DEVELOPMENT OF THE BLOOD VASCULAR SYSTEM

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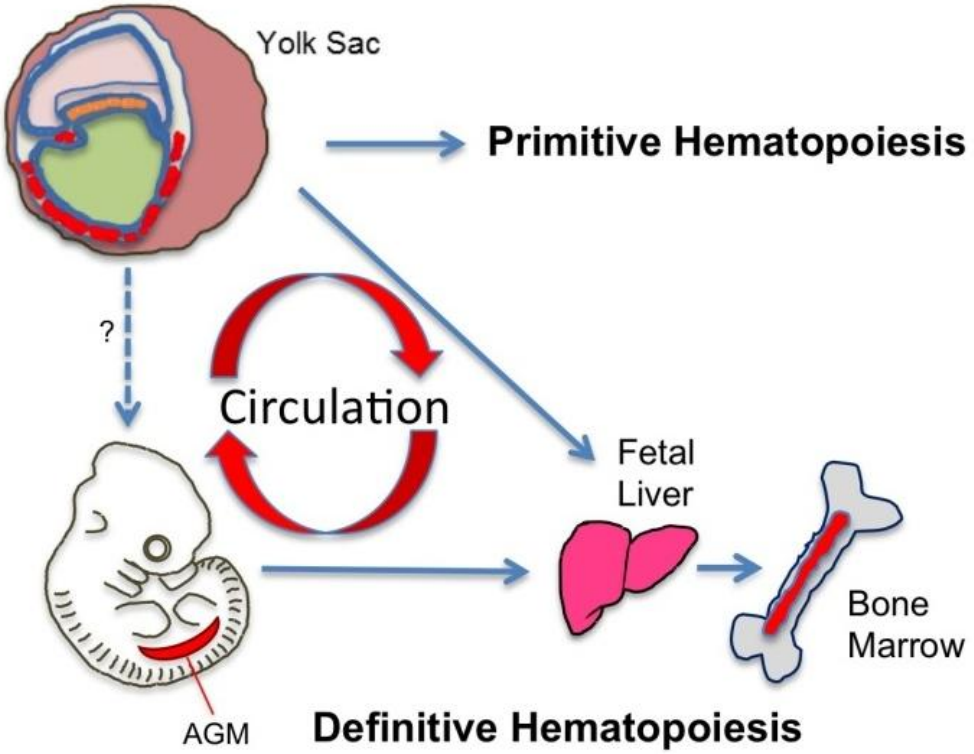
Embryology Course

HEMOPOIESIS



ttps://www.intechopen.com/books/pluripotent-stem-cell-biology-advances-in-mechanisms-methods-and-models/human-embryonic-stem-cell-derived-primitive-and-definitive-hematopoiesis

- **all blood cell are of mesodermal origin**

blood cells are first formed:

1. in the splanchnic mesoderm of the yolk sac

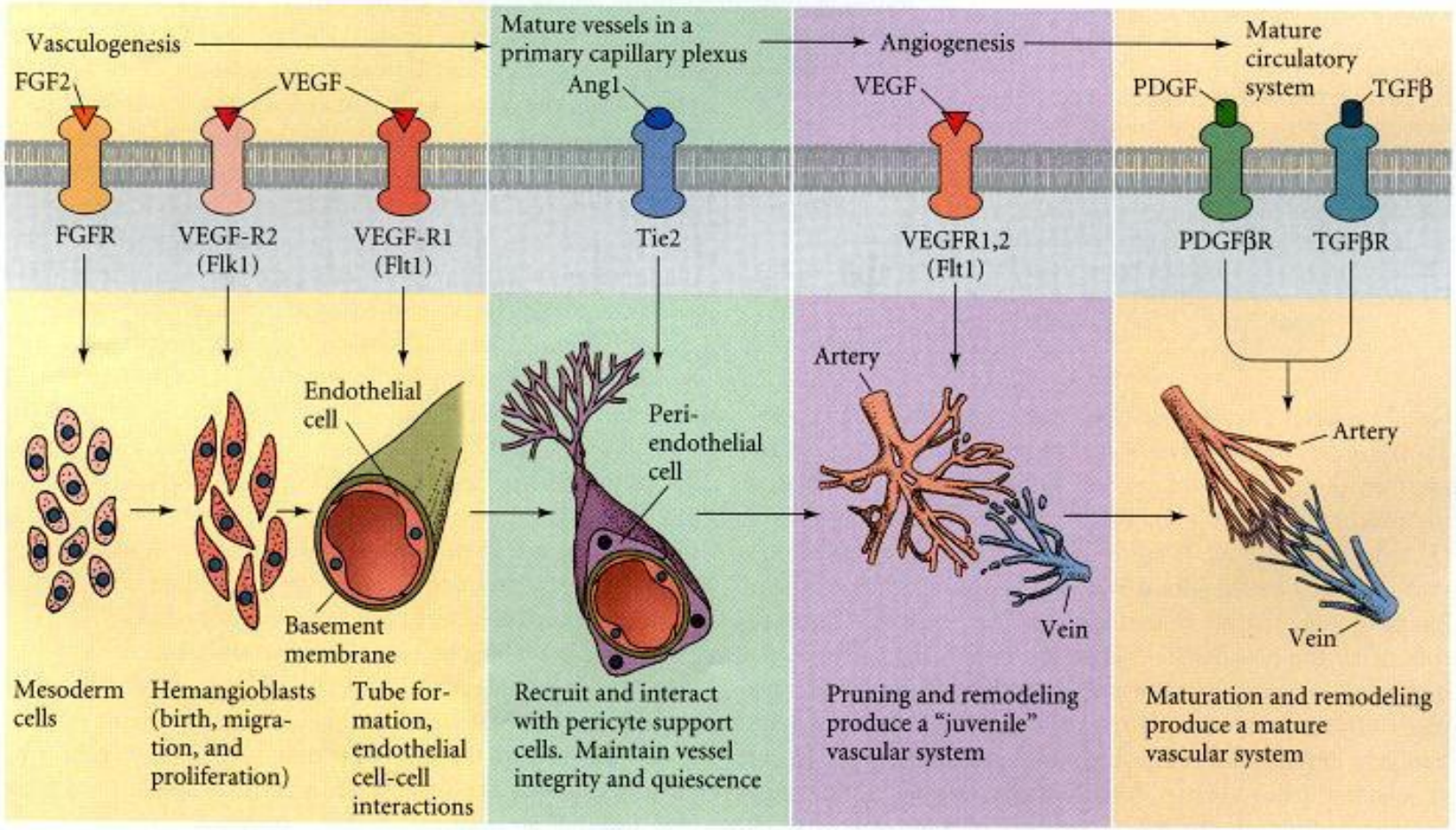
later hemopoietic activity appears in the:

1. **mesenchyme**
2. **spleen**
3. **liver**
4. **finally in the bone marrow**

- **in the last half of the fetal stage, the hemopoietic actvity of the liver decreases while that of bone marrow increases**

- bone marrow is the site of erythropoiesis and granulopoiesis in the adult

HEMOPOIESIS

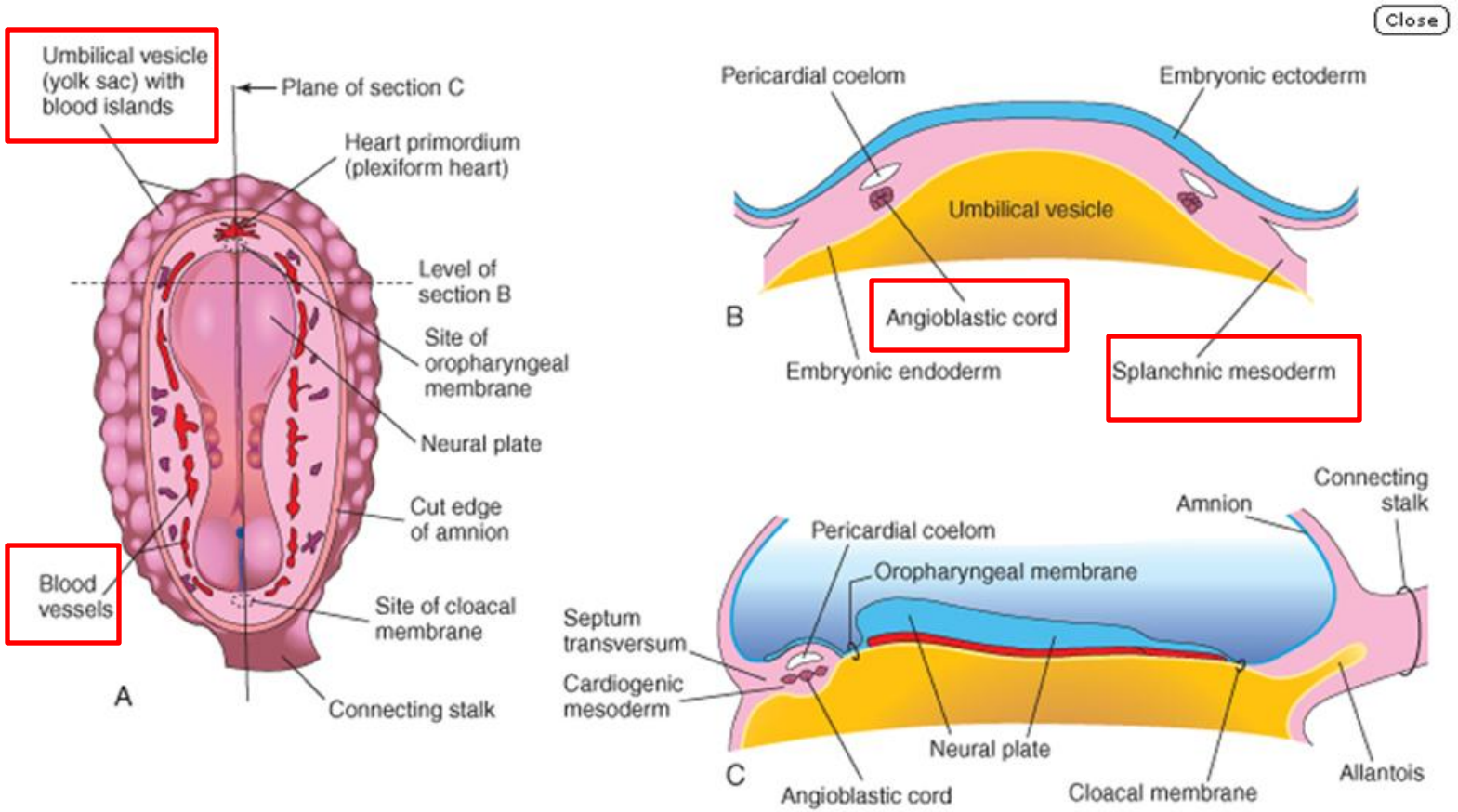


FGF: Fibroblast Growth Factor, VEGF: Vascular Endothelial Cell Growth Factor

HEMOPOIESIS

IN YOLK SAC:

- **there is a releationship between the yolk sac endoderm and the potential splanchnic mesoderm stem cells, this releationship is necessary for that stem cells to become hemopoietic**



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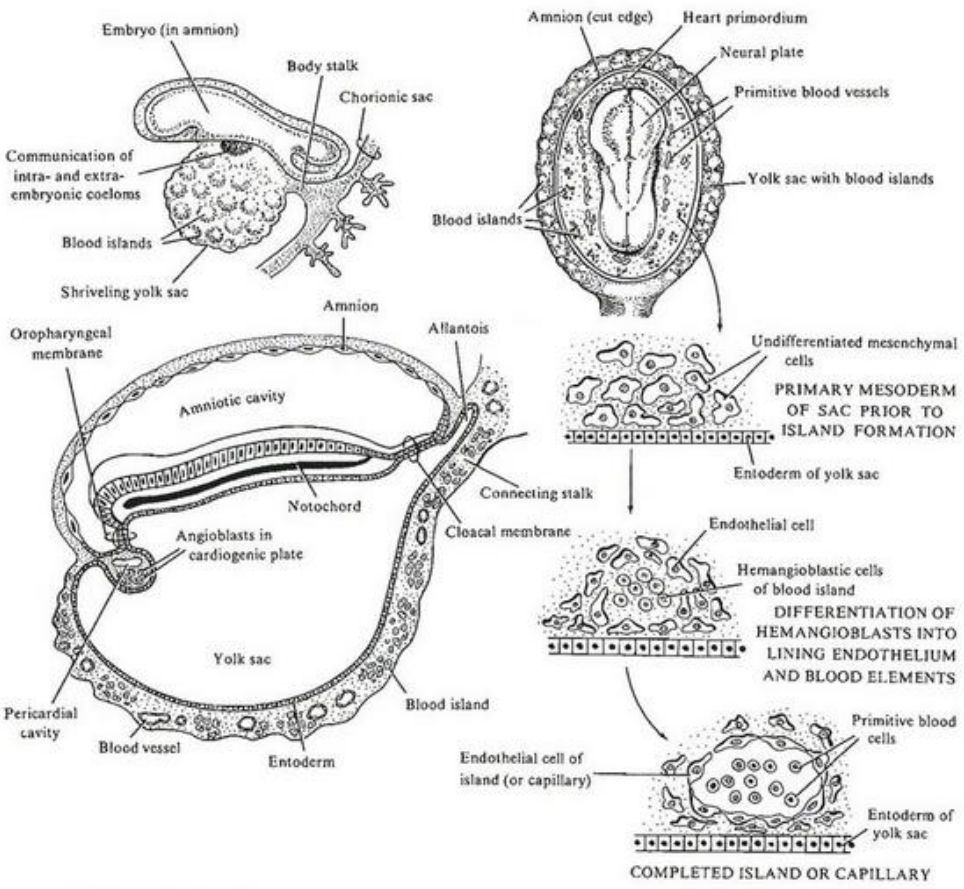
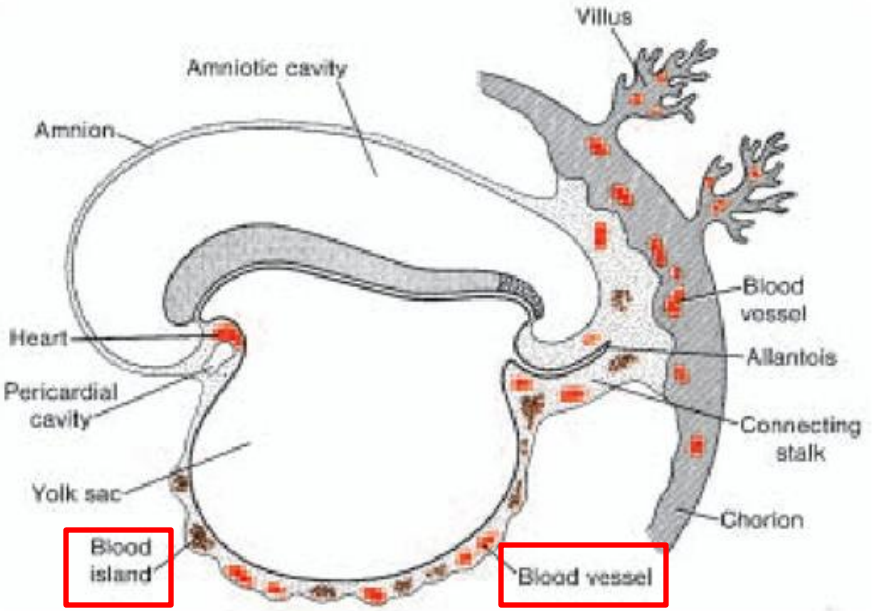
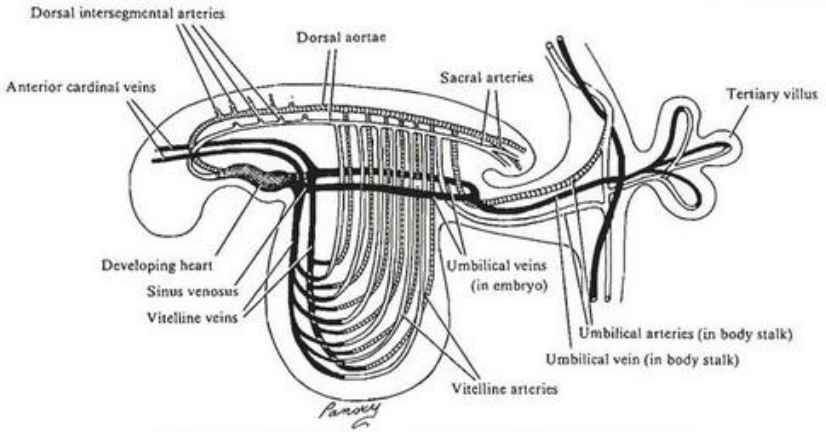






SCHEME OF EXTRA - AND INTRAEMBRYONIC VASCULARIZATION IN AN EMBRYO (ABOUT THREE WEEKS)

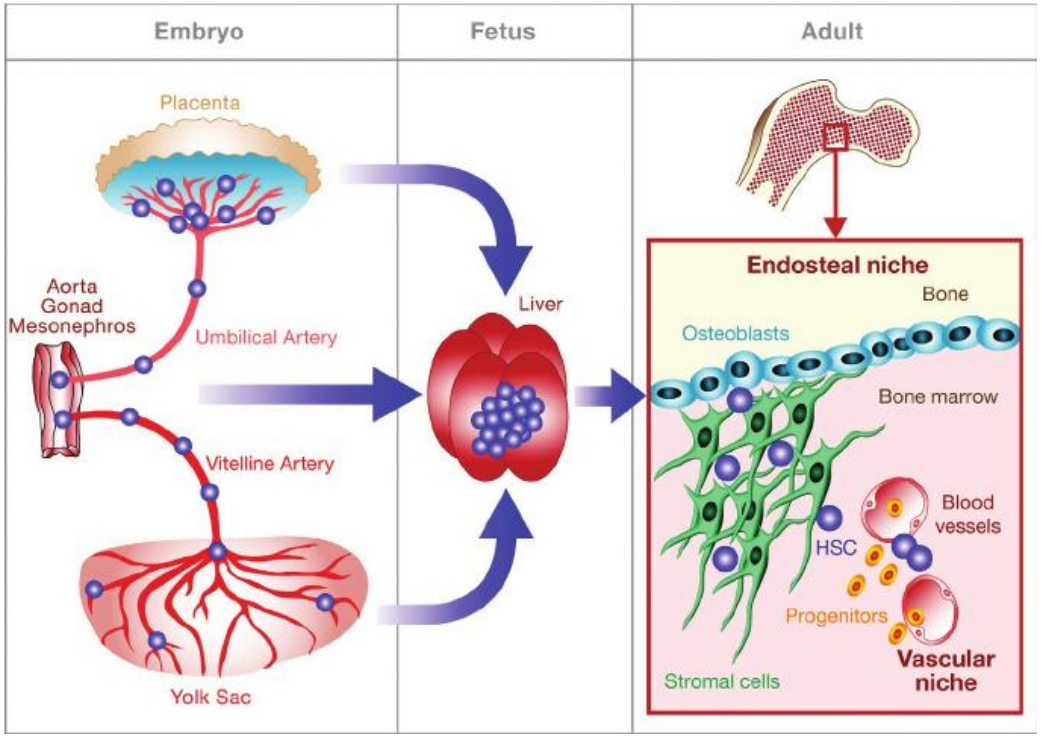
HEMOPOIESIS

IN THE EMBRYONIC LIVER:

- **all hemopoiesis appeares to begin extravascularly**

the stem cells originate:

1. **from the mesenchyme of the septum transversum**
2. **they differentiate into blood forming cells after being attached to the prehepatocytes (prehepatocatyes arise from the endodermal hepatic diverticulum)**
3. **the blood forming cells enter the hepatic sinusoids by diapedesis**

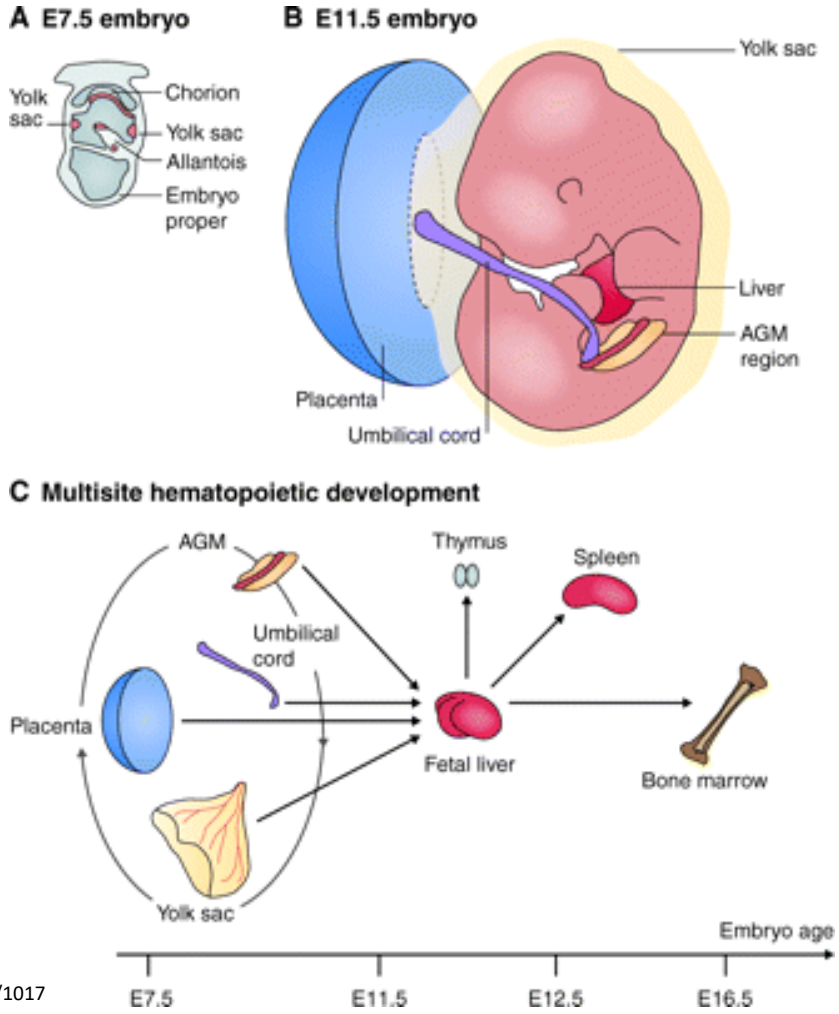


https://www.researchgate.net/figure/Development-of-the-hematopoietic-system-In-the-adult-all-blood-cell-types-are-produced_fig1_45651888

HEMOPOIESIS

IN THE SPLEEN AND BONE MARROW:

- **hemopoietic stem cells react with the reticular stroma of these organs – they differentiate into blood cells**



https://dev.biologists.org/content/138/6/1017

ANGIOGENESIS

- **histogenesis of blood vessels**

blood vessels arise:

1. **either de novo angiogenesis**
2. **or via budding (sprouting) of the endothelium of preexisting blood vessels**

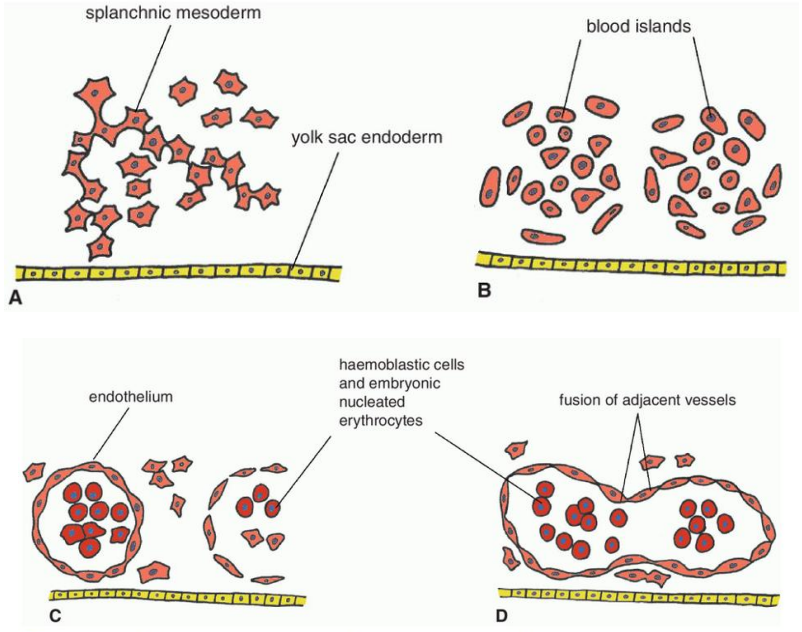
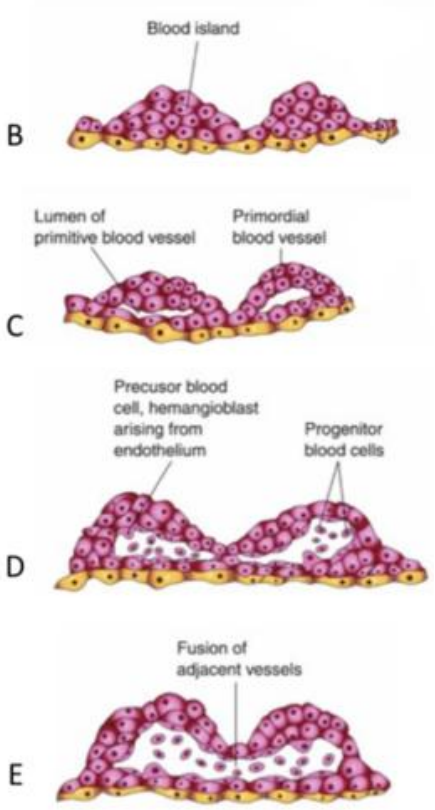
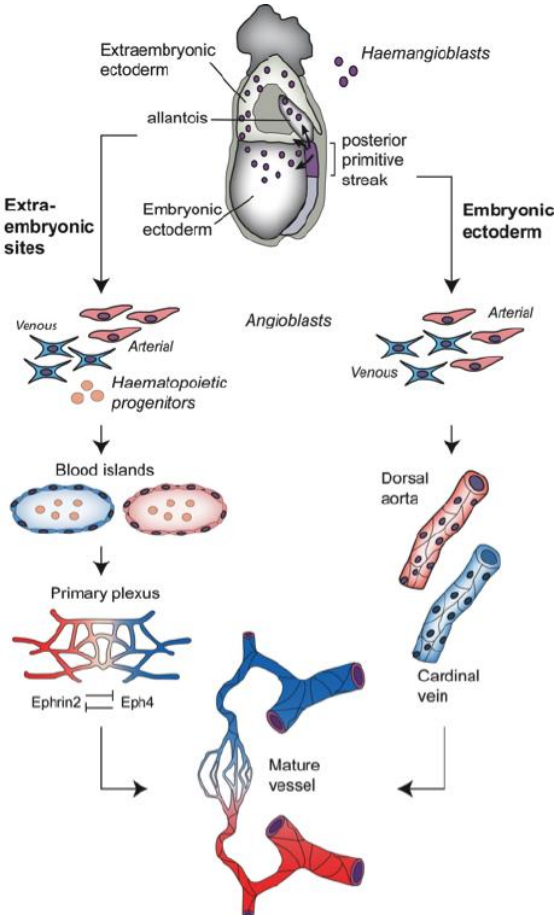


Figure 14.2 Sequential stages in the formation of blood vessels and blood cells from blood islands in the yolk sac (A to D).

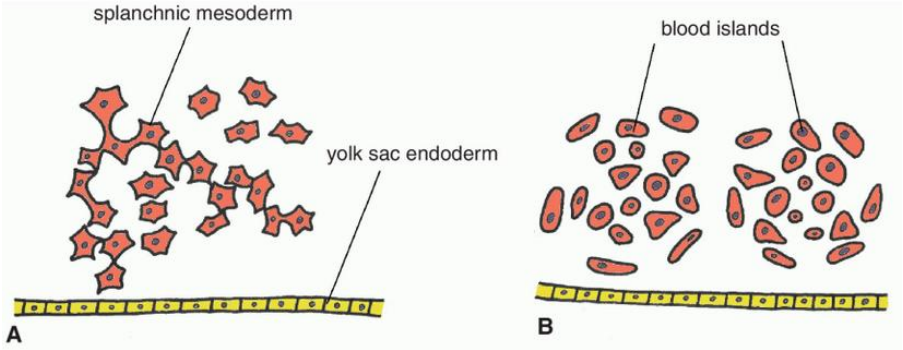
https://veteriankey.com/cardiovascular-system-4/





https://www.researchgate.net/figure/Development-of-the-circulatory-system-Haemangioblasts-appear-in-the-posterior-primitive_fig2_268261694

ANGIOGENESIS



the first vessels

1. **form de novo**
2. **they formed in the splanchnopleura of the yolk sac**
3. **the splanchnic mesodermal mesecnhymal cells aggregate into blood islands**
4. **the cells in the center of the blood islands differentiate into primitive erythrocytes**
5. **at the same time, those at the periphery form a layer of endothelial cells**
6. **the inner cells separate from the outer ones – the structure has appearance of a group of primitive erythrocytes in the lumen of a capillary space –this space is a sinusoid since the endothelium at this time lacks a basement membran**
7. **the capillary spaces enlarge until they fuse or coalesce with neigboring sinusoids**
8. **some vessels become arteries, some become veins**

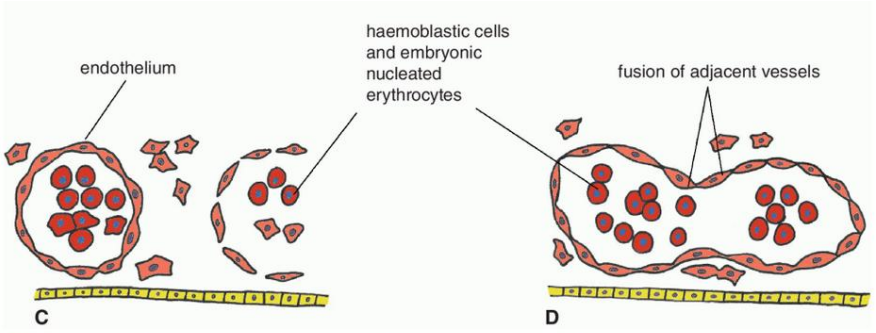
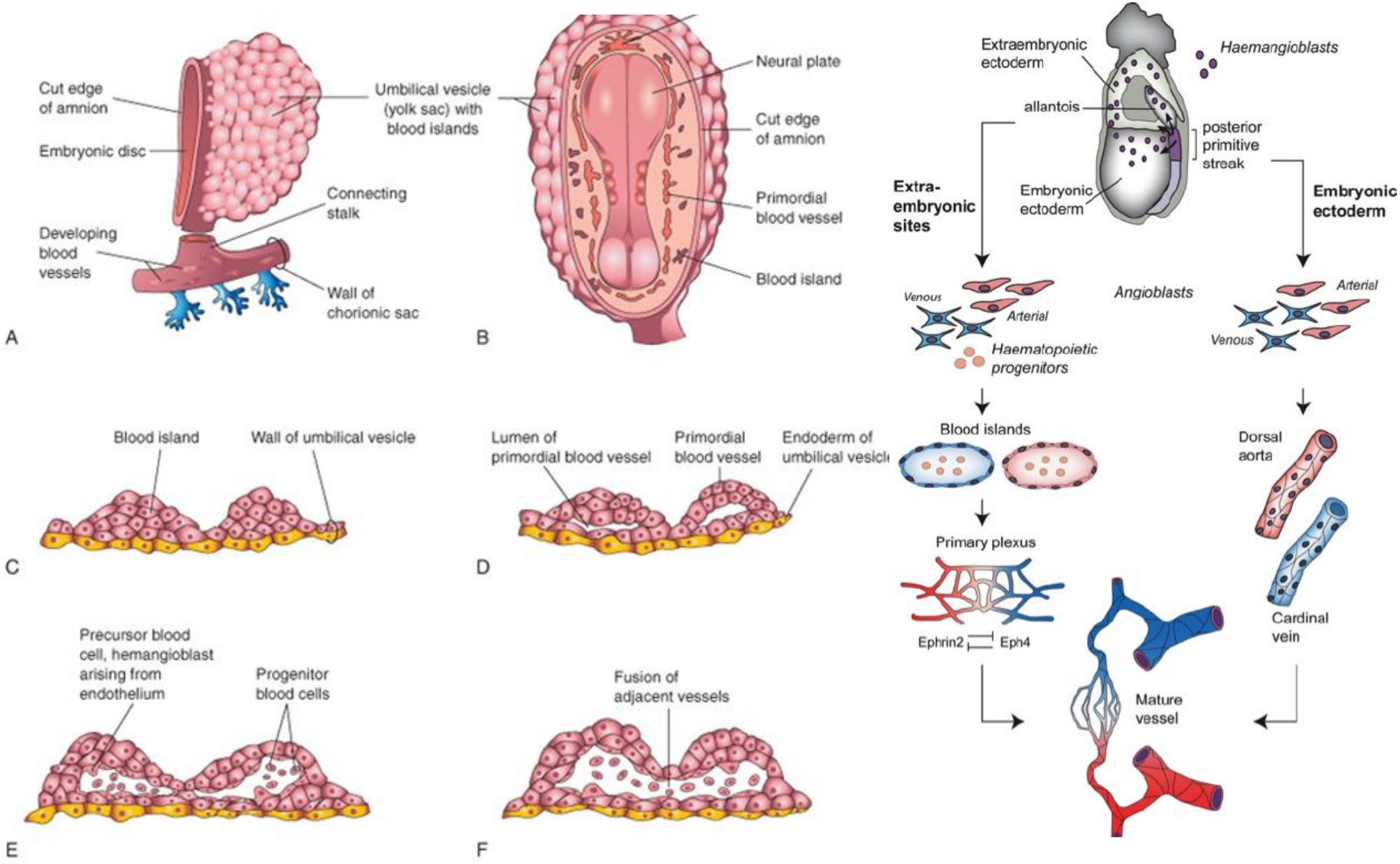


Figure 14.2 Sequential stages in the formation of blood vessels and blood cells from blood islands in the yolk sac (A to D).

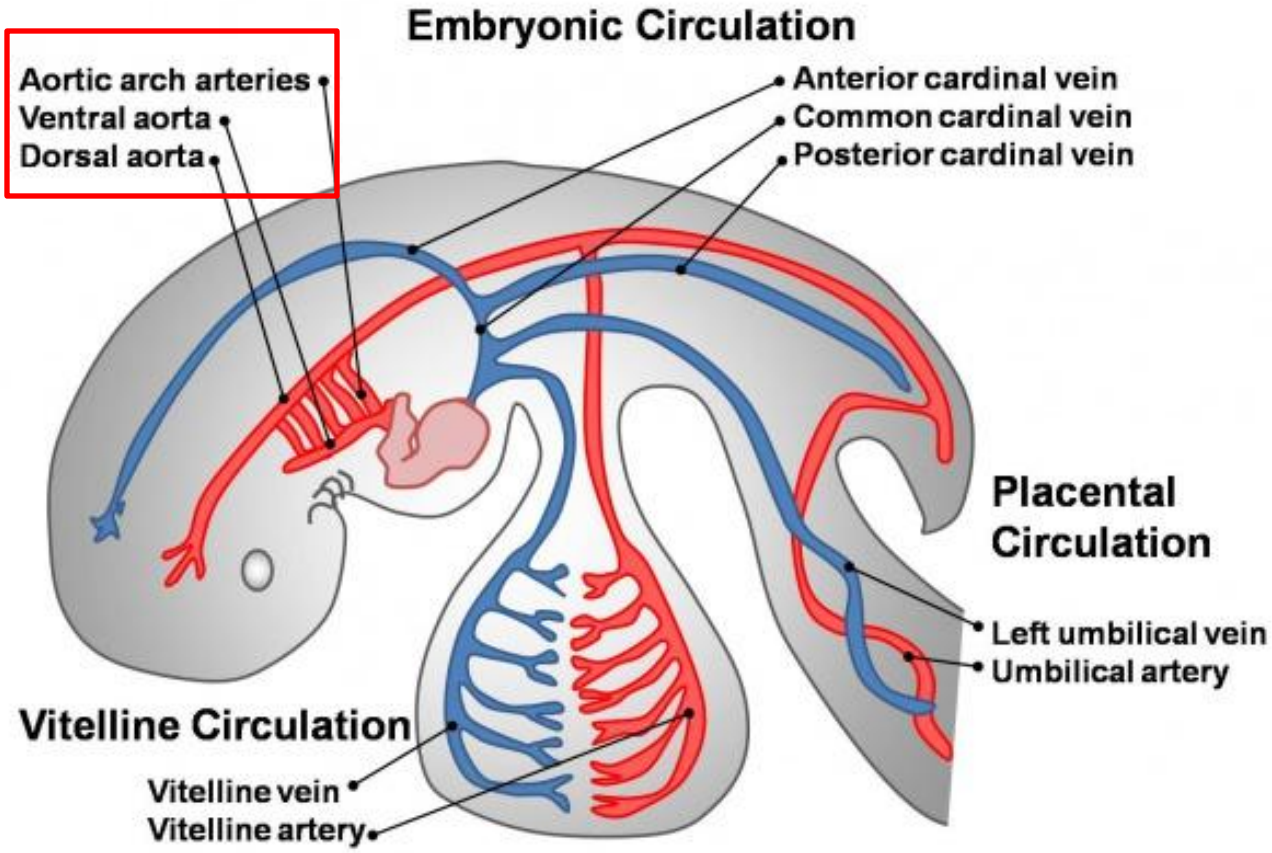
ANGIOGENESIS



ARTERIAL SYSTEM

the formation of the atrial system involves:

1. **the modification of the aortic arch system**
2. **ventral aorta**
3. **dorsal aorta**
4. **branches of aorta**



DORSAL AORTAE

DORSAL AORTAE:

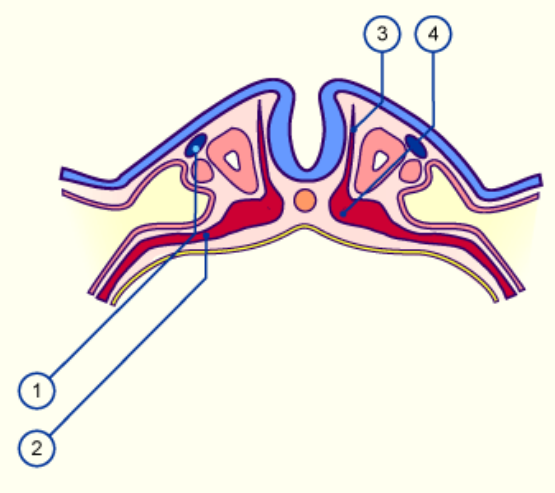
- **originally paired**

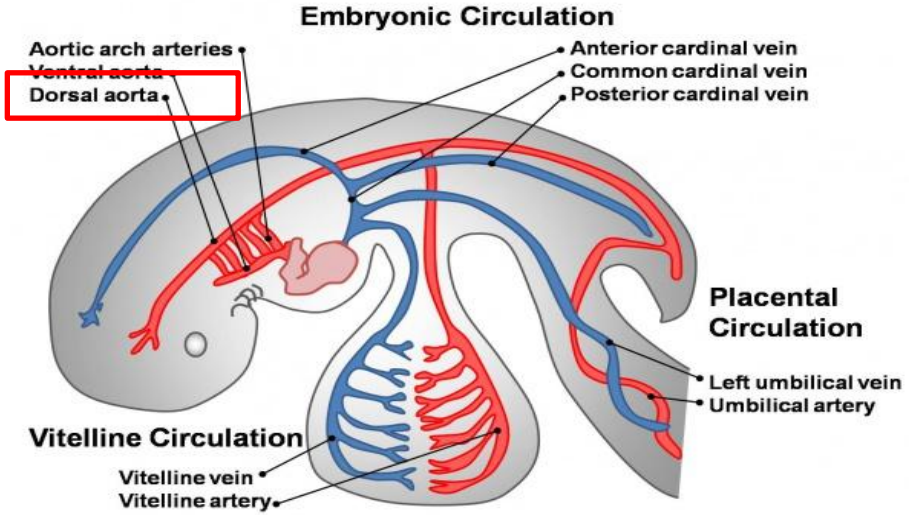
1. they fuse into a single aorta just caudal to the last aortic arch - this fusion occurs caudally at the tail region of the embryo

- **the fused dorsal aorta is the aorta in adult**

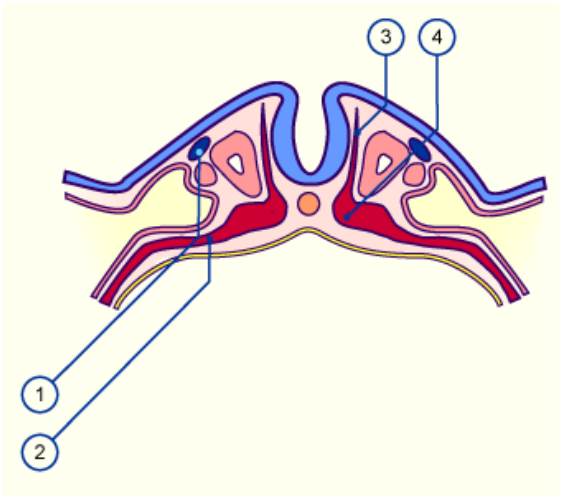
2. the dorsal aorta in the branchial area and in the area cranial to the aortic arches remain paired – extend into the head as the internal carotid arteries

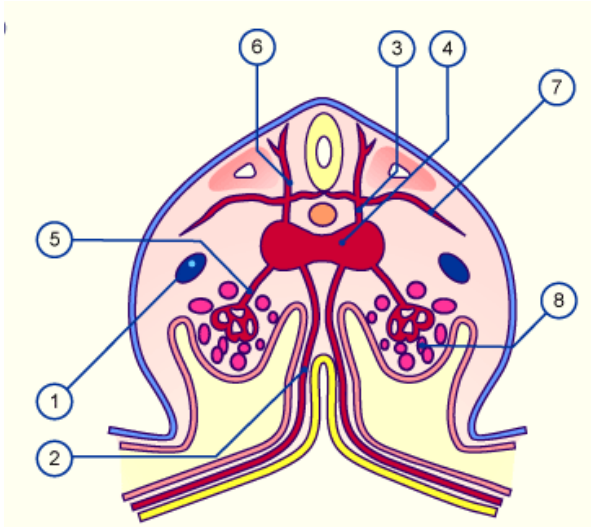
3. the right dorsal aorta between its 7th intersegmental branch and its point of fusion with the left dorsal aorta is lost

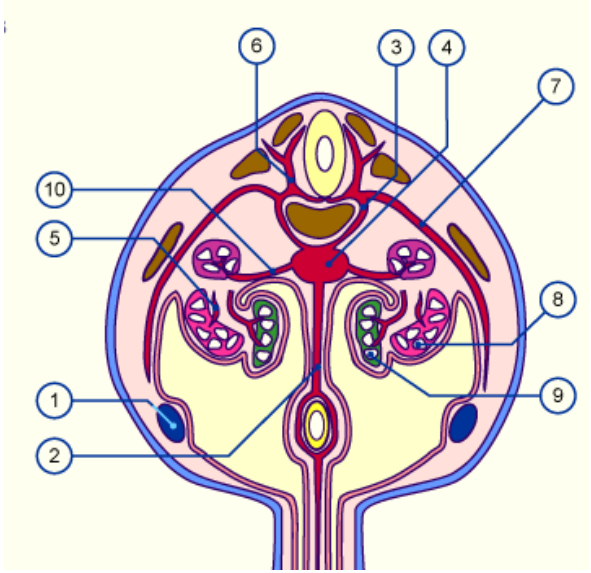




DORSAL AORTAE







1 **Umbilical vein**

2 **Ventral, visceral branches of the aorta**

3 **Dorsal intersegmental branches of the aorta**

4 **Dorsal aorta**

5 **Remainders of the lateral branches of the aorta for the mesonephros**

6 **Dorsal branches of the dorsal intersegmental branches of the aorta**

7 **Ventral branches of the dorsal intersegmental branches of the aorta (e.g., intercostal arteries)**

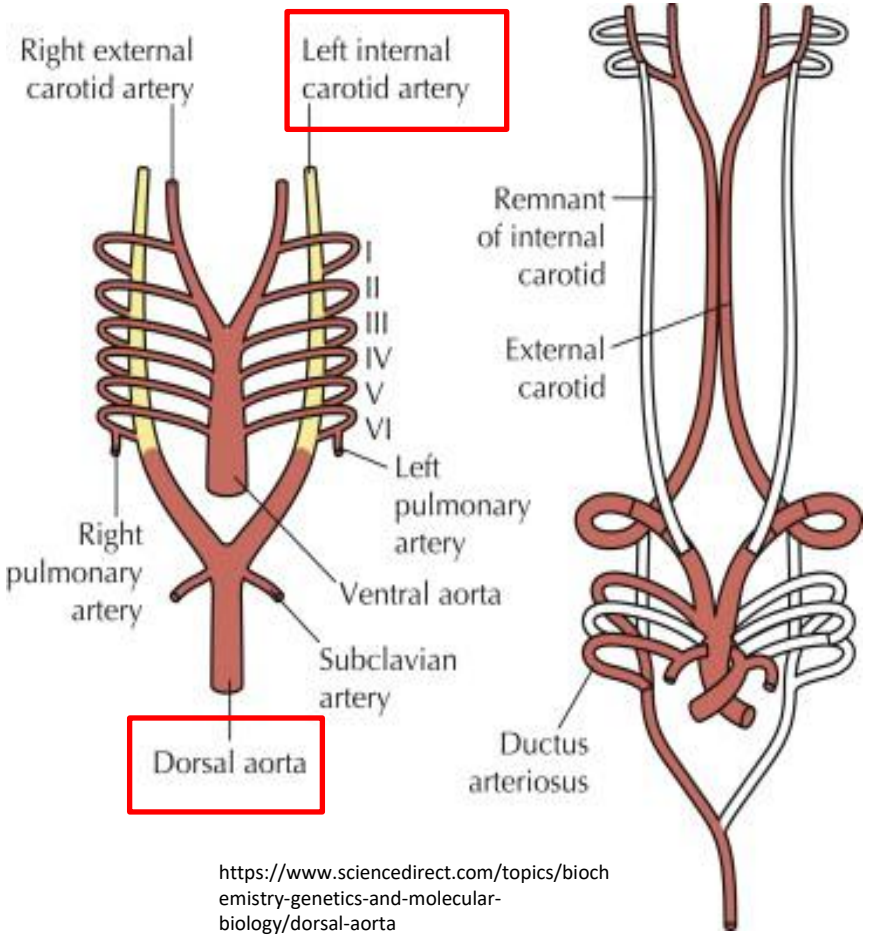
8 **Mesonephros (while atrophying)**

9 **Gonad anlage with paired gonad vessels from the lateral aortic segment arteries**

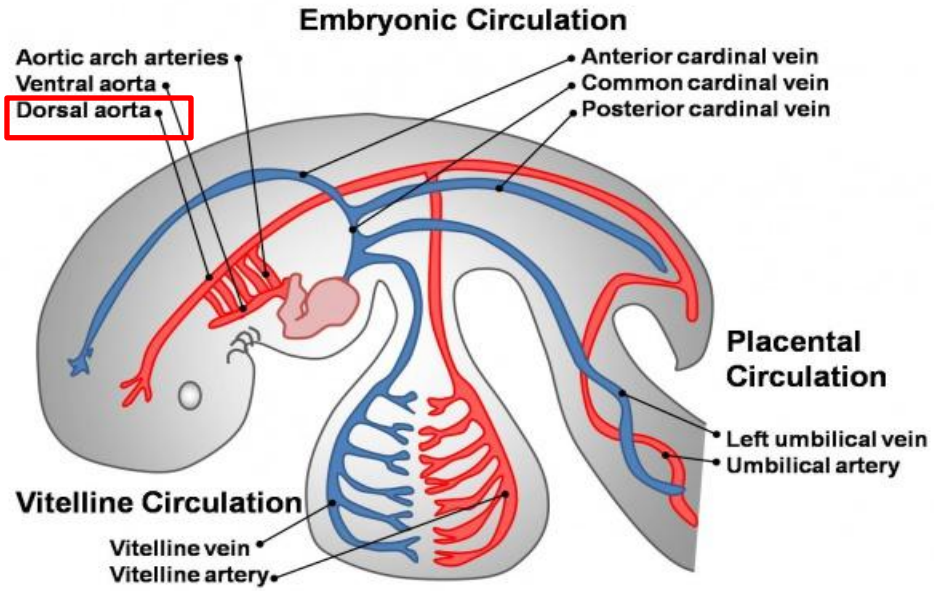
10 **Lateral segment arteries for the renal artery**

http://www.embryology.ch/anglais/pcardio/arterien02.html

DORSAL AORTAE



https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/dorsal-aorta



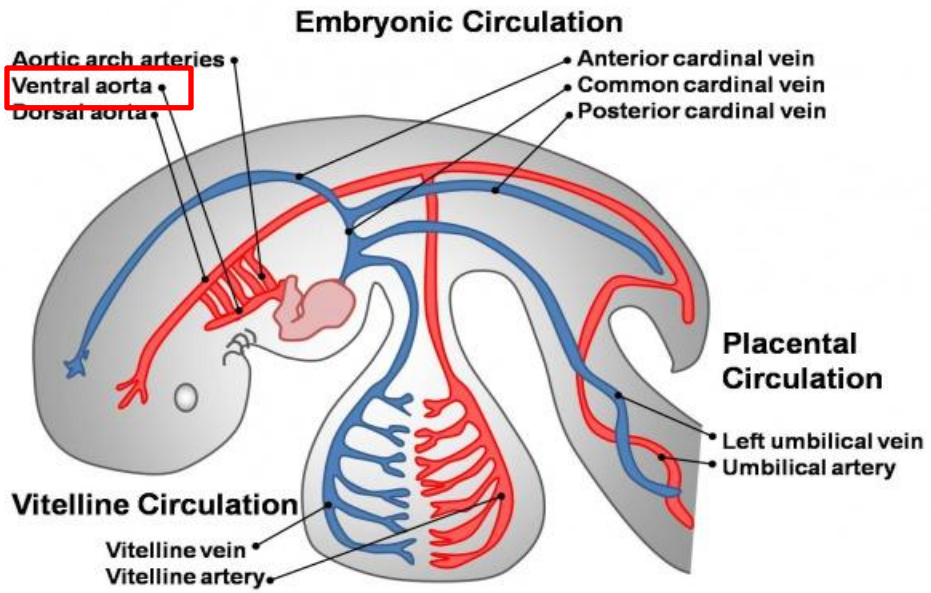
ARTERIAL SYSTEM

DORSAL AND VENTRAL AORTAE

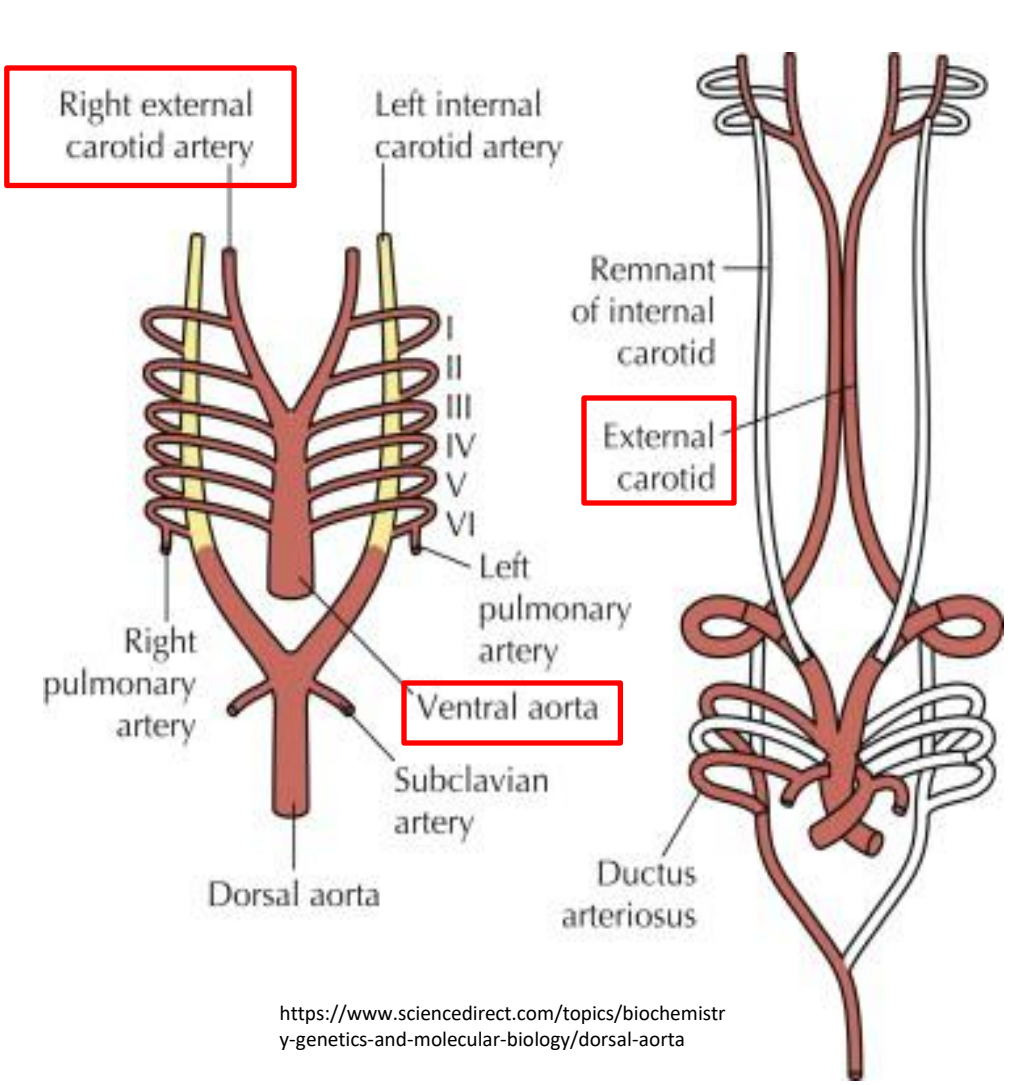
VENTRAL AORTAE:

- originally paired

- **fused near the heart**
- **the paired extensions of the ventral aorta between aortic arches III and IV. elongate to become the common carotid arteries**
- **cranial to the aortic arch III extend the ventral aortae cranially as external carotid arteries**



VENTRAL AORTAE



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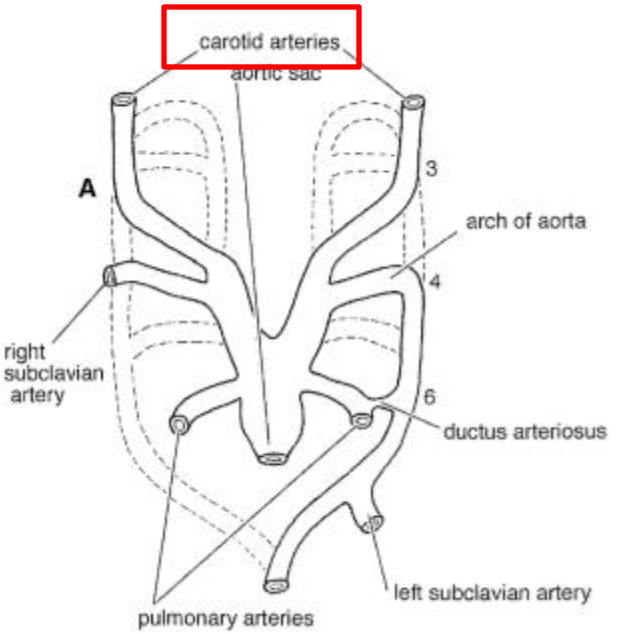
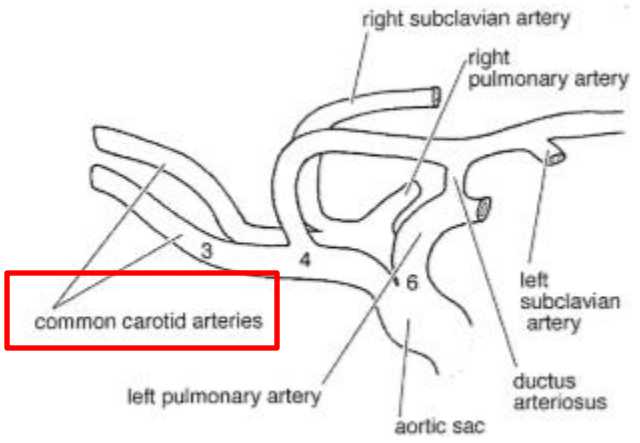


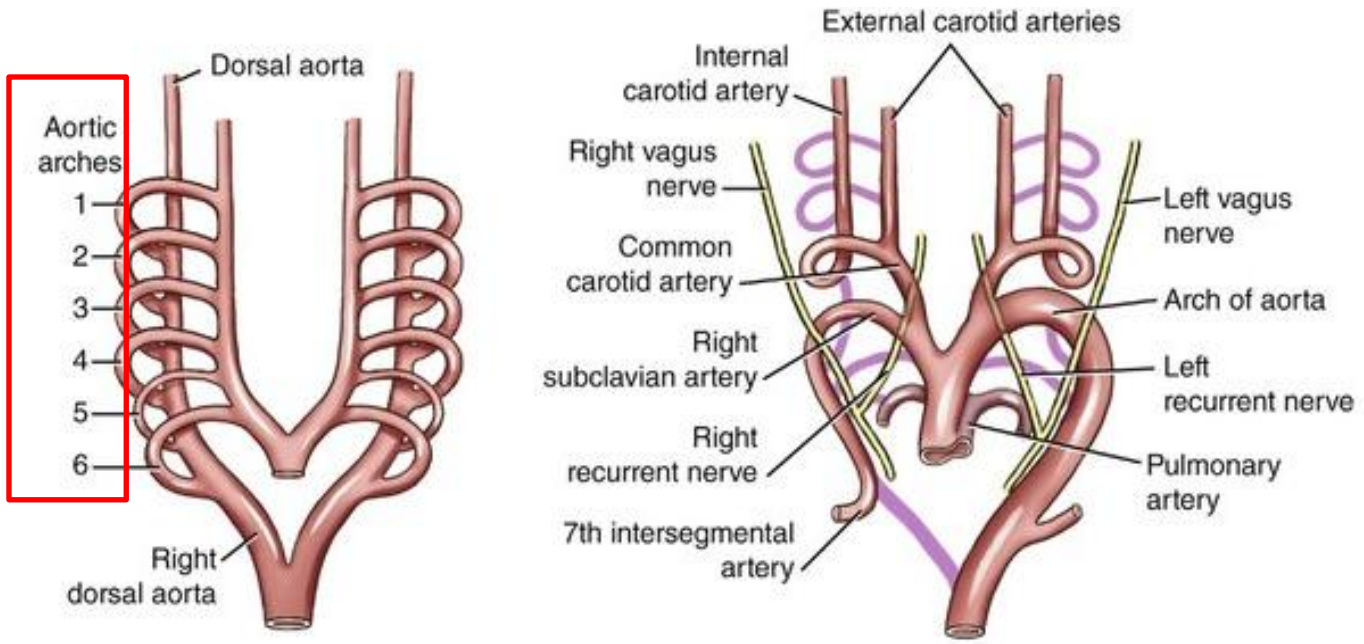


ARTERIAL SYSTEM

AORTIC ARCHES

- the aortic arches (pharyngeal arch arteries or previously referred to as branchial arches) are a series of six paired embryological vascular structures which give rise to the great arteries of the neck and head

- **they are ventral to the dorsal aorta**
- **arise from the aortic sac**



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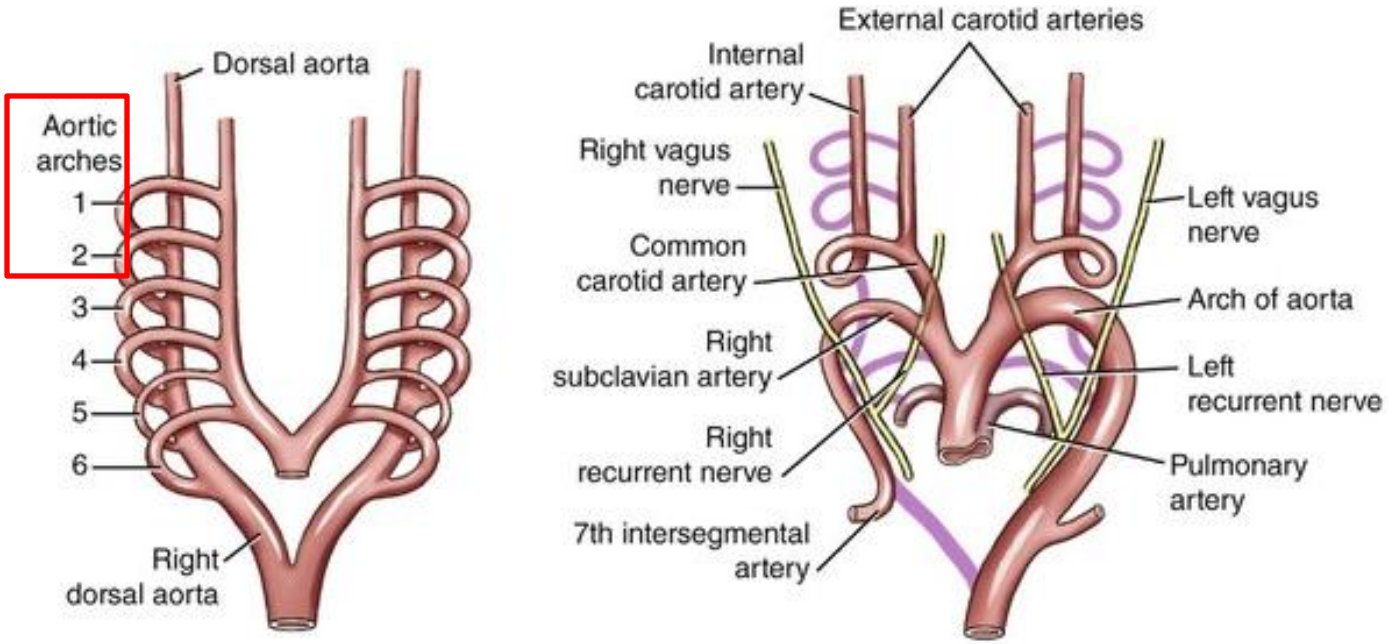
ARTERIAL SYSTEM

AORTIC ARCHES

THE FIRST TWO PAIRS OF AORTIC ARCHES:

- **lost without a trace**



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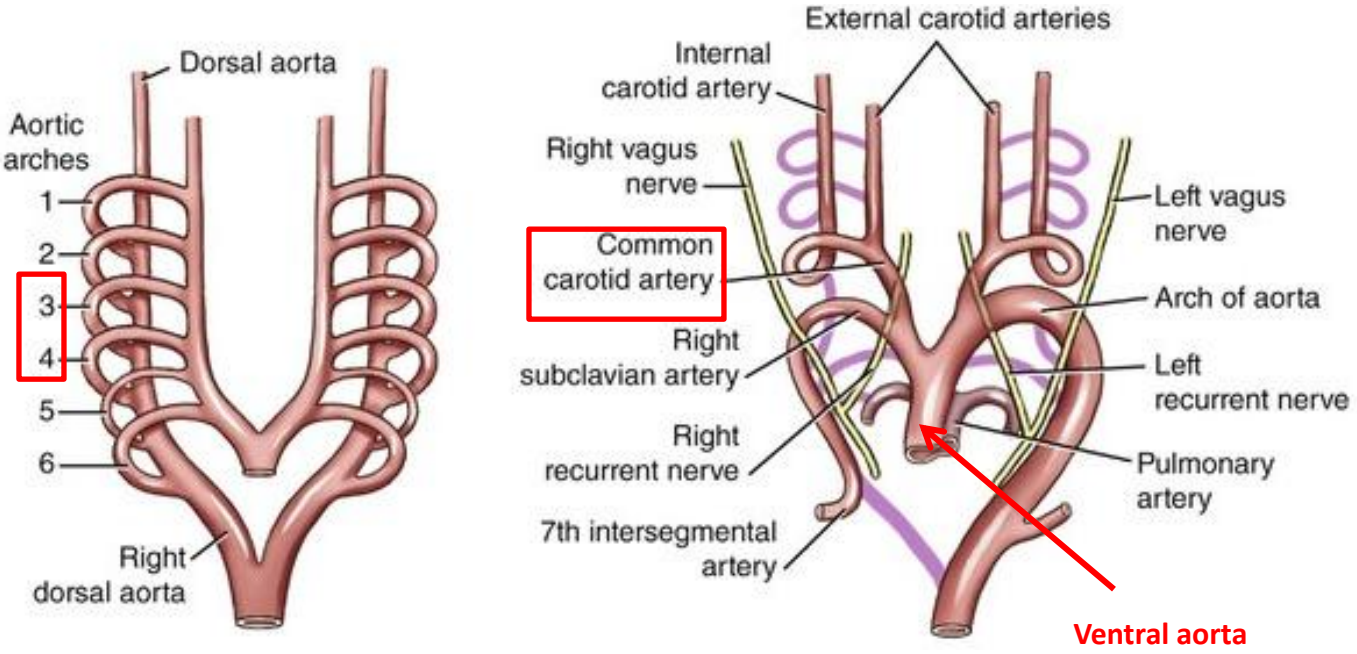
ARTERIAL SYSTEM

AORTIC ARCHES

THE THIRD PAIRS OF AORTIC ARCHES:

- **retained**
- **serve as connections between the ventral aorta and internal carotid arteries**
- **the dorsal aorta between aortic arch III and IV are lost**



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ARTERIAL SYSTEM

AORTIC ARCHES

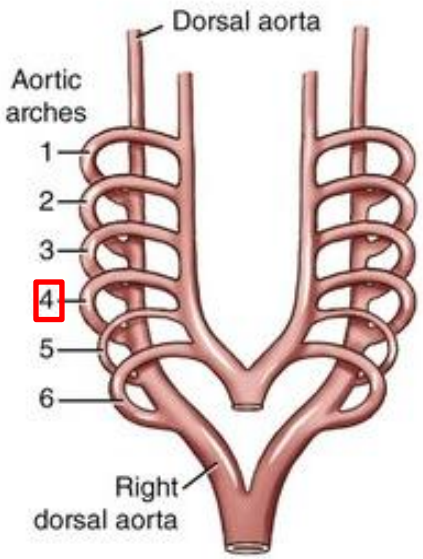
THE FOURTH PAIRS OF AORTIC ARCHES:

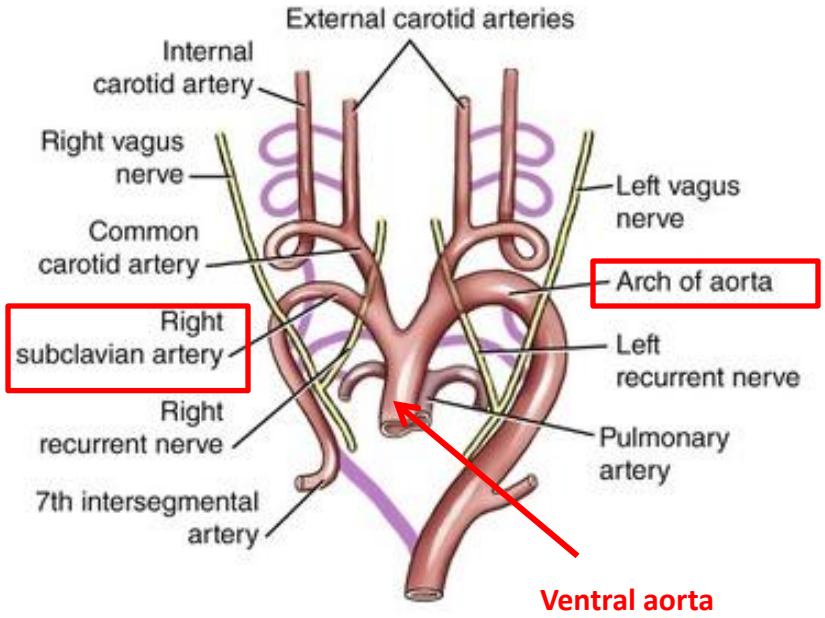
a. the right fourth aortic arch:

- **forms the proximal part of the subclavian artery**

b. the left fourth aortic arch:

- becomes the adult aortic arch





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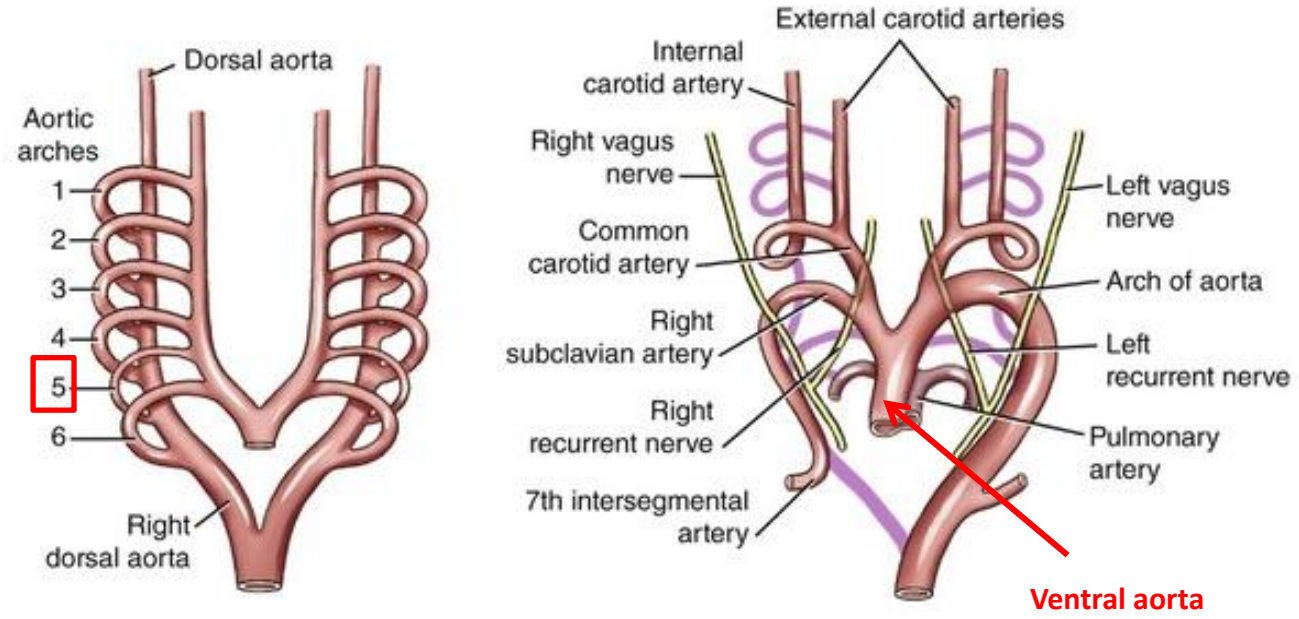
ARTERIAL SYSTEM

AORTIC ARCHES

THE FIFTH PAIRS OF AORTIC ARCHES:

- **never forms**
- **or quickly degenerates**



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ARTERIAL SYSTEM

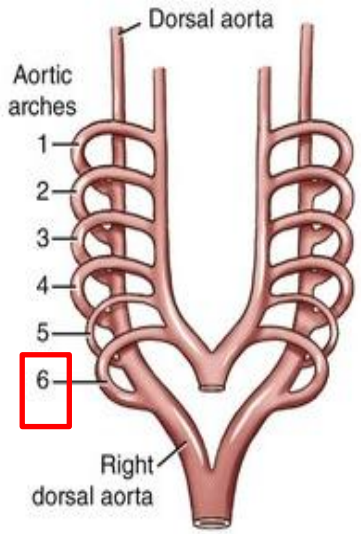
AORTIC ARCHES

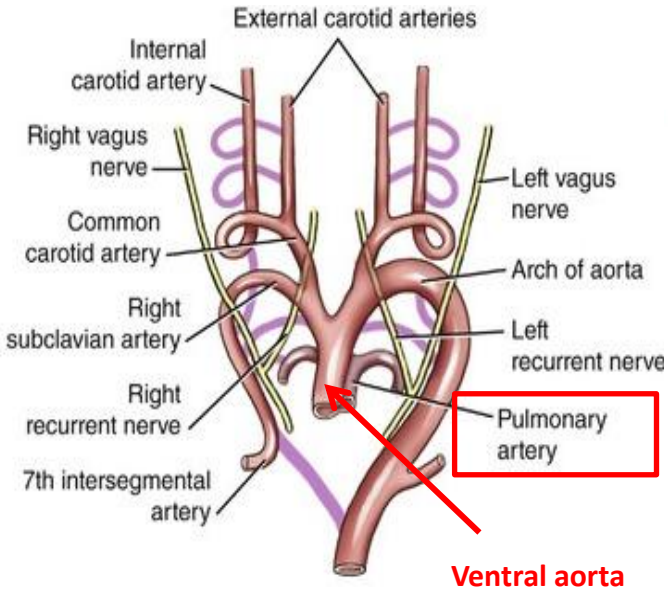
THE SIXTH PAIRS OF AORTIC ARCHES:

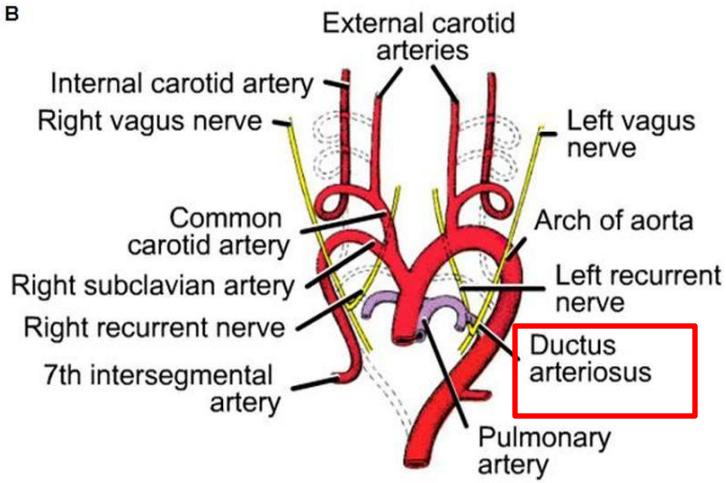
a. the proximal part of the right and the left sixth arches form the roots of the right and left pulmonary arteries

b. the distal part of the right sixth arch is lost

c. the distal part of the left sixth arch becomes the ductus arteriosus







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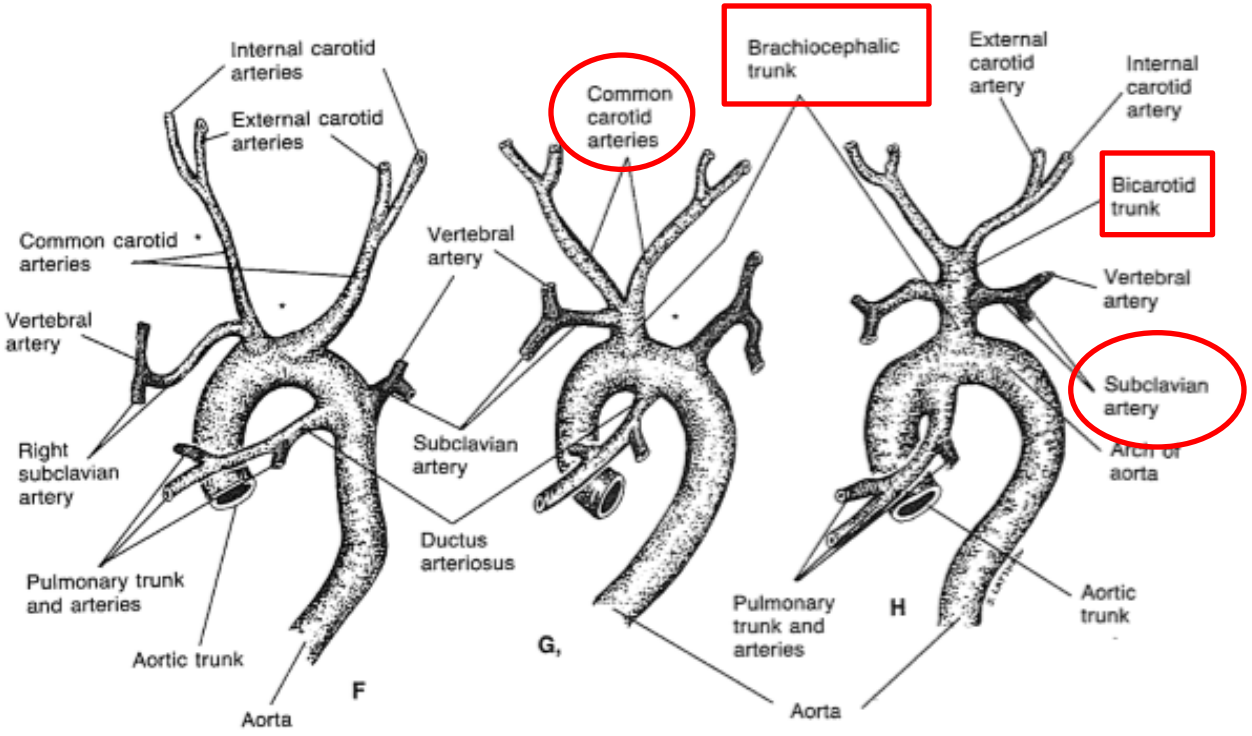
ARTERIAL SYSTEM

AORTIC ARCHES

- **the brachiocephalic trunk and bicarotid trunk formed by a series of fusions of the derivates of the aortic arch system**

- **the fusion involves movement of the junctions of the subclavian and common carotid arteries with the aorta**



ARTERIAL SYSTEM

BRANCHES OF THE DORSAL AORTA

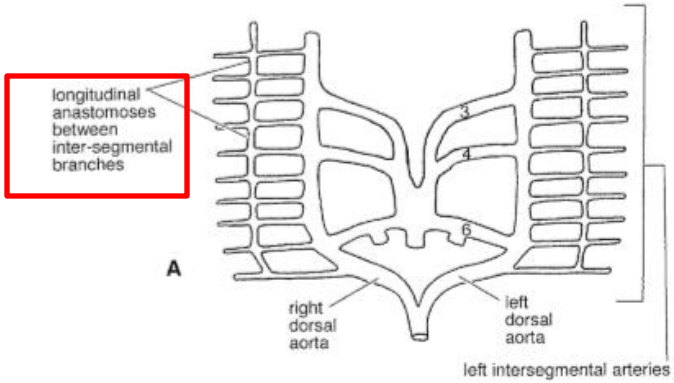
- **the aorta branches at every segment (this segmentation is indicated by the somites)**

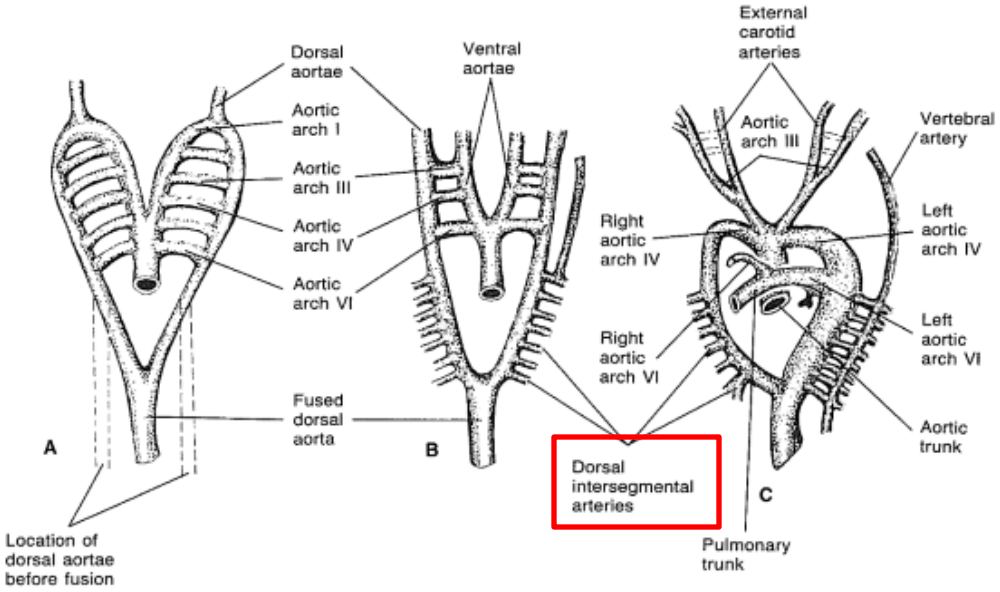
the segmental branching pattern consists of:

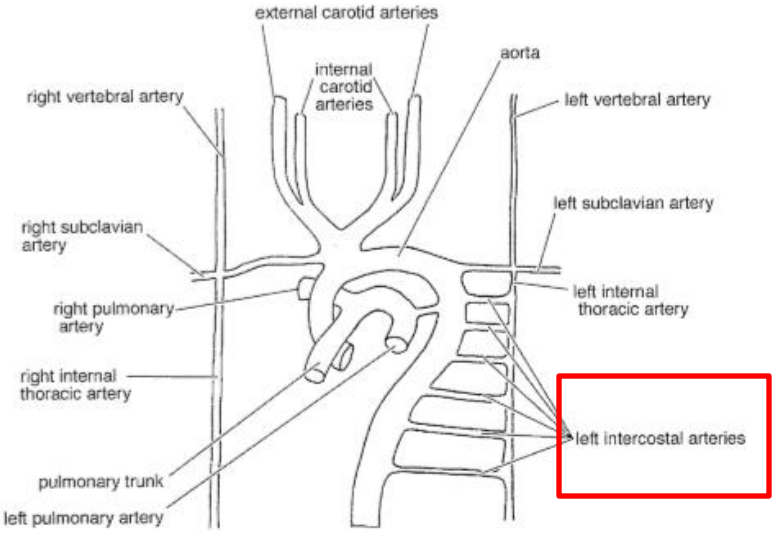
a. dorsal intersegmental branches

b. lateral intersegmental branches

c. ventral intersegmental branches





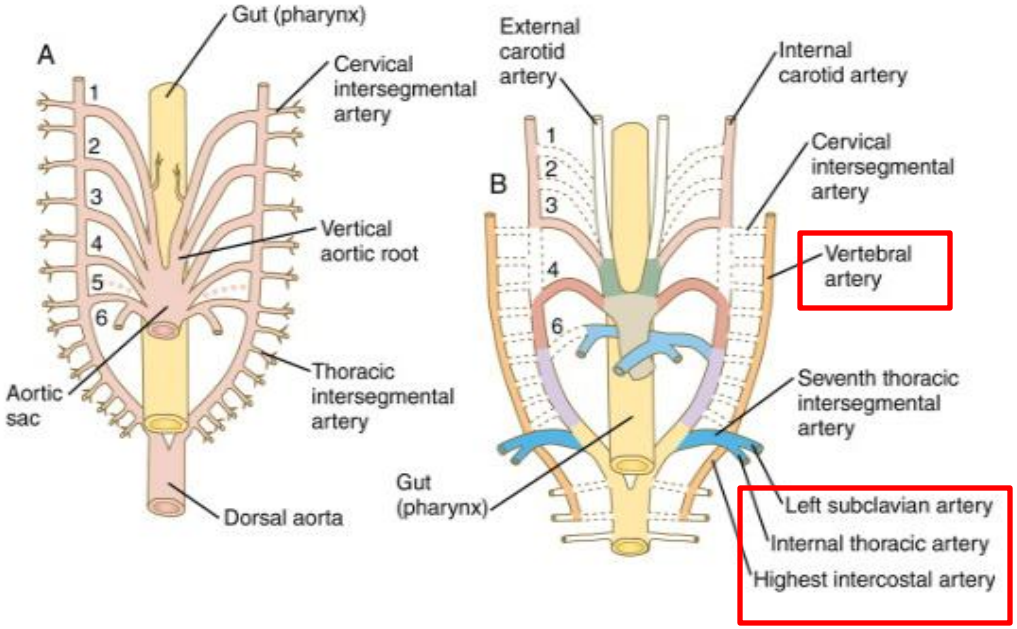


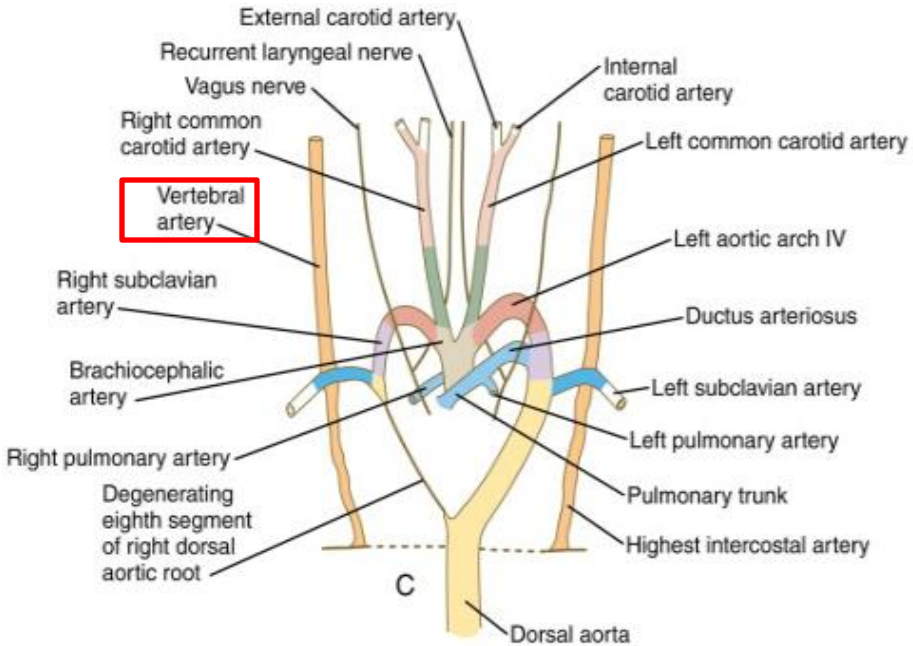
BRANCHES OF THE DORSAL AORTA

DORSAL INTERSEGMENTAL BRANCHES:

THE ARTERIAL DERIVATES ARE THE:

1. **subclavian arteries**
2. **axillary arteries**
3. **intercostal arteries**
4. **lumbal arteries**
5. **vertebral arteries**
6. **basillar arteries**





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BRANCHES OF THE DORSAL AORTA

DORSAL INTERSEGMENTAL BRANCHES:

the major derivates of them form the blood supply of the:

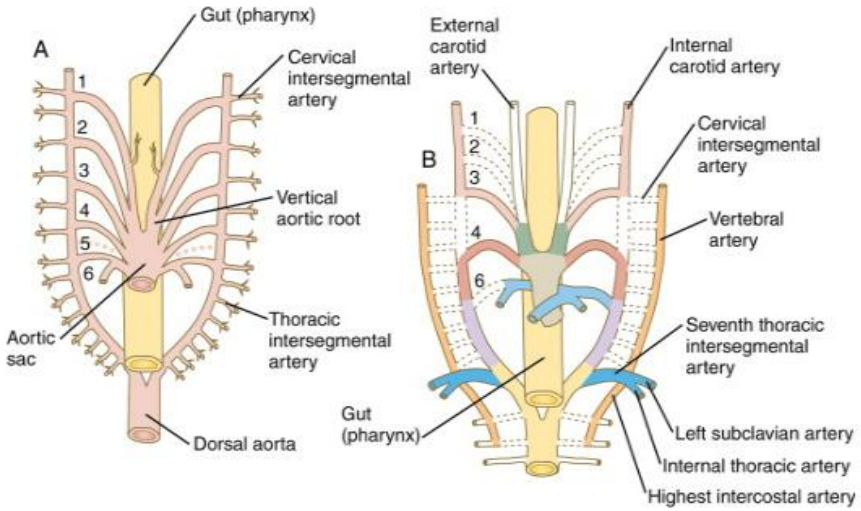
a. thoracic limbs

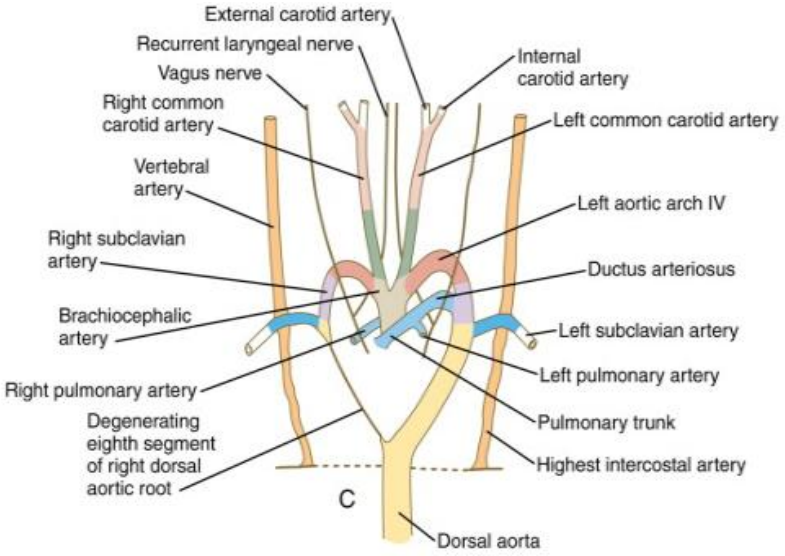
b. body

c. neck

d. trunk

e. non – carotid blood supply to the brain





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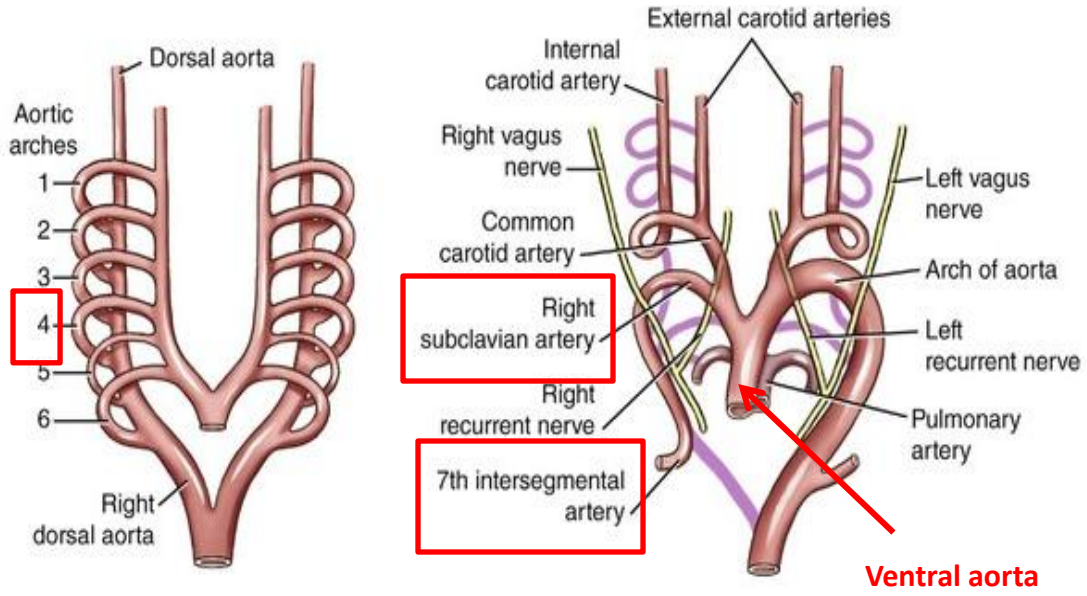
ARTERIAL SYSTEM

BRANCHES OF THE DORSAL AORTA

RIGHT SUBCLAVIAN ARTERY:

- **its proximal part formed by the right 4th aortic arch**
- **the other segments formed by the part of the right dorsal aorta caudal to the aortic arch IV**
- **remaining part formed by the 7th dorsal intersegmental branches**
- **the 7th dorsal intersegmental artery extends the subclavian artery into the axillary artery**



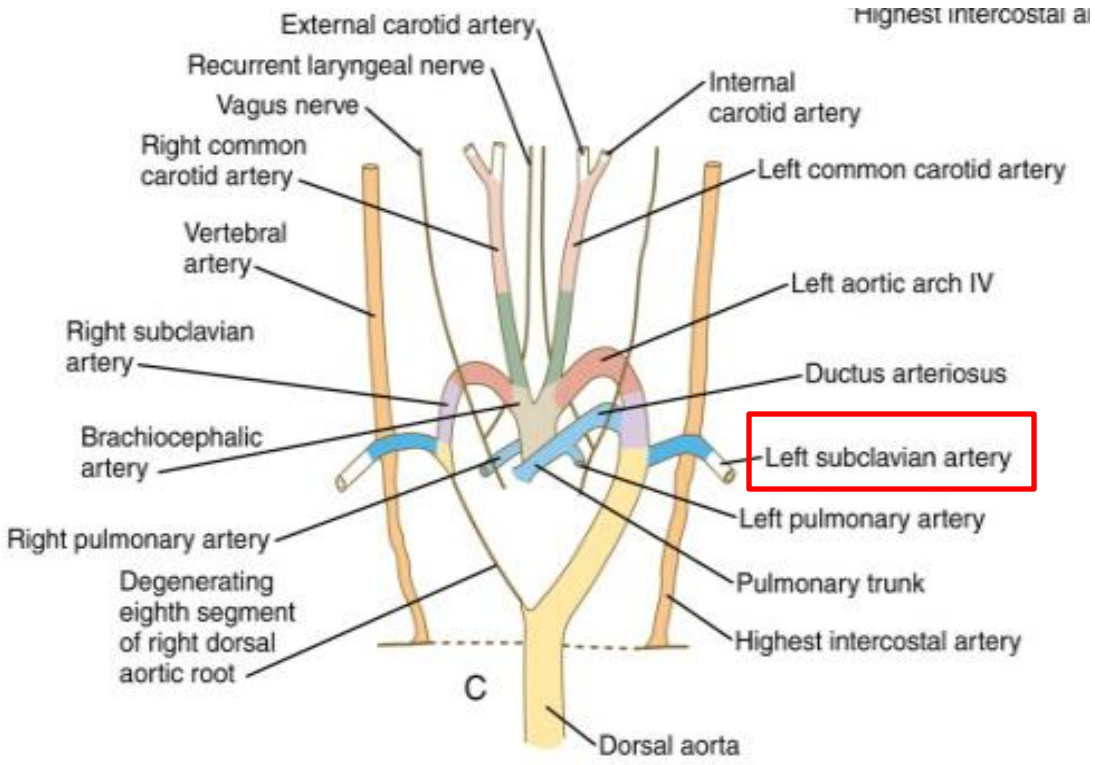
https://radiologykey.com/embryology-and-physiology-of-the-fetal-heart/

ARTERIAL SYSTEM

BRANCHES OF THE DORSAL AORTA

LEFT SUBCLAVIAN - AXILLARY ARTERY:

- **derived from the left seventh dorsal intersegmental artery**



ARTERIAL SYSTEM

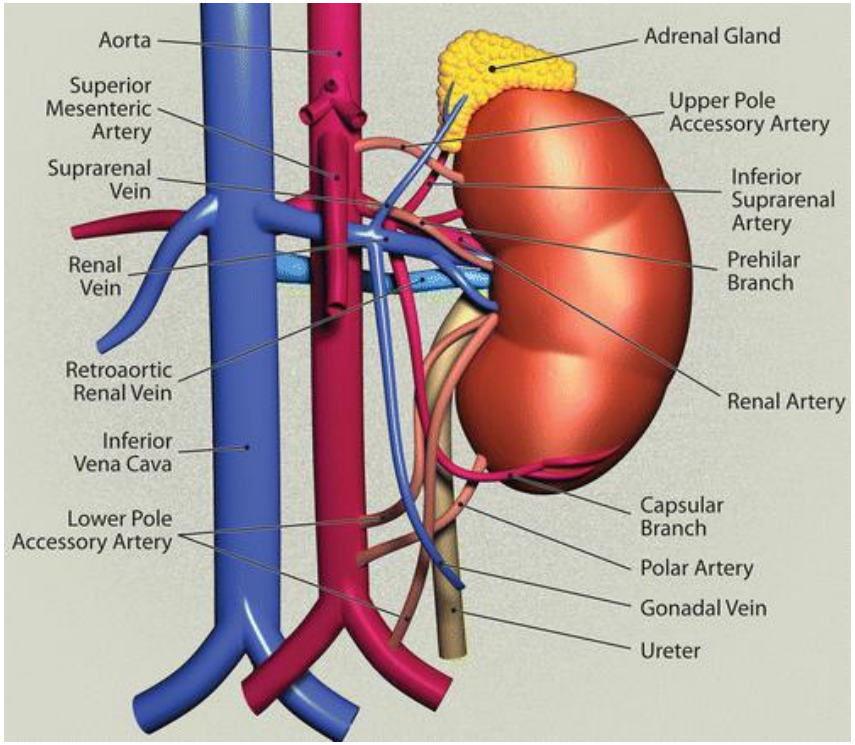
BRANCHES OF THE DORSAL AORTA

LATERAL INTERSEGMENTAL BRANCHES:

- **supply the mesonephros**
- **most of these are lost as the mesonephros wanes**

derivates of the surviving branches are:

1. **renal arteries**
2. **adrenal arteries**
3. **gonadal arteries**



https://pubs.rsna.org/doi/full/10.1148/rg.2017160060

ARTERIAL SYSTEM

BRANCHES OF THE DORSAL AORTA

VENTRAL INTERSEGMENTAL BRANCHES:

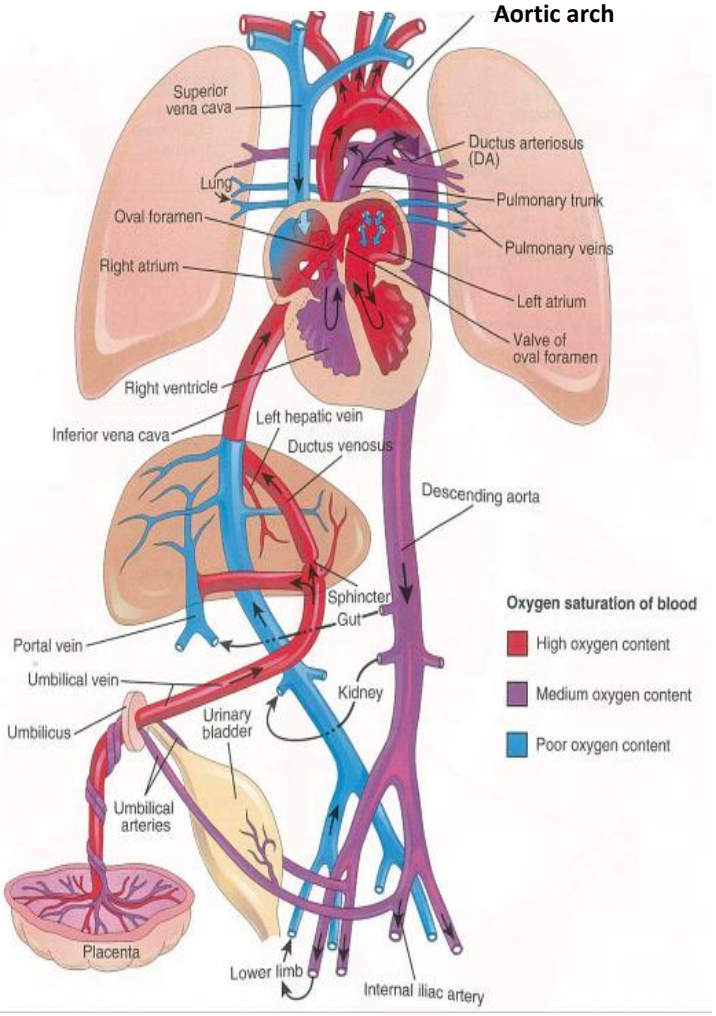
- **originally paired**
- **become fused ventrally to form single vessels**

Its derivates:

a. vitelline arteries

b. umbilical branches

c. iliac arteries



ARTERIAL SYSTEM

BRANCHES OF THE DORSAL AORTA

VENTRAL INTERSEGMENTAL BRANCHES:

VITELLINE ARTERIES:

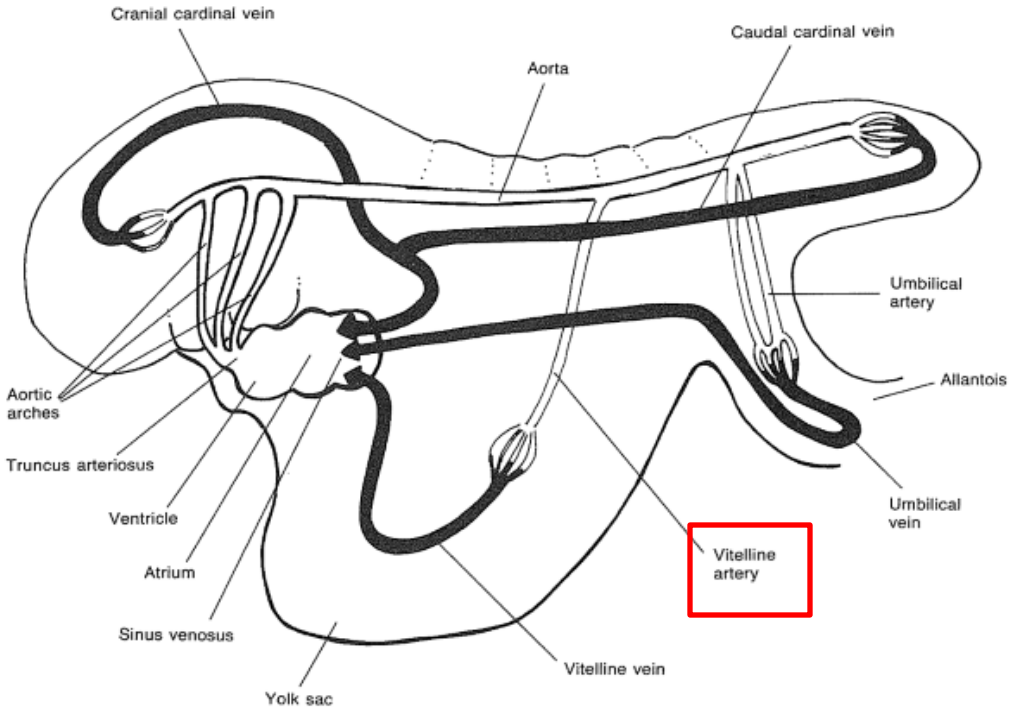
- **the vessels derived from the vitelline circulation**
- **supply the digestive tube and its derivates caudal to the diaphragm**

THE VESSELS ARE:

a. coeliac artery

b. cranial mesenteric artery

c. caudal mesenteric artery



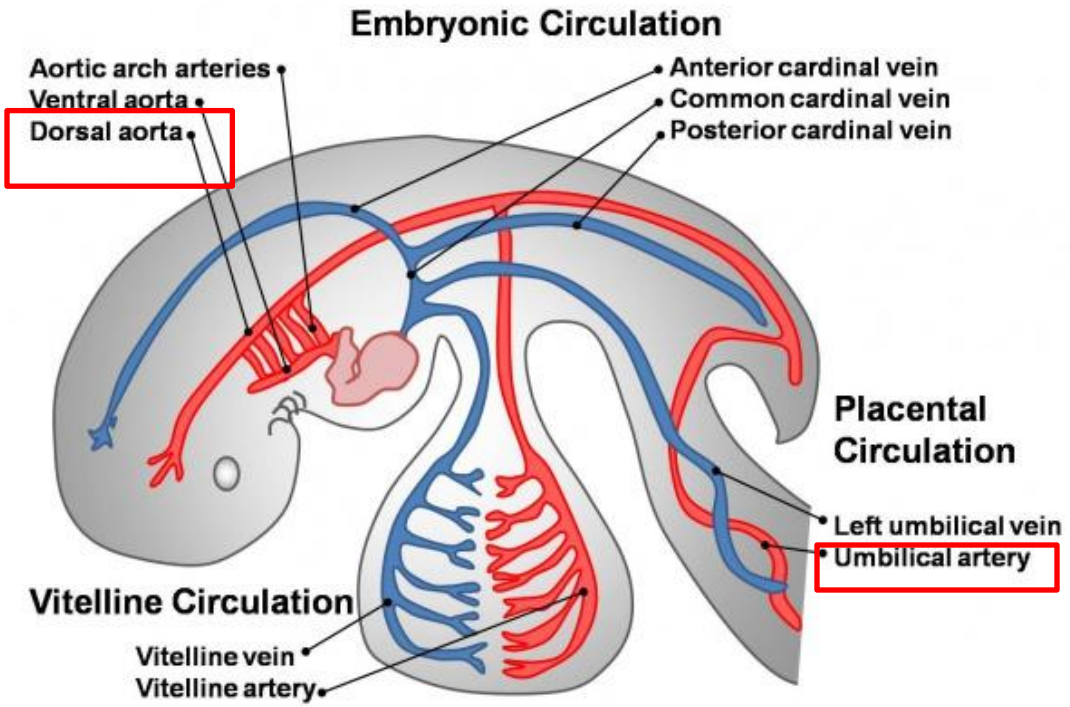
ARTERIAL SYSTEM

BRANCHES OF THE DORSAL AORTA

VENTRAL INTERSEGMENTAL BRANCHES:

UMBILICAL ARTERIES:

- **ventral branches of the aorta**
- **the umbilical arteries establish new connections with dorsal aortic branches - loose their original ventral connections**
- **supply the allantois**



ARTERIAL SYSTEM

BRANCHES OF THE DORSAL AORTA

VENTRAL INTERSEGMENTAL BRANCHES:

ILIAC ARTERIES:

- **formed by a combination of the dorsal intersegmental branches**

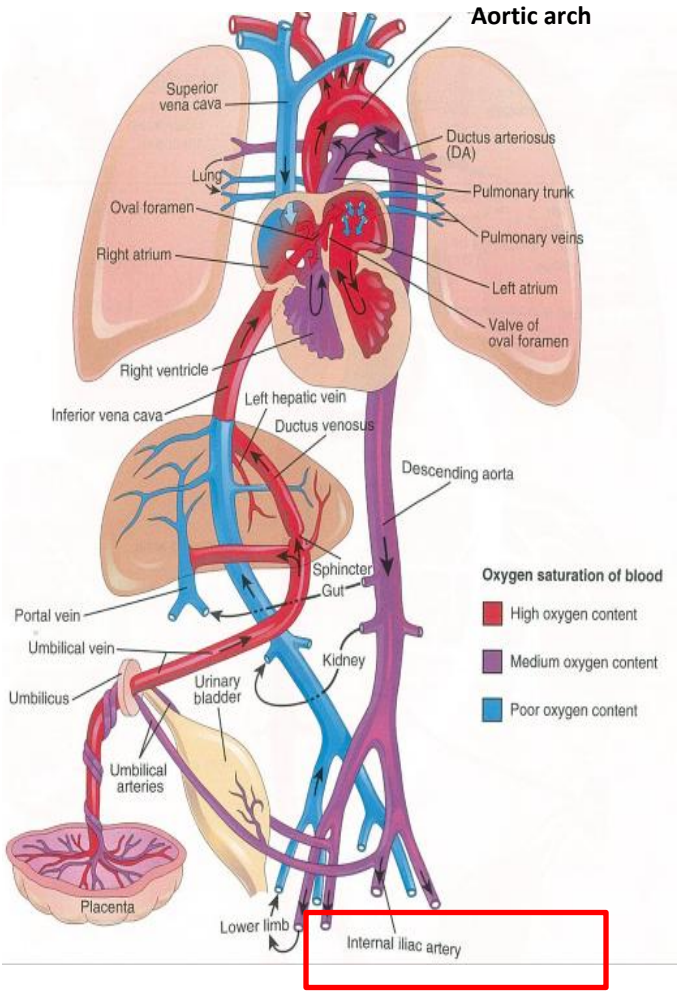
EXTERNAL ILIAC ARTERY:

- **arises from the trunk**

- **formed by the new umbilical connection**

INTERNAL ILIAC ARTERY:

- formed by the proximal part of the umbilical artery and the new branch



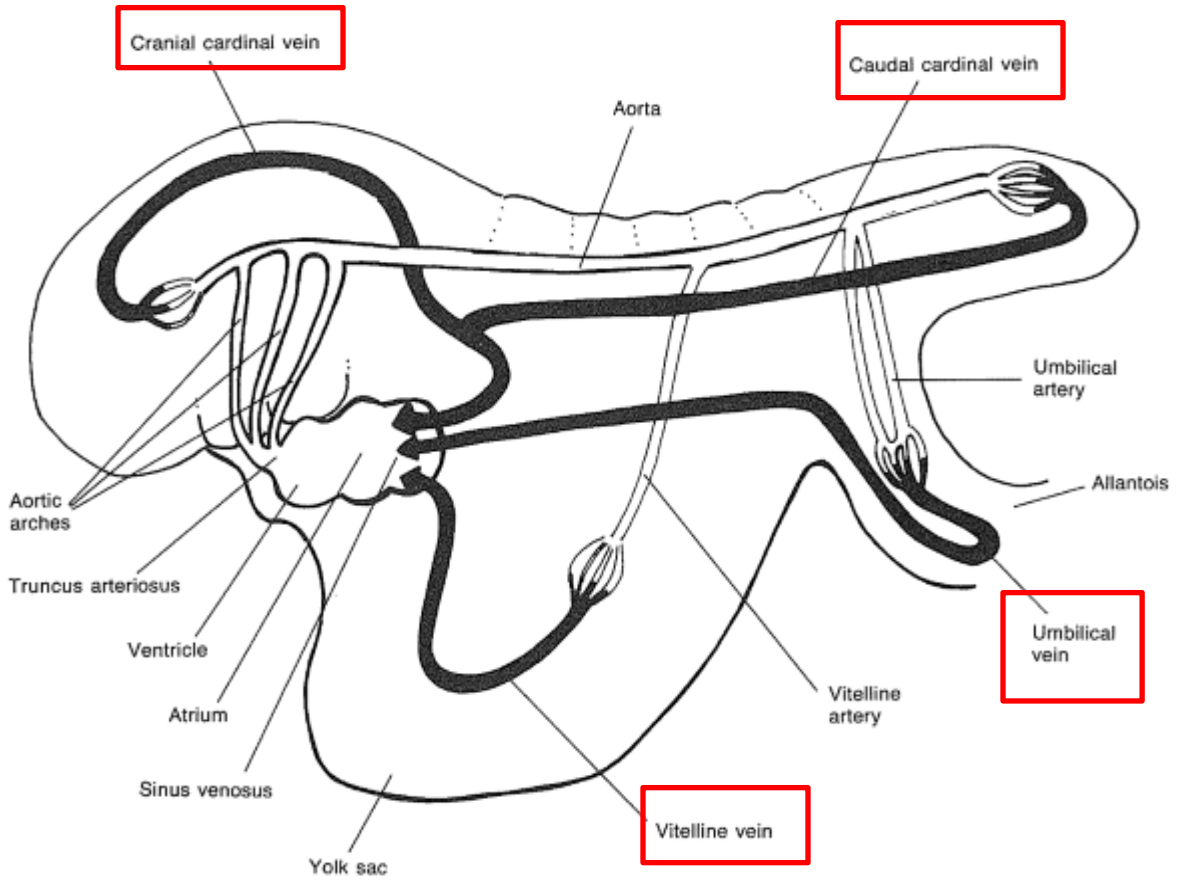
VENOUS SYSTEM

derived from the:

a. remnants of the cardinal system

b. vitelline veins

c. umbilical veins



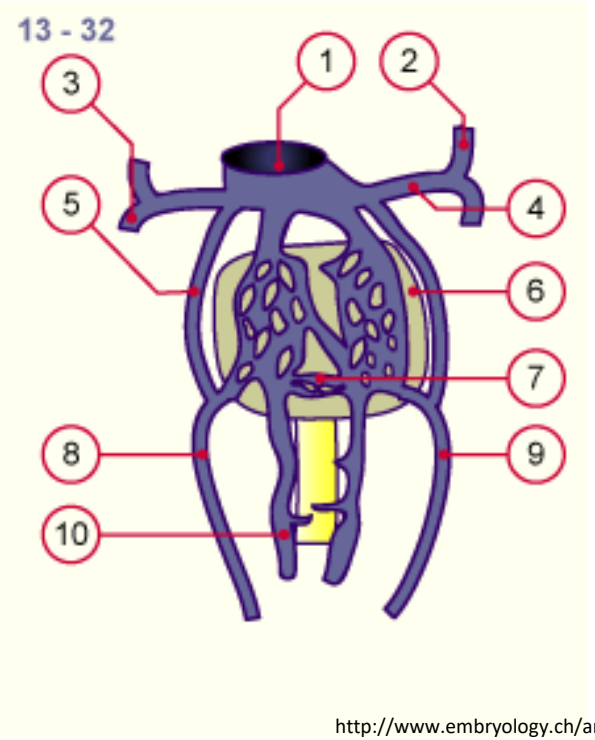
VENOUS SYSTEM

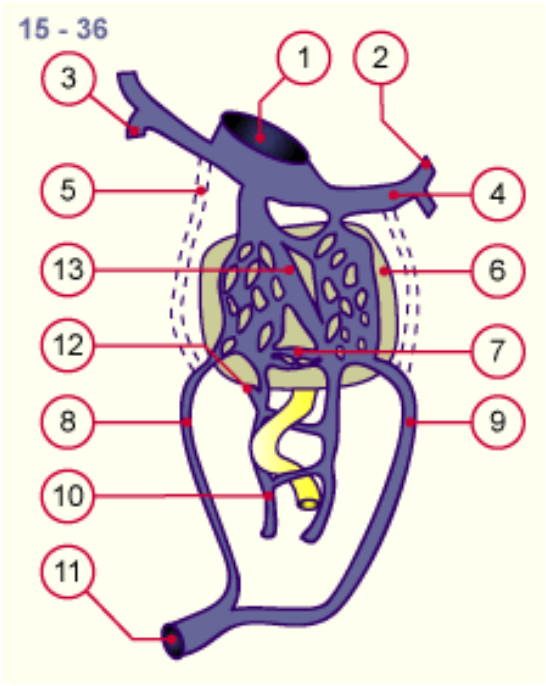
FATE OF THE VITELLINE AND UMBILICAL VEINS

- the right and the left vitelline (omphalomesenteric) veins develop three connections with each other

a. the cranial and caudal anastomoses develop ventral to the duodenum

b. the middle anastomoses develops dorsal to the duodenum





1 Sinus venosus
2 Superior cardinal vein
3 Inferior cardinal vein
4 Left common cardinal vein
5 Right umbilical vein
6 Liver
7 Anastomosis between the left and right omphalomesenteric vein
8 Right umbilical vein (prehepatic)
9 Left umbilical vein
10 Right omphalomesenteric vein
11 Umbilical vein (unpaired)
12 Inferior vena cava
13 Ductus venosus
14 Portal vein
15 Splenic vein

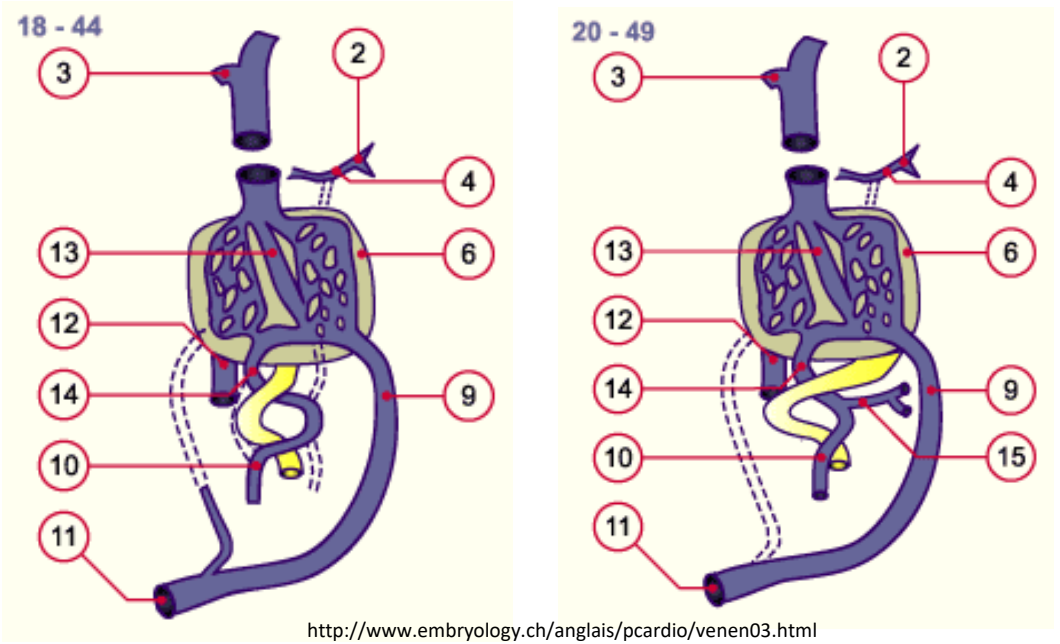
http://www.embryology.ch/anglais/pcardio/venen03.html

VENOUS SYSTEM

FATE OF THE VITELLINE AND UMBILICAL VEINS

at the level of the septum transversum the developing liver:

1. **encroaches upon the vitelline veins**
2. **breaks them up into channels, that become the hepatic sinusoids**
3. **at this level the umbilical veins – run laterally to the vitelline veins – suffer from the same encroachment**
4. **hepatic sinusoids arise mostly from the vitelline veins, lesser from the umbilical veins**



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FATE OF THE VITELLINE AND UMBILICAL VEINS

cranial to the liver:

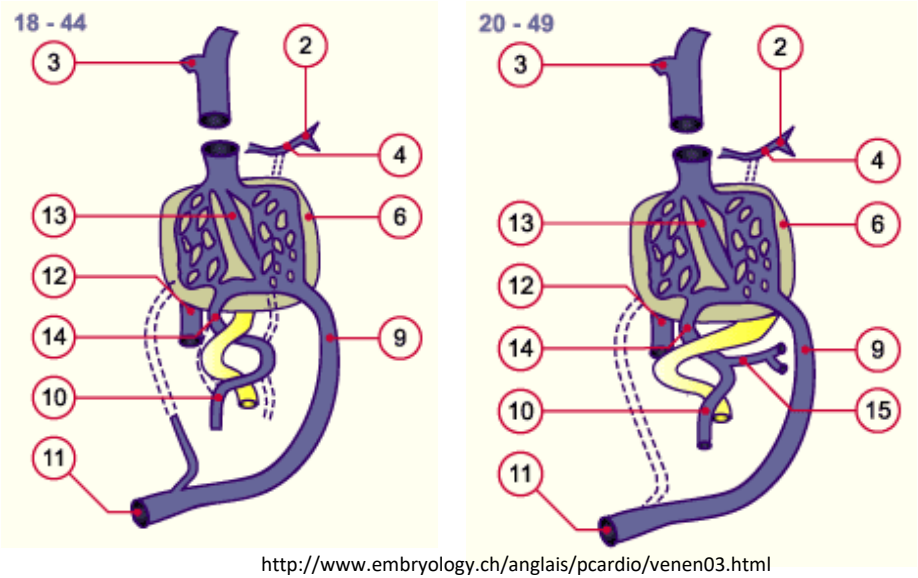
a. both vitelline veins

b. both umbilical veins enter the sinus venosus

- with the increasing growth of the right lobe of the liver the route of placental blood through hepatic sinusoids of that lobe becomes more tortuous

- the right umbilical vein disappears

c. the left umbilical vein will be connected by the ductus venosus Arantii to the sinus venous



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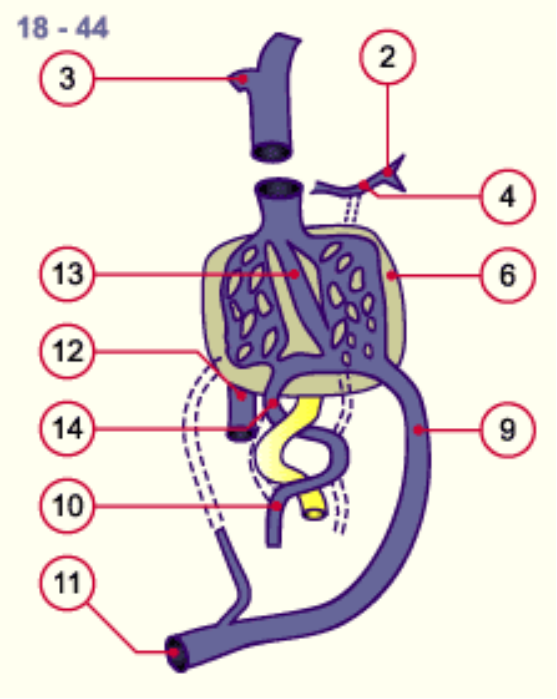
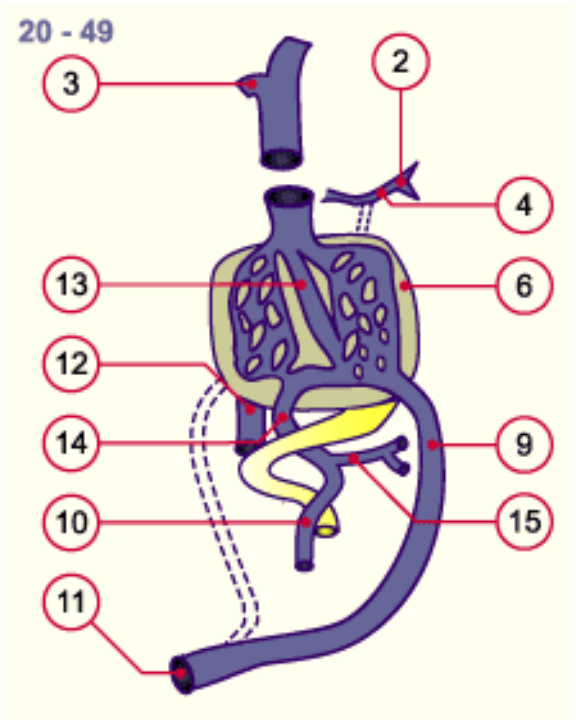
VENOUS SYSTEM

FATE OF THE VITELLINE AND UMBILICAL VEINS

DUCTUS VENOSUS ARANTII:

- **formed by the hepatic sinusoids**
- **a channel between left umbilical vein and segment of right vitelline vein, that enters the sinus venosus**





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VENOUS SYSTEM

FATE OF THE VITELLINE AND UMBILICAL VEINS

when the stomach rotates to the left:

1. **the stomach and the duodenum tend to impede the flow of blood in the left vitelline vein cranial to the middle anastomosis**

2. **the cranial mesenteric and the splenic veins form**

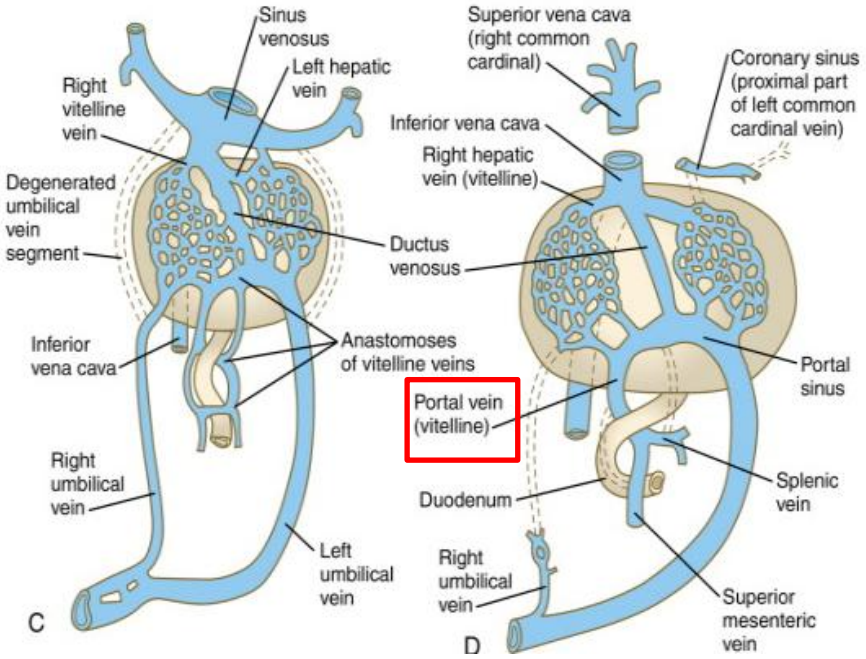
3. **the yolk sac atrophized**

4. **the blood flows through:**

a. **the left vitelline vein (between the cranial mesenteric and middle anastomosis)**

b. **the middle anastomsis**

c. **the right vitelline vein (between the middle anastomosis and the liver)**



VENOUS SYSTEM

FATE OF THE VITELLINE AND UMBILICAL VEINS

VENA PORTAE formed by the:

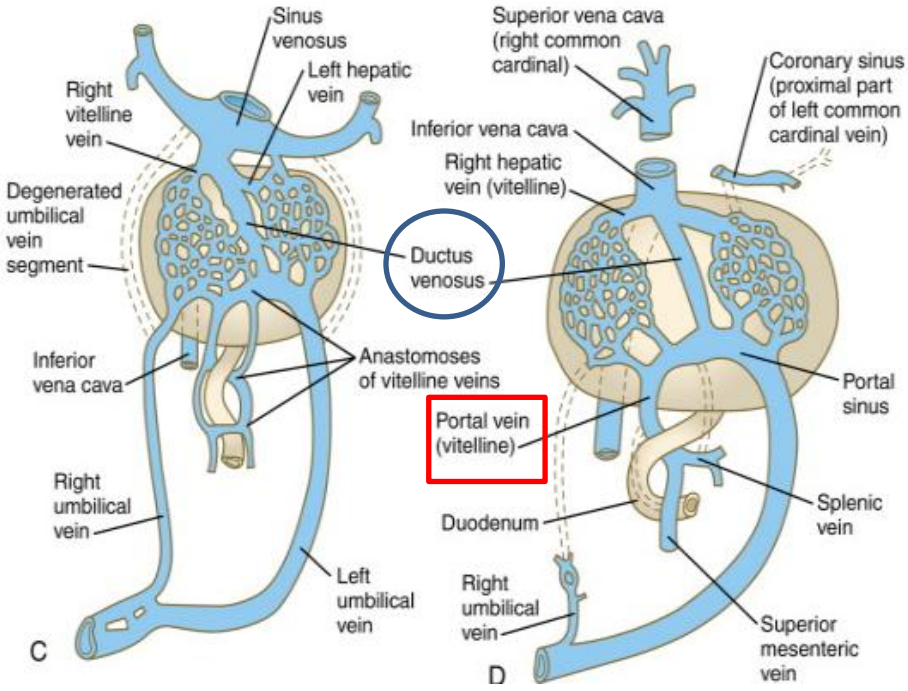
a. **the left vitelline vein**

b. **the middle anastomosis**

c. **the right vitelline vein**

- **in the embryo the portal vein establishes a connection with the ductus venosus via branches of the cranial**

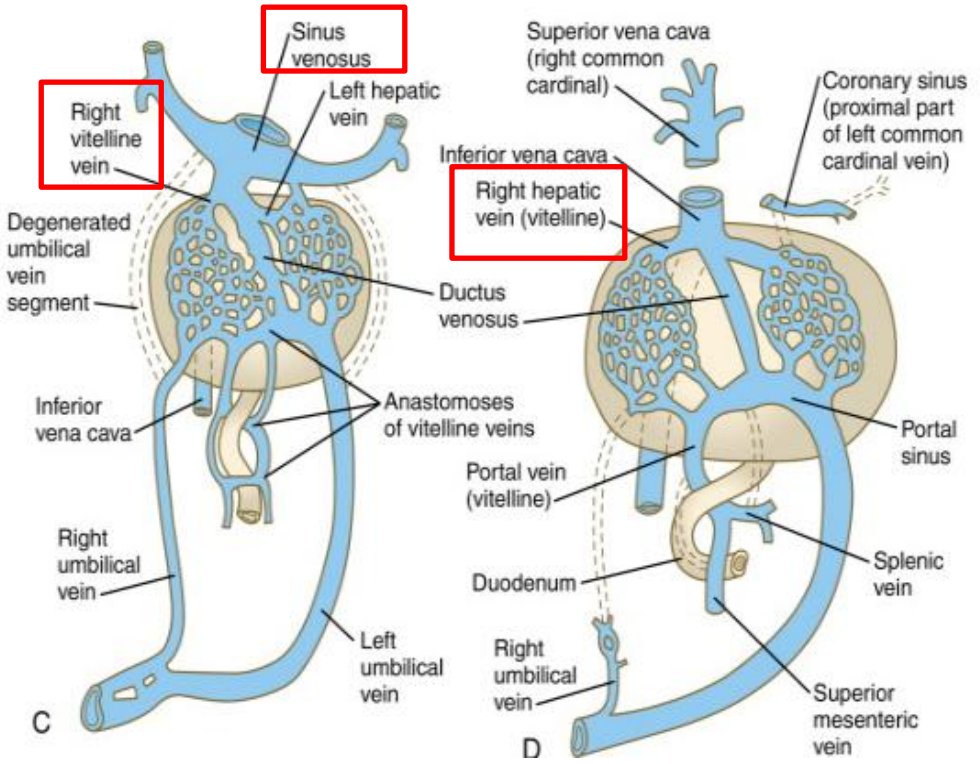
anastomosis of the vitelline veins – this connection allows portal blood and placental blood to bypass the hepatic sinusoids

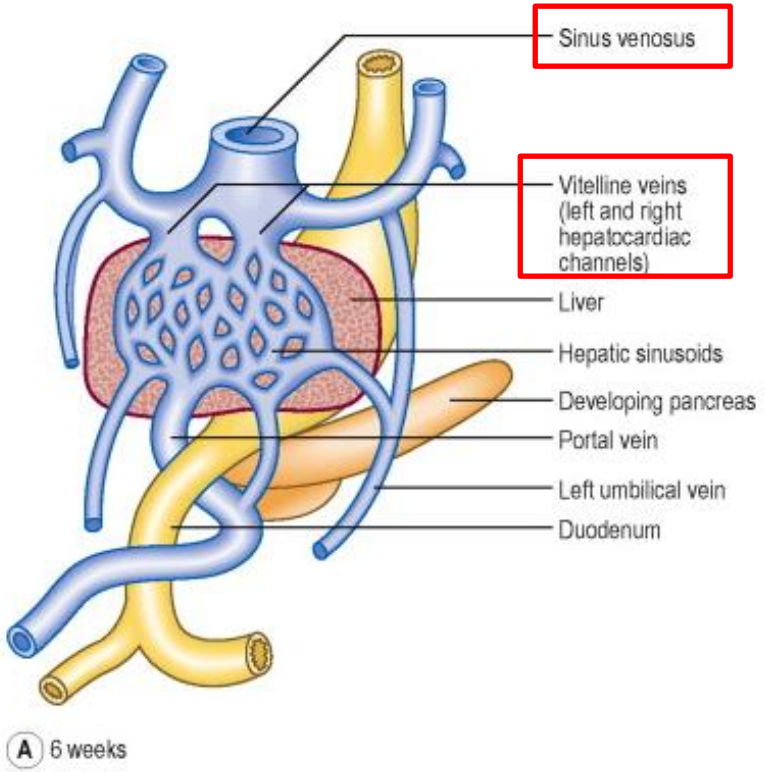


VENOUS SYSTEM

FATE OF THE VITELLINE AND UMBILICAL VEINS

- **the right vitelline vein favored cranially**
- **the left vitelline vein entering the left sinus horn which disappears**
- **the right vitelline vein is the only vein from the vitelline – umbilical system that enters the sinus venosus**
- **the cranialmost part of the right vitelline vein becomes the hepatic veins**

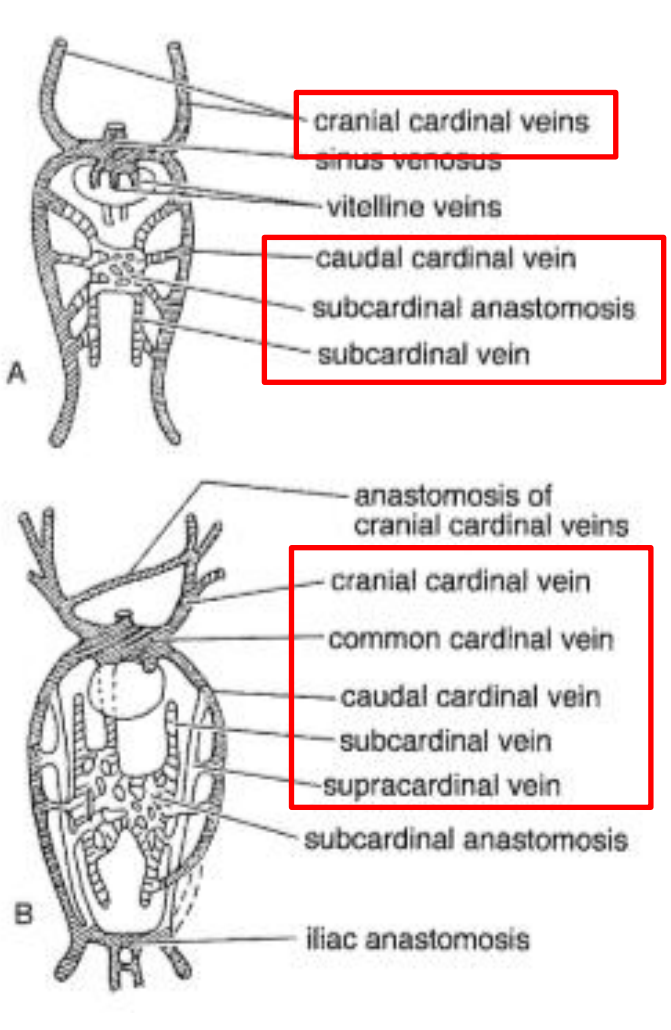




THE CARDINAL SYSTEM

is made up of several pairs of vessels:

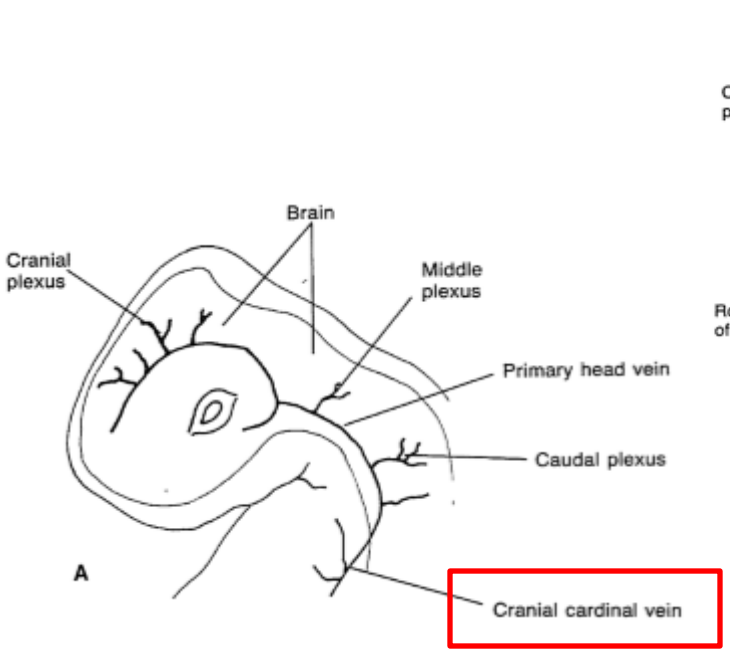
1. **cranial cardinal veins**
2. **common cardinal veins**
3. **caudal cardinal veins**
4. **supracardinal veins**
5. **subcardinal veins**

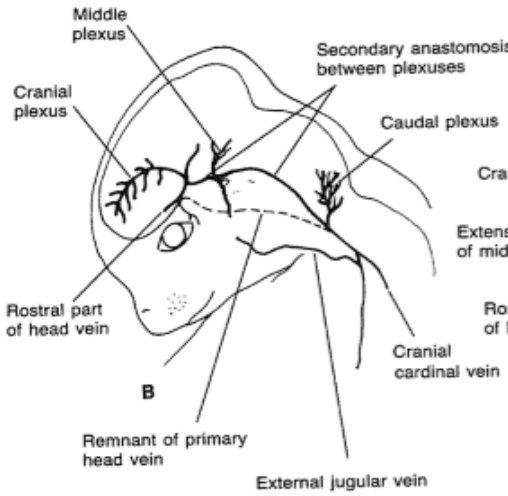


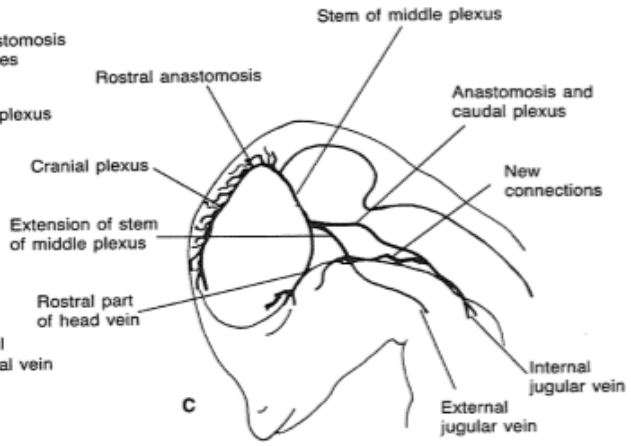
THE CRANIAL CARDINAL SYSTEM

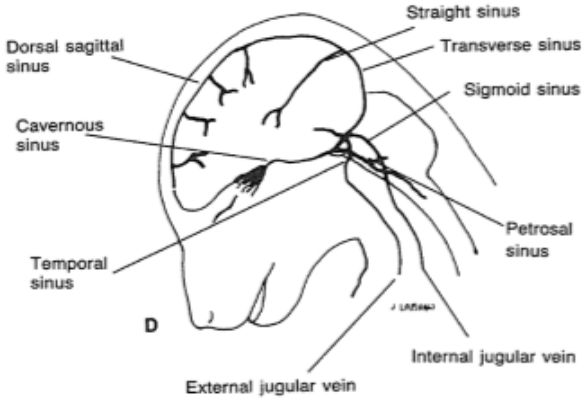
- the rostralmost part of the cranial cardinal veins are closely associated with the developing brain from the earliest stage of development

- these vessels become the dural sinuses in the adult brain









THE CRANIAL CARDINAL SYSTEM

CRANIAL VENA CAVA AND MAJOR TRIBUTARIES:

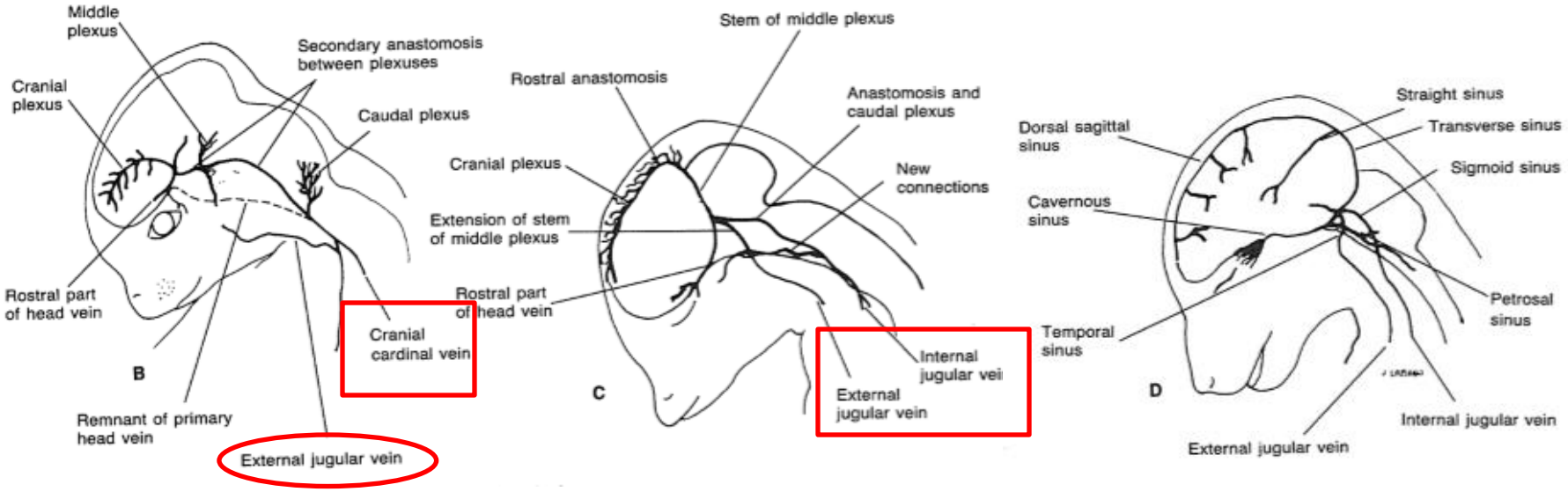
- **more caudally the cranial cardinal vein receives two newly formed veins the:**

a. subclavian vein

b. external jugular vein

- **the cardinal vein cranial becomes the internal jugular vein**

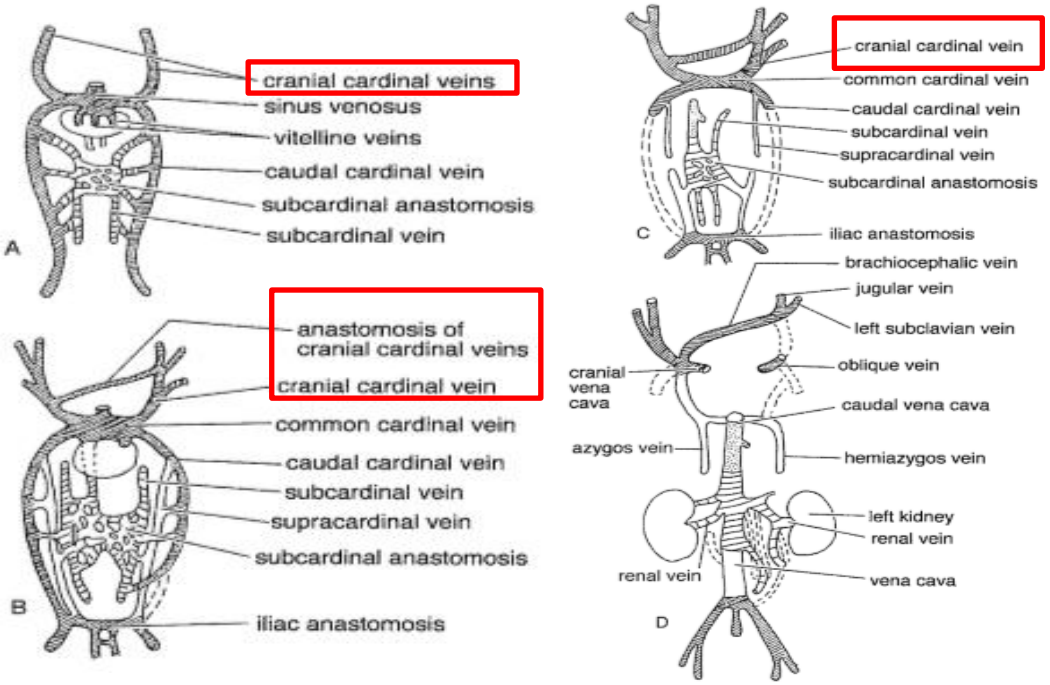
- **in domestic animals the external jugular vein becomes the main vessel for returning blood from the head**



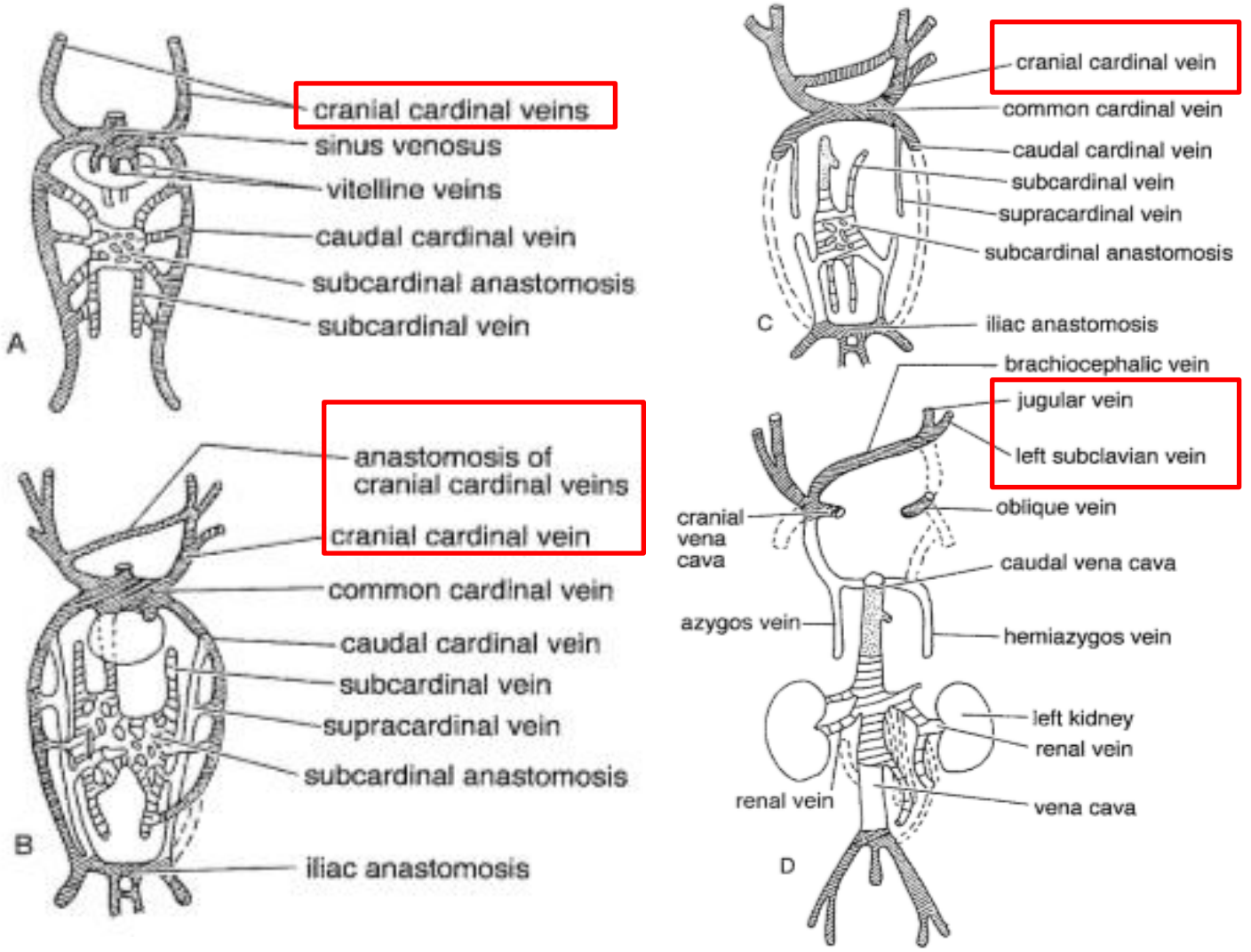
THE CRANIAL CARDINAL SYSTEM

CRANIAL VENA CAVA AND MAJOR TRIBUTARIES:

1. **caudal to the subclavian vein an anastomosis froms between the two cranial cardinal veins – that shunt leads blood from the left to the right sides (because the left sinus venosus decreases in size)**
2. **part of the left cranial cardinal vein disappears – this part lies between the anastomosis and the sinus venosus**
3. **on both side, the short segment of the cranial cardinal vein – that lies between the junction of the external jugular vein and the subclavian vein – enlarges – this becomes the caudalmost part of the external jugular vein**



THE CRANIAL CARDINAL SYSTEM



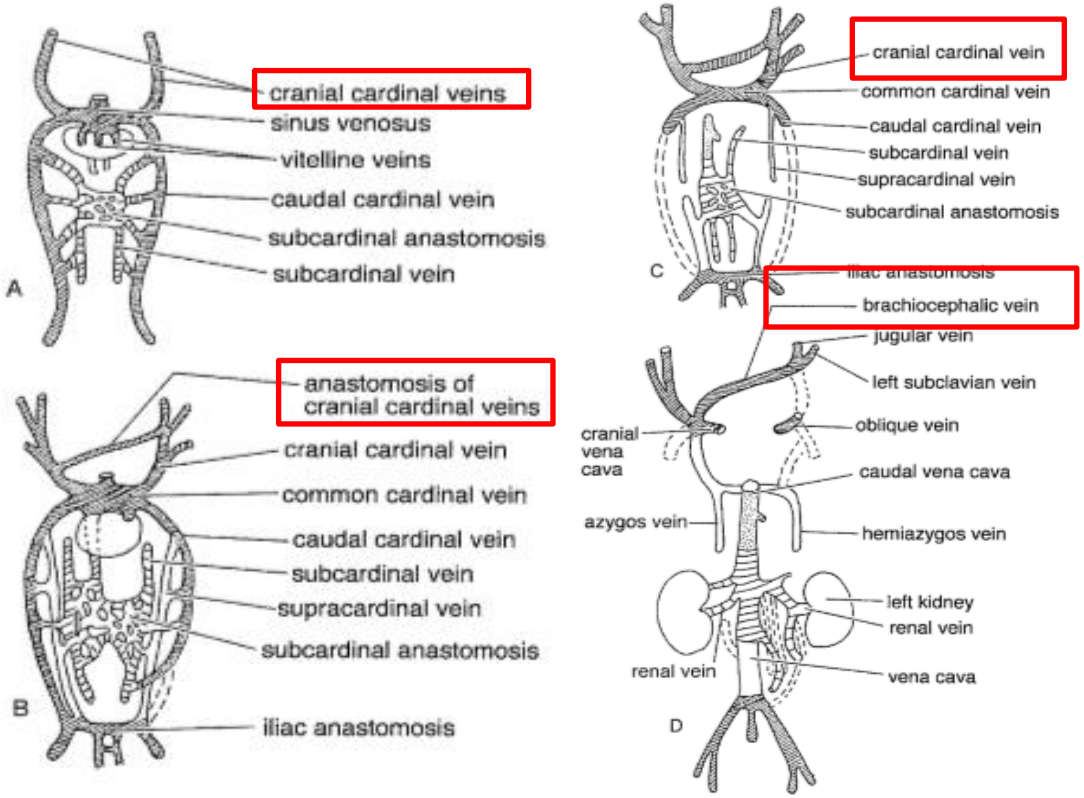
THE CRANIAL CARDINAL SYSTEM

CRANIAL VENA CAVA AND MAJOR TRIBUTARIES:

LEFT AND RIGHT BRACHIOCEPHALIC VEINS formed by the:

a. anastomosis between the two cardinal veins

b. part of the right cardinal vein, which lies between the subclavian vein and the anastomosis



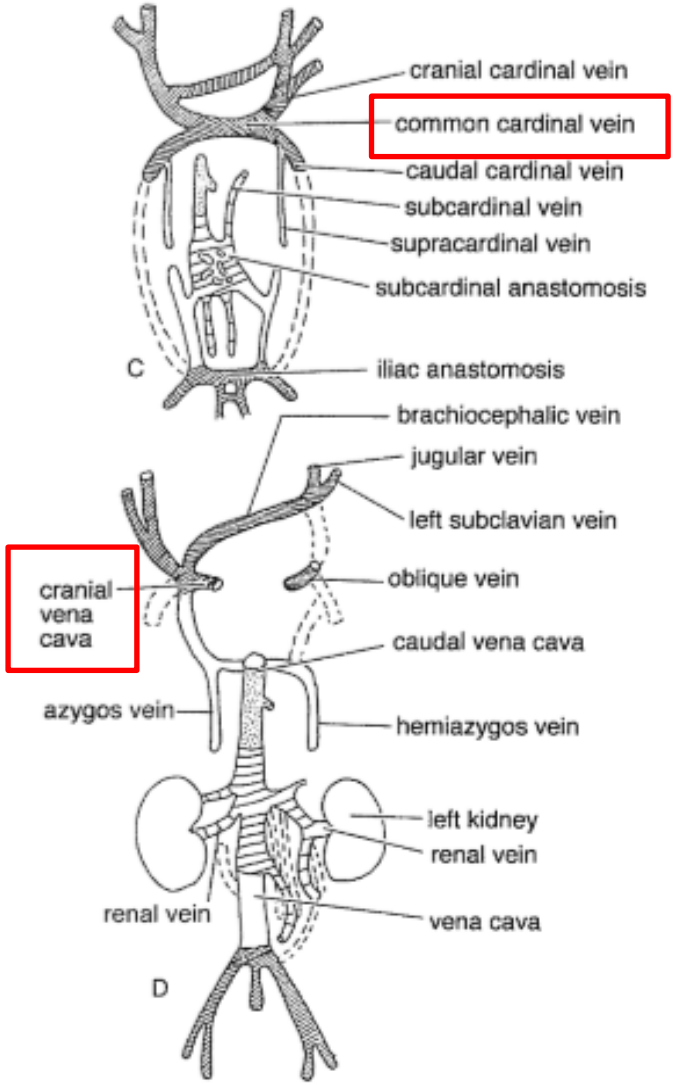
THE CRANIAL CARDINAL SYSTEM

CRANIAL VENA CAVA AND MAJOR TRIBUTARIES:

CRANIAL VENA CAVA formed by the:

a. remainder of the right cardinal vein

b. right common cardinal vein



THE CRANIAL CARDINAL SYSTEM

CRANIAL VENA CAVA AND MAJOR TRIBUTARIES:

in horse and ruminant:

- **the cranial cardinal veins cranially fuse with the external jugular veins – this fusion extends the cranial vena cava cranially – so the external jugular vein join to form the the cranial vena cava**
- **there are no brachiocephalic veins**
- **the internal jugular veins are lacking**

THE CAUDAL CARDINAL SYSTEM

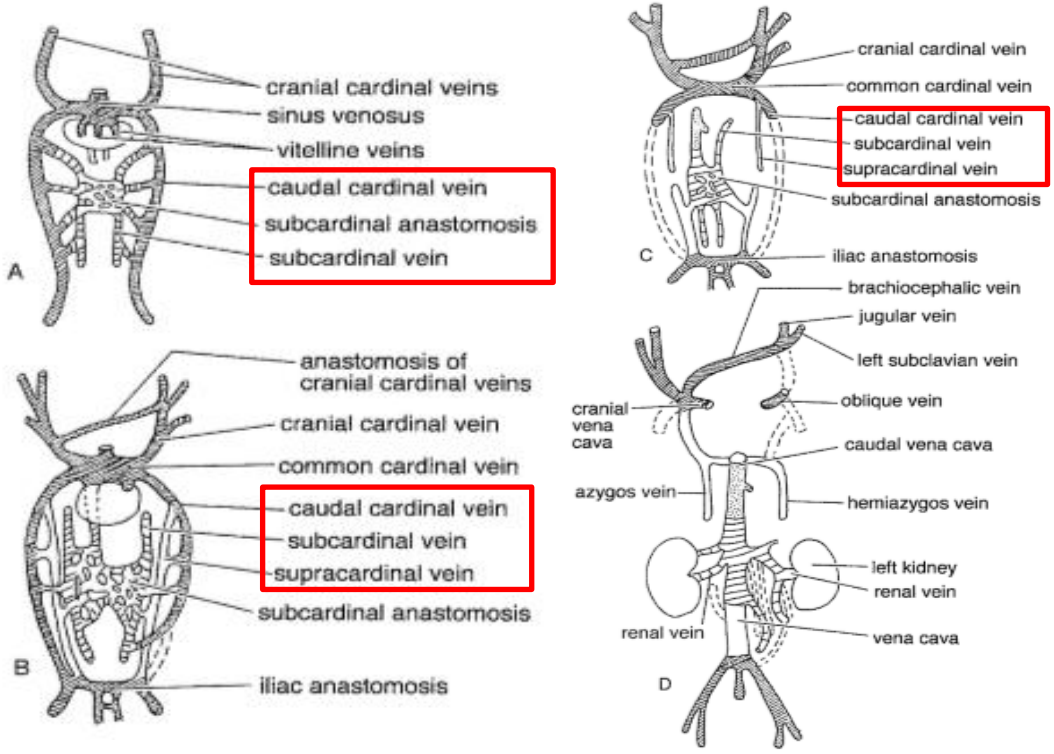
- compriesed of the three pairs of veins:

a. caudal cardinal veins

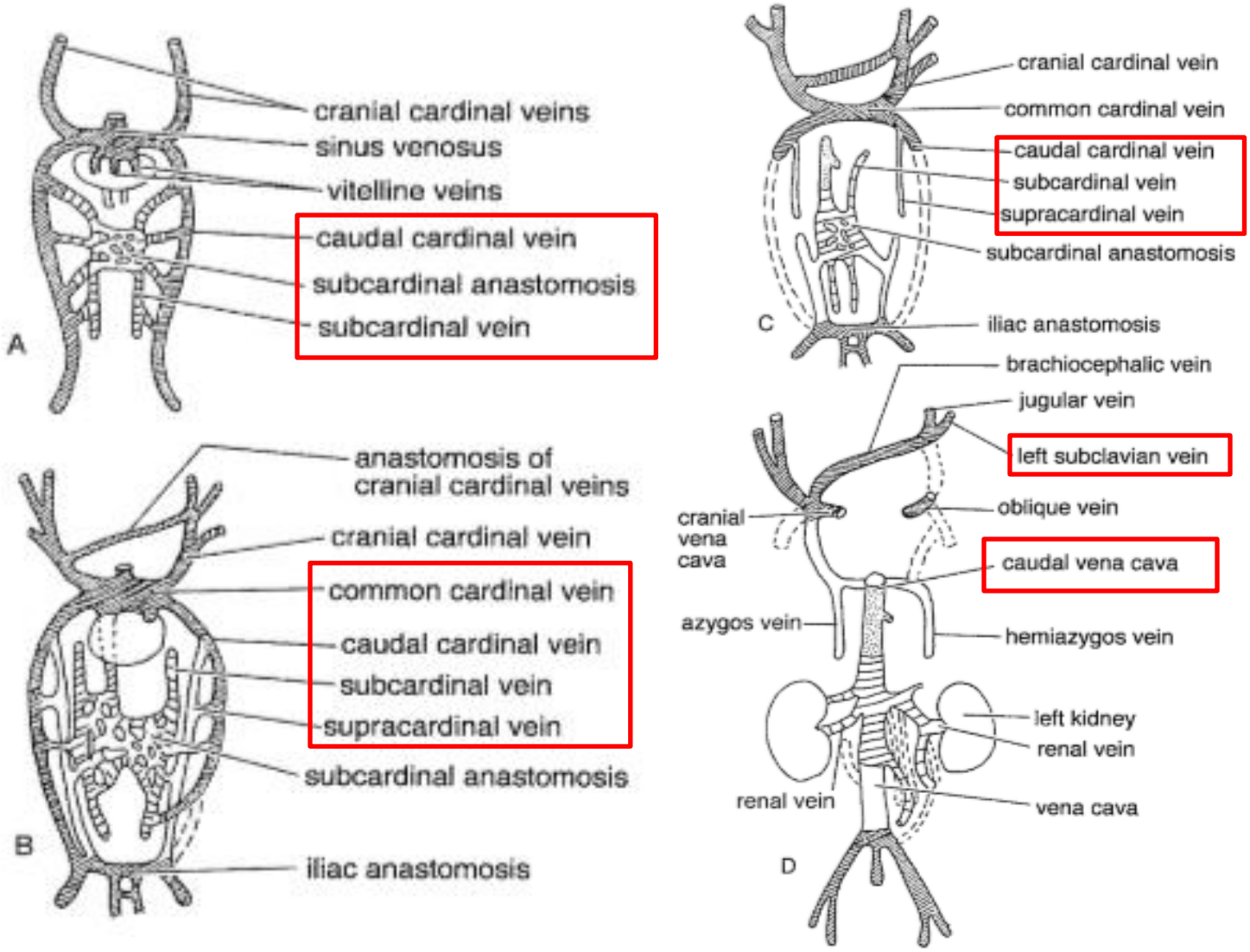
b. subcardinal veins

c. supracardinal veins

- they are surrounded by the developing mesonephric kidney and become incorporated into it



THE CAUDAL CARDINAL SYSTEM



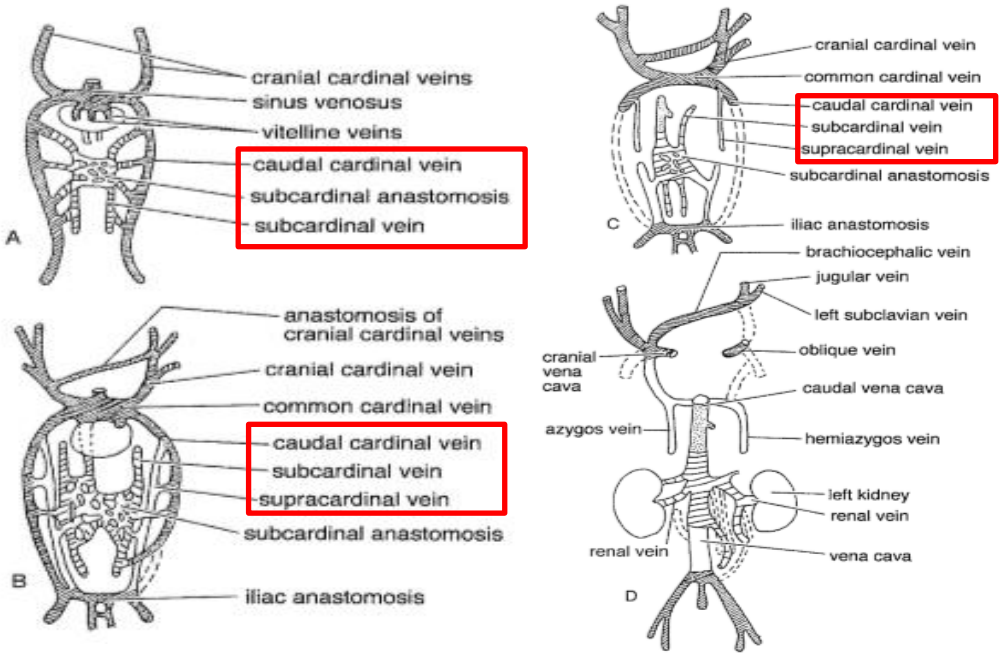
THE CAUDAL CARDINAL SYSTEM

AZYGOUS VEINS:

- **several major anastomoses form between the right and the left sides of the caudal cardinal system**

a. the most cranial anastomosis is between the right and the left caudal cardinal veins in front of the mesonephros

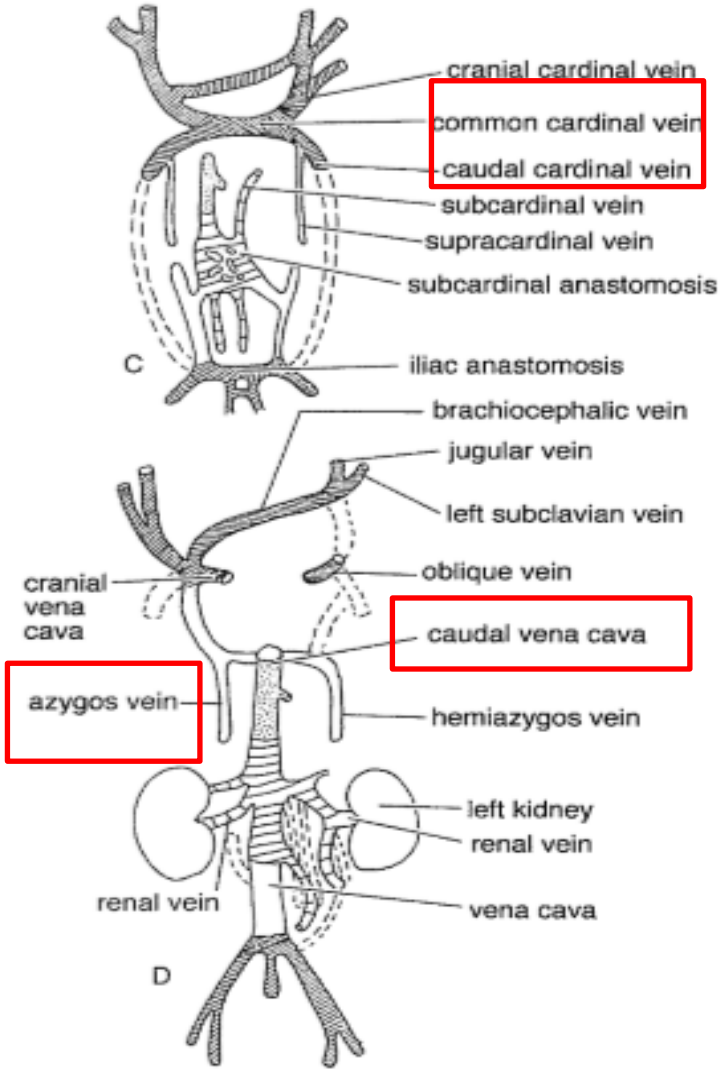
b. as the supra – and subcardinal veins develop – the mesonephros begins to disappear – the mesonephric segments of the caudal cardinal veins caudal disappear



THE CAUDAL CARDINAL SYSTEM

AZYGOUS VEINS:

1. **only the cranial portion of the right caudal cardinal vein**
2. **the anastomosis**
3. **a few remnants of the left caudal cardinal vein remain**



THE CAUDAL CARDINAL SYSTEM

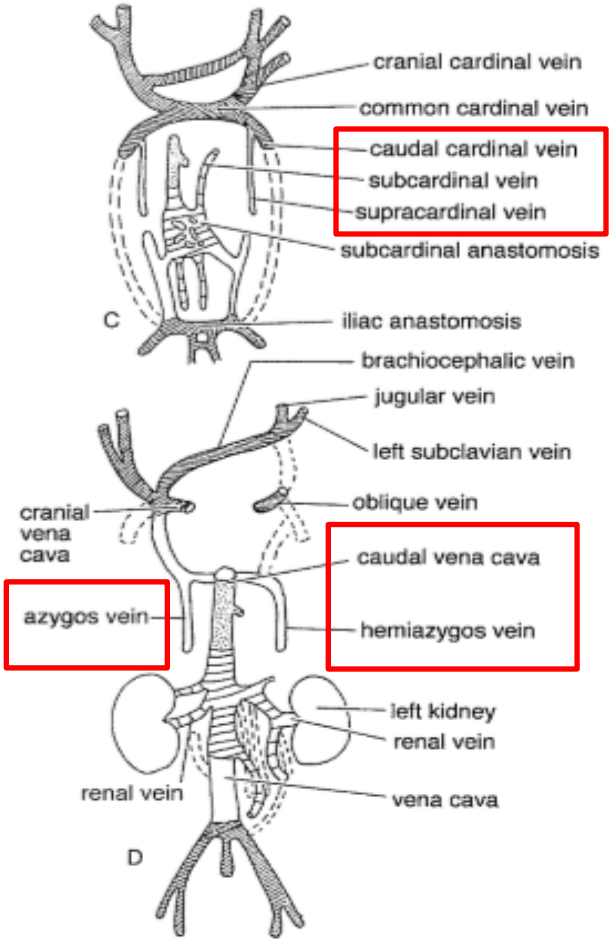
AZYGOUS VEINS:

A. RIGHT AZYGOUS VEIN:

- **the right caudal cardinal vein connects with the cranialmost part of the supracardinal vein to form the right azygous vein**

B. LEFT HEMIAZYGOUS VEIN:

- formed by the anastomosis between the right and the left sides of the caudal cardinal veins



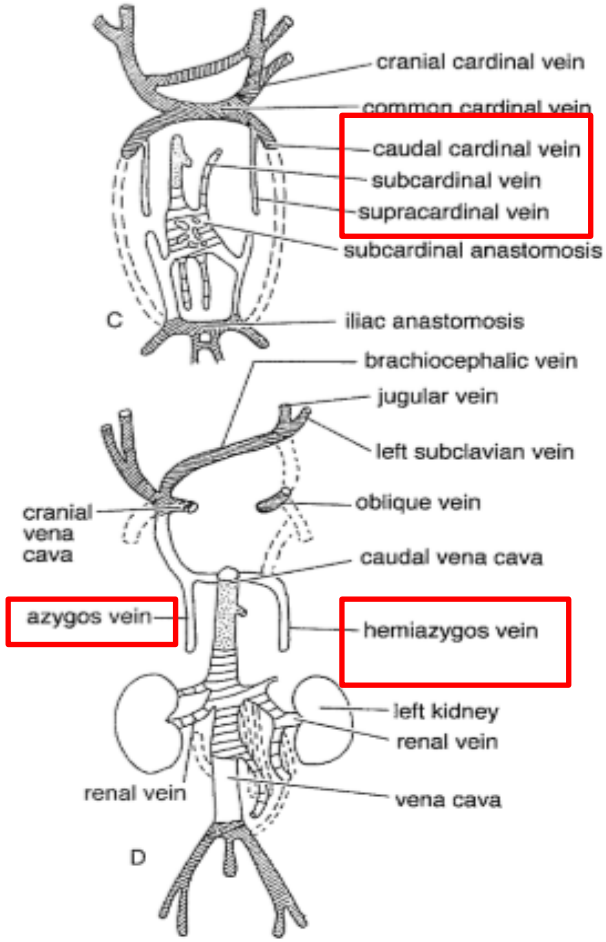
THE CAUDAL CARDINAL SYSTEM

AZYGOUS VEINS:

LEFT AZYGOUS VEIN:

- in pig, ruminant

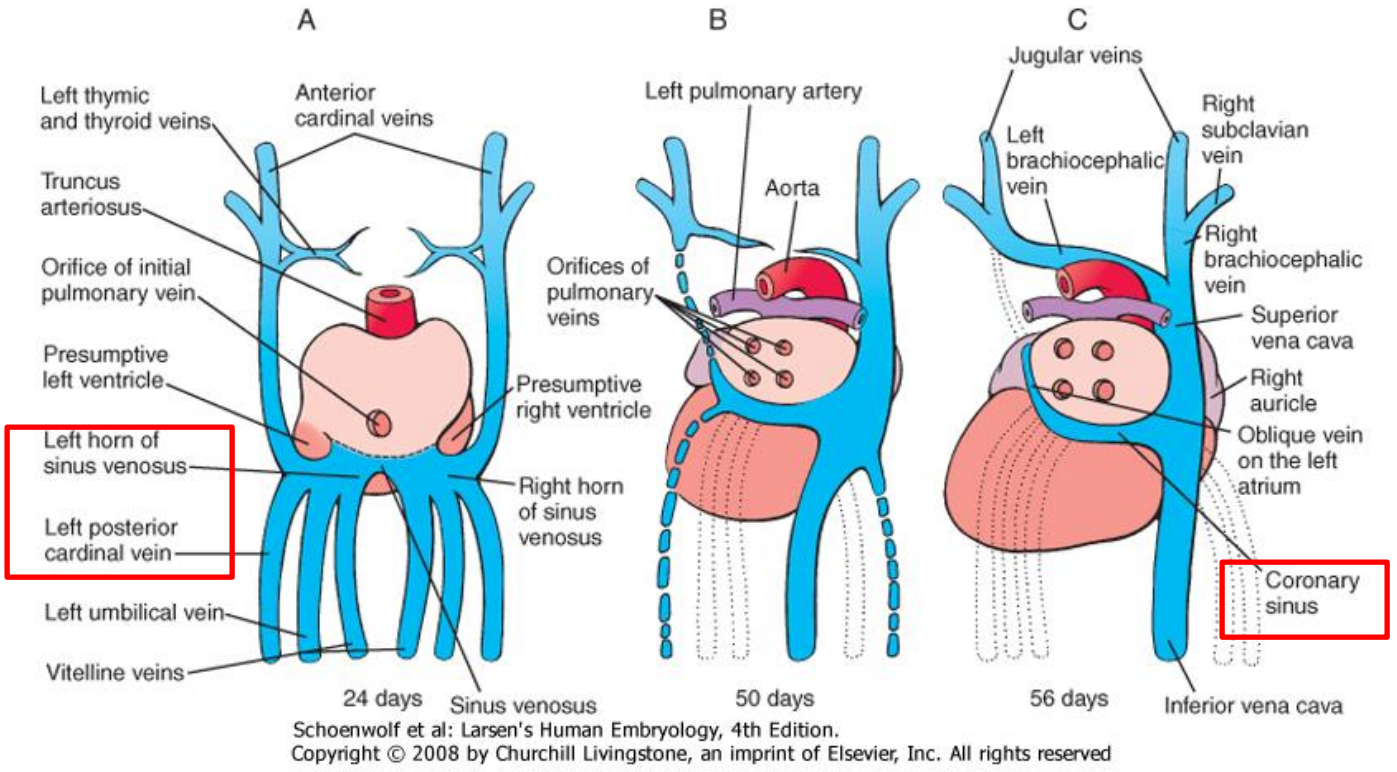
- **the cranial portion of the left caudal cardinal and supracardinal vein persists instead of the right**
- **the results is a left azygous vein, and a right hemiazygous vein**



THE CAUDAL CARDINAL SYSTEM

AZYGOUS VEINS:

- **in carnivors and horse the right azygous vein enters the vena cava cranialis**
- **in pig and ruminant the left azygous vein enters the coronary sinus**
- **the coronary sinus is the derivate of the left horn of the sinus venosus and the left common cardinal vein**



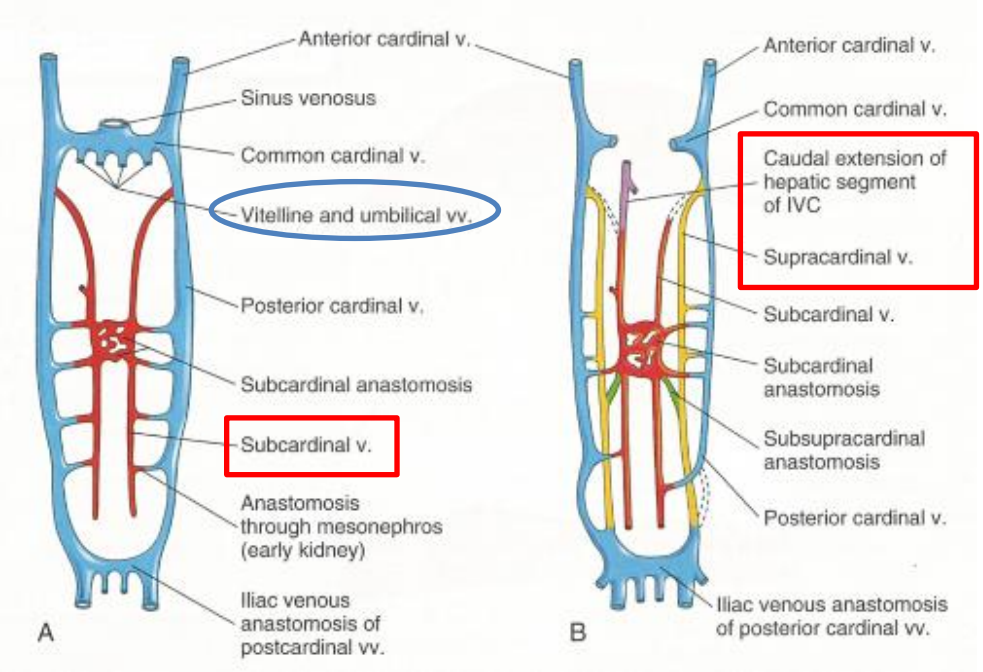
THE CAUDAL CARDINAL SYSTEM

CAUDAL VENA CAVA AND ITS MAJOR TRIBUTARIES:

1. **the cranialmost part of the right subcardinal vein establishes a connection to the cranial segment of the right vitelline vein**

2. **the rigth vitelline vein extends caudally into the mesonephric area**

3. **the rigth vitelline vein – right subcardinal connection form a segment of the caudal vena cava – the most part of the caudal vena cava formed by the right cardinal system**



THE CAUDAL CARDINAL SYSTEM

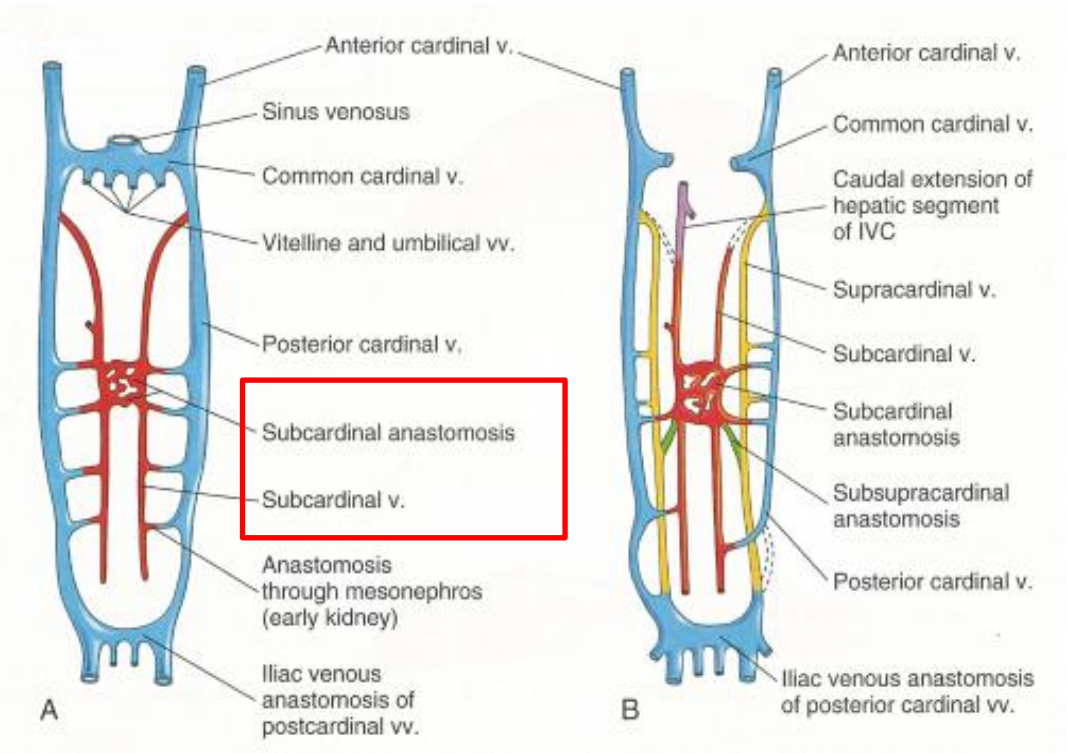
CAUDAL VENA CAVA AND ITS MAJOR TRIBUTARIES:

- **there is an anastomosis between the right and the left subcardinal veins cranial to the level of the developing metanephric kidney – this anastomosis called as the subcardinal anatomosis**

a. the subcardinal segment leads into the subcardinal anastomosis – forms the part of the vena cava caudalis, that recevies branches from the left side of the cardinal system

THESE BRANCHES ARE:

1. **left renal vein**
2. **left adrenal vein**
3. **left gonadal vein**

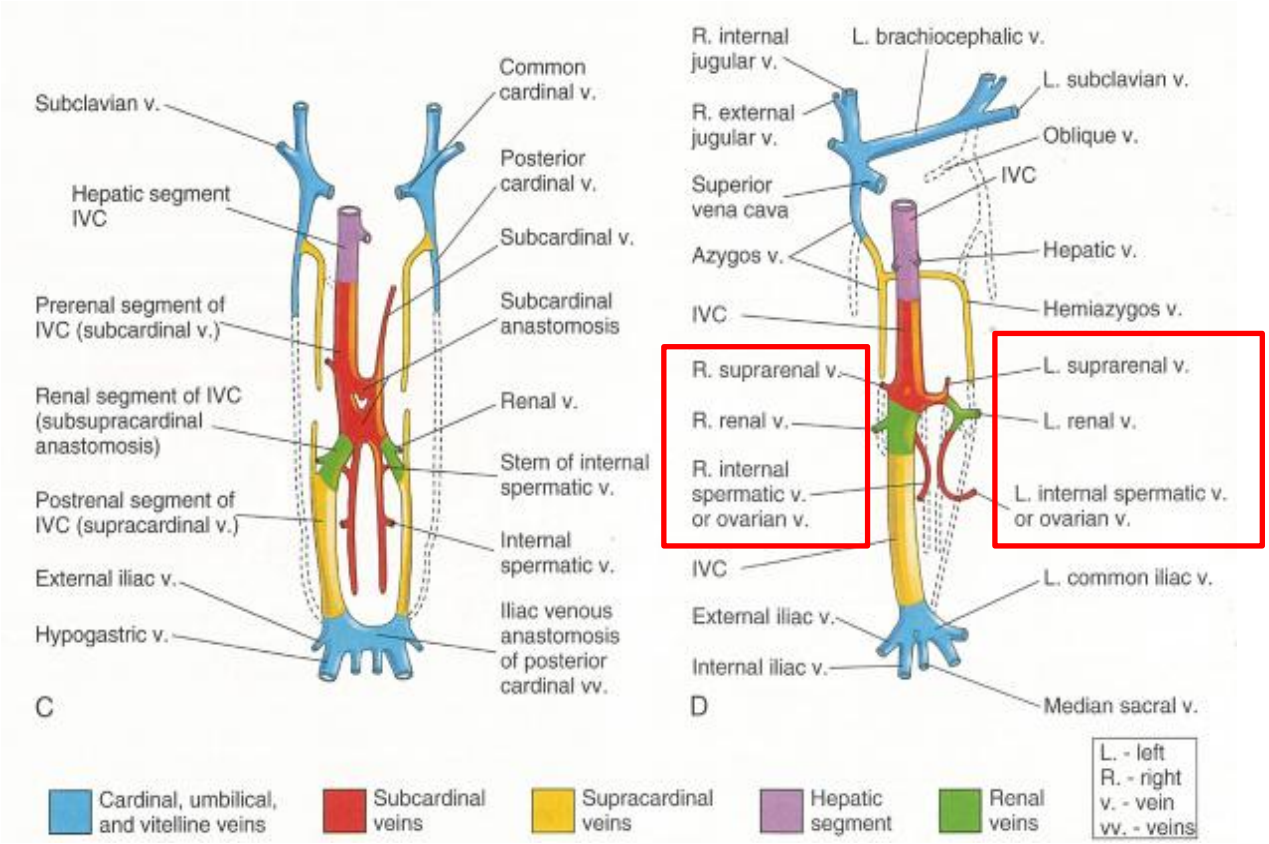


THE CAUDAL CARDINAL SYSTEM

CAUDAL VENA CAVA AND ITS MAJOR TRIBUTARIES:

THE

1. **right renal vein**
2. **right gonadal vein formed by the right sub – and supracardinal veins and the anastomotic branches between them**



THE CAUDAL CARDINAL SYSTEM

CAUDAL VENA CAVA AND ITS MAJOR TRIBUTARIES:

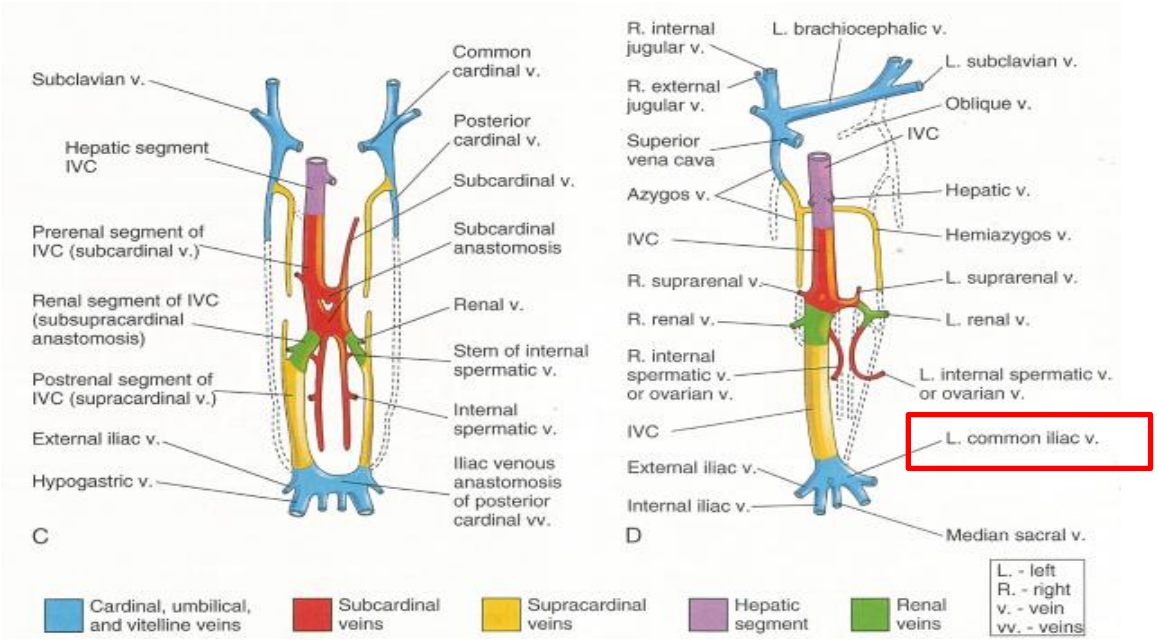
- the caudal vena cava continued caudally by segments of the right cardinal system

- **the caudal vena cava ends , when it communicates with the right caudal cardinal vein**

- **at this level an anastomosis forms between the right and the left caudal cardinal veins**

a. the right caudal cardinal vein forms the right common iliac vein

b. the anastomosis , plus the its extension by the left caudal cardinal vein form the left common iliac vein



THE CAUDAL CARDINAL SYSTEM

CAUDAL VENA CAVA formed by:

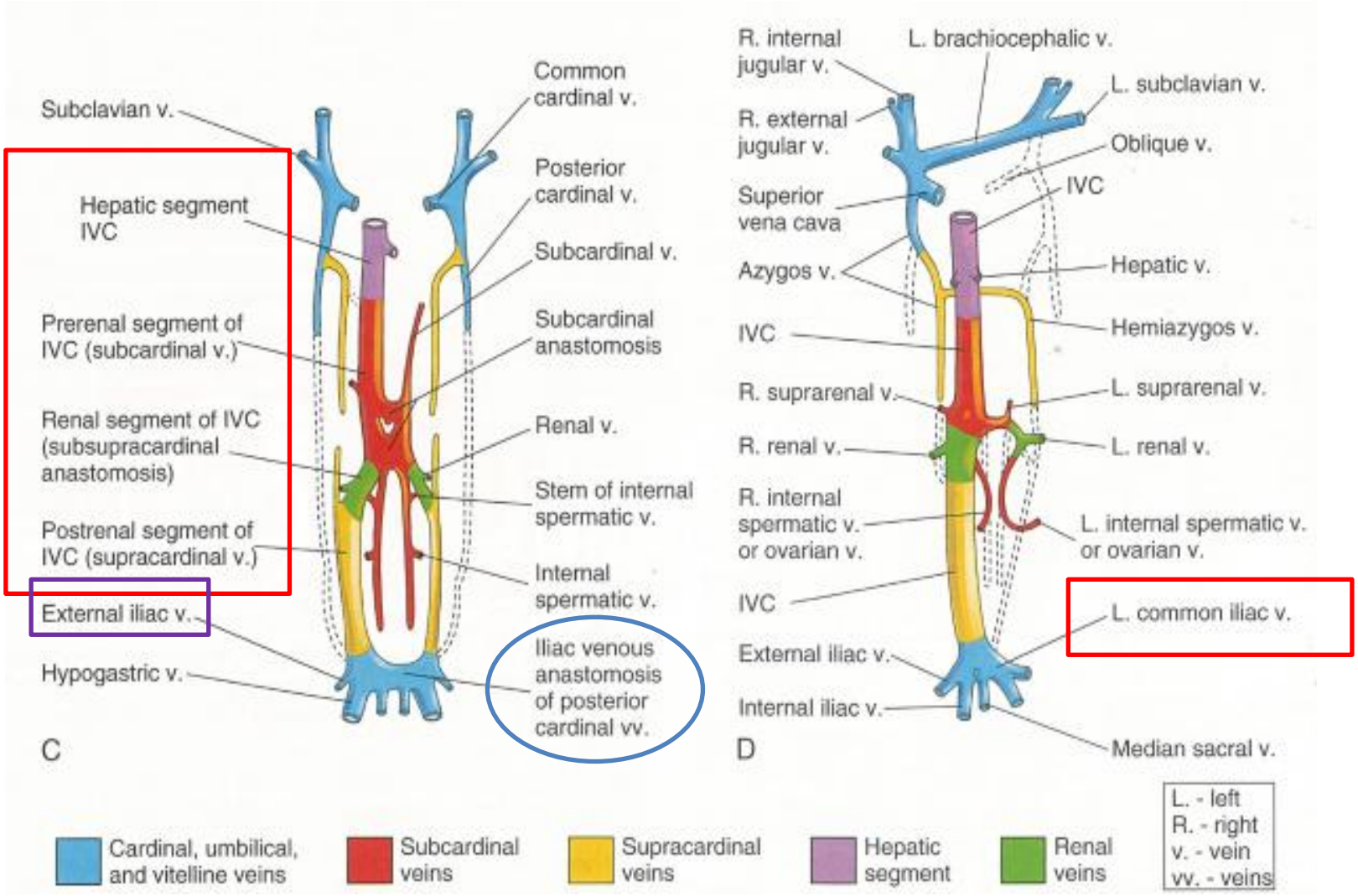
a. **right vitelline vein (including its hepatic segment and mesenteric caudal extension)**

b. **right sub – and supracardinal veins**

c. **short segment of the right caudal cardinal vein**

- **the braches of the caudal vena cava arise from the supra – and subcardinal veins and their anastomoses**
- **the cranial portion of the caudal cardinal and supracardinal veins form the right and the left azygous veins**
- **the caudal portions of the caudal cardinal veins form the common iliac veins**

THE CAUDAL CARDINAL SYSTEM



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