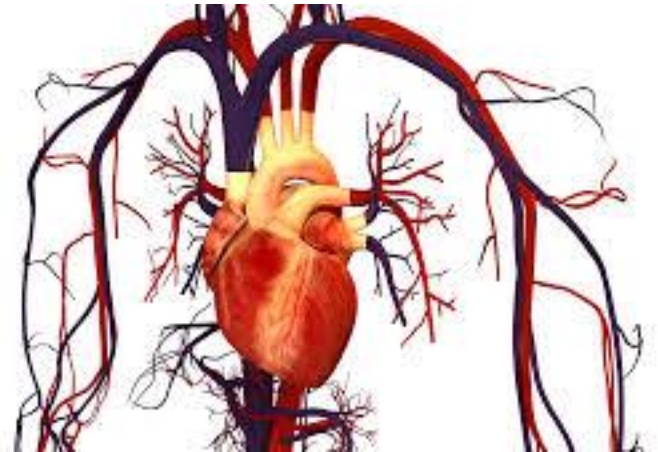


**Lecture 4**

# **Circulatory system. Heart Development**



Zaikina Elvira Ildarovna,  
*MD, PhD, Senior lecturer*

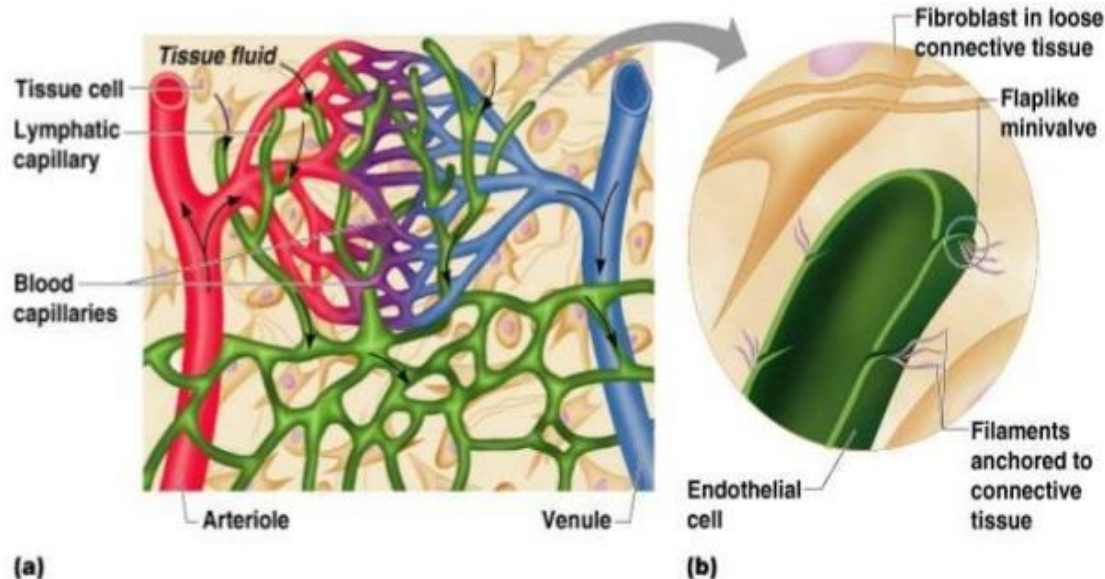
# Systema cardiovasculare

## Systema sanguineum

- closed (blood never leaves the network of vessels)
- Oxygen and nutrients diffuse across the blood vessel layers into interstitial fluid

## Systema lymphaticum

- the lymphatic capillaries are opened for interstitial fluid



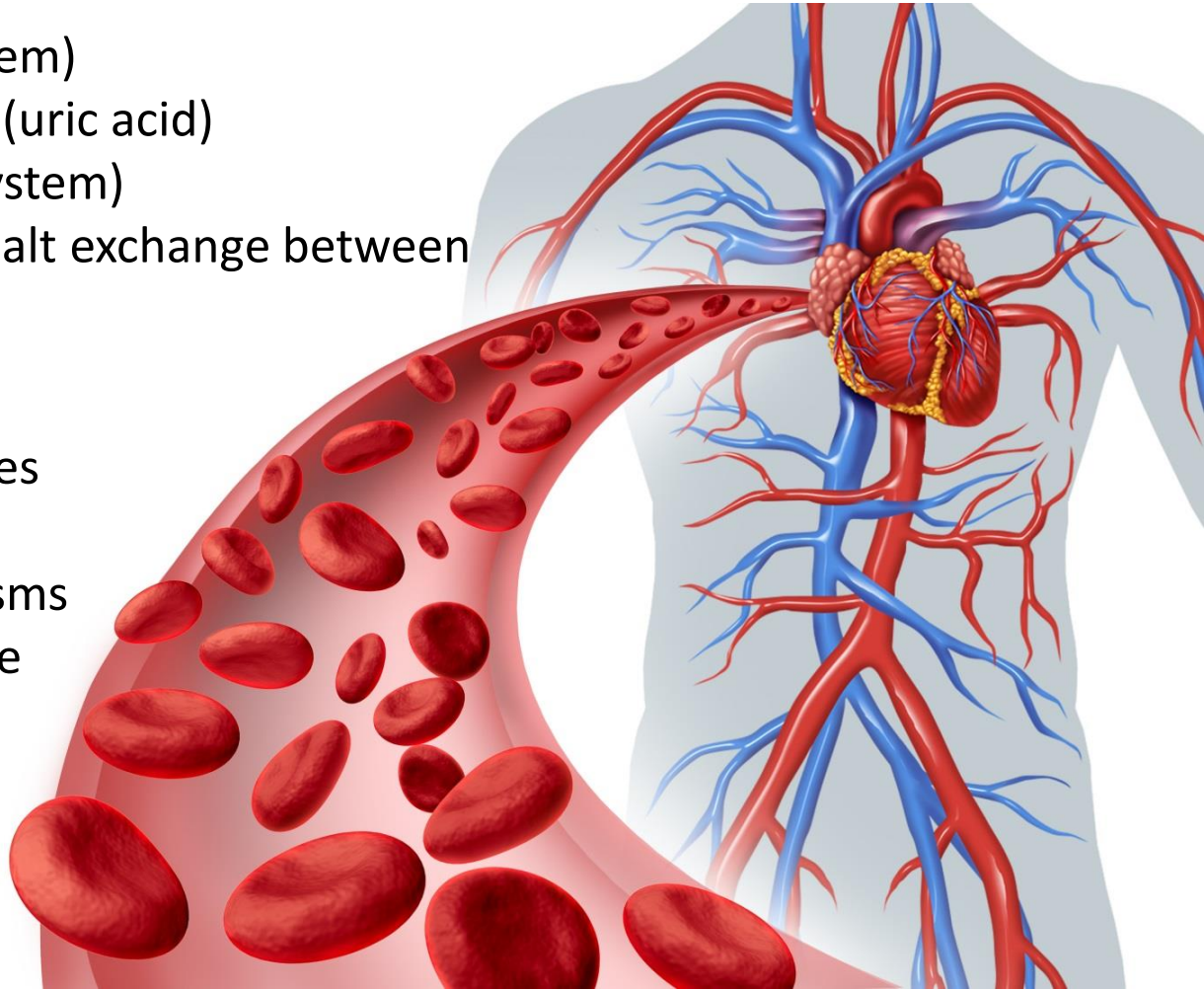
# Functions of the cardiovascular system

## 1. Transport:

- 1) Oxygen and carbon dioxide (respiratory system)
- 2) Nutrients (digestive system)
- 3) Products of metabolism (uric acid)
- 4) Hormones (endocrine system)
- 5) Water and salts (water-salt exchange between blood and tissue)

## 2. Defense:

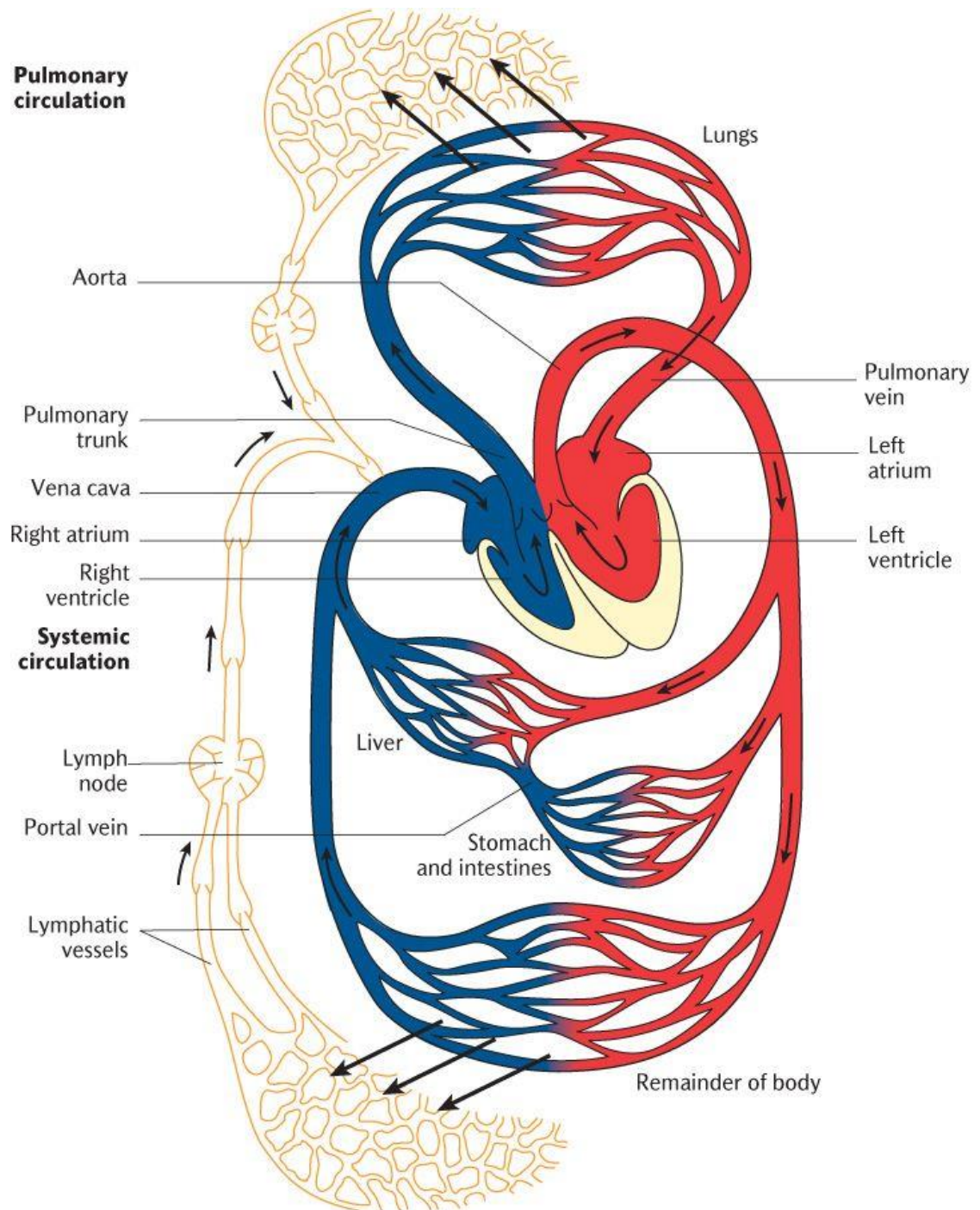
- 1) Antibodies and leukocytes protect from toxins and pathogenic microorganisms
- 2) Stabilize the temperature and pH
- 3) Protects from water loss (blood coagulation)
- 4) Maintain homeostasis





The essential components of the human cardiovascular system:

- Heart
- Blood
- Blood vessels

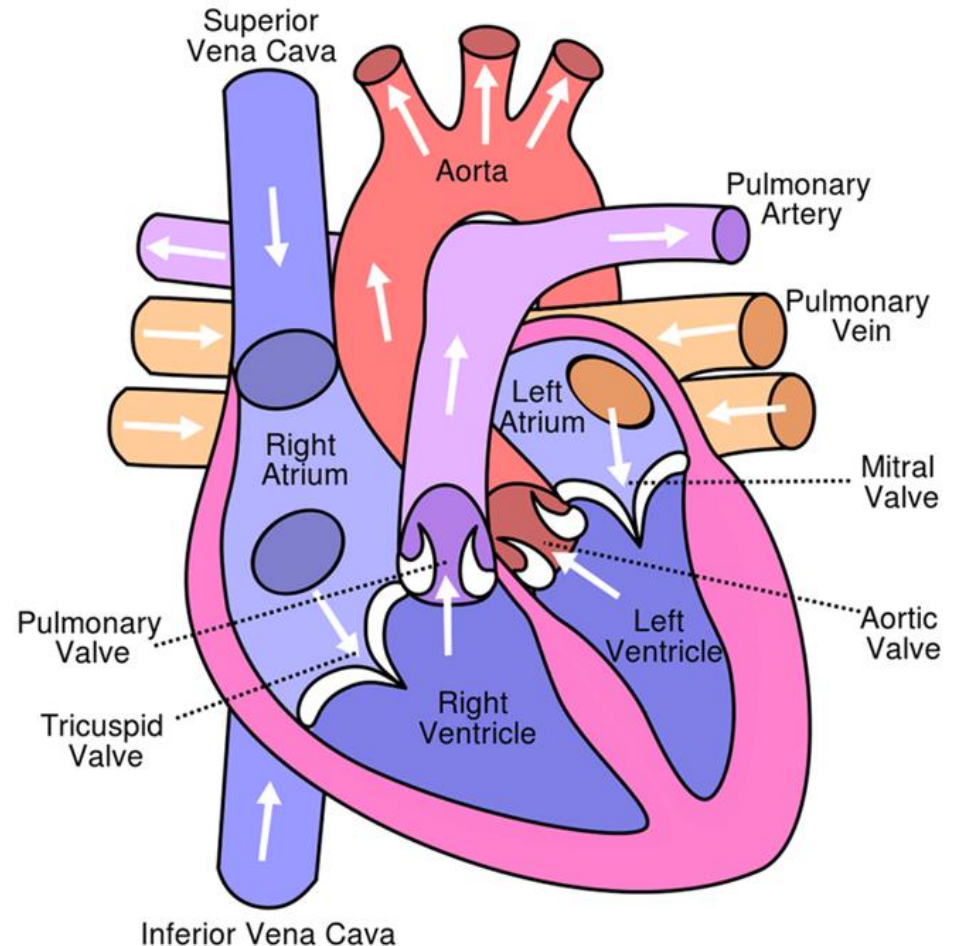


# The heart is the central organ of the cardiovascular system

- It pumps the blood through the vessels by means of the rhythmic contraction

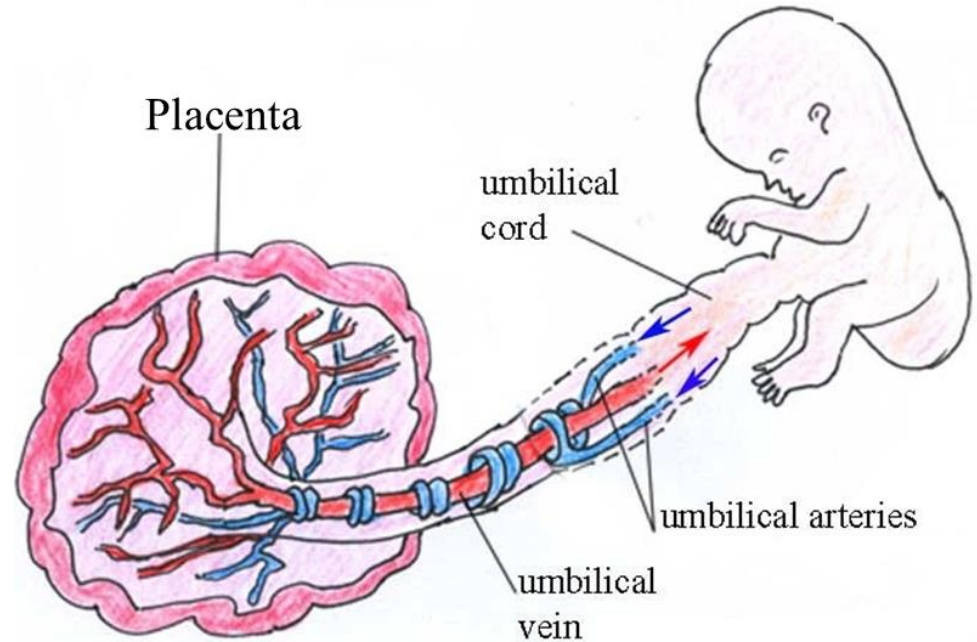
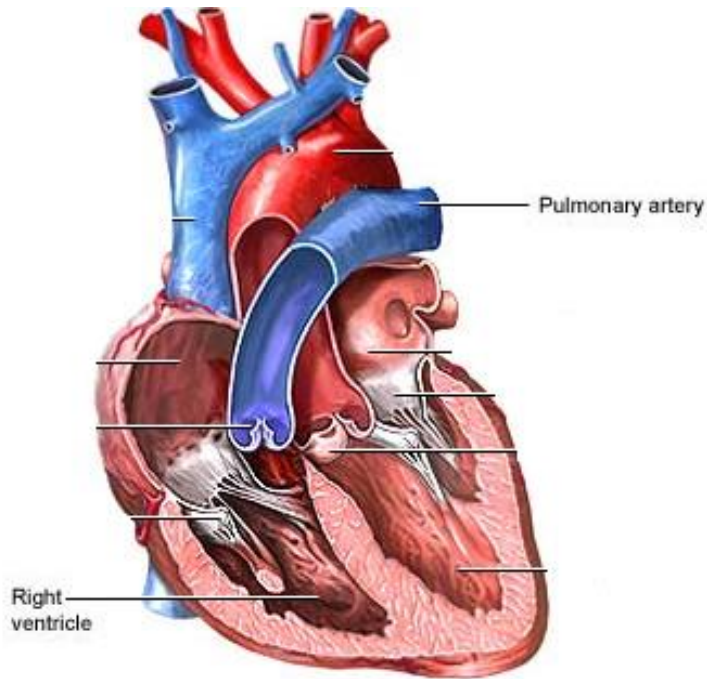
The heart is a hollow muscular organ consisting of 4 chamber:

- right and left atria
- right and left ventricles



# Arteries

blood vessels that carry **blood** (most often **arterial blood**)  
from heart ventricle to organs and tissues.



## Exceptions:

- 1) **Pulmonary arteries** – conduct **venous blood** from right ventricle to lungs
- 2) **Umbilical arteries** – conduct **venous blood** from fetus to placenta

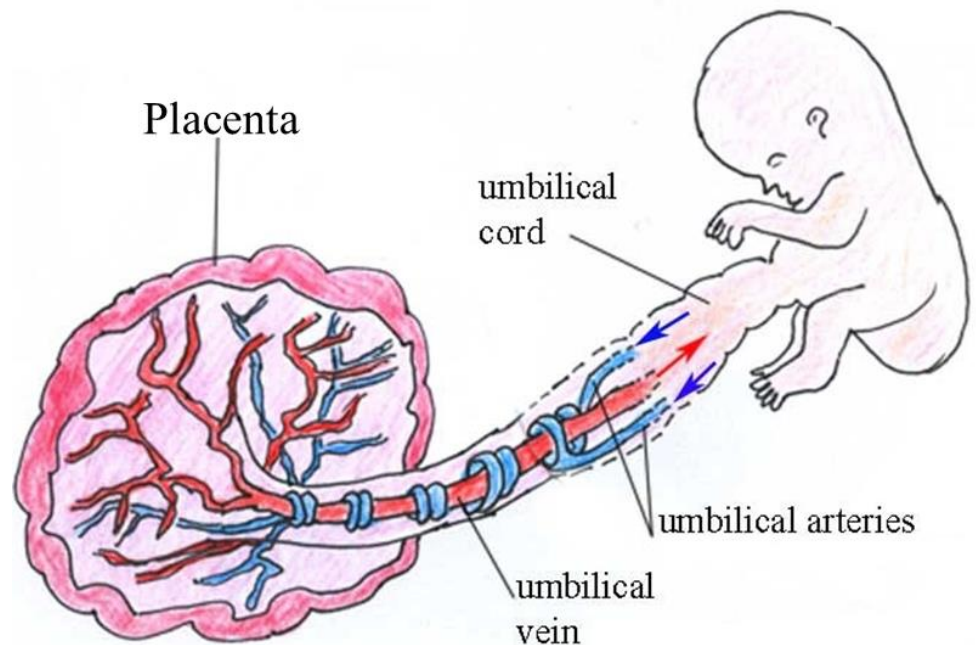
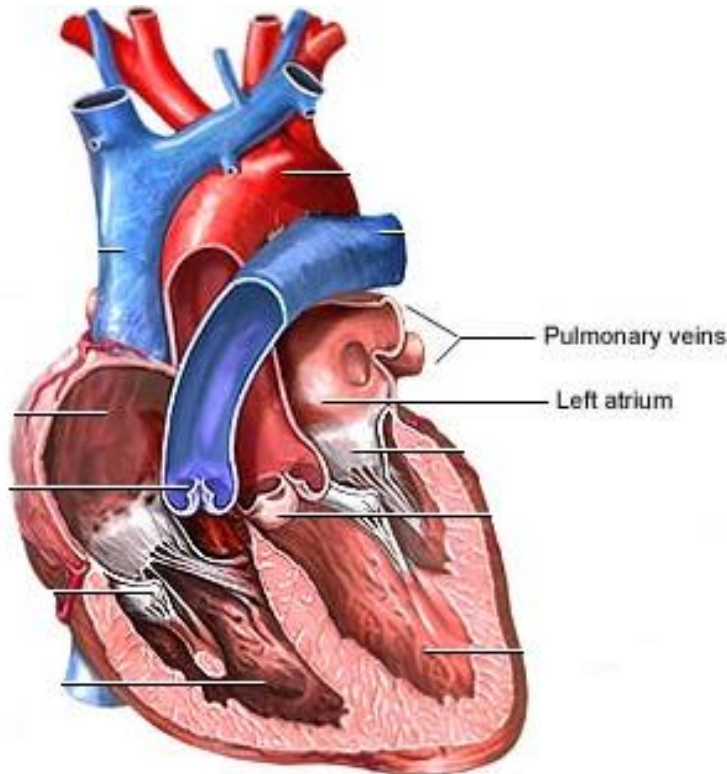


# Veins

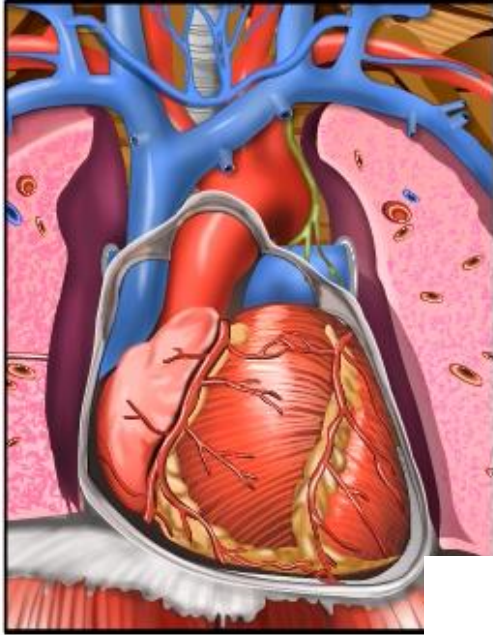
blood vessels that carry **blood** (most often **venous blood**)  
from organs and tissues to heart atrium

## Exceptions:

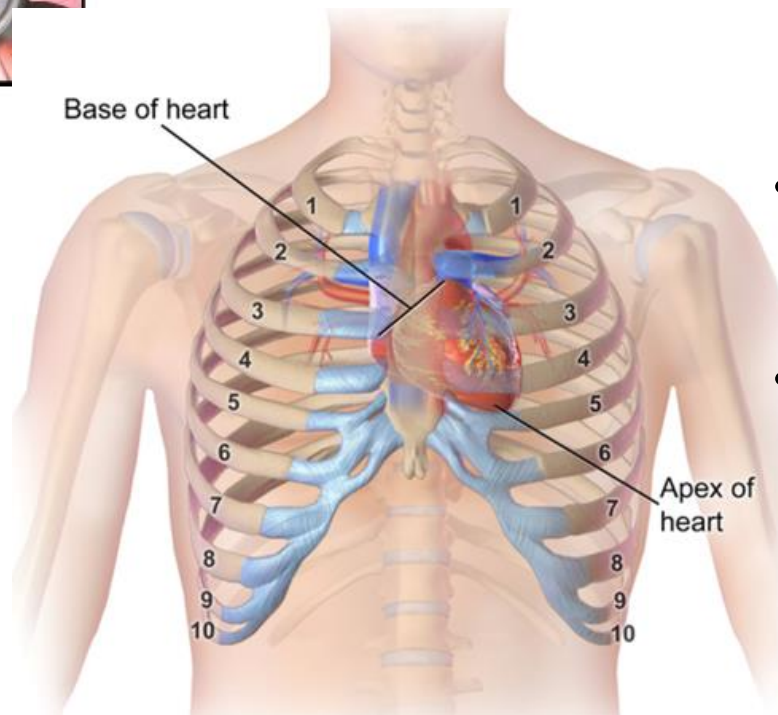
- 1) **Pulmonary veins** – conduct arterial blood from lungs to left atrium
- 2) **Umbilical veins** – conduct arterial blood from placenta to fetus



# The heart, *cor* (Latin), *cardia* (in Greek)



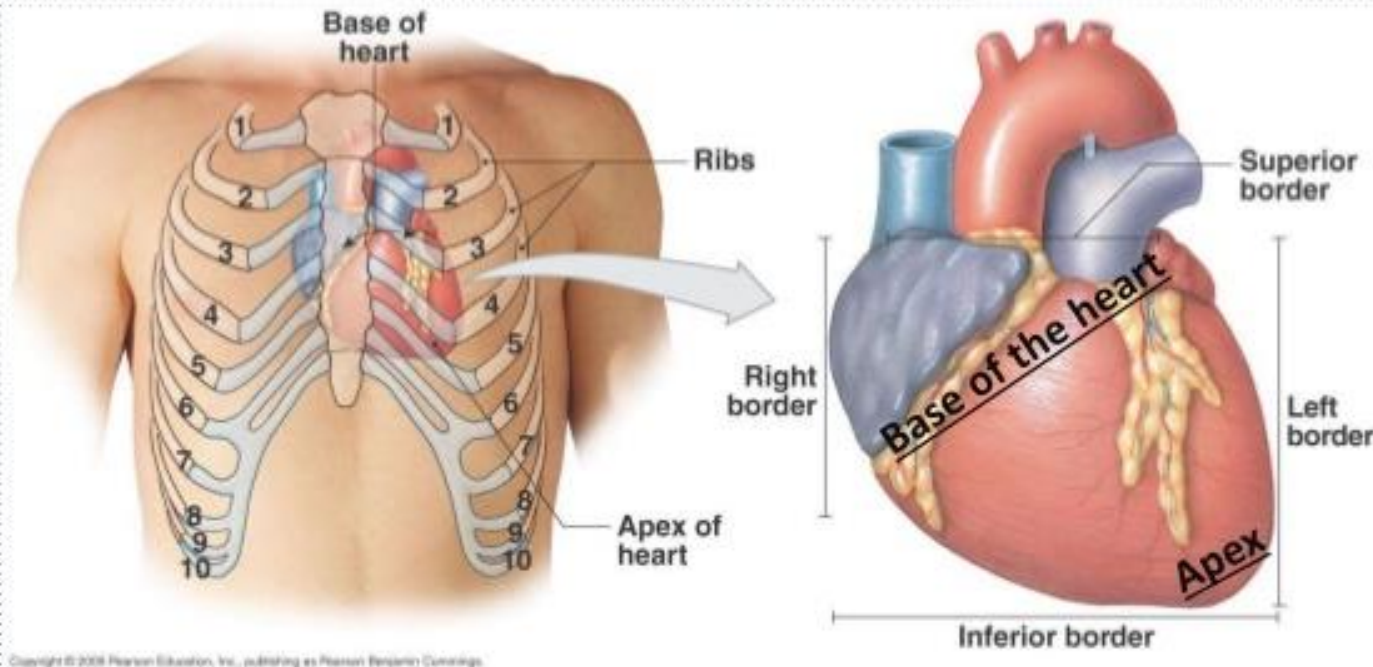
- It is a hollow muscular organ, which receives blood from the veins and pumps the blood into the arterial system.



- The heart is situated asymmetrically in the anterior mediastinum.
- Its greater part (2/3) is to the left of the midline and lesser part (1/3) is to the right of the midline.



# HEART POSITION IN THE THORAX



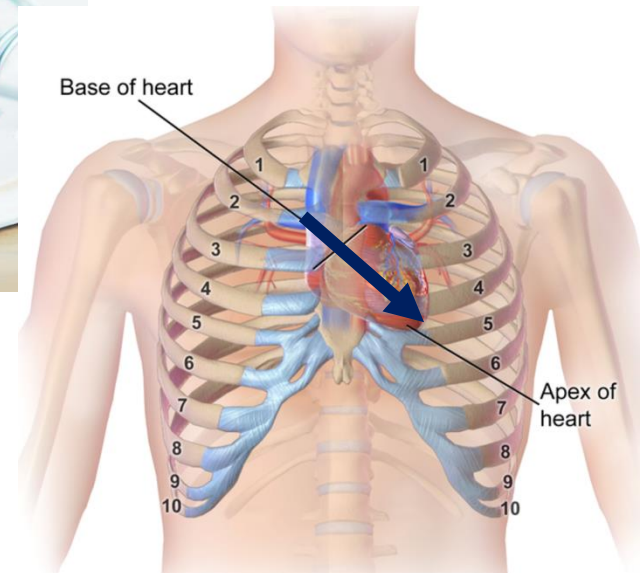
- The **base**, *basis cordis* is the superior expanded part of the heart.

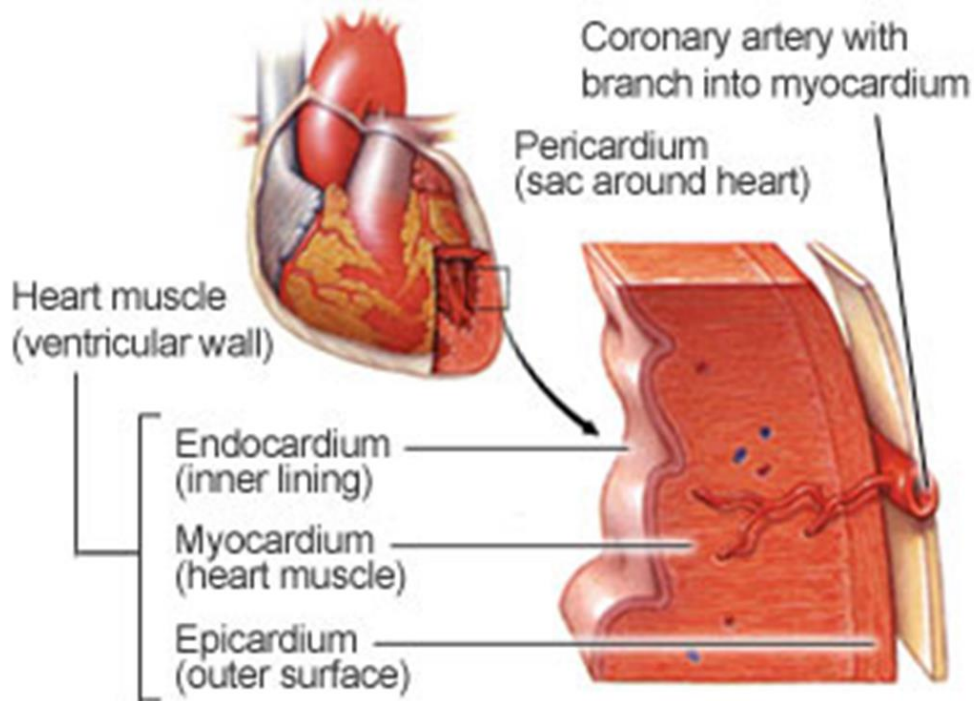
It is directed backwards and up and corresponds to both atria and to the roots of the great vessels (aorta, pulmonary trunk, superior and inferior vena cavae, pulmonary veins).

- The **apex of the heart**, *apex cordis*, is a narrow rounded part.

It is directed down, forwards and to the left.

The longitudinal axis of the heart passes obliquely:  
from above to down, from the right to the left and from back to front





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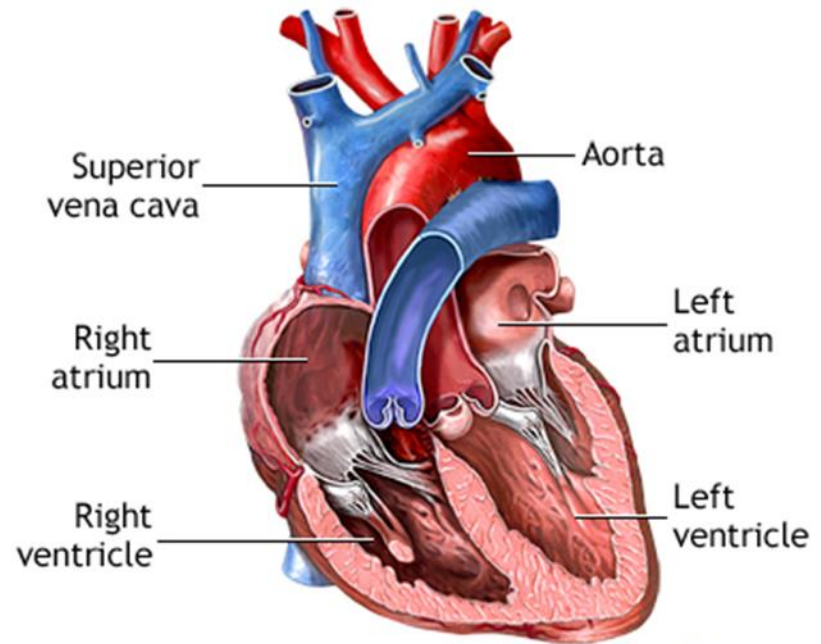
The cardiac wall is comprised of three layers

1. **Endocardium** is thin layer, which lines the cardiac chambers from inside

❖ *The cusps of the cardiac valves and of the semilunar valves of the vessels represent the reduplication of the endocardium.*

2. **Myocardium** is the thickest layer, playing the most important role

3. **Epicardium** covers the heart from outside. It is also called the visceral layer of the serous pericardium.

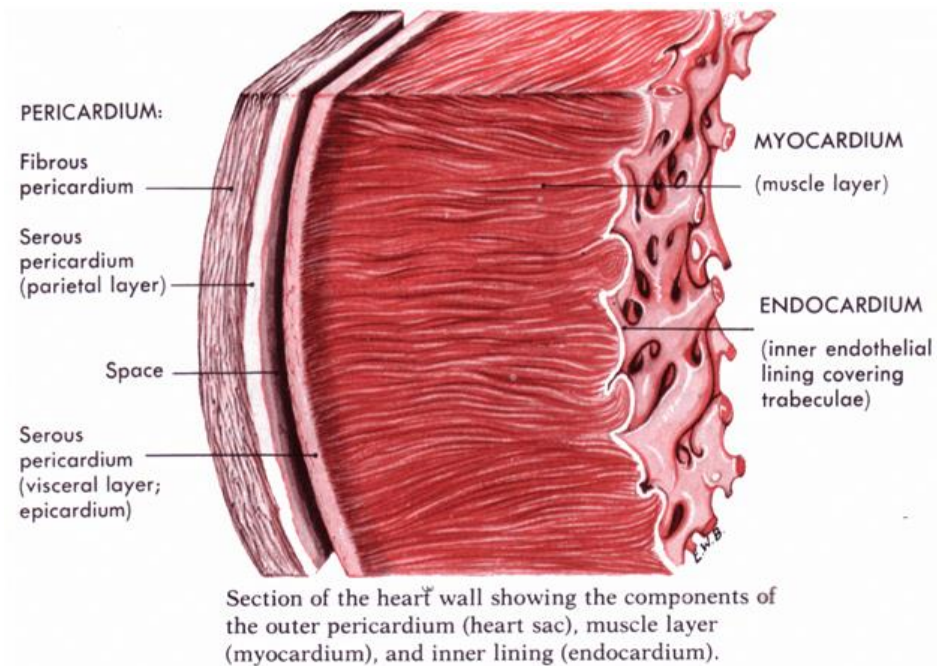
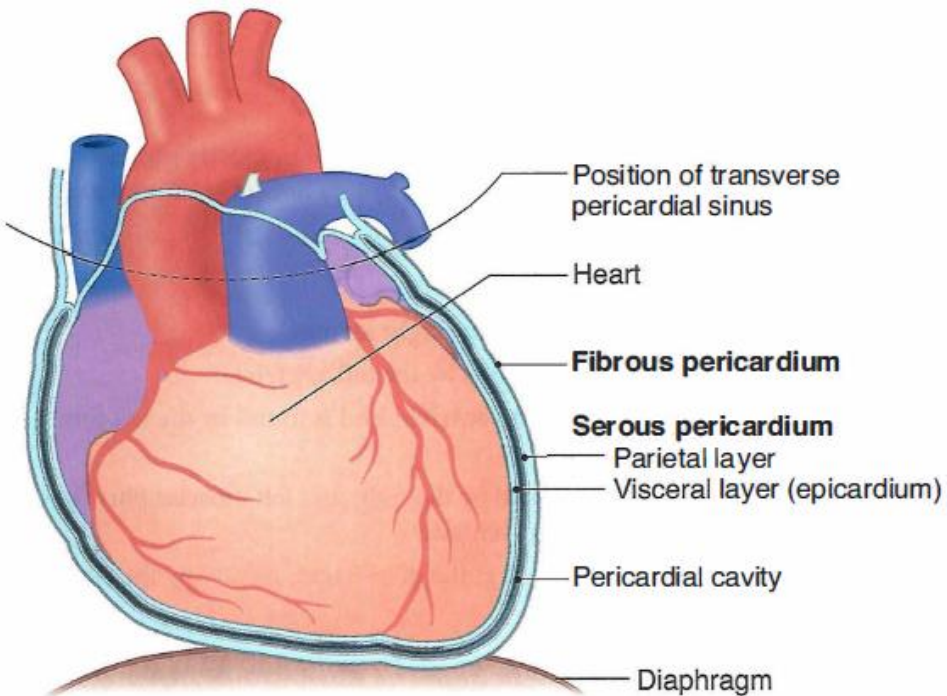




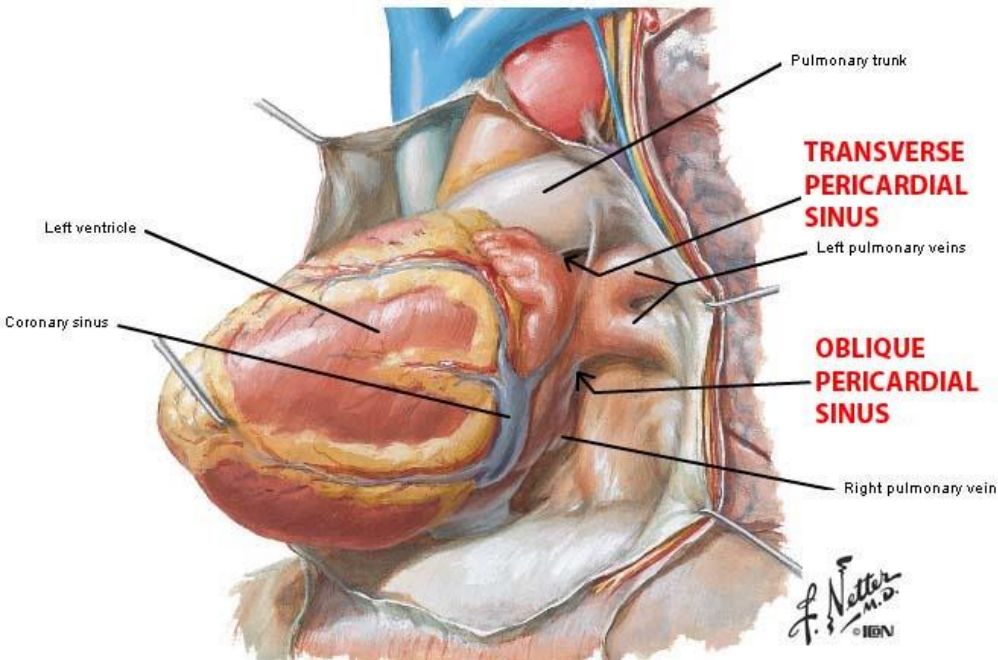
# Pericardium

Serous pericardium layers:

- Parietal
- Visceral (=epicardium)



## Pericardial Sac - Heart Drawn Out Left Lateral View

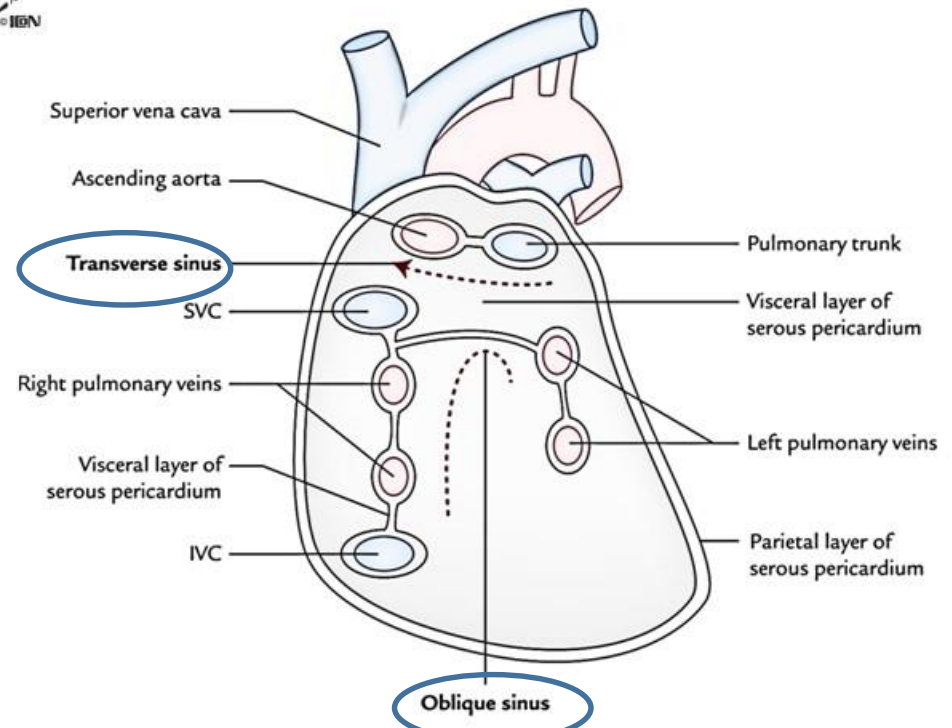


### 1. Transverse pericardial sinus

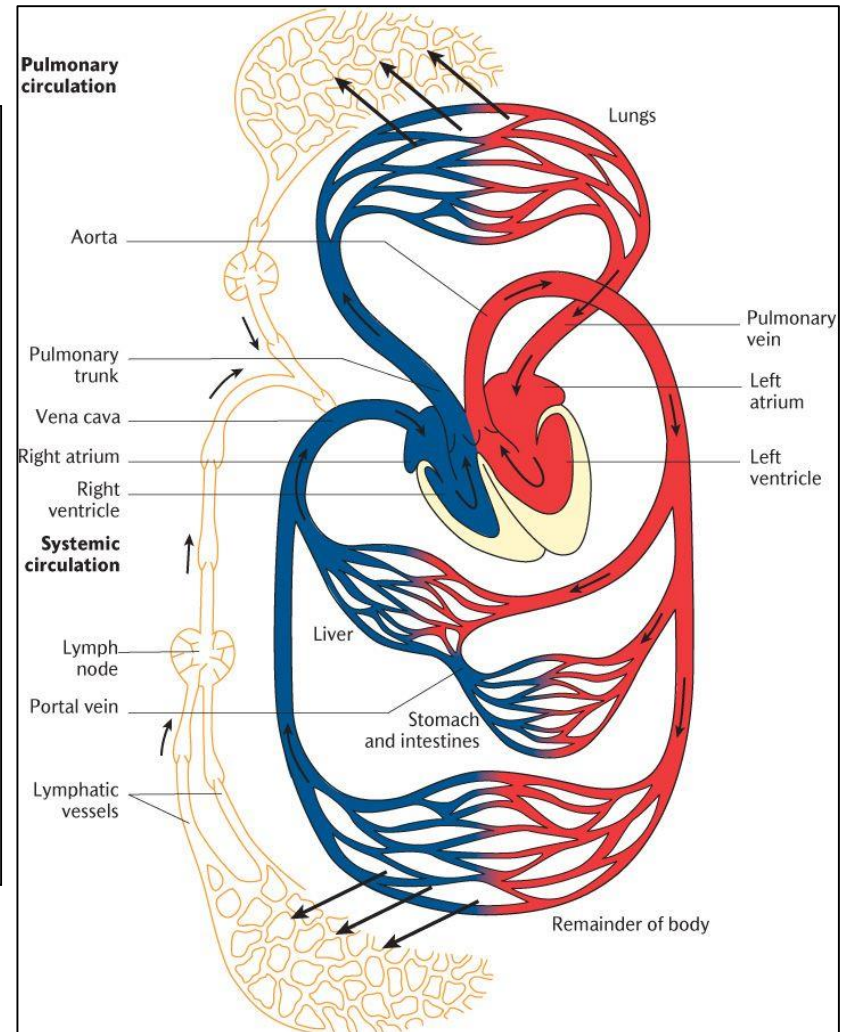
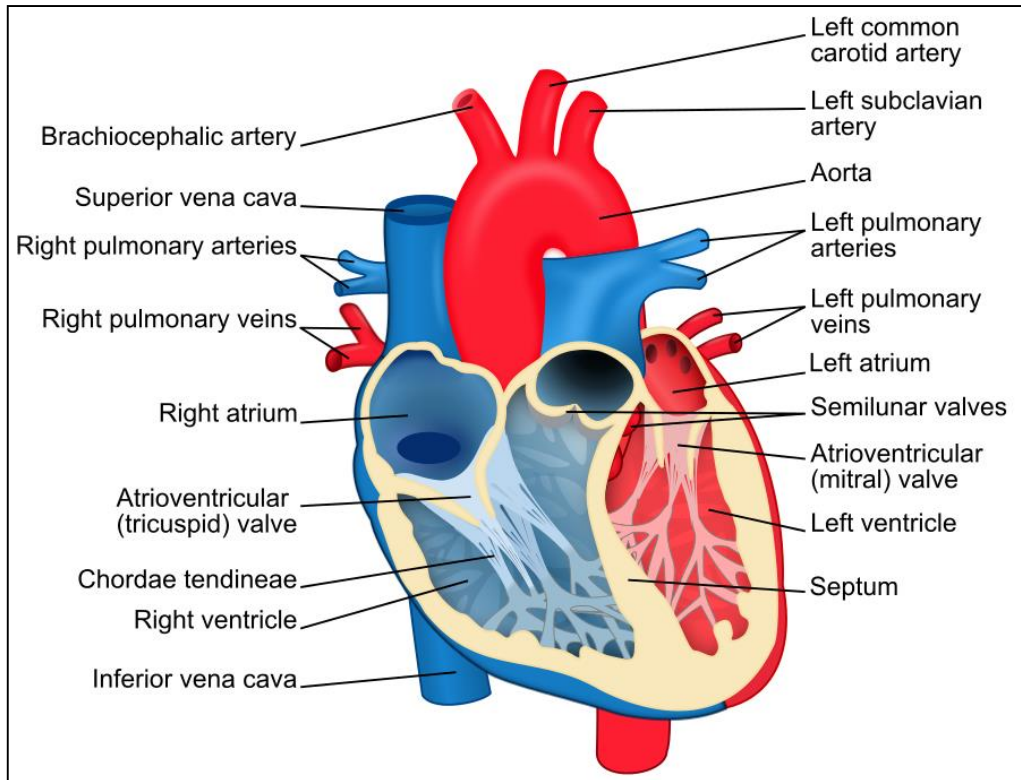
- a space posterior to the ascending aorta and pulmonary trunk and anterior to the superior vena cava and pulmonary veins
- it separates the great arteries from the great veins.
- It is useful in cardiac surgery to allow isolation of the aorta and pulmonary trunk.

### 2. Oblique pericardial sinus

- the blind, inverted, U-shaped space posterior to the heart
- bounded by reflection of serous pericardium around the 4 pulmonary veins and the inferior vena cava as they enter the heart.



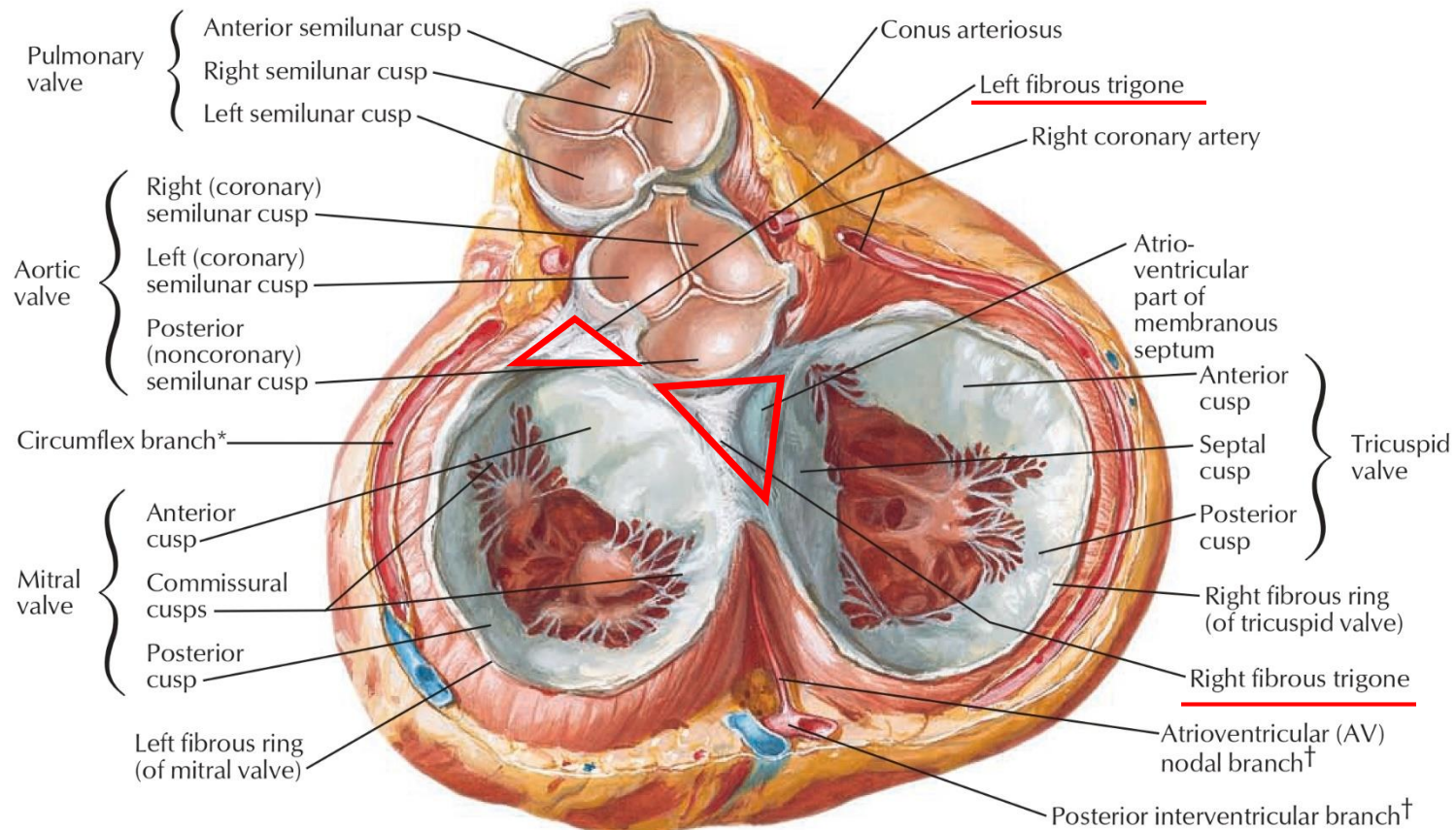
# Heart chambers





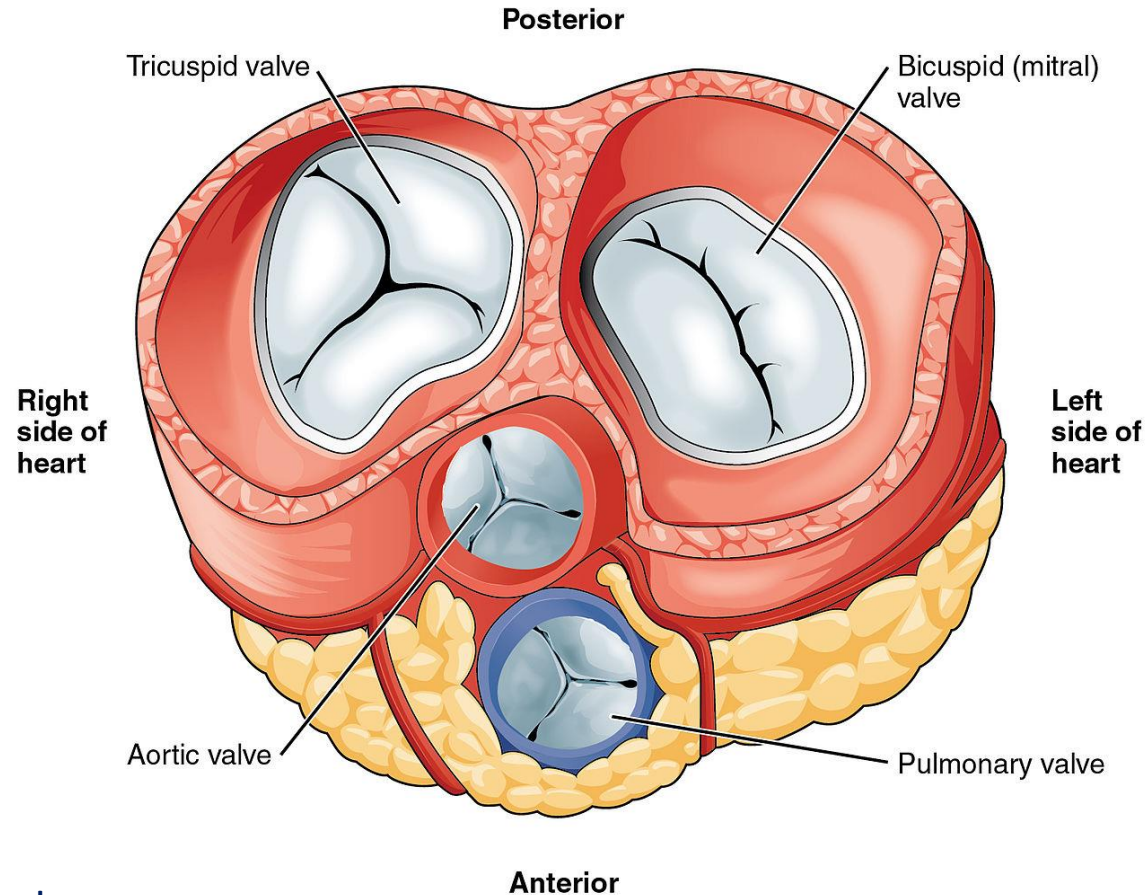
# “Soft Skeleton” of the heart

- 4 annuli fibrosis
- 2 fibrous trigones
- Membranous part of the interventriculum septum



Heart in diastole:  
viewed from base with atria removed

# Heart valves

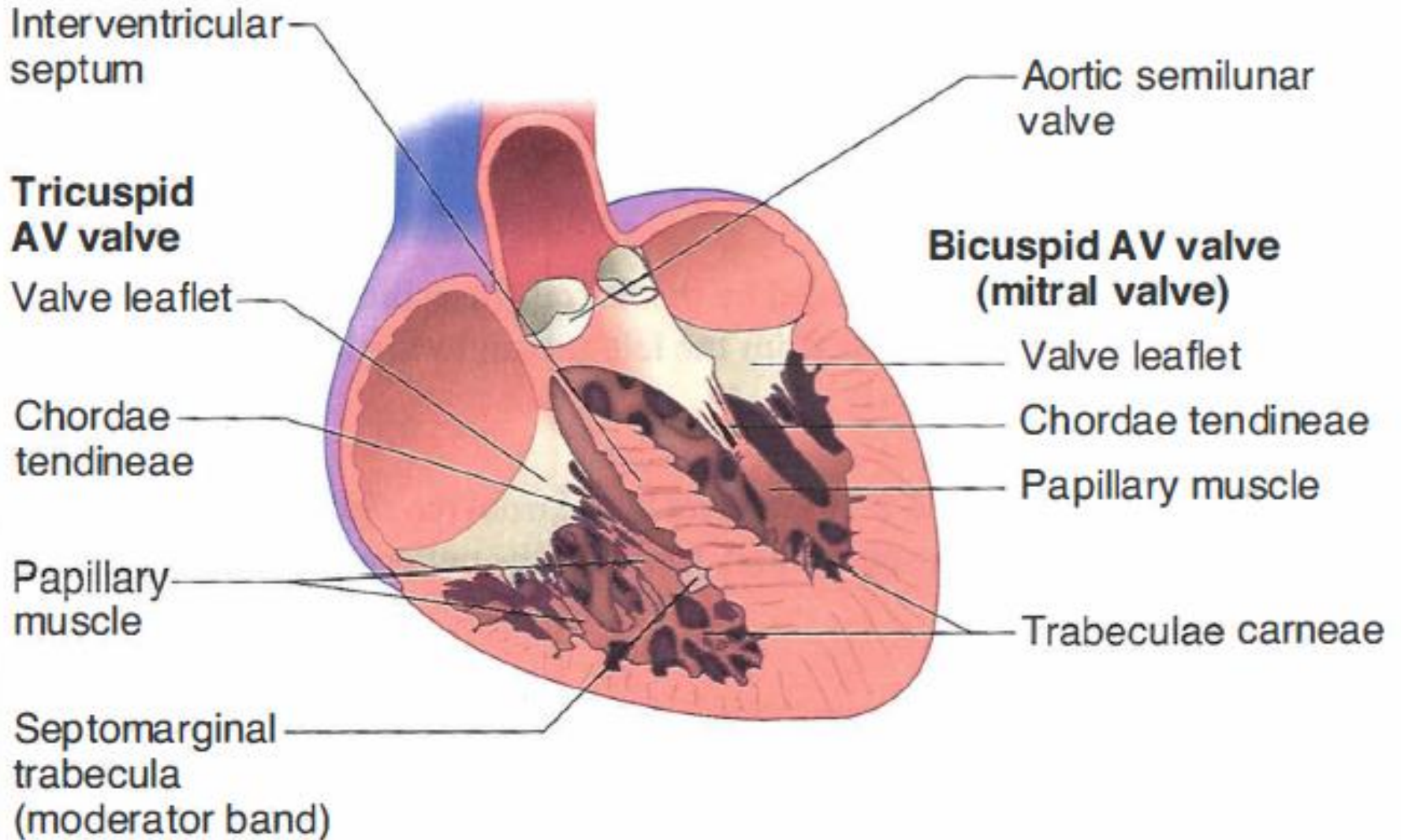


## Atrioventricular valves:

- Between left atrium and left ventricle – **bicuspid (mitral) valve**
- Between right atrium and right ventricle – **tricuspid valve**

## Semilunar valves:

- Between left ventricle and aorta – **aortic valve**
- Between right ventricle and pulmonary arteries – **pulmonary valve**

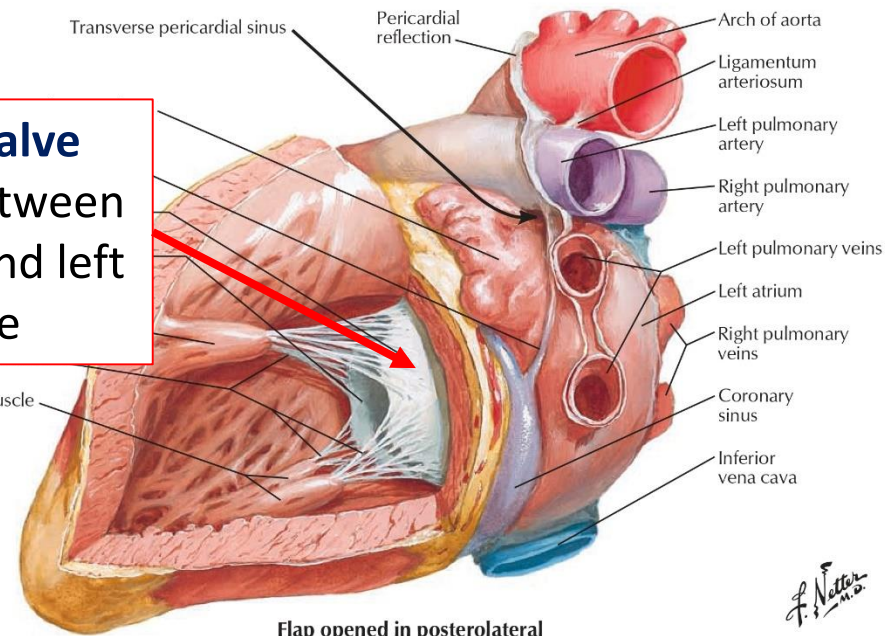


**Bicuspid valve (mitral)** – between left atrium and left ventricle

**Tricuspid valve** – between right atrium and right ventricle



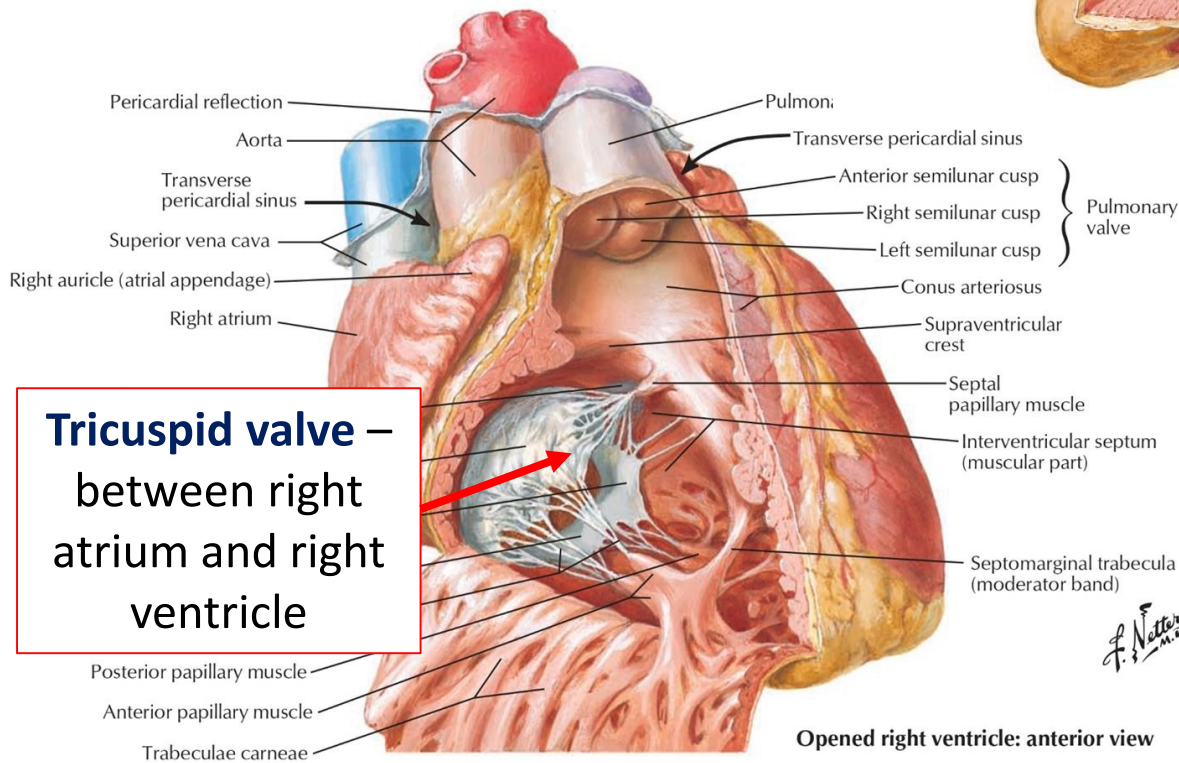
**Bicuspid valve  
(mitral) – between  
left atrium and left  
ventricle**



Flap opened in posterolateral wall of left ventricle

Posterior papillary muscle

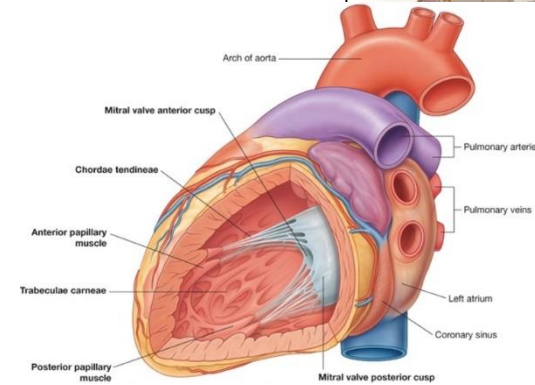
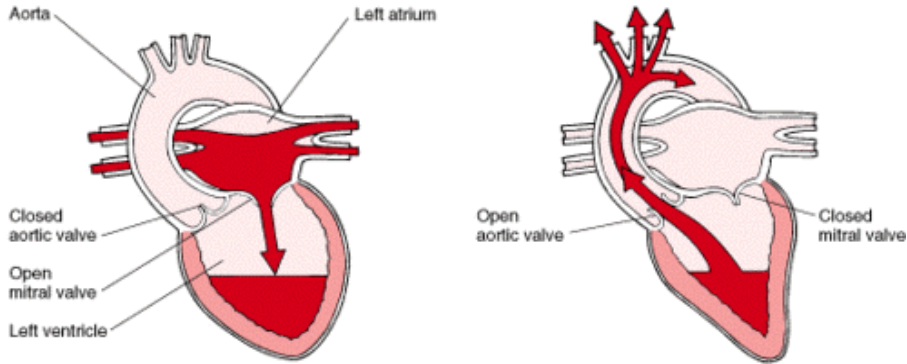
**Tricuspid valve –  
between right  
atrium and right  
ventricle**



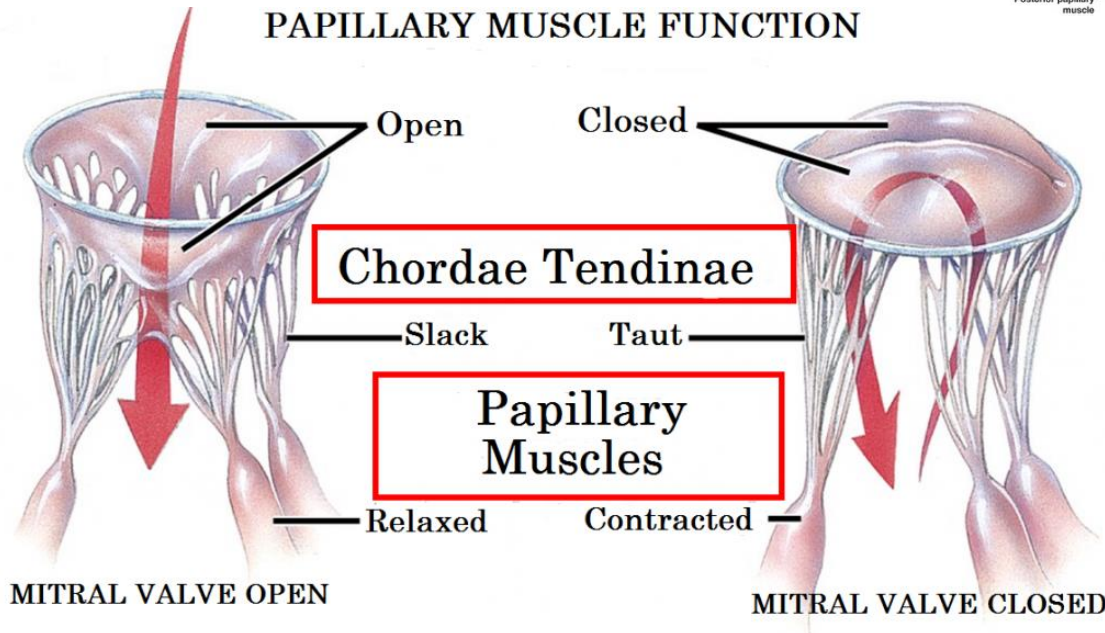
Opened right ventricle: anterior view

# Mitral valve

Normal Valve Mechanisms



## PAPILLARY MUSCLE FUNCTION



-The cusps are connected to the papillary muscles by means of the chordae tendinae.

-The chordae tendinae run from one muscle to two adjacent cusps, i.e. each papillary muscle is connected to two neighboring cusps.

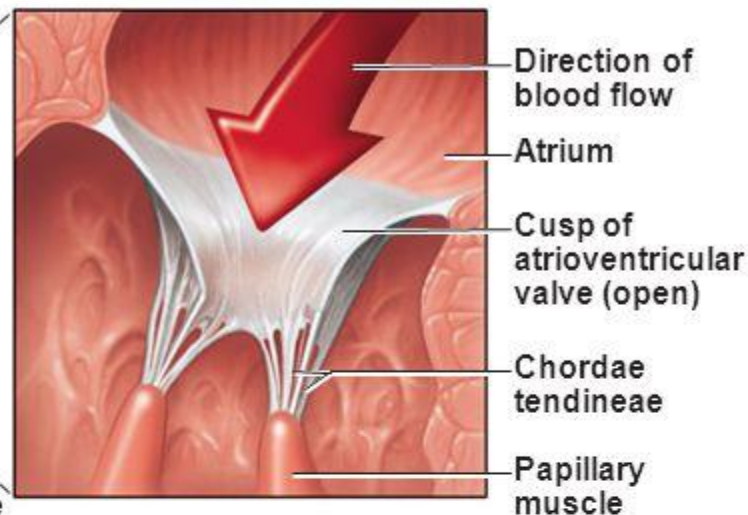
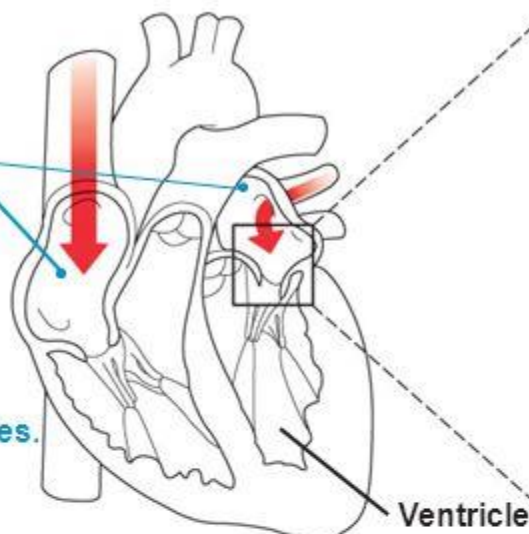
-This provides the close contact of the cusps during the systole of the ventricle resulting in the complete closure of the atrioventricular orifice.



① Blood returning to the heart fills atria, putting pressure against atrioventricular valves; atrioventricular valves are forced open.

② As ventricles fill, atrioventricular valve flaps hang limply into ventricles.

③ Atria contract, forcing additional blood into ventricles.

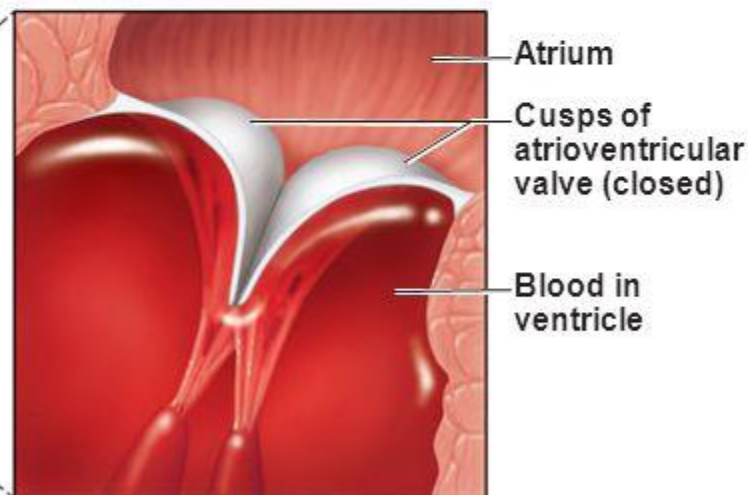
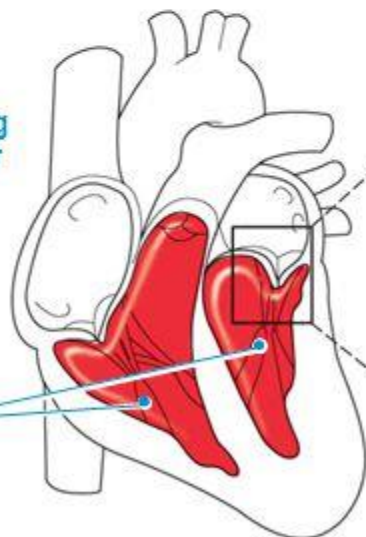


**(a) AV valves open; atrial pressure greater than ventricular pressure**

① Ventricles contract, forcing blood against atrioventricular valve cusps.

② Atrioventricular valves close.

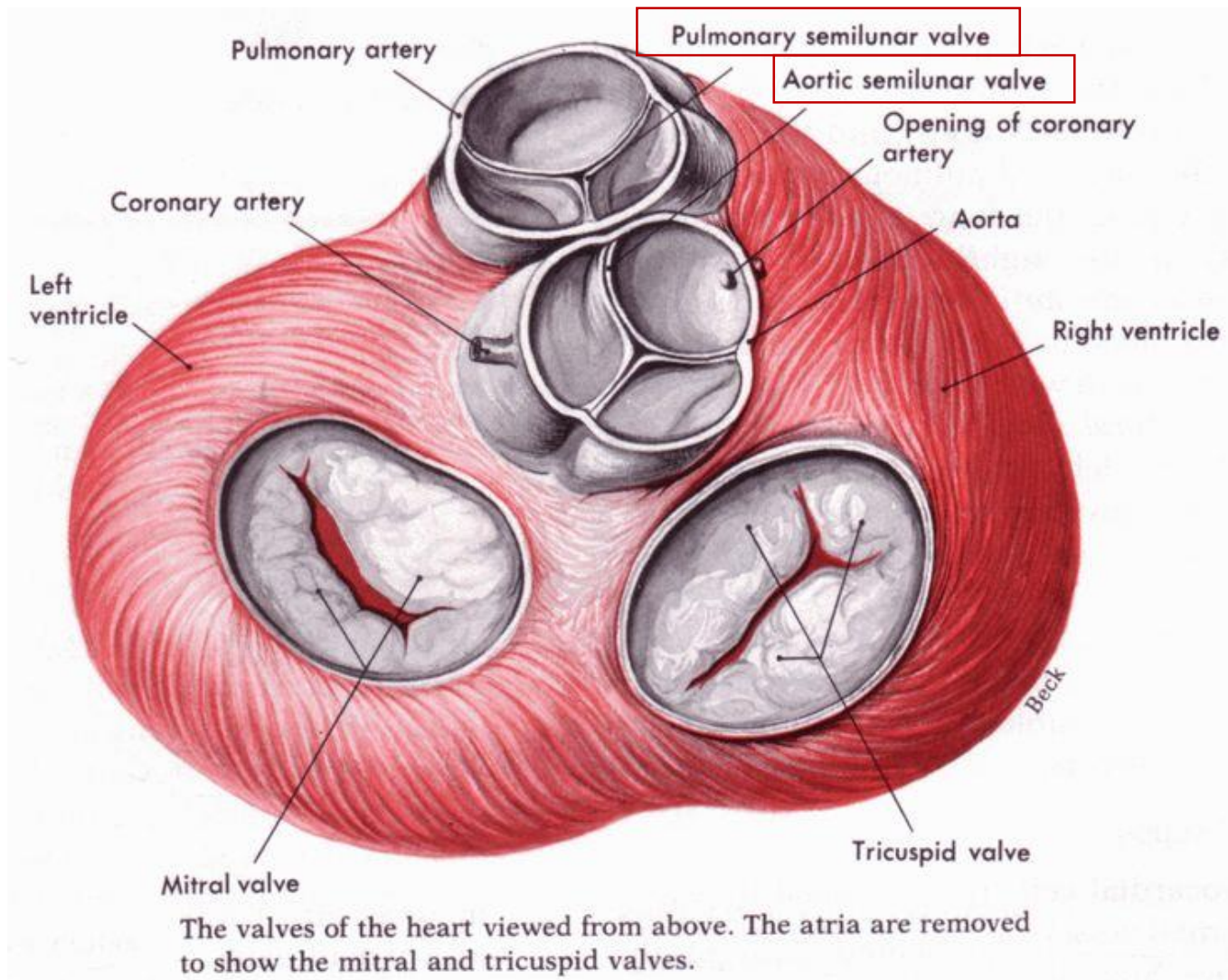
③ Papillary muscles contract and chordae tendineae tighten, preventing valve flaps from everting into atria.



**(b) AV valves closed; atrial pressure less than ventricular pressure**

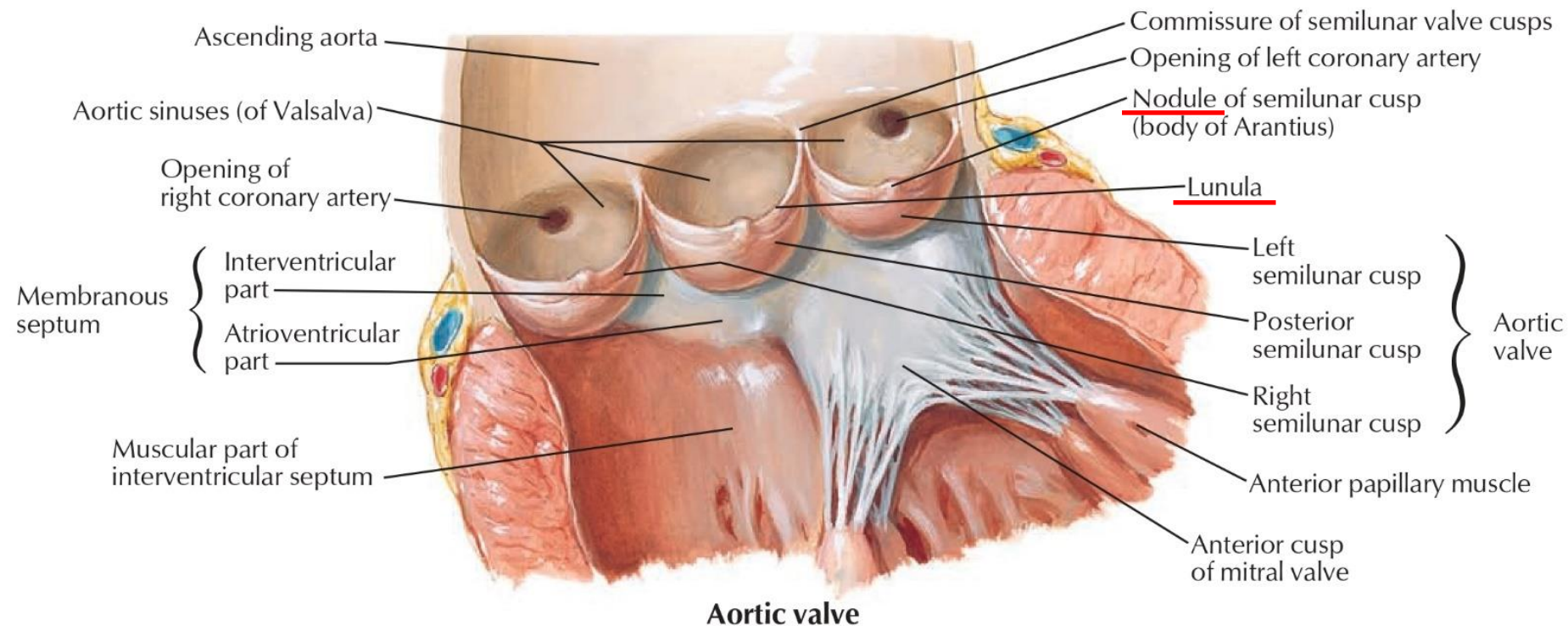


# Semilunar cusps

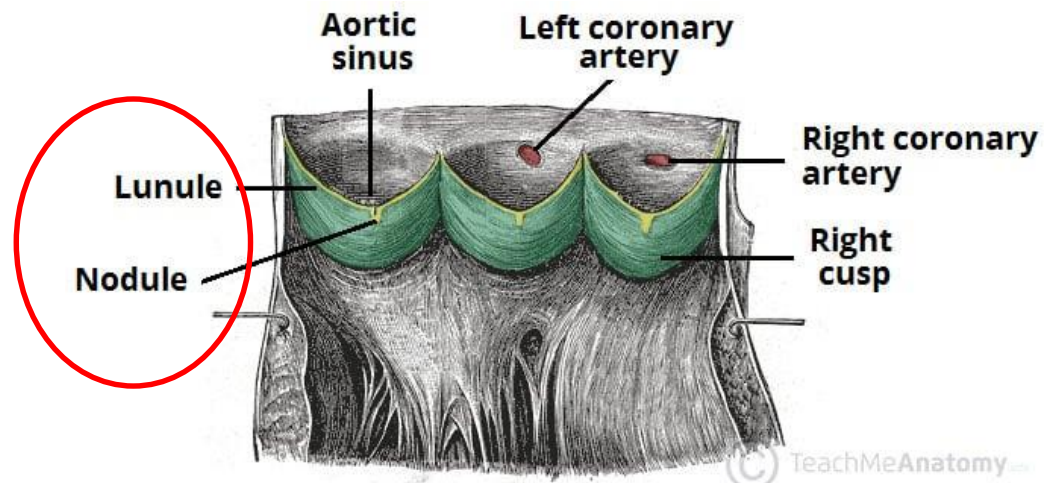


**Aortic valve** – between left ventricle and aorta

**Pulmonary valve** – between right ventricle and pulmonary trunk



During the diastole the blood fills the space between the cusps and the pulmonary trunk's wall (i.e. fills the lunules), the nodules get close to each other and contribute to more complete closure of the cusps.

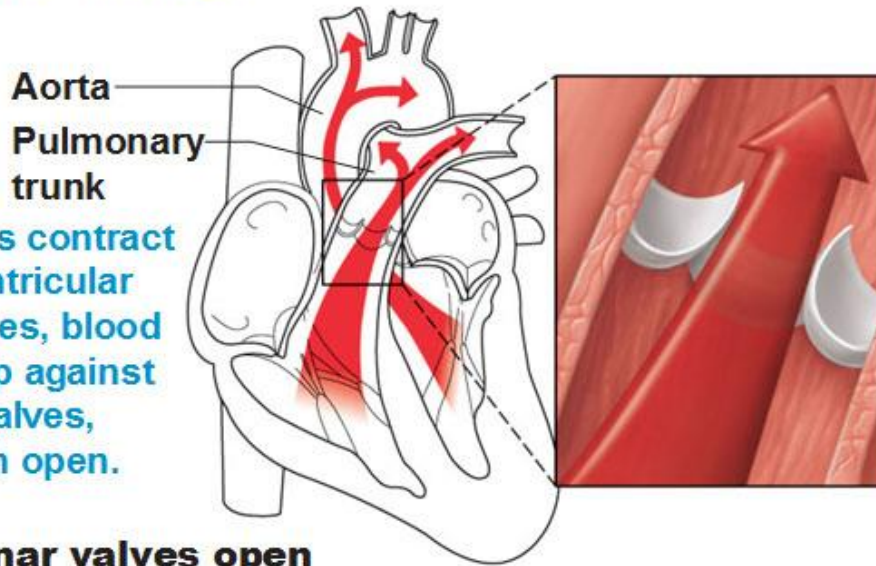




# Function of the Semilunar Valves

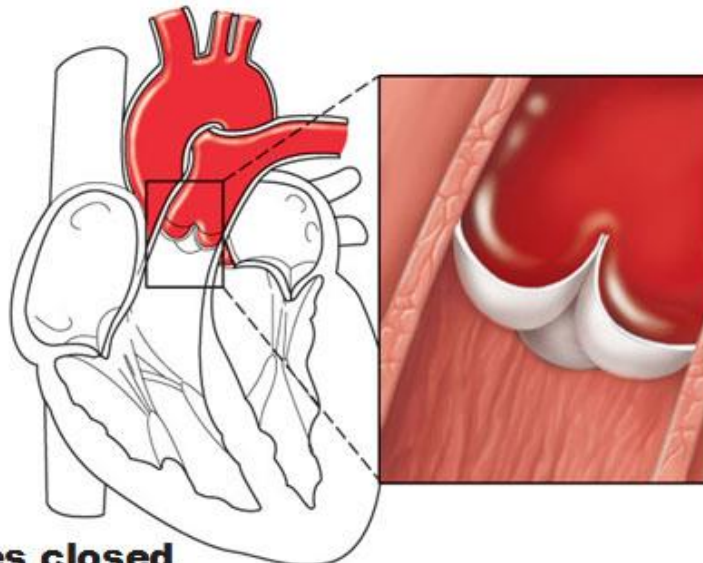
When semilunars close, you hear 2<sup>nd</sup> heart sound, with aortic slightly before pulmonary

As ventricles contract and intraventricular pressure rises, blood is pushed up against semilunar valves, forcing them open.



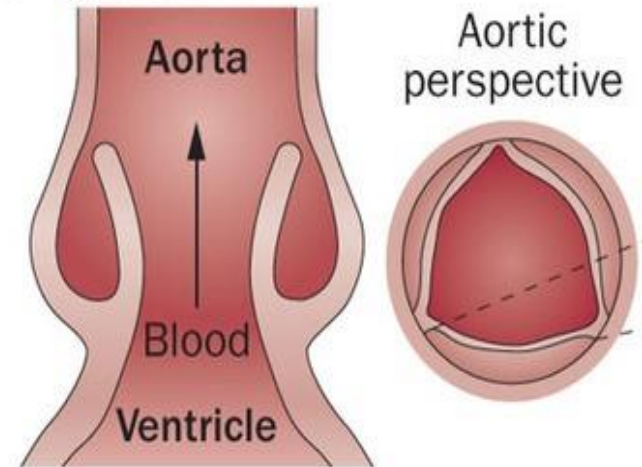
**(a) Semilunar valves open**

As ventricles relax and intraventricular pressure falls, blood flows back from arteries, filling the cusps of semilunar valves and forcing them to close.

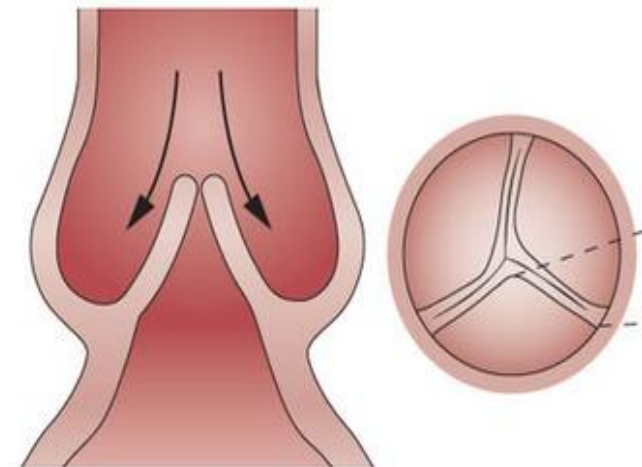


**(b) Semilunar valves closed**

**a Systole**

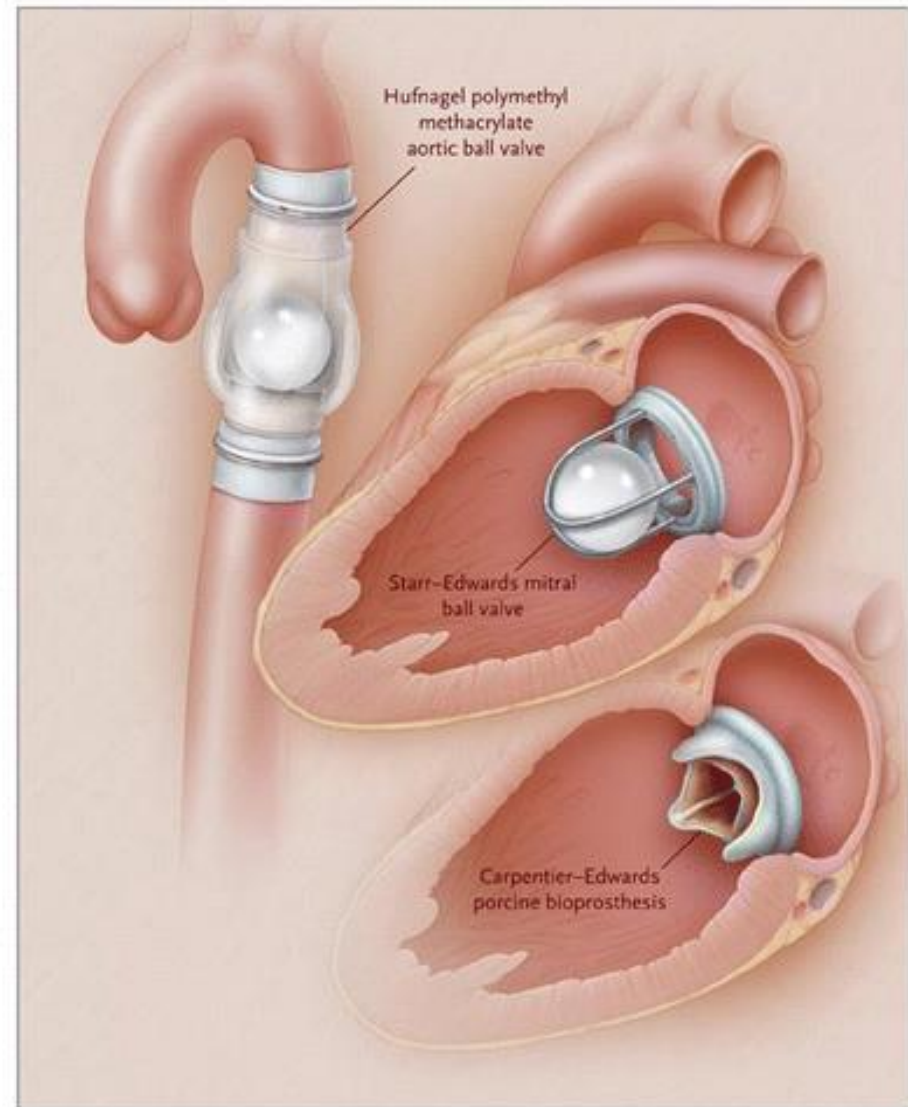
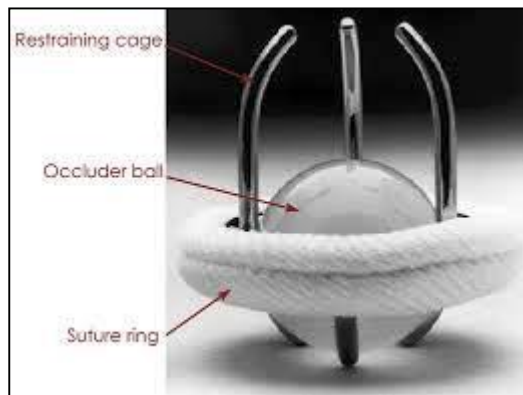
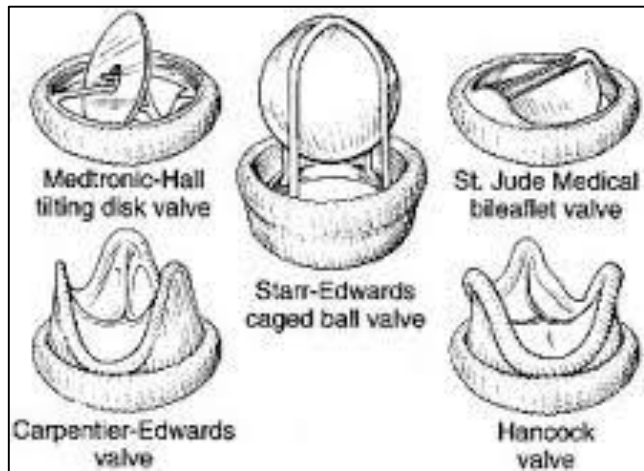


**b Diastole**

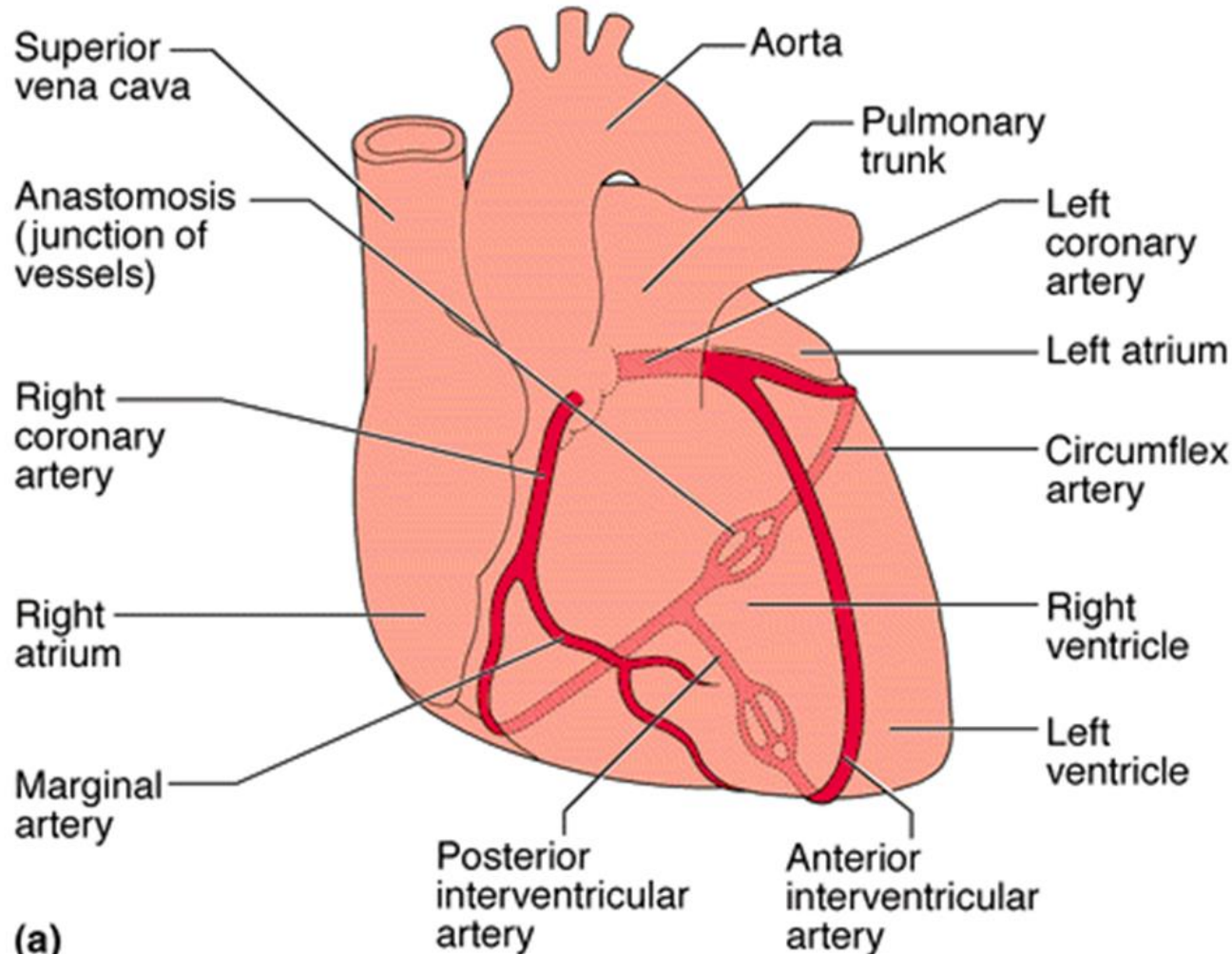




# Cusp prosthetics



# Coronary arteries



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## Left coronary artery:

- Anterior interventricular artery
- Circumflex artery

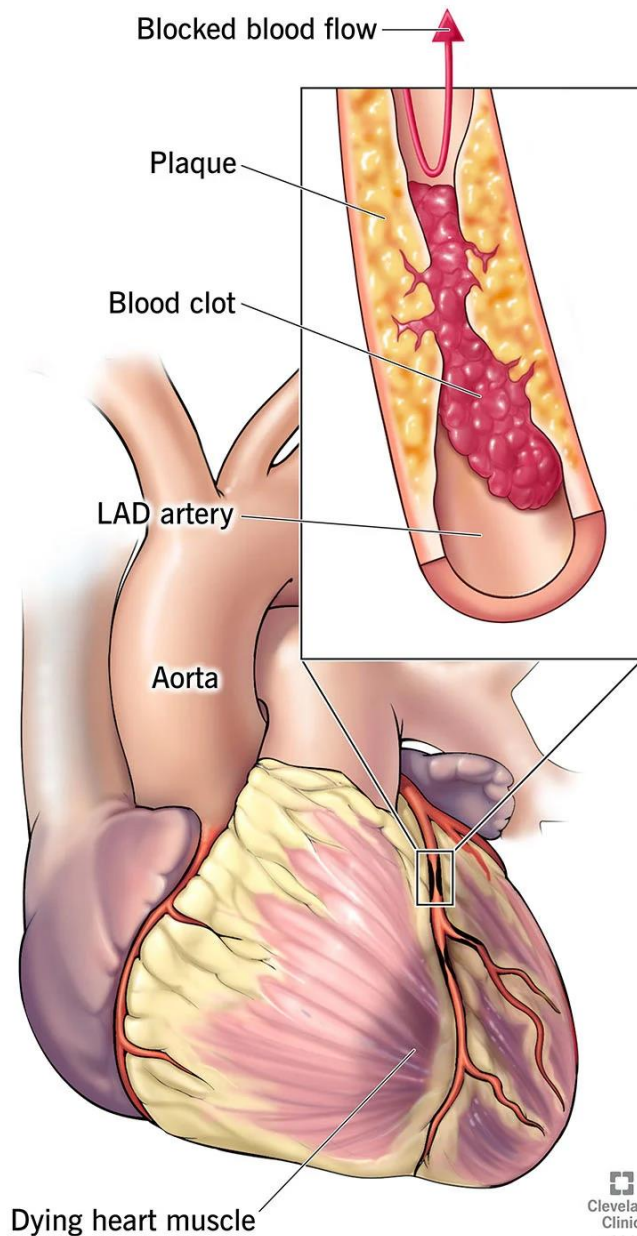
## Right coronary artery:

- Posterior interventricular artery
- Marginal artery

**Widow-maker artery**

## Widowmaker Heart Attack

*Myocardial infarction*



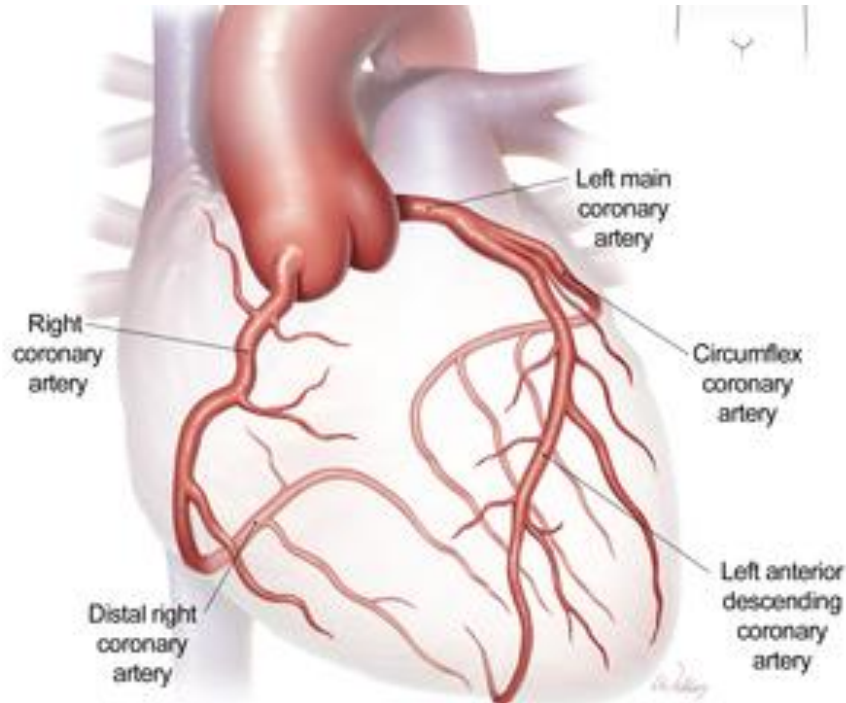
**Anterior interventricular artery =  
Left Anterior Descending artery (LAD artery)  
= Widow maker artery**

### How serious is a widowmaker heart attack?

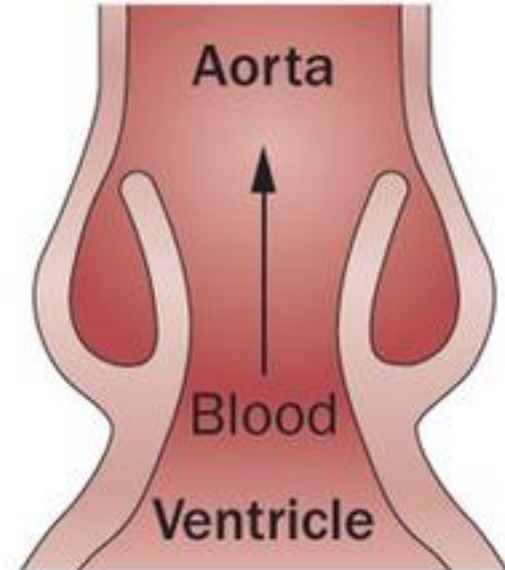
- A widowmaker heart attack is immediately life-threatening. This is because the LAD provides about 50% of your heart muscle's blood supply.



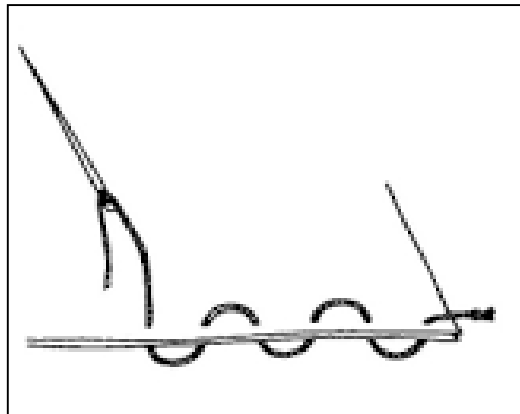
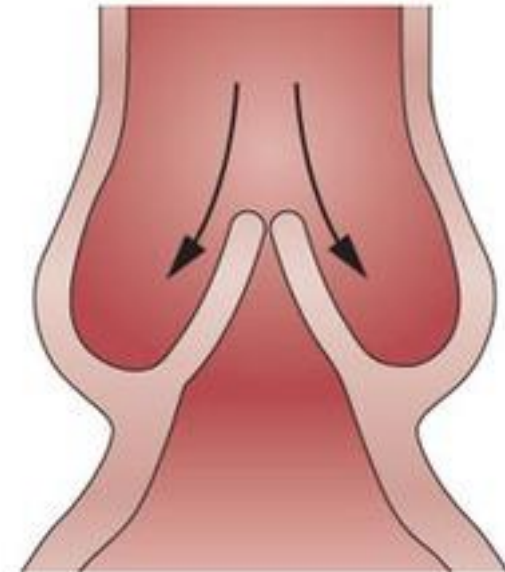
# The heart receives blood supply during diastole!



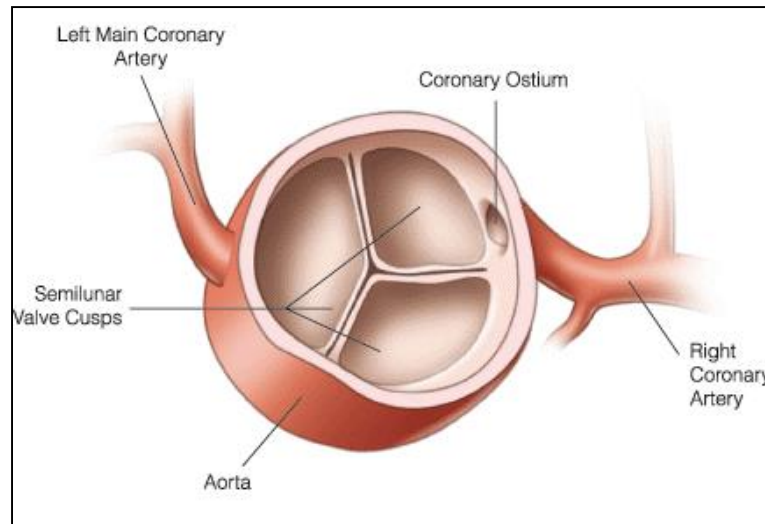
## a Systole

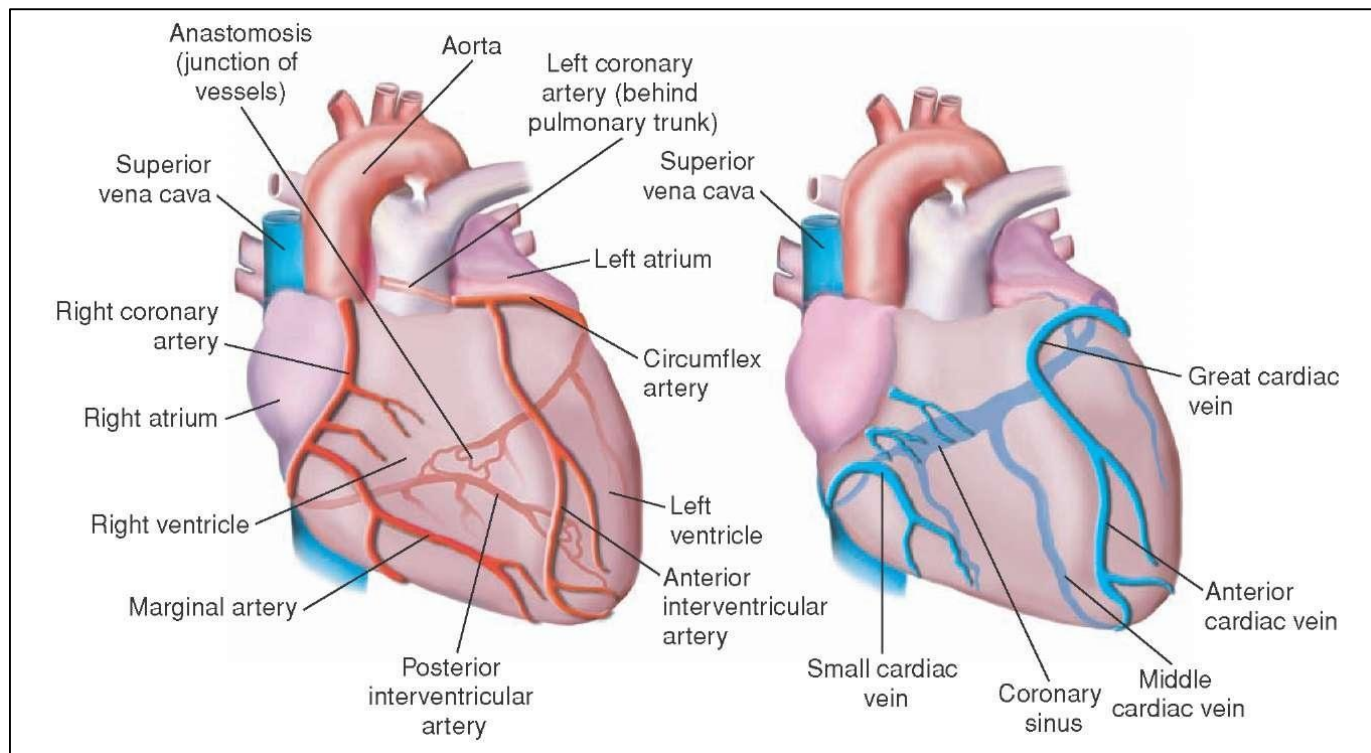


## b Diastole



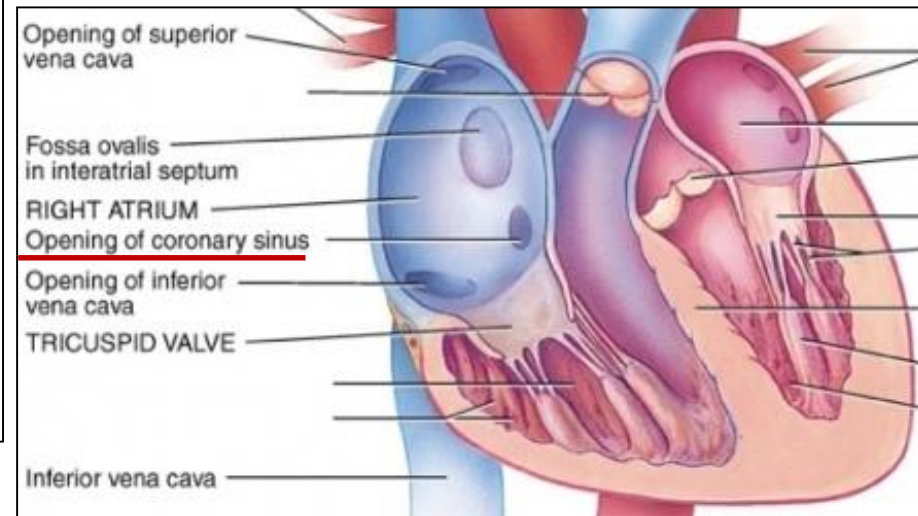
The way coronary arteries pass between cardiomyocytes

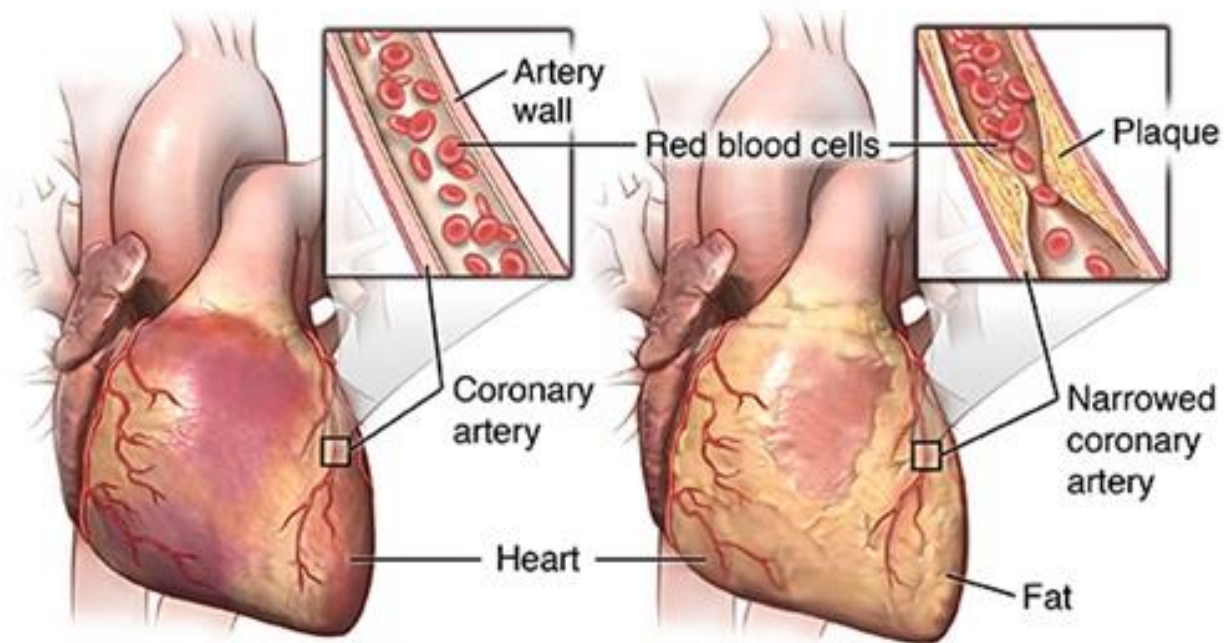




### Venous drainage of the heart:

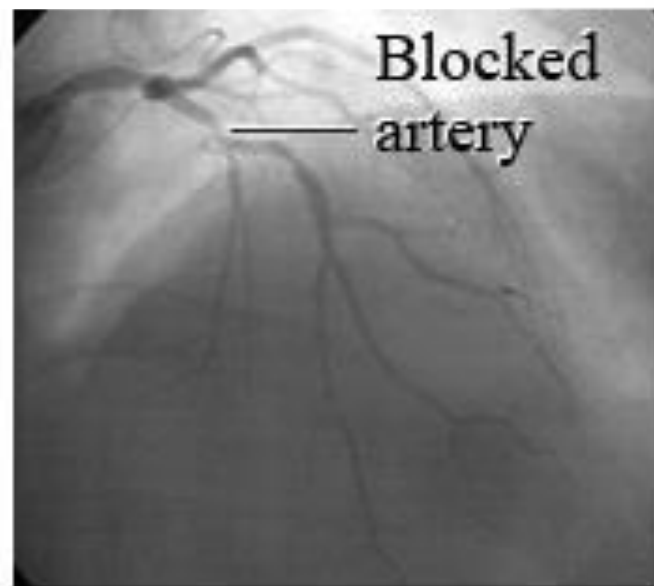
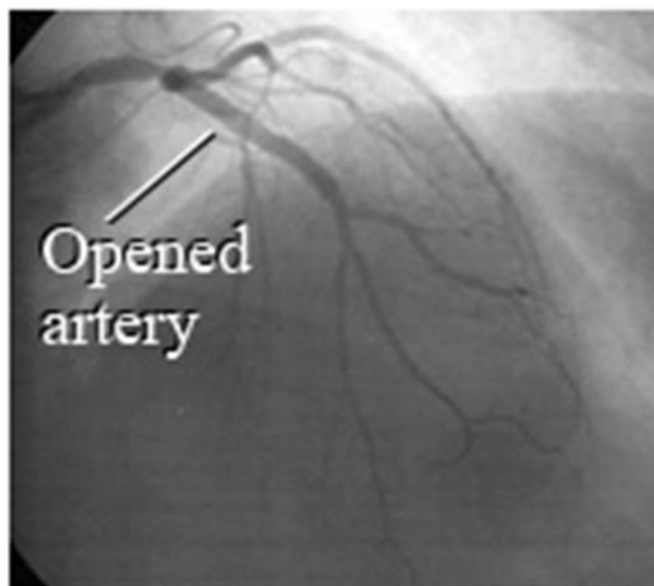
- The great cardiac vein
- The middle cardiac vein
- The small cardiac vein
- The posterior vein of the left ventricle
- The oblique vein of the left atrium
- The smallest cardiac veins and anterior cardiac veins





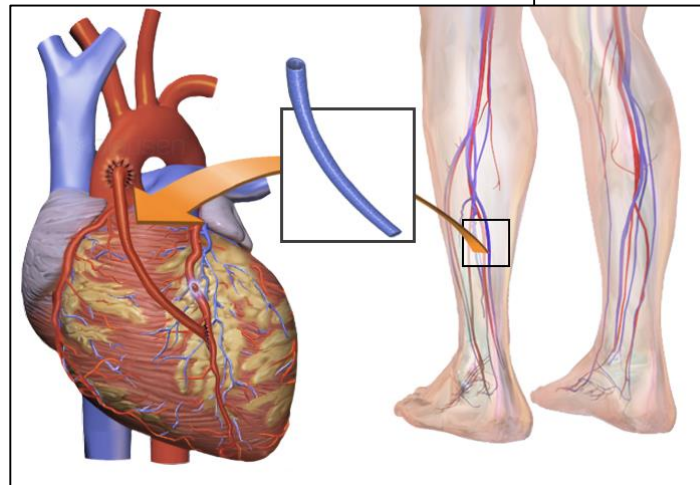
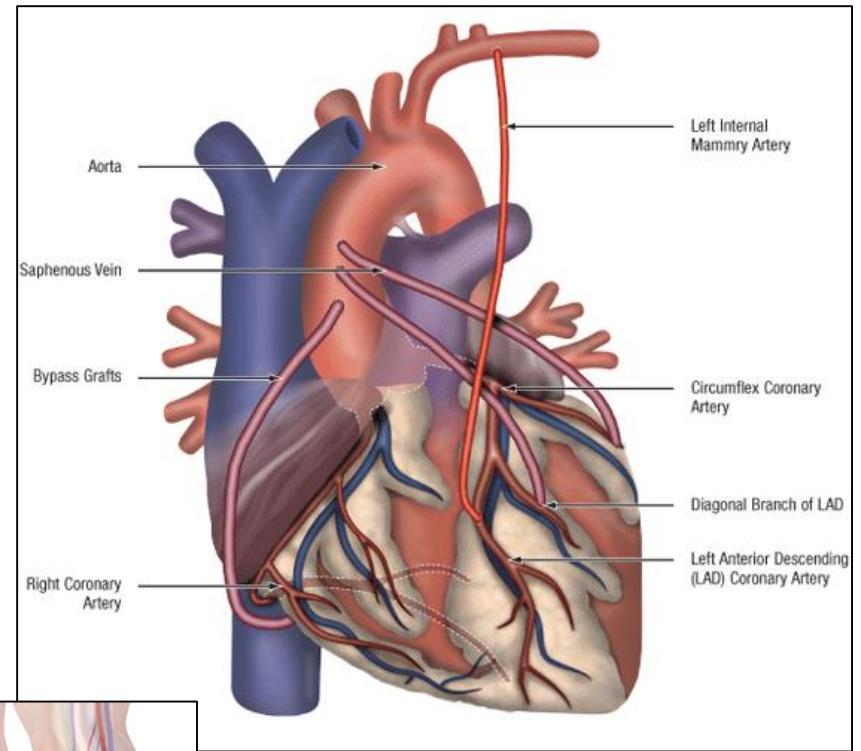
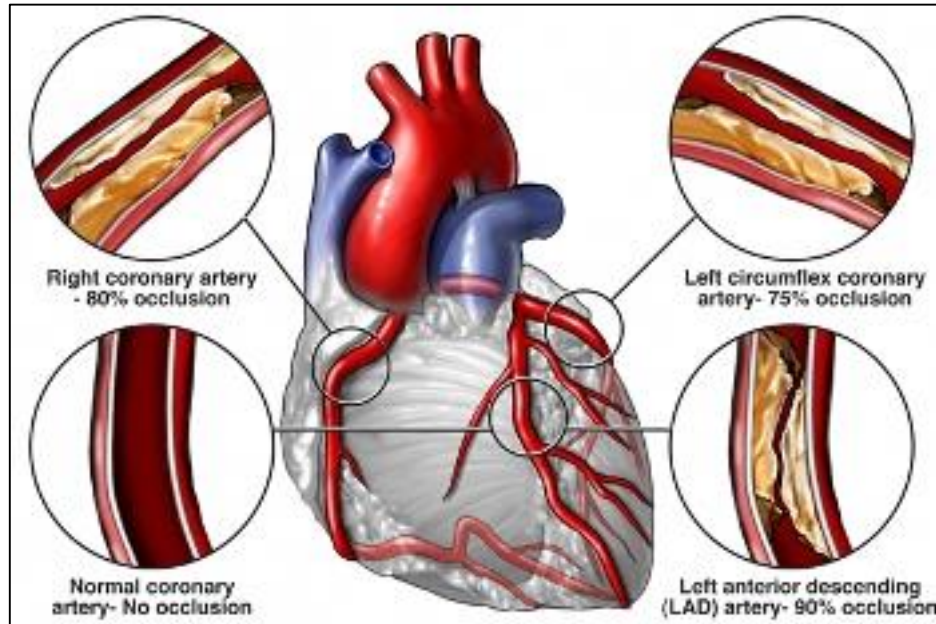
**Normal heart and artery**

**Artery with plaque buildup**

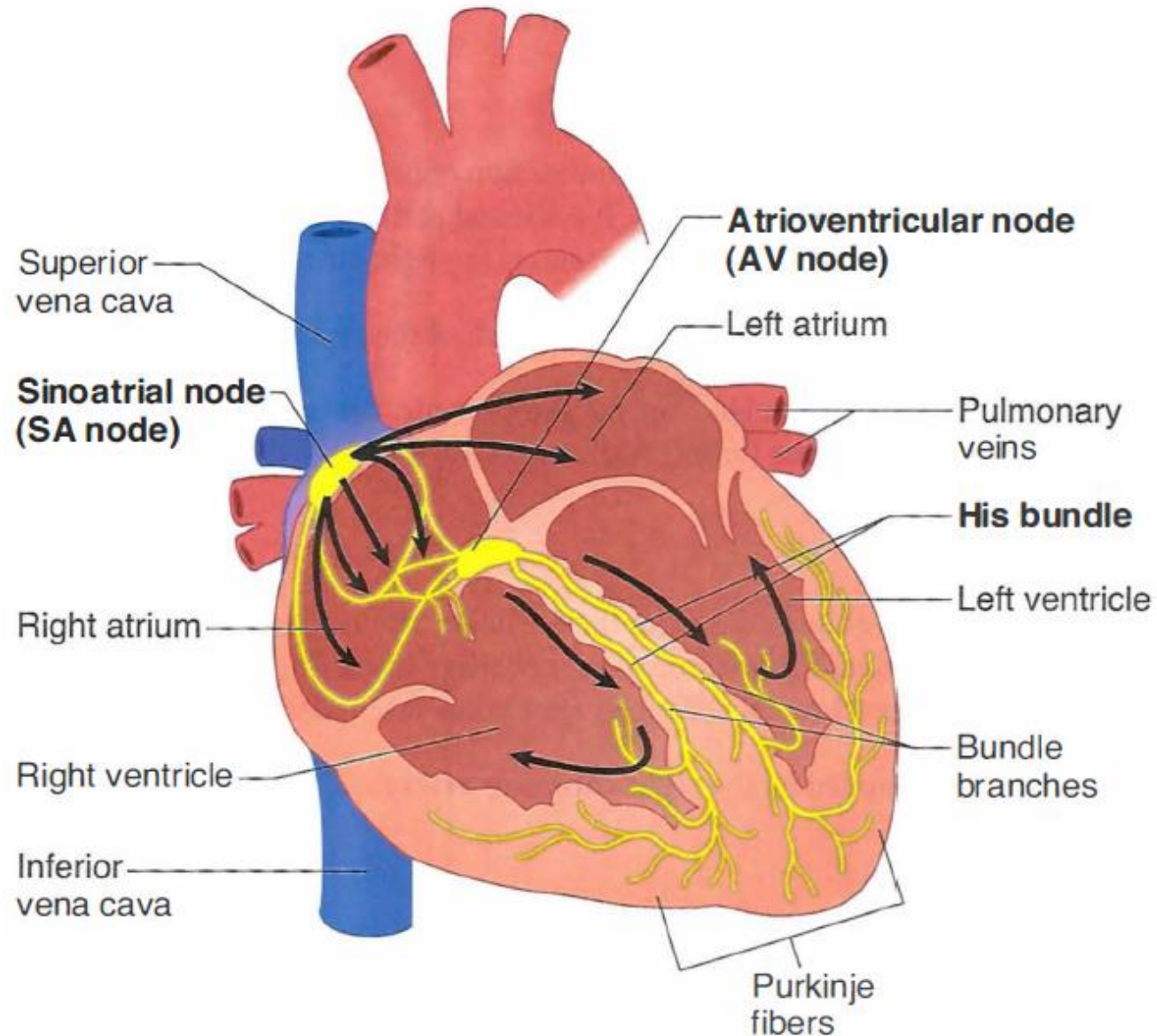




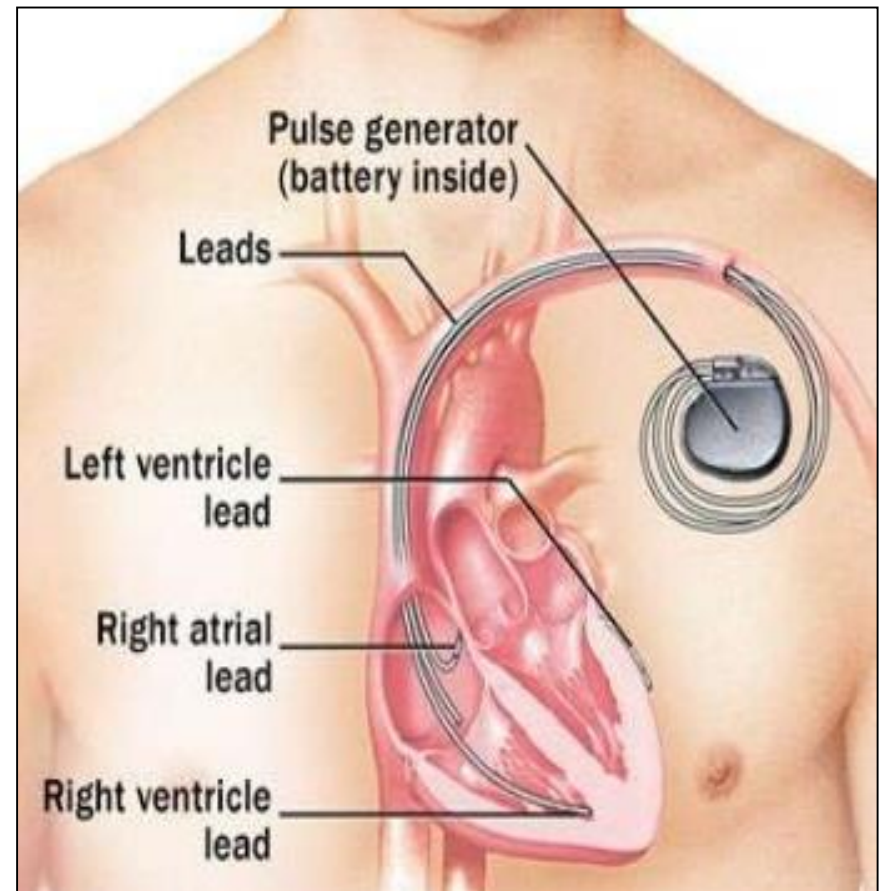
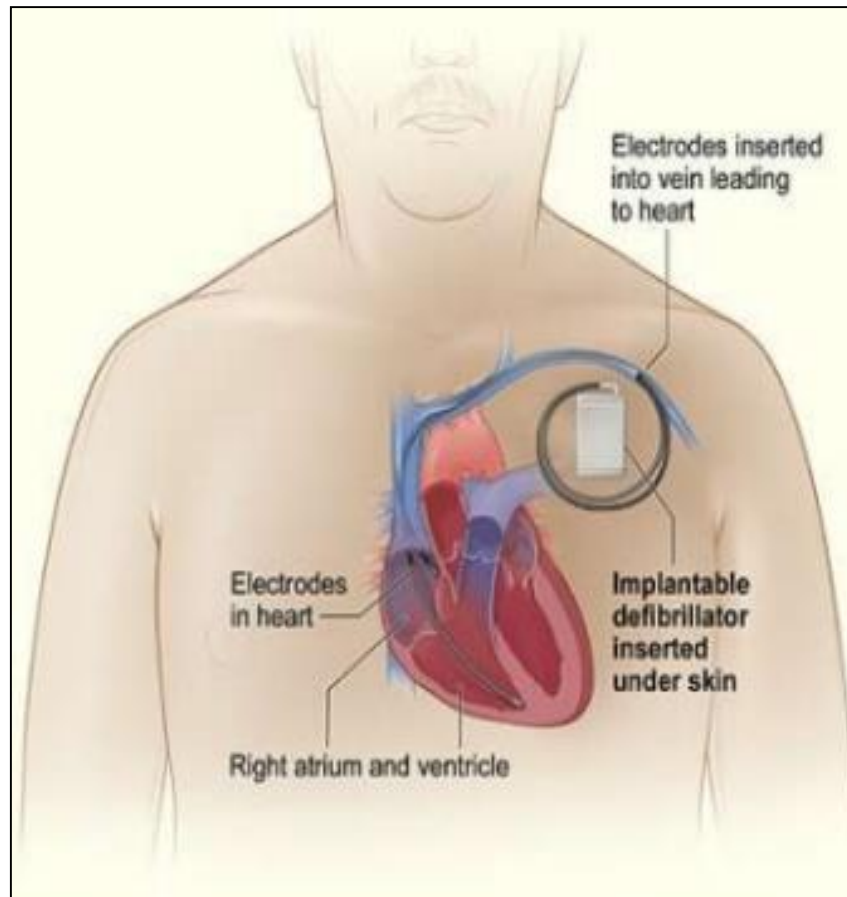
# Coronary artery bypass grafting (CABG)



# Conducting system of the heart



# Artificial pacemaker (pulse generator)



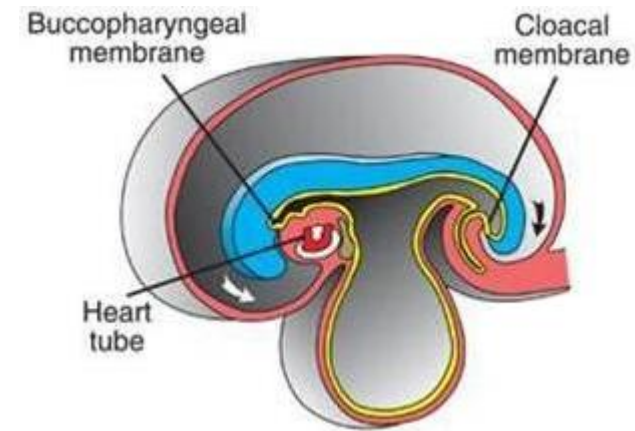
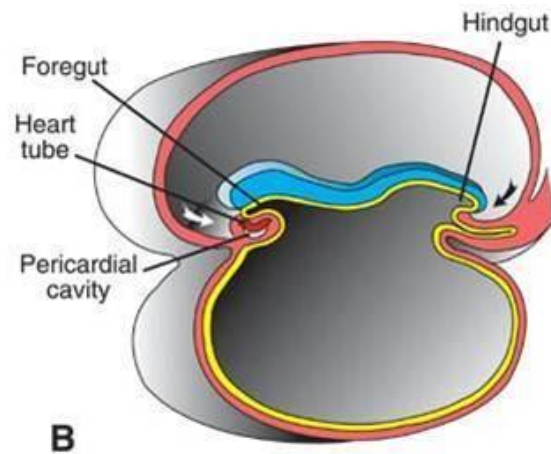
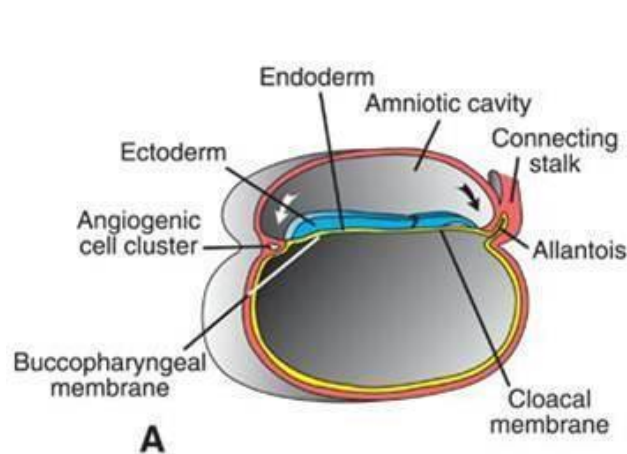
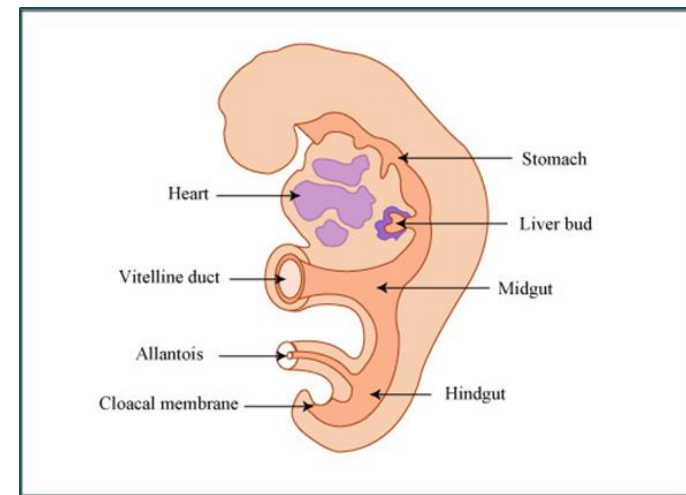


# Development of the heart



The heart begins to develop at 3 weeks of fetal development under the pharynx

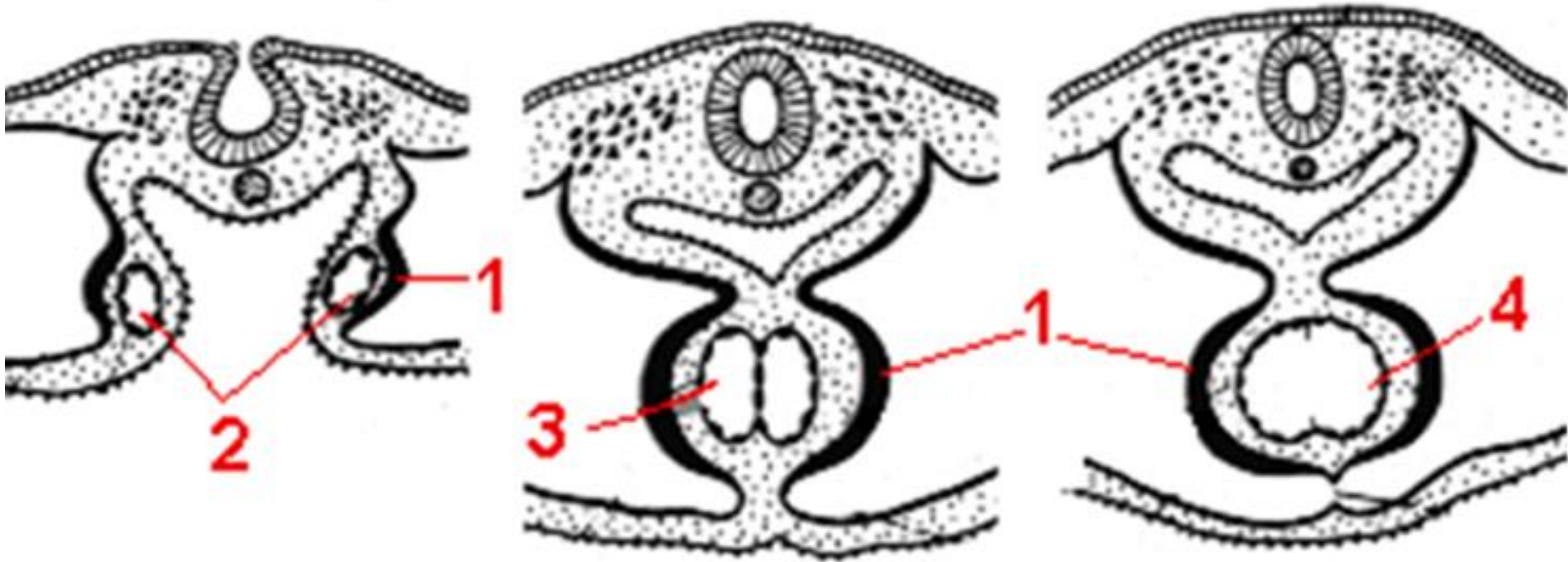
# Development of the heart



## 3<sup>rd</sup> week

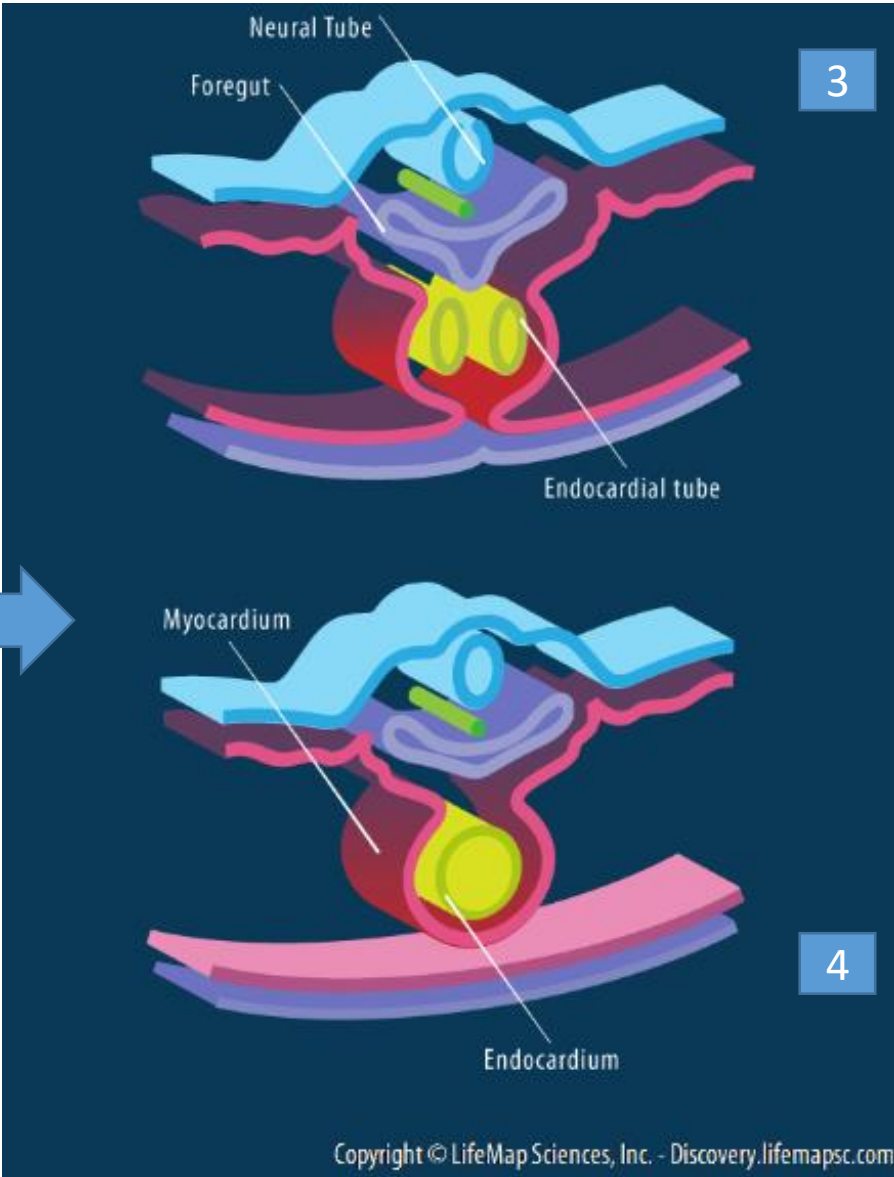
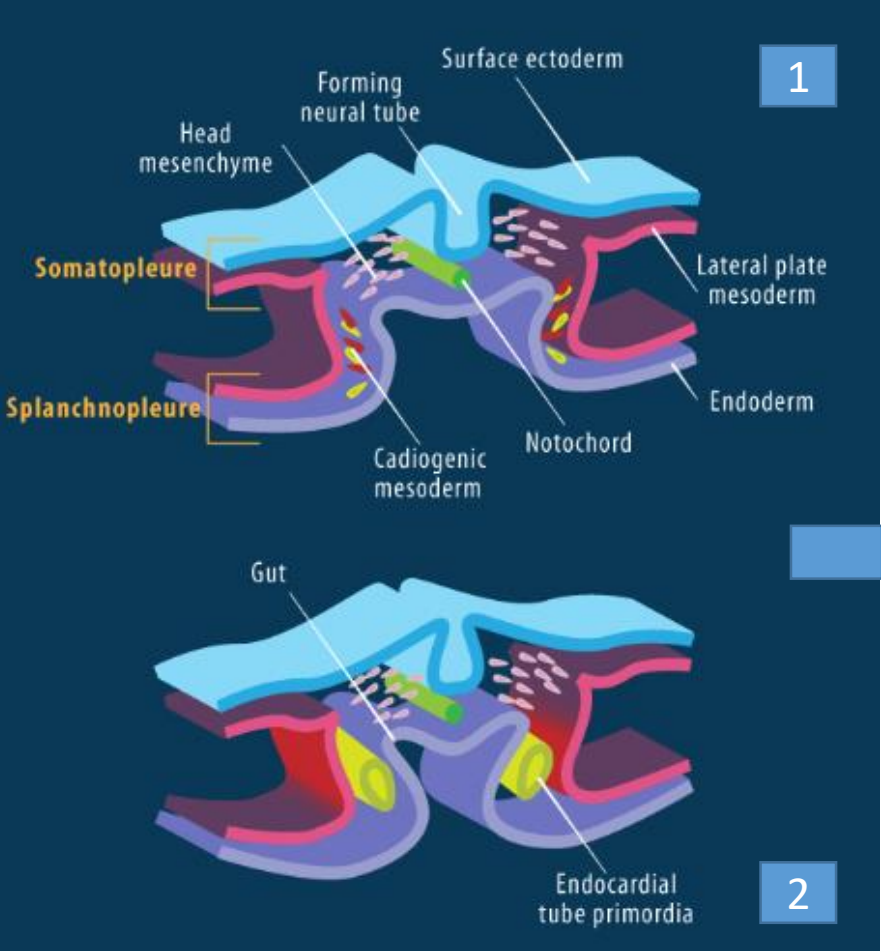
- from splanchnic mesoderm within the cardiogenic area of the cranial end of the embryo
- the cardiogenic cells condense to form a pair of primordial heart tubes

# Development of the heart



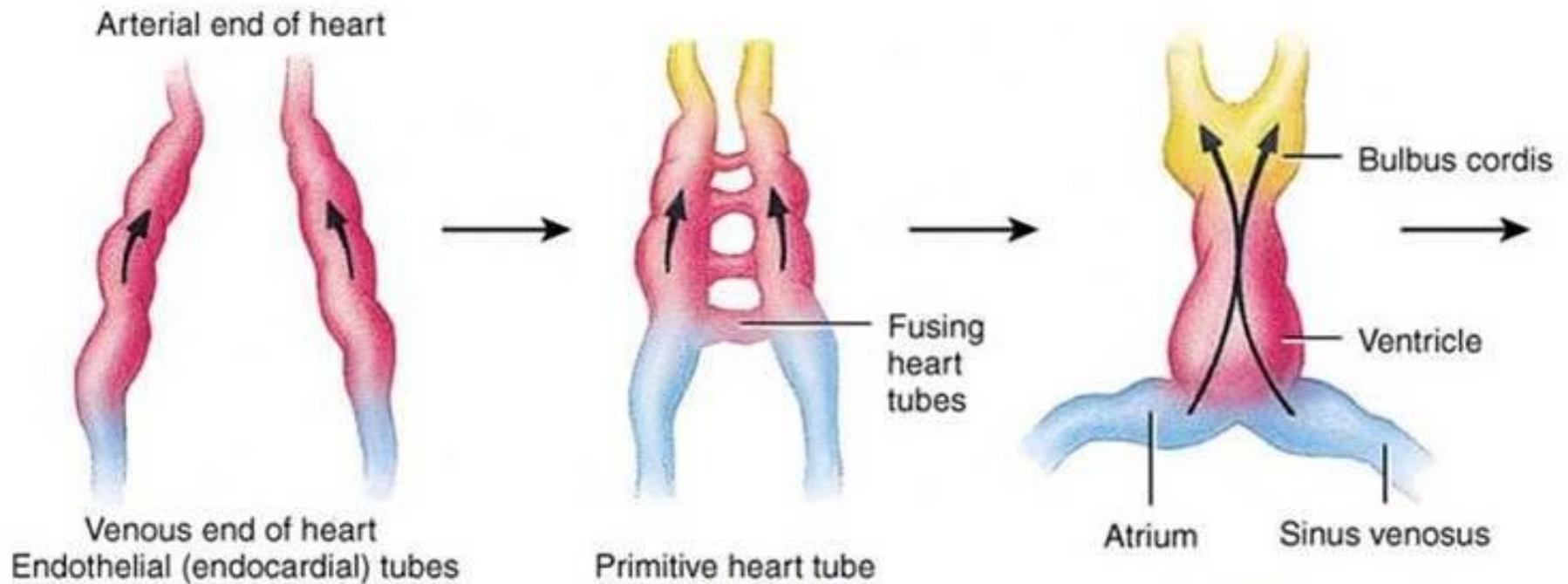
- 1 - epimyocardial plates (epicard and myocard)
- 2 – endocardial bulbs
- 3 – endocardial tubes
- 4 – tubular heart





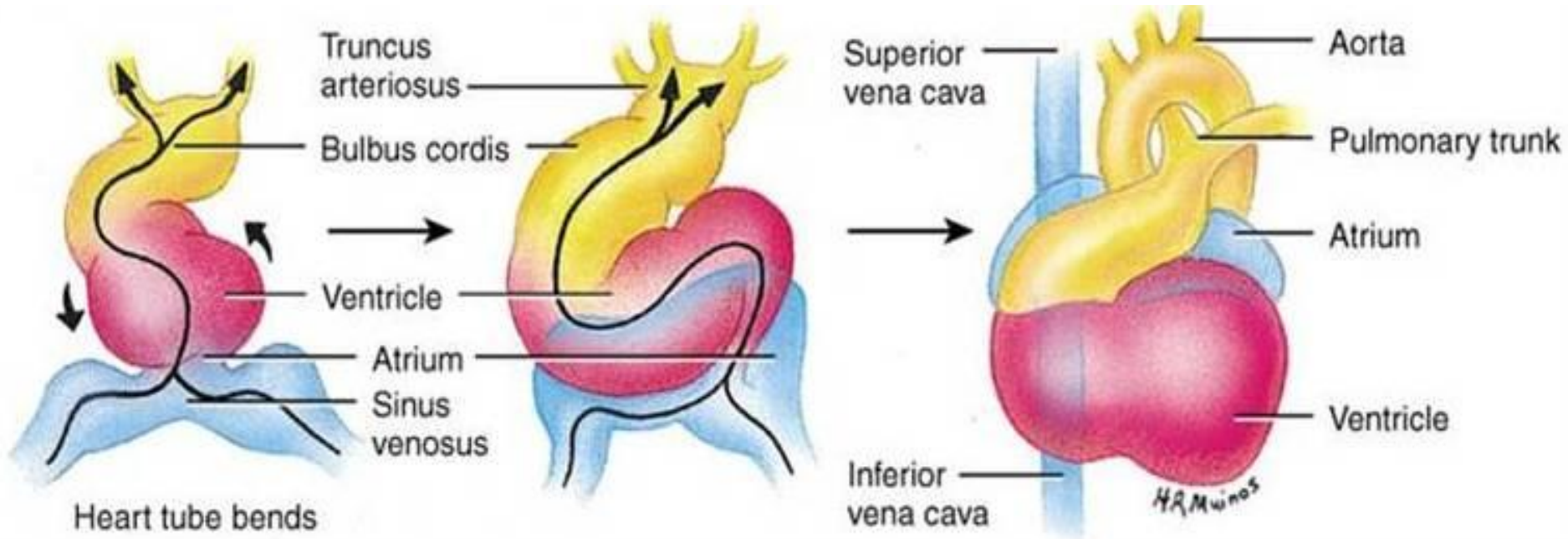
# These structures can be distinguished in the tube heart

- Arterial cone
- Single Ventricle
- Single atrium
- Venous sinus



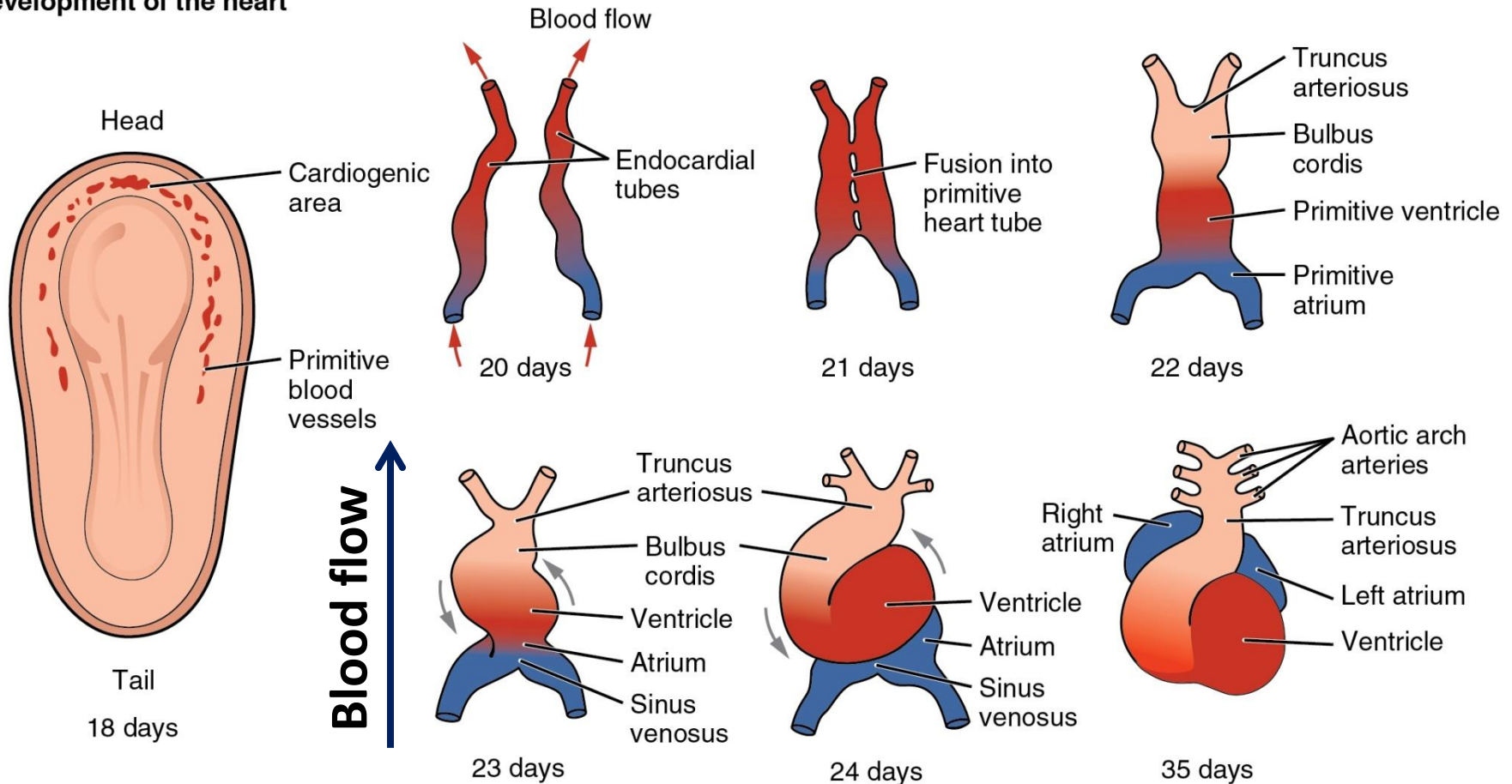
# Development of the heart

- Venous sinus and atria moves up and back
- Ventricle goes front and to the left
- Arterial cone moves front and down





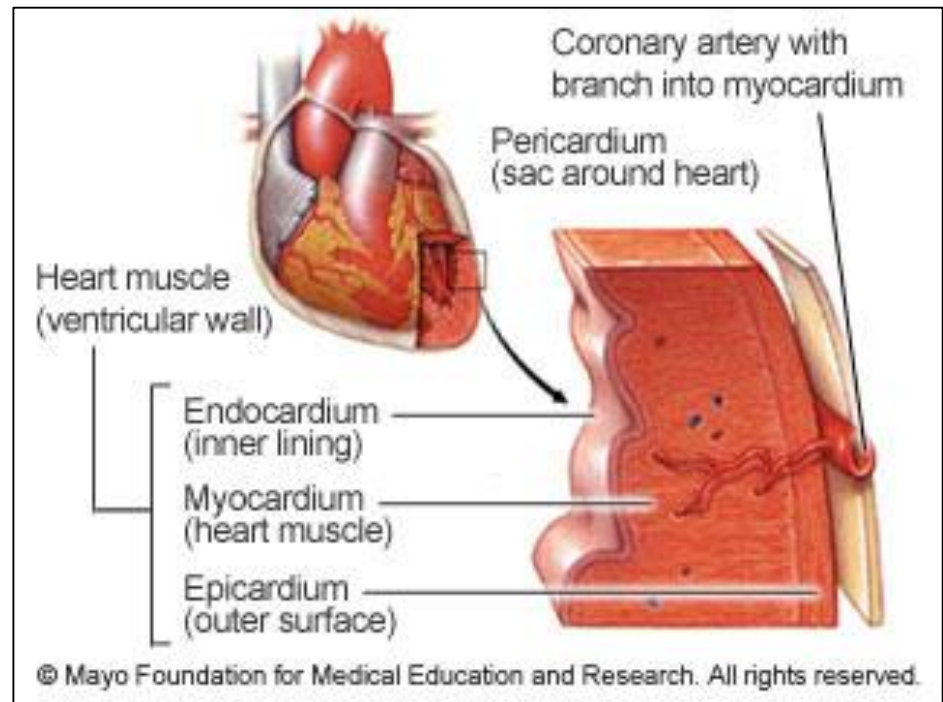
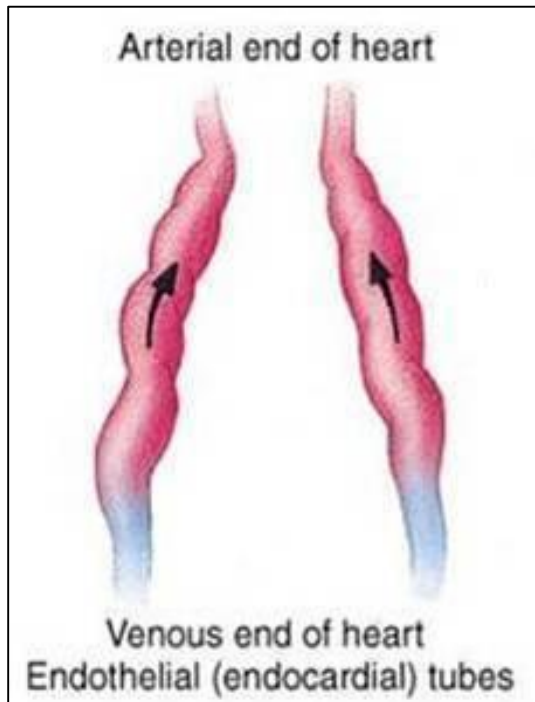
## Development of the heart



- The heart tube undergoes dextral looping (bends to the right) and rotation.
- The upper truncus arteriosus (ventricular) end of the tube grows more rapidly and folds downward and ventrally and to the right.
- The atria and sinus venosus lower part of the tube fold upward and dorsally and to the left.

**The 4<sup>th</sup> week – first contraction of the myocardium!**

# Development of the heart



Cells of the endocardial tube



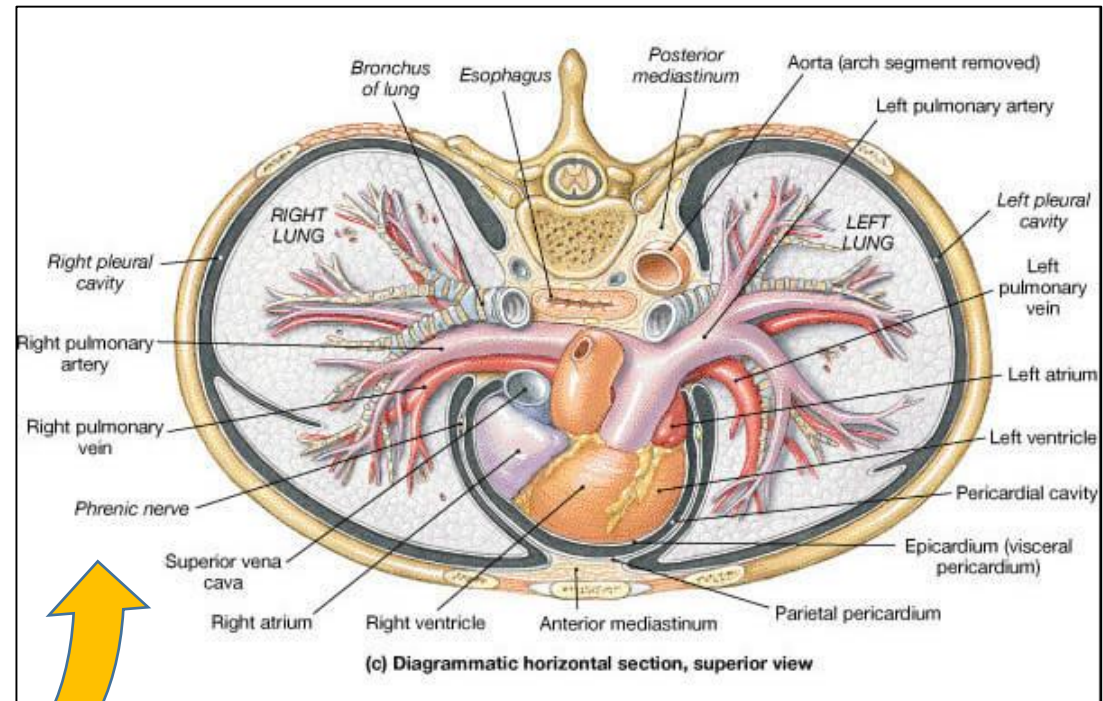
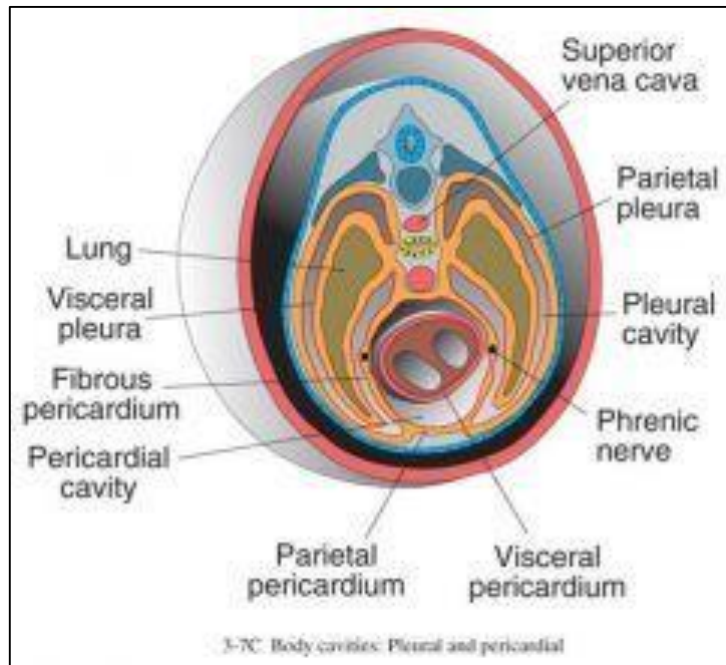
Endocardium

Visceral mesoderm  
surrounding the primitive  
heart tube



Myocardium

# Development of the pericardium



Intraembryonic body cavity (coelom)



Pericardial cavity

Somatic mesoderm



Parietal pericardium

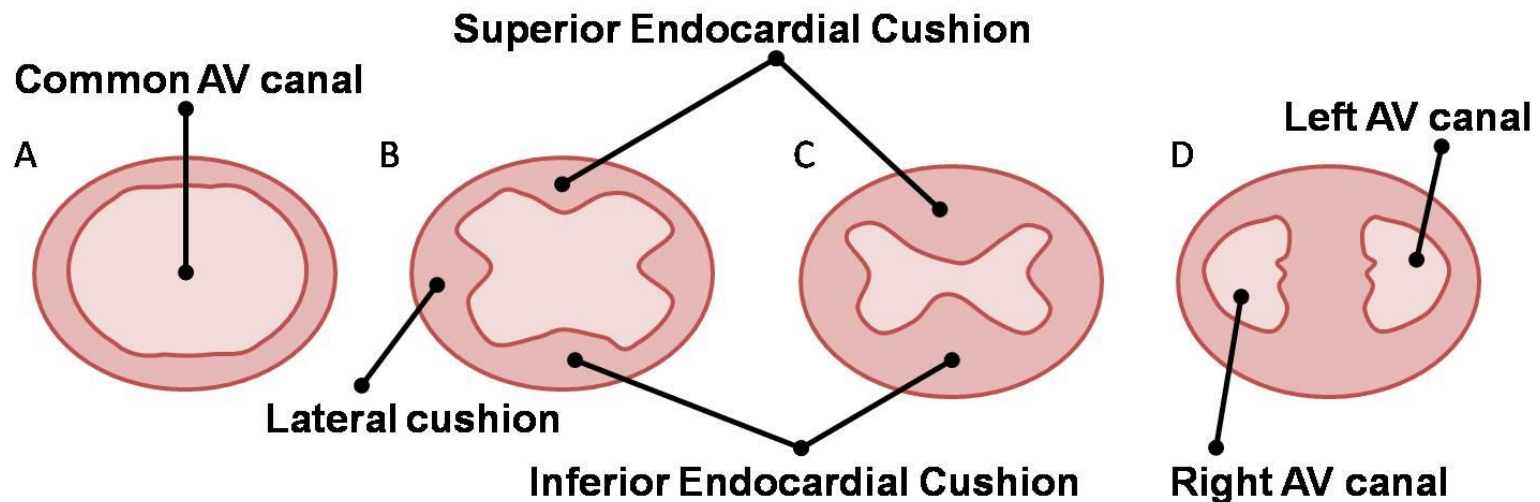
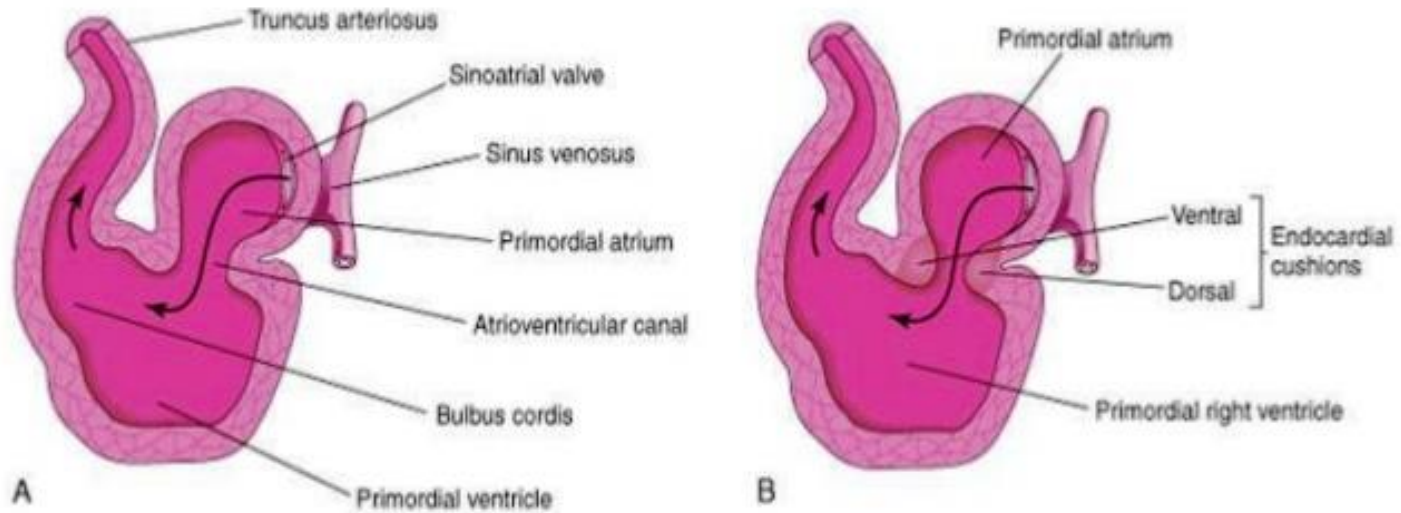
Splanchnic mesoderm



Visceral pericardium (epicardium)



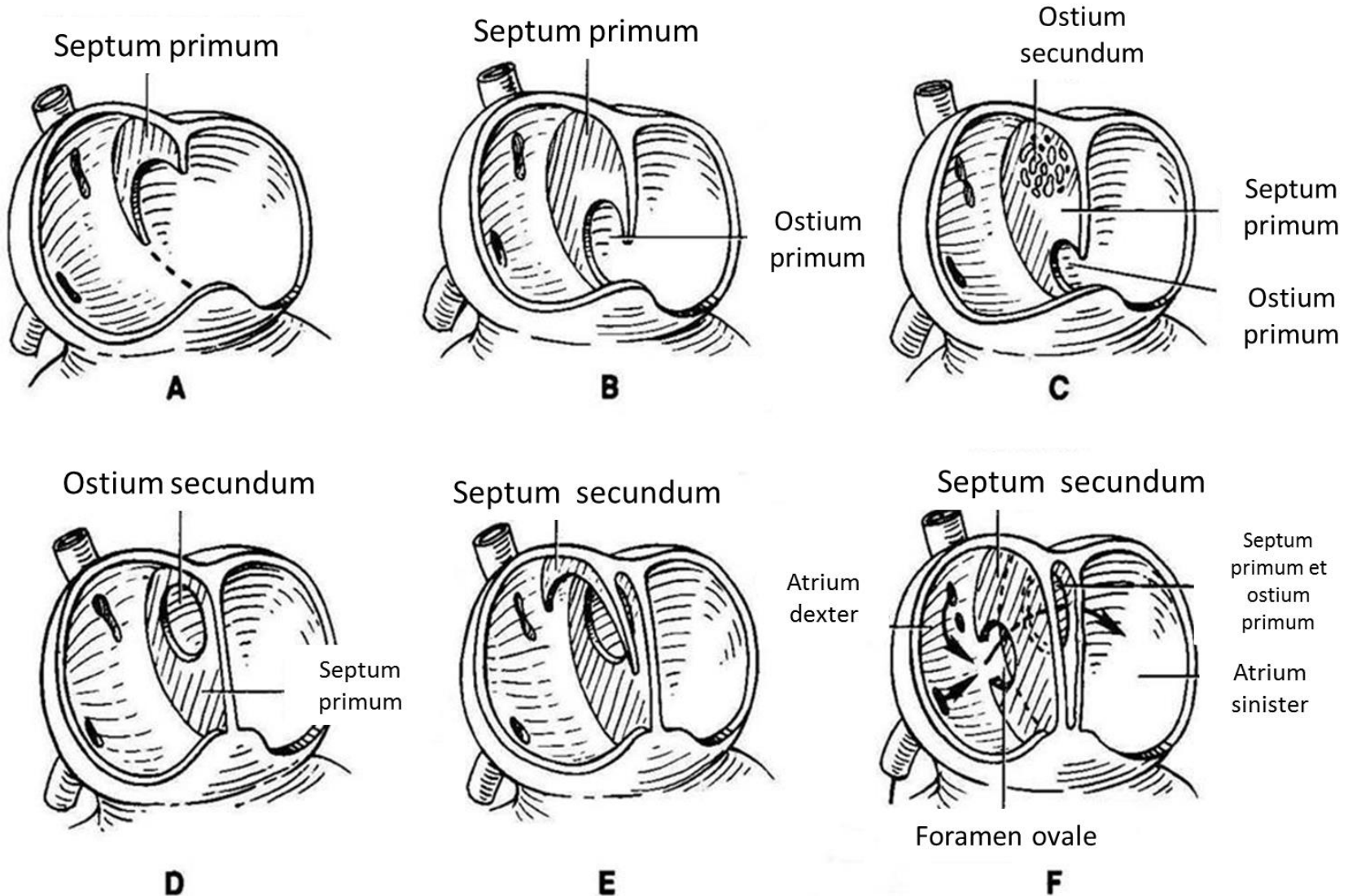
# Atrioventricular partition – formation of the AV valves (5<sup>th</sup> week)



## Partition of the heart – formation of the left (arterial) and right (venous) parts

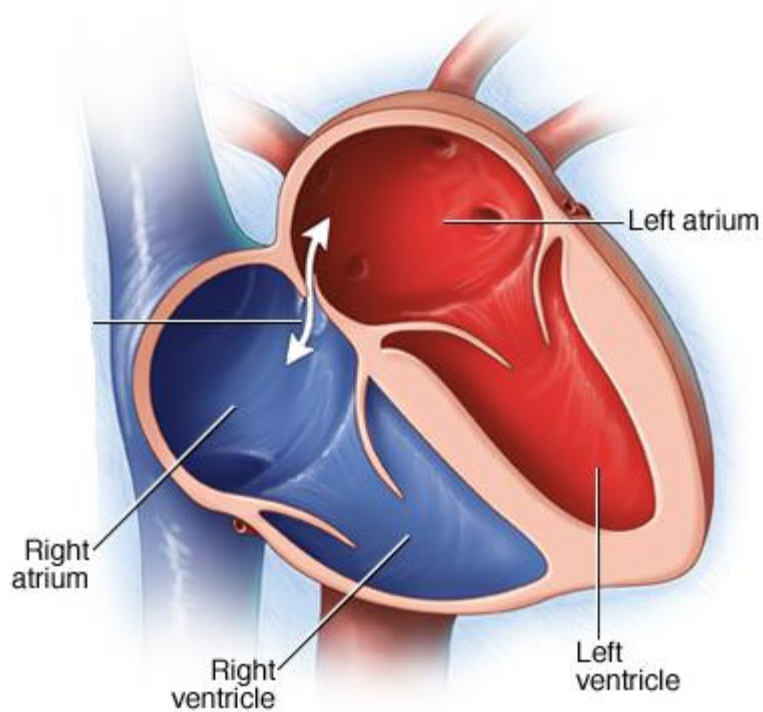
1. Development of atrial septum
2. Development of ventricular septum
3. Development of arterial truncus septum

# Partition of the left and right atrium





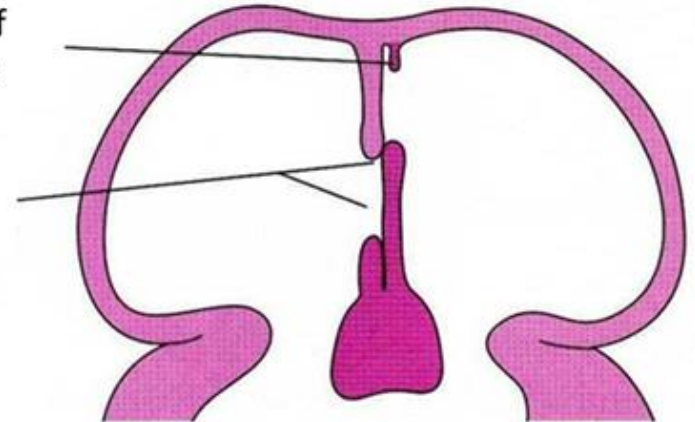
# Foramen ovale



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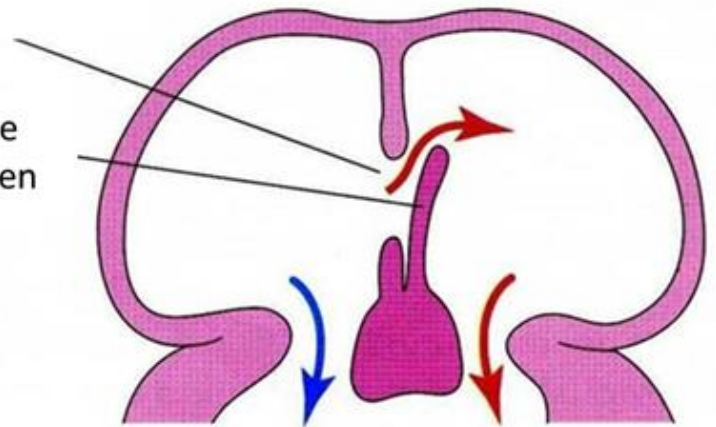
Degenerated part of the primary septum

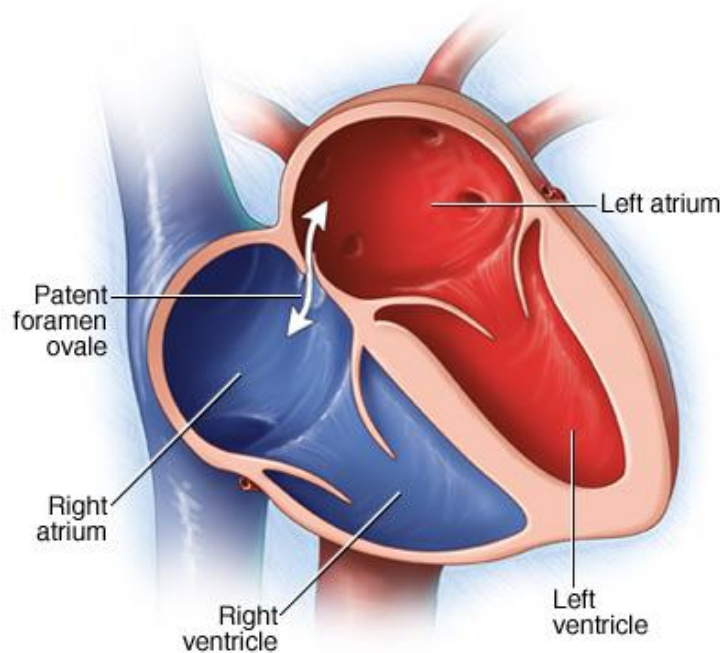
Oval foramen is closed by its valve



Oval foramen is opened

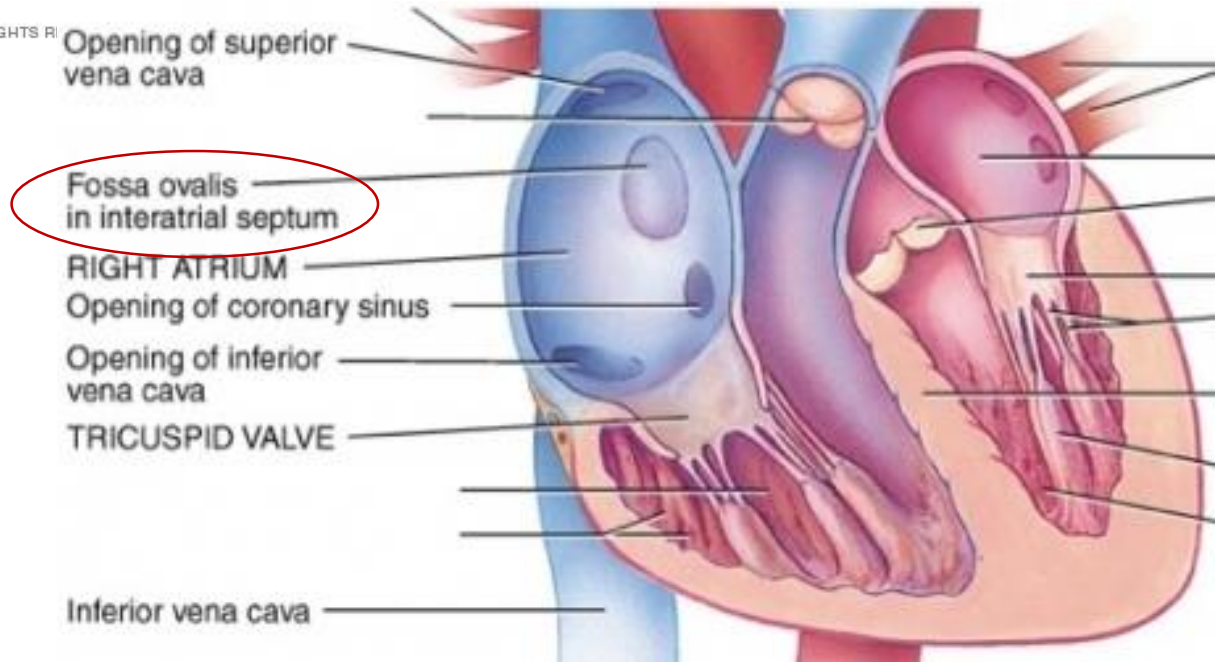
Valve of the oval foramen



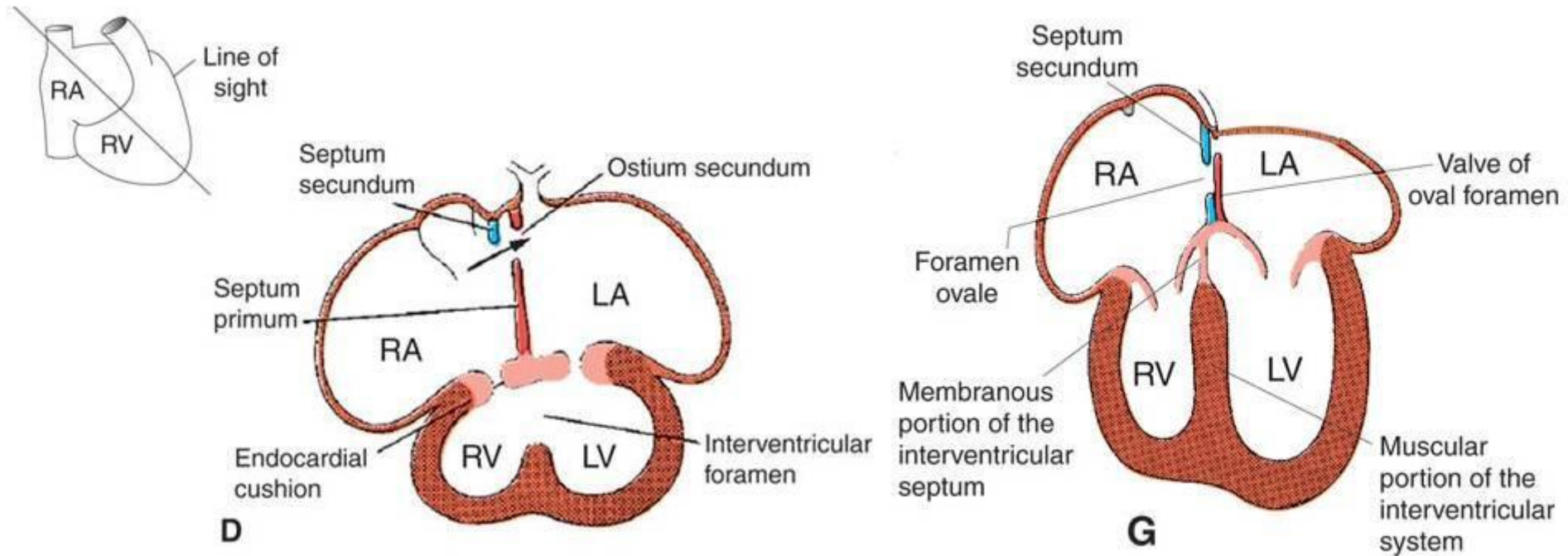


## Remnant of oval foramen – fossa ovalis

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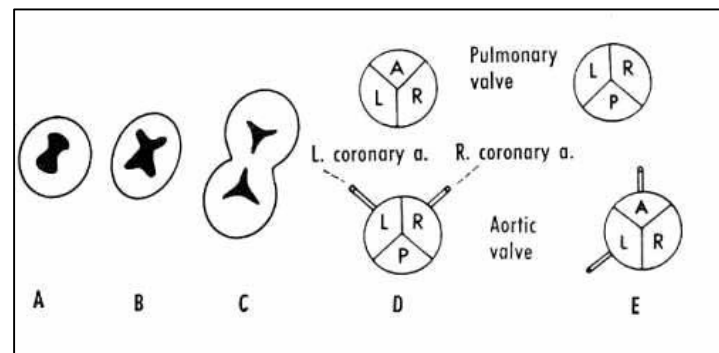
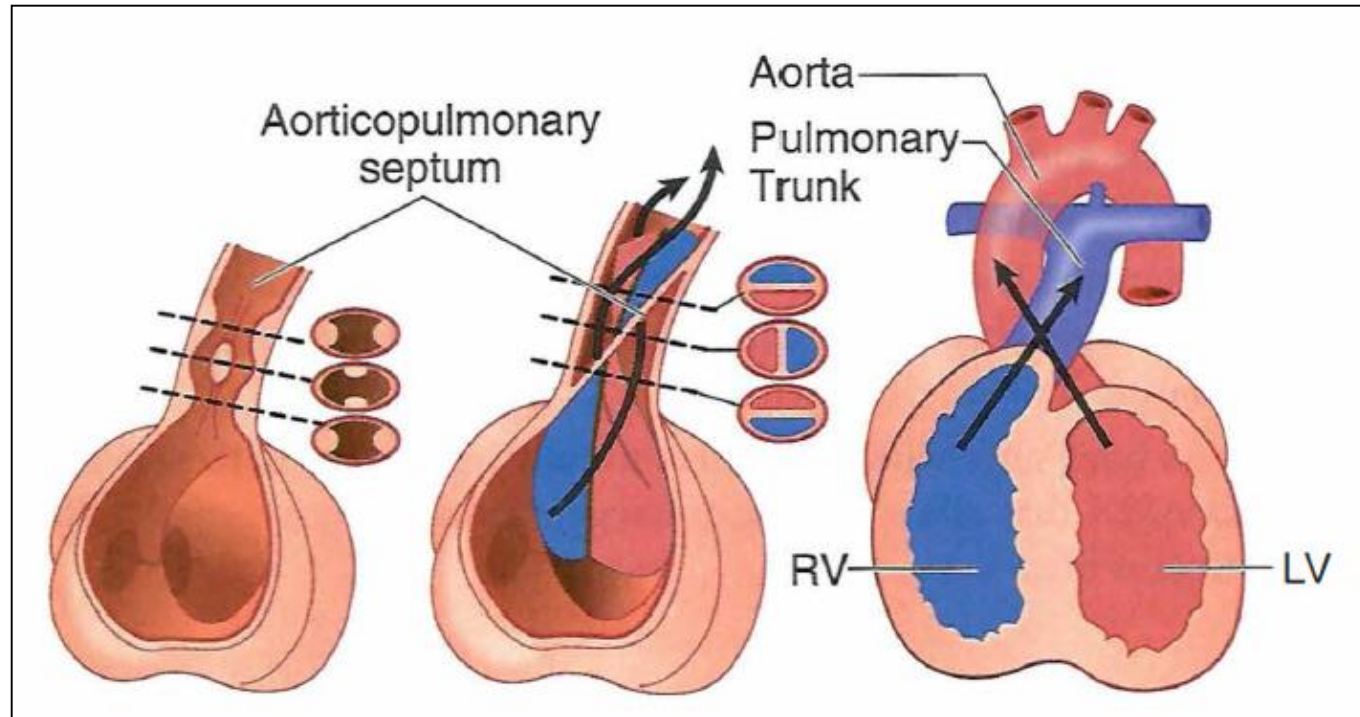


# Partition of the left and right ventricles





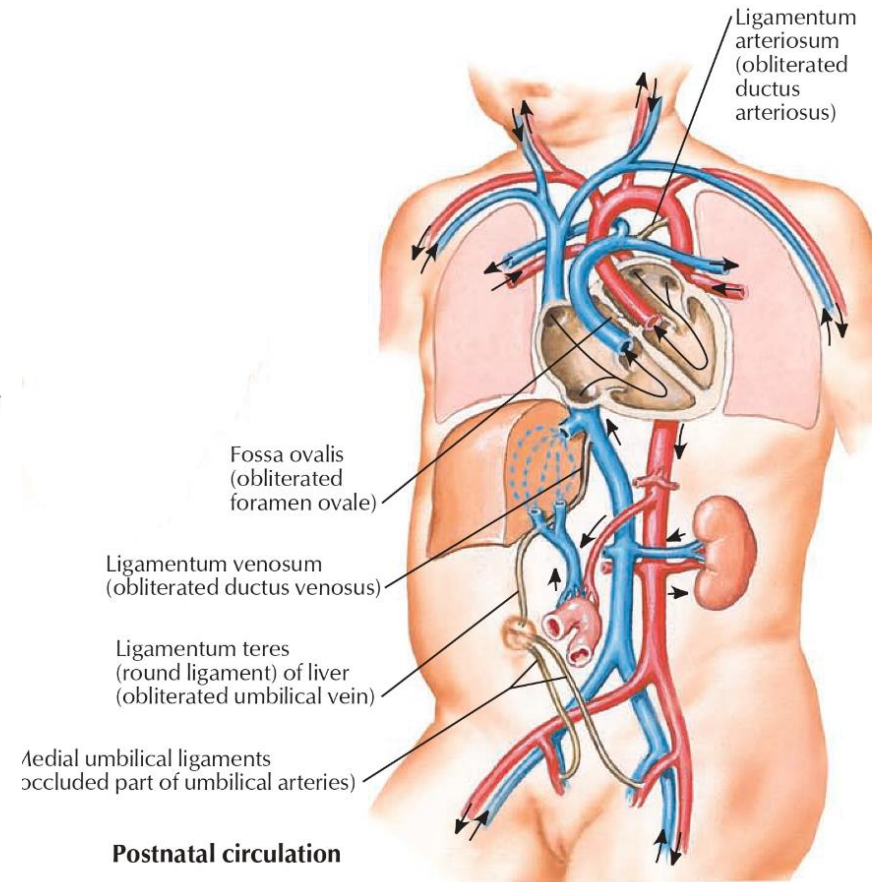
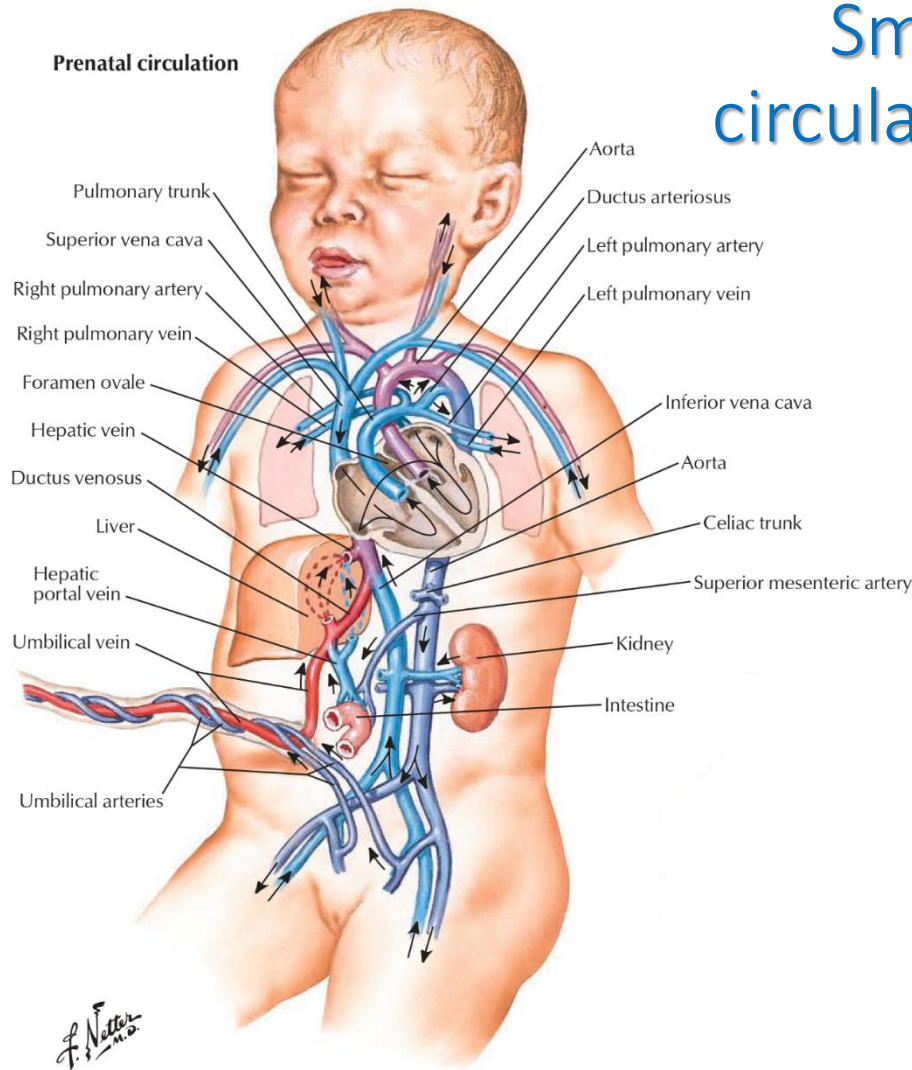
# Partition of truncus arteriosus



**Longitudinal partition** – partition of aorta and pulmonary arteries

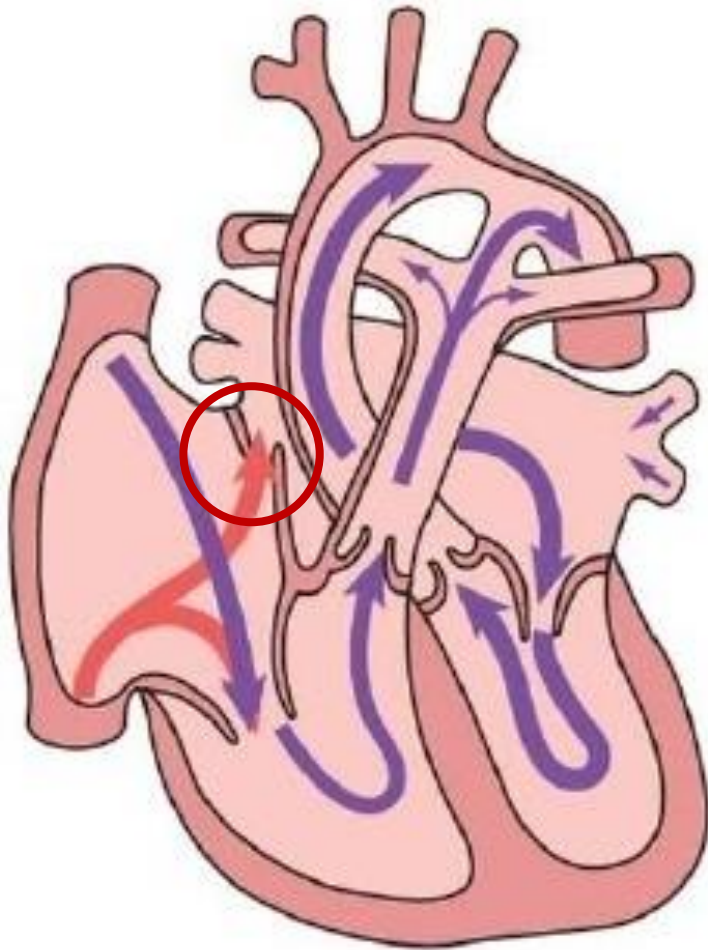
**Transverse partition** – formation of semilunar valves

# Small circle of blood circulation doesn't function

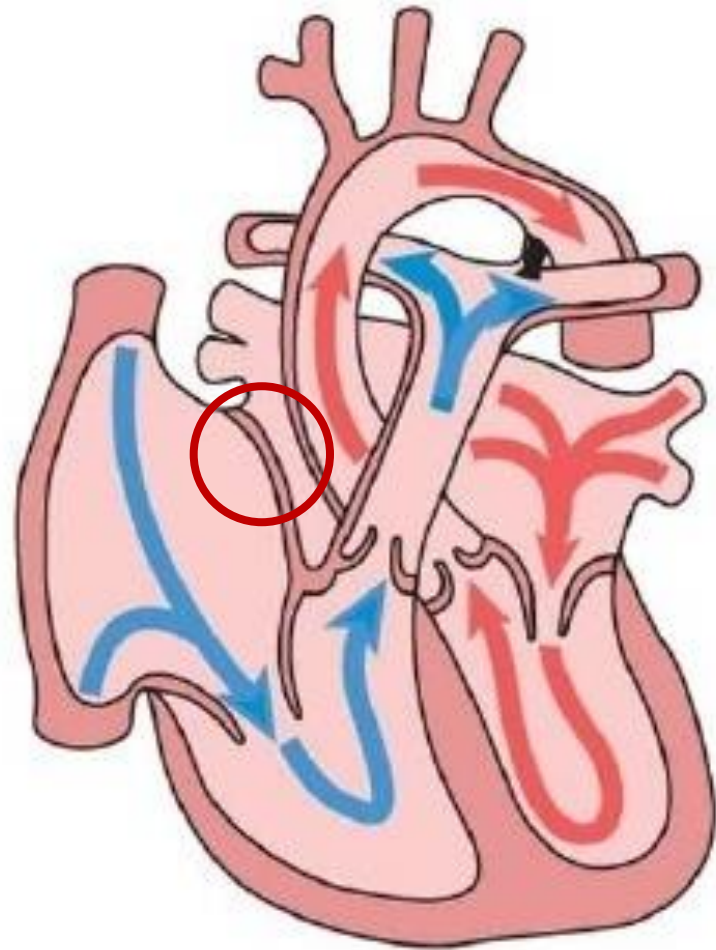


The foetus is supplied with oxygen and nutrients from the mother's blood through the placenta

# Circulatory changes at birth



Antenatal circulation

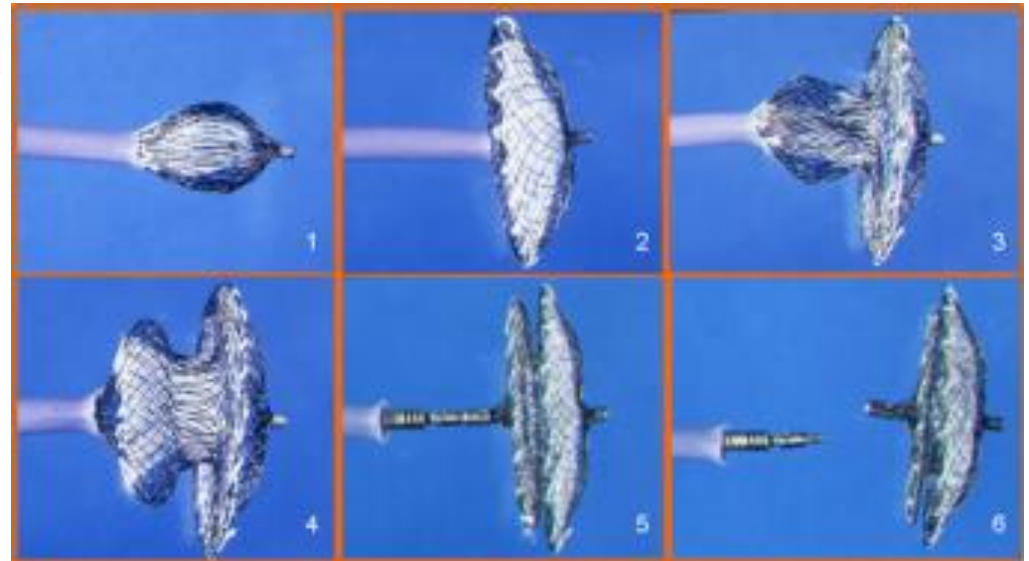
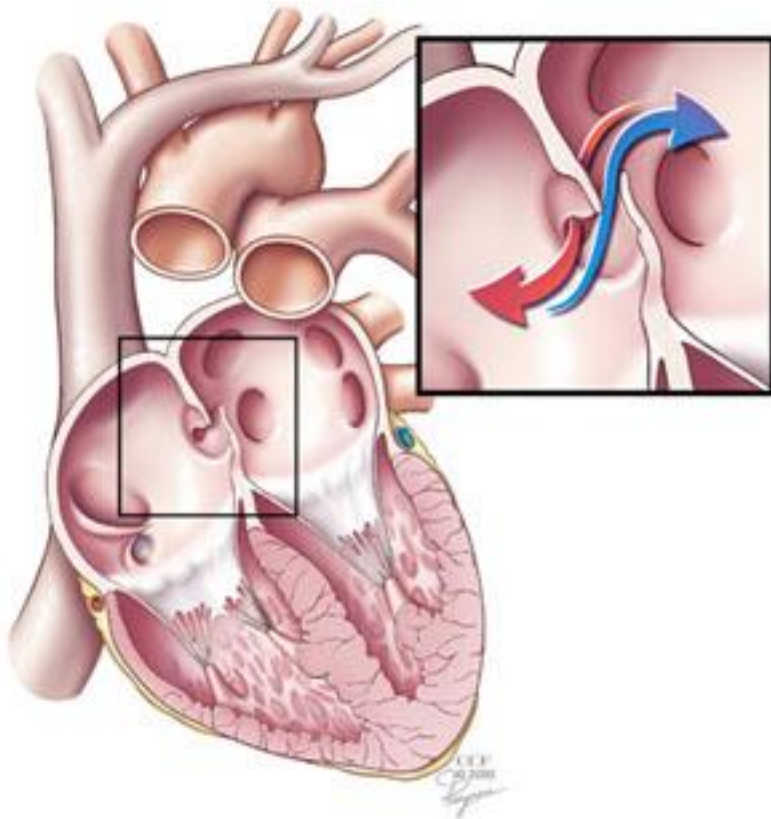


Postnatal circulation

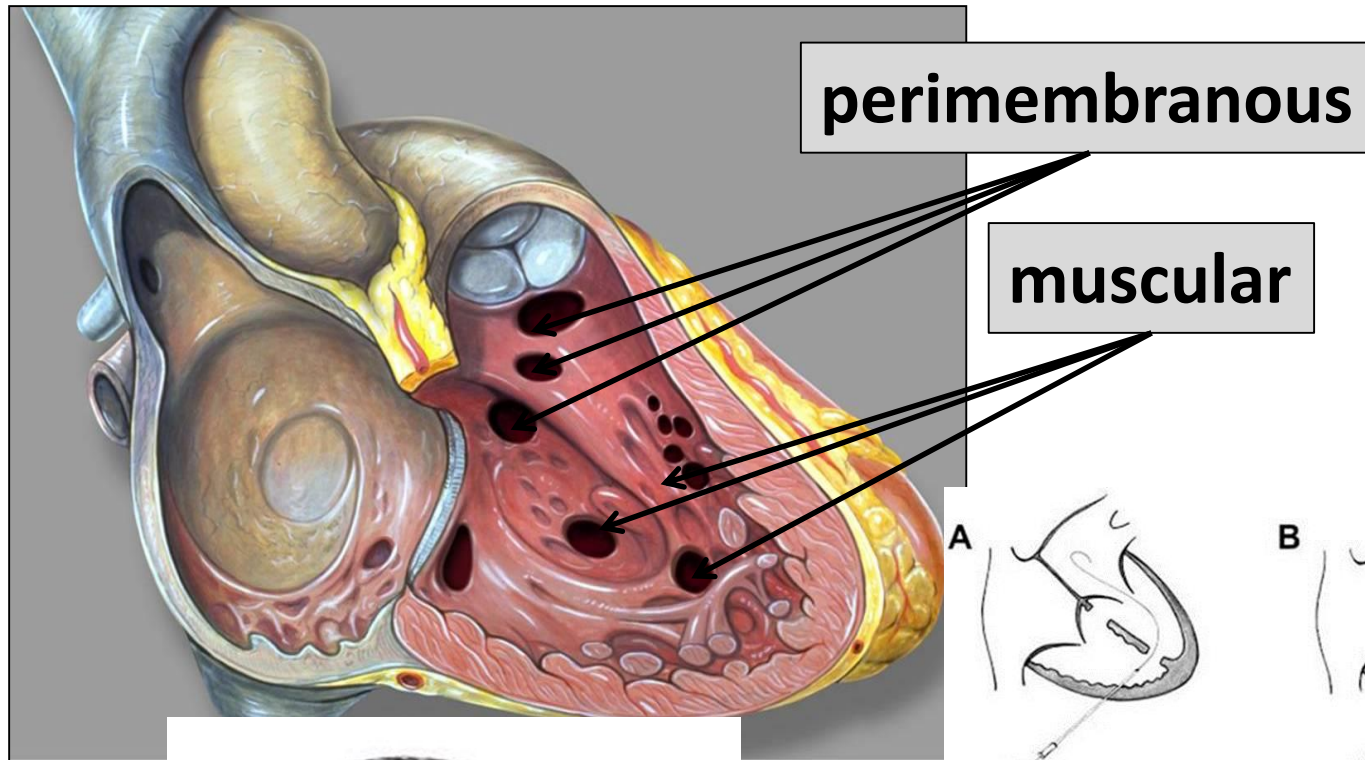


# Congenital Abnormalities of Heart and Great Vessels

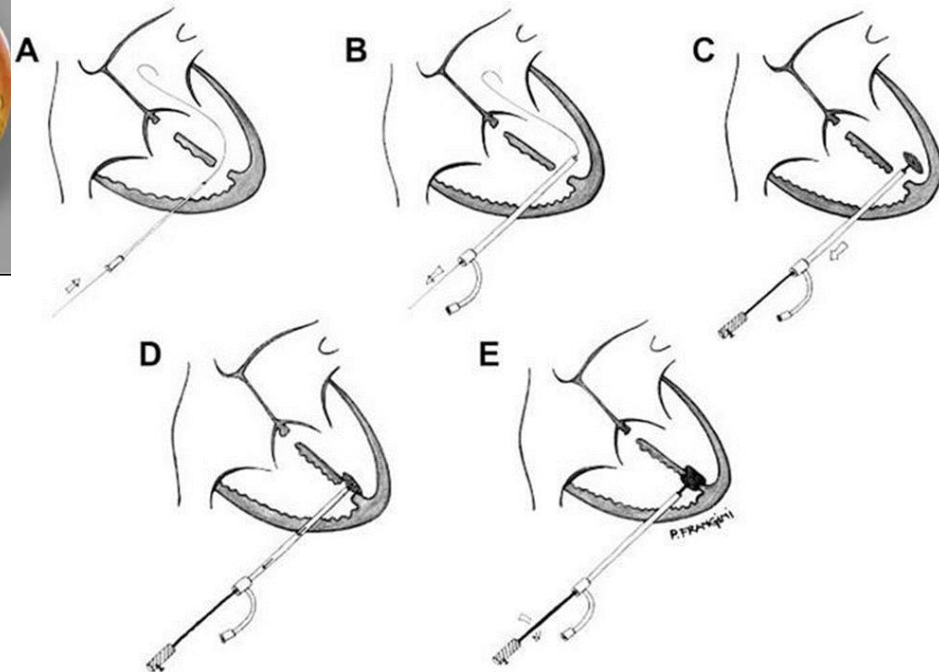
# Patent foramen ovale (PFO)



# Ventricular septum defect (VSD)

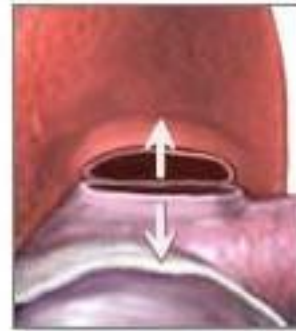
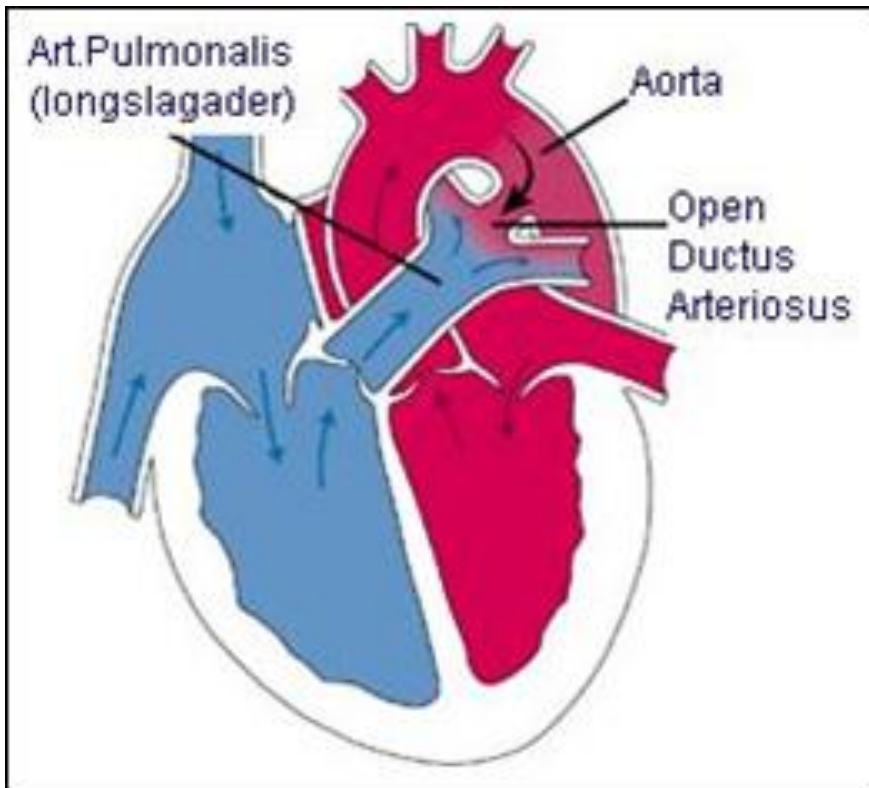


VSD Closure device





# Patent ductus arteriosus

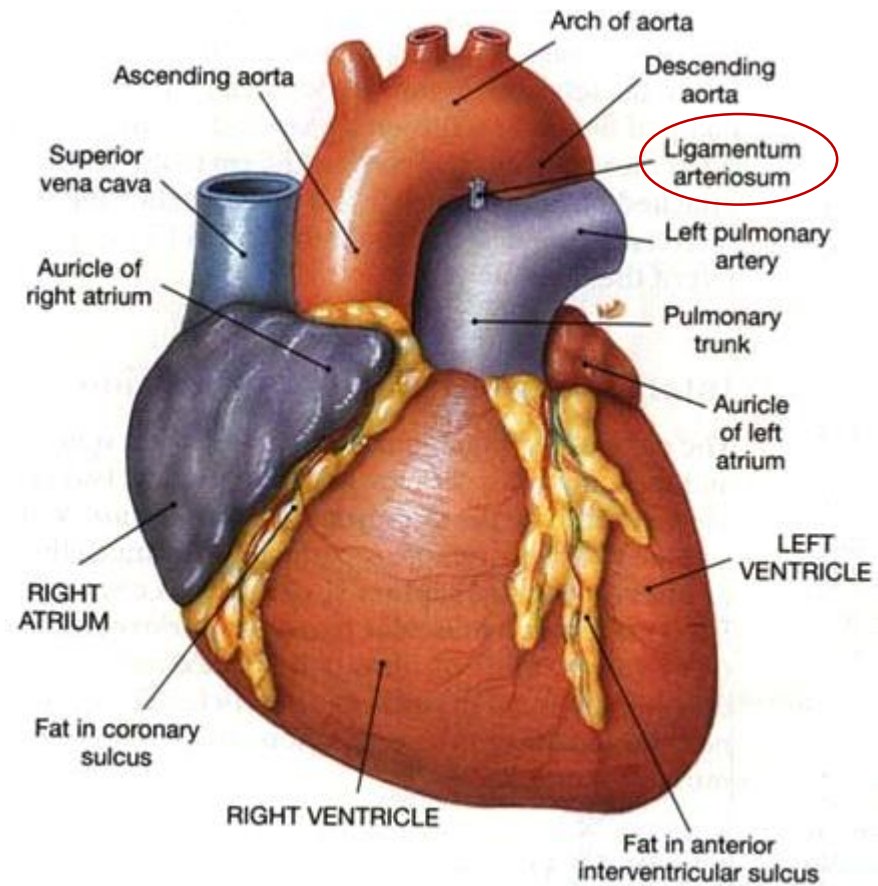
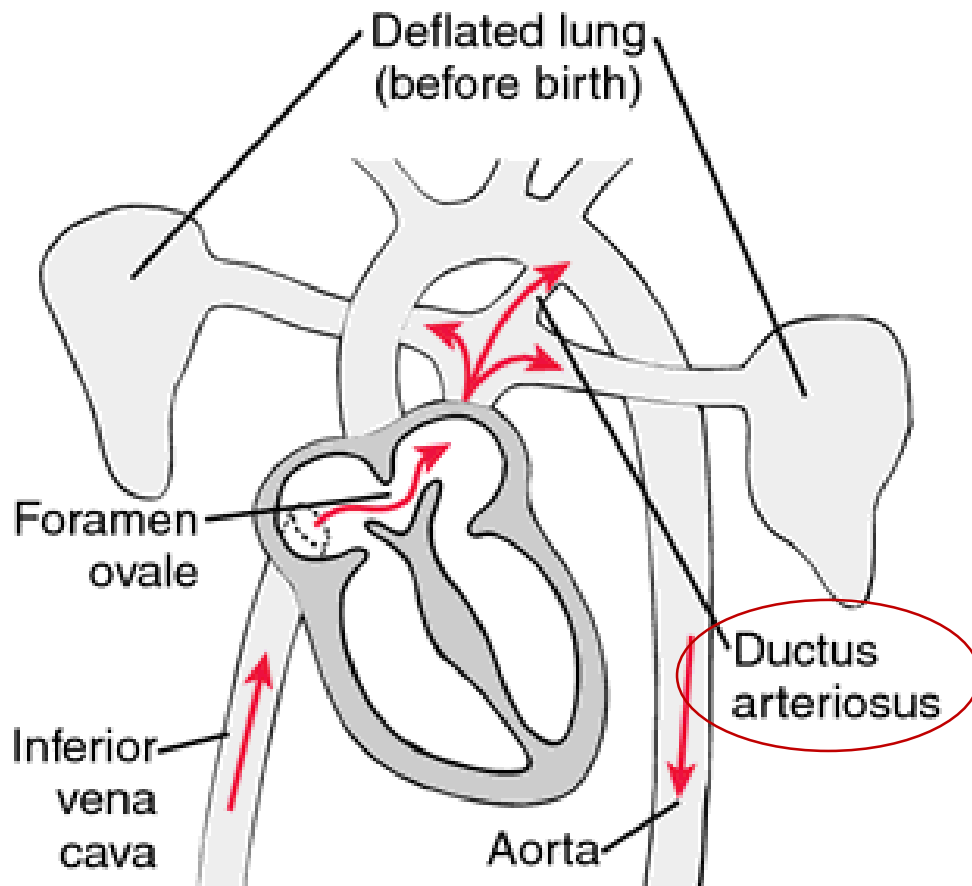


The aorta and pulmonary trunk are separated



The open ends are closed

# Ductus arteriosus

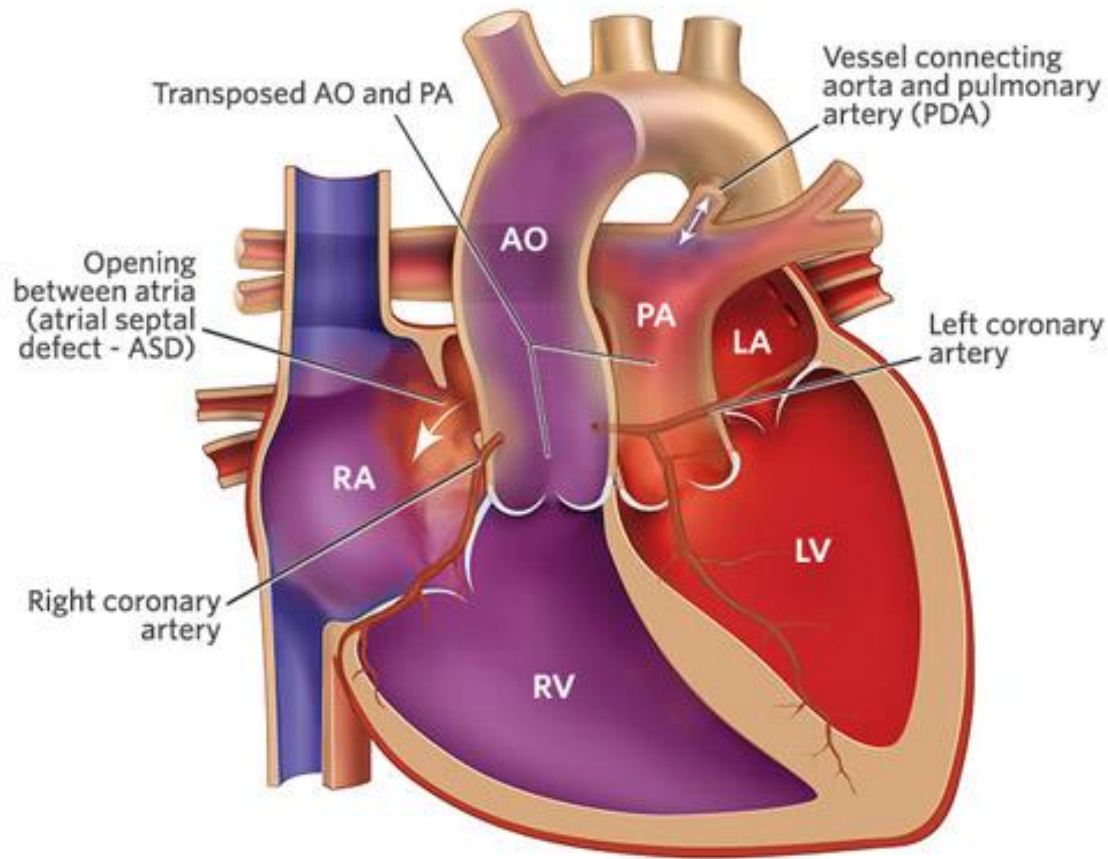


**Ductus arteriosus**



**Ligamentum arteriosum**

# The transposition of the vessels





# Fallot's Tetralogy

