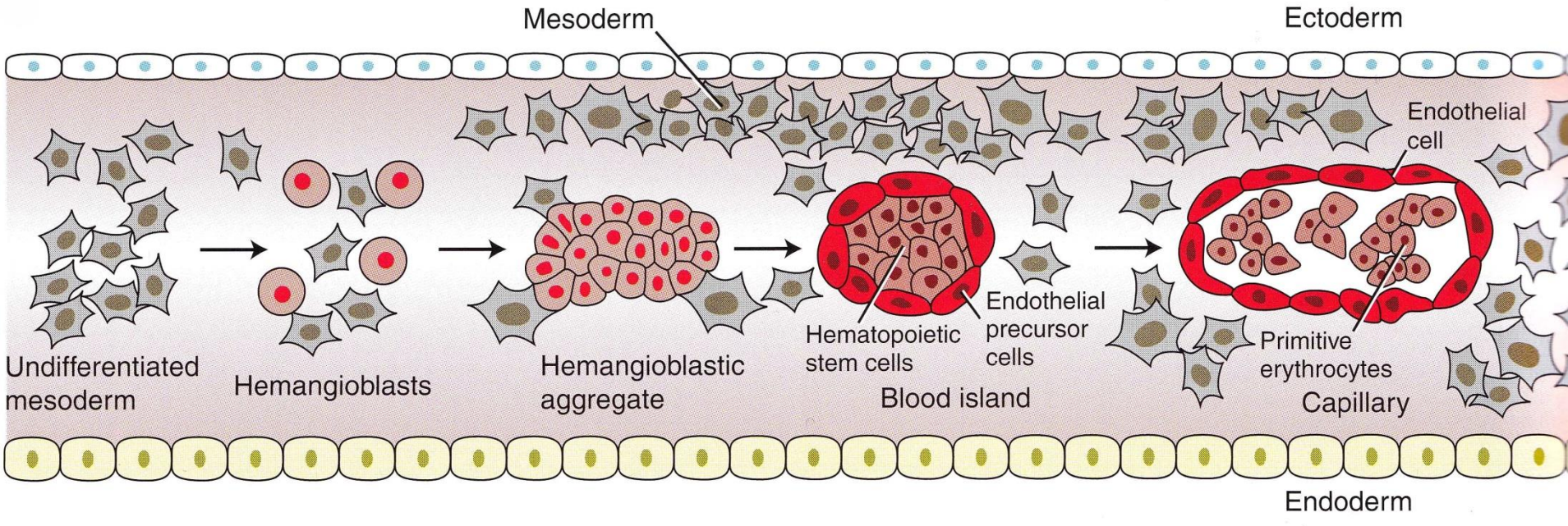
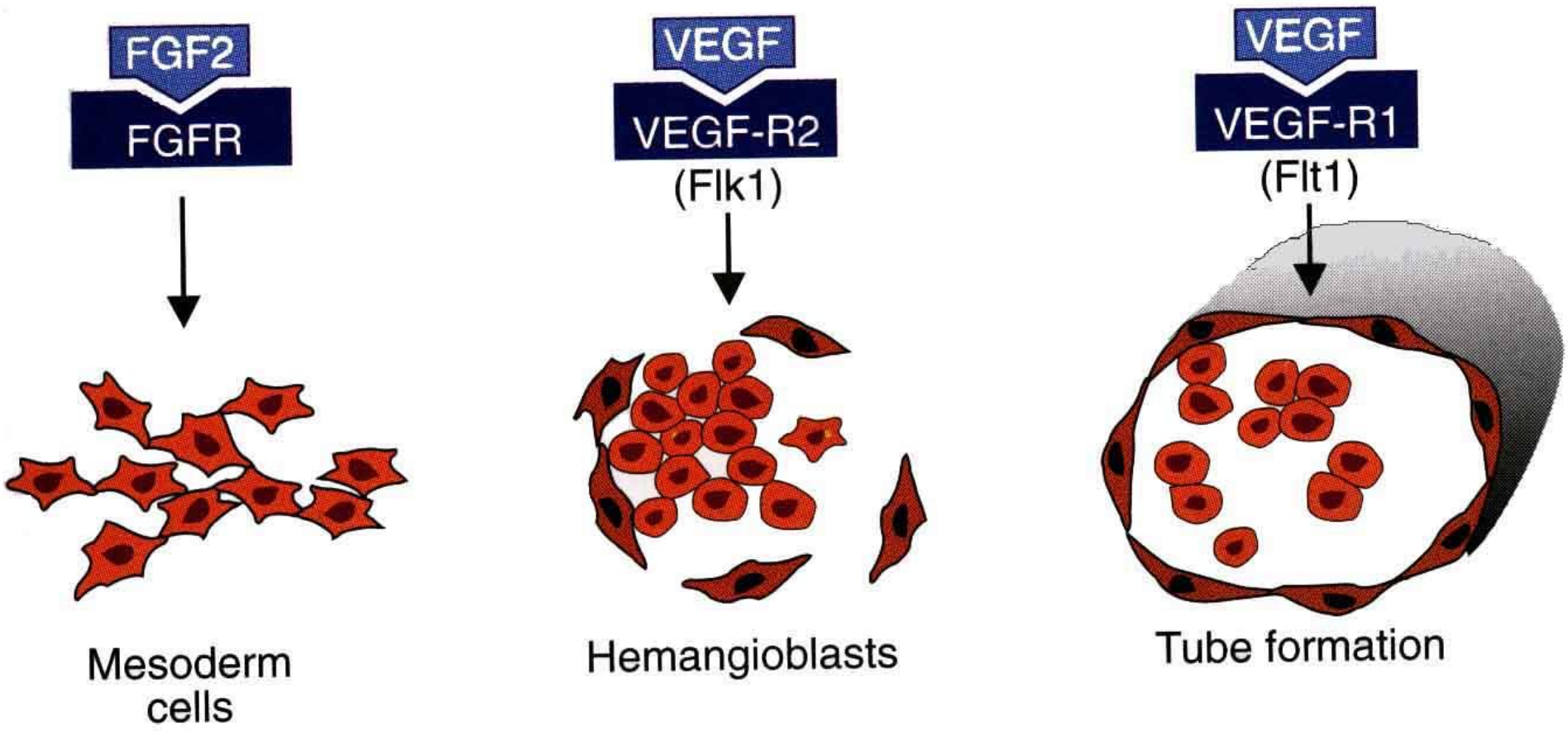
DEVELOPMENT OF VESSELS

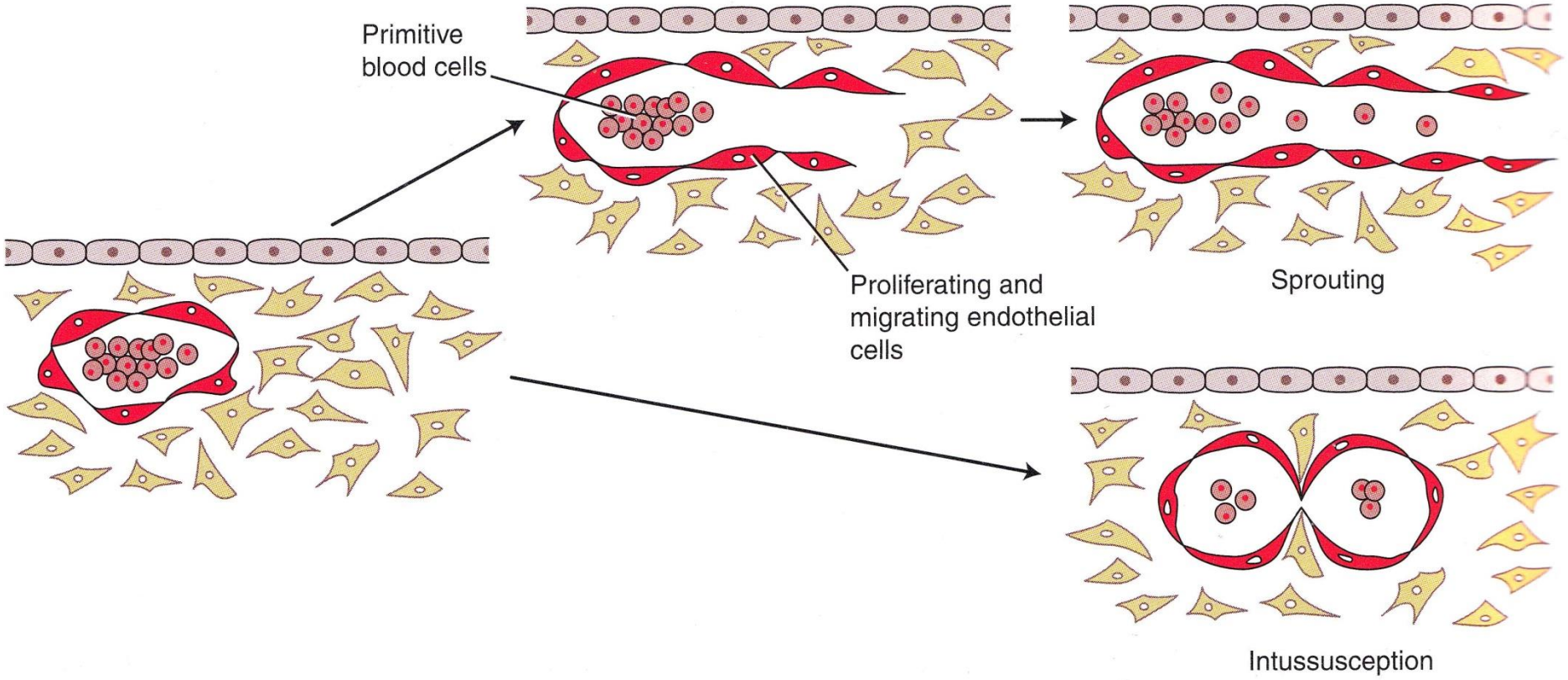
VASCULOGENESIS

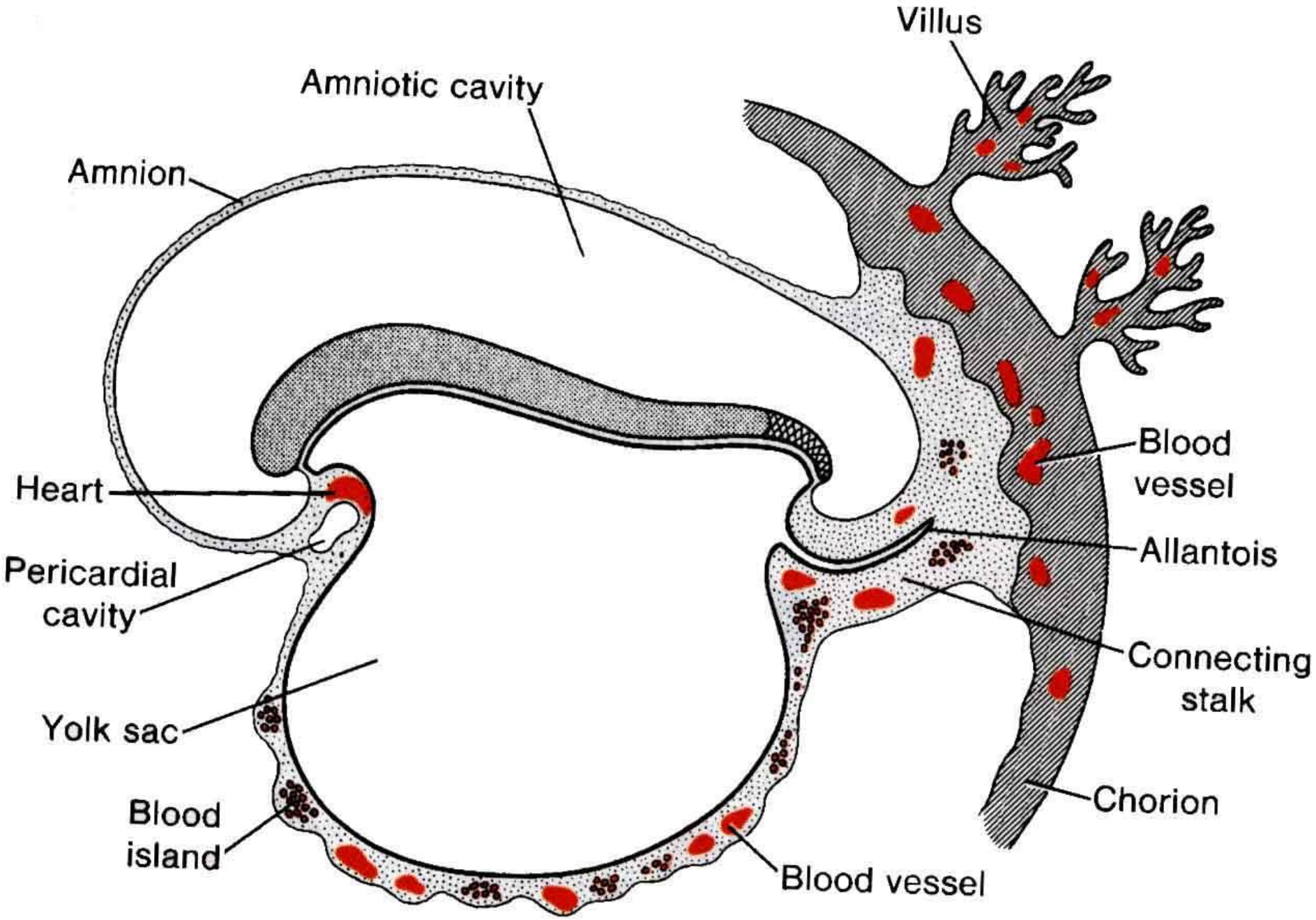


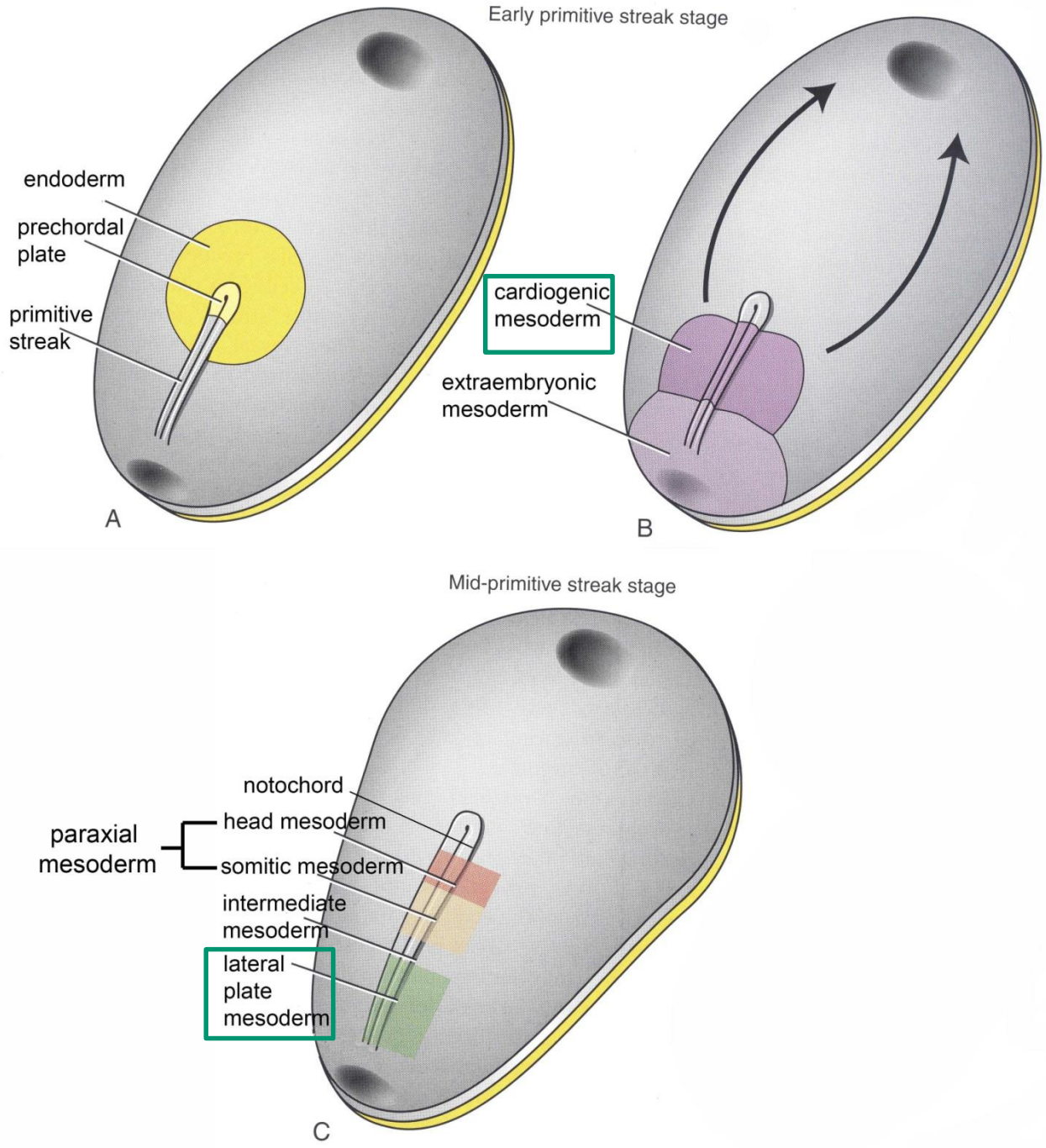


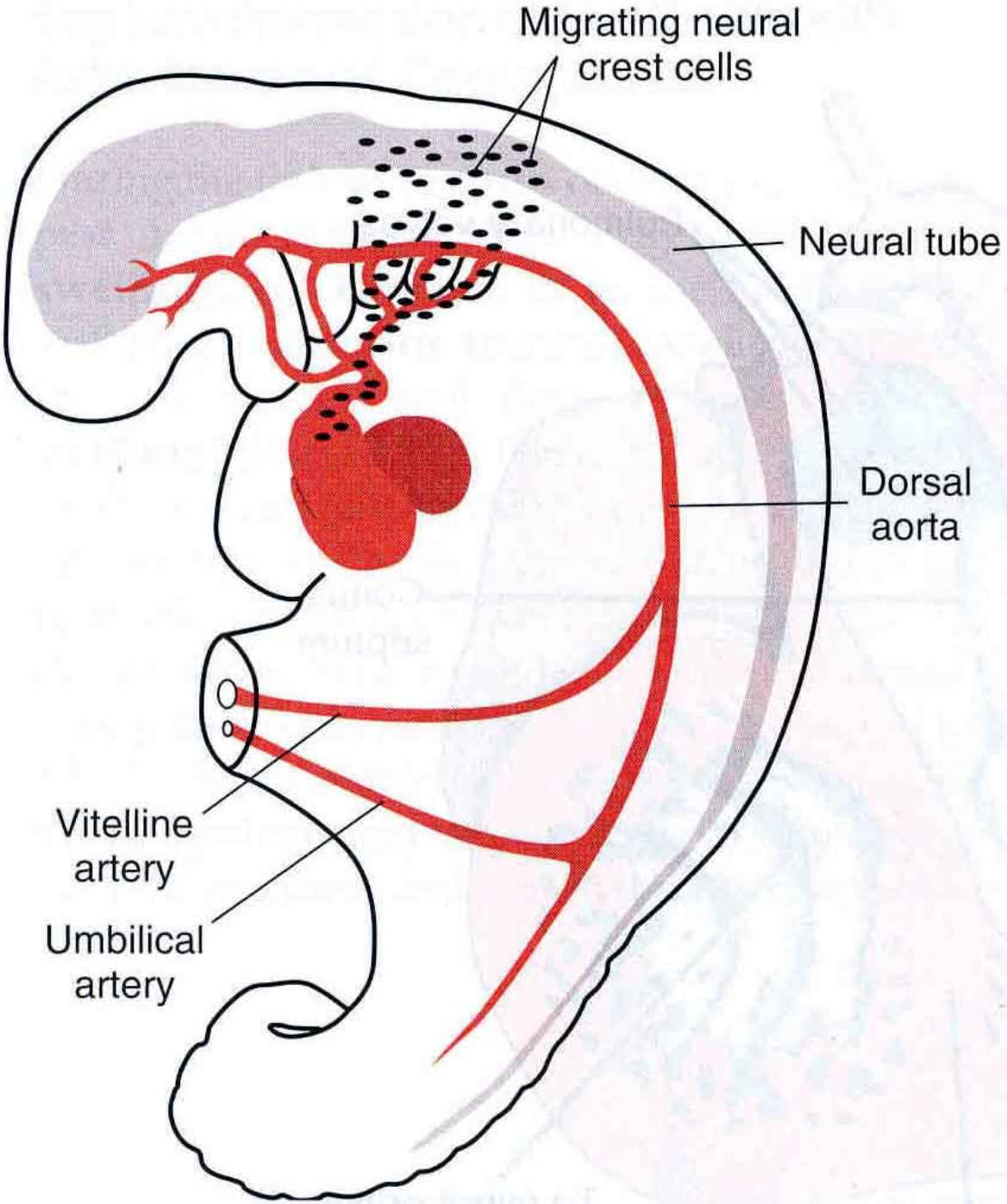
VASCULOGENESIS

ANGIOGENESIS

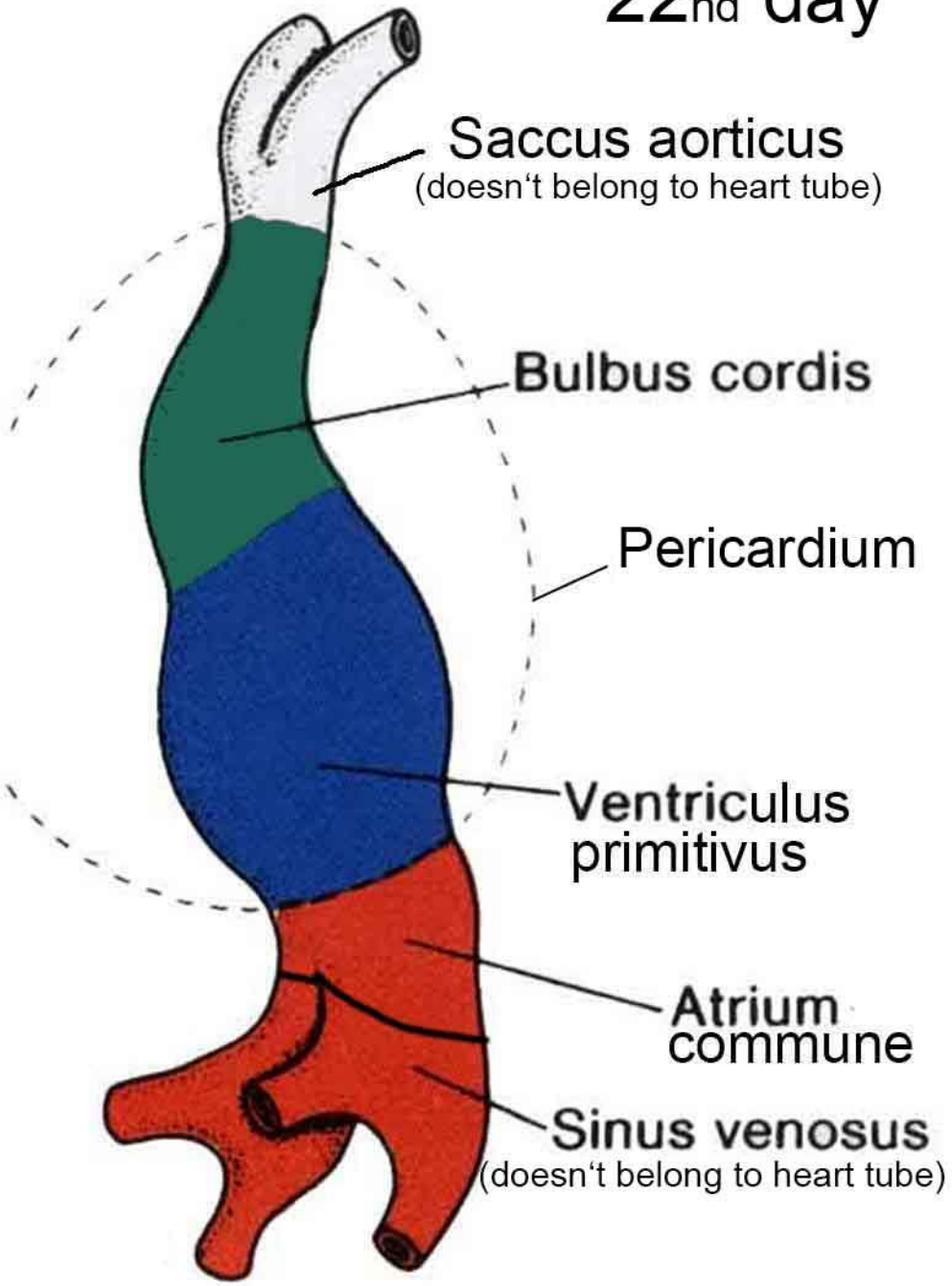



Villus
Amniotic cavity
Amnion
Blood vessel
Heart
Allantois
Pericardial cavity
Connecting stalk
Yolk sac
Chorion
Blood island
Blood vessel


Early primitive streak stage
endoderm
prechordal plate
primitive streak
A
cardiogenic mesoderm
extraembryonic mesoderm
B
Mid-primitive streak stage
notochord
paraxial mesoderm
head mesoderm
somitic mesoderm
intermediate mesoderm
lateral plate mesoderm
C


Migrating neural crest cells
Neural tube
Dorsal aorta
Vitelline artery
Umbilical artery

22nd day

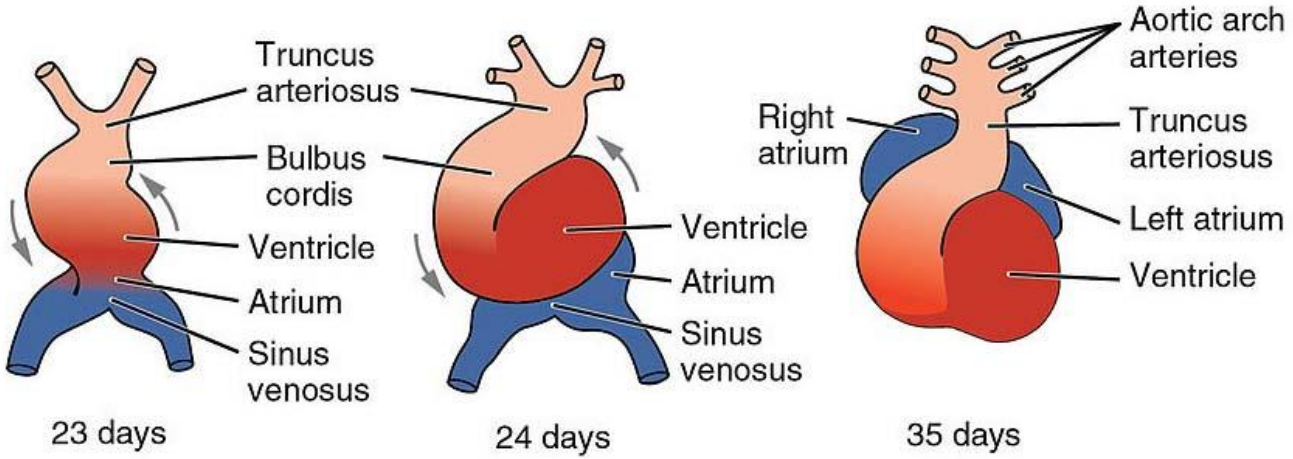

Saccus aorticus
(doesn‘t belong to heart tube)
Bulbus cordis
Pericardium
Ventriculus primitivus
Atrium commune
Sinus venosus
(doesn‘t belong to heart tube)

Formation of the cardiac loop

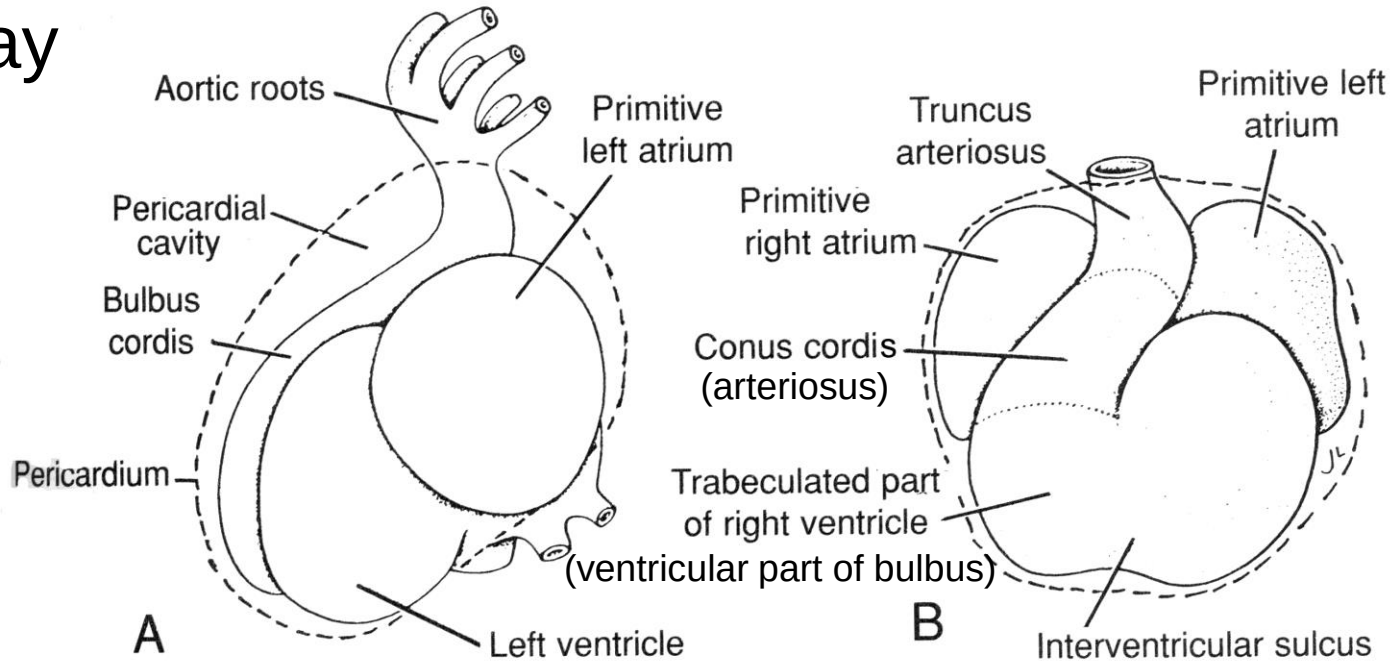
Cephalic portion bends ventrally, caudally, to the right

Caudal portion (atrial) shifts dorsally, cranially, to the left

Completed by day 28



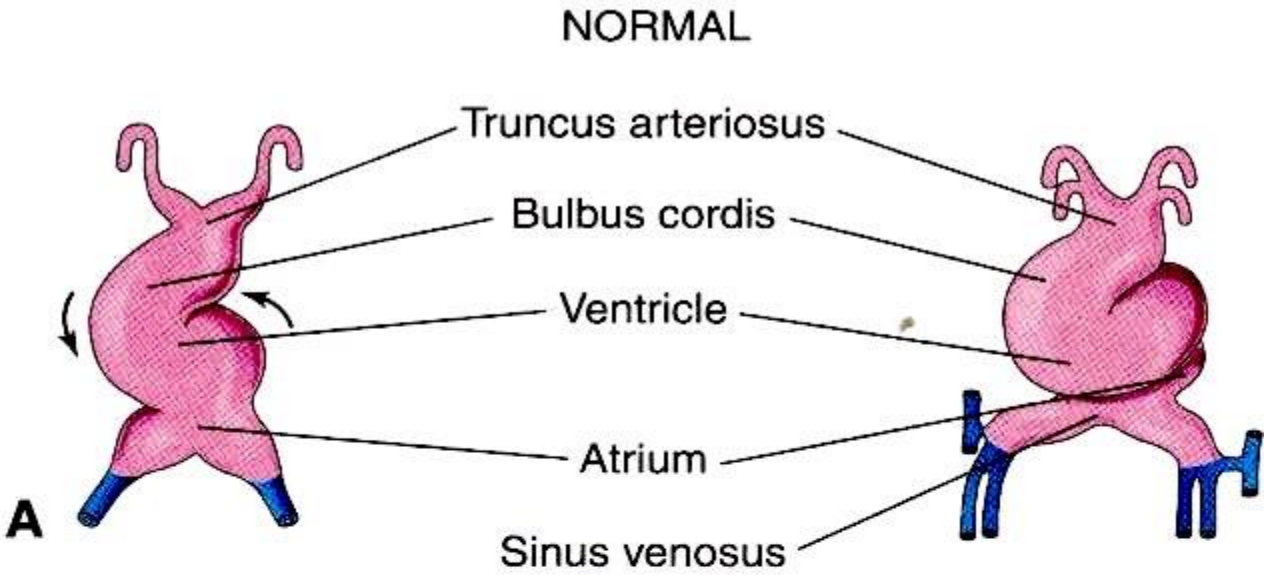
28th day

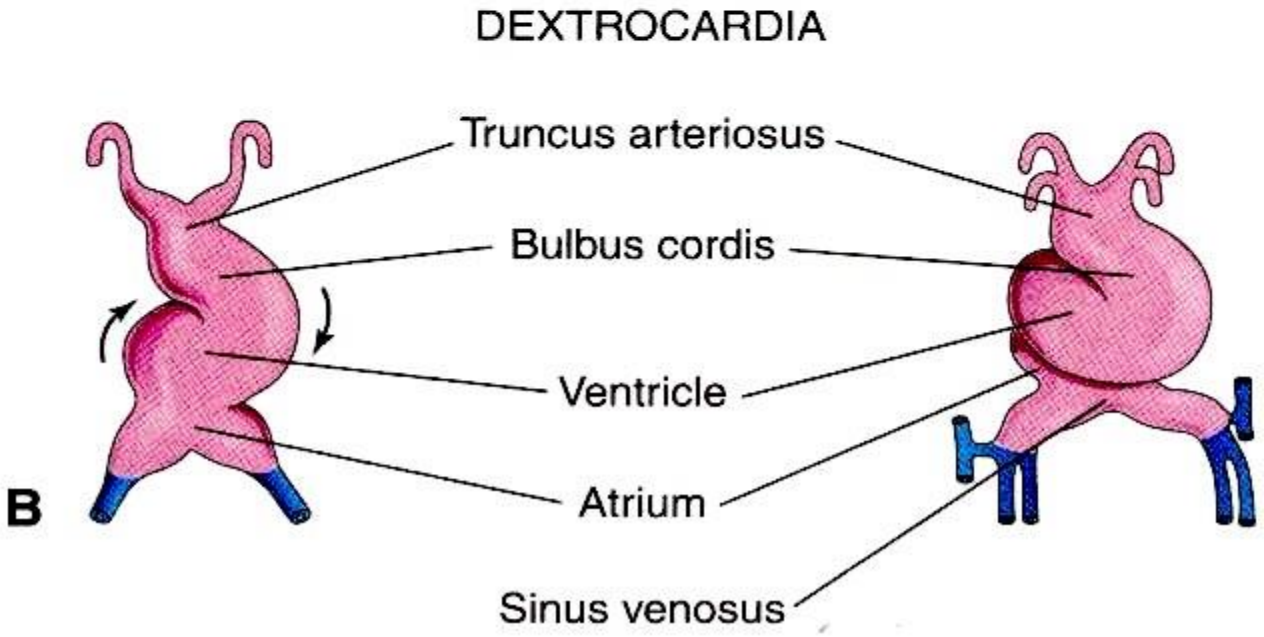

Aortic roots
Primitive left atrium
Pericardial cavity
Bulbus cordis
Pericardium
Left ventricle
A
Truncus arteriosus
Primitive left atrium
Primitive right atrium
Conus cordis (arteriosus)
Trabeculated part of right ventricle (ventricular part of bulbus)
Interventricular sulcus
B


C

Abnormality in looping process

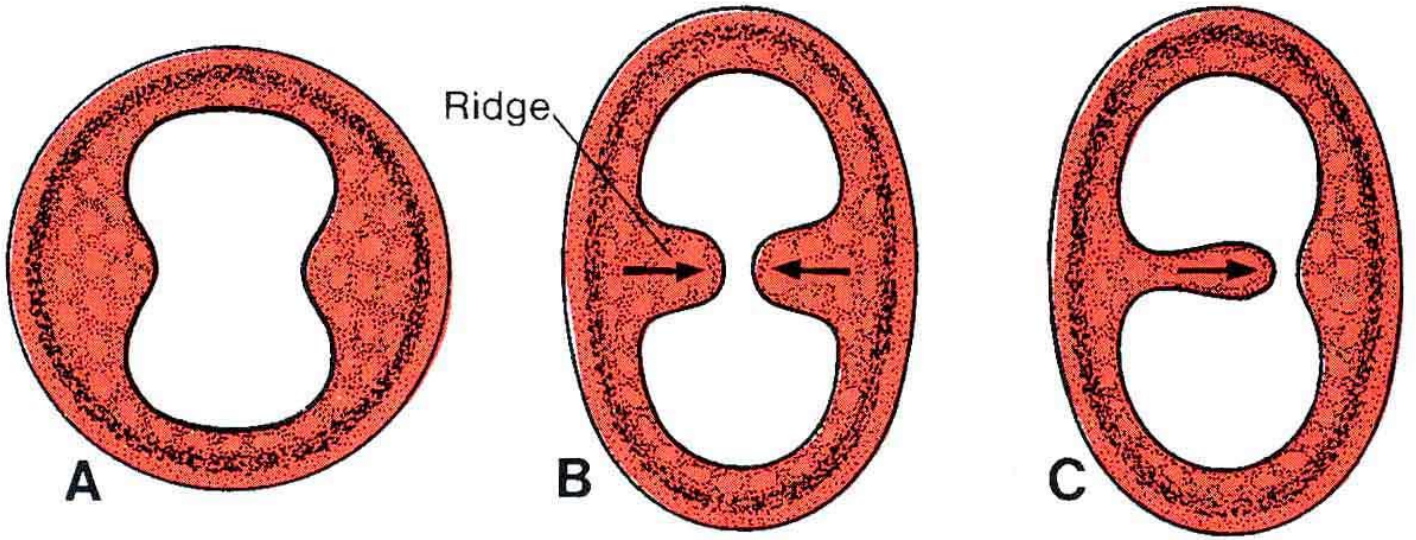
dextrocardia





SEPTATION OF
ATRIA, VENTRICLES AND HEART OUTLET

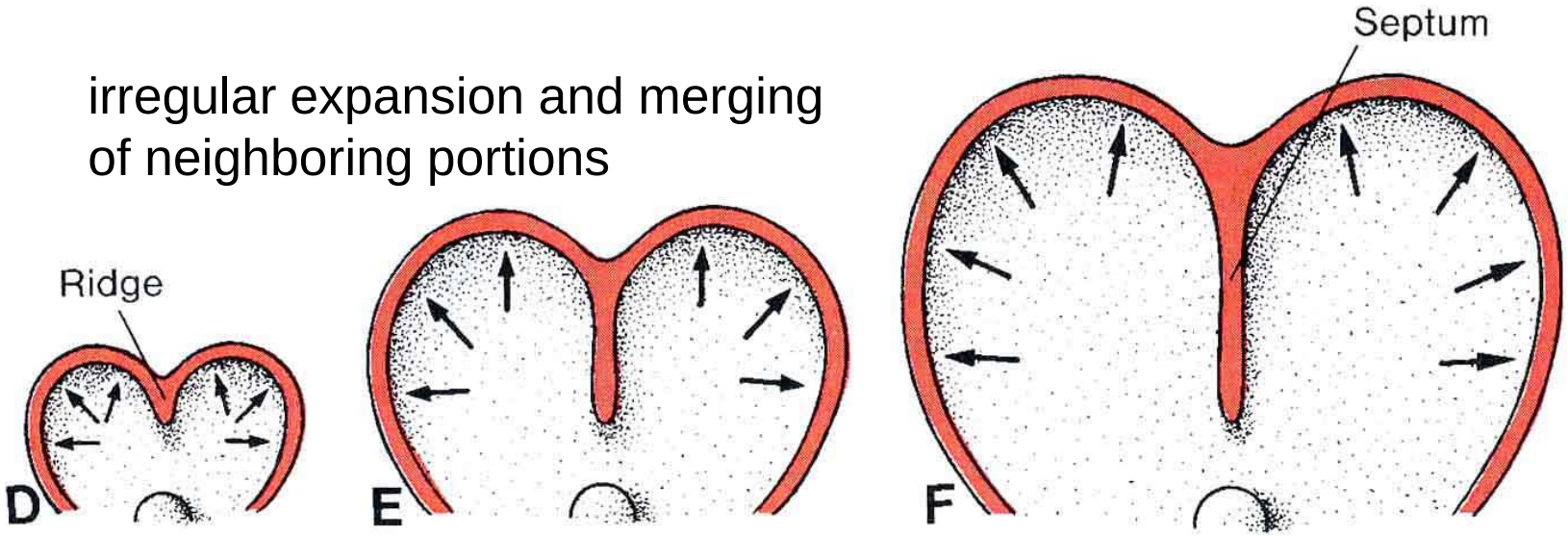
Methods of formation of cardiac septa



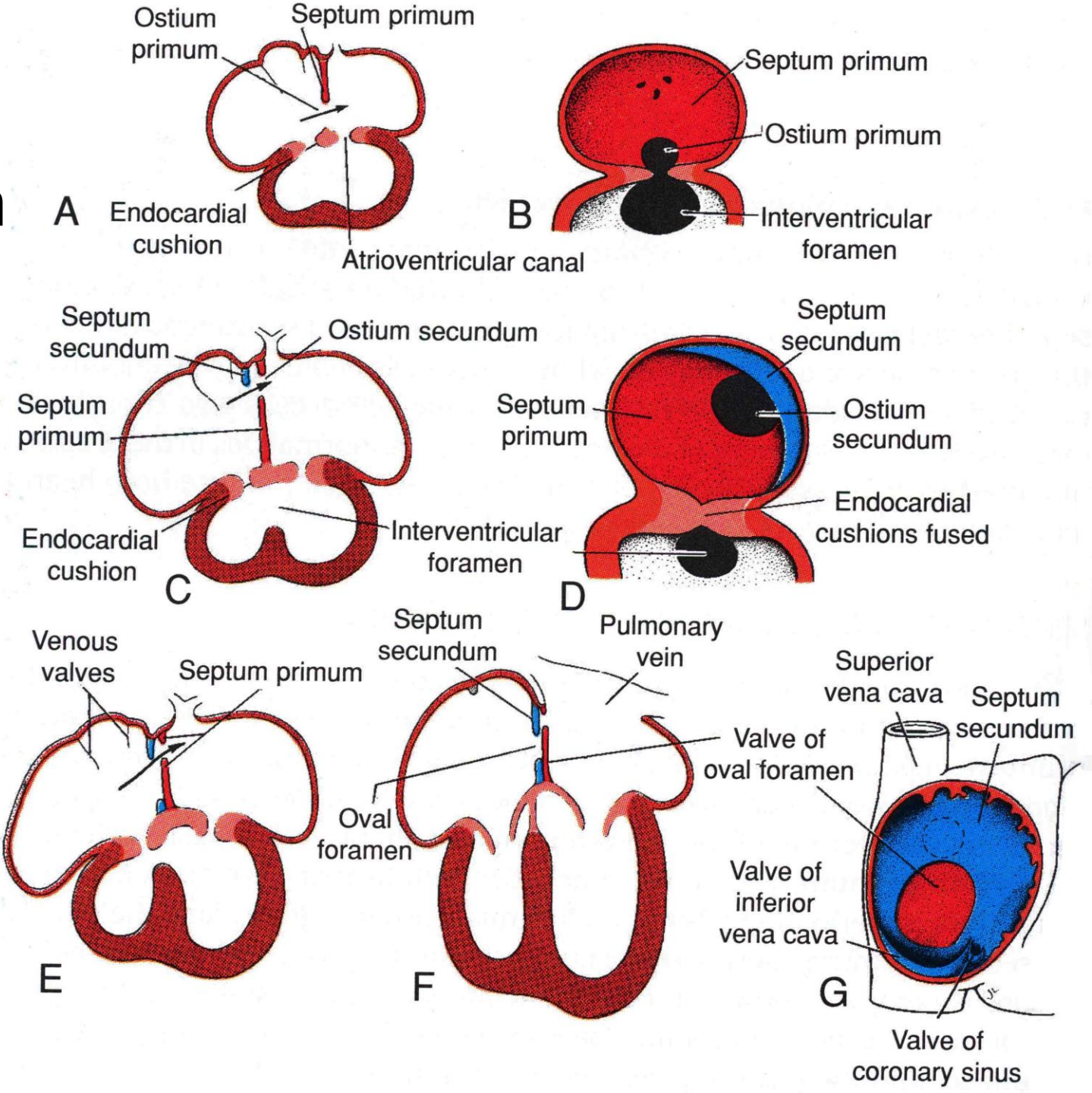
growth of 2 opposite ridges

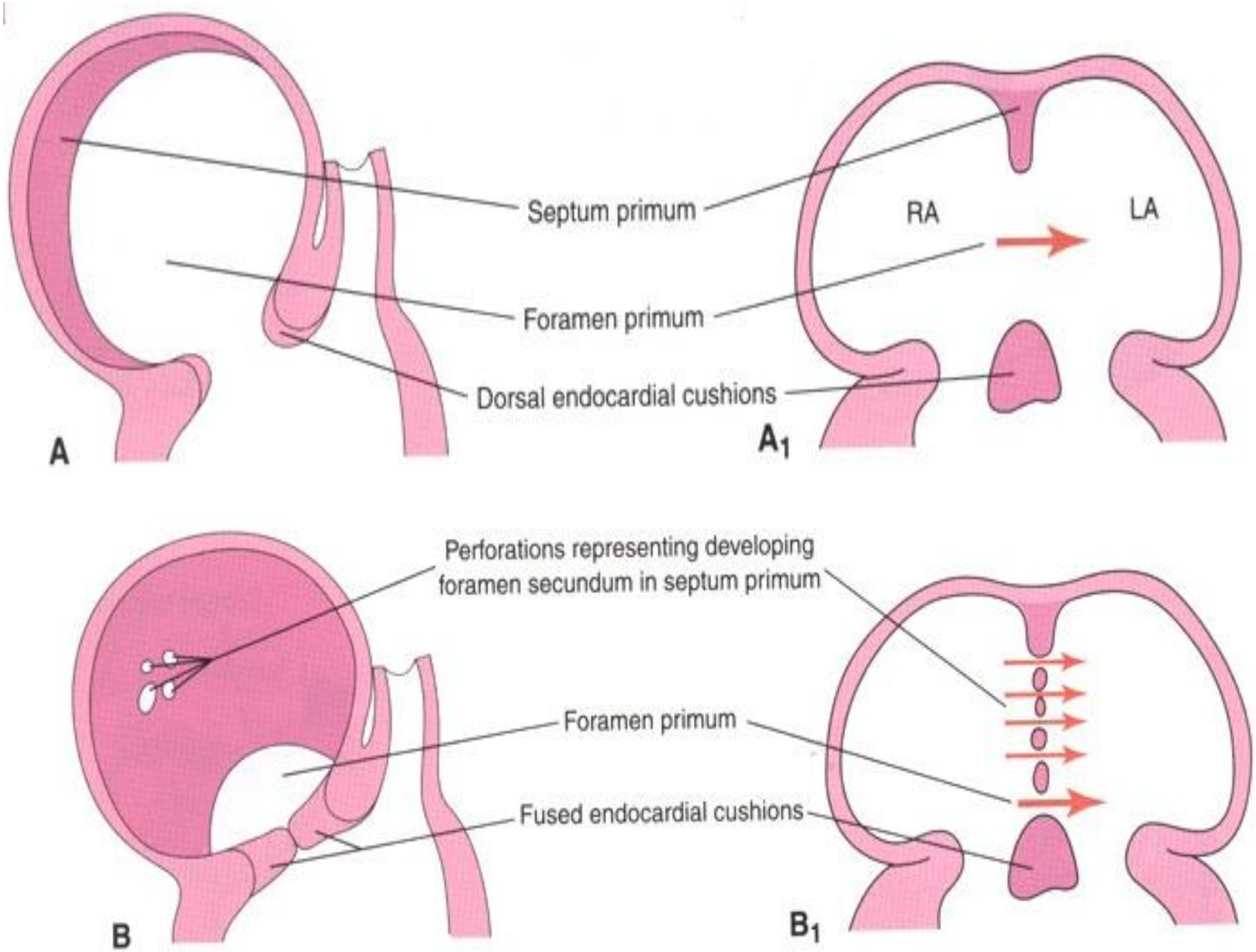
growth of 1 ridge

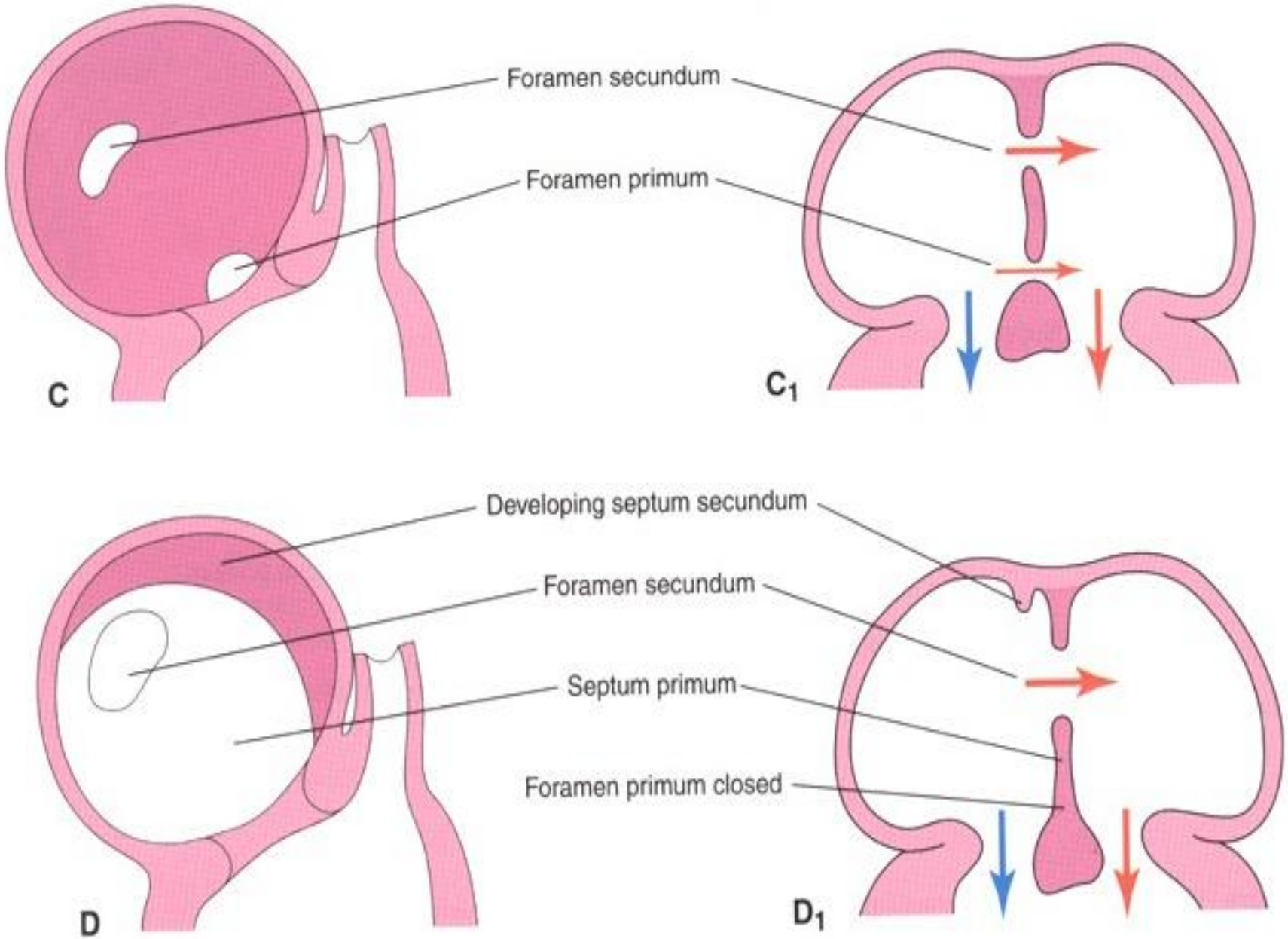
irregular expansion and merging of neighboring portions

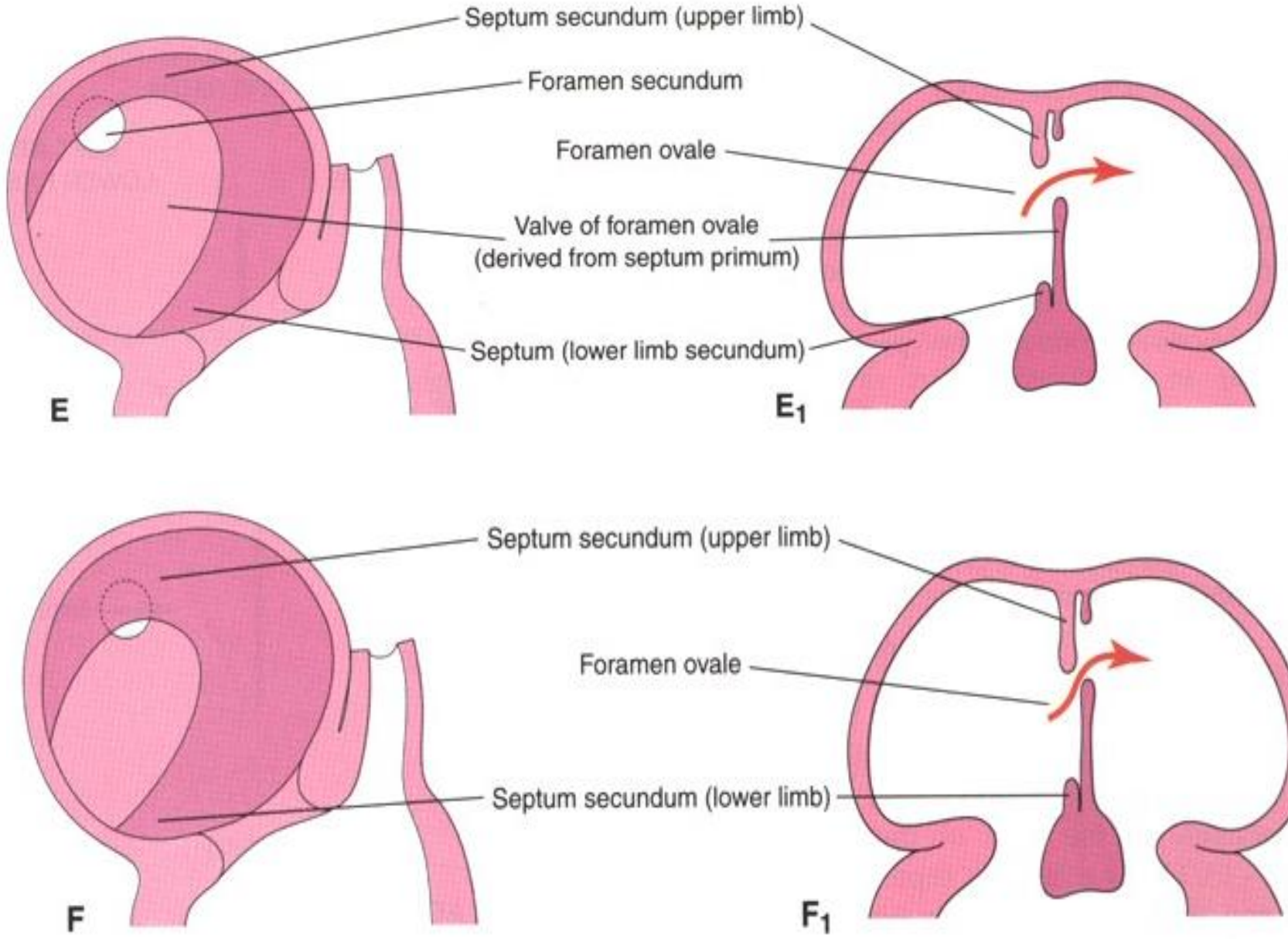


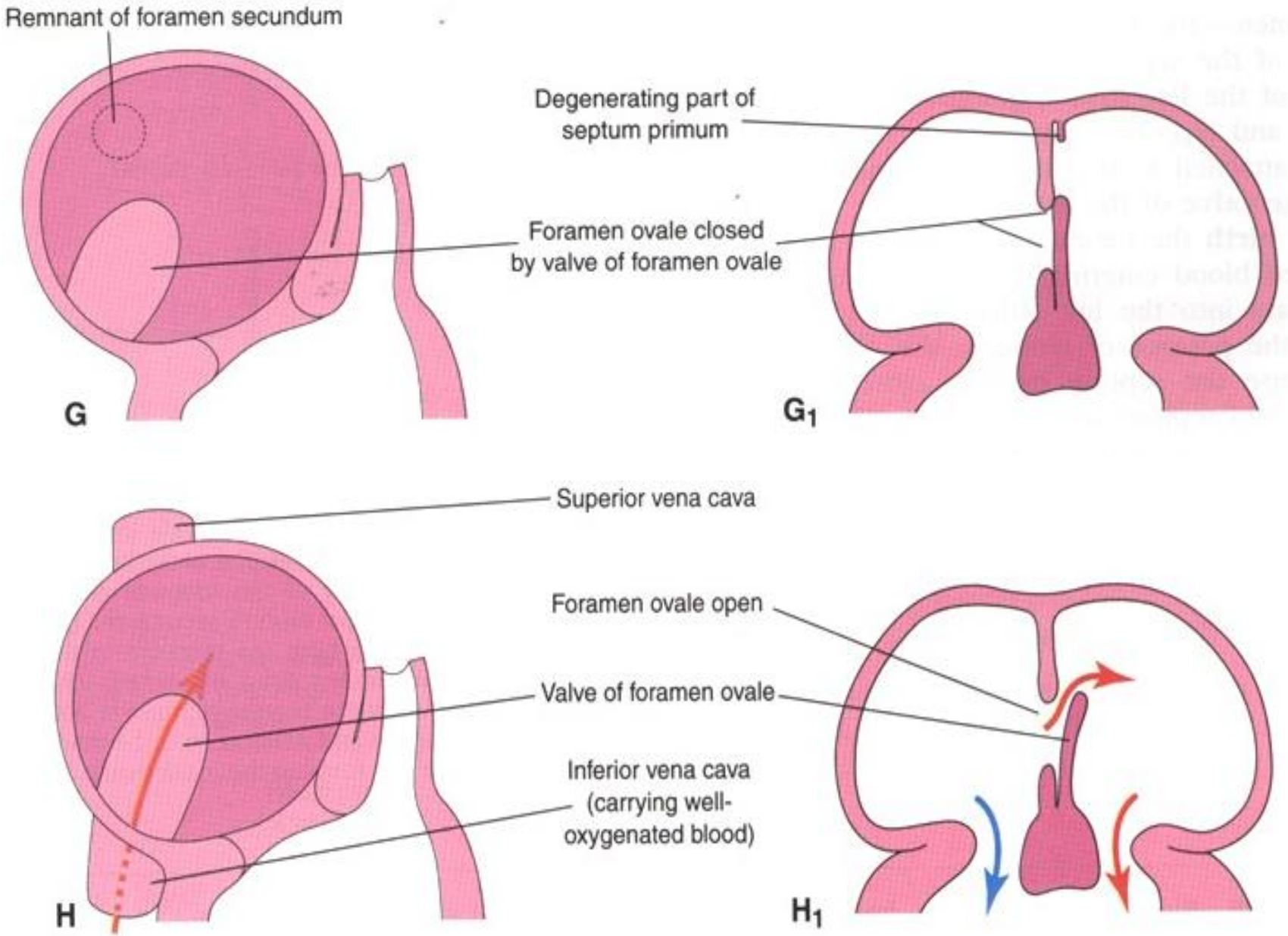
Atrial and AV septation

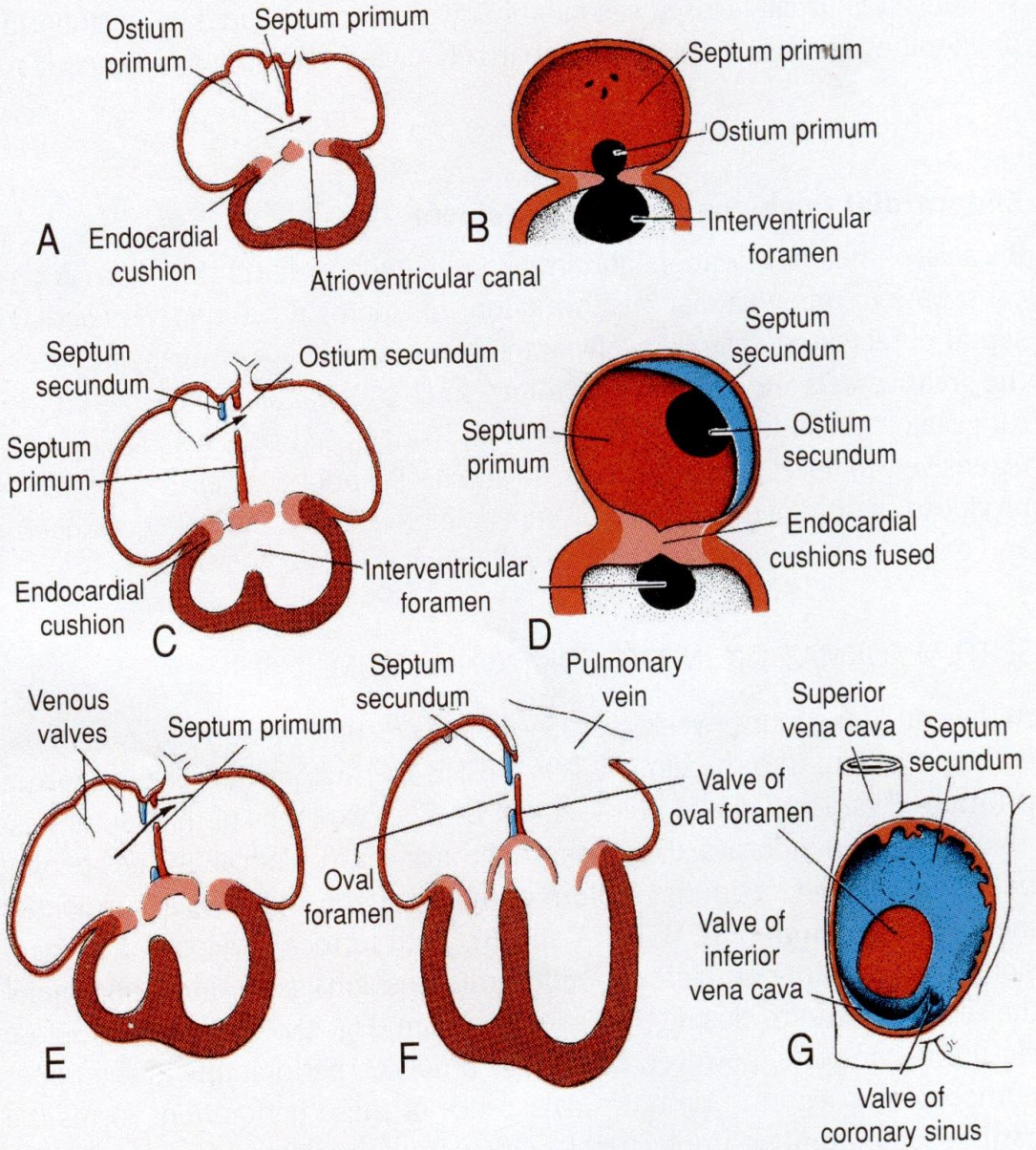



Septum primum
Foramen primum
Dorsal endocardial cushions
A
RA
LA
A1
Perforations representing developing
foramen secundum in septum primum
Foramen primum
Fused endocardial cushions
B
B1

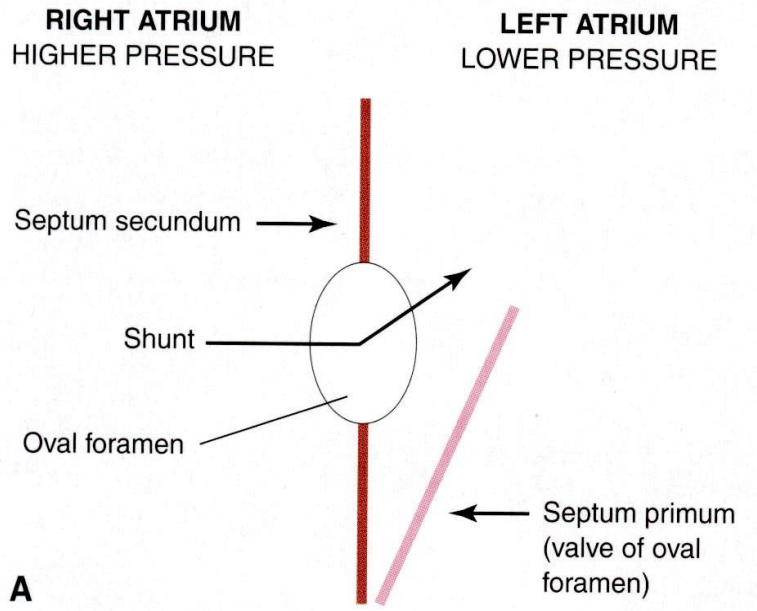

Foramen secundum
Foramen primum
C
C1
Developing septum secundum
Foramen secundum
Septum primum
Foramen primum closed
D
D1

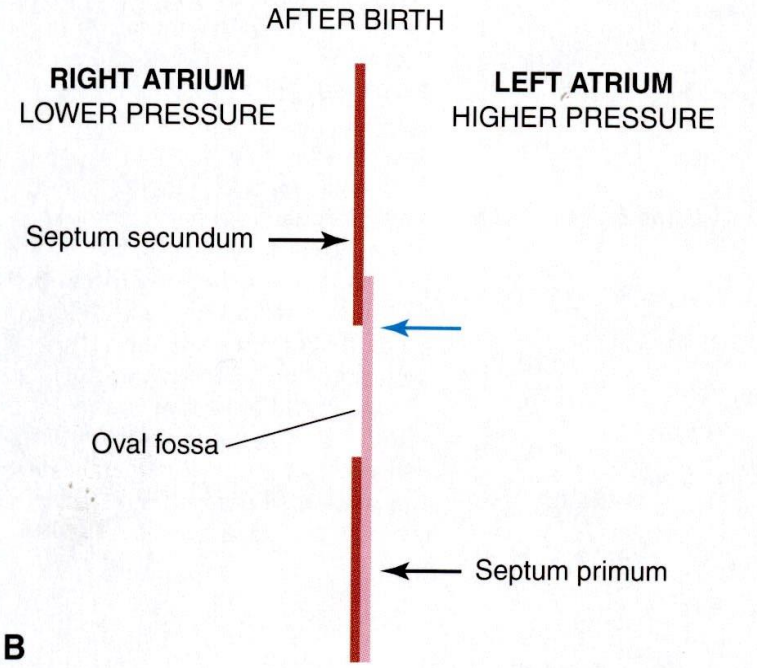

Septum secundum (upper limb)
Foramen secundum
Foramen ovale
Valve of foramen ovale
(derived from septum primum)
Septum (lower limb secundum)
E
E1
Septum secundum (upper limb)
Foramen ovale
Septum secundum (lower limb)
F
F1

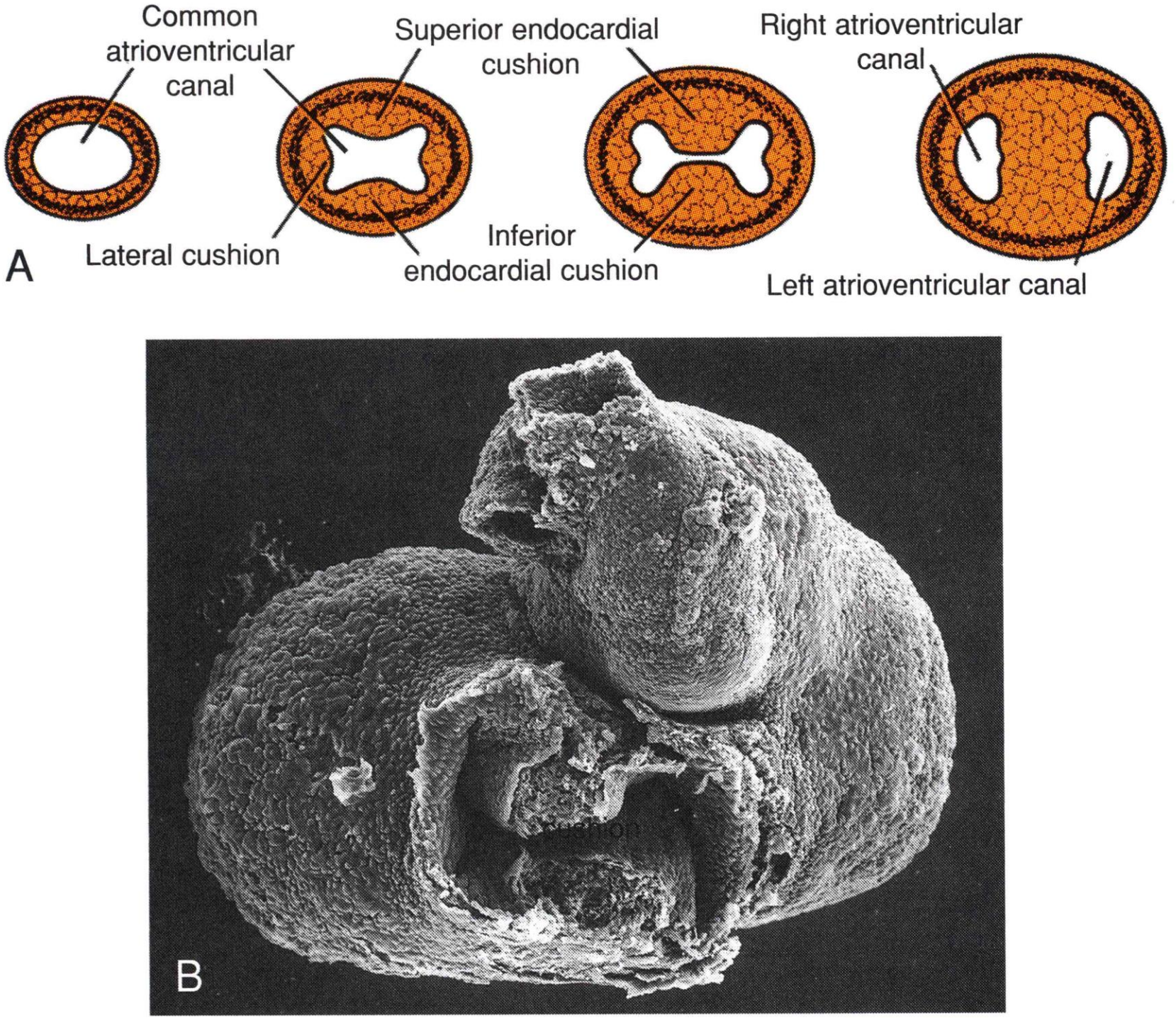

Remnant of foramen secundum
Degenerating part of septum primum
Foramen ovale closed by valve of foramen ovale
G
G1
Superior vena cava
Foramen ovale open
Valve of foramen ovale
Inferior vena cava (carrying well-oxygenated blood)
H
H1



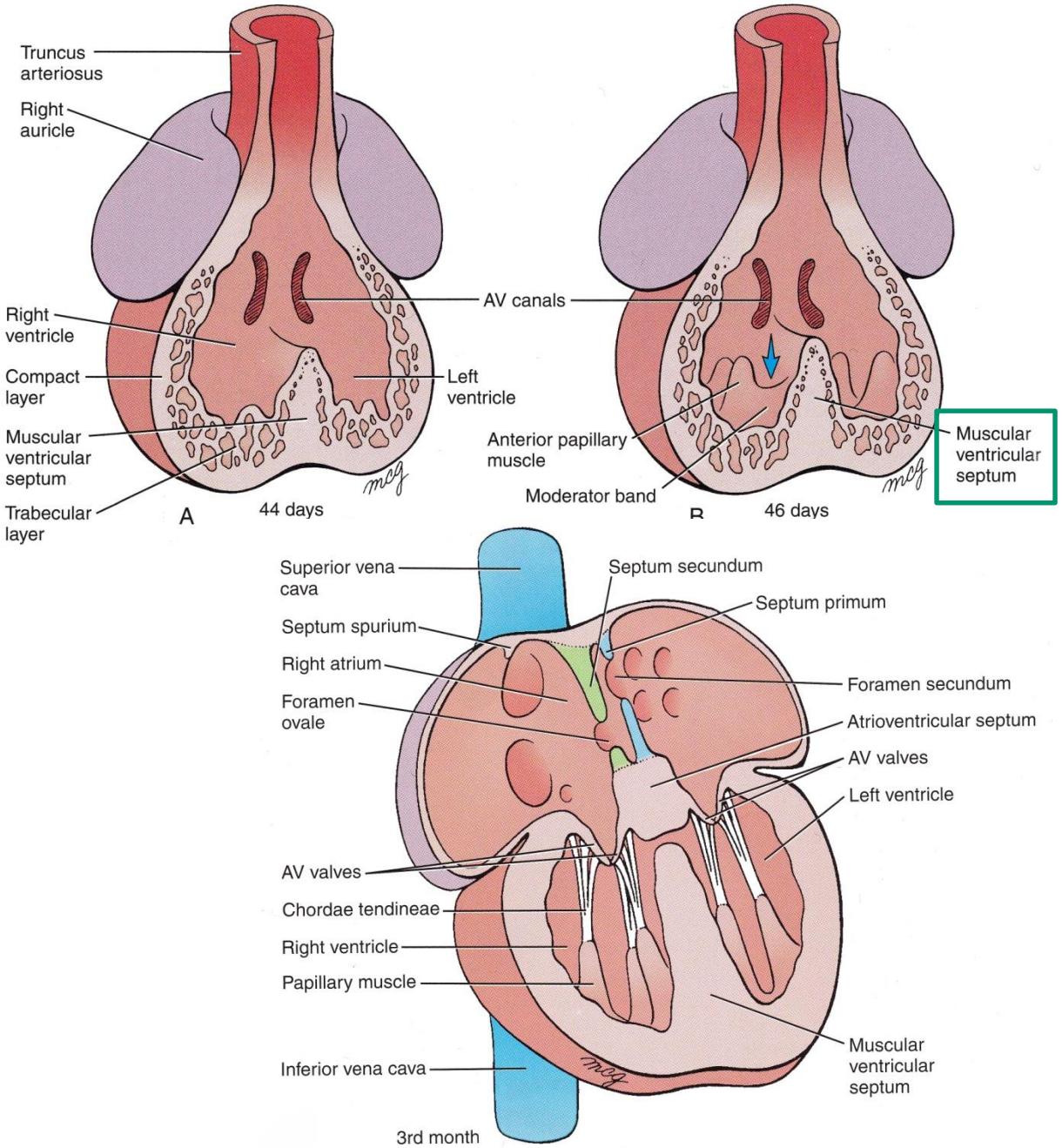
Atrial septa at various stages of development. **A.** 30 days (6 mm). **B.** Same stage as **A,** viewed from the right. **C.** 33 days (9 mm). **D.** Same stage as **C,** viewed from the right **E.** 37 days (14 mm). **F.** Newborn. **G.** The atrial septum from the right; same stage as **F.**

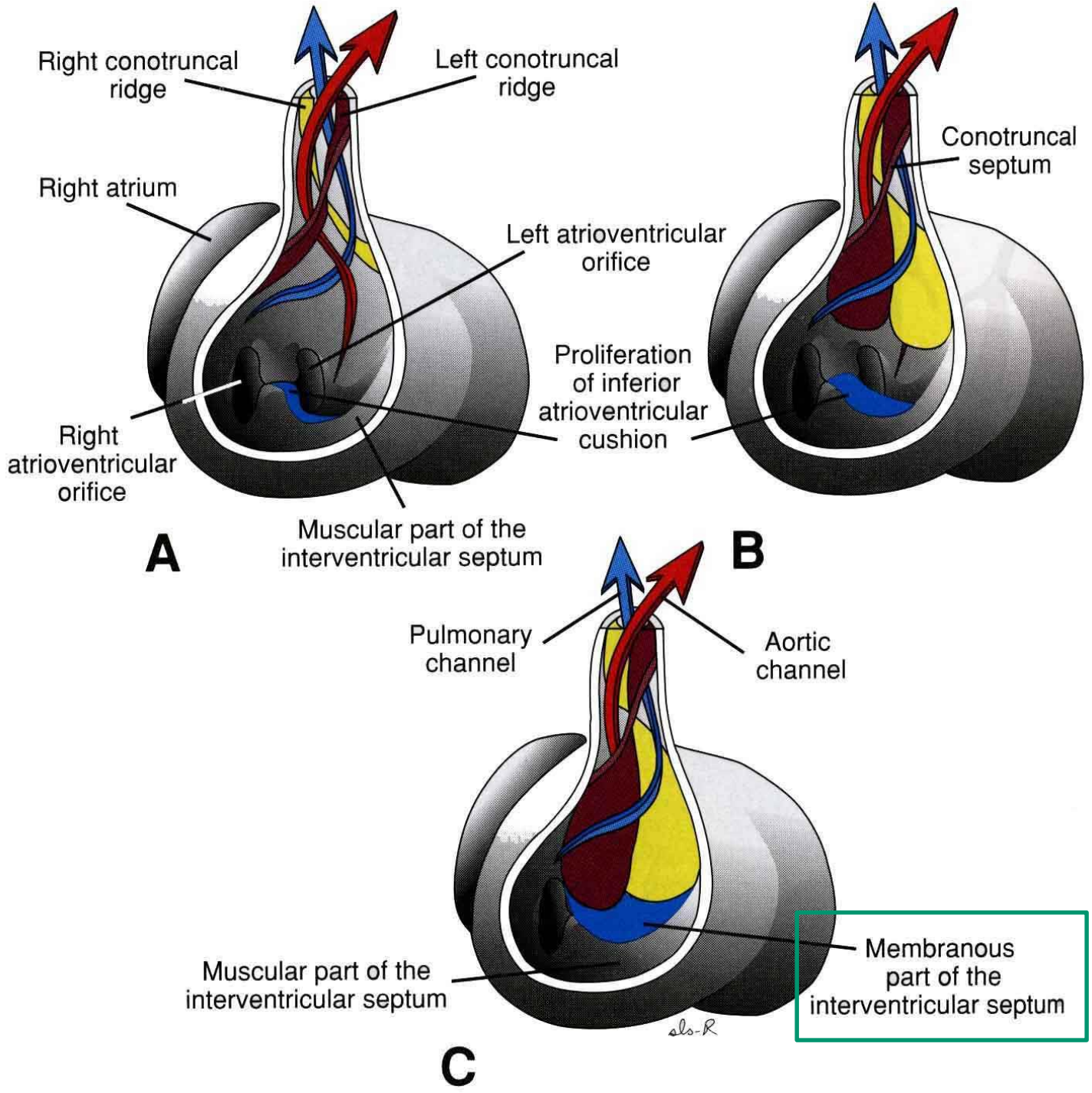


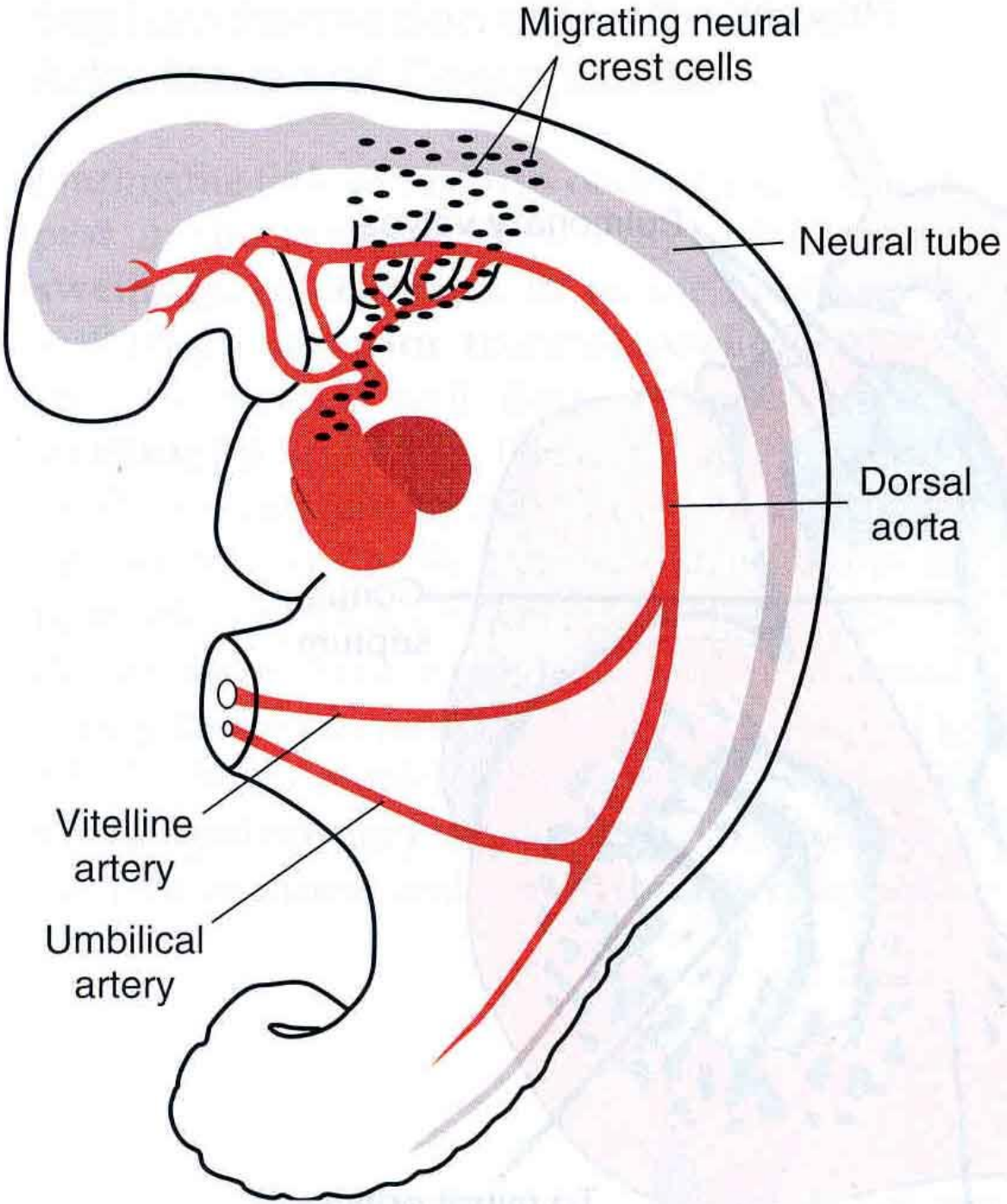



Common atrioventricular canal
Superior endocardial cushion
Right atrioventricular canal
A
Lateral cushion
Inferior endocardial cushion
Left atrioventricular canal
B

Ventricular septation



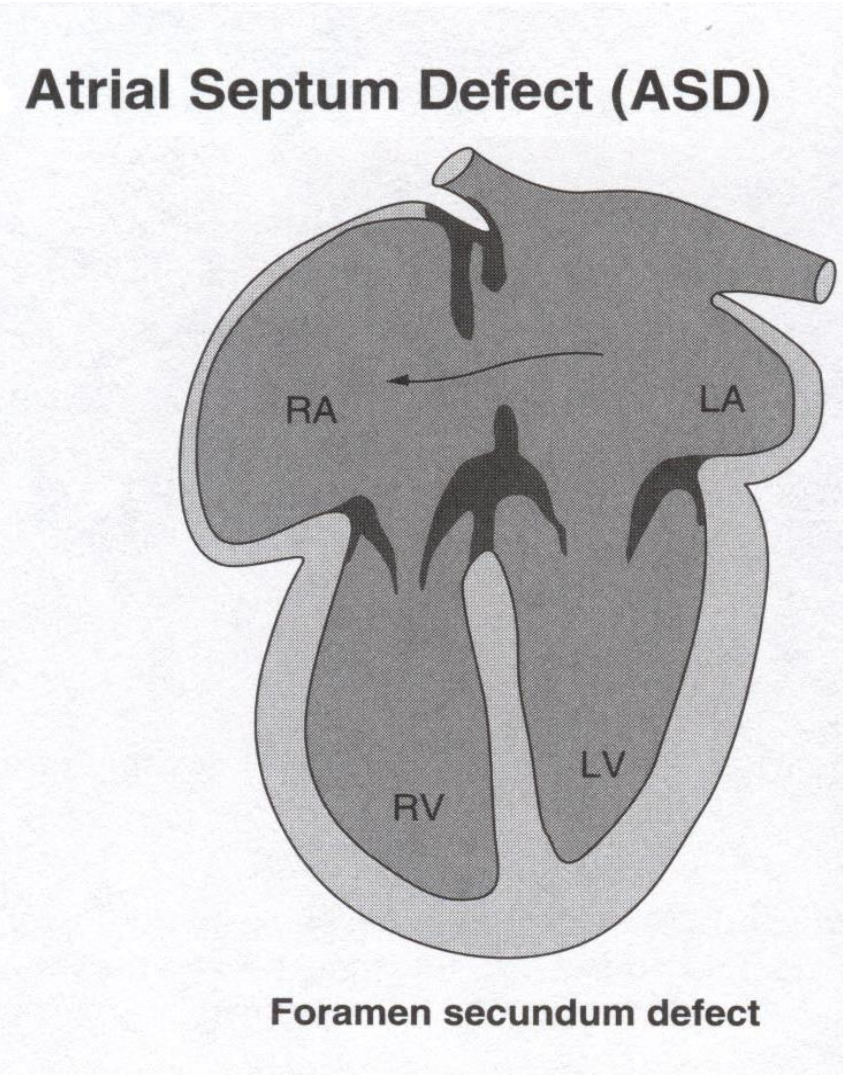

Right conotruncal ridge
Left conotruncal ridge
Right atrium
Left atrioventricular orifice
Right atrioventricular orifice
Muscular part of the interventricular septum
A
Conotruncal septum
Proliferation of inferior atrioventricular cushion
B
Pulmonary channel
Aortic channel
Muscular part of the interventricular septum
Membranous part of the interventricular septum
C

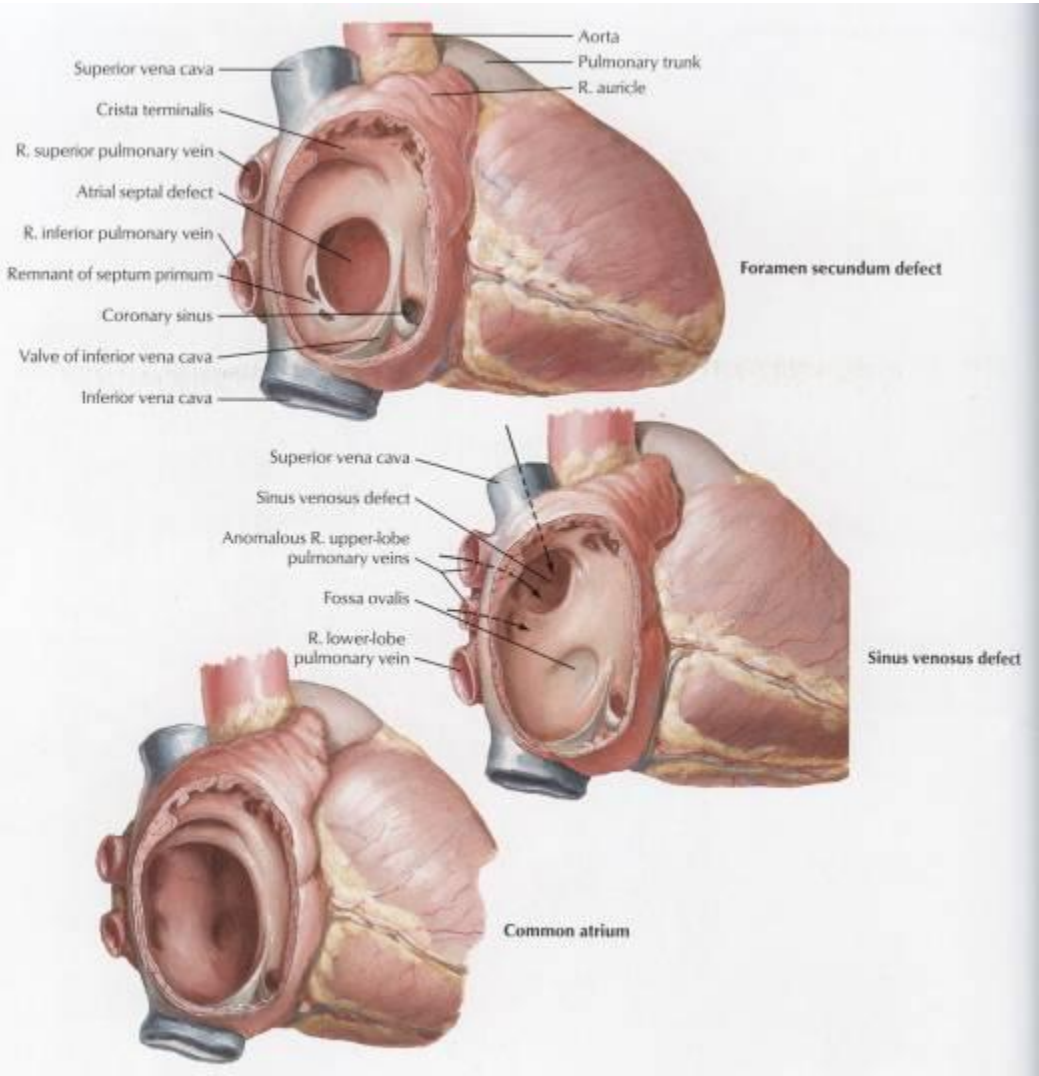

Migrating neural crest cells
Neural tube
Dorsal aorta
Vitelline artery
Umbilical artery

Atrial septal defect

Small defects - clinical symptoms may be delayed (age 30)

Forament ovale patens



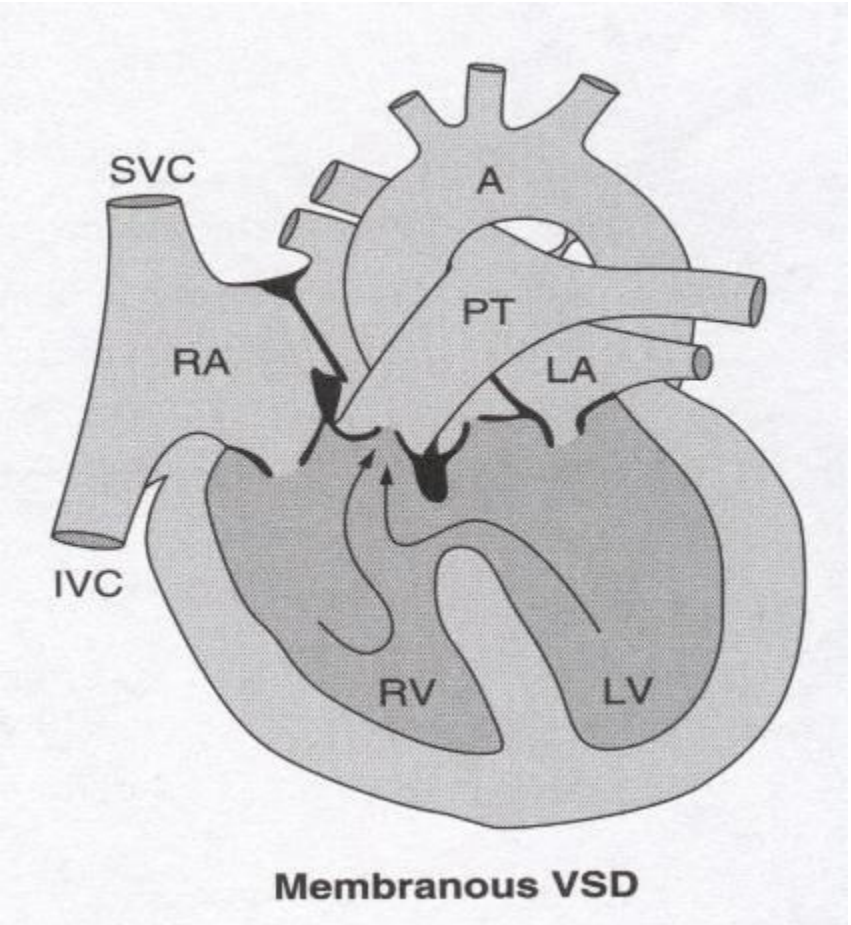


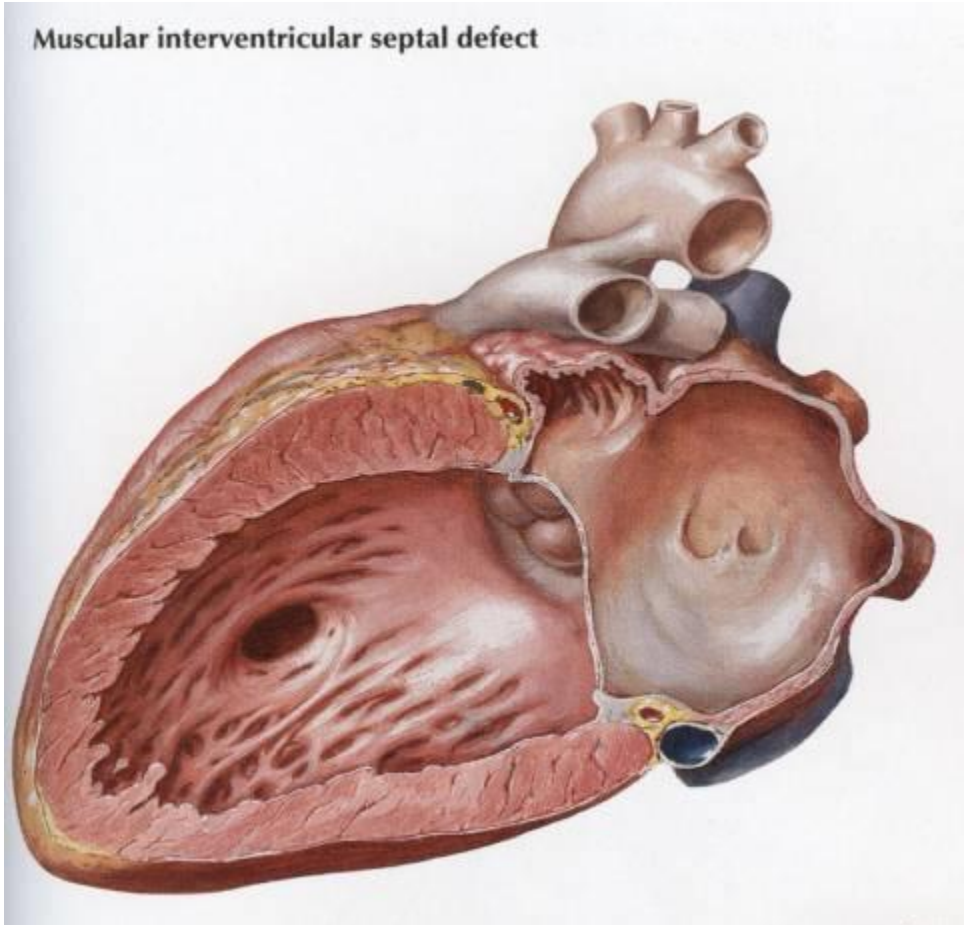
Ventricular septal defect

left to right shunting of blood, excessive fatigue upon exertion

• pulmonary blood flow is increased resulting in pulmonary hypertension

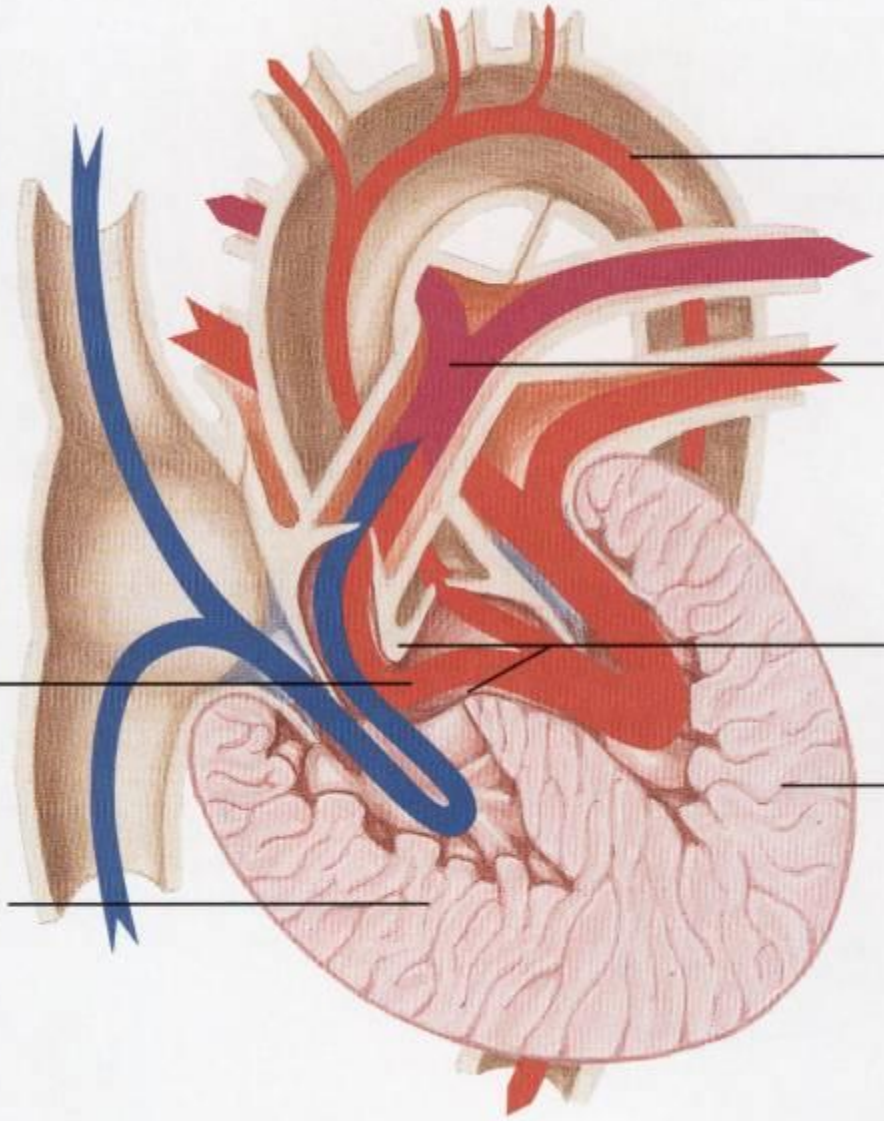
•later pulmonary resistance causes right to left shunting of blood and cyanosis (Eisenmenger syndrome)





Ventricular septal defect

Pathophysiology of ventricular septal defect



Decreased systemic flow

Increased pulmonary flow (pulmonary volume overload)

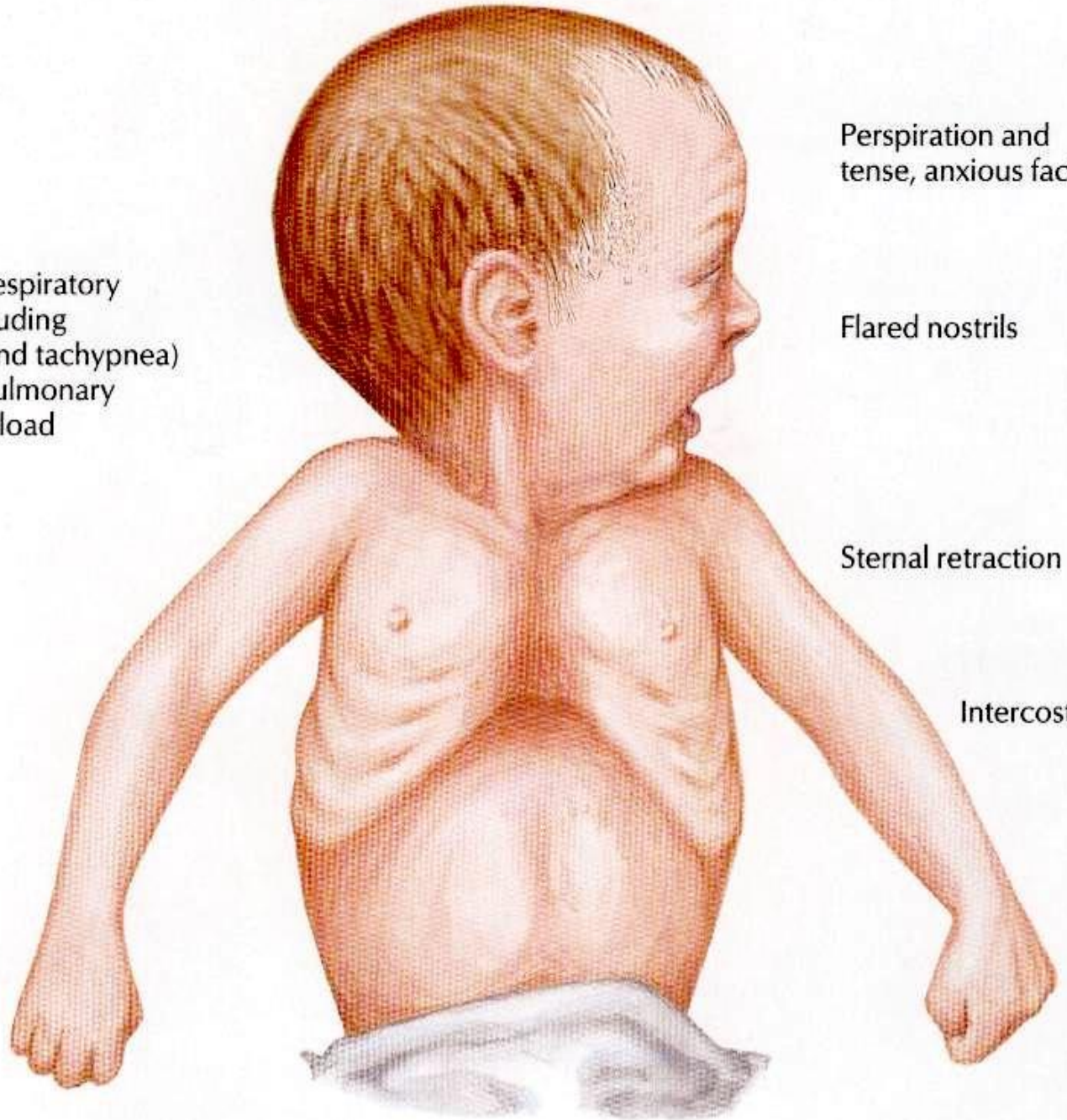
Left-to-right shunt through ventricular septal defect

Ventricular septal defect

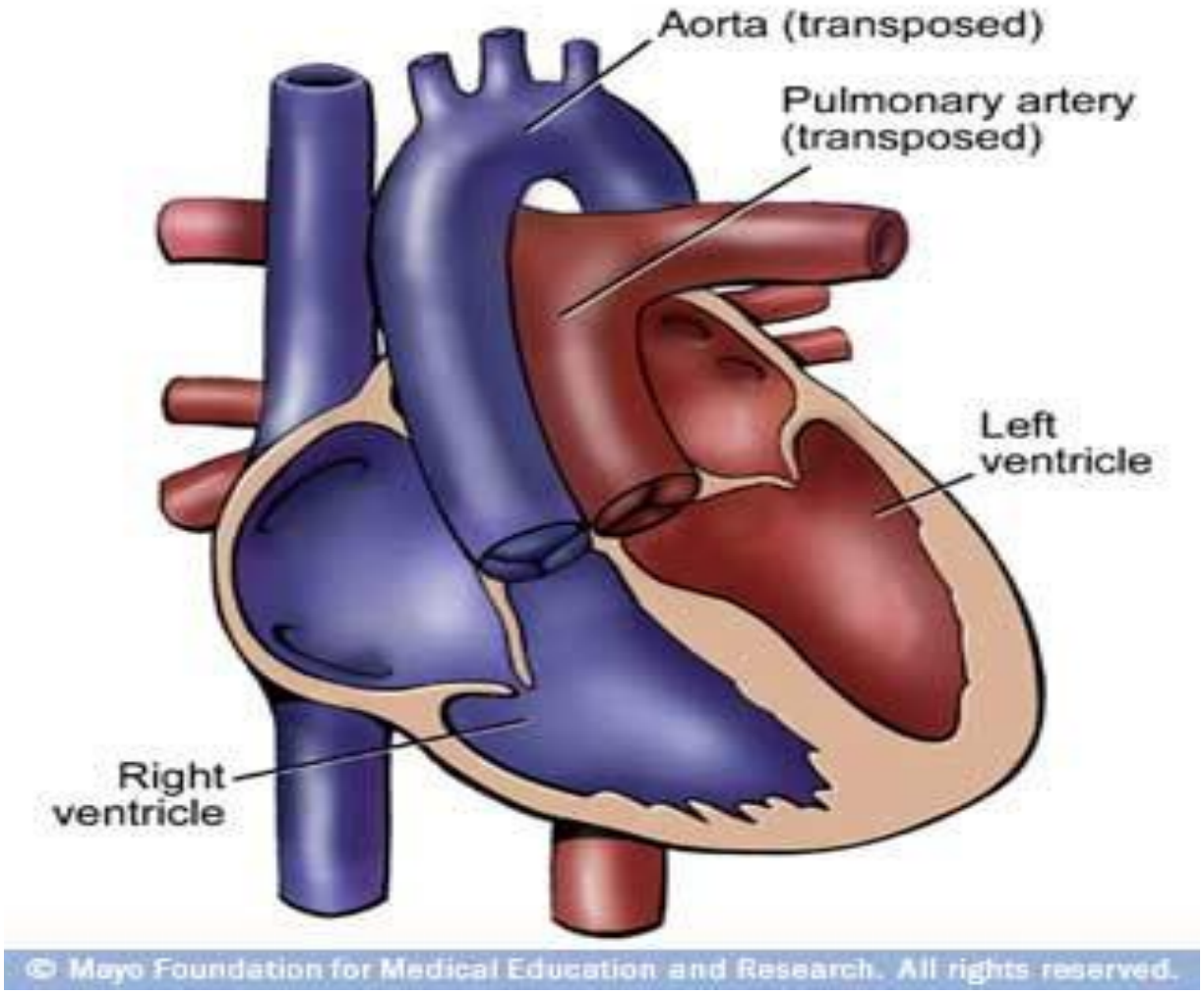
Left ventricular hypertrophy

Right ventricular hypertrophy

Clinical characteristics of too much pulmonary flow (pulmonary volume overload)

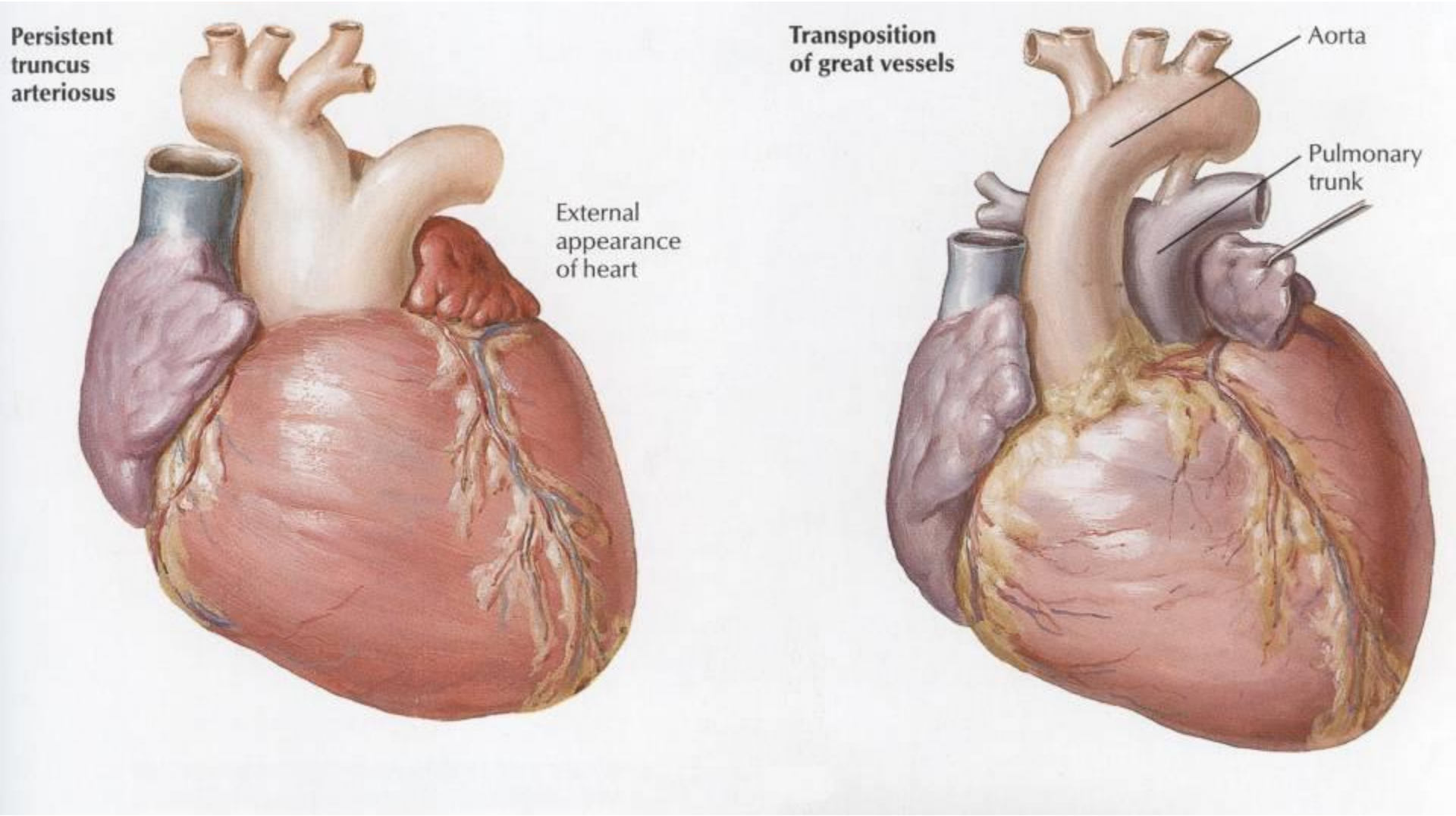


Transposition of great arteries



Persistent truncus arteriosus

Transposition of great vessels



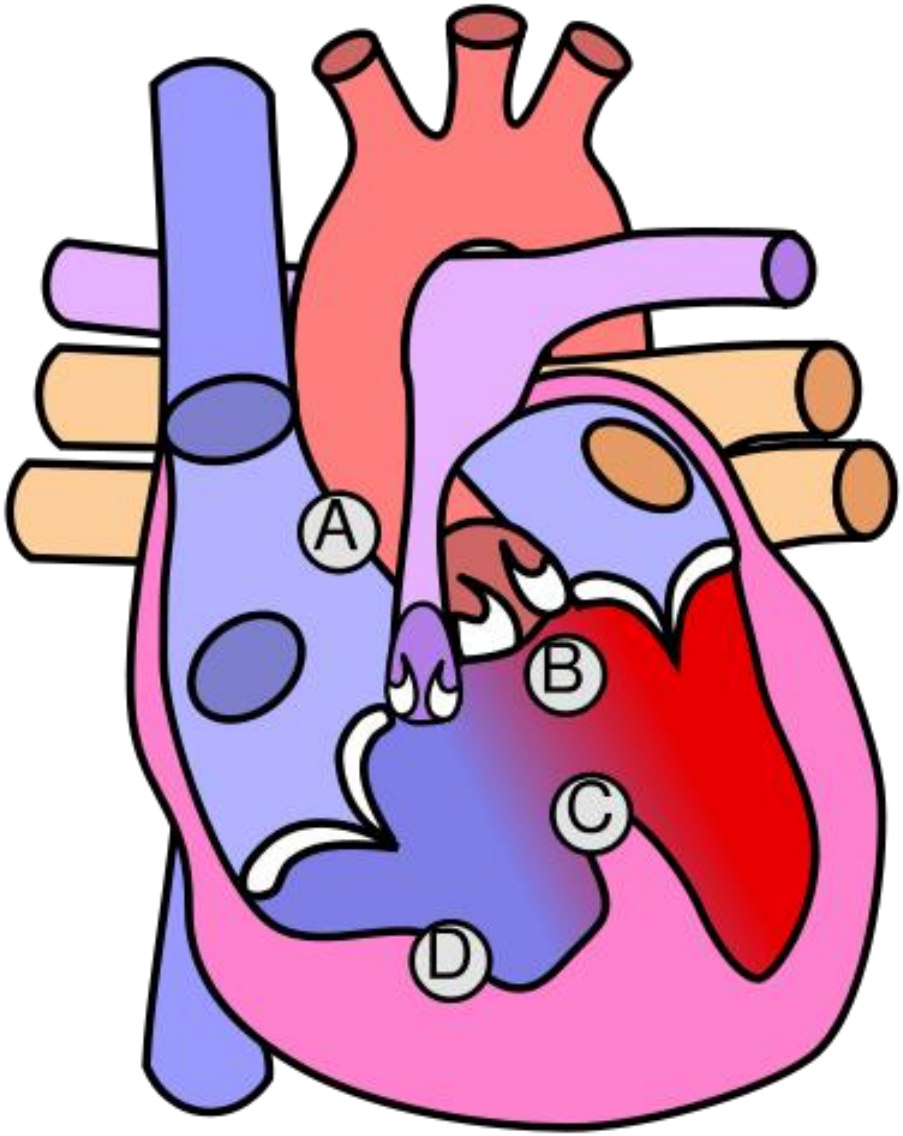
Tetralogy of Fallot

A – dextroposition of aorta (overriding aorta)

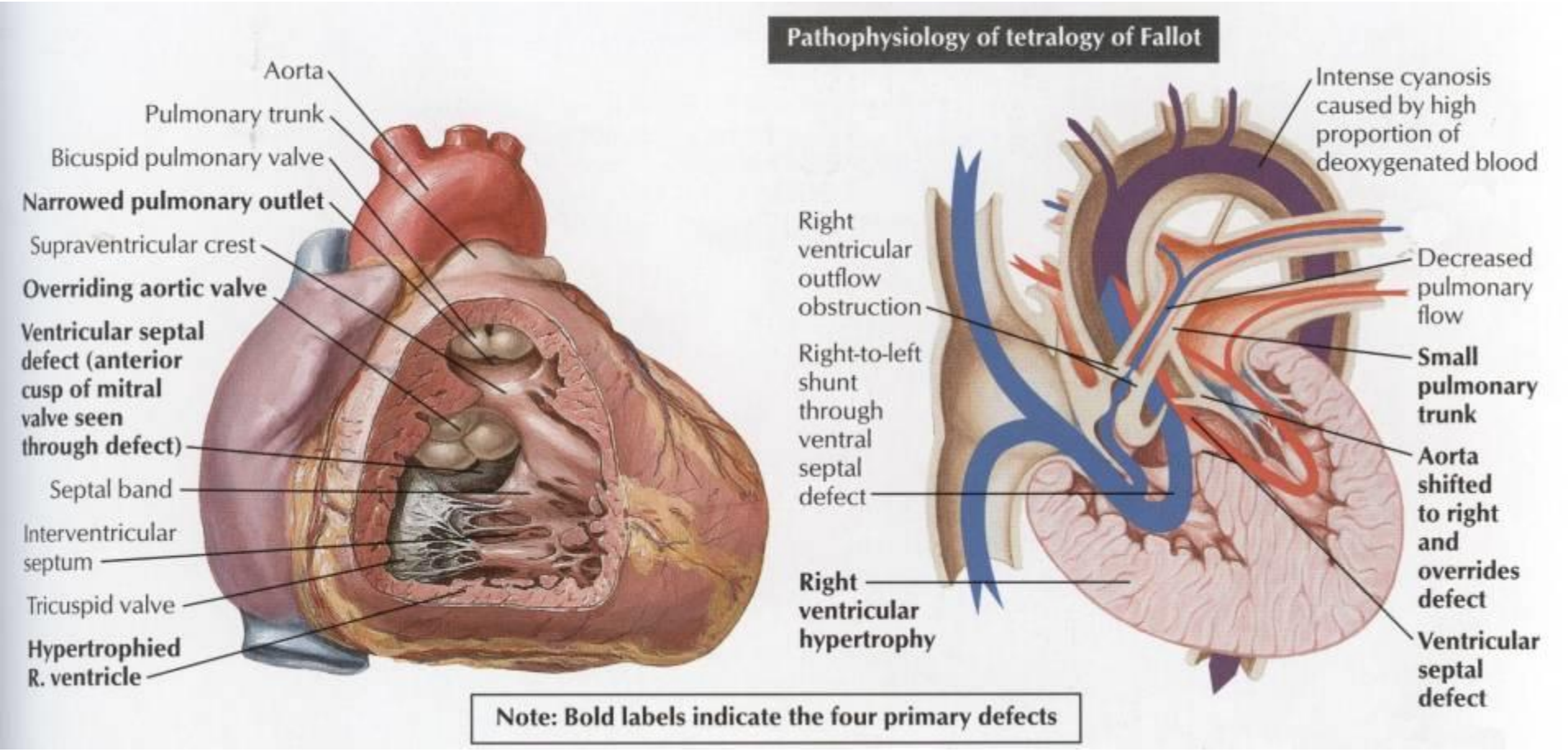
B – pulmonary stenosis (obstruction to right ventricle outflow)

C – ventricular septal defect

D – right ventricular hypertrophy



Tetralogy of Fallot

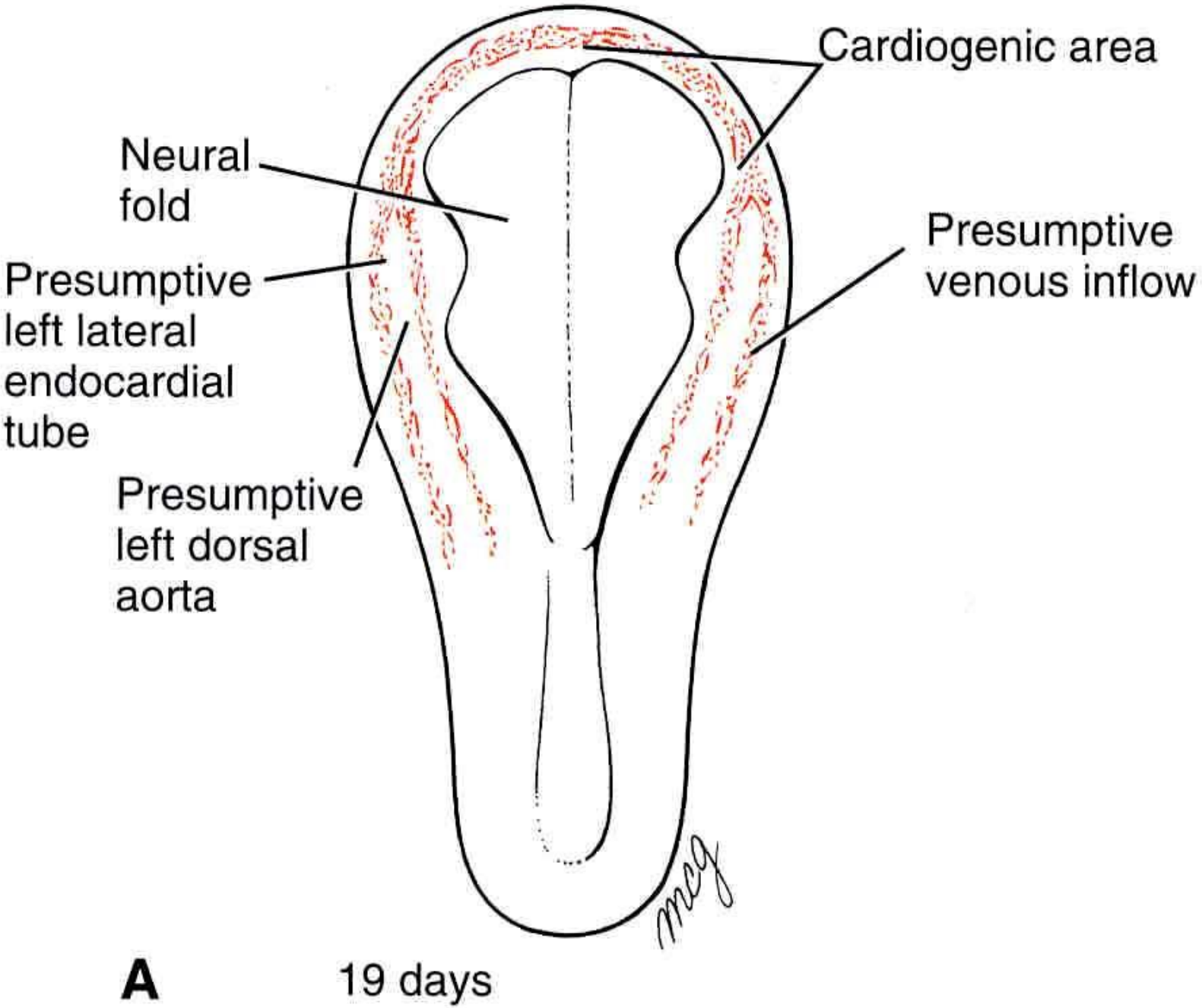


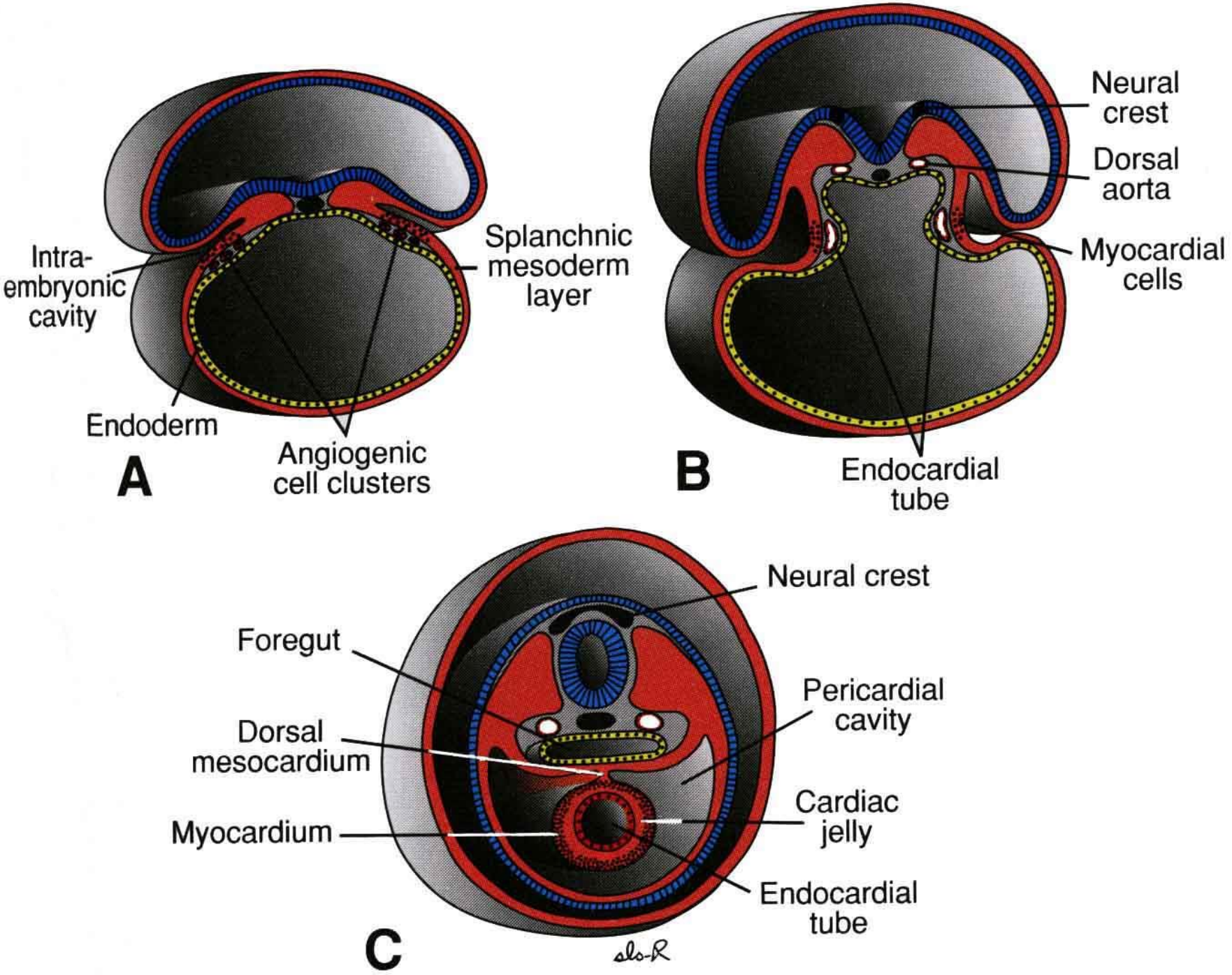
Clinical characteristics of too little pulmonary flow

Cyanosis

Clubbing of fingers

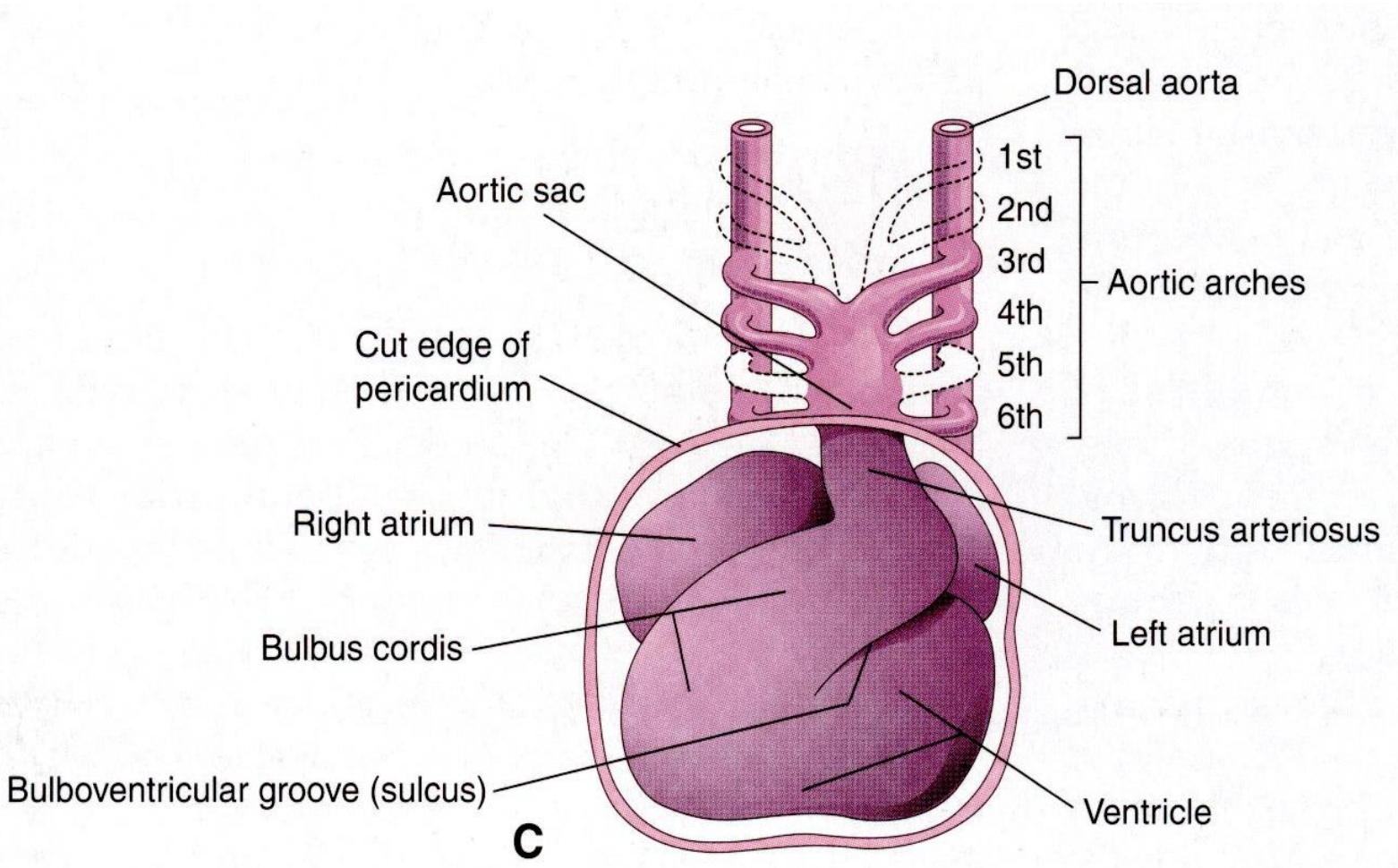
DEVELOPMENT OF ARTERIES

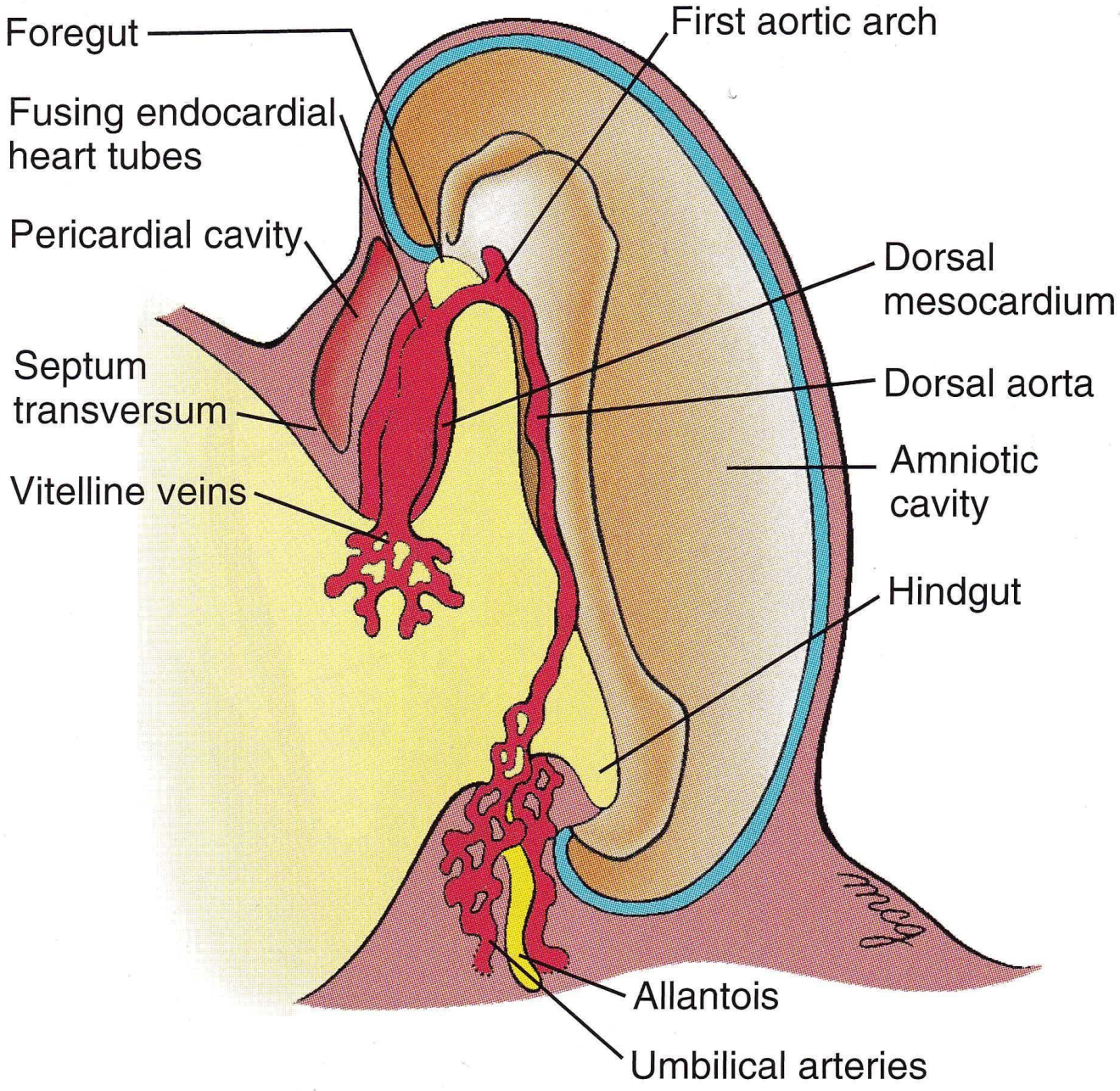

Cardiogenic area
Neural fold
Presumptive venous inflow
Presumptive left lateral endocardial tube
Presumptive left dorsal aorta
A
19 days

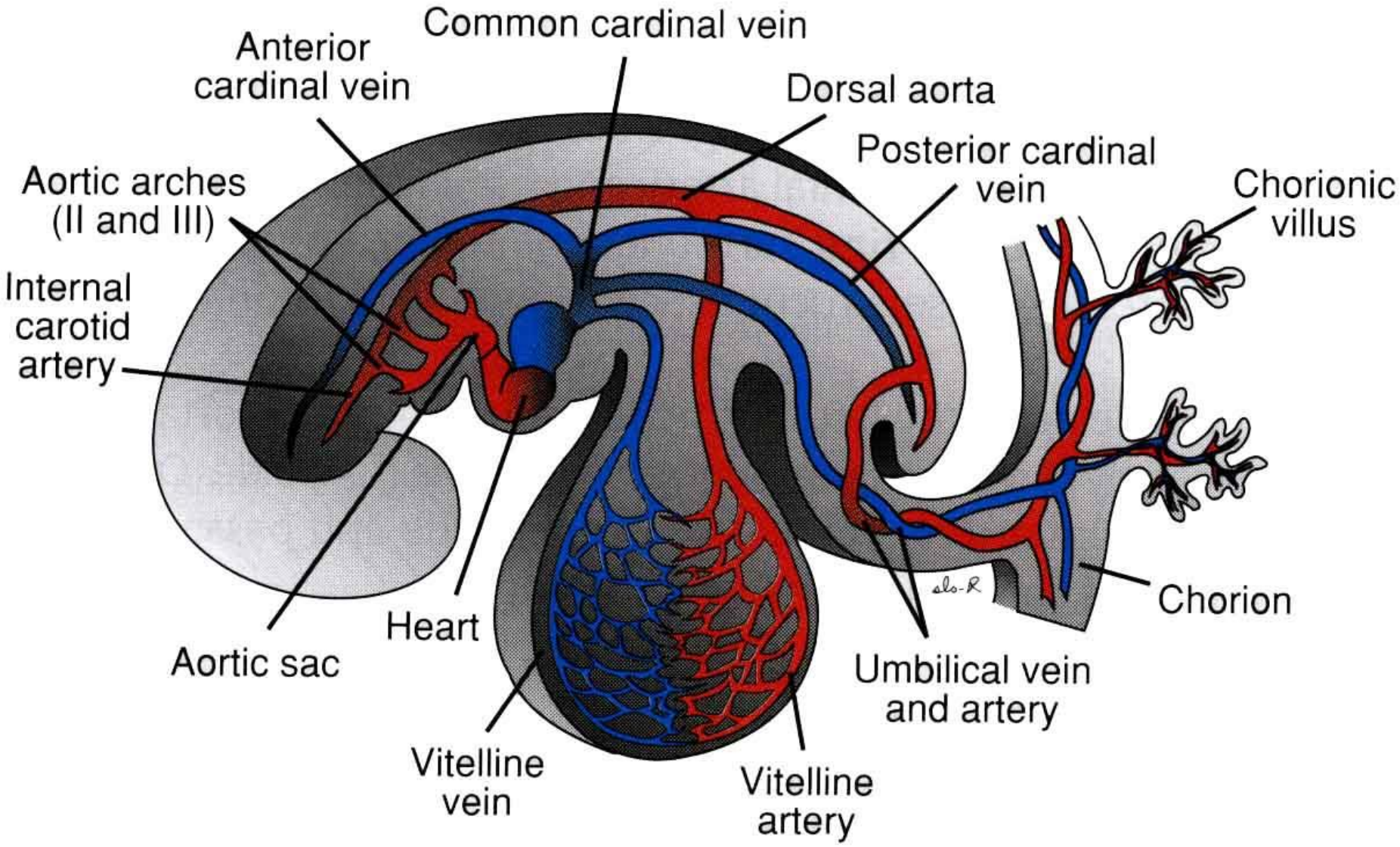

Intra-
embryonic
cavity
Splanchnic
mesoderm
layer
Endoderm
Angiogenic
cell clusters
A
Neural
crest
Dorsal
aorta
Myocardial
cells
B
Endocardial
tube
Neural crest
Foregut
Pericardial
cavity
Dorsal
mesocardium
Cardiac
jelly
Myocardium
Endocardial
tube
C
slo-R

Arteries associated with heart

- truncus arteriosus → saccus aorticus → aa. arcuum pharyngeorum (aortic arches)

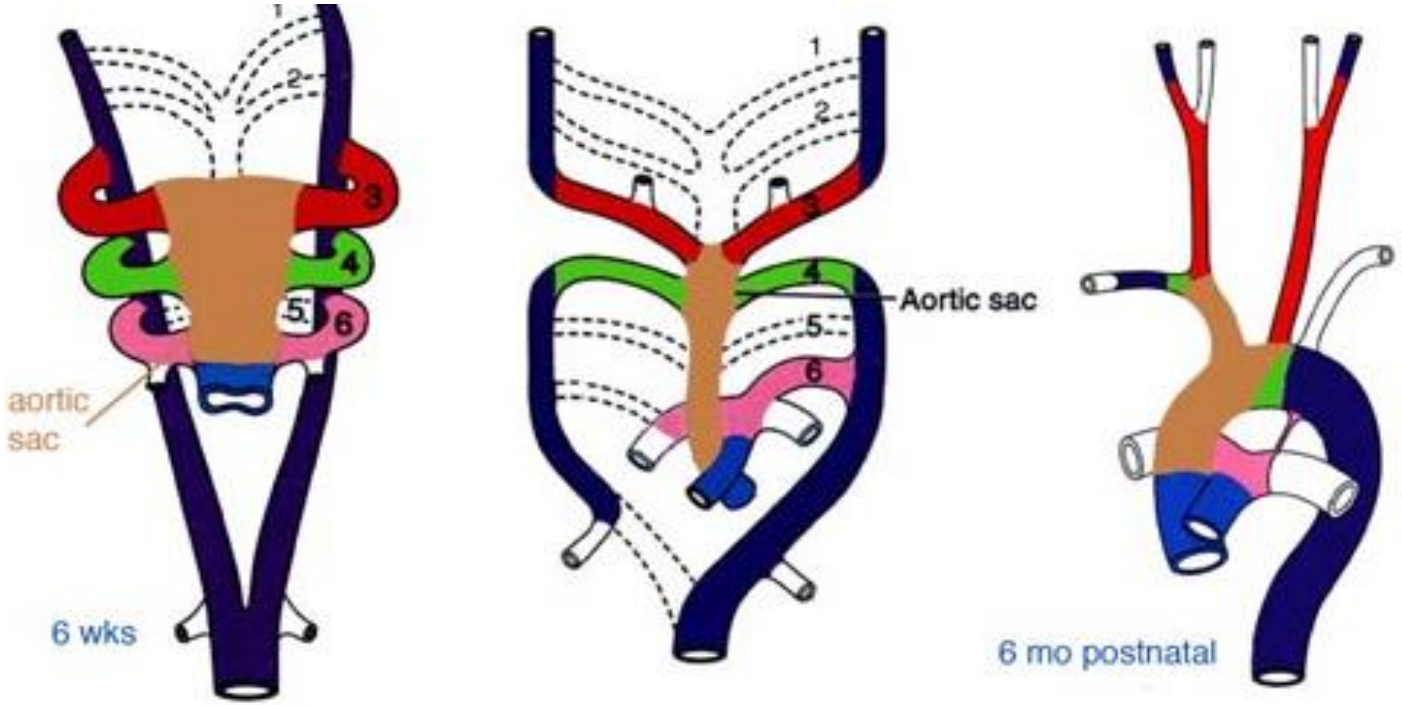



Foregut
Fusing endocardial heart tubes
Pericardial cavity
Septum transversum
Vitelline veins
First aortic arch
Dorsal mesocardium
Dorsal aorta
Amniotic cavity
Hindgut
Allantois
Umbilical arteries


Common cardinal vein
Anterior cardinal vein
Dorsal aorta
Posterior cardinal vein
Aortic arches (II and III)
Chorionic villus
Internal carotid artery
Chorion
Heart
Aortic sac
Umbilical vein and artery
Vitelline vein
Vitelline artery

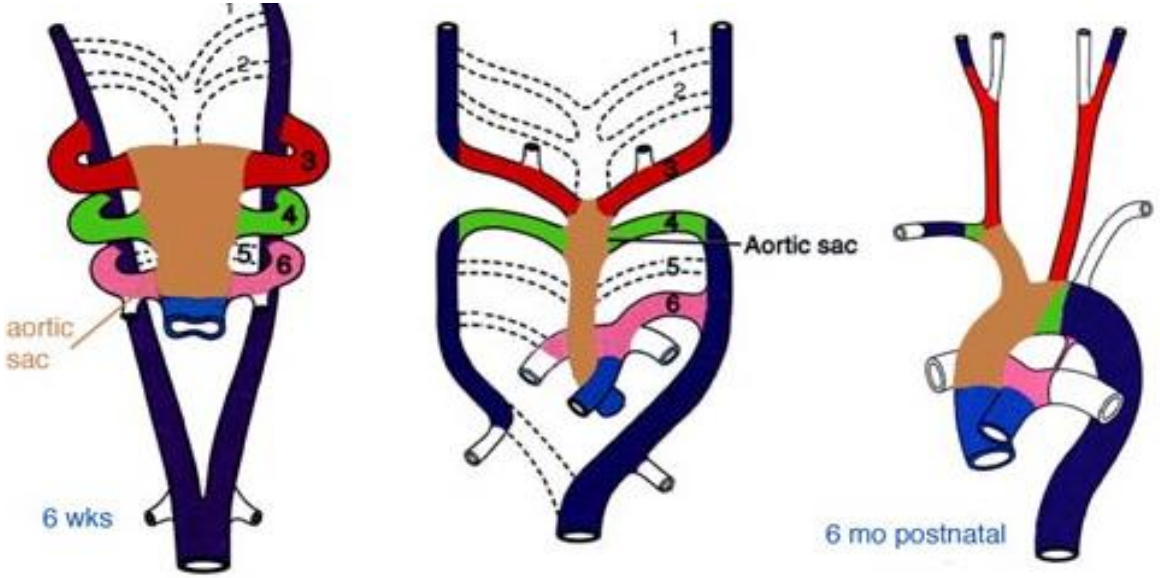
Aortic arches derivatives I

- 1st pair – arteria maxillaris
- 2nd pair – arteria stapedia
- **3rd pair** – central – ***arteria carotis communis***
  – peripheral – ***arteria carotis interna***



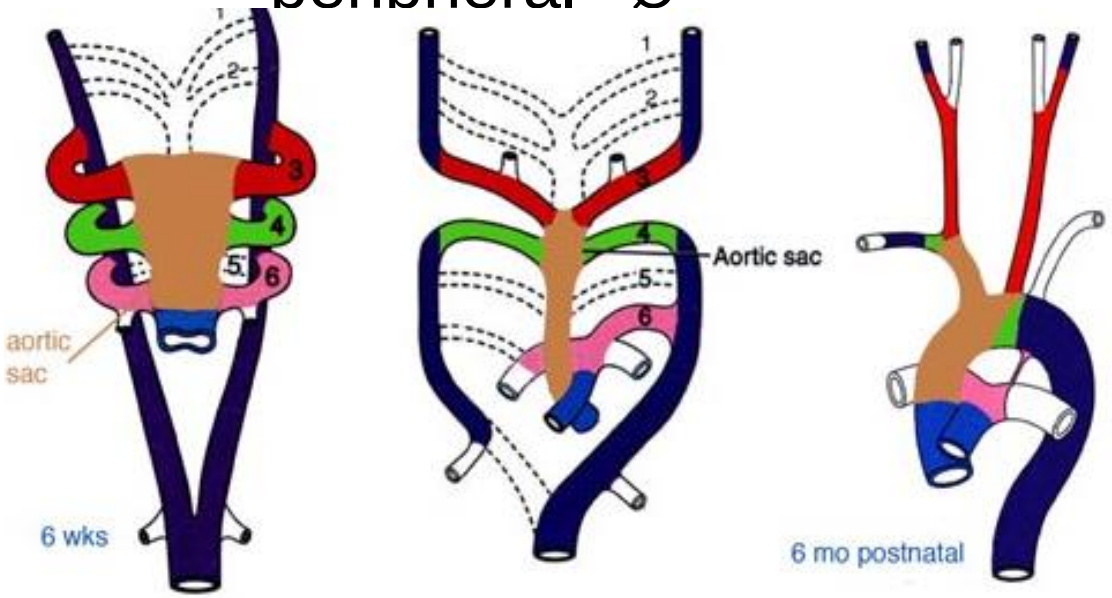
Aortic arches derivatives II

- **4th pair**
  - left – part of the ***arcus aortae***
  - right – ***a. subclavia dx.***
    - *peripheral part of a. subclavia dx. is derived from aorta dorsalis dextra*
  - a. subclavia sin. is **NOT** derived from the 4th aortic arch but from 7th intersegmental artery



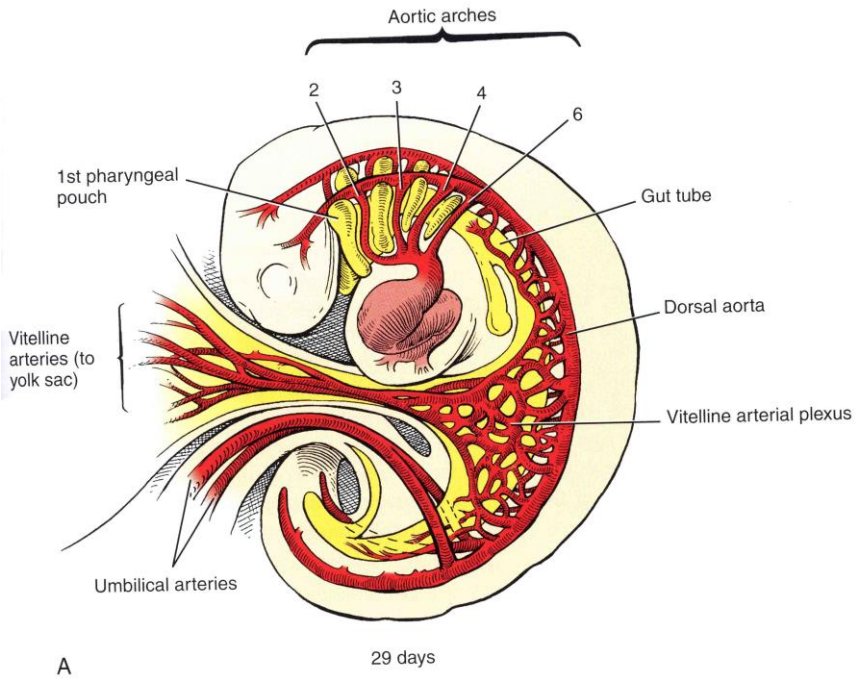
Aortic arches derivatives III

- 5th – Ø
- **6th pair**
  - left central ***left pulmonary artery***
    peripheral ***ductus arteriosus (Botali)***
  - right central ***right pulmonary artery***
    peripheral Ø



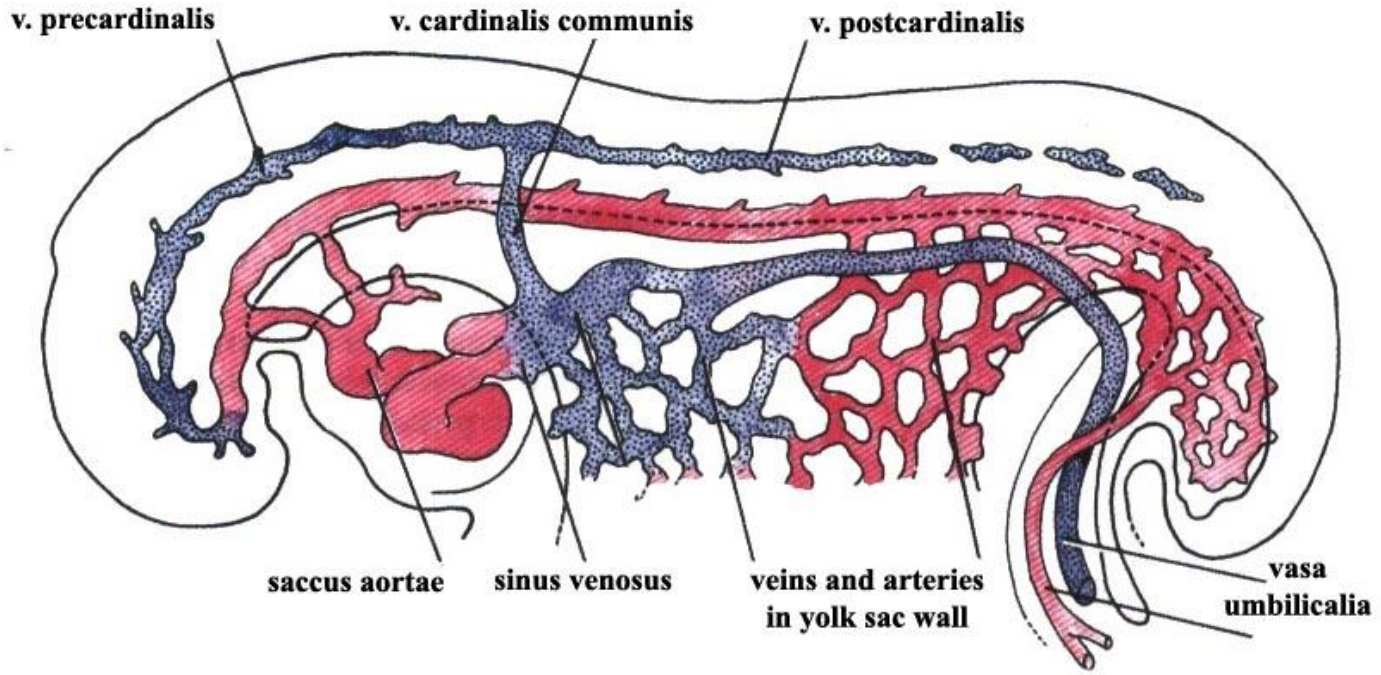
Branches of dorsal aortae

- aa. segmentales ventrales
  - aa. omphalomesentericae (vitellinae) → truncus coeliacus, a. mesenterica superior et inferior
  - aa. umbilicales → trunci umbilicales → aa. illiacae
- aa. segmentales laterales → aa. renales, suprarenales, testiculares, ovaricae .....
- aa. intersegmentales → aa. vertebrales, subclaviae (whole left, peripheral part of right), intercostales, hypogastricae, epigastricae.....
- a. sacralis mediana



Arteriae omphalomesentericae (vitellinae)

- number of paired arteries
- supply yolk sac
- develop in vascular supply of gut → truncus coeliacus, arteria mesenterica superior et inferior



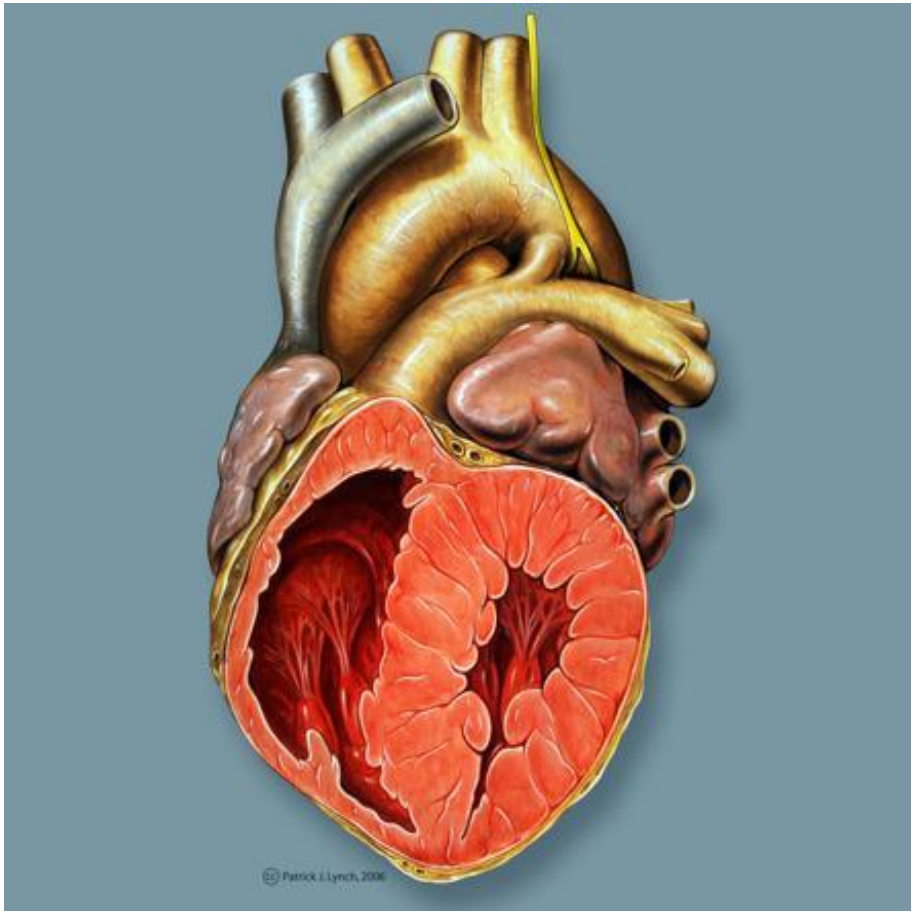
Arteriae umbilicales

- paired branches
  - central: truncus umbilicalis from aorta dorsalis
  - peripheral: within mass of diverticulum allantoicum
- to placenta (originally to allantois) in embryonic (connective) stalk or later in umbilical cord
- persist as arteriae iliacae internae and vesicales superiores
  - central: pars patens
  - peripheral: ligamentum umbilicale mediale = pars occlusa

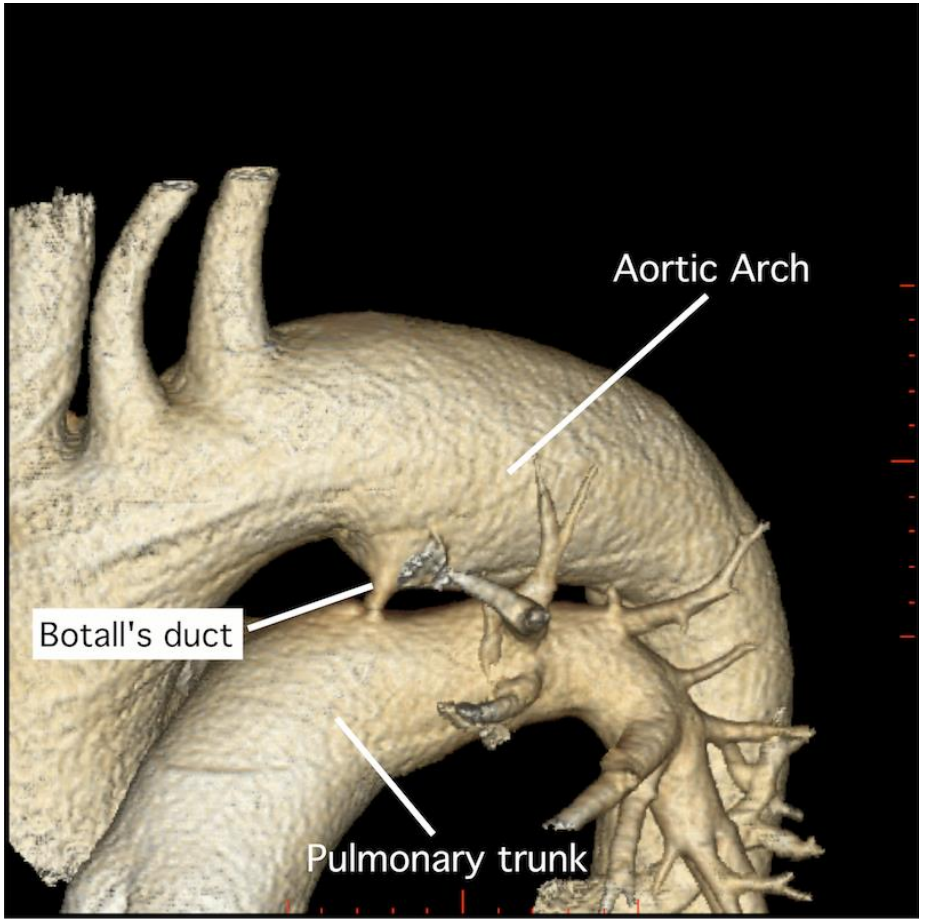
Malformation of arteries

- Ductus arteriosus patens
- Coarctatio aortae
- Arcus aortae duplex
- Arcus aortae dexter
- Arteria lusoria
  - abnormal origin of the right subclavian artery – obliteration of right aortic arch – origin of 7^{th} segmental artery

Ductus arteriosus Botalli
Botall's duct

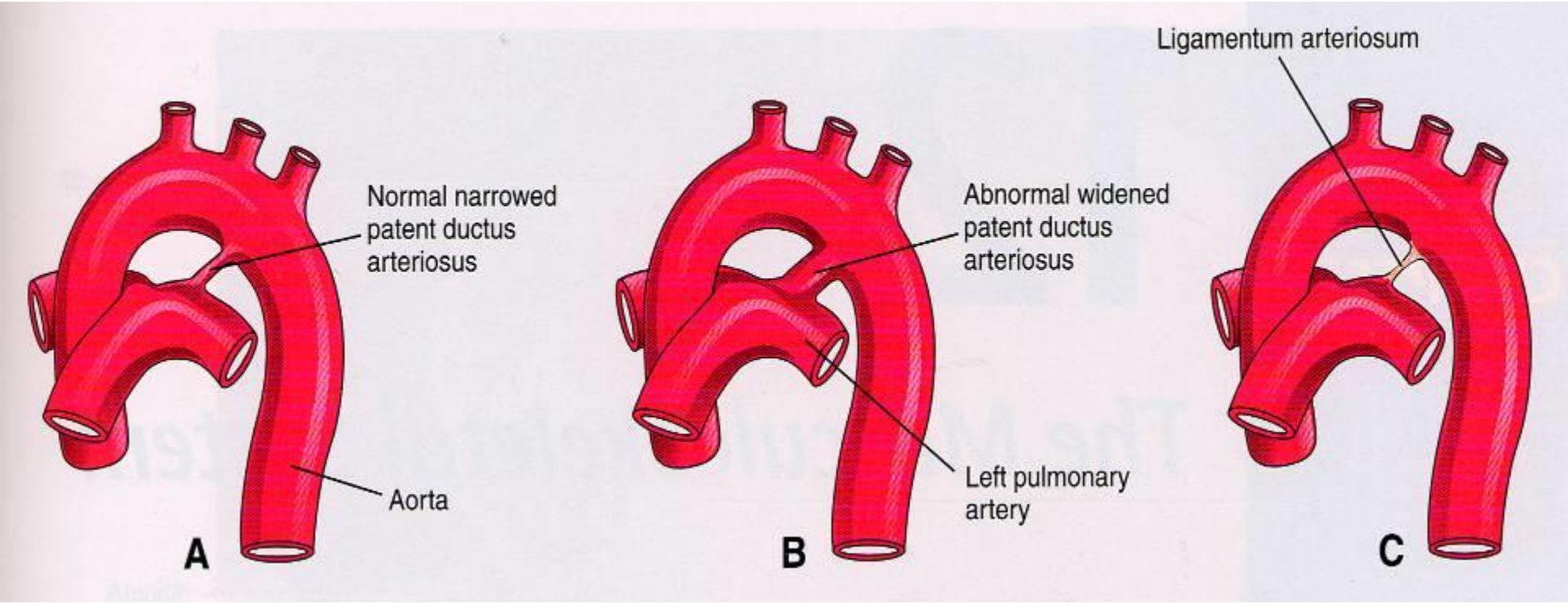


http://images.radiopaedia.org/images/25225/2f0aae3edc1fc18ff46cff5a40bb39_gallery.jpg

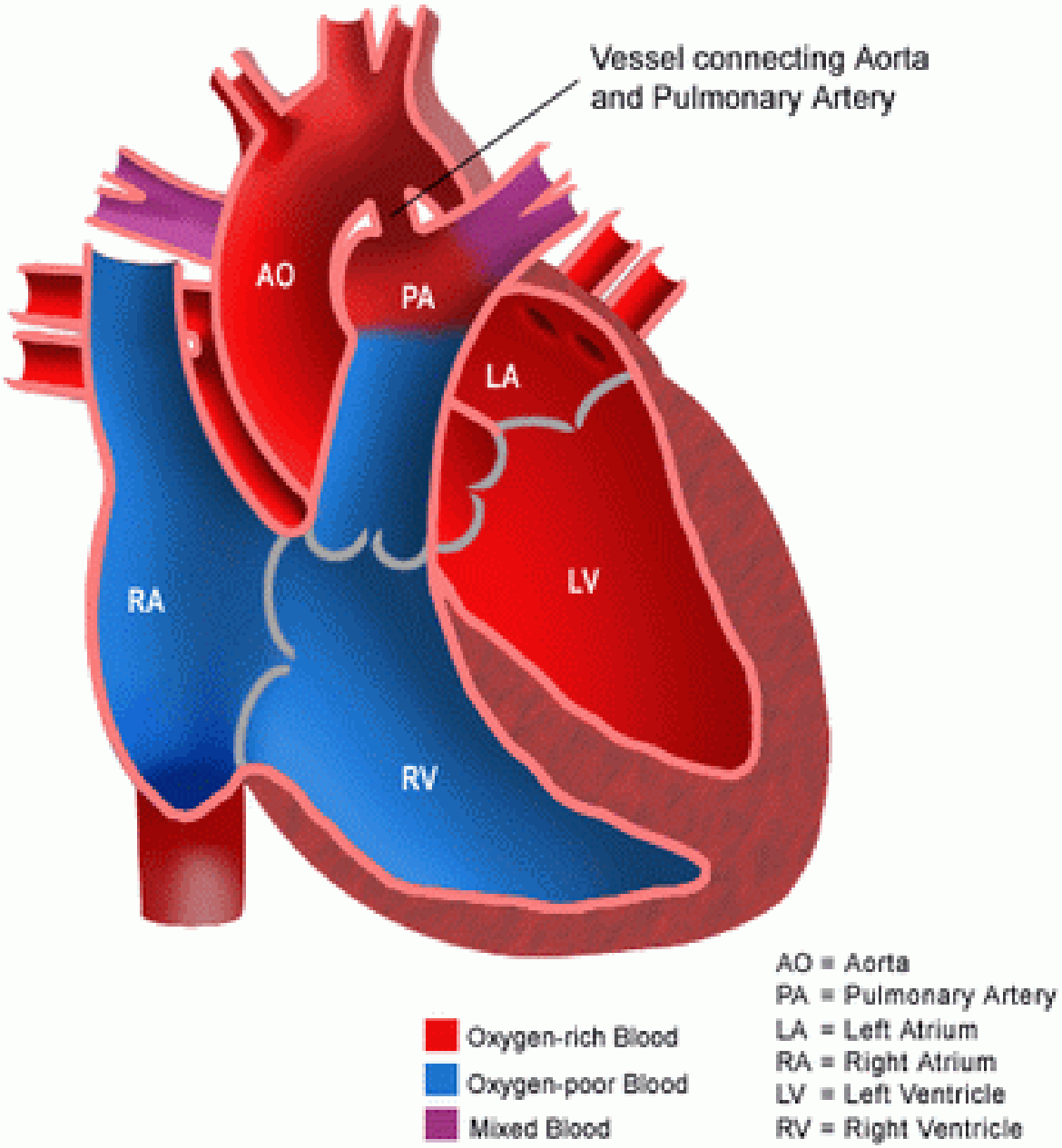


http://posterng.netkey.at/esr/viewing/index.php?module=viewimage&task=&mediafile_id=366756&201101302145.gif

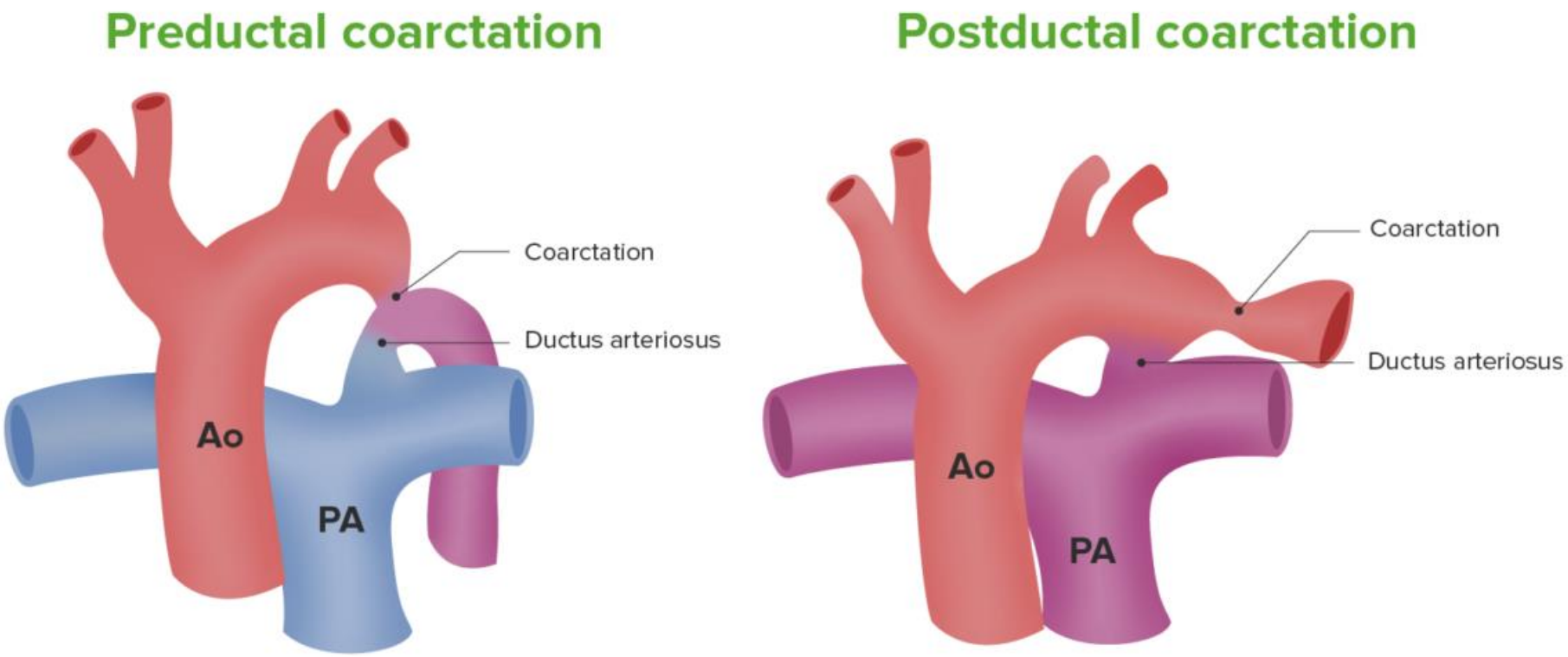
Ductus arteriosus patens



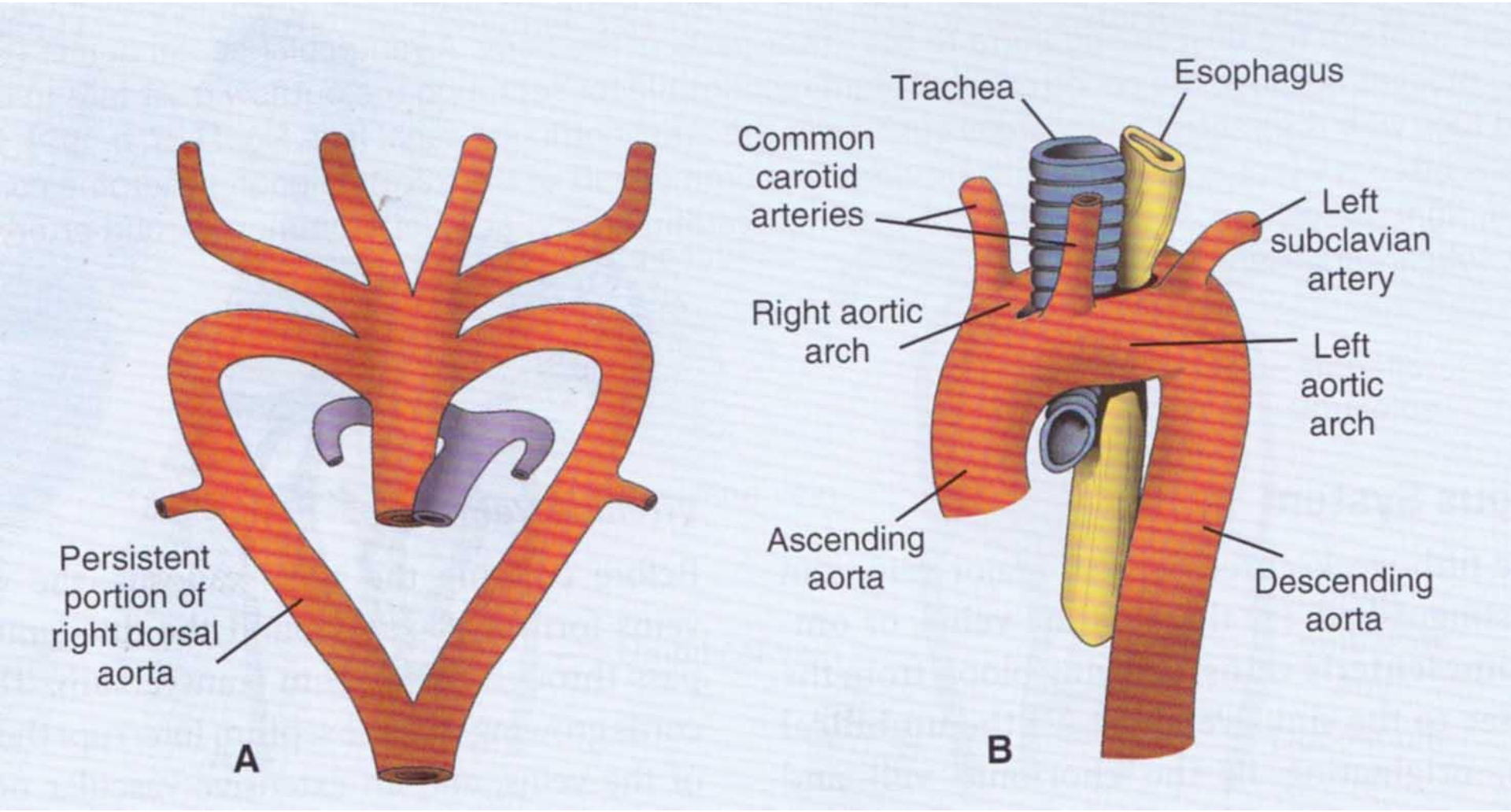
Patent Ductus Arteriosus (PDA)



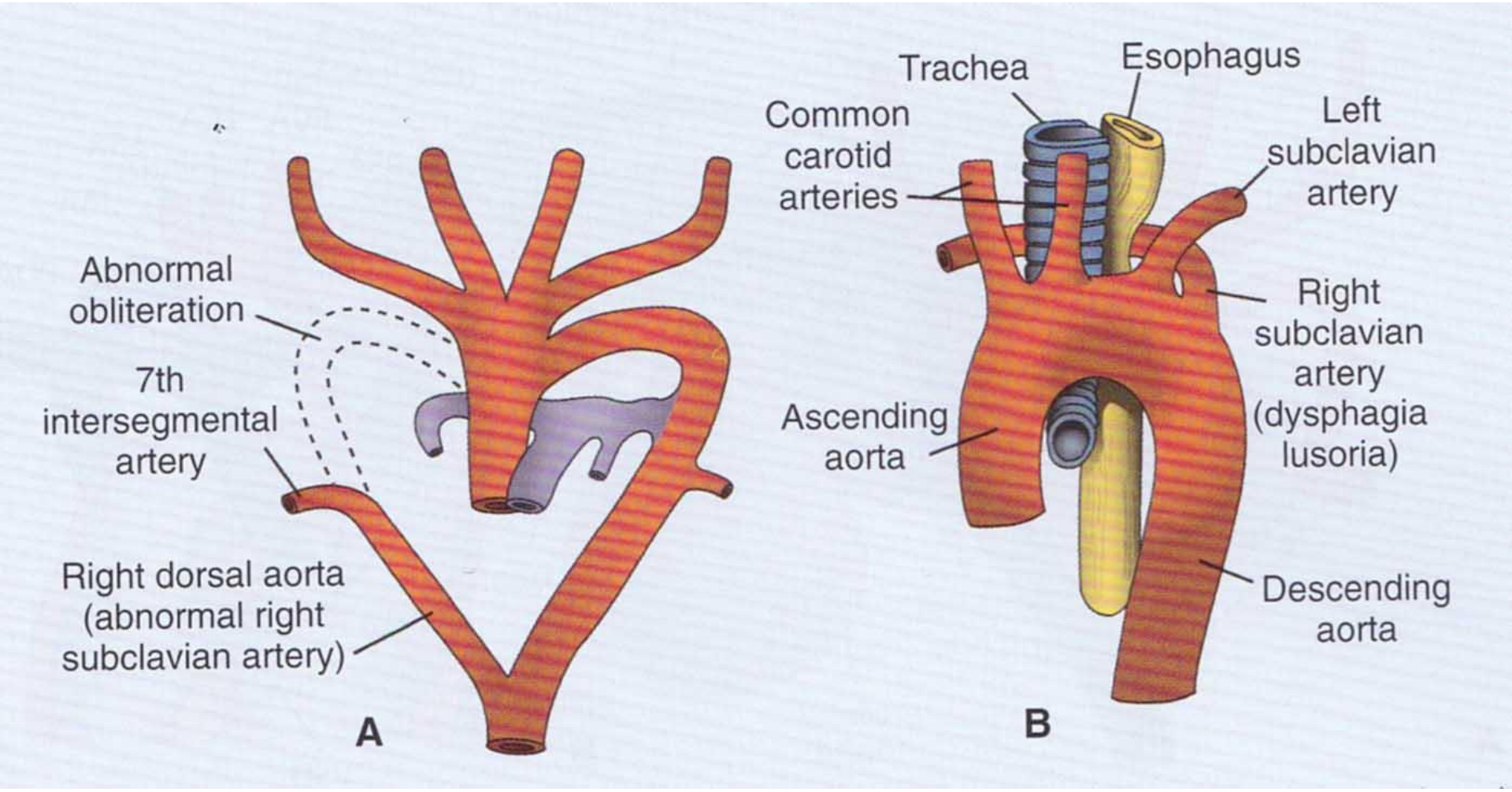
Coarctatio aortae



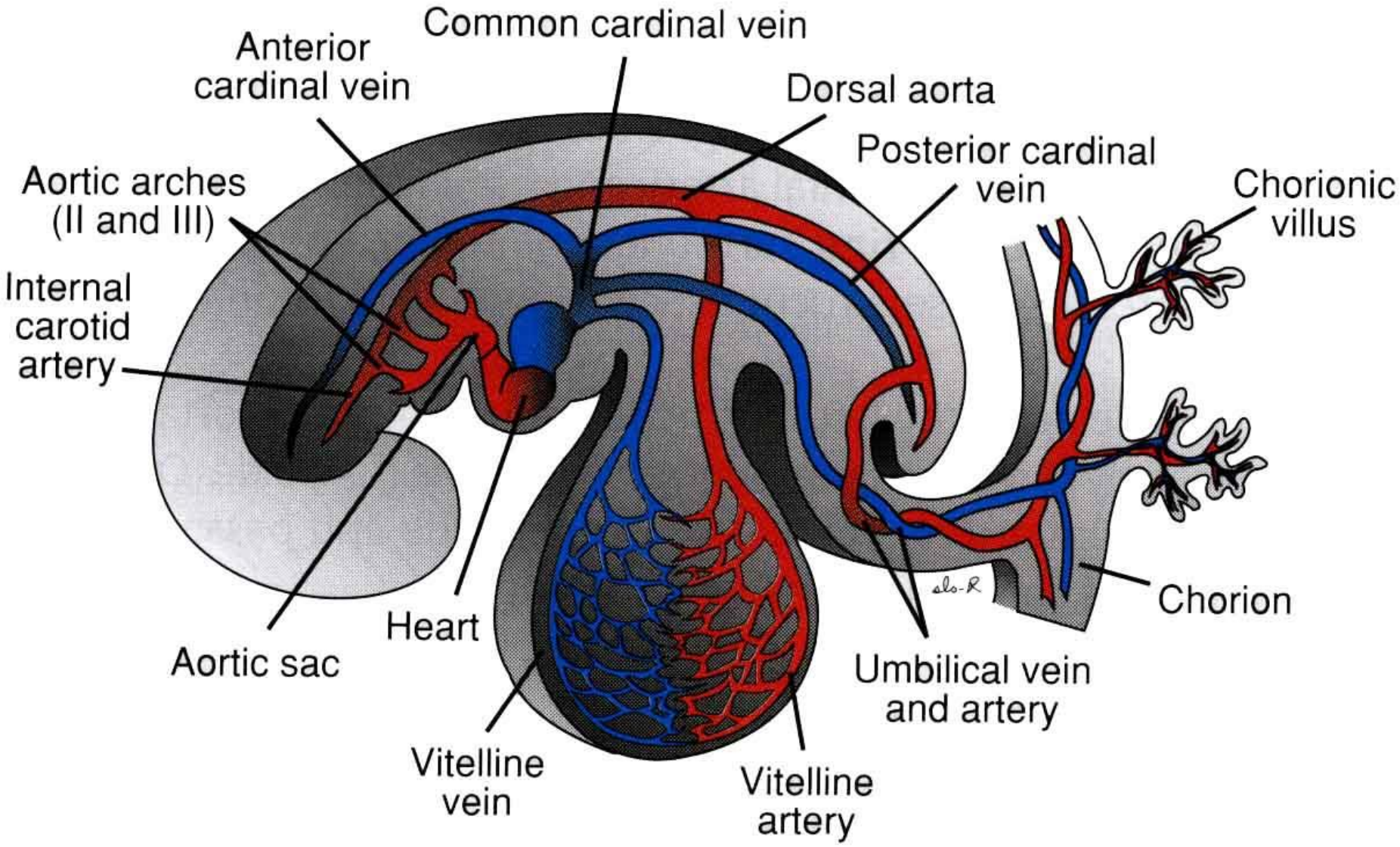
Double aortic arch



Arteria lusoria



DEVELOPMENT OF VEINS

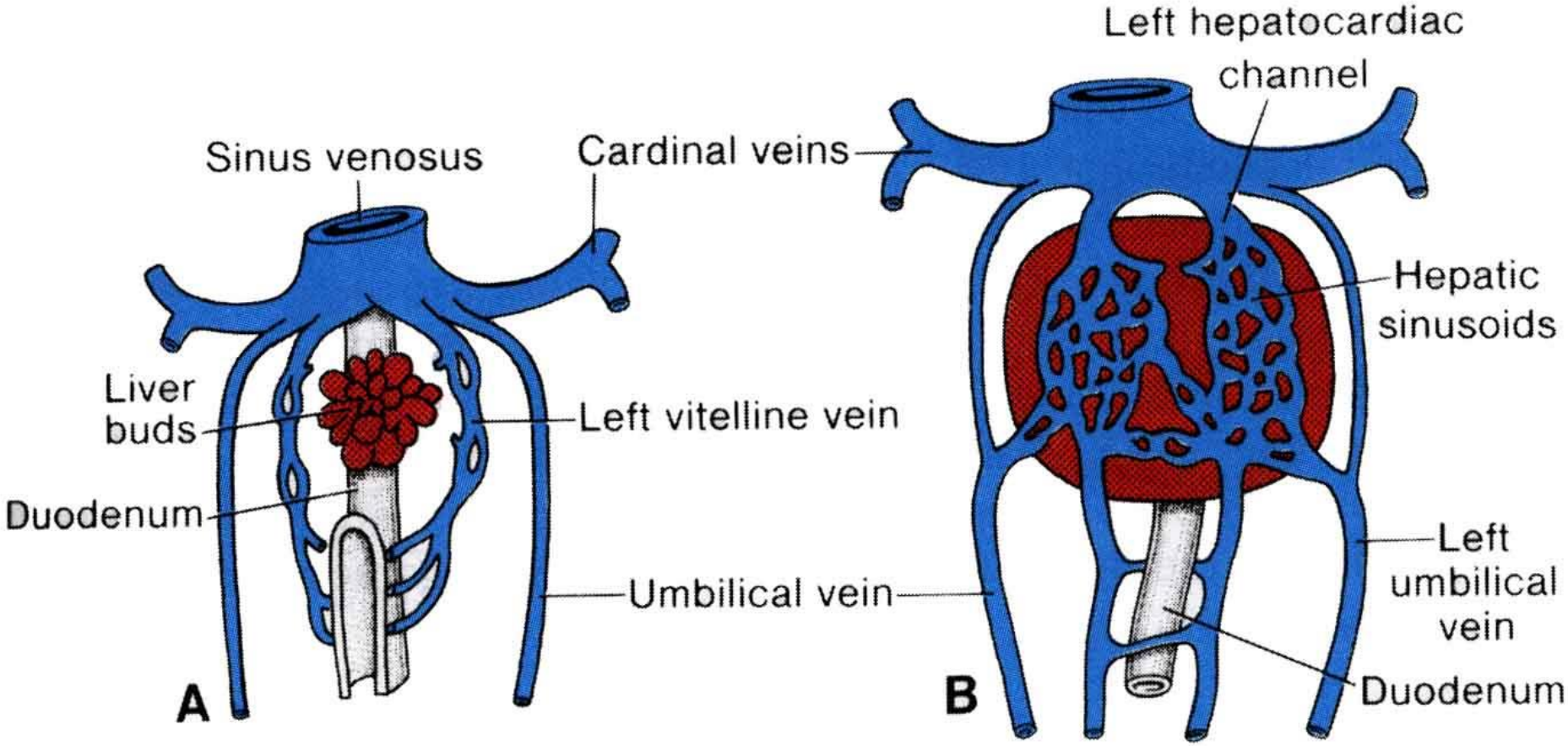

Common cardinal vein
Anterior cardinal vein
Dorsal aorta
Posterior cardinal vein
Aortic arches (II and III)
Chorionic villus
Internal carotid artery
Chorion
Heart
Aortic sac
Umbilical vein and artery
Vitelline vein
Vitelline artery

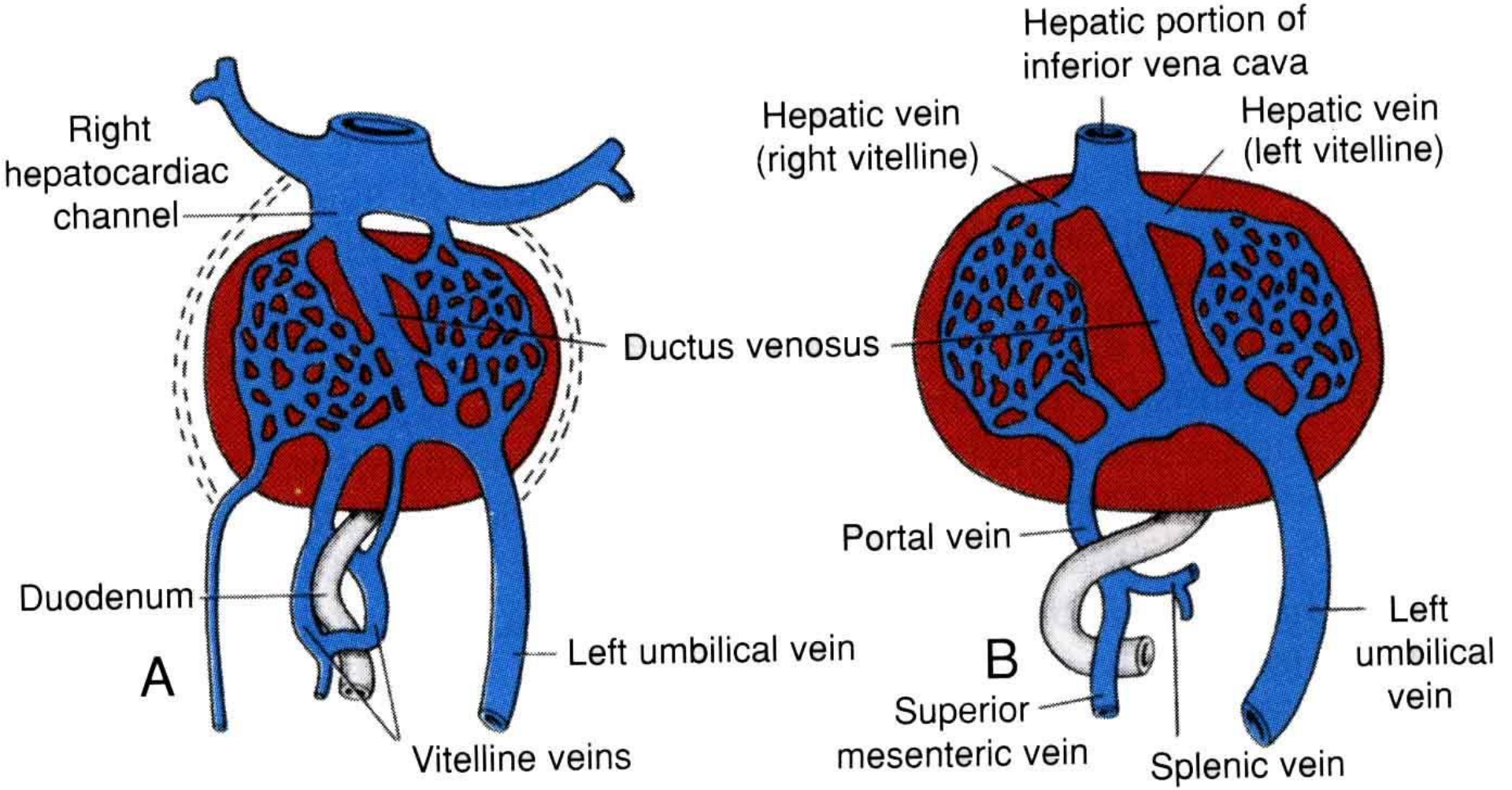
Veins associated with heart

- ***Venae omphalomesentericae* (*vv. vitellinae*)**
  - poorly oxygenated blood from yolk sac

- ***Venae umbilicales***
  - well-oxygenated from chorionic villi of placenta

- ***Venae cardinales communes* (ductus Cuvièri)**
  - poorly oxygenated blood from body of embryo


Sinus venosus
Cardinal veins
Liver buds
Left vitelline vein
Duodenum
Umbilical vein
A
Left hepatocardiac channel
Hepatic sinusoids
Left umbilical vein
Duodenum
B


Right
hepatocardiac
channel
Ductus venosus
Duodenum
Left umbilical vein
A
Vitelline veins
Hepatic portion of
inferior vena cava
Hepatic vein
(right vitelline)
Hepatic vein
(left vitelline)
Portal vein
Left
umbilical
vein
B
Superior
mesenteric vein
Splenic vein

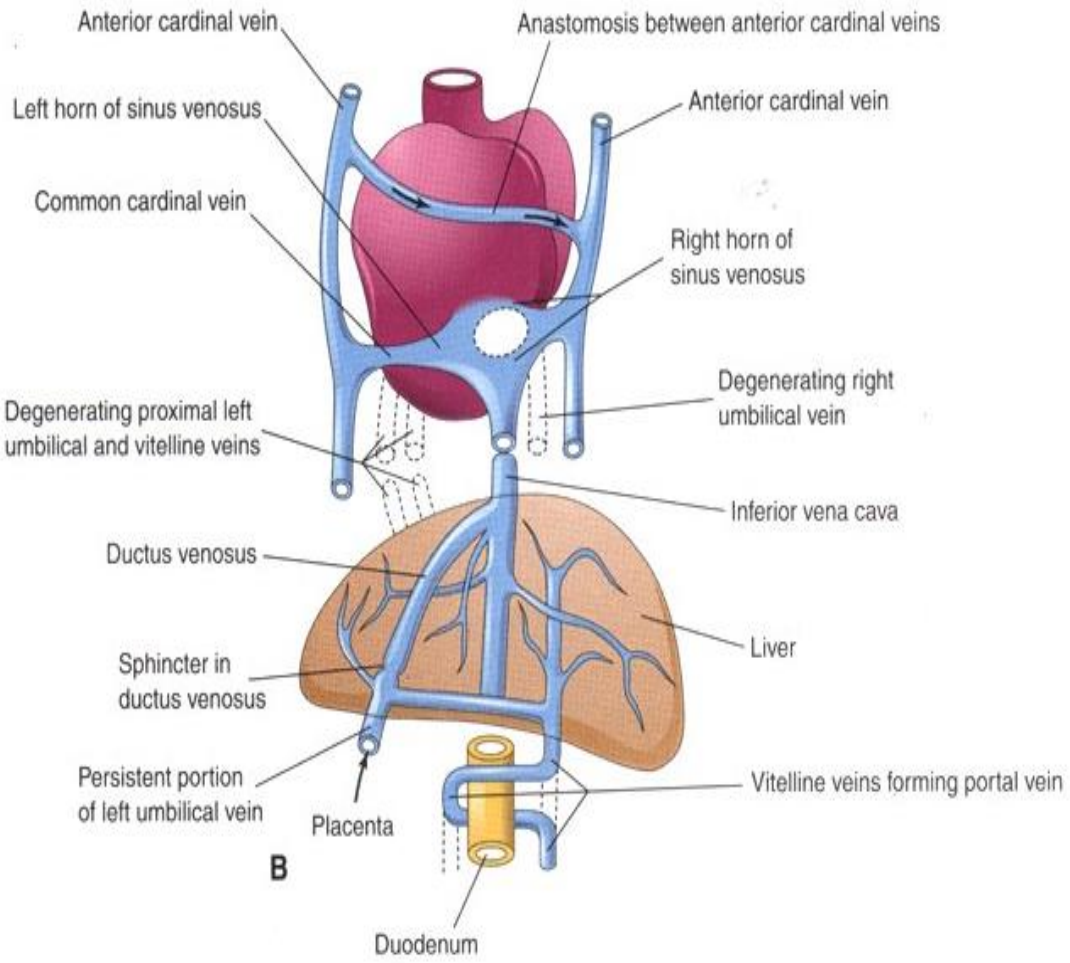
Venae omphalomesentericae (vitellinae)

➔ **venae hepaticae**

from remnants of right omphalomesenteric vein

➔ **venae portae**

from an anastomotic network around duodenum



Vena portae preduodenalis

rare

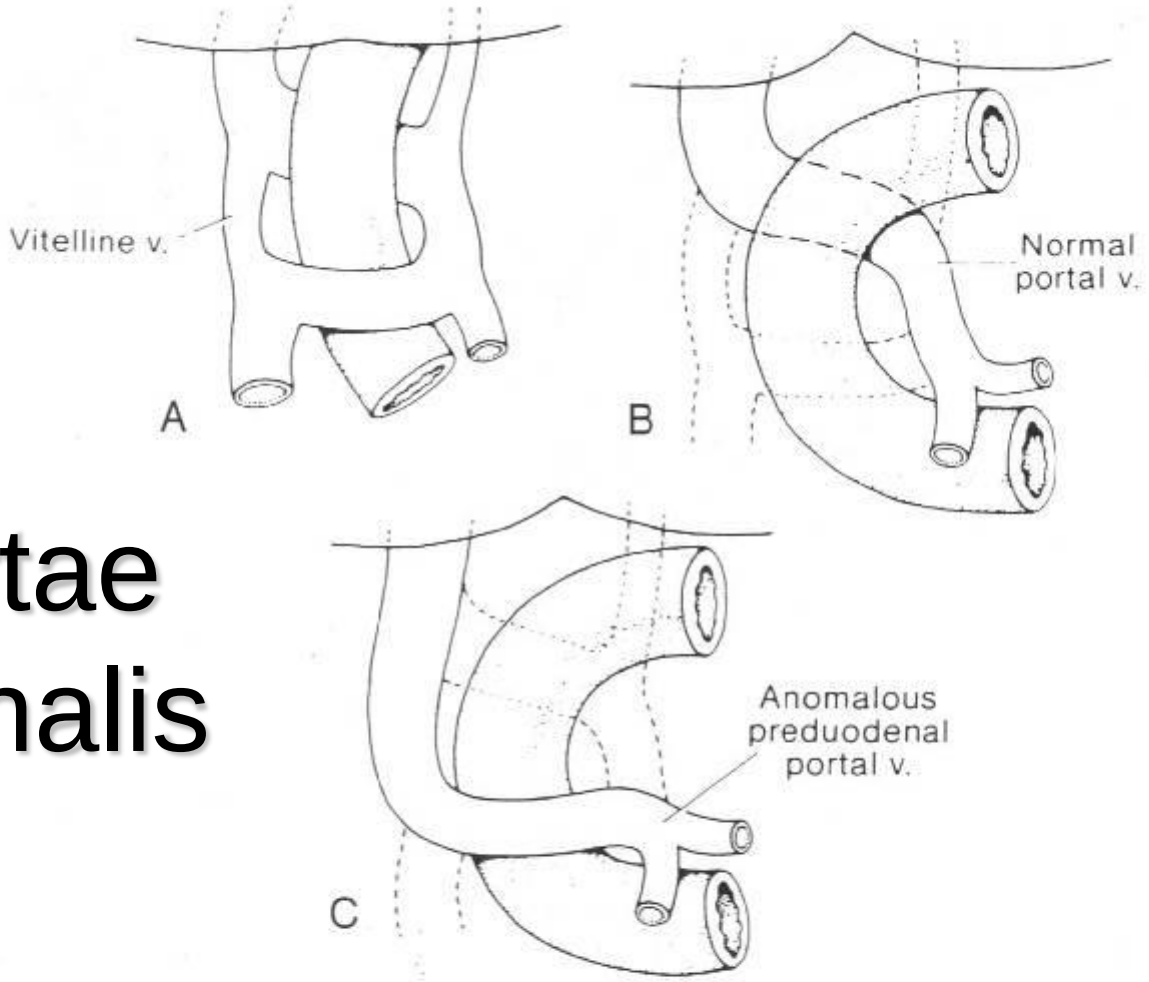
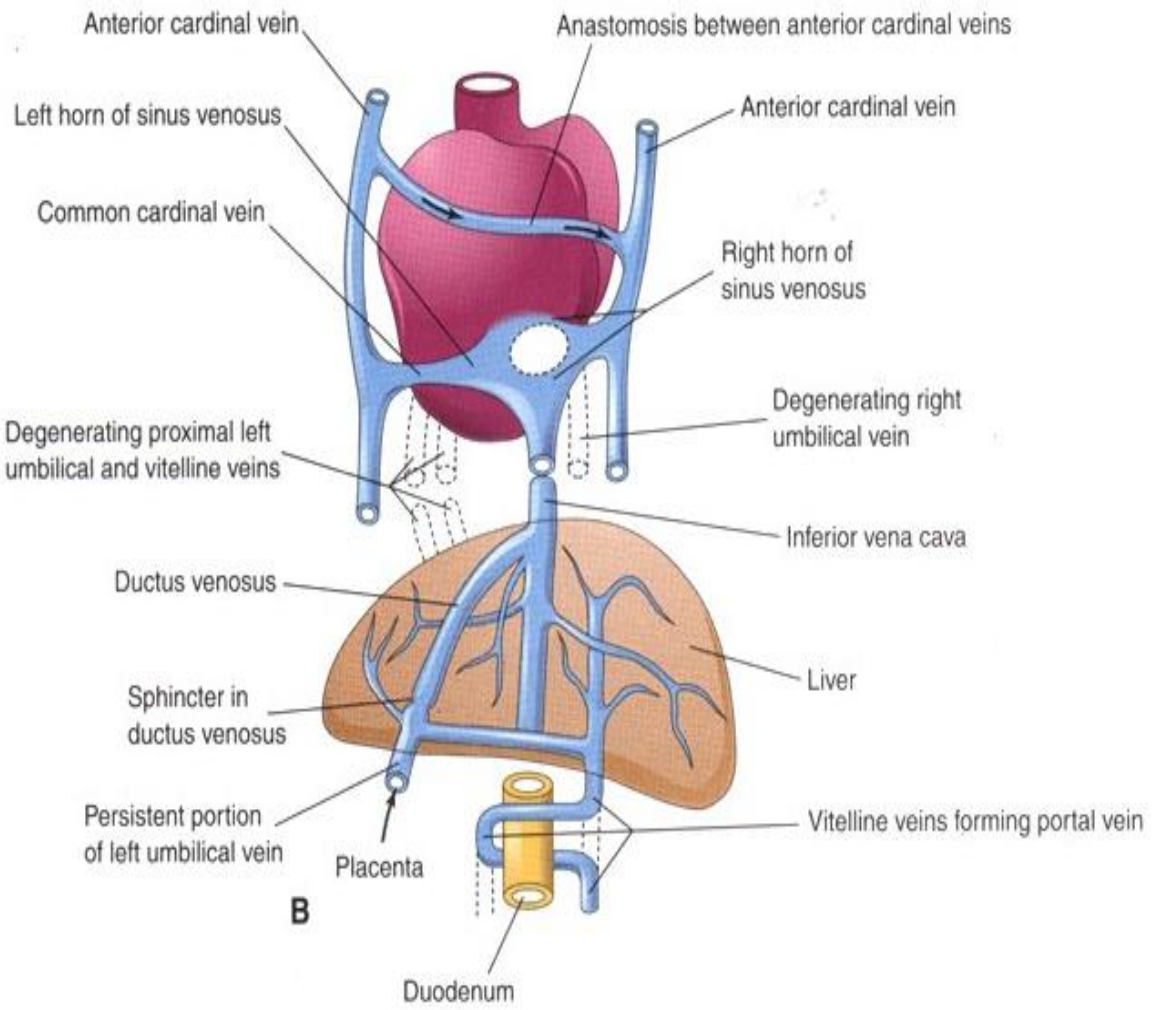


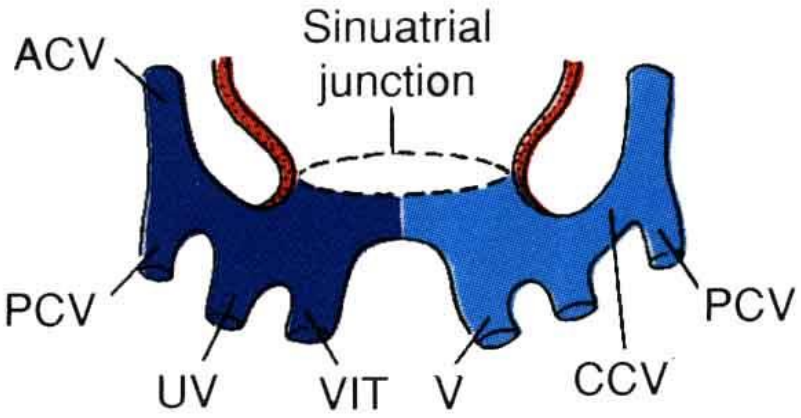
Figure 6. Embryonic origin of preduodenal portal vein. *A,* Embryonic extrahepatic communications between vitelline veins (V). *B,* Normal development; persistent superior communicating vein forms a part of normal, postduodenal portal vein. *C,* Anomalous persistent inferior communicating vein forms a part of an anomalous preduodenal portal vein. (*From* Colborn GL, Gray SW, Pemberton LB, et al: The duodenum. Am Surg 55(part 3):469, 1989; with permission.)

Venae umbilicales

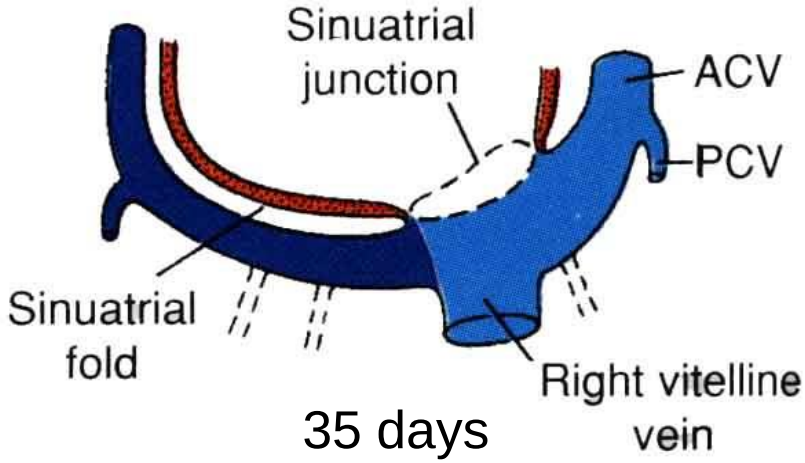
- right and part of left vein degenerate
- persistent part of left vein becomes **vena umbilicalis**
- venous shunt detouring liver – **ductus venosus**



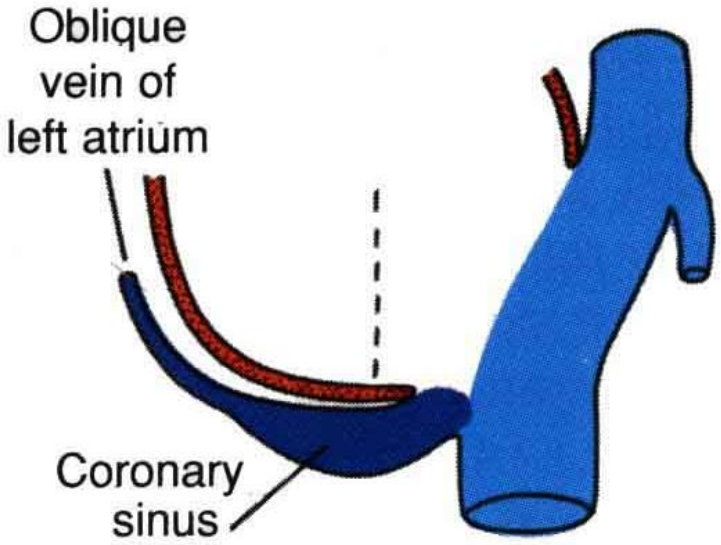
Sinus venosus



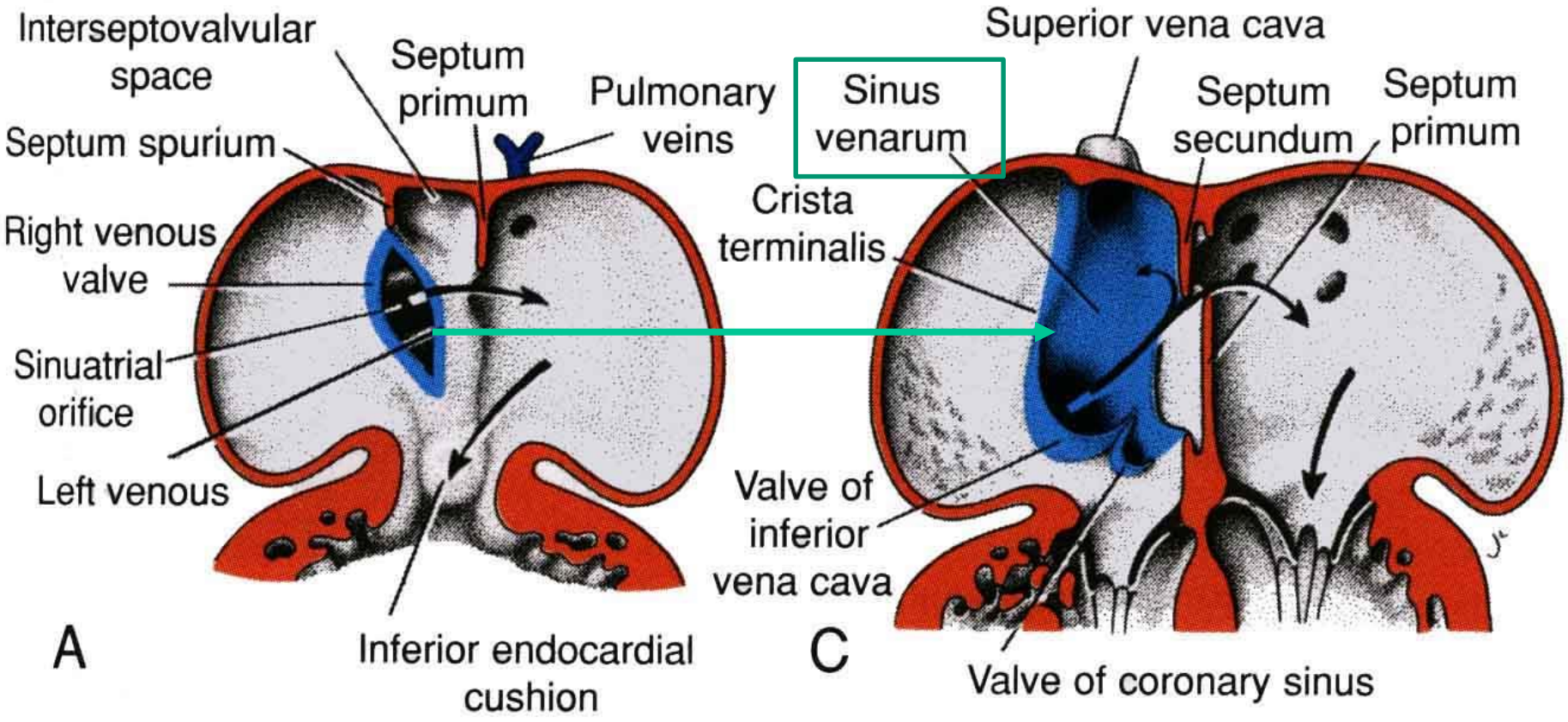
24 days



35 days



fetus



5th week

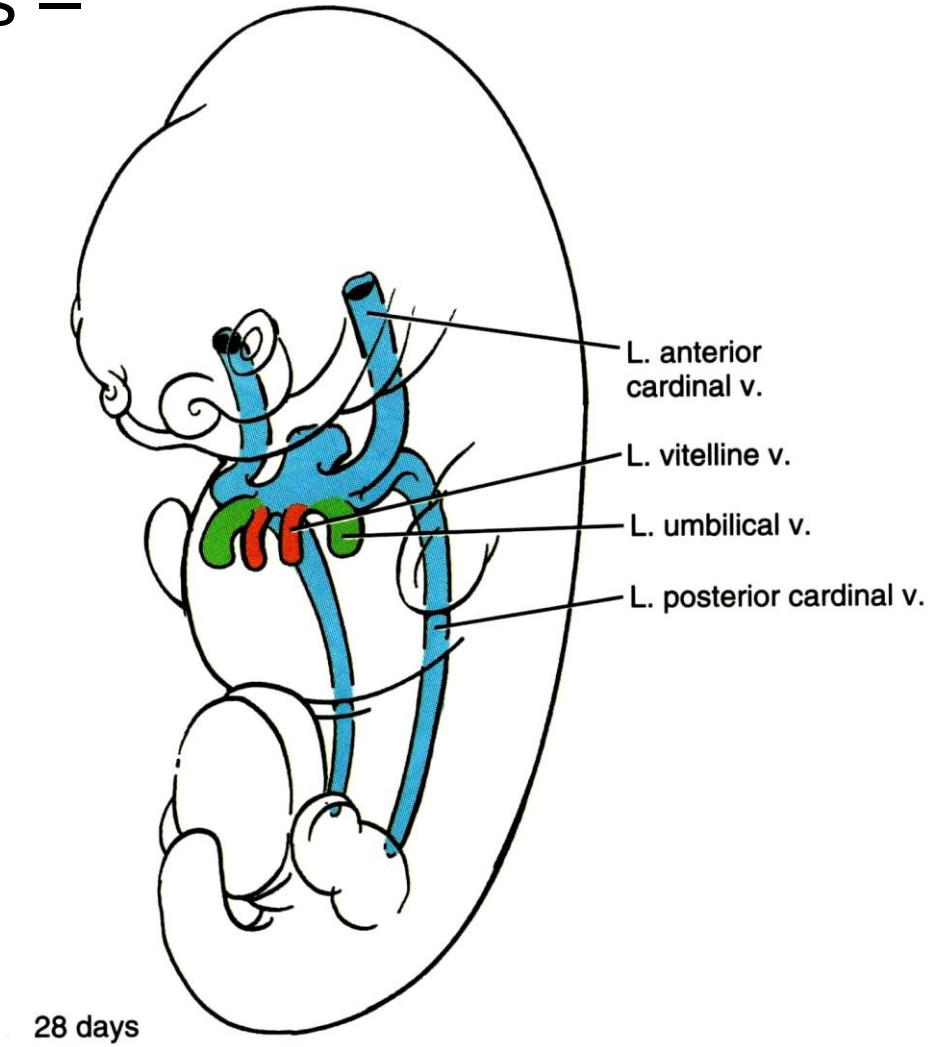
fetus

Venae cardinales

Vena cardinalis communis – ductus Cuvieri

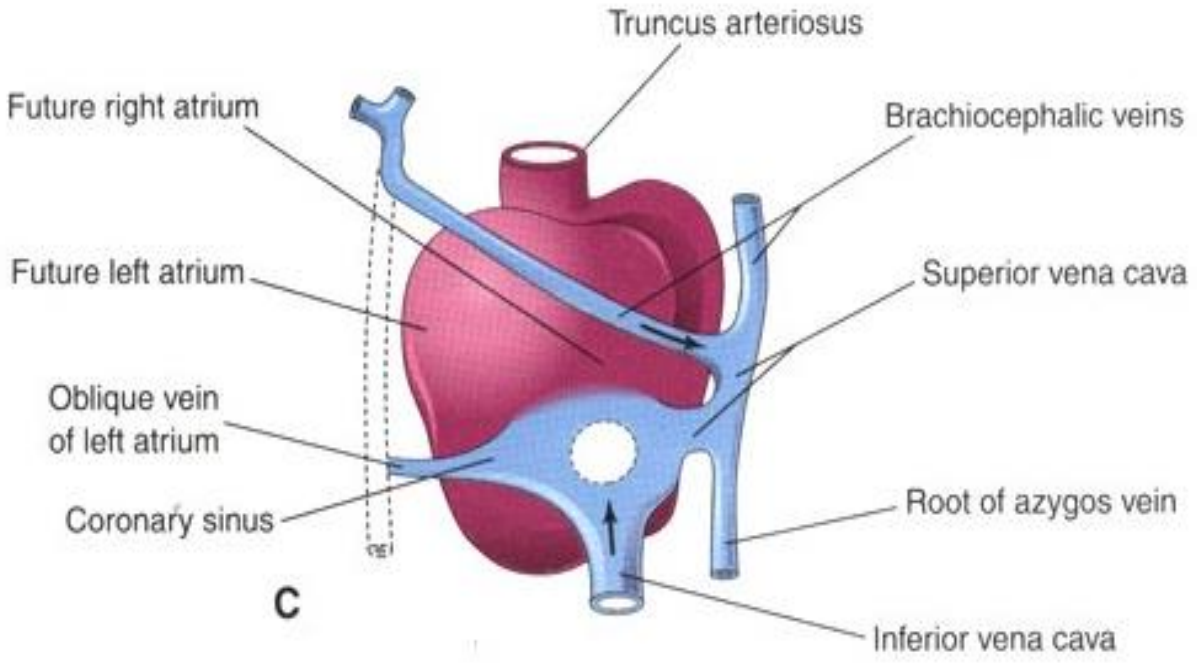
Vena cardinalis anterior (precardinalis)

Vena cardinalis posterior (postcardinalis)

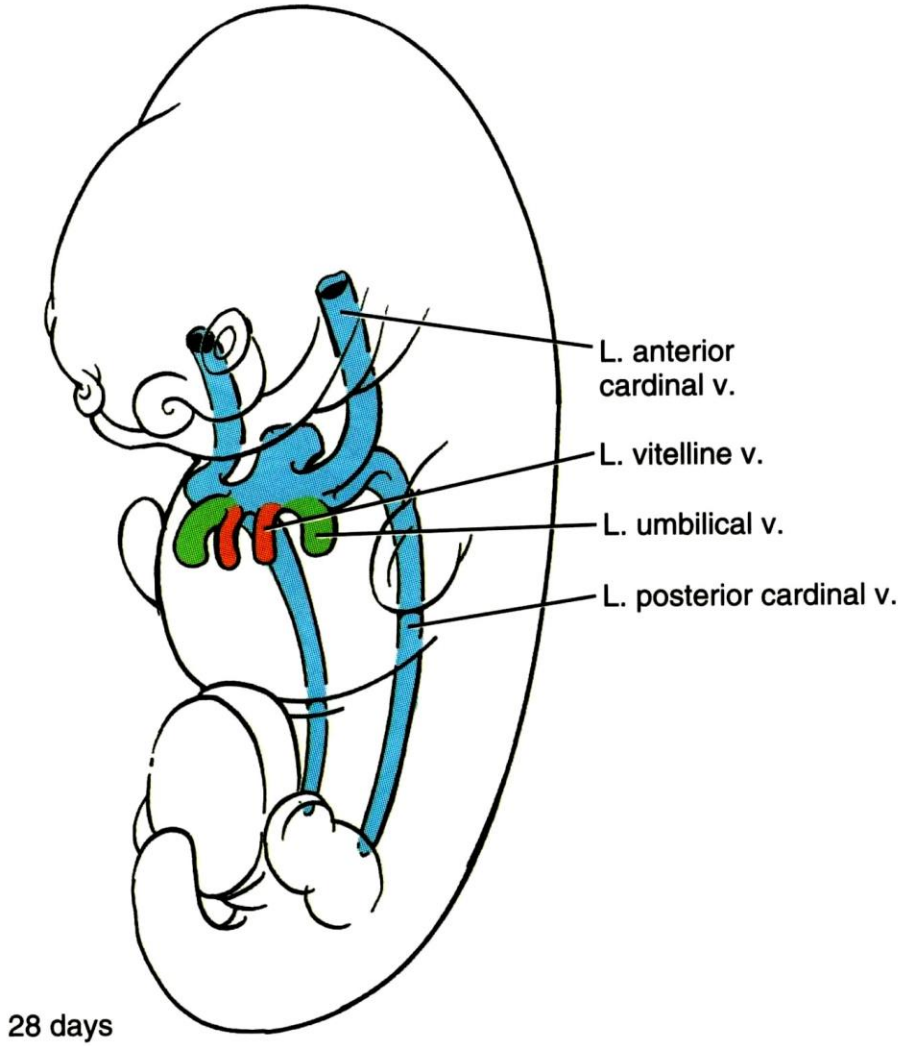


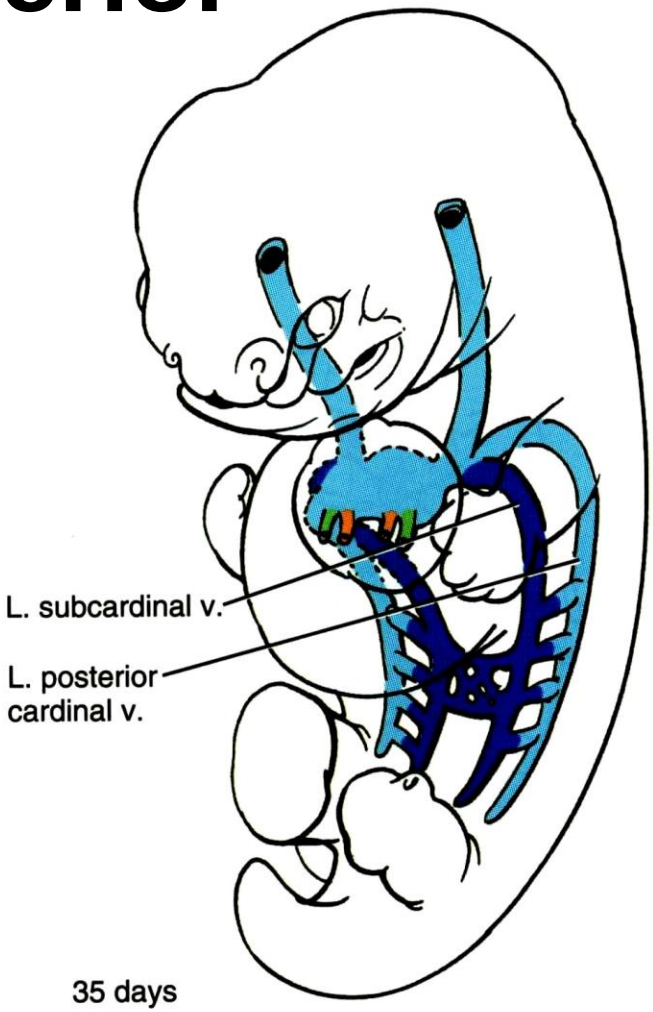
Vena cava superior

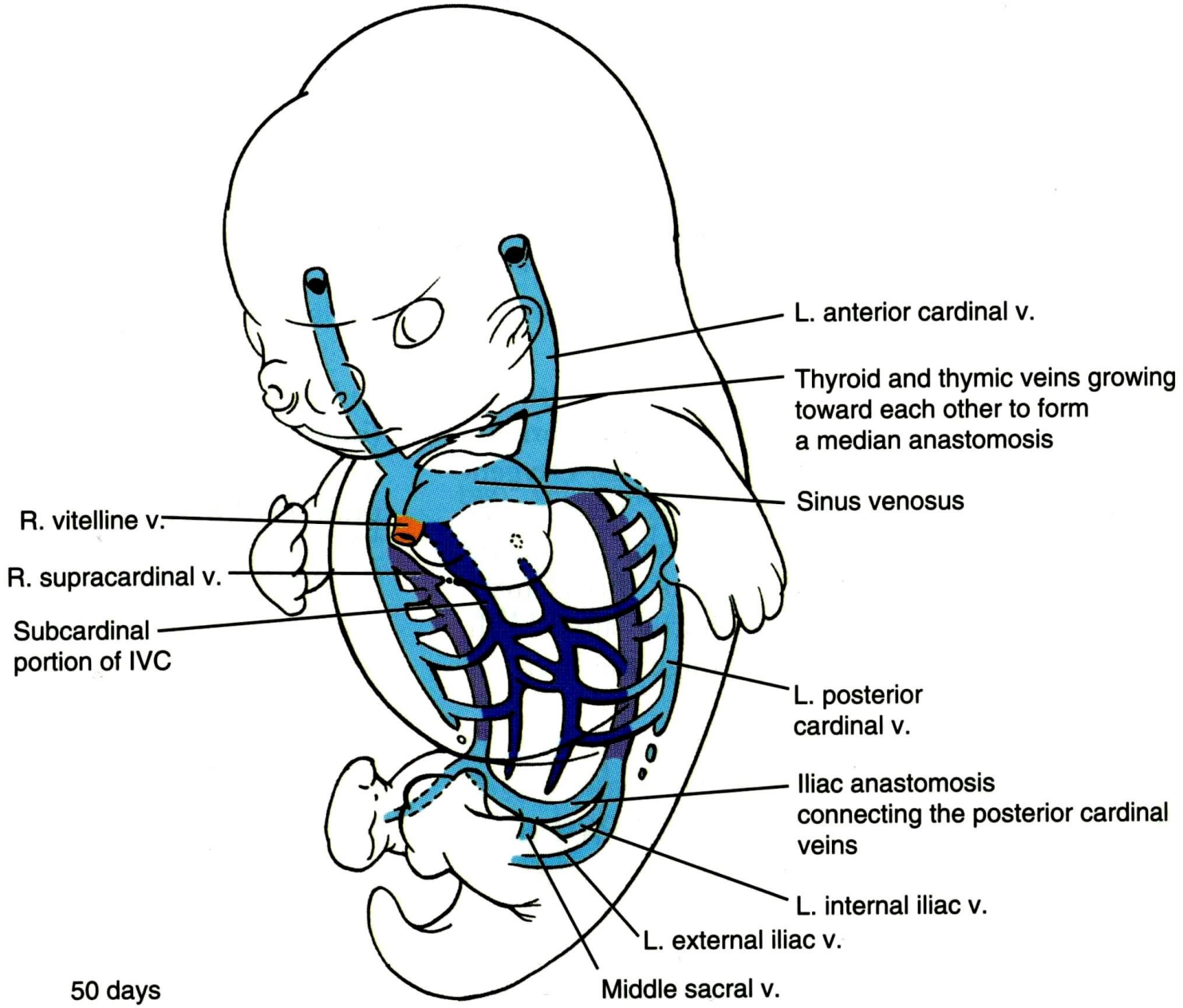
- an oblique anastomosis shunt takes blood from left to right → **v. brachiocephalica sinistra**
- right precardinal vein and right common cardinal vein → **vena cava superior**

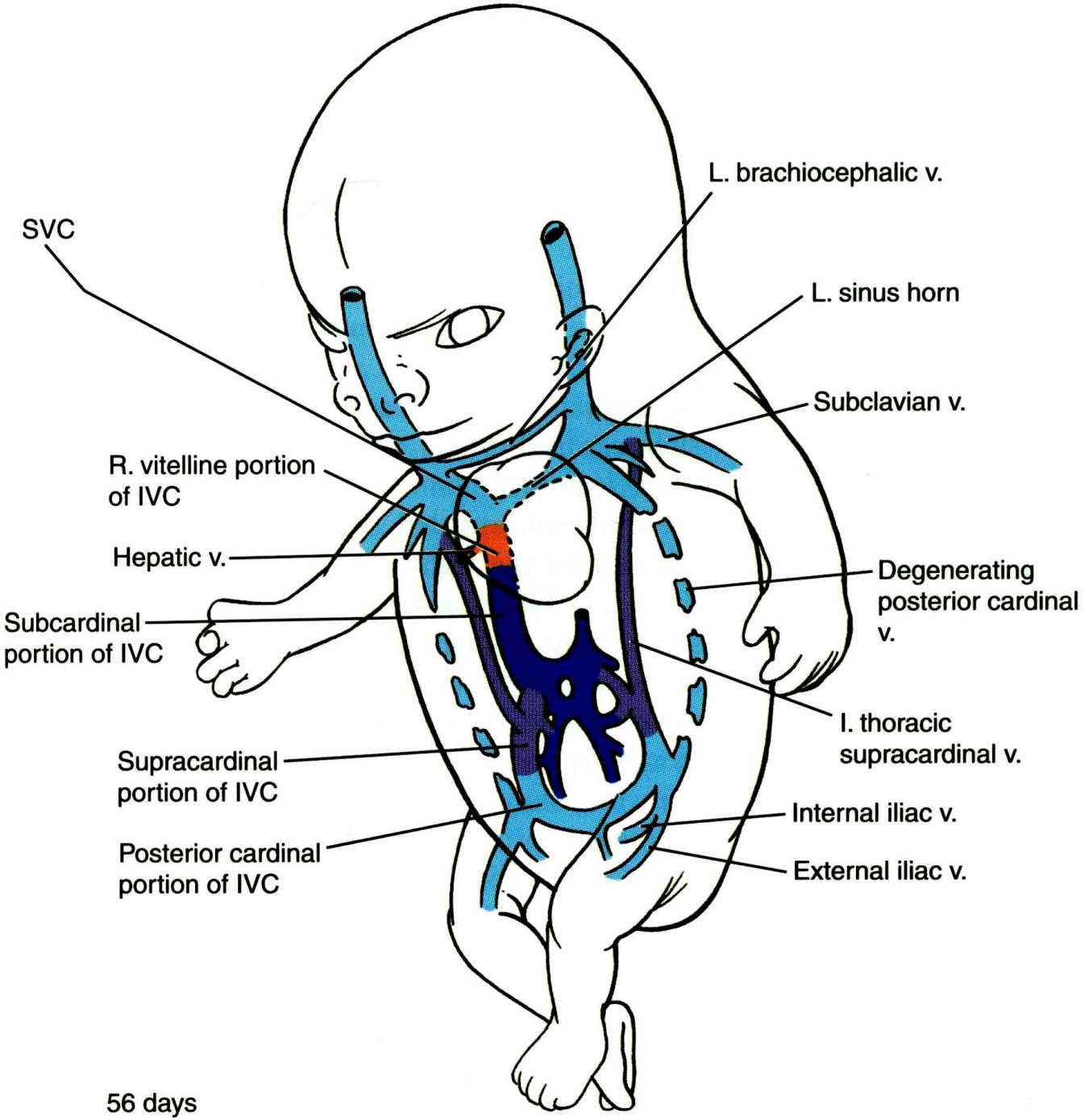


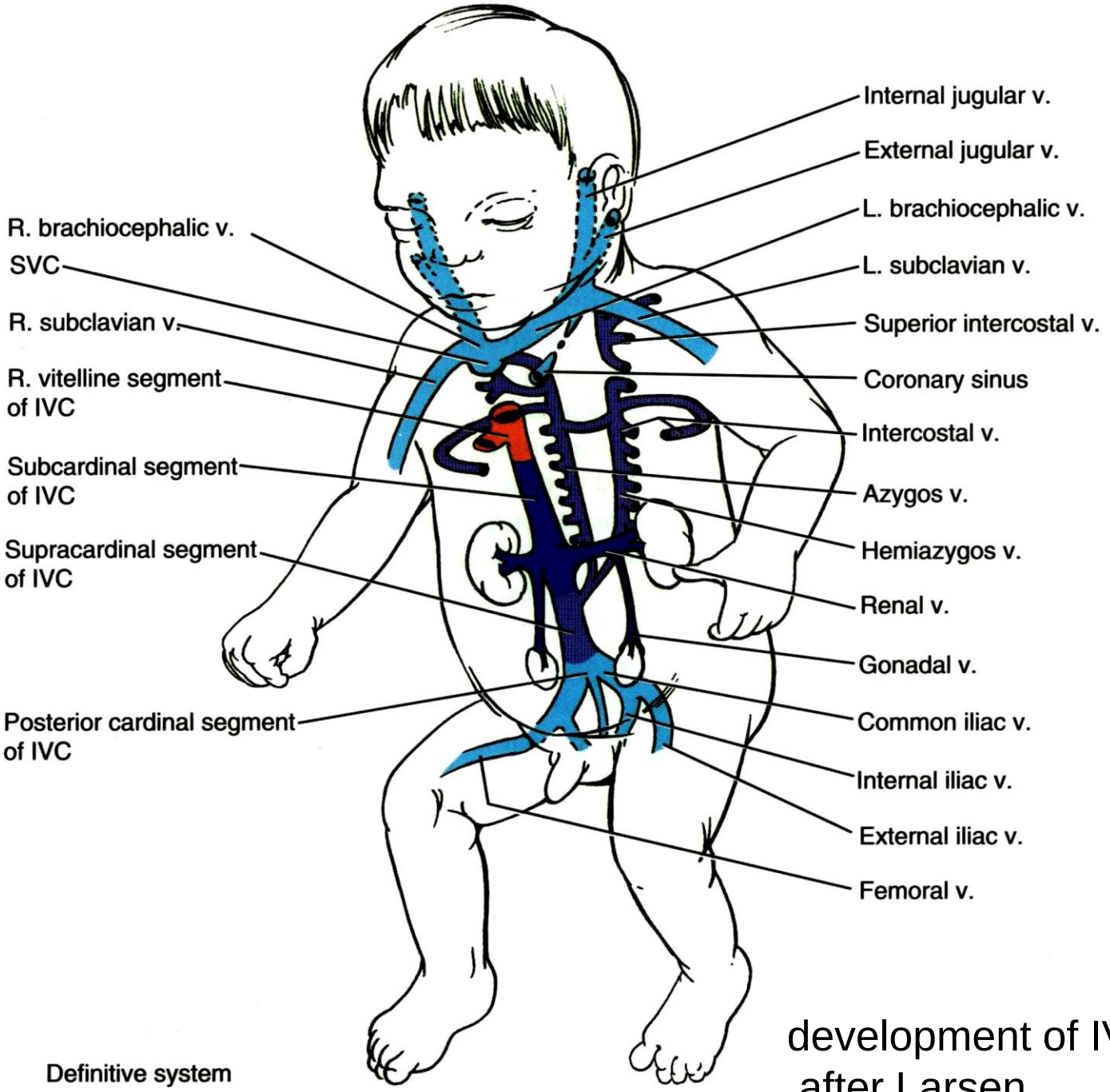
Vena cava inferior



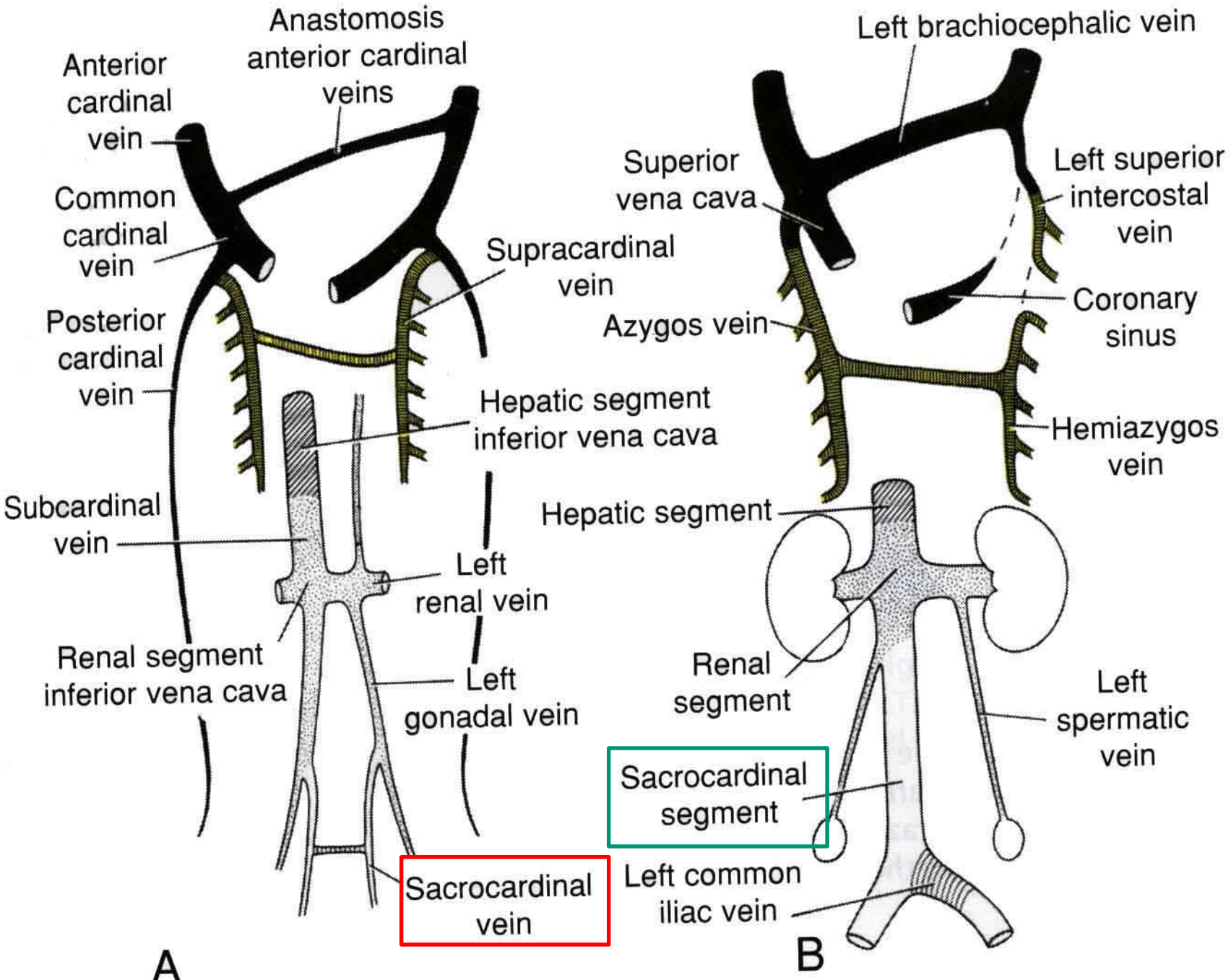



L. anterior cardinal v.
Thyroid and thymic veins growing toward each other to form a median anastomosis
Sinus venosus
R. vitelline v.
R. supracardinal v.
Subcardinal portion of IVC
L. posterior cardinal v.
Iliac anastomosis connecting the posterior cardinal veins
L. internal iliac v.
L. external iliac v.
Middle sacral v.
50 days


L. brachiocephalic v.
SVC
L. sinus horn
Subclavian v.
R. vitelline portion of IVC
Hepatic v.
Degenerating posterior cardinal v.
Subcardinal portion of IVC
I. thoracic supracardinal v.
Supracardinal portion of IVC
Internal iliac v.
Posterior cardinal portion of IVC
External iliac v.
56 days

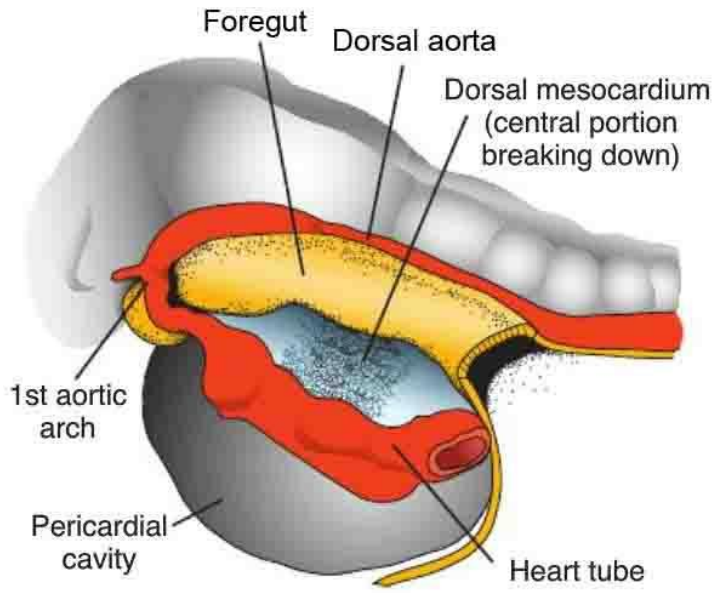


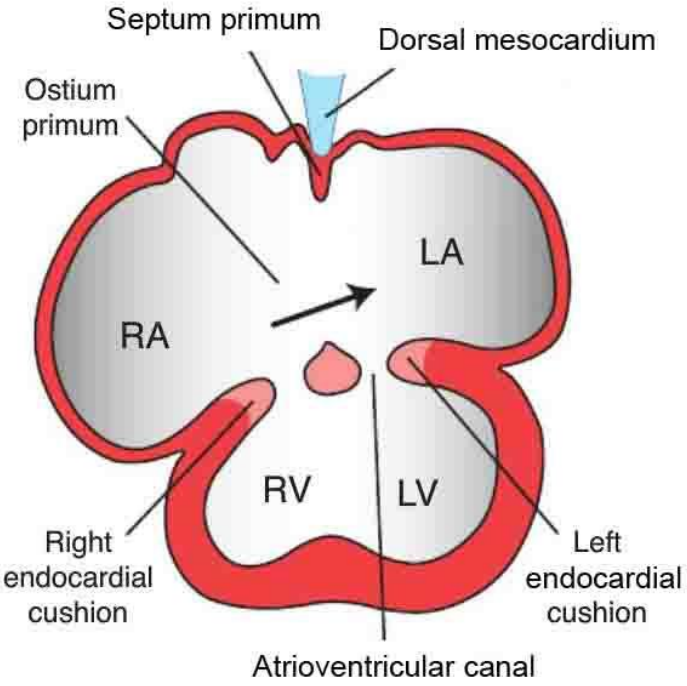
development of IVC
after Larsen

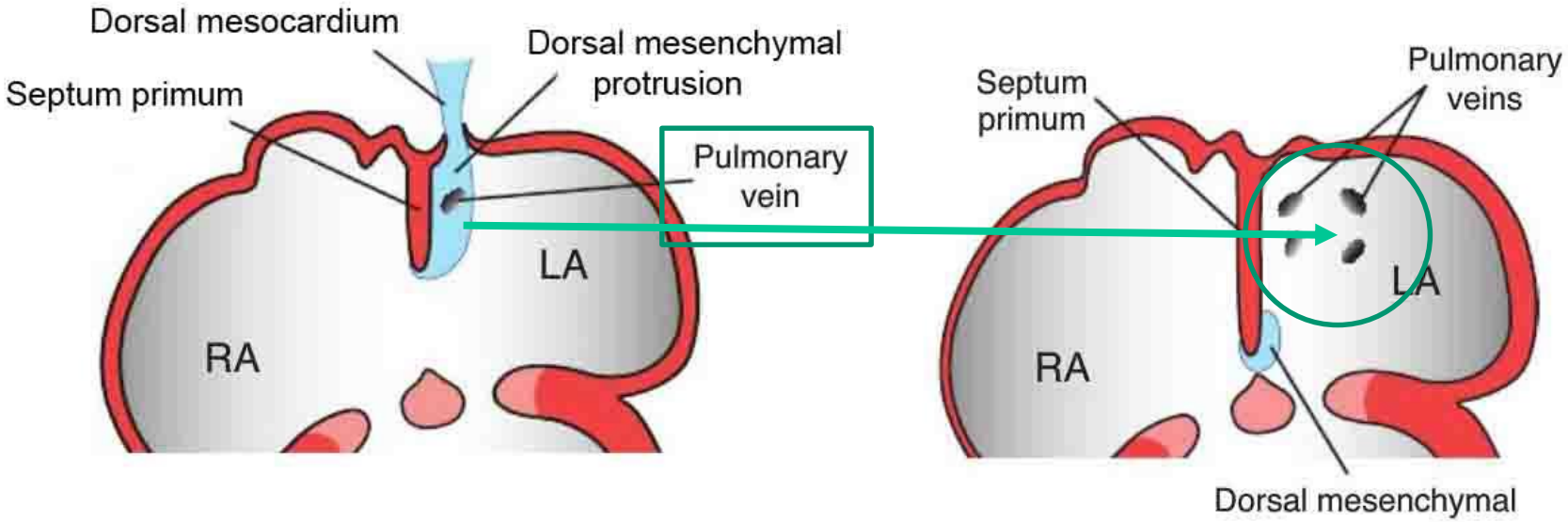


development of IVC after Sadler

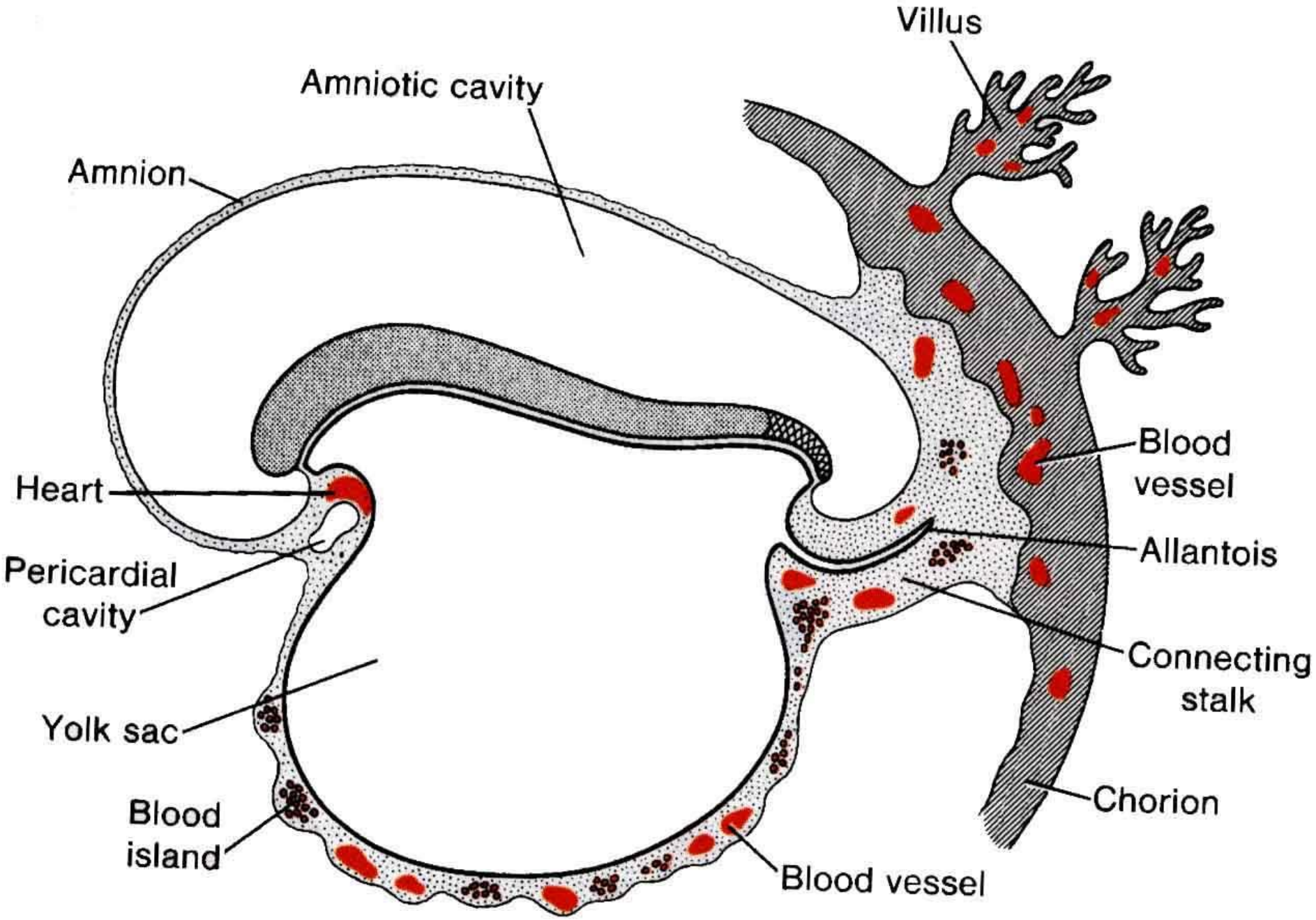
Pulmonary veins



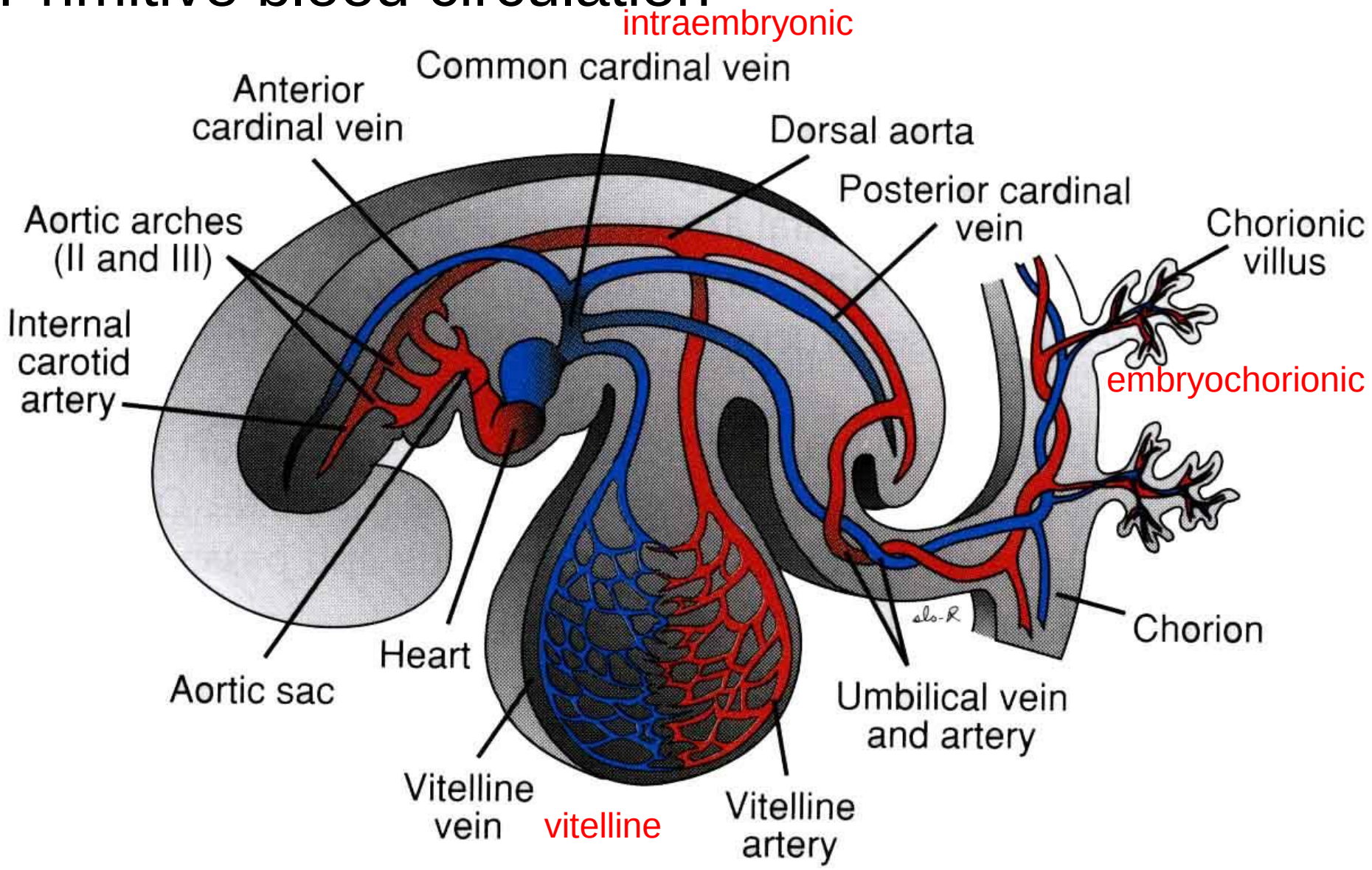




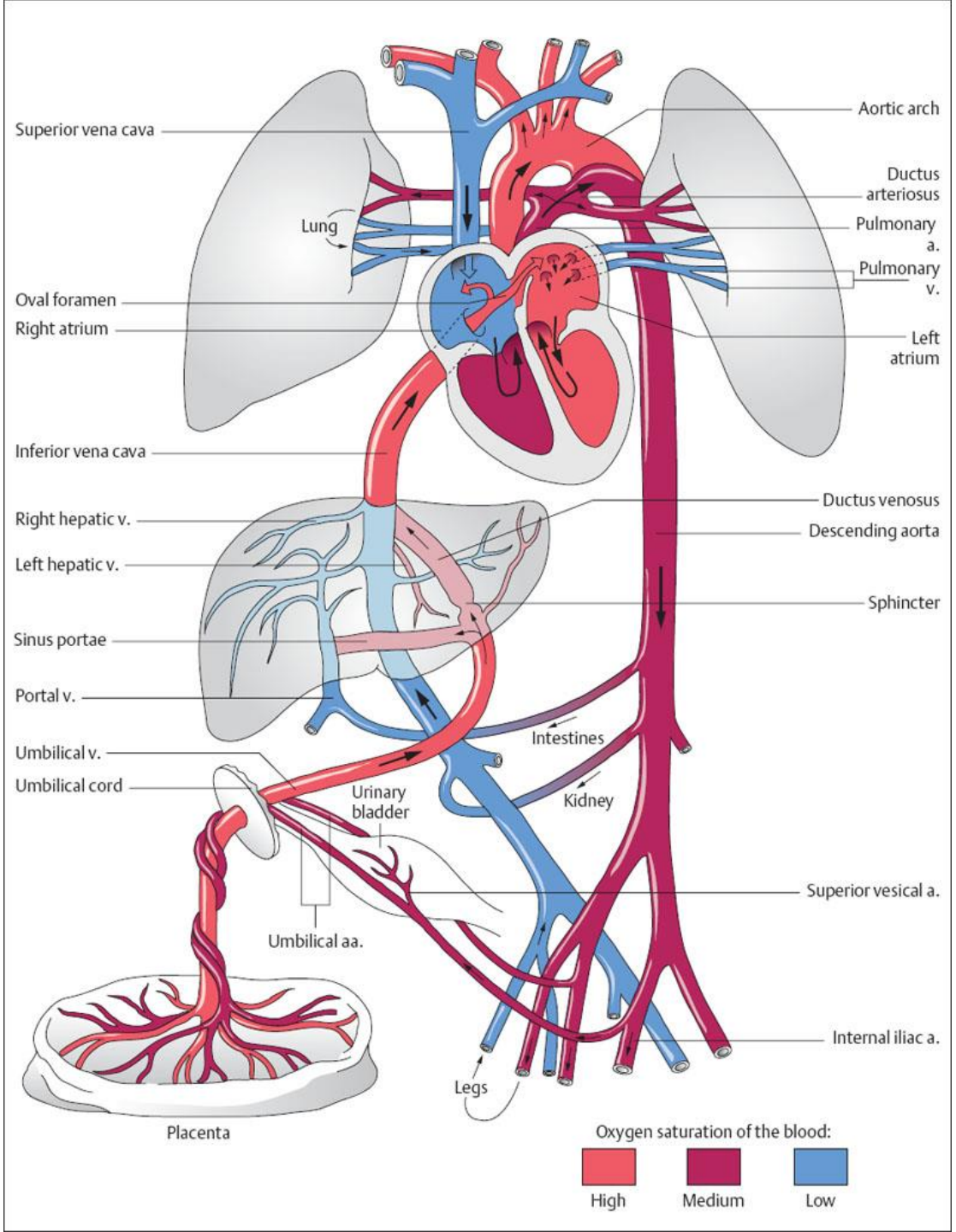
PRIMITIVE AND FETAL BLOOD CIRCULATION


Villus
Amniotic cavity
Amnion
Blood vessel
Heart
Allantois
Pericardial cavity
Connecting stalk
Yolk sac
Chorion
Blood island
Blood vessel

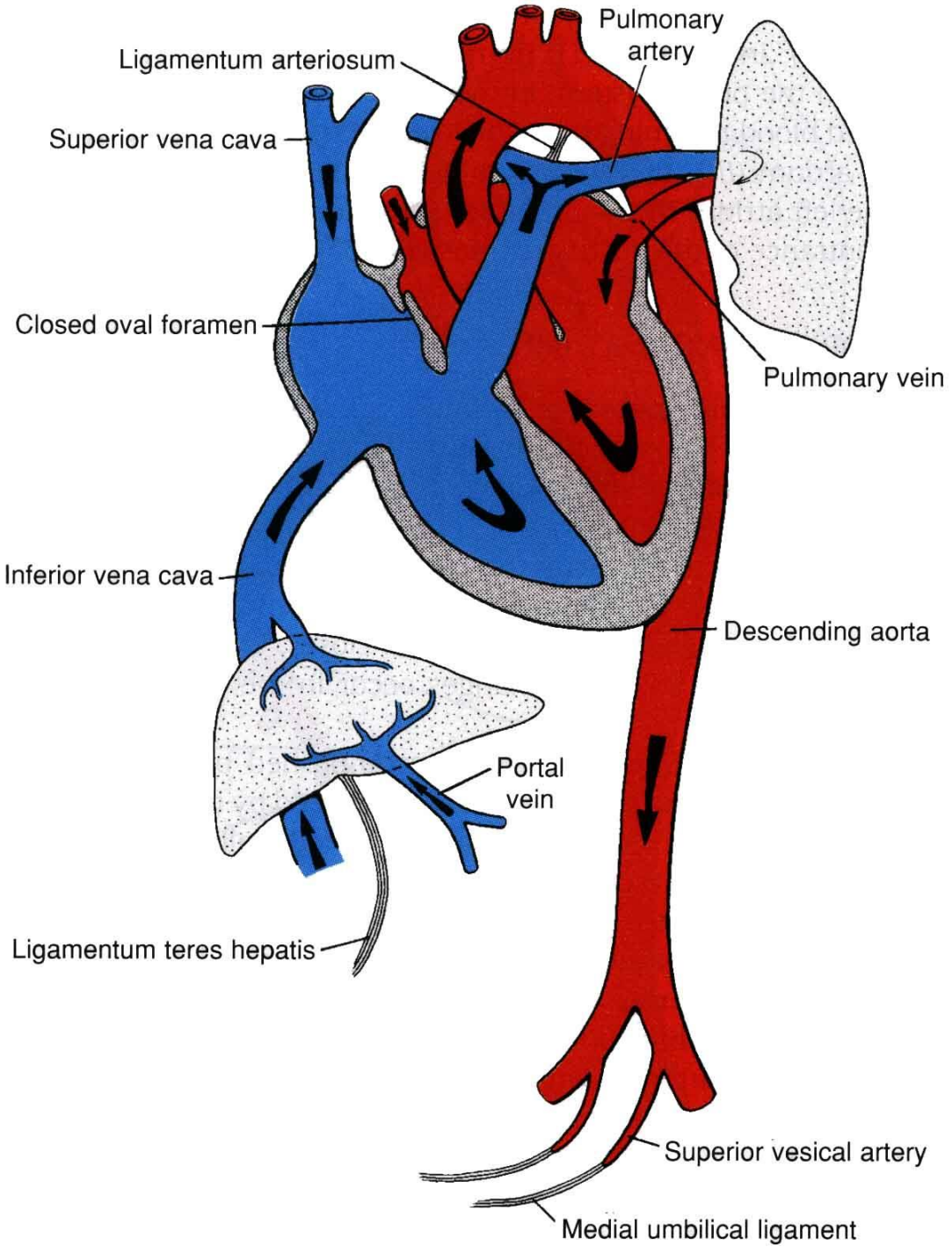
Primitive blood circulation



Fetal blood circulation

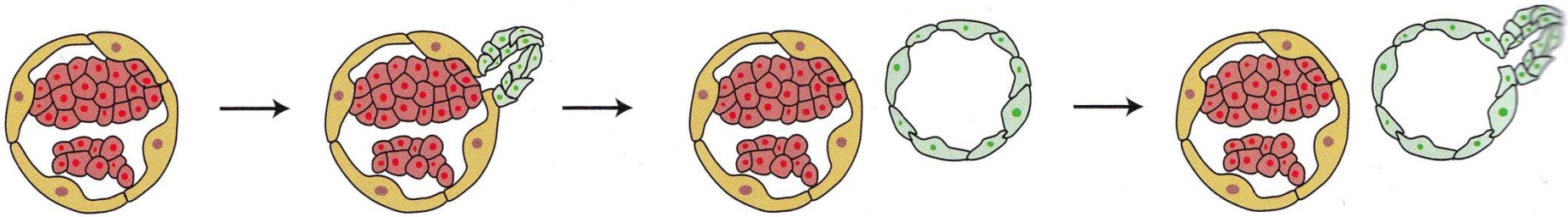


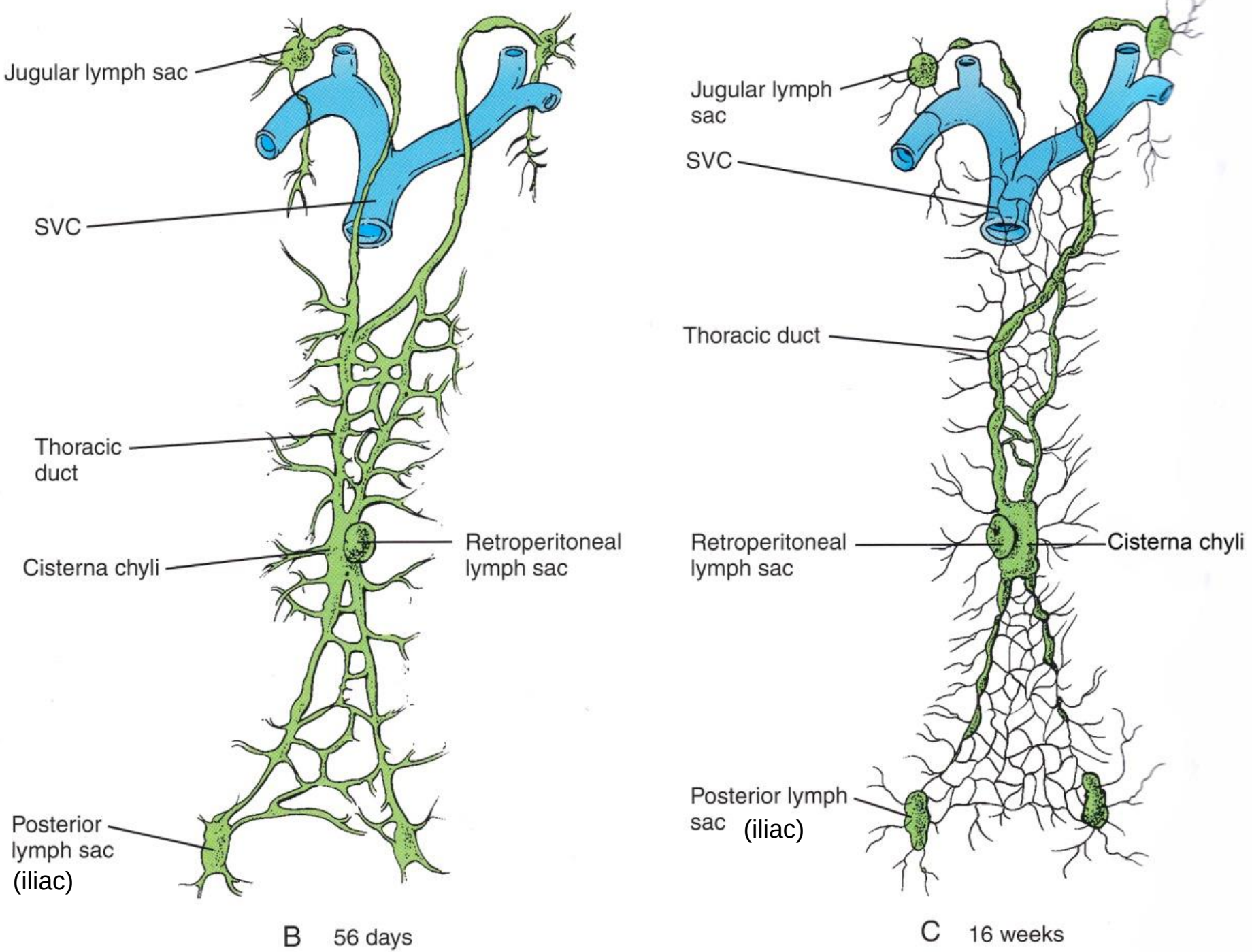
Changes at birth



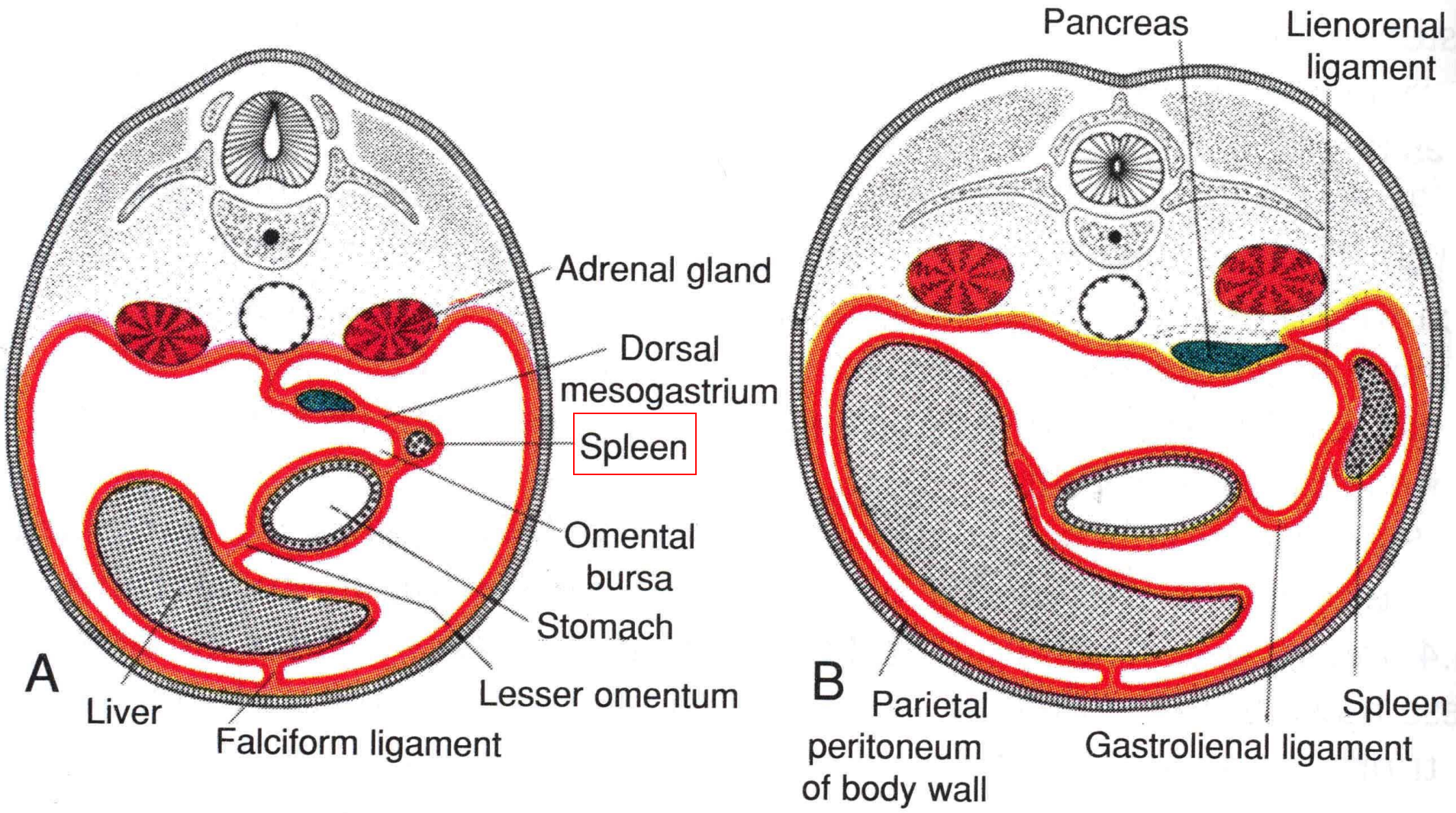
DEVELOPMENT OF LYMPHATIC VESSELS, NODES AND SPLEEN

LYMPHATIC SACS AND VESSELS




Jugular lymph sac
SVC
Thoracic duct
Cisterna chyli
Retroperitoneal lymph sac
Posterior lymph sac
(iliac)
B 56 days
Jugular lymph sac
SVC
Thoracic duct
Retroperitoneal lymph sac
Cisterna chyli
Posterior lymph sac
(iliac)
C 16 weeks

SPLEEN


Adrenal gland
Dorsal mesogastrium
Spleen
Omental bursa
Stomach
Lesser omentum
A
Liver
Falciform ligament
Pancreas
Lienorenal ligament
B
Parietal peritoneum of body wall
Spleen
Gastrolienal ligament

Fin.