothelial cell lining
2. Subendothelial layer
3. Internal elastic membrane

Tunica media
1. Smooth muscle cells, collagen fibers
2. Elastic fenestrated lamellae
3. External elastic lamina

Tunica adventitia
1. Mostly collagen fibers
2. Elastic fibers (not lamellae)
3. Fibroblasts and macrophages
4. Vasa vasorum

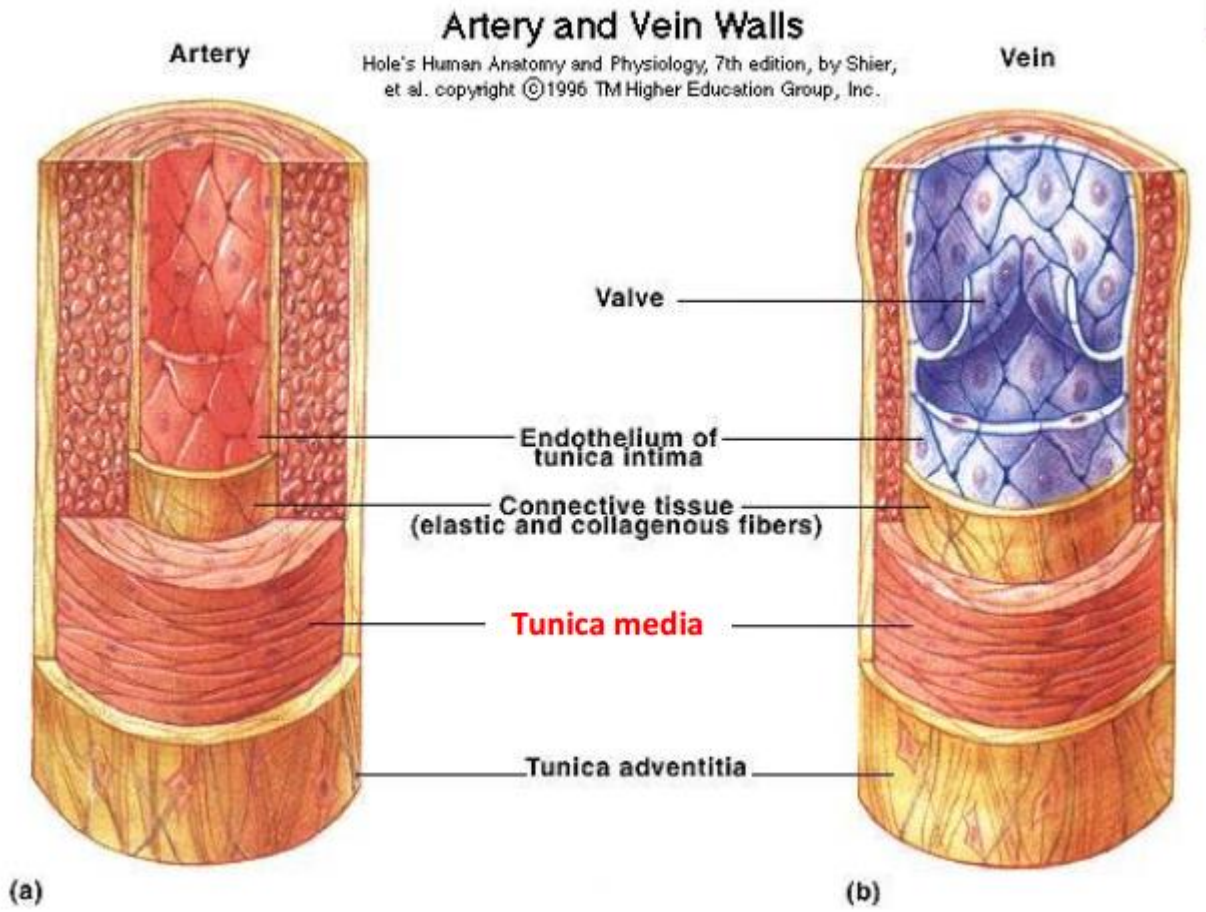
BLOOD VESSEL WALL

- TUNICA INTIMA:
  - It is the innermost layer and it is exposed to the blood
  - It is lined by endothelium (simple squamous epithelial cells in blood vessels) overlying a basement membrane and a sparse layer of loose connective tissue
  - It acts as a selectively permeable barrier
  - It secretes chemicals that stimulate dilation or constriction of blood vessels
  - It normally repels platelets and coagulation factors that may form a clot
  - During inflammation or infection, endothelial cells produce cell-adhesion molecules that induce leukocytes to adhere to the surface



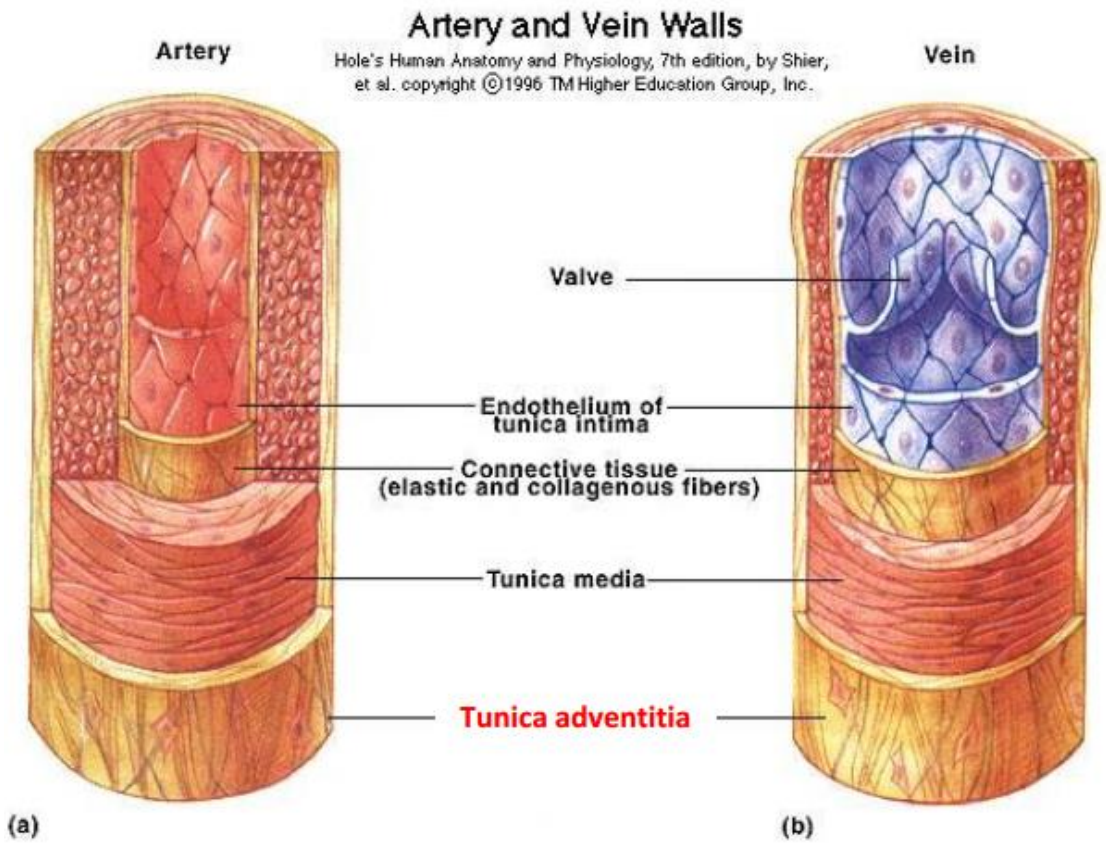
BLOOD VESSEL WALL

- TUNICA MEDIA:
  - It is the middle layer
  - It consists of smooth muscle, collagen, and elastic tissue
  - It strengthens vessels and prevents blood pressure from rupturing them
  - Changes in diameter of blood vessels is brought about the smooth muscle in the tunica media



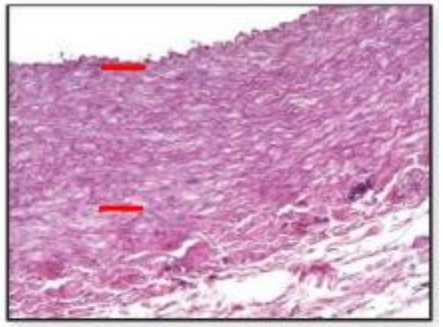
BLOOD VESSEL WALL

- TUNICA EXTERNA (ADVENTITIA):
  - It is the outermost layer
  - It consists of loose connective tissue that often merges with that of neighbouring blood vessels, nerves or other organs
  - Macrophages, collagen fibres, and fibroblasts can be found in this layer
  - It anchors the vessel and provides passage for small nerves and lymphatic vessels
  - Vaso vasorum – these are small vessels that supply blood to the outer half of the larger vessels
    - Blood from the lumen nourishes the inner half of the vessels by diffusion

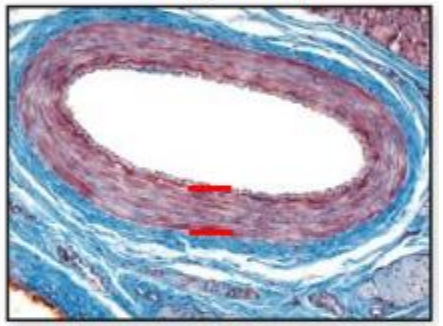


DIFFERENCE IN VESSEL WALLS

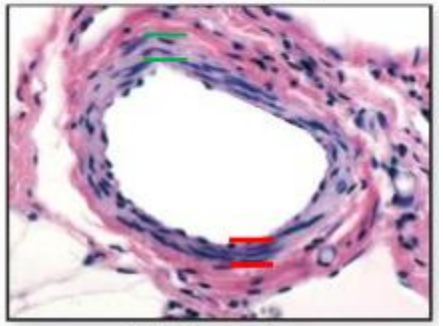
Thin-walled vessel	Thick-walled vessel
Tunica intima	Tunica intima
Tunica media	Tunica media
Tunica externa	
	Tunica externa



Large artery

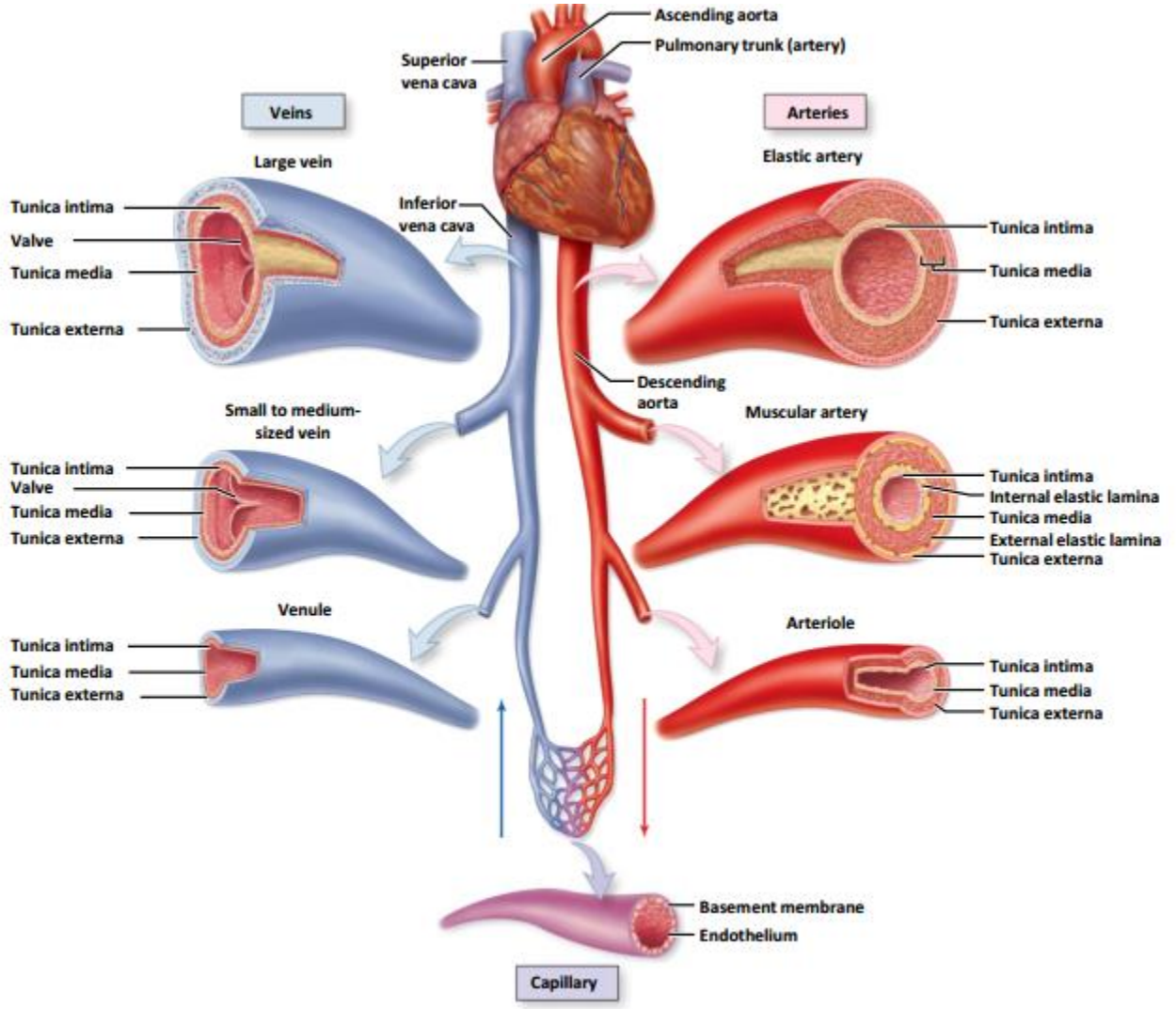


Medium artery



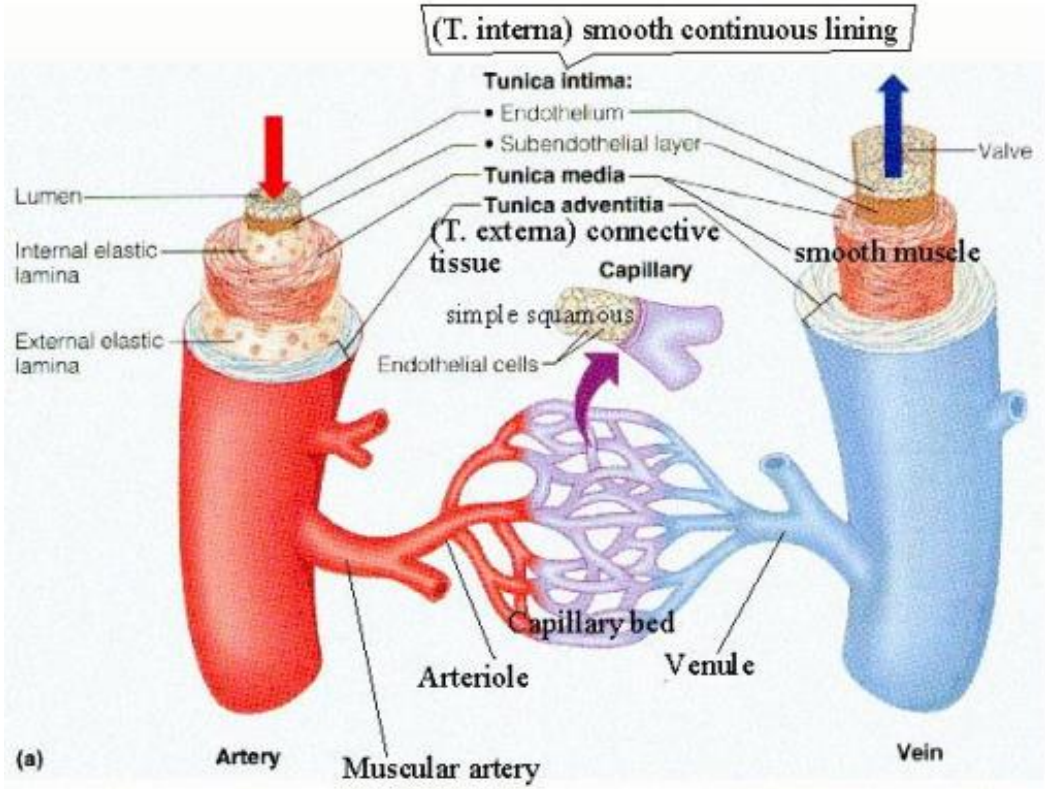
Medium vein

COMPARISON OF BLOOD VESSELS



STRUCTURAL FEATURES OF BLOOD VESSELS

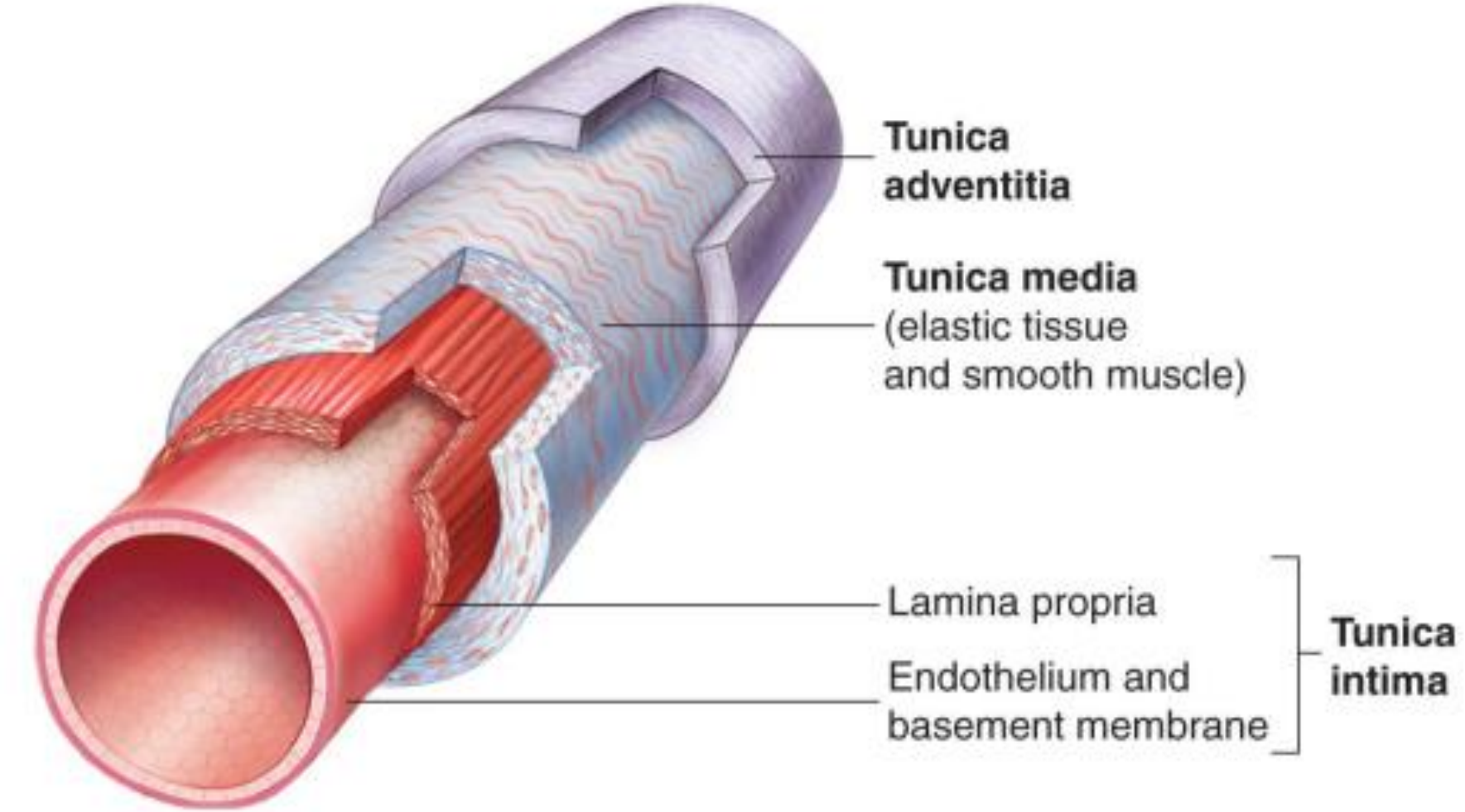
- ARTERIES
  - Thick walls and abundant elastic tissue
  - Elastic arteries
  - Muscular arteries
  - Arterioles
- CAPILLARIES
  - Site of exchange with tissues
- VEINS
  - Thinner walls than arteries, contain less elastic tissue and fewer smooth muscle cells
  - Venules
  - Small veins
  - Medium or large veins



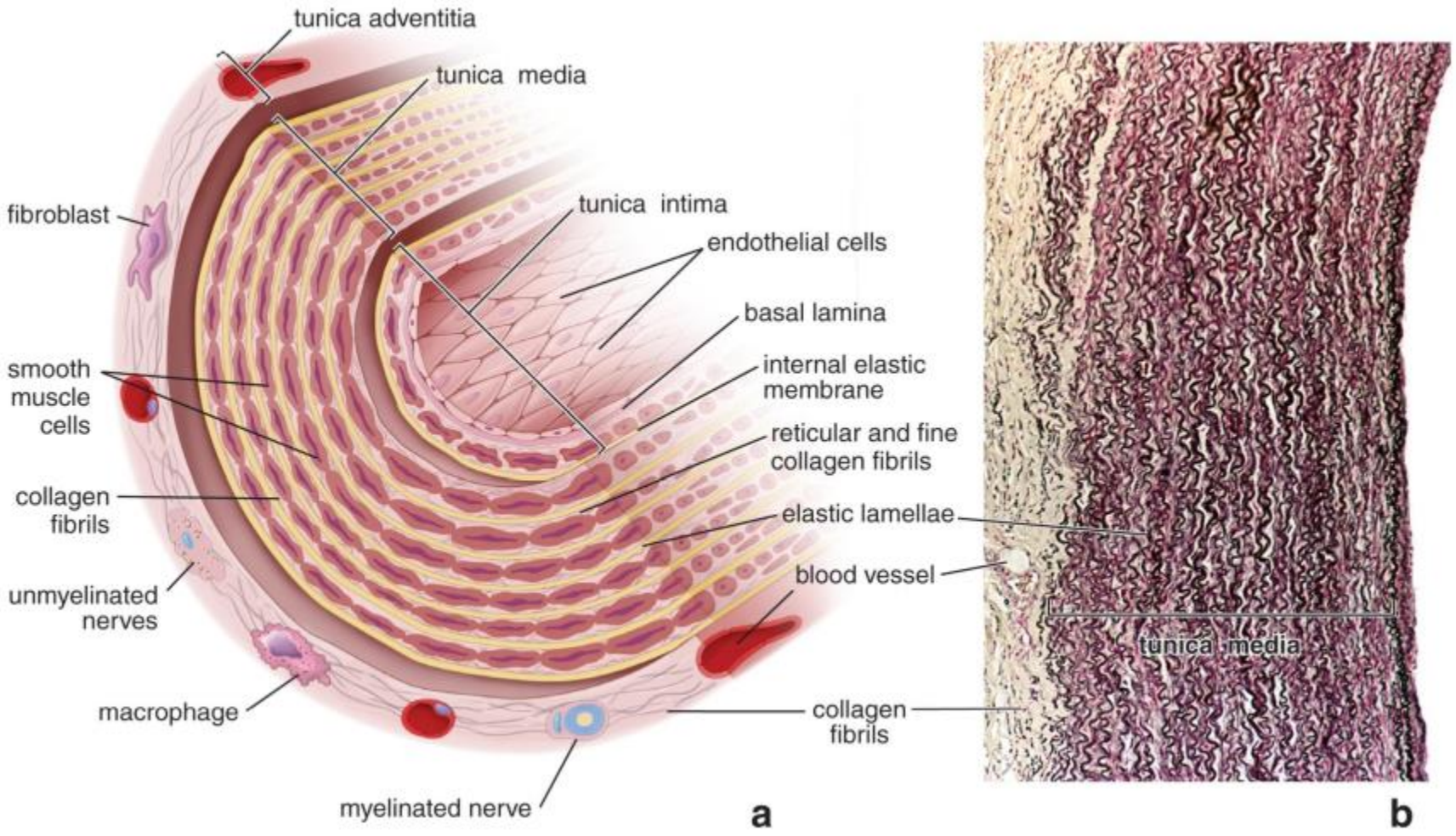
ARTERIES

- ELASTIC ARTERIES
  - They are also known as conducting arteries
  - They have the largest diameters and are the most elastic
  - They have more elastic tissue than smooth muscle tissues
  - They have relatively thin tunica intima and tunica adventitia
  - They possess very thick tunica media, with about 40 – 60 concentrically arranged elastic tissue
  - Examples include aorta, pulmonary arteries, common carotid arteries and common iliac arteries
  - The abundant elastic tissues give the arteries elastic properties, that way the arteries can adjust to accommodate different blood volumes and varying blood pressures

ELASTIC ARTERY



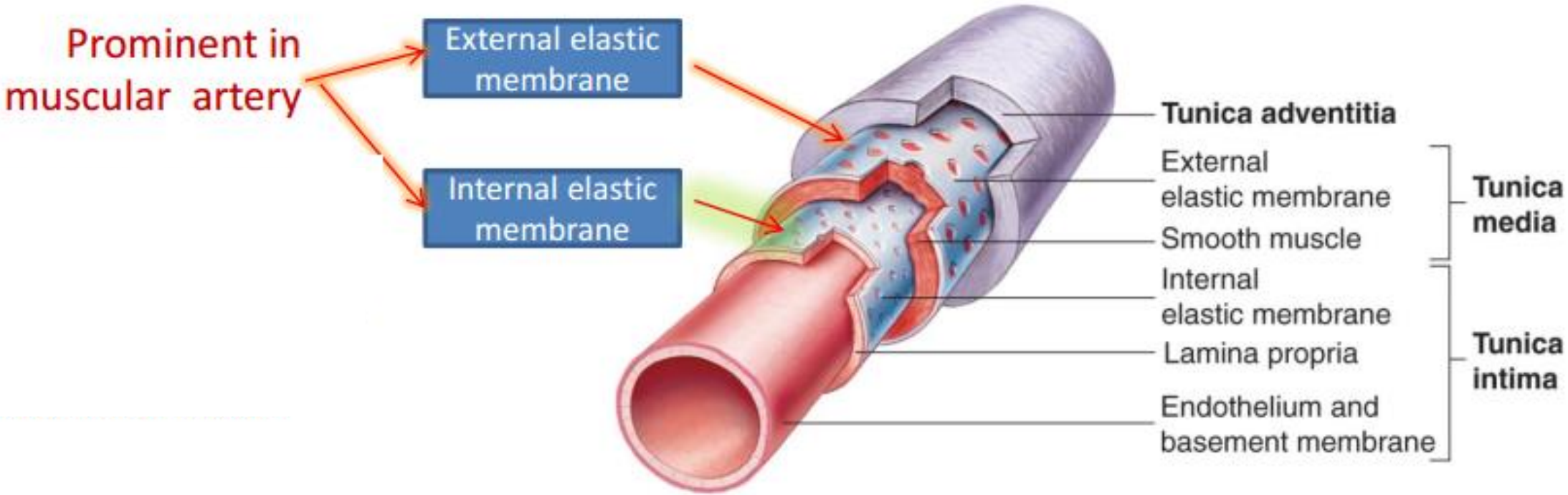
ELASTIC ARTERY



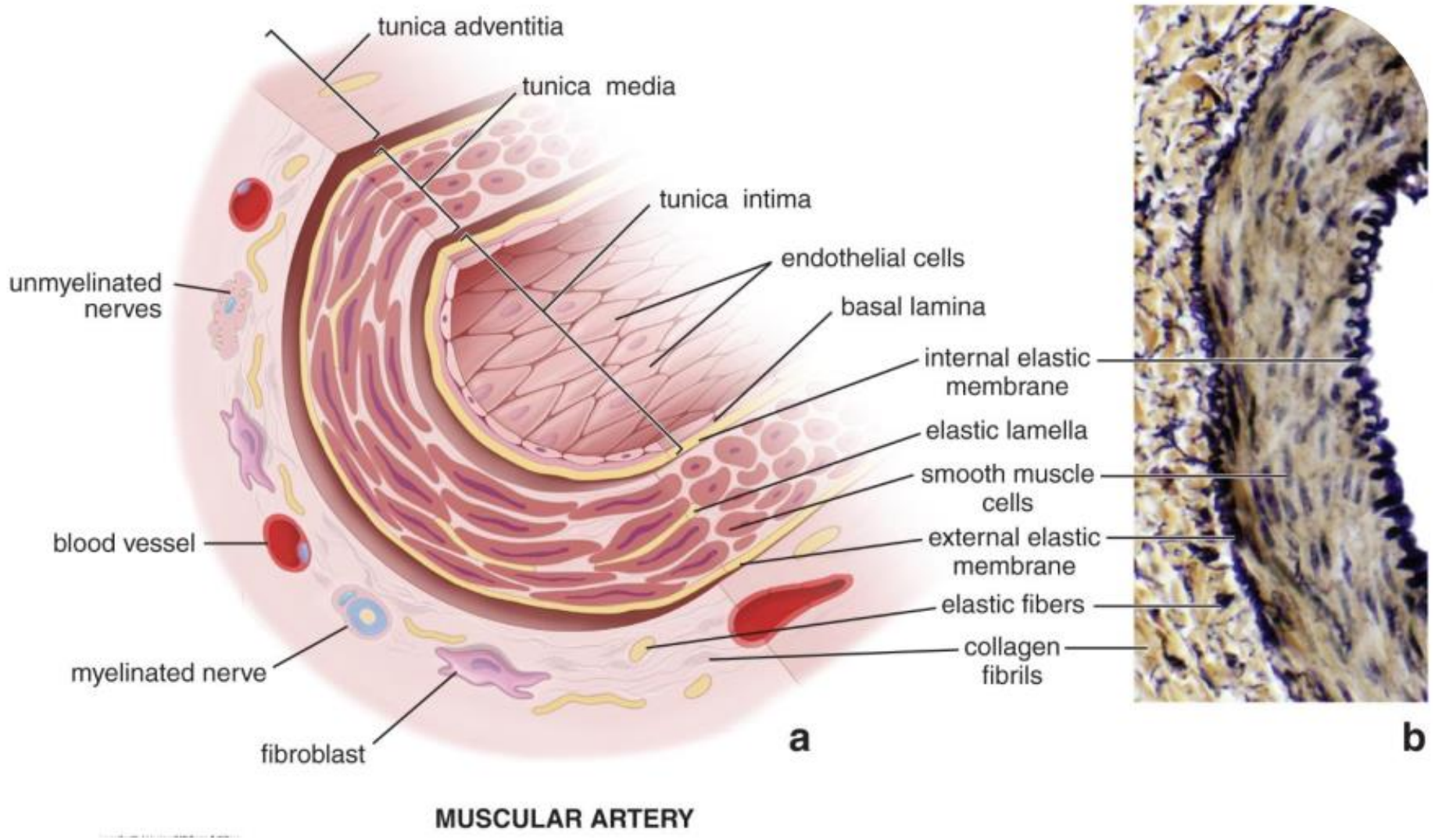
ARTERIES

- MUSCULAR ARTERIES
  - They are also known as medium, or distributing arteries
  - Smooth muscle allows vessels to regulate blood supply by constricting or dilating
  - They possess thick tunica media to a huge layer of smooth muscle (about 25 – 40 layers)
  - They possess thin tunica intima
  - They supply blood to the muscles and the smaller muscular arteries are adapted for vasodilation and vasoconstriction
  - Examples include brachial and femoral arteries

MUSCULAR ARTERY

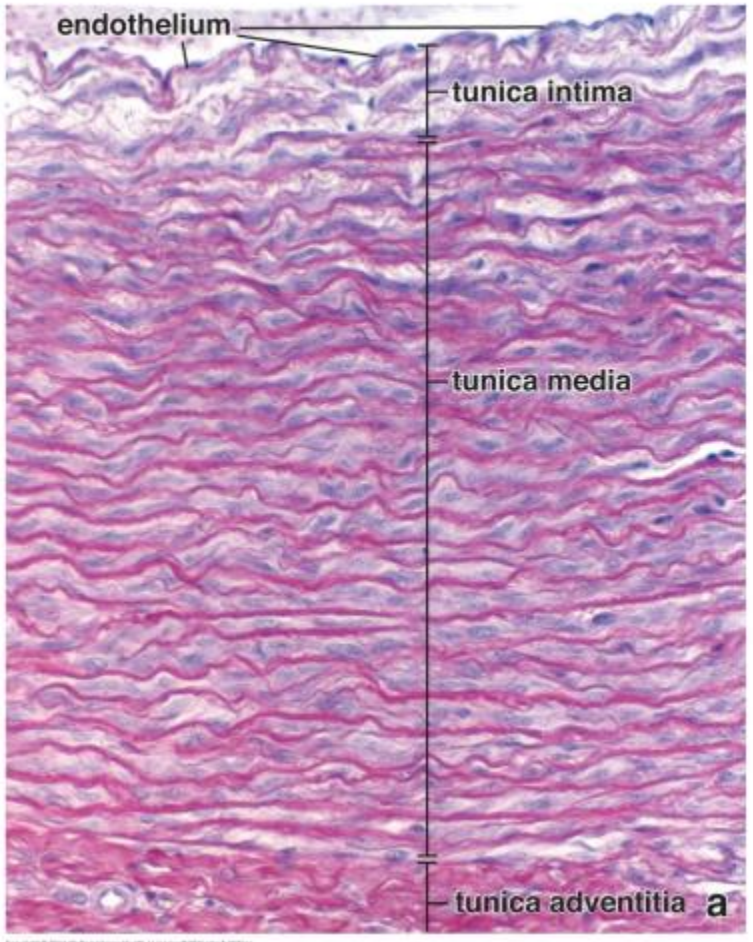


MUSCULAR ARTERY

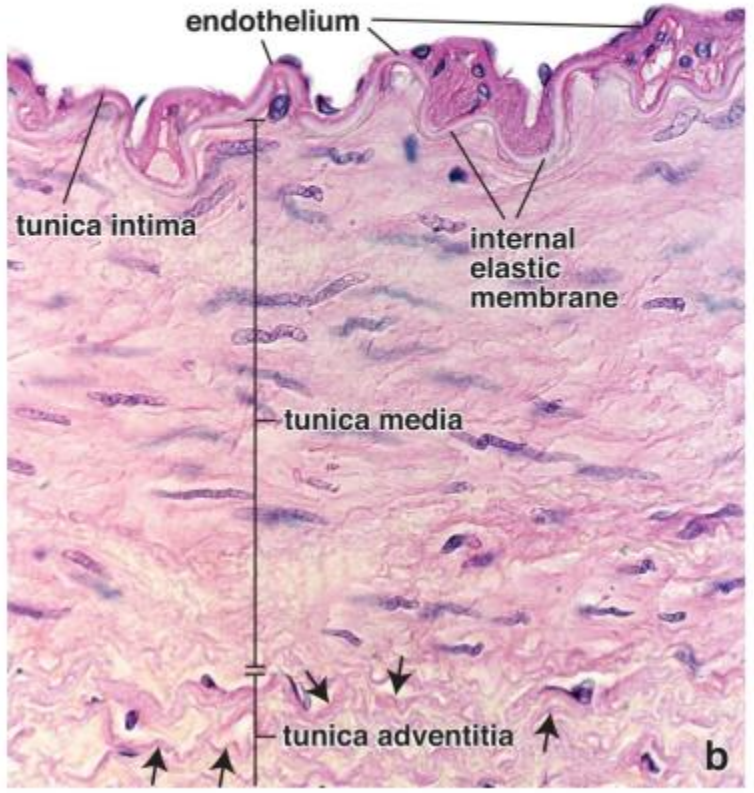


ELASTIC AND MUSCULAR ARTERIES

Elastic artery
(tunica media – elastic fibers)



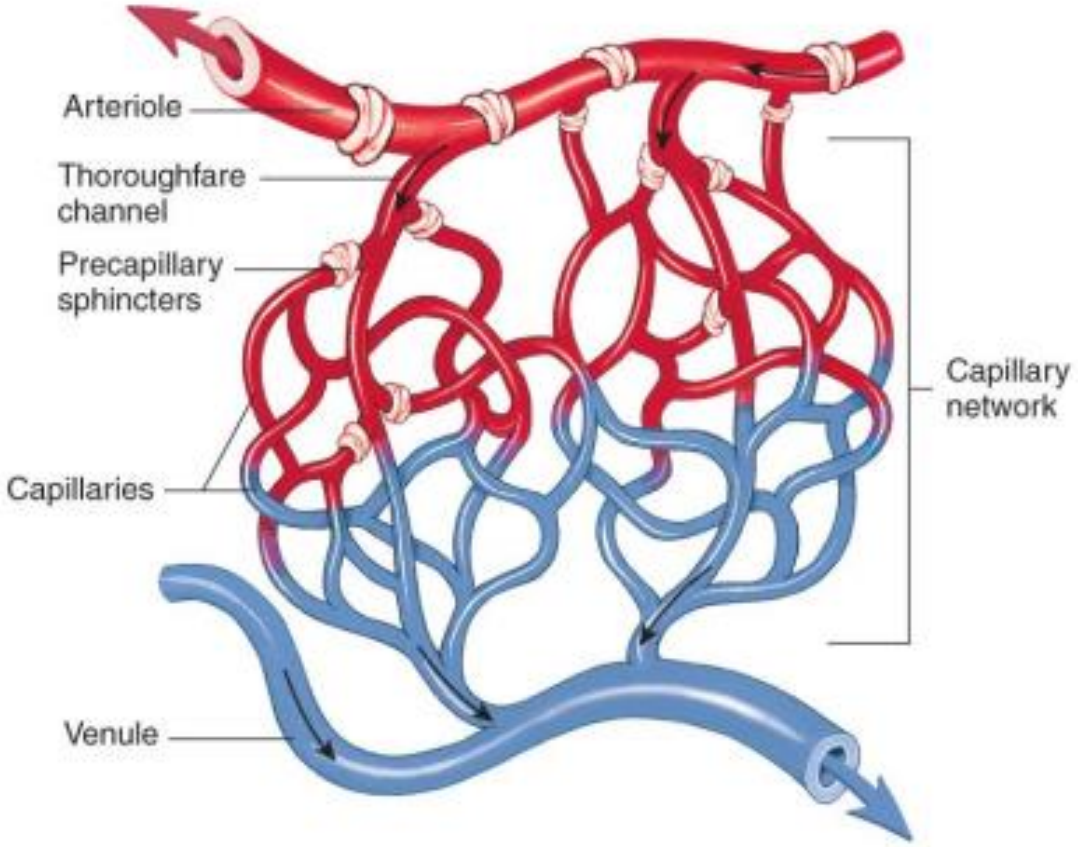
Muscular artery
(tunica media – smooth muscles)



ARTERIOLES

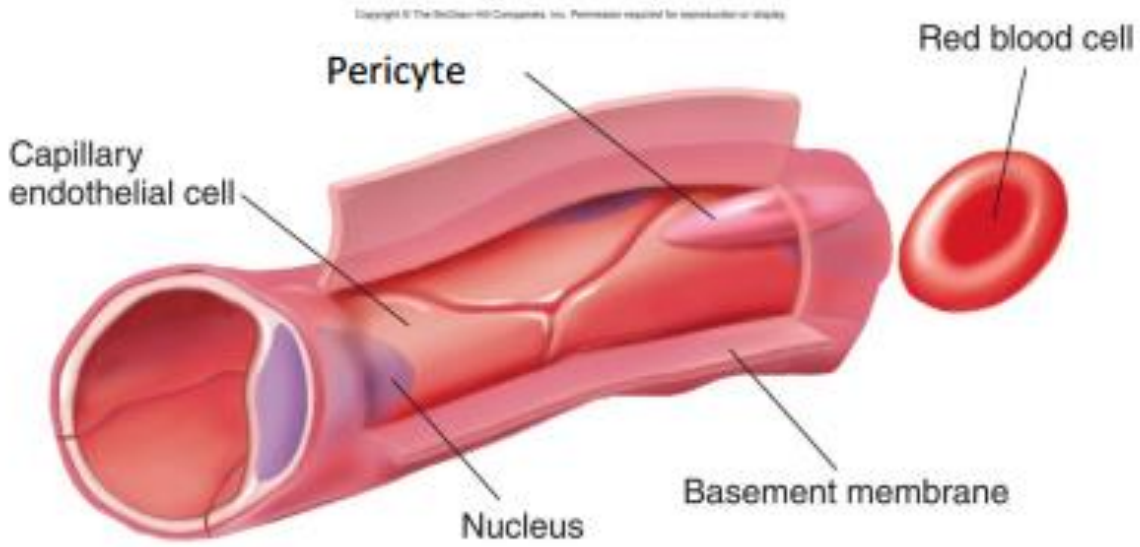
- They transport blood from small arteries to capillaries
- They are the smallest arteries where the three tunics can be differentiated
- They are capable of vasoconstriction and vasodilation
  - Metarterioles are short vessels that link arterioles to capillaries
  - They contain small muscle cells that form precapillary sphincters
  - They control blood flow to capillary bed

- NB – THOROUGHFARE CHANNELS – this is a direct connection between an arteriole and a venule without passing through capillaries

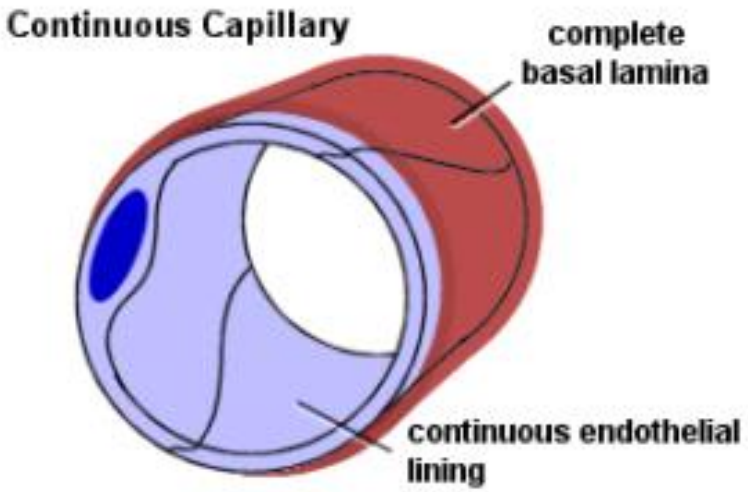


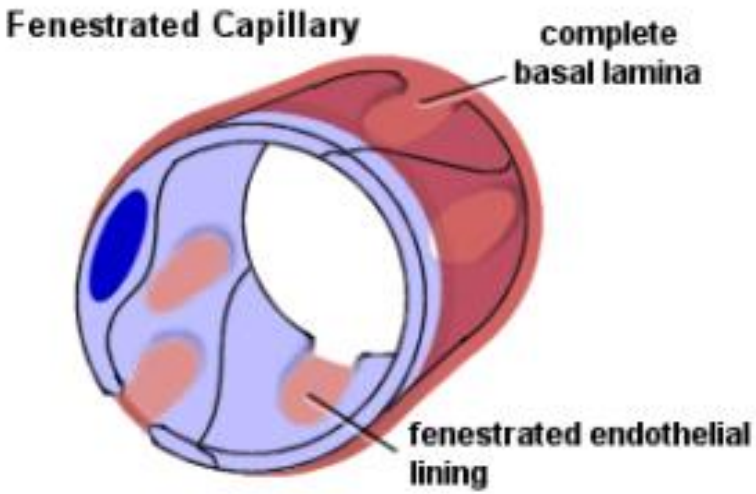
CAPILLARIES

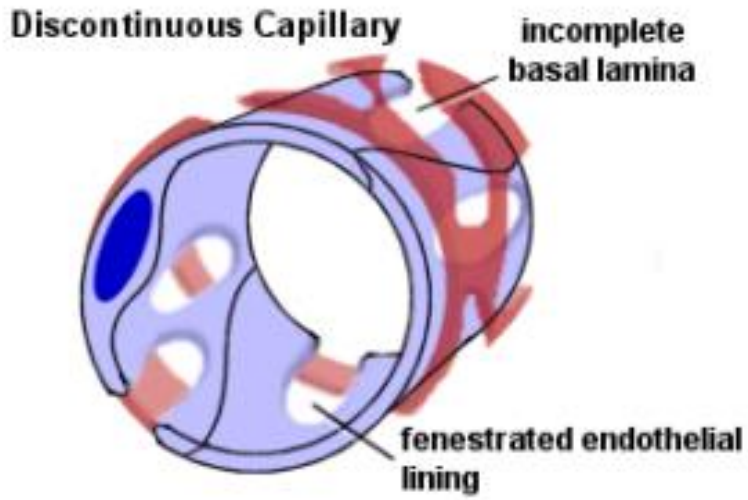
- They have thin walled single endothelial cell layer, basement membrane and a delicate layer of loose connective tissue
- They are specialized for exchange of substances
- They contain pinocytotic vesicles
- Pericytes are also present:
  - They have their own basement membranes
  - They may develop into smooth muscle cells (capillary into arteriole)



TYPES OF CAPILLARIES



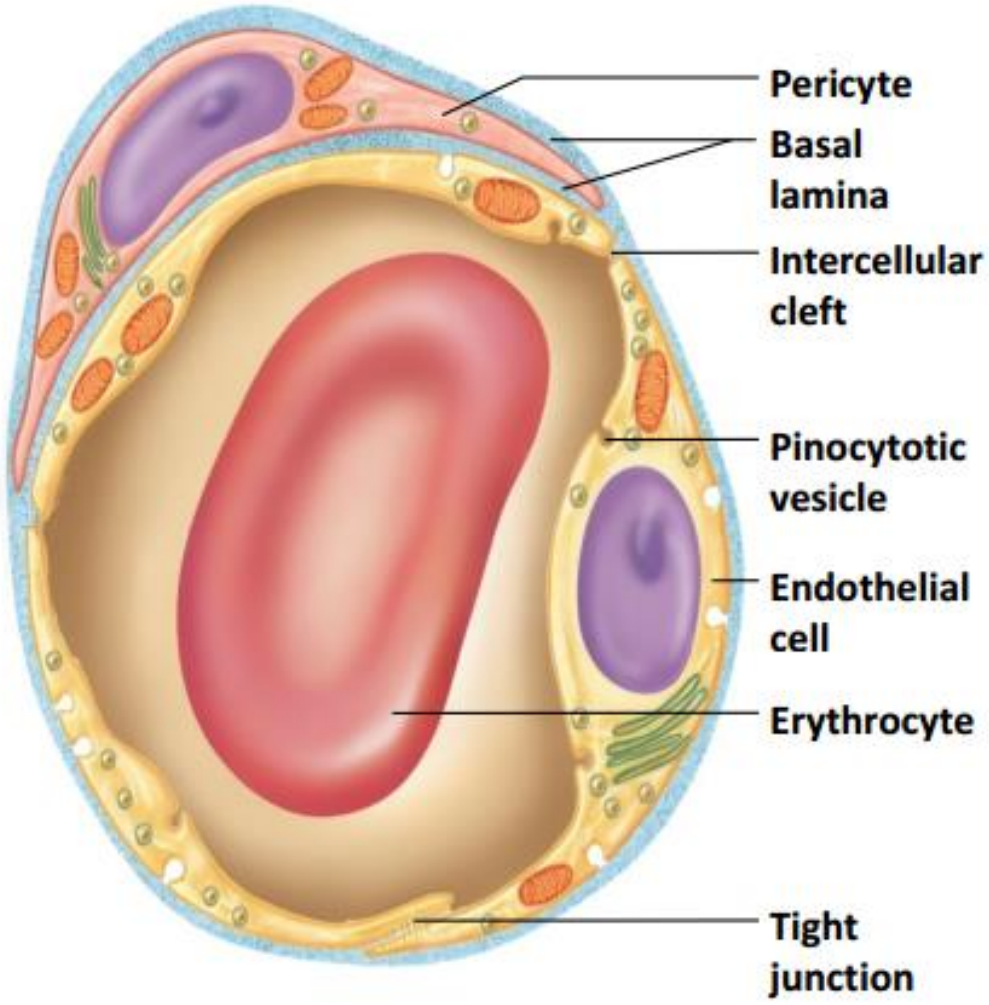




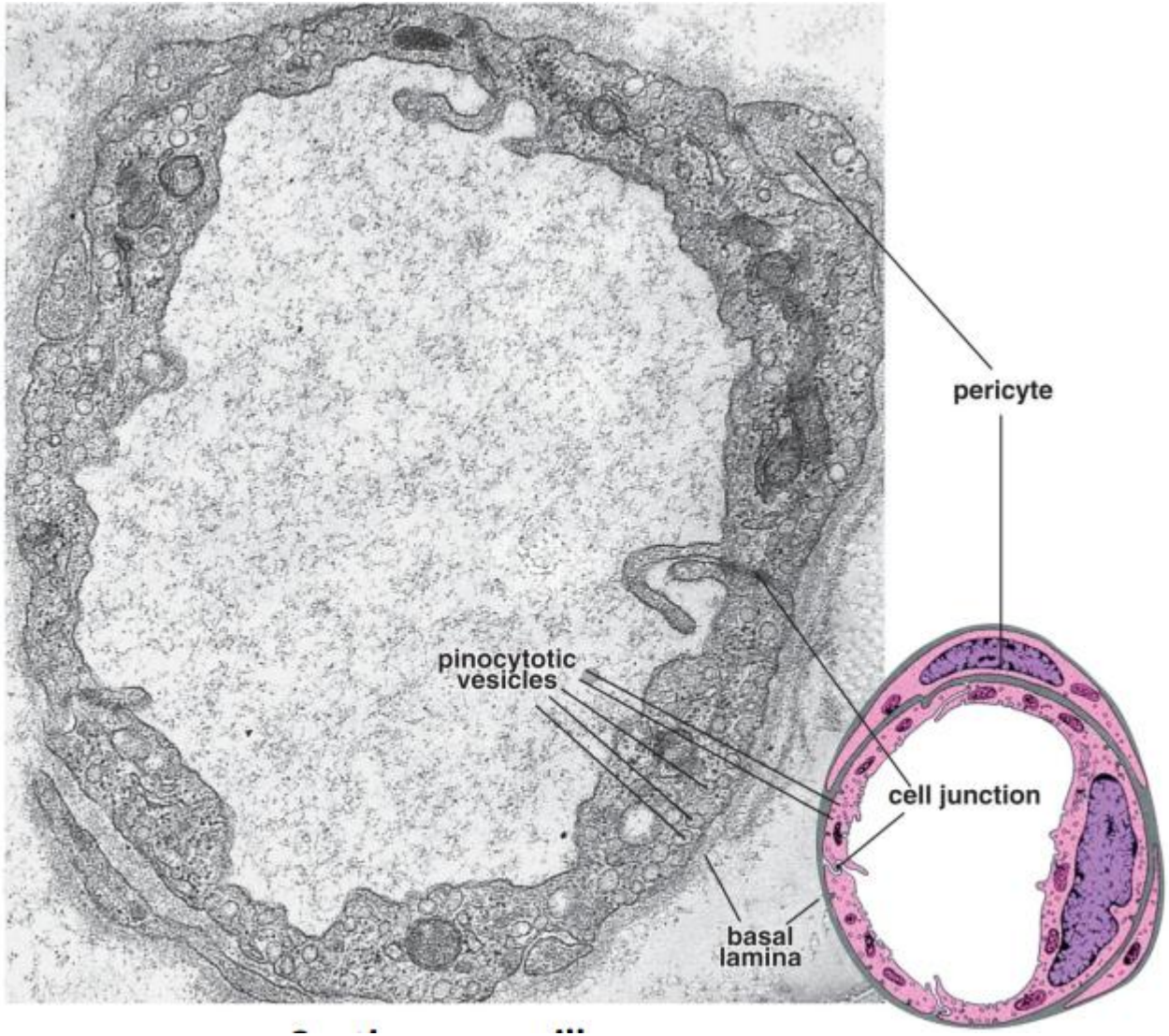
Sinusoids or Sinusoidal capillary

CONTINUOUS CAPILLARIES

- They have relatively thick cytoplasm and the capillary walls are continuous
- Tight junctions are present between adjacent endothelial cells
- They are less permeable to large molecules
- They contain pinocytotic vesicles
- They can be found in muscle and nervous tissues
- NB – tight junctions is complete in brain capillaries which forms the blood brain barrier

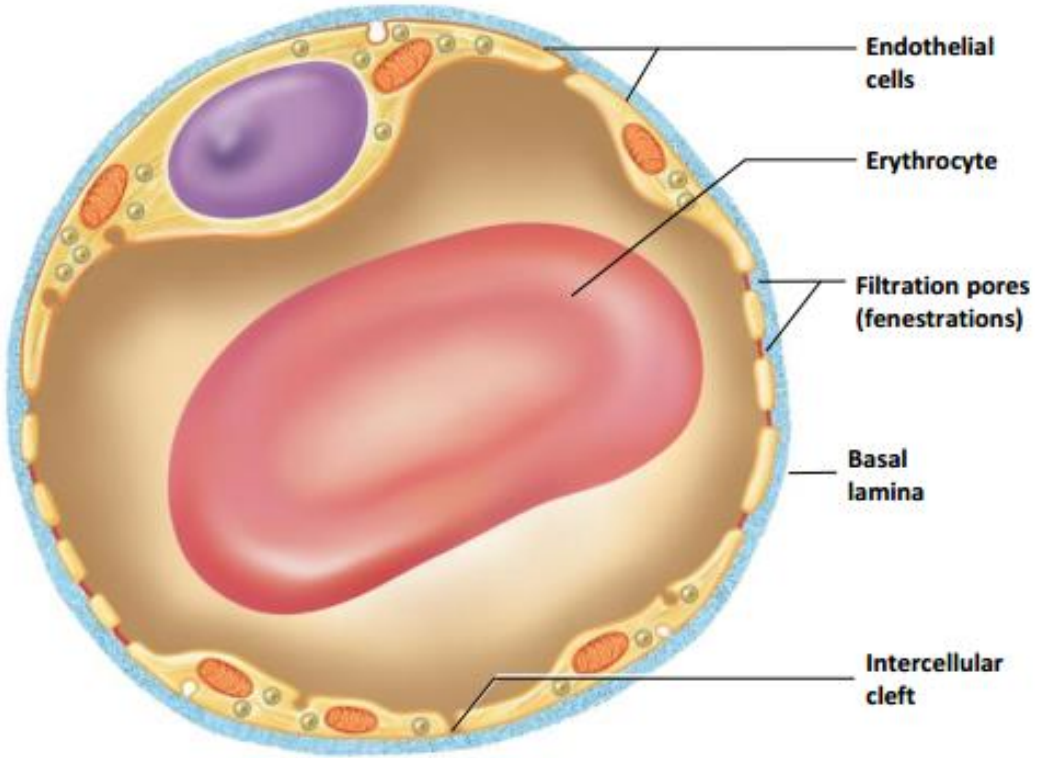


CONTINUOUS CAPILLARIES

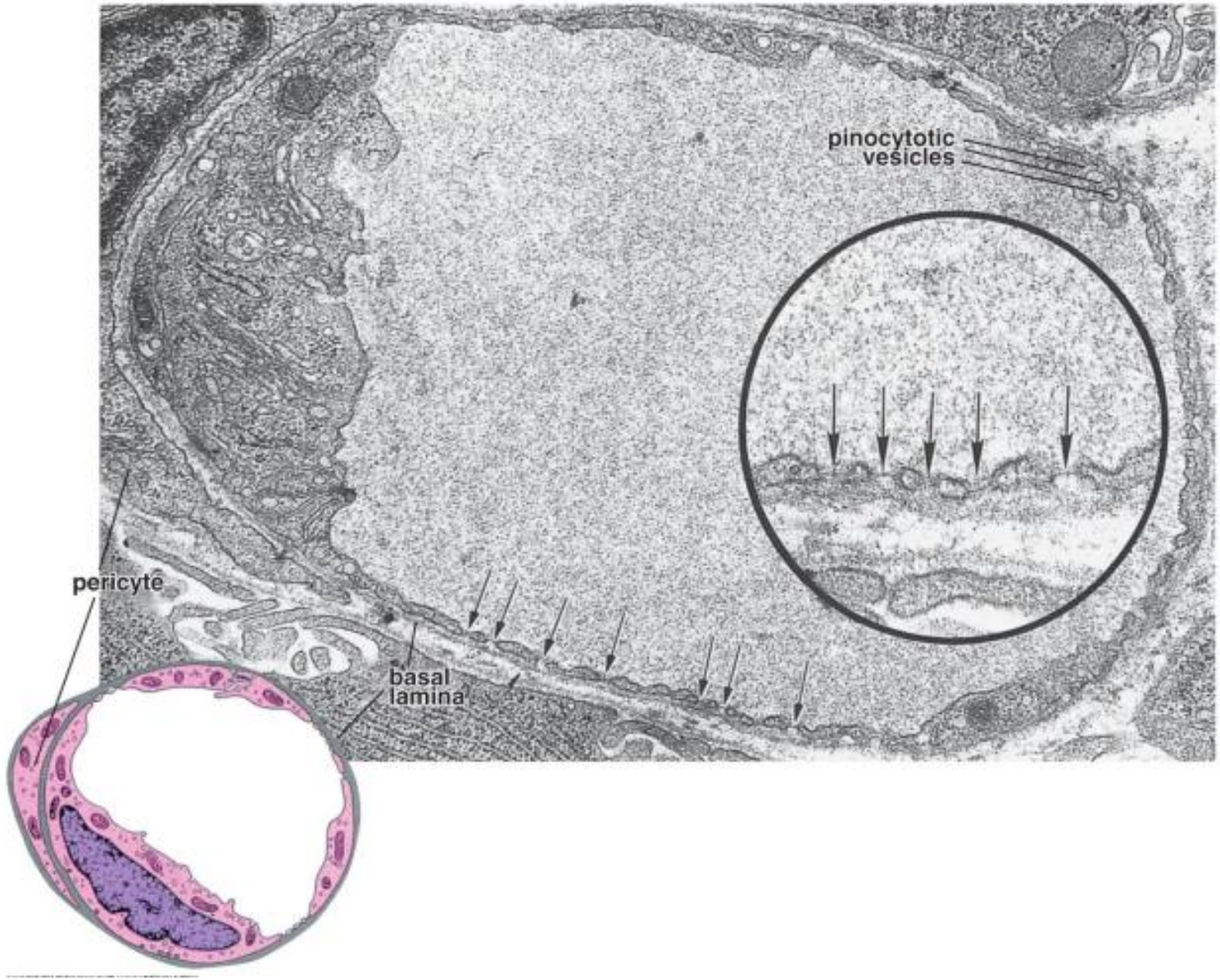


FENESTRATED CAPILLARIES

- They have thin cytoplasmic walls and the capillary wall is perforated at intervals by pores (fenestrations)
- Materials can cross the cell through the fenestrations
- They are fond in the kidneys and endocrine glands

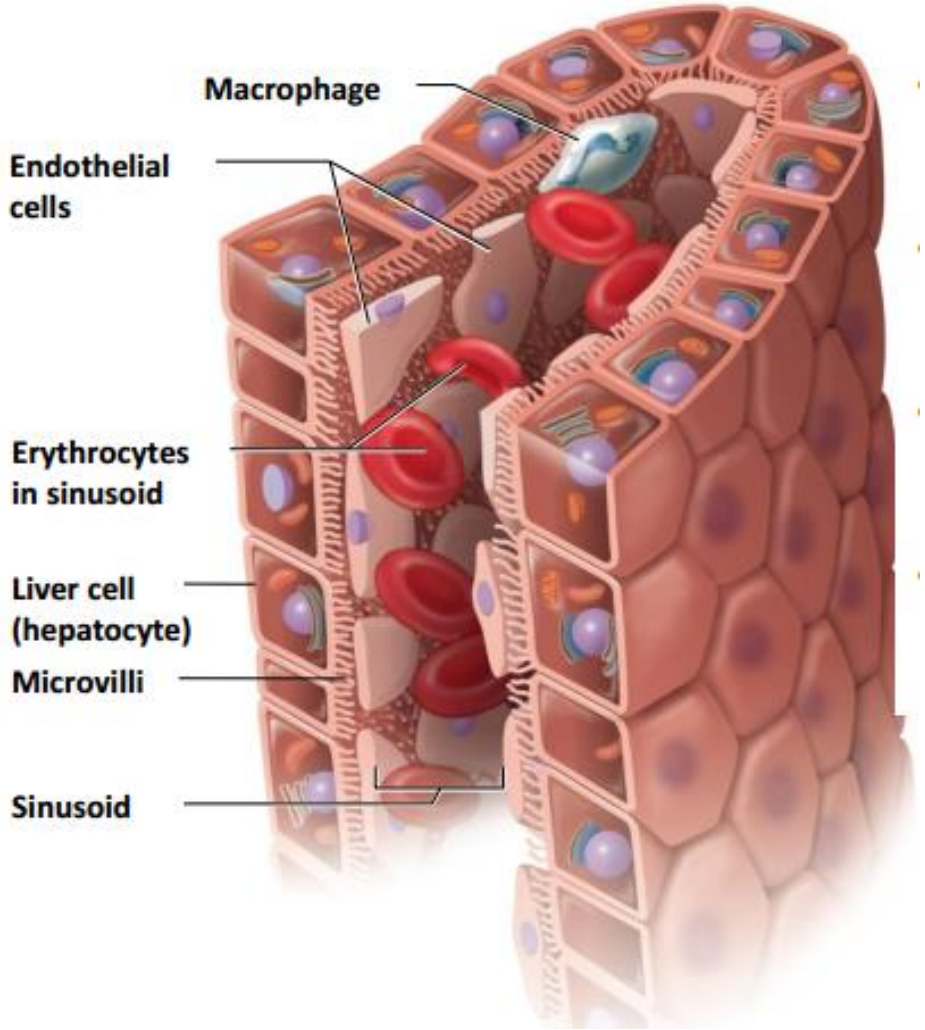


FENESTRATED CAPILLARIES



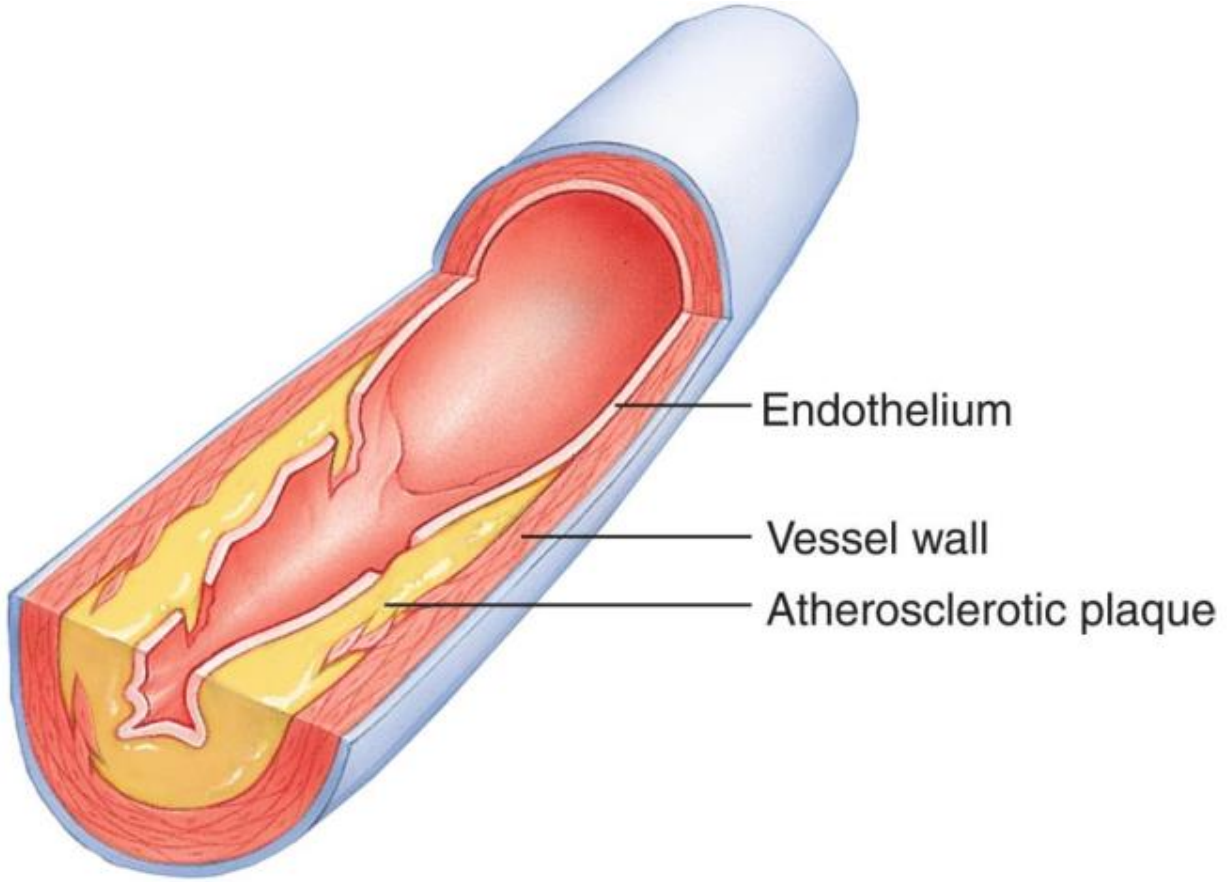
DISCONTINUOUS CAPILLARIES

- They are also known as sinusoidal capillaries
- They have large diameters – the largest of all the capillary types
- They have wide spaces between adjacent endothelial cells, through which materials can move freely in and out, as it is seen in the sinusoids of the liver
- Examples include liver, spleen and bone marrow



AGING OF ARTERIES

- As individuals advance in age, changes occur in arterial walls
- The most important of those changes are
  - Arteriosclerosis: This is a degenerative change in arteries, making them less elastic
  - Atherosclerosis: This is the deposition of plaques on arterial walls
- In both cases, blood flow is impaired and it could have deleterious effects on the health of the individual

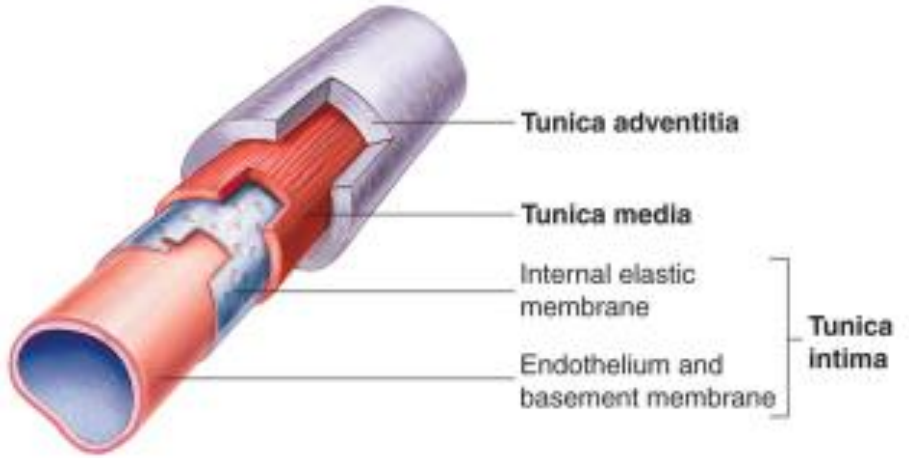


VEINS

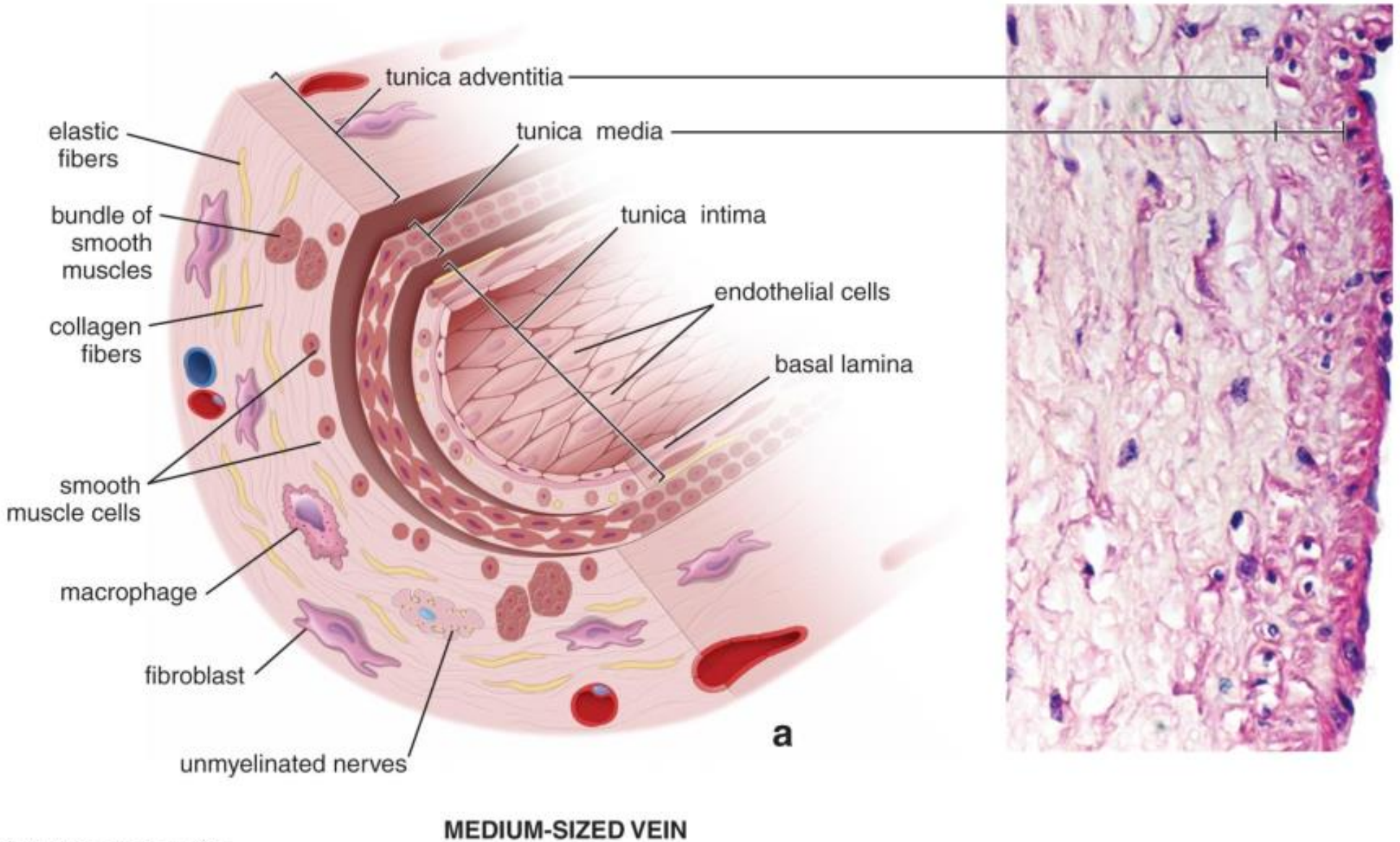
- VENULES
  - These are very small veins that drain the capillary network
  - They have endothelial cells, basement membranes with few muscle cells
  - As the diameter of venules increase, the amount of smooth muscle in the tunica media increases too
- SMALL VEINS
  - Tunica intima is thin
  - Tunica media is thin with circular smooth muscle
  - Tunica adventitia is well developed and is made of longitudinally arranged collagenous elastic fibers

VEINS

- MEDIUM VEINS
  - They serve as a go-between between small veins and large veins
- Large veins
  - Tunica intima is thin
  - Endothelial cells are present, thin layer of connective tissue and a few scattered elastic fibers
  - Tunica media is thin and poorly developed
  - Tunica adventitia is thick and a predominant layer with spirally arranged collagen fibers, elastic lamellae, and longitudinal smooth muscle
- NB – despite the thinness of the tunica media, vessel diameter can still be regulated because blood pressure in veins is low
- The predominant layer in medium and large veins is the tunica adventitia

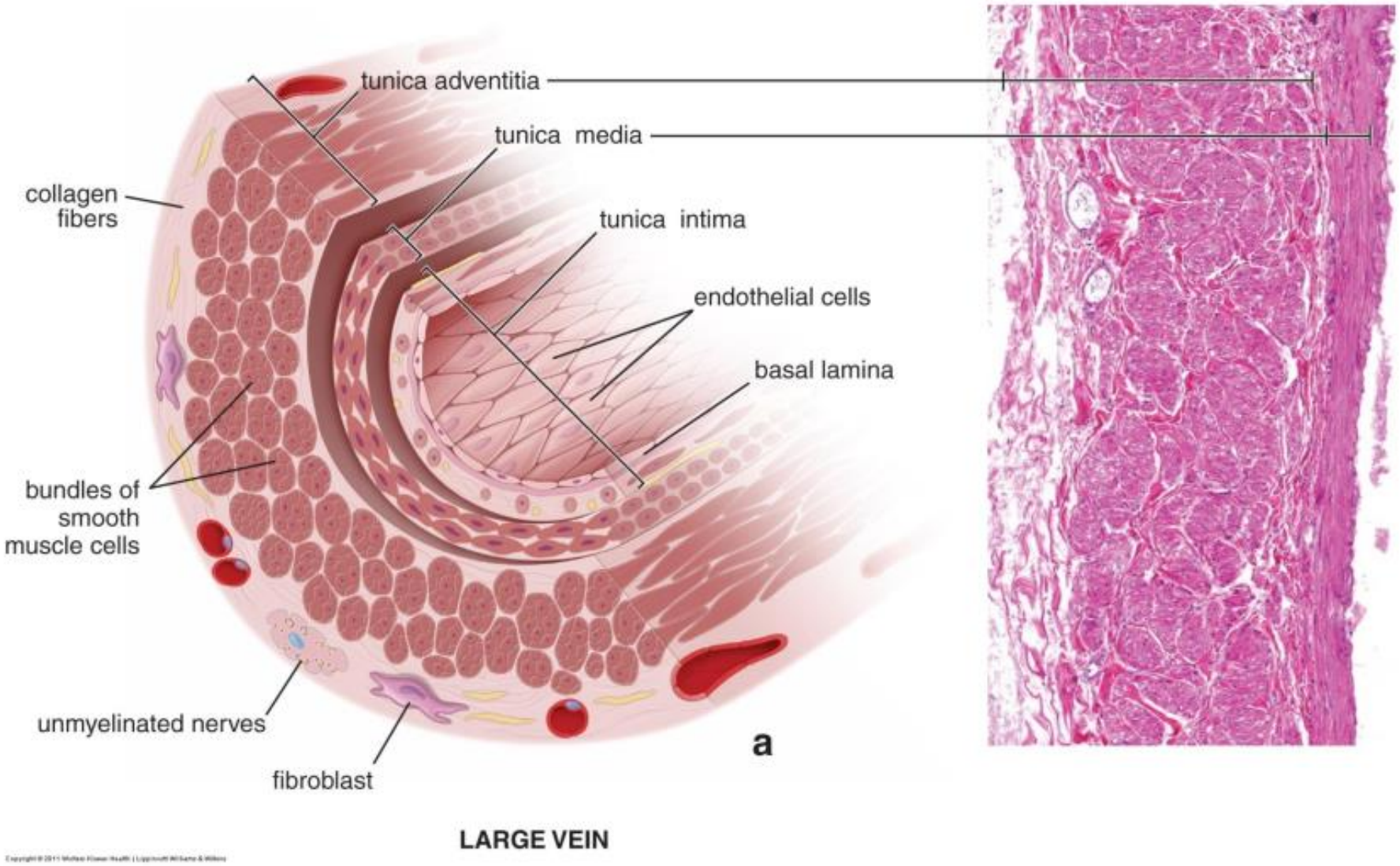


VEINS



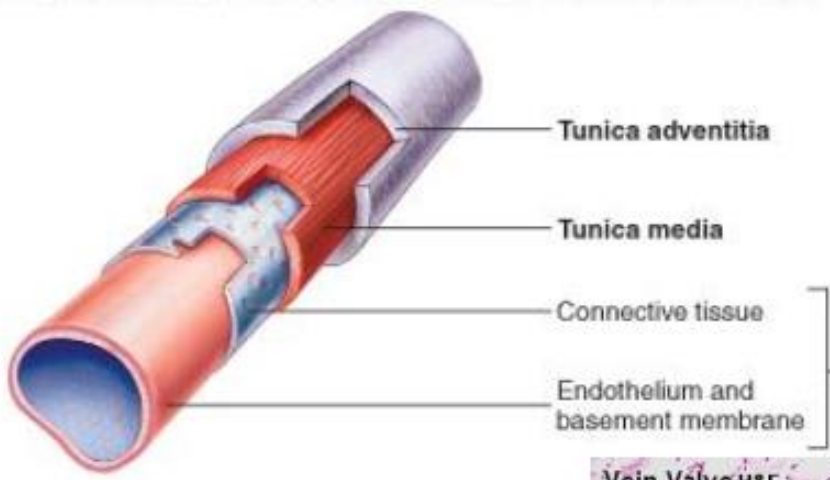
MEDIUM-SIZED VEIN

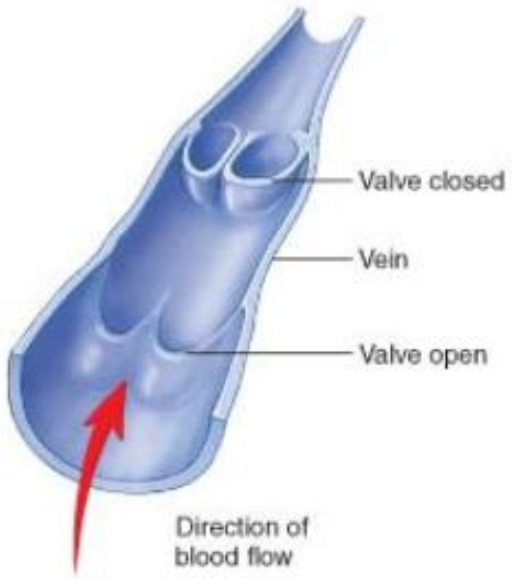
VEINS

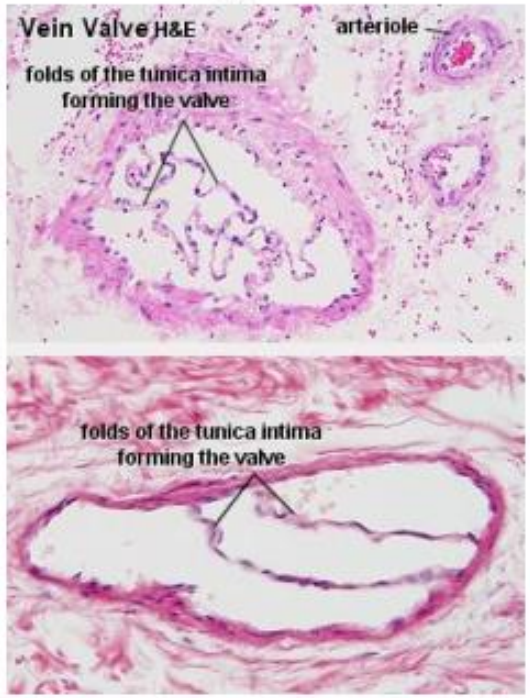


LARGE VEIN

VEINS


Tunica adventitia
Tunica media
Connective tissue
Endothelium and basement membrane
Tunica intima

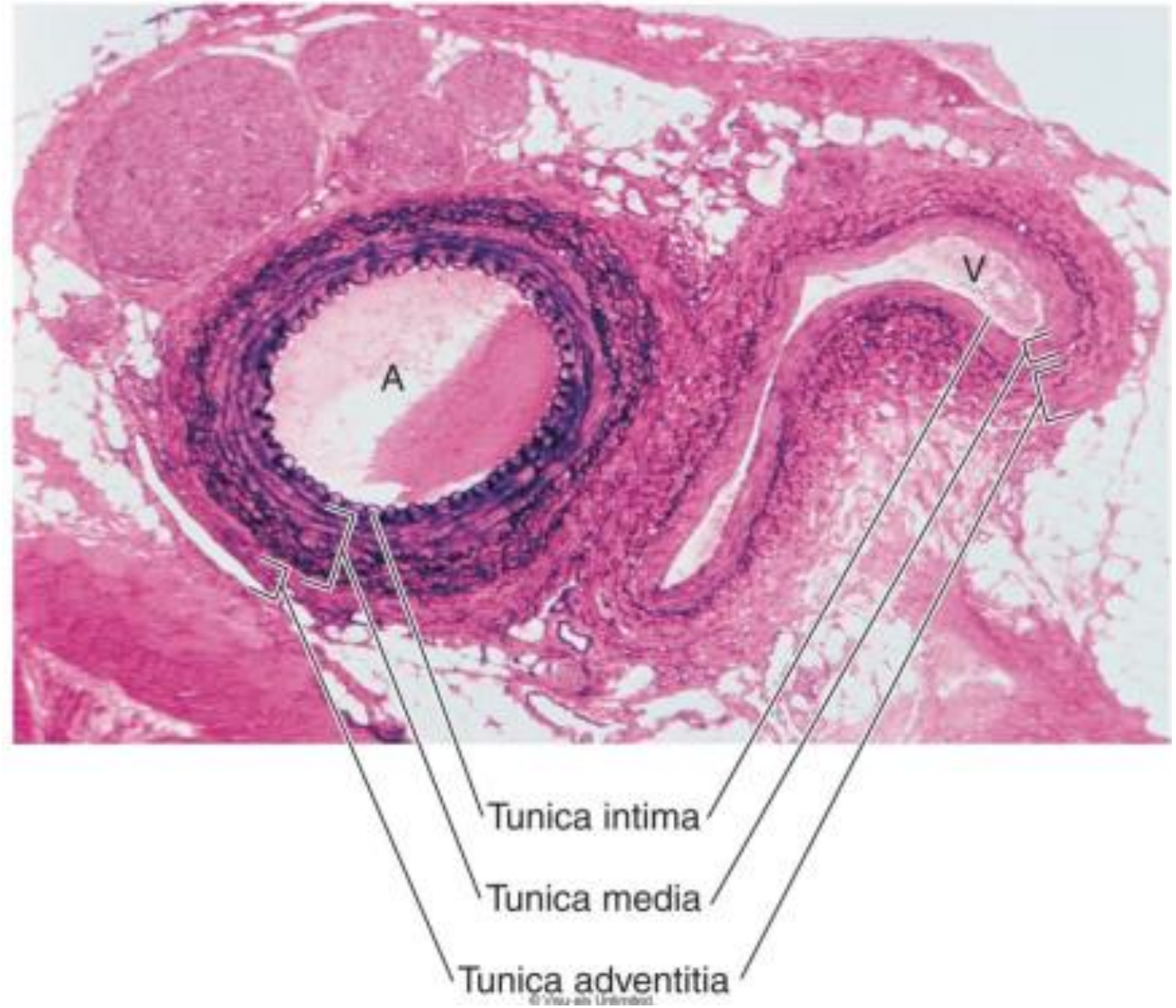

Valve closed
Vein
Valve open
Direction of blood flow


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

DIFFERENCES BETWEEN ARTERIES AND VEINS

ARTERIES	VEINS
They carry blood at high pressure	They carry blood at low pressure
Possess more smooth muscle than collagen fibers in tunica media	Possess more collagen fibers than smooth muscles in tunica media
Possess highly developed elastic fibers/lamellae in the tunica media	Possess thin tunica media with poorly developed elastic fibers
Smooth muscles and other components are arranged CIRCULARLY in tunica media, this allows changes in diameter to regulate blood pressure and flow	Collagen fibers and other components are arranged in LONGITUDINAL layer, this is to prevent excess stretching of vessel wall
Valves are absent	Valves are present, to prevent backflow of blood

DIFFERENCES BETWEEN ARTERIES AND VEINS



CLINICAL CORRELATES

- Ischemic heart disease – It is a group of pathological conditions in which there is imbalance in oxygen supply and demand
  - There are several types:
    - Angina pectoris – this occurs when there is mild, reversible ischemia without necrosis
      - The pain is dull and diffused, it often goes away after bedrest
    - Myocardial infarction – this is a severe and long ischemic condition in which necrosis occurs
      - The pain is more severe and is not relieved by taking rest
      - The pain is usually associated with autonomic upset such as sweating in cold weather, tachycardia, nausea and vomiting
    - Sudden cardiac death – In this case, the ischemia has affected a part of the conducting system of the heart, or a large section of the heart has become affected. This causes dysrhythmia and eventual death of the individual. It often occurs suddenly
    - Chronic ischemic heart disease – this usually occurs over a prolonged period of time. As myocardial cells become necrotic and are replaced by fibrotic tissue, it eventually gets to a stage that the heart can no longer contract because of the deleterious depletion of the myocardial cells. This can lead to heart failure

CLINICAL CORRELATES

- Cardiac tamponade – this occurs when excess fluid (blood or pericardial effusion) rapidly accumulates in the pericardial cavity
  - It is commonly caused by both blunt and penetrating chest injuries
  - It is also caused by myocardial rupture or inflammation of the pericardium (pericarditis)
  - It is a life threatening condition in which accumulating fluid compresses the heart, preventing the heart's chambers from filling properly with blood
    - Relieving the pressure is usually accomplished with pericardiocentesis (a procedure to drain the fluid from the pericardial cavity)
- Mitral valve collapse – this occurs when papillary muscles lose their attachment to the ventricular wall due to myocardial infarction.
  - It can also be caused by immunological response to infections occurring on the tendinous cords. The immune cells in their bid to ward off and destroy the pathogens can end up destroying part of the tendinous cords.
  - Mitral valve collapse can lead to a backflow of blood from the ventricles into the left atrium, which will push blood back into the lungs and increase. The weakest point in the pulmonary circulation is the pulmonary capillaries.
    - Increased pressure in the pulmonary capillaries will lead to the oozing of the fluid into the lungs, this makes the lungs boggy (wet lung or pulmonary oedema), and it causes difficulty in breathing (dyspnea)

QUESTIONS

- Explain in detail how ischemia can cause dyspnea
- What is the relationship between immunological reactions in the heart and difficulty in breathing?
- Differentiate between Purkinje cells and Purkinje fibers
- Highlight the importance of the fibrous skeleton of the heart
- Highlight the differences between myocardial infarction and angina pectoris
- Explain the following
  - Mitral valve prolapse
  - Cardiac tamponade

QUESTIONS

- Why is it improper for the both the atria and ventricles to be stimulated at once?
- What differentiates muscular arteries from elastic arteries?
- State the peculiarities of veins