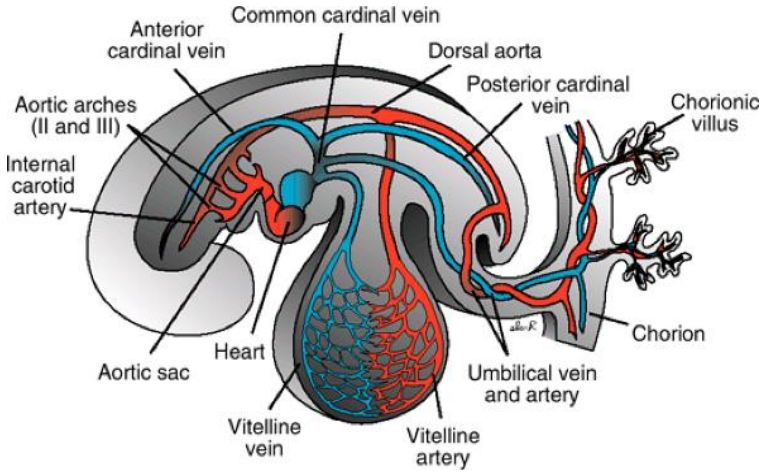
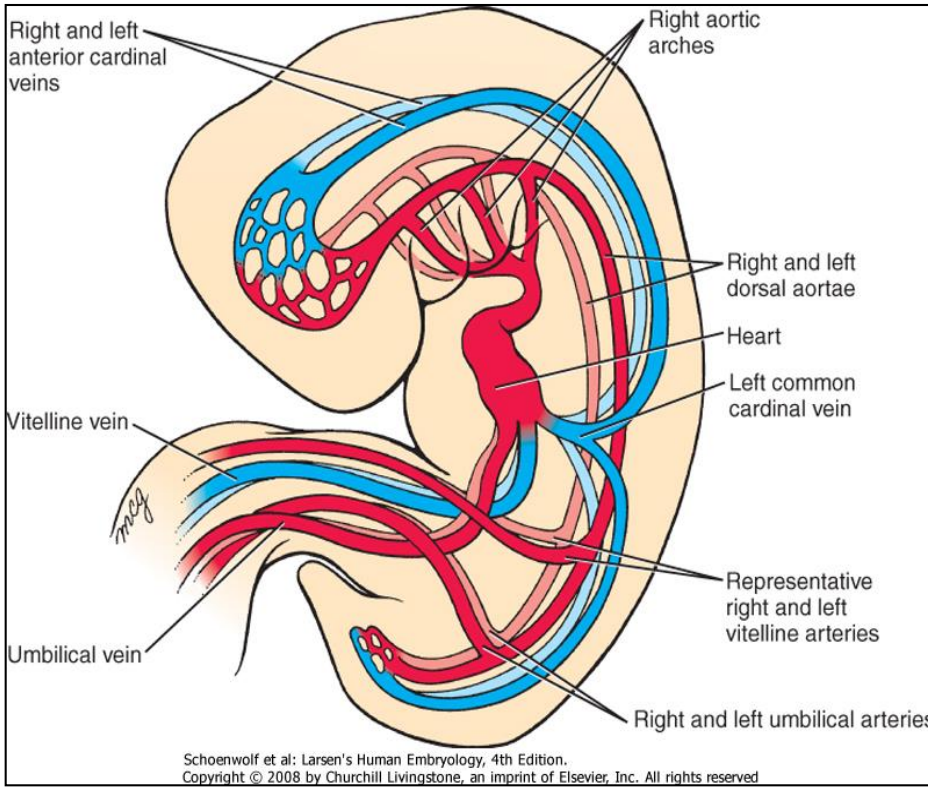
Development of the Vascular system

Heart-Vasculature connections

major vessels develop at same time as endocardial tube

- Inflow (right and left sinus horns)
  - 3 paired vessels
    - **common cardinal veins**
    - **vitelline veins**
    - **umbilical veins**
- Outflow
- **Three pairs of aortic arch arteries and the paired dorsal aortae that circulate blood to the head and trunk**



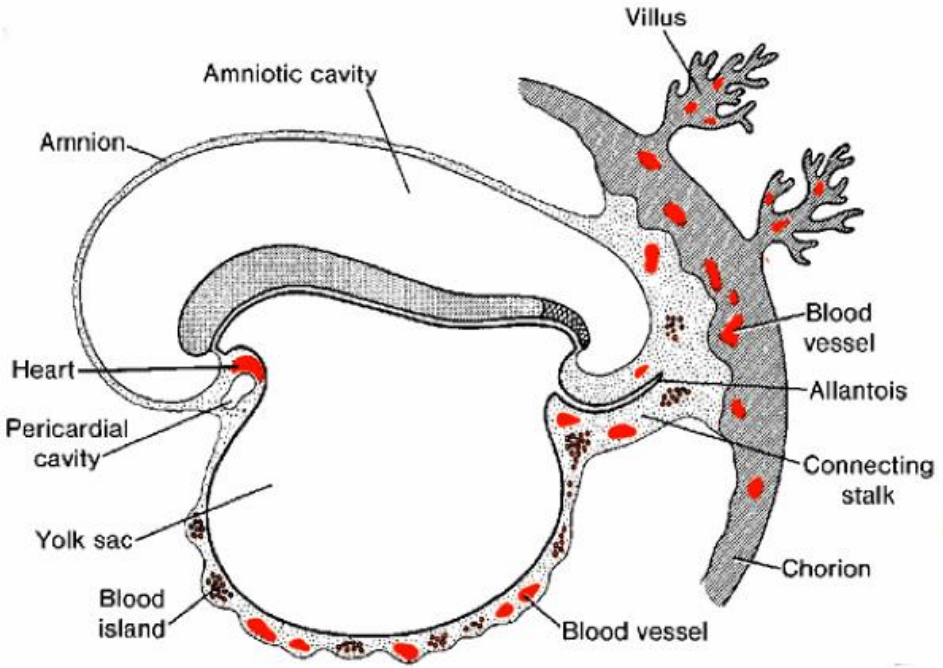


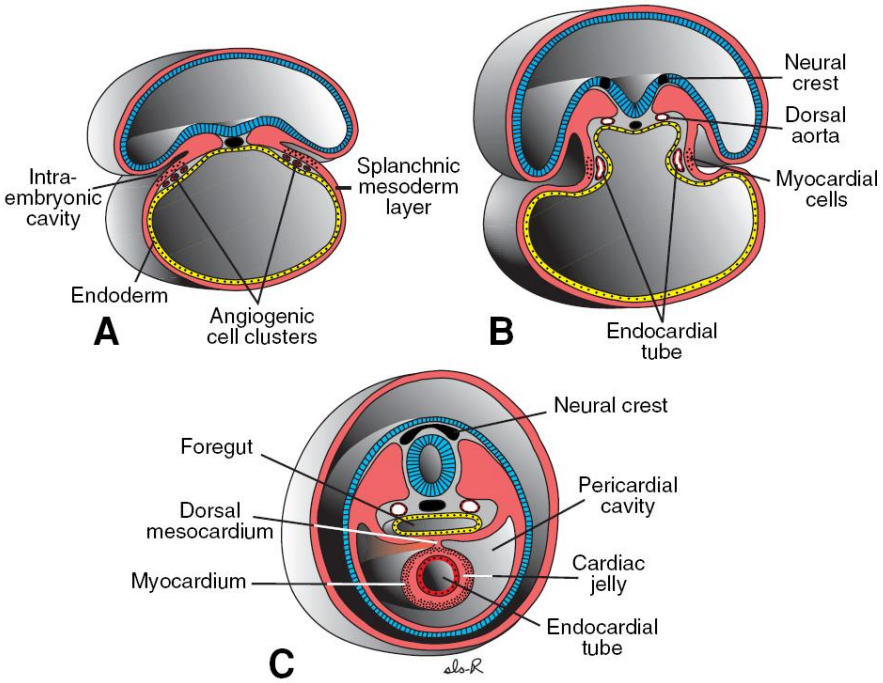
Vasculature Development

Extraembryonic vasculature

- From 17th day
  - splanchnic mesoderm of yolk sac
    - **hemangioblastic aggregates**
      - **Primitive hematopoietic stem cells**
      - **endothelial precursor cells**

- Intraembryonic vasculature
- On day 18
  - splanchnic mesoderm of embryonic disc
  - later in paraxial mesoderm





Vasculogenesis & Angiogenesis

Vasculogenesis (primary embryonic vasculature formation)

de novo blood vessel formation

Endothelial precursors differentiate into endothelial cells

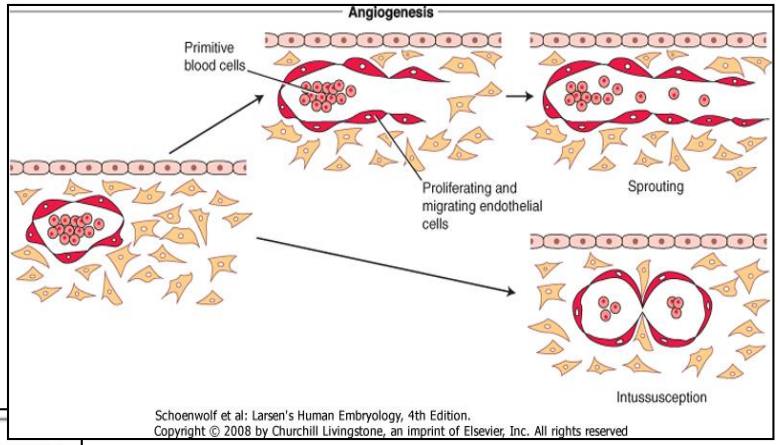
organize into networks of small vessels

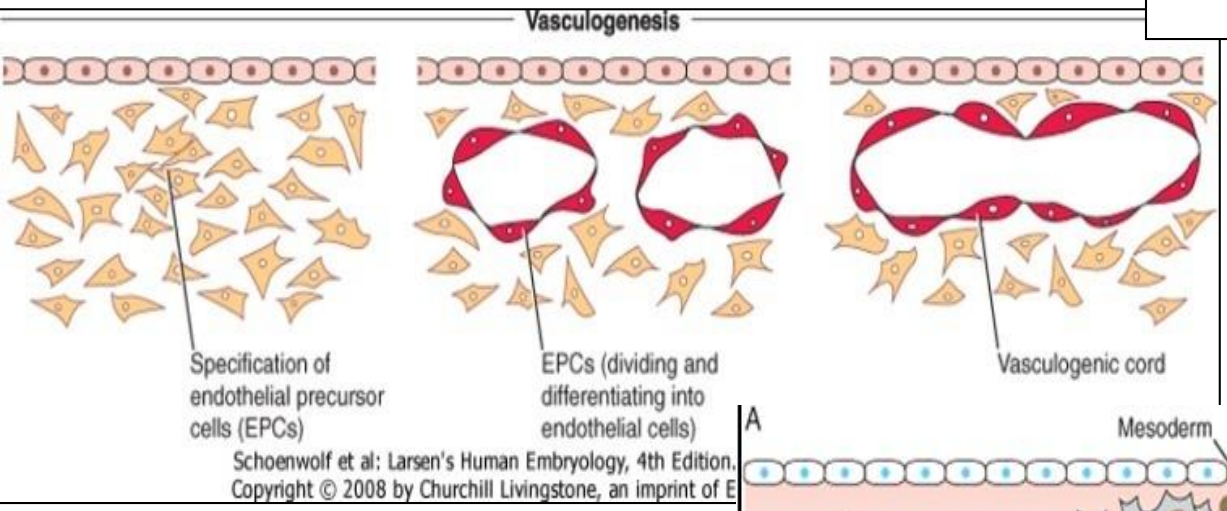
Grow and invade other tissues

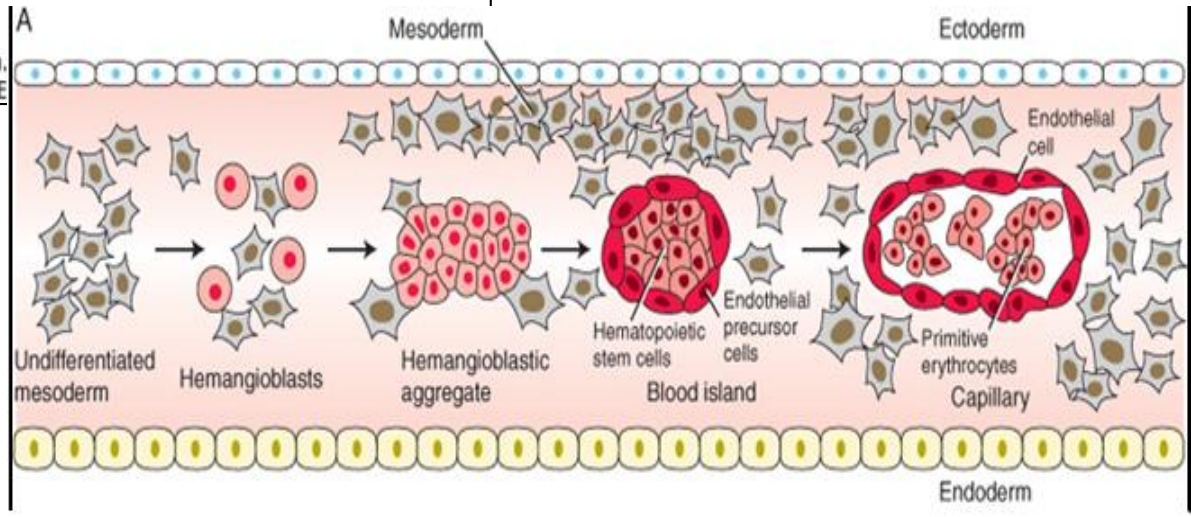
Angiogenesis

primitive vasculature expansion and remodeling

Budding and sprouting from existing endothelial cords



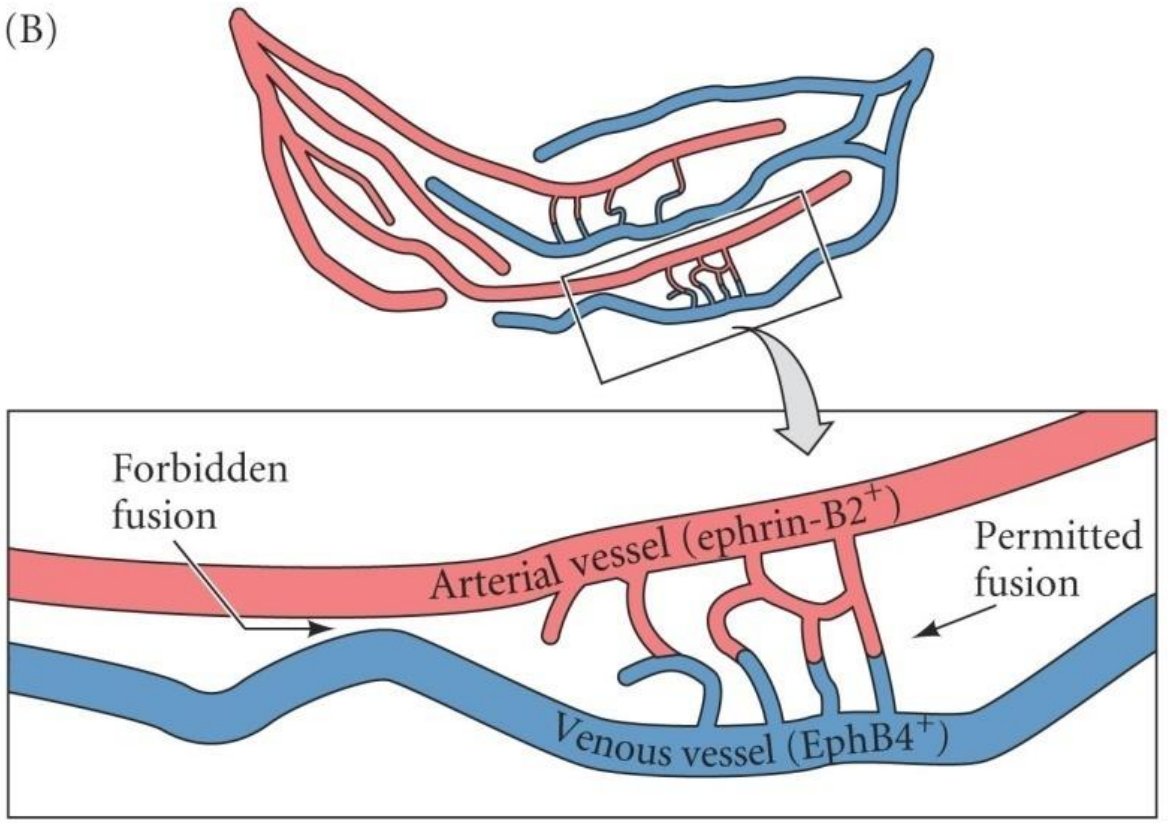




Arteries and *veins* differences

differences in directions of blood flow, morphology and physiology

- Flow dynamics in capillary-sized vessels
  - Flow increases (arterial vessels)
  - Floe decreases (venous vessels)



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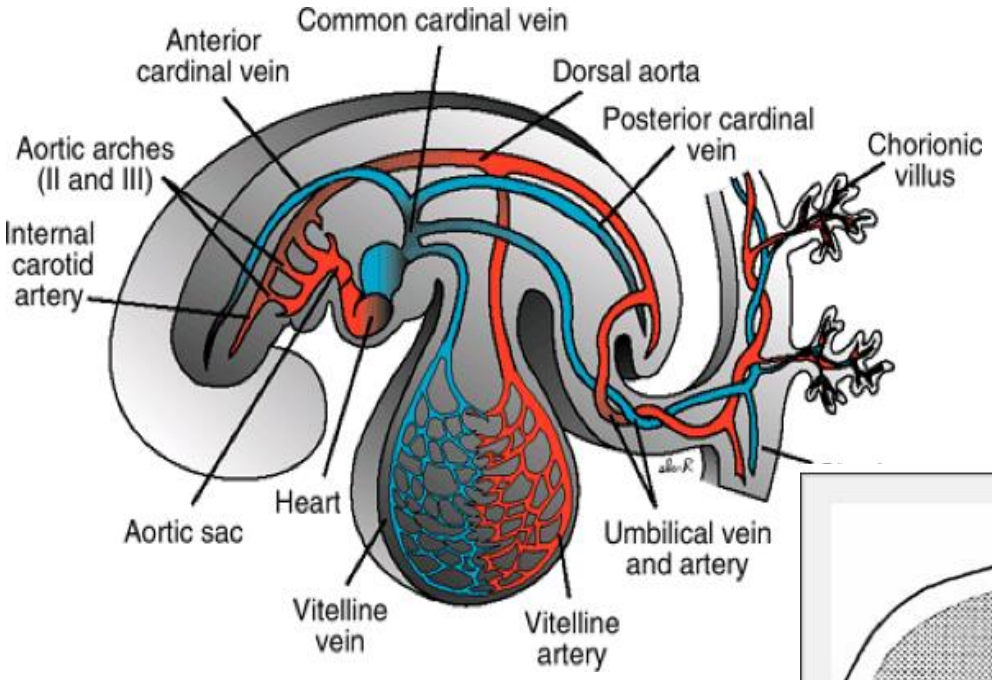
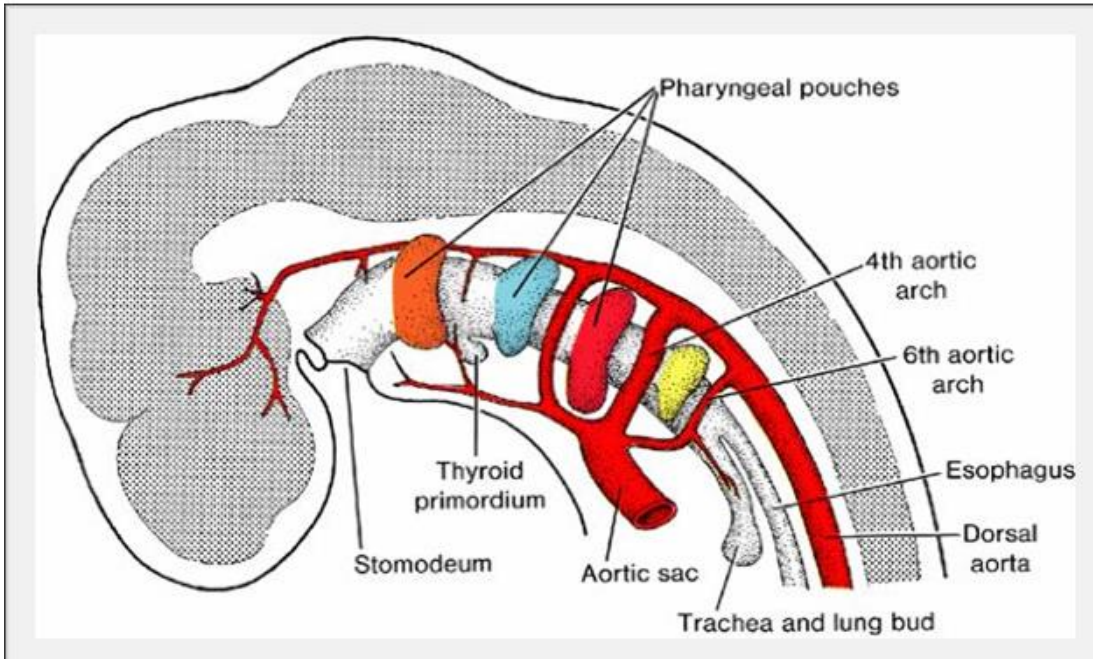
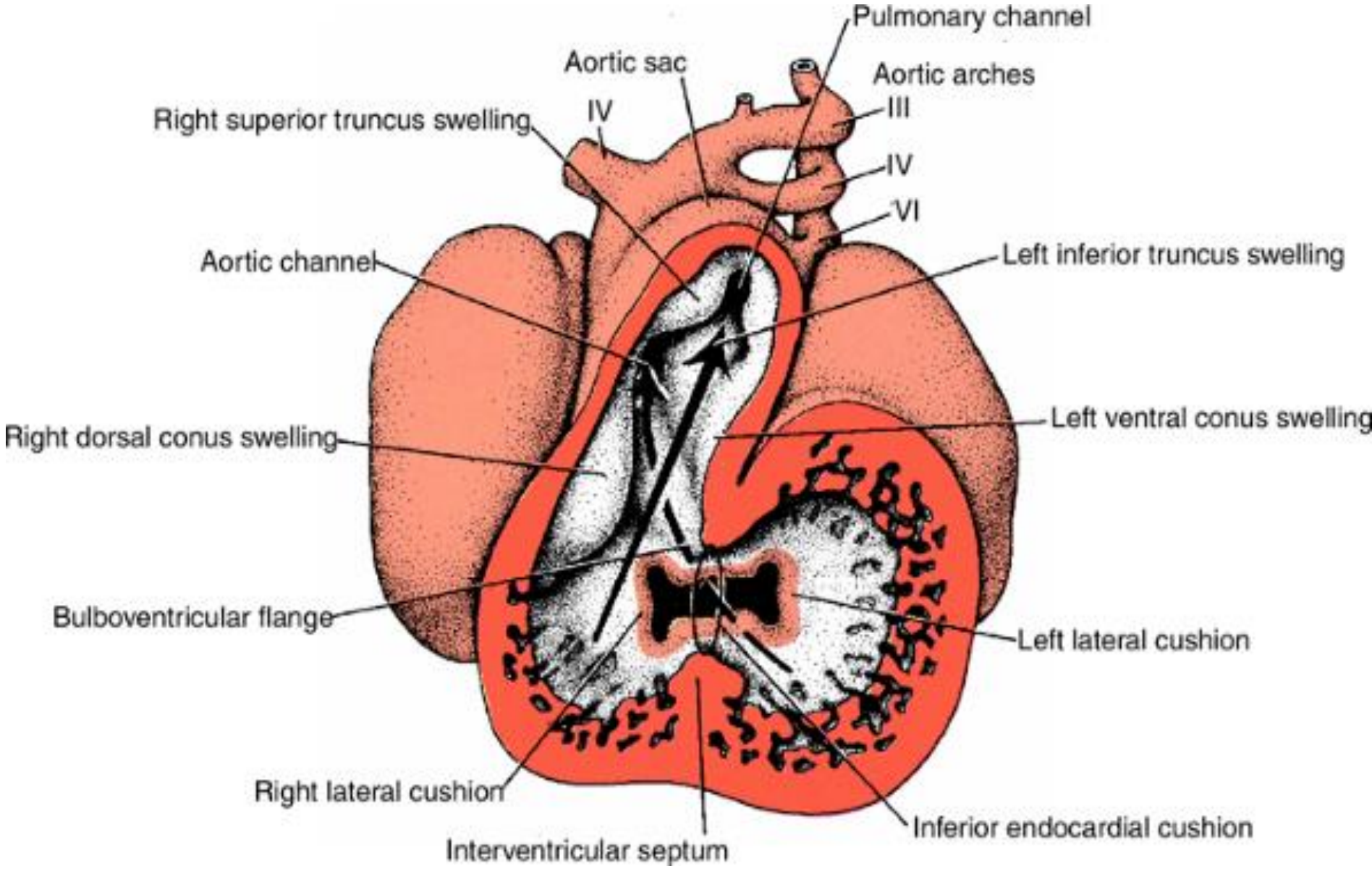
Development of Aortic Arches

4th and 5th weeks

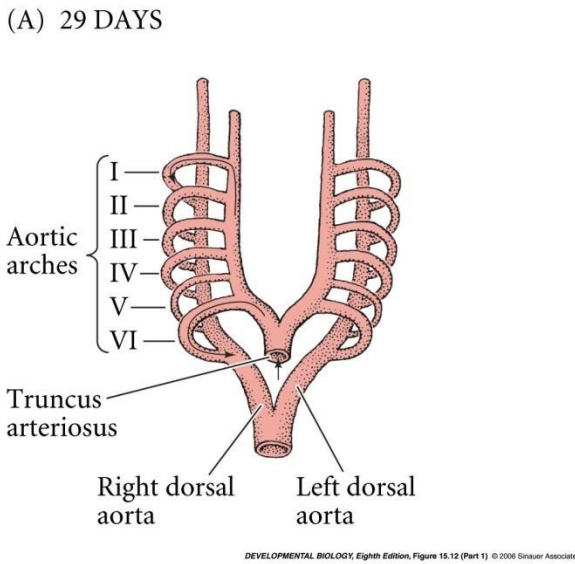


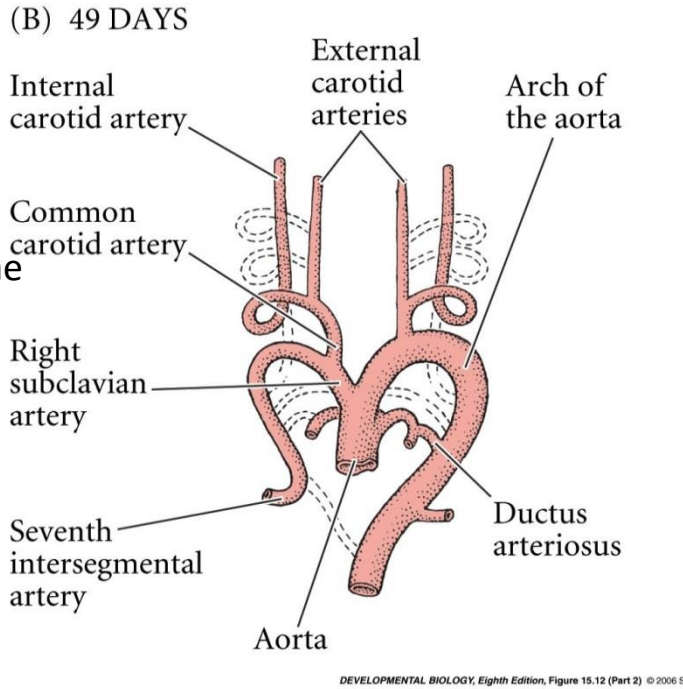



Pulmonary channel
Aortic sac
Aortic arches
Right superior truncus swelling
IV
III
IV
VI
Aortic channel
Left inferior truncus swelling
Right dorsal conus swelling
Left ventral conus swelling
Bulboventricular flange
Left lateral cushion
Right lateral cushion
Inferior endocardial cushion
Interventricular septum

Aortic Arches (1, 2, 3)

- **First aortic arches**
  - portions of **maxillary arteries**
- **second aortic arches**
  - part of the **hyoid** and **stapedial arteries**
- **third aortic arches**
  - **common carotid arteries**
  - proximal portion of **internal carotid arteries**
    - distal portion derived from cranial extensions of dorsal aortae
    - **external carotid arteries** sprout from the common carotids

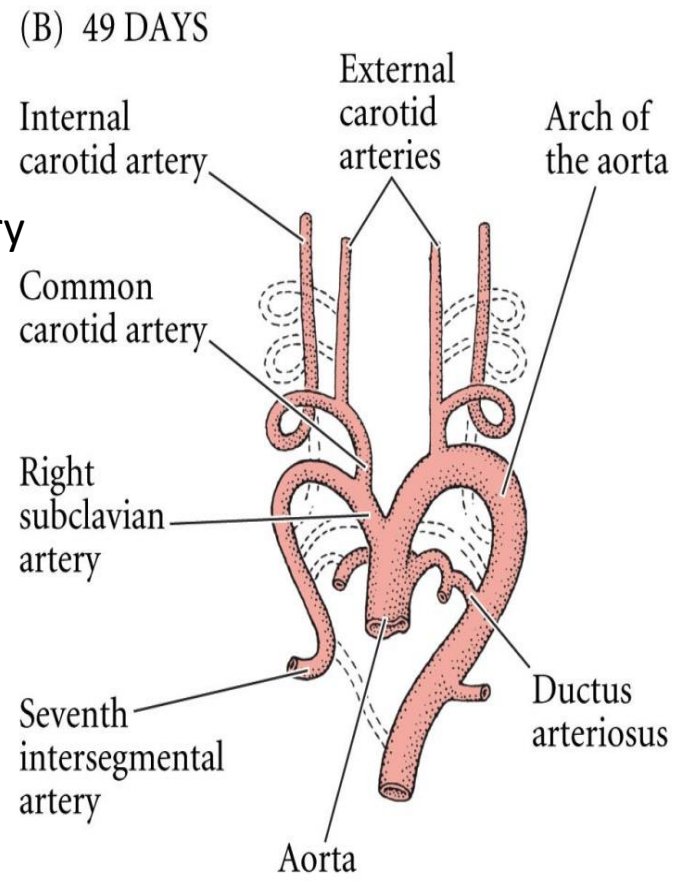




Aortic Arches (Right 4th)

By the 7th week

- **Right subclavian artery**
  - (1) right fourth arch
  - (2) short segment of right dorsal aorta
  - (3) right seventh intersegmental artery.
- region of **aortic sac** connected to right fourth artery
  - **brachiocephalic artery (Right)**
  - **proximal portion of aortic arch (Left)**



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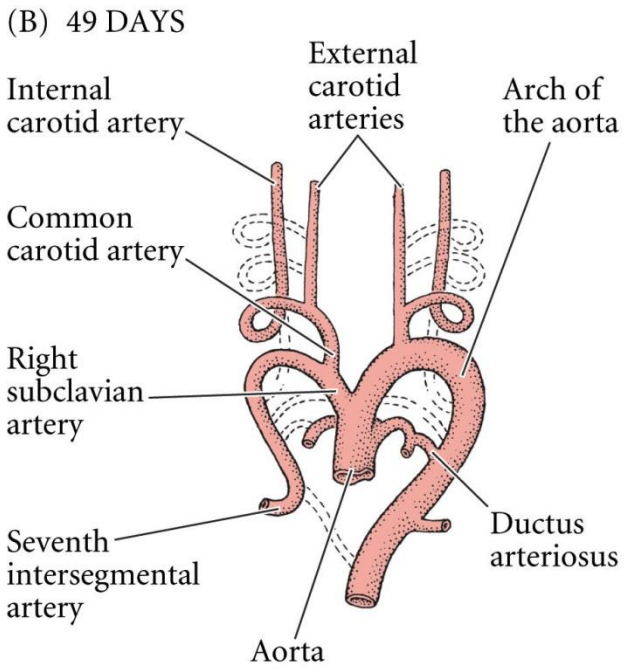
Aortic Arches (Left 4th)

- **Left fourth aortic arch + small segment of aortic sac**
  - **aortic arch**
  - most cranial portion of **descending aorta**

- **Left seventh intersegmental artery**
  - **left subclavian artery**

segments of dorsal aorta connecting 3rd and 4th arch (**carotid duct**) disappear



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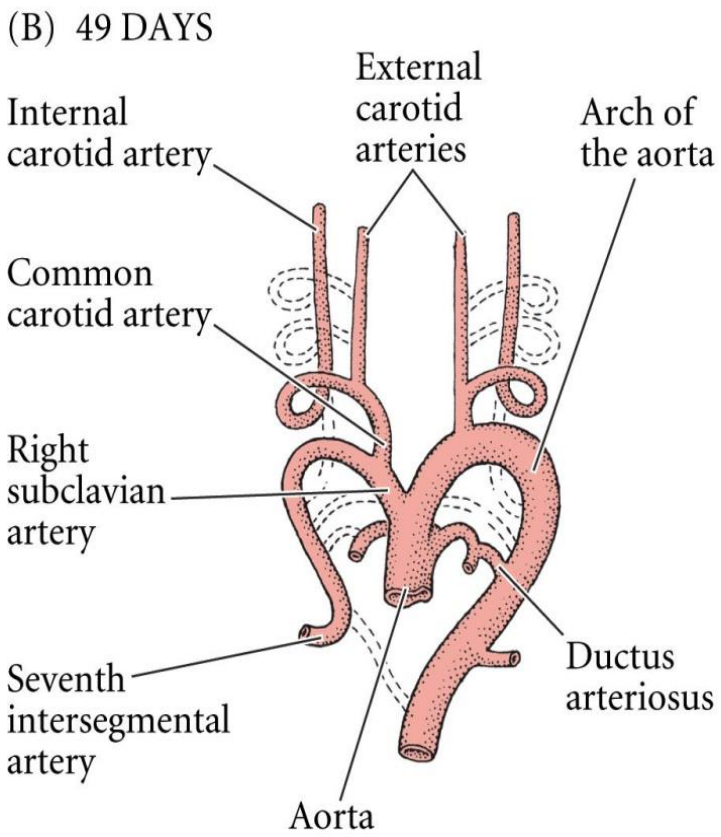
Aortic Arches (6)

Right and left 6th arches arise from proximal end of aortic sac

- By the 7th week
  - Right 6th arch
    - disappears distal connection with dorsal aorta
    - Right pulmonary artery
  - Left sixth arch
    - remains complete
      - distal portion forms **ductus arteriosus**
        - » **ligamentum arteriosum**
        - » **left pulmonary artery**



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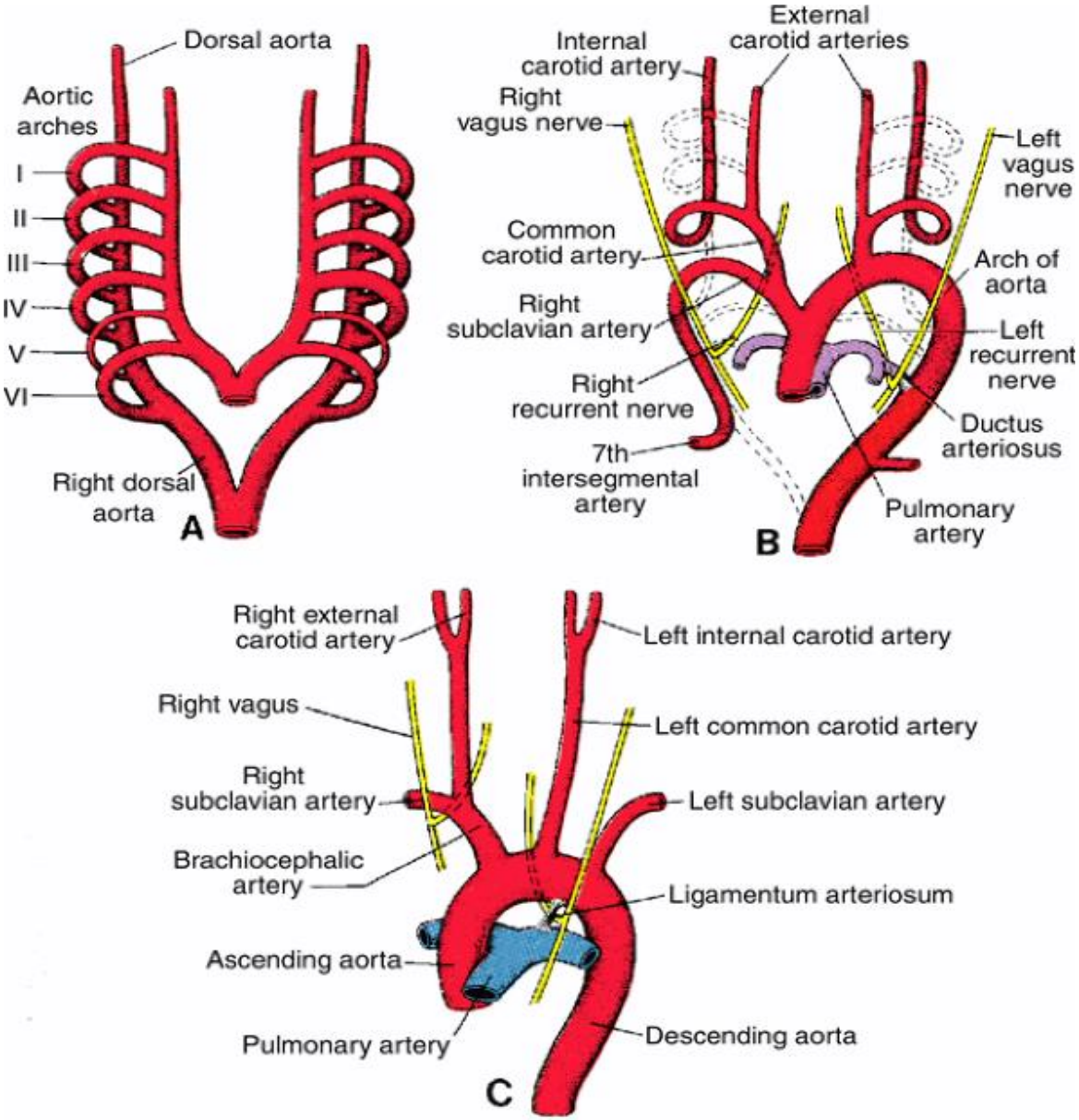
- **Left and right recurrent laryngeal nerves**
- **Originally arise below the level of 6th arch**



Dorsal Aorta and ventral Branches

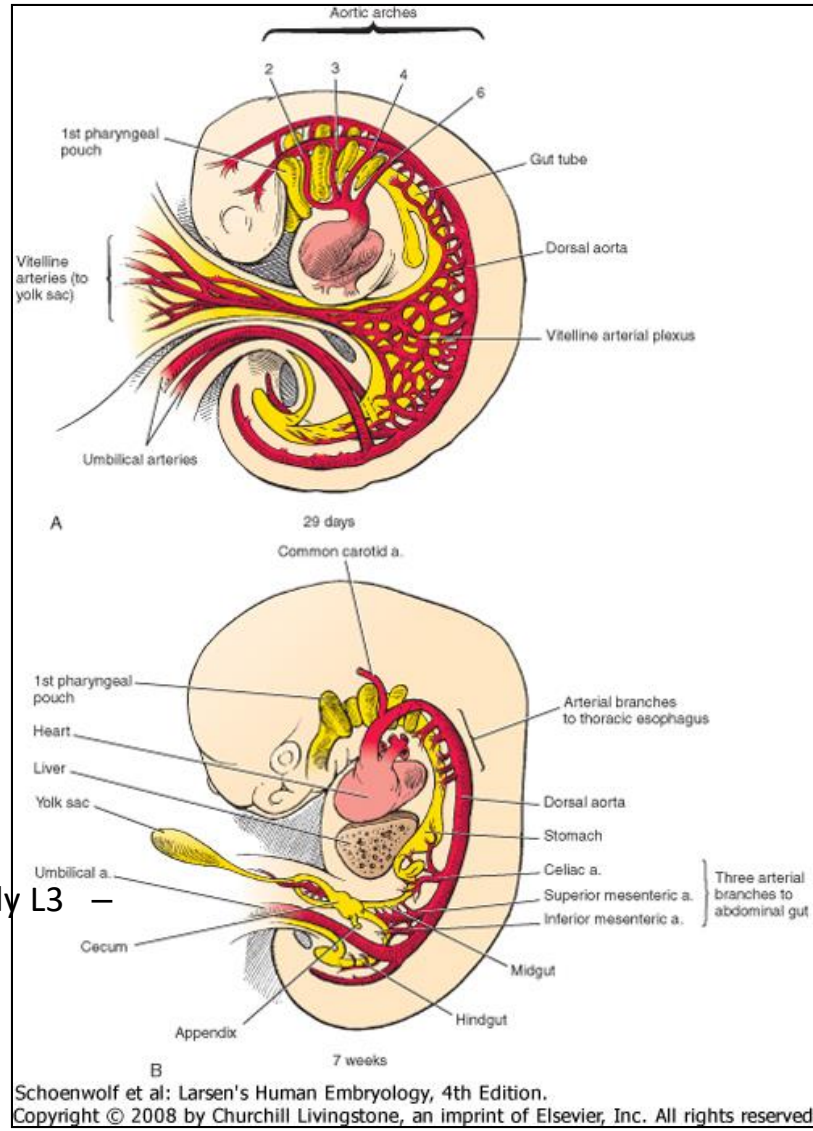
Dorsal aorta

- Left dorsal aorta
- Merged left & right aorta (T4-L4)

vitelline system

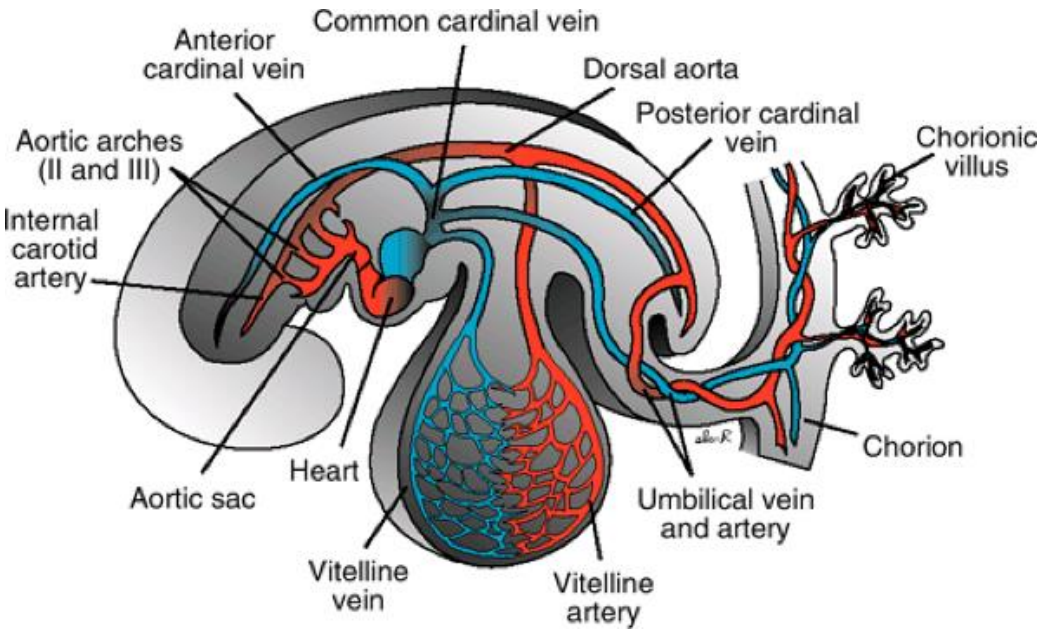
- blood vessels arising from yolk sac wall
  - **Cranial to the diaphragm (5 pairs)**
    - supply thoracic esophagus
  - **Caudal to the diaphragm (3 pairs)**
    - **celiac artery (abdominal foregut)**
      - initially at C7, finally at T12
    - **superior mesenteric artery (midgut)**
      - Initially T2, finally L1
    - **inferior mesenteric artery (hindgut)**

initially T12, finally L3 –



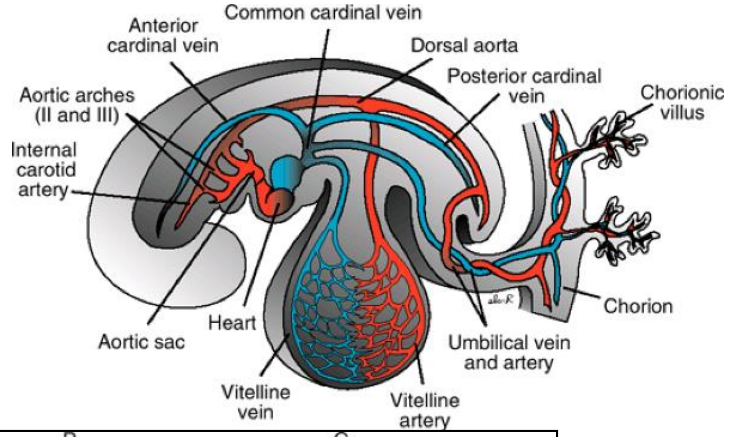
Dorsal Aorta and umbilical arteries

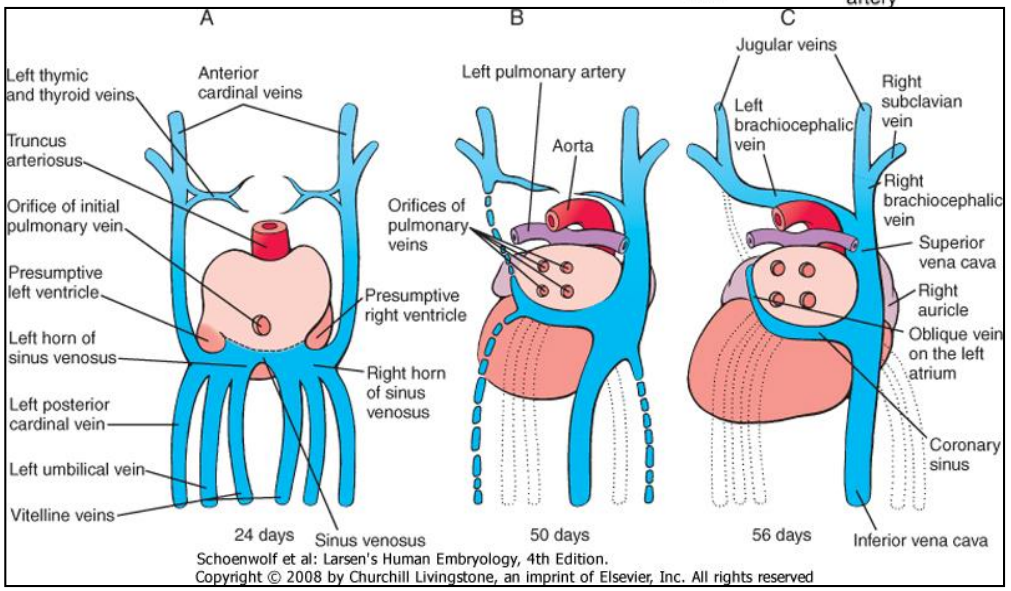
- **umbilical arteries** develop in connecting stalk early in the 4th week (earliest embryonic arteries to arise)
  - initially connected with paired dorsal aorta
  - secondary connected with branch of dorsal aorta (**common iliac artery**)
- After birth
  - **proximal portions of umbilical arteries**
    - **Internal iliac**
    - **superior vesical arteries**
  - **distal parts obliterated**
    - **medial umbilical ligaments**



Embryonic venous system

- Initial bilaterally symmetric System
  - **vitelline system**
    - Drains gastrointestinal tract and derivatives
  - **umbilical system**
    - carries oxygenated blood from the placenta
  - **cardinal system**
    - Drains head, neck, and body wall



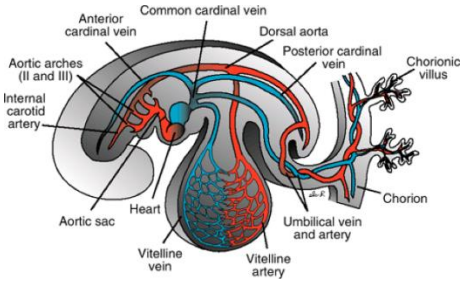


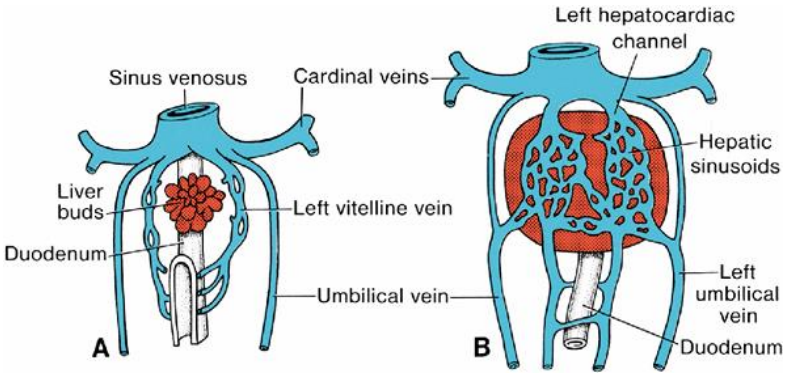
- shift of systemic venous to right atrium remodeled to adult patterns

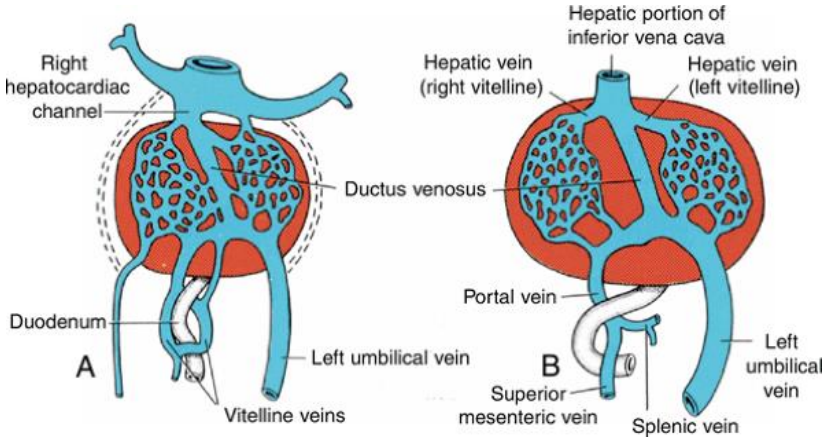
Vitelline Veins

Gives Rise to **Liver Sinusoids, Portal System, and a Portion of Inferior Vena Cava**

- vitelline plexuses in septum transversum
  - surrounded by growing liver cords
    - **liver sinusoids**
    - **Ductus venosus**
- left vitelline vein diminishes by sinus horn regression
- Right vitelline vein
  - cranial portion (between liver and heart)
    - **hepatocardiac portion of inferior vena cava**
  - Segment caudal to developing liver and anastomoses
    - **portal system**
      - **portal vein**
      - **superior mesenteric vein**

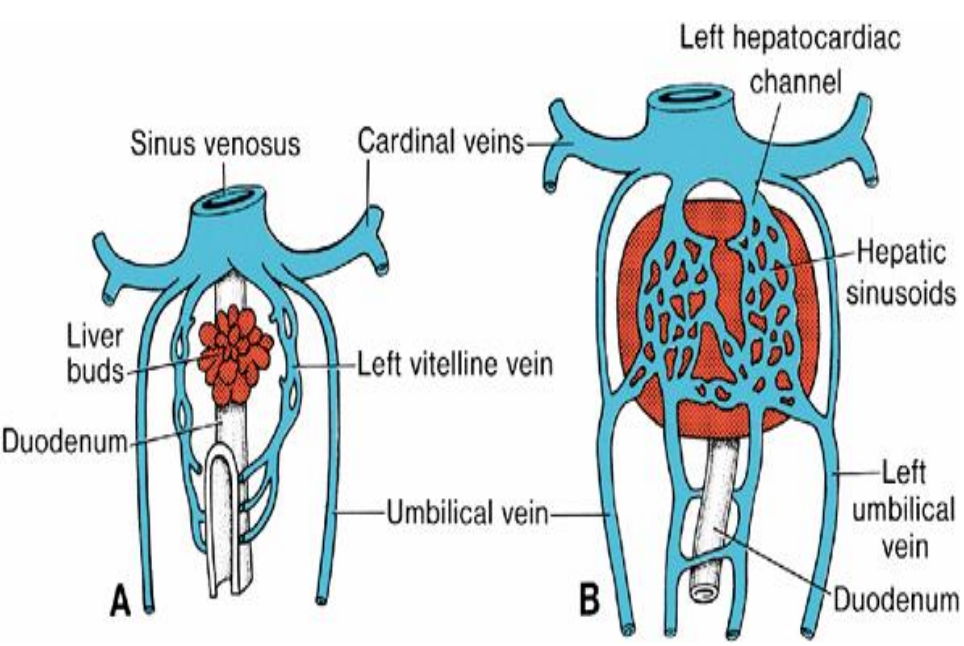


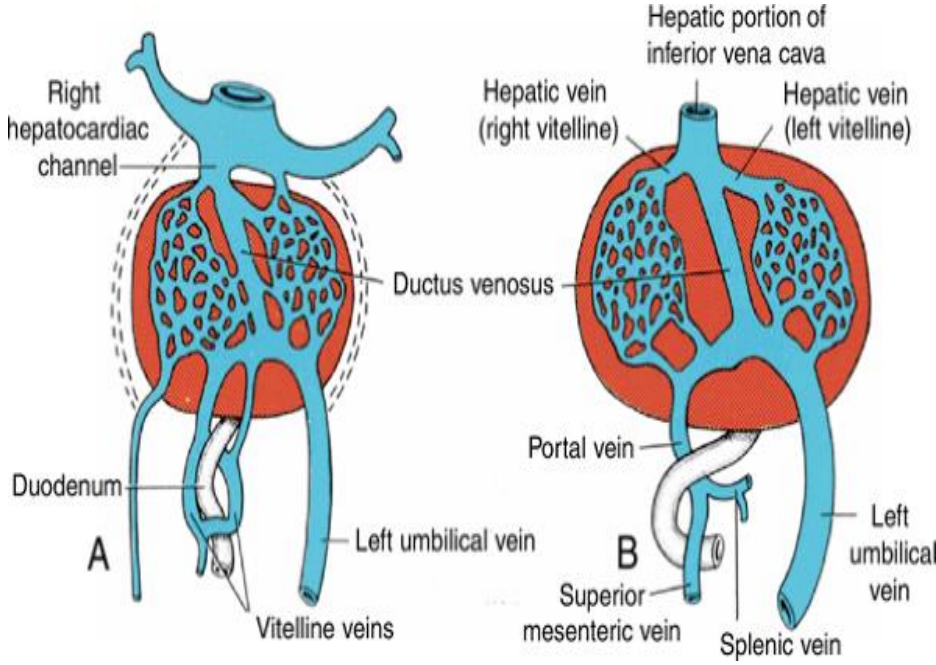




Umbilical Veins

- During second month
  - right umbilical vein completely obliterated
  - left umbilical vein persists
    - Left umbilical vein: **ligamentum teres hepatic**
    - dactus venosus: **ligamentum venosum**





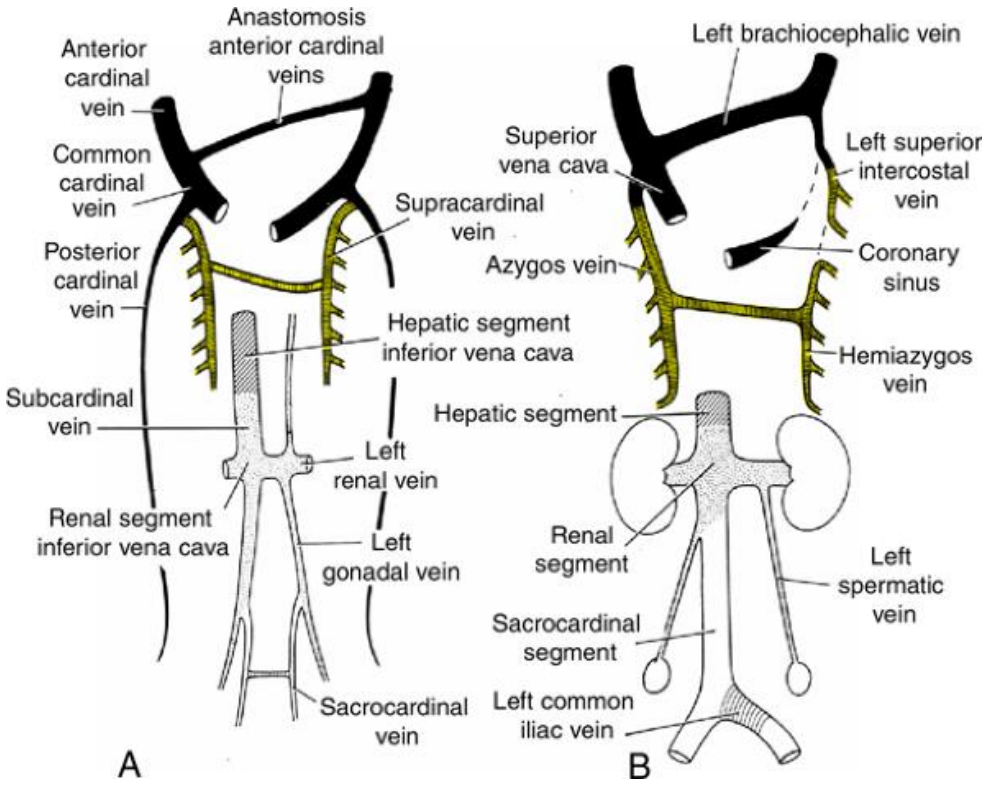
Cardinal Veins

During 4th week

- **Anterior, posterior** and **common cardinals**

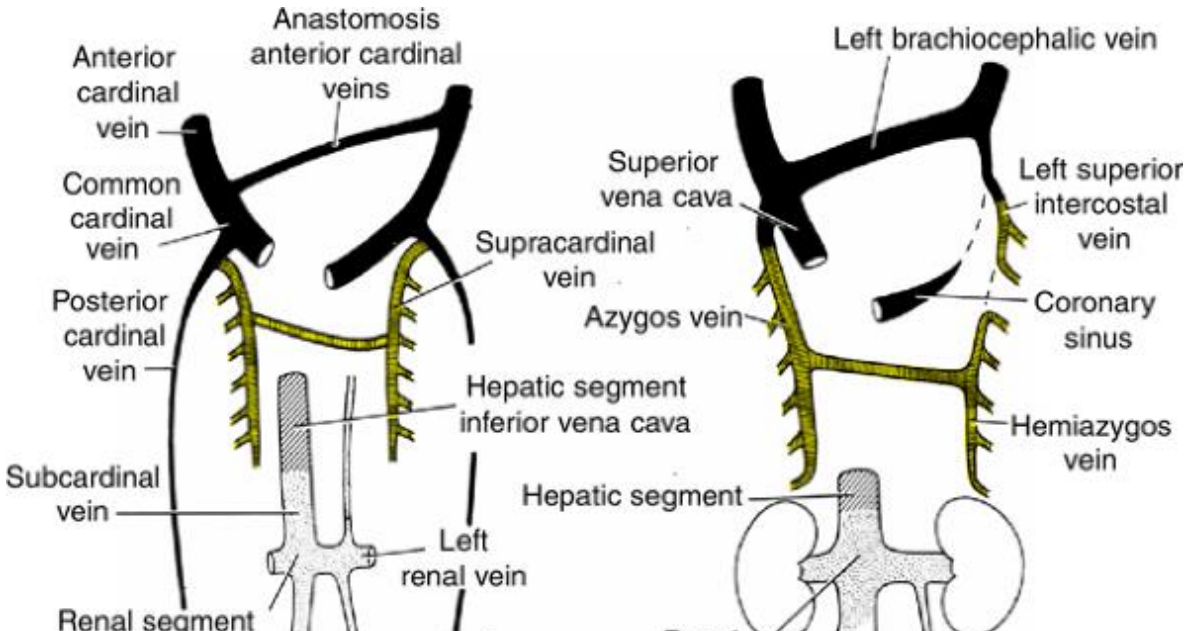
During 5-7th week

- **subcardinal veins**
  - sprout from base of posterior cardinals (end of 6th week)
  - mainly drain kidneys
- **supracardinal veins**
  - Drain body wall via intercostal veins



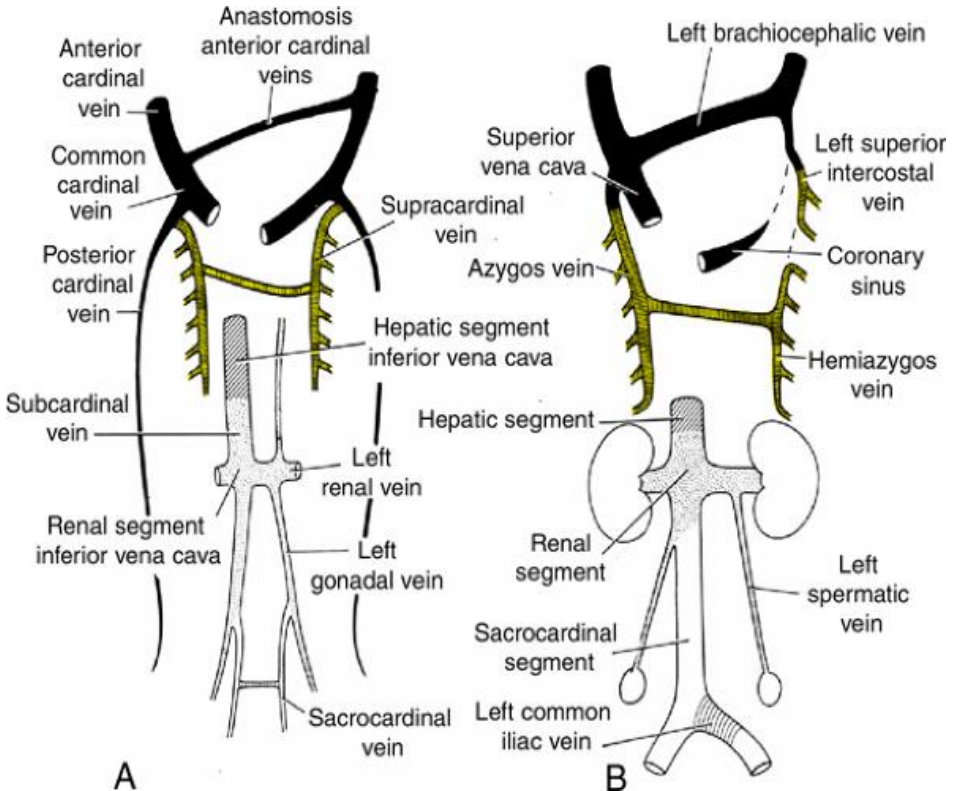
Anterior cardinal veins

- cranial portions of anterior cardinal veins
  - **internal jugular veins**
- **external jugular veins**
  - capillary plexuses in face become connected Internal jugular veins
- **anastomosis between the anterior cardinal veins**
  - **left brachiocephalic vein**
- **superior vena cava**
  - right common cardinal vein
  - proximal portion of right anterior cardinal vein



Posterior cardinal veins

- become obliterated over most of their length
- proximal portion of **left posterior cardinal vein**
  - entering into the left brachiocephalic vein
    - **left superior intercostal vein**
      - receives blood from 2 an 3rd intercostal spaces.
- most caudal portions of posterior cardinals *(Sacrocardinal)*
- (including a large median anastomosis)
  - Form new anastomosis with supracardinal veins
    - common iliac veins
    - caudalmost (sacral portion) of IVC



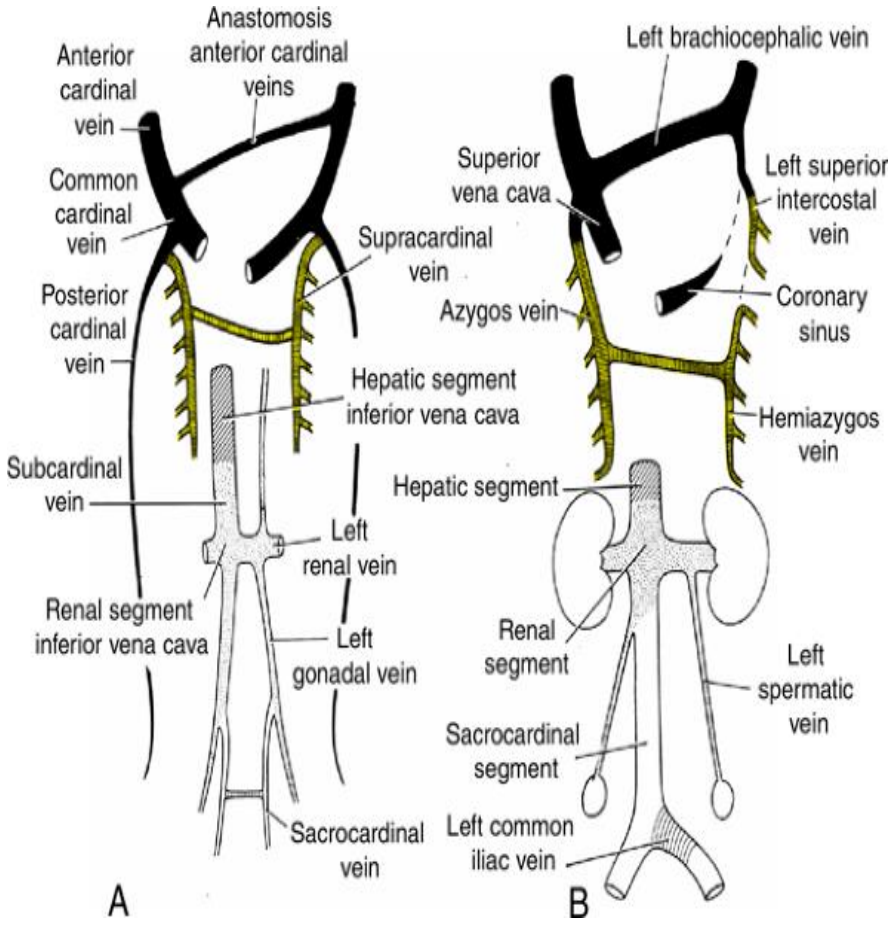
Subcardinal veins

By 7-8th weeks sprout from base of posterior cardinals

- **subcardinal veins**
  - lateral anastomoses
    - with posterior cardinals
  - median anastomoses
    - **left renal vein**

by the 9th week

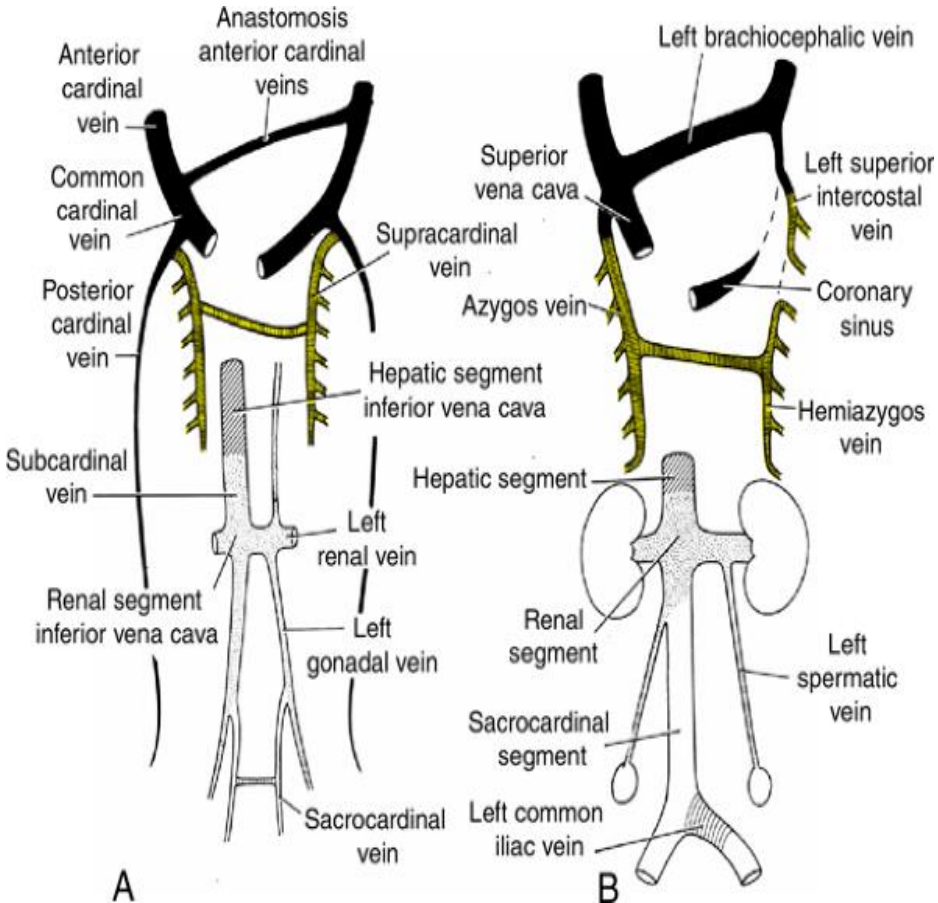
- **left subcardinal vein**
  - Regress
    - distal portion remains as **left gonadal vein**
- **right subcardinal vein**
  - loses its original connection
  - develops a new anastomosis with segment of right vitelline vein
    - **renal segment of the inferior vena cava**



Supracardinal veins

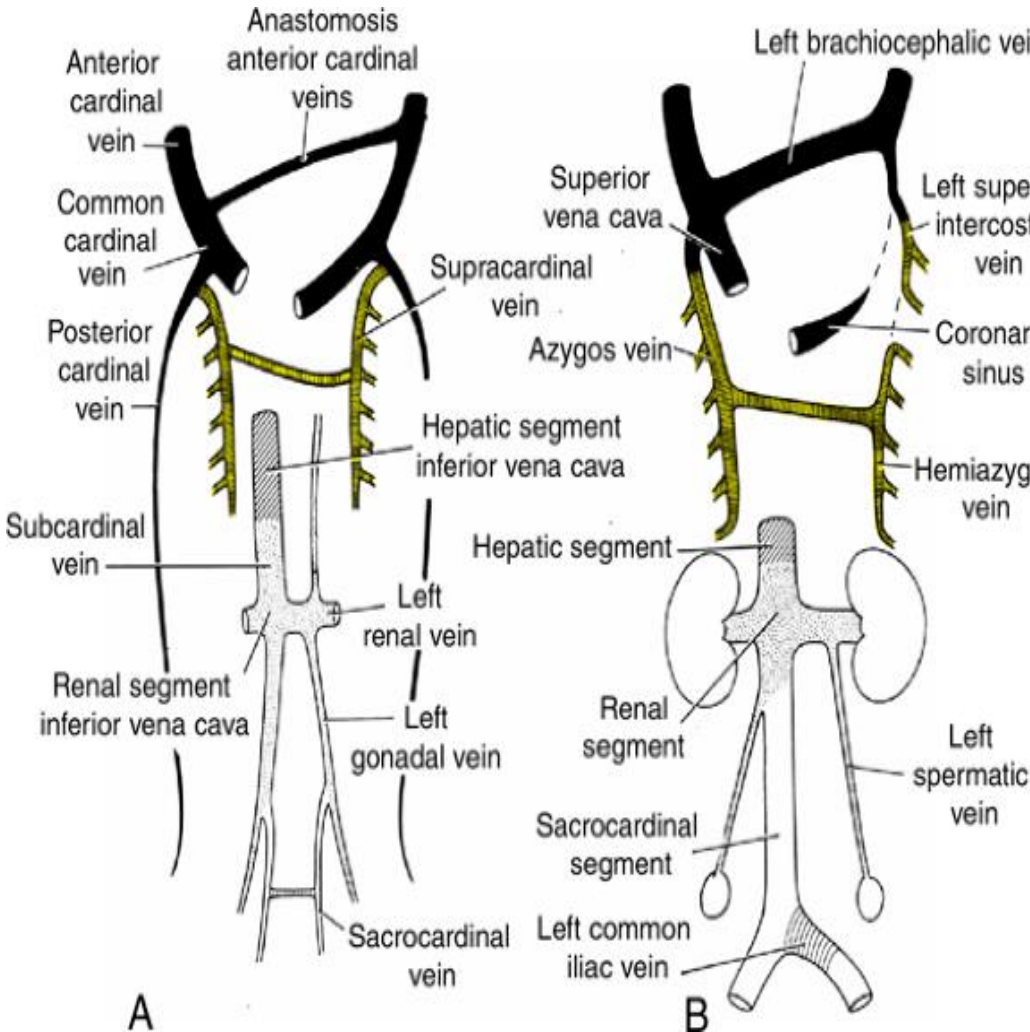
with obliteration of major portion of posterior cardinal veins

- supracardinal veins assume a greater role in draining the body wall (segmental **intercostal veins**)
- The veins sprout from base of posterior cardinals
- right supracardinal vein
  - Cranial portion
    - 4th to 11th right intercostal veins
      - Main portion of azygos vein
  - abdominal portion
    - anastomoses with right subcardinal vein
      - segment of IVC just inferior to kidneys
- **azygos vein**
  - right supracardinal vein
  - portion of posterior cardinal vein
- left supracardinal vein
  - 4th to 7th intercostal veins
    - **hemiazygos vein**
- inferior portion obliterated



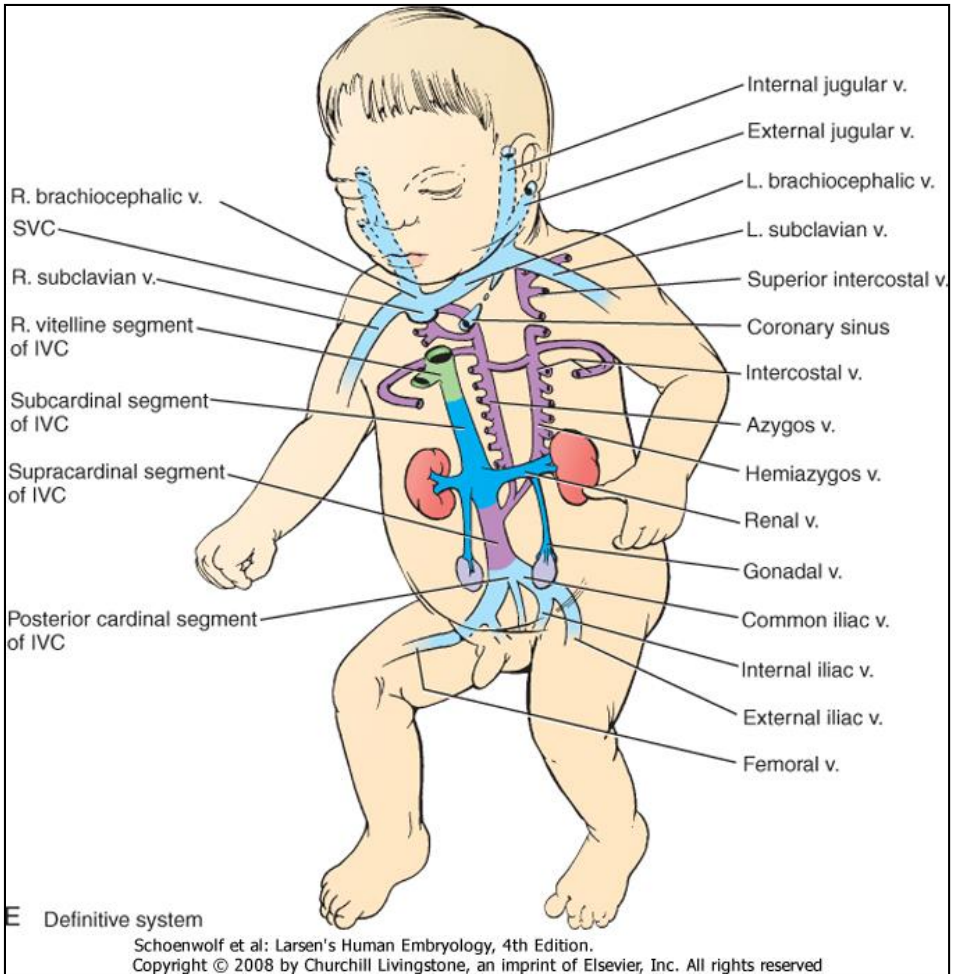
Sacrocardinal
(caudal segment of post. Cardinal) veins

- their **anastomosis**
  - **left common iliac vein**
- Left sacrocardinal vein
  - Cranial portion
    - Regress
- right sacrocardinal vein
  - Cranial portion
    - sacrocardinal segment of inferior vena cava
  - Caudal portion
    - Right common iliac vein



Inferior Vena Cava

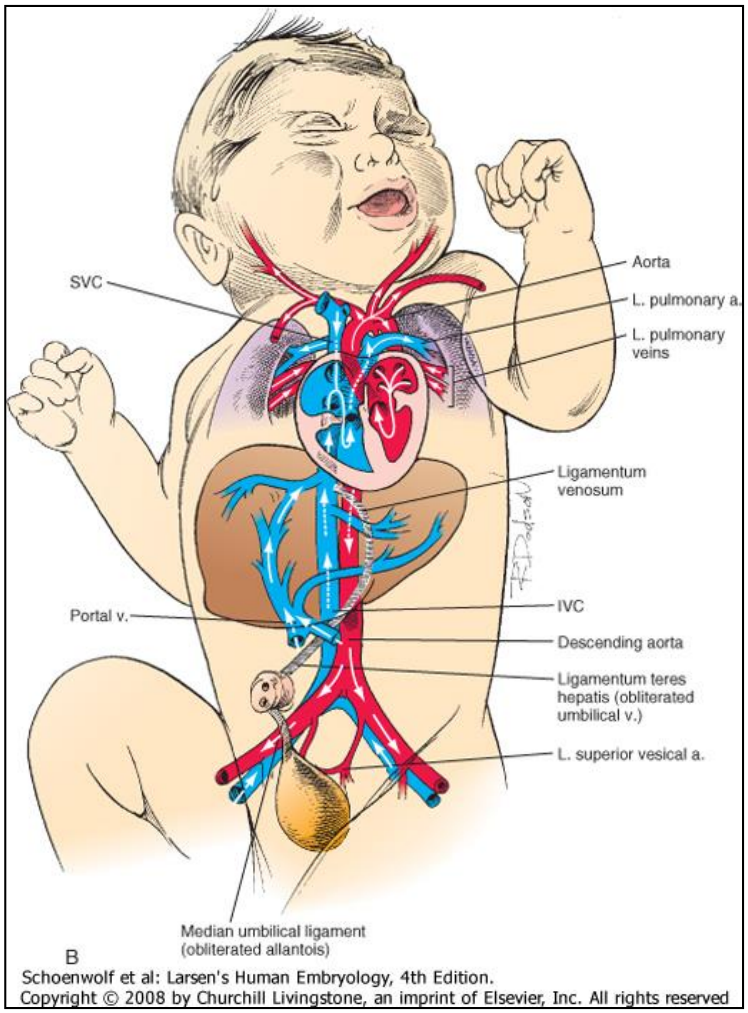
- (1) right vitelline vein
- (2) right subcardinal vein
- (3) right supracardinal vein
- (4) caudal portions of posterior cardinals



Circulatory Changes at Birth

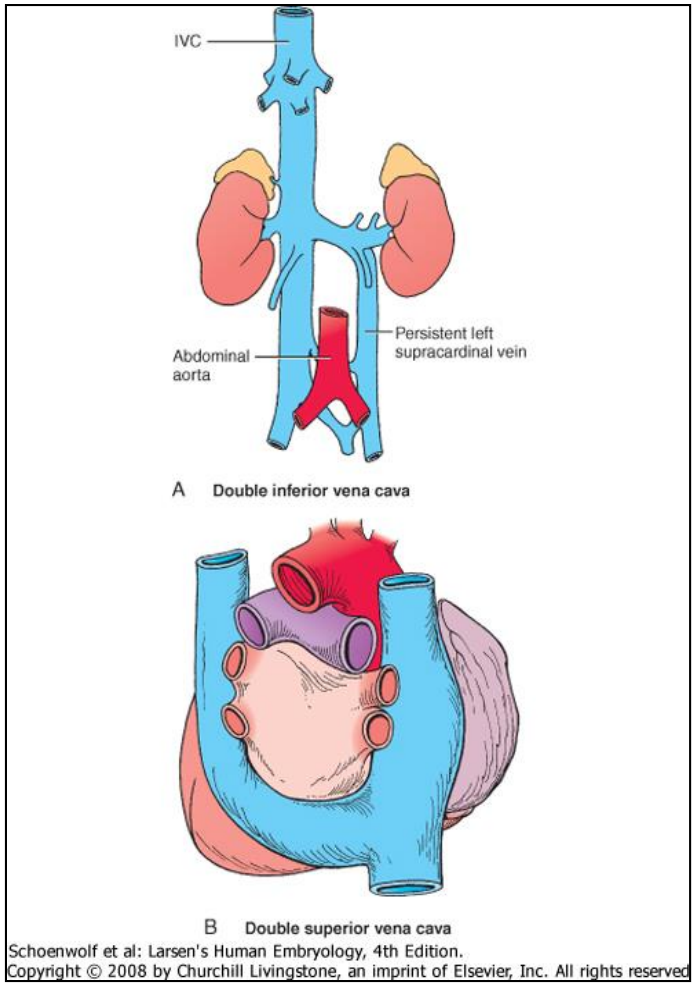
by cessation of placental blood flow and the beginning of respiration

- Closure of umbilical arteries
  - medial umbilical ligaments
  - proximal portions
    - superior vesical arteries
- Closure of umbilical vein
  - ligamentum teres hepatis
- Closure of ductus venosus
  - ligamentum venosum.
- Closure of ductus arteriosus
  - ligamentum arteriosum
- Closure of oval foramen



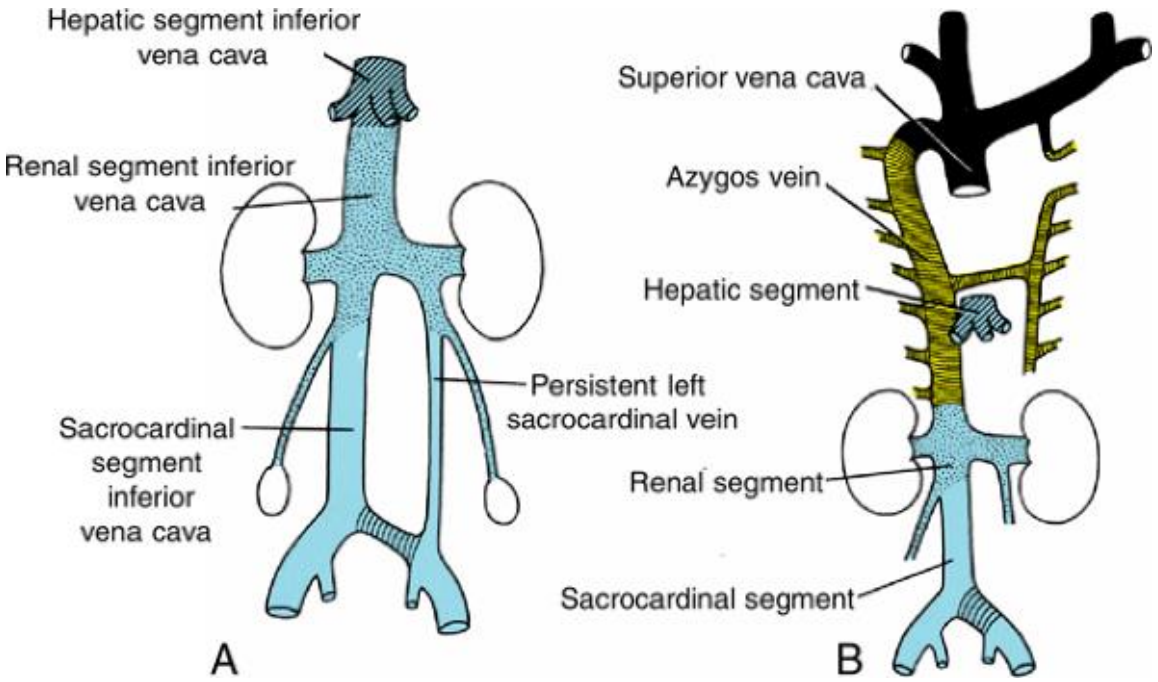
Venous System Defects

- *A*, double inferior vena cava
  - Preservation of left supracardinal vein
- *B*, double superior vena cava
  - Preservation of left anterior cardinal
    - left superior vena cava empties into coronary sinus



Venous System Defects

- Double inferior vena cava
  - Preservation of left sacrocardinal vein
- Absent inferior vena cava
  - lower half of body drained by azygos vein
  - hepatic vein enters heart at site of IVC



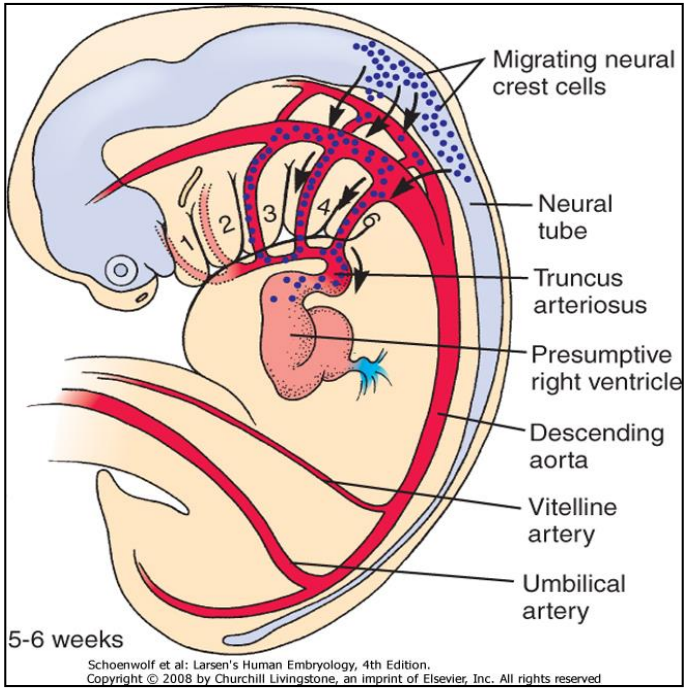
Endocardial Cushions and Heart Defects

- **Atrial, ventricular septal** and **great vessels** defects
- **DiGeorge sequence**

abnormal neural crest development.–

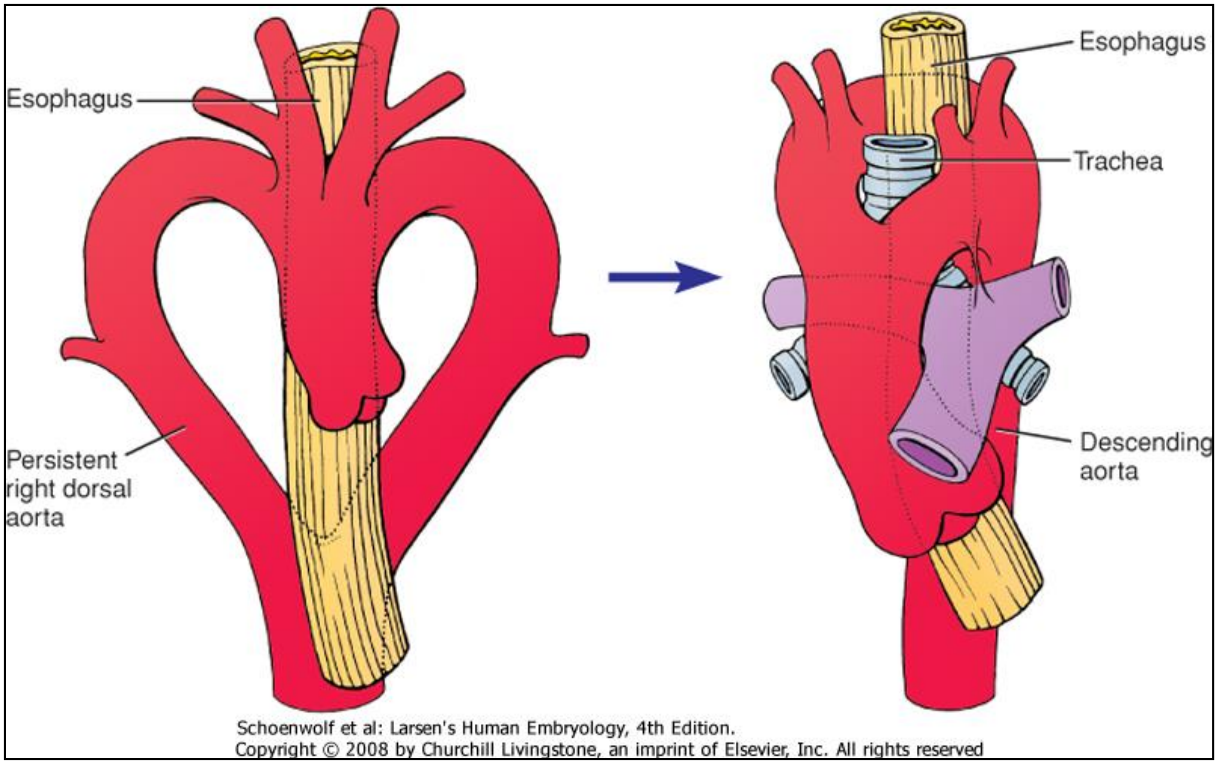
- facial defects
- thymic hypoplasia
- parathyroid dysfunction
- cardiac abnormalities

outflow tract–



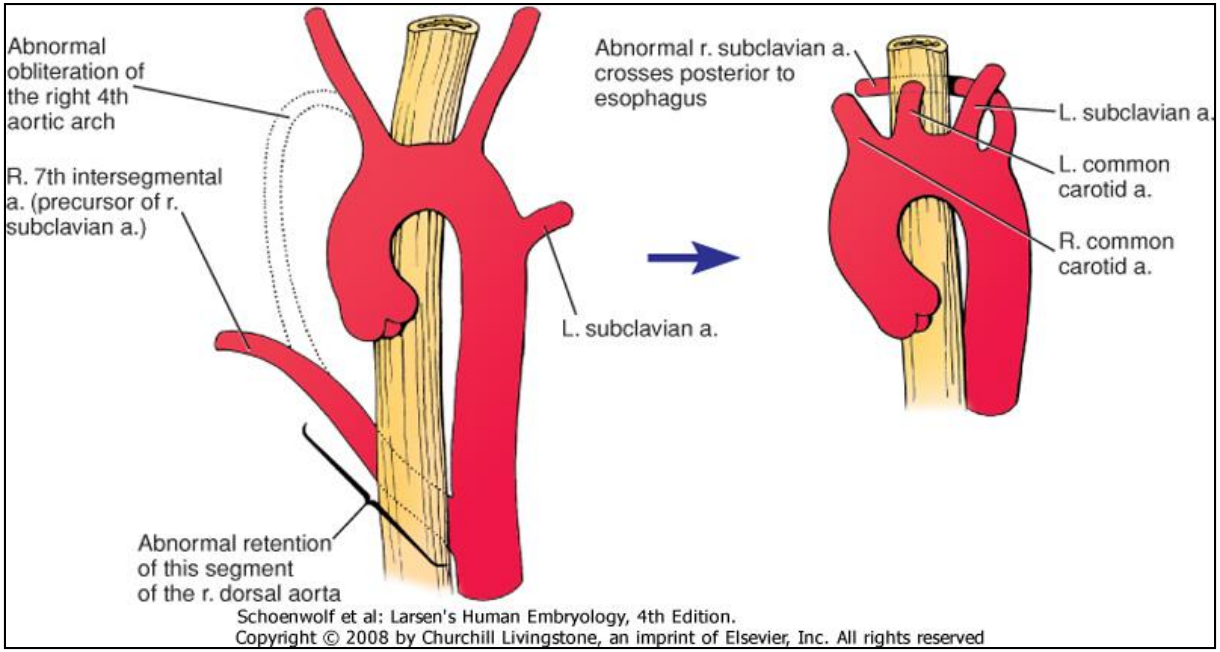
Arterial System Defects

- double aortic arch
  - failure of right dorsal aorta regression
  - esophagus and trachea enclosed in double arch



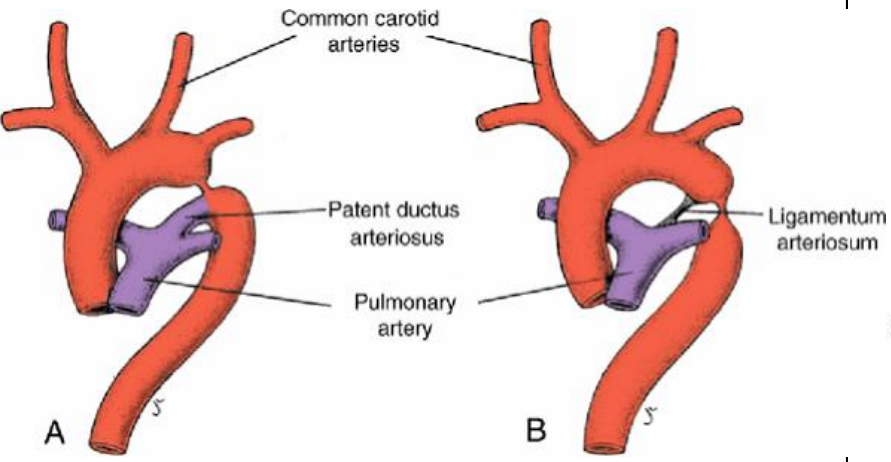
Arterial System Defects

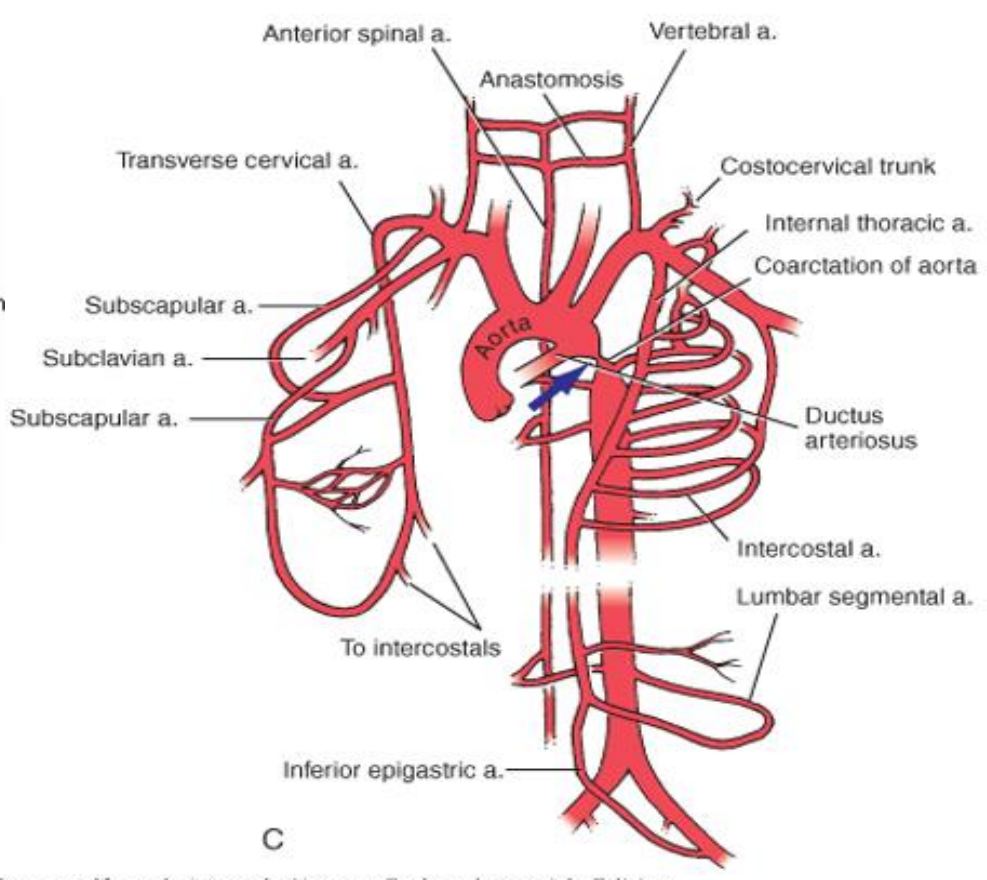
- right subclavian artery anomalous
  - Retention of right dorsal aorta at level of 7th intersegmental artery –
  - abnormal regression of right 4th aortic arch –



Arterial System Defects

- Coarctation of the aorta
  - **A.** Preductal type –
  - **B.** Postductal type –
- caudal part of body supplied by large internal thoracic and intercostal arteries





Arterial System Defects

- Right aortic arch