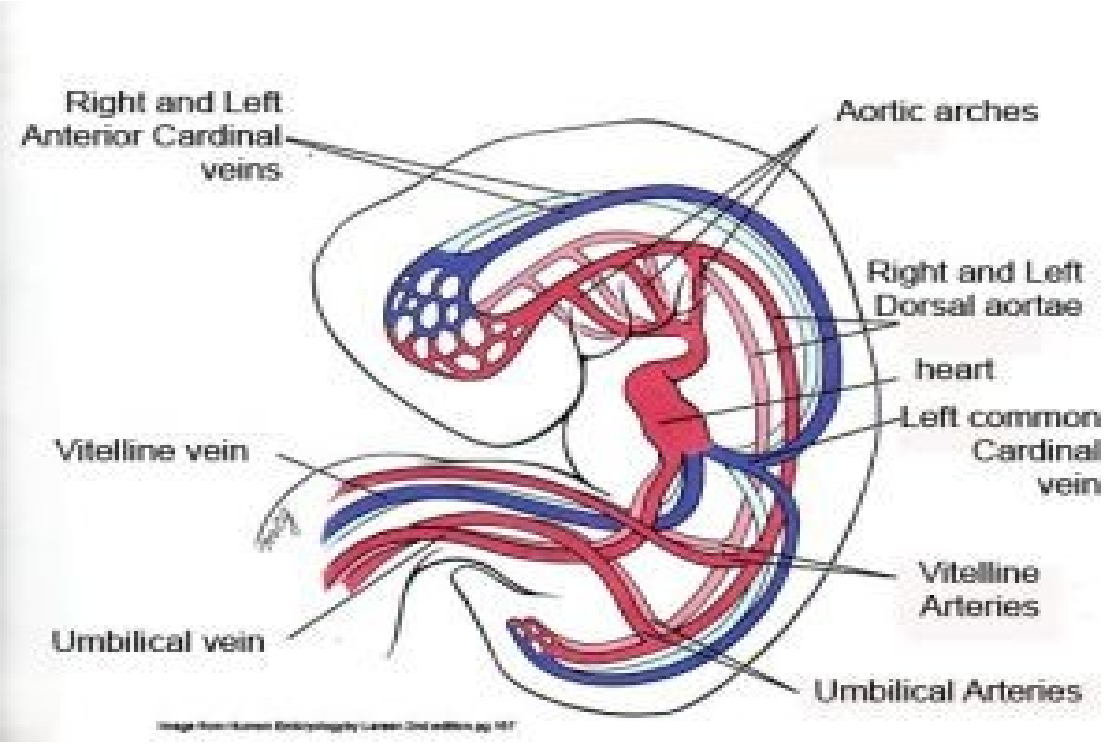
Development of cardiovascular system

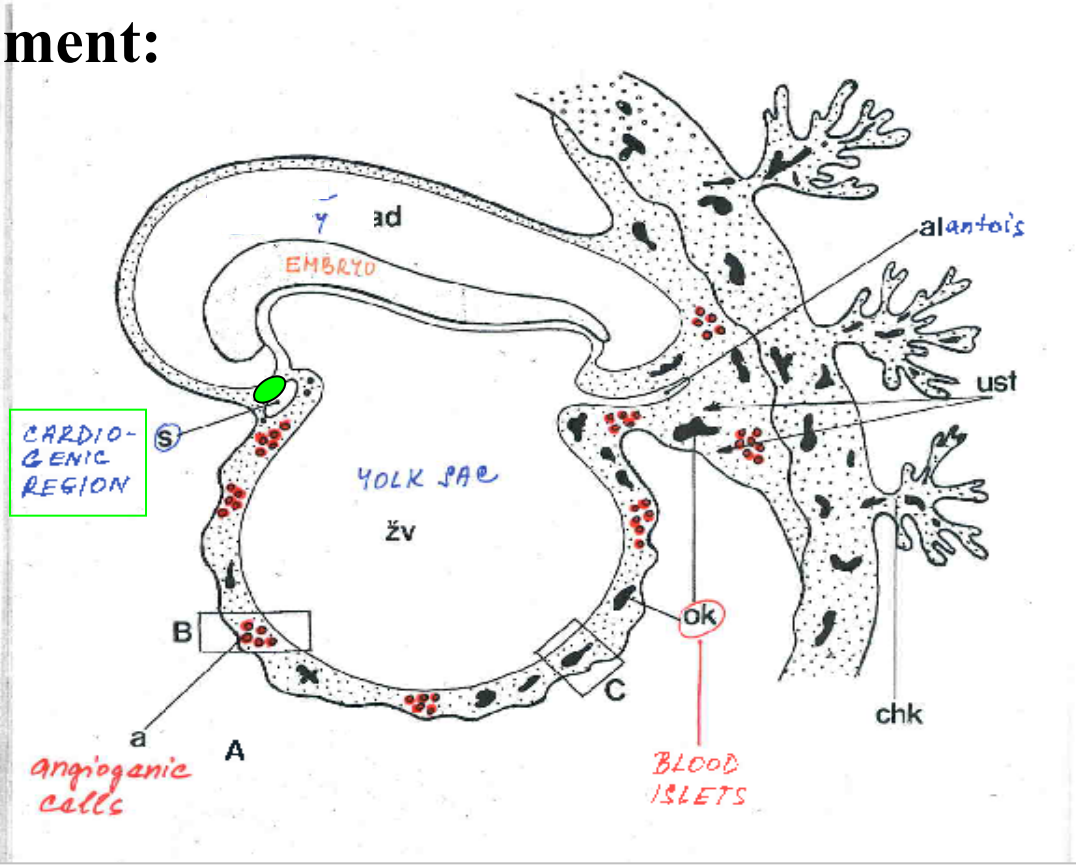
Primordium of the heart and vessels – in the middle of the 3rd week
The heart begins to beat at 22-23 days
Sono registration – during the 4th week



- Primitive blood circulation.
- Heart development (dev. of heart tube, septa and valves)
- Aortal arches and their derivatives.
- Fetal blood circulation.
- Cardiovascular system malformations.

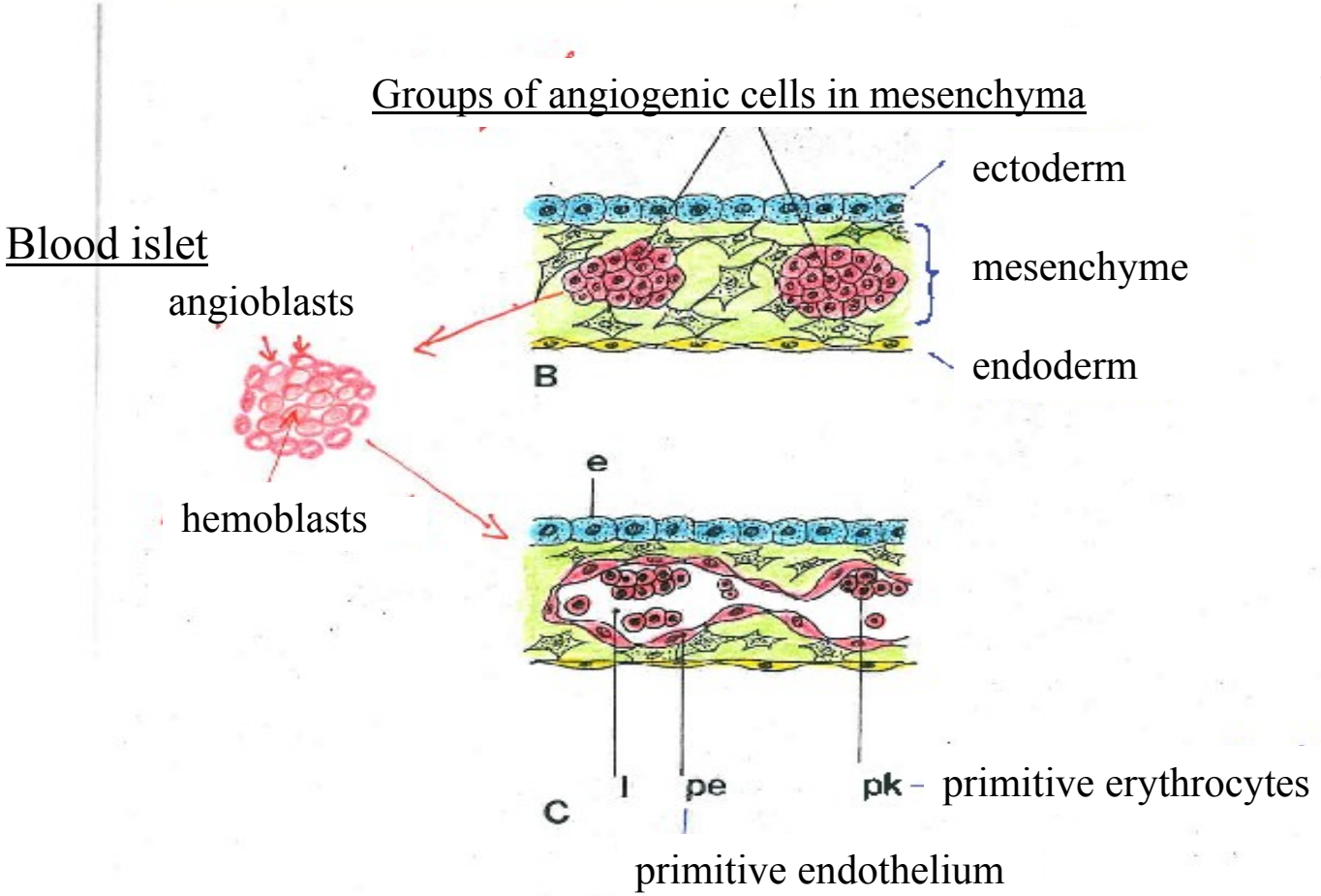
Vessels development:
(from week 3)

hemangiogenesis
- blood islands
(insulae sanguinae)



DAY 15 – 16 in extraembryonic mesoderm of
- yolk sac *(vasa omphalomesenterica /vitellina/),*
- connecting stalk and placenta *(vasa umbilicalia)*

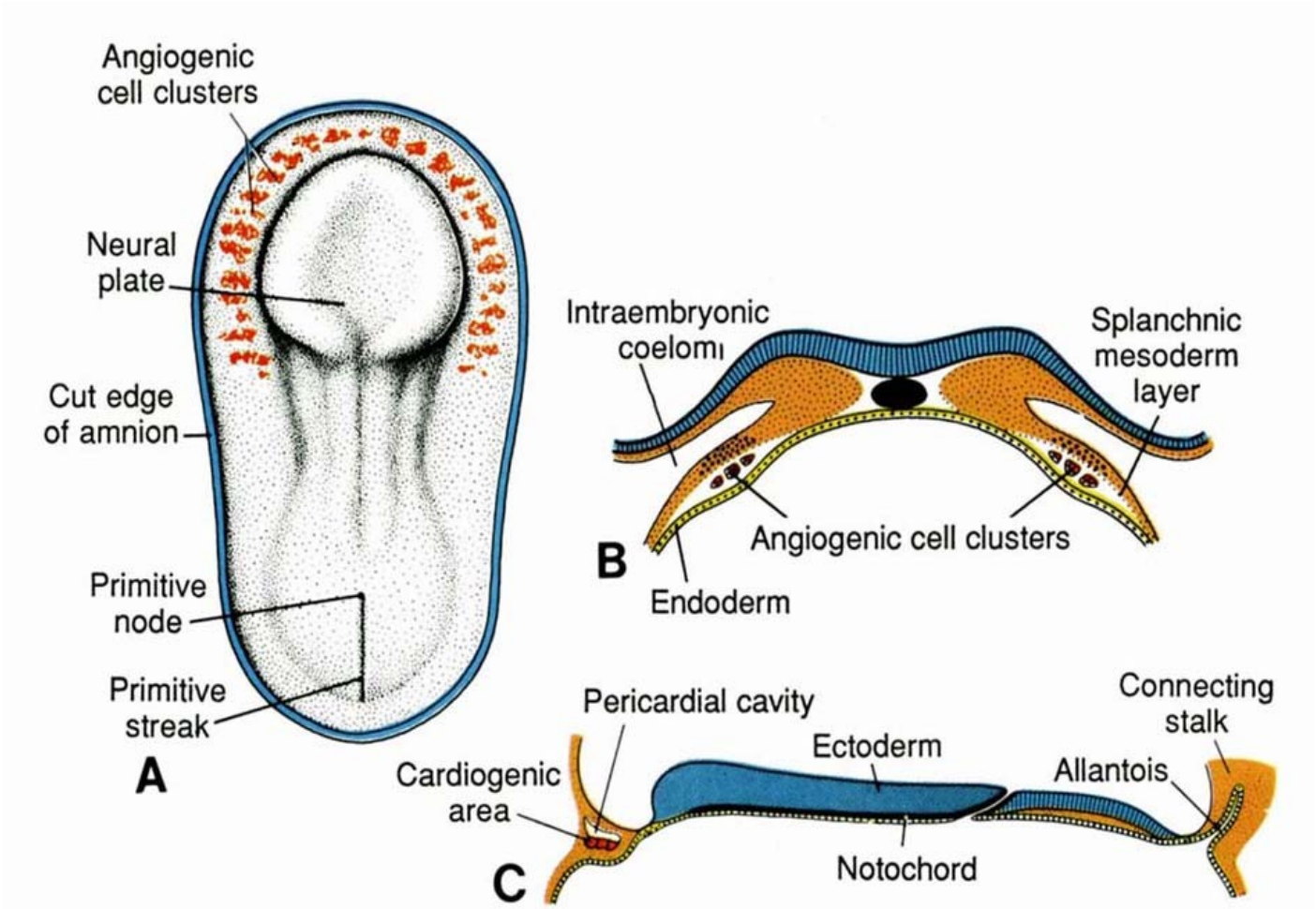
DAY 17 – 18 in mesenchyme of embryo



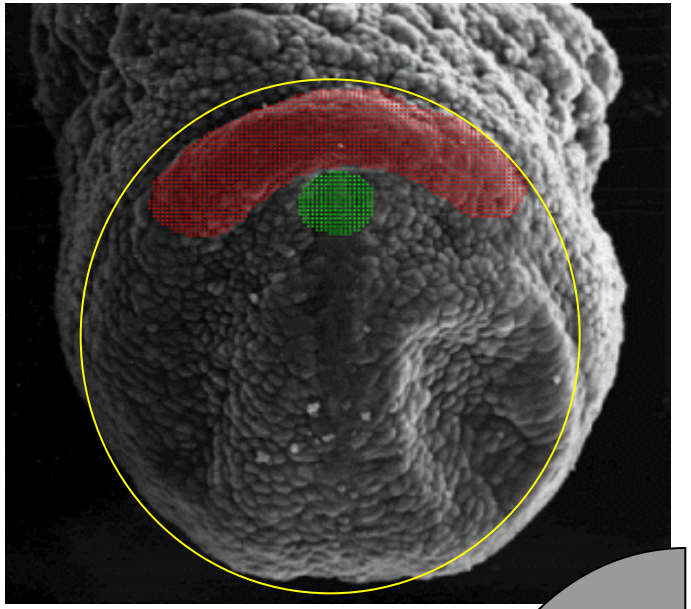
Differentiation of mesenchymal cells ⇒ angiogenic cells:

- angioblasts ⇨ endothelium (at the periphery of blood islets)
- hemoblasts ⇨ primitive erythrocytes (in the center of blood islets)

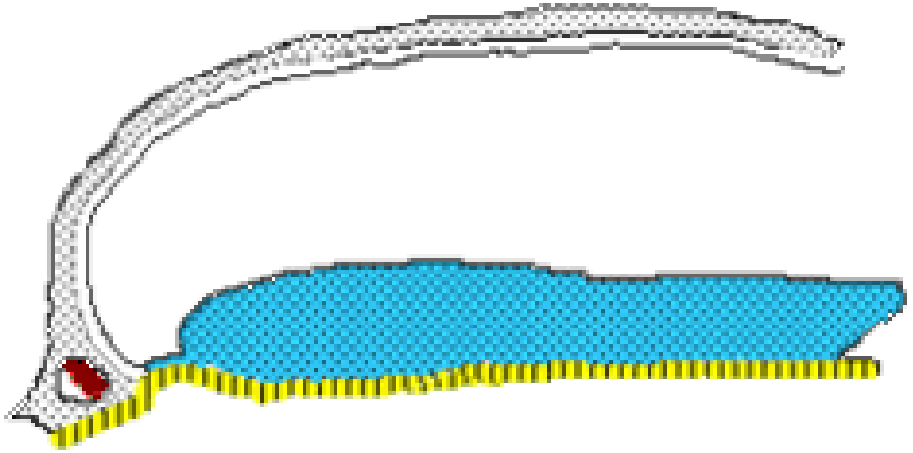
angiogenic cells form a "horseshoe-shaped" space between somatic and splanchnic layer of mesoderm = **pericardial cavity**.
Two endothelial tubes arrise in splanchnic mesoderm. The ventral portion with tubes forms the **cardiogenic area** ⇨ **two heart tubes**, while the lateral portions form the **dorsal aortae**.

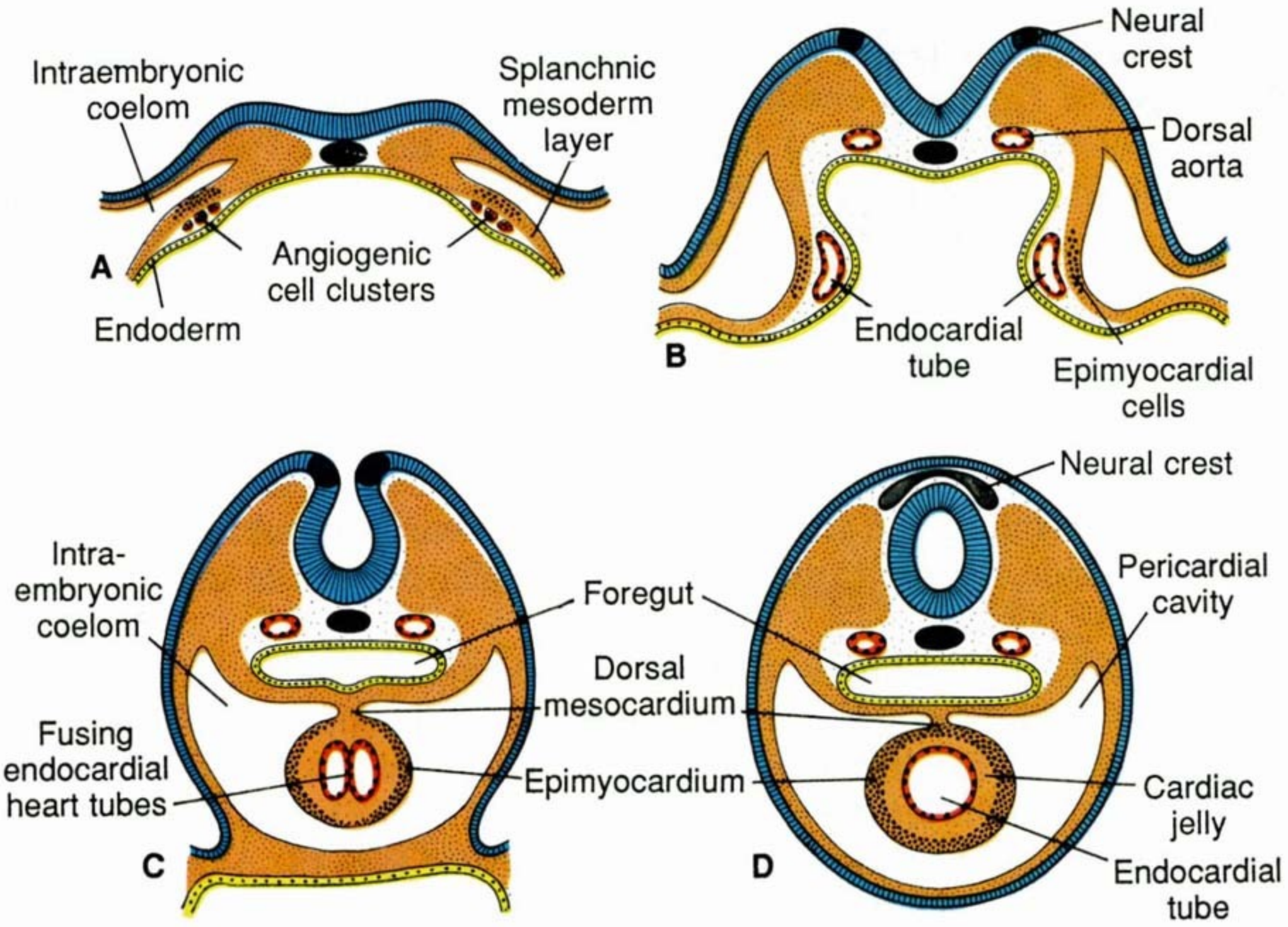


Pericardial cavity
Cardiogenic area
A^1
Amniotic cavity
A^1 B^1
Heart tube
Pericardial cavity
B^1
Amnion
Neural plate
Connecting stalk
Allantois
Prochordal plate
Notochord
A
Cloacal membrane
Foregut
Hindgut
Heart tube
B
Buccopharyngeal membrane
Dorsal mesocardium
Cloaca
C
Pericardial cavity
Cloacal membrane

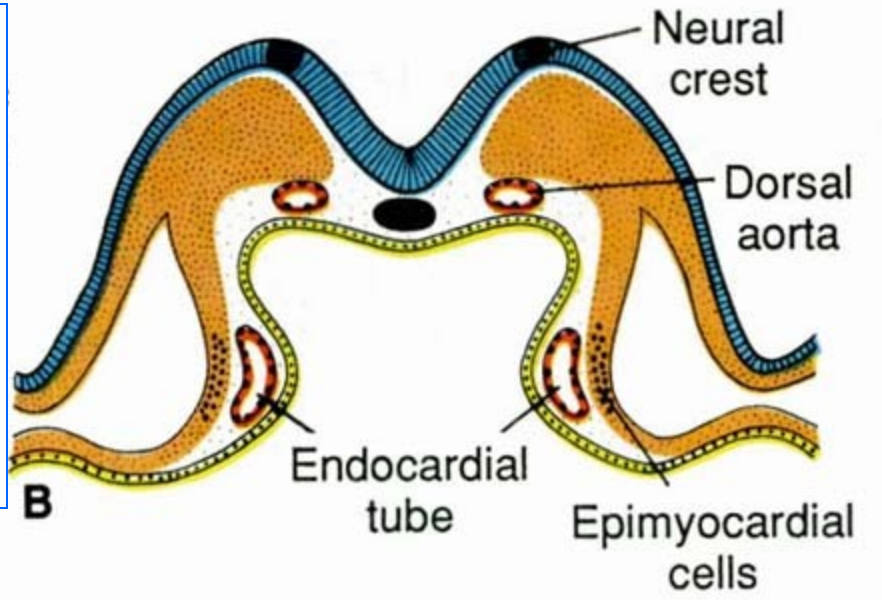


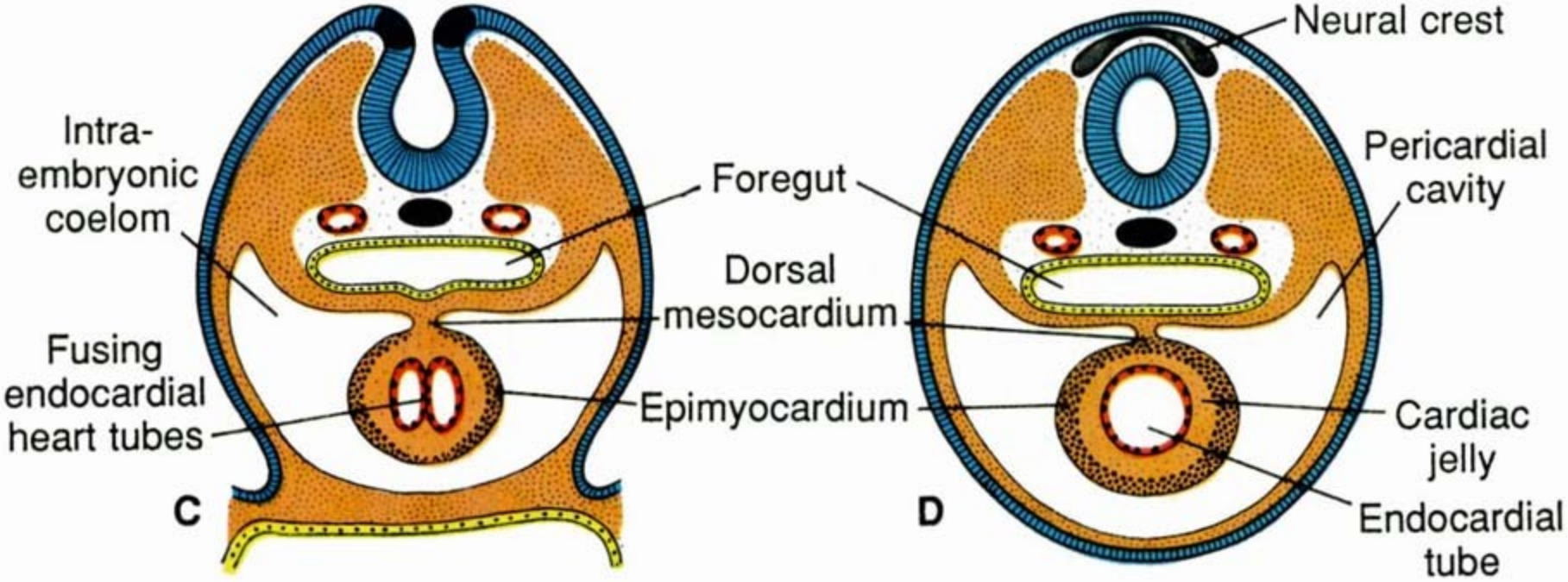
Cardiogenic region just cranial to the prechordal plate.



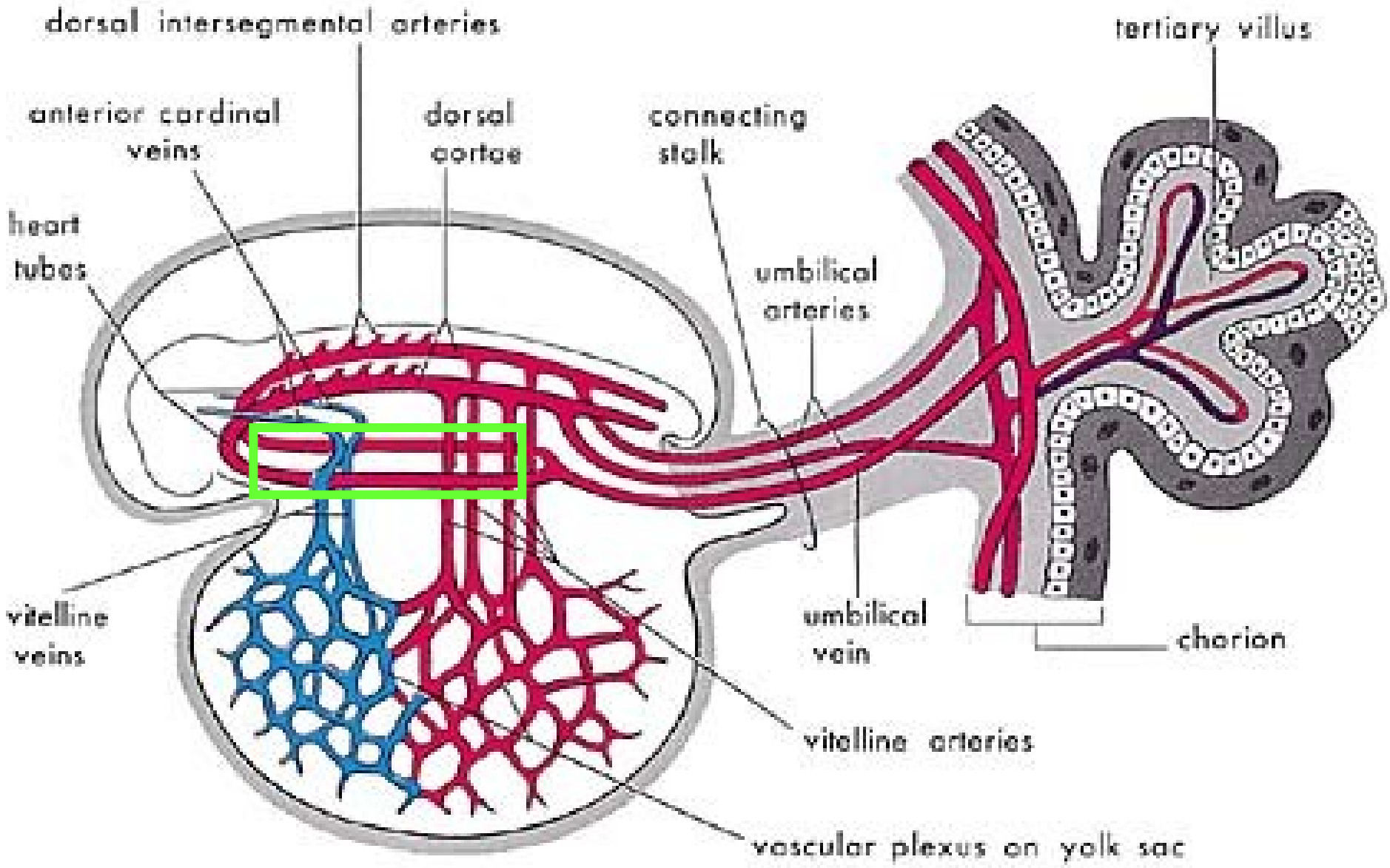

Intraembryonic coelom
Splanchnic mesoderm layer
A
Angiogenic cell clusters
Endoderm
Neural crest
Dorsal aorta
B
Endocardial tube
Epimyocardial cells
Intra-embryonic coelom
Foregut
Dorsal mesocardium
Fusing endocardial heart tubes
Epimyocardium
C
Neural crest
Pericardial cavity
D
Cardiac jelly
Endocardial tube

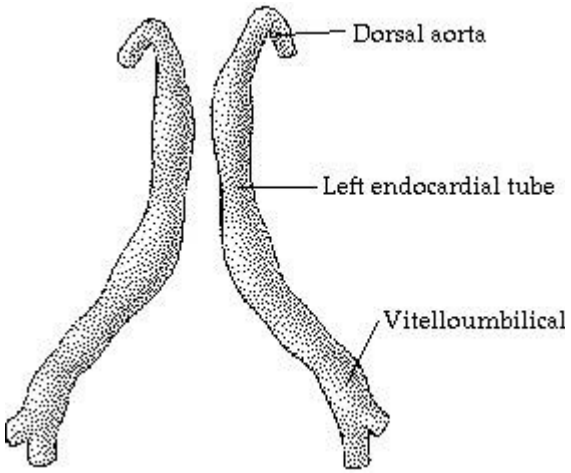
- ⇨ Fusion of heart tubes
- ⇨ mesocardium dorsale
- ⇨ diferentiation of heart wall:
  - endocardium
  - heart jelly
  - epimyocardium





Vitelline, umbilical and intraembryonic vessels fuse together and form the primitive blood circulation (≠ fetal blood circulation!)





Dorsal aorta

Aortic sac

Bulbus cordis

Primitive ventricle

Pericardial cavity

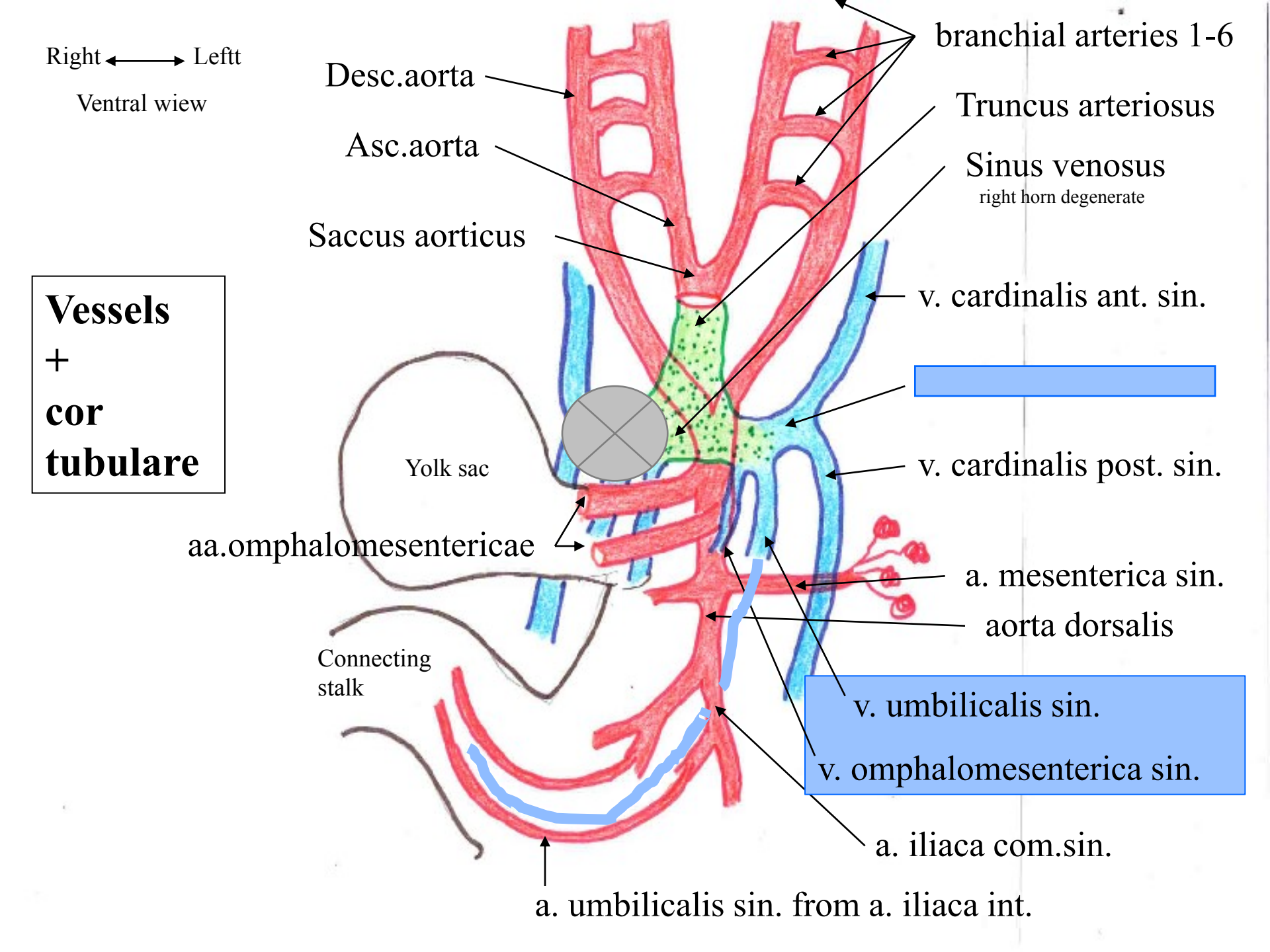
Atrioventricular sulcus

Cor tubulare simplex

Primitive atria

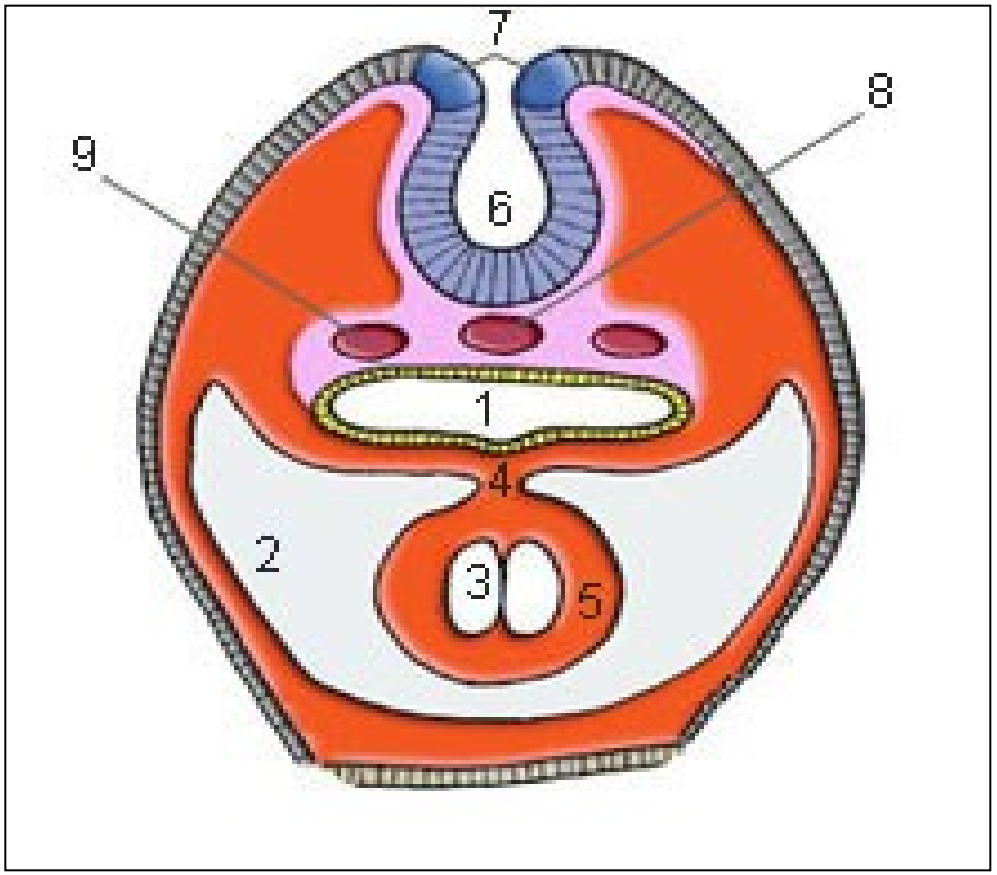
Sinus venosus

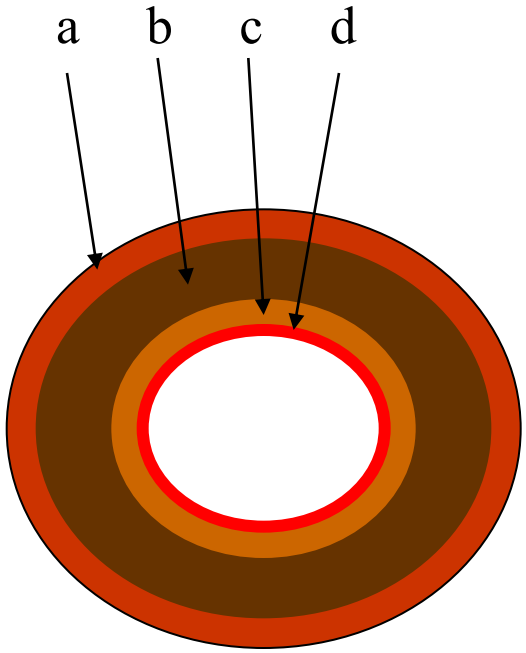
Septum transversum


Right ⟷ Leftt
Ventral wiew
Vessels + cor tubulare
branchial arteries 1-6
Desc.aorta
Truncus arteriosus
Asc.aorta
Sinus venosus
right horn degenerate
Saccus aorticus
v. cardinalis ant. sin.
Yolk sac
v. cardinalis post. sin.
aa.omphalomesentericae
a. mesenterica sin.
aorta dorsalis
Connecting stalk
v. umbilicalis sin.
v. omphalomesenterica sin.
a. iliaca com.sin.
a. umbilicalis sin. from a. iliaca int.

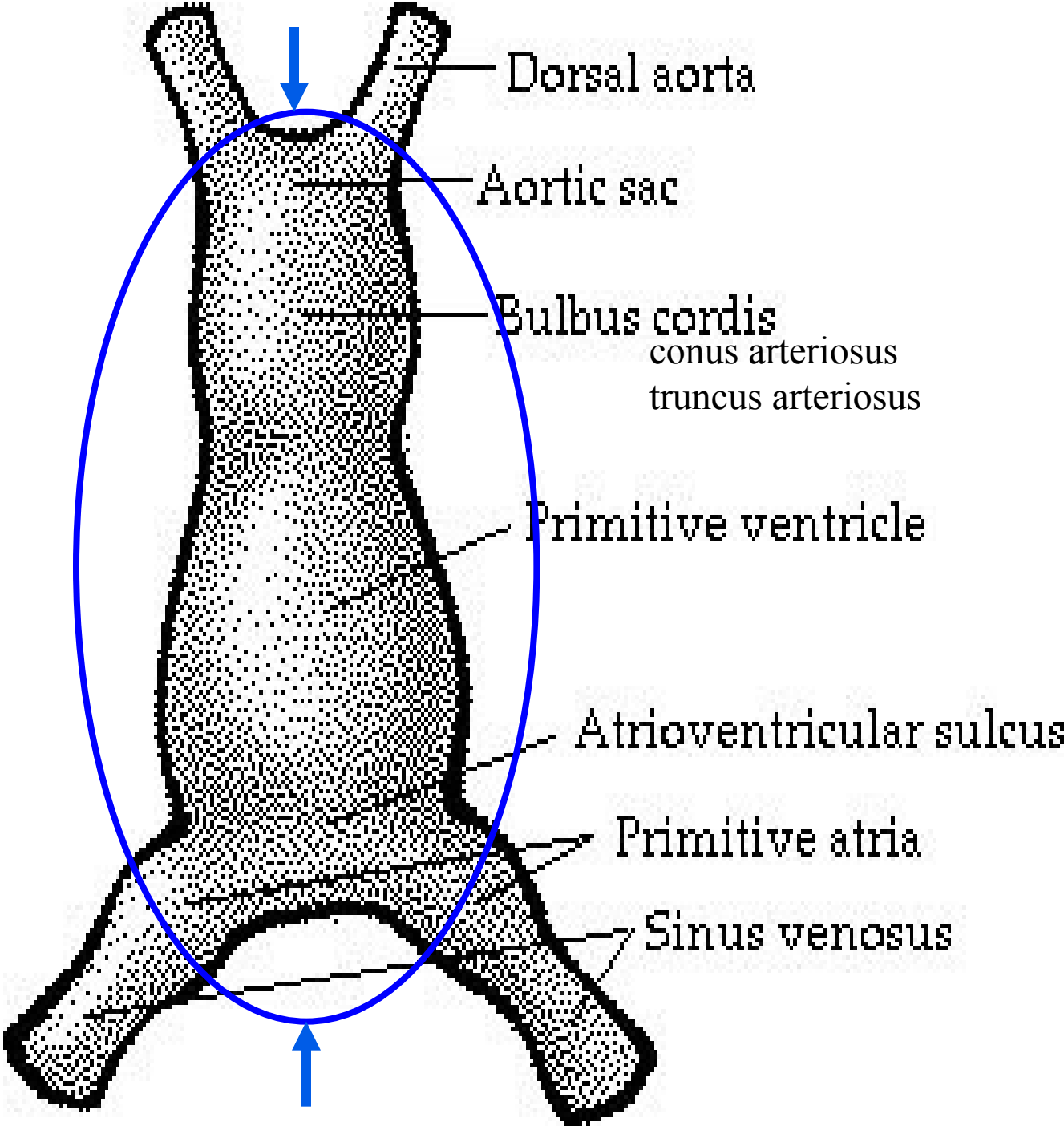
Histogenesis of heart tube wall

COR TUBULARE SIMPLEX– temporarily suspended on **mesocardium dorsale** (4). Visceral mesoderm (splanchnopleura, 5) propagates and forms myoepicardial coat ⇨ **myocardium (b)** + **epicardium (a)**. Below endothelium (d) – layer of cardiac jelly ⇨ **subendocardiac connective tissue (c)**.



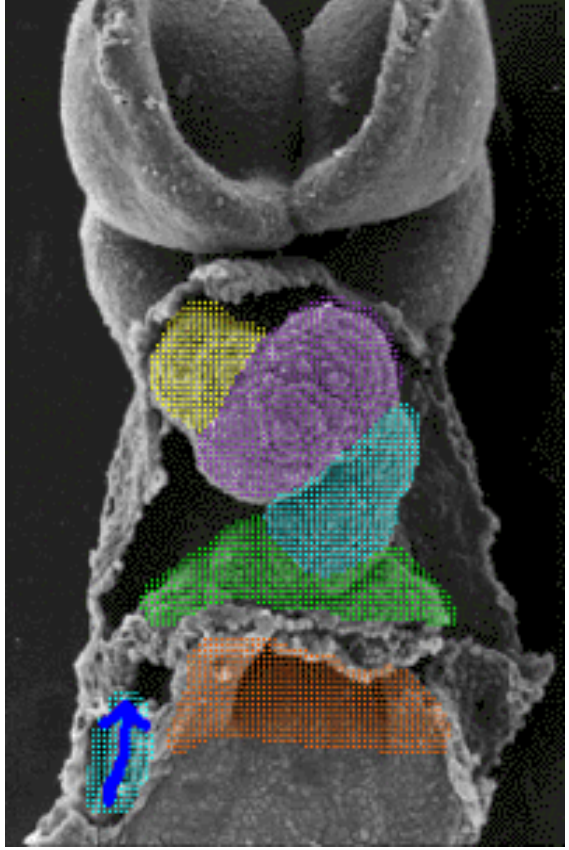


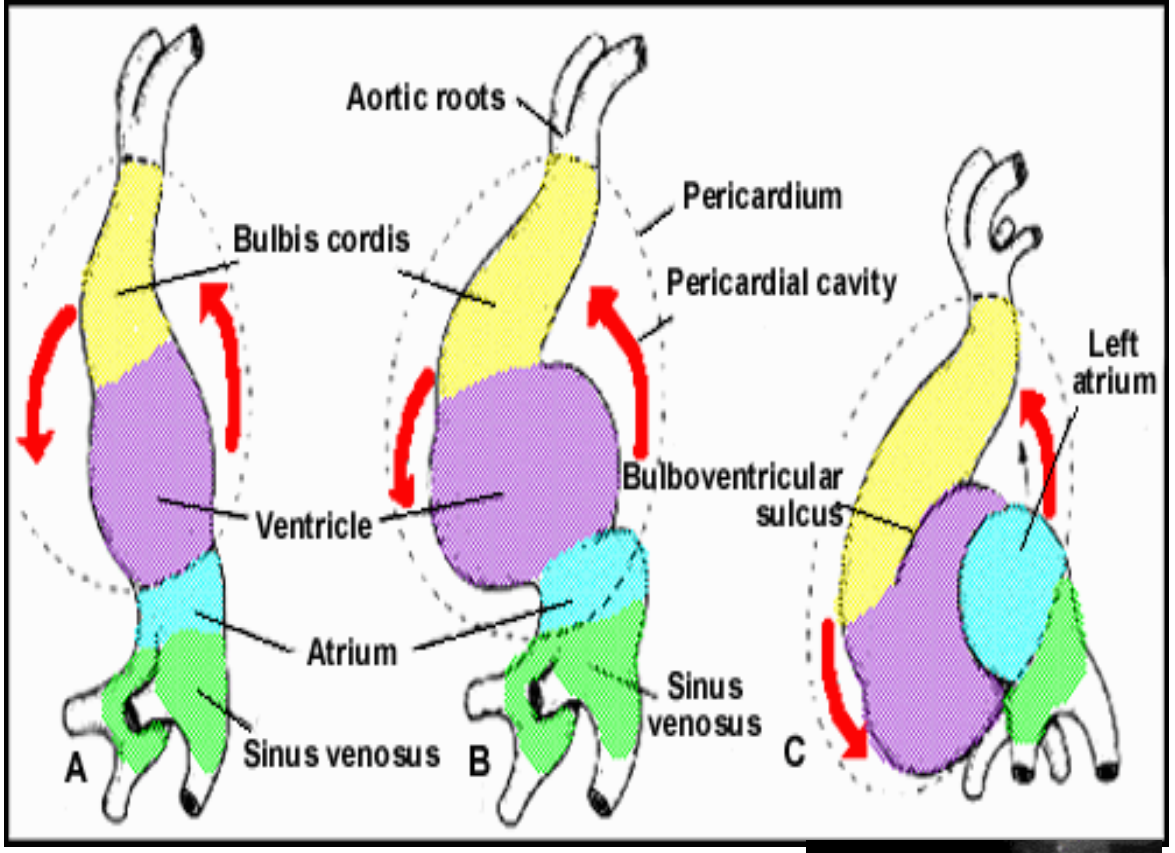
Heart tube*(s)*



Pericardial cavity

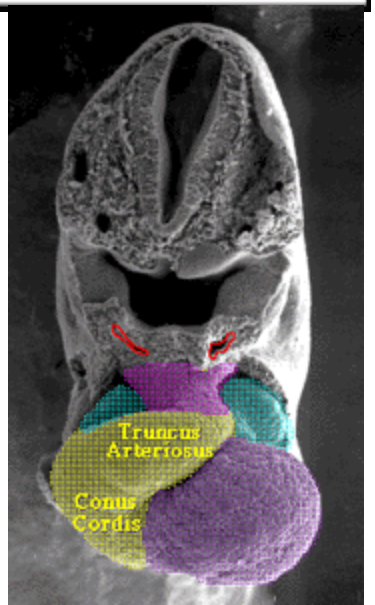
(arrows show fixed postioin of cranial and caudal end of the heart tube)



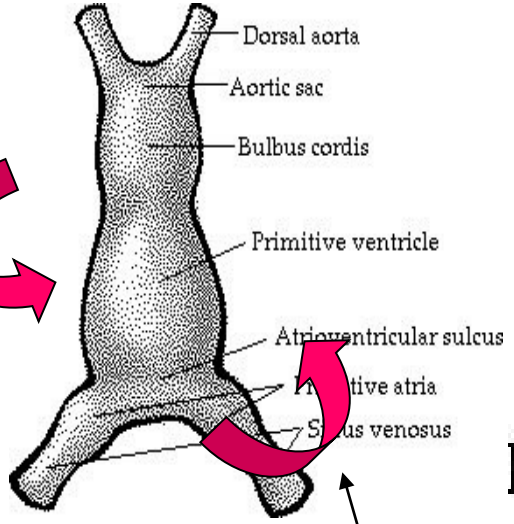


Looping of the heart tube

- because growth of the heart tube is faster than growth of the pericardial cavity and both ends of tube are hold by pericardium.



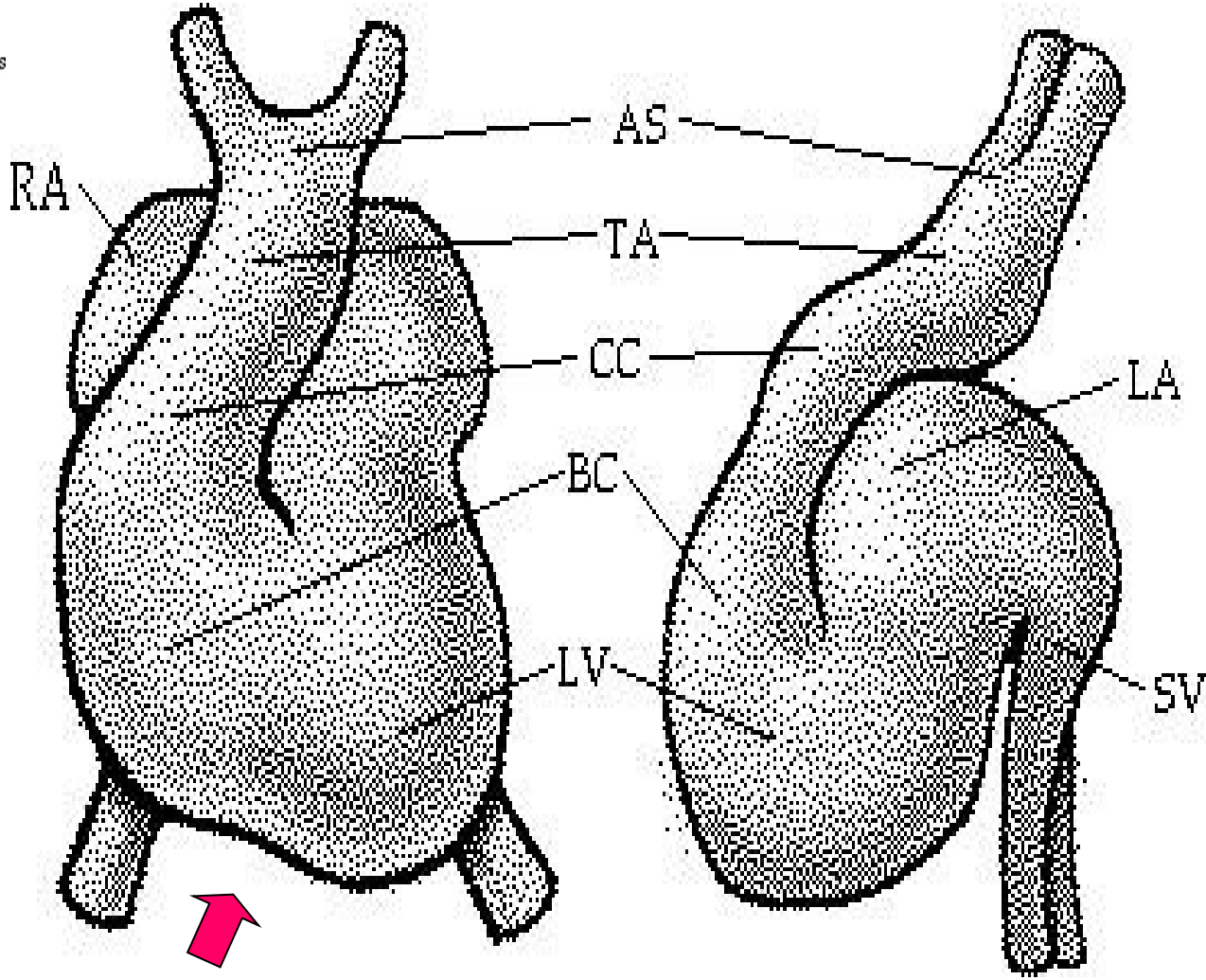
Bulboventricular loop



Ventro-caudally to the right

Dorso-cranially

Cor sigmoideum



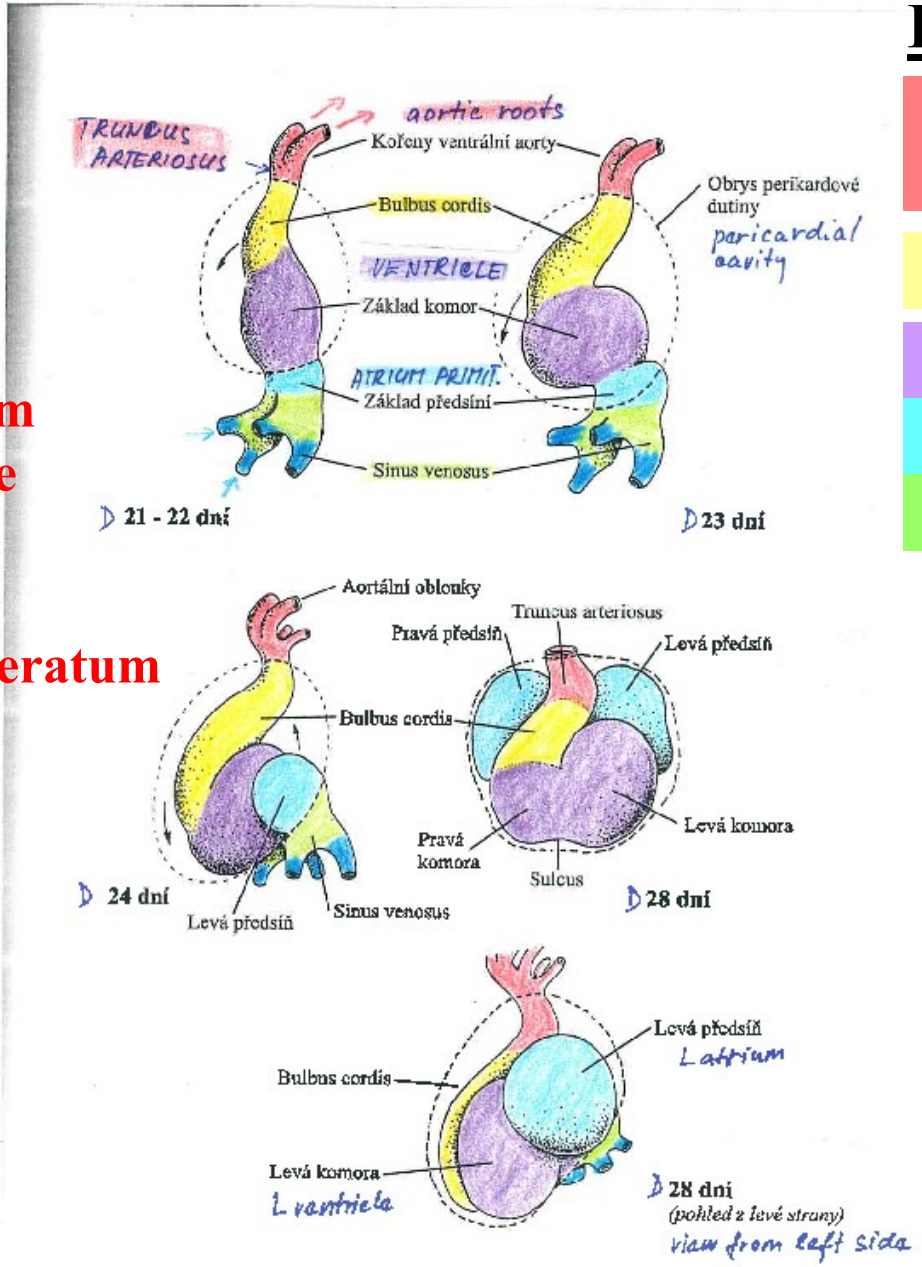
ventral view

lateral view

Cor
tubulare
simplex

Cor
sigmoideum
uniloculare

Cor
quadricameratum



Heart tube

Truncus arteriosus + saccus aorticus

Bulbus cordis

Ventriculus

Atrium

Sinus venosus

vv. cardinales communes

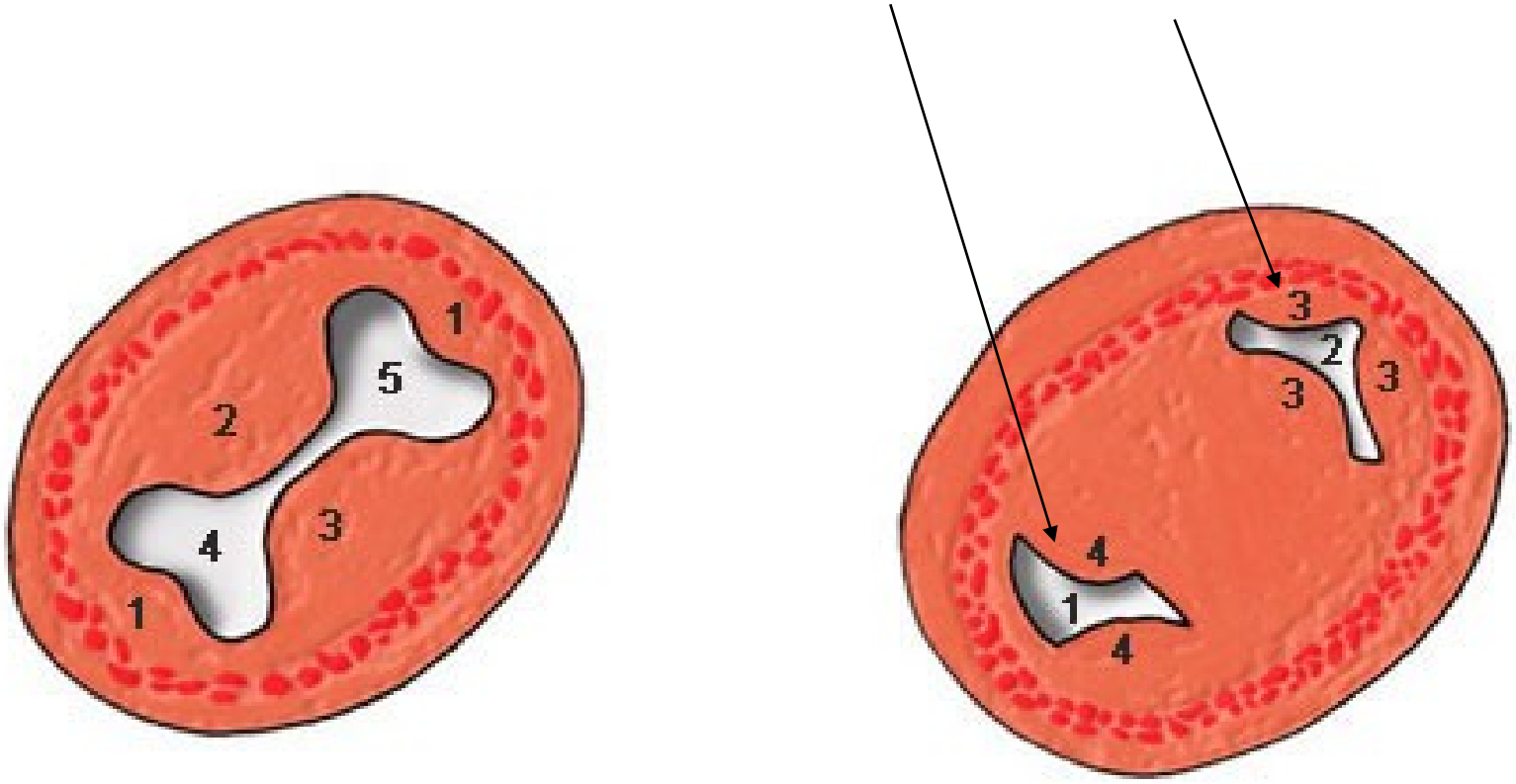
vv. umbilicales

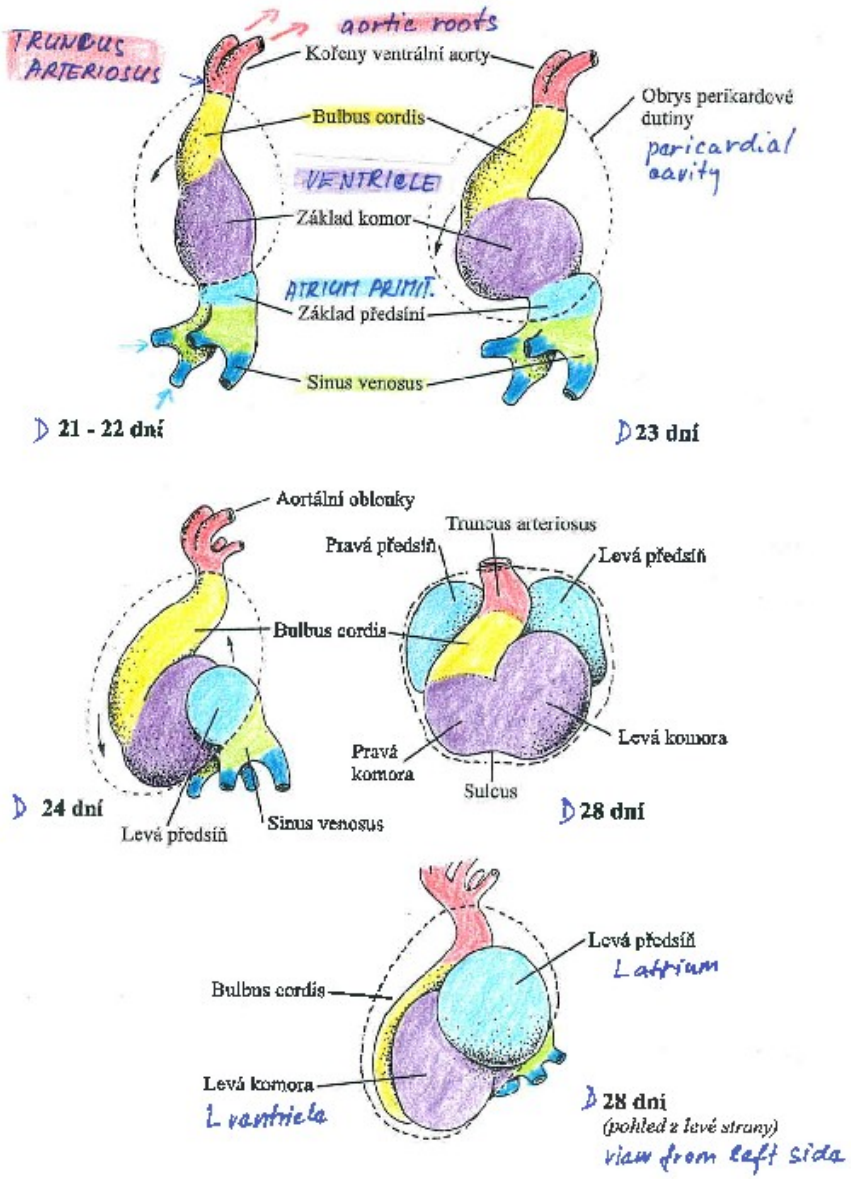
vv. vitellinae

Septum atrioventriculare

A/ Endocardial cushions – from dorsal (3) and ventral (2) wall of atrioventrikular canal. Grow against each other and seperate right and left AV canal (4, 5).

B/ Lateral interventricular cushions – **bicuspid** + **tricuspid AV valve.**

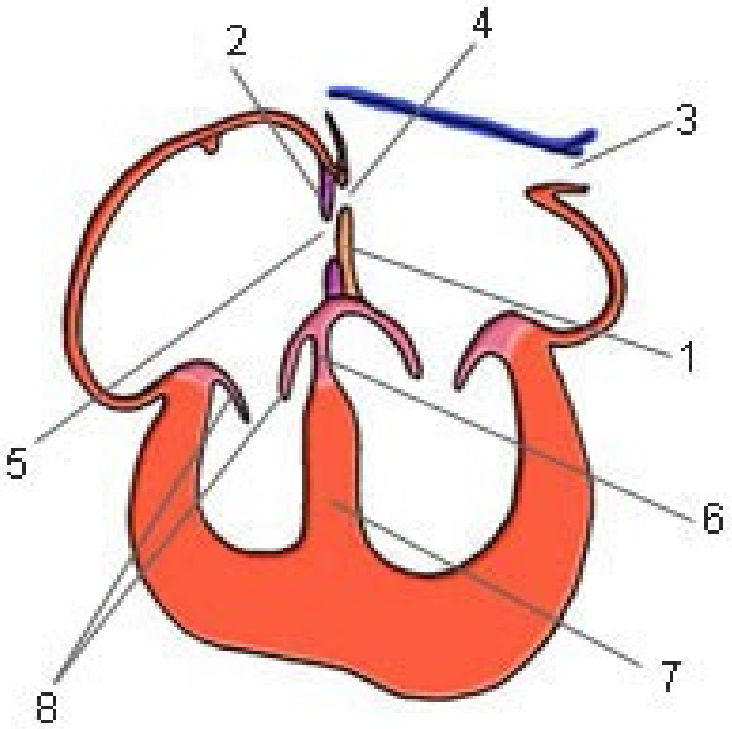




Ventriculus

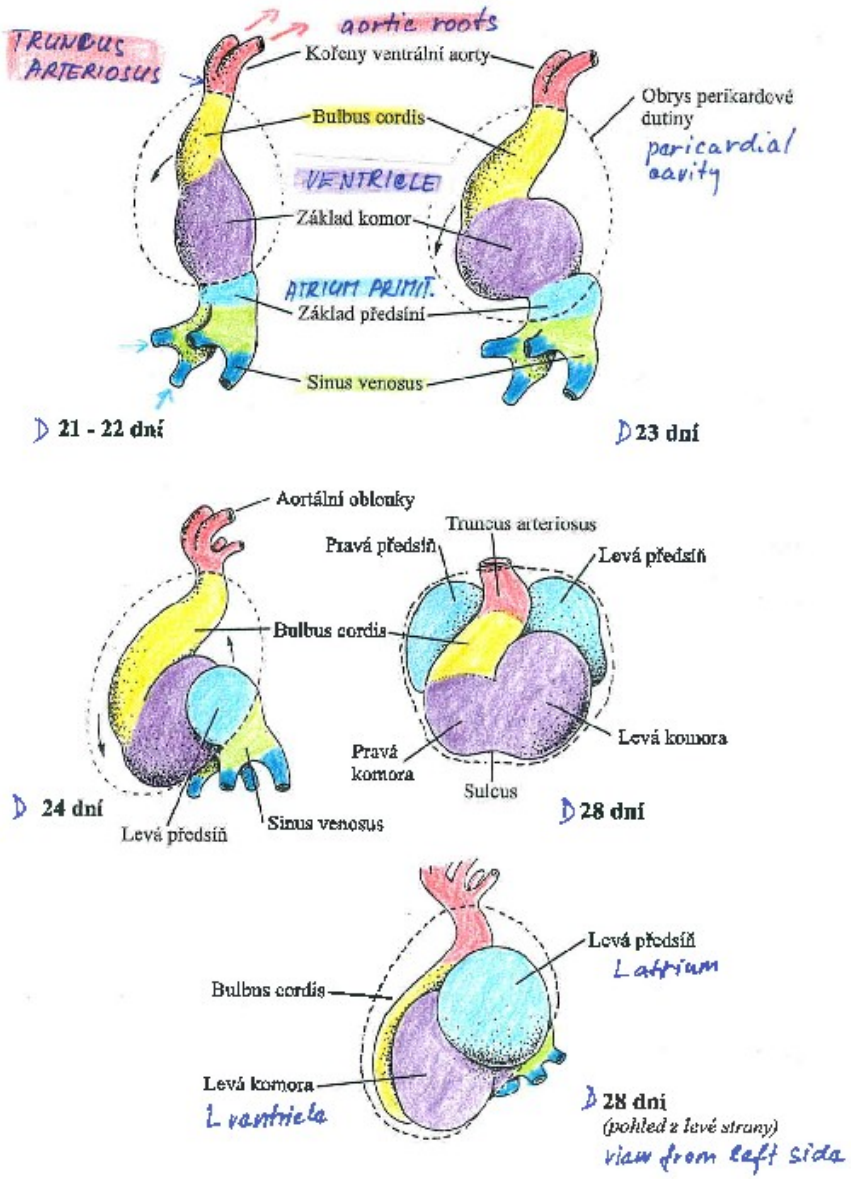
Septum interventriculare

Grows from apex cordis craniallly to AV septum



6 - membranózní část septa

7 - IV septum

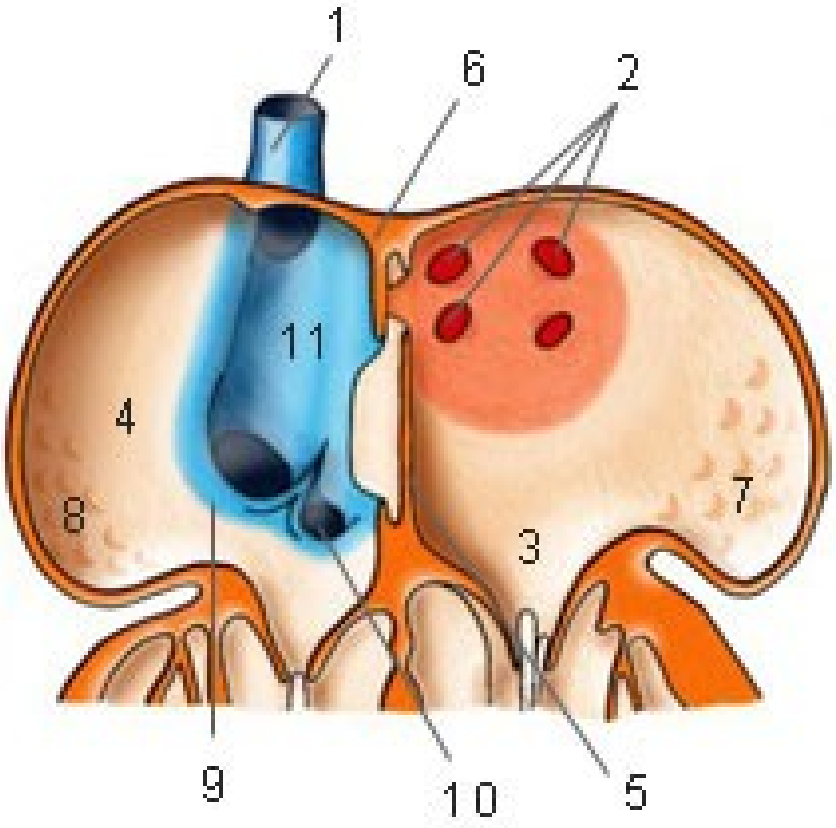


Atrium

Septum atriorum

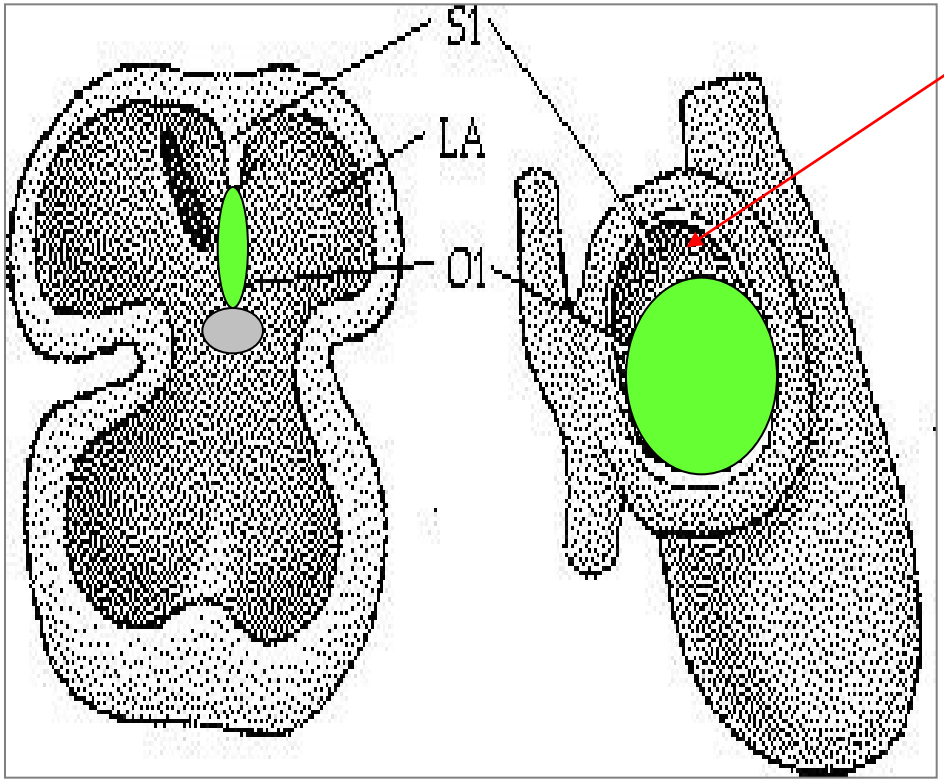
-septum primum s ostium primum (obliteration); ostium secundum

-septum secundum with foramen ovale



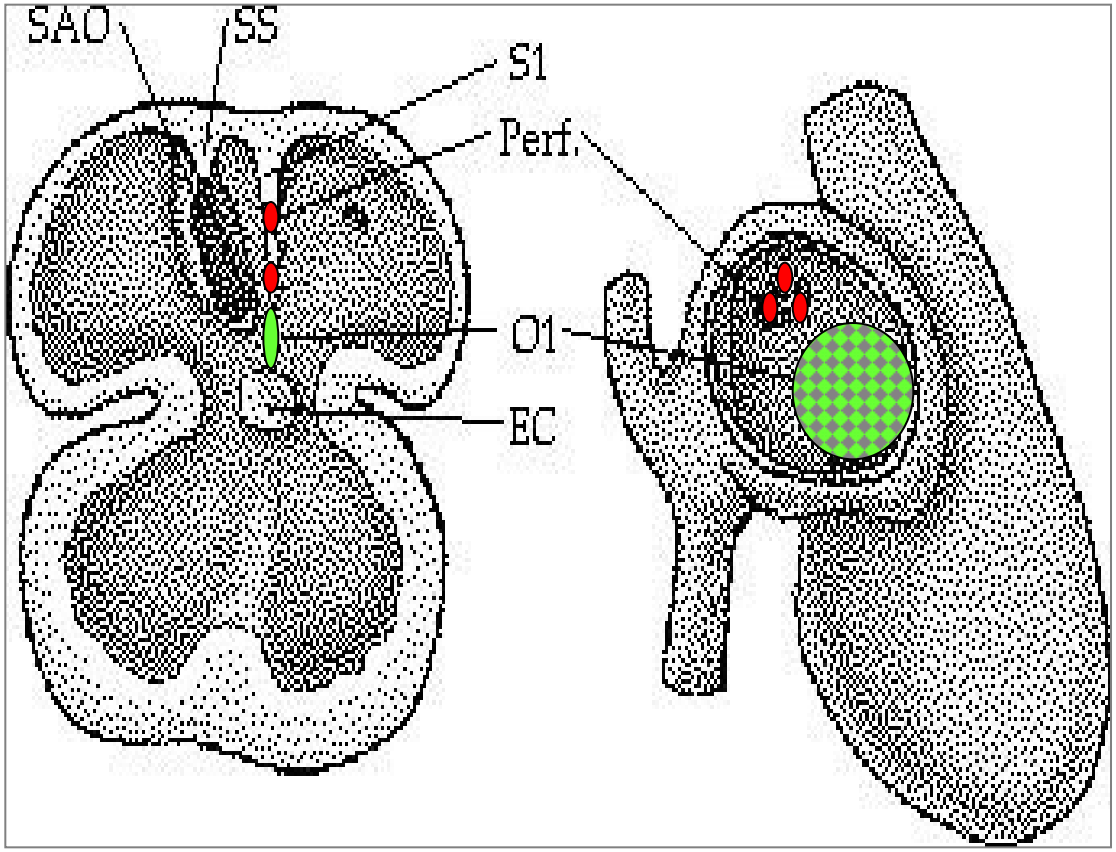
Septum primum

Grows from dorsocranial wall – ostium primum (caudally), closes later, and ostium secundum (above) appears by cell apoptosis



S1 – septum primum, O1 – ostium secundum

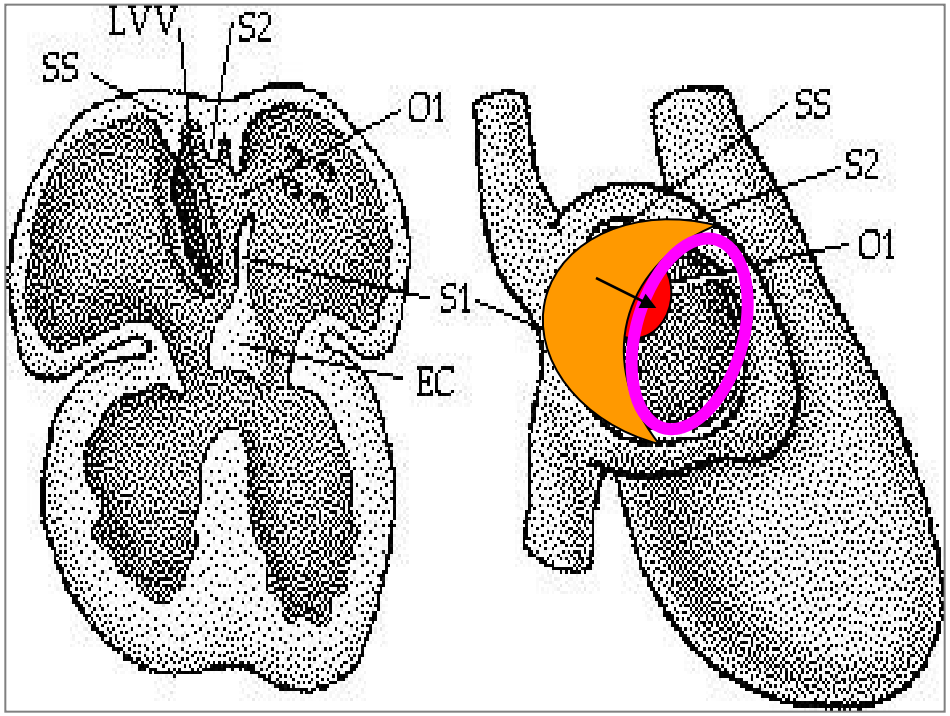
In septum primum by cell apoptosis foramen secundum will arrise



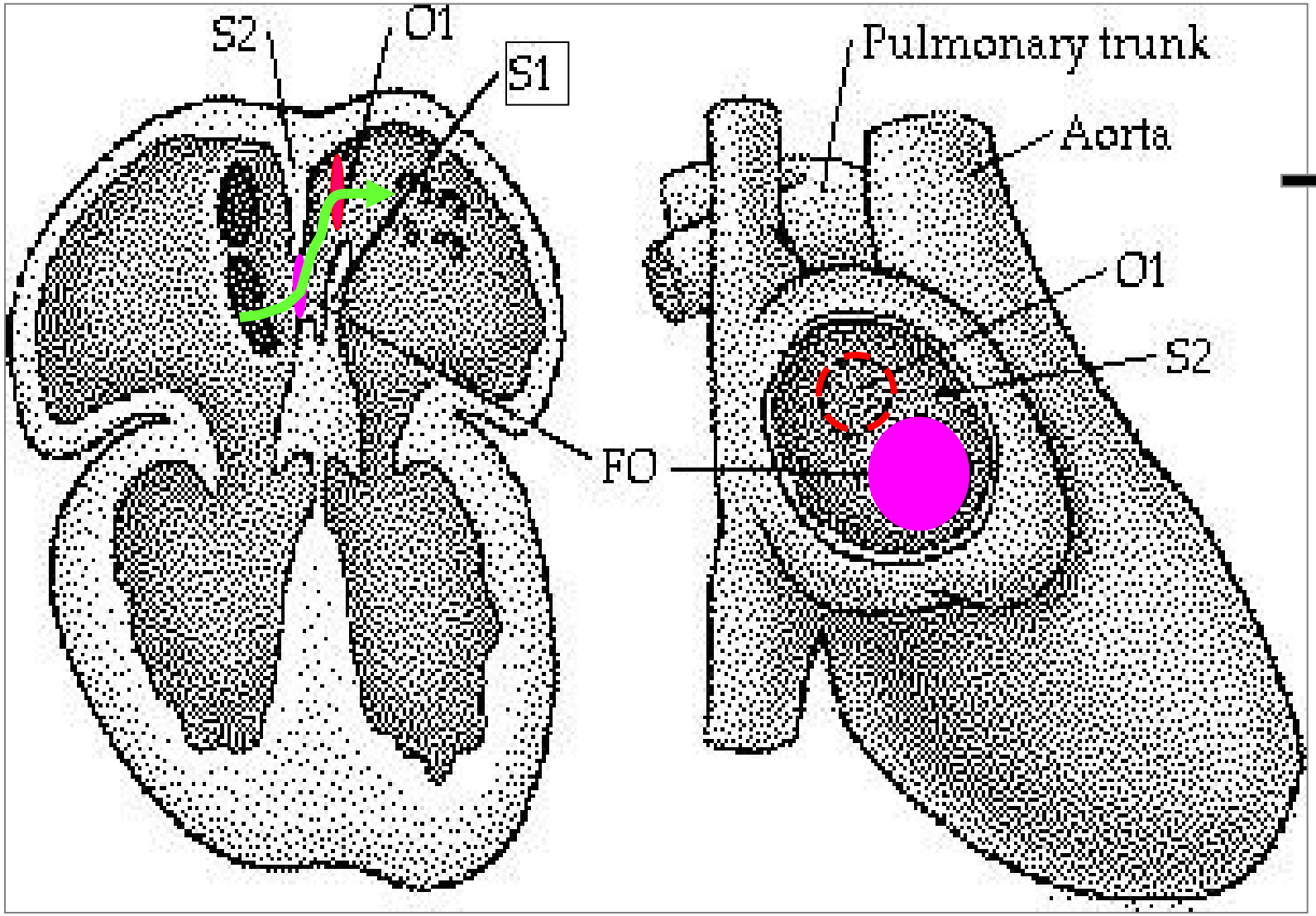
S1 – septum primum, SS – septum spurium,
O1 – ostium primum, EC – endocard. cushion,
Perf – perforation of ostium secundum,
SAO – sinoatrial orifice,

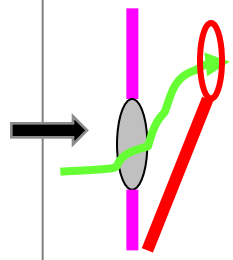
Septum secundum

-semicircular fold, does not reache endocardial cushions;
-covers foramen secundum in septum primum and by its free lower margin surrounds foramen ovale

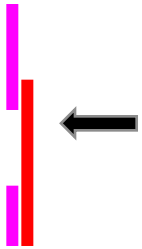


S1 – septum primum, S2 – septum secundum, SS – septum spurium,
O1 – foramen secundum, FO – foramen ovale,
EC – endocard. cushion,
LVV – left venous valve



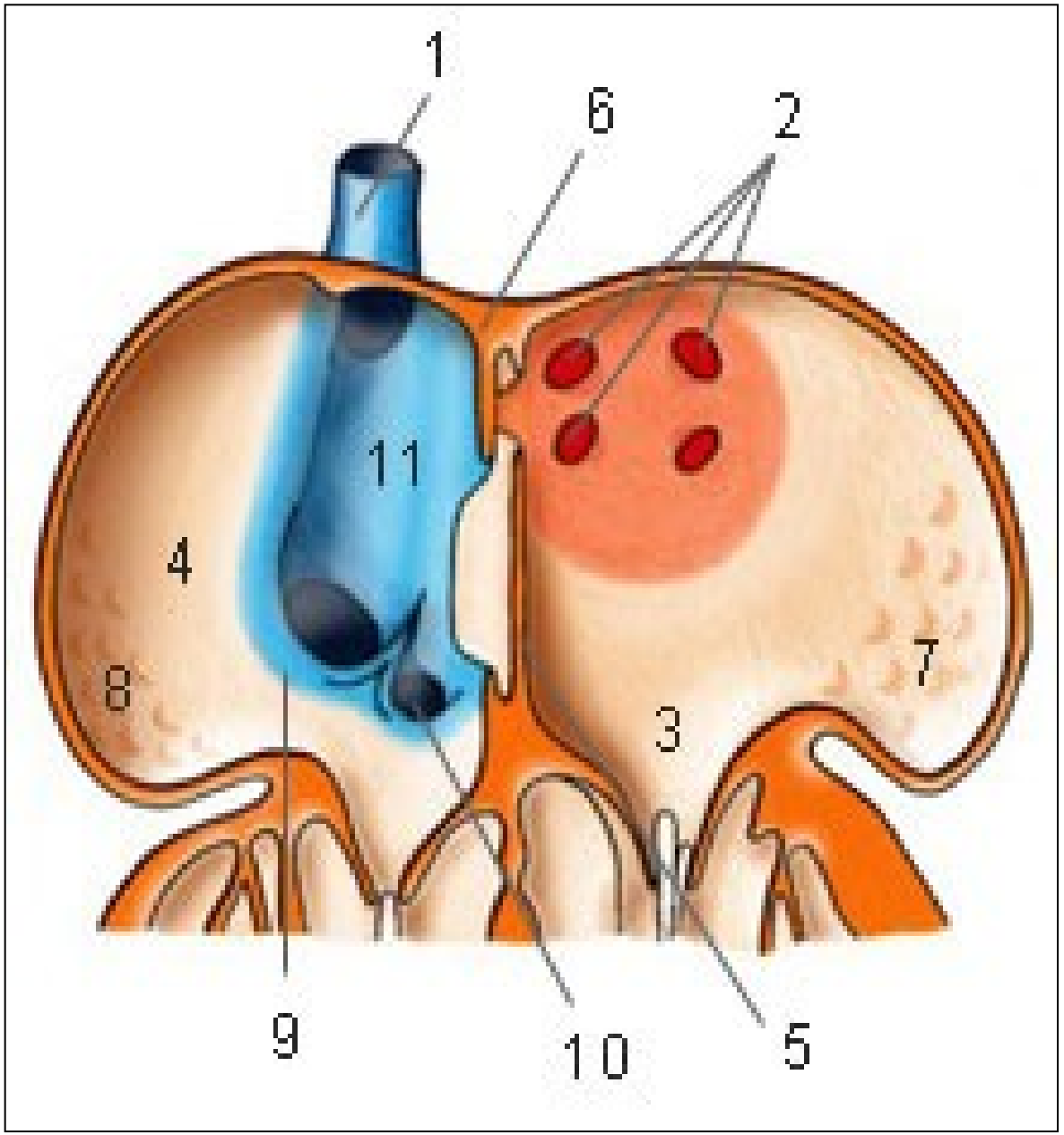


before and after birth

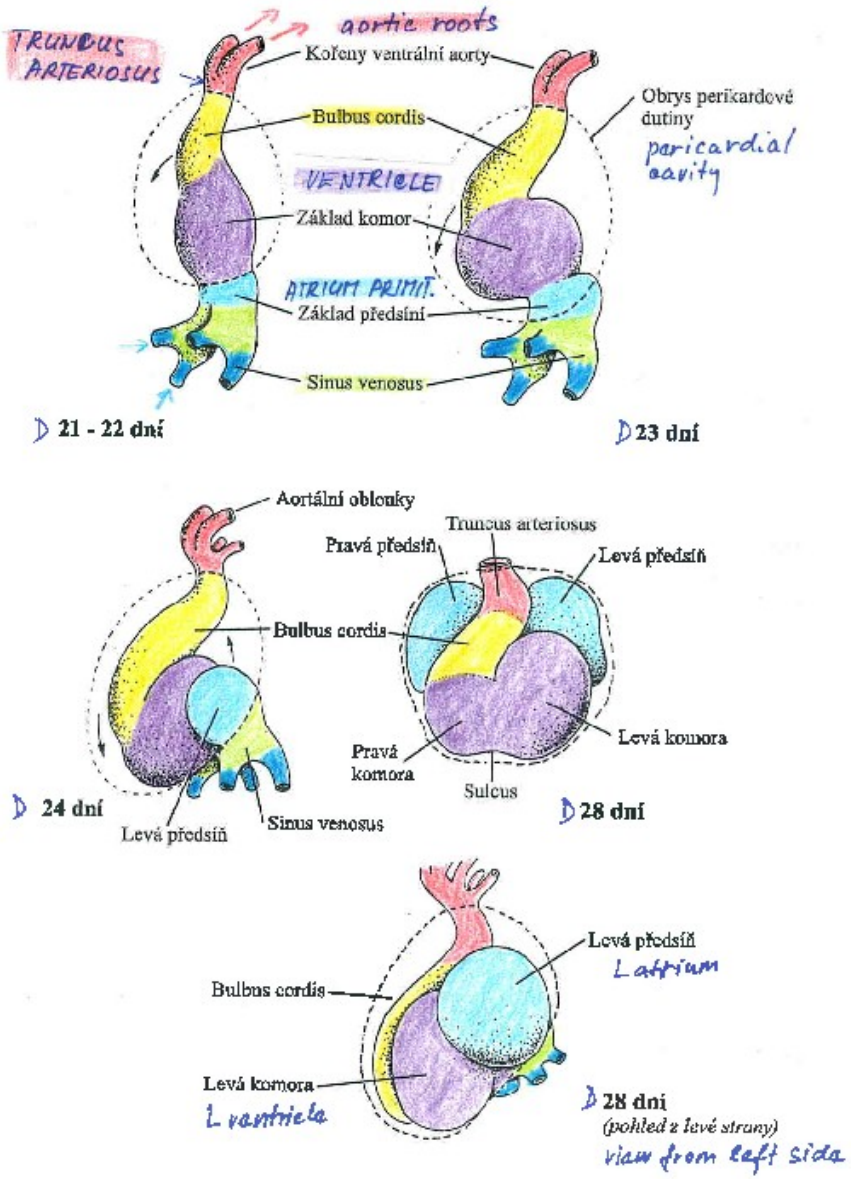


S1 – septum primum (valvula foraminis ovalis), S2 – septum secundum, SS – septum spurium, O1 – foramen secundum, FO – foramen ovale, EC – endokardový polštářek, Perf – perforace, SAO – sinoatriání orificium, LVV – levá venózní chlopeň

Blood from v. cava under pressure flows from the right atrium into the left.



1. Vena cava superior
2. Venae pulmonales
3. Atrium sin.
4. Atrium dx.
5. Septum primum
6. Septum secundum
7. Primitive left atrium
8. Primitive right atrium
9. Valve of vena cava inferior
10. Valve of sinus coronarius
11. Sinus venosus



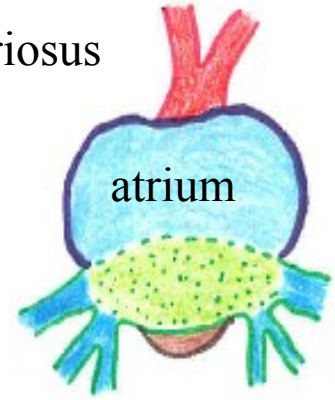
Sinus venosus

- vv. cardinales communes
- vv. umbilicales
- vv. vitellinae

Left veins obliterate and
- left part of sinus venosus ⇨ sinus coronarius
- right part of sinus venosus ⇨ part of right atrium wall

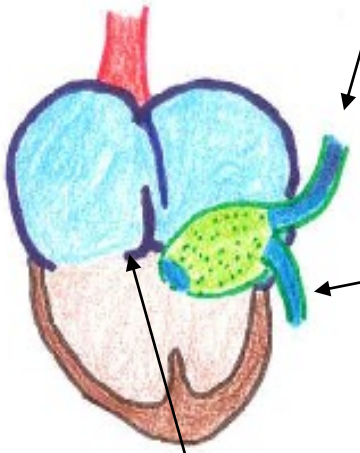
Sinus venosus + atria

Truncus arteriosus



Sinus venosus:
-transvesal part
-R + L horns:

- v. cardinalis comm.
- v. umbilicalis
- v. omphalomesenterica



On the right side:

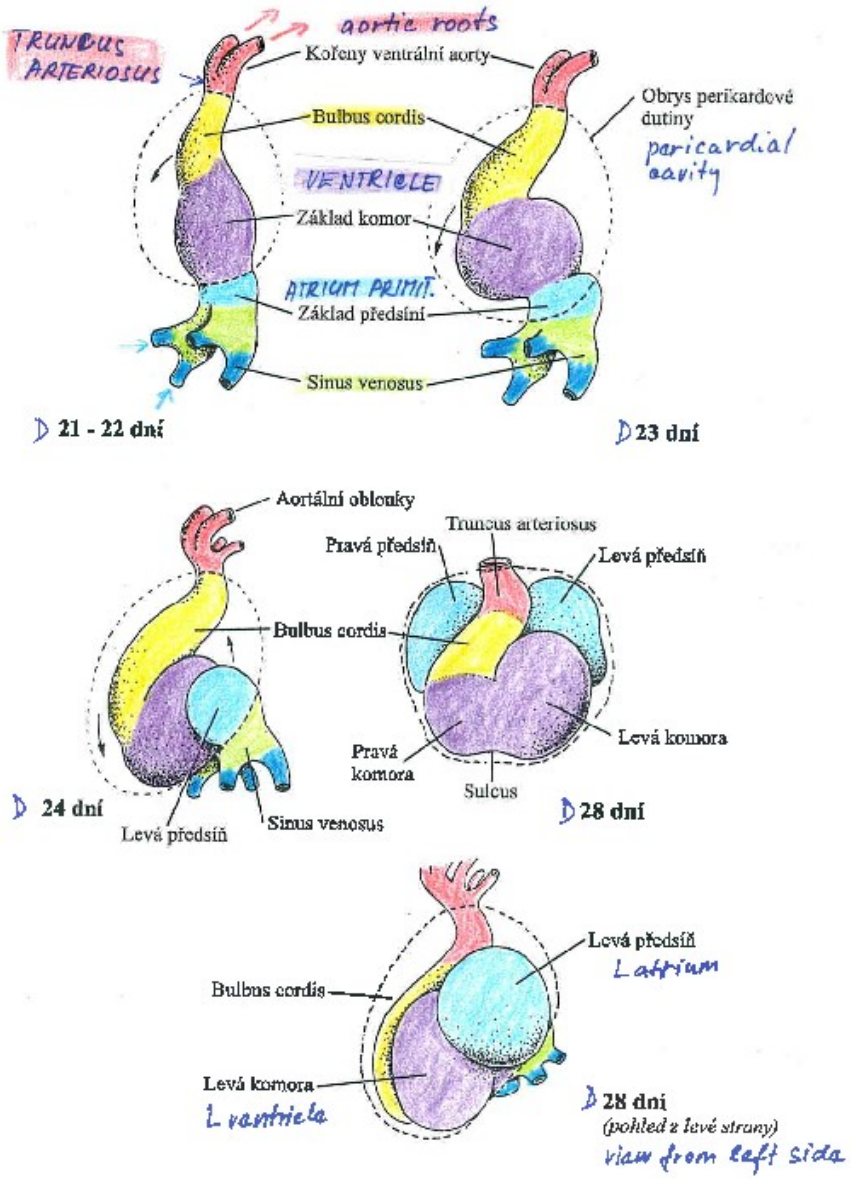
v. cava sup.
from v. cardin. comm. dx.+ v. precardin. dx.

v. cava inf.
(posthepatic part)
from v. omphalomes. dx.

On the left side:

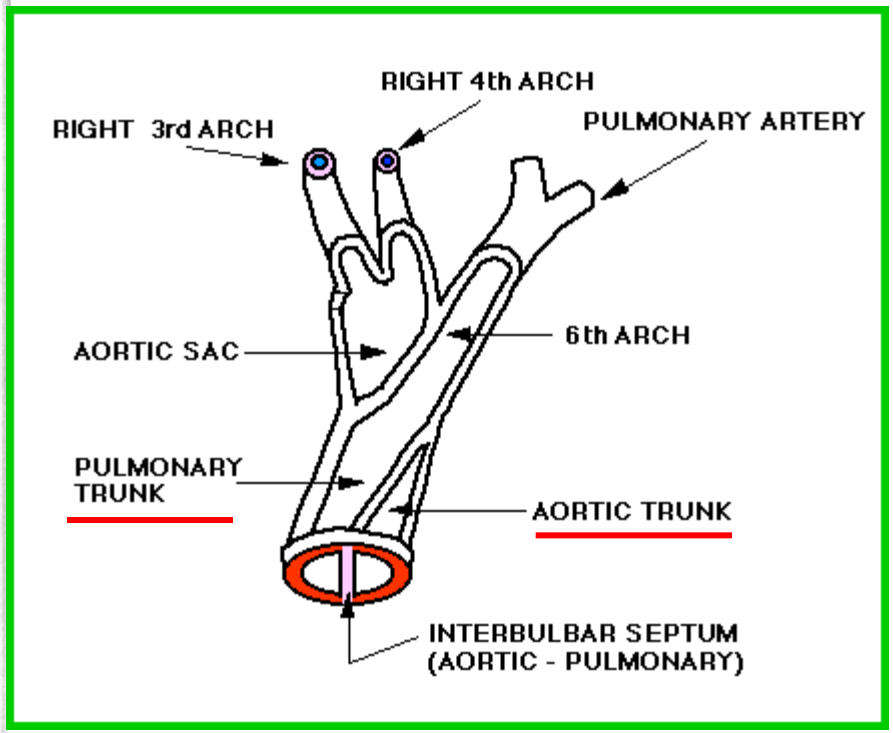
veins obliterate and give rise to
sinus coronarius

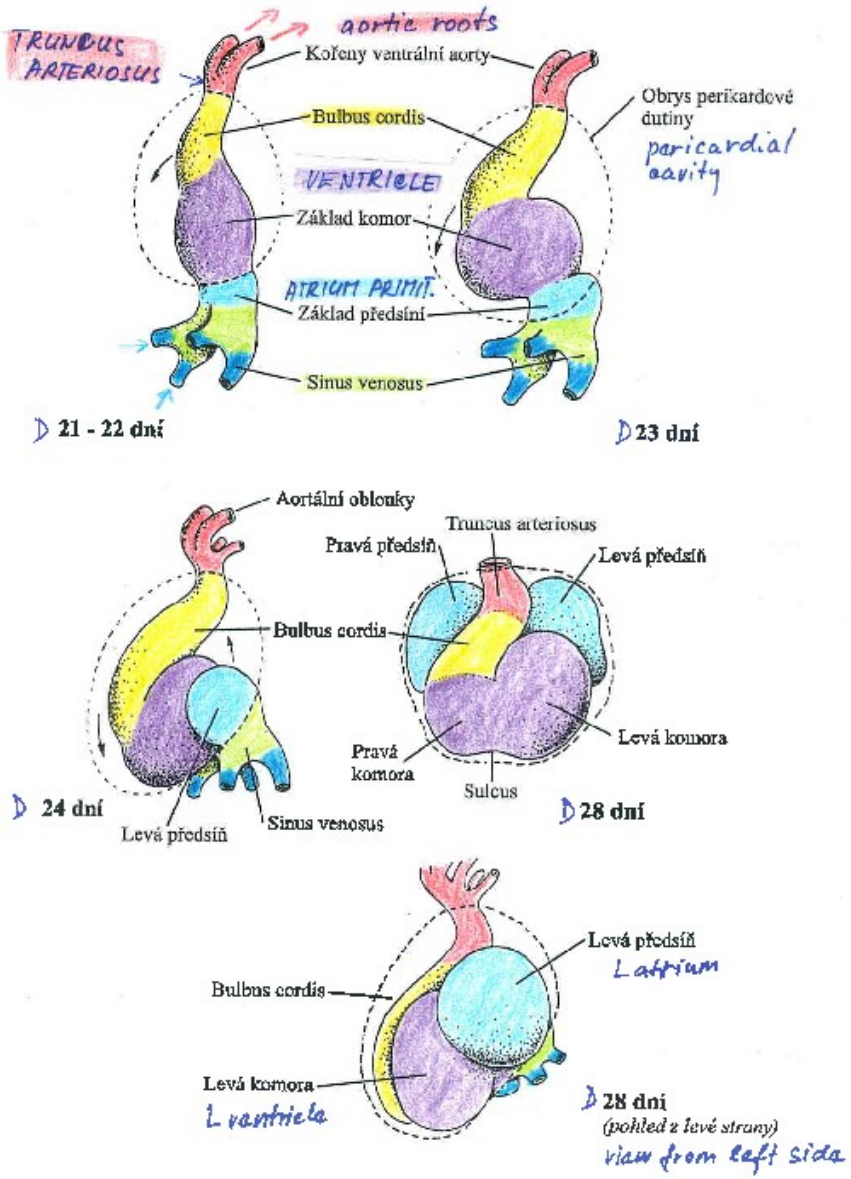
(pictures - view from dorsal side)



Truncus arteriosus + aortic sac

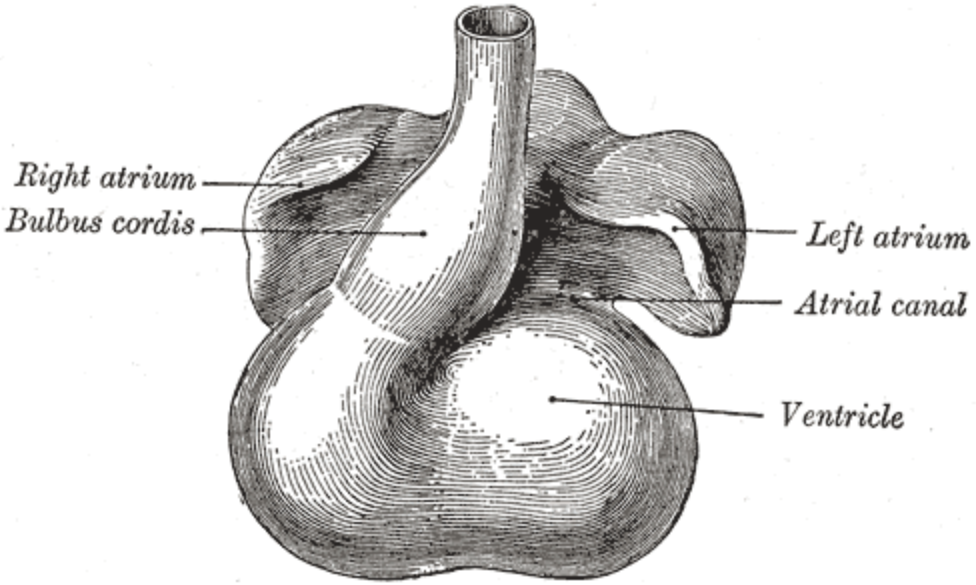
separates into:
-2 aortic roots with 6 pairs of aortic arches

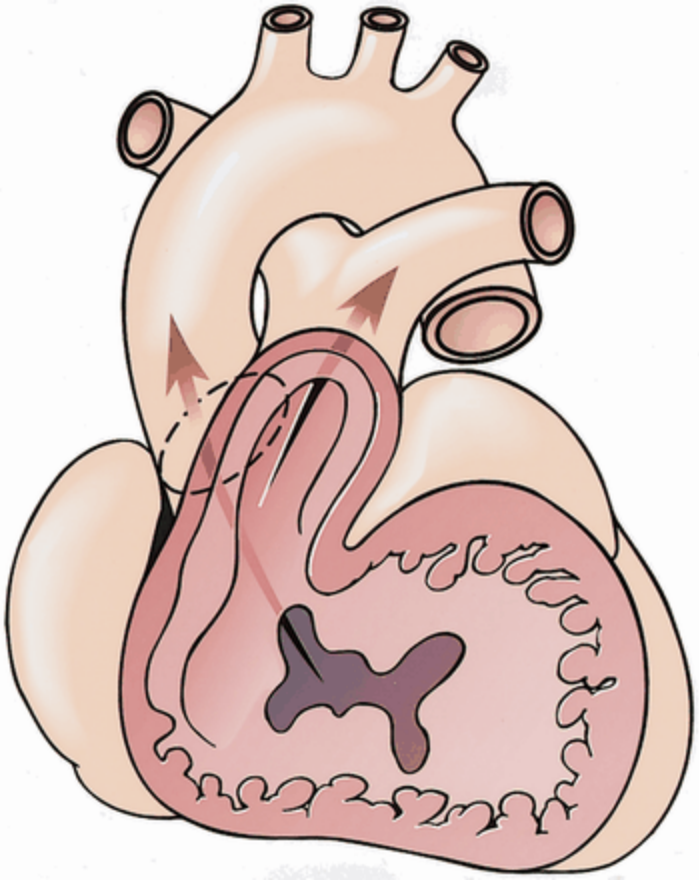


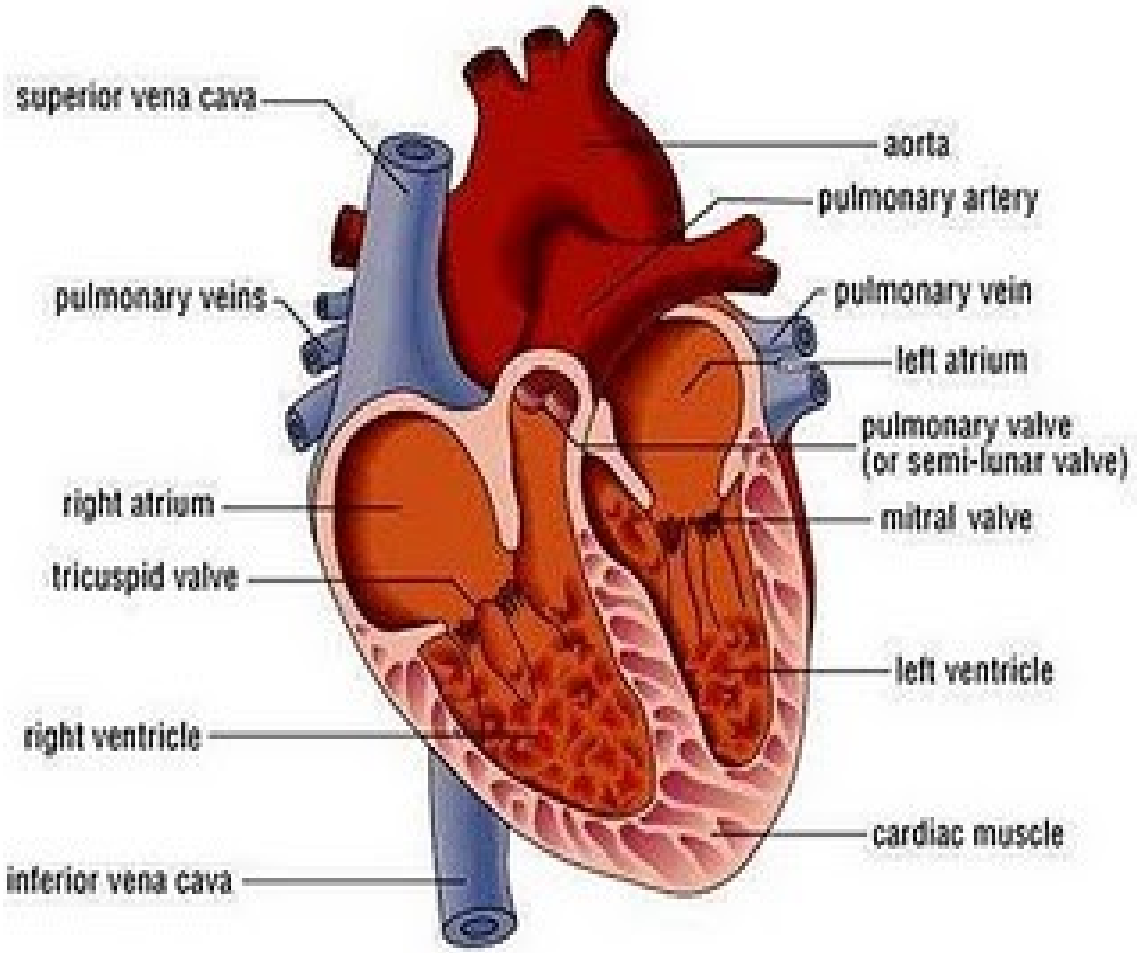


Bulbus cordis

- cranial – truncus arteriosus
- middle – conus arteriosus
-caudal – part of ventricle wall



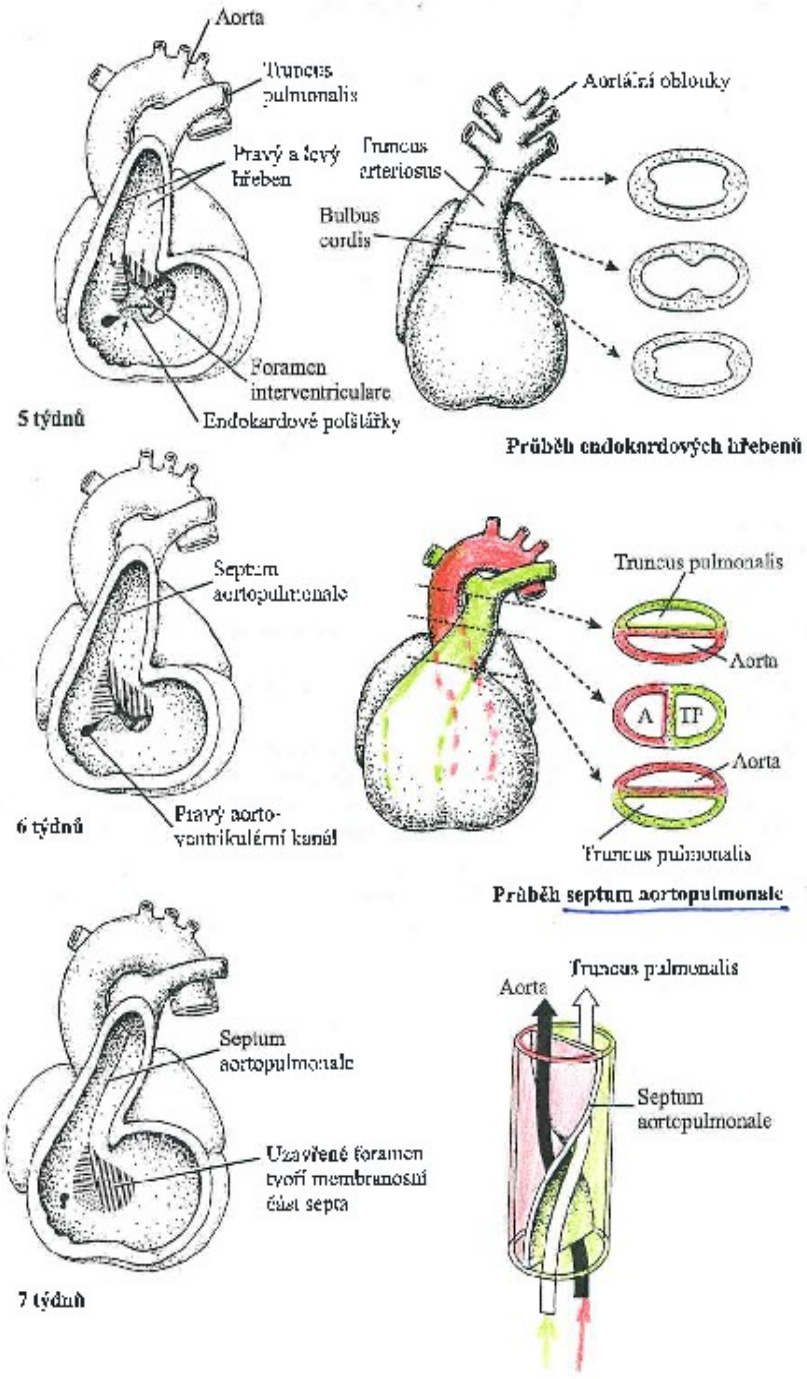




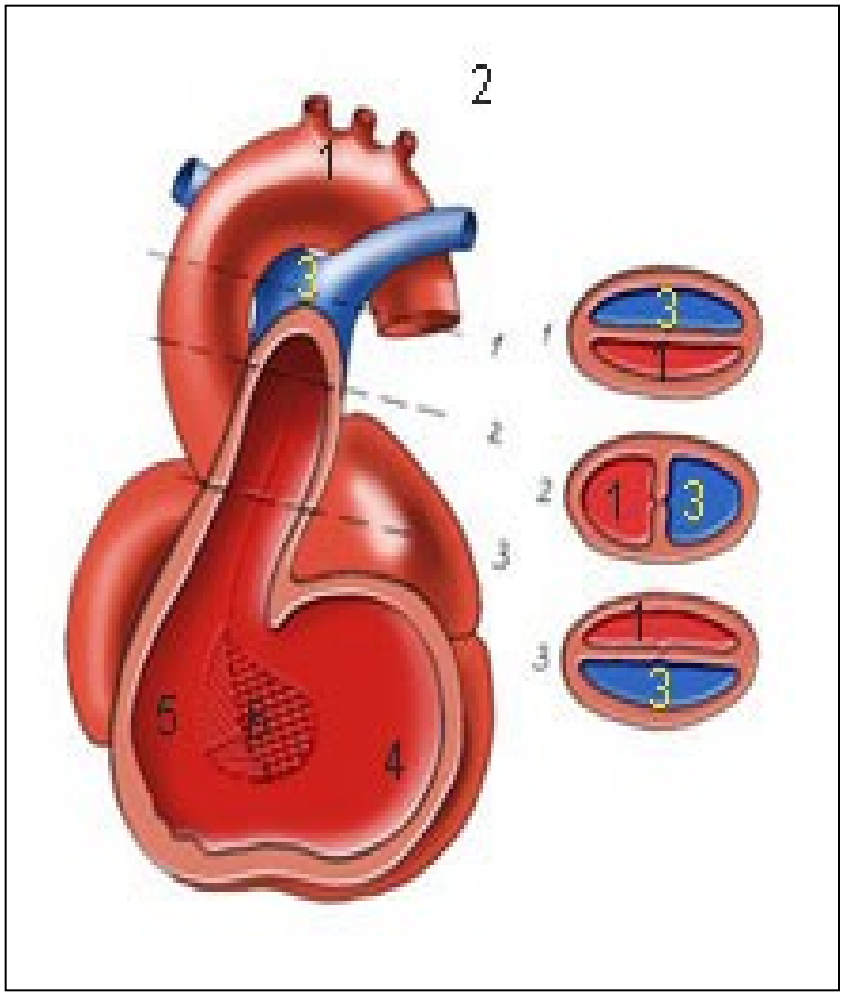
Bulbus cordis – participate in ventricle wall;
in RV - conus arteriosus, in LV – sinus aortae.

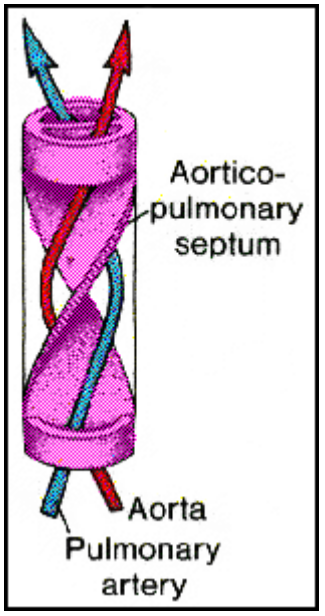
Bulbus cordis a truncus arteriosus

a pair of opposing ridges appear in walls of bulbus cordis and truncus arteriosus. These ridges twist around each other, forming spiral **aortico-pulmonary septum**.
This septum divides bulbus cordis and truncus arteriosus into two channels, the **aorta** and the **truncus pulmonalis**.
It also participates in the closure of the interventricular foramen

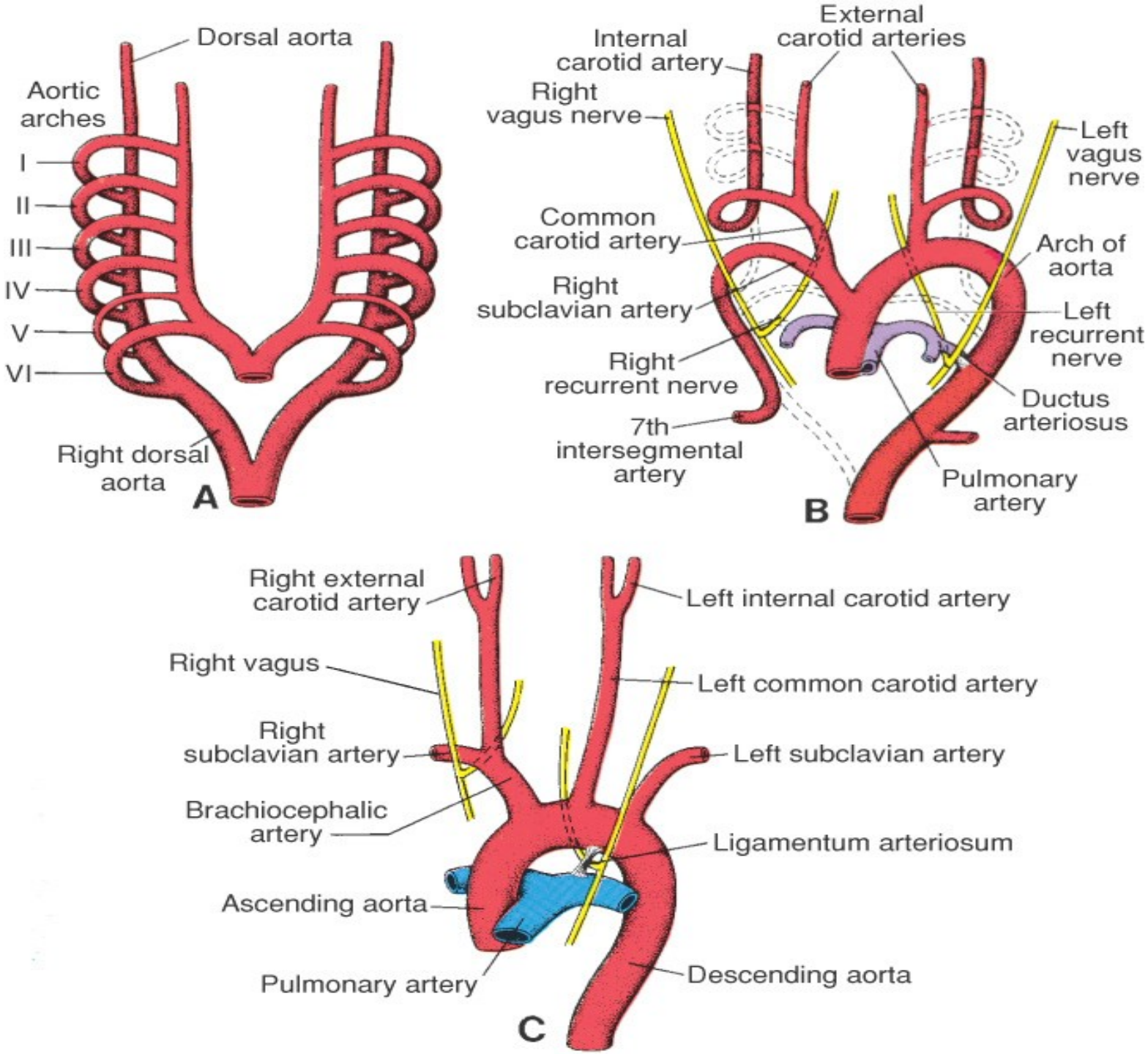


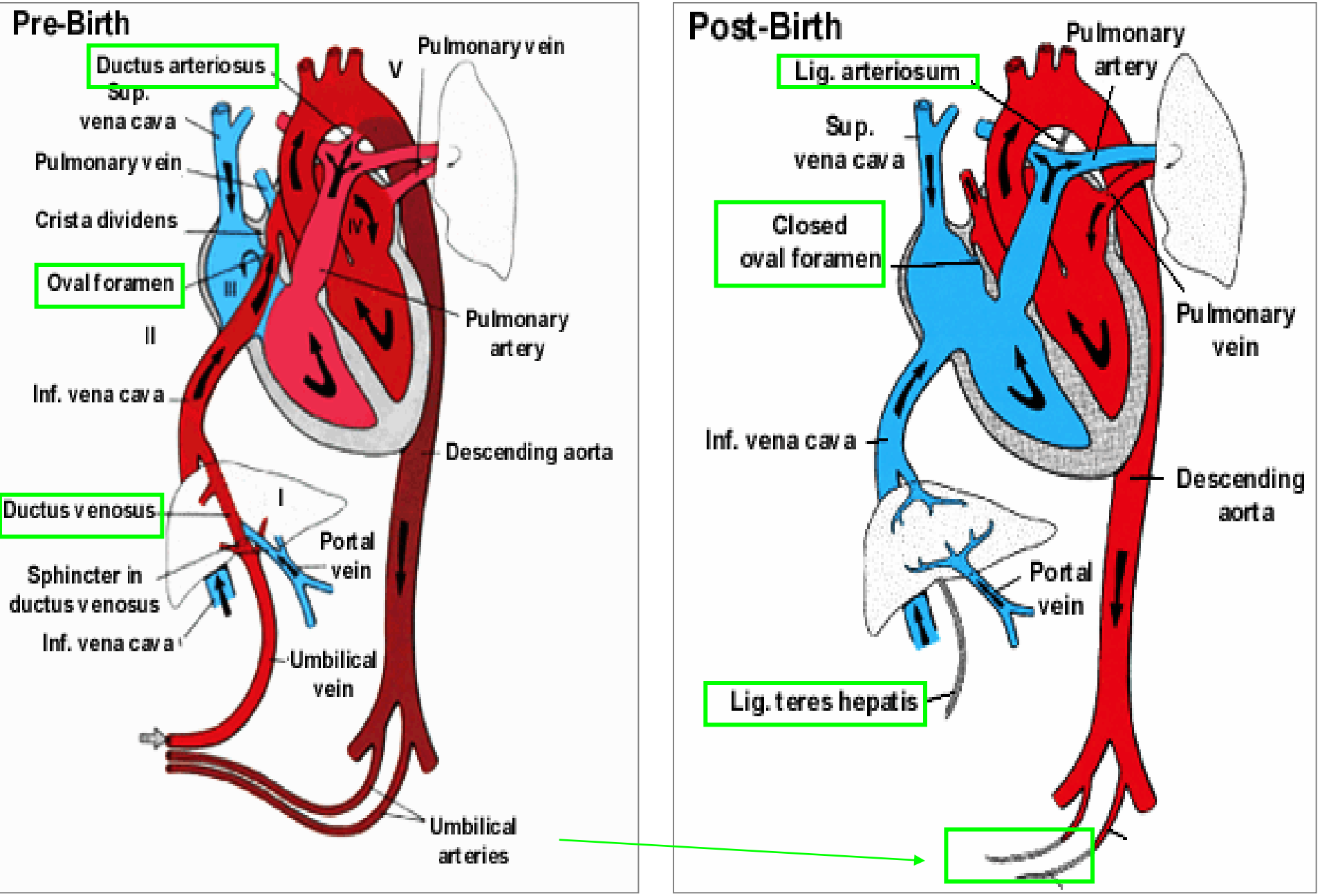
Septum aortopulmonale



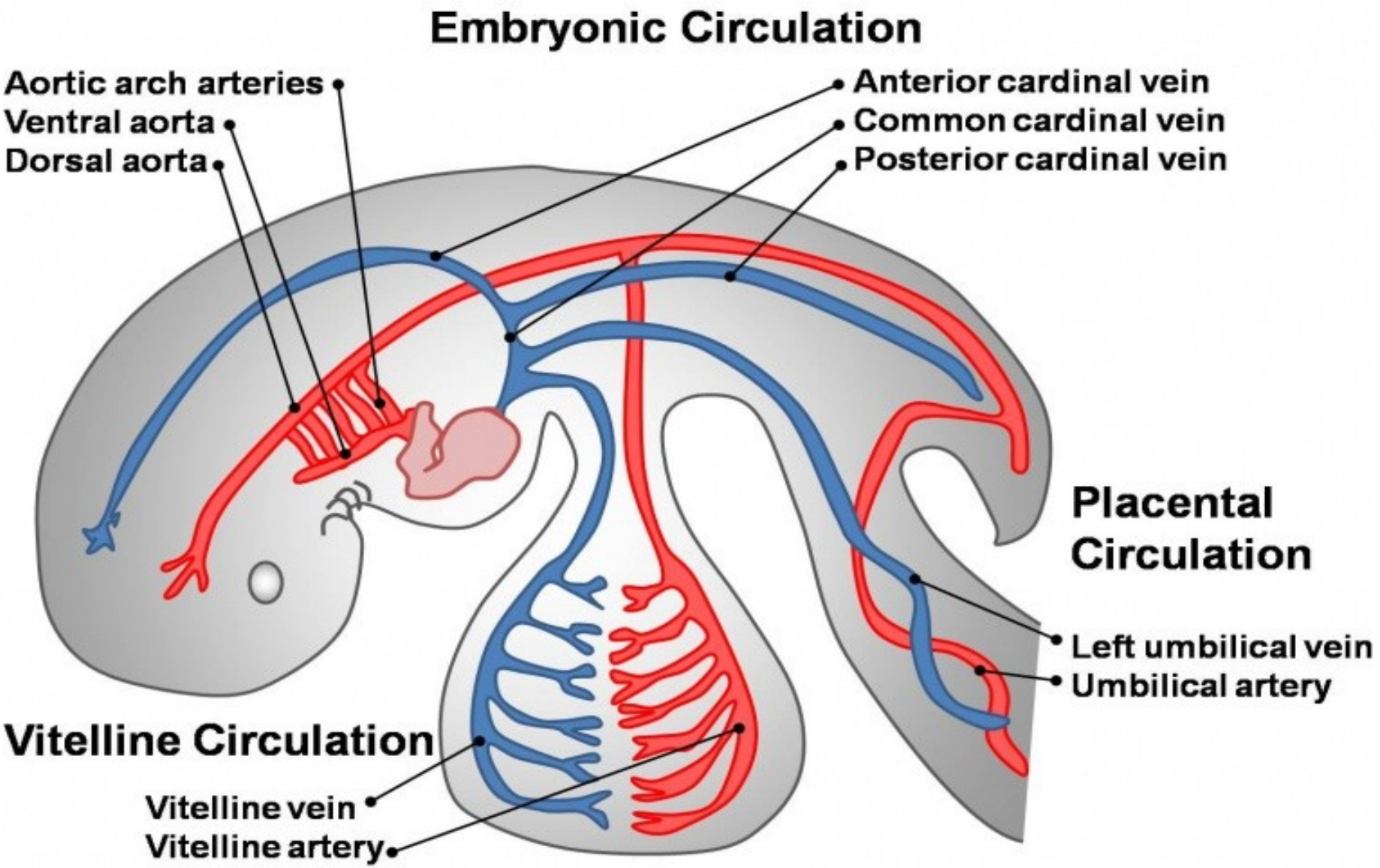


1. Aorta
2. a. pulmonalis sin.
3. Truncus pulmonalis
4. Septum interventriculare (muscular part)
5. right ventricle
6. membranous part of septum interventriculare


Dorsal aorta
Aortic arches
I
II
III
IV
V
VI
Right dorsal aorta
A
External carotid arteries
Internal carotid artery
Right vagus nerve
Left vagus nerve
Common carotid artery
Arch of aorta
Right subclavian artery
Left recurrent nerve
Right recurrent nerve
Ductus arteriosus
7th intersegmental artery
Pulmonary artery
B
Right external carotid artery
Left internal carotid artery
Right vagus
Left common carotid artery
Right subclavian artery
Left subclavian artery
Brachiocephalic artery
Ligamentum arteriosum
Ascending aorta
Pulmonary artery
Descending aorta
C


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

Primitive blood circulation



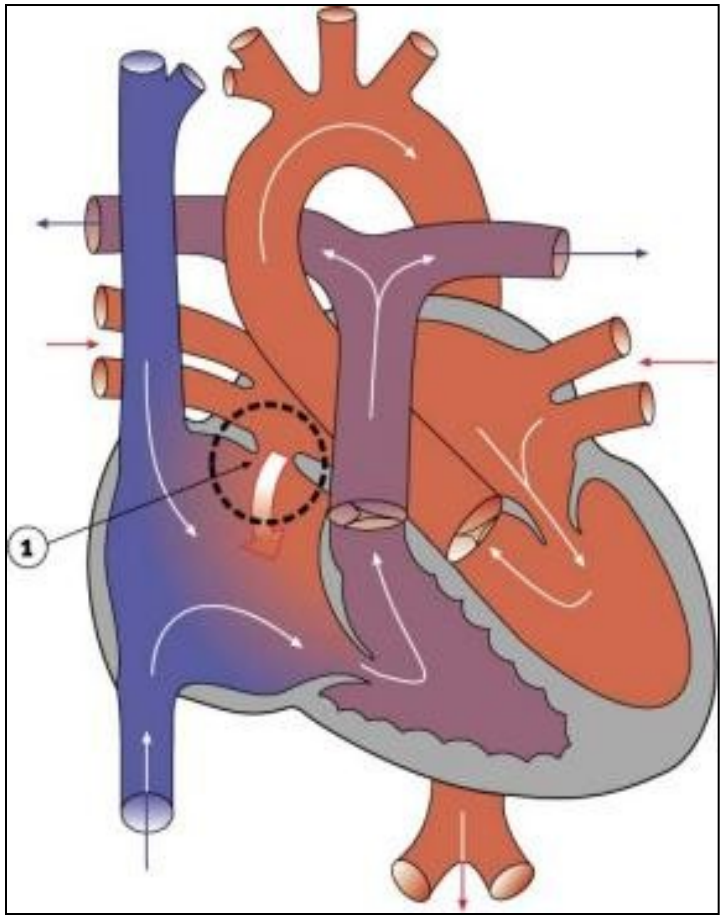
Congenital malformations in CVS

(the most frequent)

- With **left – right shunt** (without cyanosis)
  atrial septum defect
  ventricular septum defect
  ductus arteriosus apertus (= patens, = persistens)
- With **right – left shunt** (with cyanosis)
  Fallot tetralogy
  transposition of great vessels
  truncus arteriosus (common aorticopulmonal canal)
  tricuspid valve atresia
- Without shunt
  coarctation of aorta
  aortic stenosis
  pulmonary stenosis
  dextrocardia (+situs inversus)
  ectopia cordis

Atrial Septal Defects

a group of common congenital anomalies defects occuring in a number of different forms and more often in females.

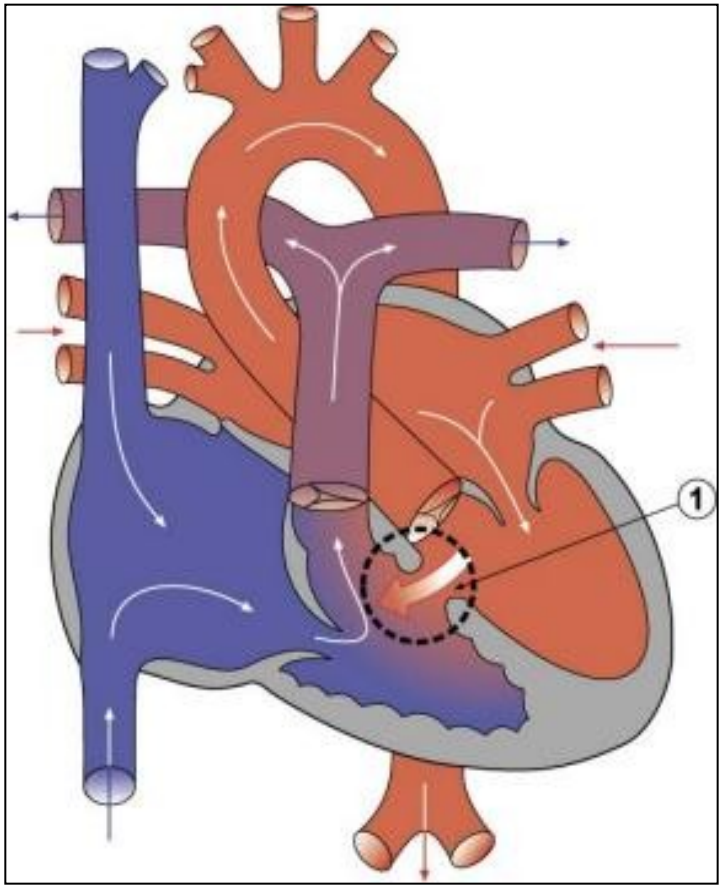


patent foramen ovale

left-right shunting

Ventricular Septal Defect

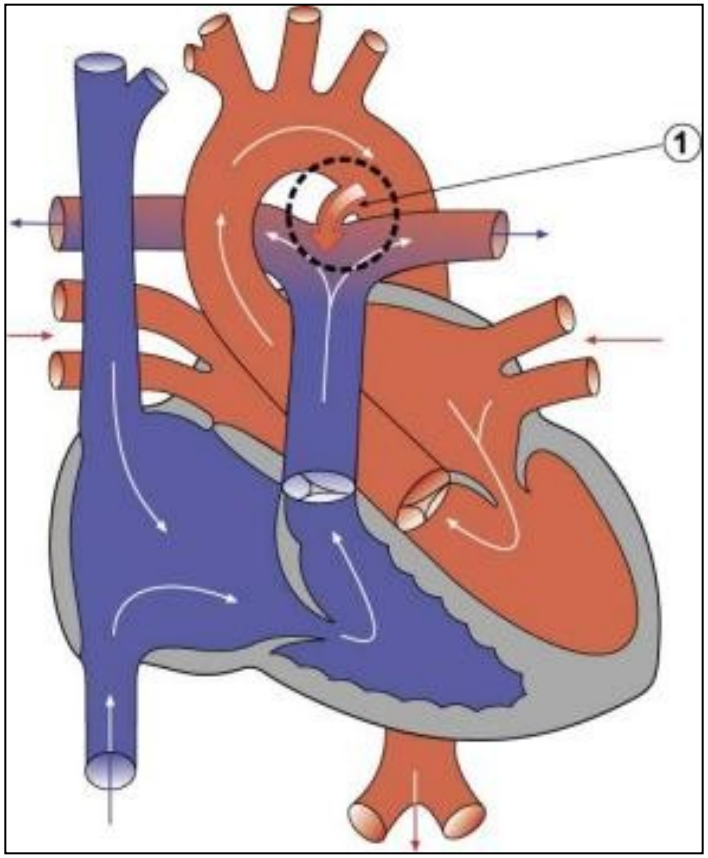
The Ventricular Septal Defect occurs in the interventricular septum, and is more frequent in males that females.



left-right shunting

Patent Ductus Arteriosus

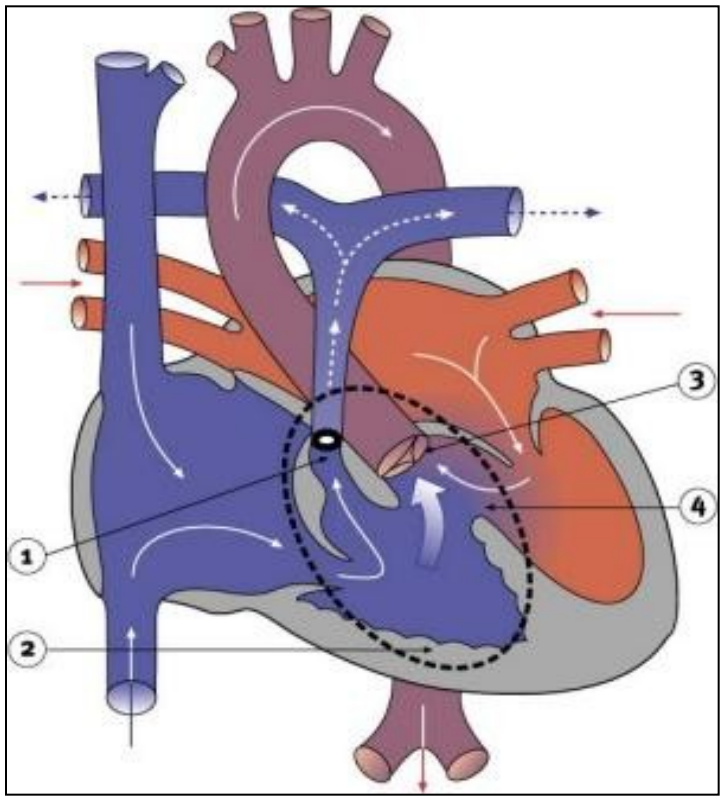
occurs commonly in preterm infants, can close spontaneously (by day three in 60% of normal term neonates) the remainder are ligated simply and with little risk.



left-right shunting

Tetralogy of Fallot

Named after Etienne-Louis Arthur Fallot (1888) who described it as "*la maladie blue*" and is a common developmental cardiac defect. The syndrome consists of a number of cardiac defects *possibly stemming from abnormal neural crest migration*.



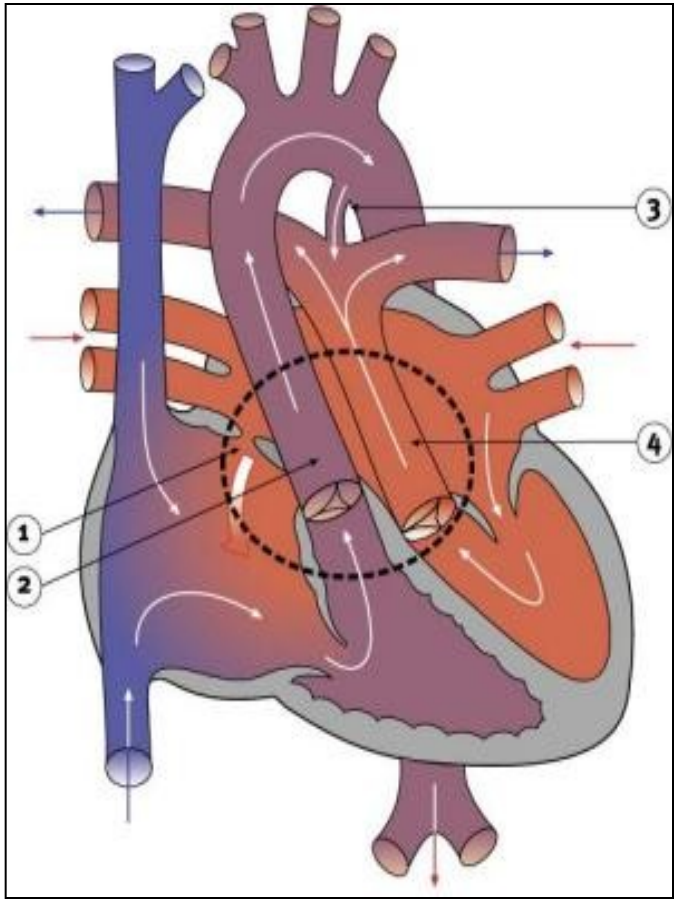
consists of:

1. ventricular septal defect
2. pulmonary stenosis (valvular or infundibular)
3. results in an overriding aorta
4. right ventricular hypertrophy

right-left shunting

Transposition of Great Vessels

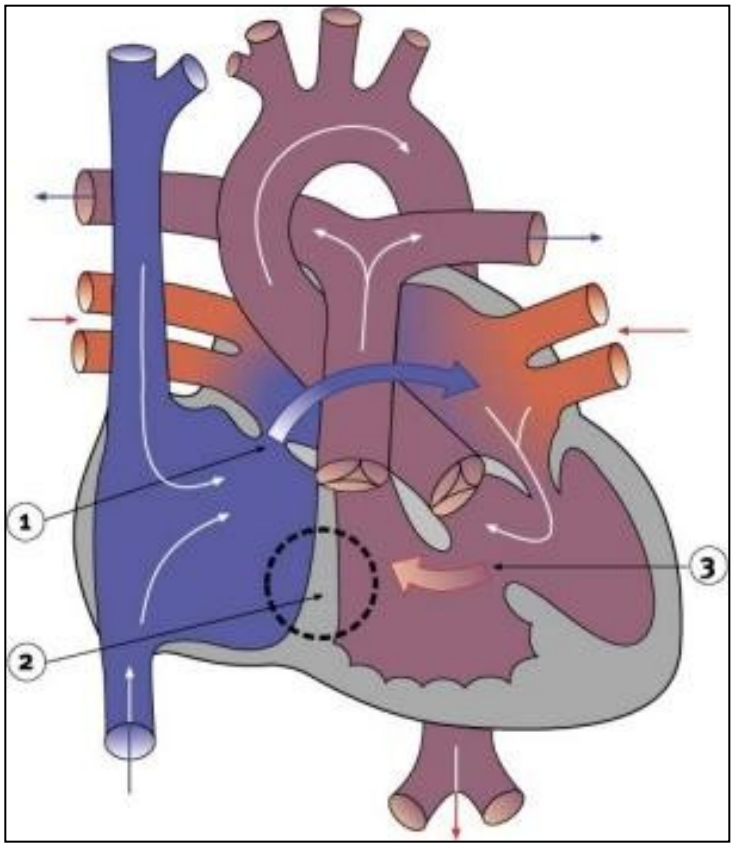
Characterized by aorta arising from right ventricle and pulmonary artery from the left ventricle and often associated with other cardiac abnormalities (e.g. ventricular septal defect).



right-left shunting

Tricuspid Atresia

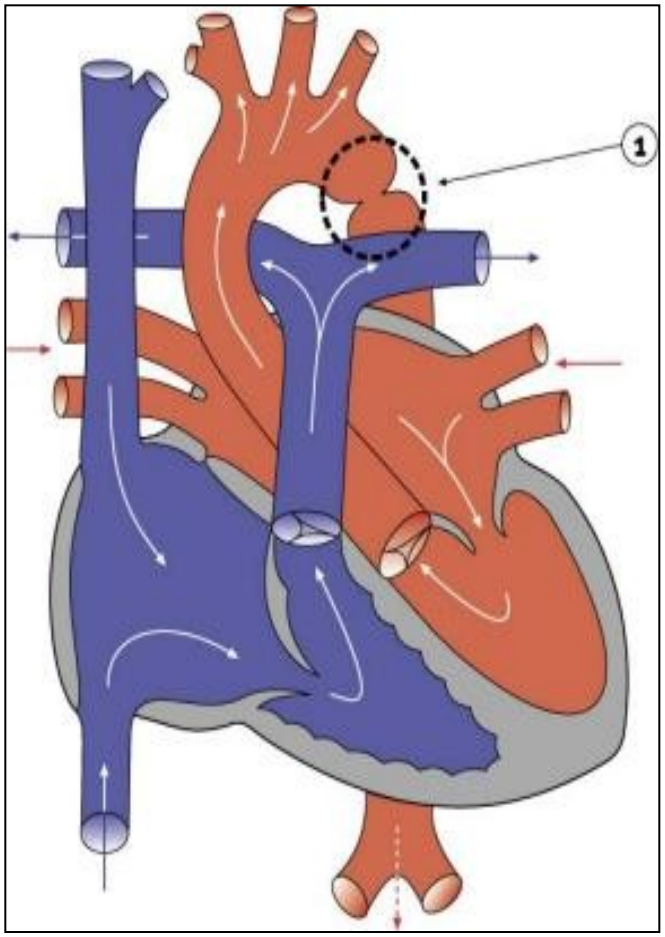
Blood is shunted through an atrial septal defect to the left atrium and through the ventricular septal defect to the pulmonary artery. The shaded arrows indicate mixing of the blood.



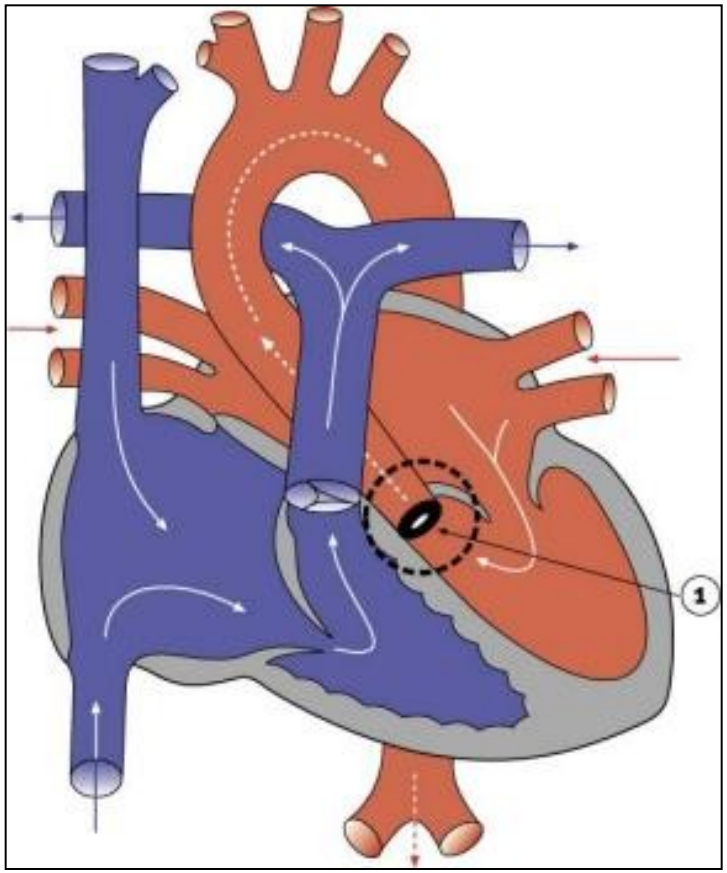
right-left shunting

Coarctation of Aorta (preductal or postductal)

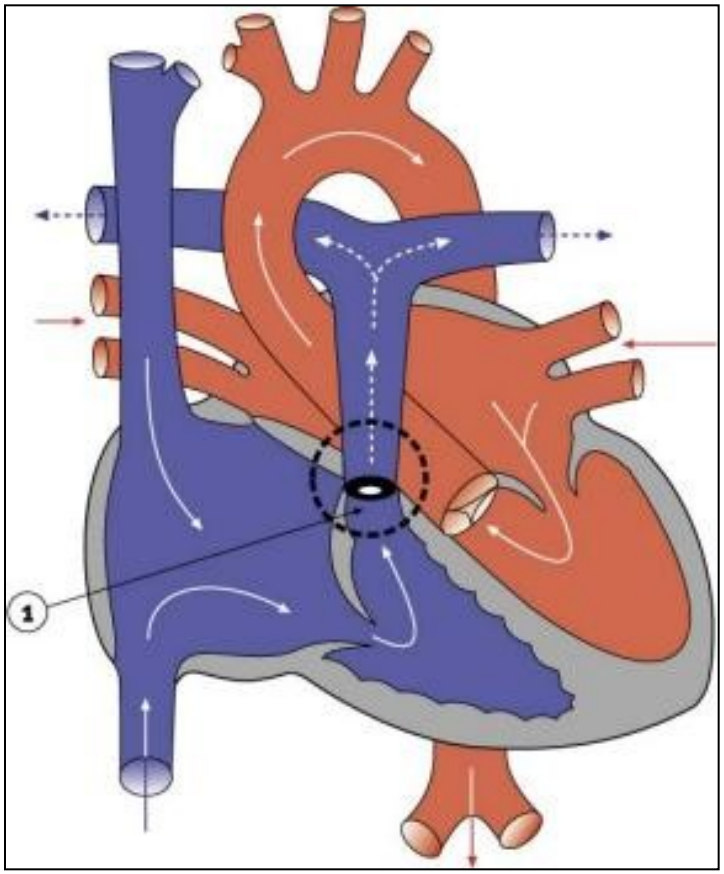
before or behind ductus arteriosus



Aortic Stenosis

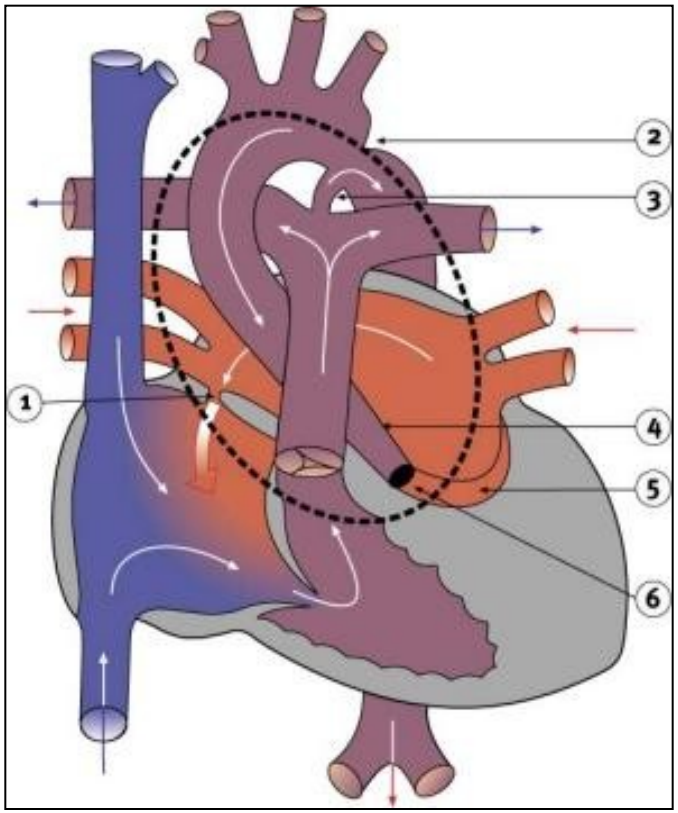


Pulmonary Stenosis

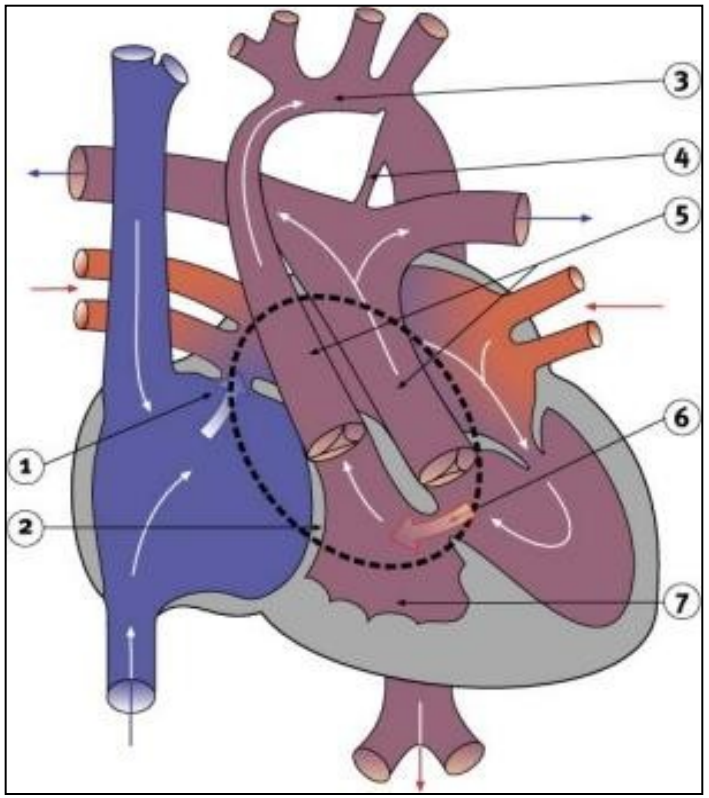


Hypoplastic Left Heart

Characterized by hypoplasia (underdevelopment or absence) of the left ventricle obstructive valvular and vascular lesion of the left side of the heart.



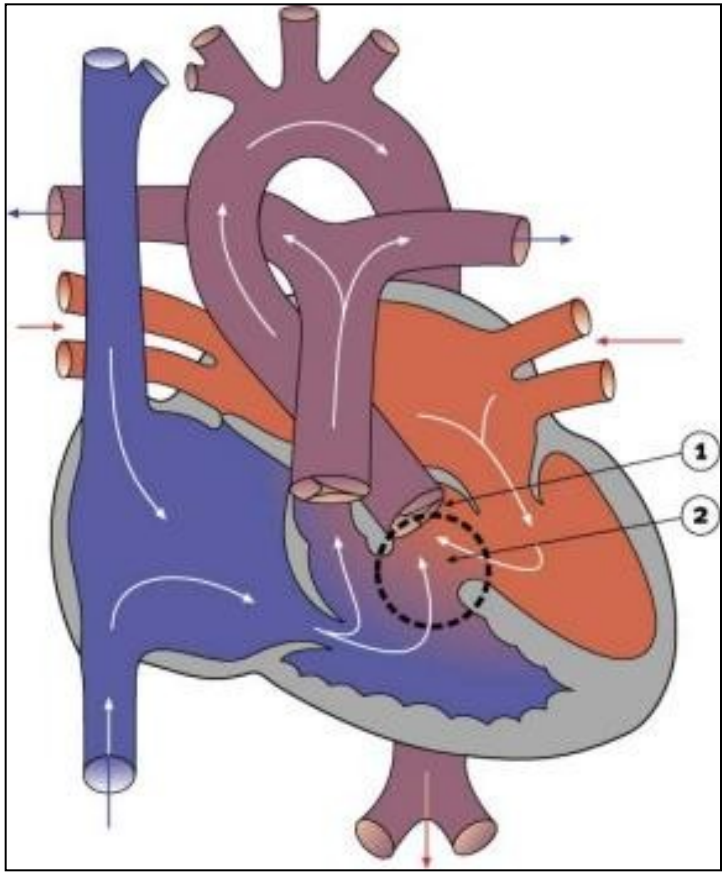
hypoplastic left hear



functional hypoplastic left heart

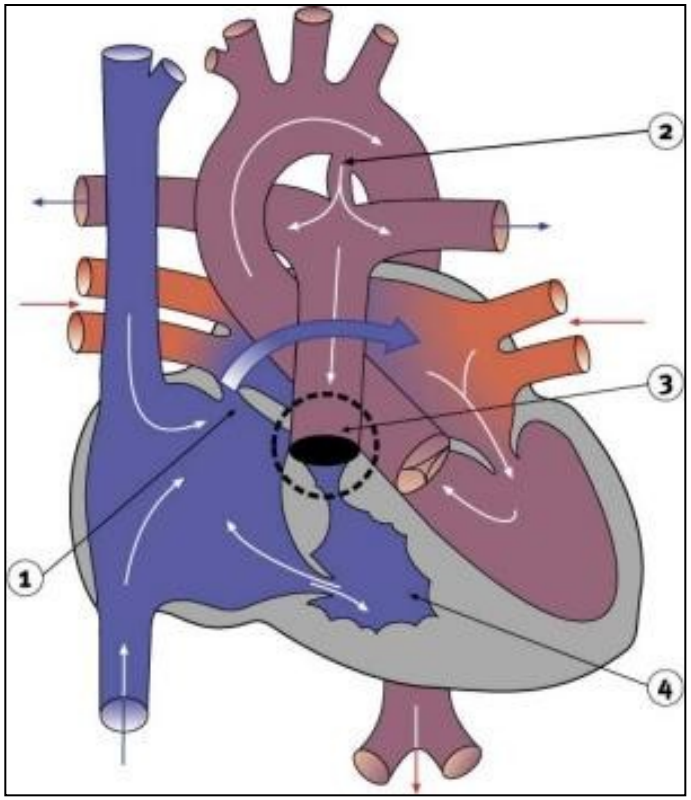
Double Outlet Right Ventricle

De-oxygenated blood enters the aorta from the right ventricle and is returned to the body.



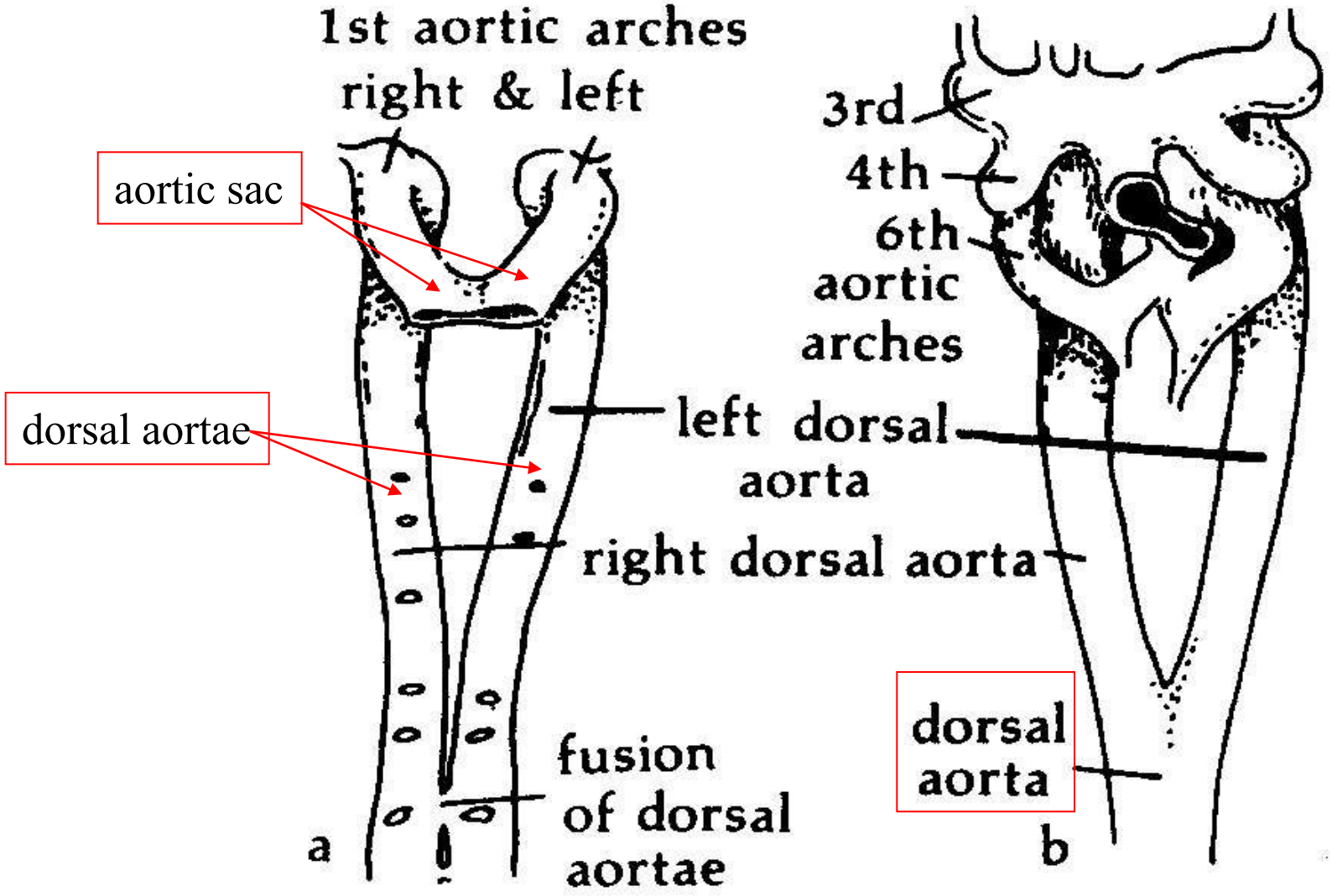
Pulmonary Atresia

Abnormal blood flow (as indicated by the shaded blue arrow) is from the right atrium and right ventricle through an atrial septal defect to the left side of the heart. Blood can reach the pulmonary arteries only through a patent ductus arteriosus.

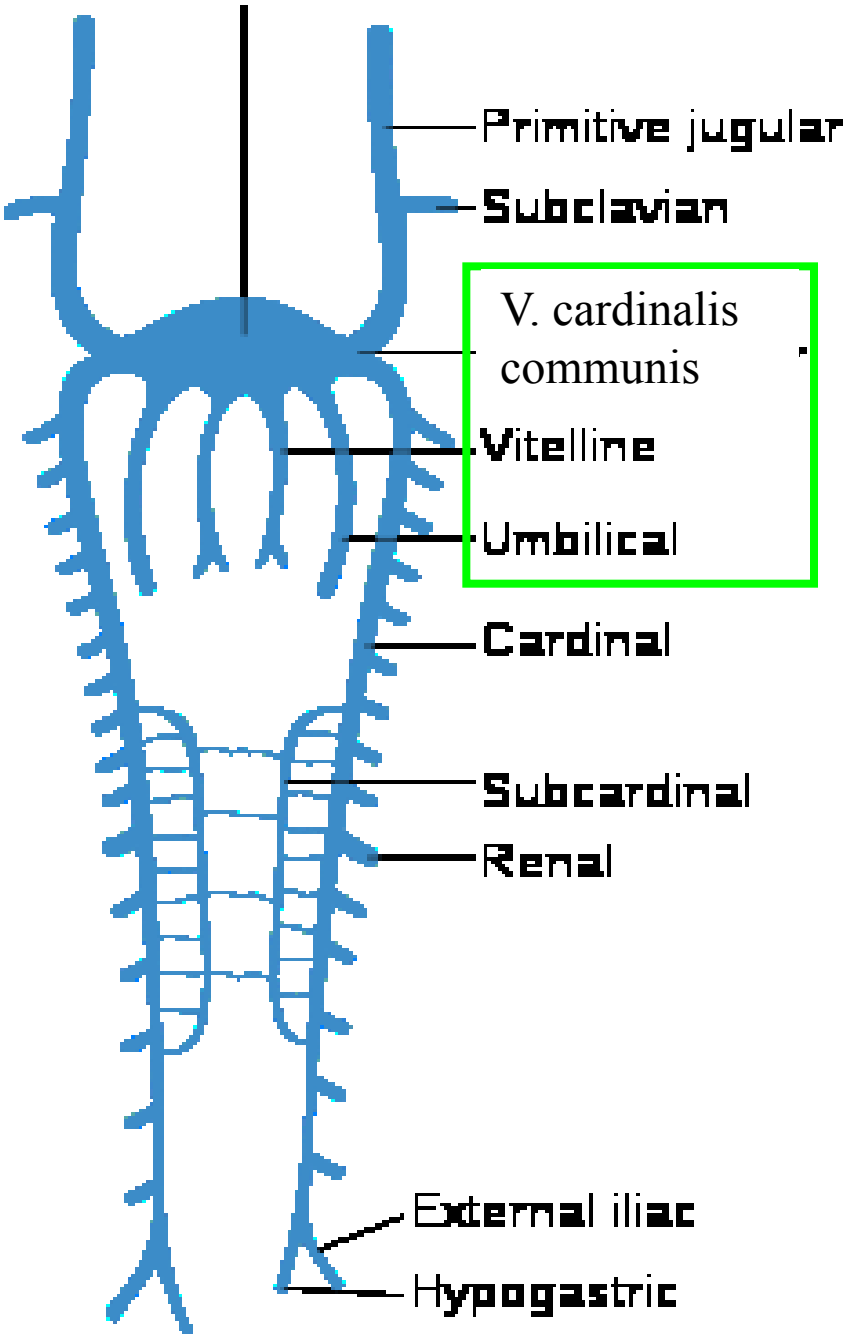


more images follow

arterial end of heart tube



Veins entering venous end of herat tube: sinus venosus



Development of veins

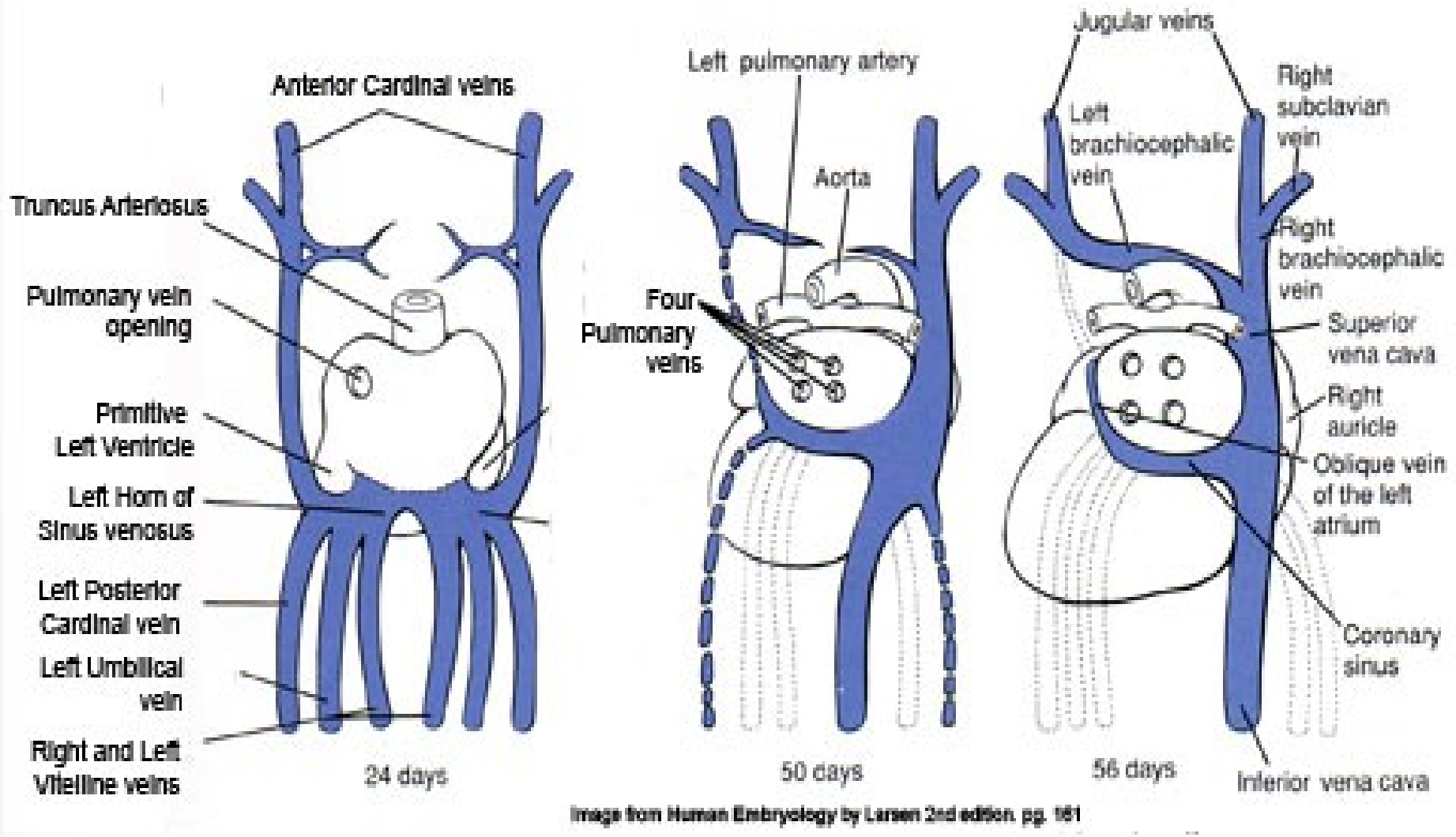
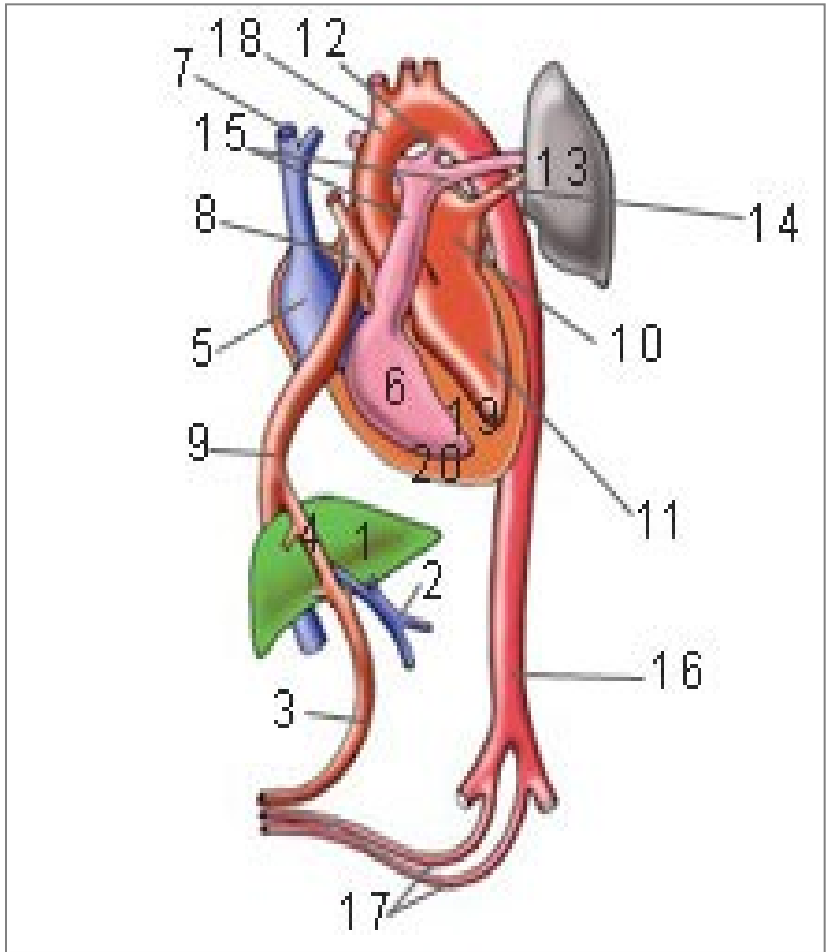
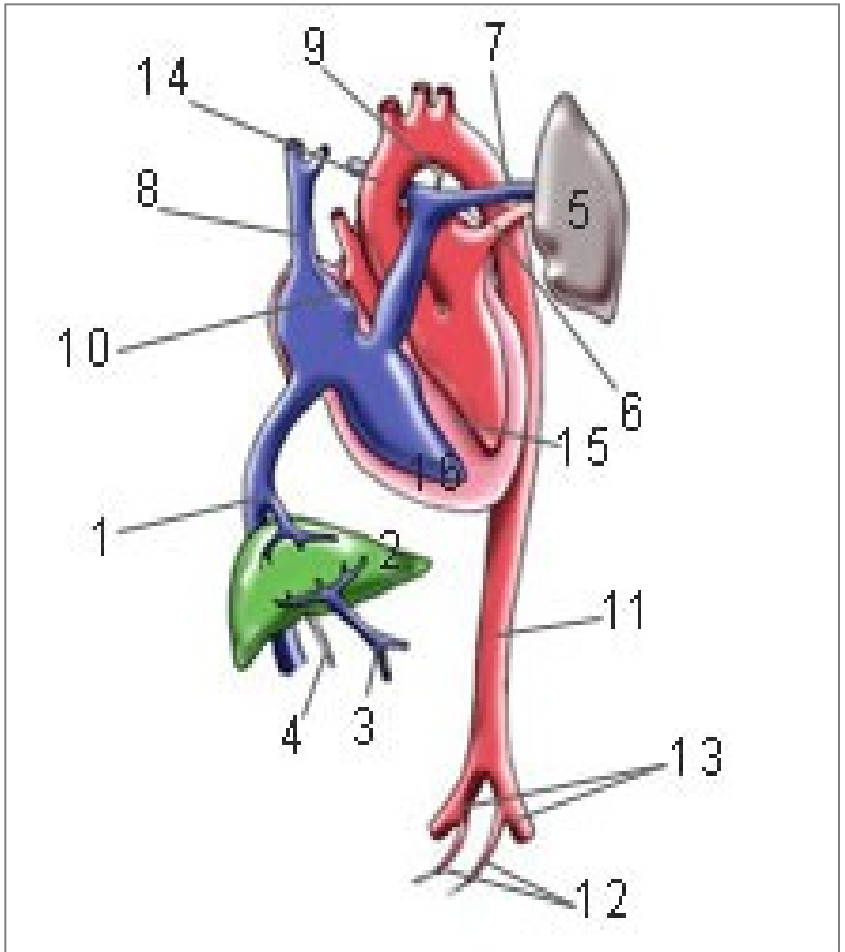
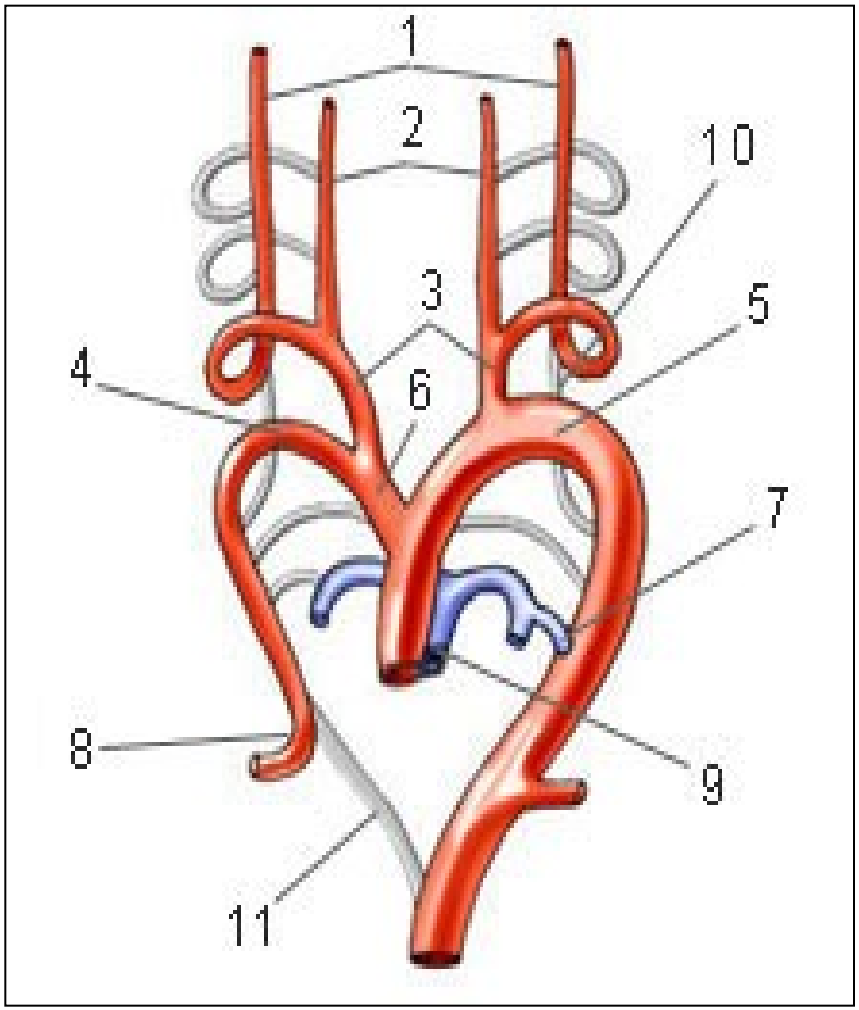


Image from Human Embryology by Larsen 2nd edition. pg. 161

At birth, the circulation of the fetal blood through the placenta is stopped and the lungs begin to function.
The foramen ovale, ductus arteriosus, ductus venosus and umbilical vessels subsequently obliterate and transform into corresponding ligaments.







1. Internal carotid artery
2. External carotid artery
3. Common carotid artery
4. Right subclavian artery
5. Arch of aorta
6. Brachiocephalic artery
7. Ductus arteriosus
8. 7th intersegmental artery
9. Pulmonary artery
10. Carotid duct
11. Obliterated right dorsal aorta