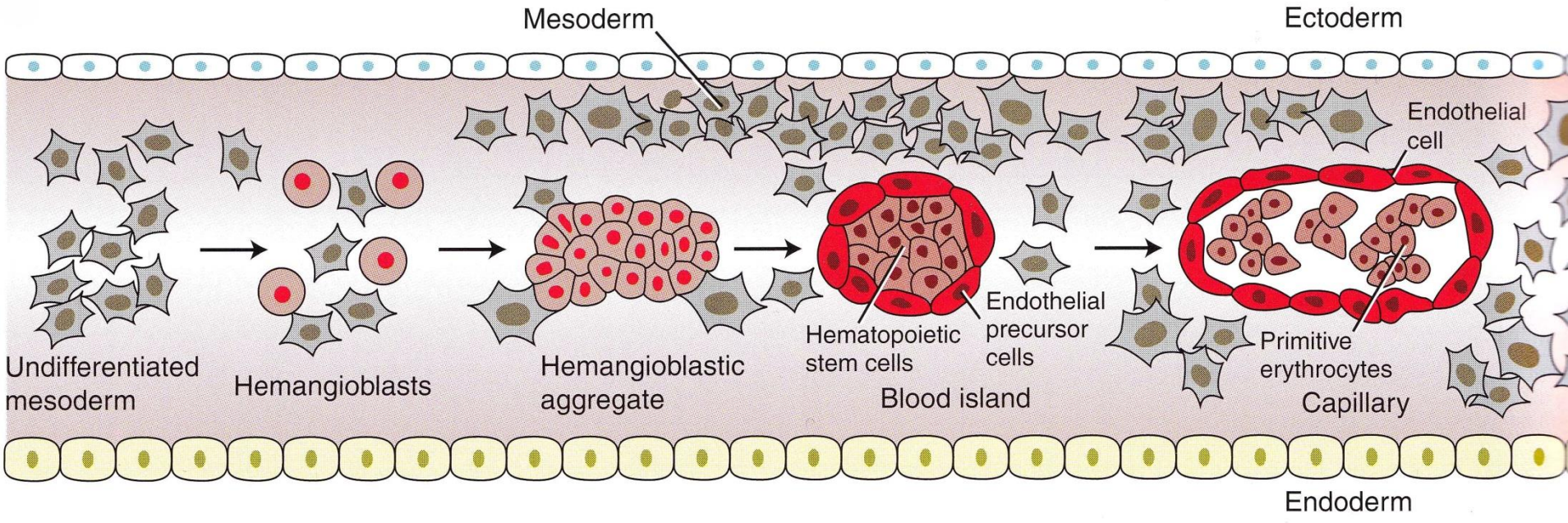
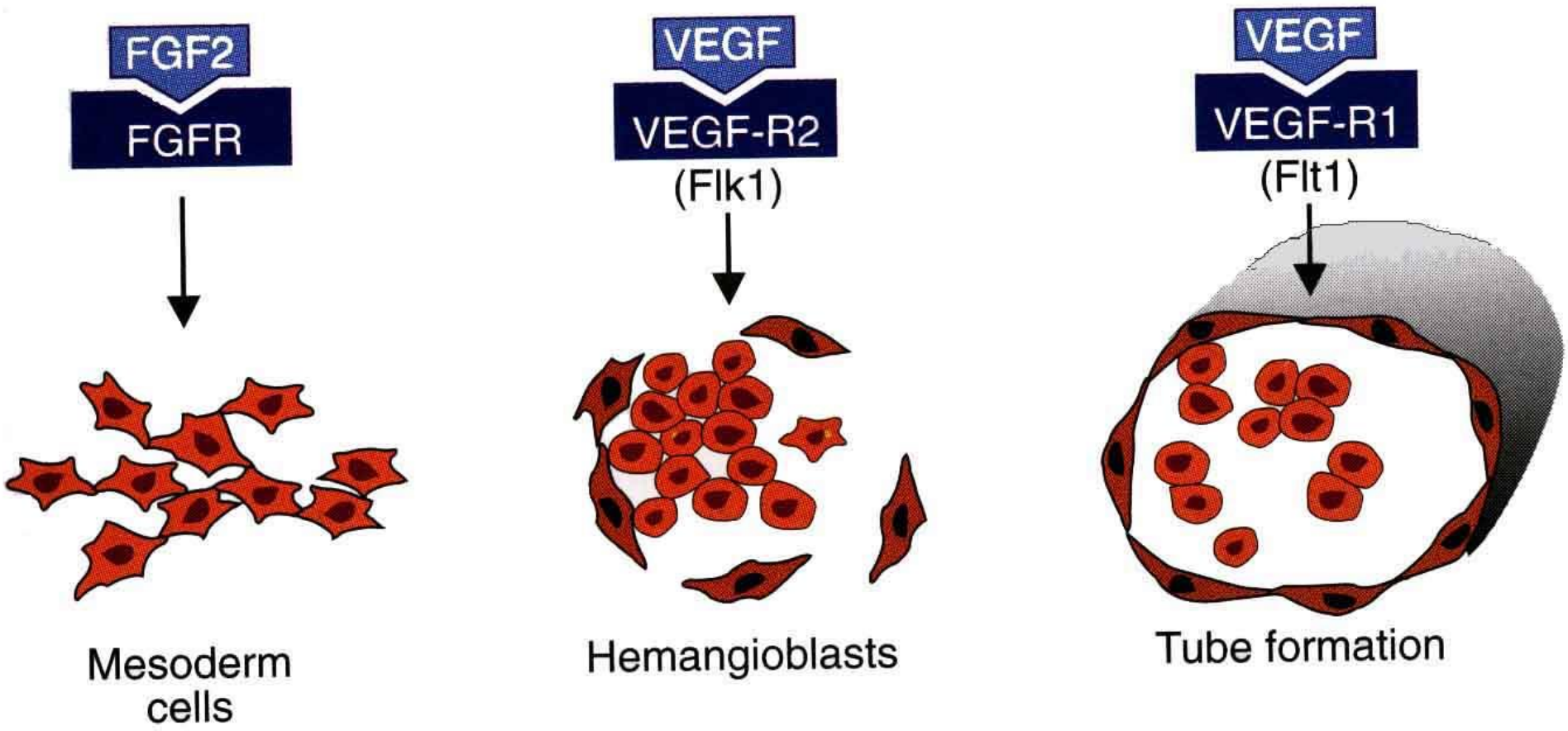
DEVELOPMENT OF HEART

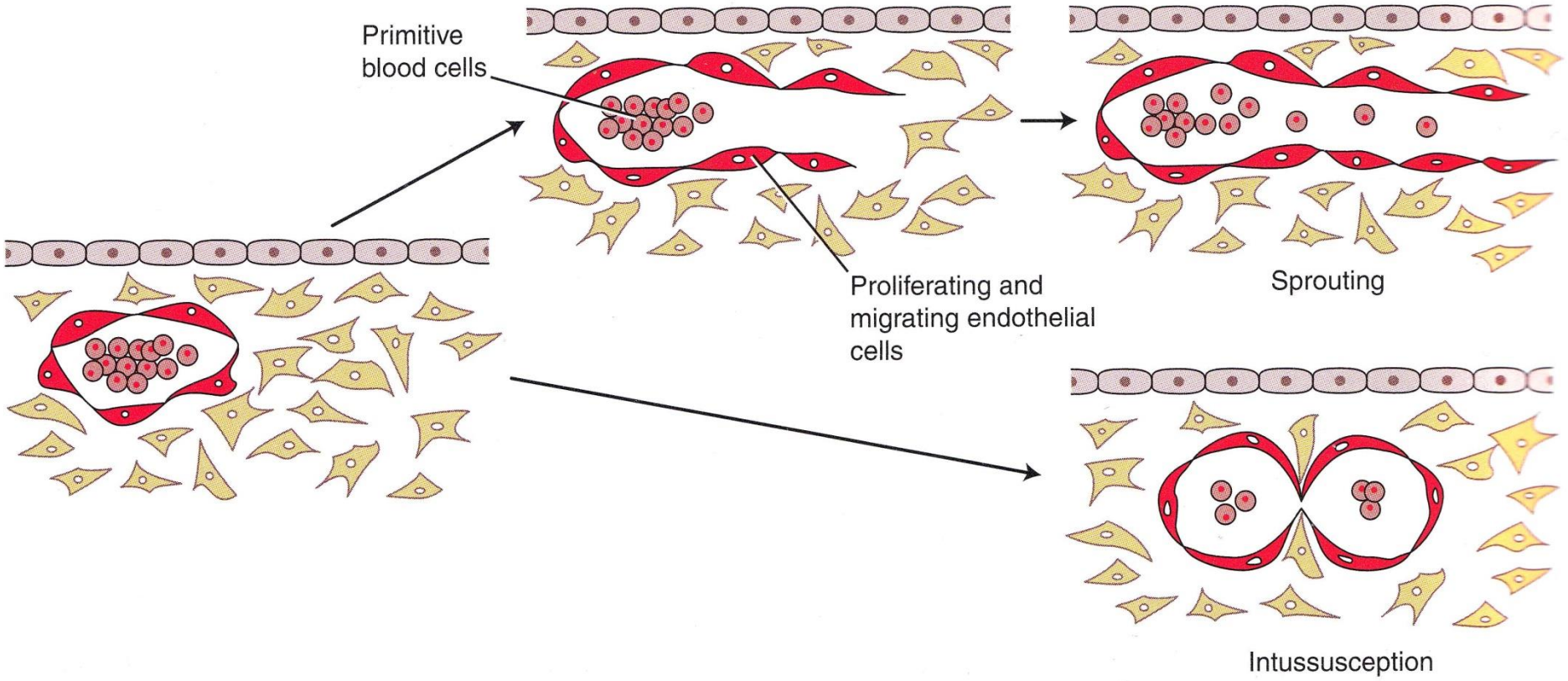
VASCULOGENESIS

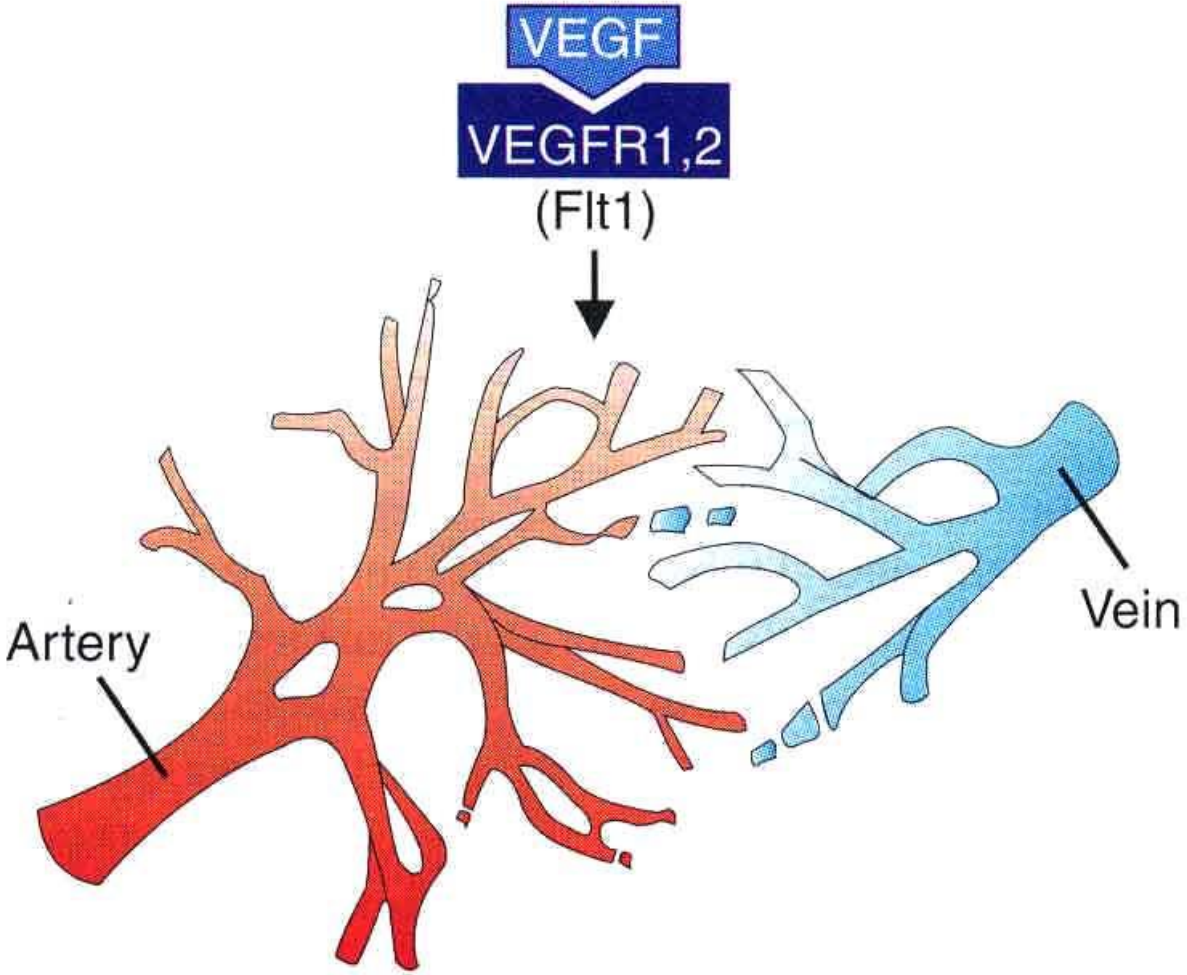




VASCULOGENESIS

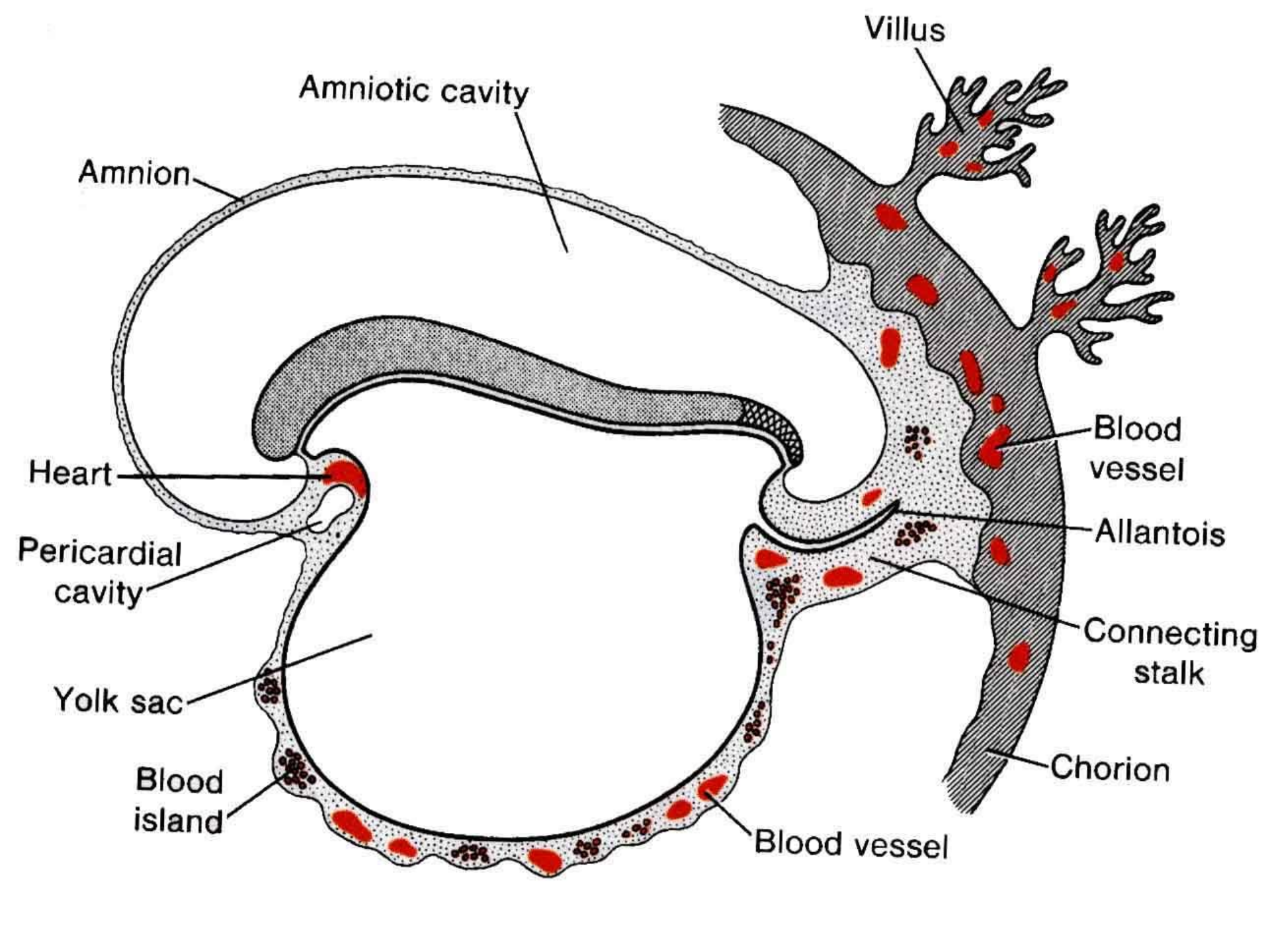
ANGIOGENESIS





ANGIOGENESIS

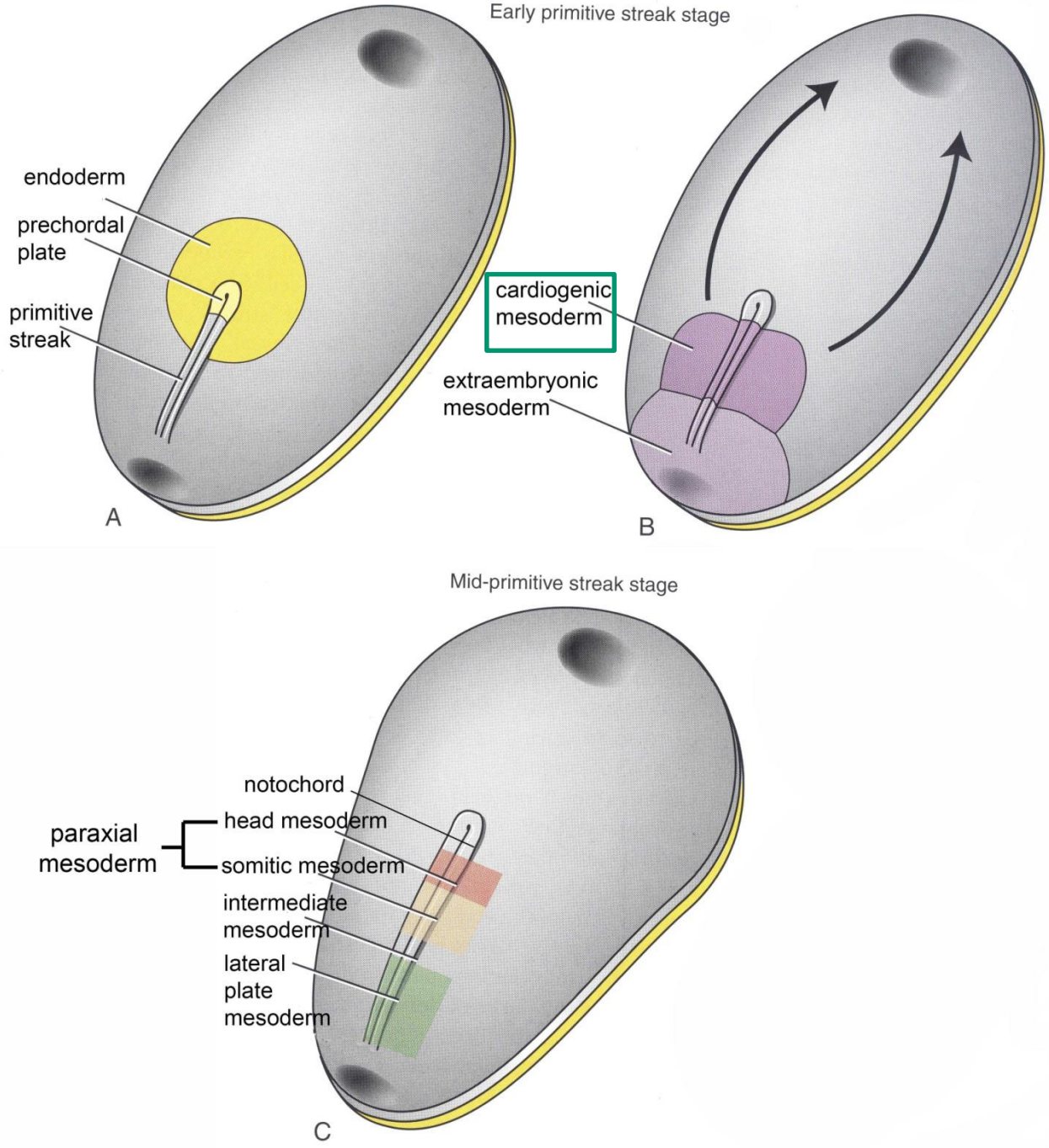
also
TGFβ
PDGF

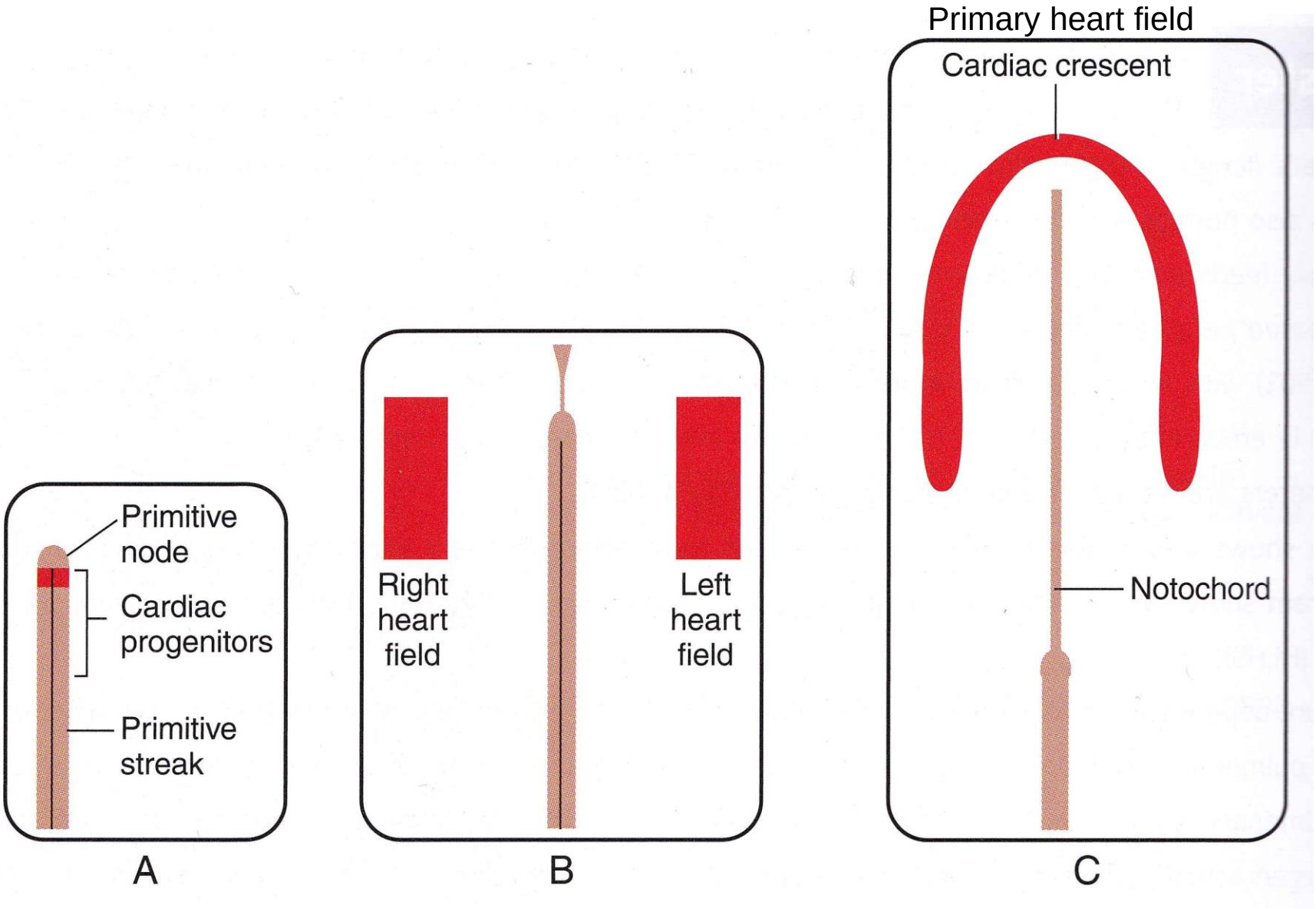

Villus
Amniotic cavity
Amnion
Blood vessel
Heart
Allantois
Pericardial cavity
Connecting stalk
Yolk sac
Chorion
Blood island
Blood vessel

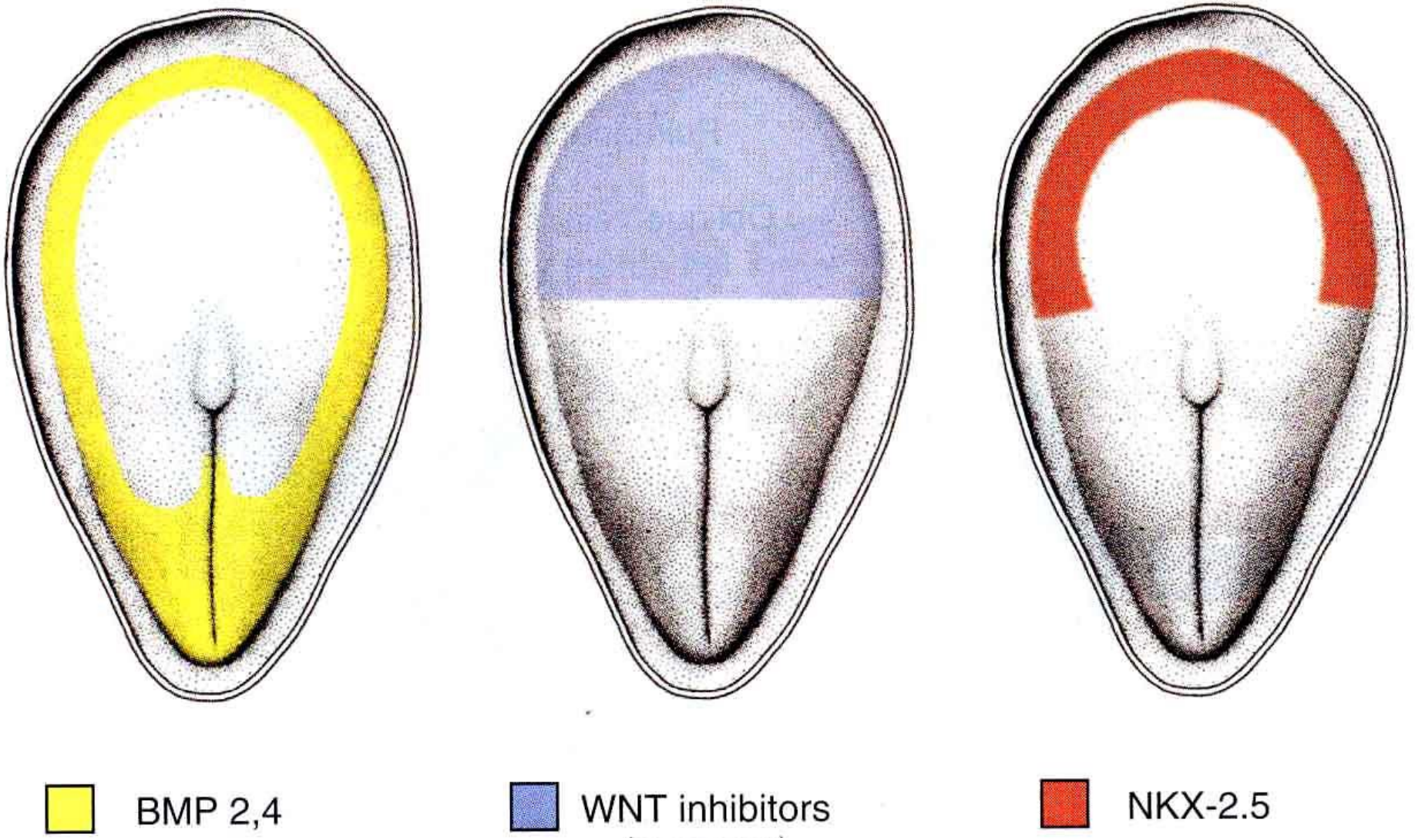
Development of heart

1. primordia (cor tubulare duplex) day18-22
2. heart tube (cor tubulare simplex) day 21-24
3. heart loop (cor sigmoideum) day 23-28
4. embryonic heart day 27-56
   (septation day 27-37)
5. fetas heart day 57- birth

cardiac contractions – day 22-30 – uncoordinated contractions (shuttle flow)
day 30-32 – beginning of embryochorionic circulation, frequency 140-160/min

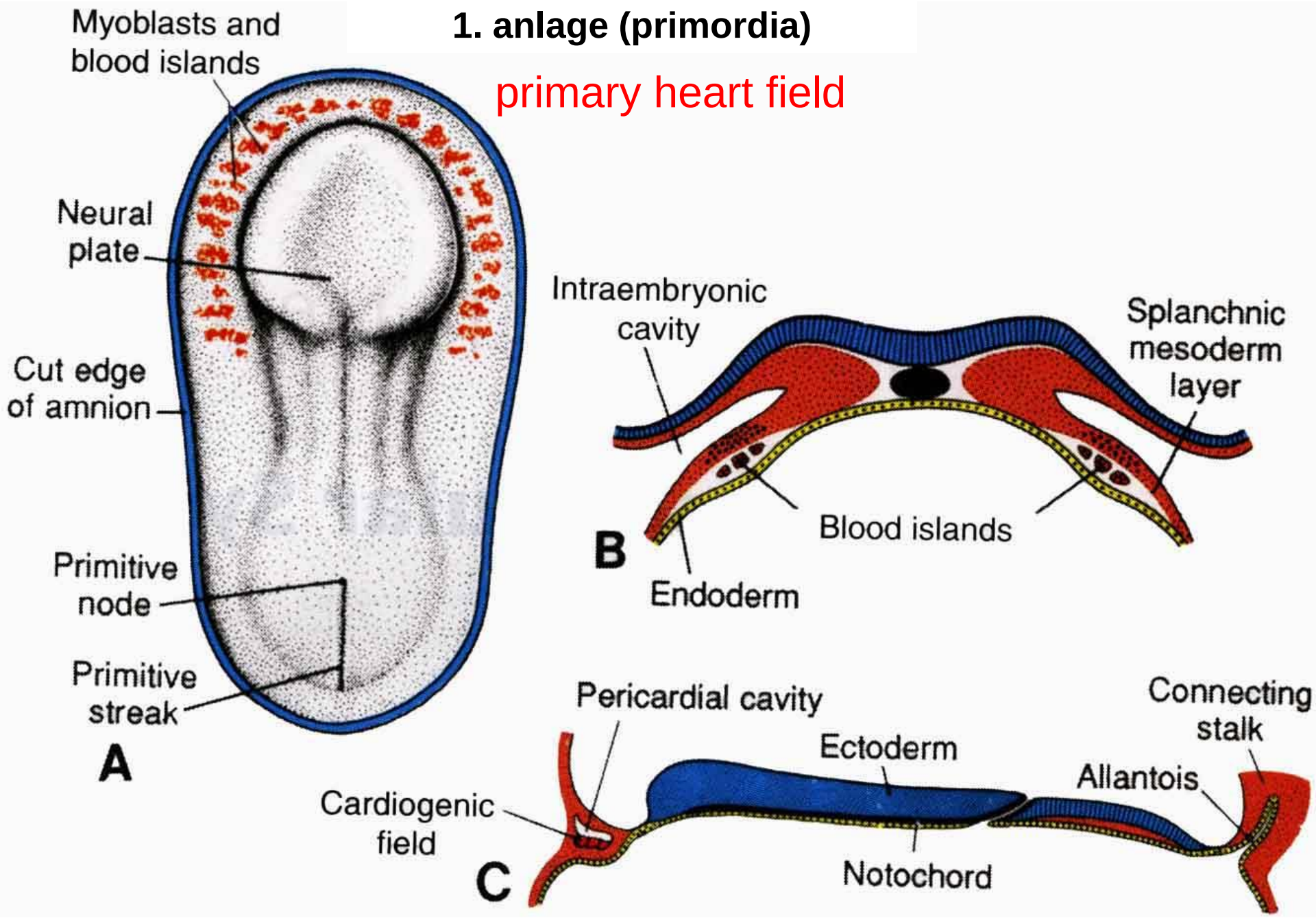

Early primitive streak stage
endoderm
prechordal plate
primitive streak
A
cardiogenic mesoderm
extraembryonic mesoderm
B
Mid-primitive streak stage
notochord
paraxial mesoderm
head mesoderm
somitic mesoderm
intermediate mesoderm
lateral plate mesoderm
C


Primary heart field
Cardiac crescent
Primitive node
Cardiac progenitors
Primitive streak
Right heart field
Left heart field
Notochord
A
B
C

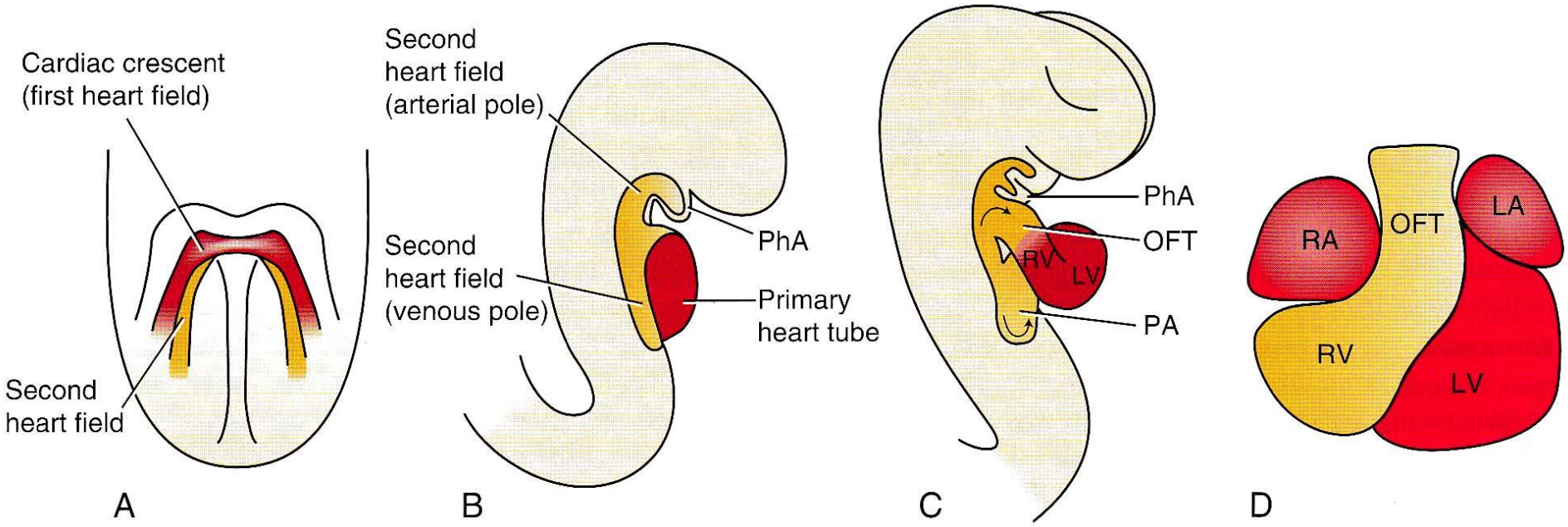

BMP 2,4
endoderm,
lateral plate mesoderm
WNT inhibitors
(Crescent, Cerberus)
endoderm
NKX-2.5

1. anlage (primordia)

primary heart field

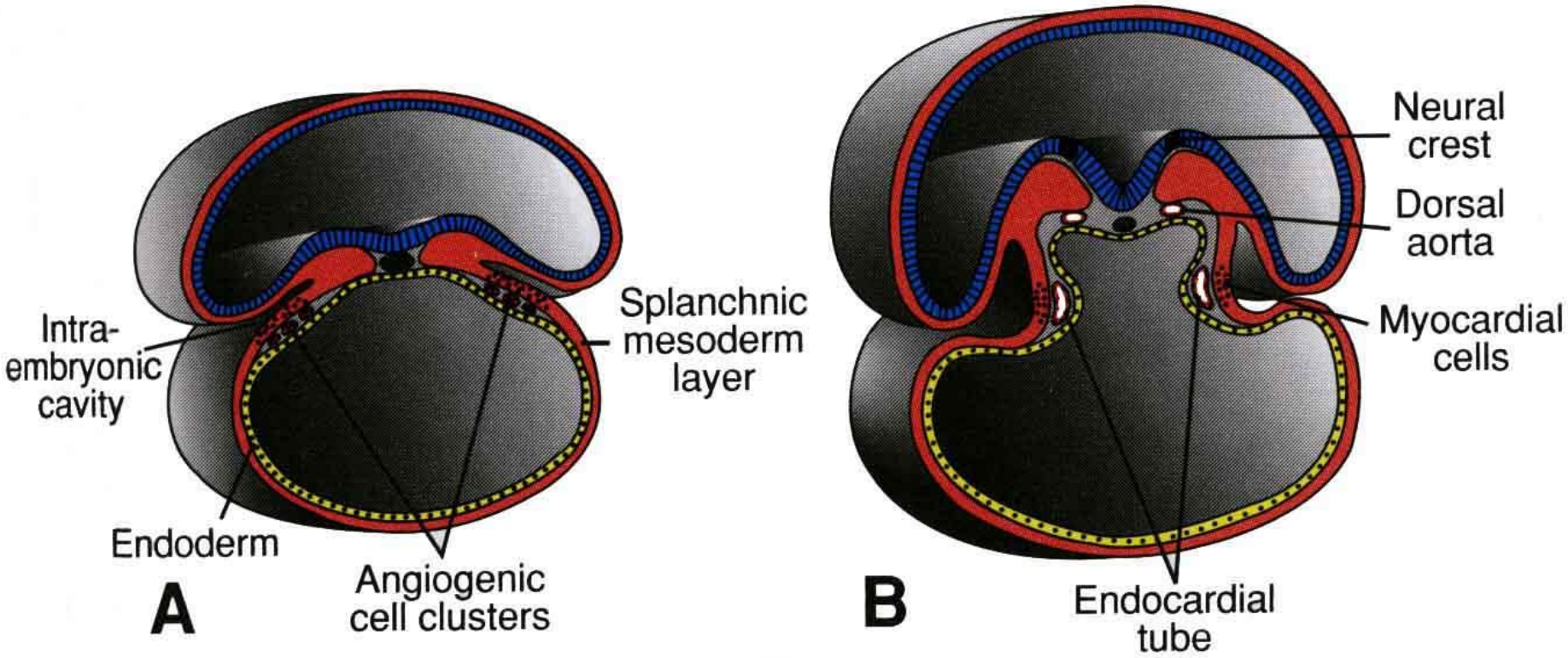


secondary heart field

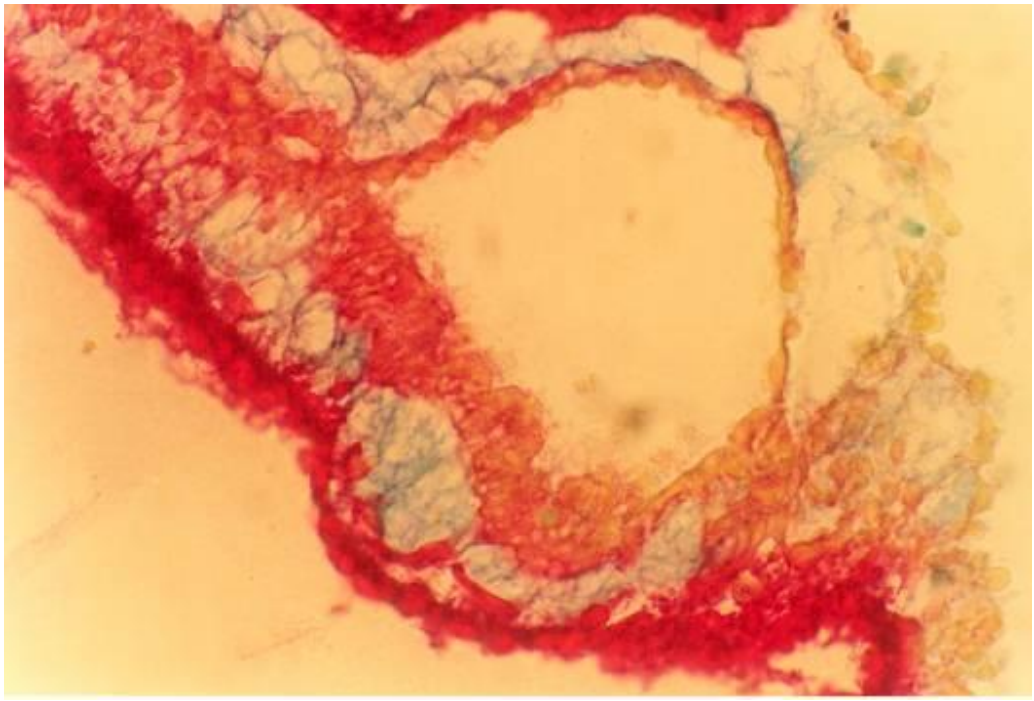


- develops later dorsomedially from the primary heart field
- its differentiation is controled by the same factors as the formation of primary hear field (Bmp, Wnt inhibitors)
- it contributes to the development of primitive atrium (PA), right ventricle (RV) and outflow tract (OFT)

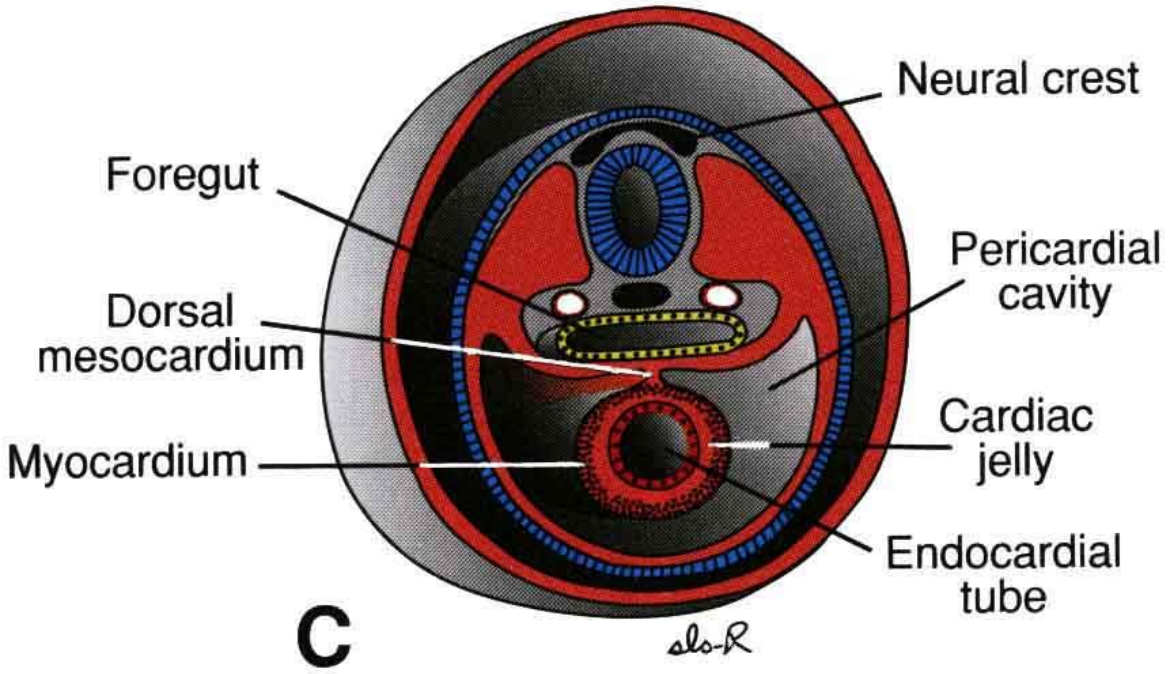
Schoenwolf ,G.C. et al.: Larsen's Human Embryology, Elsevier 2015



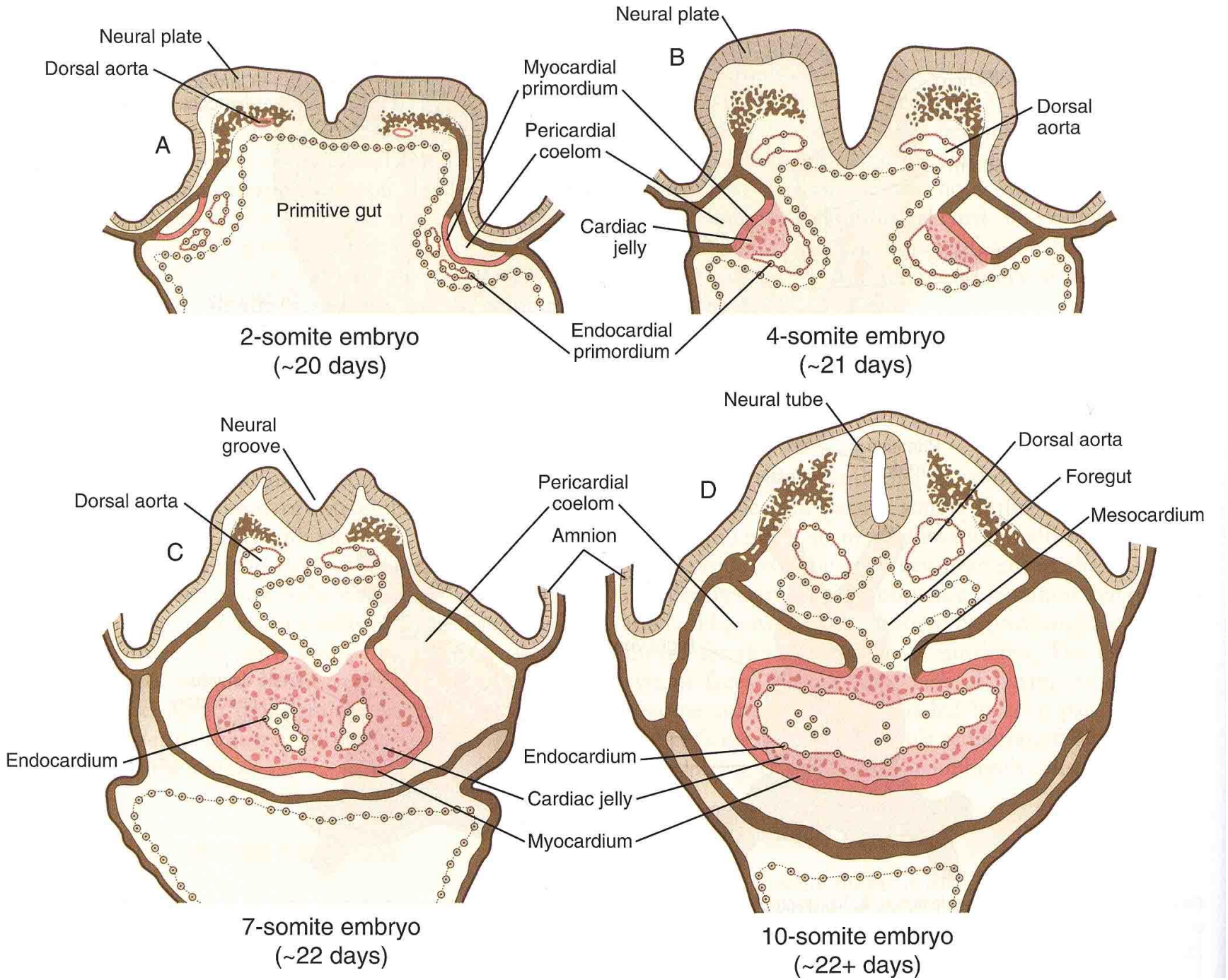
cor tubulare duplex

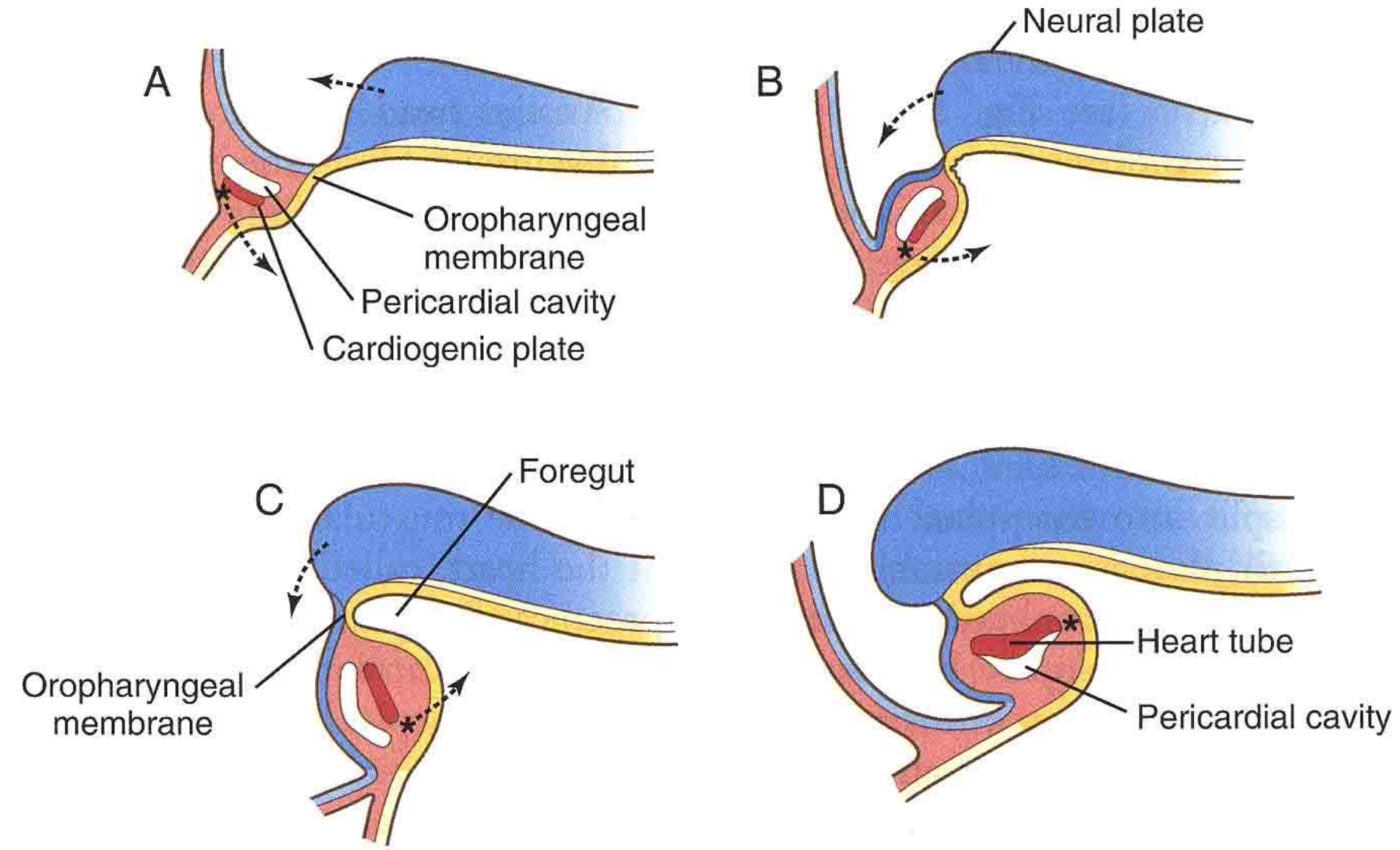


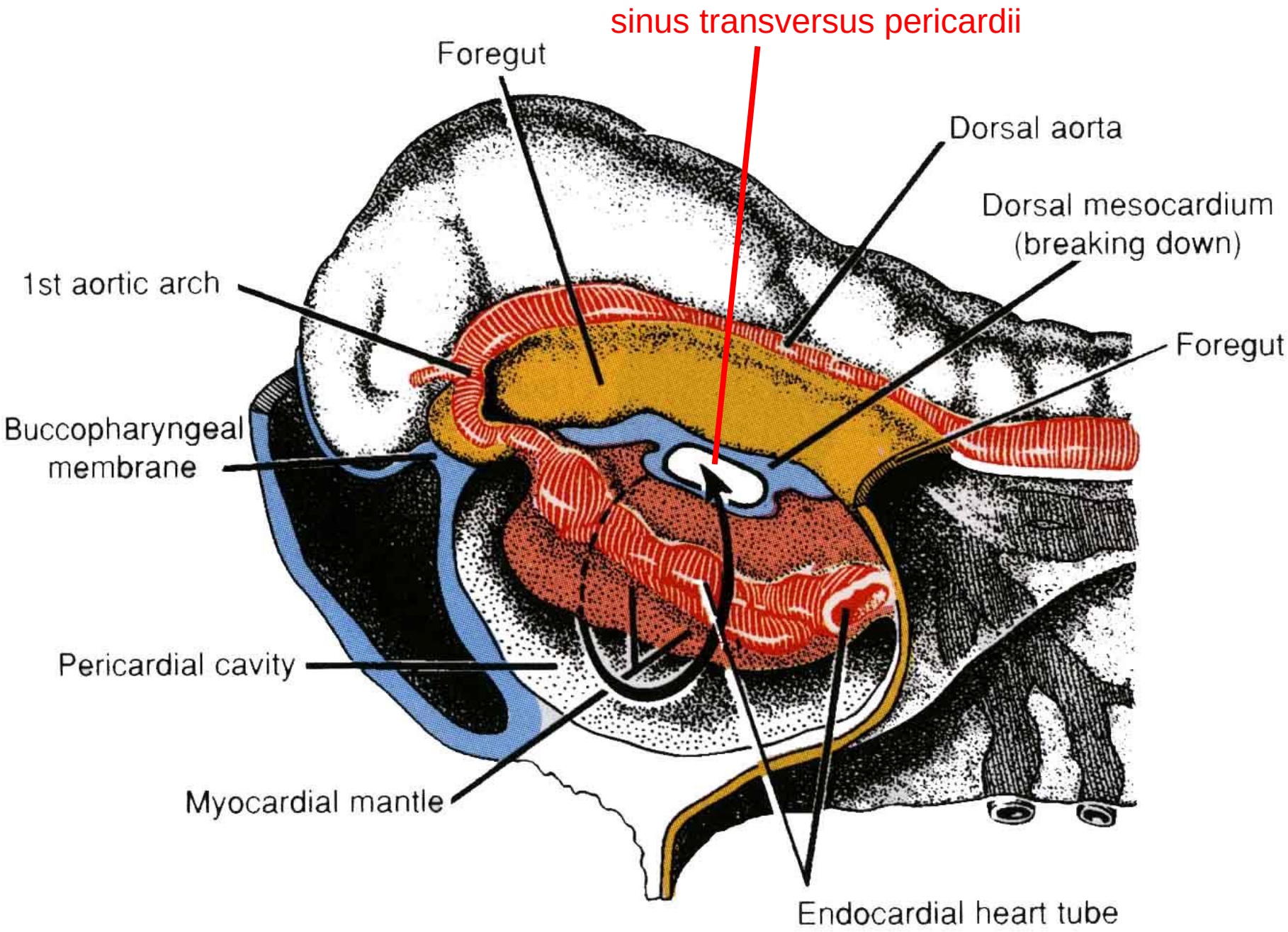
2. heart tube

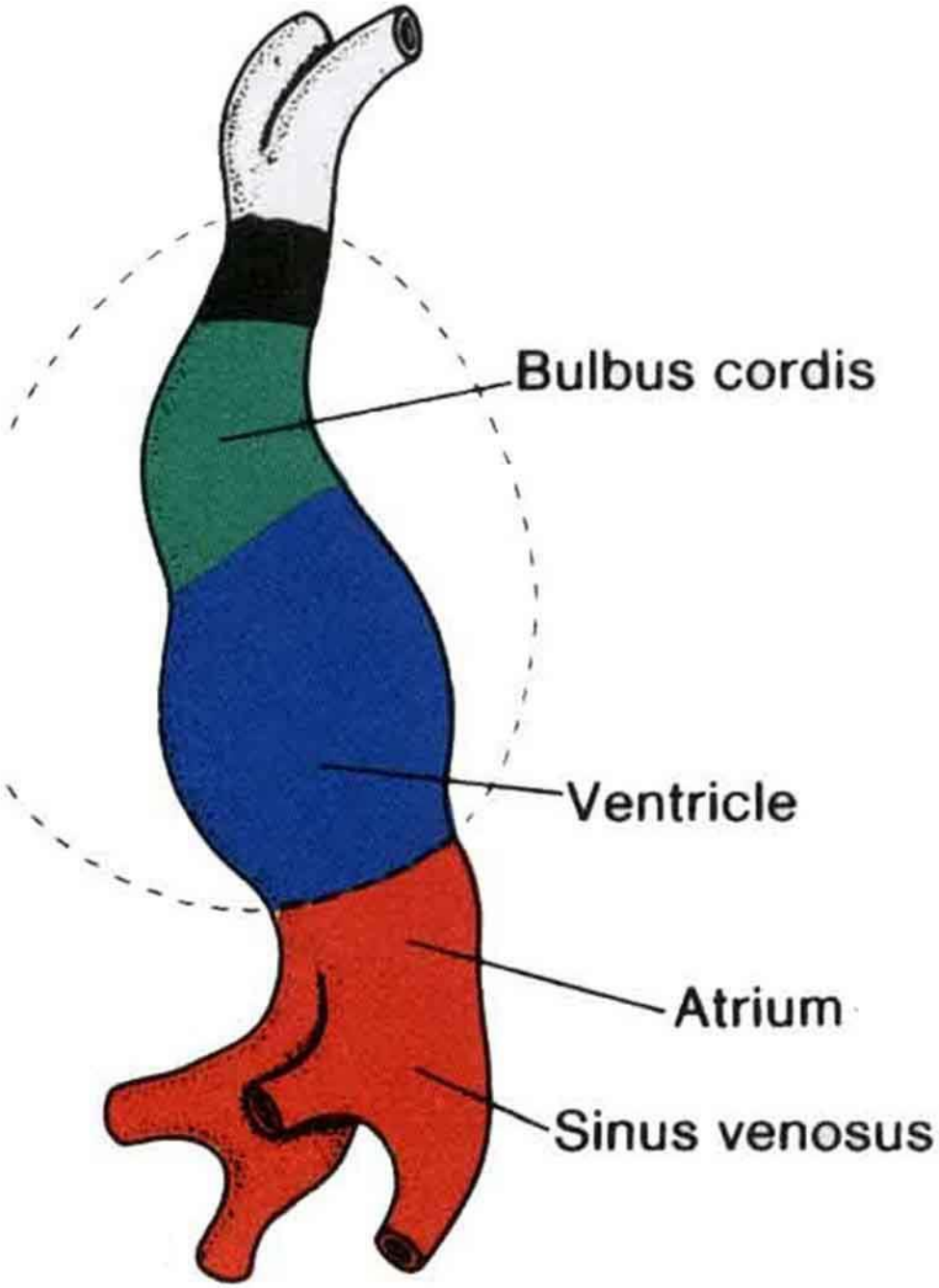


cor tubulare simplex


Neural plate
Dorsal aorta
A
Primitive gut
Myocardial primordium
Pericardial coelom
Endocardial primordium
2-somite embryo
(~20 days)
Neural plate
B
Dorsal aorta
Cardiac jelly
4-somite embryo
(~21 days)
Neural groove
Dorsal aorta
C
Endocardium
Pericardial coelom
Amnion
Cardiac jelly
Myocardium
7-somite embryo
(~22 days)
Neural tube
Dorsal aorta
Foregut
Mesocardium
D
Endocardium
10-somite embryo
(~22+ days)


A
Oropharyngeal membrane
Pericardial cavity
Cardiogenic plate
B
Neural plate
C
Foregut
Oropharyngeal membrane
D
Heart tube
Pericardial cavity


sinus transversus pericardii
Foregut
Dorsal aorta
Dorsal mesocardium
(breaking down)
1st aortic arch
Foregut
Buccopharyngeal
membrane
Pericardial cavity
Myocardial mantle
Endocardial heart tube

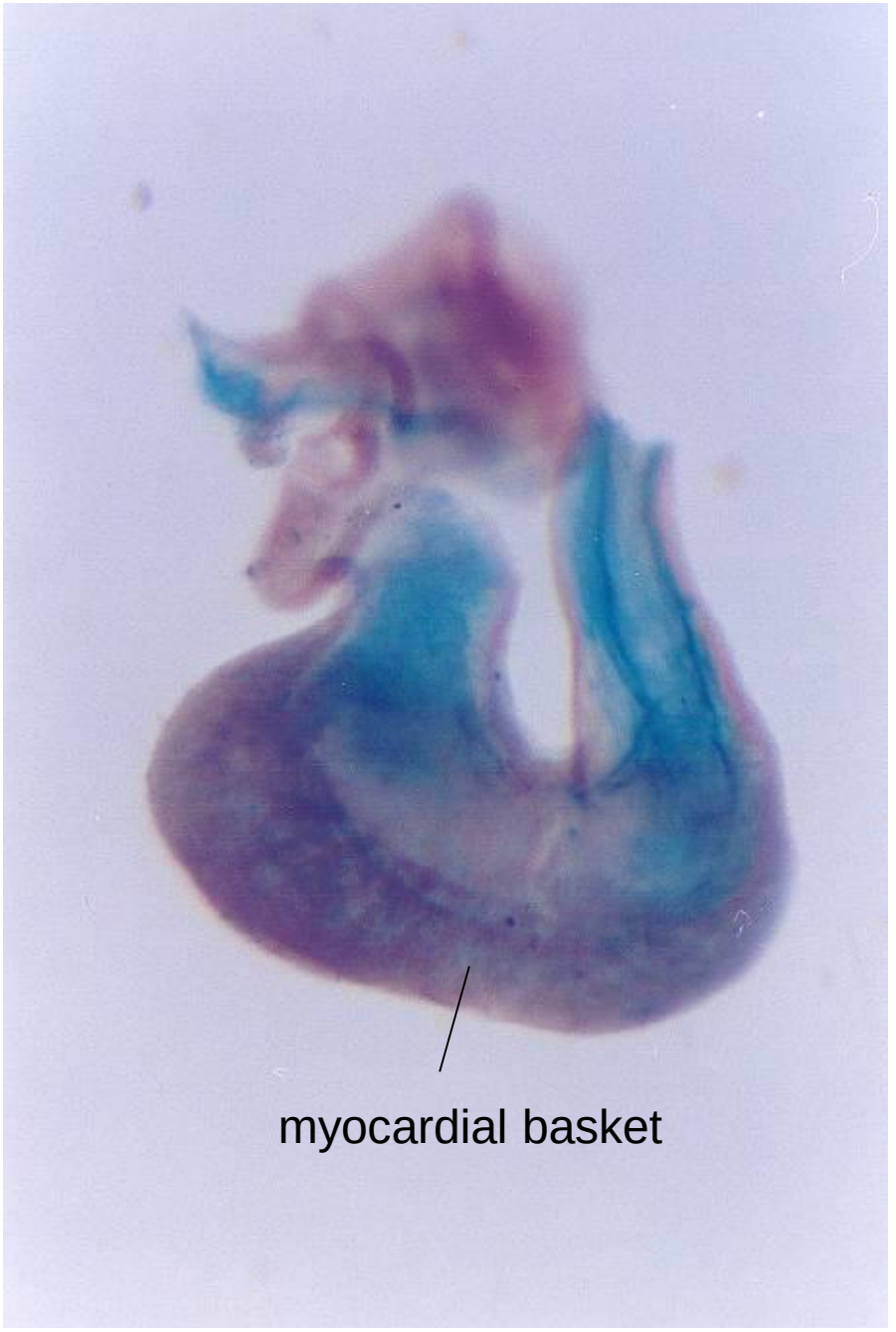

Bulbus cordis
Ventricle
Atrium
Sinus venosus

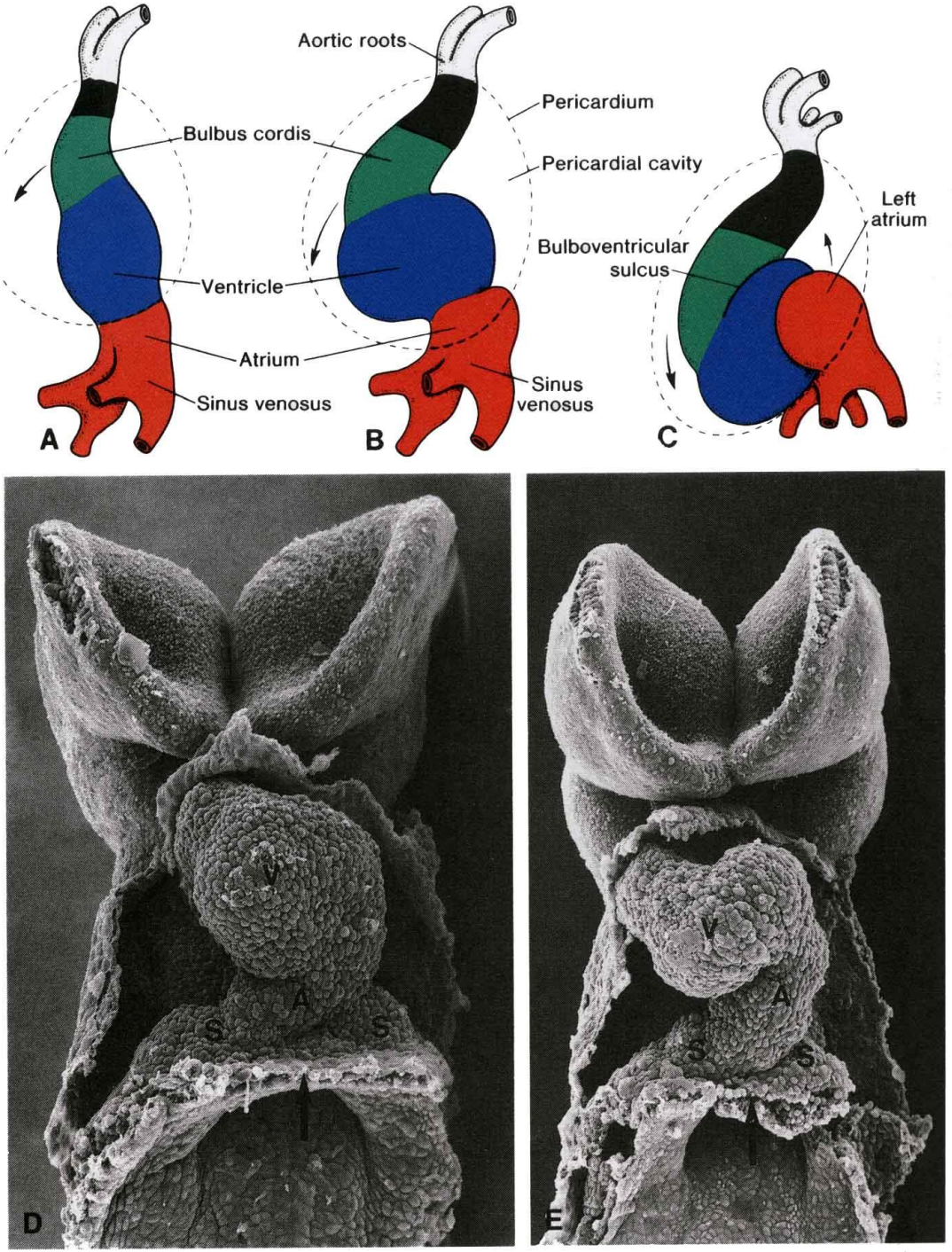
Heart development

sinus venosus	• right atrium - sinus venarum cavarum
• common atrium	• both atria (separated with *crista terminalis*) – auricles (appendages)
• primitive ventricle • bulbus cordis	• trabeculated part of the left ventricle • Proximal part: trabeculated part of the right ventricle • Midportion: conus cordis (outflow of both ventricles) • Distal part: truncus arteriosus (roots and proximal portion of aorta and pulmonary trunk)
saccus aorticus	• ascending aorta, pulmonary trunk

3. heart loop

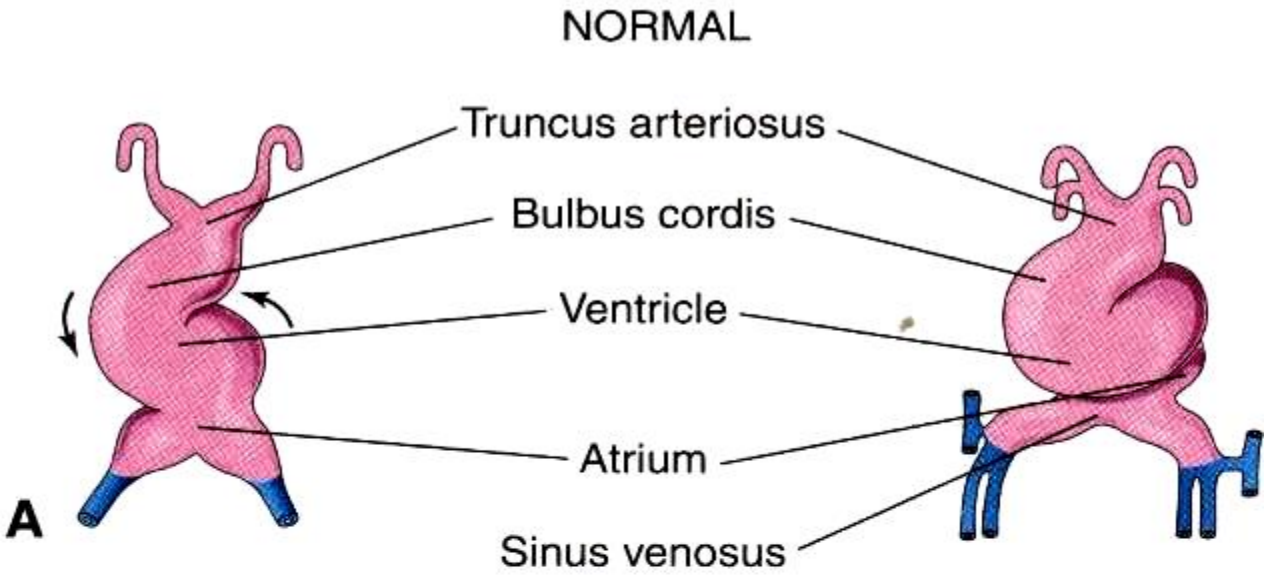
(cor sigmoideum)

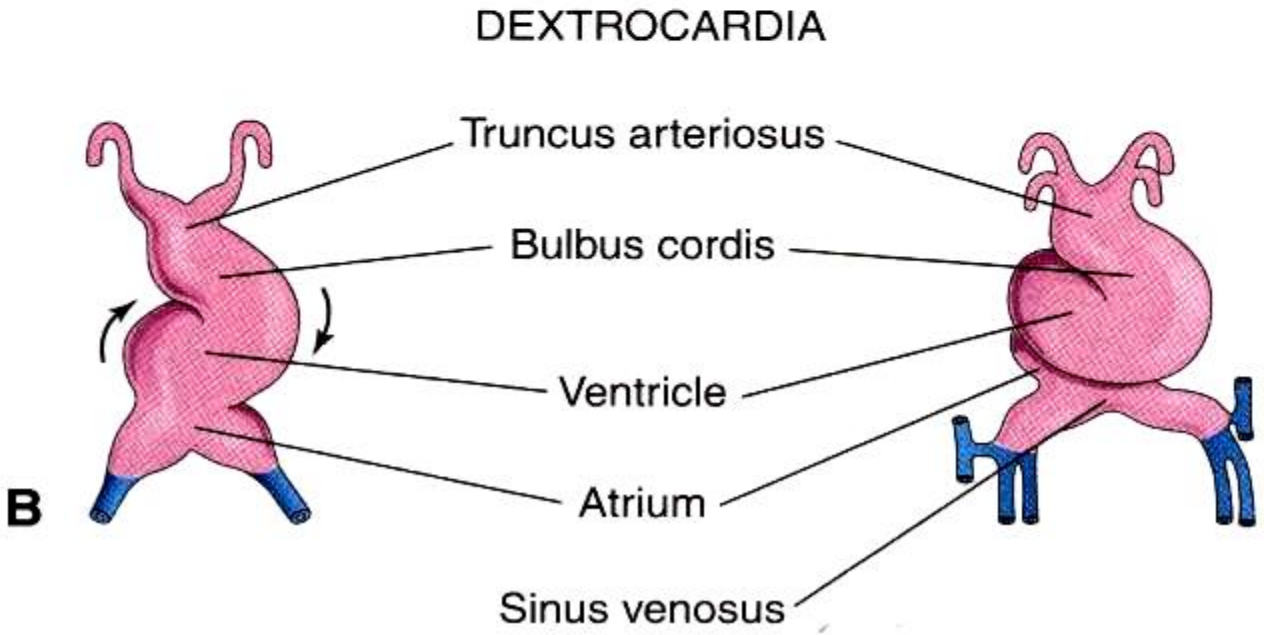



Aortic roots
Pericardium
Bulbus cordis
Pericardial cavity
Left atrium
Bulboventricular sulcus
Ventricle
Atrium
Sinus venosus
Sinus venosus
A
B
C
V
A
S
S
D
V
A
S
S
E

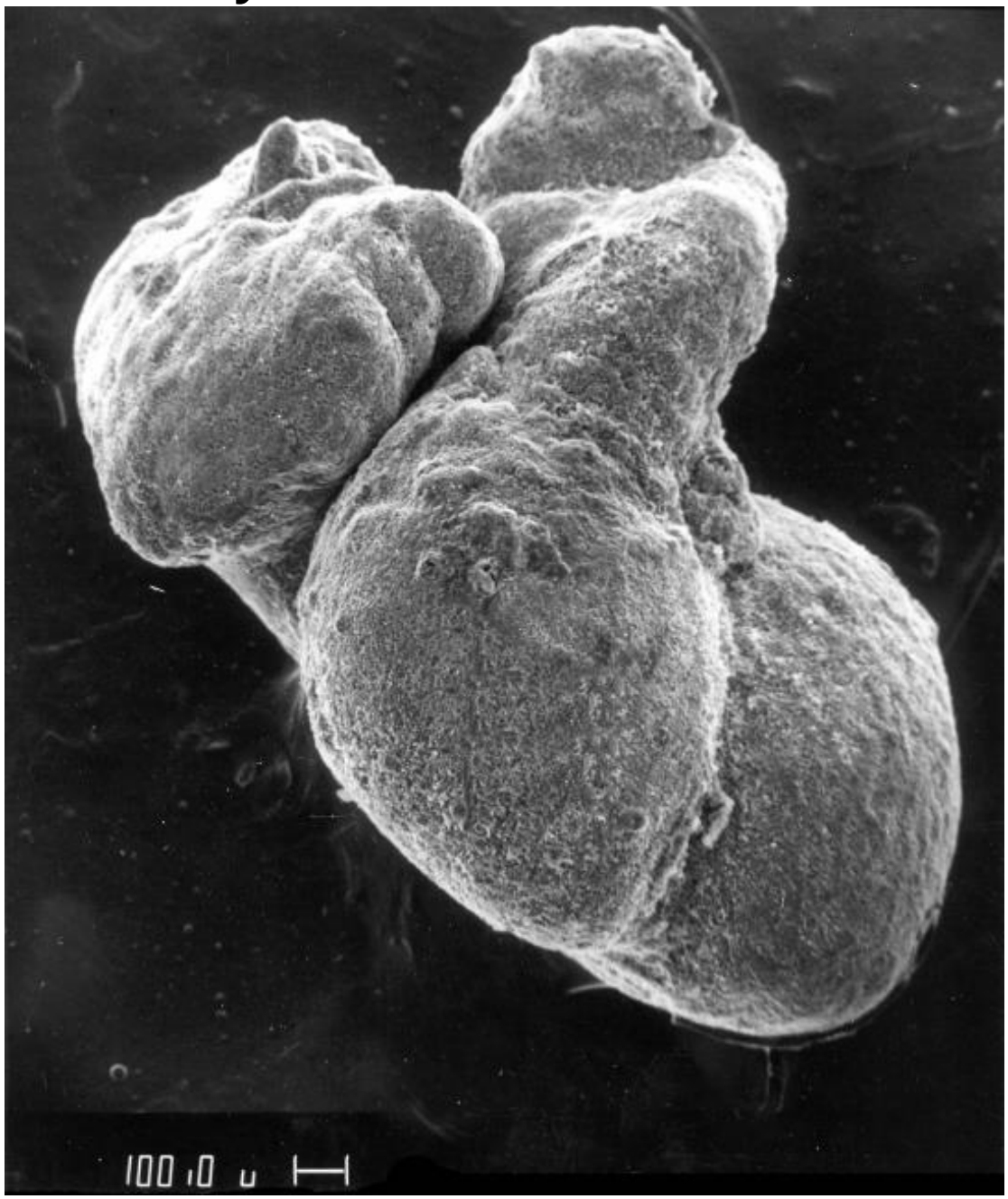
Abnormality in looping process

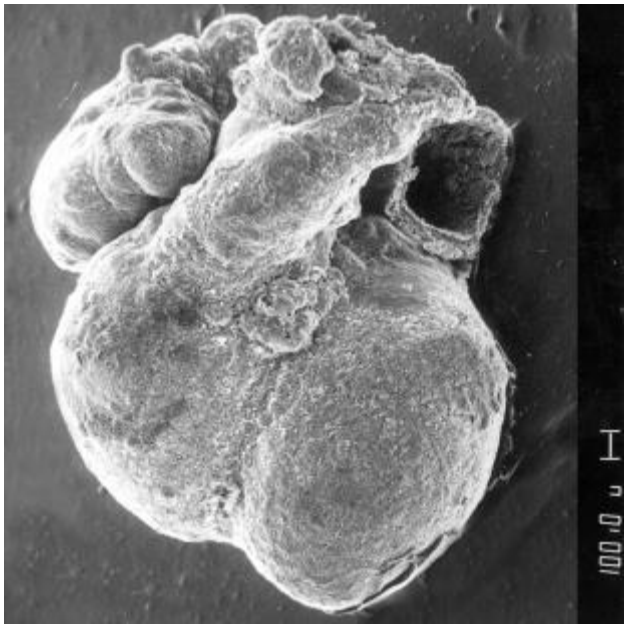
dextrocardia

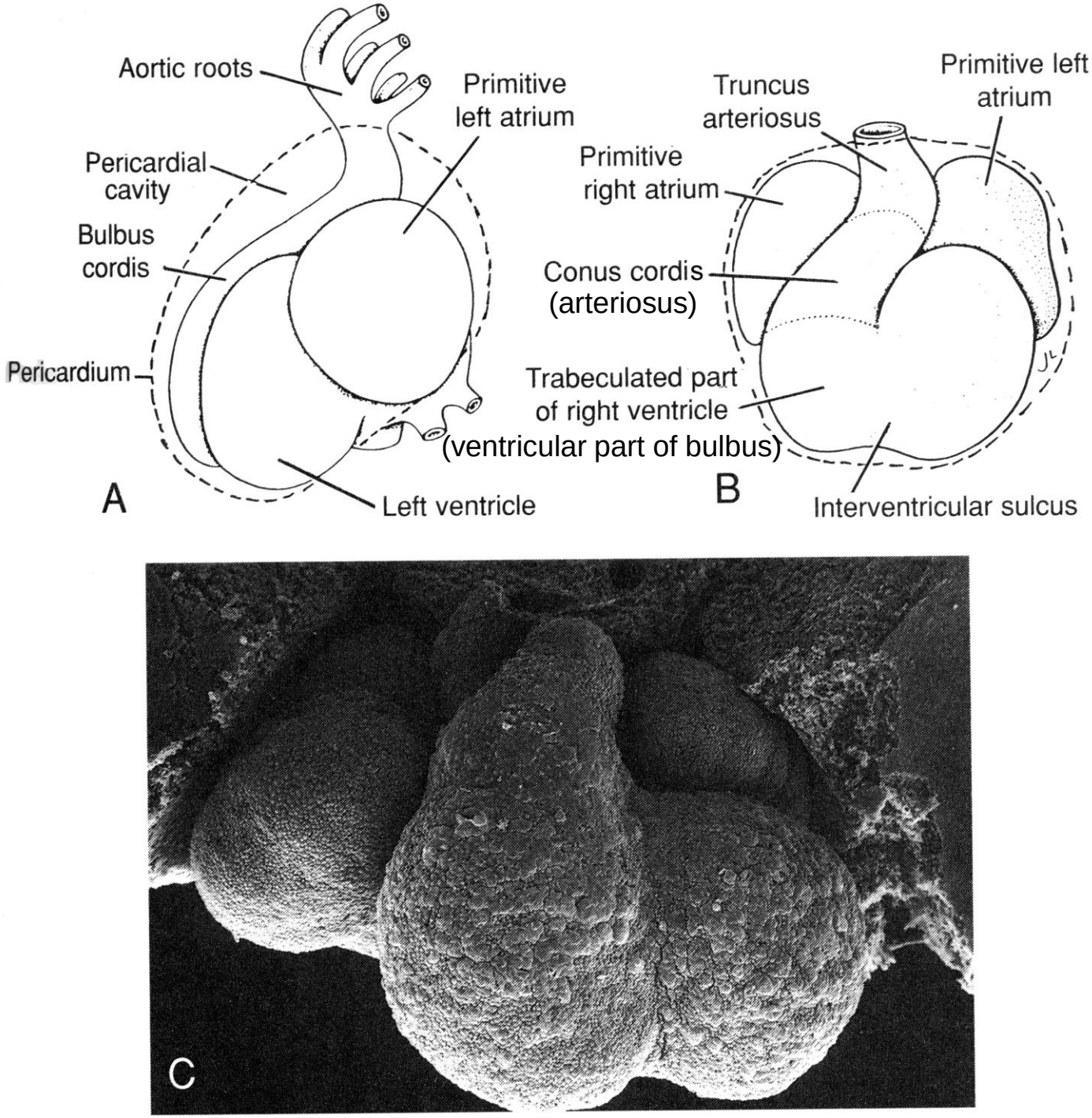


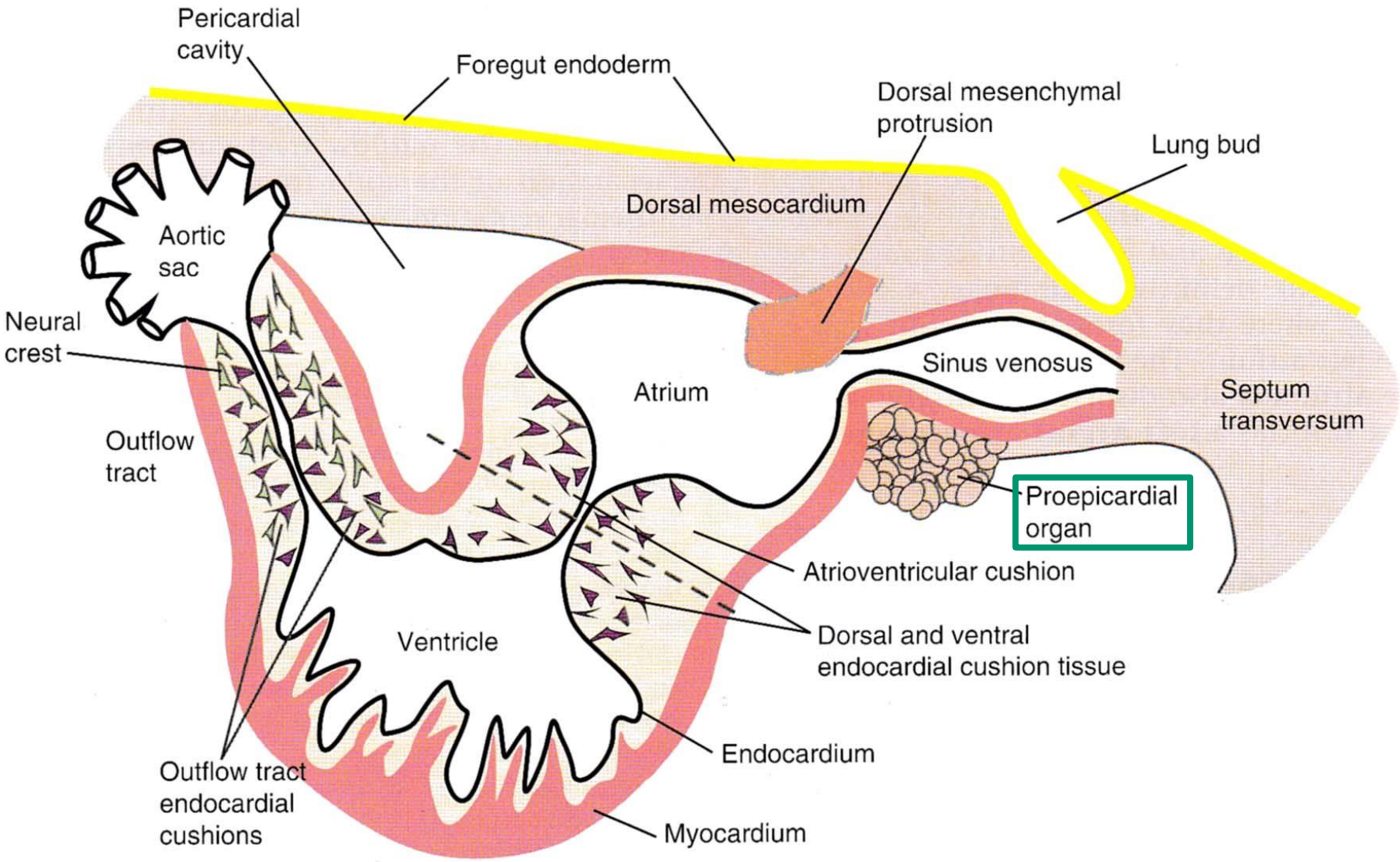


4. embryonic heart



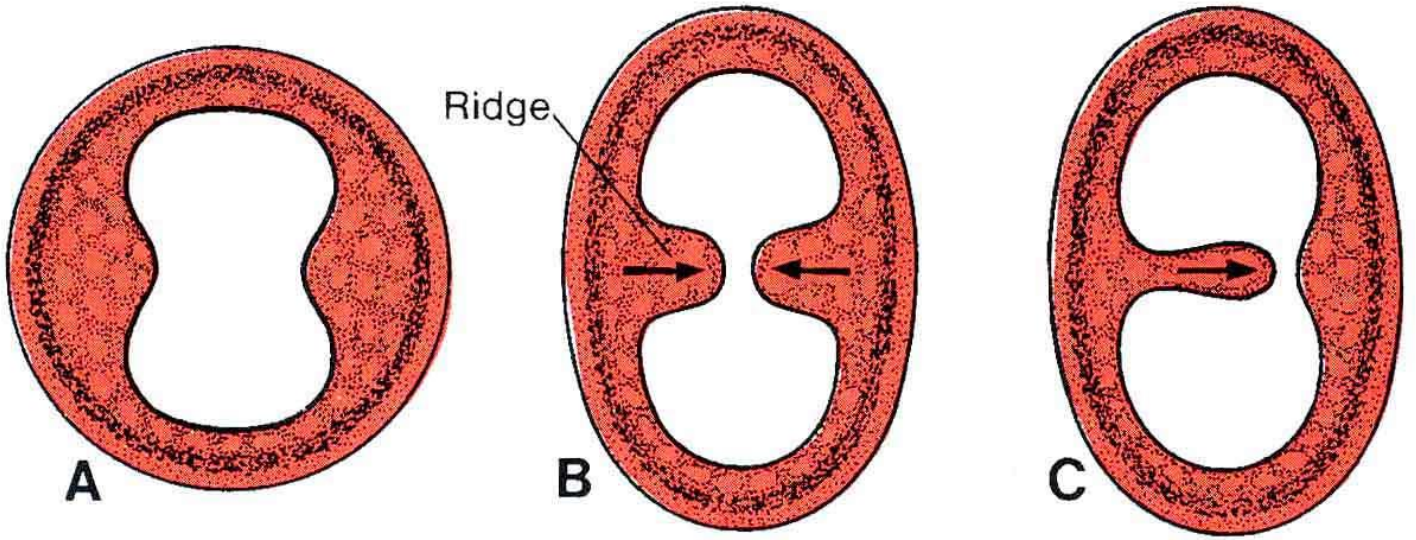



Aortic roots
Primitive left atrium
Pericardial cavity
Bulbus cordis
Pericardium
Left ventricle
A
Truncus arteriosus
Primitive left atrium
Primitive right atrium
Conus cordis (arteriosus)
Trabeculated part of right ventricle (ventricular part of bulbus)
Interventricular sulcus
B
C


Pericardial cavity
Foregut endoderm
Dorsal mesenchymal protrusion
Lung bud
Dorsal mesocardium
Aortic sac
Neural crest
Sinus venosus
Atrium
Septum transversum
Outflow tract
Proepicardial organ
Atrioventricular cushion
Dorsal and ventral endocardial cushion tissue
Ventricle
Endocardium
Outflow tract endocardial cushions
Myocardium

SEPTATION OF
ATRIA, VENTRICLES AND HEART OUTLET

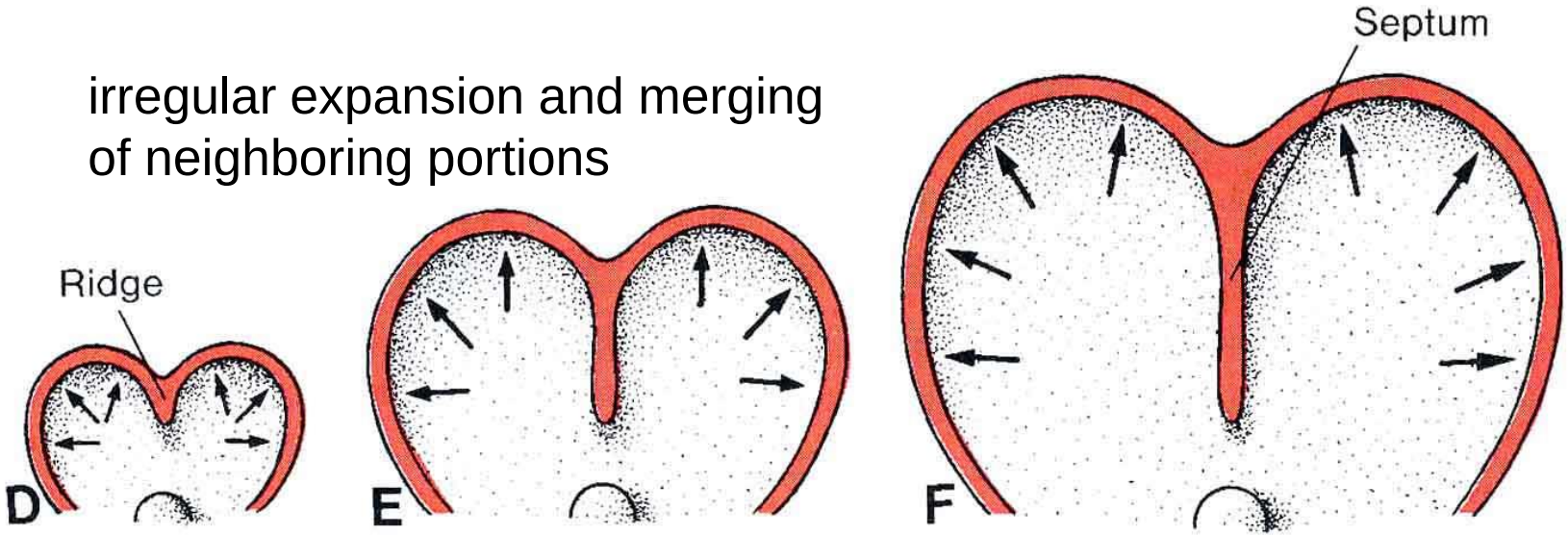
Methods of formation of cardiac septa



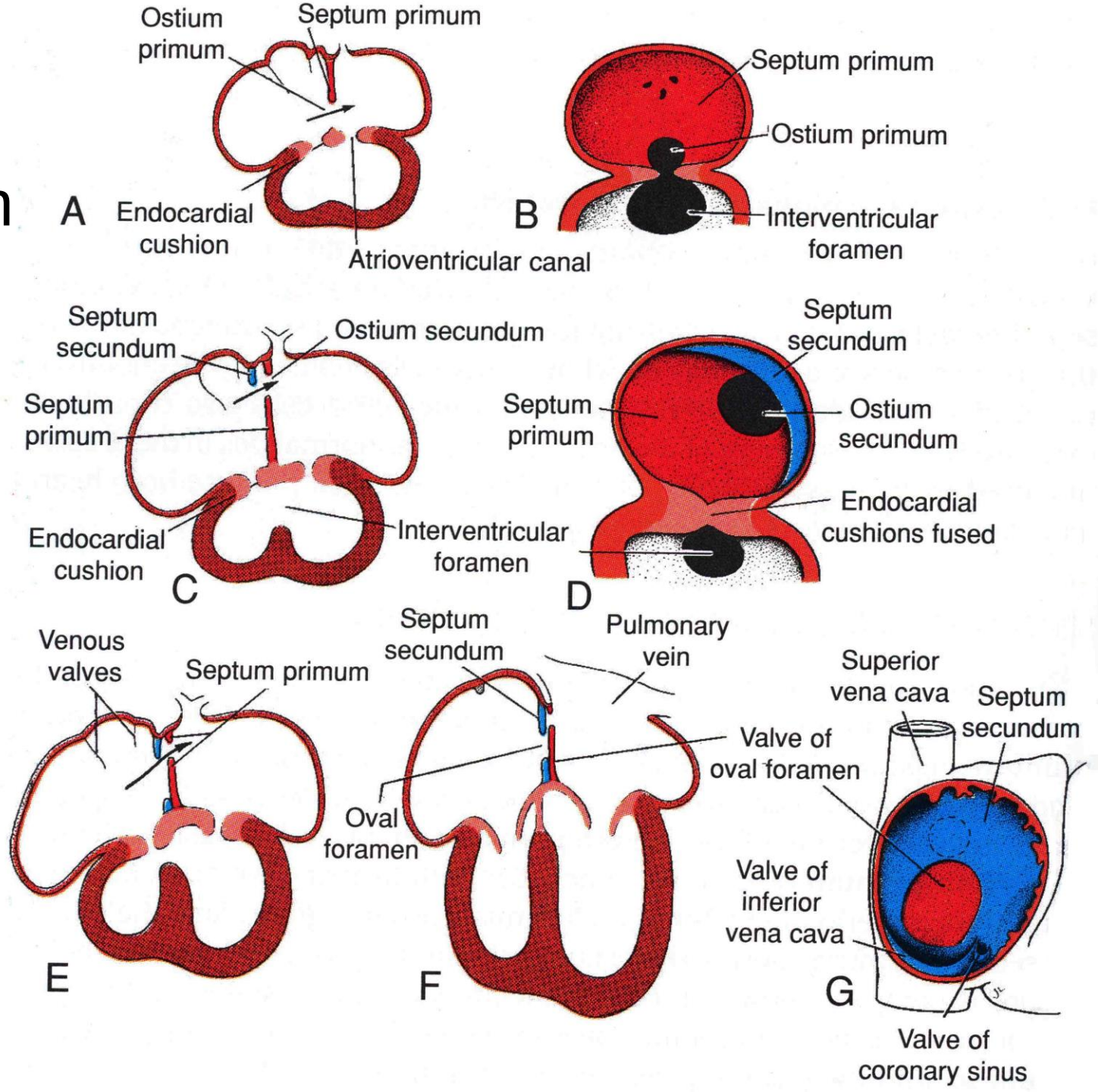
growth of 2 opposite ridges

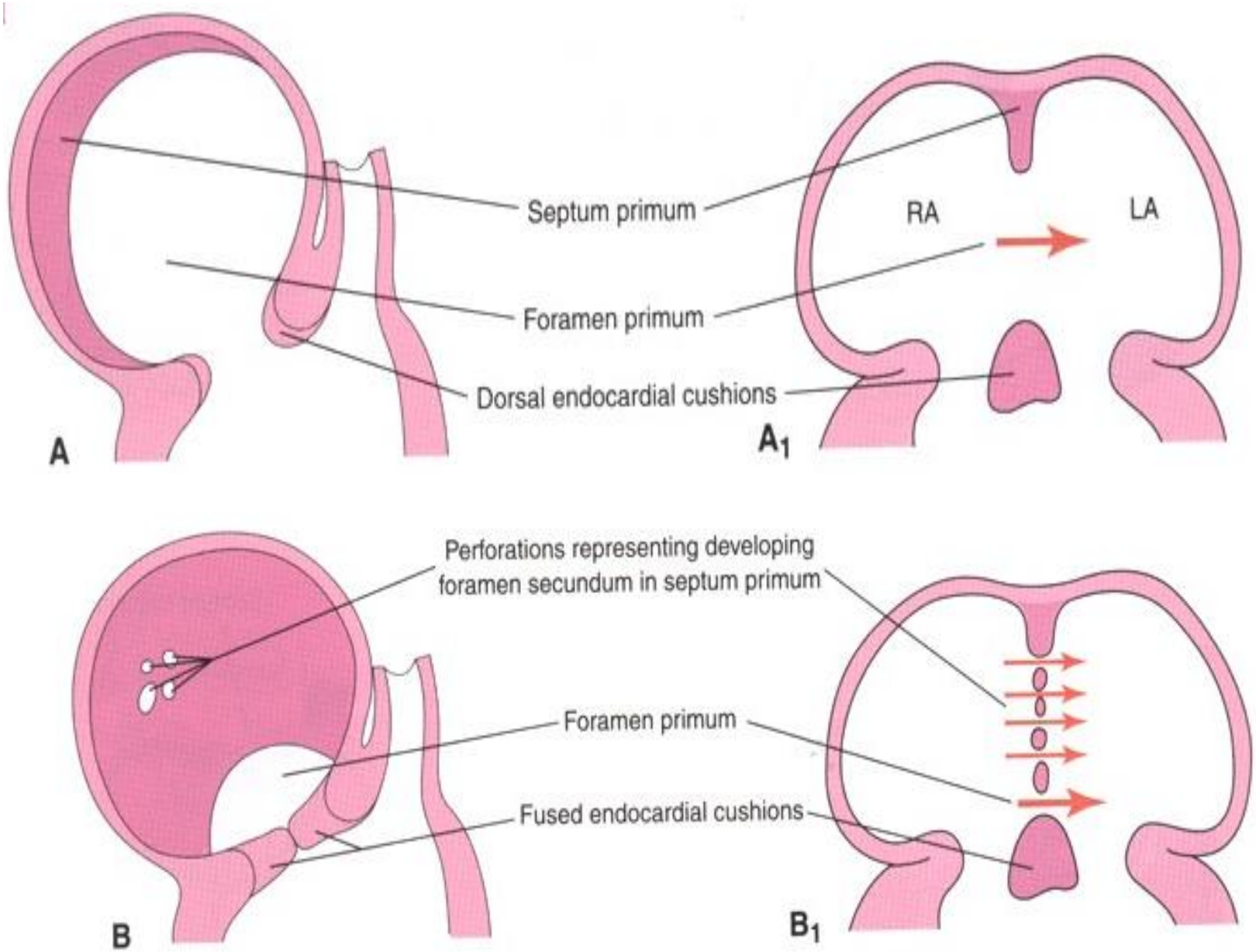
growth of 1 ridge

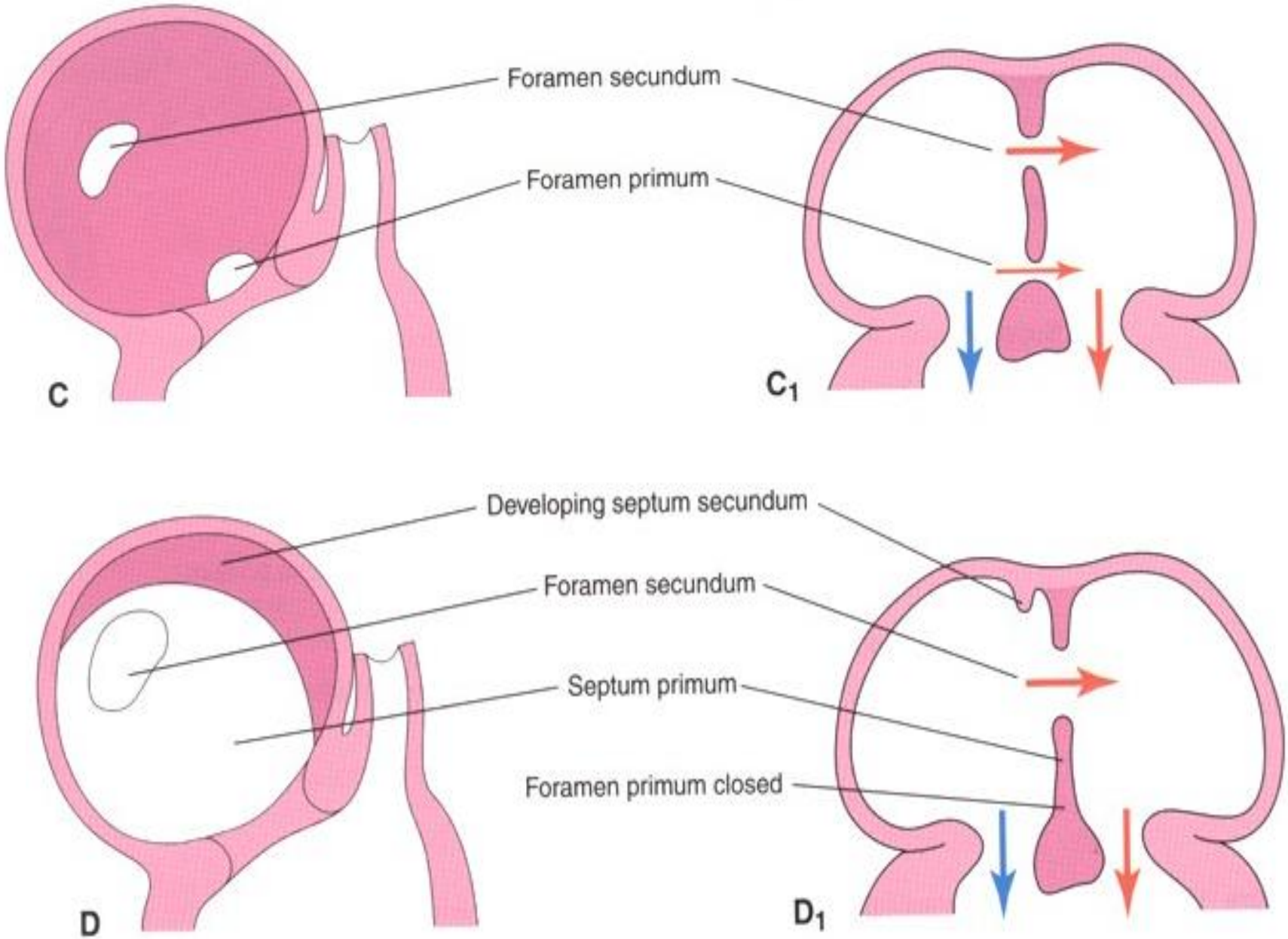
irregular expansion and merging of neighboring portions

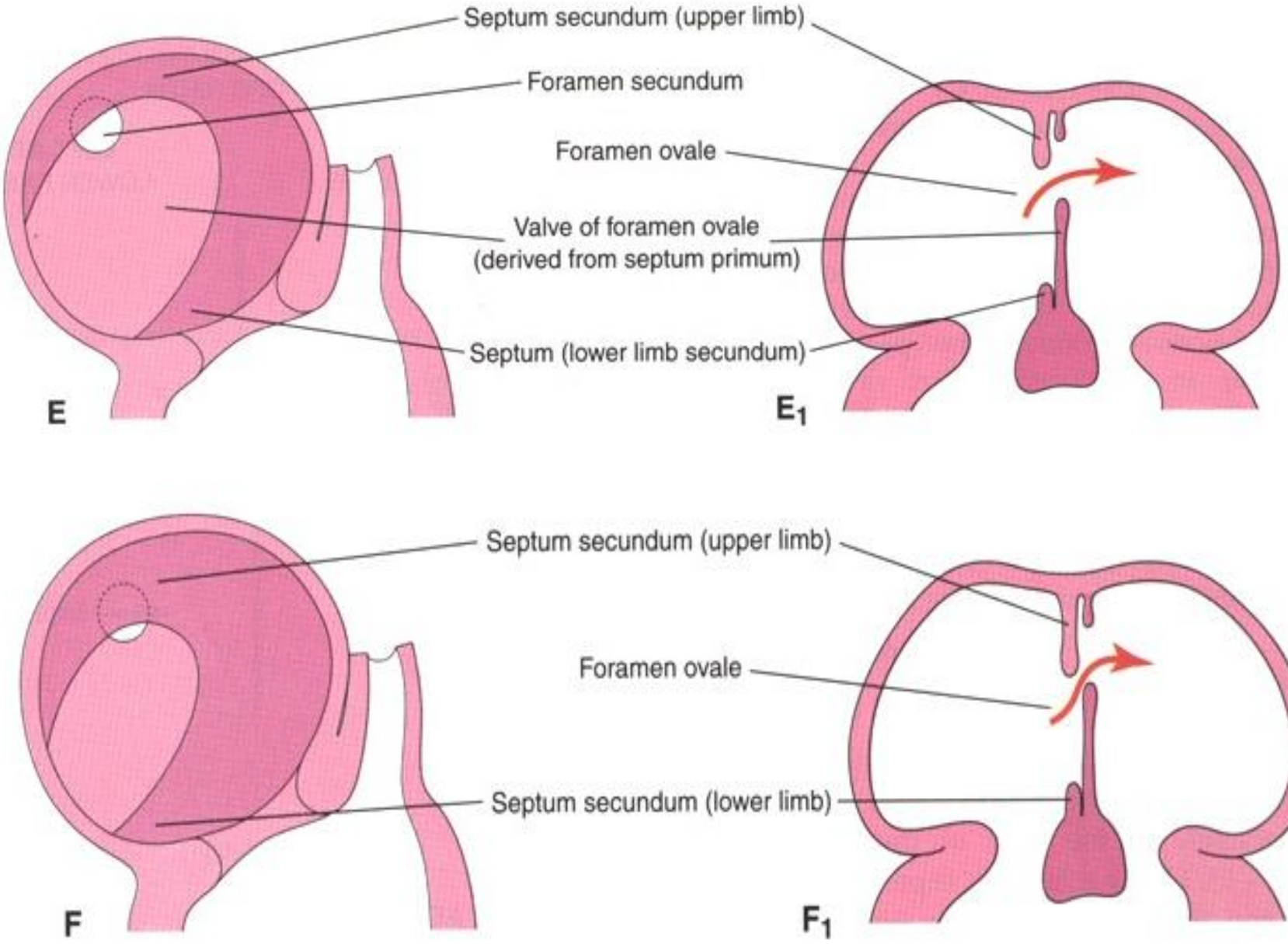


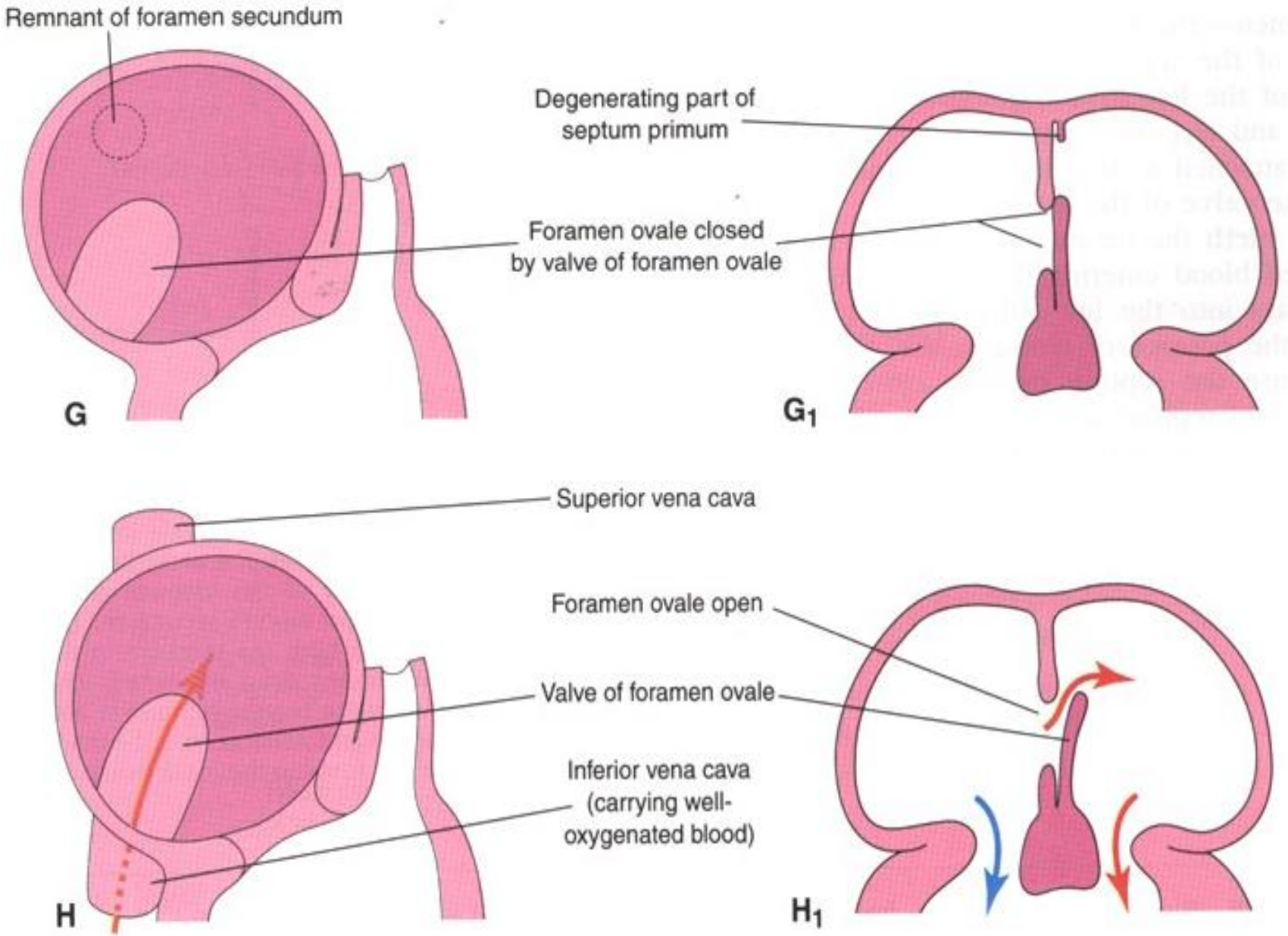
Atrial and AV septation

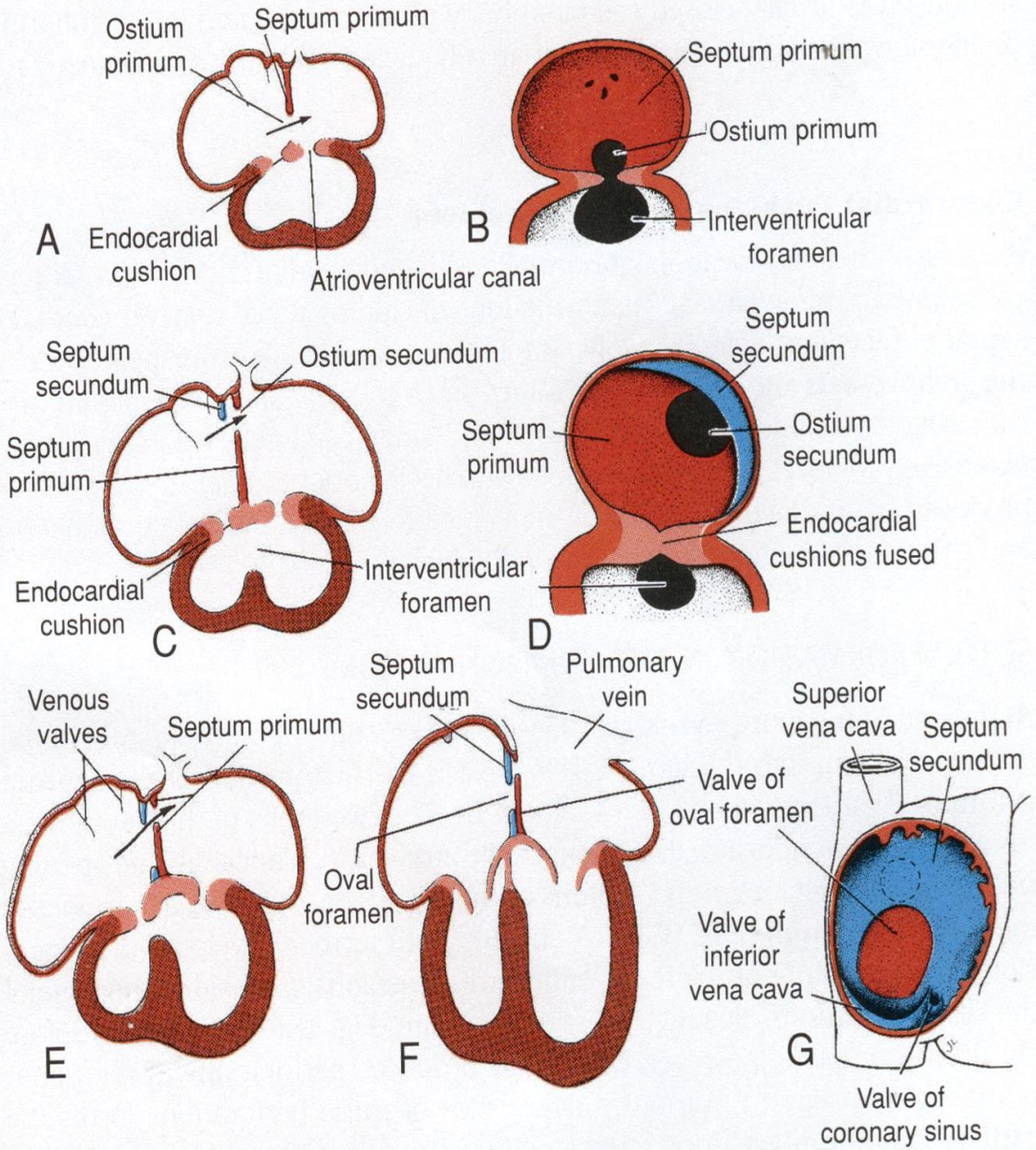



Septum primum
Foramen primum
Dorsal endocardial cushions
A
RA
LA
A1
Perforations representing developing
foramen secundum in septum primum
Foramen primum
Fused endocardial cushions
B
B1

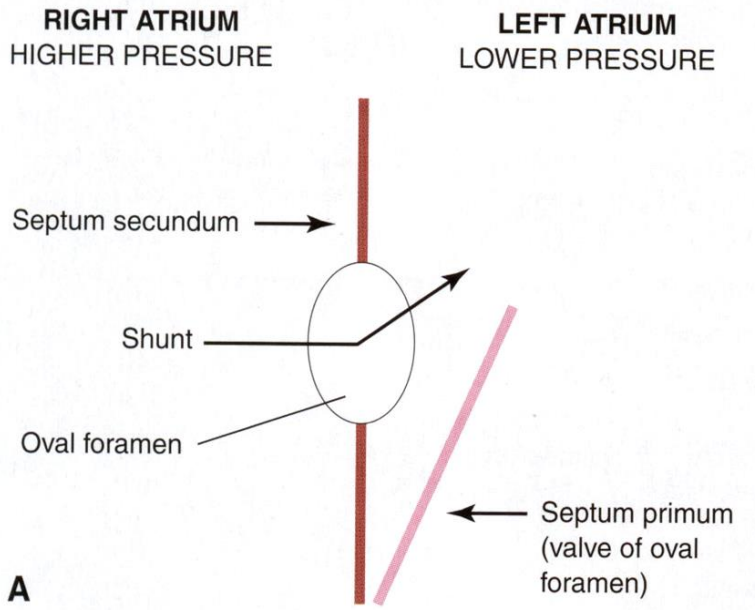

Foramen secundum
Foramen primum
C
C1
Developing septum secundum
Foramen secundum
Septum primum
Foramen primum closed
D
D1

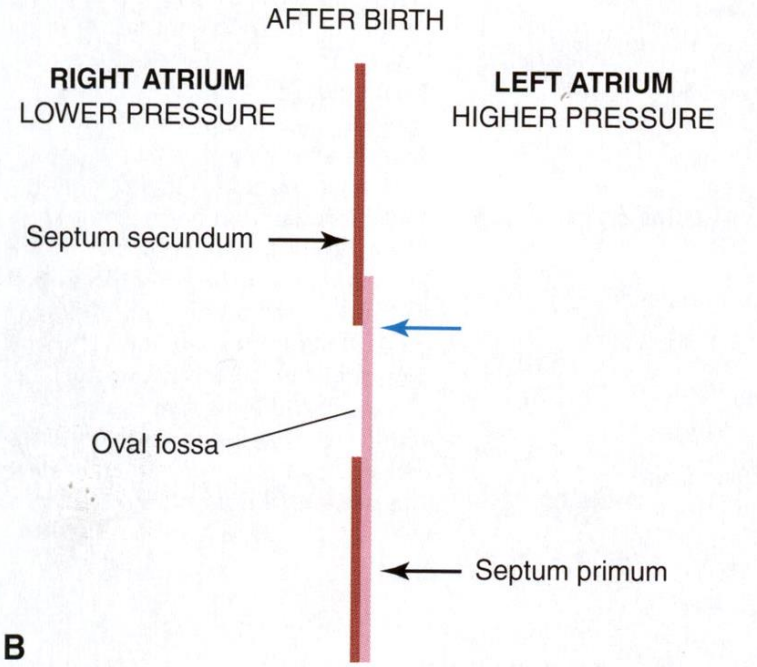

Septum secundum (upper limb)
Foramen secundum
Foramen ovale
Valve of foramen ovale
(derived from septum primum)
Septum (lower limb secundum)
E
E1
Septum secundum (upper limb)
Foramen ovale
Septum secundum (lower limb)
F
F1

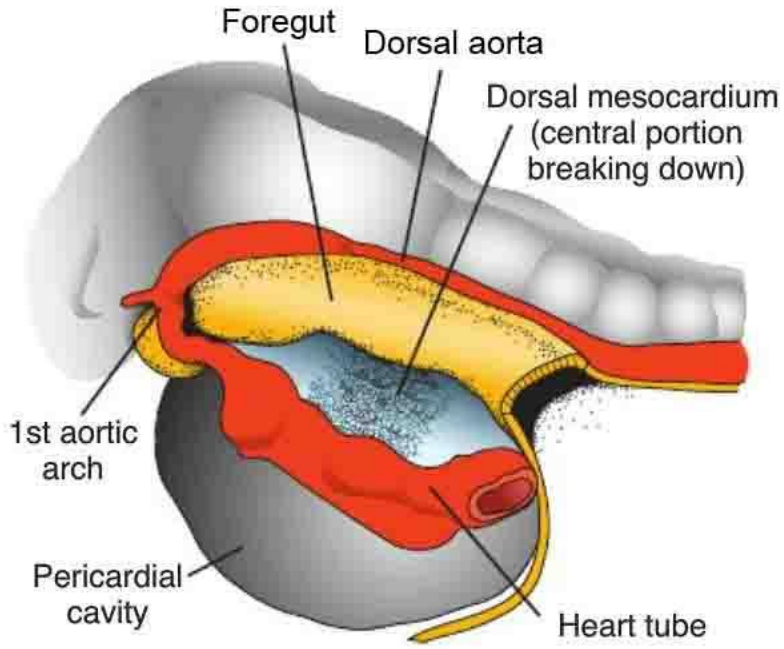

Remnant of foramen secundum
Foramen ovale closed by valve of foramen ovale
G
Degenerating part of septum primum
G1
Superior vena cava
Valve of foramen ovale
Inferior vena cava (carrying well-oxygenated blood)
H
Foramen ovale open
H1

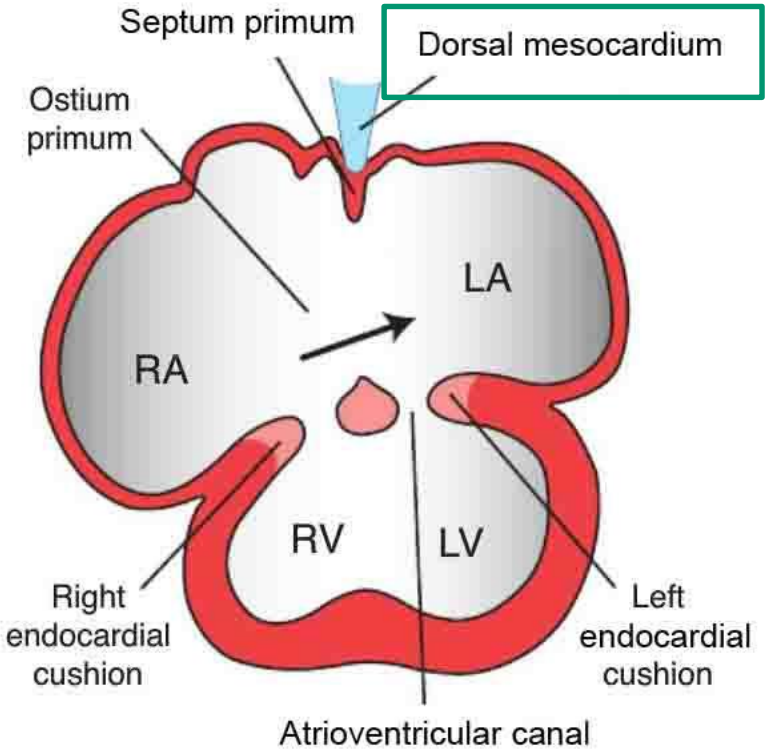


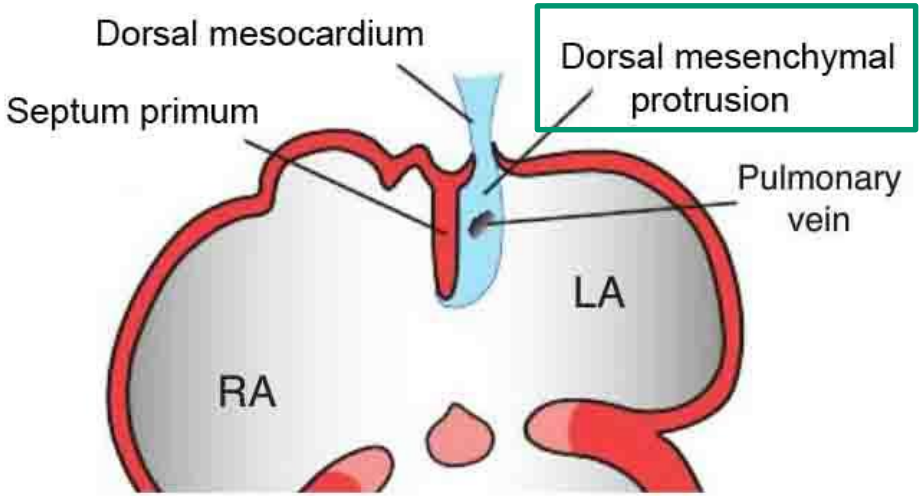
Atrial septa at various stages of development. **A.** 30 days (6 mm). **B.** Same stage as **A,** viewed from the right. **C.** 33 days (9 mm). **D.** Same stage as **C,** viewed from the right **E.** 37 days (14 mm). **F.** Newborn. **G.** The atrial septum from the right; same stage as **F.**

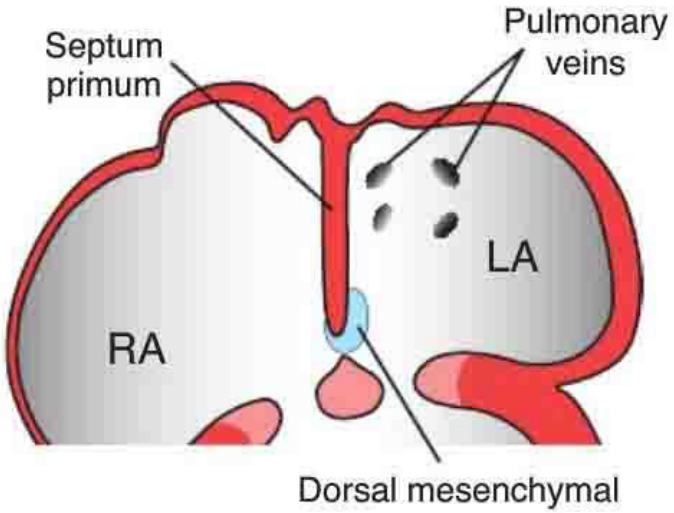




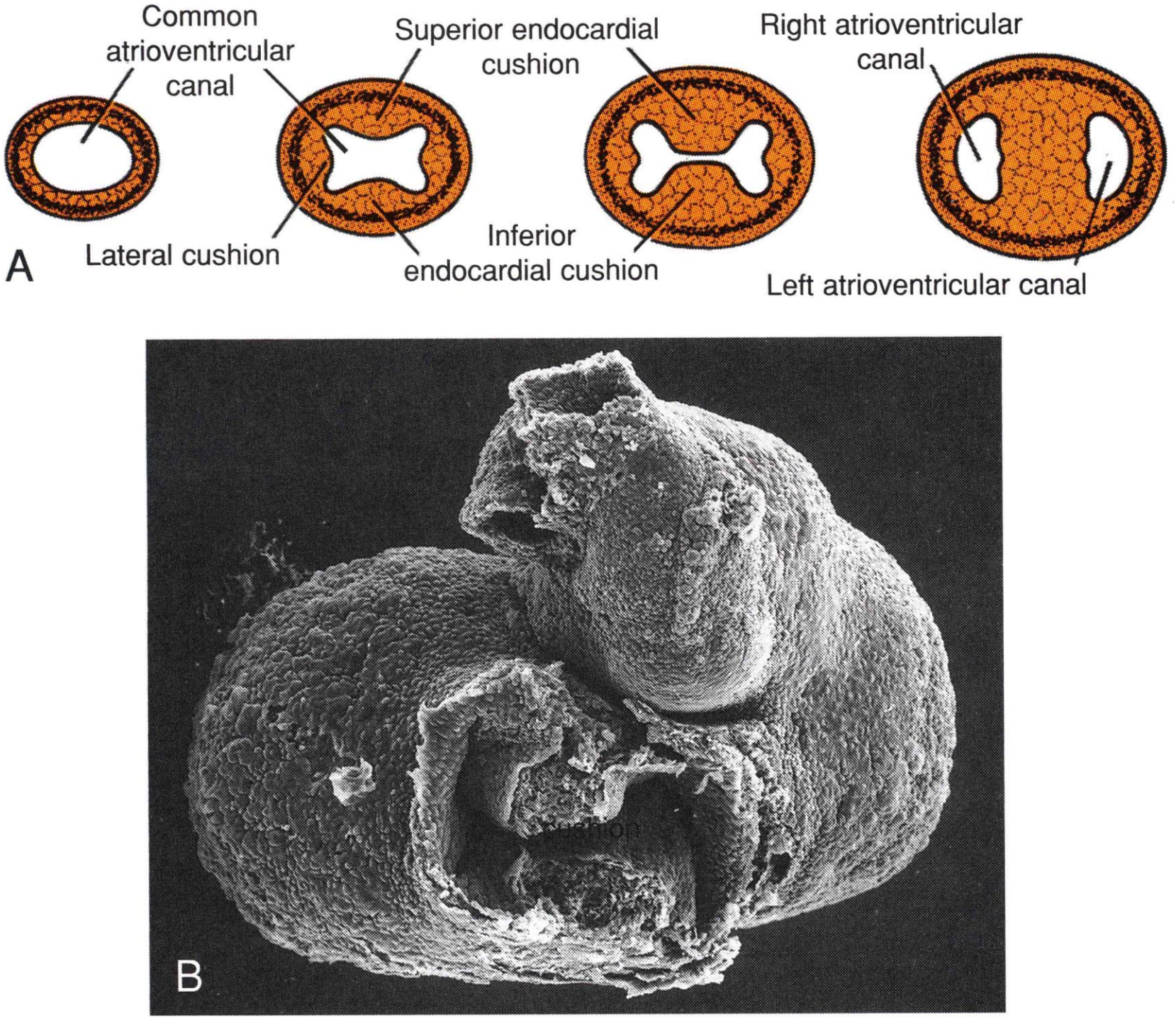

Foregut
Dorsal aorta
Dorsal mesocardium
(central portion
breaking down)
1st aortic
arch
Pericardial
cavity
Heart tube


Septum primum
Dorsal mesocardium
Ostium
primum
LA
RA
RV
LV
Right
endocardial
cushion
Left
endocardial
cushion
Atrioventricular canal

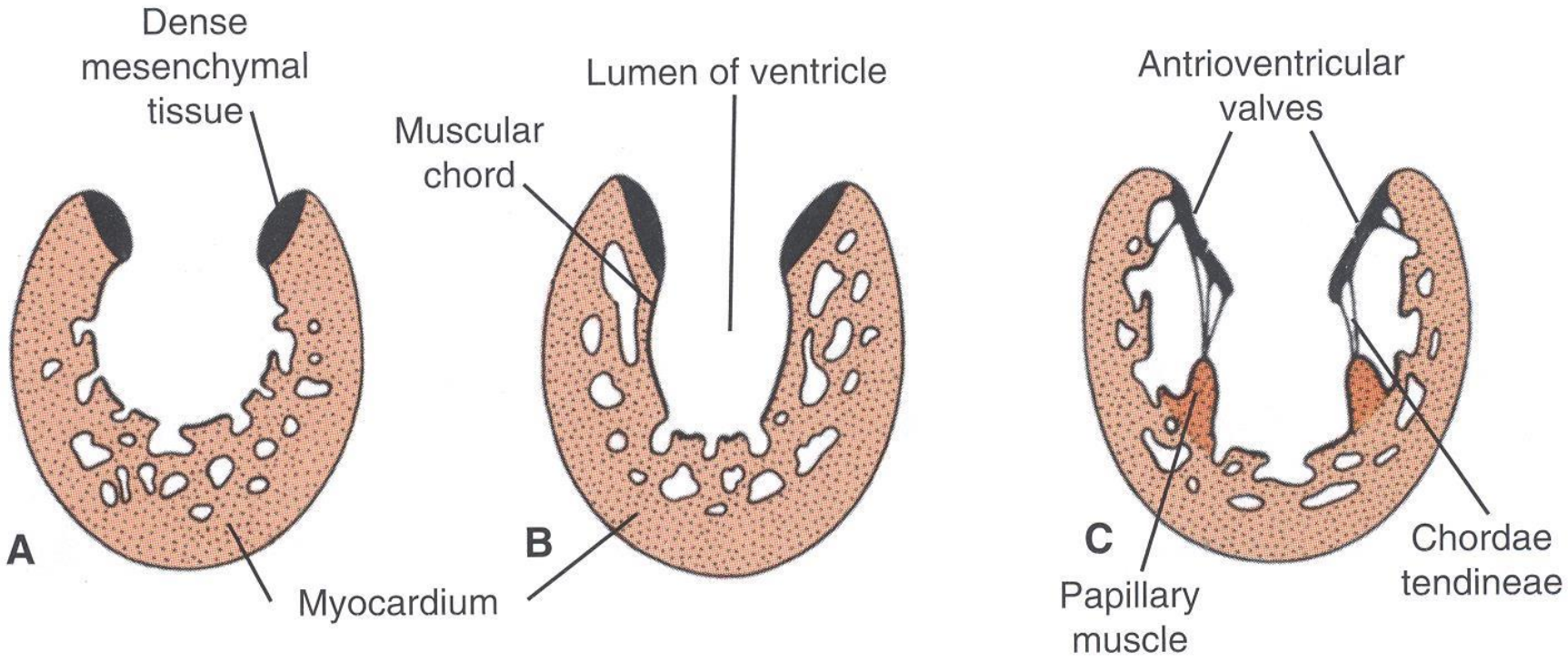

Dorsal mesocardium
Dorsal mesenchymal
protrusion
Septum primum
Pulmonary
vein
LA
RA


Septum
primum
Pulmonary
veins
LA
RA
Dorsal mesenchymal

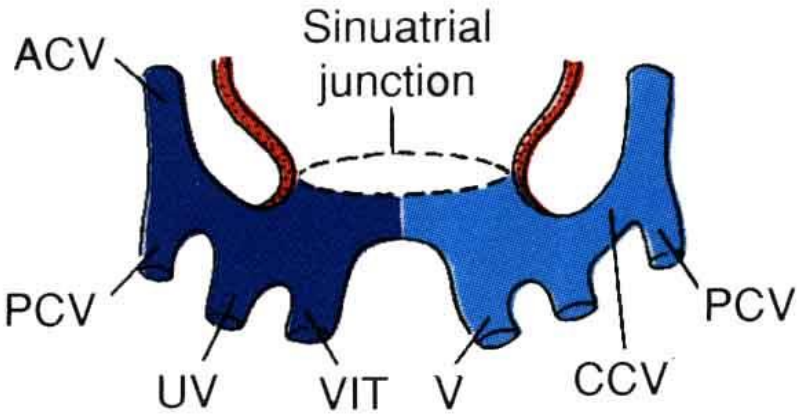
cap


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

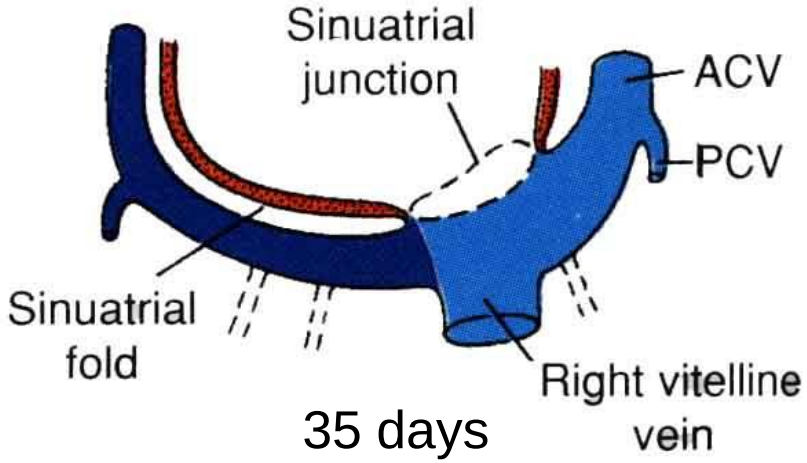
Formation of AV valves



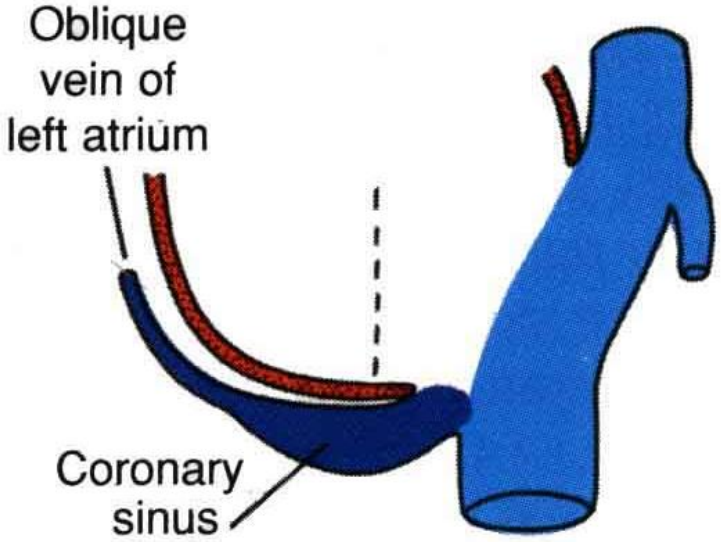
Sinus venosus



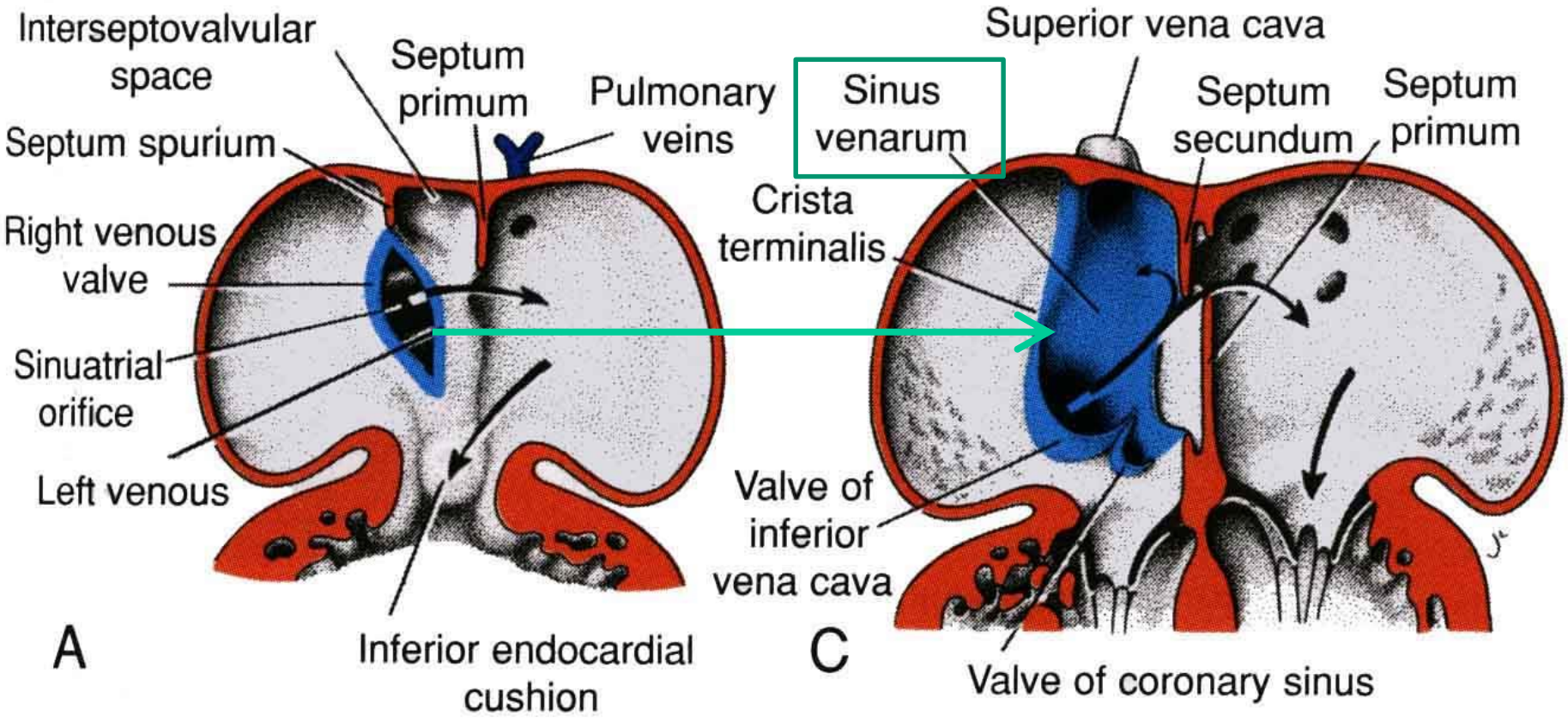
24 days



35 days



fetus

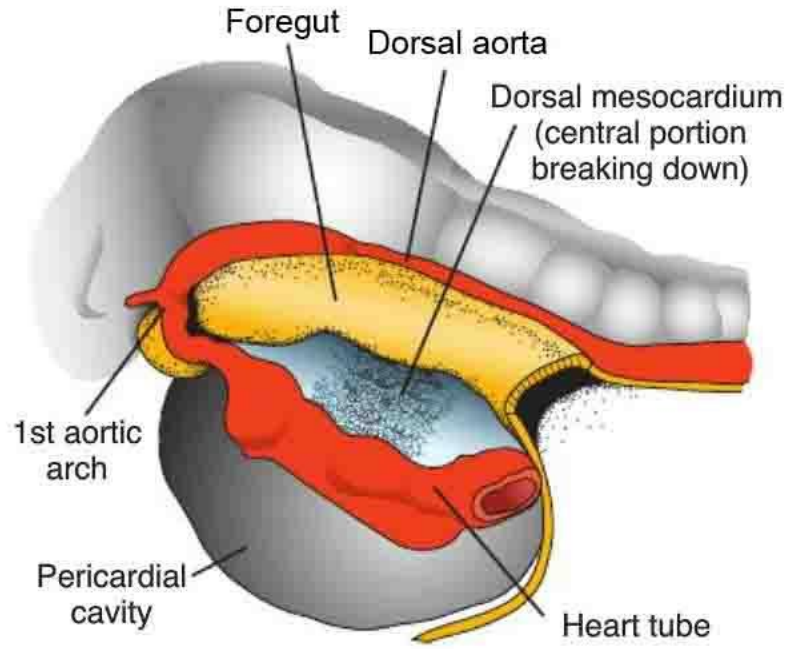


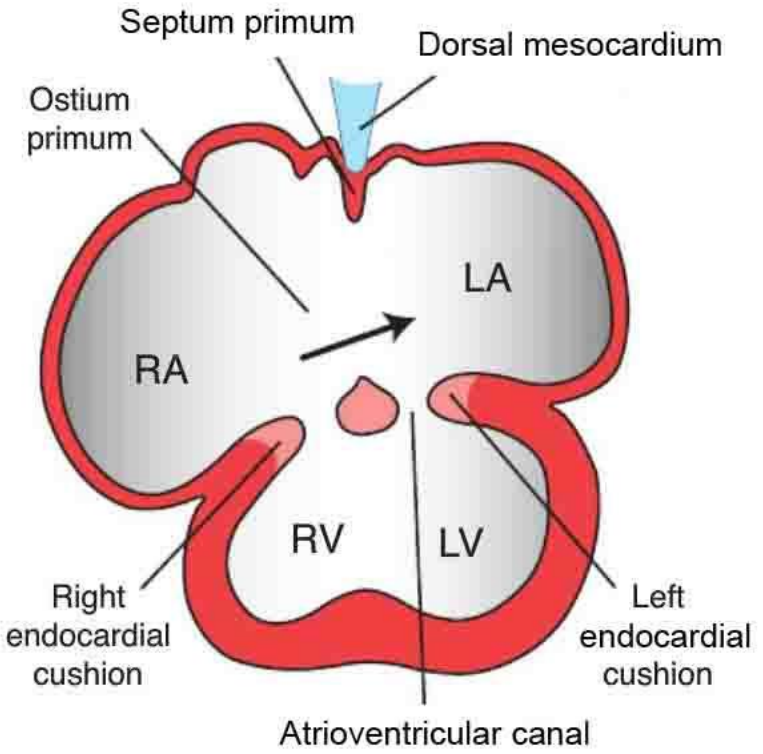
5th week

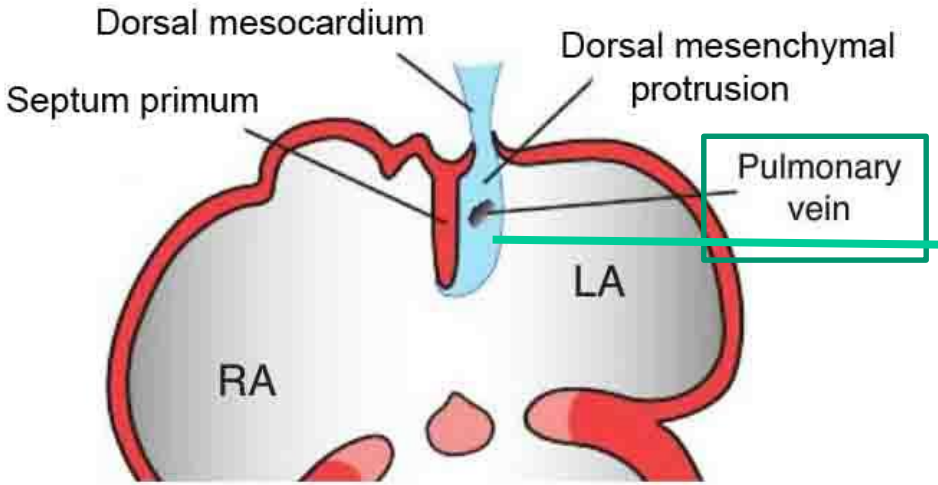
fetus

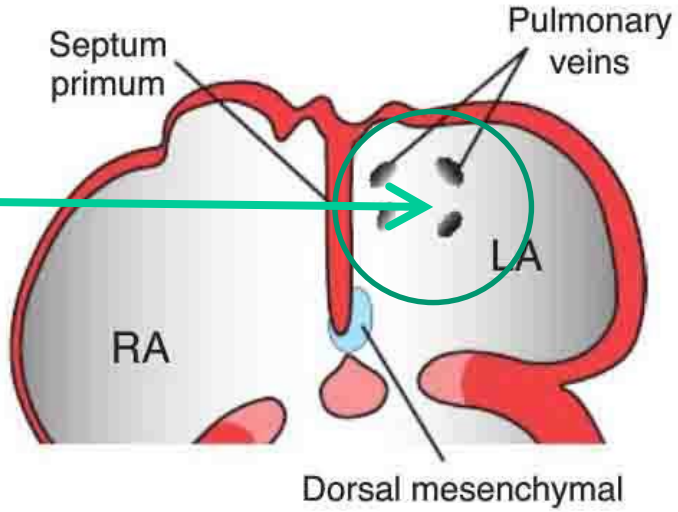
Changes in sinus venosus

- right horn
  - enlarges, receives all the blood from cranial regions of body (VCS), from placenta and caudal regions of body (VCI)
  - becomes incorporated into wall of right atrium (sinus venarum cavarum)
- left horn
  - decreses in size and importance
  - becomes ***sinus coronarius*** and ***vena obliqua atrii sin.***
- valvulae sinuatriales
  - dx: valvula VCI + valvula SC
  - sin: part of interatrial septum


Foregut
Dorsal aorta
Dorsal mesocardium
(central portion
breaking down)
1st aortic
arch
Pericardial
cavity
Heart tube

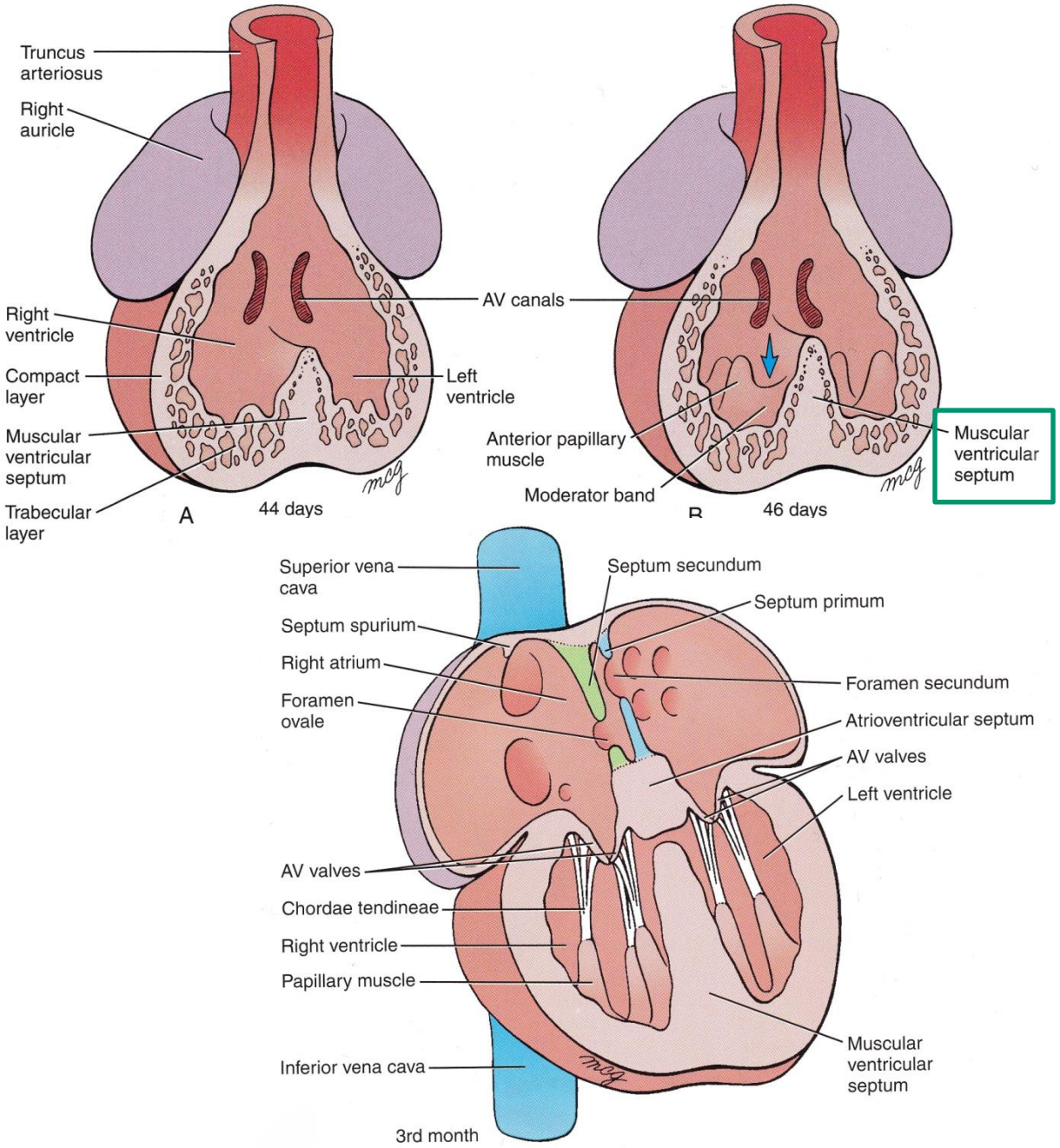

Septum primum
Dorsal mesocardium
Ostium
primum
LA
RA
RV
LV
Right
endocardial
cushion
Left
endocardial
cushion
Atrioventricular canal

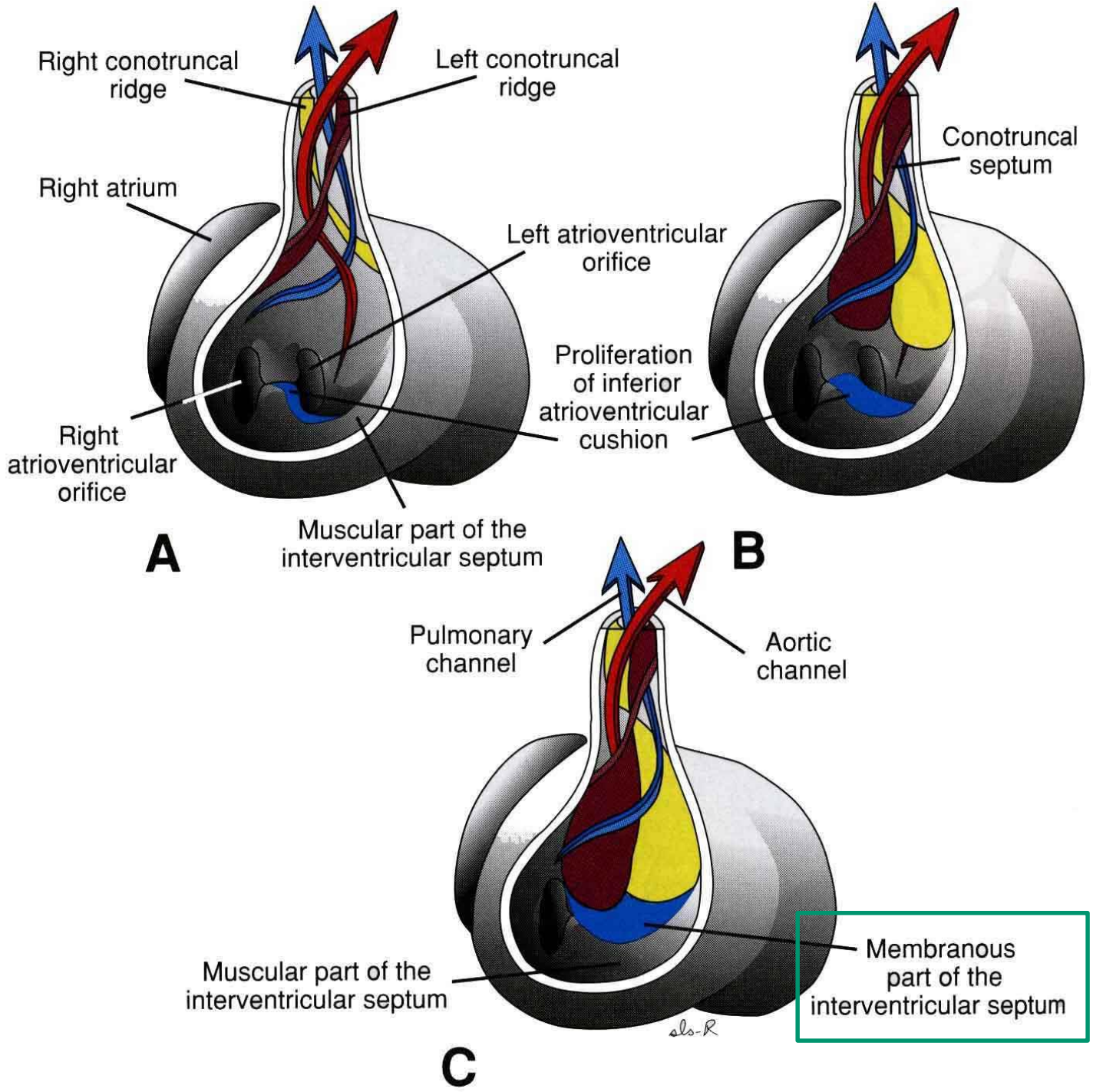

Dorsal mesocardium
Dorsal mesenchymal
protrusion
Septum primum
Pulmonary
vein
LA
RA

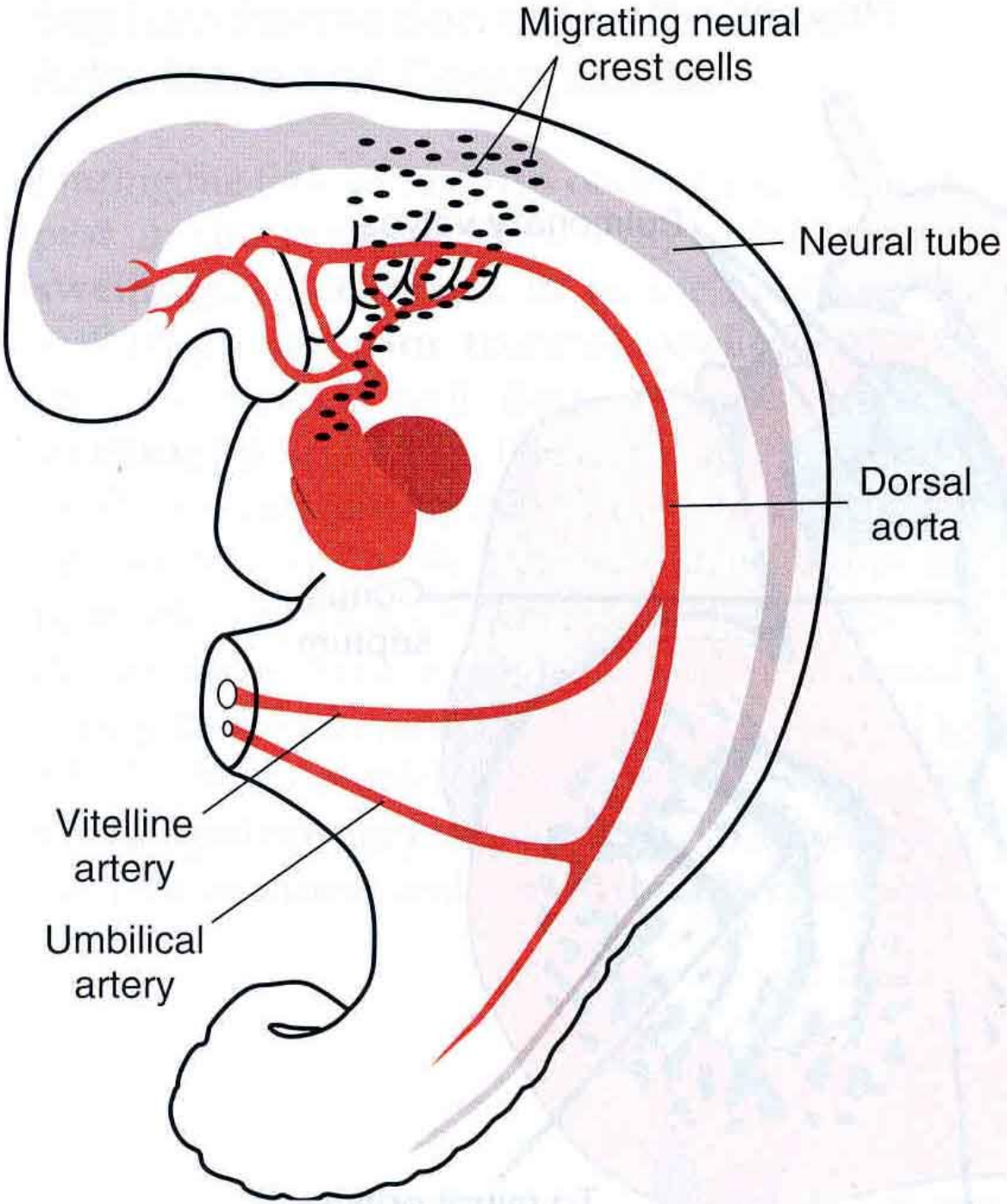

Septum
primum
Pulmonary
veins
LA
RA
Dorsal mesenchymal

cap

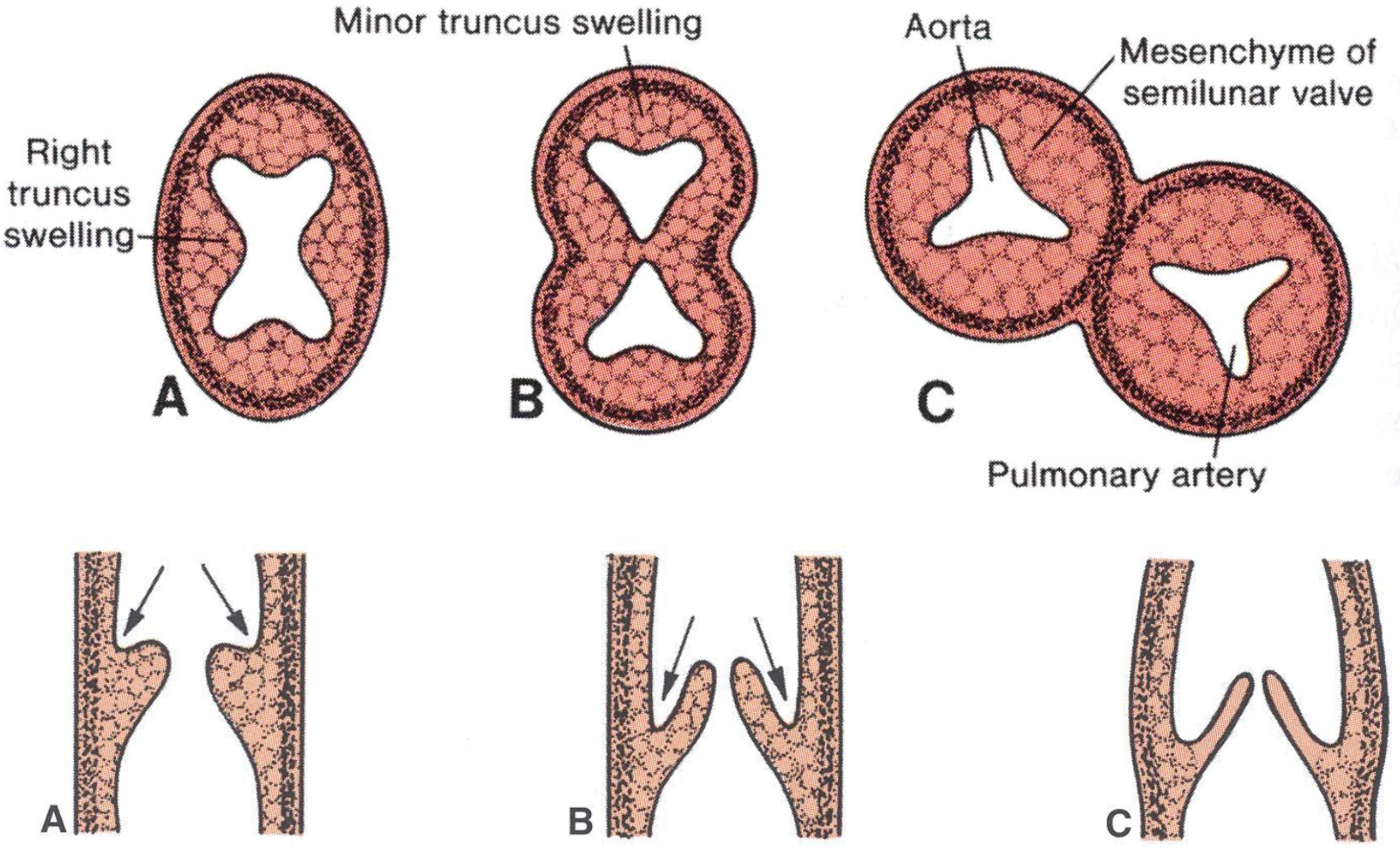
Ventricular septation



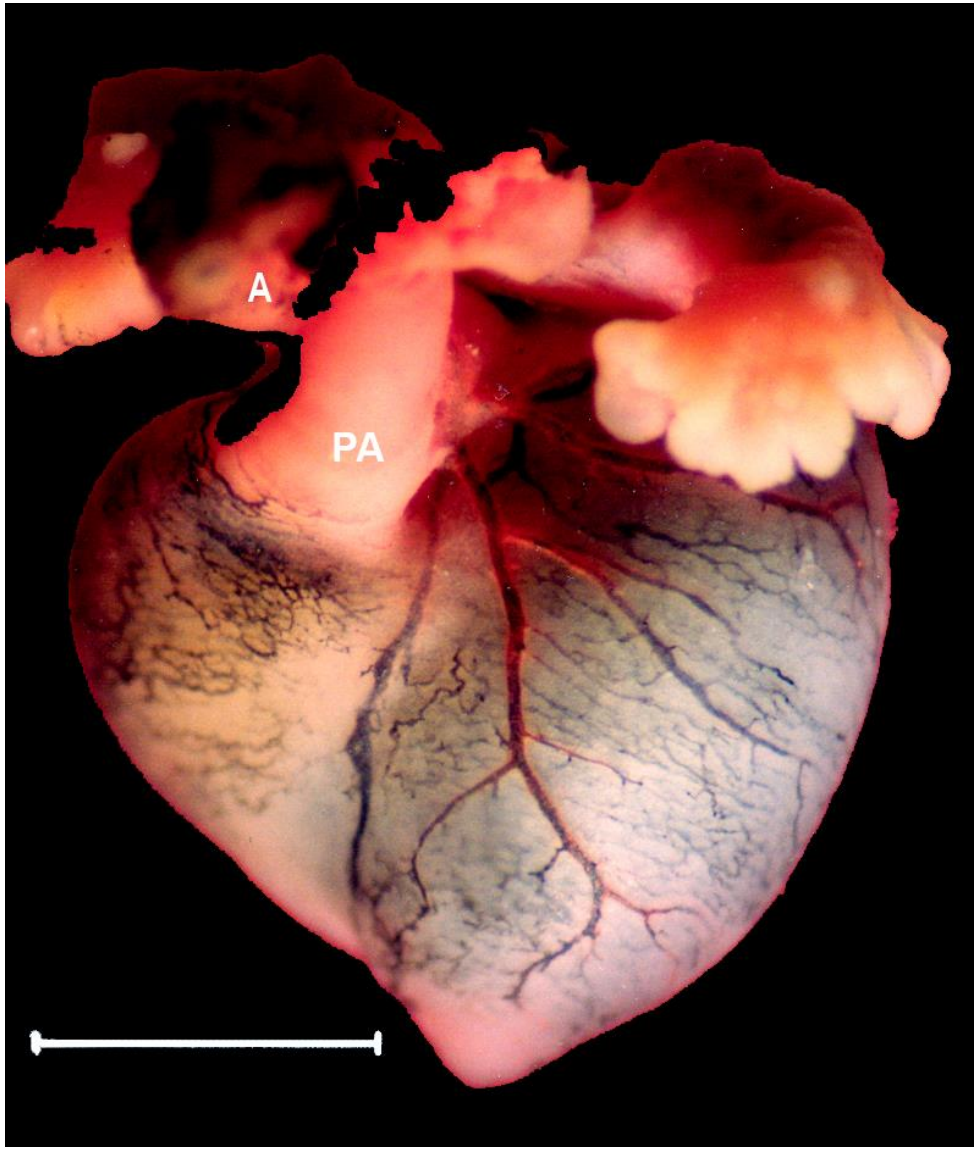

Right conotruncal ridge
Left conotruncal ridge
Right atrium
Left atrioventricular orifice
Right atrioventricular orifice
Muscular part of the interventricular septum
A
Conotruncal septum
Proliferation of inferior atrioventricular cushion
B
Pulmonary channel
Aortic channel
Muscular part of the interventricular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

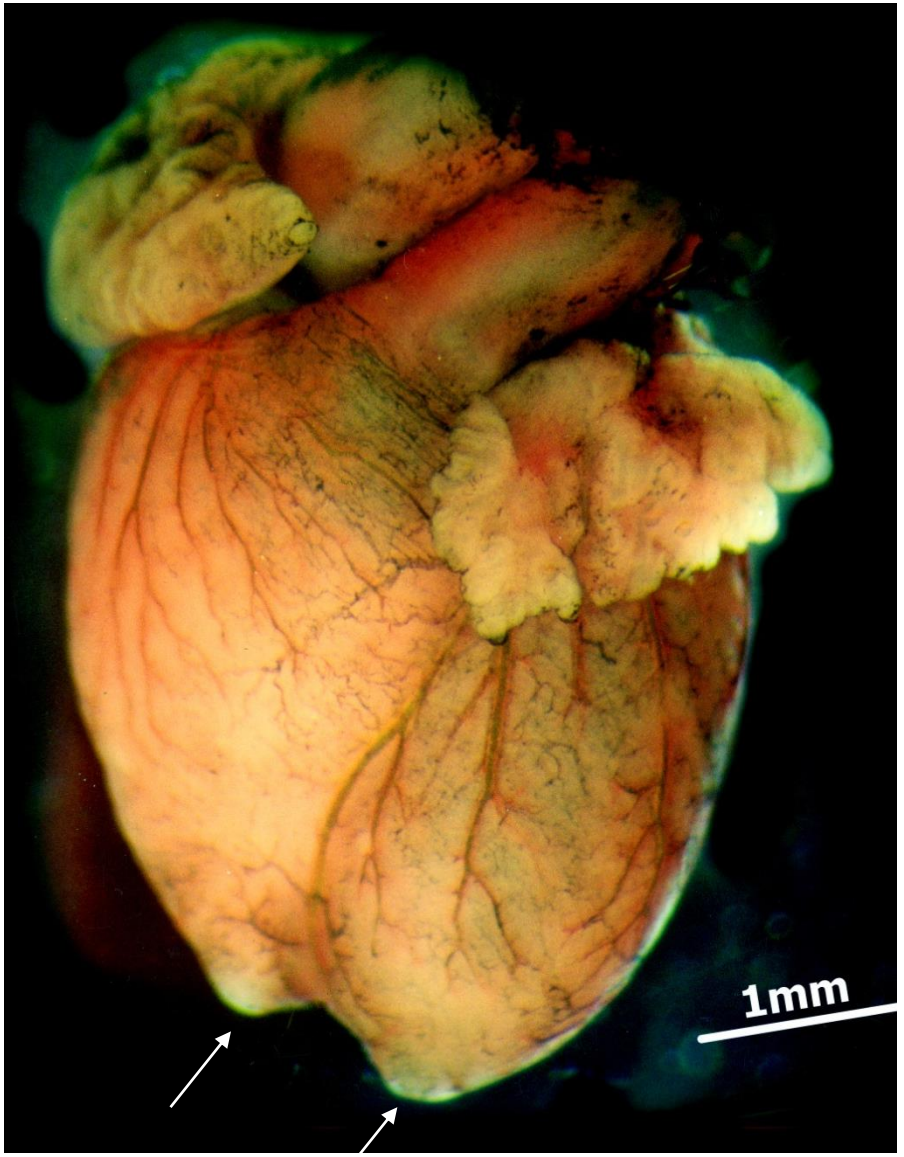

Migrating neural crest cells
Neural tube
Dorsal aorta
Vitelline artery
Umbilical artery

Semilunar valves



fetal heart

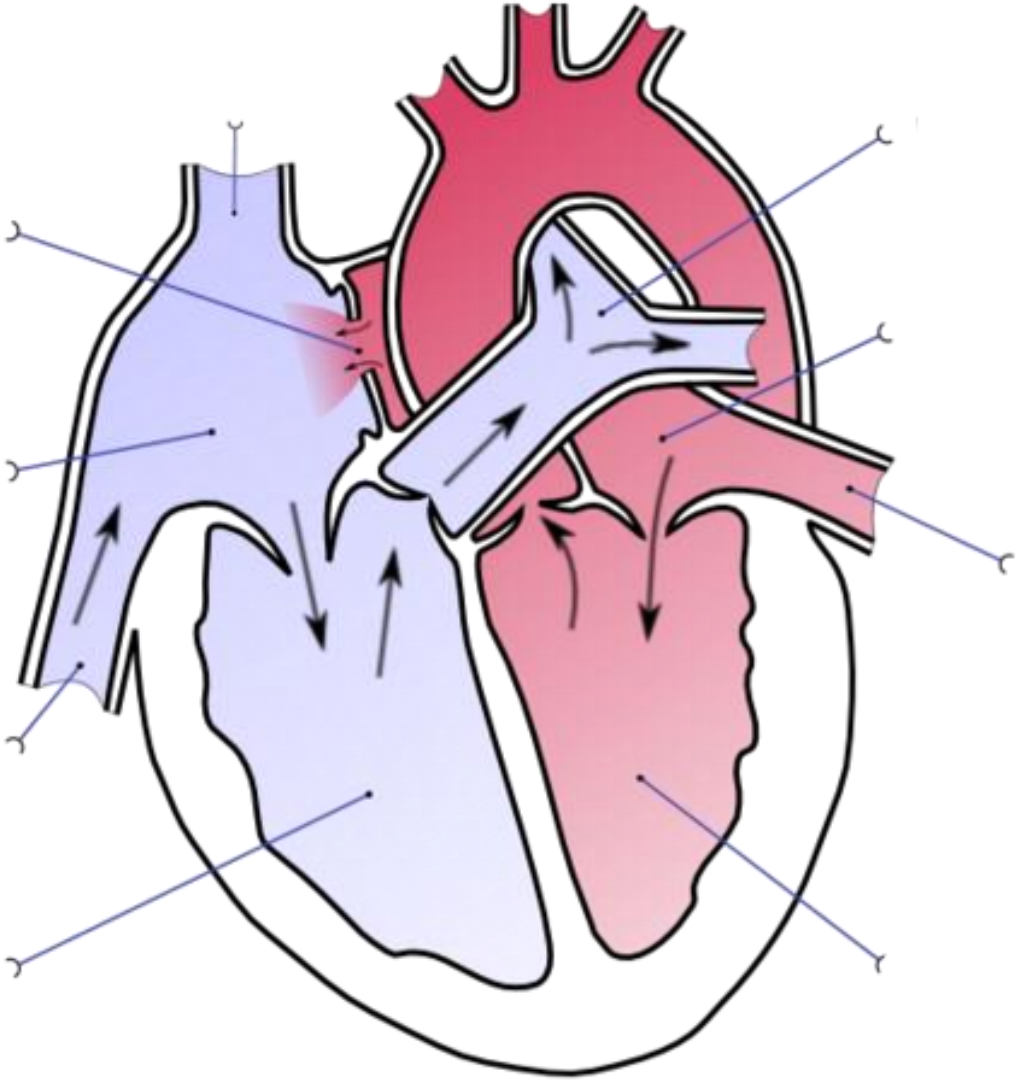




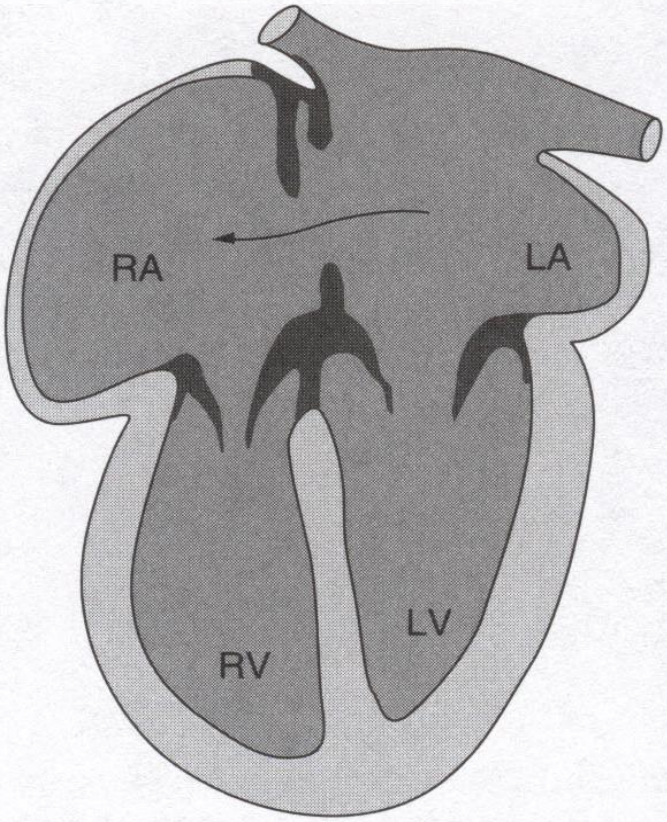
Atrial septal defect

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

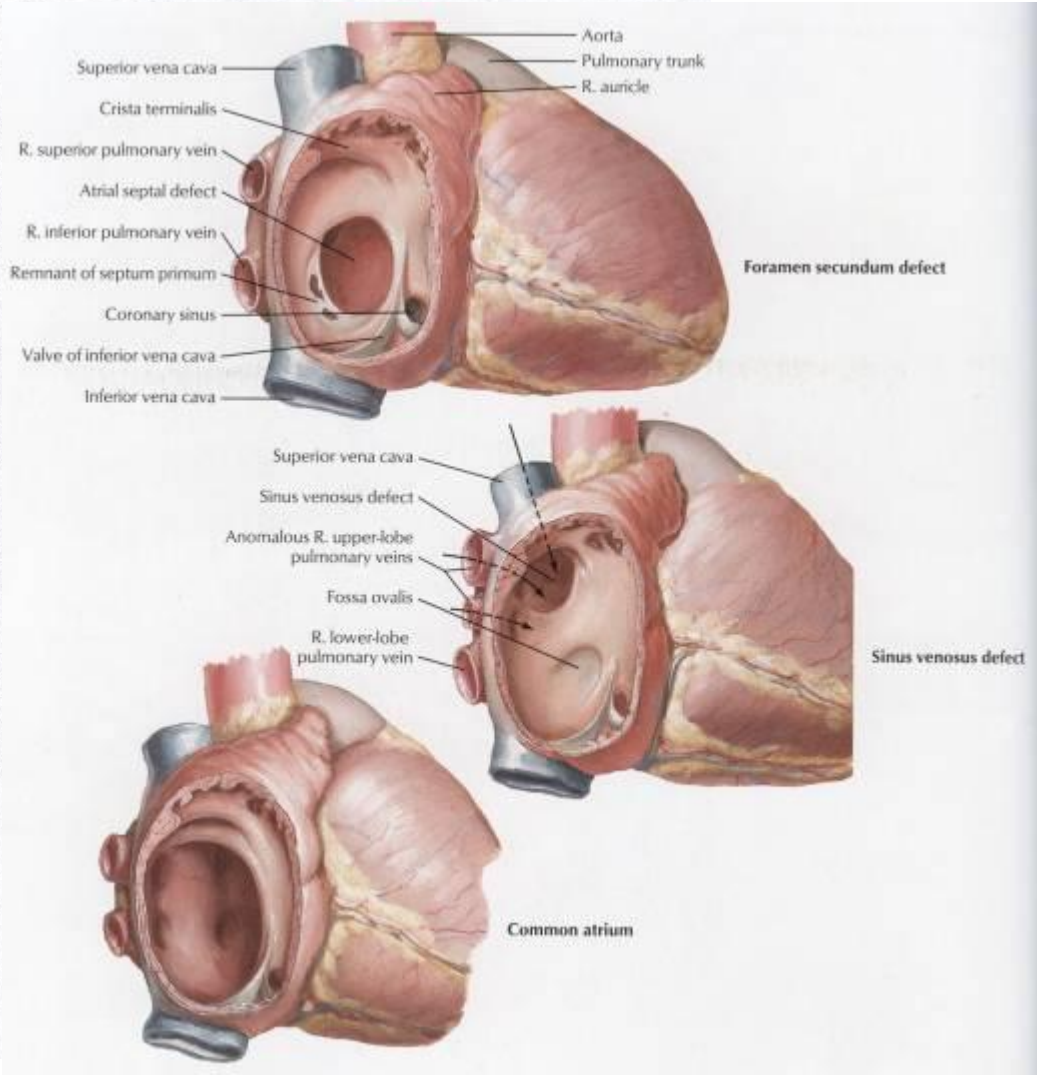
Foramen ovale patens



Atrial Septum Defect (ASD)



Foramen secundum defect



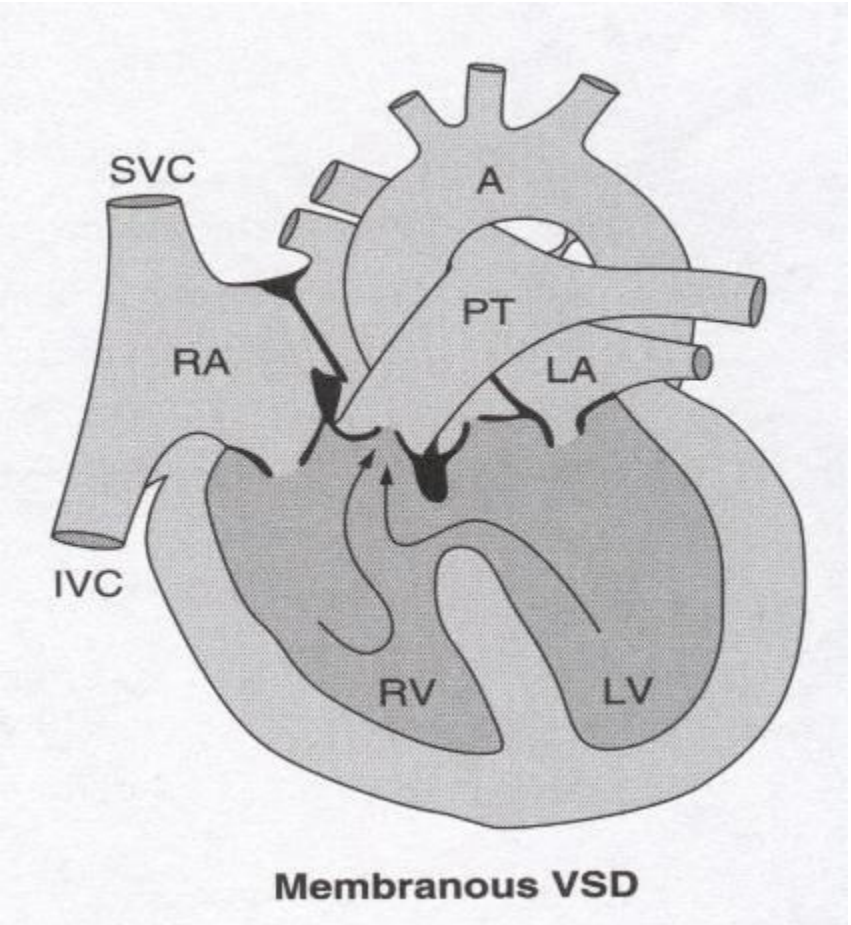
Larger defects - clinically remarkable left-to-right shunt, right overload, pulmonary hypertension, dyspnea, congestive heart failure

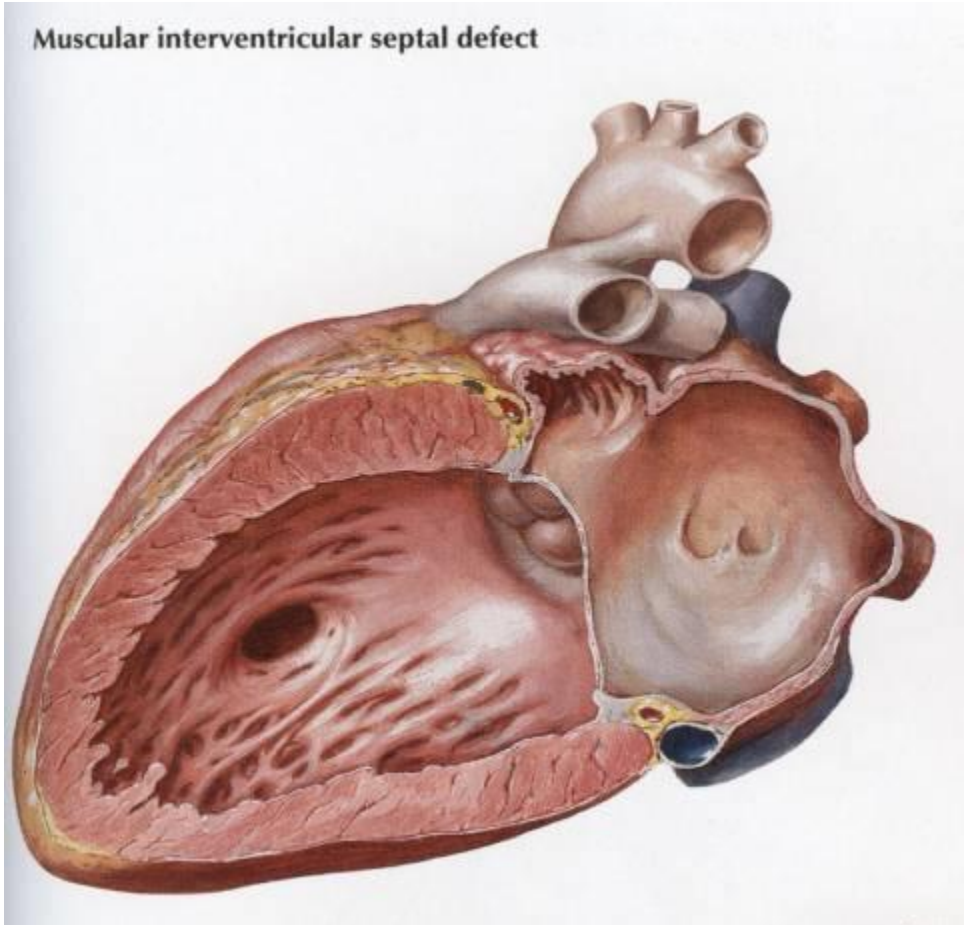
Ventricular septal defect

left to right shunting of blood, excessive fatigue upon exertion

• pulmonary blood flow is increased resulting in pulmonary hypertension

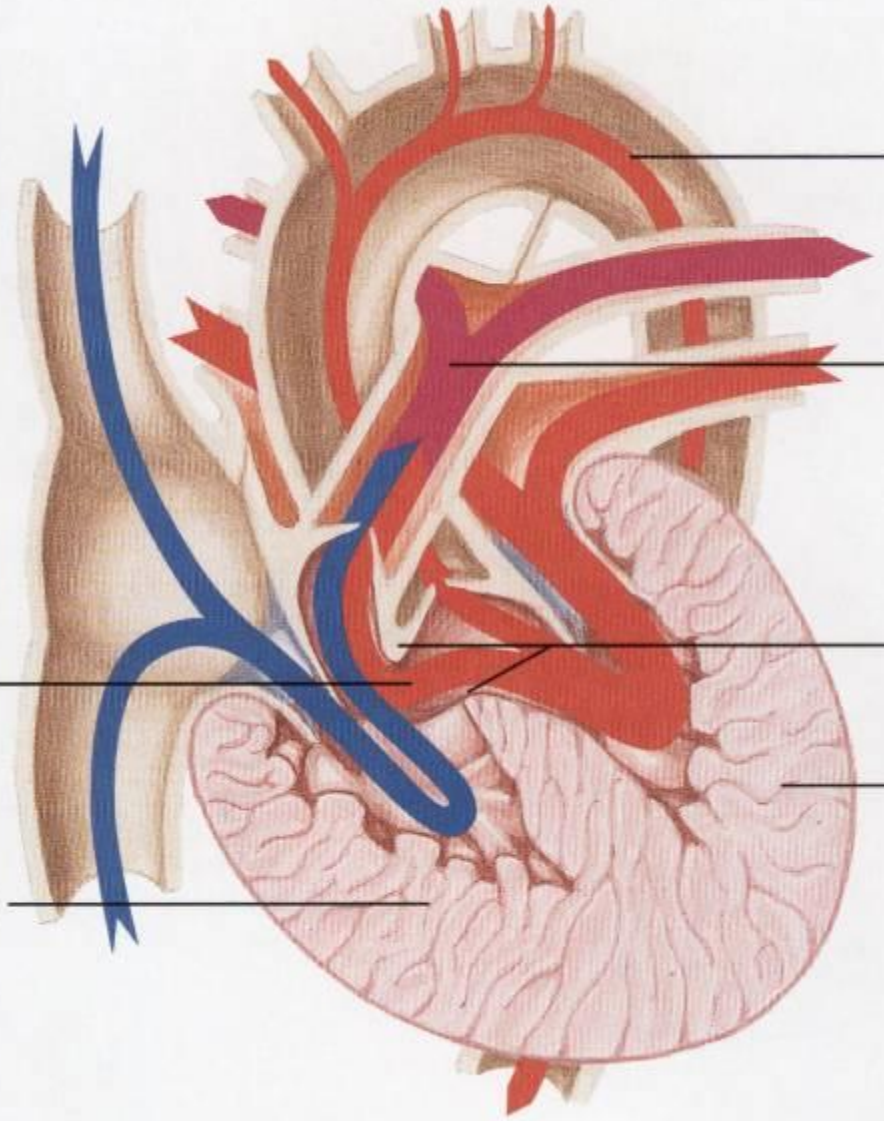
•later pulmonary resistance causes right to left shunting of blood and cyanosis (Eisenmenger syndrome)





Ventricular septal defect

Pathophysiology of ventricular septal defect



Decreased systemic flow

Increased pulmonary flow (pulmonary volume overload)

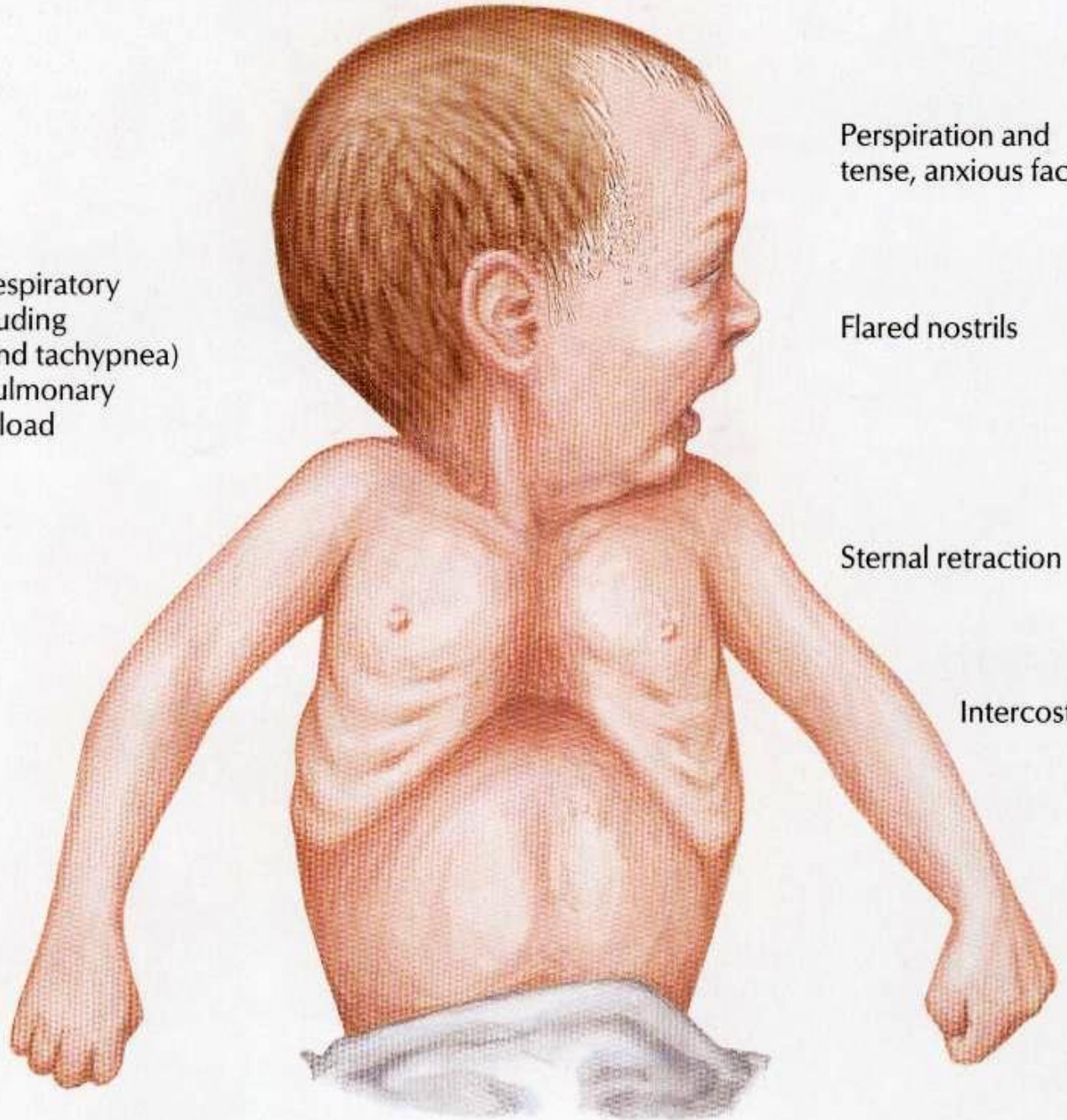
Left-to-right shunt through ventricular septal defect

Ventricular septal defect

Left ventricular hypertrophy

Right ventricular hypertrophy

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



Infant with respiratory distress (including orthopnea and tachypnea) caused by pulmonary volume overload

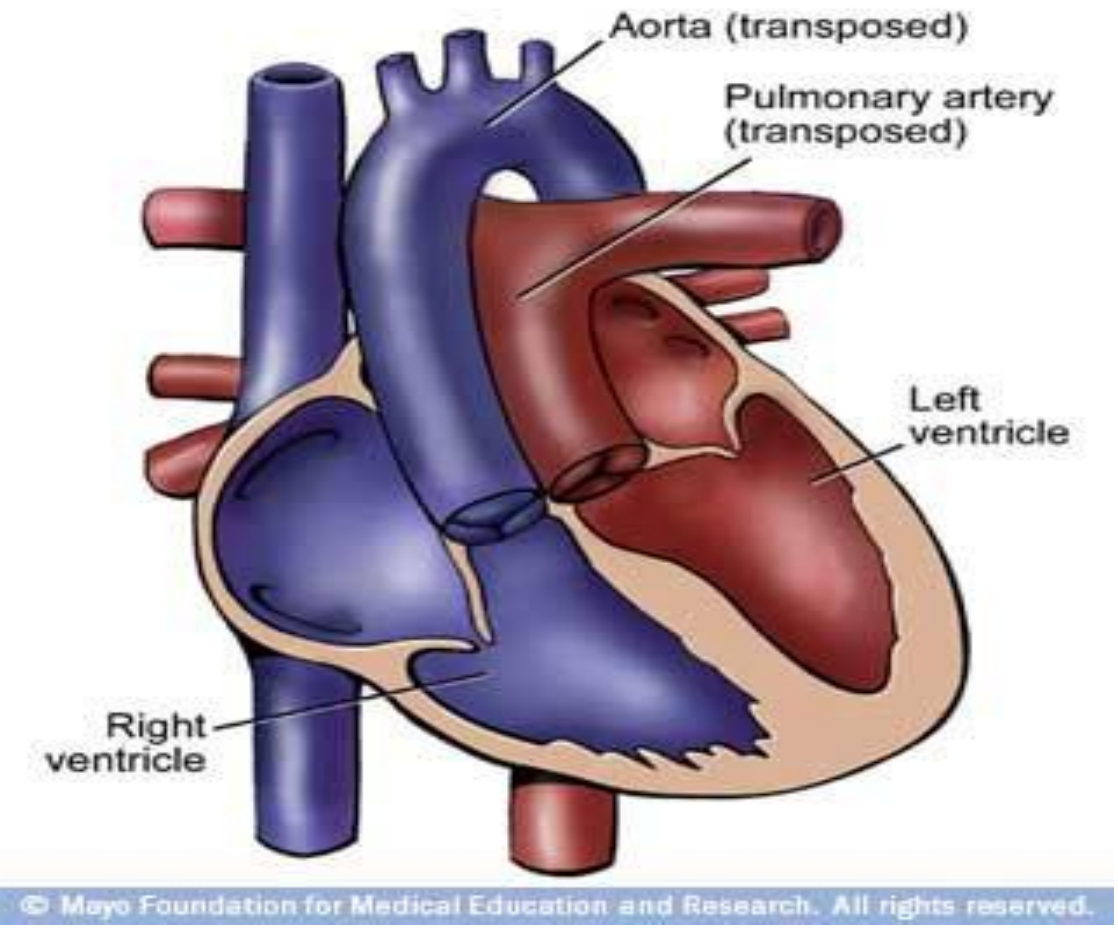
Perspiration and tense, anxious facies

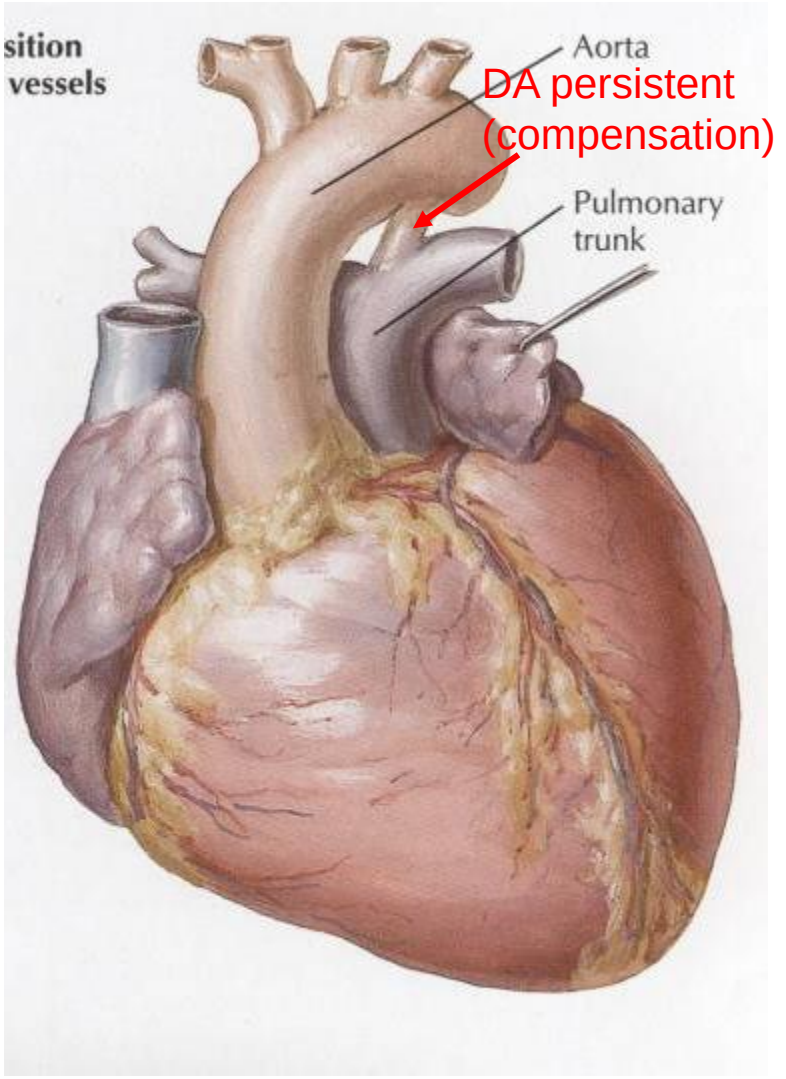
Flared nostrils

Sternal retraction

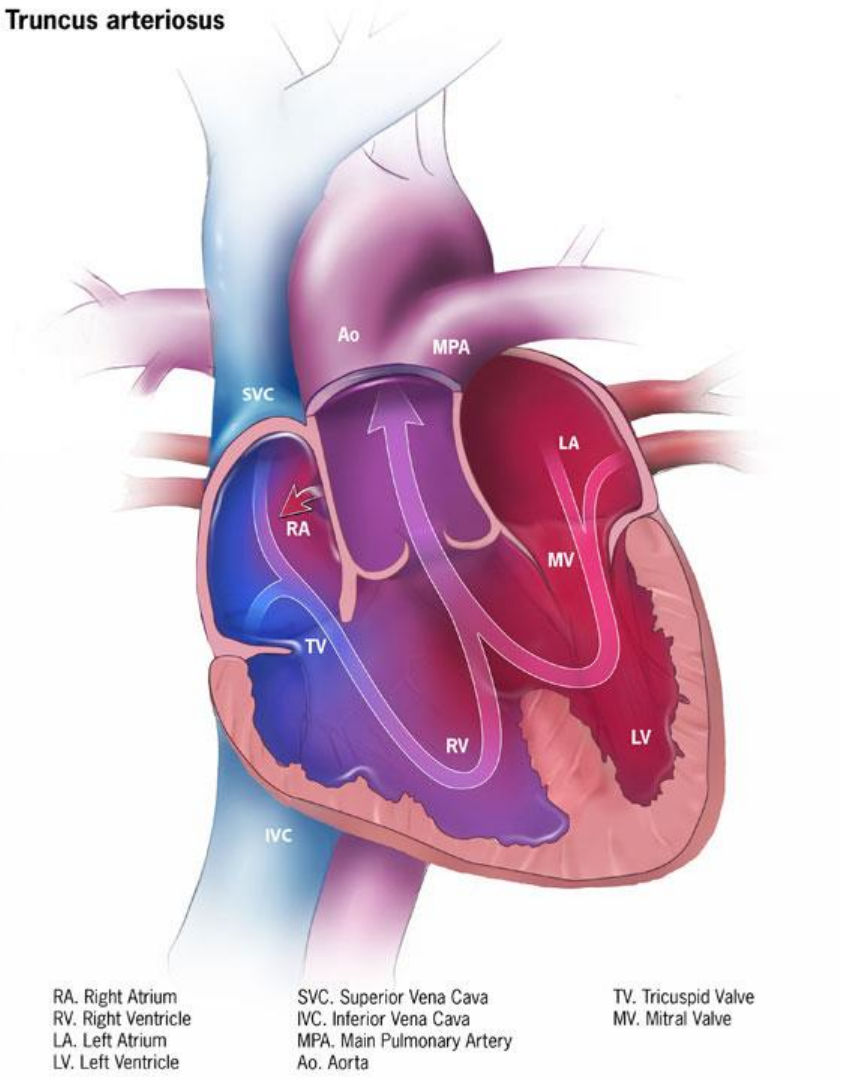
Intercostal retractions

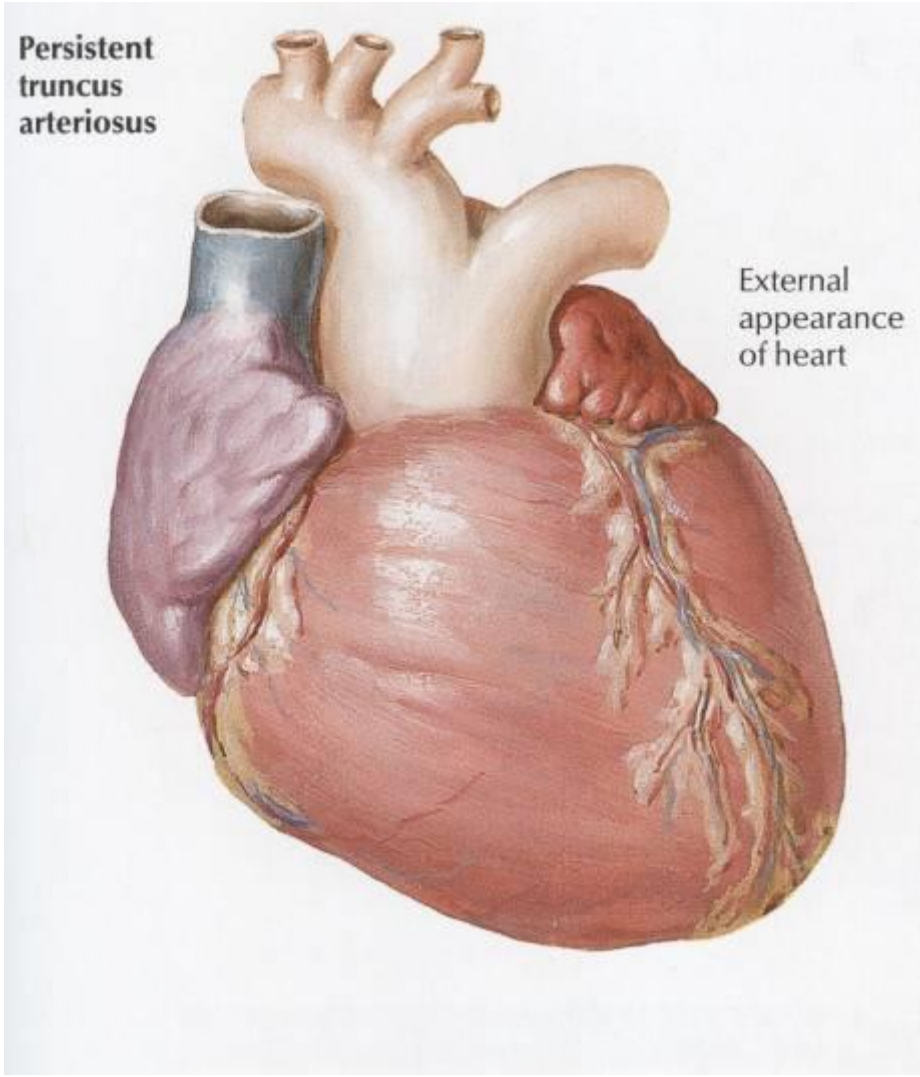
Transposition of great arteries





Persistent truncus arteriosus





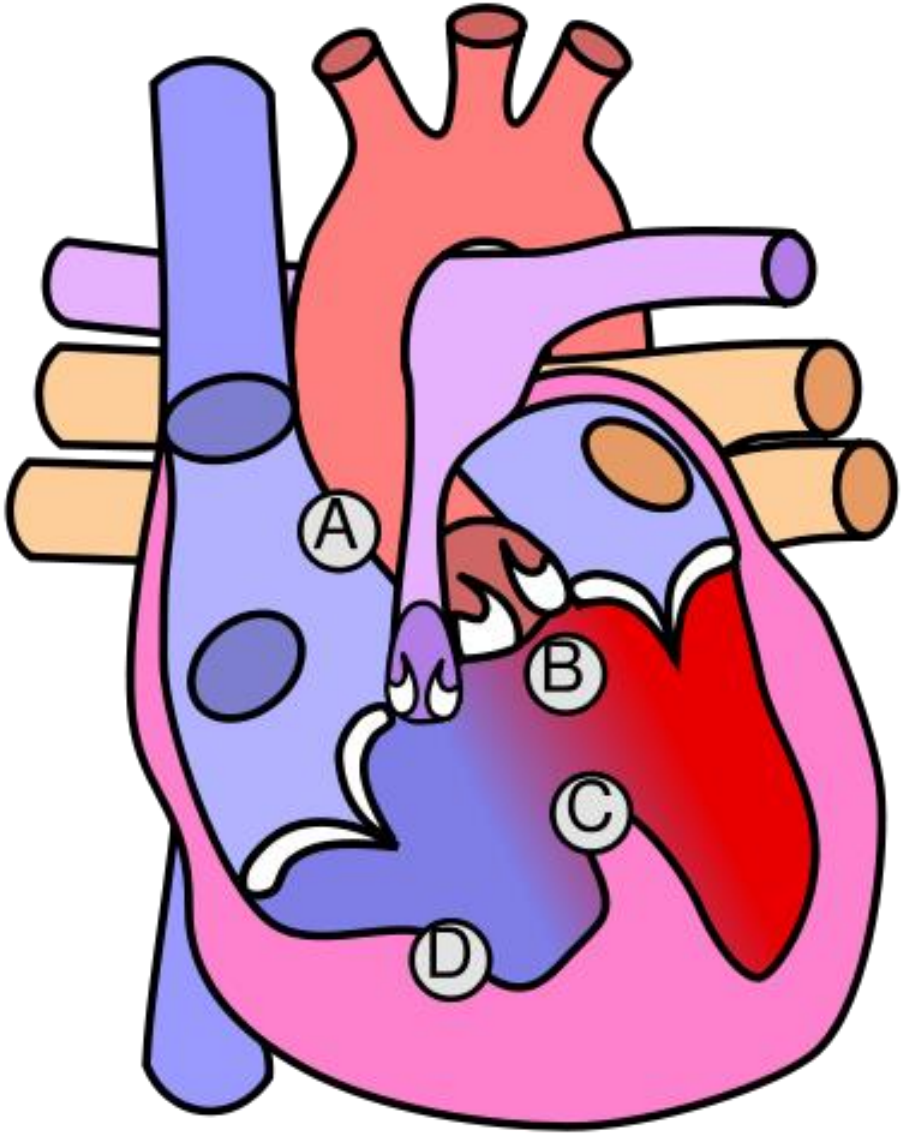
Tetralogy of Fallot

A – dextroposition of aorta (overriding aorta)

B – pulmonary stenosis (obstruction to right ventricle outflow)

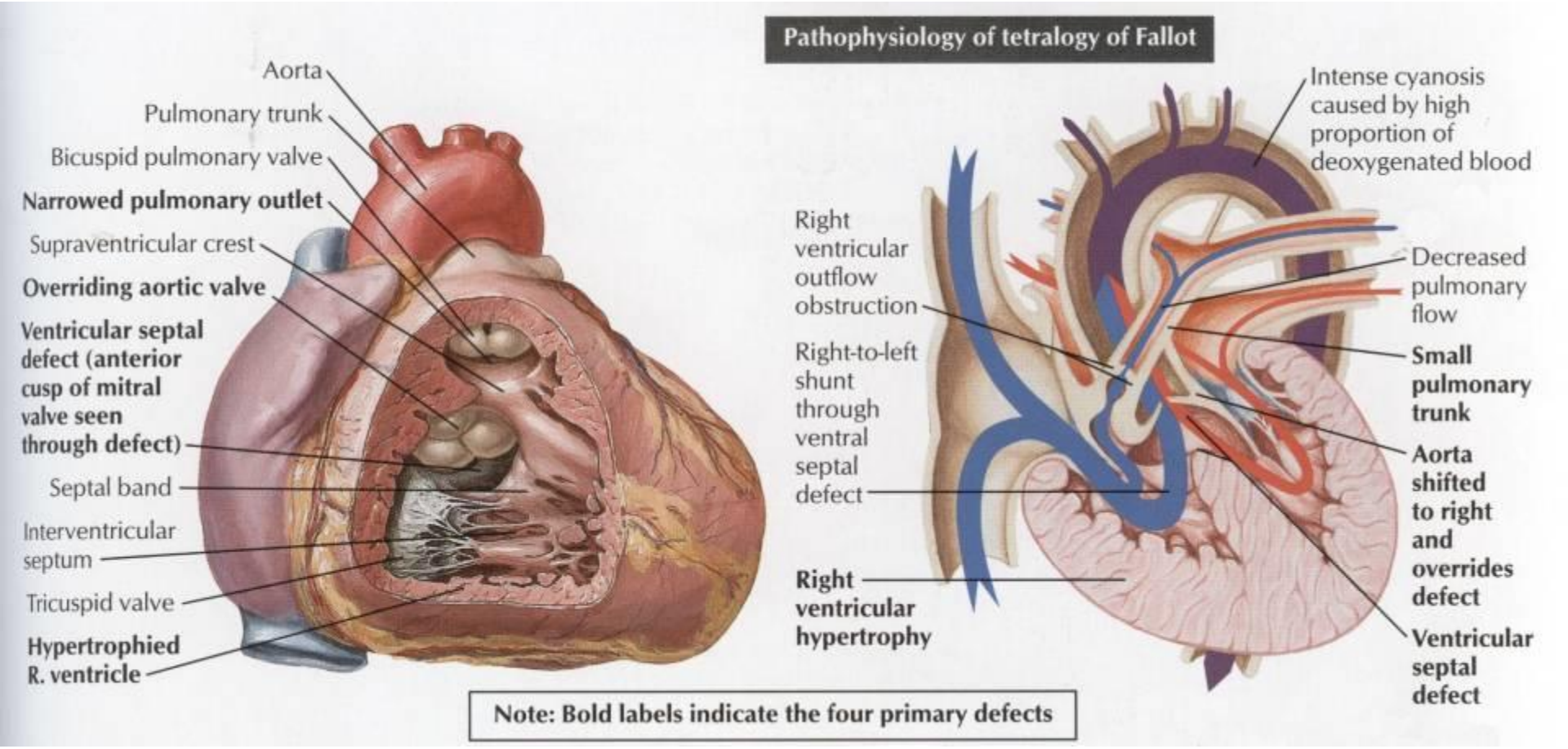
C – ventricular septal defect

D – right ventricular hypertrophy



Tetralogy of Fallot

1 ‰



Clinical characteristics of too little pulmonary flow

Cyanosis

Clubbing of fingers