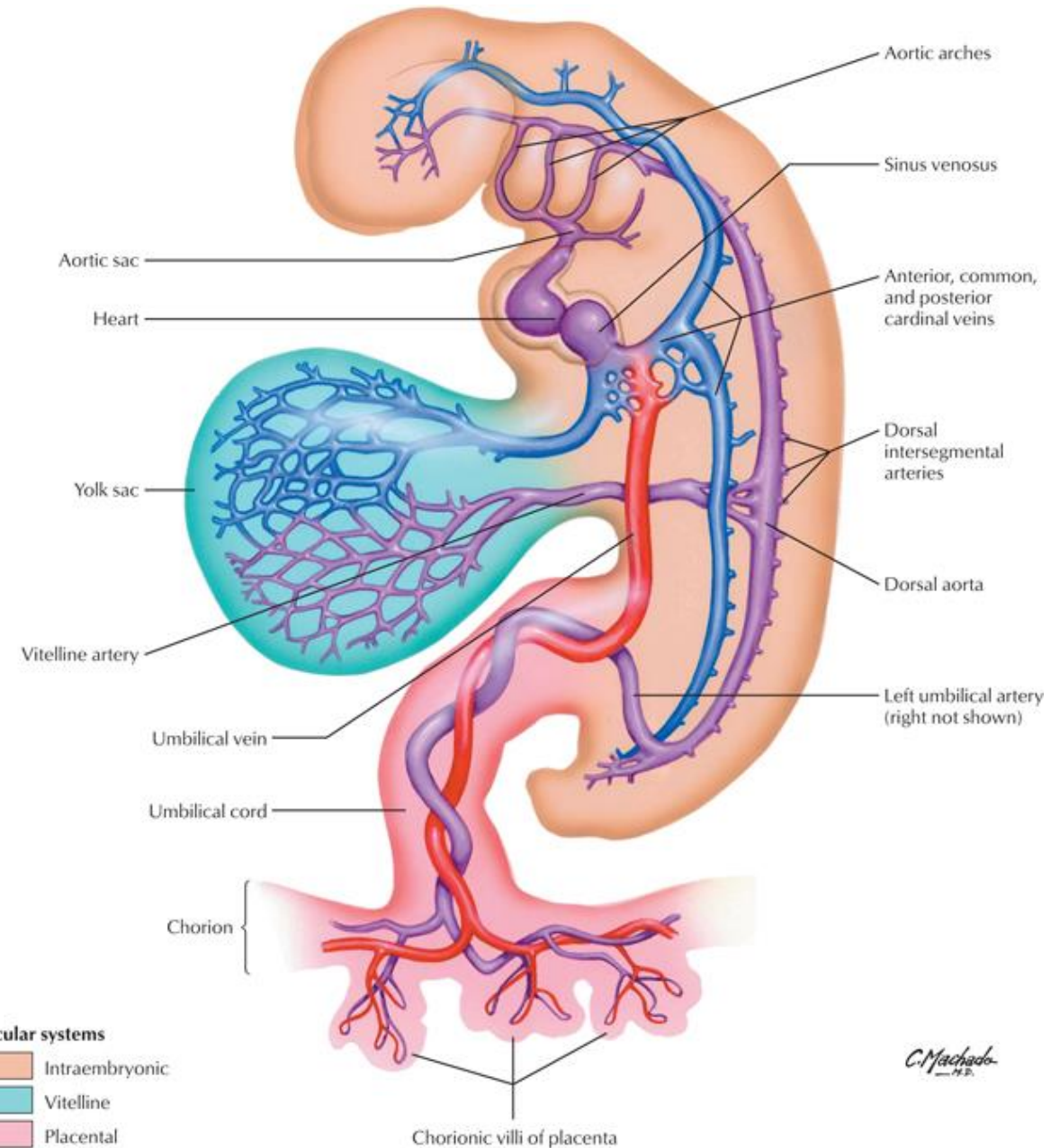


# Cardiovascular System Development

12. 12. 2023

Anna Malečková

anna.maleckova@lfp.cuni.cz



**Vascular systems**  
Intraembryonic  
Vitelline  
Placental

Cochard: Netter's Atlas of Human Embryology  
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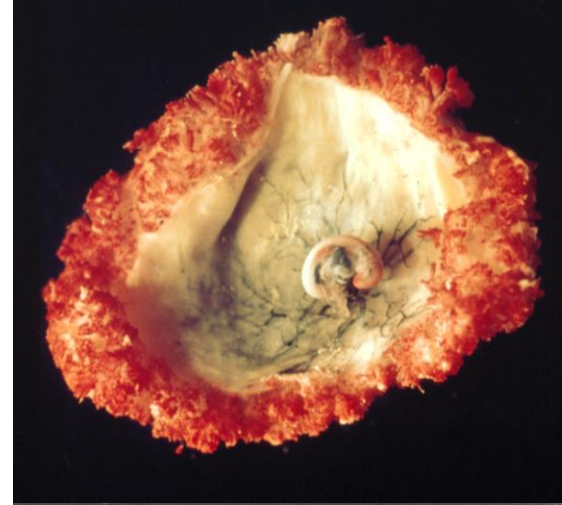
C. Machado

# Vascular development

- Blood islands
- Primitive embryonic circulation and its unification
- Arterial system and aortic arches
- Arterial developmental defects
- Venous system

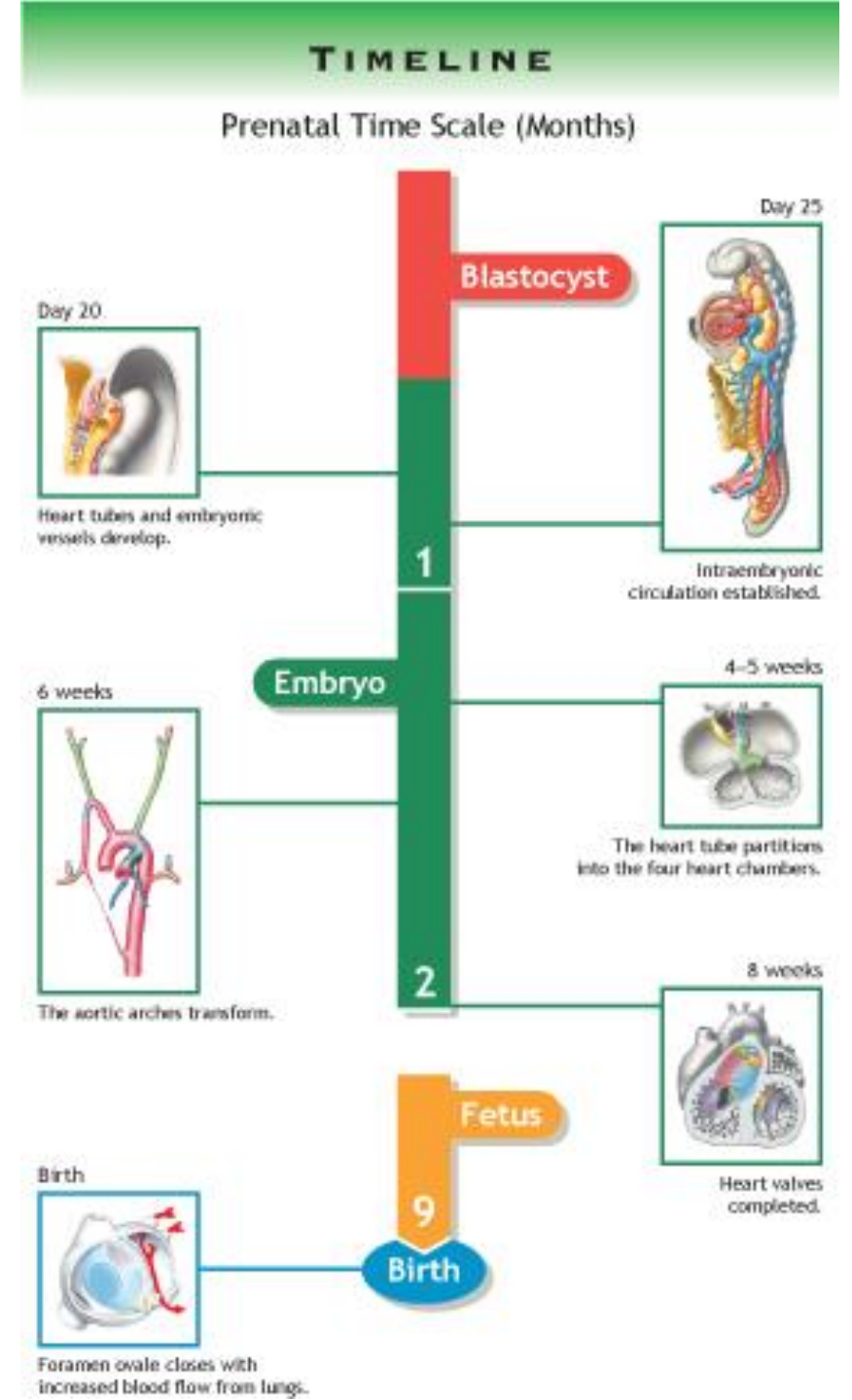
# Heart development

- Heart tube and cardiac looping
- Atrial septation
- Ventricular septation
- Heart developmental defects
- Fetal circulation



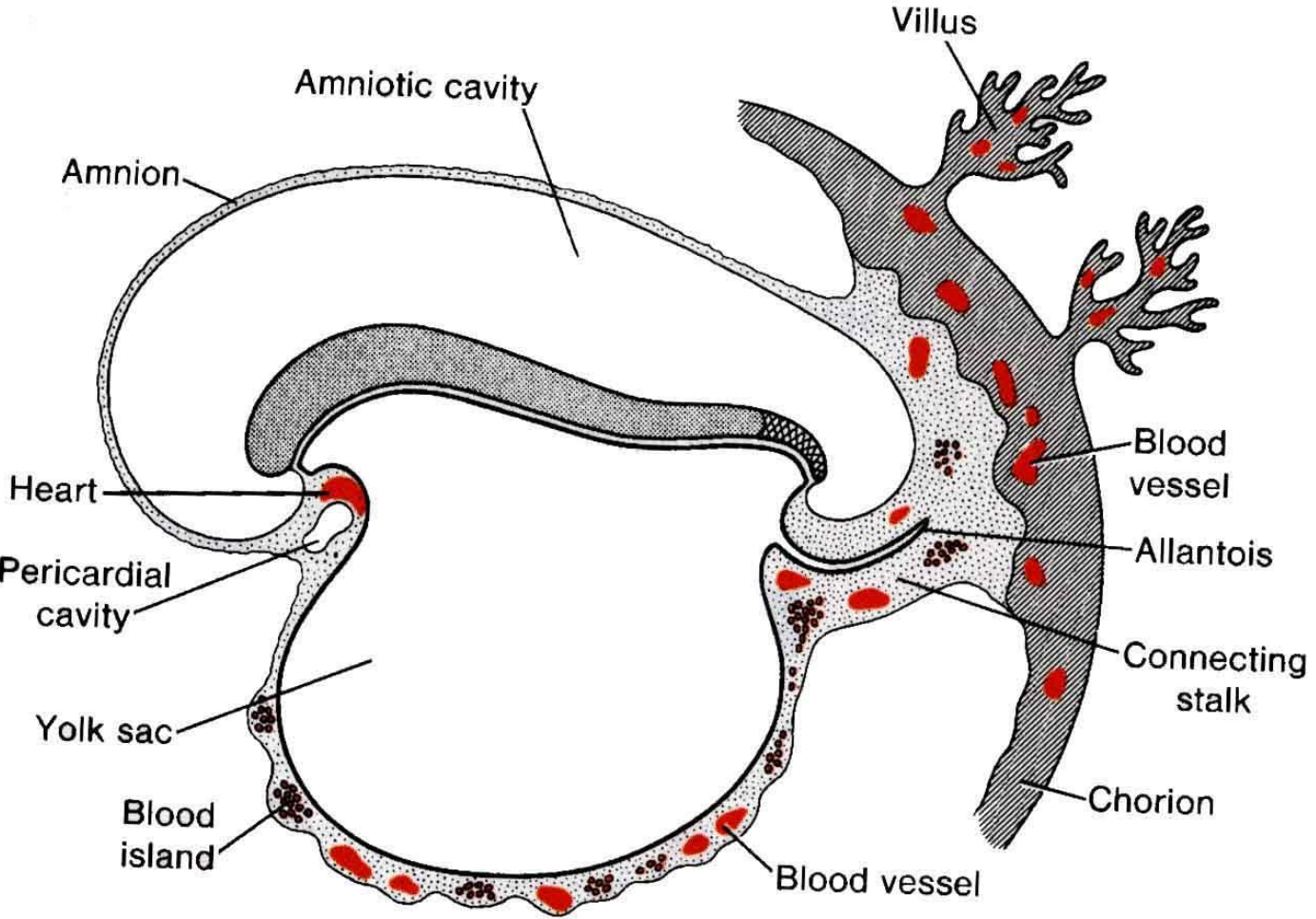
# Timeline of Cardiovascular System Development

- Day 20: heart tube and embryonic vessels develop
- Day 22: heart contractions
- Day 25: intraembryonic circulation established
- Week 4–5 : heart tube partitions into four chambers
- Week 6: aortic arches remodeling
- Week 8: heart valves are completed

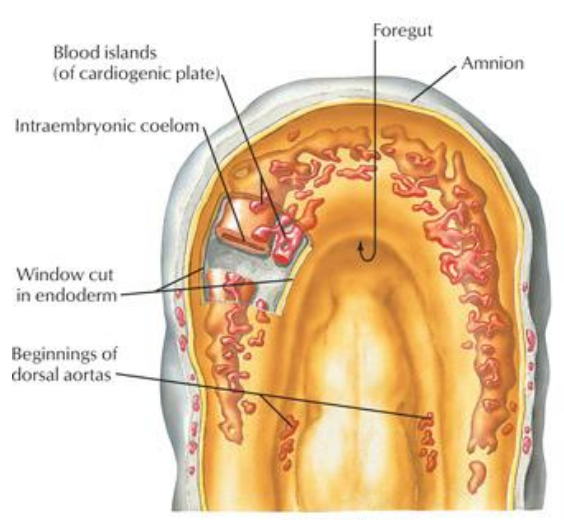




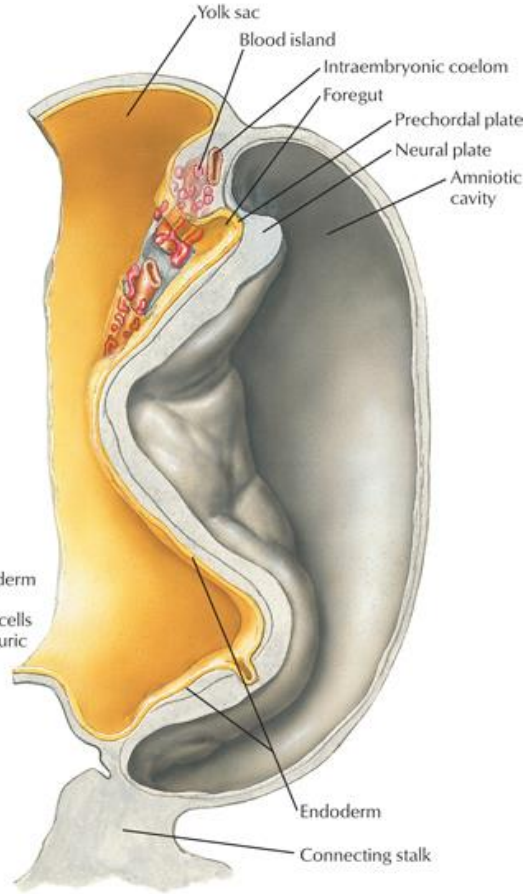
# Blood islands – extraembryonal mesenchyme



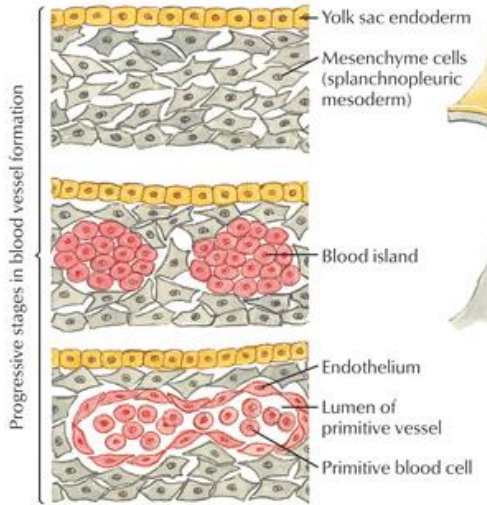
Presomite stage (1.5-mm embryo) at approximately 20 days



Ventral dissection

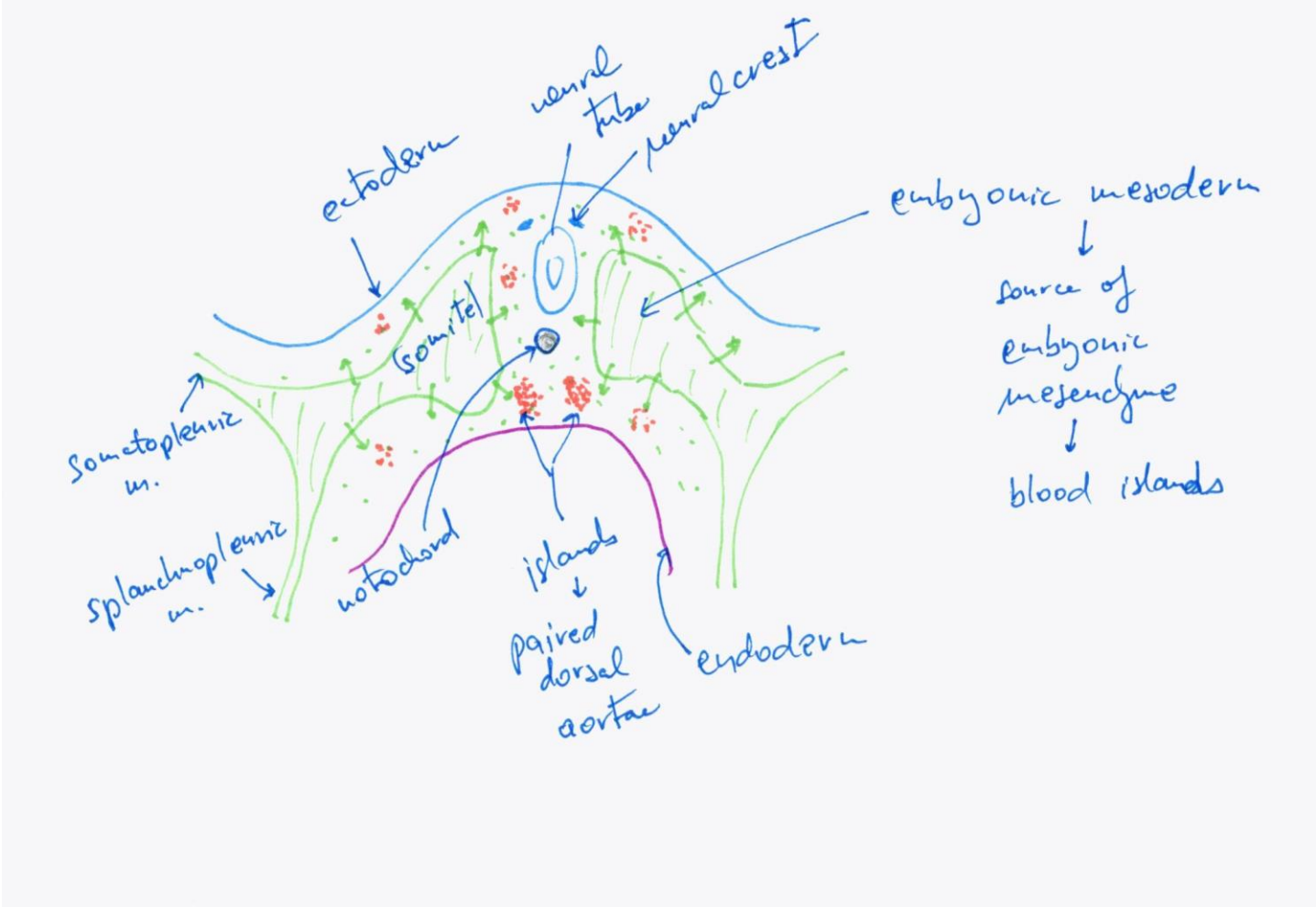


Sagittal dissection (paramedian)



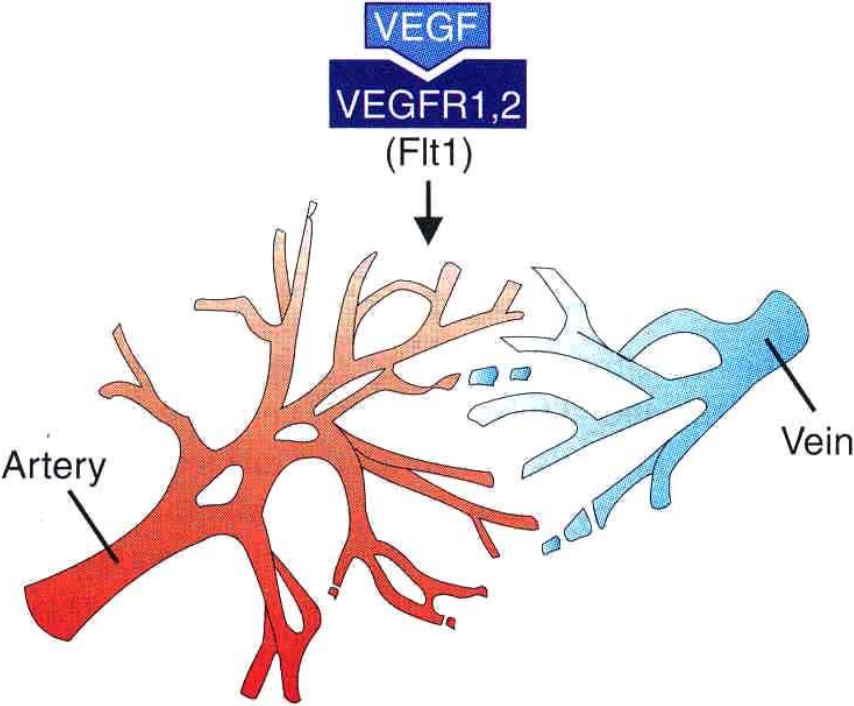
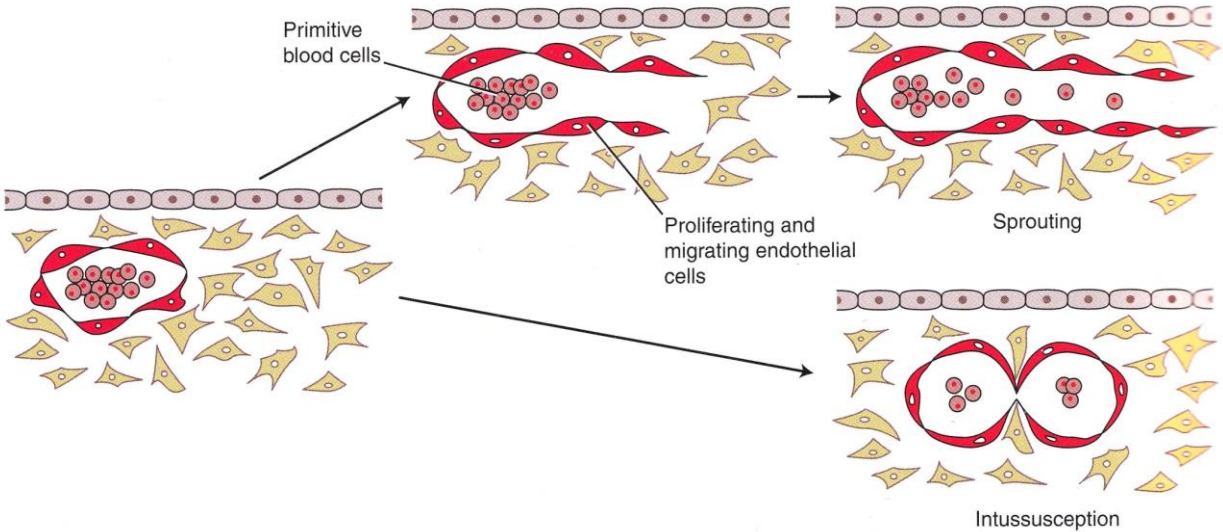
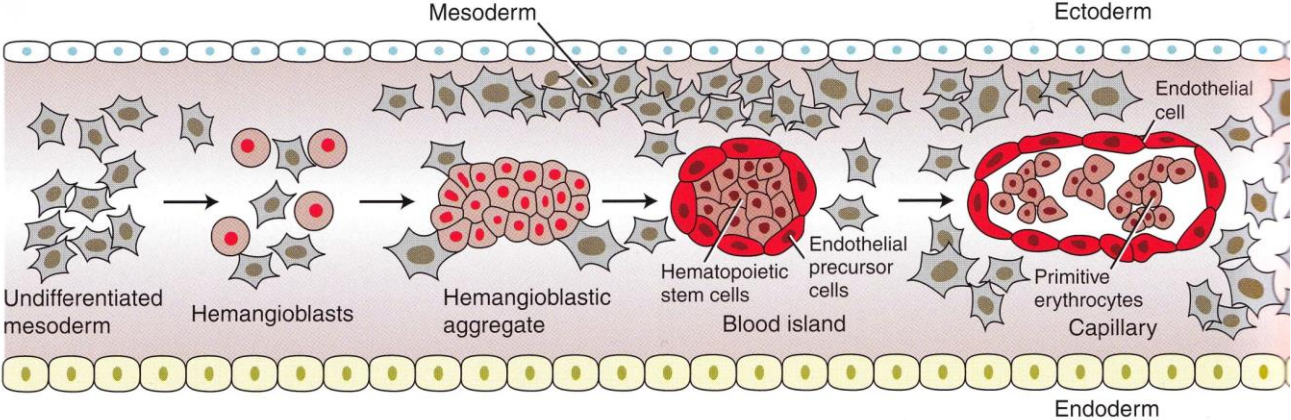
Cochard: Netter's Atlas of Human Embryology  
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# Blood islands – intarembryonal mesenchyme

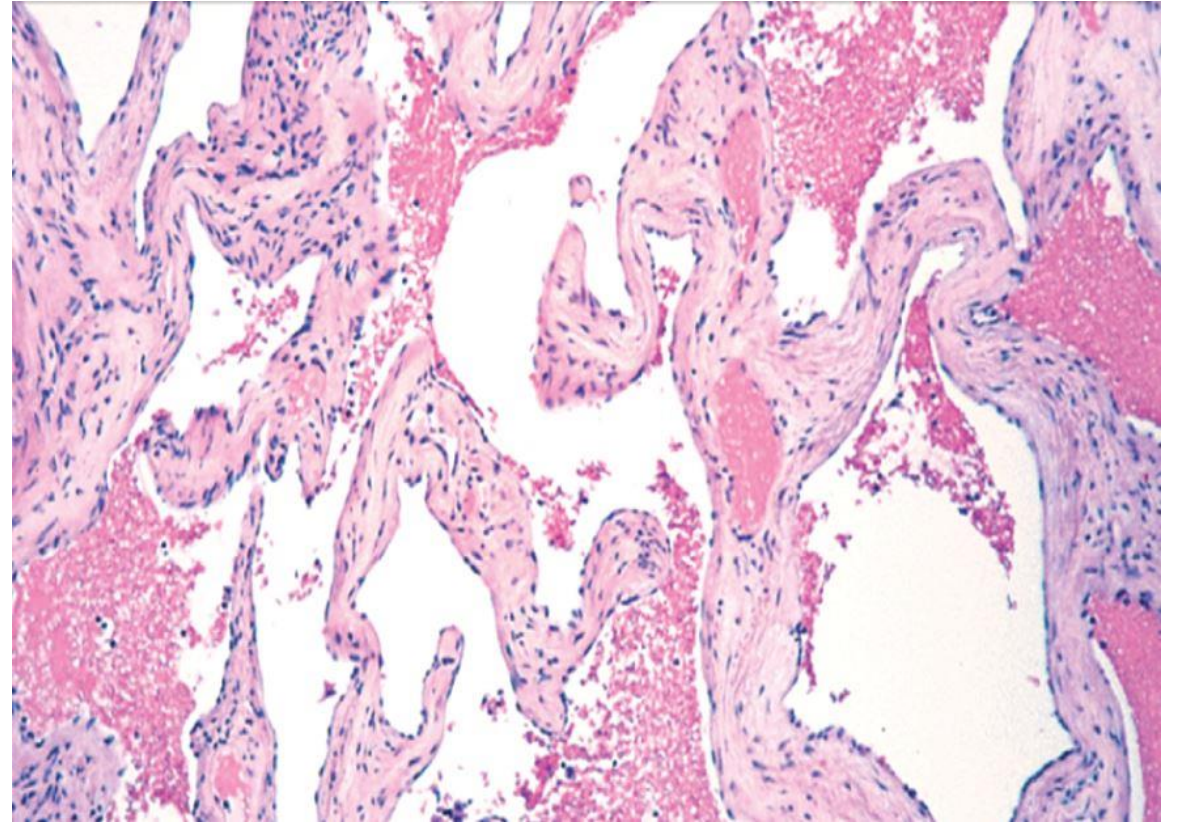




# Vasculogenesis - angiogenesis

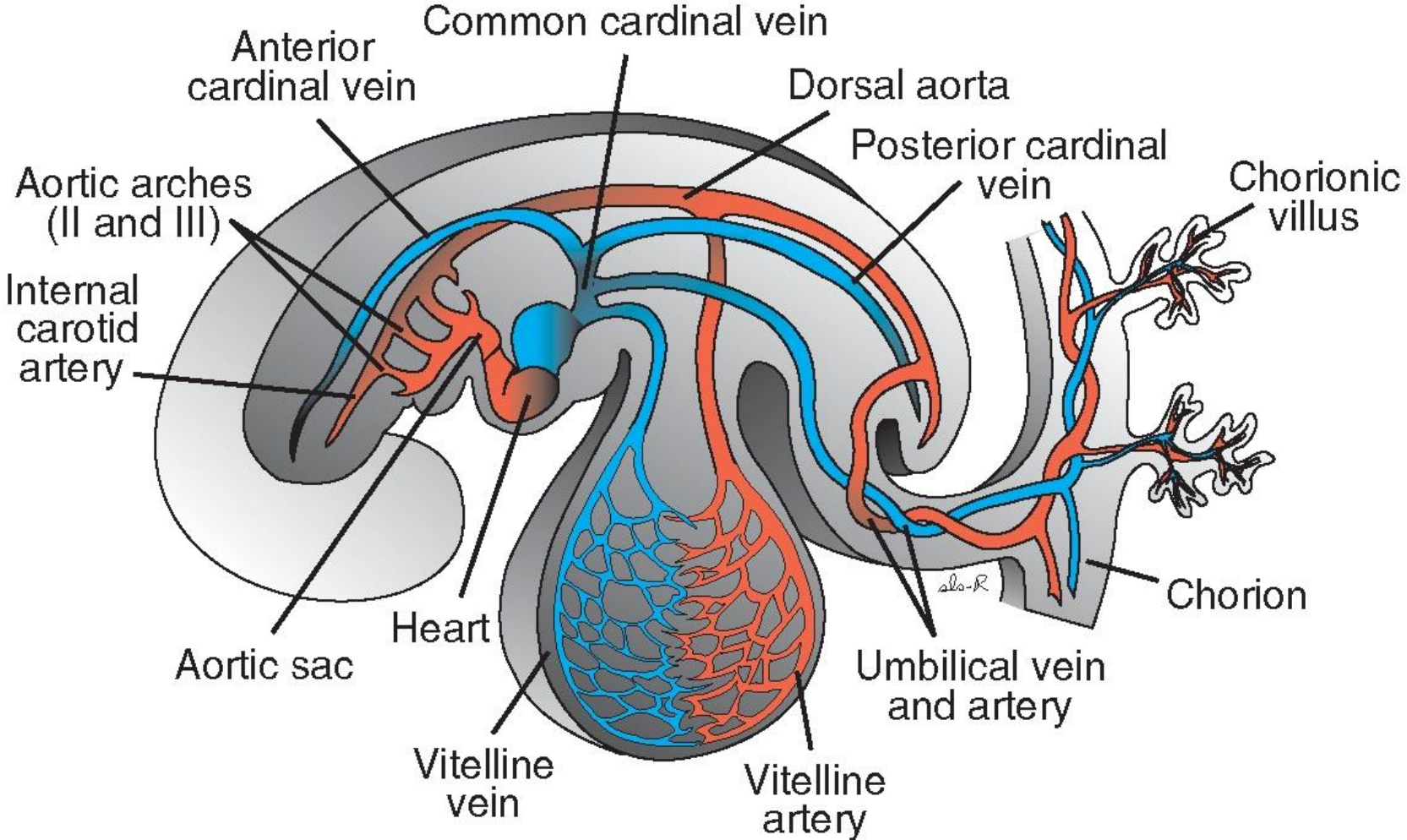


# Hemangioma



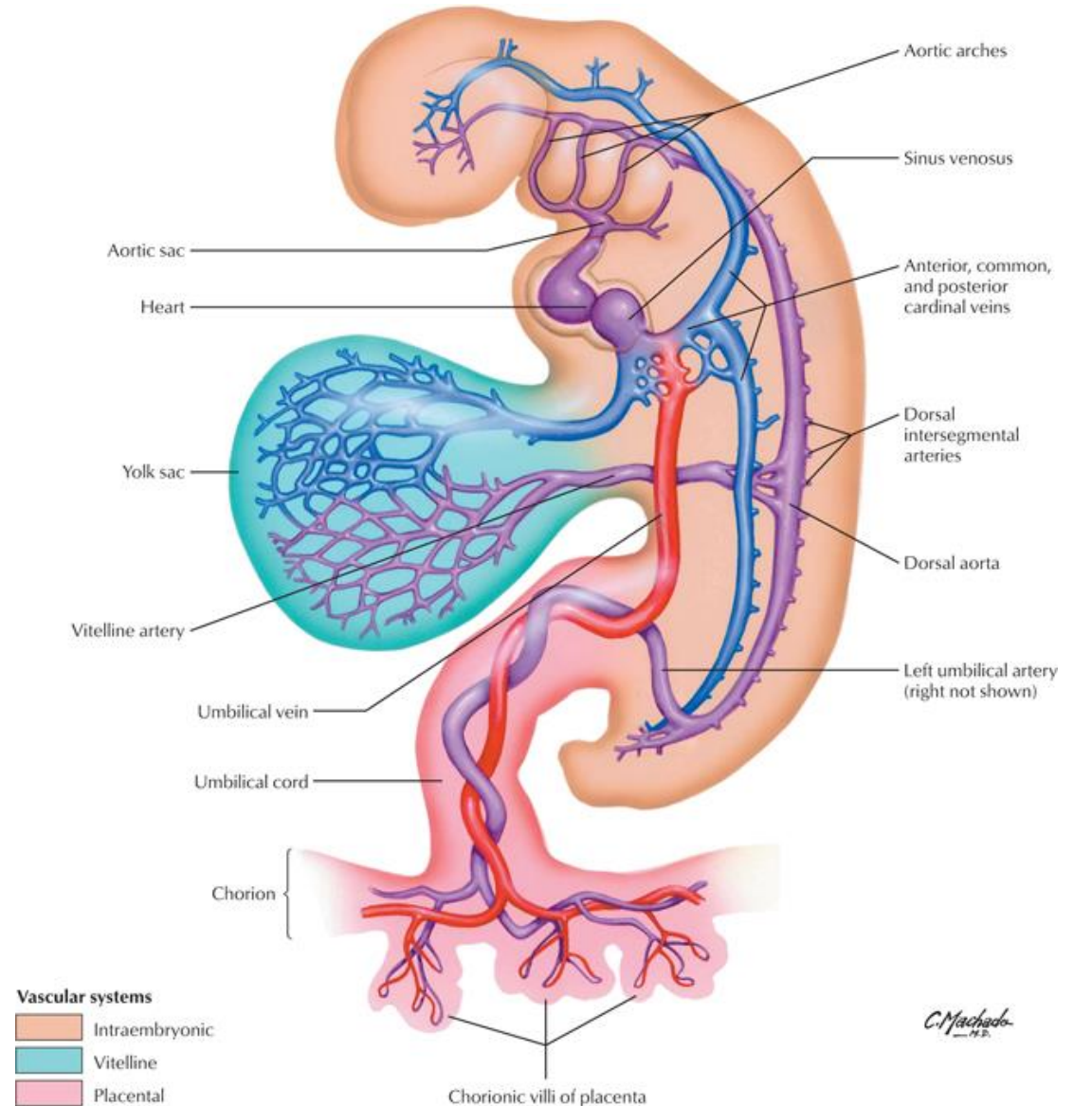


# Primitive bilateral embryonic circulation



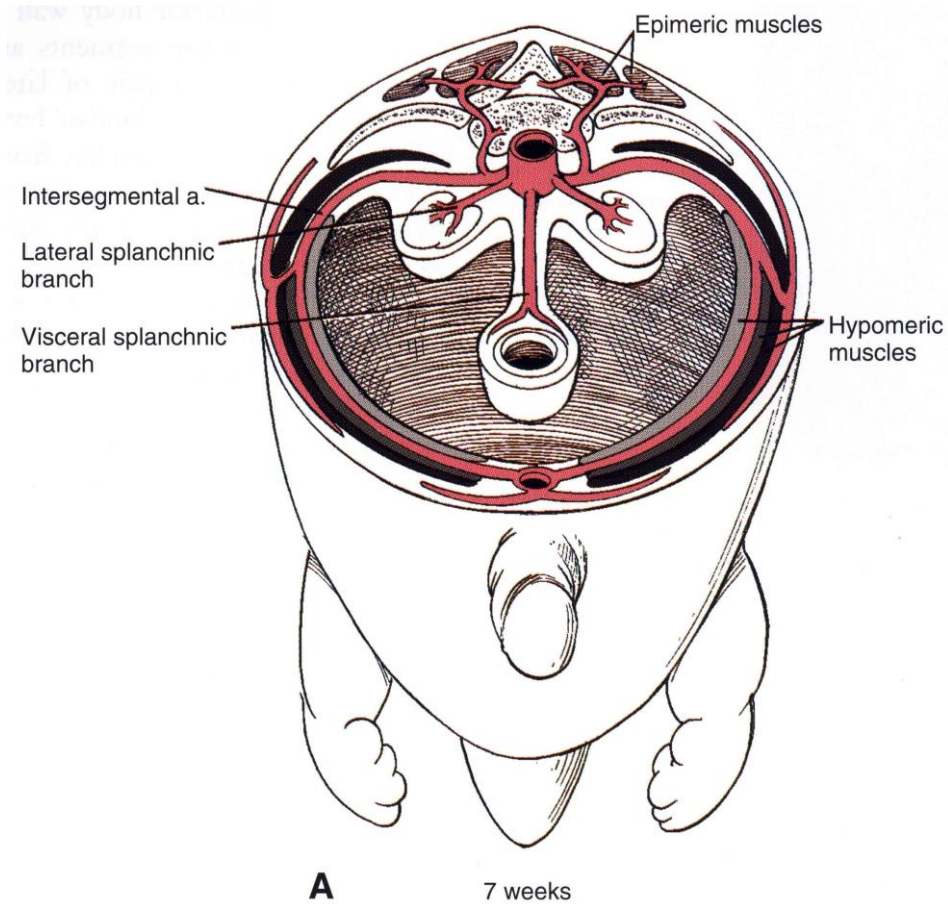
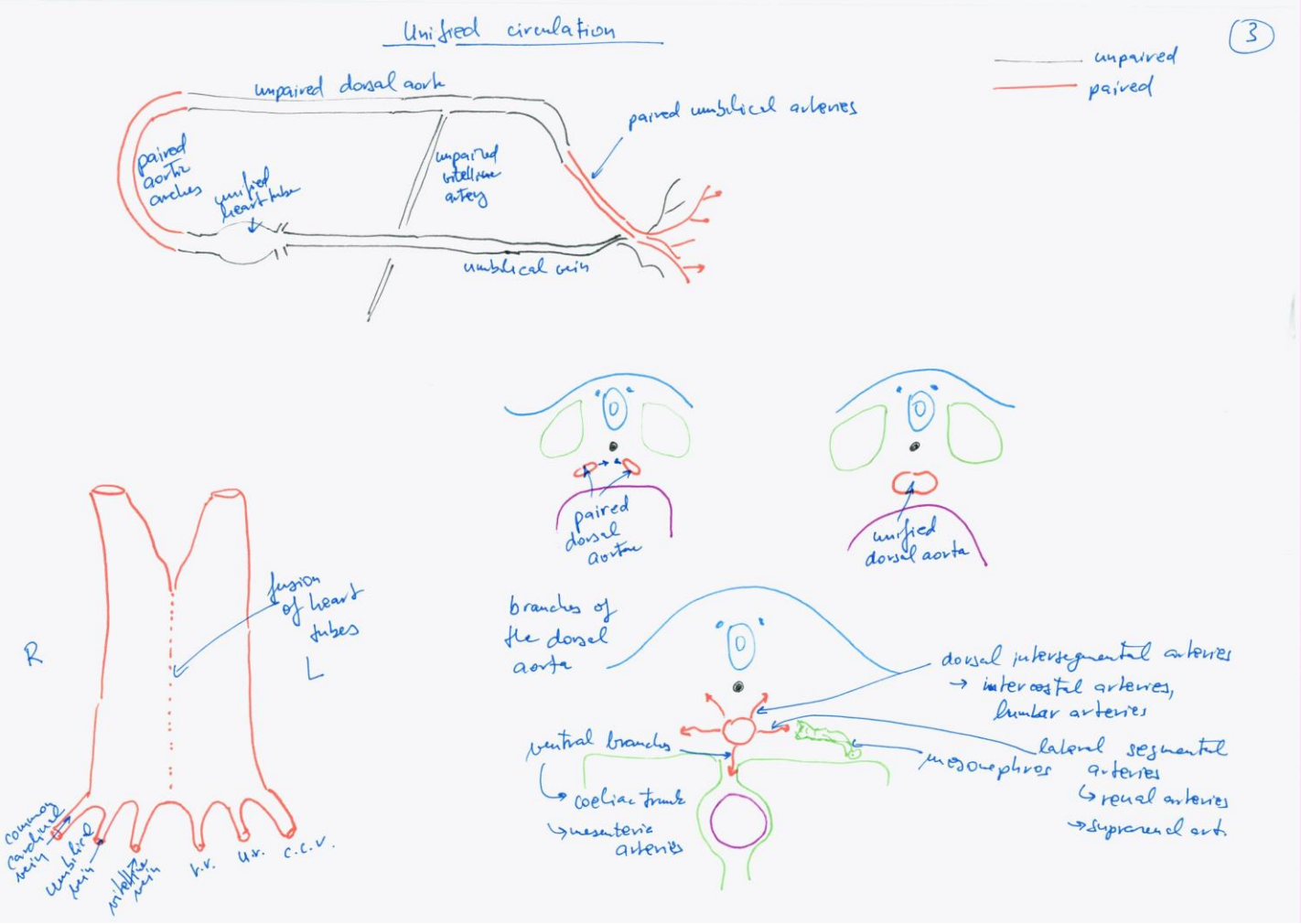


# Primitive bilateral embryonic circulation



C. Machado  
— 1912

# Unified circulation





# Branches of Dorsal Aorta

## aa. segmentales ventrales

### aa. vitellinae (omphalomesentericae)

- truncus coeliacus
- a. mesenterica superior
- a. mesenterica inferior

### aa. umbilicales

- aa. iliacae int., aa. vesicales sup.
- After birth - ligg. umbilicalia medialis

## aa. segmentales laterales

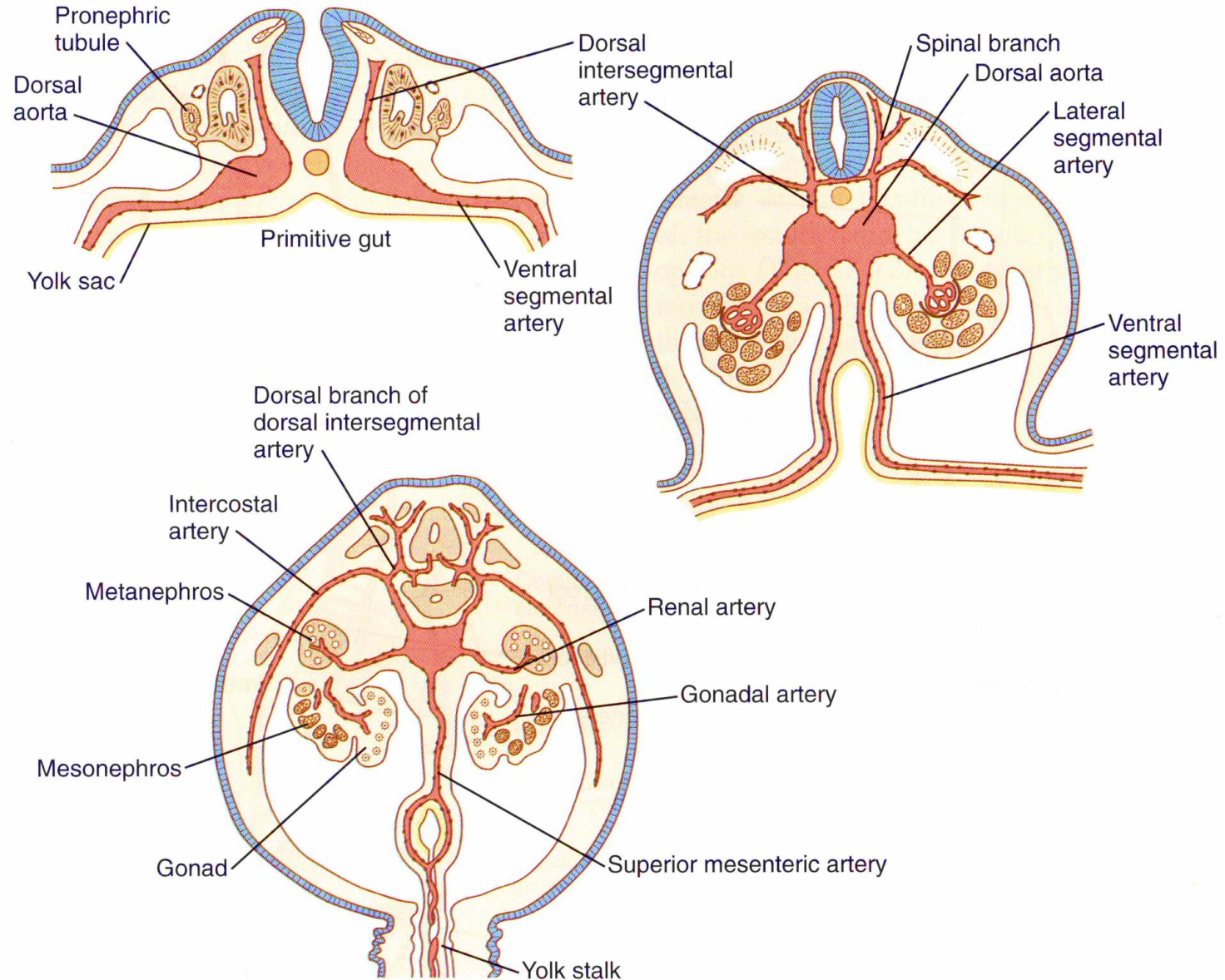
- aa. renales, aa. suprarenales,
- aa. testiculares, aa. ovaricae

VESSELS VARIABILITY!

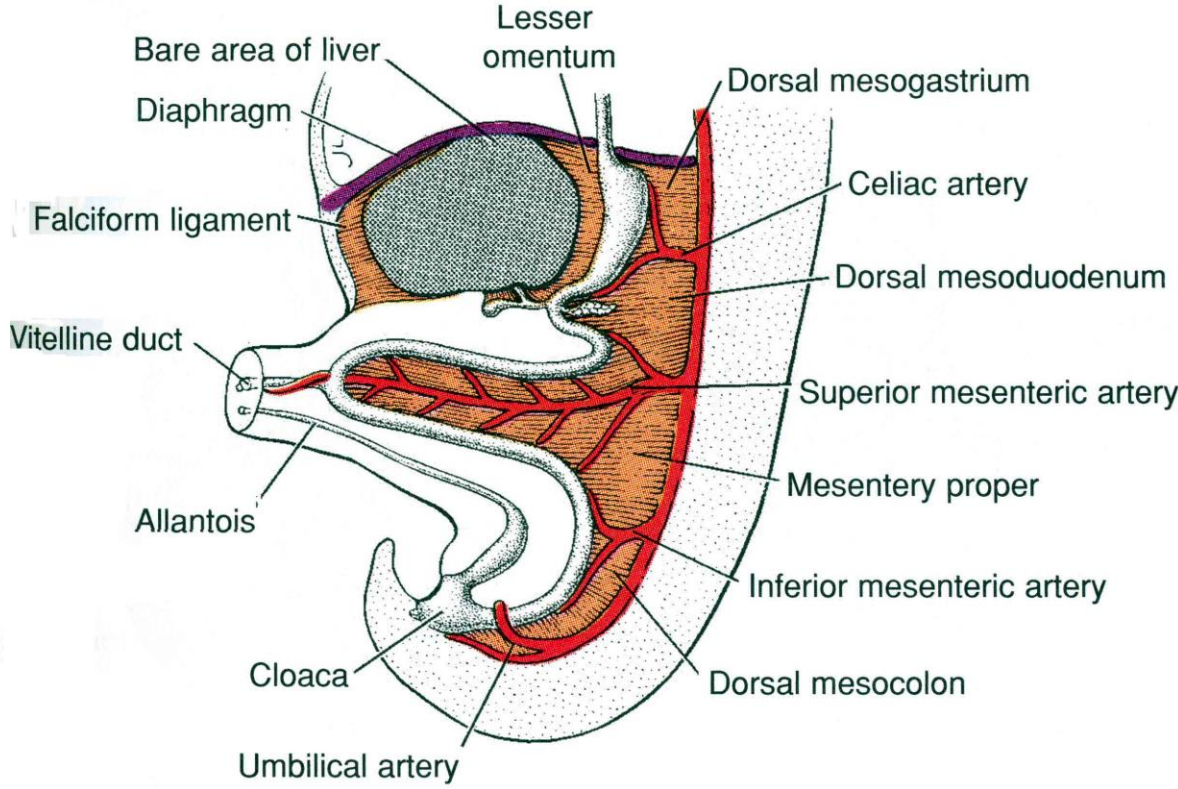
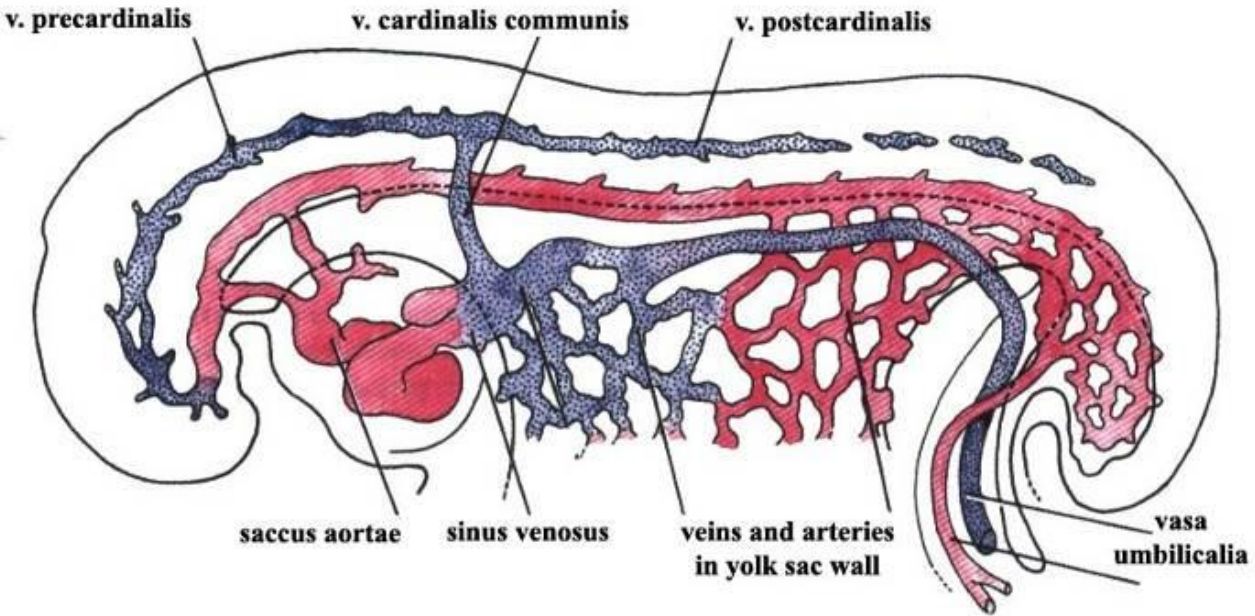
## aa. intersegmentales (dorsal branches)

- aa. vertebrales
- aa. subclaviae (left)
- aa. intercostales...

## (a. sacralis mediana)



# Ventral Branches of Dorsal Aorta

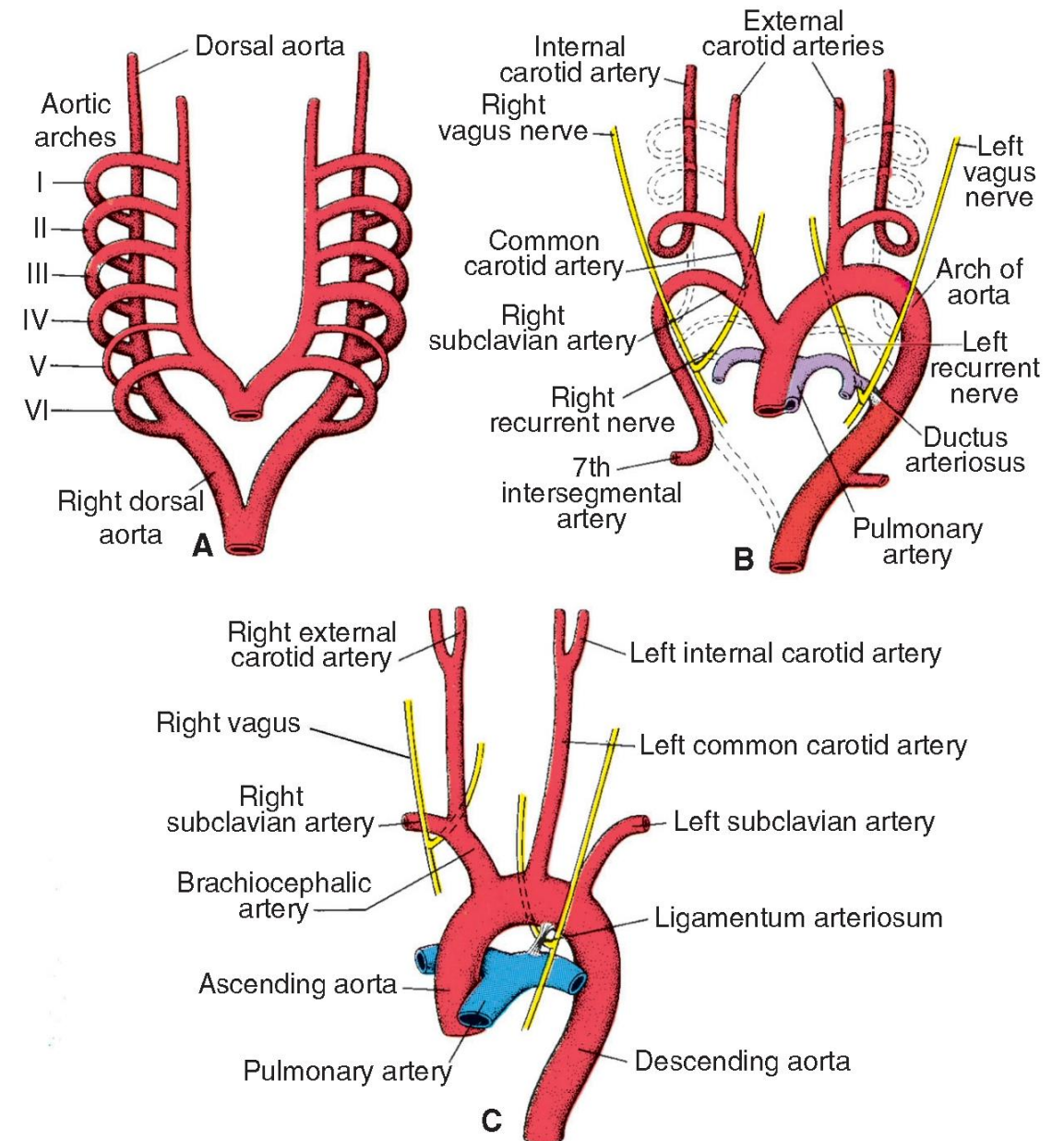




# Aortic arches remodeling

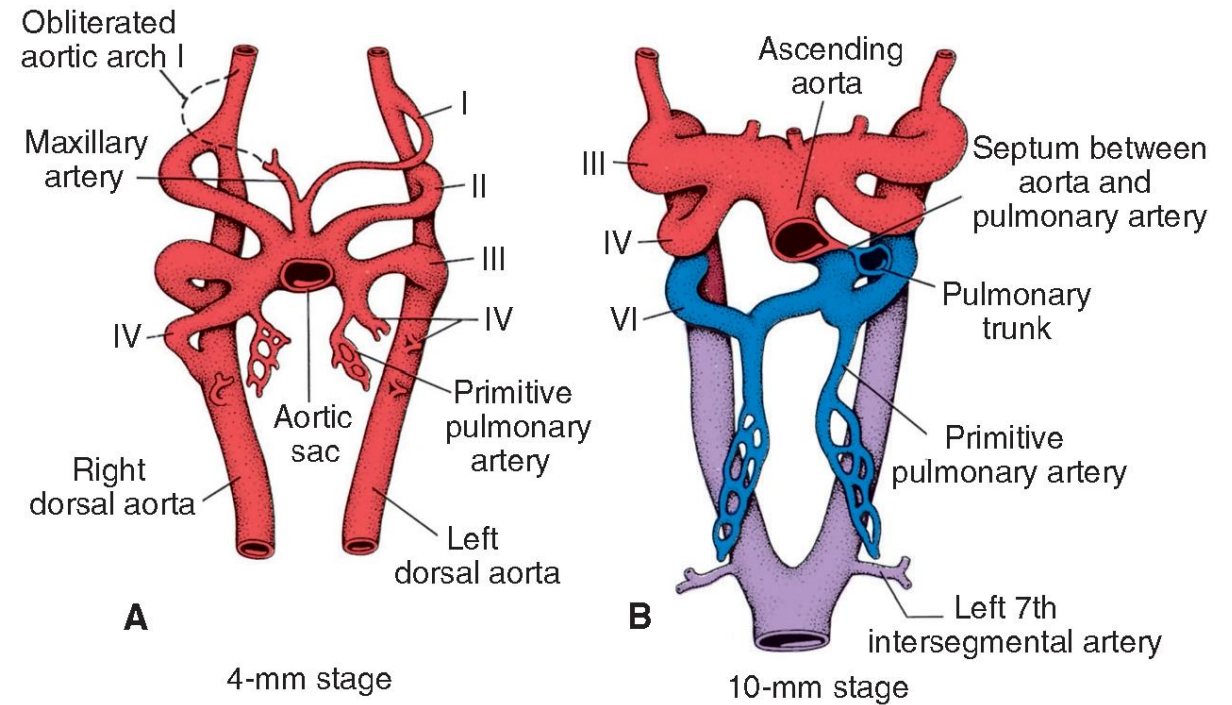
Arch	Left	Right
1	a. maxillaris	a. maxillaris
2	a. stapedia	a. stapedia
3	a. carotis communis prox. part of a. carotis interna	a. carotis communis prox. part of a. carotis interna
4	arcus aortae	a. subclavia dextra
6	a. pulmonalis sinistra ductus arteriosus Botalli	a. pulmonalis dextra

\* **a. subclavia sinistra** is derived from 7<sup>th</sup> a. intersegmentalis  
(dorsal branch of dorsal aorta)



# Aortic arches remodeling

Arch	Left	Right
1	a. maxillaris	a. maxillaris
2	a. stapedia	a. stapedia
3	a. carotis communis prox. part of a. carotis interna	a. carotis communis prox. part of a. carotis interna
4	arcus aortae	a. subclavia dextra
6	a. pulmonalis sinistra ductus arteriosus Botalli	a. pulmonalis dextra



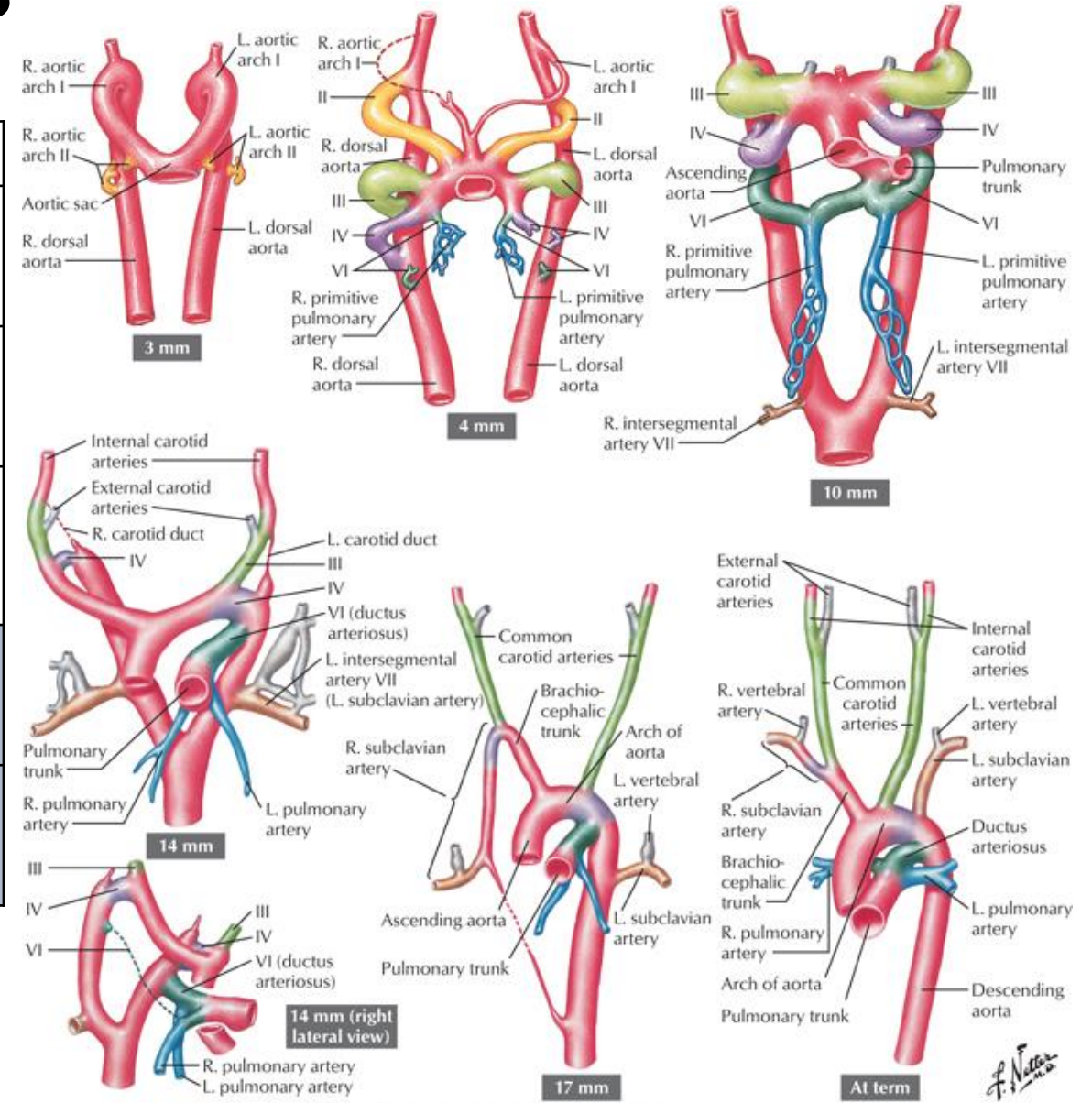
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\* **a. subclavia sinistra** is derived from 7<sup>th</sup> a. intersegmentalis (dorsal branch of dorsal aorta)



# Aortic arches remodeling

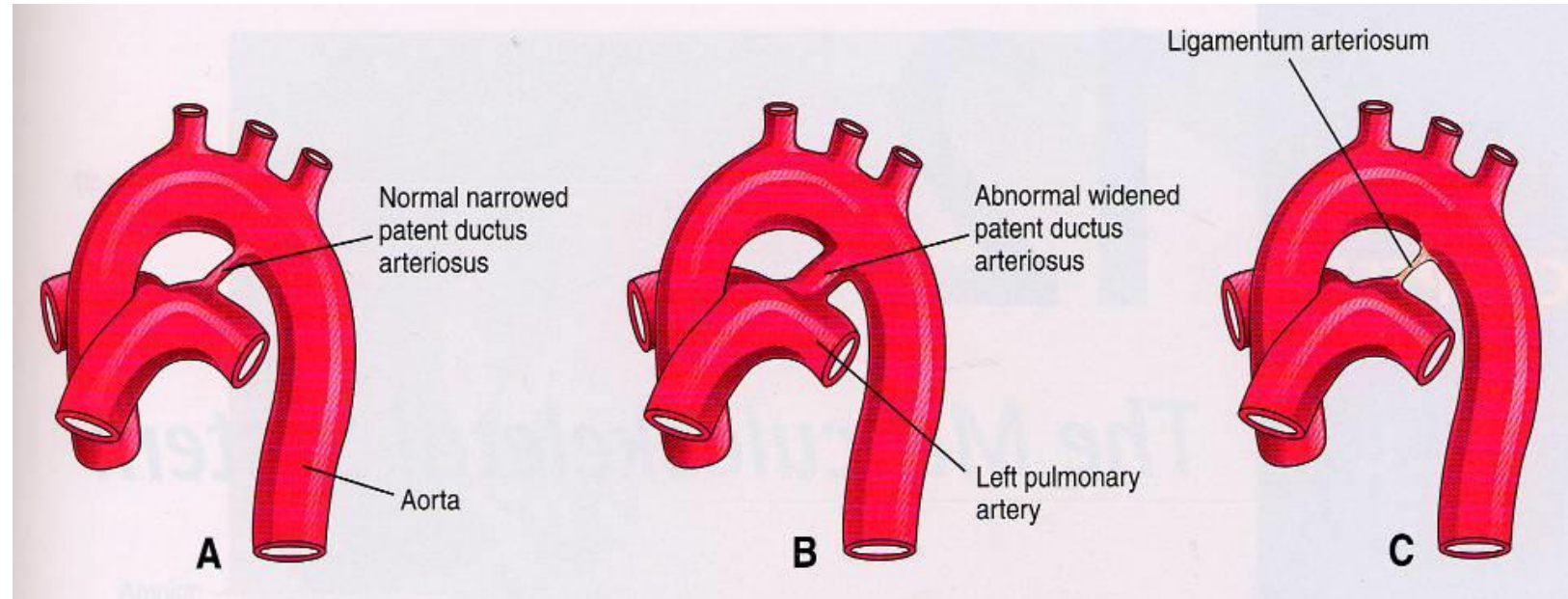
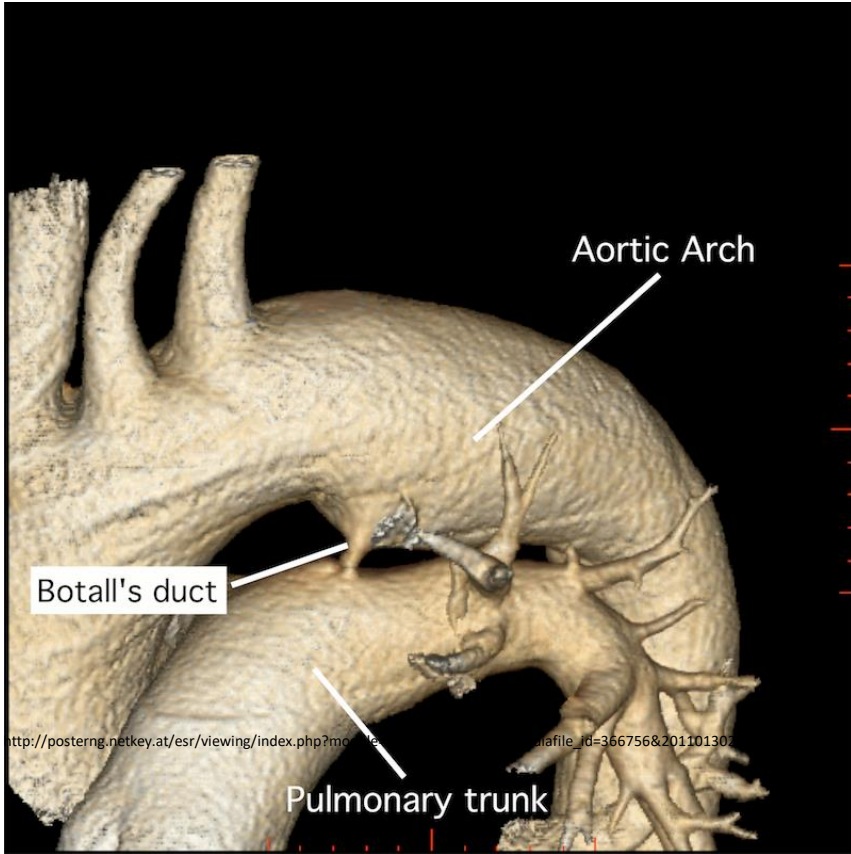
Arch	Left	Right
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\* **a. subclavia sinistra** is derived from 7<sup>th</sup> a. intersegmentalis (dorsal branch of dorsal aorta)

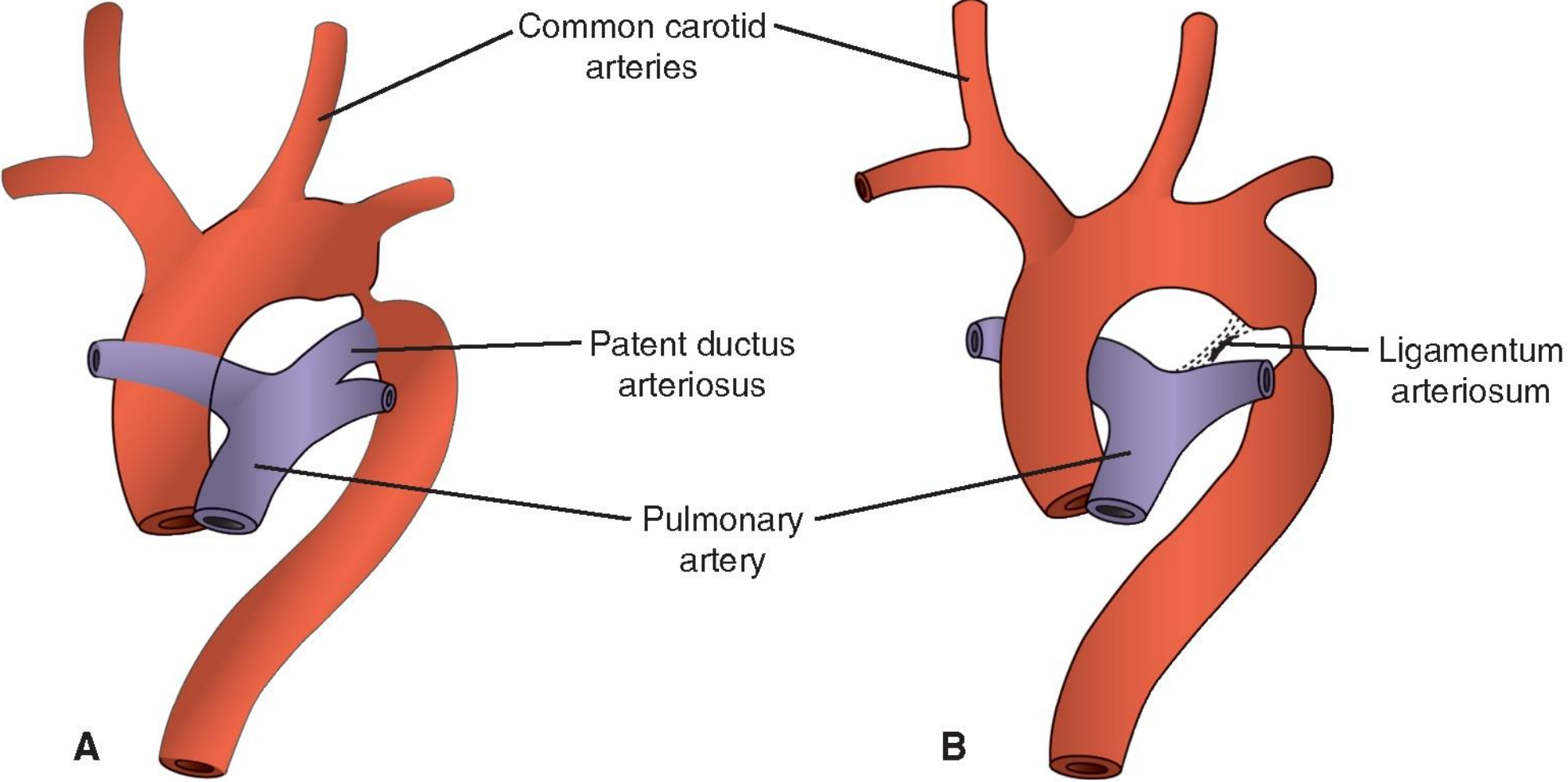
# Arterial developmental defects

## *Ductus arteriosus patens*



# Arterial developmental defects

## *Coarctation of the aorta*



**A**

Preductal type

**B**

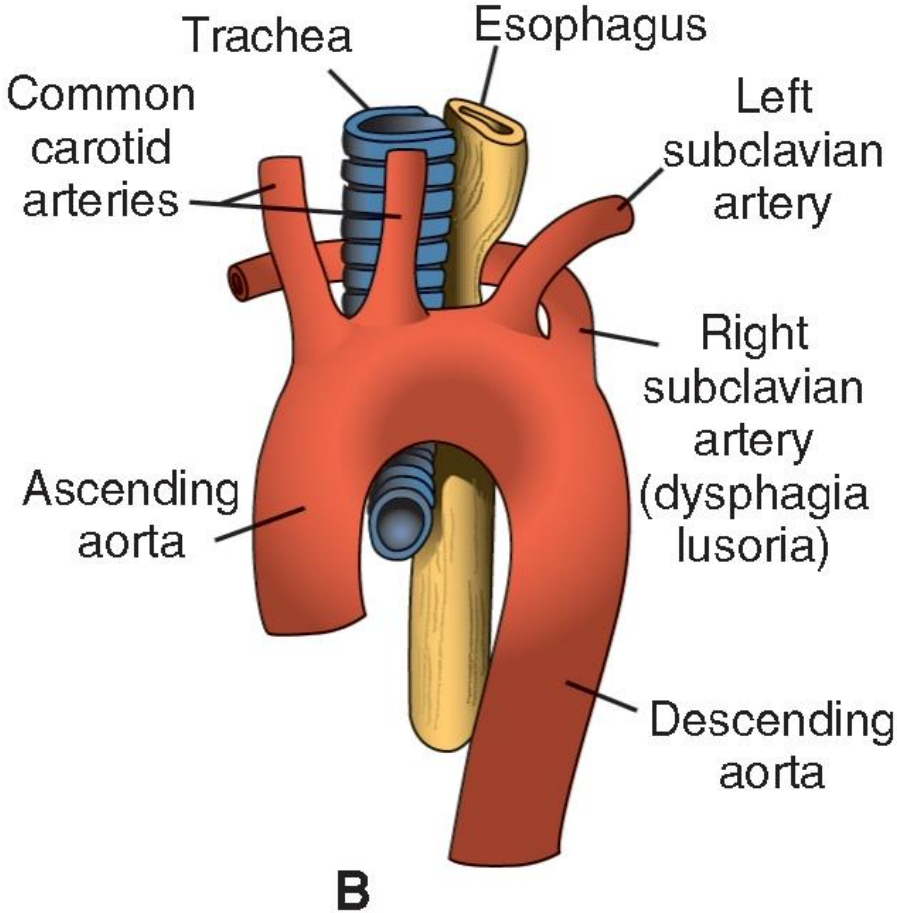
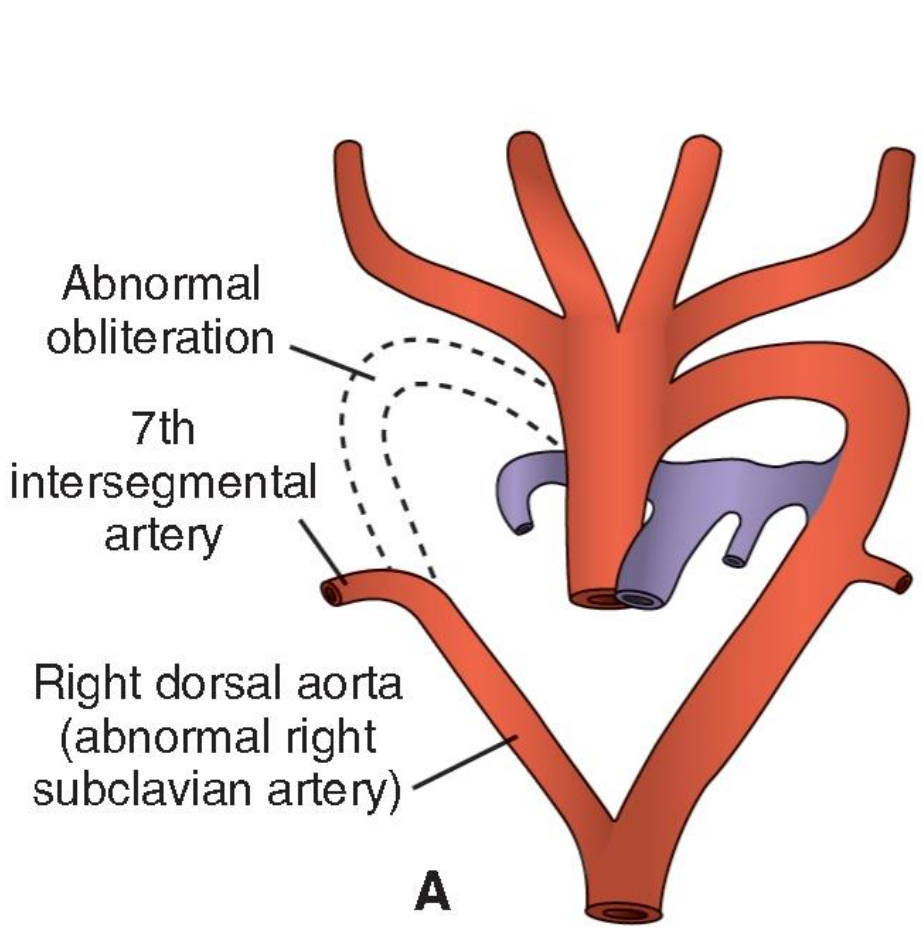
Postductal type

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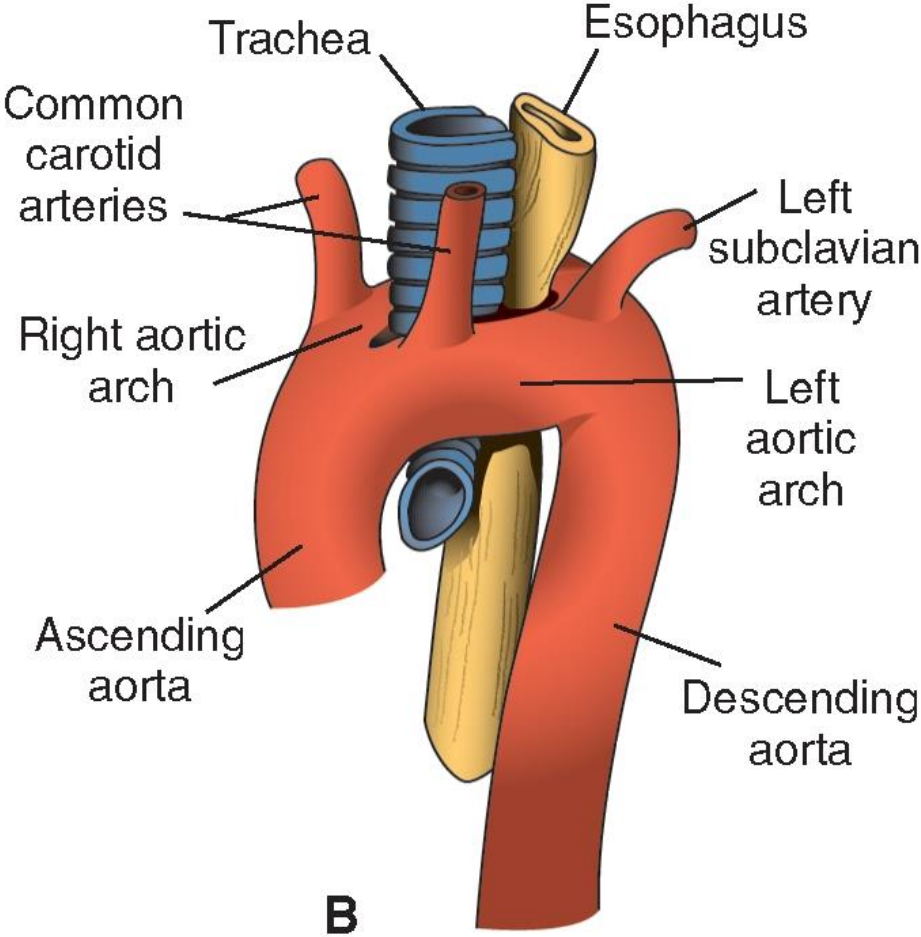
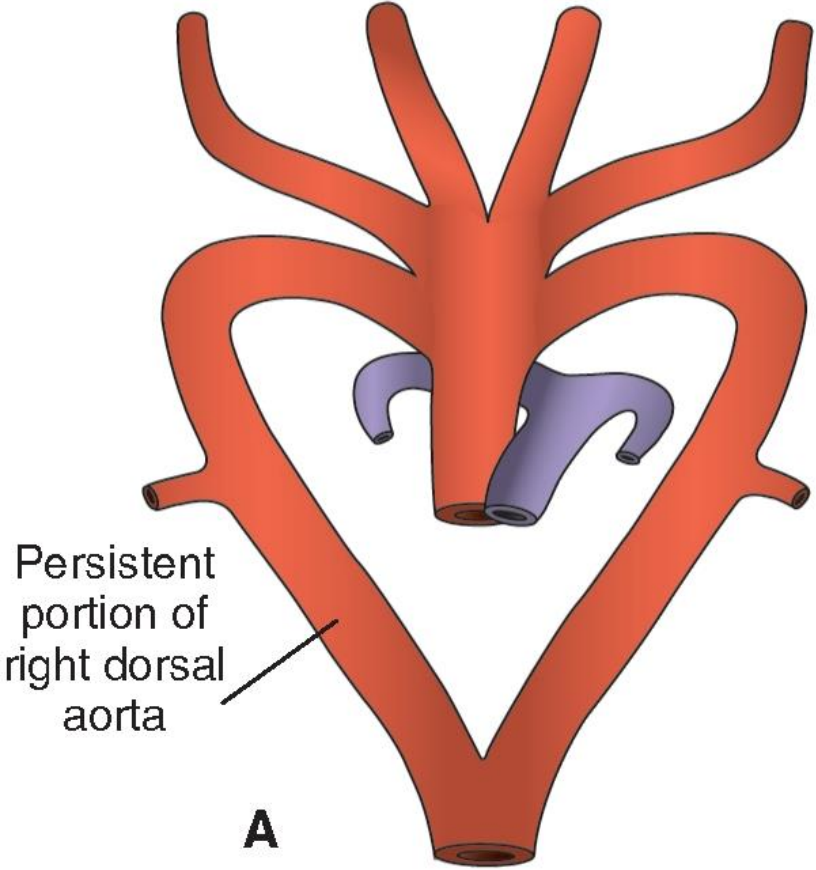
# Arterial developmental defects

## *Abnormal origin of the right a. subclavia*

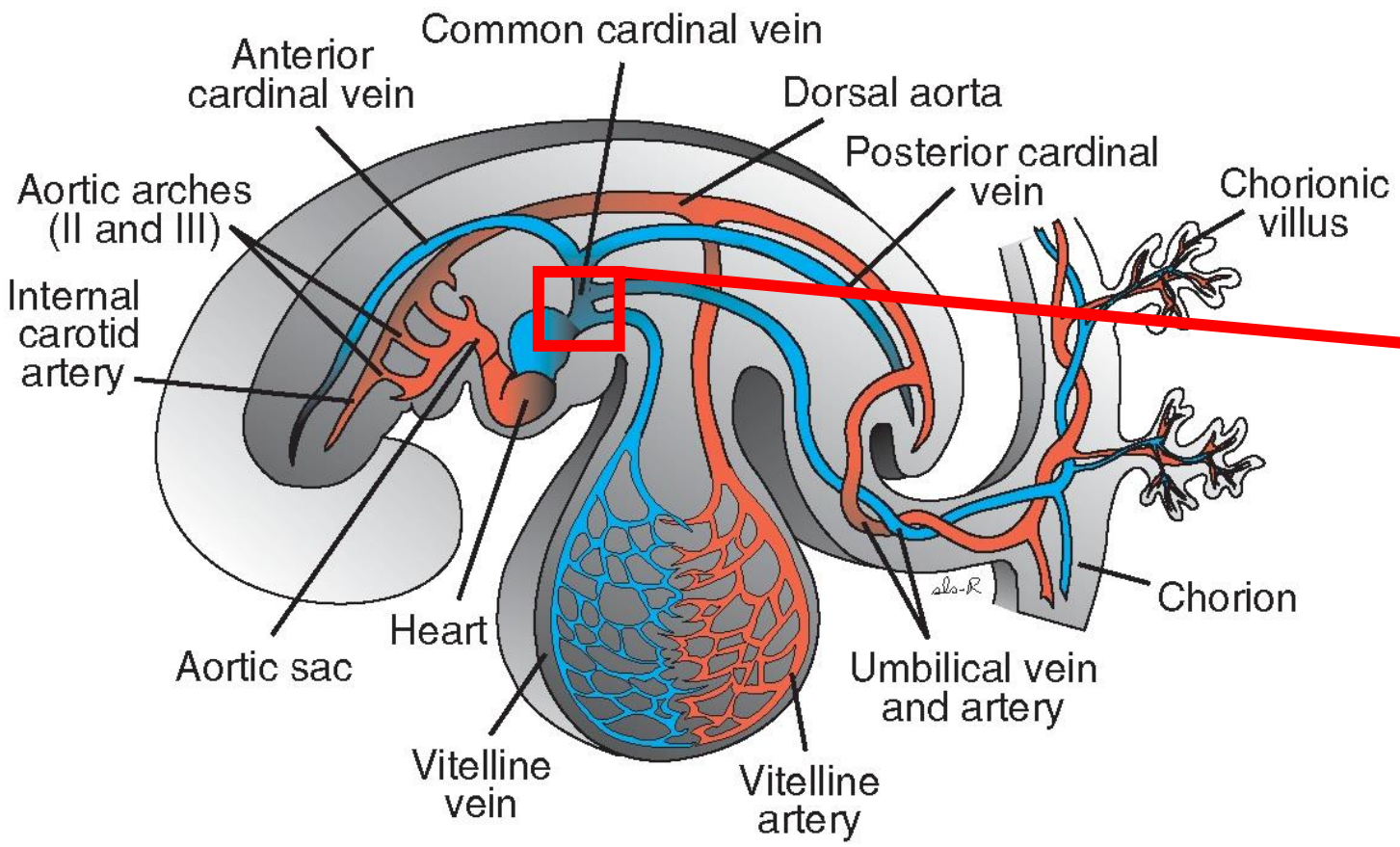


# Arterial developmental defects

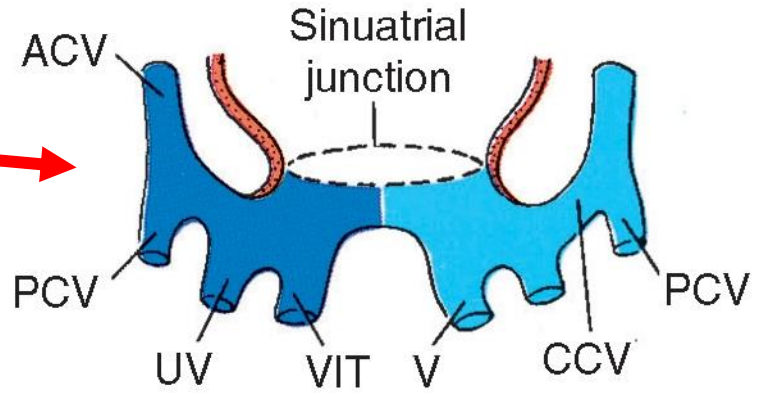
## *Double aortic arch*



# Venous system



## Sinus venosus





# Venous system

## v. umbilicalis (sinistra)

ductus venosus – lig. venosum

lig. teres hepatis

## vv. vitellinae

hepatic sinusoids

vv. hepaticae

Intrahepatal parts of IVC

vena portae – plexus near duodenum

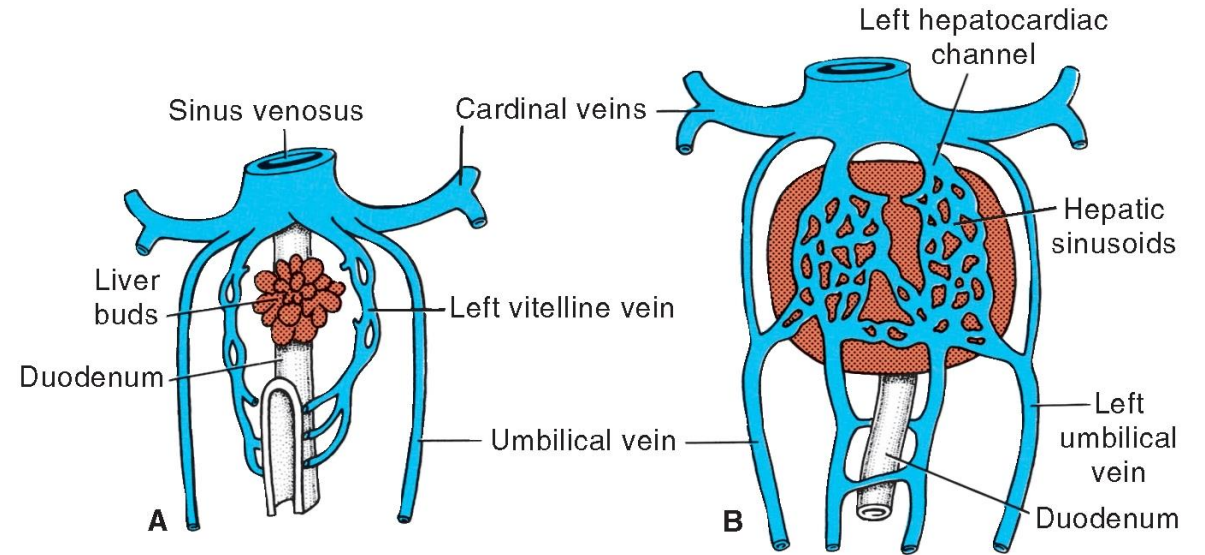
## v. cardinalis anterior

SVC (from v. cardinalis communis dextra)

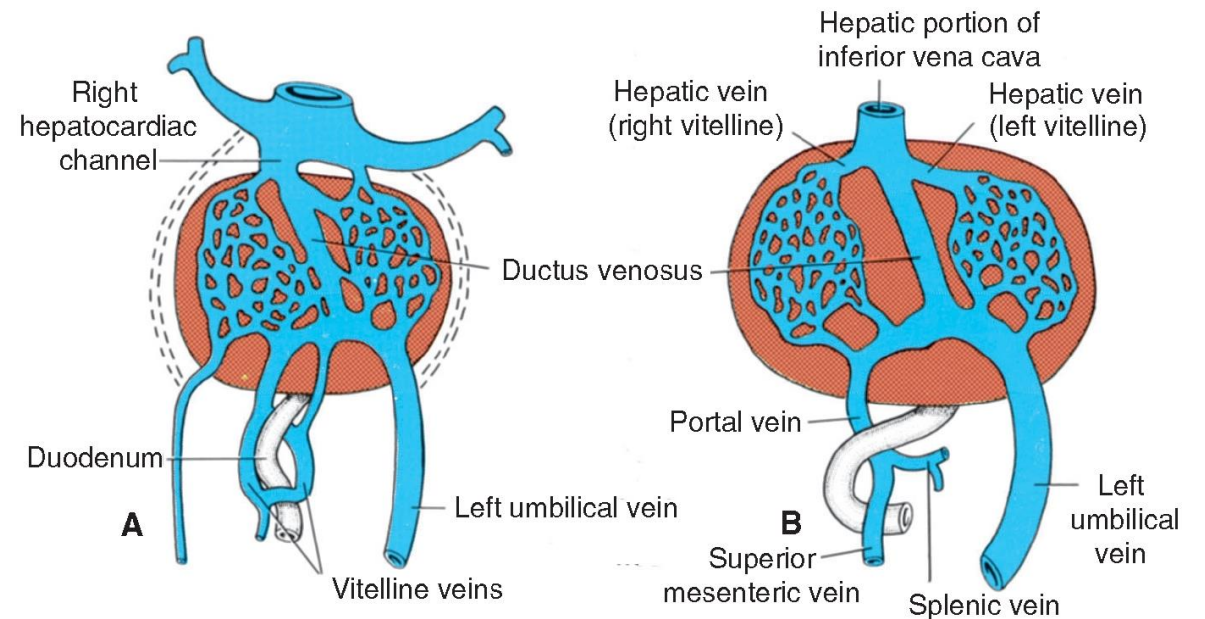
v. brachiocephalica sinistra

v. jugularis interna

## v. cardinalis posterior obliterates



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# Venous system

## vv. subcardinales (renal region)

proximal parts of VCI

vv. renales, vv. suprarenales

vv. testiculares/ovaricae

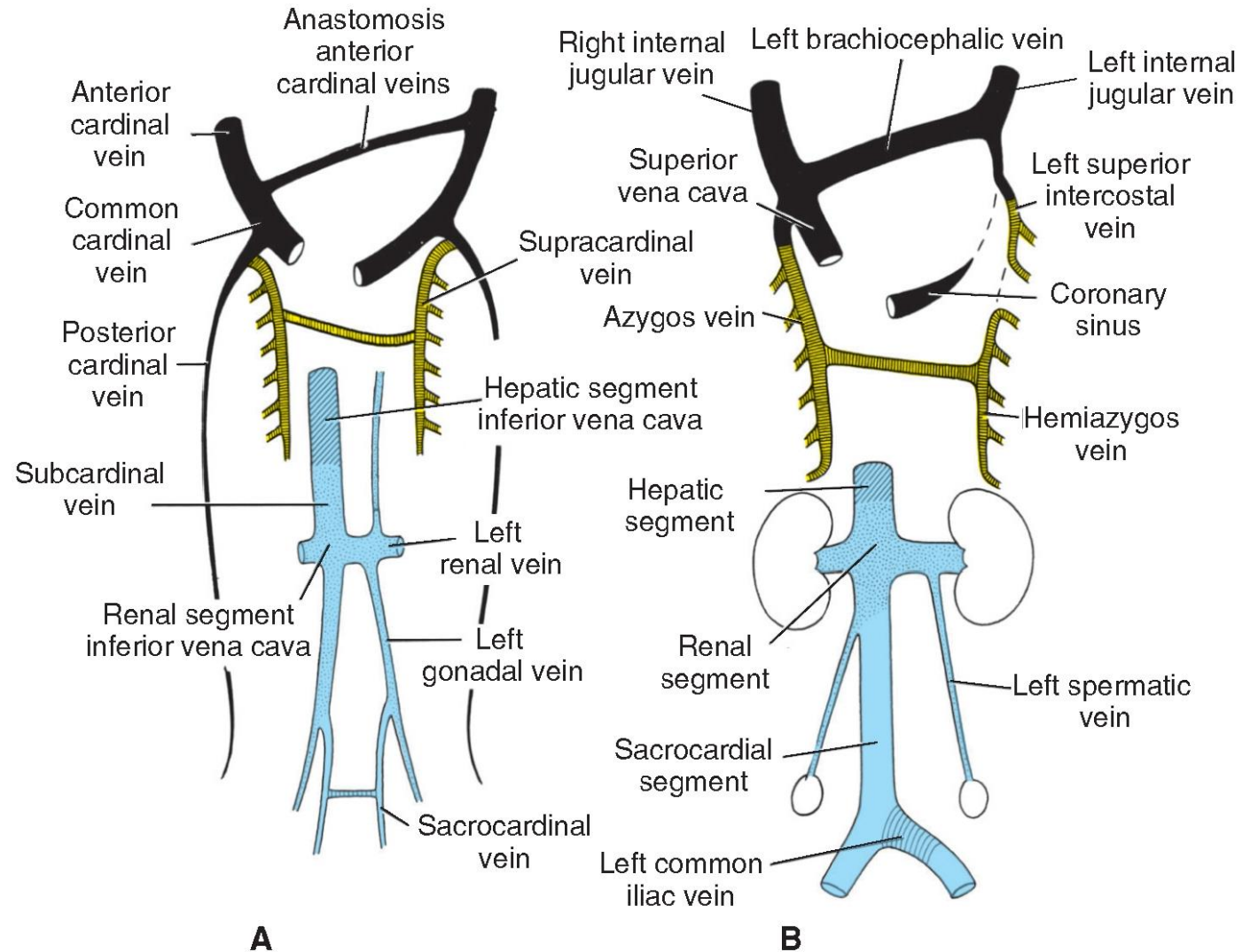
lig. teres hepatis

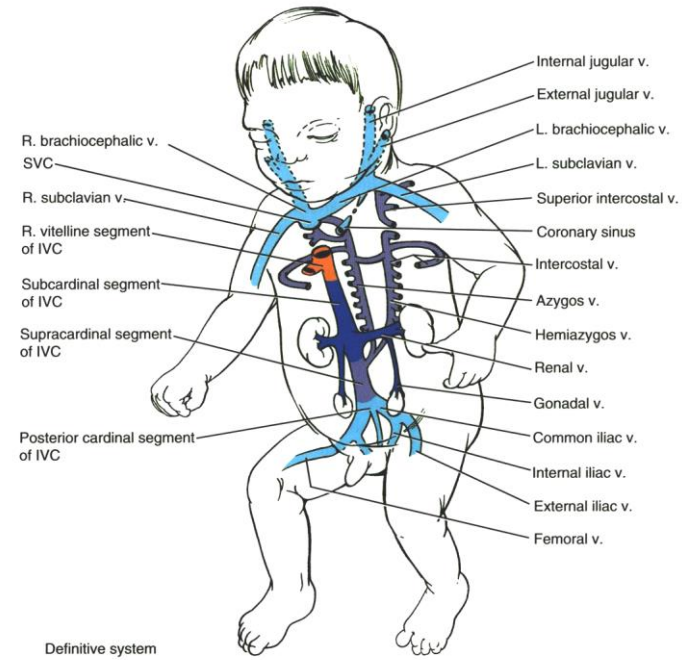
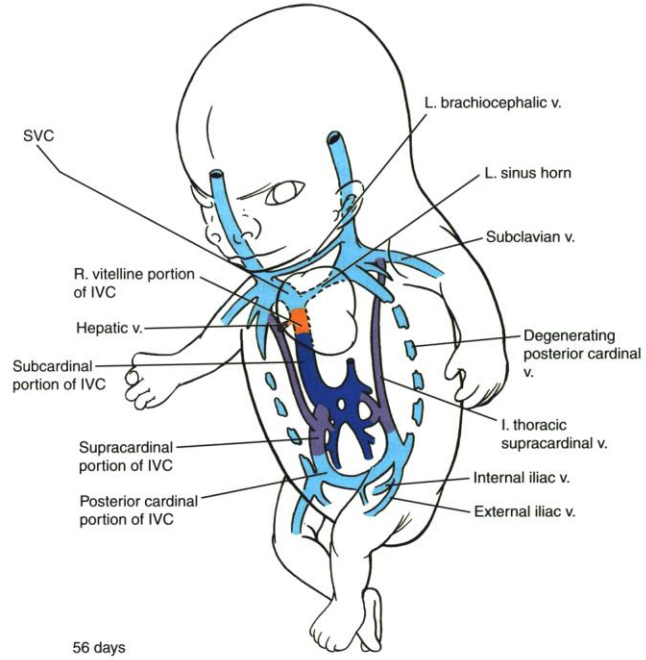
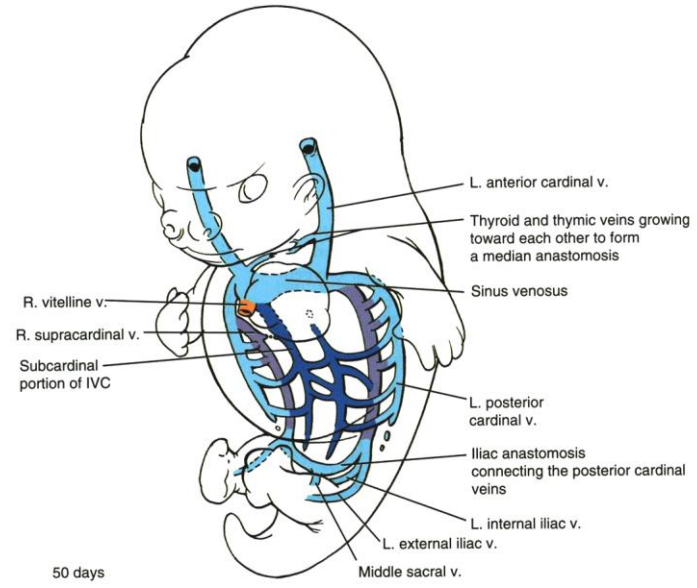
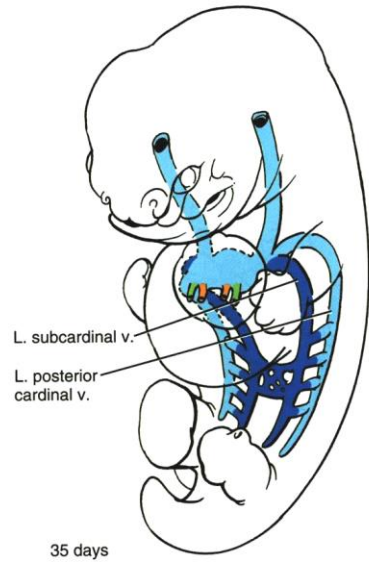
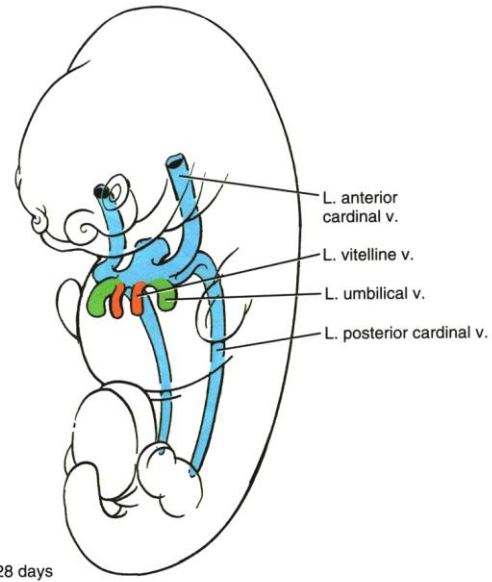
## vv. supracardinales

v. azygos (right)

v. hemiazygos (left)

part of VCI between kidneys and liver





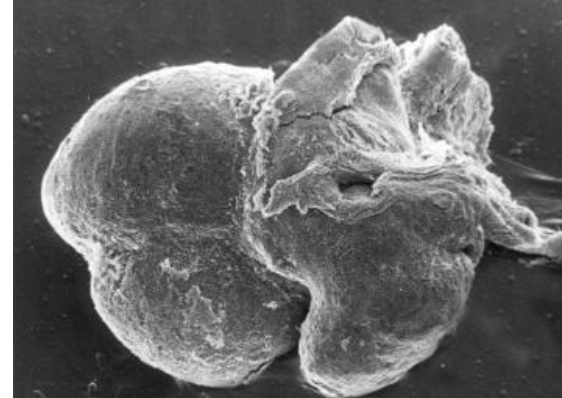


# Vascular development

- Blood islands
- Primitive embryonic circulation and its unification
- Arterial system and aortic arches
- Arterial developmental defects
- Venous system

# Heart development

- Heart tube and cardiac looping
- Atrial septation
- Ventricular septation
- Heart developmental defects
- Fetal circulation



1. primordia (cor tubulare duplex)  
day 18-22
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. fetal heart  
day 57- birth

# Heart development

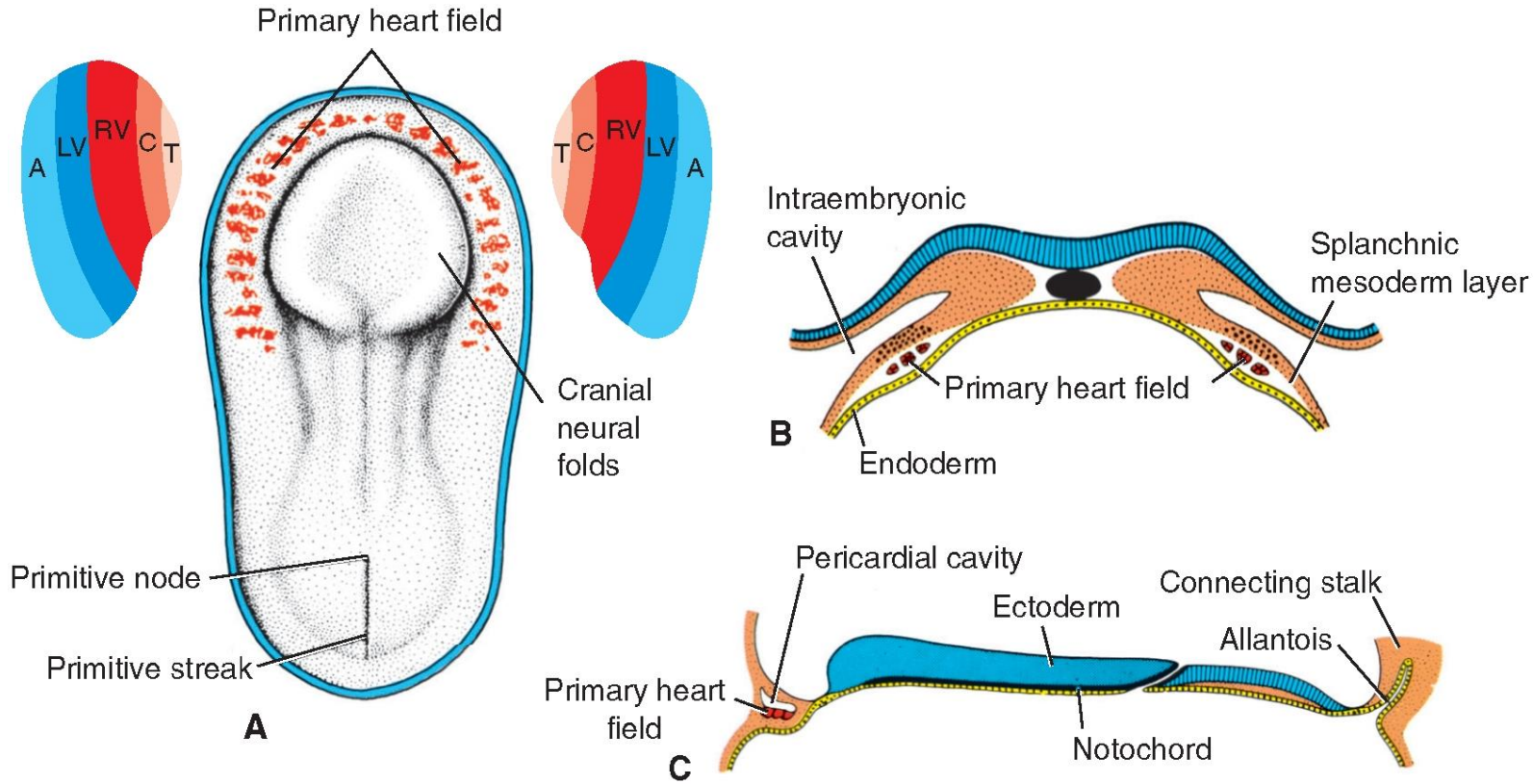
- Heart tube and cardiac looping
- Atrial septation
- Ventricular septation
- Heart developmental defects
- Fetal circulation

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

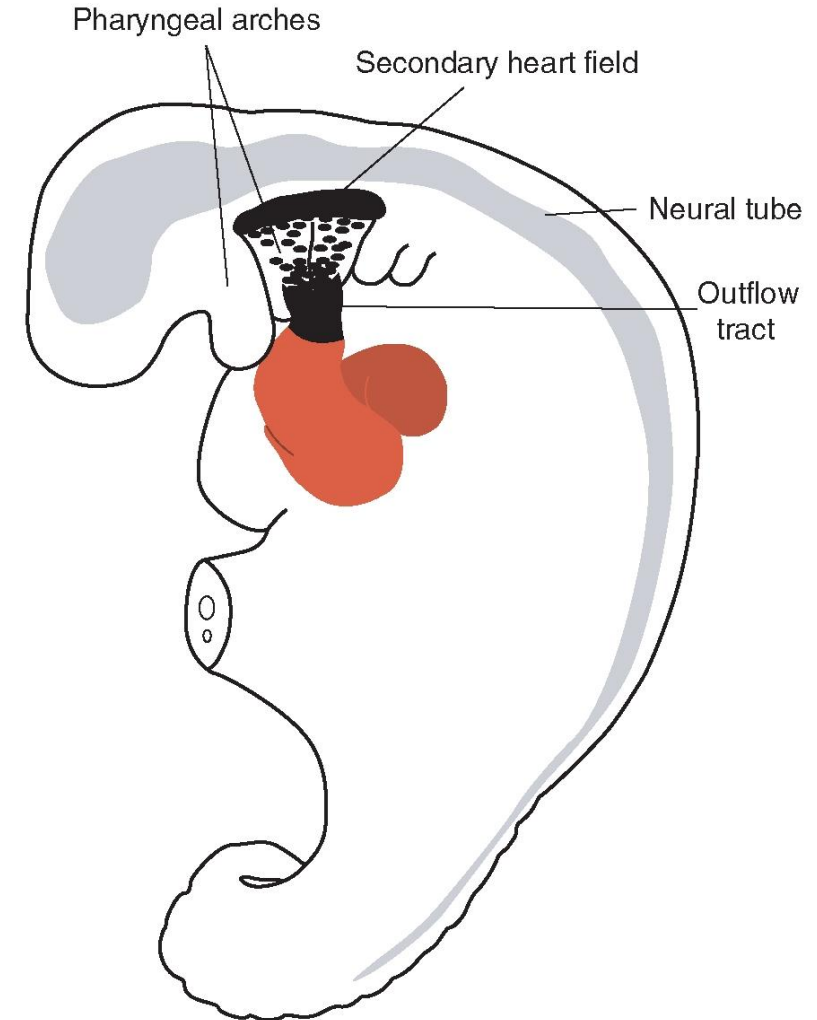


# Heart development

## Primary and secondary heart field



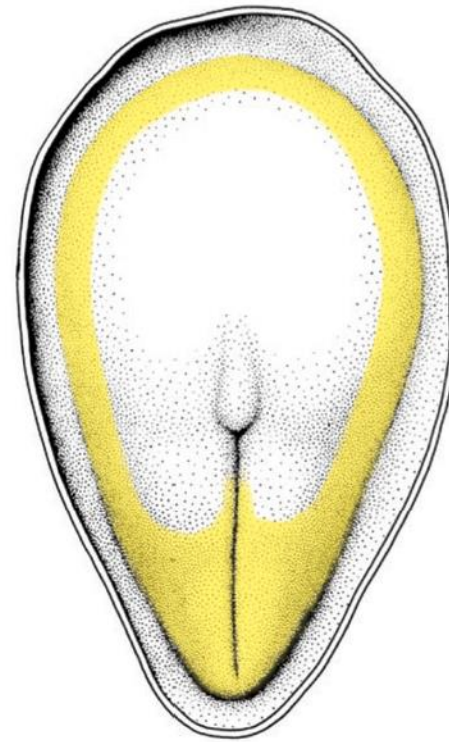
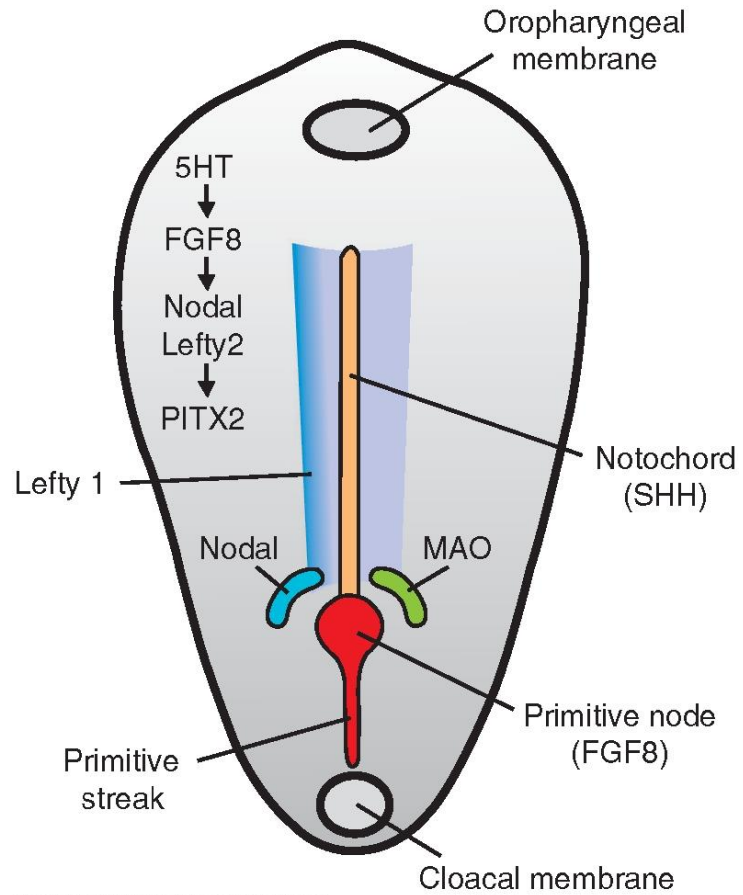
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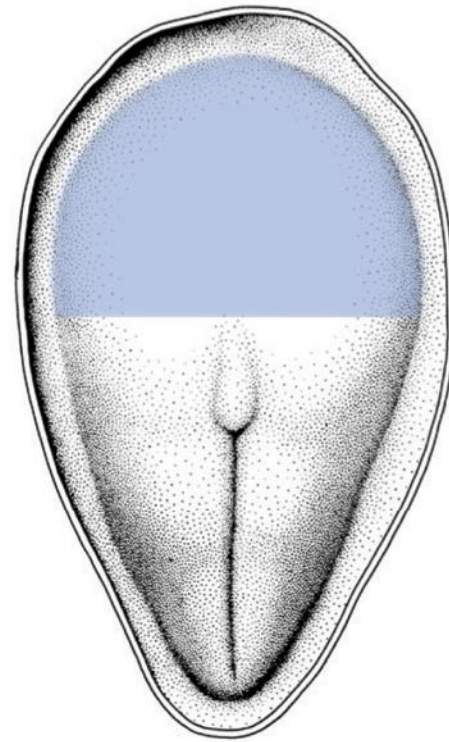
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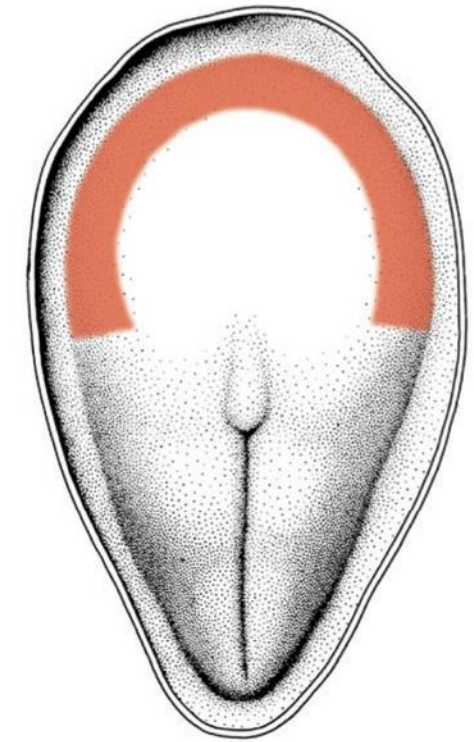
# Heart development – regulation mechanisms



■ BMP 2,4



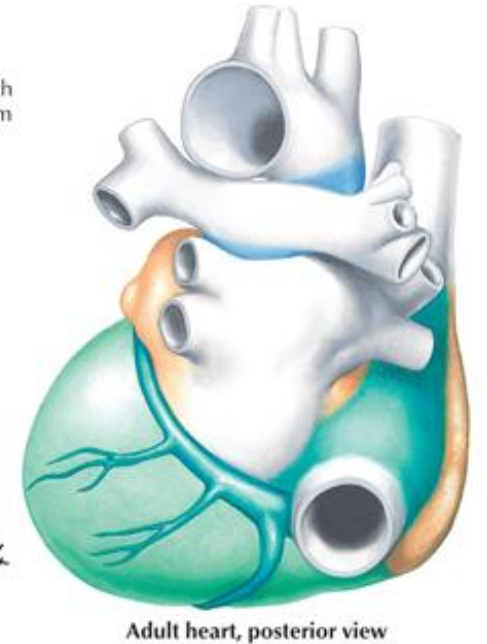
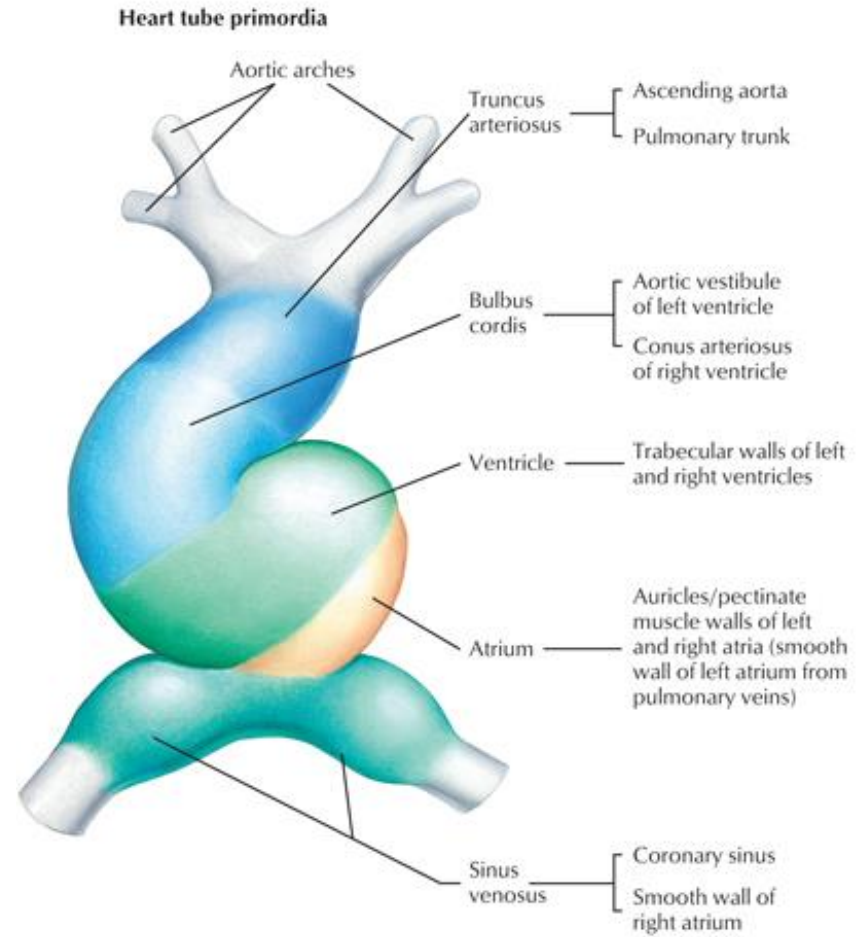
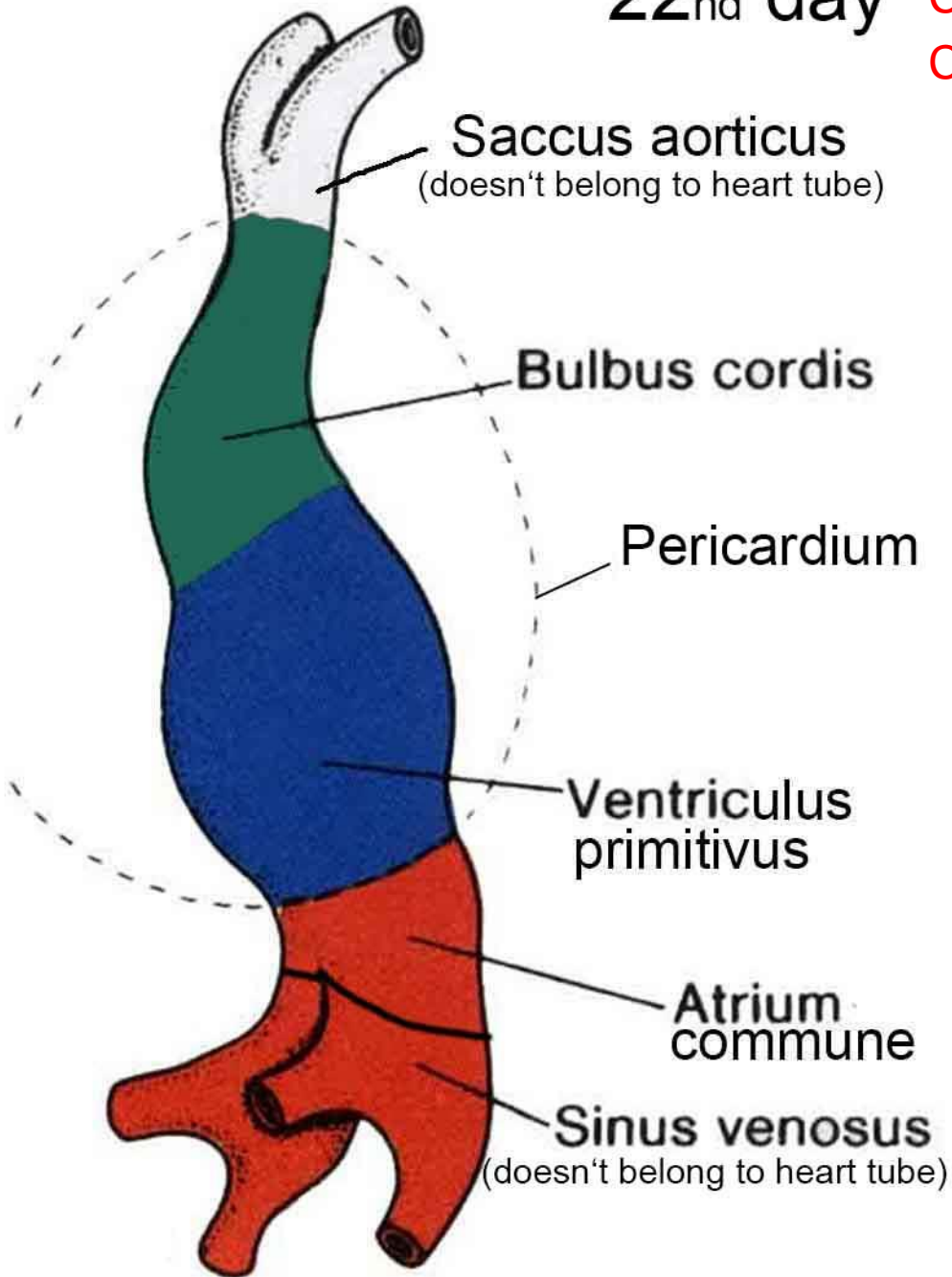
■ WNT inhibitors (crescent)



■ NKX-2.5

22<sup>nd</sup> day

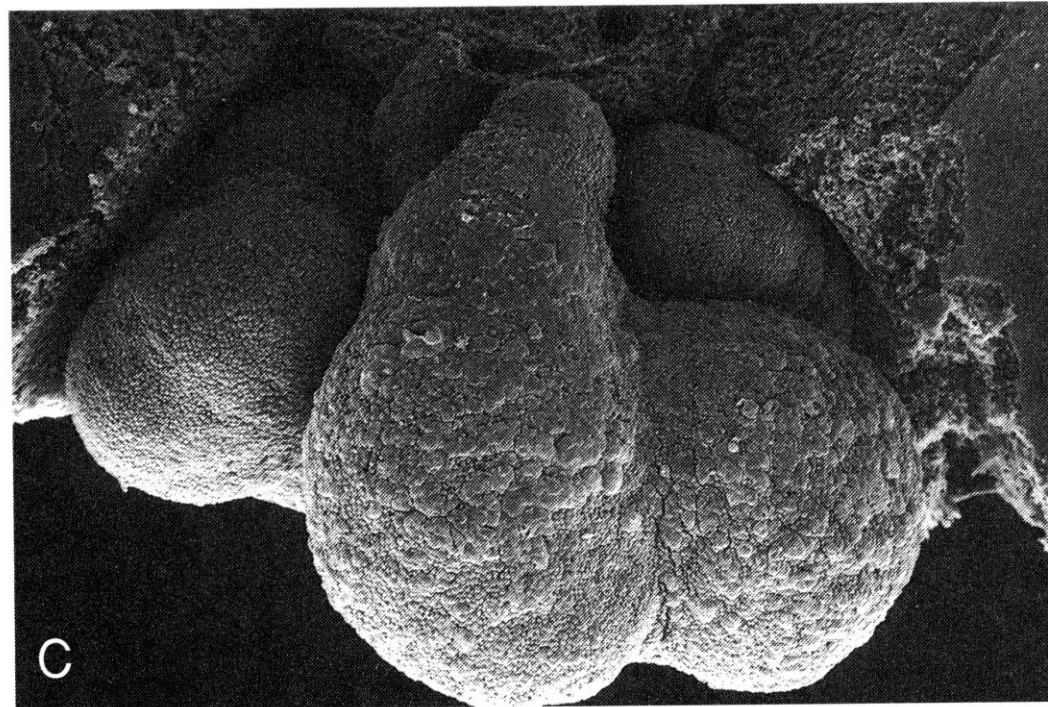
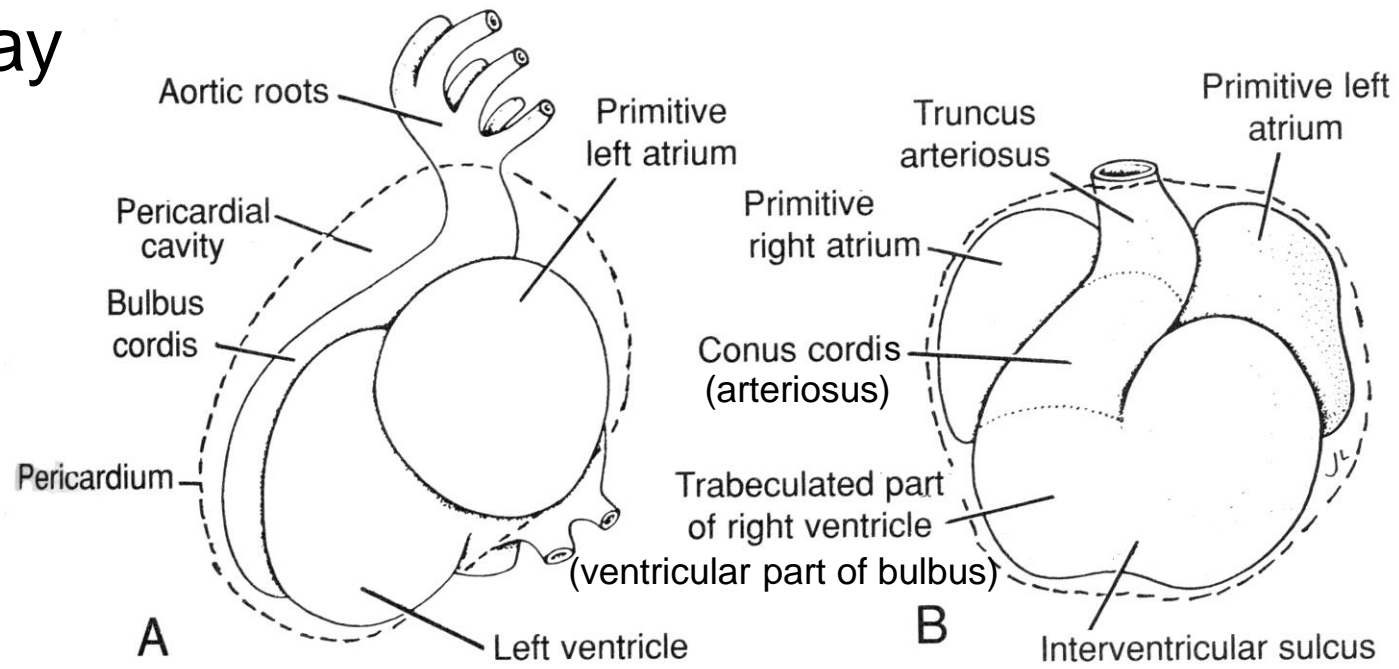
Cephalic portion bends ventrally, caudally, to the right  
Caudal portion (atrial) shifts dorsally, cranially, to the left



Completed by day 28

C. Machado

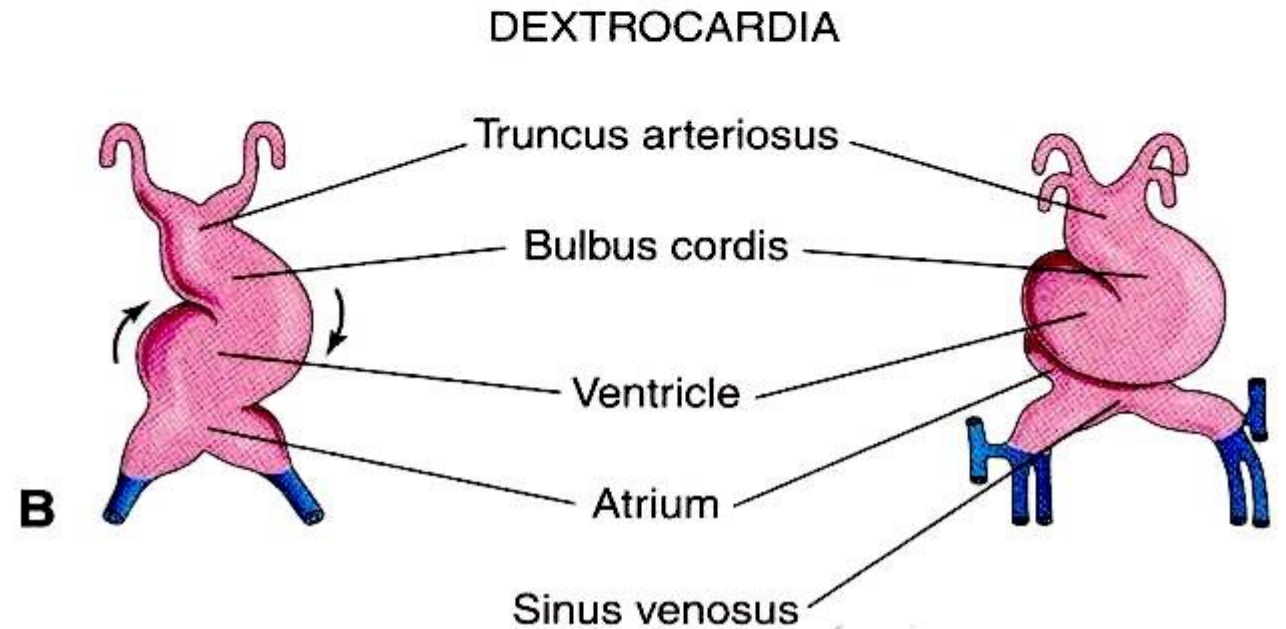
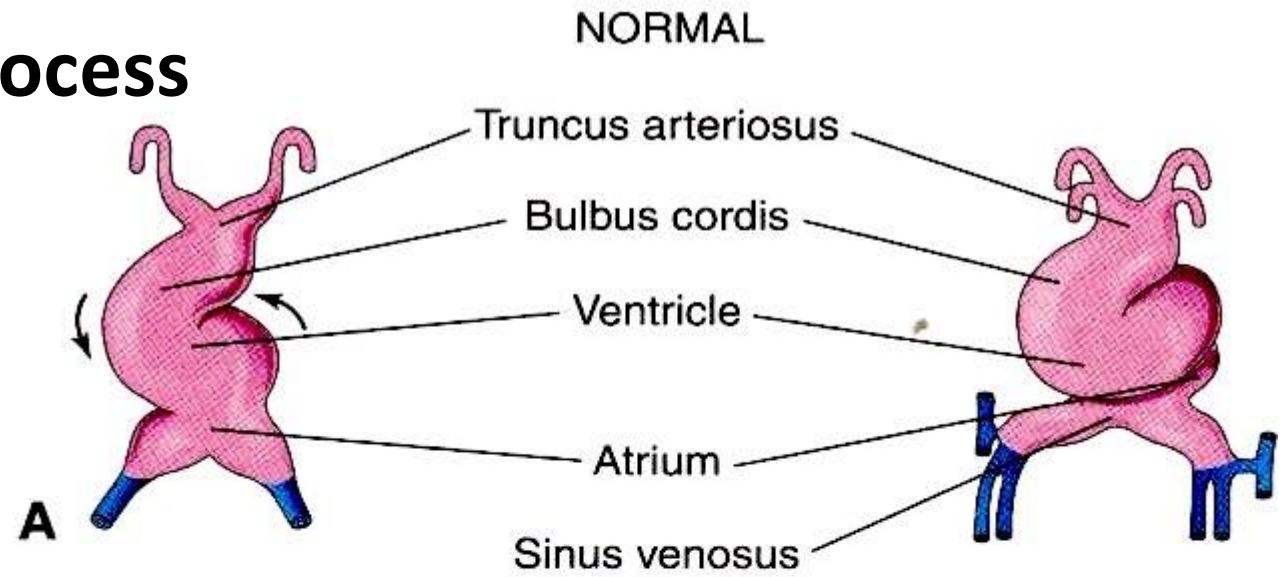
28<sup>th</sup> day



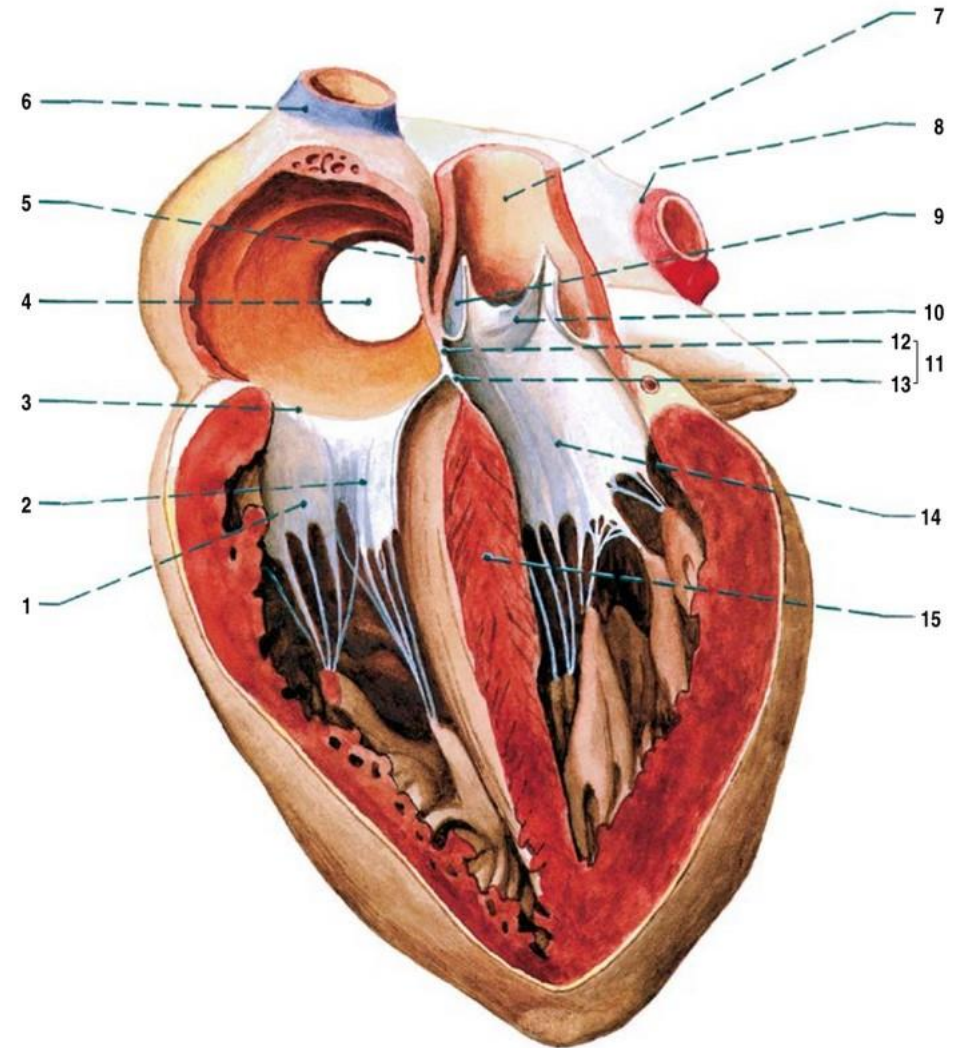
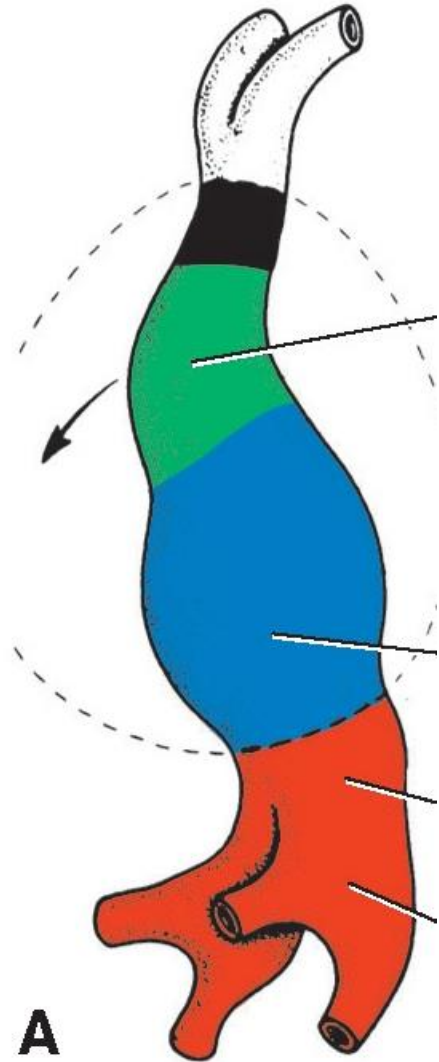


# Abnormality in looping process

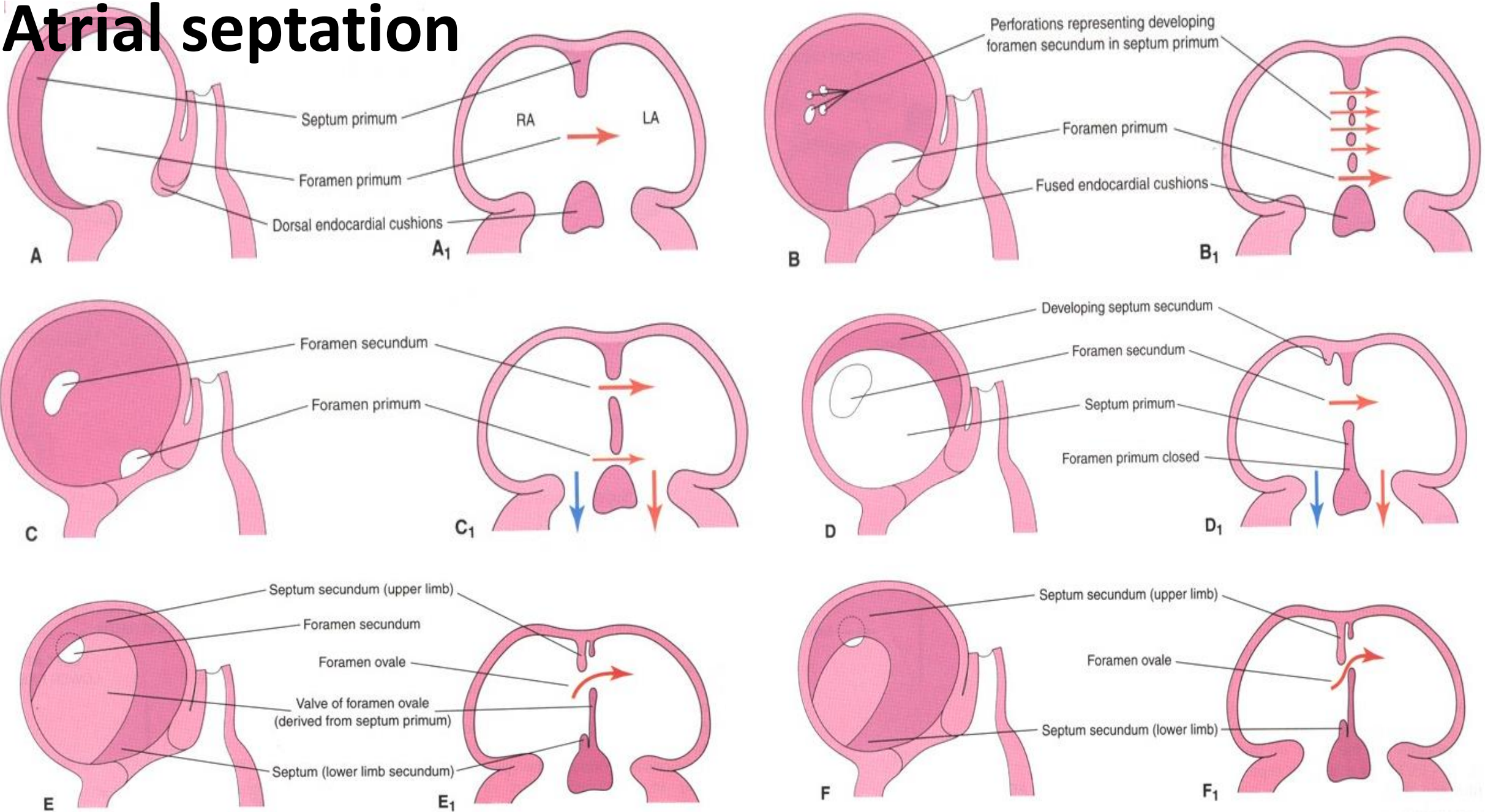
dextrocardia



# SEPTATION OF ATRIA, VENTRICLES AND HEART OUTFLOW



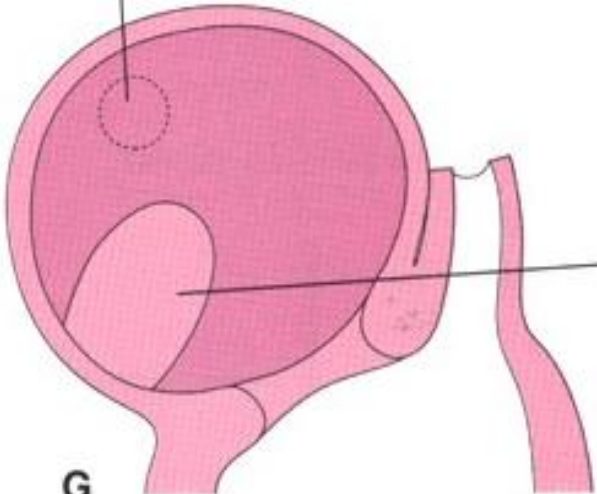
# Atrial septation





# Atrial septation

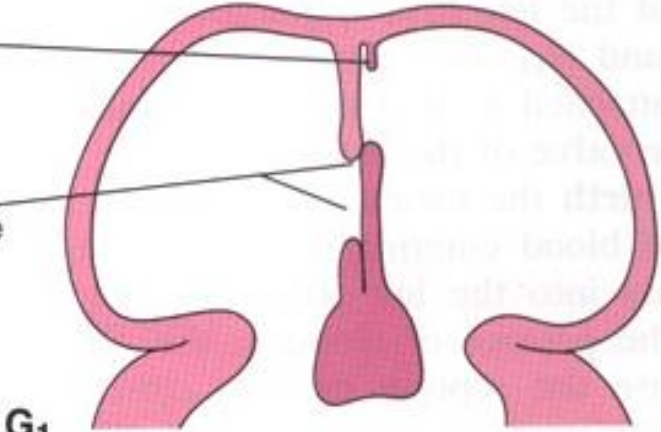
Remnant of foramen secundum



G

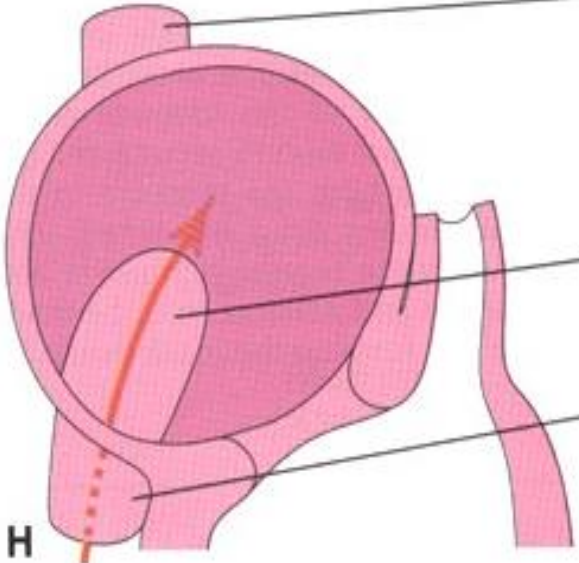
Degenerating part of septum primum

Foramen ovale closed by valve of foramen ovale



G1

Superior vena cava

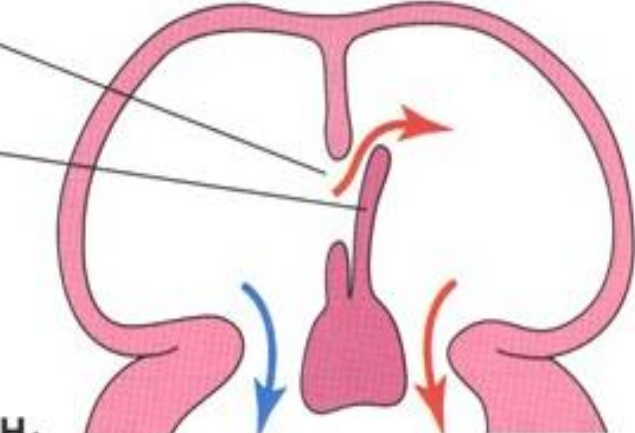


H

Foramen ovale open

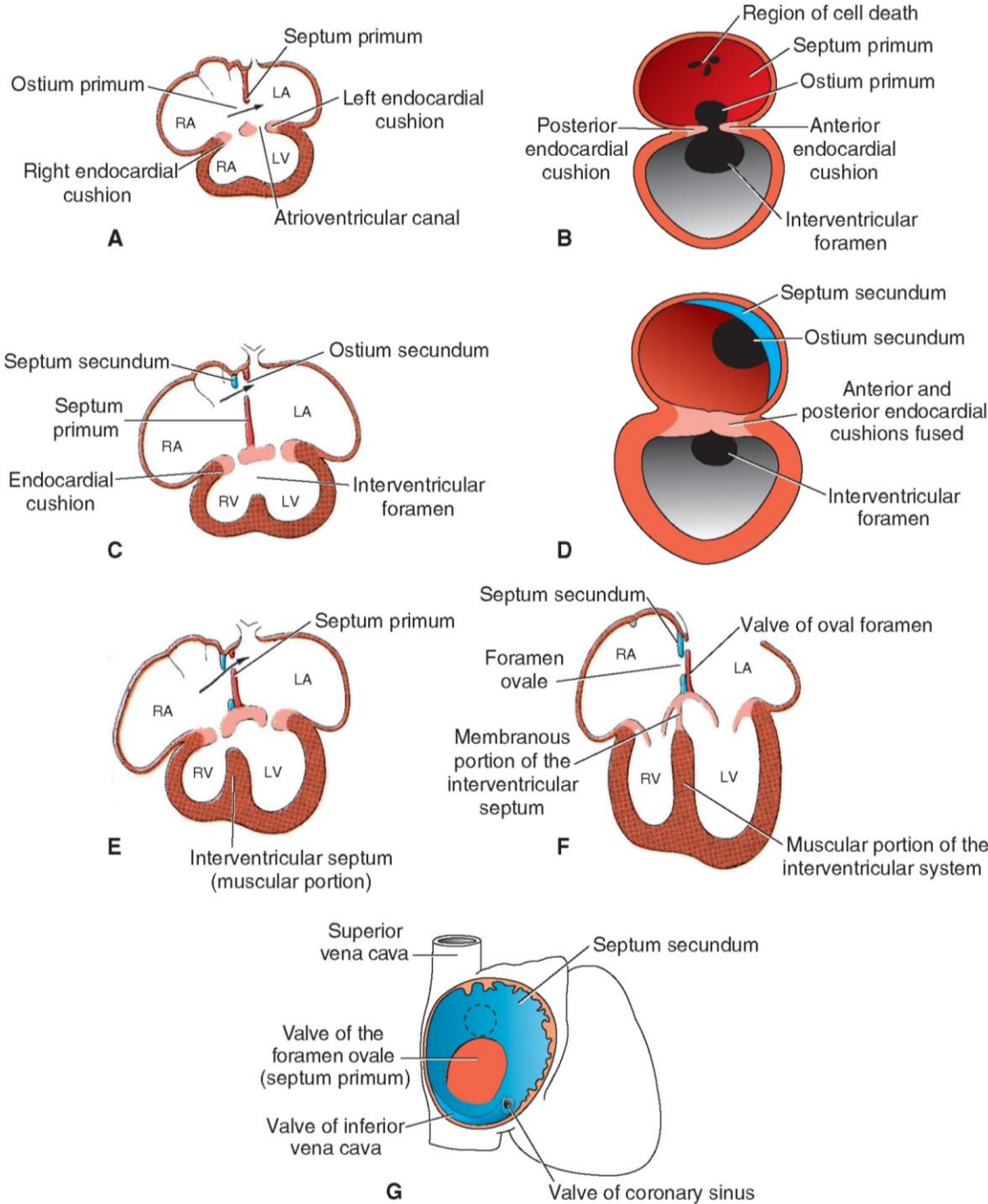
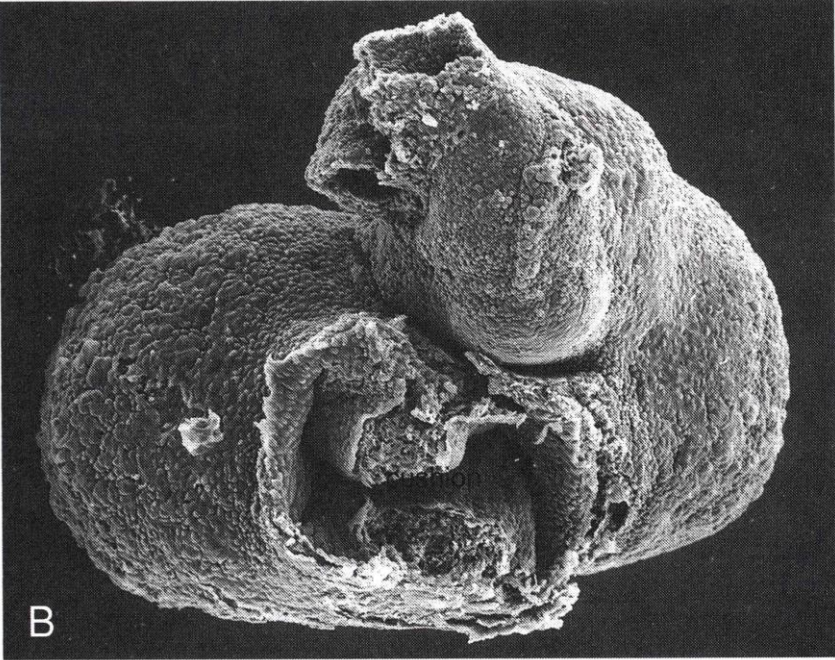
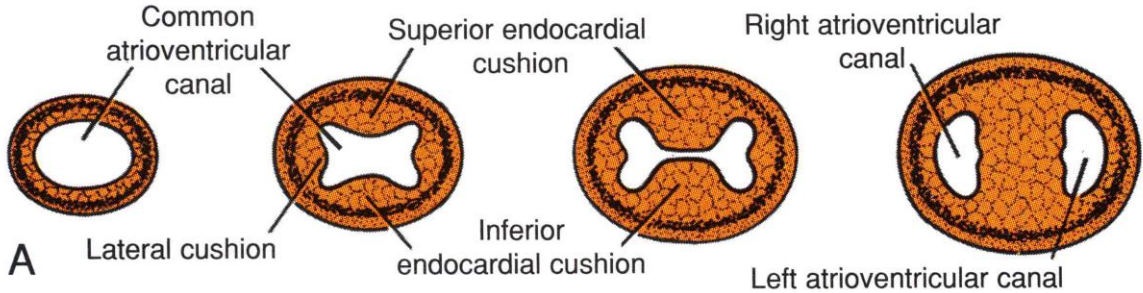
Valve of foramen ovale

Inferior vena cava (carrying well-oxygenated blood)



H1

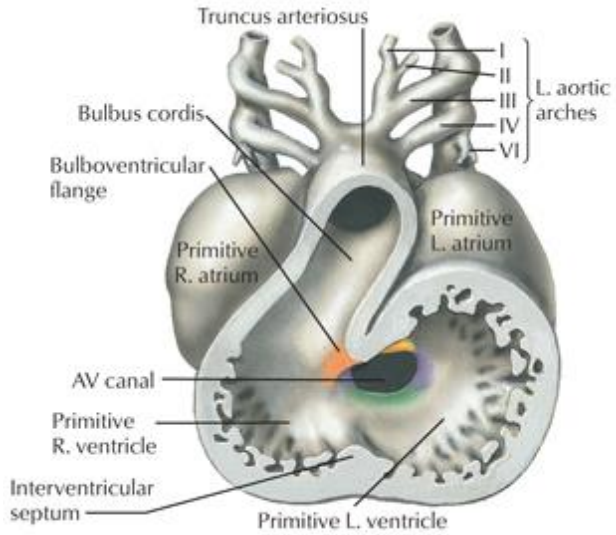
# Atrioventricular septation



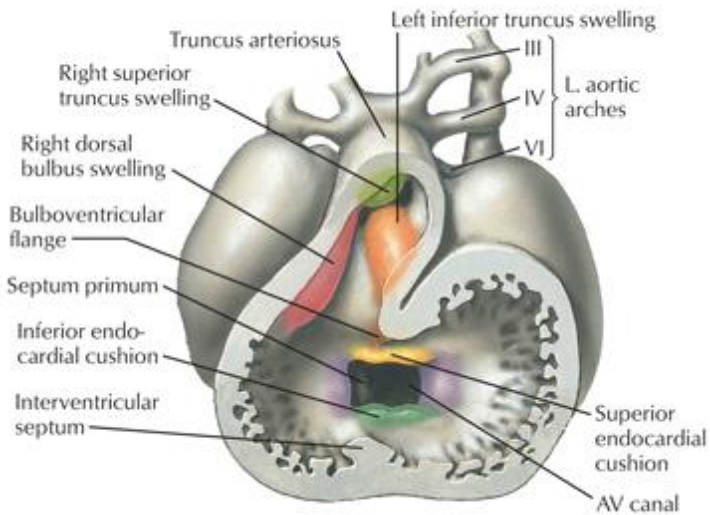


# Ventricular septation

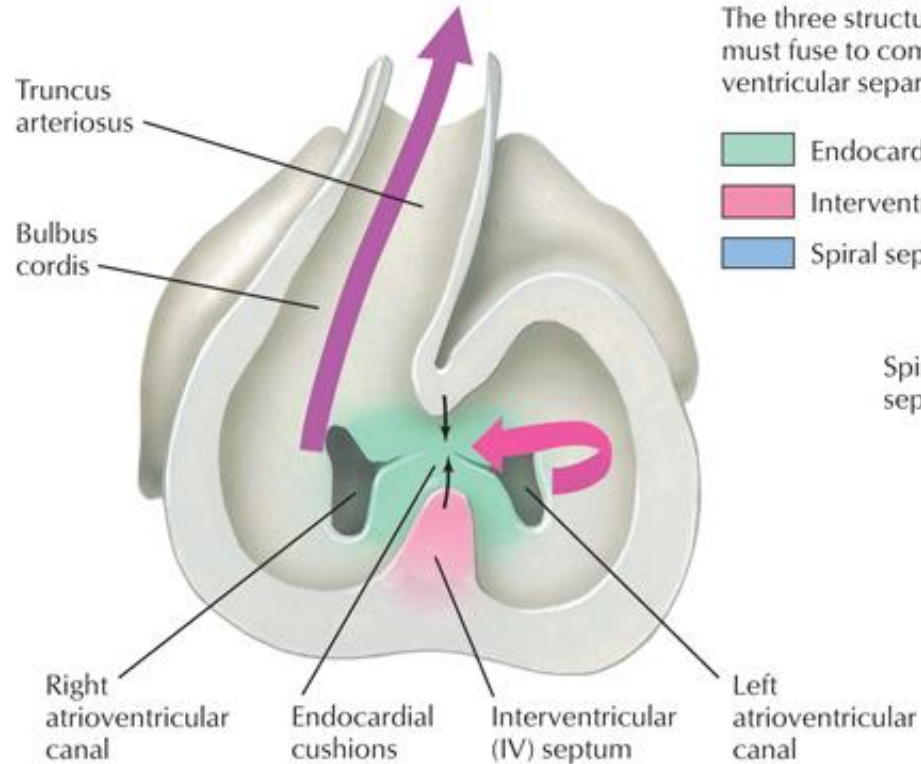
4 to 5 mm (approximately 27 days)



6 to 7 mm (approximately 29 days)



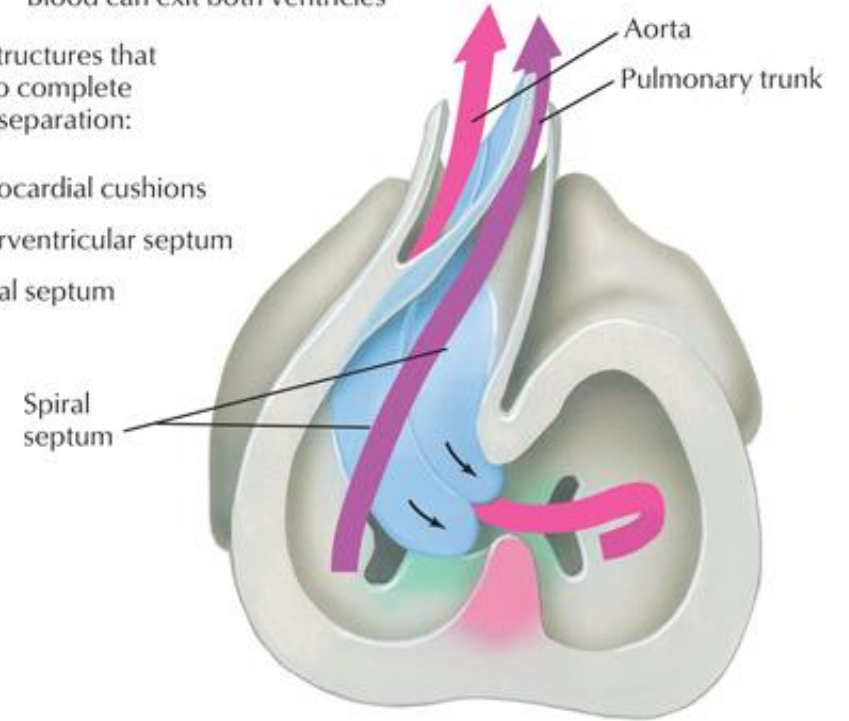
**Without the spiral septum**  
No exit for blood in left ventricle



**With the spiral septum**  
Blood can exit both ventricles

The three structures that must fuse to complete ventricular separation:

- Endocardial cushions
- Interventricular septum
- Spiral septum



*C. Machado*  
—M.D.



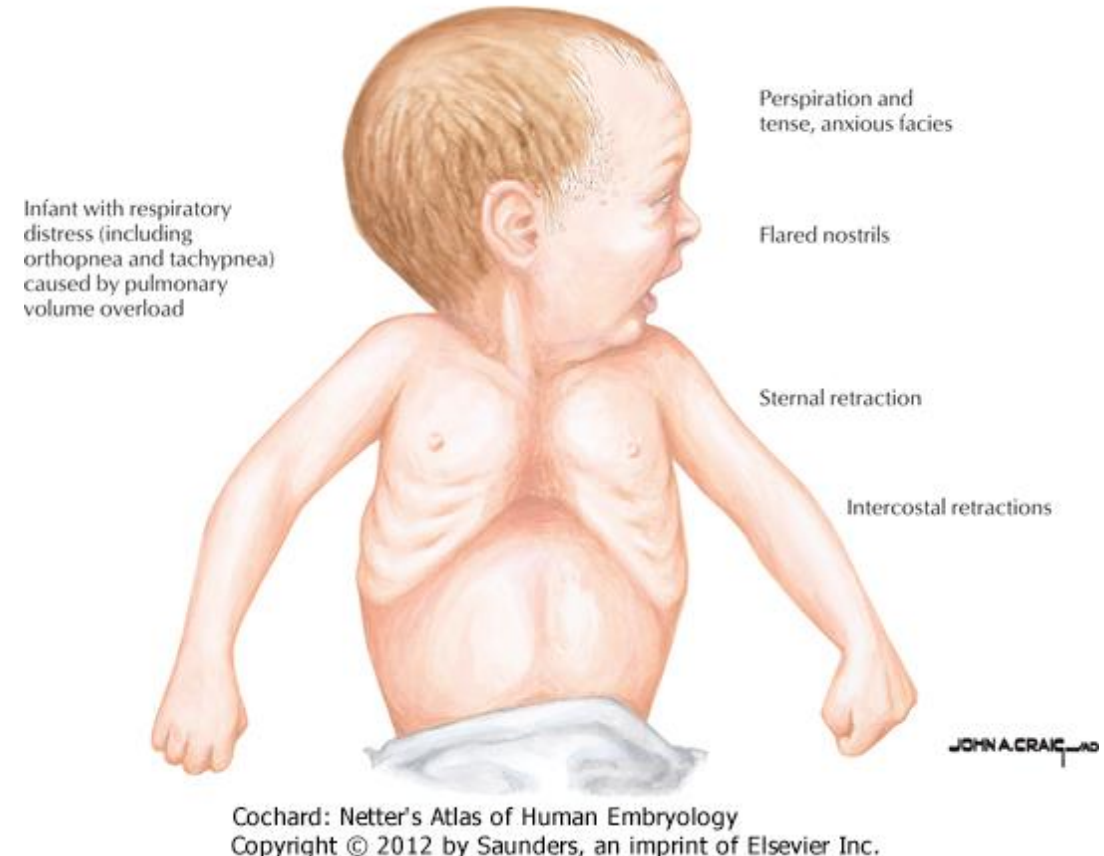
# Heart Defects

- Occurring roughly in 1 of each 100 births – the most common birth defects
- Long development, extensive remodelling, postnatal changes in circulation
- Leading cause of neonatal and infant death in preterm births
- Multifactorial origin
  - Genetics–trisomies (21, 13, 18), point mutations
  - Environmental factors–maternal infection(rubeolla), alcohol, drugs (Li), maternal diabetes mellitus etc.

Clinical characteristics of too little pulmonary flow



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



# Heart Defects

**Too little pulmonary flow** (e.g., pulmonary stenosis, right ventricular outflow obstruction)

- Cyanosis and respiratory distress
- Clubbing of fingers

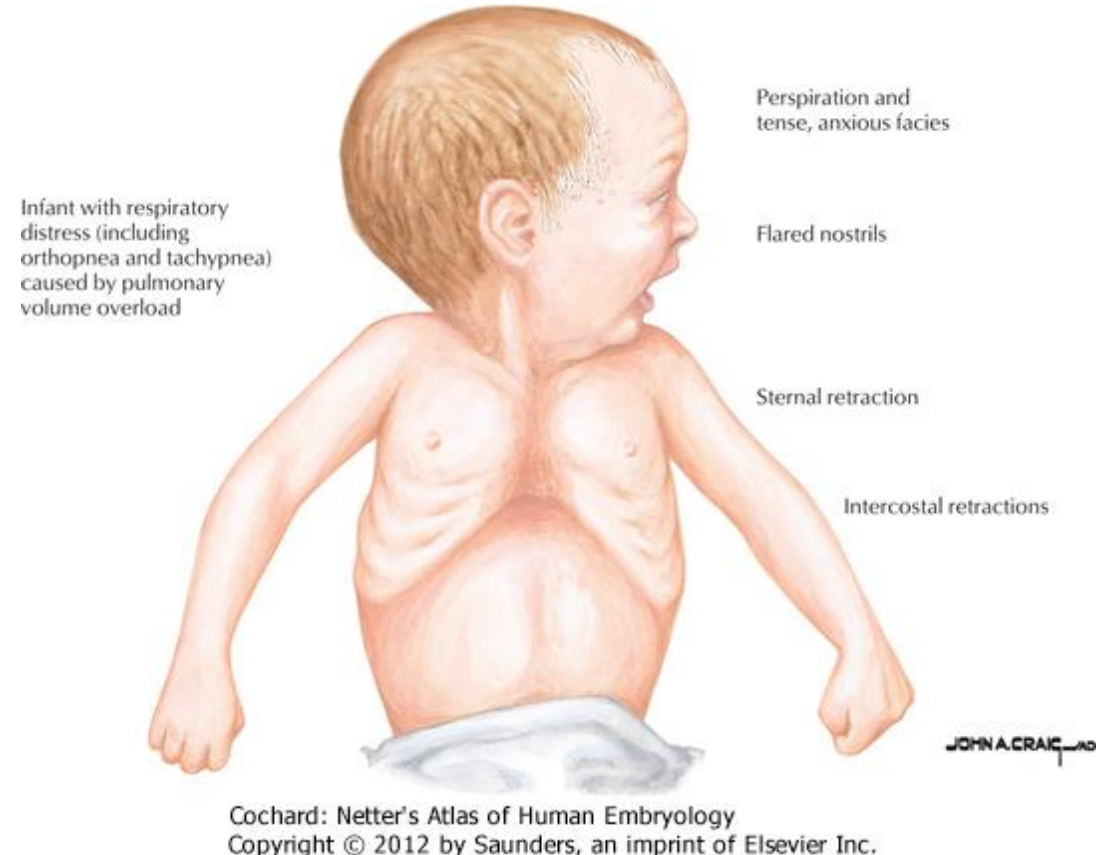
**Too much pulmonary flow** (pulmonary volume overload, abnormal communication between the ventricles or great arteries)

- Respiratory distress with tachypnea
- Sternal retraction, tense, anxiety, intercostal retractions
- Thickening of the pulmonary arteries, pulmonary hypertension, reverted right-to-left shunt

Clinical characteristics of too little pulmonary flow

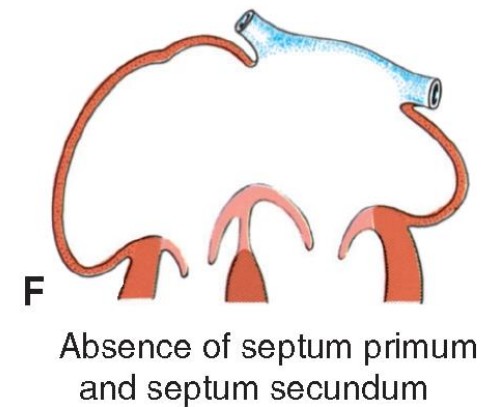
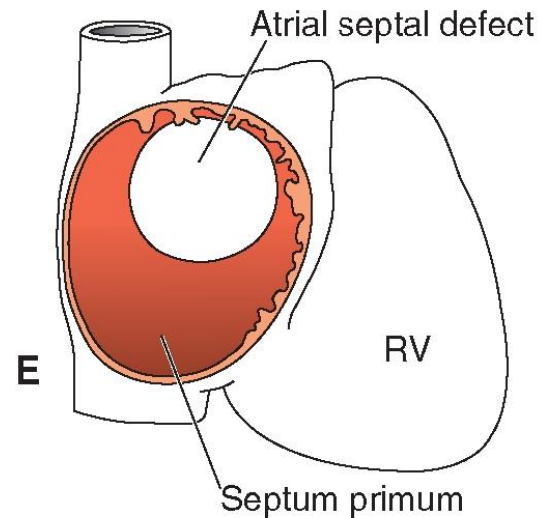
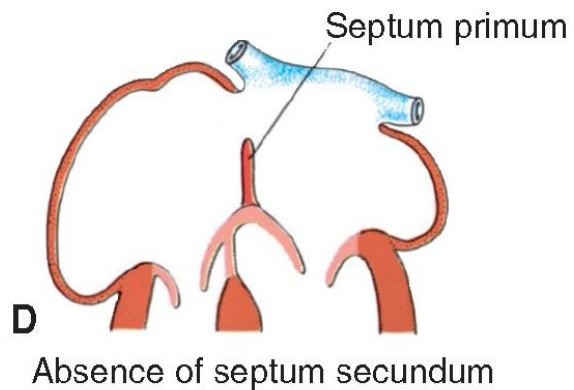
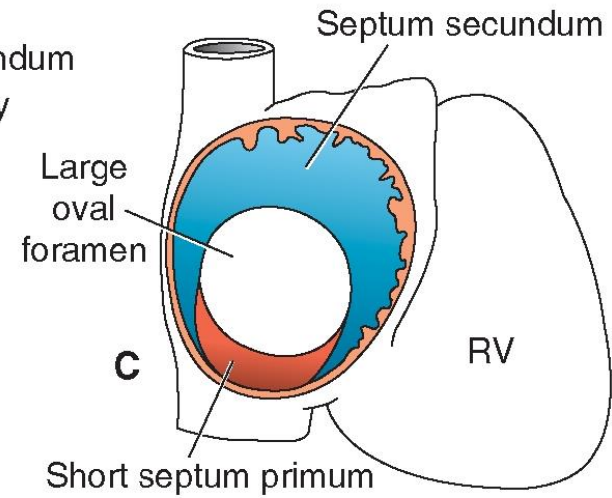
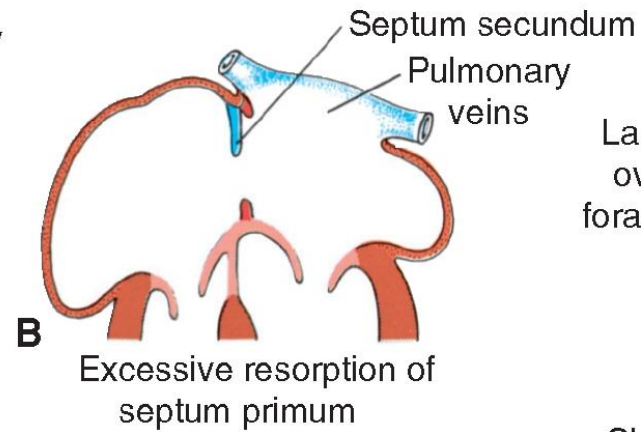
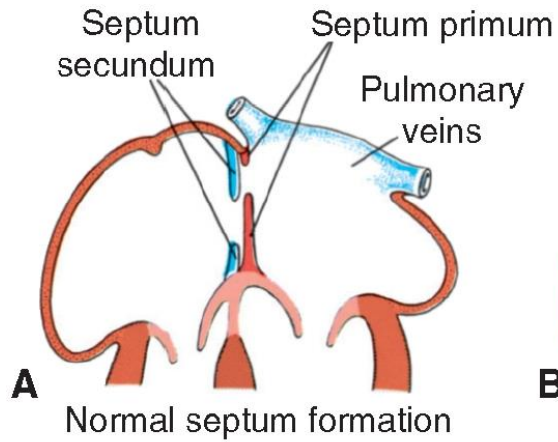


Clinical characteristics of too much pulmonary flow (pulmonary volume overload)



# Heart Defects

## Atrial septal defects



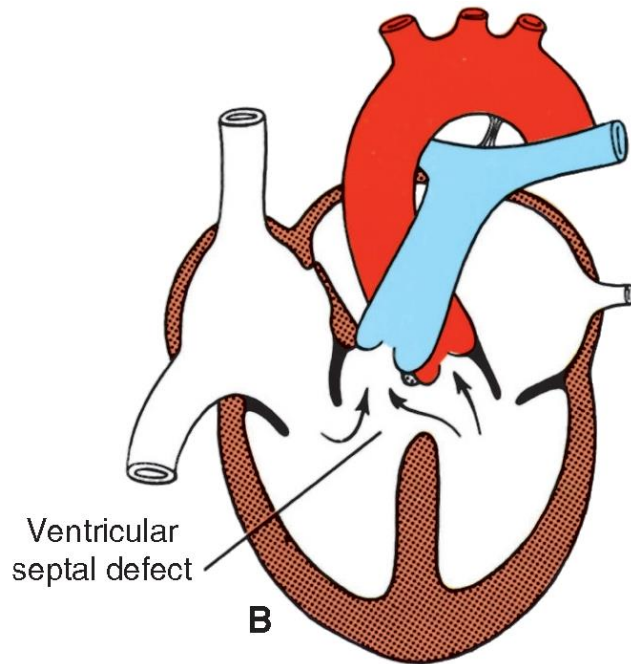
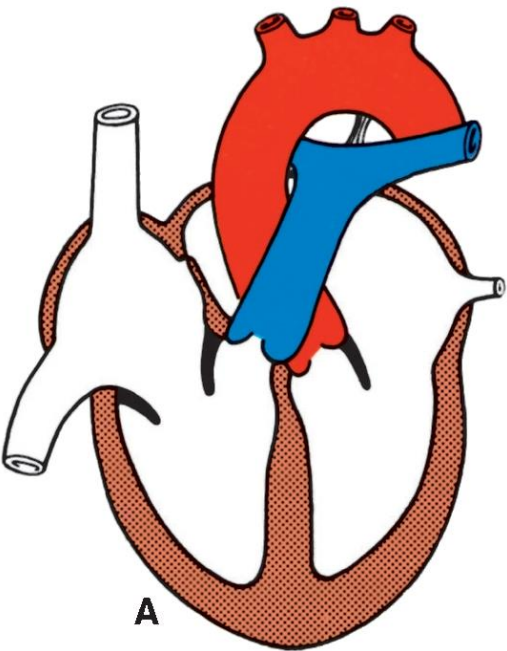
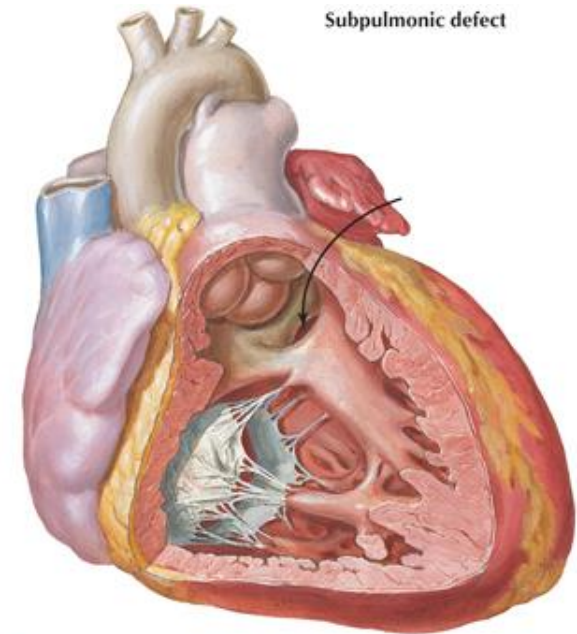
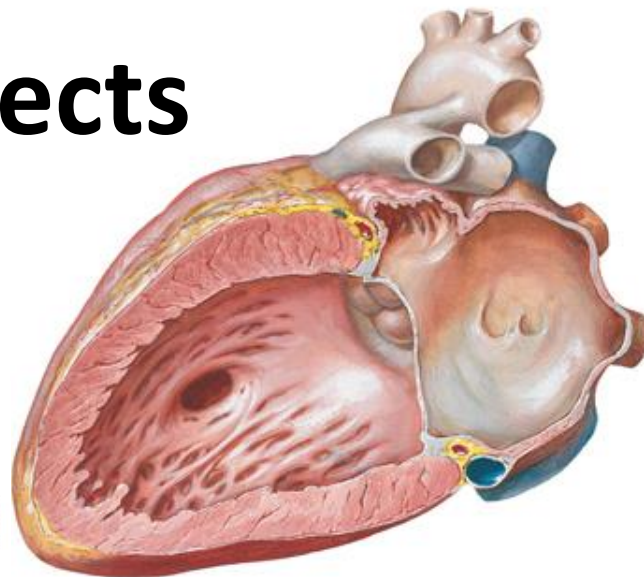


# Heart Defects

## Ventricular septal defects

Muscular interventricular septal defect

Subpulmonic defect

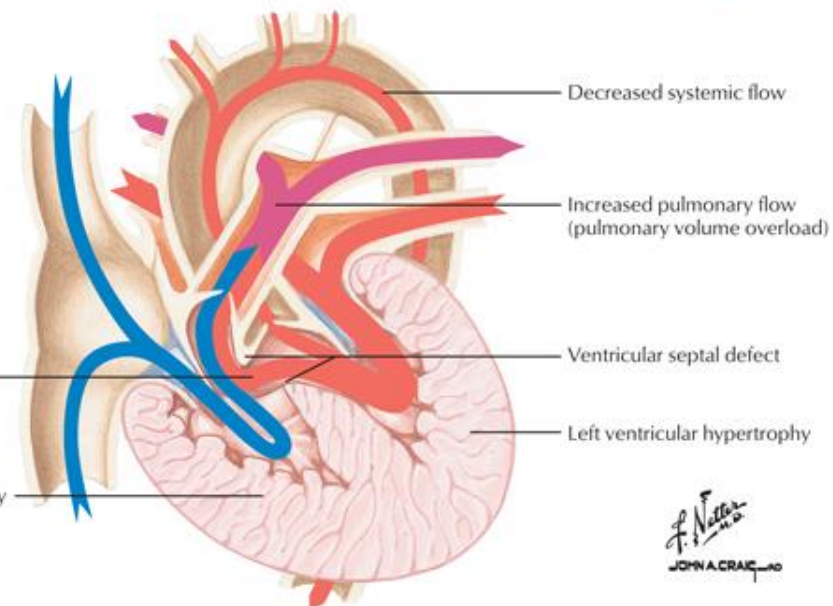


Ventricular septal defect

Pathophysiology of ventricular septal defect

Left-to-right shunt through ventricular septal defect

Right ventricular hypertrophy

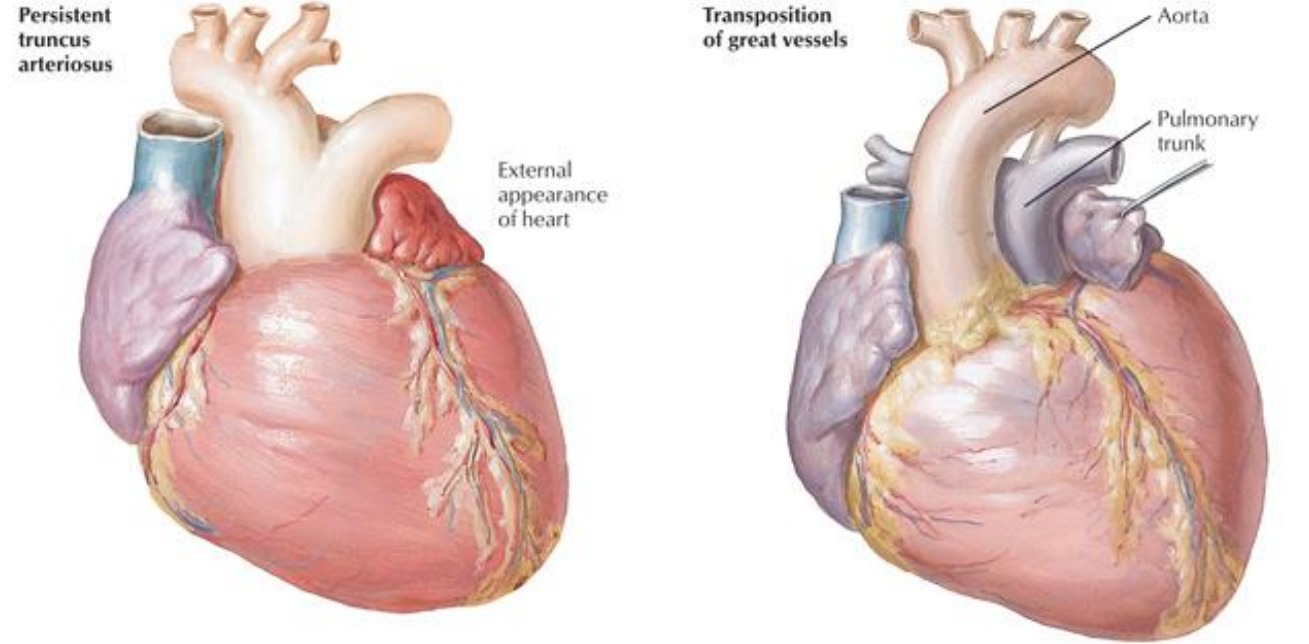


*F. Netter M.D.*  
JOHN A. CRAIG, MD

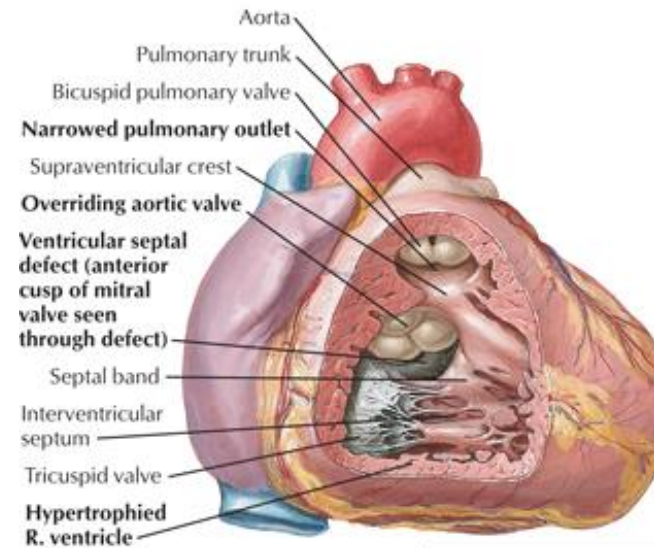
# Heart Defects

## Tetralogy of Fallot

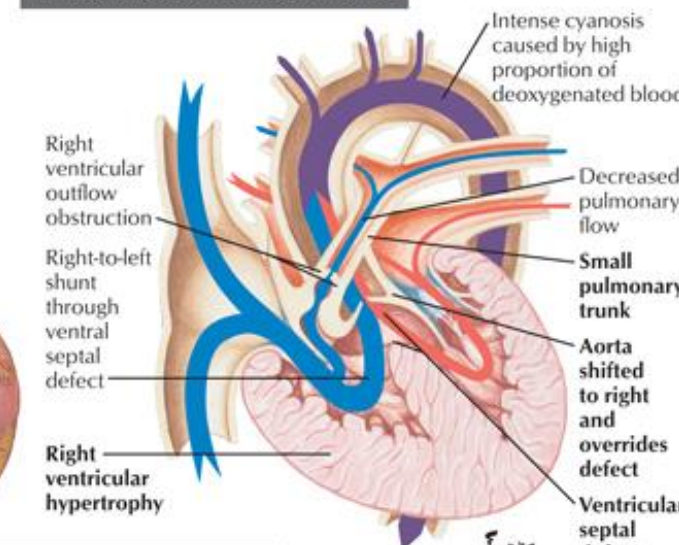
- Ventricular septal defect
- Pulmonary stenosis (narrow RV outflow region)
- Overriding aorta arising directly above the septal defect
- Hypertrophy of the RV



Tetralogy of Fallot



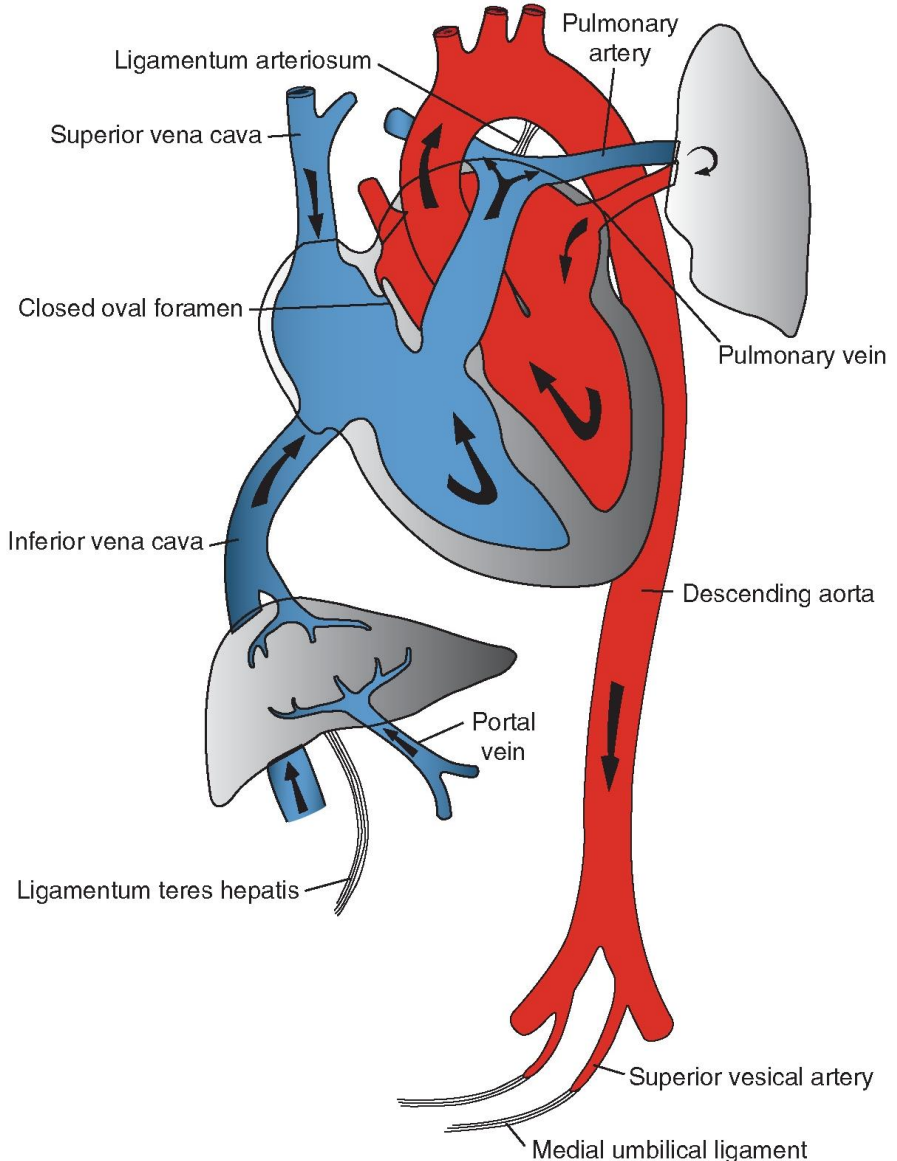
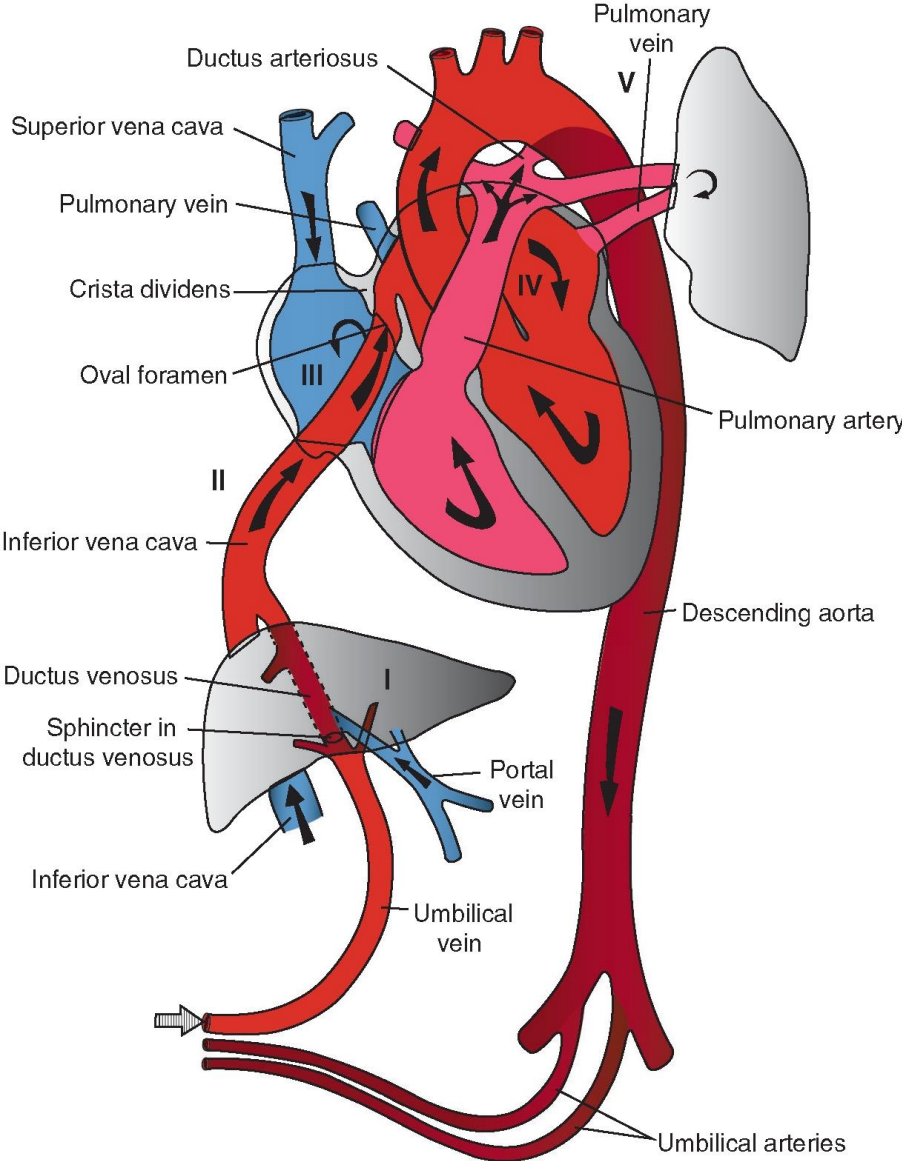
Pathophysiology of tetralogy of Fallot



Note: Bold labels indicate the four primary defects



# Circulation before and after birth





# Thank you for your attention!

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