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Development of the Vascular System

VASCULOGENESIS formation of the blood vessels from blood island

ANGIOGENESIS Sprouting of vessels from the preexisting vessels

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- Once the process of vasculogenesis establishes a primary vascular bed, which include **dorsal aorta and cardinal veins,** additional vasculature is added by angiogenesis

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ARETERIAL SYSTEM

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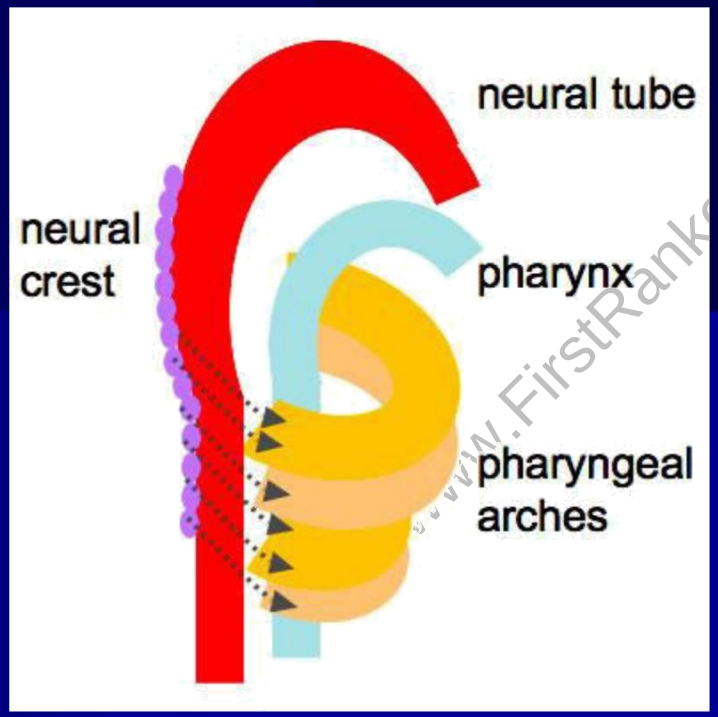
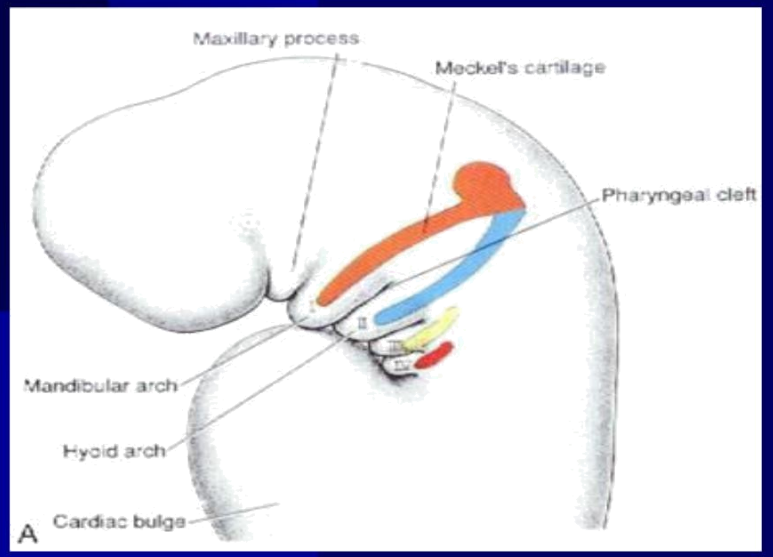
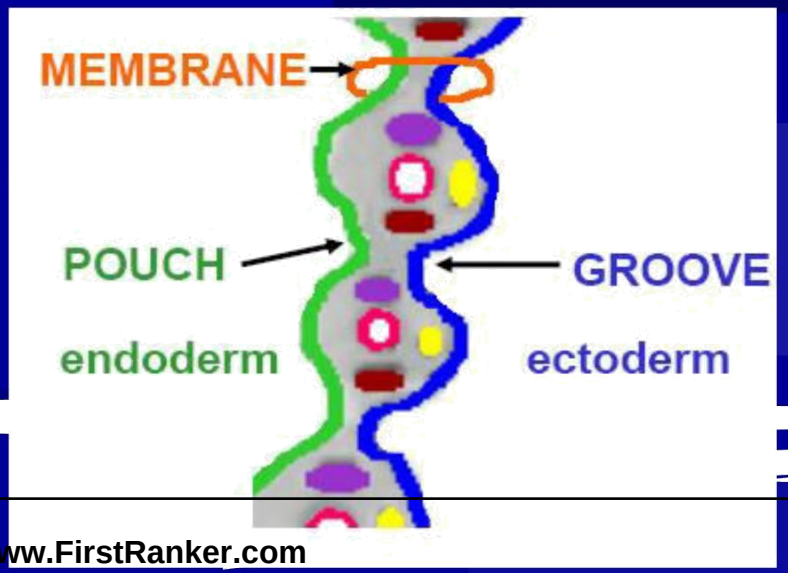
PHARYNGEAL ARCHES







Pharyngeal arches and their vessels appear in a craniocaudal sequence, so that they are not present simultaneously all the time.

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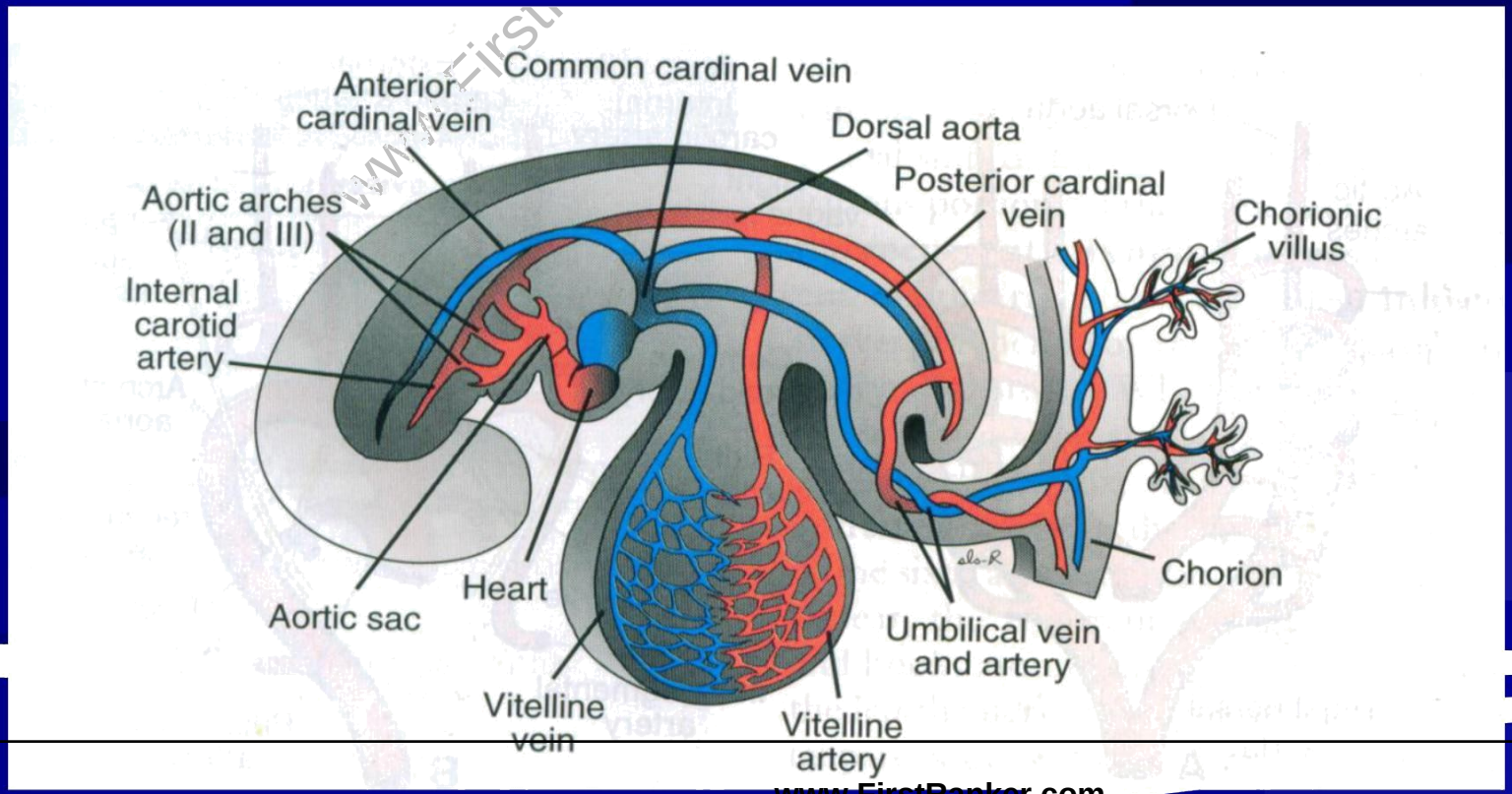
AORTIC ARCHES

- Are the arteries that arise from the **aortic sac and supply the pharyngeal arches.**
- The aortic sac contributes a branch to each new arch as it forms, thus giving rise to total of five pairs of arteries.



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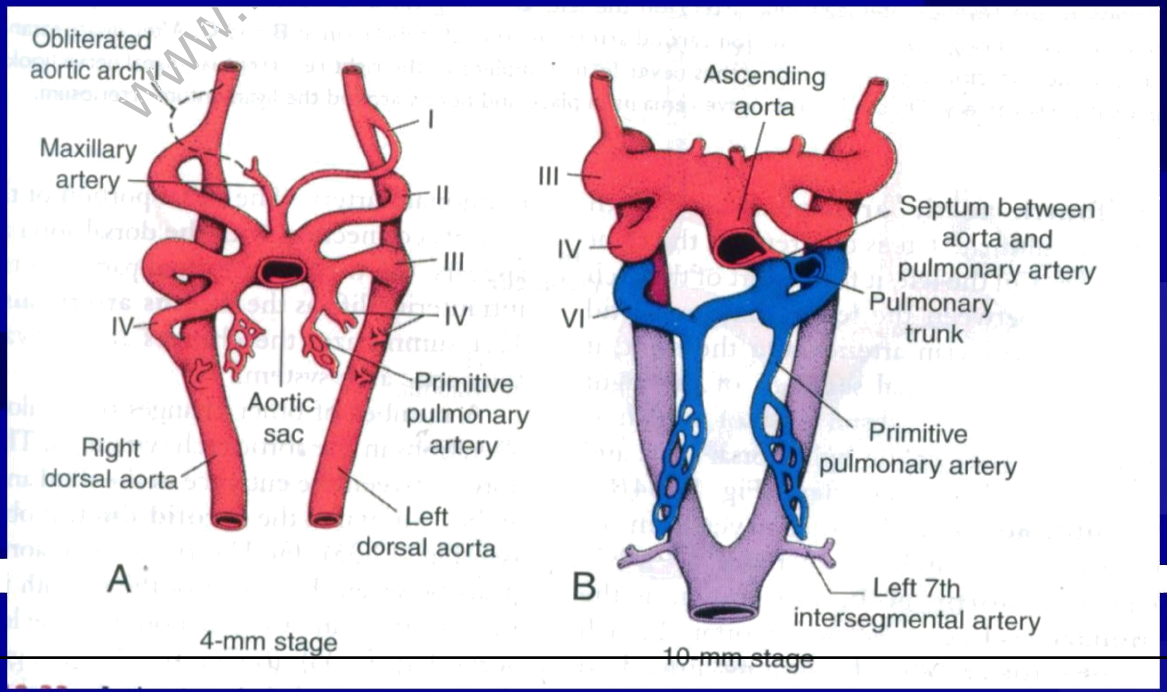
- The aortic arches terminate in the right and left dorsal aortae which later fuse in the caudal region to form single vessel.
- Division of the truncus arteriosus by the aortopulmonary septum divides the outflow channel of the heart into the **ventral aorta** and the **pulmonary artery.**
- The aortic sac then forms right and left horns, which subsequently give rise to the **brachiocephalic artery** and the proximal segment of the **arch of aorta** respectively.



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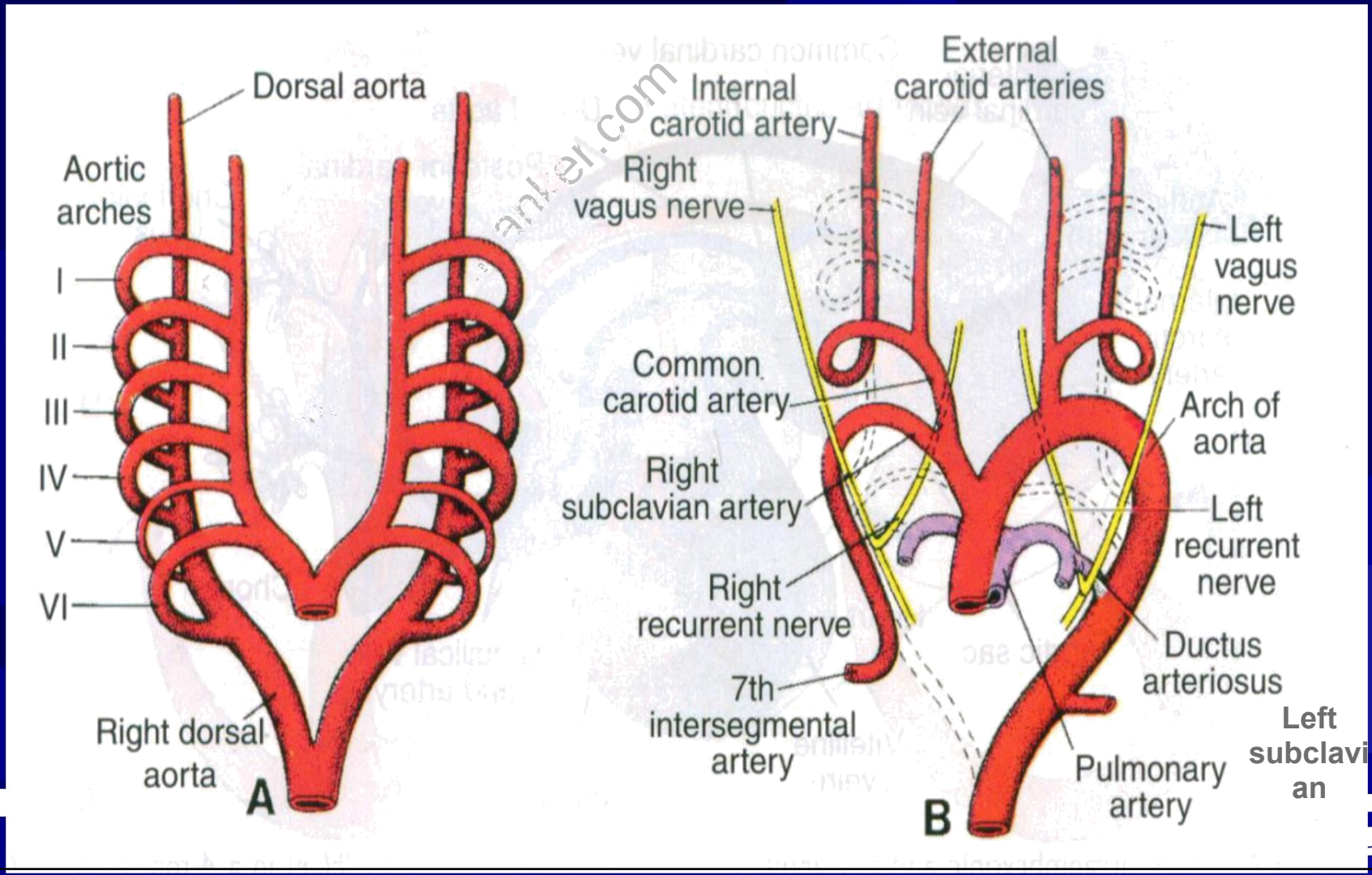
CHANGES IN AORTIC ARCHES



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artery

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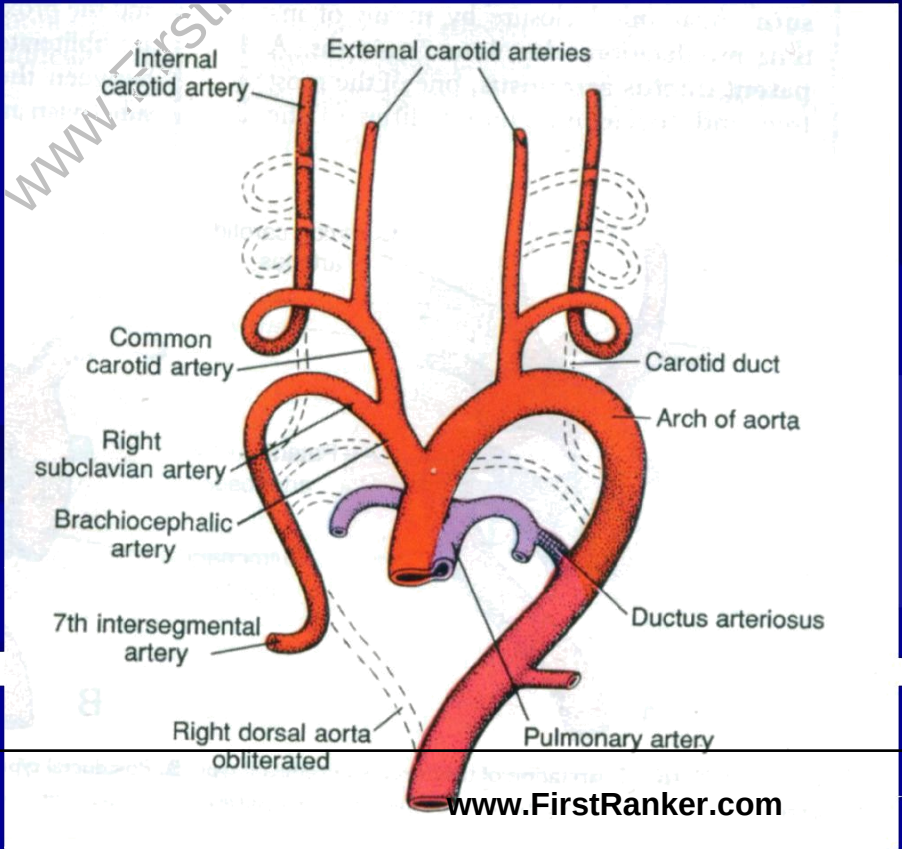
OTHER CHANGES IN THE ARCH SYSTEM

- The dorsal aorta located between the entrance of the 3rd and 4th arches, known as the **carotid** duct, is obliterated.
- The right dorsal aorta disappears between the origin of the 7th intersegmental artery and the junction with the left dorsal aorta.



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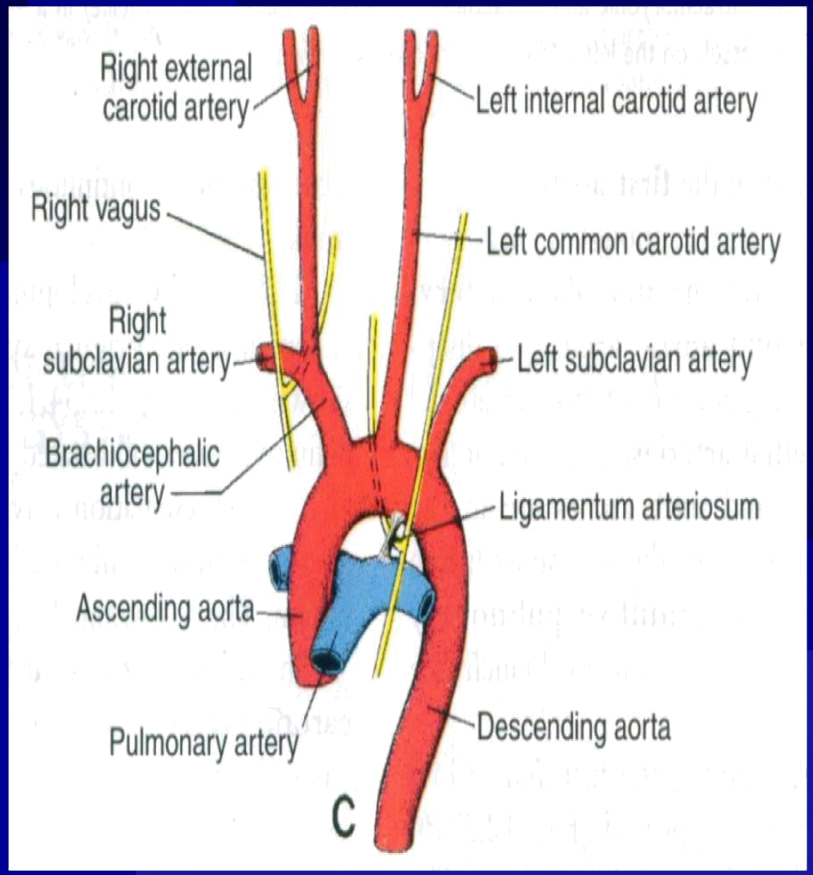
- Cephalic folding, growth of the forebrain, and elongation of the neck cause the heart to descend into the thoracic cavity.
- Carotid and brachiocephalic arteries elongate considerably.
- Origin of the left subclavian artery shifts higher up until it comes close to the origin of the left common carotid artery.



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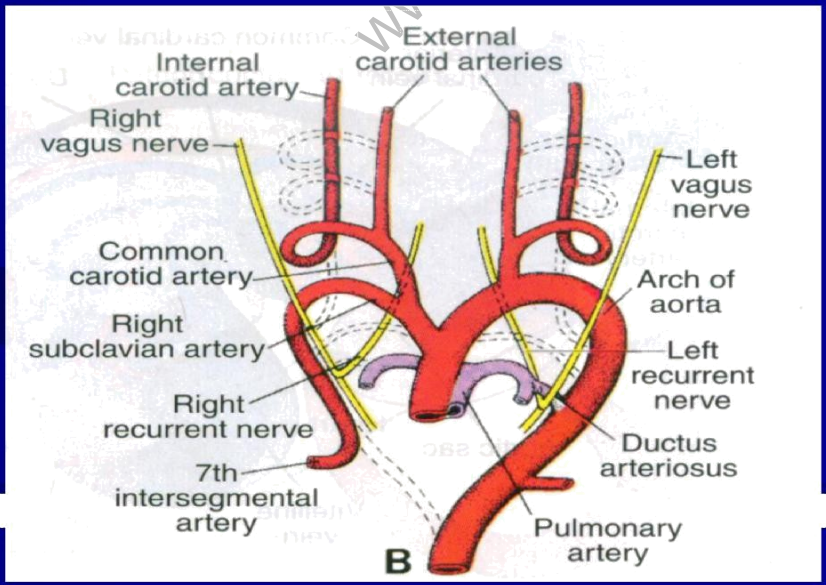
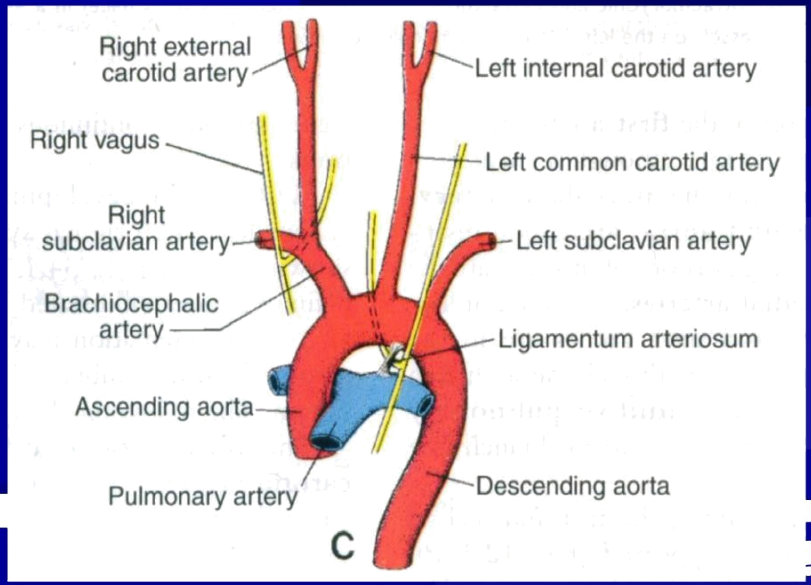
- The course of the **recurrent laryngeal nerve** (6th pharyngeal arch) becomes different on the right and left sides.
- When the heart descends, they hook around the 6th aortic arches and then ascend again to the larynx, thus accounting for their recurrent course.





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DERIVATIVES OF THE AORTIC ARCHES

- 1 Maxillary arteries
- 2 Hyoid and stapedial arteries
- 3 Common carotid and first part of the internal carotid arteries
- 4 Left side - Arch of the aorta from the left common carotid to the left subclavian arteries
  Right side - Right subclavian artery (proximal portion)
- 6 Left side - Left pulmonary artery and ductus arteriosus
  Right side - Right pulmonary artery

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INTERSEGMENTAL ARTERIES

- Approx. 30 segmental branches of dorsal aorta carry blood to somites and their derivatives.
- Persisting segmental arteries —
  - Intercostal
  - Lumbar
  - Common iliac
  - Lateral sacral
  - Median sacral

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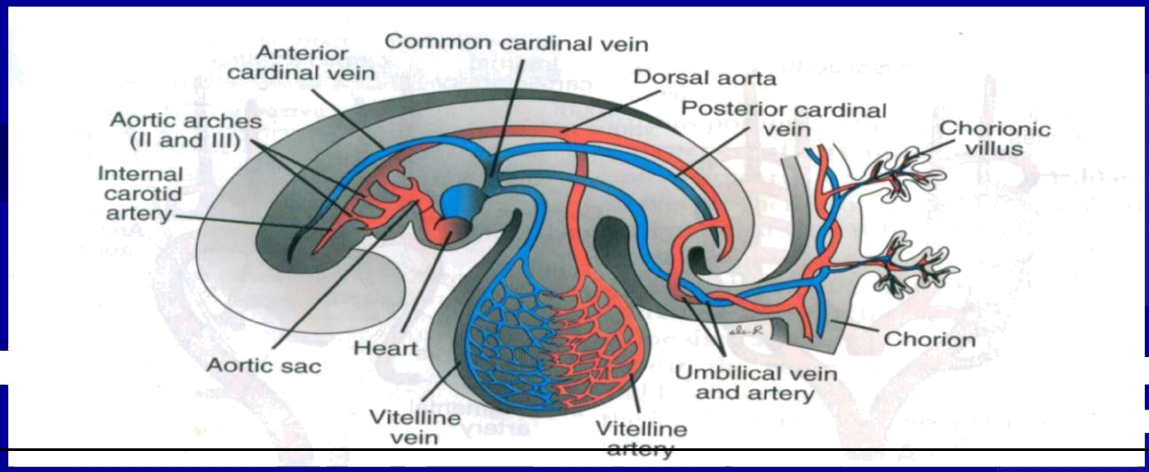
UNPAIRED BRANCHES FROM THE DORSAL AORTA

- Caudal end of the dorsal aorta becomes the **median sacral artery**
- The **vitelline arteries,** initially a number of paired vessels supplying the yolk sac, gradually fuse and forms arteries located in the dorsal mesentery of the gut.

  In the adult they are represented by the celiac, superior mesenteric, and inferior mesenteric arteries.

  These vessels supply derivatives of the foregut, midgut, and hindgut respectively



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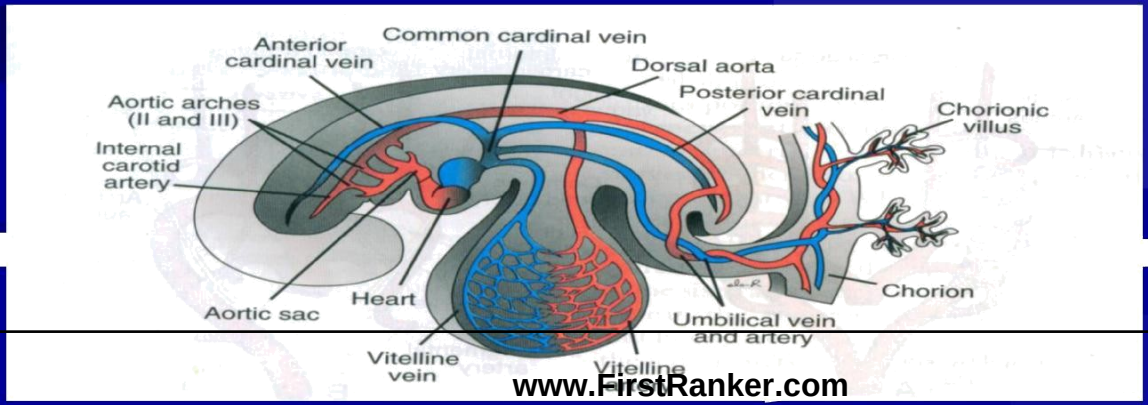
PAIRED UMBILICAL ARTERIES

The **umbilical arteries**, initially paired ventral branches of the dorsal aorta. During the 4th week, each artery acquires a secondary connection with the dorsal branch of the aorta, the **common iliac artery**, and loses its original origin.

- Carry deoxygenated blood to the placenta.

After birth:

- The proximal portions become the internal iliac artery and superior vesical artery.
- Distal parts degenerate and become the median umbilical ligaments.



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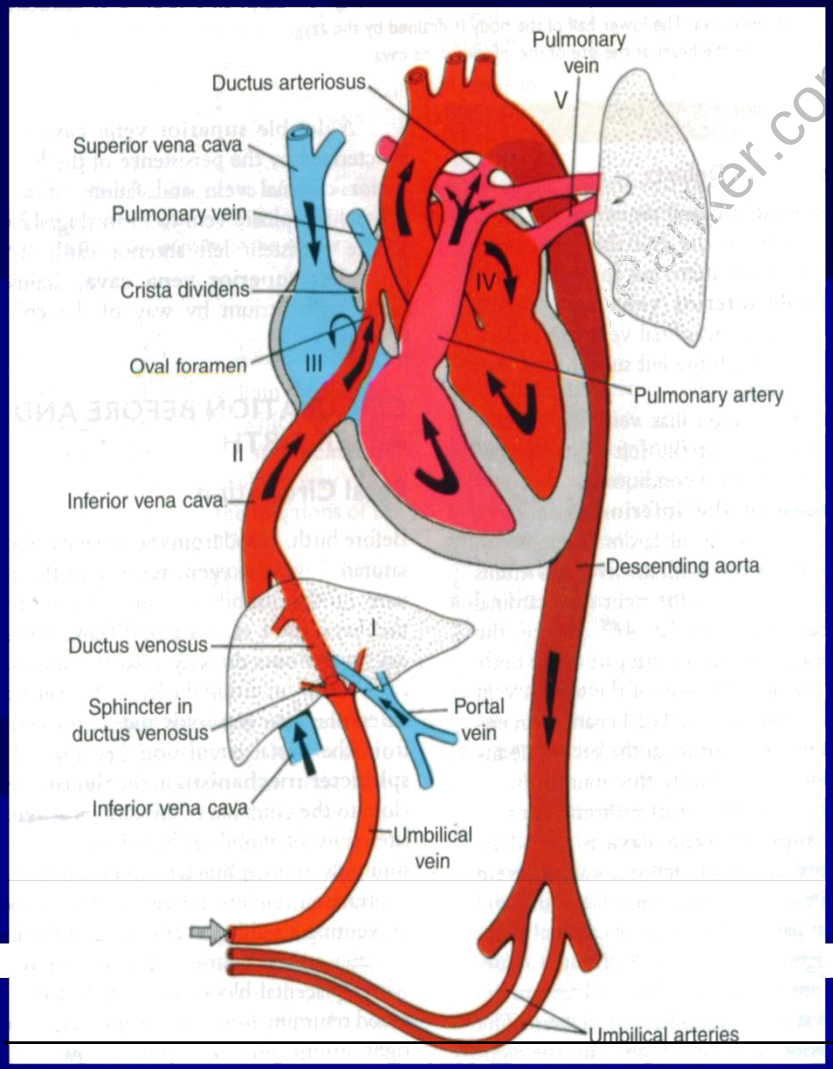

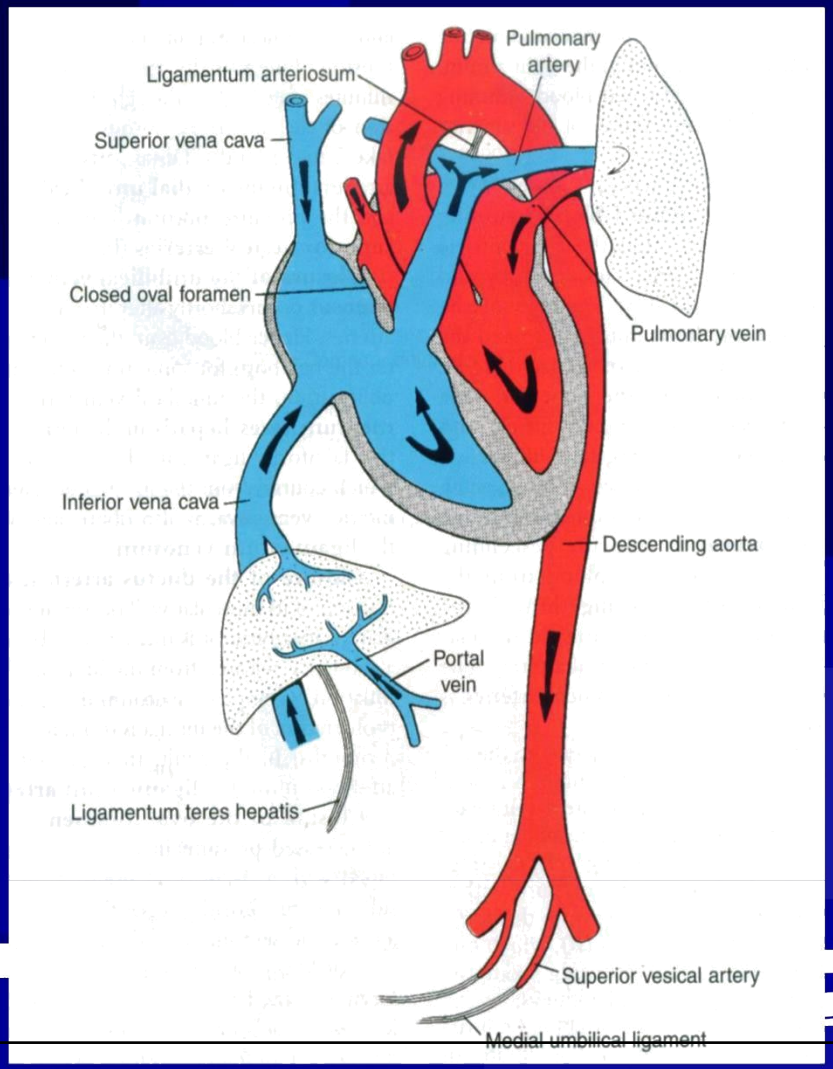

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CORONARY ARTERIES

- Two sources
  - angioblast
  - epicardium
  - Neural crest cells
- Connection of coronary arteries to Aorta occurs by in growth of arterial endothelial cells into aorta

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CONGENITAL ANOMALIES

1. PATENT DUCTUS ARTERIOSUS

- is one of the most frequently occurring abnormalities of the great vessels, especially in premature infants. There is a large difference between aortic and pulmonary pressures and the increased blood flow through the ductus prevents its closure.

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2) COARCTATION OF AORTA

- Aortic lumen below the origin of the left sub-clavian artery is significantly narrowed.
- Is of two types:
  - Preductal : ductus arteriosus persists
  - Postductal : ductus arteriosus is usually obliterated

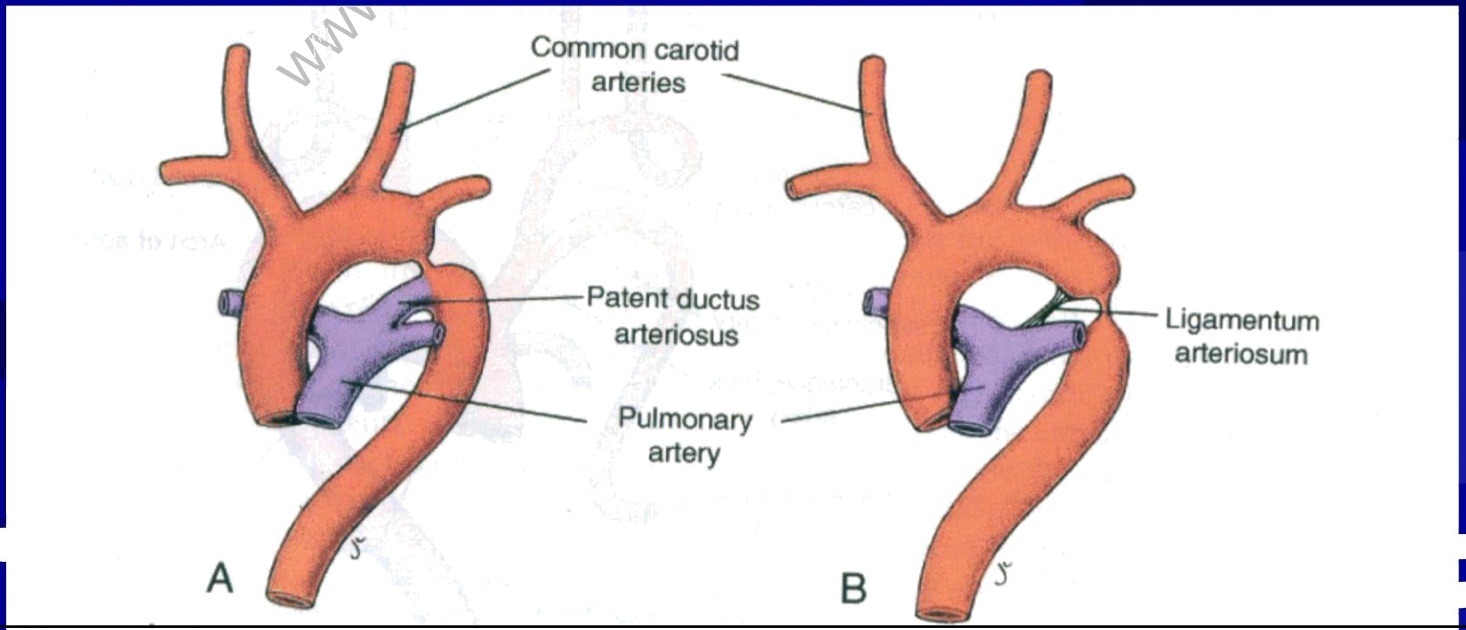

Figure 12.36 Coarctation of the aorta. **A.** Preductal type. **B.** Postductal type. The caudal part of the body is supplied by large hypertrophied intercostal and internal thoracic arteries.

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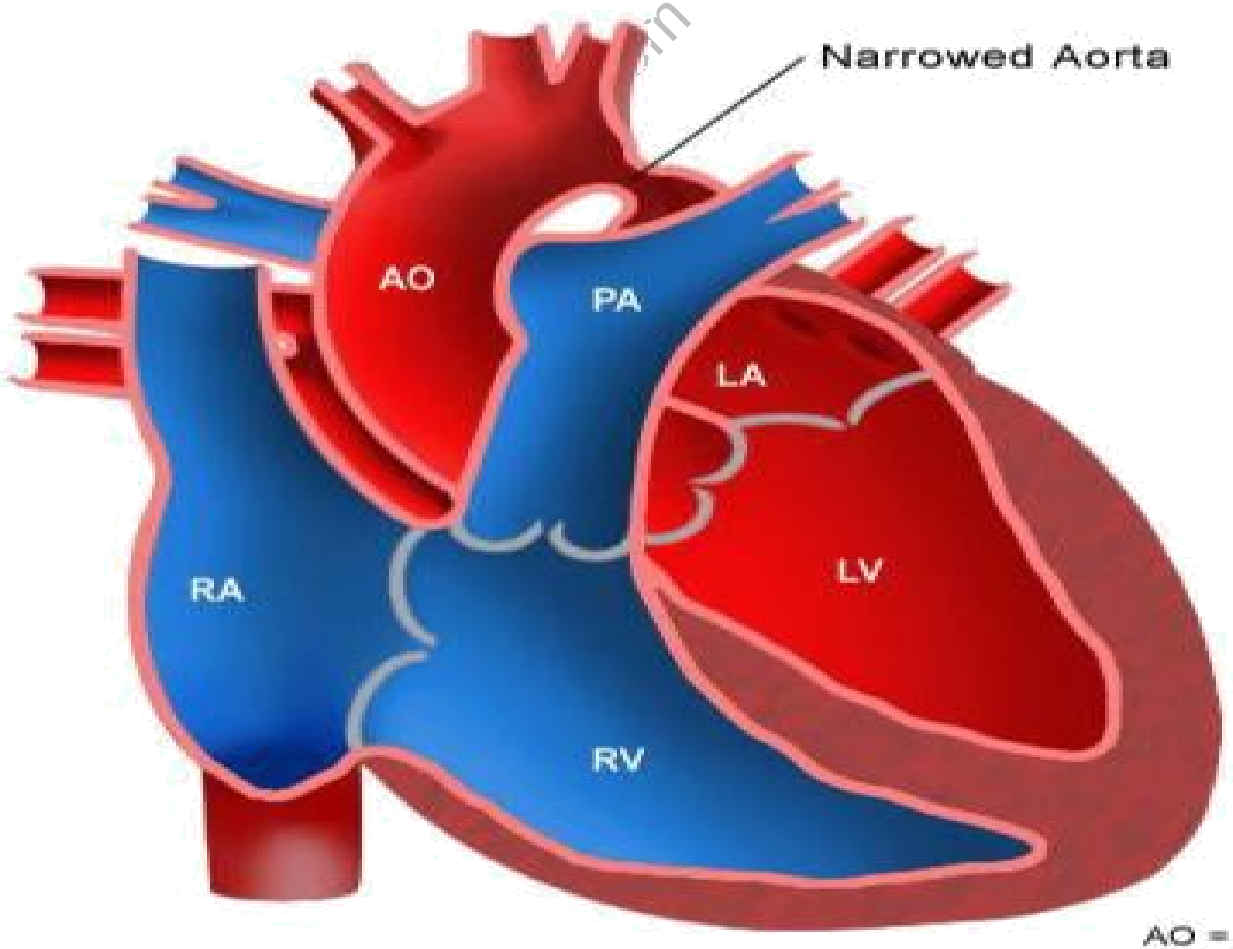
Coarctation of the Aorta



Oxygen-rich Blood

AO = Aorta
PA = Pulmonary Artery
LA = Left Atrium
RA = Right Atrium
LV = Left Ventricle
RV = Right Ventricle

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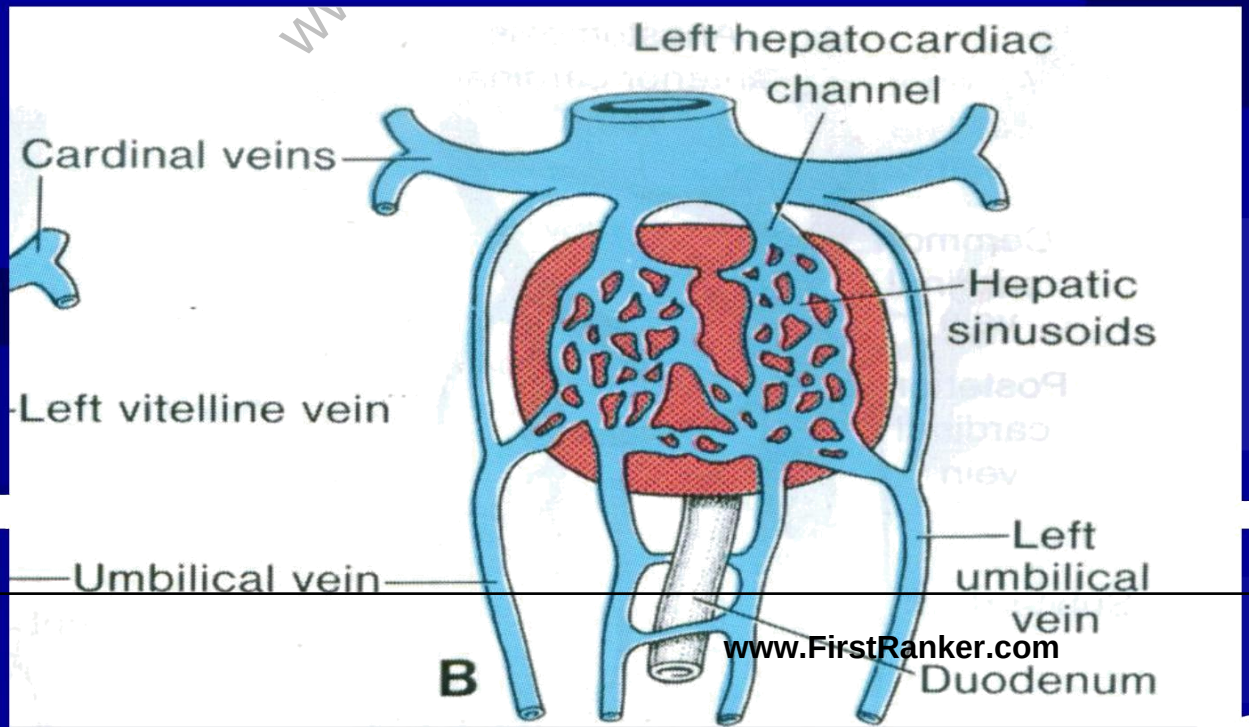
VENOUS SYSTEM

- At 5th week three pairs of major veins can be seen
  - **Vitelline or omphalomesenteric veins**, carrying blood from the yolk sac to the sinus venosus
  - **Umbilical veins**, originating in the chorionic villi and carrying oxygenated blood to the embryo.
  - **Cardinal veins**, draining the body of the embryo proper.



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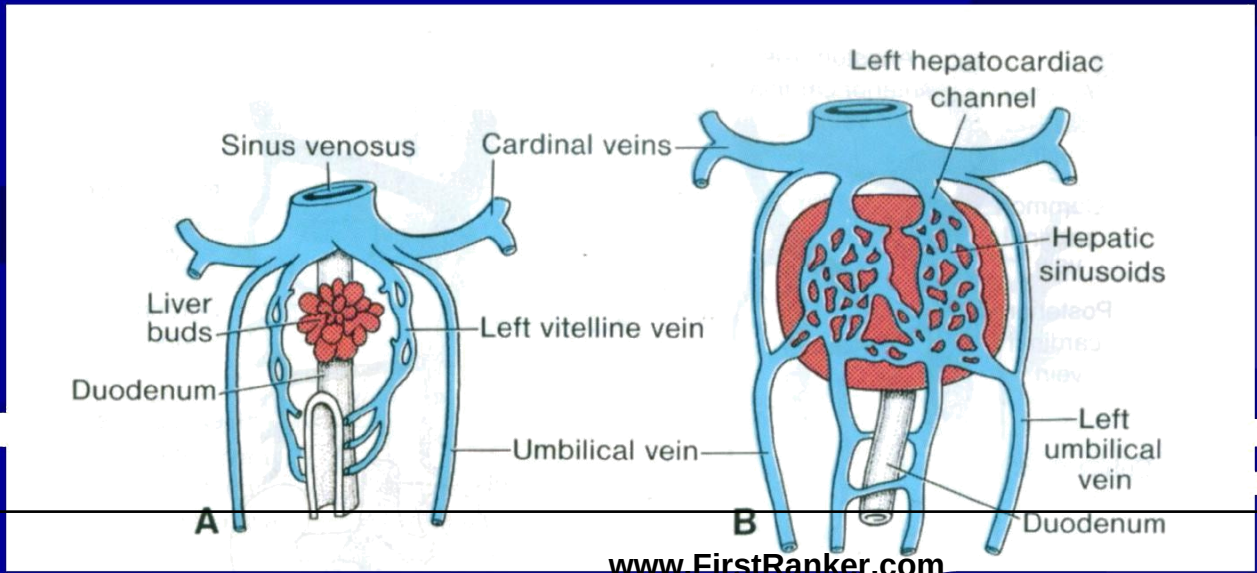
VITELLINE VEINS

- Before entering the sinus venosus, the vitelline veins form a plexus around the duodenum and pass through the septum transversum.
- The liver cords growing into the septum interrupt the course of veins and an extensive vascular network is formed known as the **hepatic sinusoids**.



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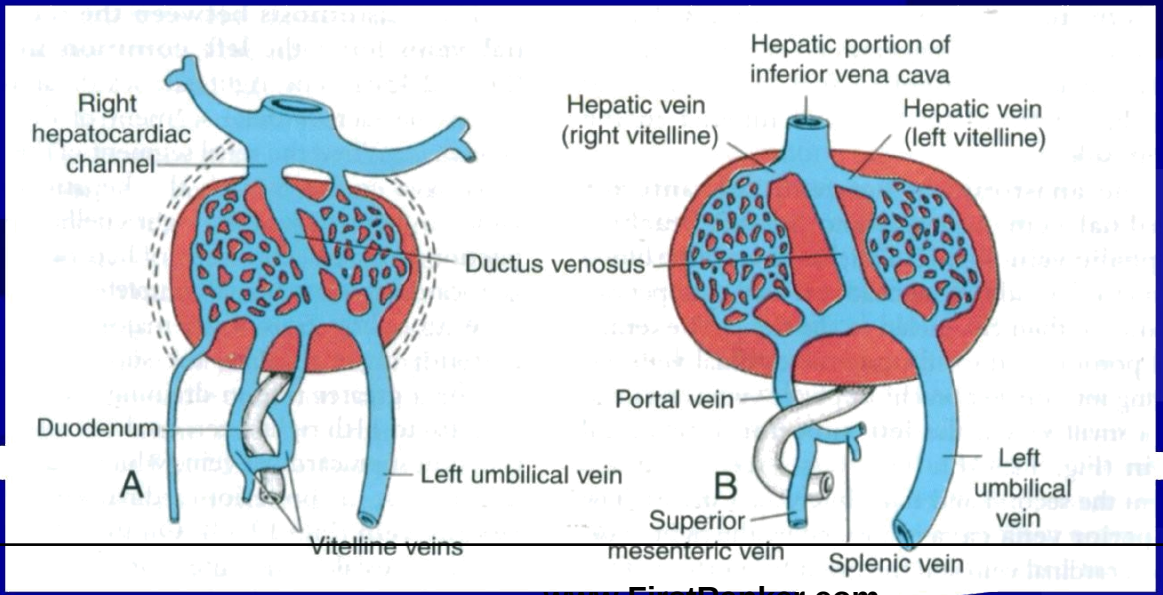
- With reduction of left sinus horn, blood from the left side of the liver is rechanneled toward the right resulting in the enlargement of the right vitelline vein (right hepatocardiac channel).
- Ultimately, the right hepatocardiac channel forms the **hepatocardiac portion of the inferior vena cava.**
- The proximal part of the left vitelline vein disappears.
- The anastomotic network around the duodenum develops into a single vessel, the **portal vein**.
- The **superior mesenteric vein,** which drains the primary intestinal loop is derived from the right vitelline vein. The distal portion of the left vitelline vein also disappears.



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Derivatives of Vitelline veins

- Inferior Vena Cava
- Hepatic veins
- The portal vein
- Superior Mesenteric Vein

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UMBILICAL VEINS

- The proximal part of both umbilical veins and the remainder of the right umbilical vein disappear, so that the left vein is the only one to carry blood from the placenta to the liver.
- With increase of the placental circulation, a direct communication is formed between the left umbilical vein and the right hepatocardiac channel, the ductus venosus.
- This vessel bypasses the sinusoidal plexus of the liver.
- After birth, the left umbilical vein and the ductus venosus are obliterated and form the **ligamentum teres hepatic** and **ligamentum venosum,** respectively.

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CARDINAL VEINS

- During the 4th week, the cardinal veins form the main venous drainage system of embryo.
- This system consists of:
  - **Anterior cardinal veins** which drain the cephalic part of the embryo
  - **Posterior cardinal veins** which drain the remaining part of the body of the embryo.
  - The anterior and posterior veins join before entering the sinus horn and form the short **common cardinal veins**.

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ANTERIOR CARDINAL VEINS

- The anterior cardinal vein become connected by an oblique anastomosis during the 8th week.
  - Shunts blood from left to right.
  - Anastomosis between the Anterior Cardinal vein develops into left Brachiocephalic vein
  - Right anterior cardinal vein and the right common cardinal vein become the SVC.

The anterior cardinal vein become connected by an oblique anastomosis during the 8^{th} week.

Shunts blood from left to right.

Anastomosis between the Anterior Cardinal vein develops into left Brachiocephalic vein

Right anterior cardinal vein and the right common cardinal vein become the SVC.

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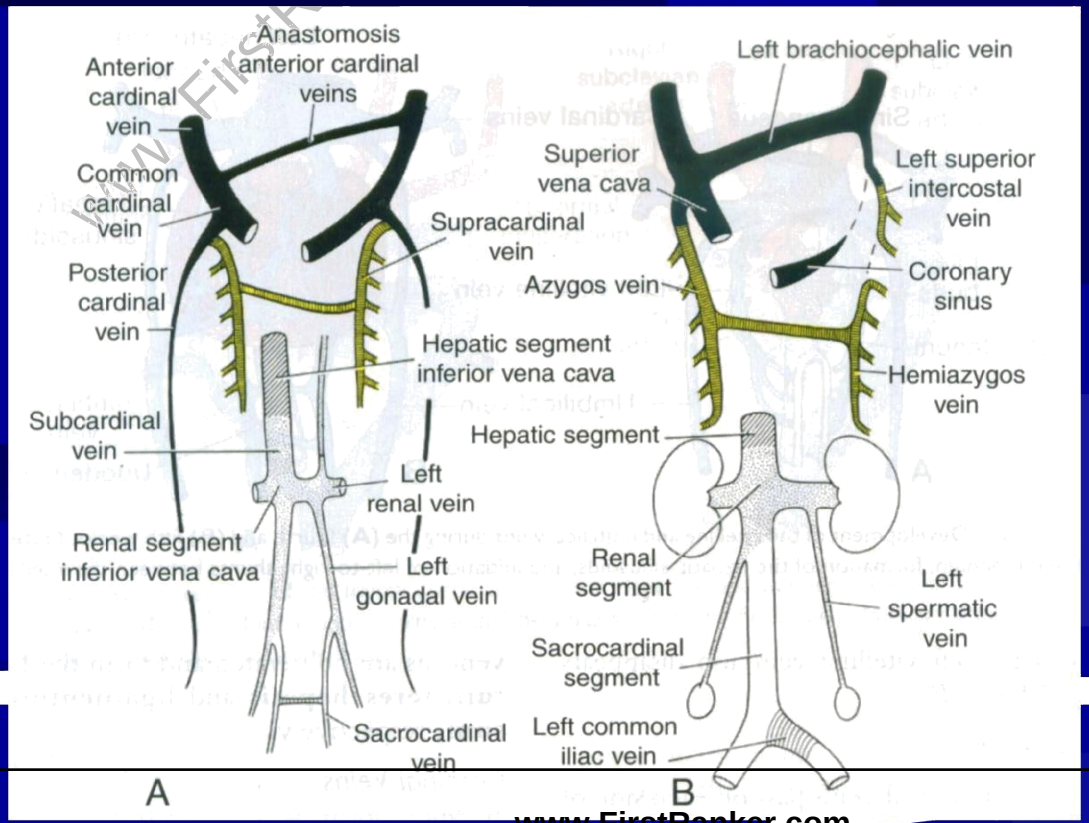
- During the 5th to 7th week, a number of additional veins are formed.
  - **Subcardinal veins** which mainly drain the kidneys
  - **Sacrocardinal veins** which drain the lower extremities
  - **Supracardinal veins** which drain the body wall by way of the intercostal veins, thus taking over the functions of the posterior cardinal veins.



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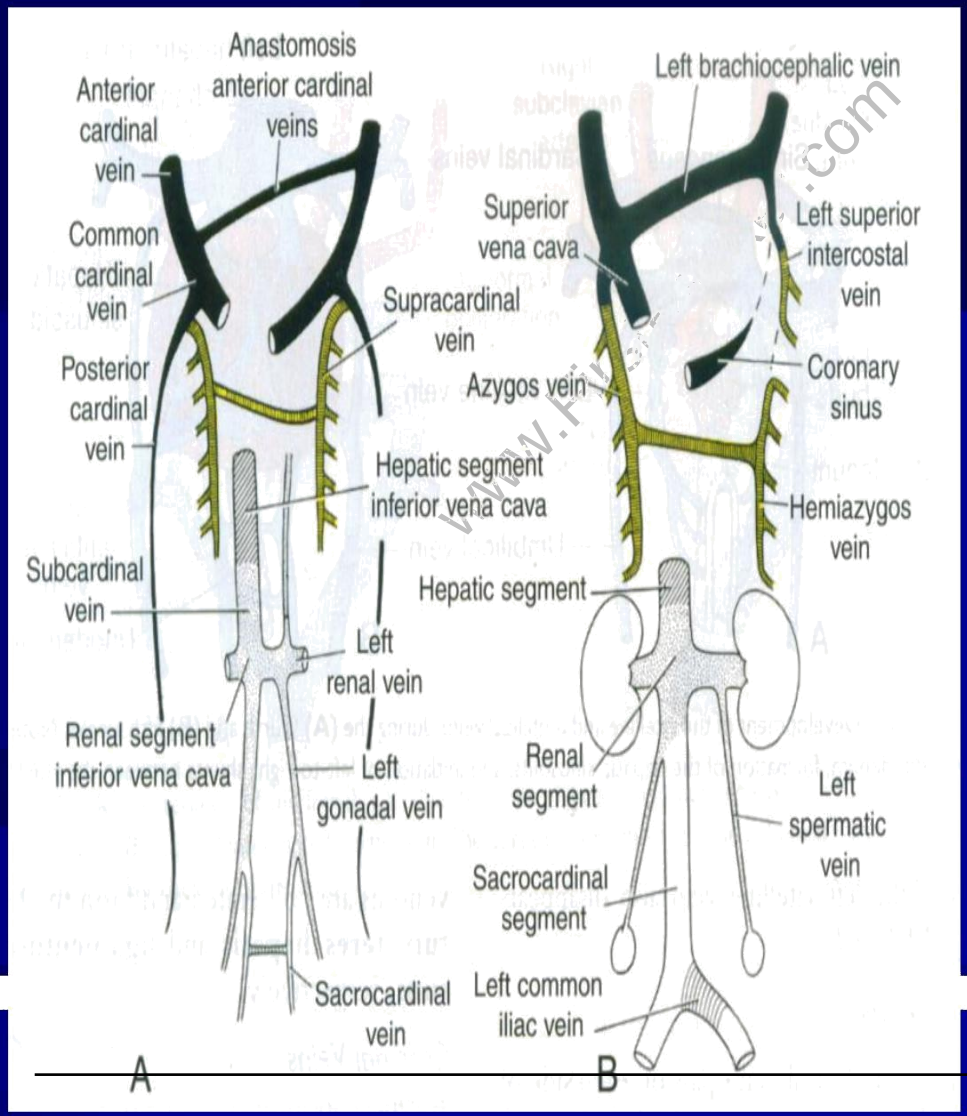
Posterior Cardinal vein



- Major tributaries of the posterior cardinal veins
  - Subcardinal veins
  - Supracardinal veins
  - Sacrocardinal veins

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- Formation of the vena cava system is characterized by the appearance of anastomoses between left and right in such a manner that the blood from the left is channeled to the right side.

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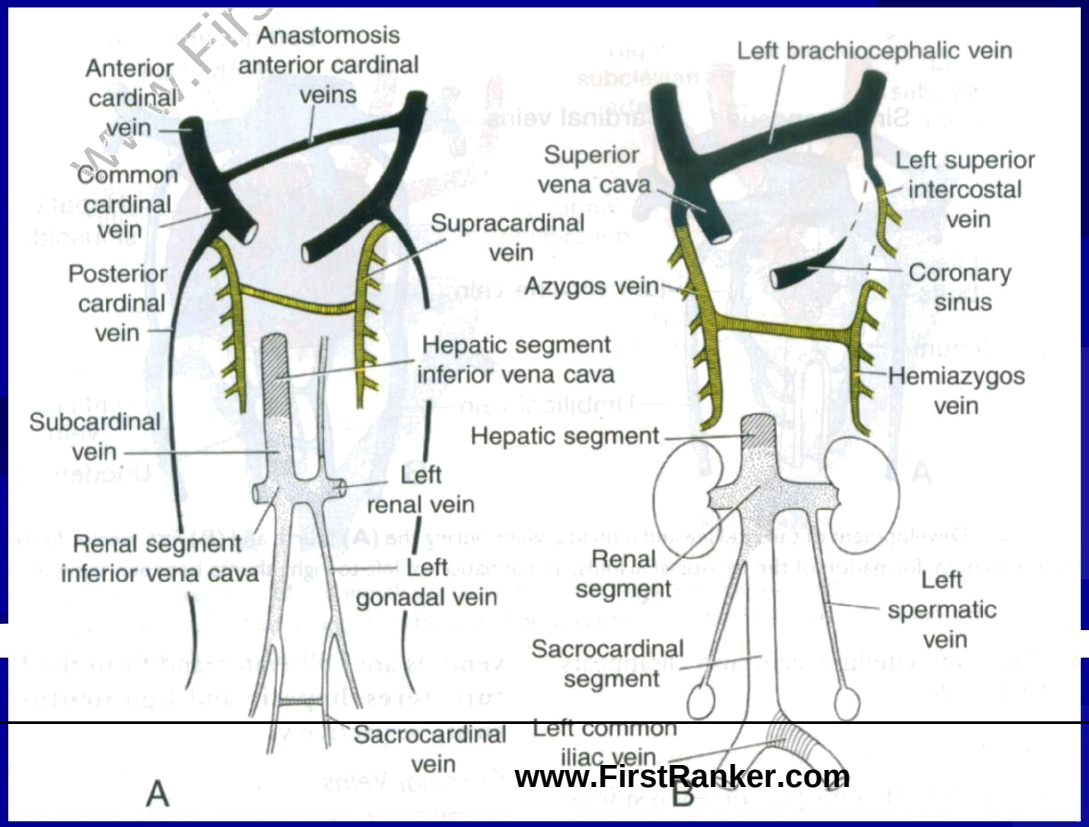
- The anastomosis between the cardinal veins develops into the **left brachiocephalic vein**.
- Most of the blood from the left side of the head and the left upper extremity is then channeled to the right.
- The terminal portion of the left posterior cardinal vein entering into the left brachiocephalic vein is retained as a small vessel, the **left superior intercostal vein**.
- This vessel receives blood from the 2nd and 3rd intercostal spaces.
- The **superior vena cava** is formed by the right common cardinal vein and the proximal portion of the right anterior cardinal vein.



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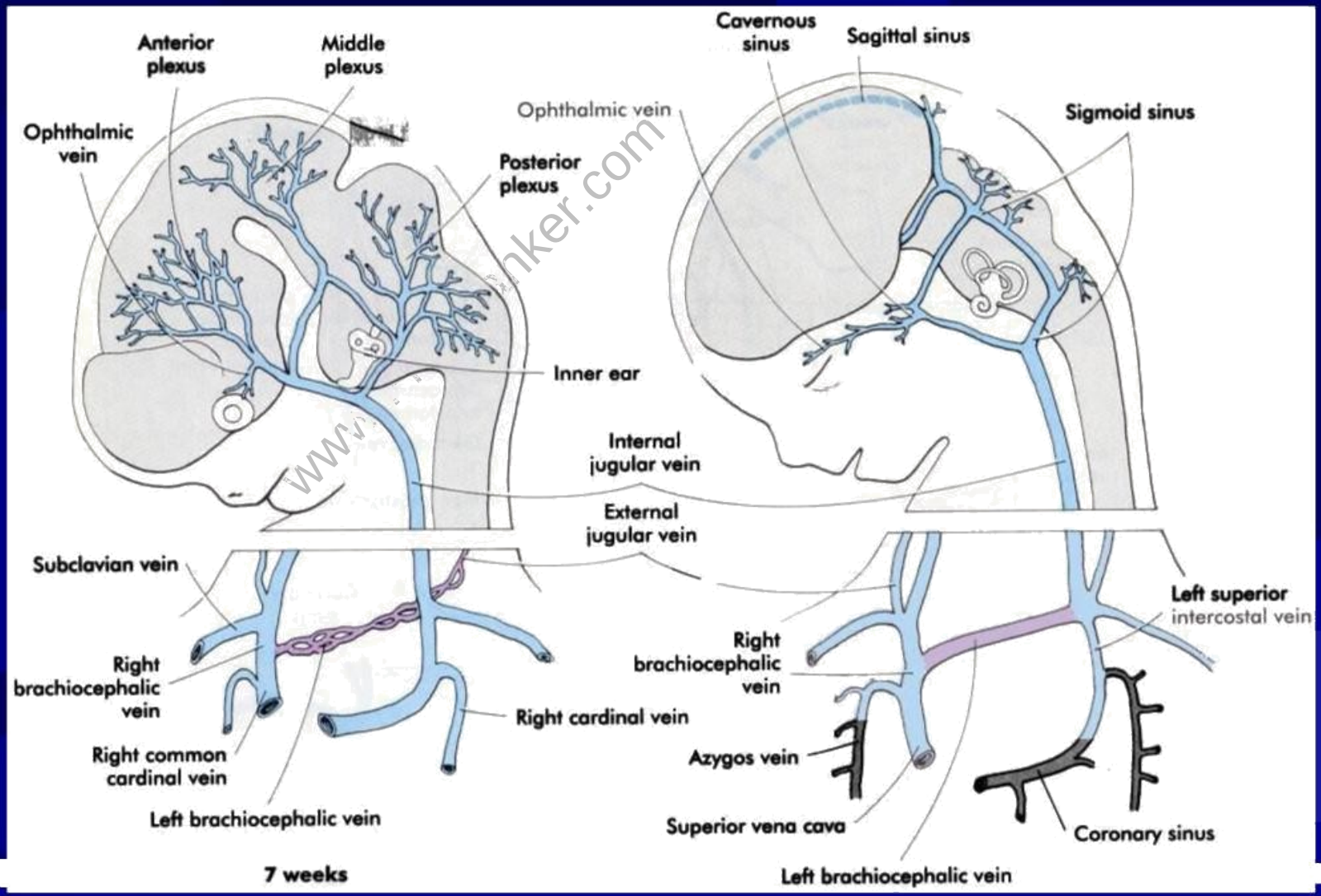

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Formation of Inferior vena cava

- The **anastomosis between the subcardinal veins** forms the **left renal vein**.
- When this communication has been established, the left subcardinal vein disappears and only its distal portion remains as the **left gonadal vein**.
- Hence the right subcardinal vein becomes the main drainage channel and develops into the **renal segment of the inferior vena cava**.

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- The **anastomosis between the sacrocardinal veins** forms the **left common iliac vein.**
- The right sacrocardinal vein becomes the sacrocardinal segment of the inferior vena cava.
- When the renal segment of the inferior vena cava connects with the hepatic segment, which is derived from the right vitelline vein, the inferior vena cava is complete.
- It thus consists of a hepatic segment, renal segment and a sacrocardinal segment.

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Azygos and Hemiazygos veins

- With obliteration of the major portion of the posterior cardinal veins, the supracardinal veins gain in importance.
- The 4th to 11th right intercostal veins empty into the right supracardinal vein, which together with a portion of the posterior cardinal vein, forms the **azygos vein**.
- On the left, the 4th to 7th intercostal veins enter into the left supracardinal vein, and the left supracrdinal vein empties into the azygos vein and is then known as the **hemiazygos vein**.

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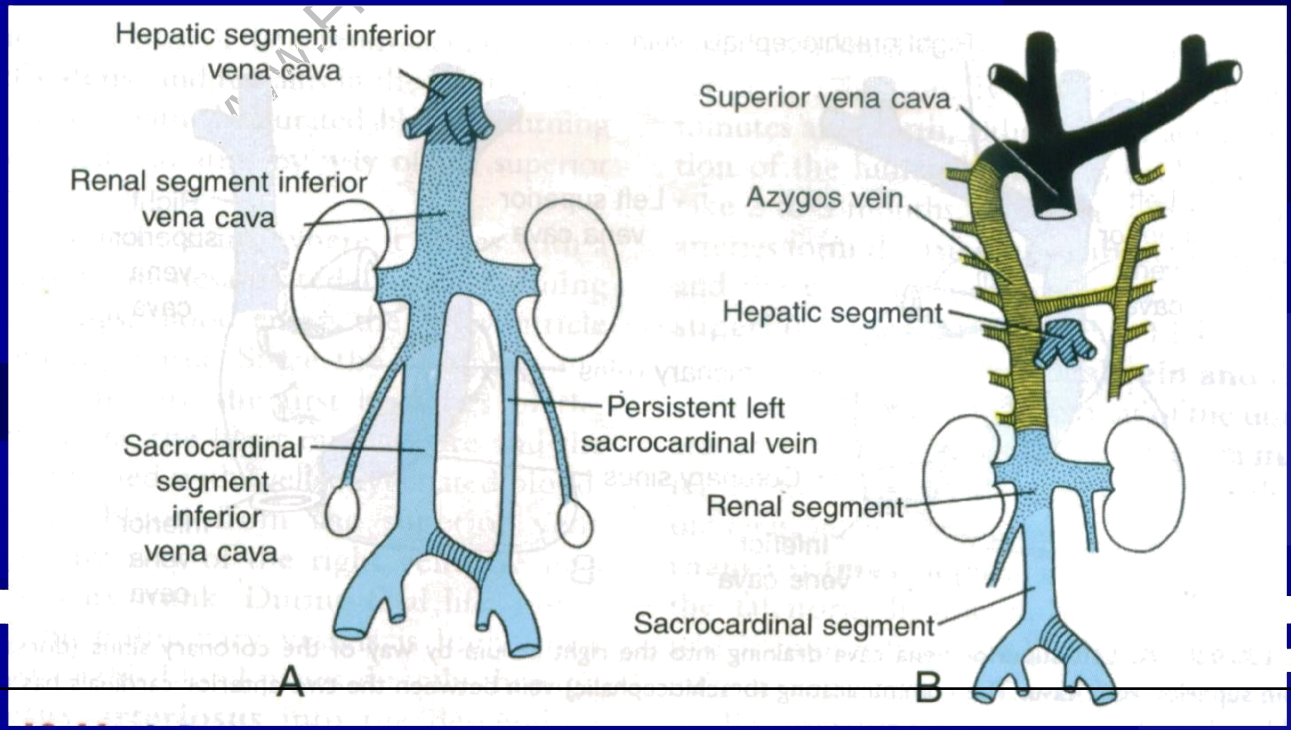
CONGENITAL ANOMALIES

- **DOUBLE INFERIOR VENA CAVA**
- **ABSENCE OF INFERIOR VENA CAVA**



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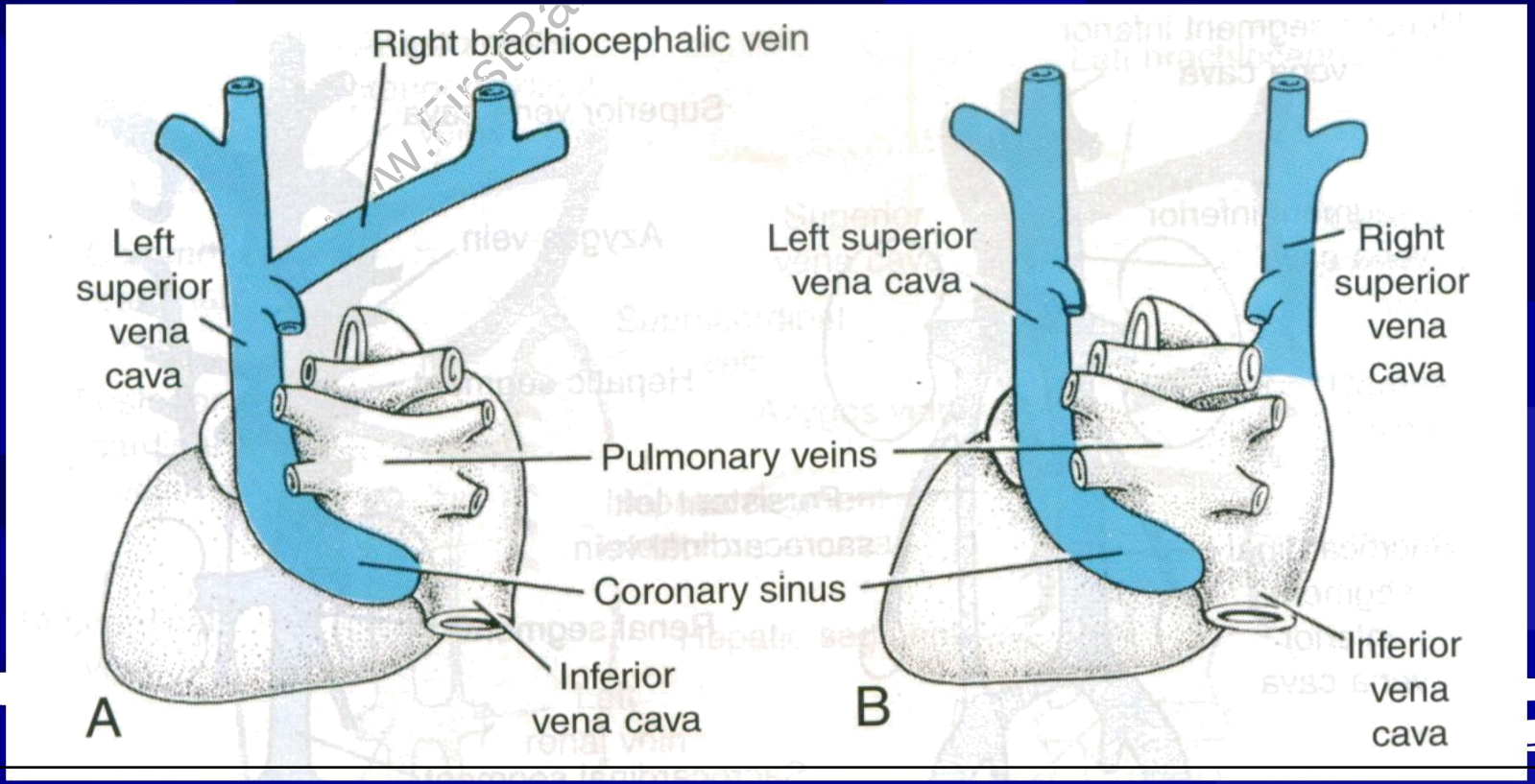
- LEFT SUPERIOR VENA CAVA
- DOUBLE SUPERIOR VENA CAVA



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CIRCULATORY CHANGES AT BIRTH

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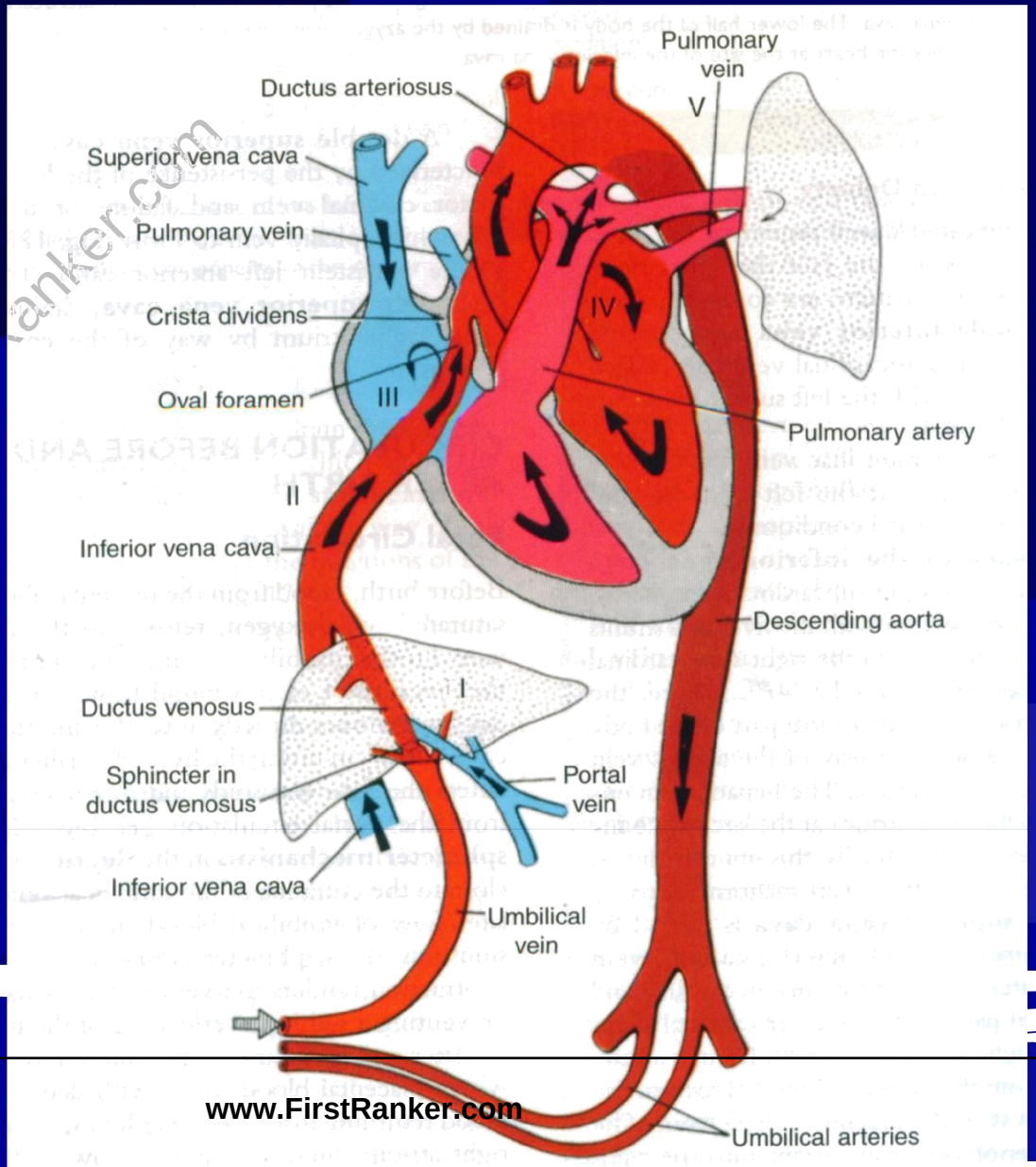
FETAL CIRCULATION

BEFORE BIRTH



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CHANGES AT BIRTH

1. **Closure of the umbilical arteries**
   - It is accomplished by contraction of smooth musculature in their walls and is probably caused by thermal and mechanical stimuli and change in oxygen tension. The distal parts of the umbilical arteries form the medial umbilical ligament, while the proximal portions remain open as the superior vesical arteries.
2. **Closure of the umbilical vein and ductus venosus**
   - This occurs shortly after that of umbilical arteries. After obliteration, umbilical vein forms the ligamentum teres hepatic in the lower margin of the falciform ligament. The obliterated ductus venosus forms the ligamentum venosum.
3. **Closure of the ductus arteriosus**
   - It occurs by contraction of its muscular wall almost immediately after birth and is mediated by **bradykinin**, released from the lungs during initial inflation. The obliterated ductus arteriosus forms the ligamentum arteriosum.
4. **Closure of the foramen ovale**
   - This is caused by an increased pressure in the left atrium combined with decreased pressure on the right side. With the first breath, the septum primum is pressed against the septum secondum. Constant apposition gradually leads to fusion of the two septa in about a year.

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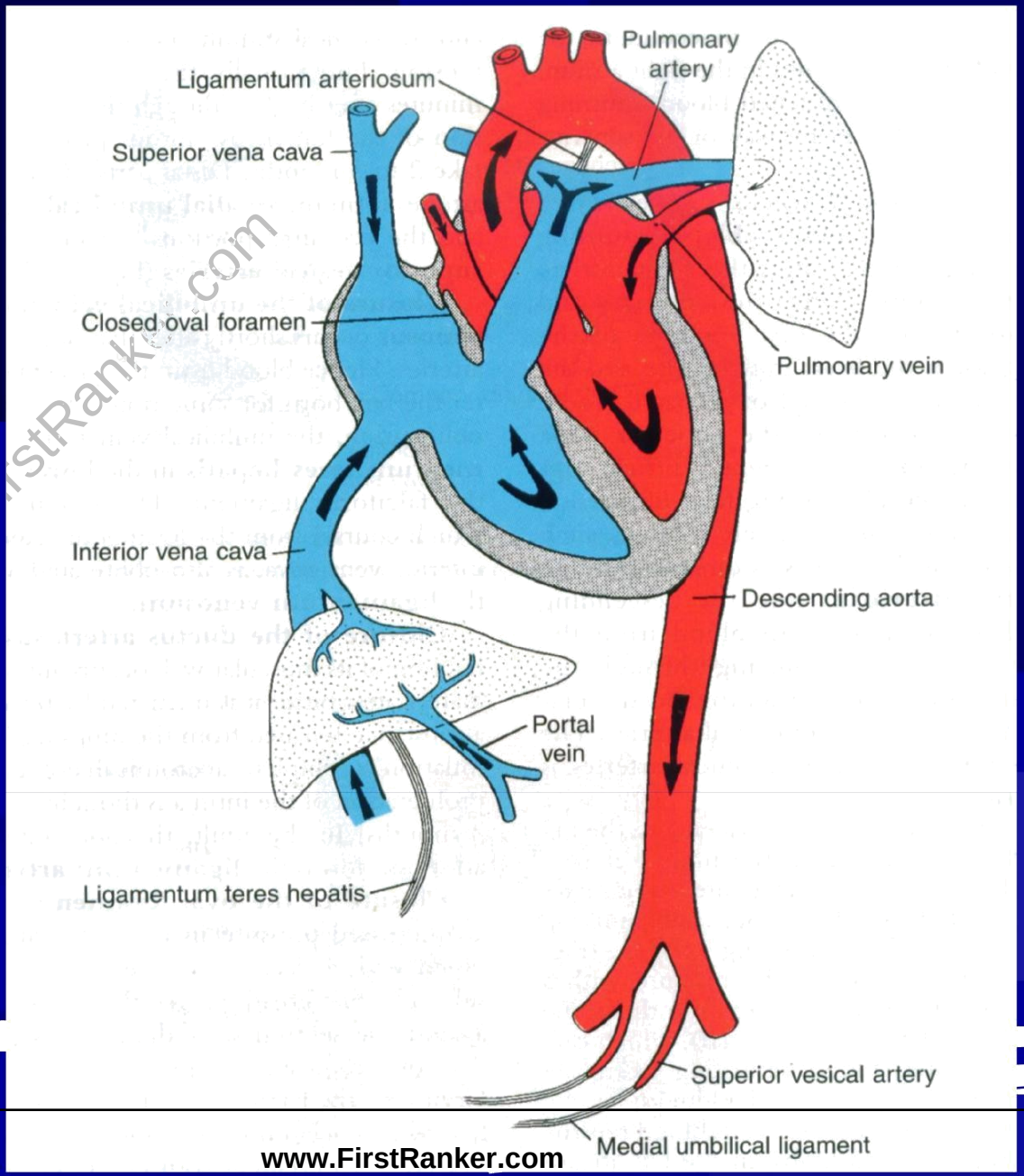
AFTER BIRTH



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LYMPHATIC SYSTEM

- The lymphatic system begins its development later than the cardiovascular system and does not appear until the 5th week of gestation.
- The origin of lymphatic vessels is not clear, but they may form from mesenchyme in situ or may arise as sac like outgrowths from the endothelium of veins.

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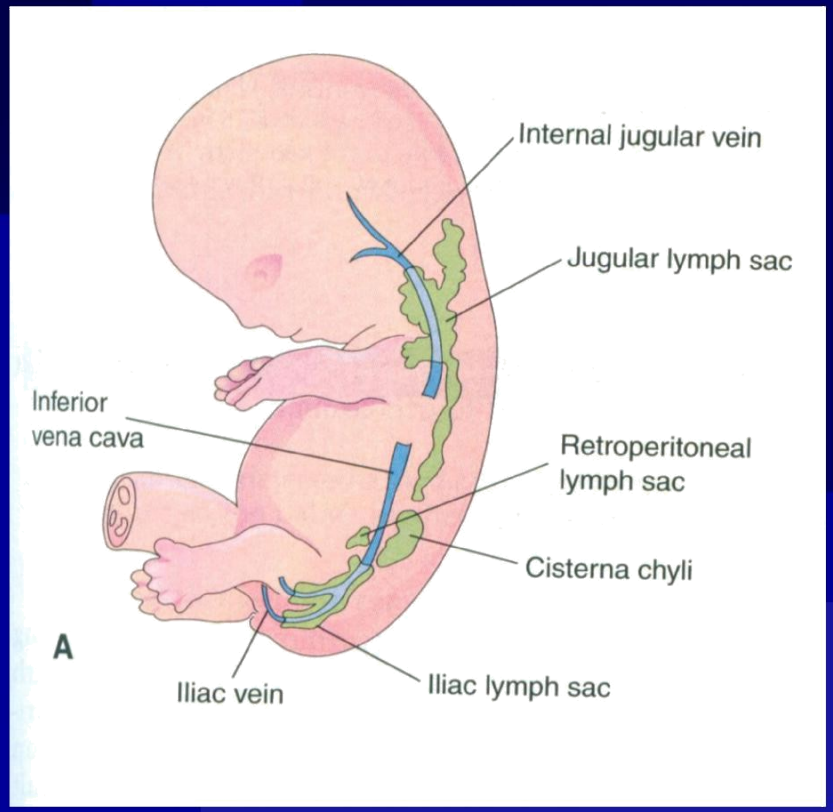
- As a result, six primary lymph sacs are formed:
  - Two **jugular**, at the junction of the subclavian and anterior cardinal veins
  - Two **iliac**, at the junction of the iliac and posterior cardinal veins
  - One **retroperitoneal**, near the root of the mesentery
  - The **cisterna chyli**, dorsal to the retroperitoneal sac.



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- Numerous channels connect the sacs with each other and also drain lymph from the limbs, body wall, and head and neck.
- Two main channels, the right and left thoracic ducts, join the jugular sacs with the cisterna chyli and soon an anastomosis forms between these ducts.
- The **thoracic duct** then develops from the distal portion of the right thoracic duct, the

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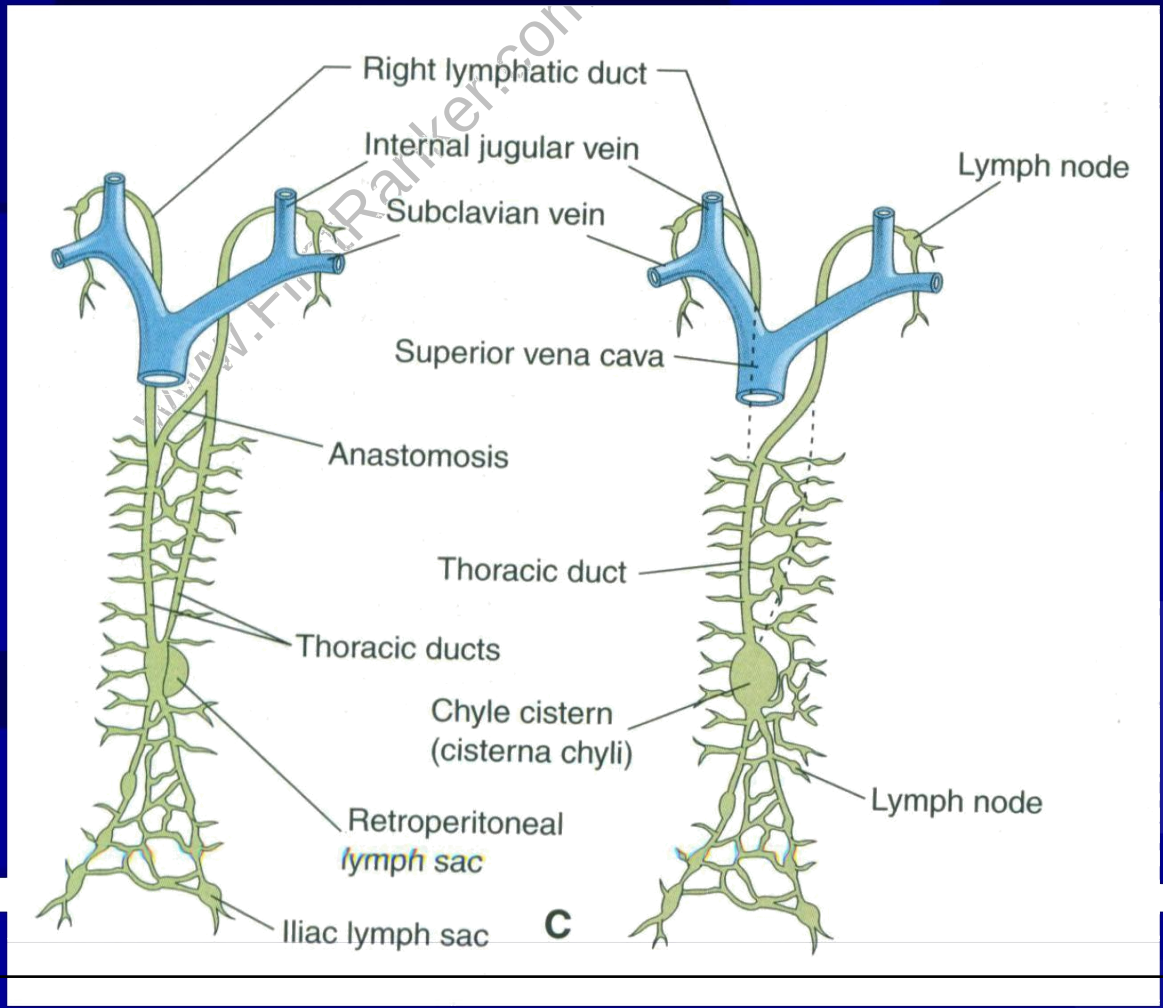
NINE WEEKS

FETAL PERIOD



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- The **right lymphatic duct** is derived from the cranial portion of the right thoracic duct.
- Both ducts maintain their original connections with the venous system and empty into the junction of the internal jugular and subclavian veins.

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