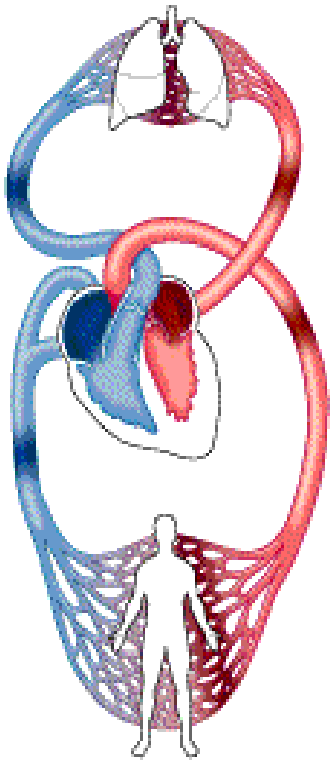
Cardiovascular system

(circulatory system)



The cardiovascular system consists of the heart and a closed system of vessels: the arteries, veins, and capillaries.

The heart is the muscular organ that pumps the blood around the circuit of vessels.

Characteristics of c-v system

- is an unique and complex hydraulic system
- is a closed circle ("circulatory system")
- is elastic

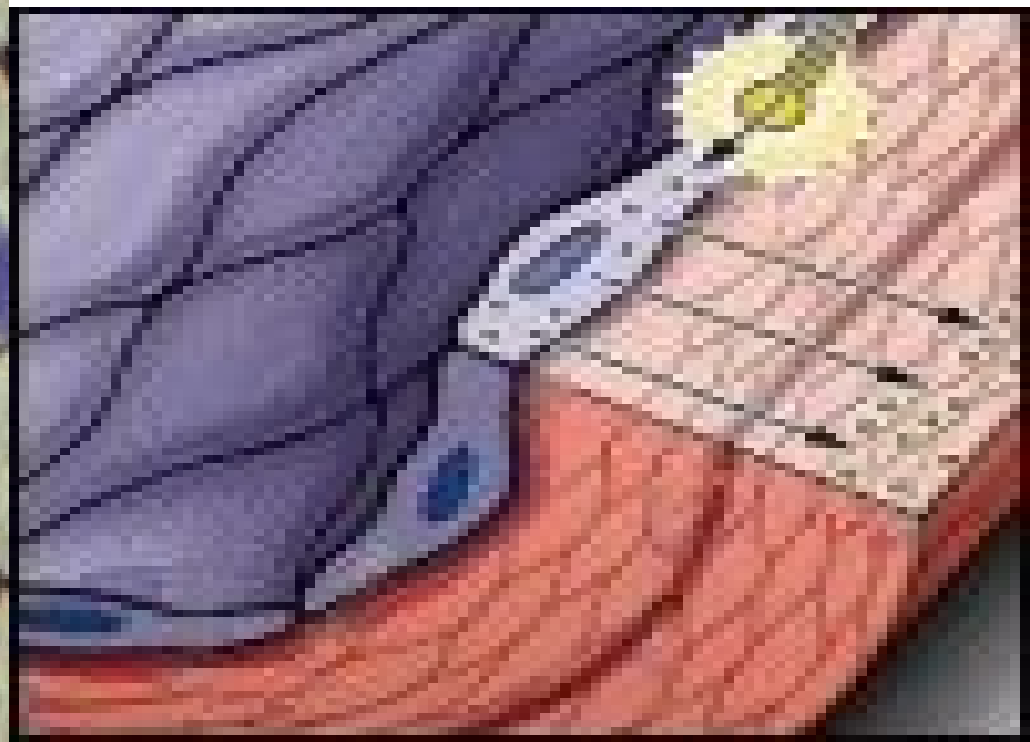
Function of c-v system

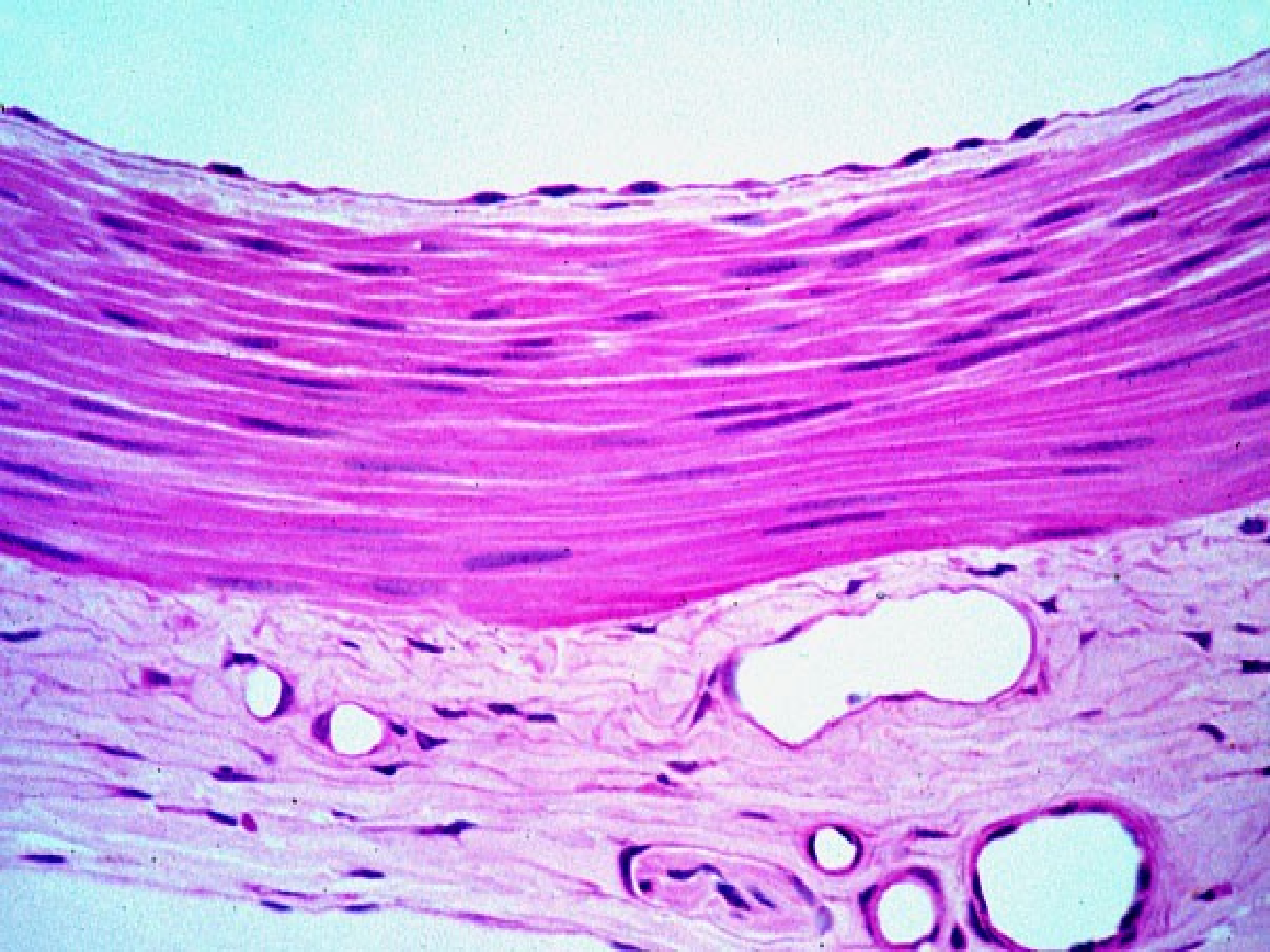
- to maintain homeostasis and an optimal cellular environment.
- transport function of oxygen, nutrients and waste products
- lining endothelium is important for these functions; is waterproof and incoagulable

Endothelium

is a specialized form of mesenchyme-derived epithelium

simple squamous epithelium – one layer of flattened cells forms a thin, waterproof and antithrombogenic lining of all blood vessels, heart and lymphatic vessels





Endothelial cells (1,2) in ELM

ERY

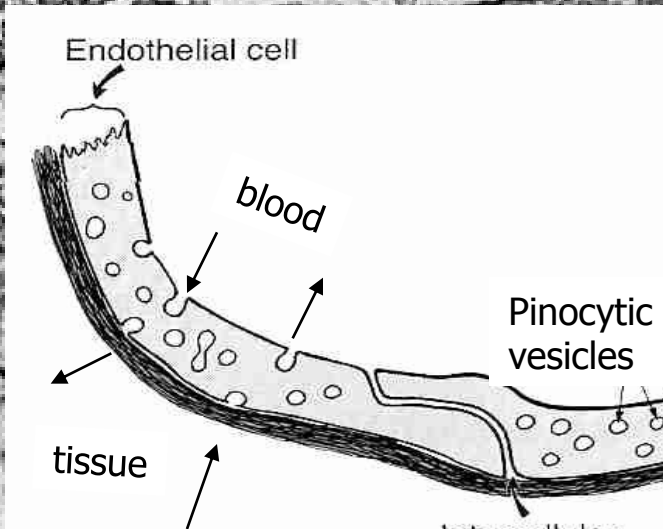
lumen

Pinocytic vesicles

Zonula occludens

2

1



Function of endothelium

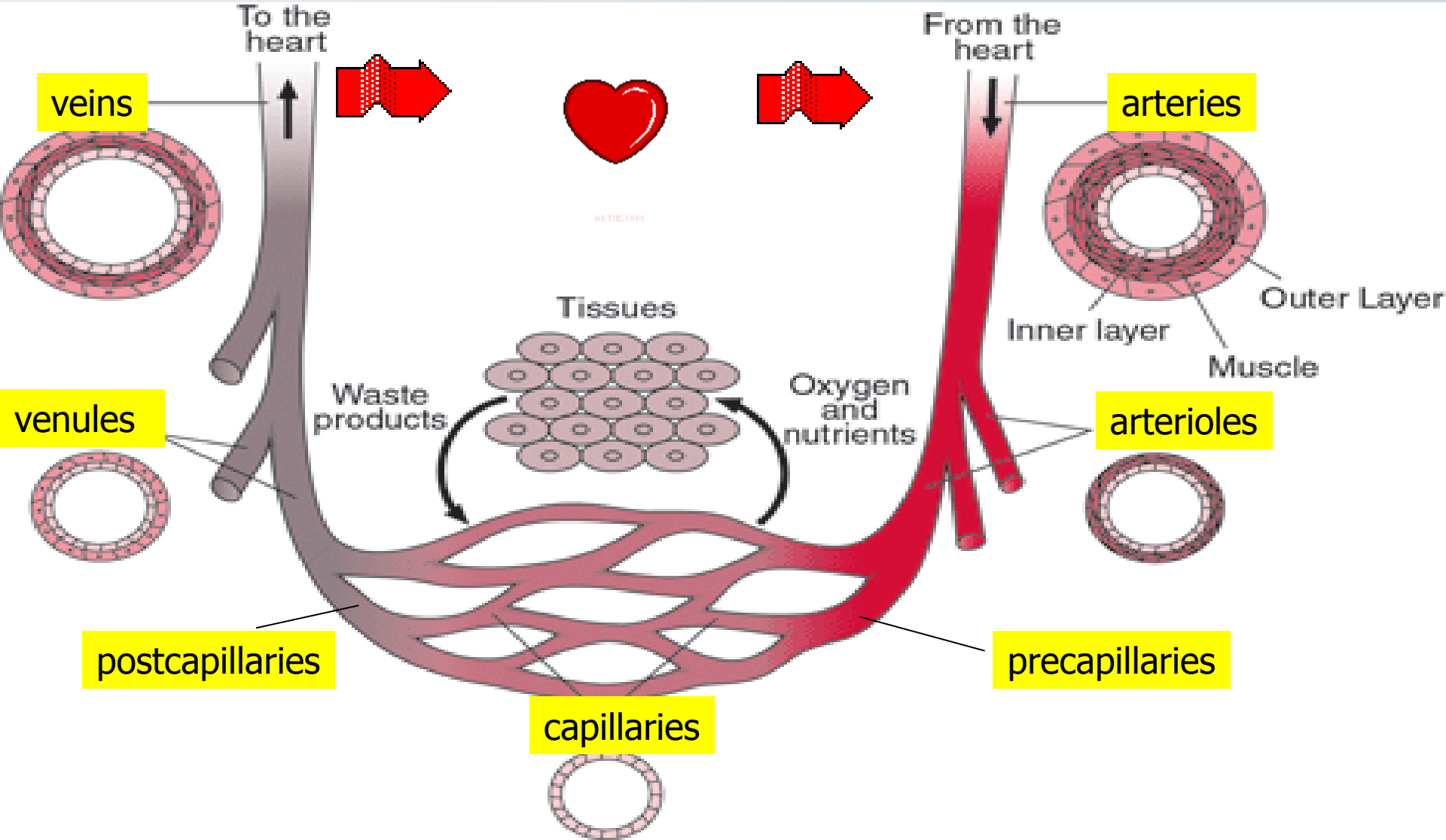
- the control of blood pressure by vasoconstriction and vasodilation,
- blood clotting,
- formation of new blood vessels (angiogenesis),
- control of the passage of materials and the transit of white blood cells into and out of the blood,
- in some organs, there are highly differentiated endothelial cells to perform specialized 'filtering' functions (renal glomerulus in kidney, blood-brain barrier, placental barrier).

Blood vessels are categorized by function

- Arteries conduct blood away from the heart and have proportionately more smooth muscle and elastic tissue than veins of comparable size.
  - Arteries are commonly sub-categorized into elastic arteries (*the largest one*), muscular arteries (*middle-sized*), and arterioles.
- Veins return blood to the heart.

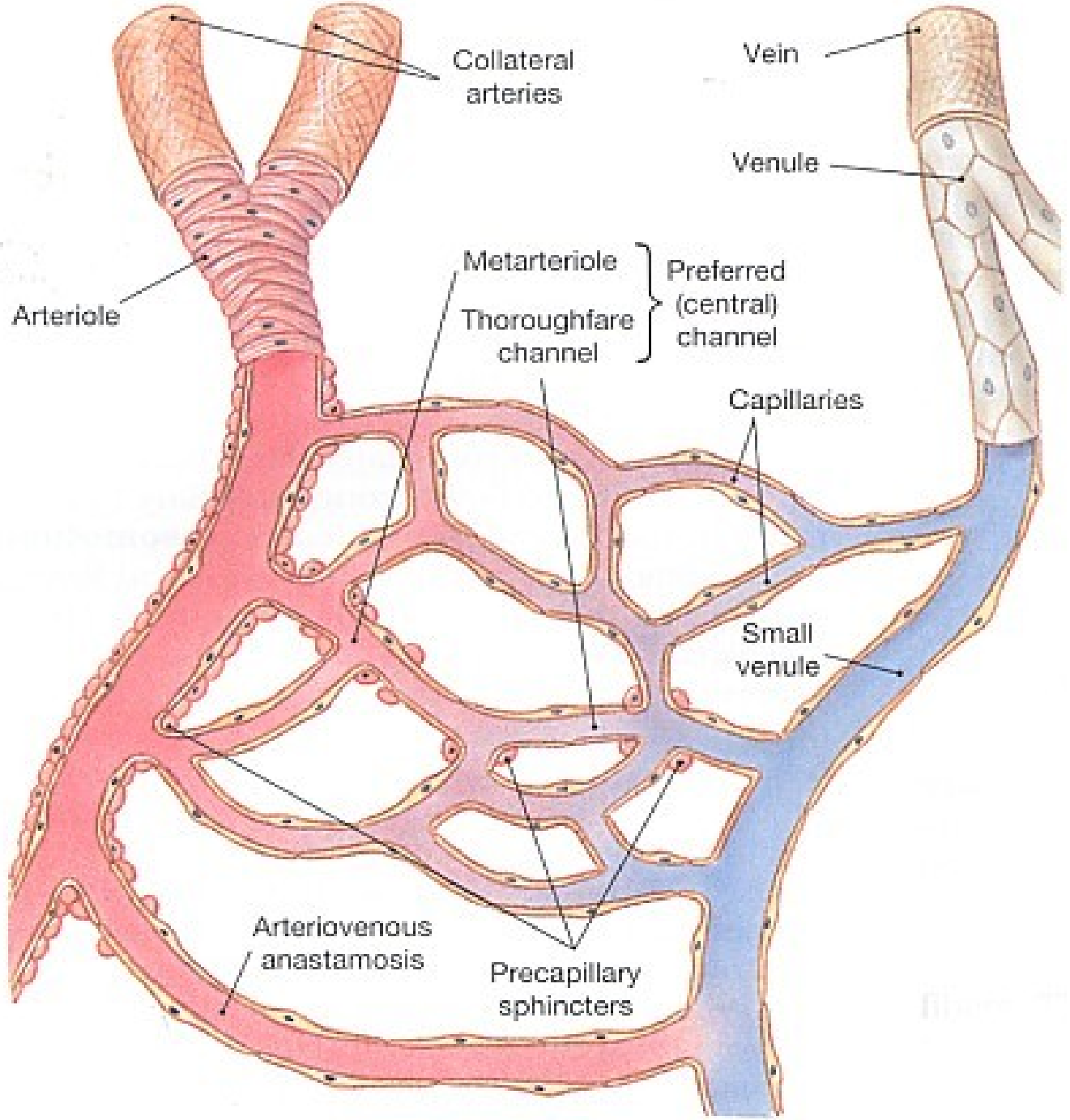
The composition of the wall varies among arteries and veins.

Bloodstream organization



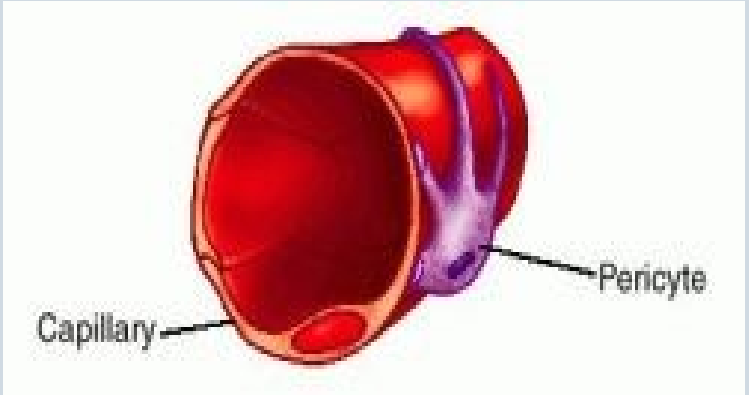
Blood capillaries

Network of the smallest, thin- walled vessels, situated between arterial and venous portion of circuit



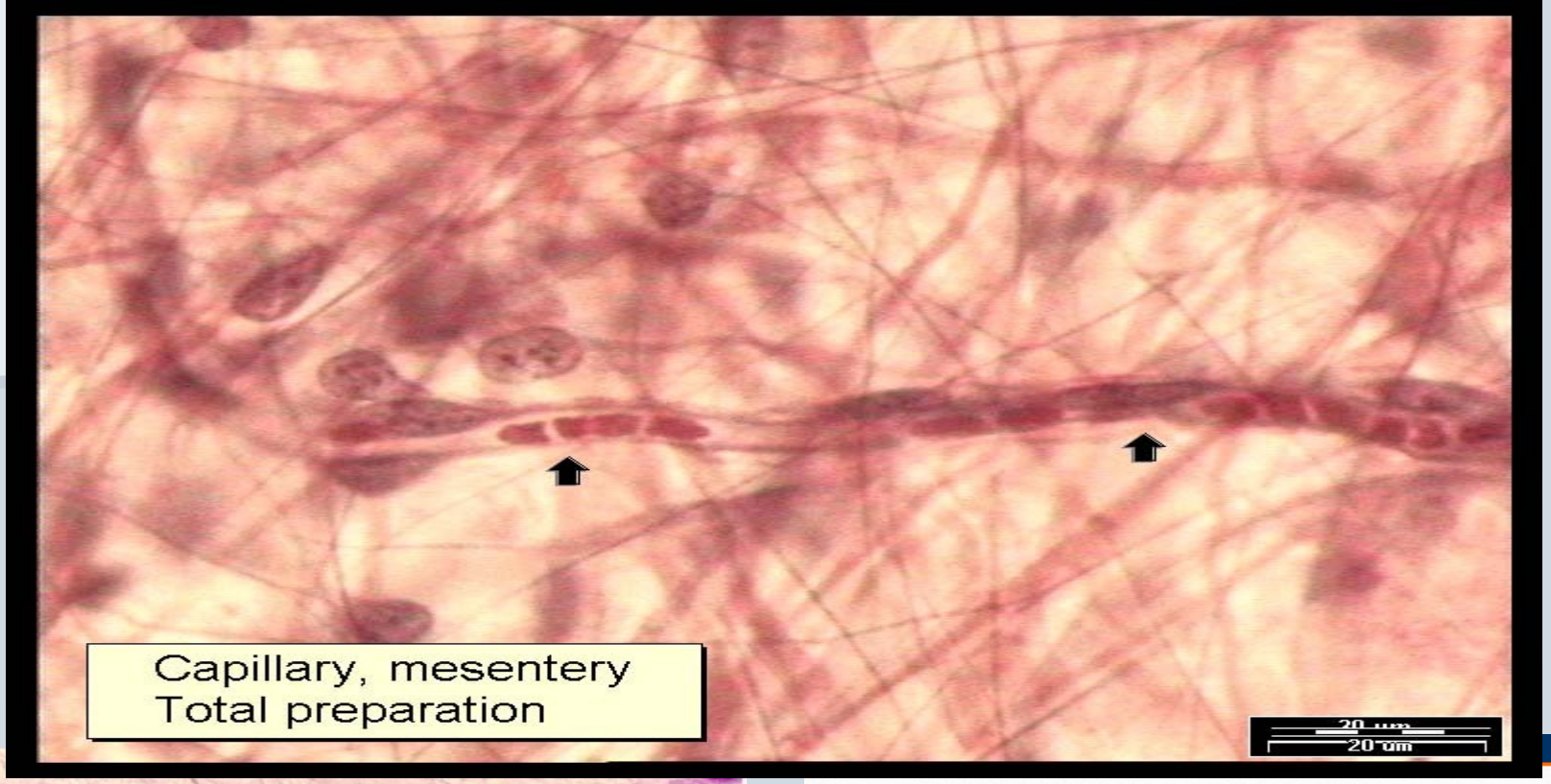
Blood capillaries

- diameter from about 8 μm (to 30-40 μm)
- lumen is lined by 1-2 endothelial cell
- reticular fibers surround the capillaries
- capillary bed between arteries and veins
- pericytes



3 types of capillaries

- continuous
- fenestrated
- sinusoids

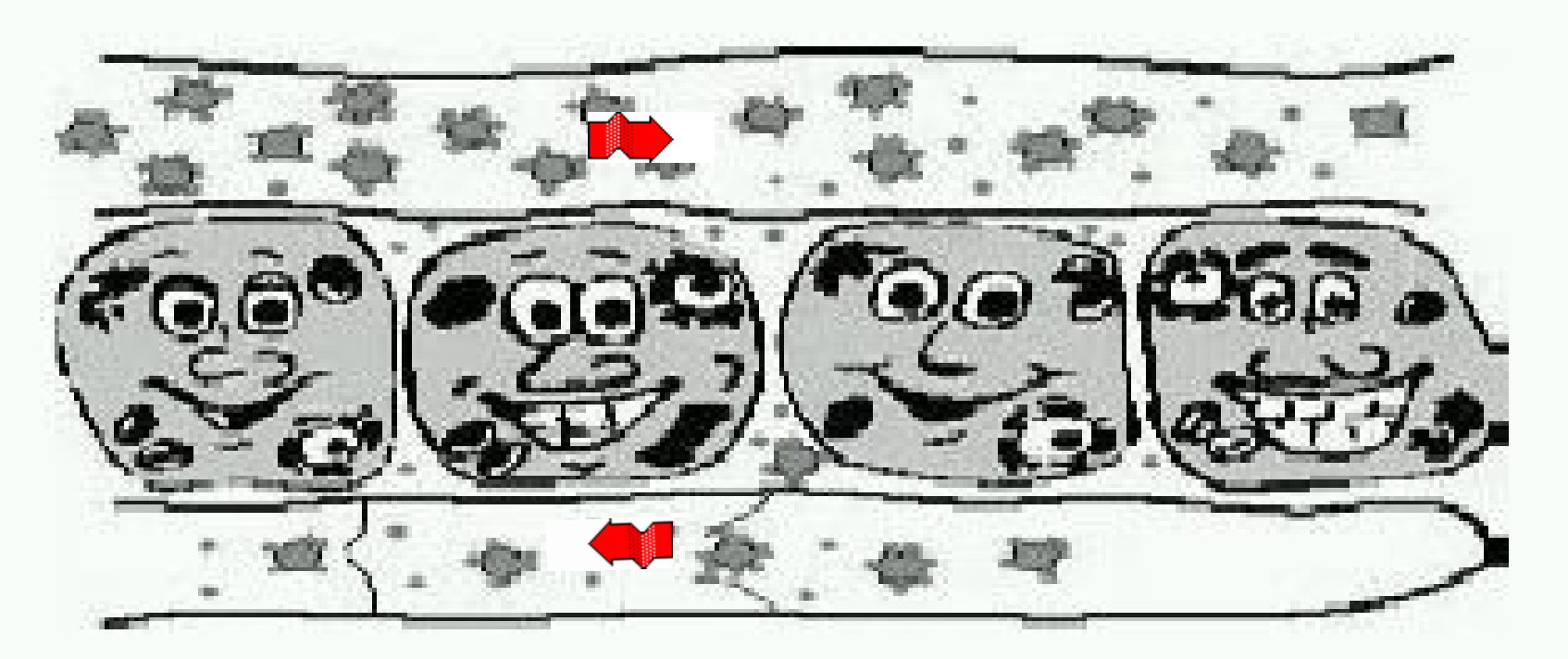

Capillary, mesentery
Total preparation
20 um
20 um


capillary


2 µm
Source: Exerc Sport Sci Rev © 2004 American College of Sports Medicine

Function of capillaries (1)

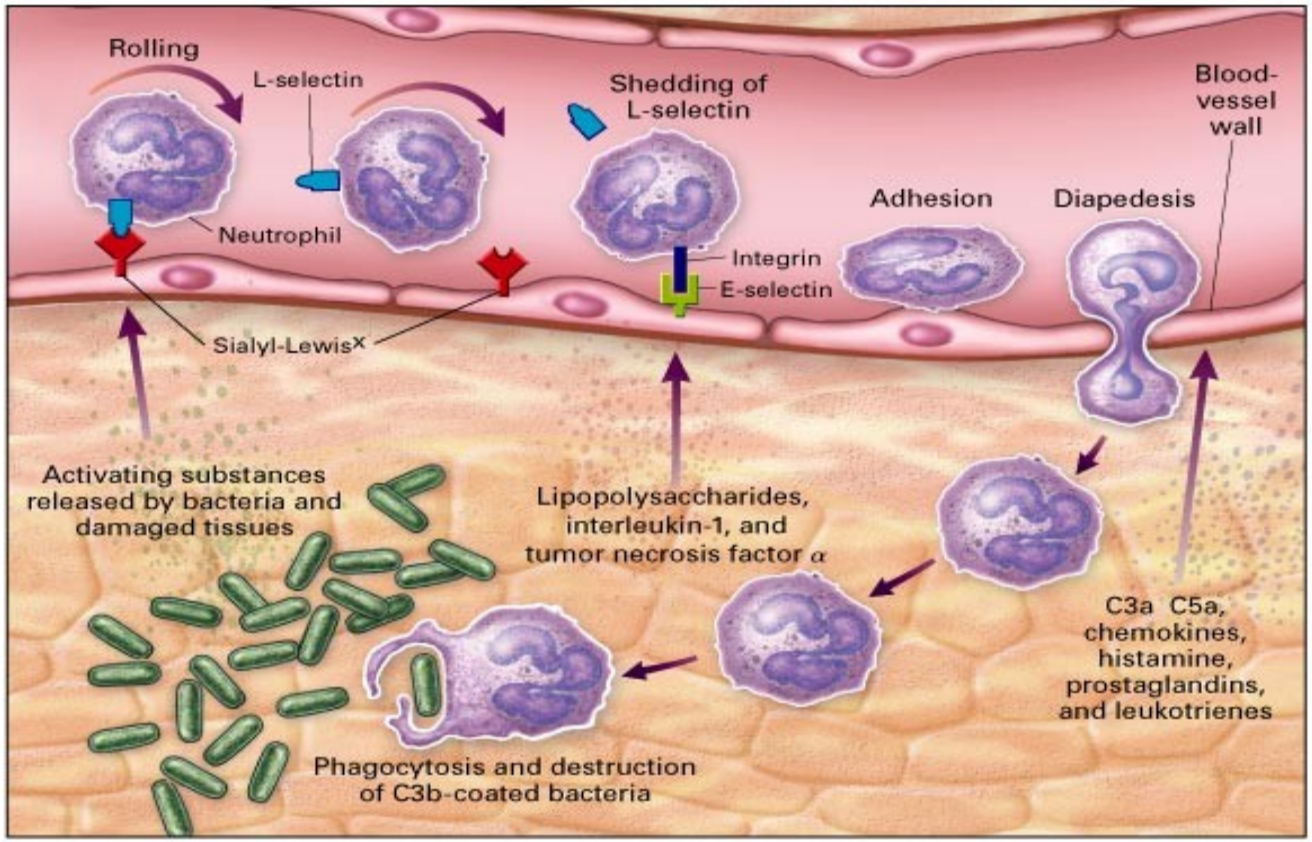
- respiratory gasses, nutrients and waste products change between blood and tissues



The illustration shows satistied cells in well vascularized tissue ☺

Function of capillaries (2)

- allow the blood cells to pass throughout their wall into the connective tissue (by diapedesis)



Neutrophils

↳ microphages

Eosinophils

Basophils

↳ heparinocytes

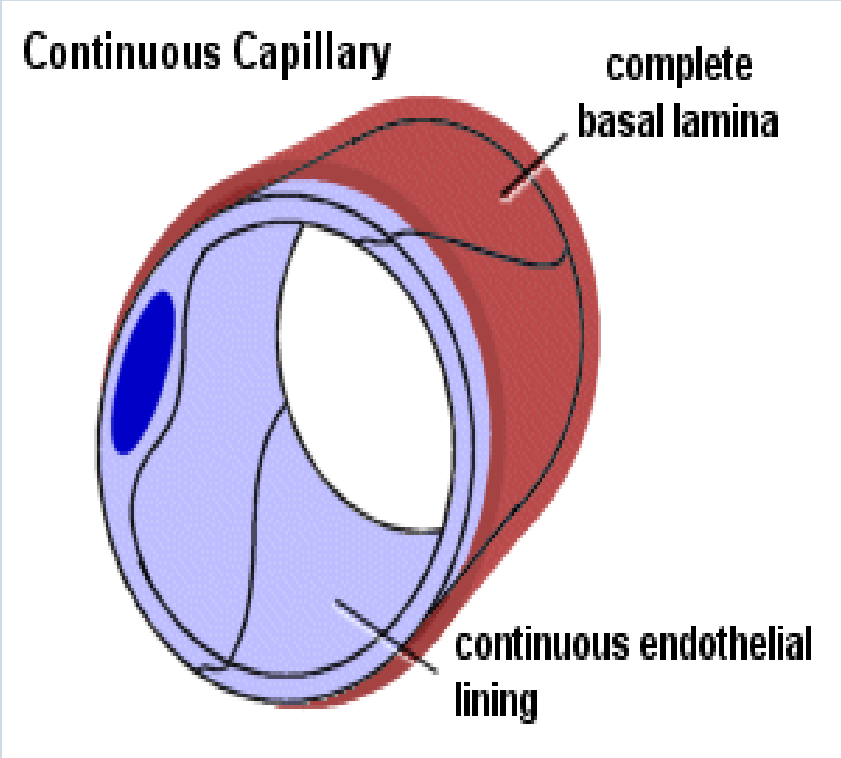
Lymphocytes

Monocytes

↳ macrophages

Continuous capillaries

- The smallest: cca 8 μm
- The wall:
  - endothelium – 1-2 cells
  (zonulae occludentes and nexuses)
  - lamina basalis
  - pericytes
  - reticular fibers
- only allow small molecules, water and ions to diffuse

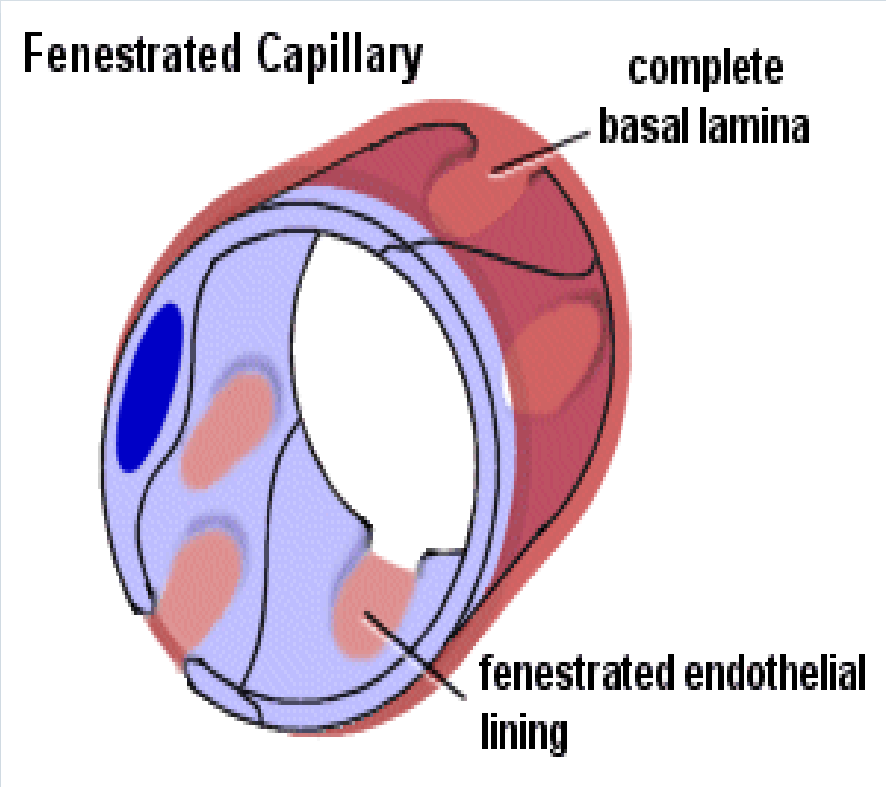


Example of occurrence:
muscle tisue, brain


Capillary

Fenestrated capillaries

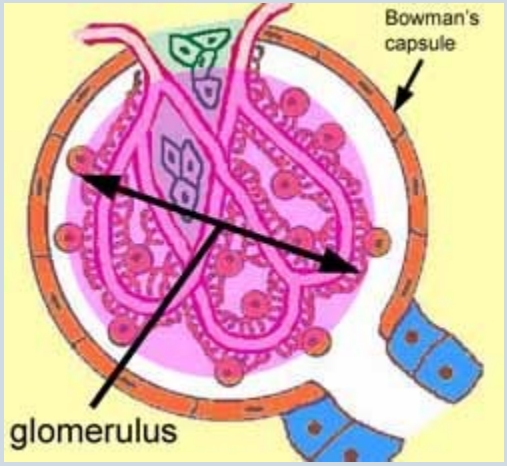
- Endothelial cells with fenestra („windows“) 70 nm ∅, diaphragm (thinner than plasma membrane) boards fenestrum
- continuous basal lamina
- in the organs with quic and intensive metabolism and substances change
- allow small molecules and limited amounts of protein to diffuse

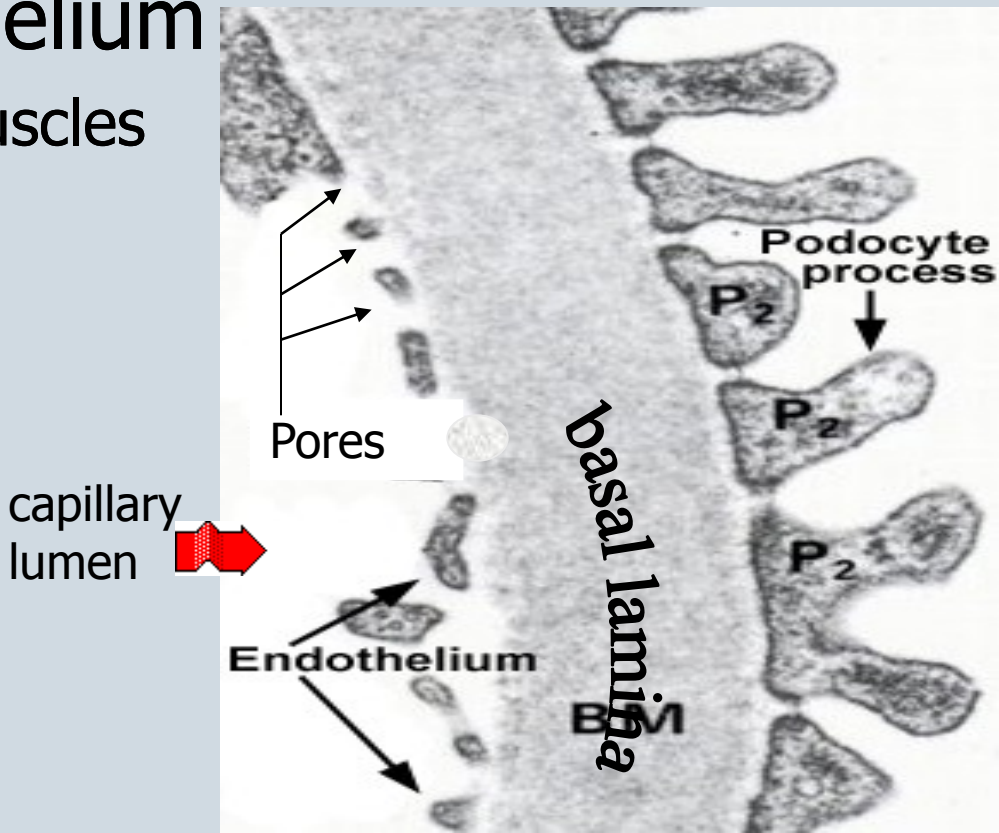


Exampl of occurrence:
intestinal villi, endocrine glands

Capillaries with pores

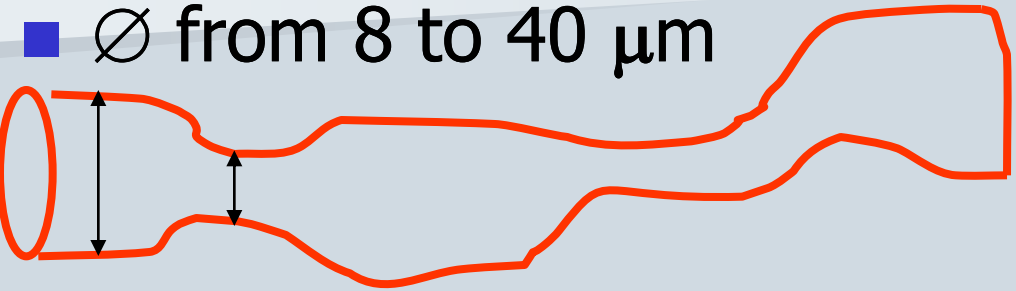
- special type of fenestrated capillaries
- not fenestra with diaphragm, but opened pores are in endothelium
- in glomeruli of renal corpuscles



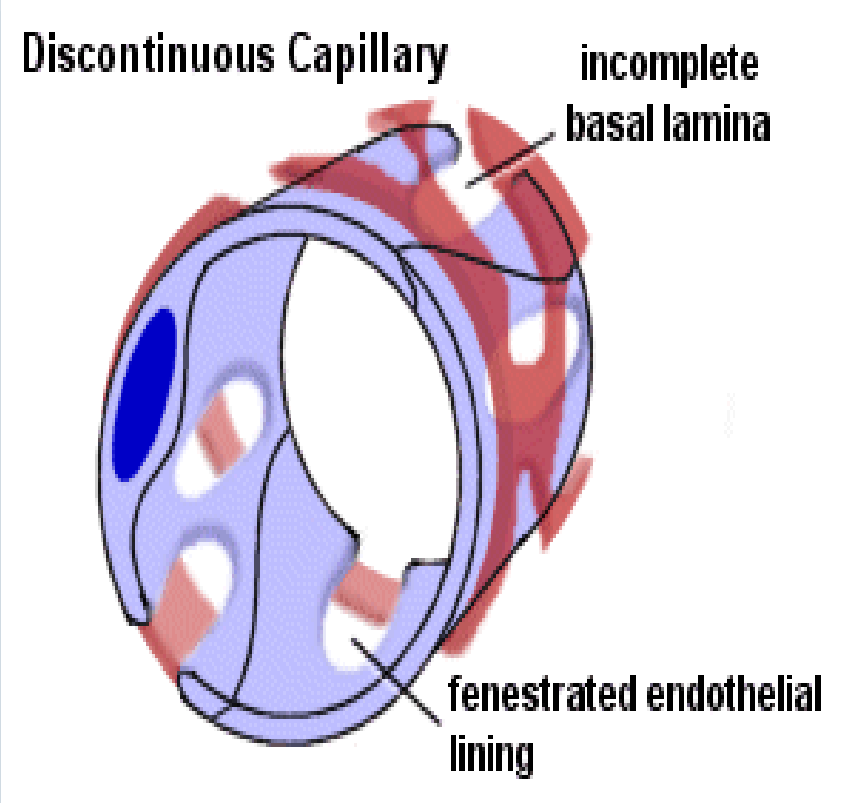


Sinusoidal capillaries (**sinusoids**)

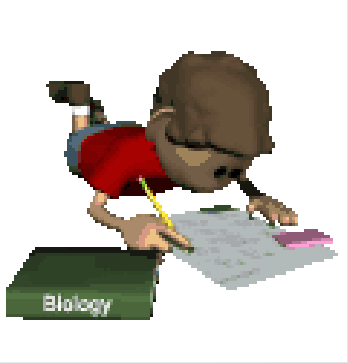
- ∅ from 8 to 40 μm



- endothelium – fenestra, pores and intercellular clefts; some cells are able to phagocyte
- incomplete basal lamina
- reticular fibers
- allow erytrhocytes and serum proteins to enter.

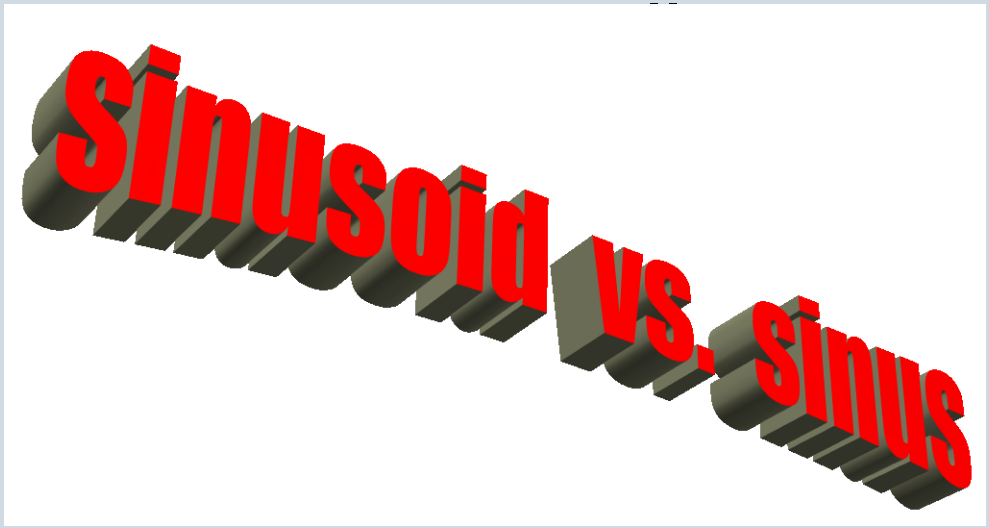


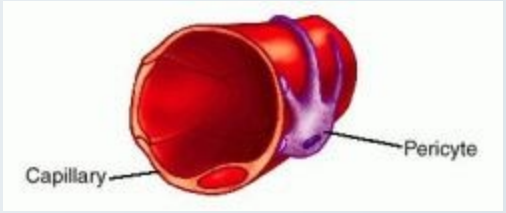
Example of occurrence:
liver, spleen, bone marrow



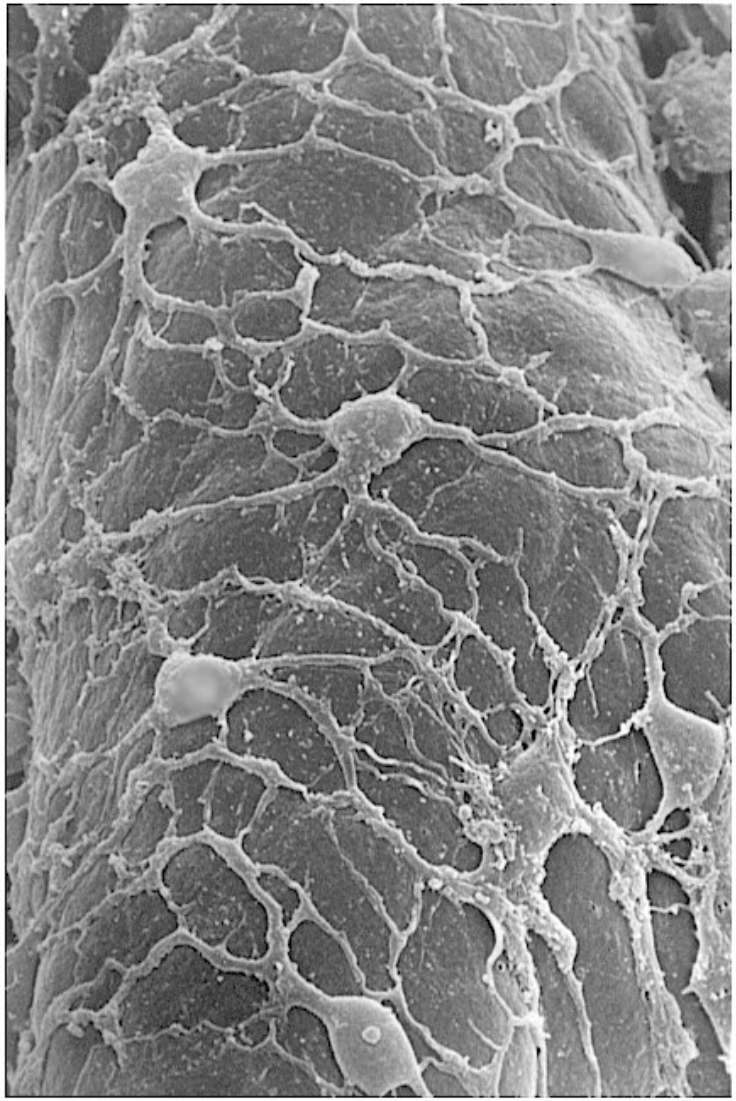
Remember!

- Sinusoid = type of blood capillary (between arterial and venous part of bloodstream)
- Sinus = venous sinus belong to **venous**, of bloodstream

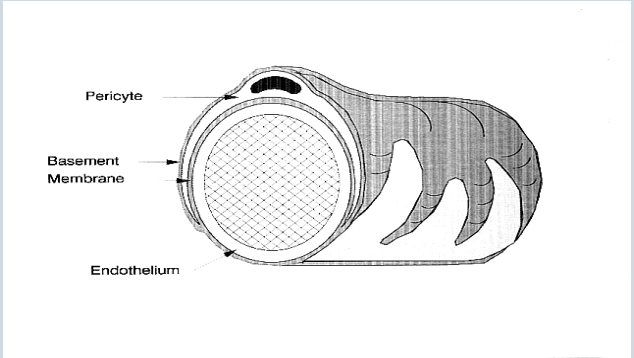




Pericytes



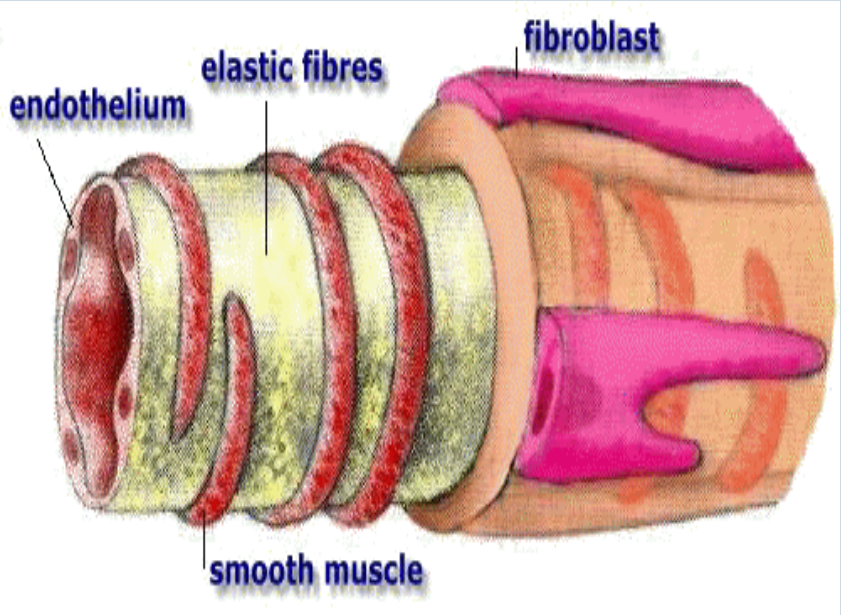
- cytoplasmic processes around capillary,
- contain actin, myosin, tropomyosin
- their own basal lamina fuses together with that one of capillary

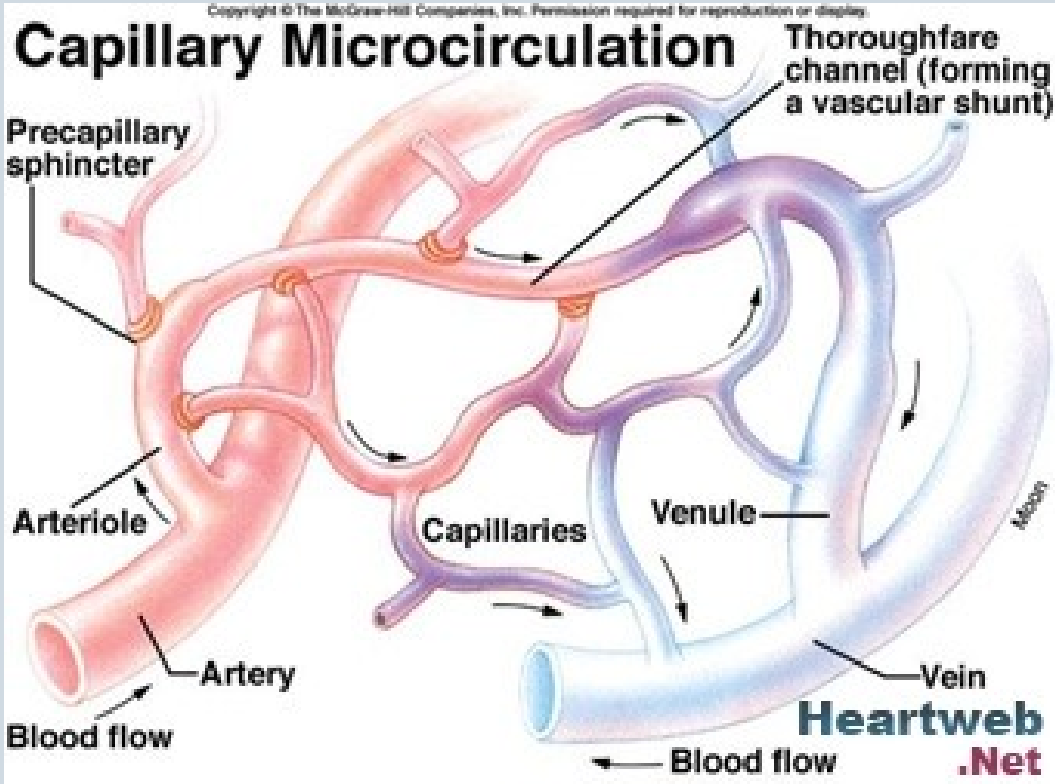


Precapillaries - Postcapillaries

- ∅ 12 – 40 μm
- **endothelium + LB, elastic + collagen fibers, smooth muscle cells**
- **precapillary sphincters**

- ∅ to 200 μm
- **endothelium + LB, smooth muscle cells**





Structure of blood vessel wall – generally –

- **tunica interna (intima)**

  endothelium + subendothelial connective tissue

  membrana elastica interna

- **tunica media**

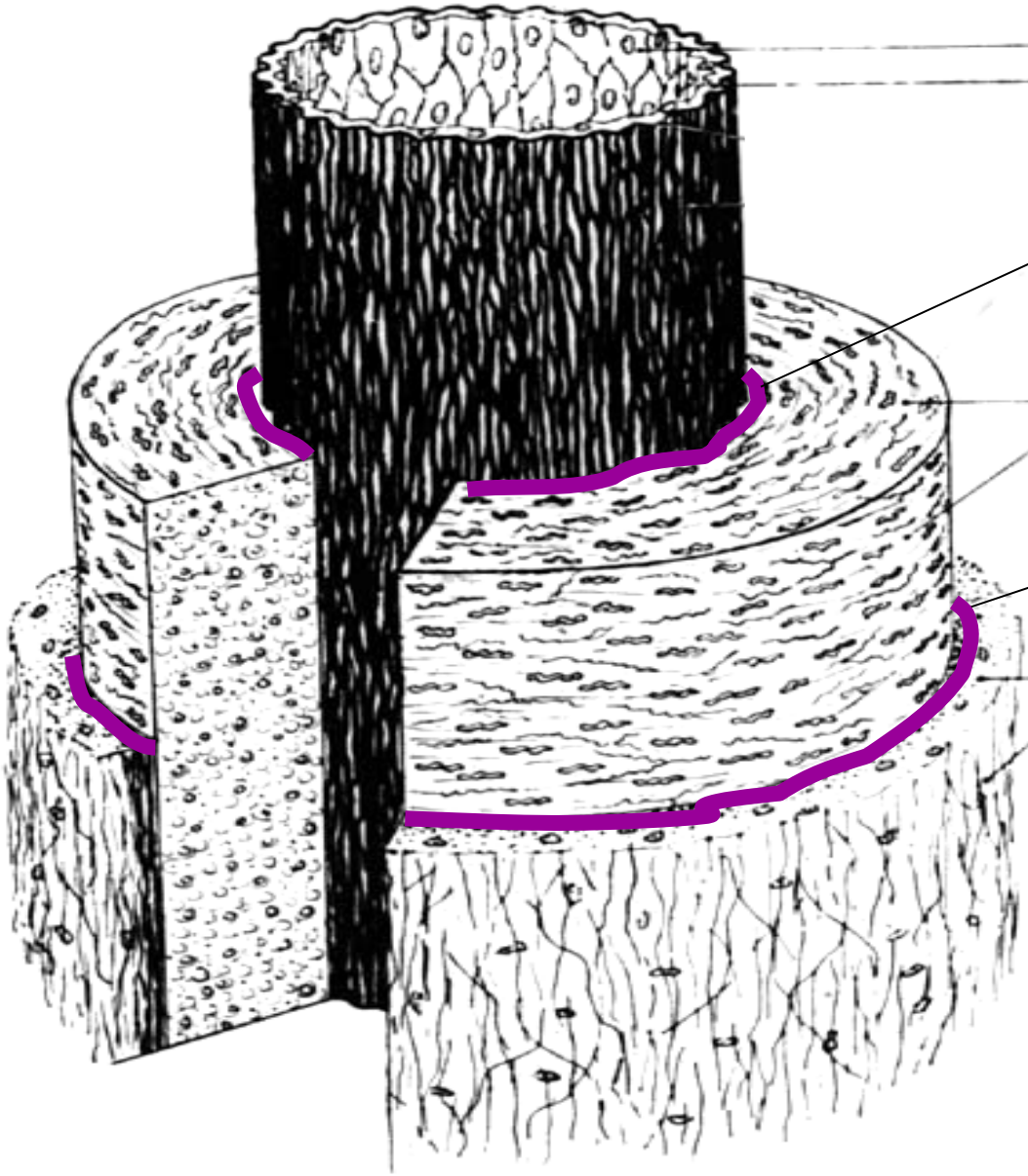
  smooth muscle tissue – circularly oriented

  membrana elastica externa

- **tunica externa (adventitia)**

  loose connective tissue + nerves + vasa vasorum

  (+ longitudinal smooth muscle – only in veins)



Endothelium

Tunica interna
<lungitudinally>

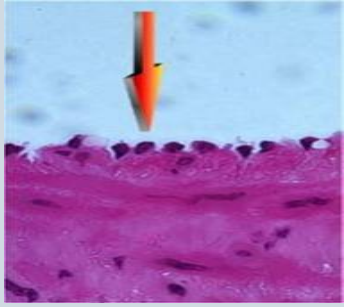
Membrana elastica interna

Tunica media
<circularlly>

(Membrana elastica externa)

Tunica externa
<longitudinally>

Tunica interna (*intima*) TI



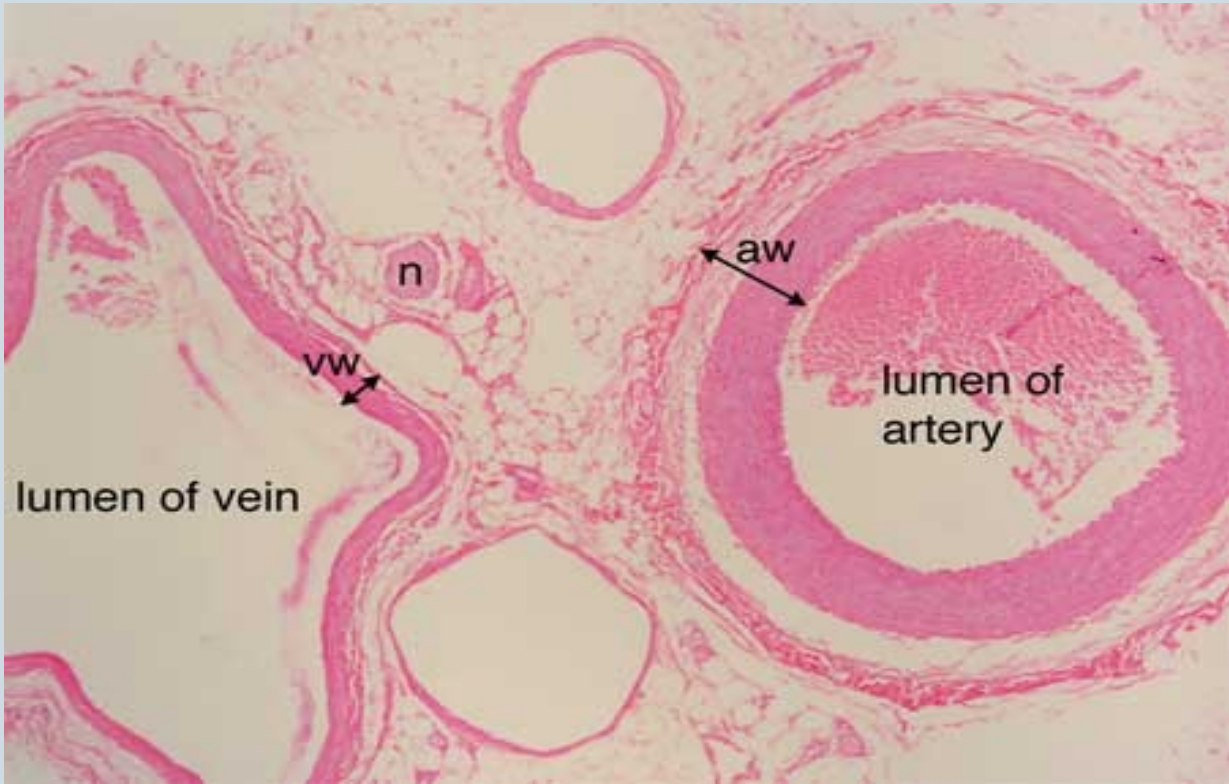
- **endothelium**
- **subendothelial connective tissue** – thin layer of elastic + collagen fibers *(longitudinally oriented)*

Tunica media TM

- consists of smooth muscle cells and elastic membranes in varying proportions

  (circularly oriented)

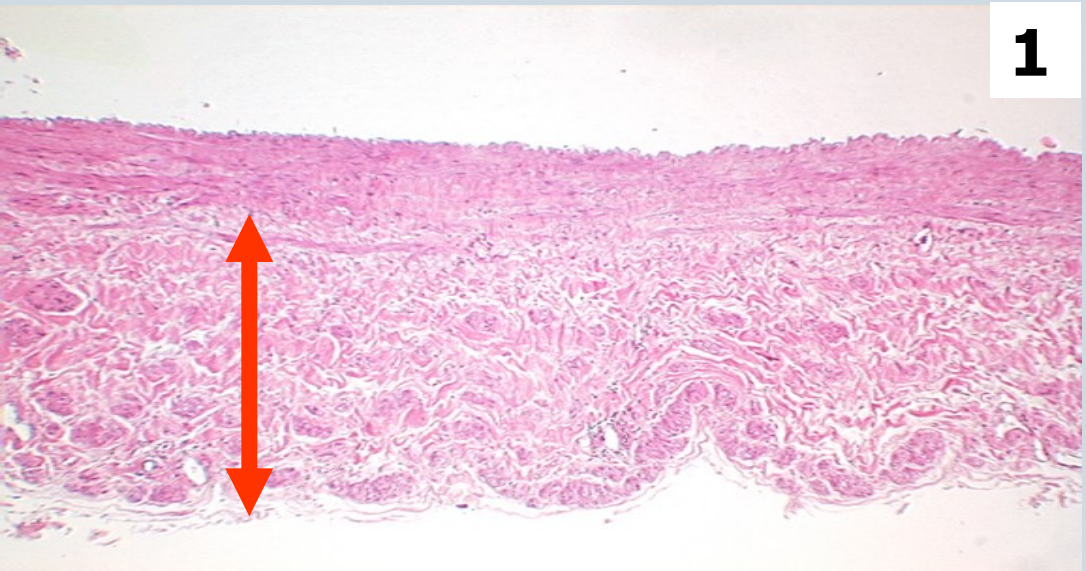
- is thicker in arteries than in veins

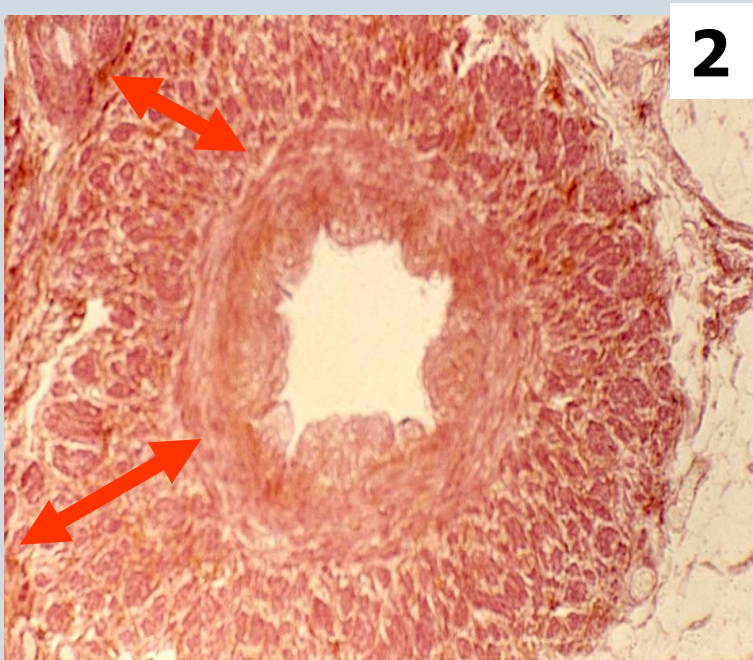


Compare aw – vw:

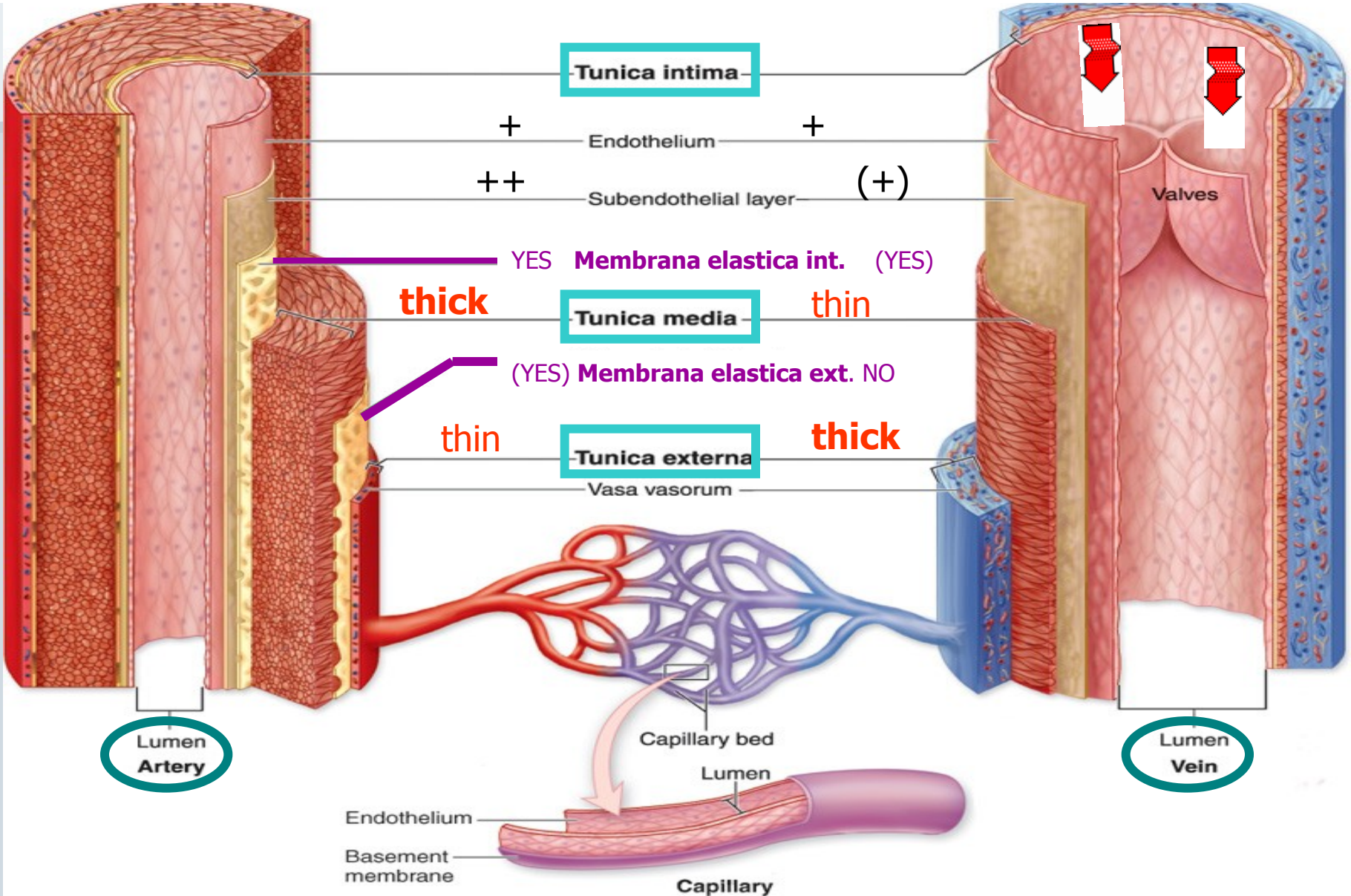
Tunica externa (*adventitia*) TA

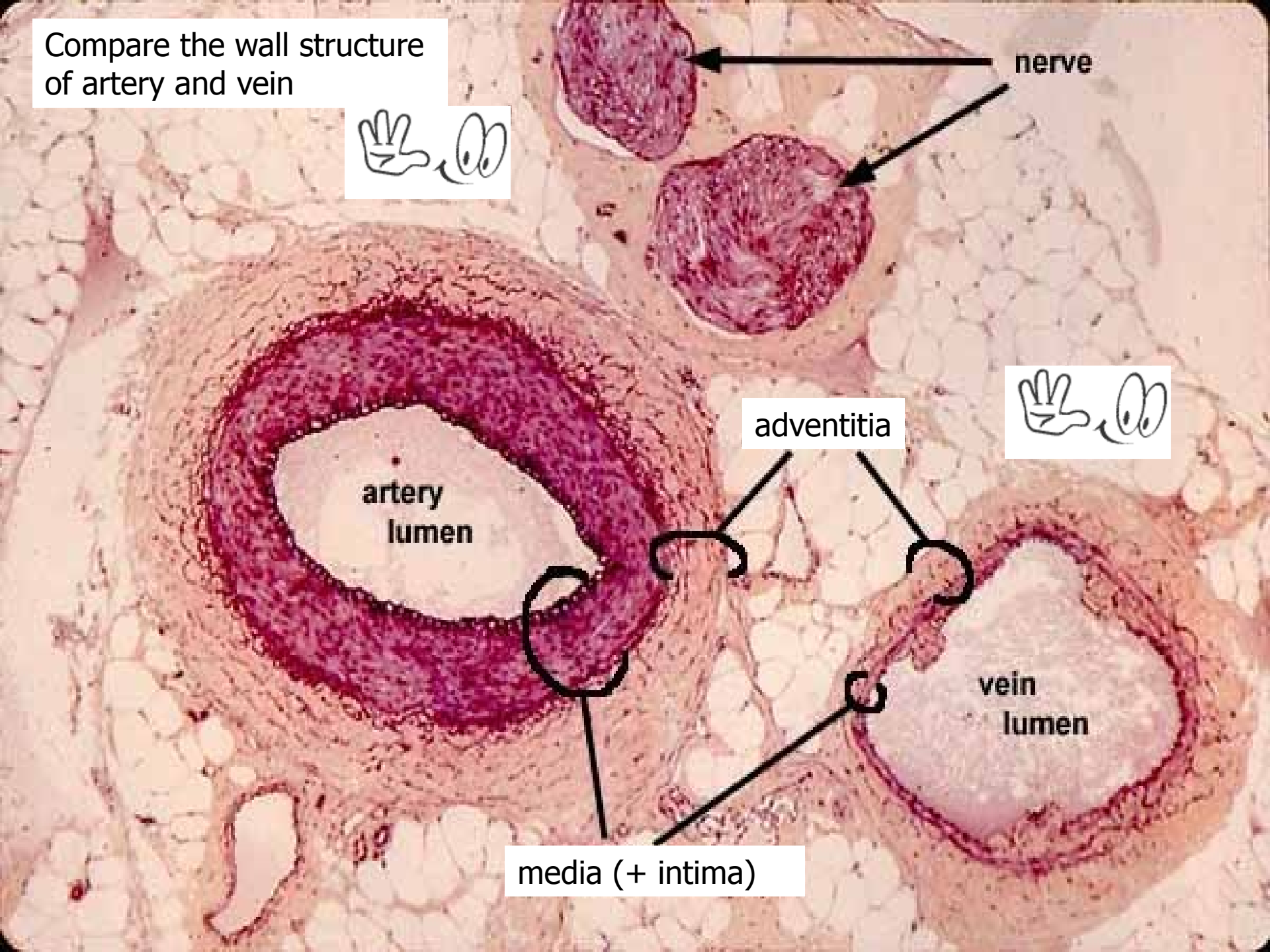
- fibrous connective tissue + smooth muscle cells in veins *(logitudinally)*
- is thicker in vein; is the thickest layer in large veins [1] and veins of low limbs [2]
- contains vessels and nerves (vasa et nervi vasorum) in large vessels





Structural differences between arteries and veins – generally:




Compare the wall structure of artery and vein
nerve
adventitia
artery lumen
vein lumen
media (+ intima)

Arterial part of bloodstream

According to diameter, morphological differences and ratio of elastic fibers and smooth muscle cells:

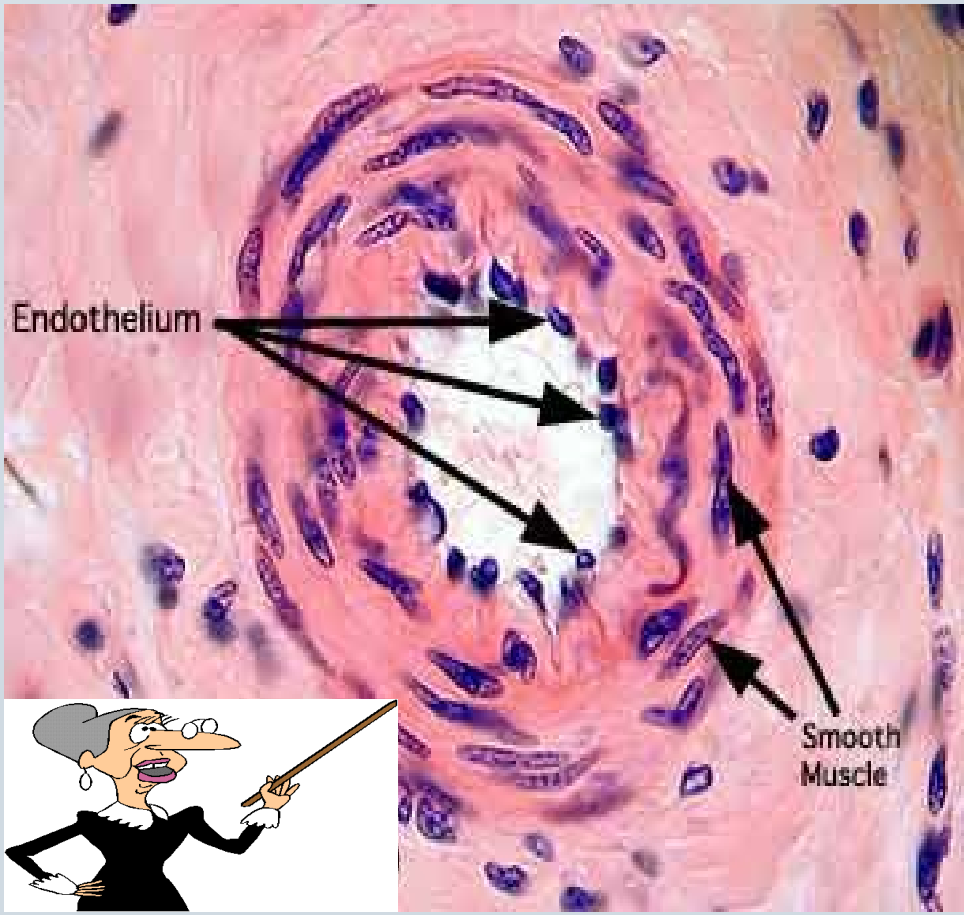
- Arterioles ∅ < 0.5 mm
- Muscular arteries (small and middle-sized)
  ∅ 0.5 – 1 mm
- Elastic arteries (large: aorta and arteries growing from aorta)

Arteriole

- ∅ < 0.5 mm

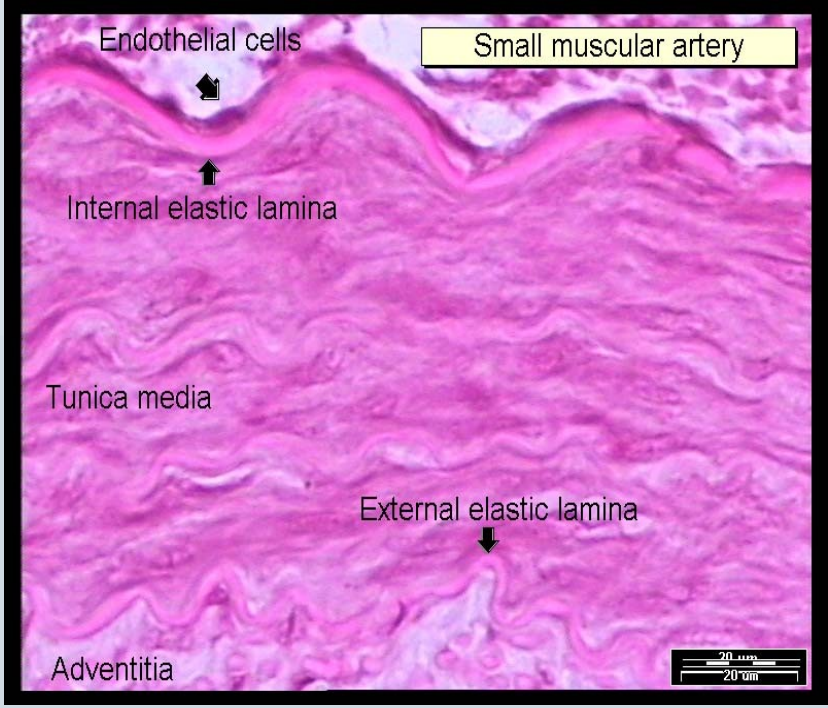
The wall

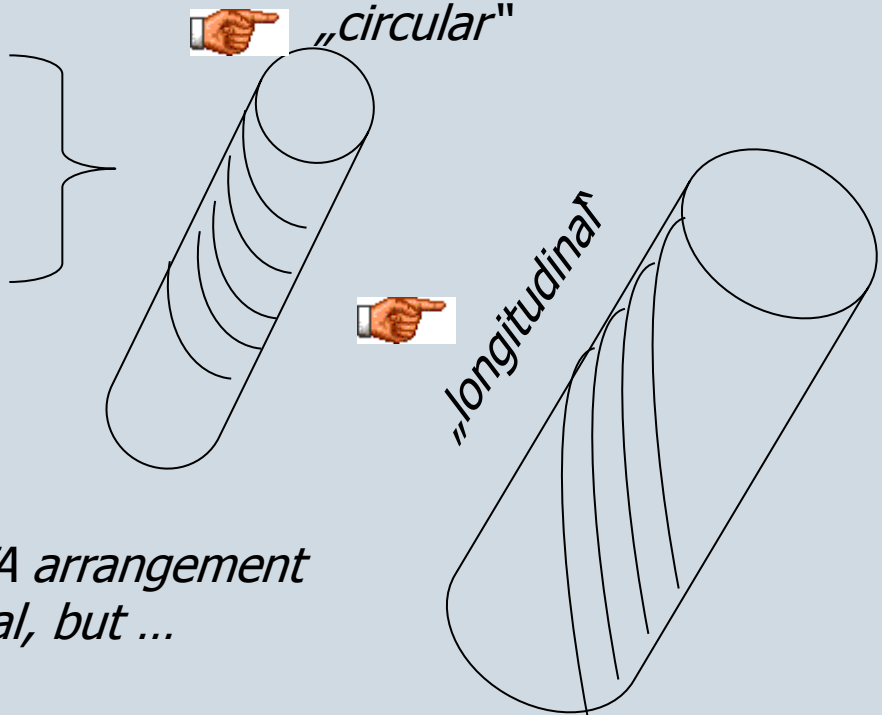
- TI: endothelium + subendothelium
- *membrana elastica int.*
- TM: smooth muscle cells (cca circular 5 layers)
- TA: fibrocytes, reticular (+collagen) fibers



Muscular artery

- TI: endothelium + subendothelium (with smooth muscle cells (longit.)
- *membrana elastica int.*
- TM: up to 40 layers of smooth muscle cells, elastic and collagen fibers
- *membrana elastica ext.*
- TA: loose connective tissue

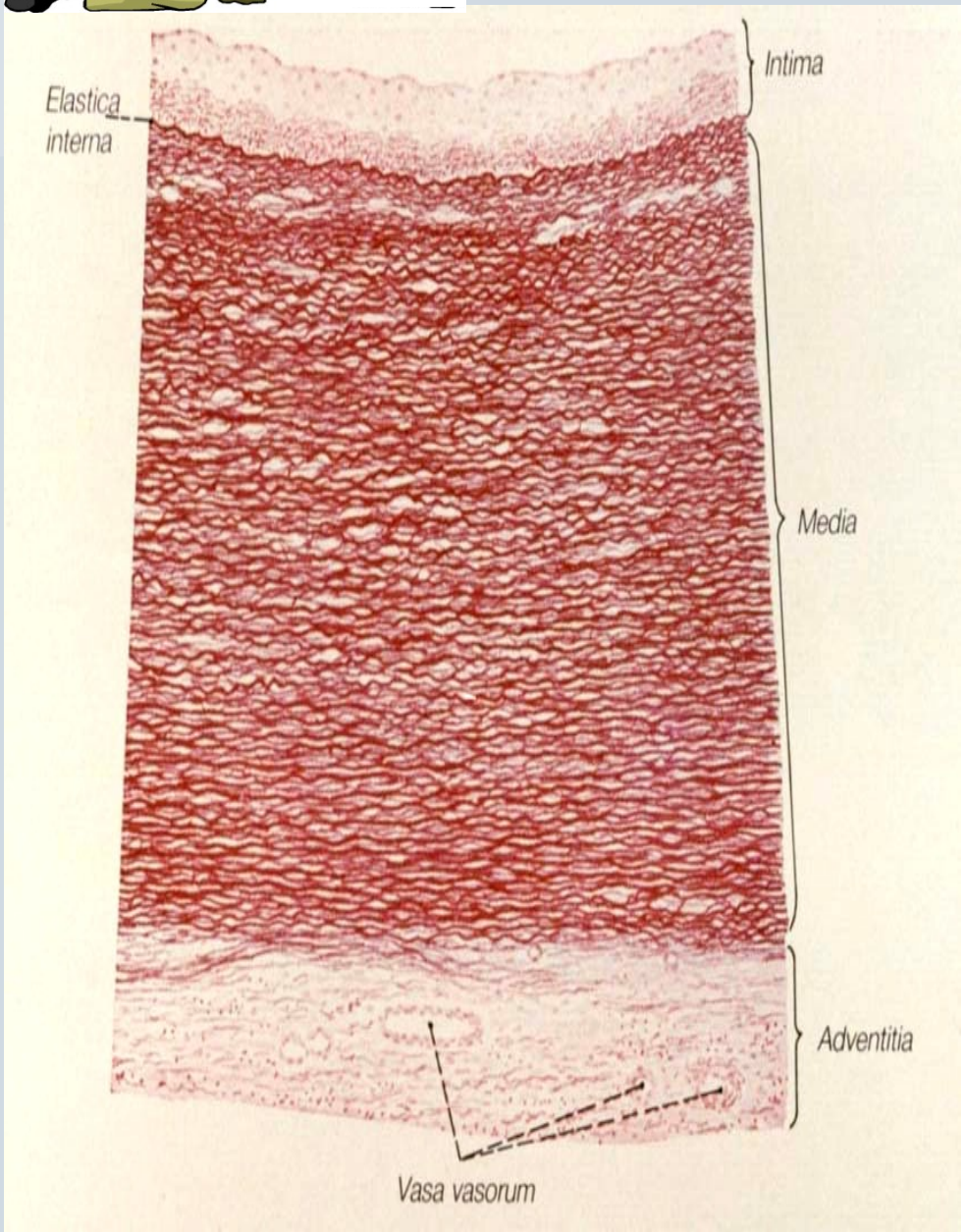




TM+TA arrangement is spiral, but …

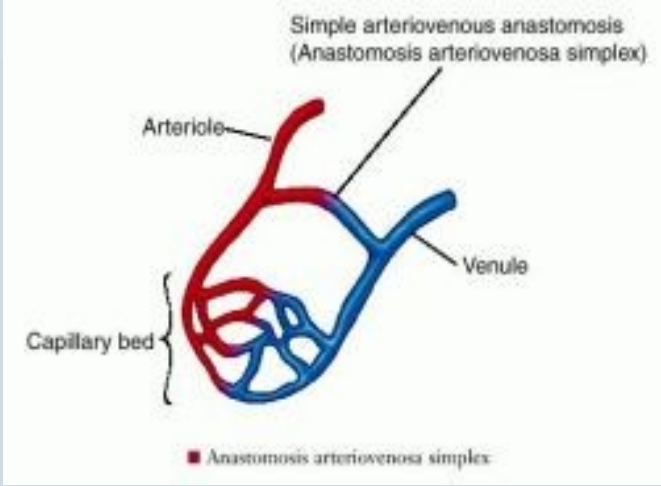
Elastic artery

- TI: endothelium + subendothelium (100 μm wide layer of connective t.)
- TM: up to 40-60 layers of fenestrated elastic membranes, small amount of smooth muscle cells and reticular fibers
- TA: loose connective tissue (+ vasa et nervi vasorum)



Different types of arteries

- Arteriovenous anastomosis
  (artery contains smooth muscle cells in the wall before vein)

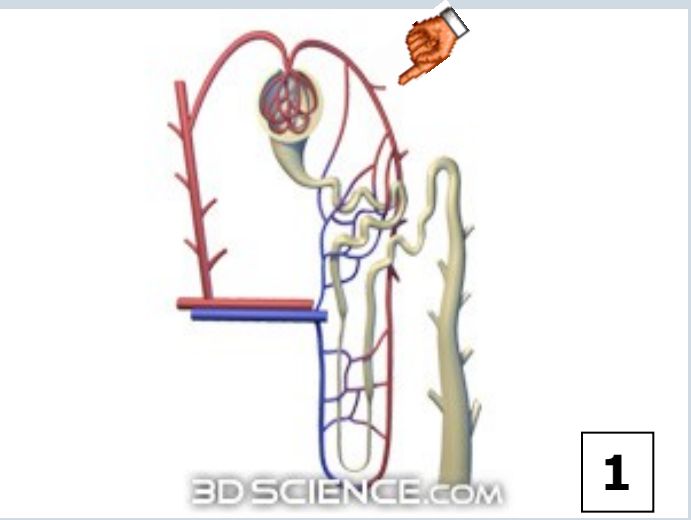


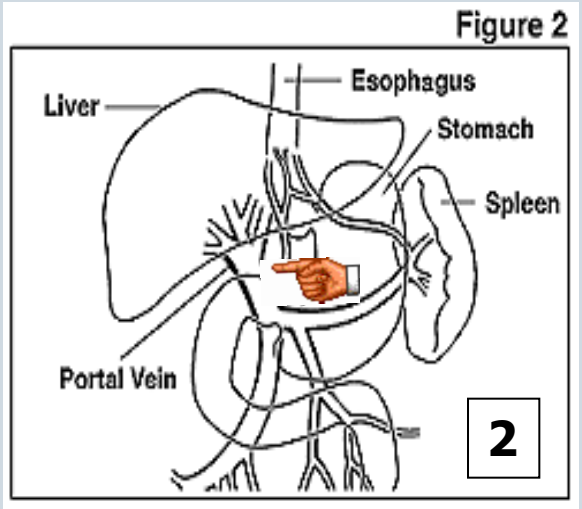
- Arteries with intimal pillows
  (smooth muscle cells form pillows in t.media)

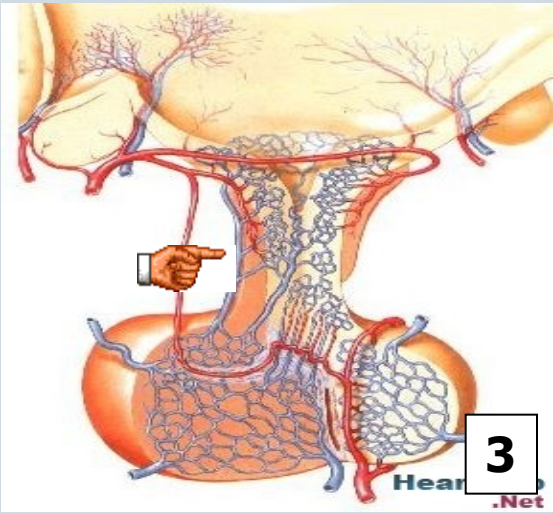
– *lumen can be closed by their contraction*

Portal circulation: arterial or venous

- two capillary systems side-by-side





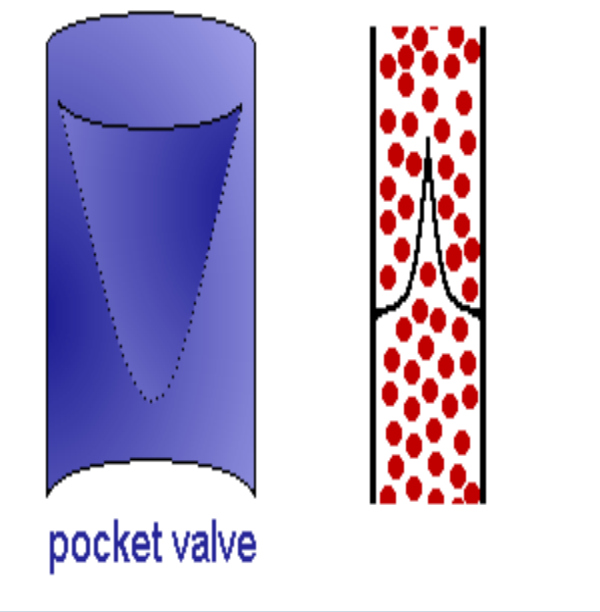


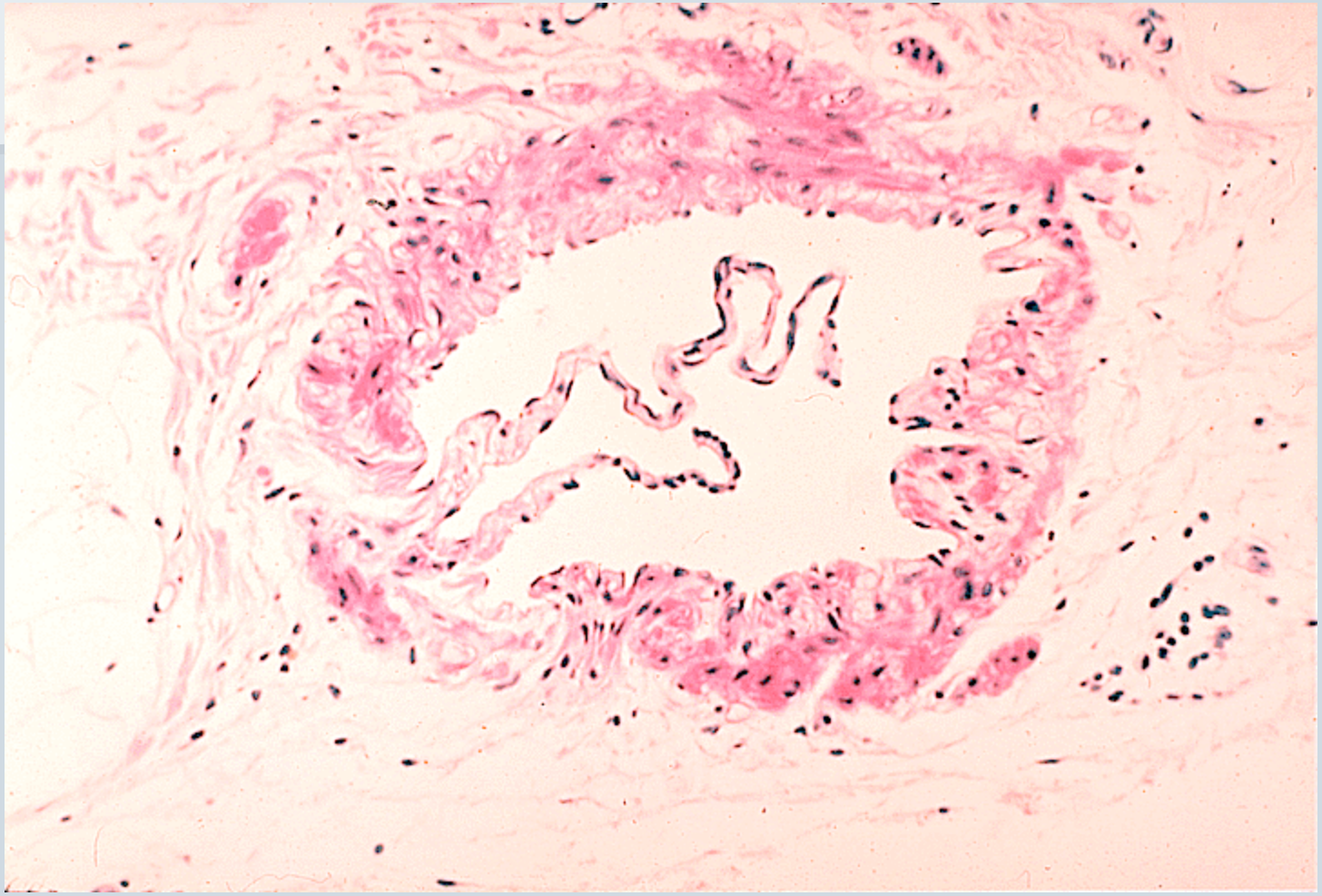
	capillaries →	vessel	→ capillaries	WHERE?
1:	glomerulus	eferent arteriole	renal tubules capillaries	in KIDNEY
2:	GIT organs	vena portae	hepatic sinusoids	in LIVER
3:	hypothalamus	hypophyseal vein	adenohypophysis	in HYPOPHYSIS

Venous part of bloodstream

- Venules ∅ 0.2 – 1 mm
- Small and medium sized veins ∅ 1 – 9 mm
- Large veins (v. cava inf. et. sup. - the largest vein)

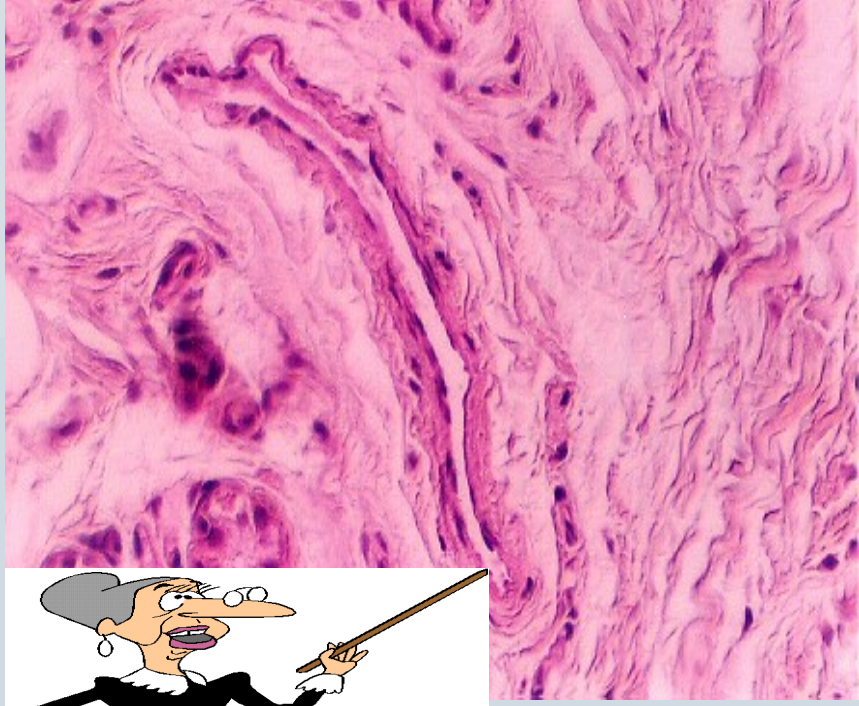
- **Valves**
  - pocket-like duplication of endothelium scaffolded by elastic c.t.
  - protection against venous reccurence

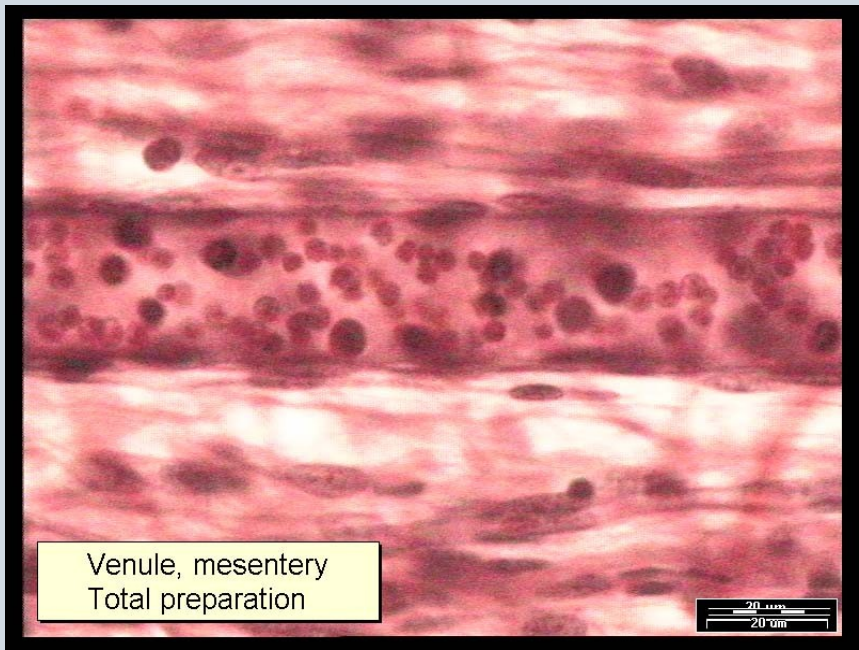


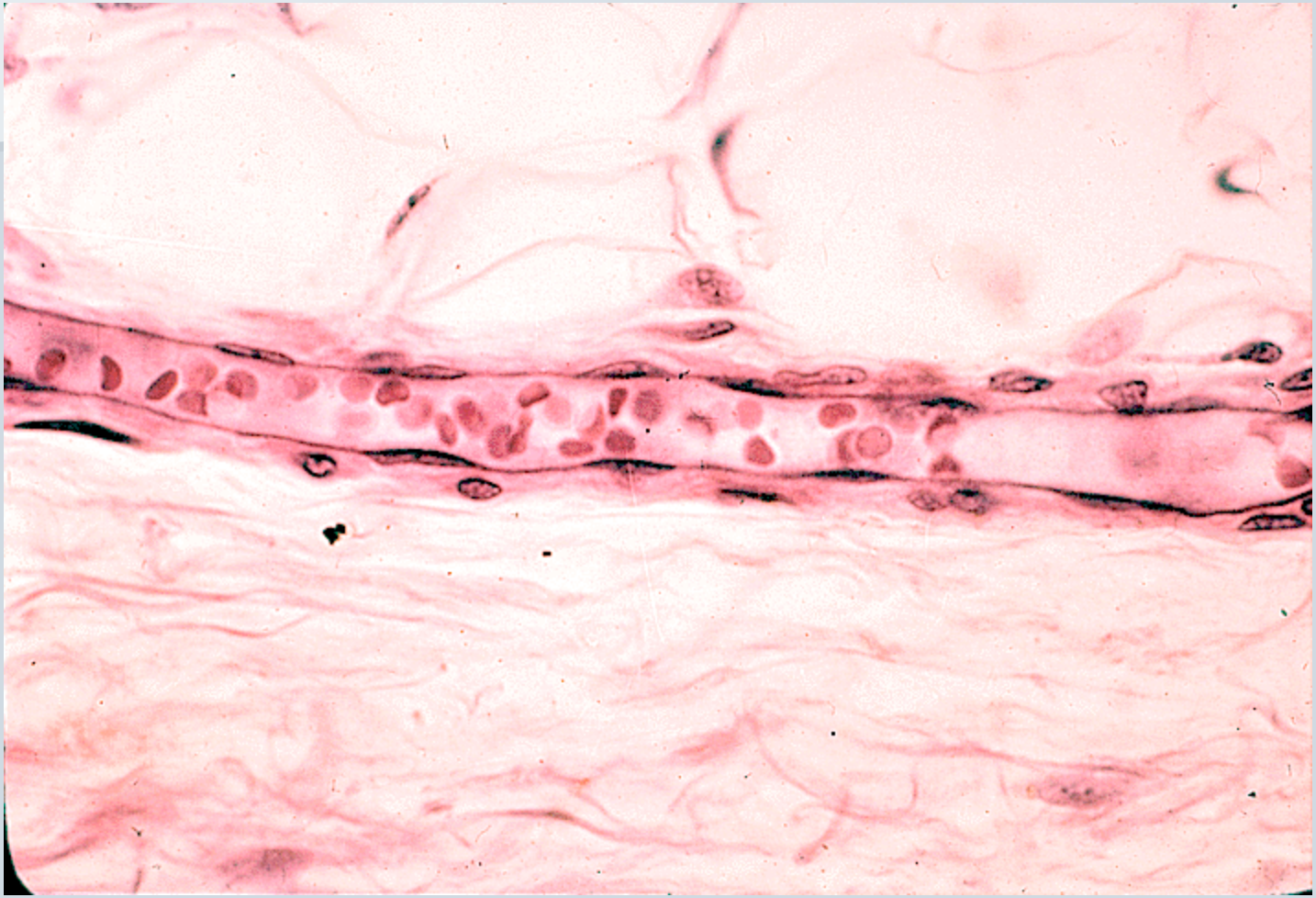


Venule

- ∅ < 0.2 - 1 mm
- **The wall**
- TI: endothelium only
- TM: smooth muscle cells (cca circular 1-3 layers)
- TA: thick layer of loose connective tissue

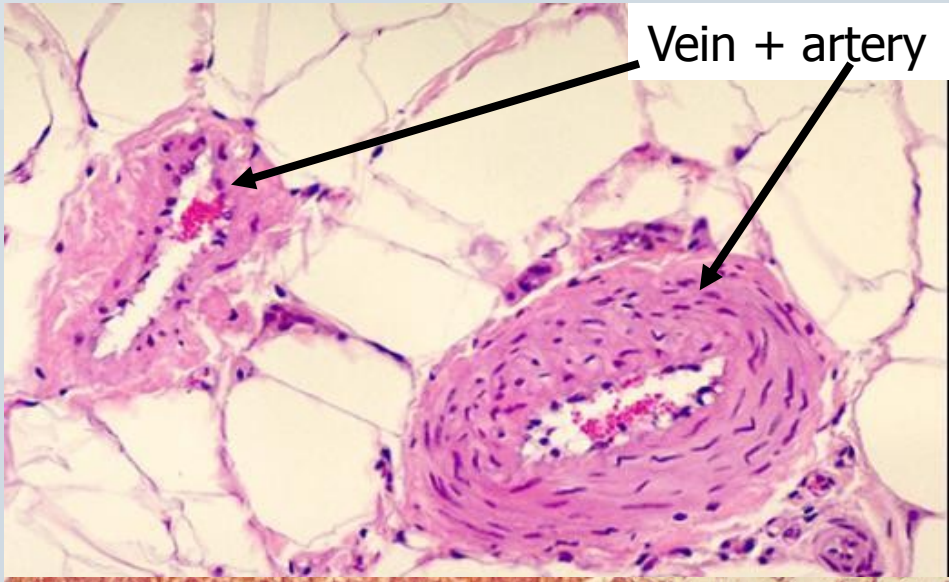


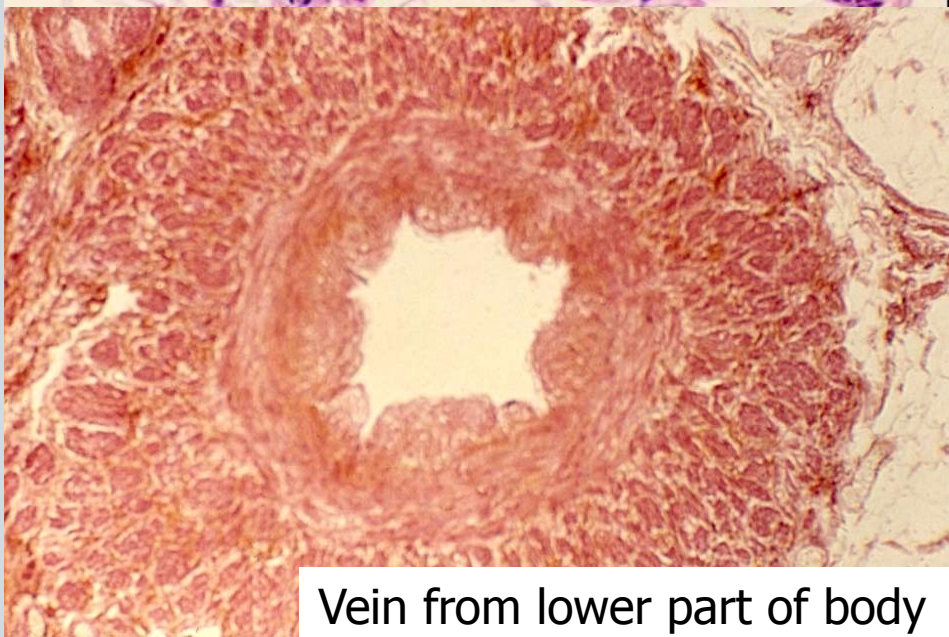




Small and medium-sized venules

- ∅ 1 – 9 mm
- TI: endothelium + irregular layer of subendothelium + valves
- TM: irregular, thin layer of smooth muscle cells, elastic and collagen fibers
- TA: thick layer of loose connective tissue with smooth muscle cells

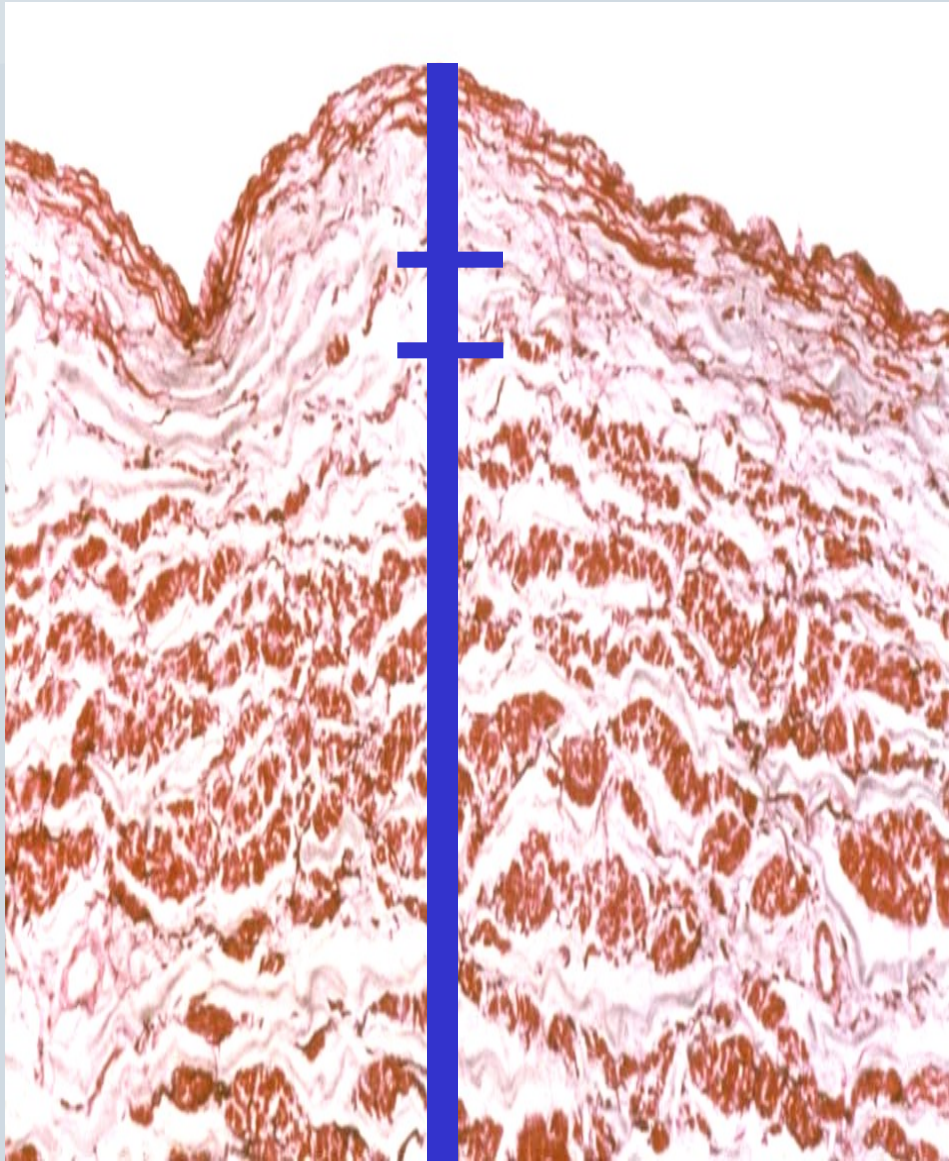




Vein from lower part of body

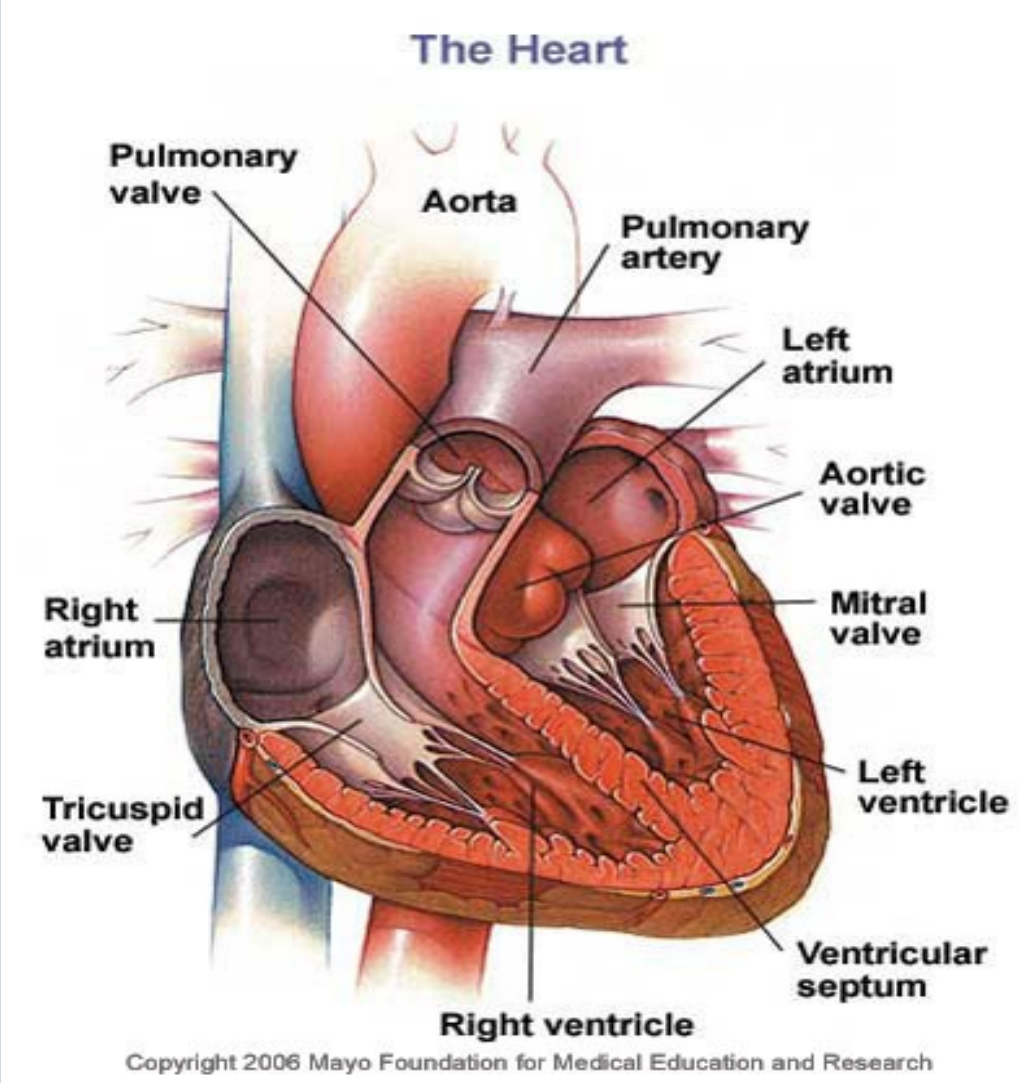
Large veins

- TI: endothelium + subendothelium (+smooth muscle cells)
- TM: thin layer of connective tissue + reduced amount of smooth muscle cells
- TA: longitudinal bundles of smooth muscle cells in loose connective tissue (vasa et nervi vasorum)

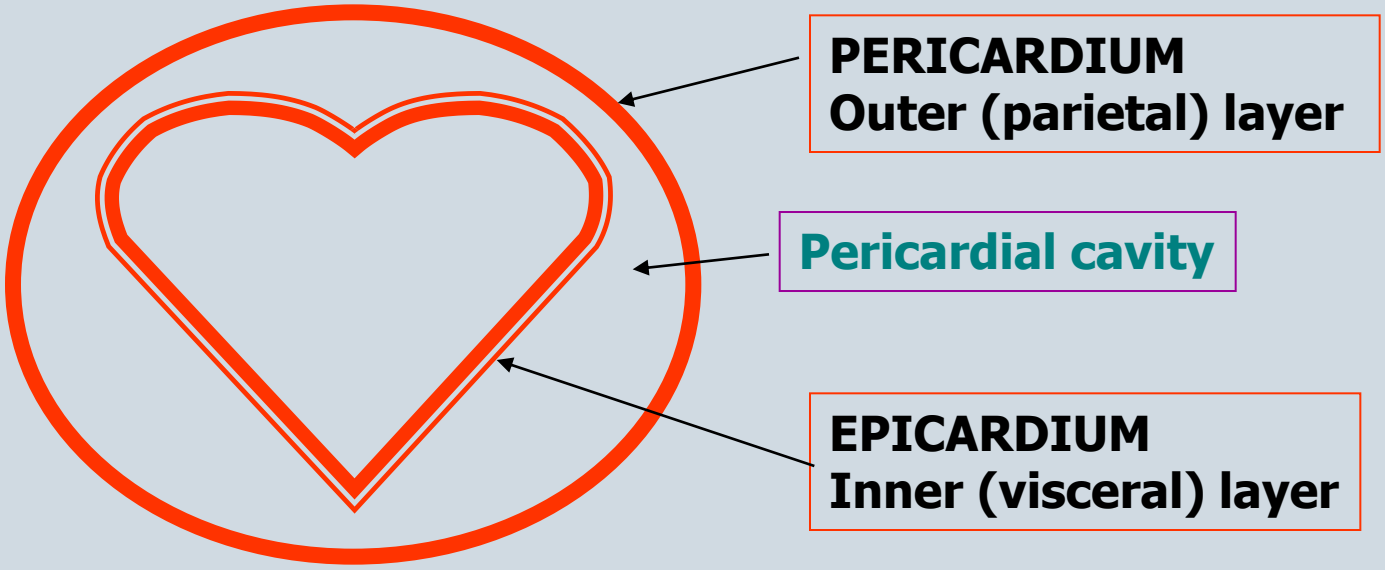


The heart is the hardest working muscle in the human body.

- Hollow muscular organ – blood pump
- Rythmic contraction
- Involuntary muscle



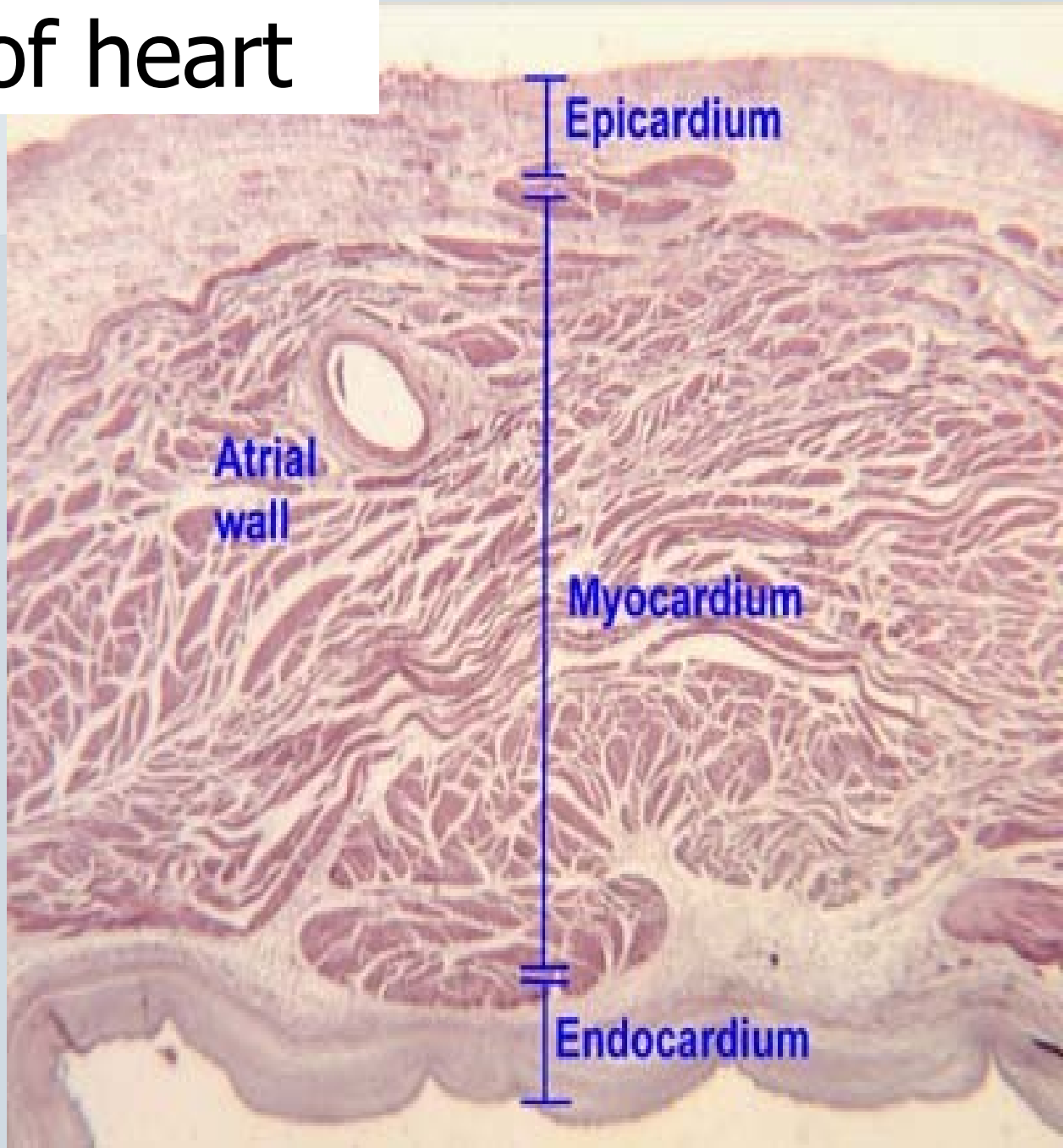
Pericardial sac:
pericardium + epicardium

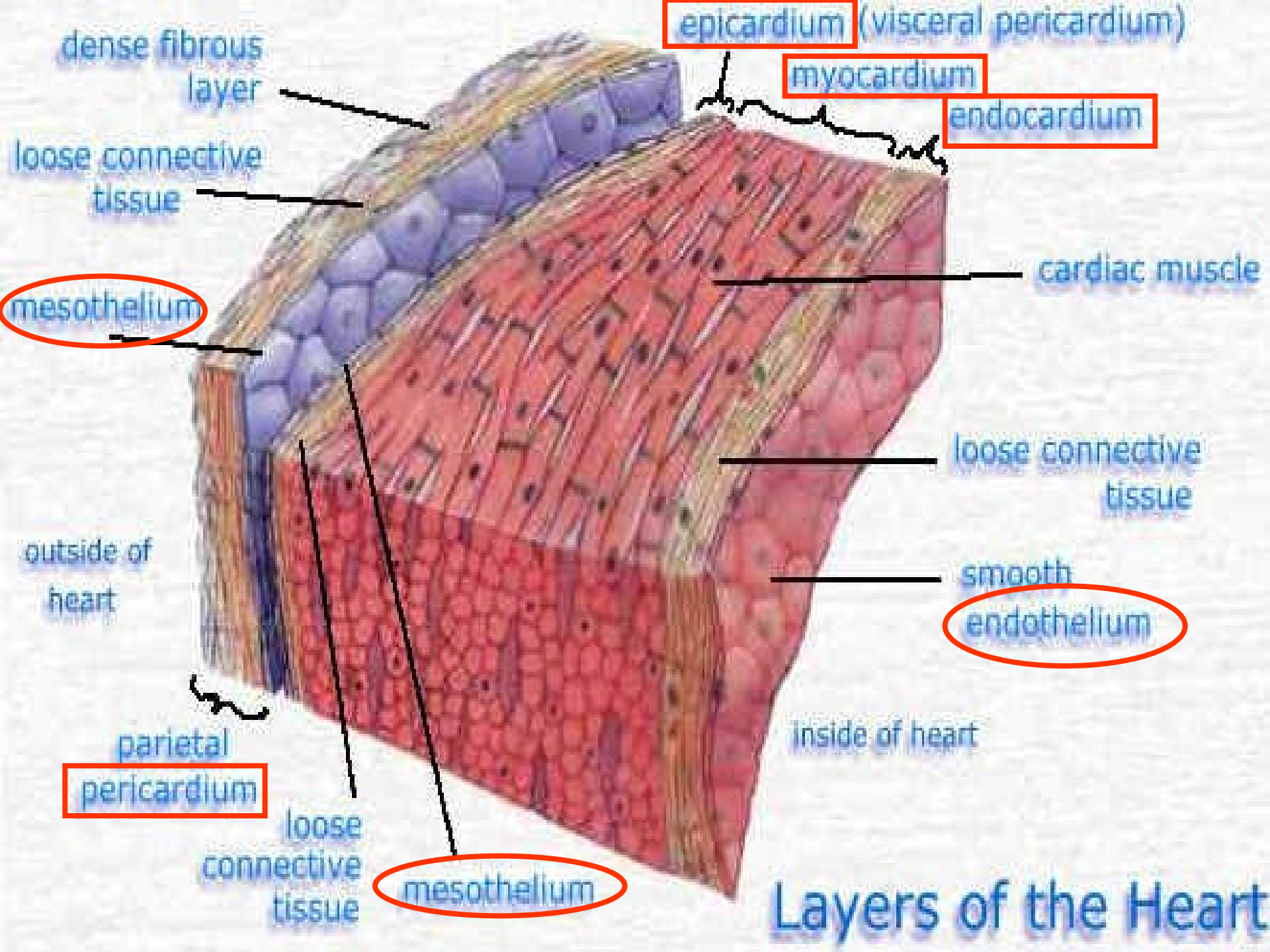


Pericardial cavity - contains 15 – 50 ml of serous fluid serves as lubricans;
- is lined with mesothelium

The wall of heart

- Epicardium
- Myocardium
- Endocardium




epicardium (visceral pericardium)
myocardium
endocardium
dense fibrous layer
loose connective tissue
cardiac muscle
mesothelium
loose connective tissue
outside of heart
smooth endothelium
inside of heart
parietal pericardium
loose connective tissue
mesothelium
Layers of the Heart

Endocardium

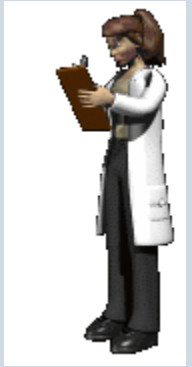
(homologous to intima of blood vessels)

Consists of:

- **Endothelium**
- **Subendothelium** – thin connective tissue layer
- **Elastic-muscular layer** – dense c.t. (elastic fibers, smooth m. cells)
- **Subendocardium** – c.t. + vessels, nerves and distal part of **conducting system (ventricular bundles and Purkinje fibers)**

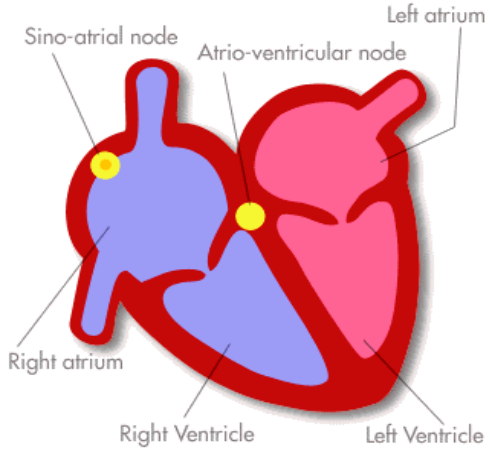
Attention!

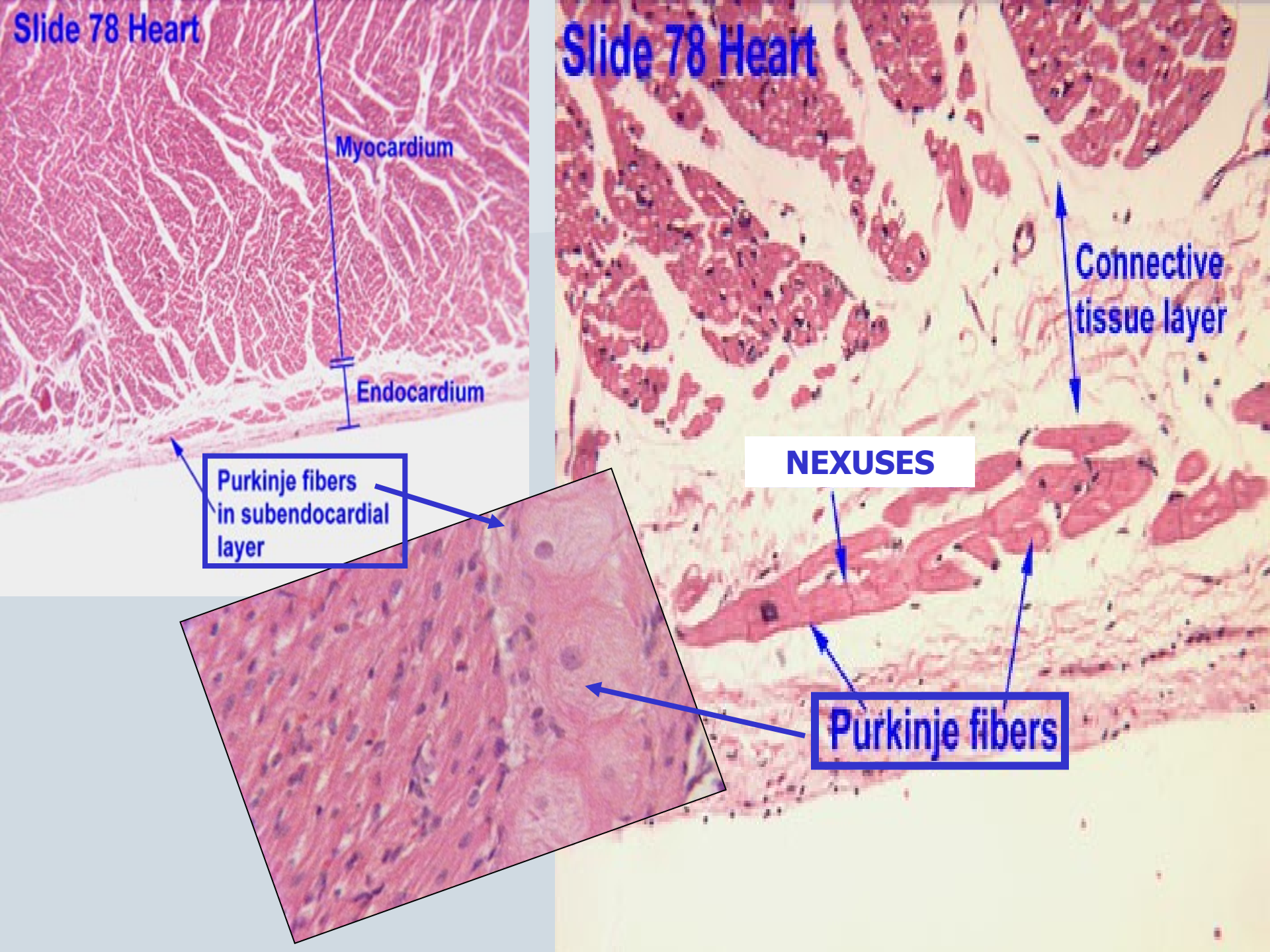
Purkinje fibers ≠ **Purkinje cells**



Heart Structure

Conducting System

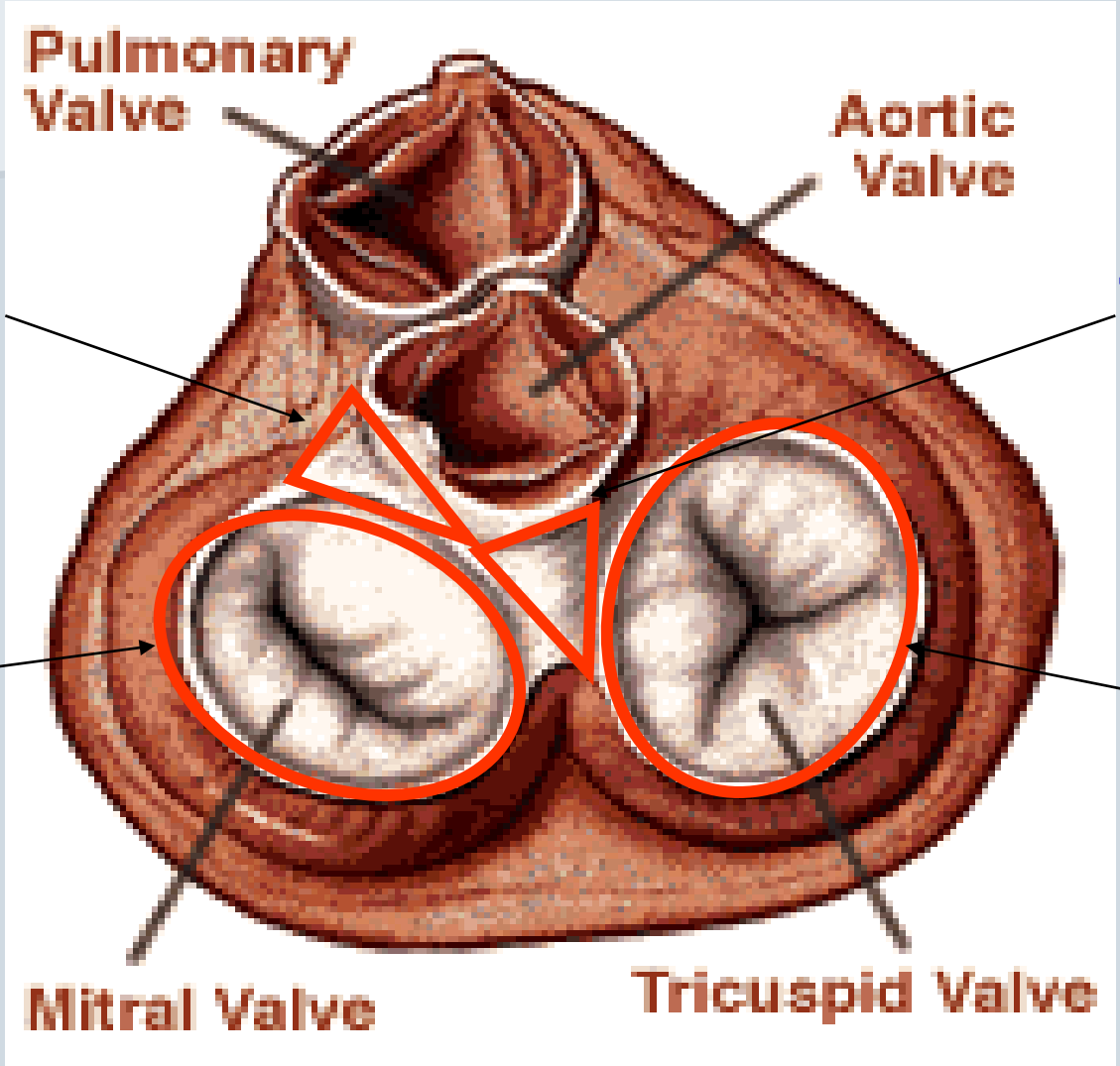



Slide 78 Heart
Myocardium
Endocardium
Purkinje fibers in subendocardial layer
Slide 78 Heart
Connective tissue layer
NEXUSES
Purkinje fibers

Myocardium

- cardiomyocytes — „working“
  „conducting“
- cells in right ventricle – **natriuretic factor** (when intravascular volume increases, this factor is released and causes natriuresis and diuresis in kidney)
- **atrial myocardium is thinner than ventricular**
- **„left heart“ myocardium is thinner than „right heart“**
- **cords of cardiomyocytes are ended on heart skelston**
- **damage of myocardium - infarction**
- **low regeneration of myocardium – by scar (decreases function of heart muscle)**

Heart skeleton



Trigonum fibrosum sin.

Trigonum fibrosum dx.

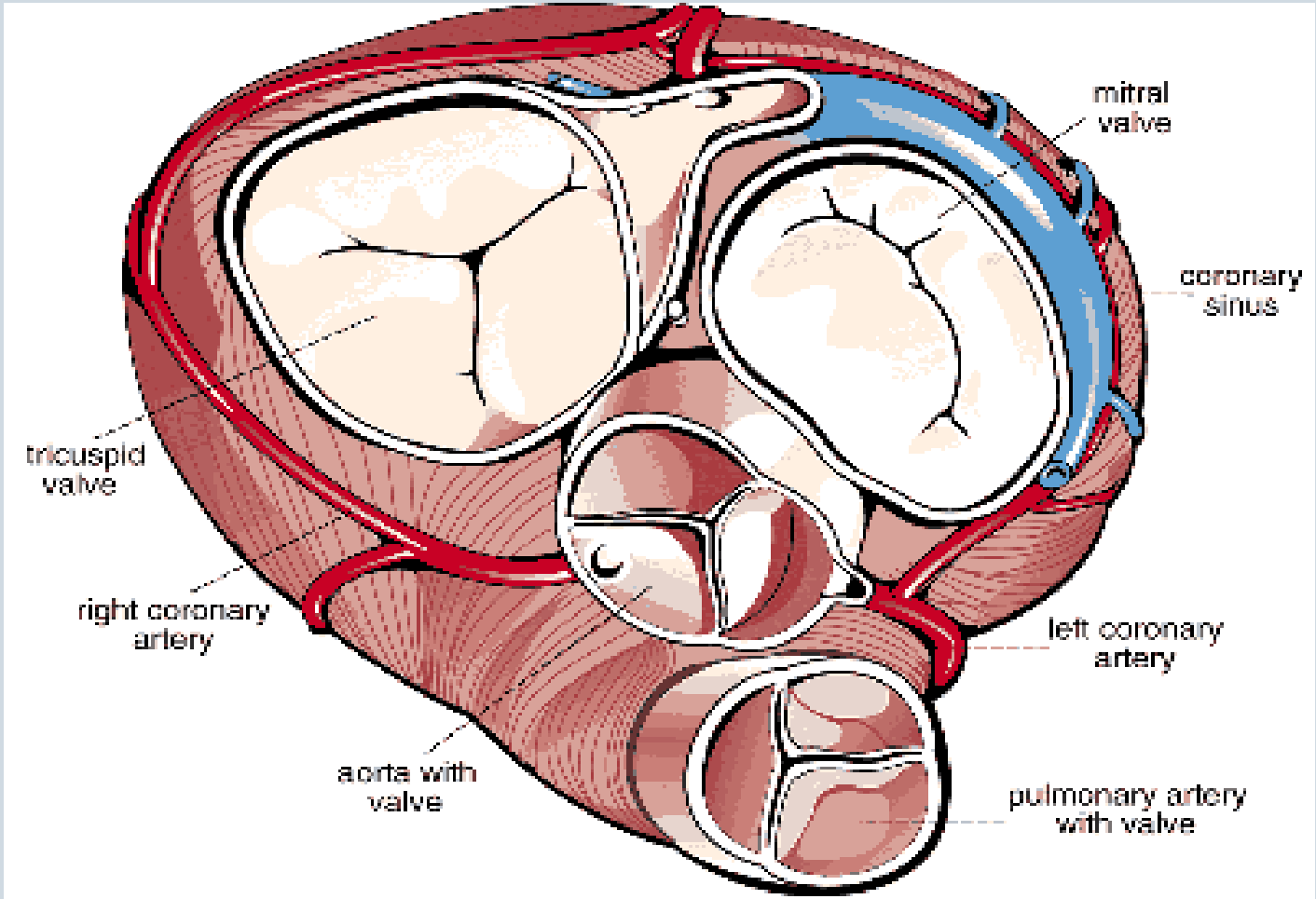
Anulus fibrosus sin.

Anulus fibrosus dx.

Pars membranacea interventricularis

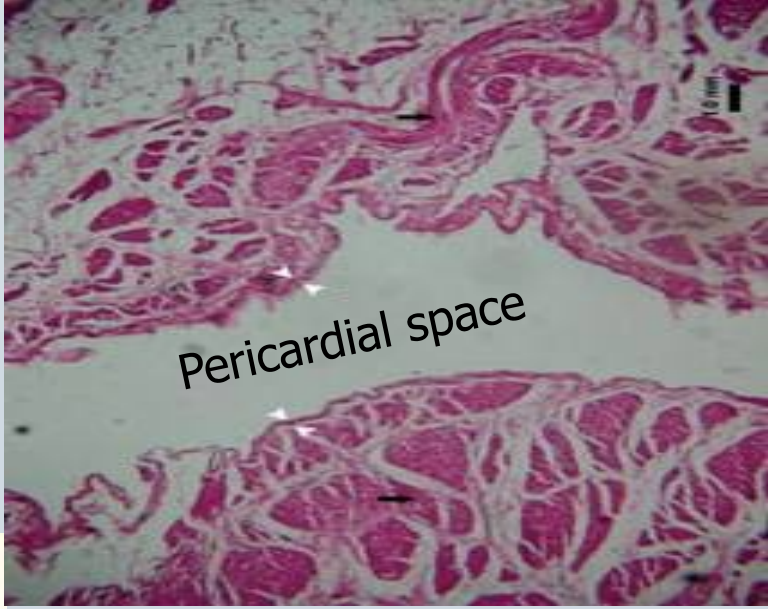
Endocardial valves

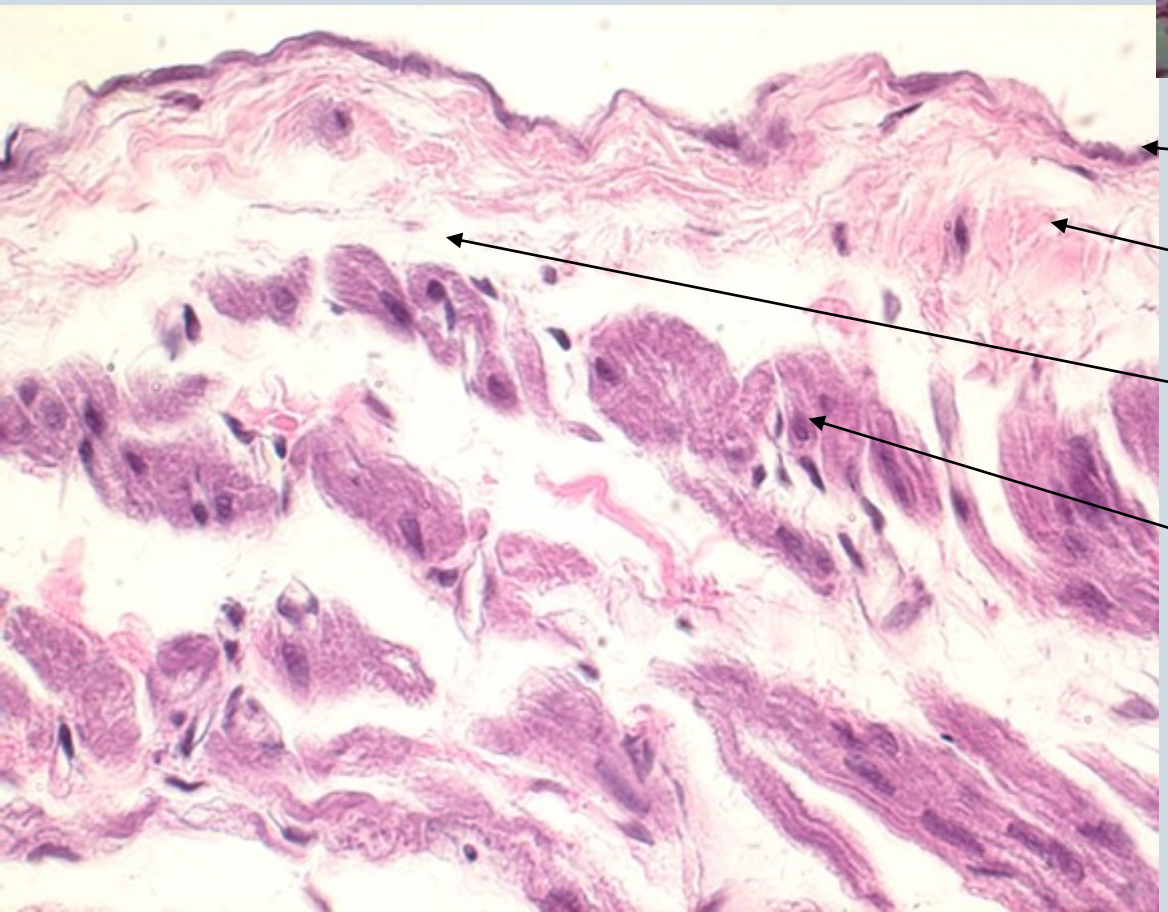
Plates of dense connective tissue (continuous with heart skeleton) covered with endocardium.



Epicardium

Mesothelium lines pericardial space
and so it covers outer surface of epicardium
and inner surface of pericardiu



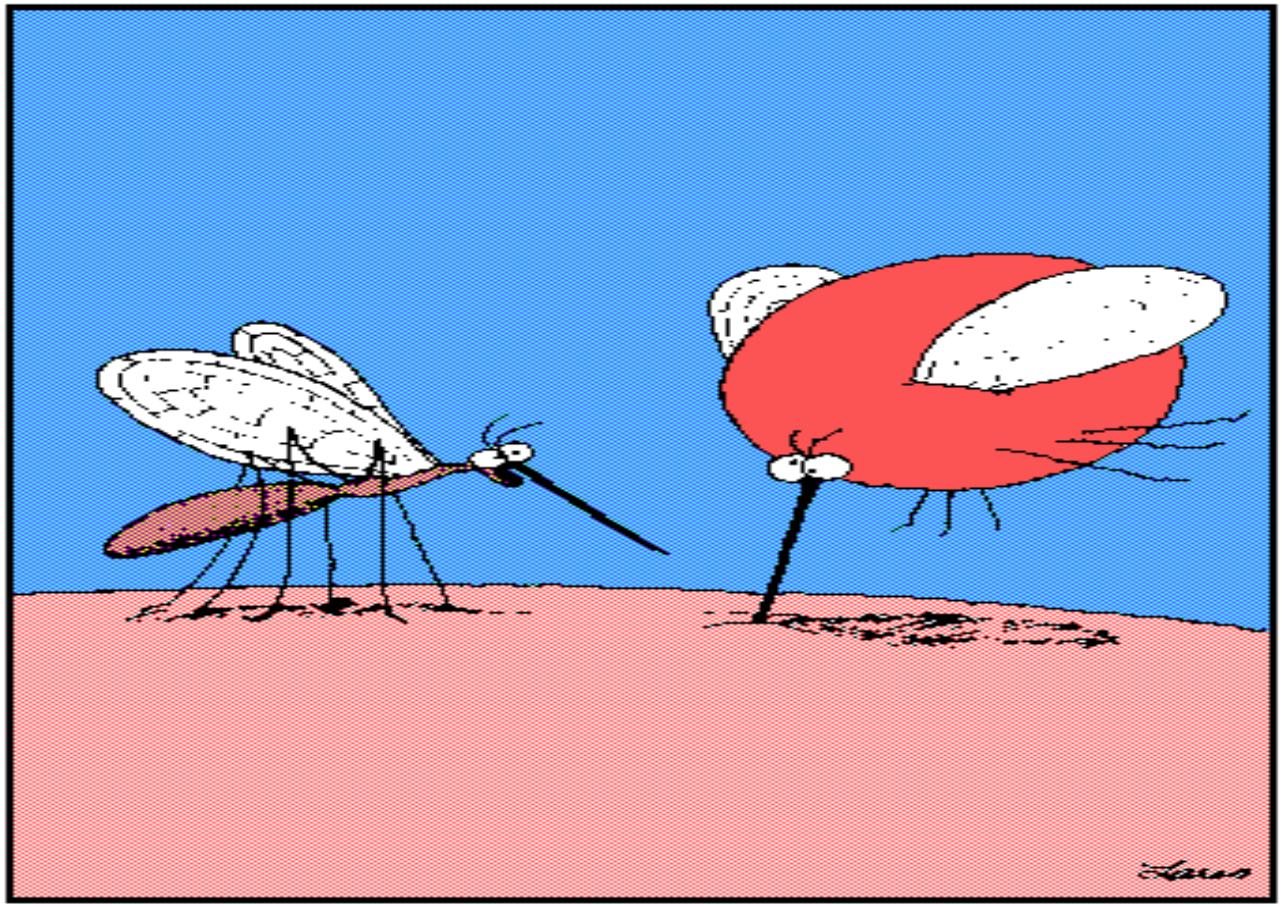


mesothelium

connective tissue

subepicardial c.t.

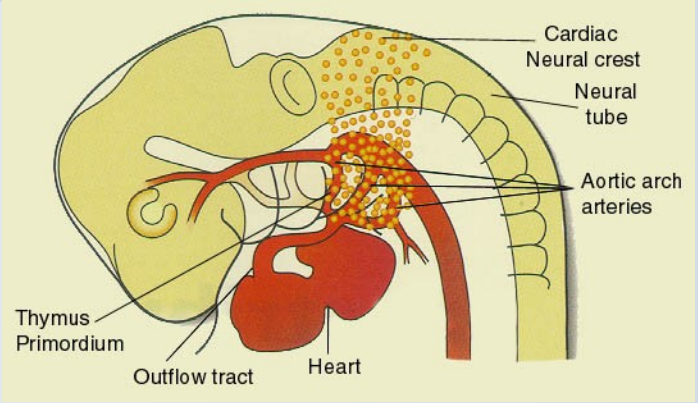
myocardium



hearty thanks for your attention

Practice No. …

- **Slides:**
- 59. Artery of the muscular type with a vein (HE)
- 60. Artery of the muscular type with a vein (orcein)
- 61. Aorta (cross-section, HE)
- 62. Aorta (cross-section, orcein)
- 63. Vena cava (HE)
- 65. Myocardium (Heidenhain´s hematoxylin)

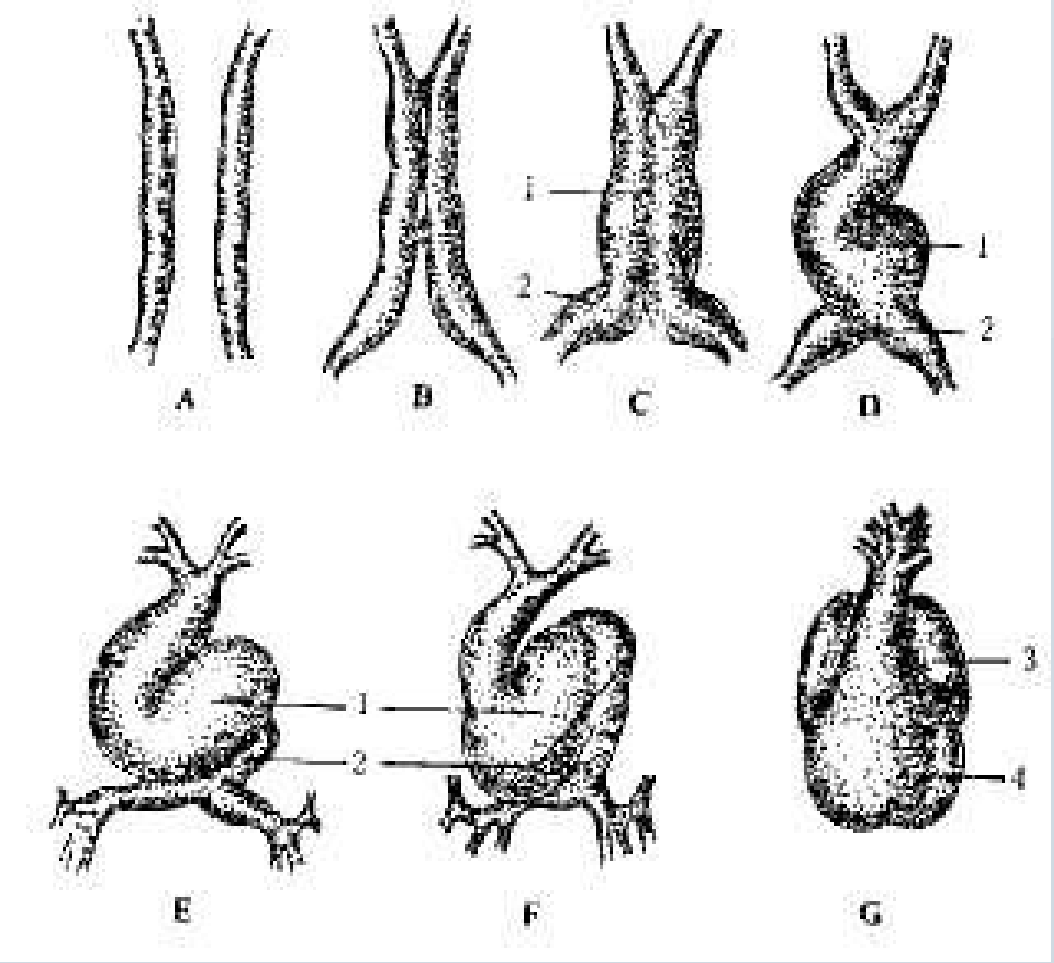


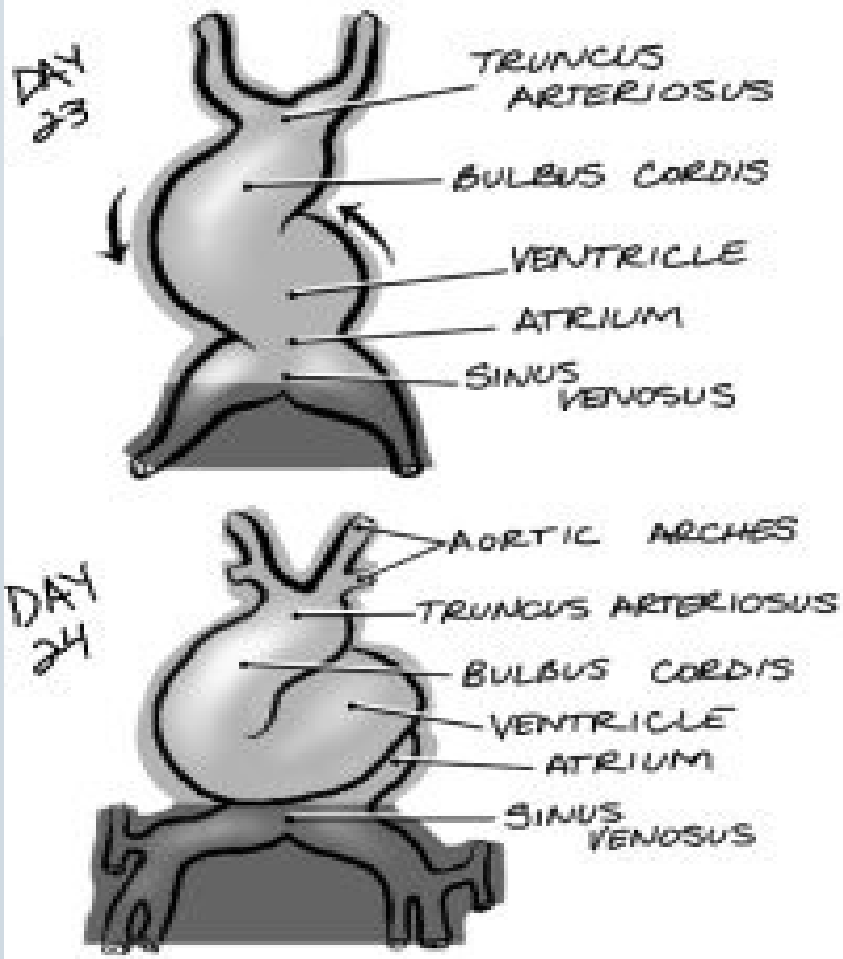
Embryology: Cardiovascular system

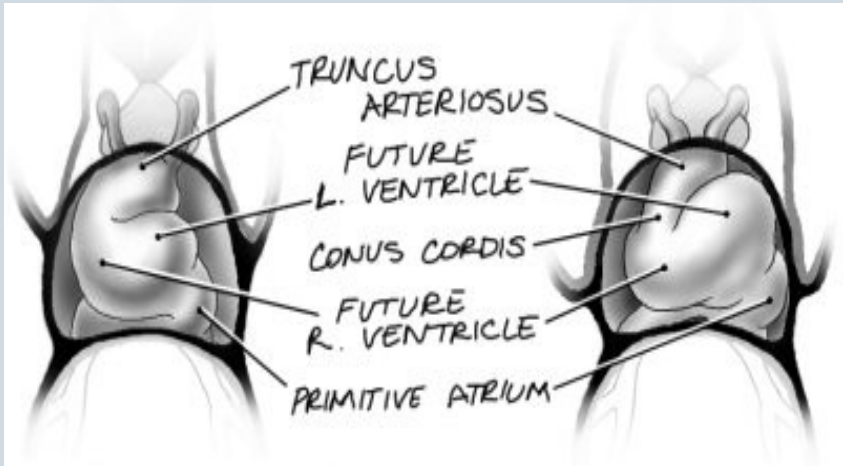
Development
of
heart and vessels

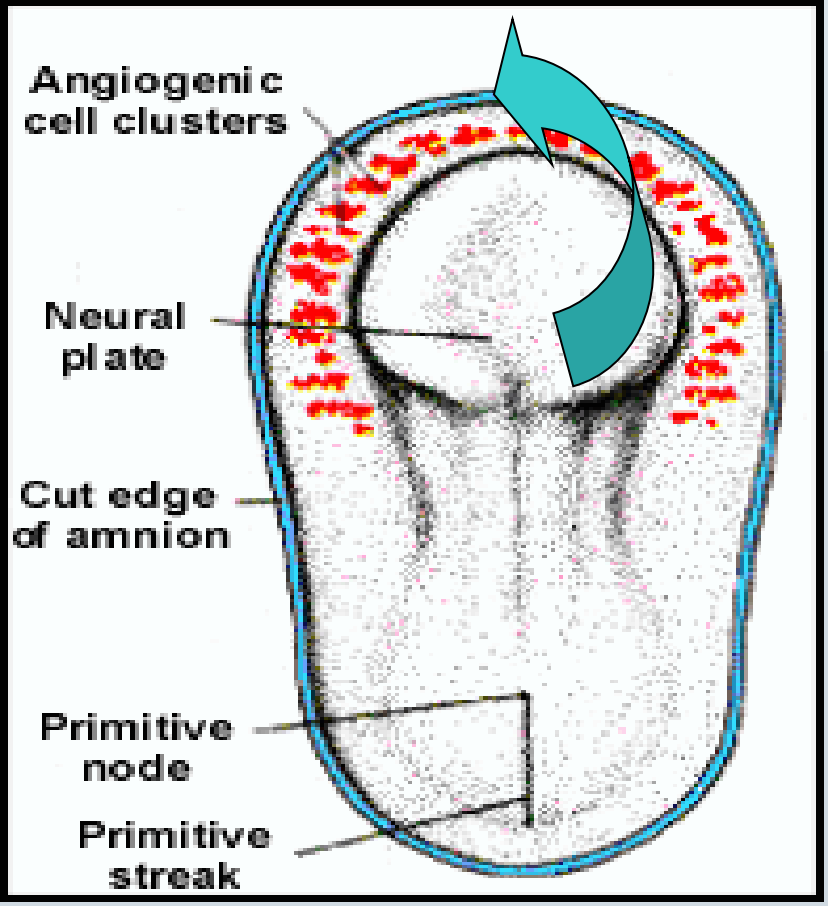
Embryological Timetable

- Week 3 day 20 – cardiogenic plate
- day 21 – endocardial tubes
- Week 4 day 22 – fusion into single tube
- day 23 – first contraction
- day 25 – cardiogenic loop
- Week 7 day 49 – 4-chamber heart


A
B
1
2
C
1
2
D
1
2
E
F
3
4
G

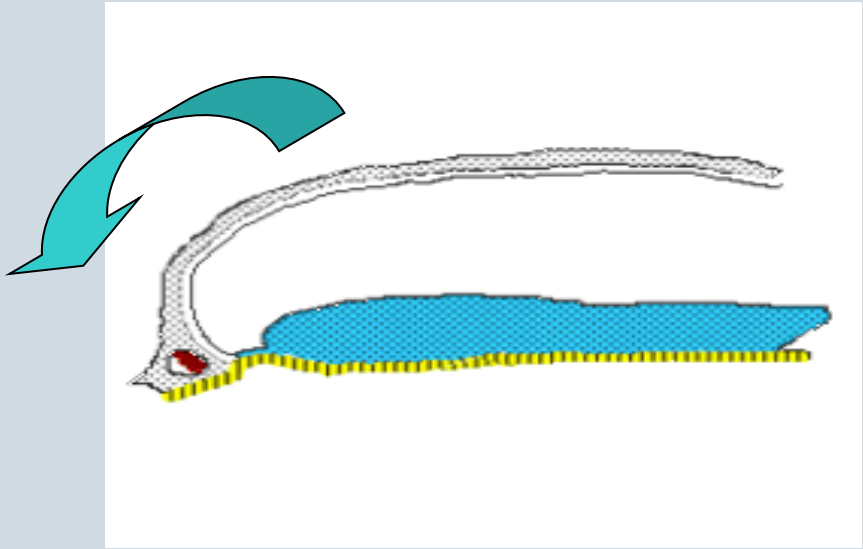

DAY 23
TRUNCUS ARTERIOSUS
BULBUS CORDIS
VENTRICLE
ATRIUM
SINUS VENOSUS
DAY 24
AORTIC ARCHES
TRUNCUS ARTERIOSUS
BULBUS CORDIS
VENTRICLE
ATRIUM
SINUS VENOSUS

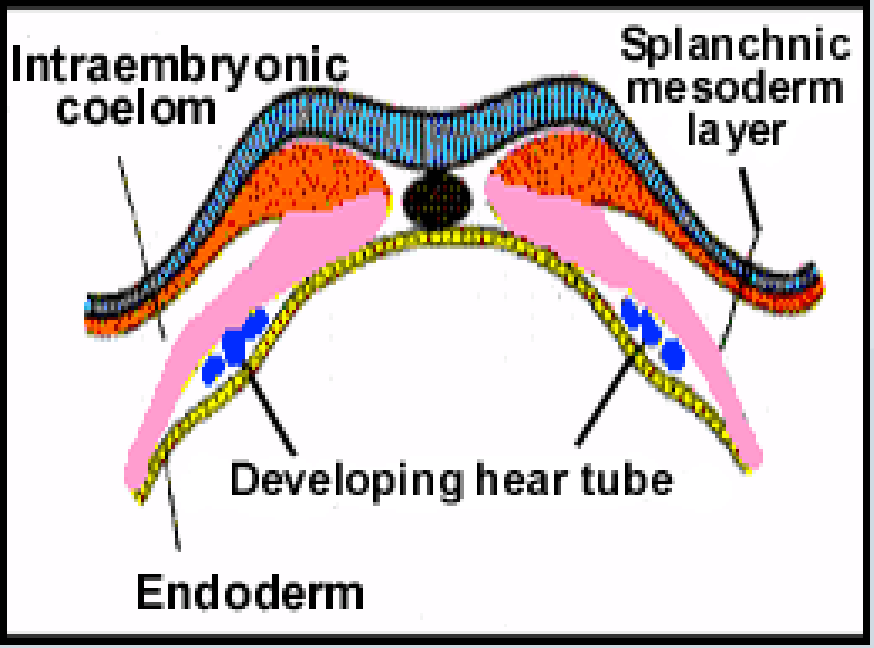

TRUNCUS ARTERIOSUS
FUTURE L. VENTRICLE
CONUS CORDIS
FUTURE R. VENTRICLE
PRIMITIVE ATRIUM

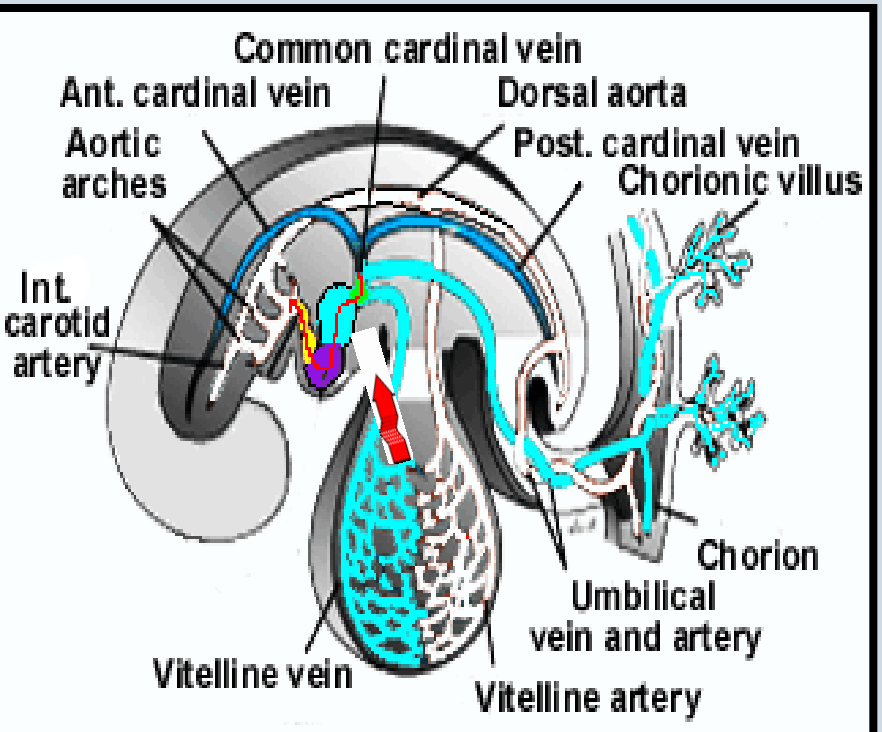


The cardiogenic (heart-forming) region is initially located at the anterior rim of the embryonic disc (rostral to the prechordal plate).

As the embryo grows, the developing heart assumes a position ventral to the forming forebrain and foregut.







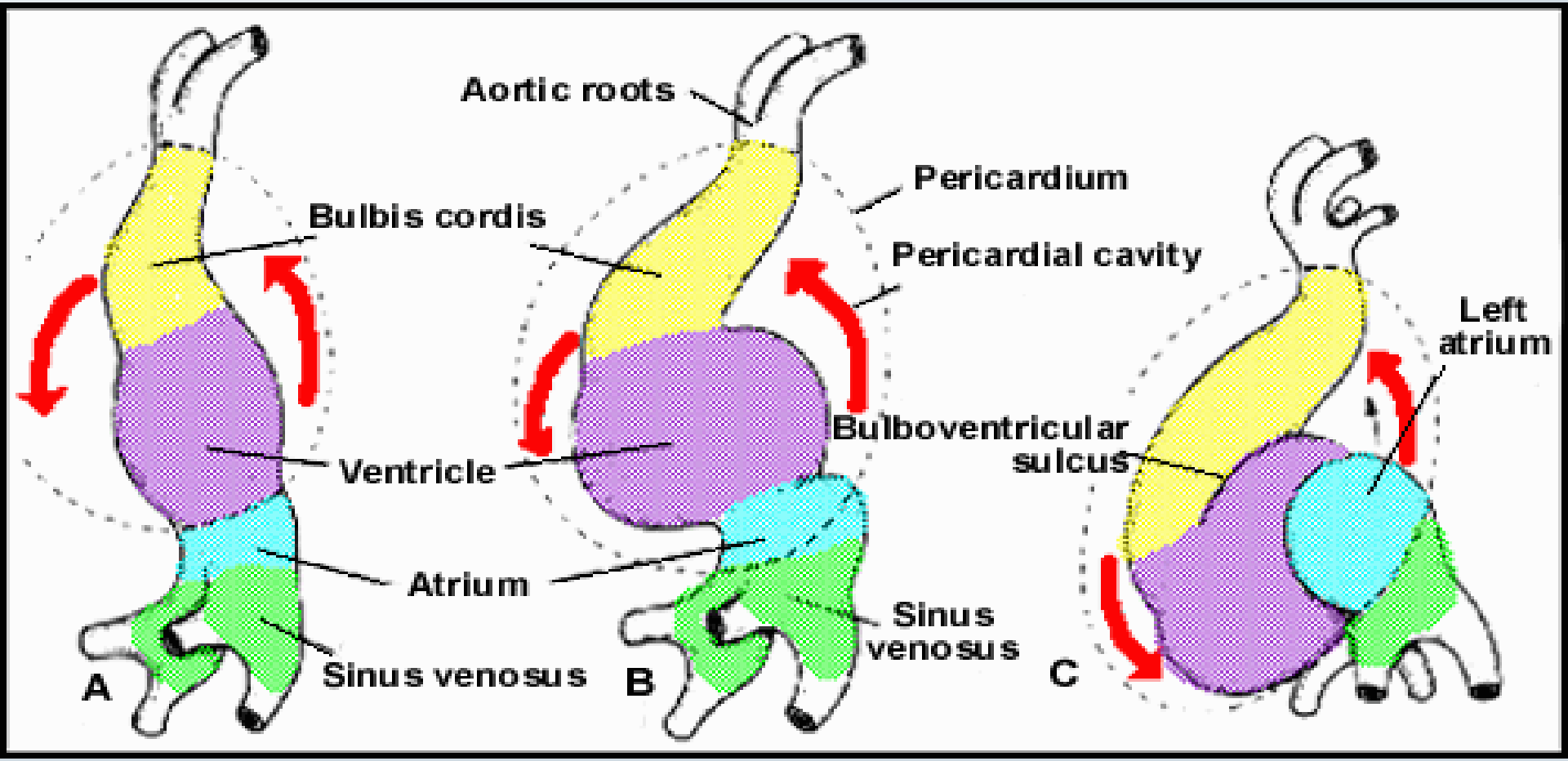
Fusion of the vascular channels in the cardiogenic region results in formation of endothelially-lined heart tube which is surrounded by a layer of splanchnic mesoderm.

The intraembryonic coelom in this region becomes the pericardial cavity.

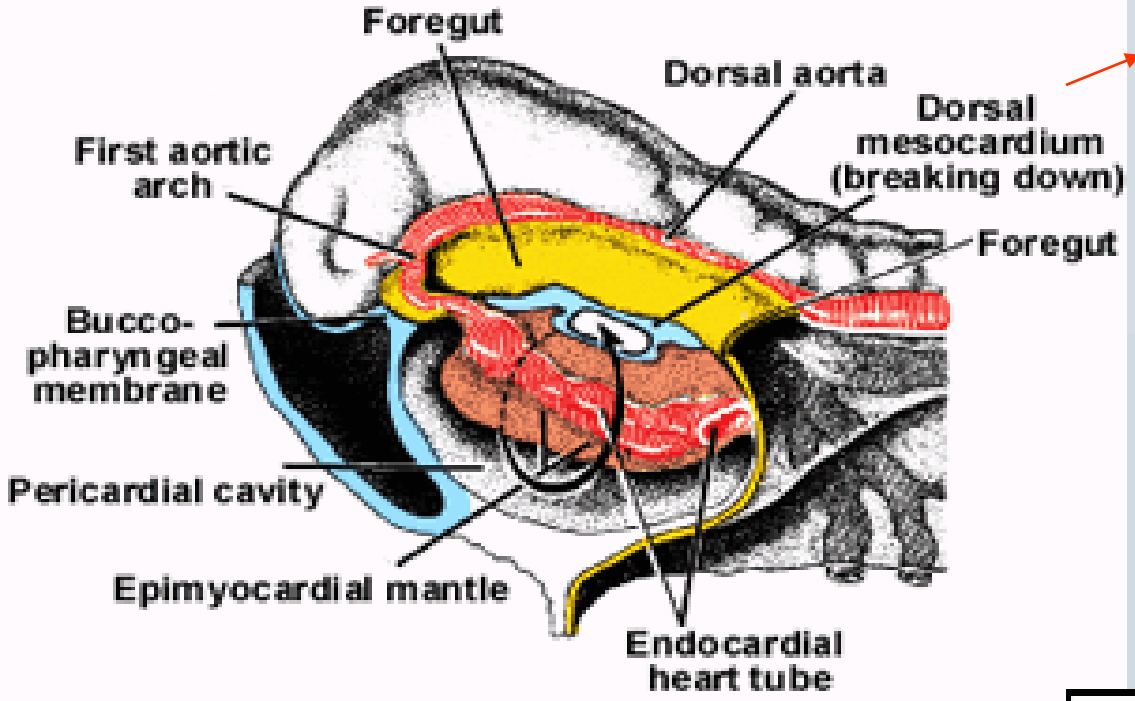
the position of the forebrain, foregut and septum transversum relative to the developing heart.

septum transversum is located just below the developing heart, which at this stage, begins to beat.

As the heart tube elongates and begins to loop, the blood flows into the sinus venosus, then into the primitive atria, ventricles and bulbous cordis before entering the visceral arch vessels.

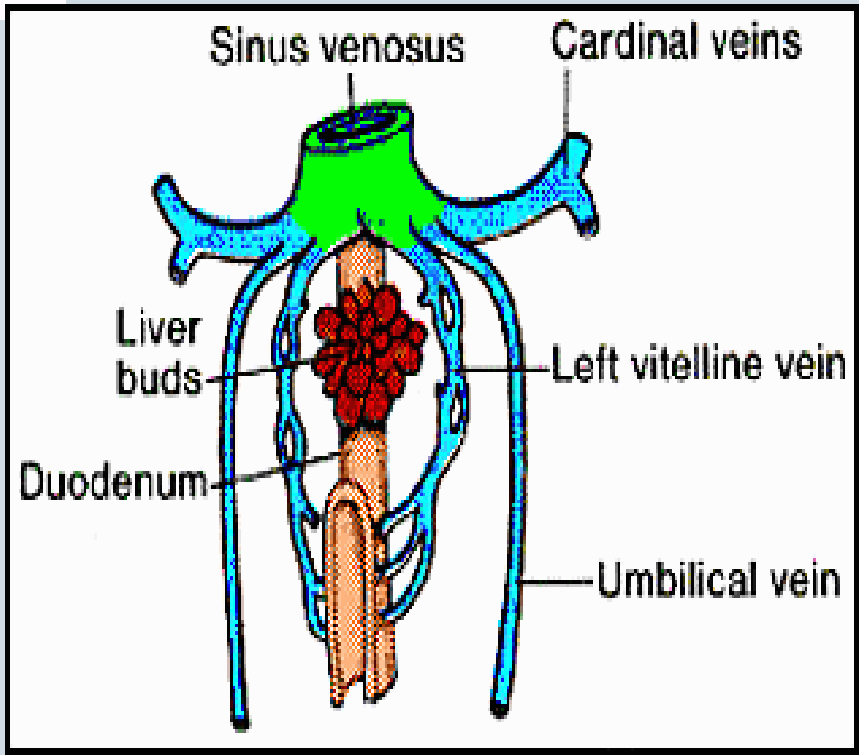


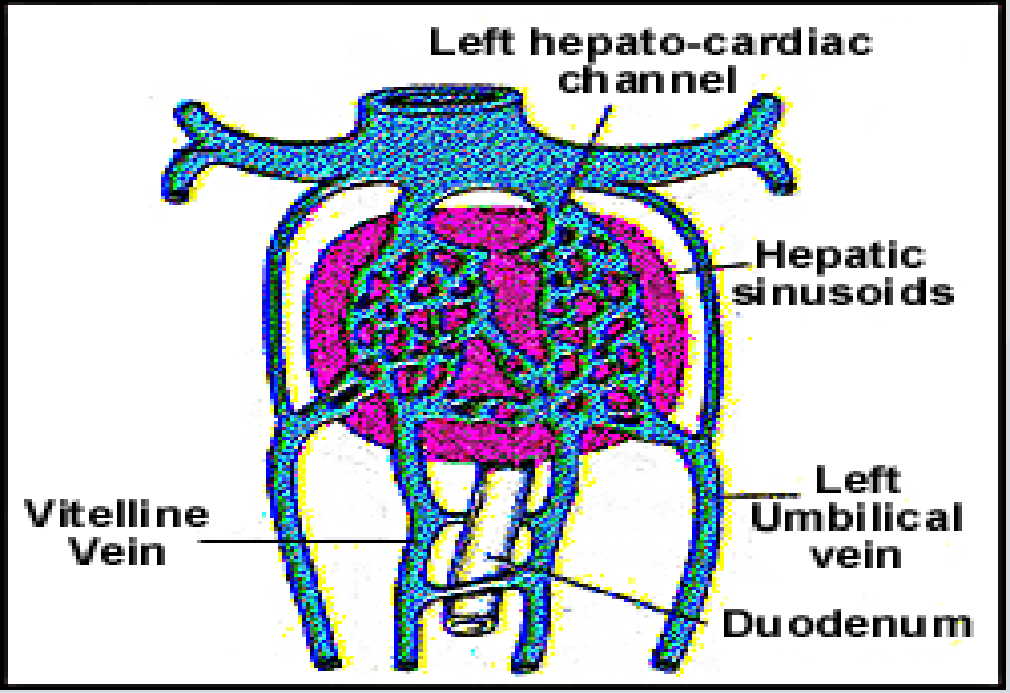
As the heart tube elongates and bends, the atrial segment assumes a position cranial to the ventricular segment.



the dorsal mesocardium suspends the heart from the dorsal body

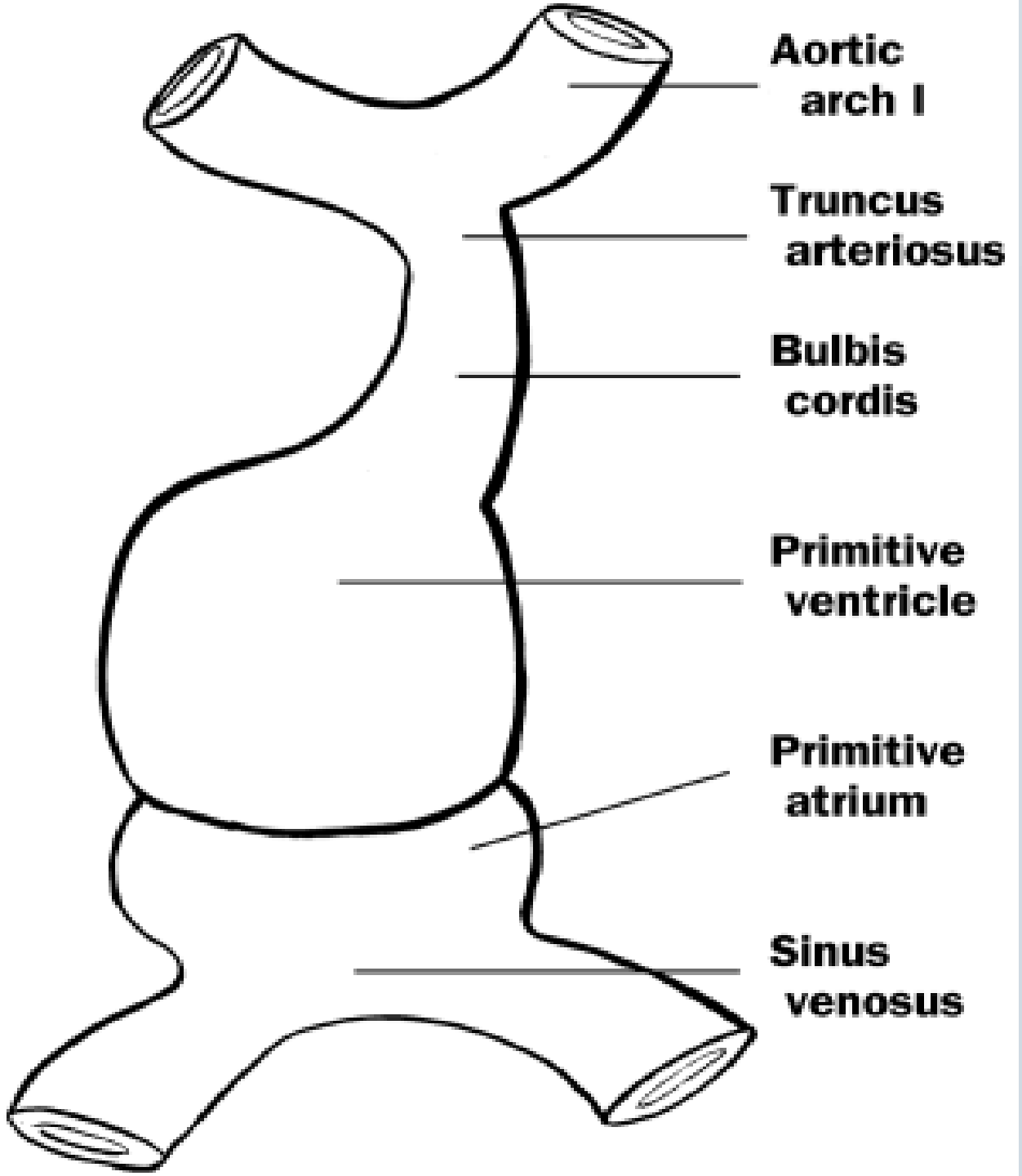
Blood flow into the sinus venosus is from three pairs of vessels: the cardinal veins that drain the embryo proper, the vitelline veins from the yolk sac, and the umbilical veins from the placenta.



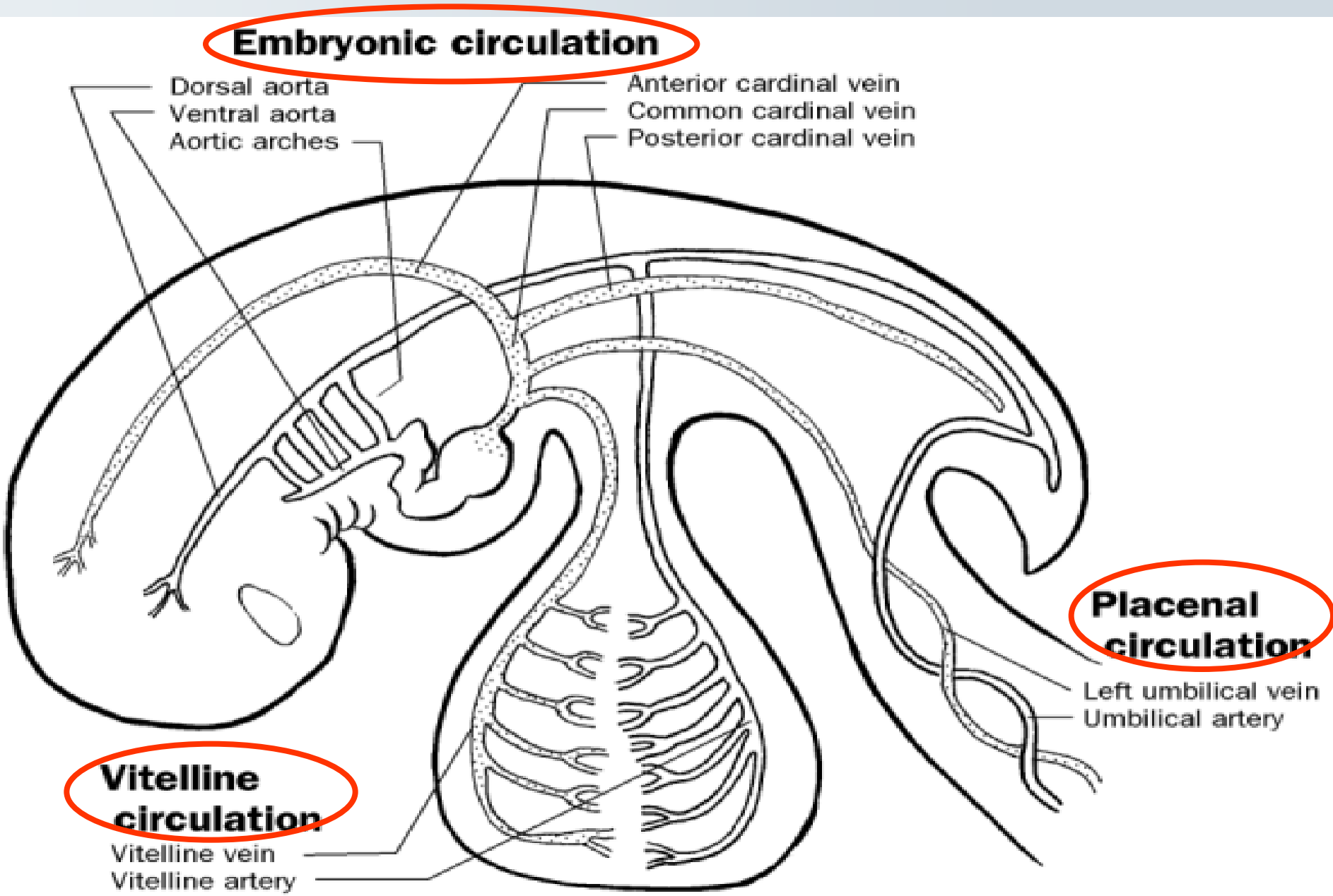


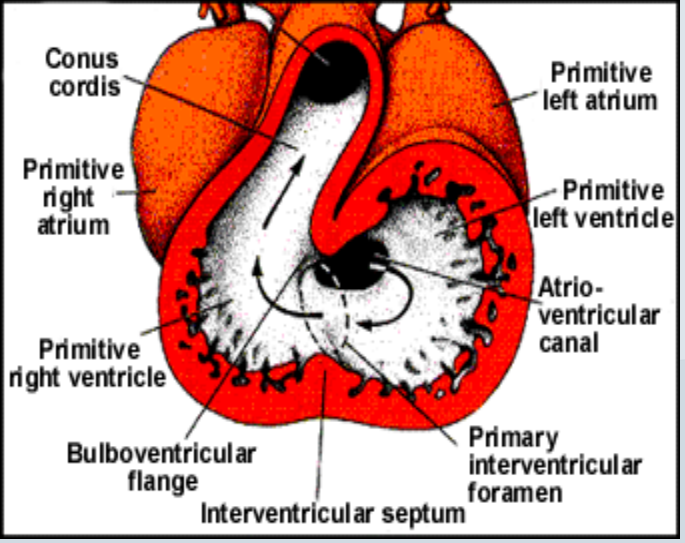
The umbilical and vitelline veins traverse the liver which forms within the tissue of the septum transversum.

Ductus venosus (Arantii) !

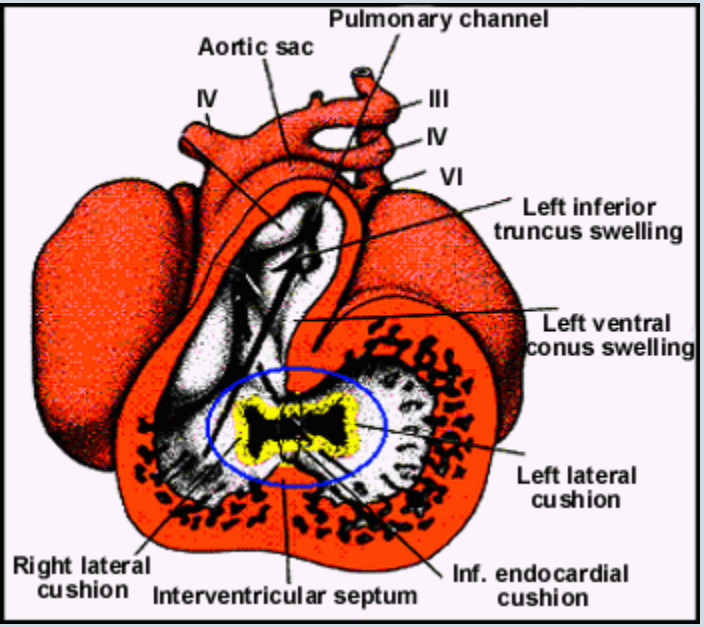

Aortic arch I
Truncus arteriosus
Bulbis cordis
Primitive ventricle
Primitive atrium
Sinus venosus

Primitive blood circulation (≠ fetal blood circulation)

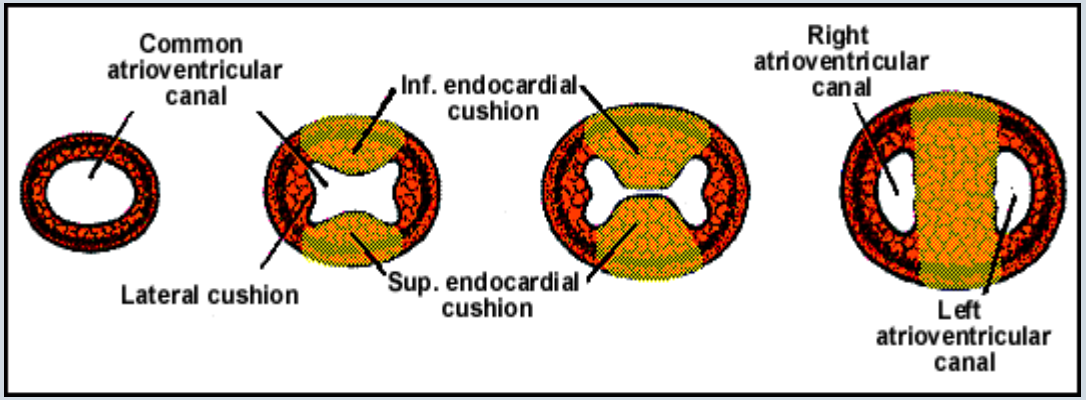




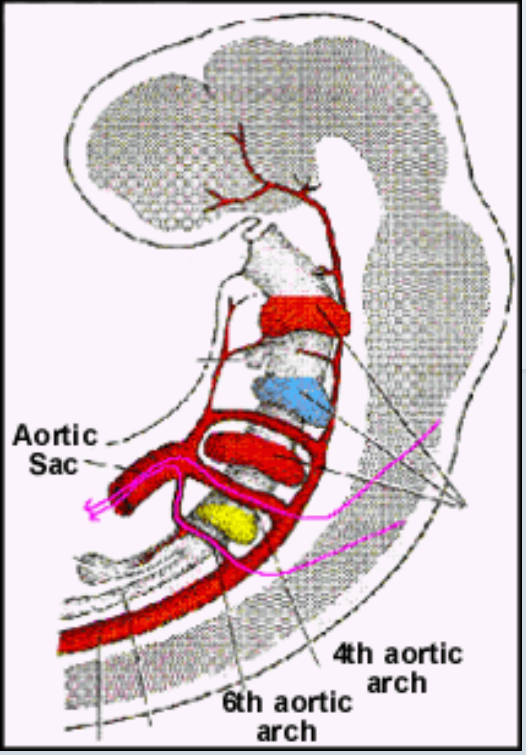
the course of blood flow through this part of the heart. The truncus arteriosus will later divide to form the aorta and pulmonary trunk.



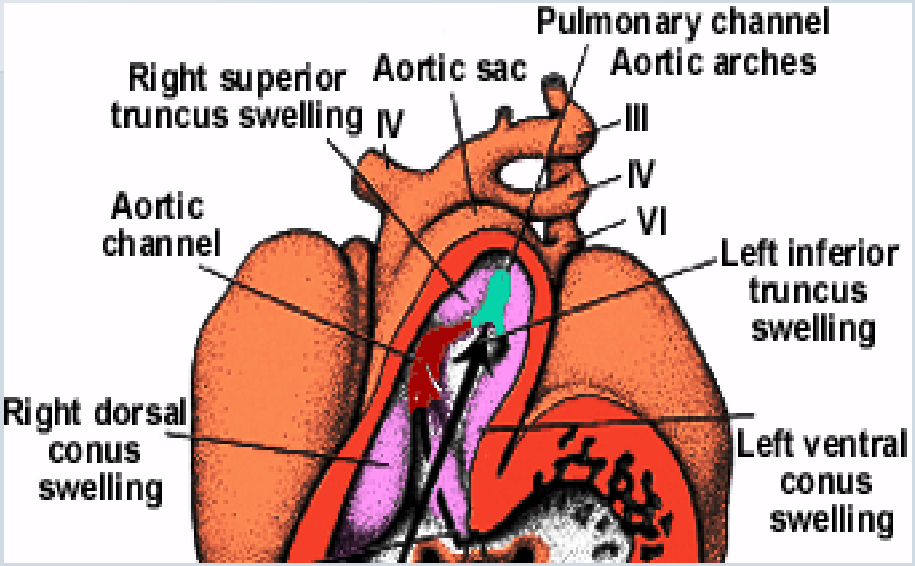
superior, inferior, right, and left endocardial cushion are around the atrioventricular canal.

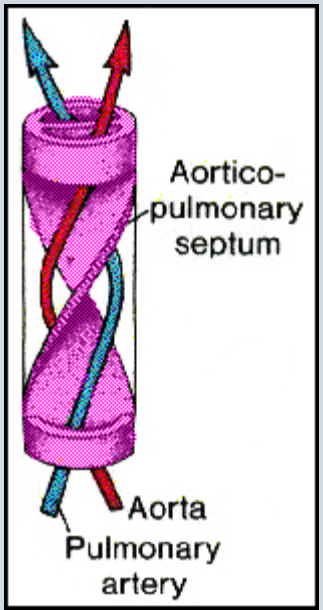


The superior and inferior cushions must fuse to separate the atrioventricular (AV) canal into a right and left channel. cushions form also to separate the outflow tract of the heart into a pulmonary and aortic trunk.



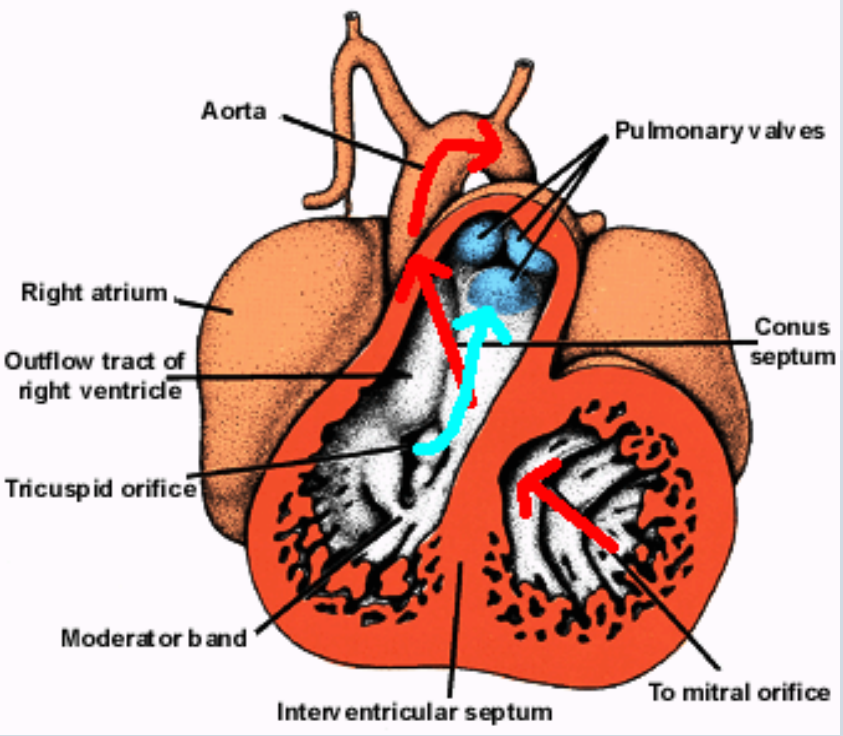
neural crest cells that form at the level of the 4th and 6th aortic arches populate the forming truncal cushions.



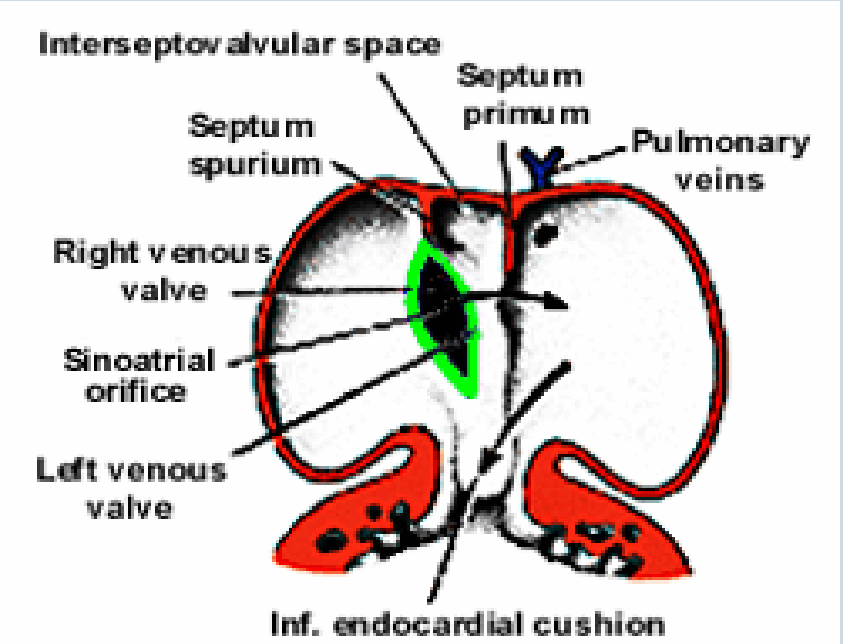


These cushions must fuse to form the aorticopulmonary septum separating pulmonary and aortic trunks.

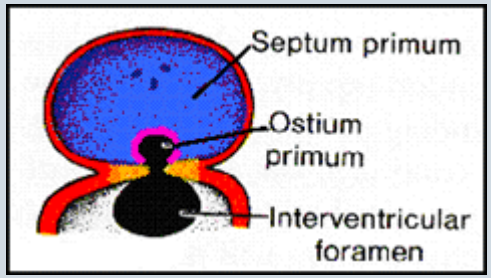
change in position is indicative of the spiraling of the aorticopulmonary septum, aorta and pulmonary artery



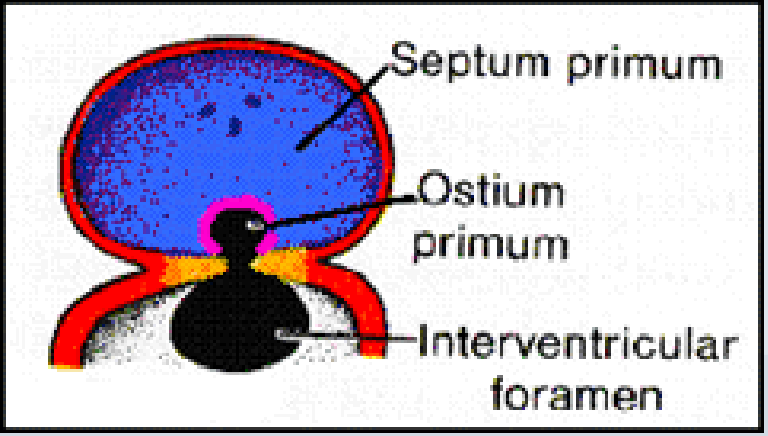
Fusion of the outflow tract cushions results in separation of the blood flow; the blood exits the left ventricle through the aorta and exits the right ventricle through the pulmonary artery.

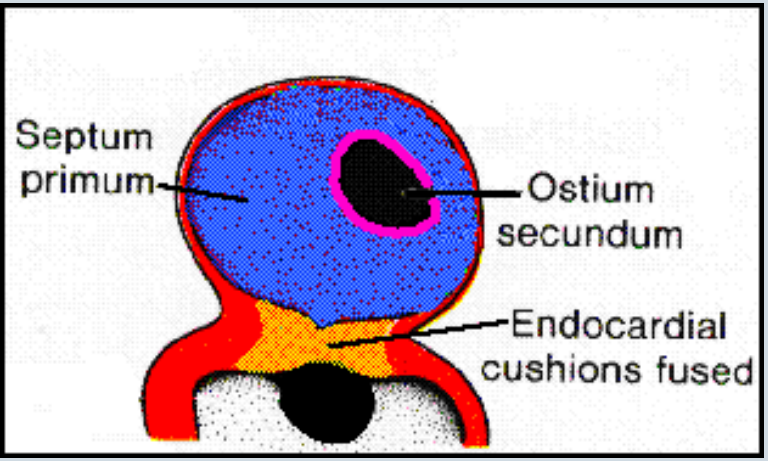


sinoatrial orifice since it is at the junction of the sinus venosus and the primitive atrium.

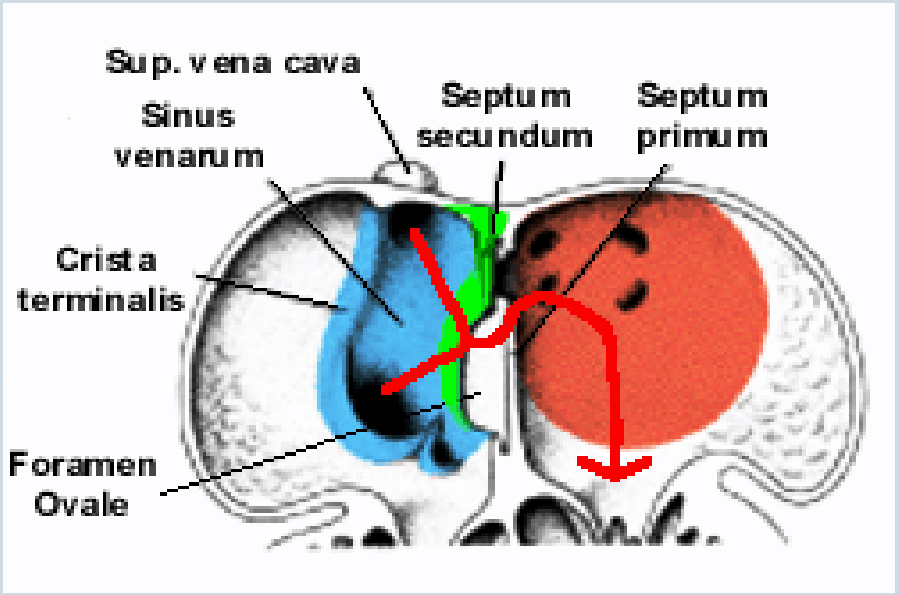


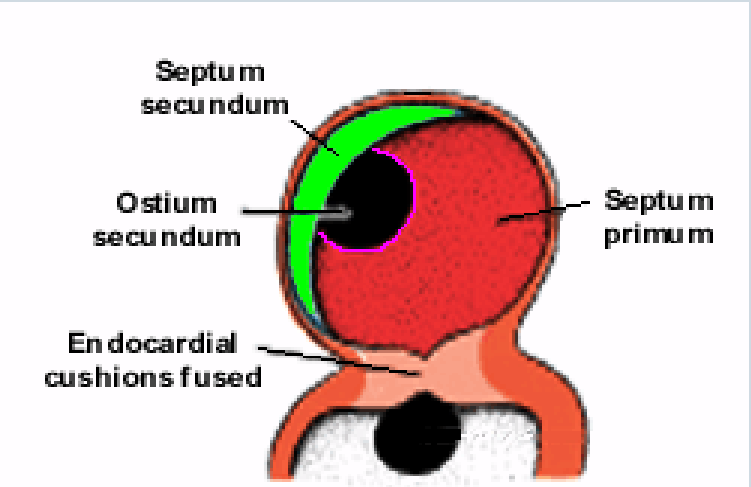
The atrial chambers are divided by septum primum, which grows down to fuse with the endocardial cushions.



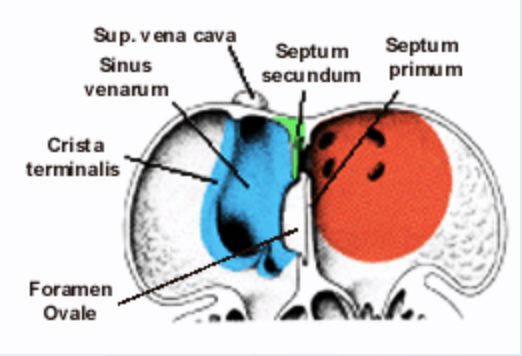


An opening, the ostium sccundum, forms in the septum primum.

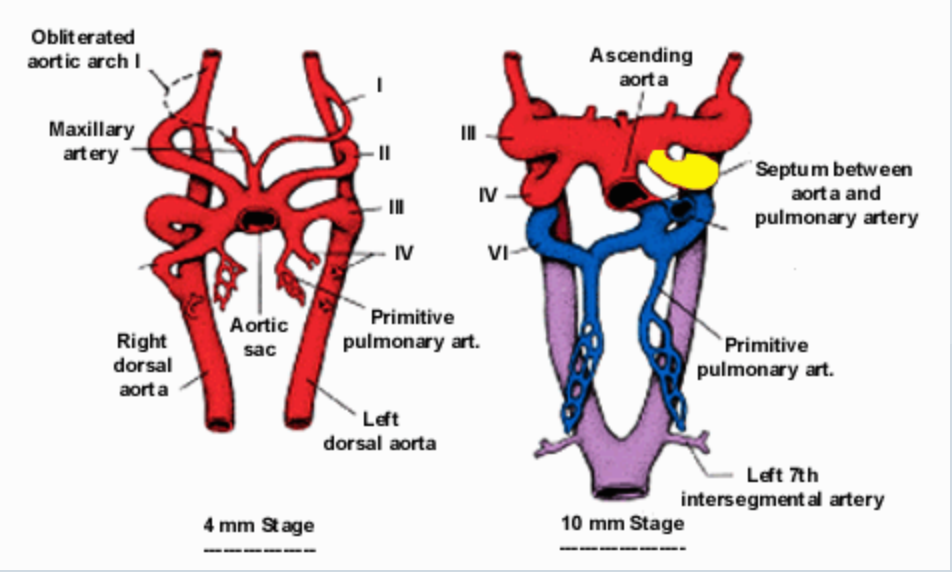




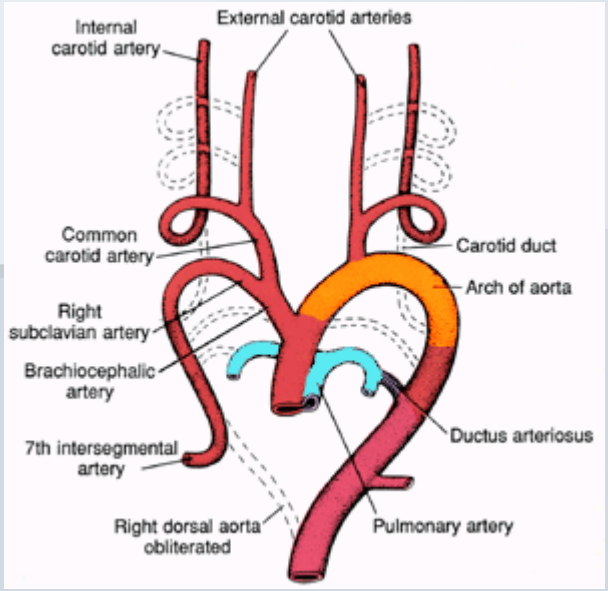
Septum secundum, remains incomplete.
The resulting opening is termed the foramen ovale.



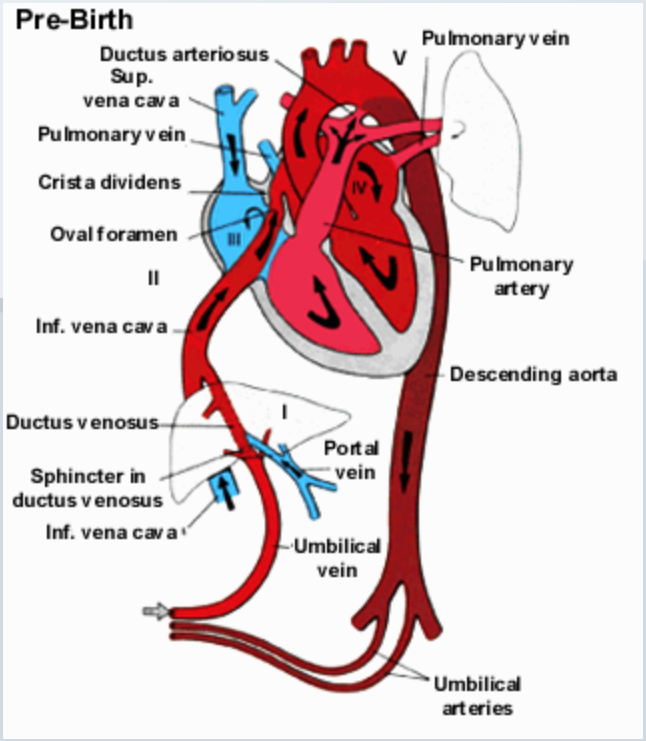
The primitive atria form the auricles, the rough-walled portions of the definitive atria. Incorporation of the walls of the sinus venosus on the right and the pulmonary veins on the left forms the smooth-walled portions of the definitive atria.

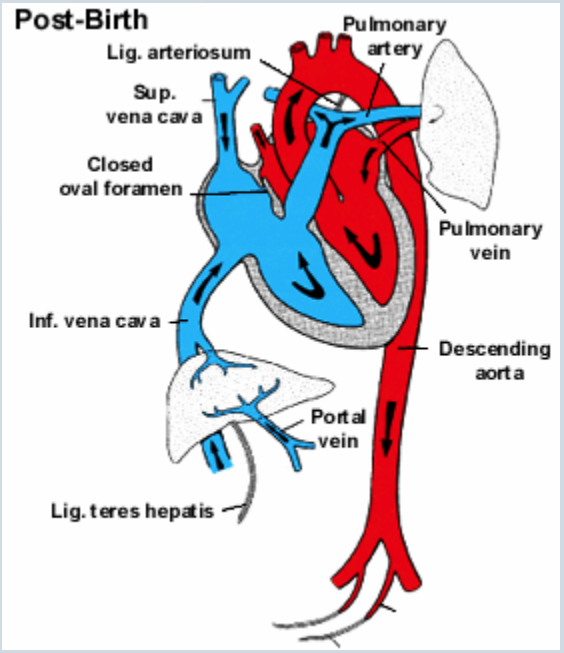


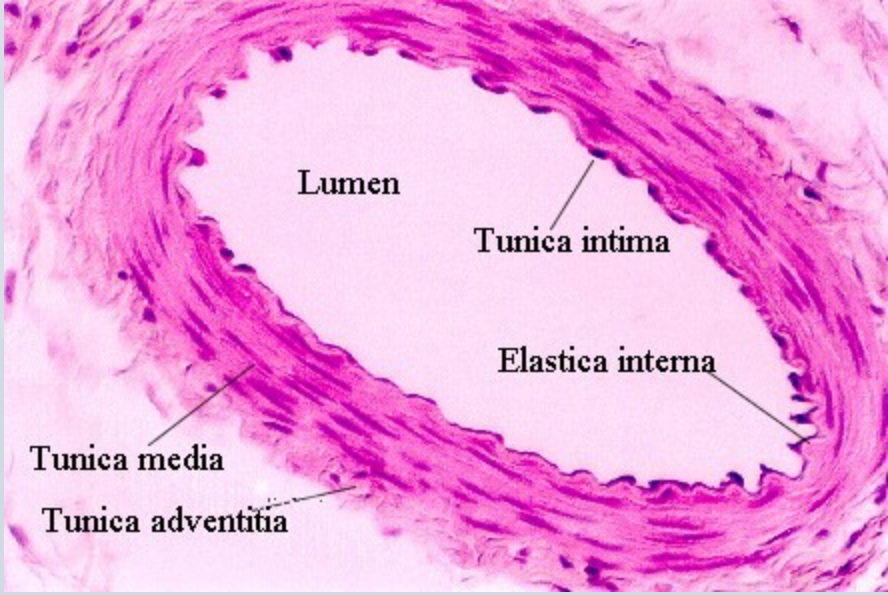
The aortic vessels, which extend from the aortic sac to the paired dorsal aortae, develop and regress asymmetrically.
The left 4th arch and the left 6th arch . . .

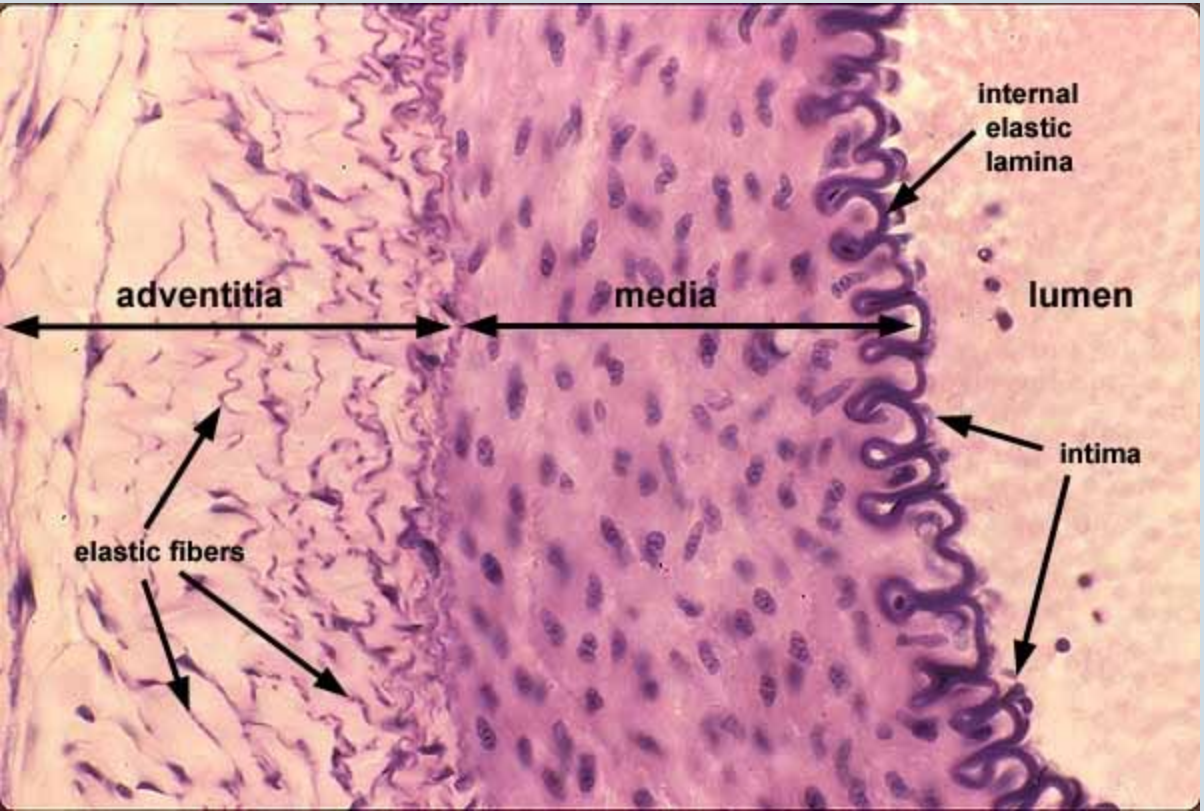


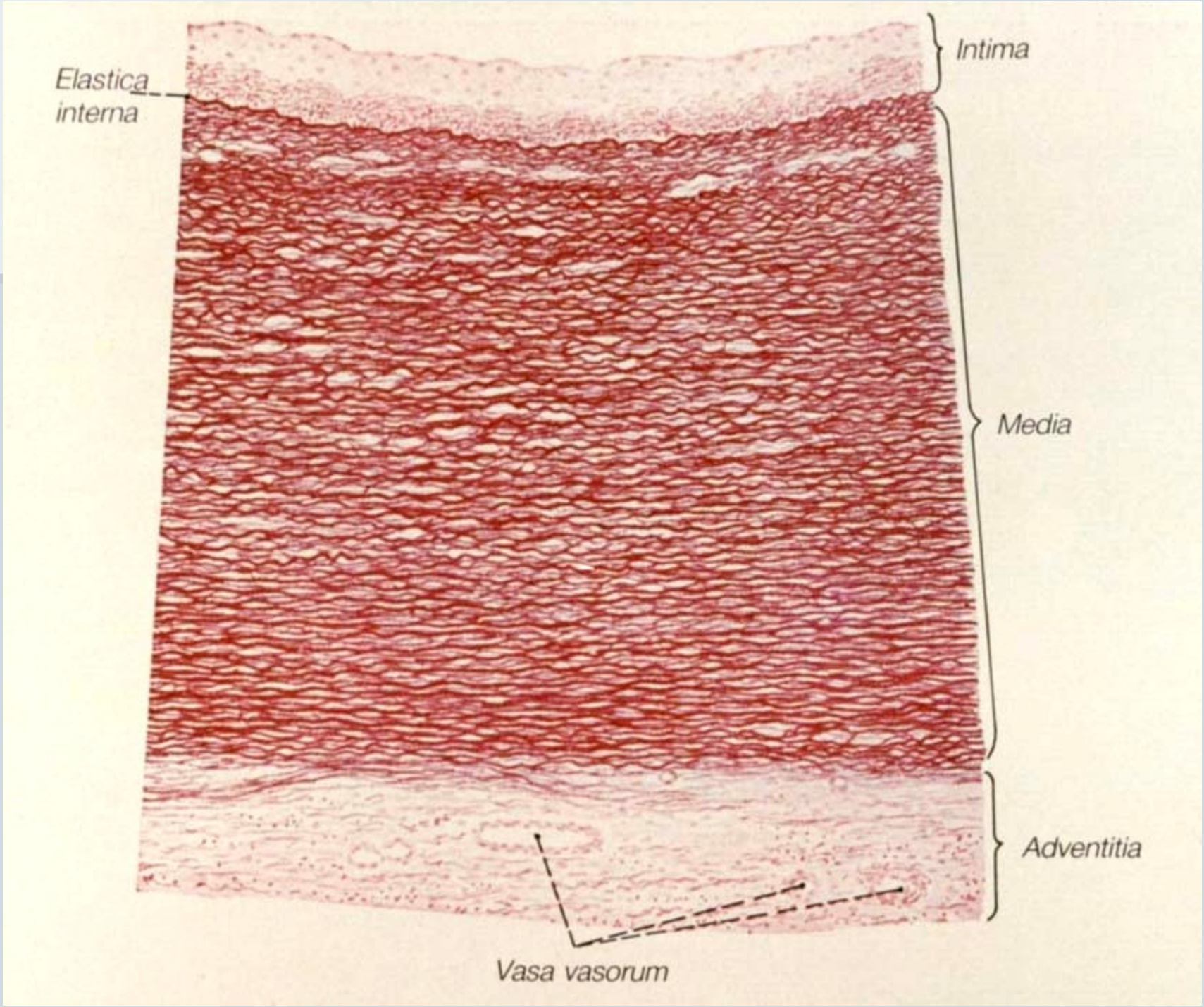
contribute to the aortic arch and the pulmonary artery and ductus arteriosus

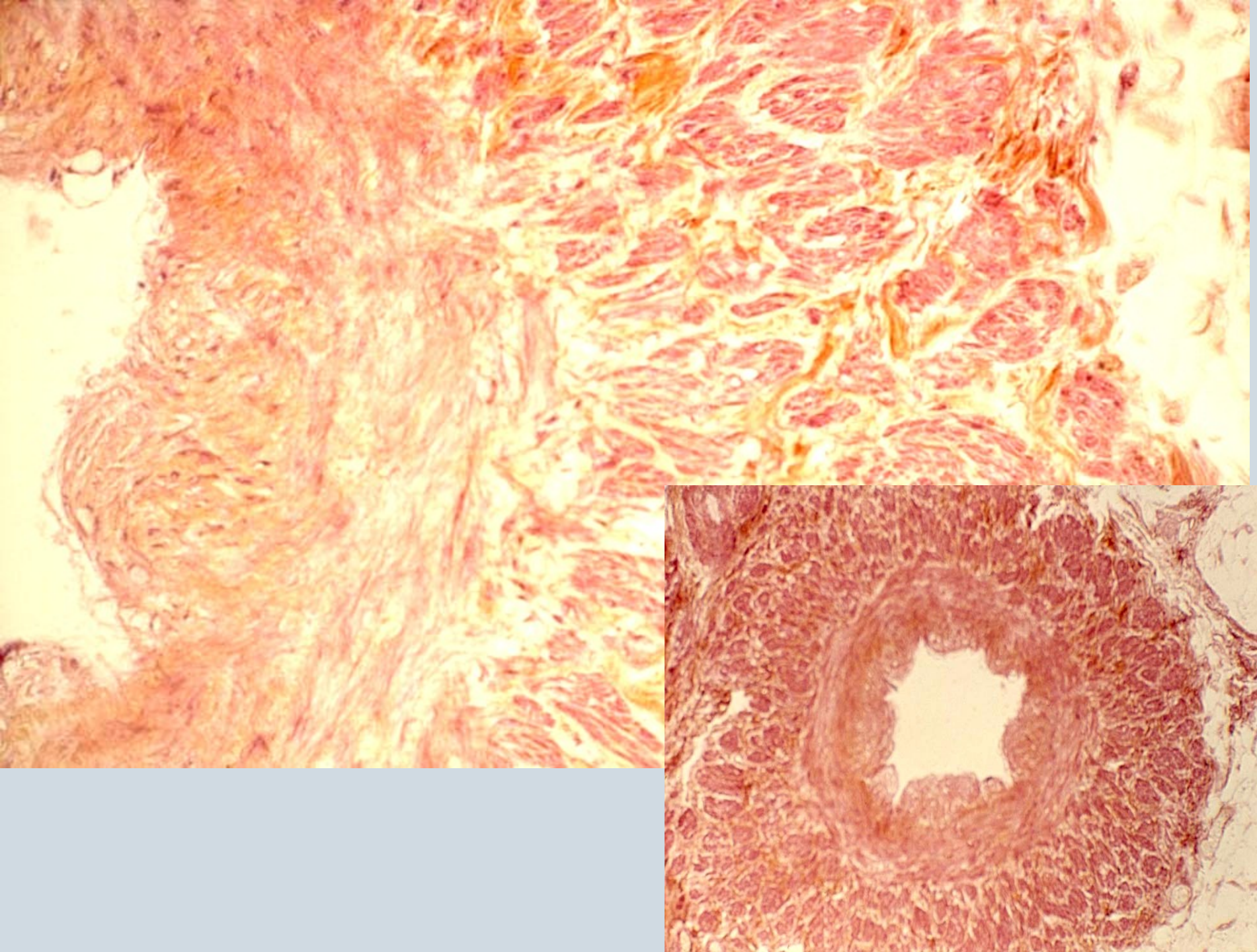

Pre-Birth
Ductus arteriosus
Sup.
vena cava
Pulmonary vein
Crista dividens
Oval foramen
II
Inf. vena cava
Ductus venosus
Sphincter in
ductus venosus
Inf. vena cava
Pulmonary vein
V
IV
III
Pulmonary
artery
Descending aorta
I
Portal
vein
Umbilical
vein
Umbilical
arteries

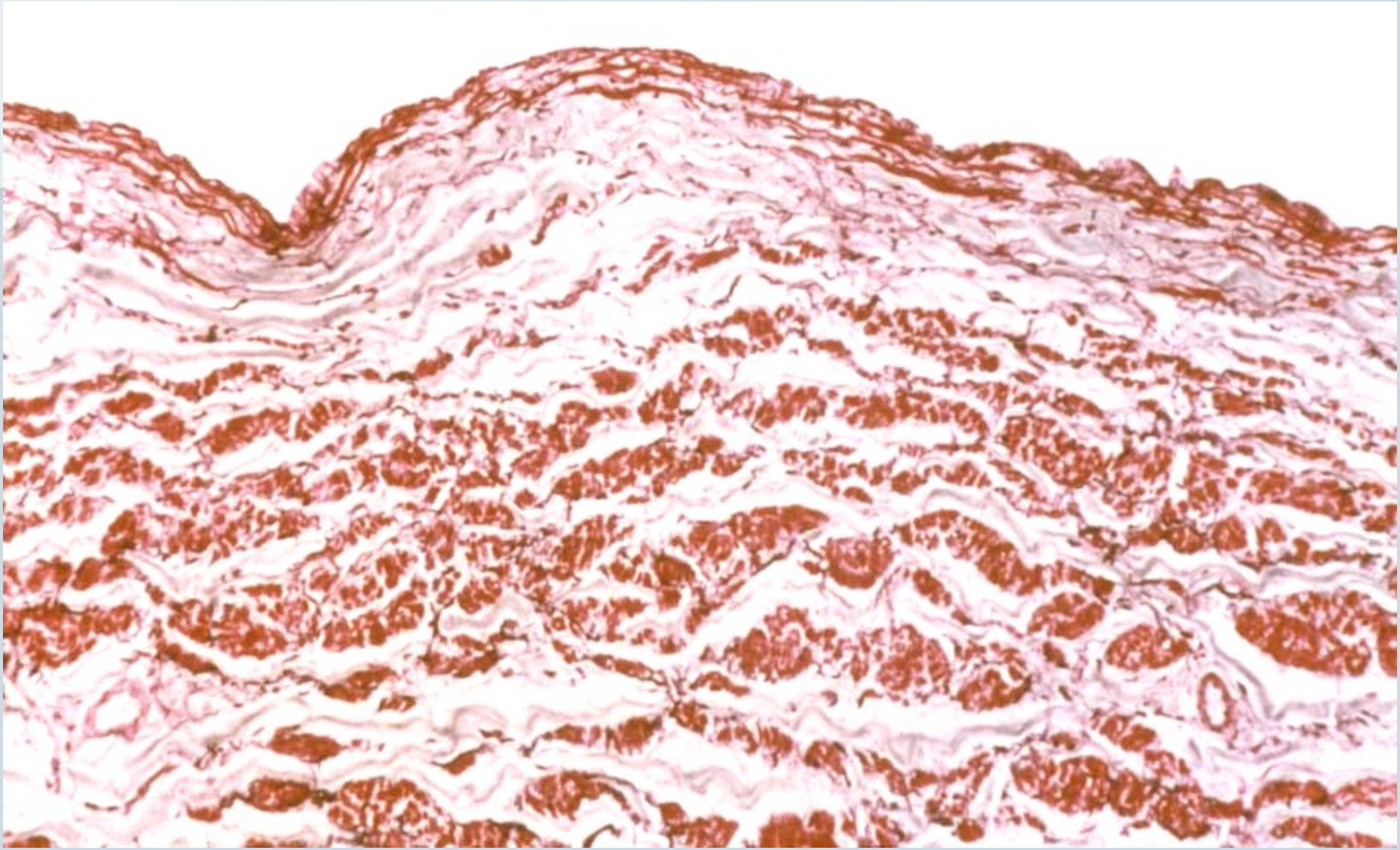

Post-Birth
Lig. arteriosum
Pulmonary
artery
Sup.
vena cava
Closed
oval foramen
Pulmonary
vein
Inf. vena cava
Descending
aorta
Portal
vein
Lig. teres hepatis

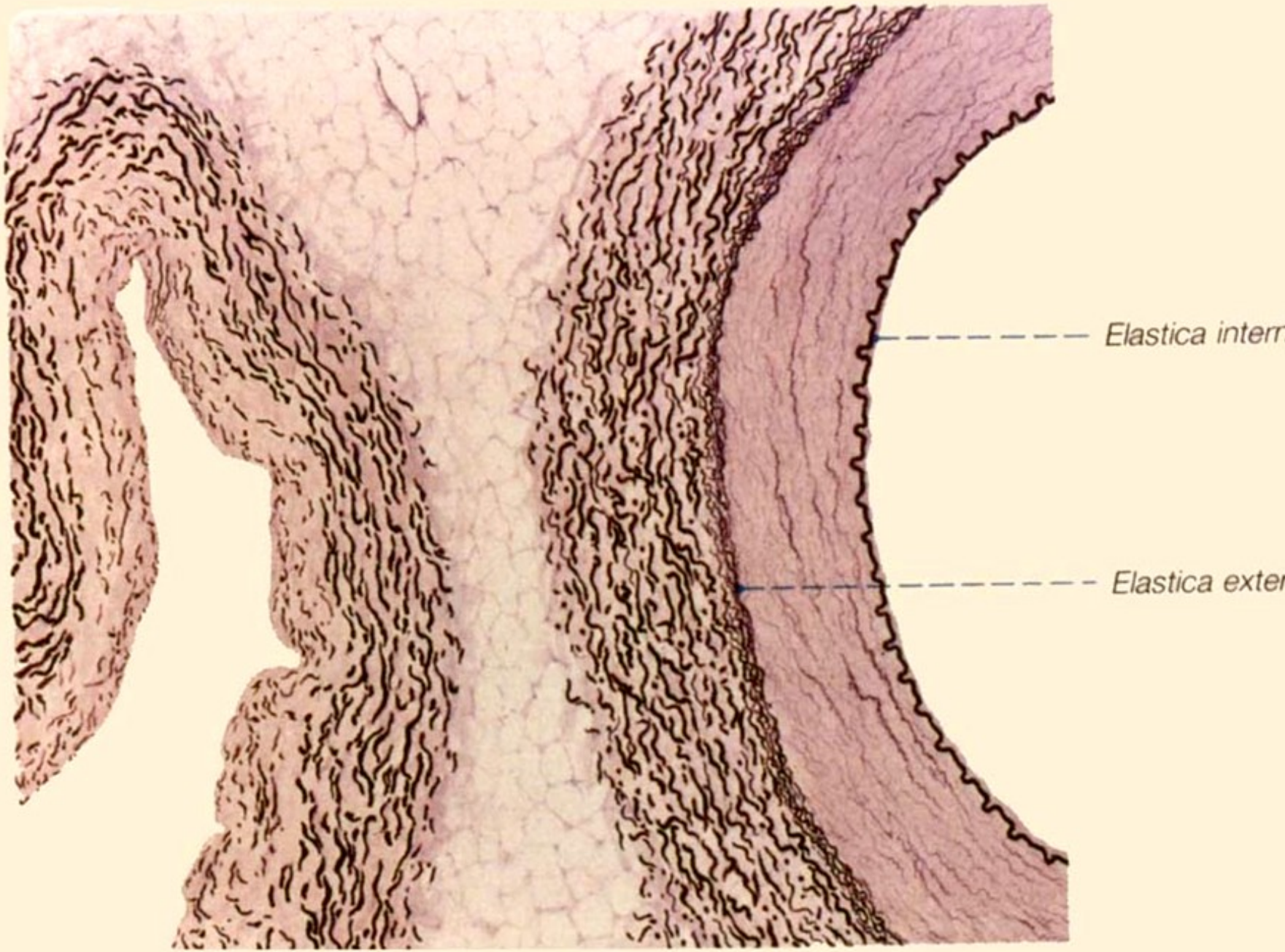

Lumen
Tunica intima
Elastica interna
Tunica media
Tunica adventitia

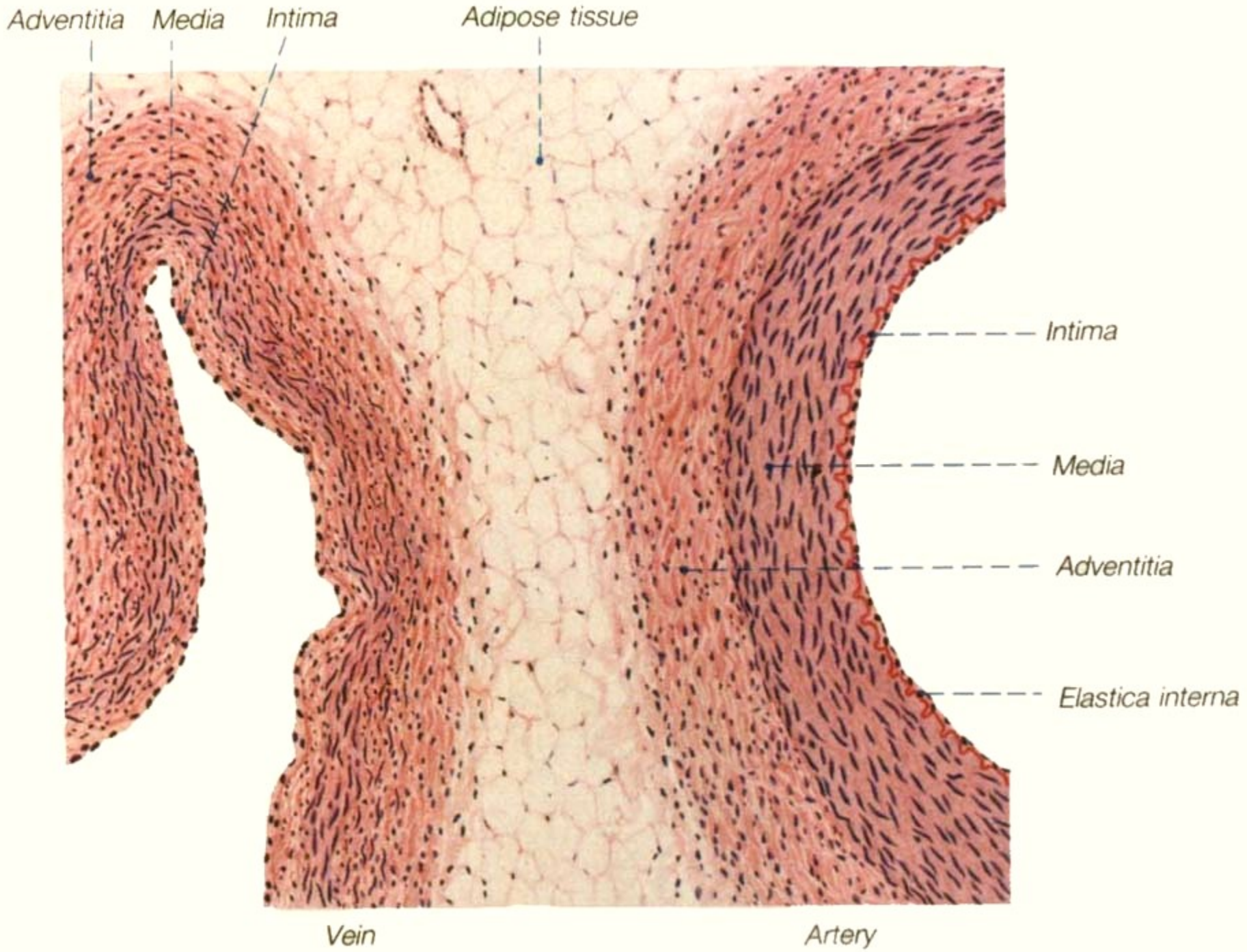

internal
elastic
lamina
adventitia
media
lumen
intima
elastic fibers

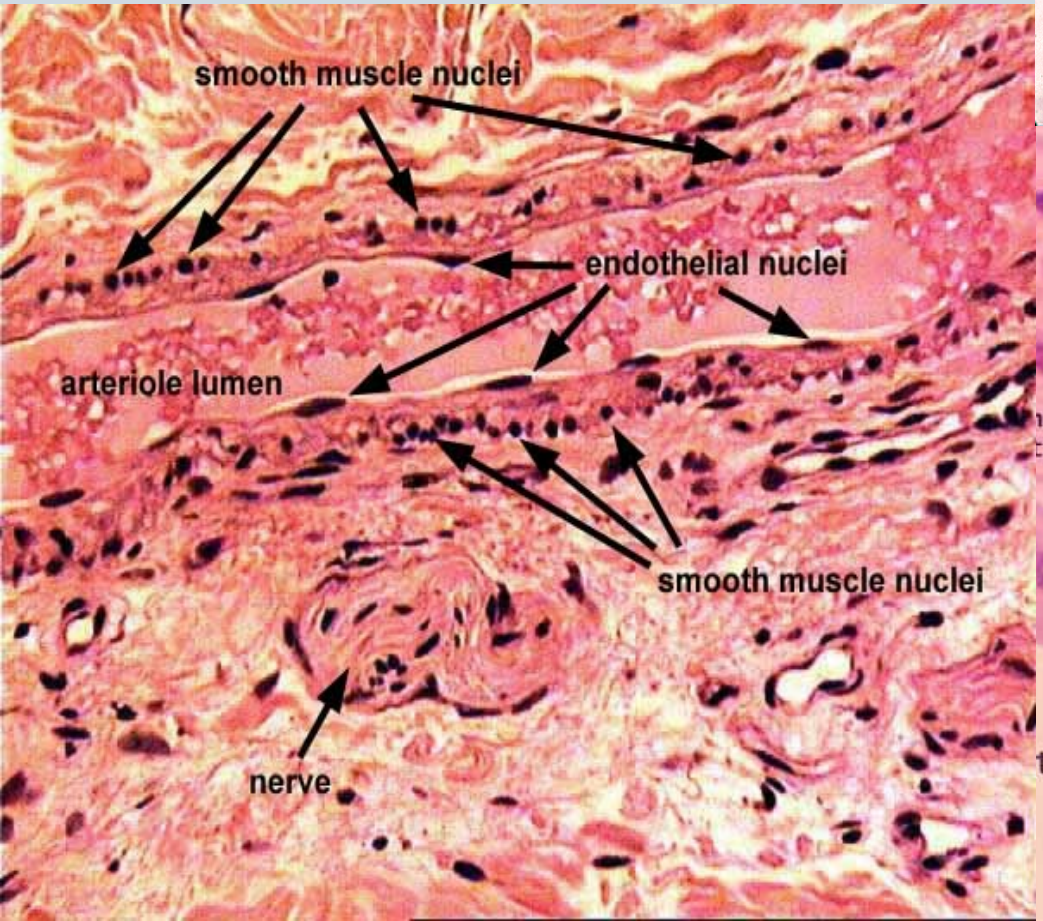

Intima
Elastica interna
Media
Adventitia
Vasa vasorum

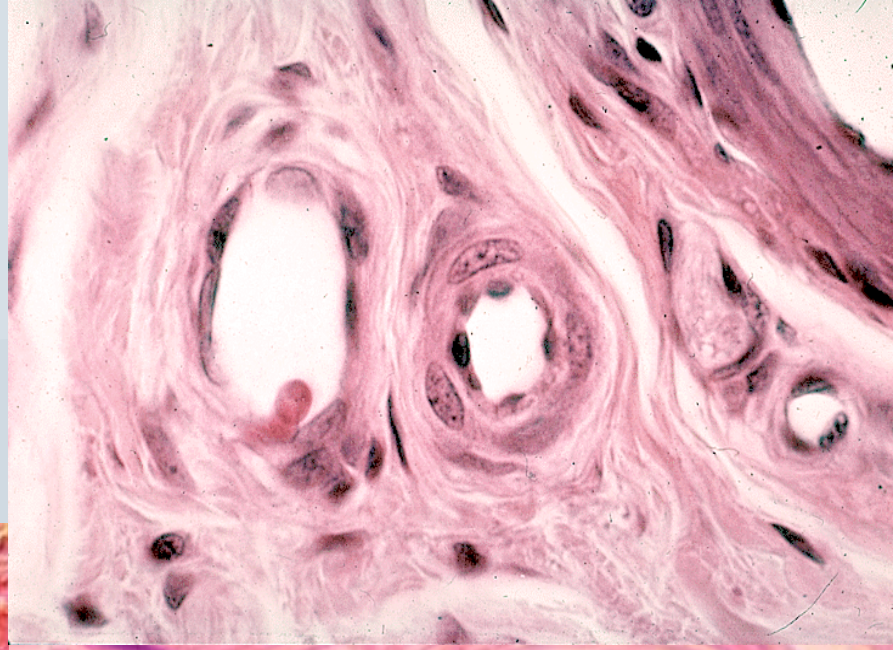


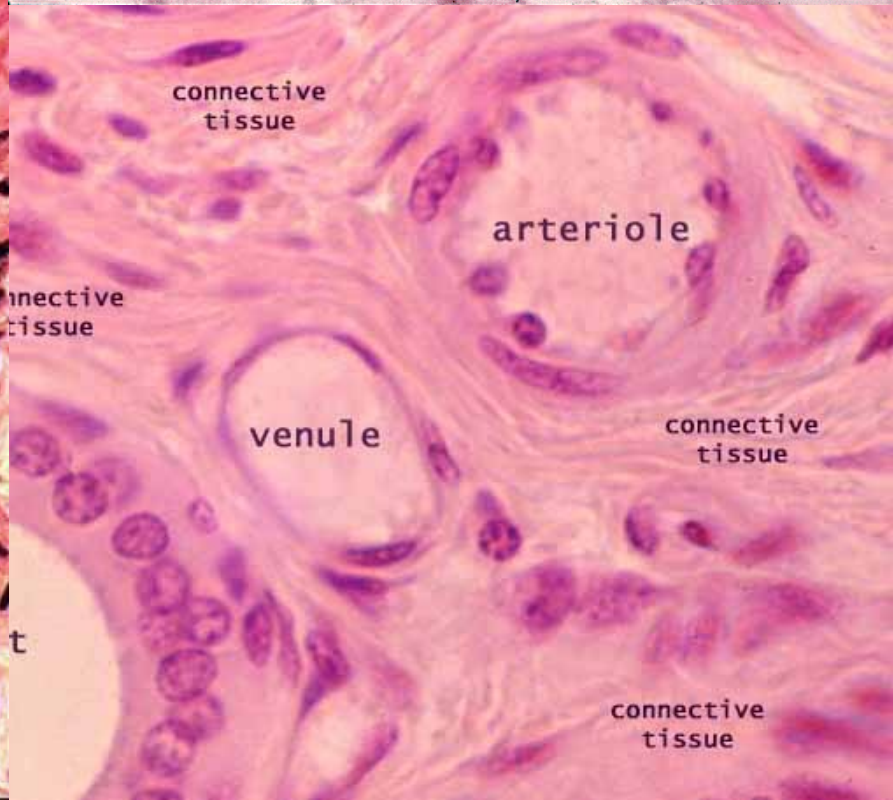



Elastica interr
Elastica exter


Adventitia
Media
Intima
Adipose tissue
Intima
Media
Adventitia
Elastica interna
Vein
Artery


smooth muscle nuclei
endothelial nuclei
arteriole lumen
smooth muscle nuclei
nerve




connective tissue
arteriole
venule
connective tissue
connective tissue