The Cardio-VASCULAR System

- ○ Anatomy
- ○ Histology
- ○ Pathology
- ○ Pharmacology
- ○ Physiology
- ○ Microbiology
- ● **EMBRYOLOGY**

Lec #: **1**

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- ○ Handout
- ● Sheet
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EMBRYOLOGY - 1

It's an easy lecture; the doctor keeps repeating the same information all over the lecture. I recommend reading the handout with the sheet because the doctor didn't mention everything.

We will start by studying the formation of the blood vessels. The heart itself was a blood vessel.

The beginning of blood vessels are: capillary >arteriole>artery> branching

- The early appearance of blood vessels are called blood islands; a group of mesodermal cells in the wall of the yolk sac, stalk and chorion.

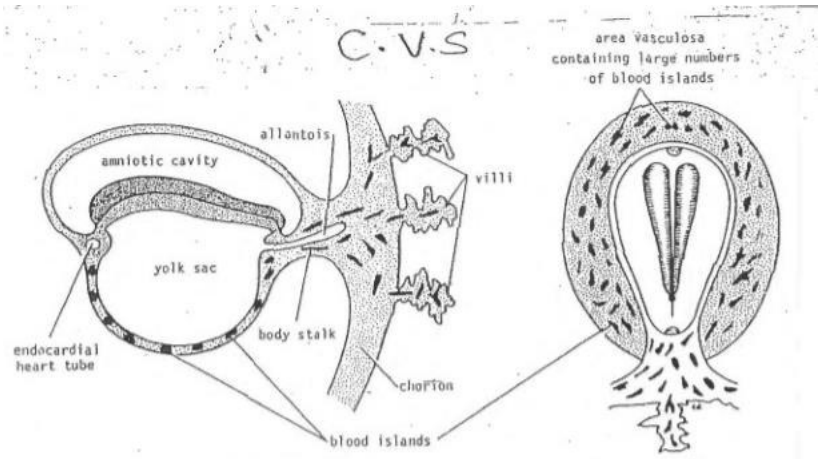


Fig. 7-1. Longitudinal section of embryo showing the appearance of blood islands in the splanchnic mesoderm of the wall of the yolk sac. Similar islands are appearing in the body stalk. These will ultimately join and form, with the capillaries in the chorionic villi, the extra-embryonic circulation.

Fig. 7-2. Embryonic disc as seen from above. The amnion has been cut away and removed.

- The peripheral cells of each island became flattened and form the **endothelial lining** of the vessels
- The central cells of the blood island form the primitive **blood cells.**

These blood islands unite together to form larger blood vessels.

Blood islands >> Capillary >> Arteriole >> Artery, and this is how blood vessels are formed. Mesodermal in origin.

These islands are found in the yolk sac, stalk, chorion and villi. All of them are outside the embryo. The same way blood vessels are formed in the embryonic disc, then a connection will happen between blood vessels in and out the disc.

Early stages

Figure A: We look at the embryonic disc from above, and we can see the disc, ectoderm endoderm and in between the intraembryonic mesoderm. -This is the appearance in the 3rd week-. And dorsal to the disc we find the amniotic cavity and ventral to it the yolk sac.

- Intraembryonic mesoderm differentiates into 3 parts (paraxial mesoderm, intermediate mesoderm and lateral plate mesoderm)
- Paraxial give us:

1- Dermatome and myotome.

- Intermediate:

2- Urogenital system

- Lateral plate:

3- Many cavities appear and they unite to form a single cavity> intra embryonic ceolom > will form pericardial, pleural and peritoneal cavities.

There are two parts of embryonic disc that lack mesoderm (formed by an ectoderm and an endoderm only) which break and become two orifices and they're:
1) Buccopharyngeal membrane (future mouth).
2) Anal membrane (anus).

Now look at the disc from above we'll see parts of the mesoderm and the lateral plate cavities which unite to form one cavity and these cavities are divided to somatic and visceral layers.
In the visceral layer, blood vessels will appear through blood islands that will form capillaries, arterioles and arteries which are called primitive blood vessels, these will develop into primitive blood tube.
There will be two of them, one on the right and one on the left, these two tubes will unite and form a single heart tube.

HOW?
The embryo was a plate, then through lateral folding it became cylindrical (like our own body which is cylindrical) this is called cephalocaudal folding which is folding of the head and the tail.
Lateral folding achieves joining of the right and left primitive tubes to form a single heart tube.

This part of the yolk sac when lateral fold happens, the two primitive heart tubes approximate to each other and unite.
Pericardial cavities in the right and left also unite to form a single pericardial cavity.

The tubes took layers from the wall of the pericardium which are: myocardium and epicardium.

The part of the yolk sac -which is the future gut- that is located dorsal to the tube, becomes a part of the foregut, which will be located dorsal to the heart. Does this make any sense? Yes sure, esophagus in the posterior mediastinum, dorsal to the heart, separated from each other by the pericardium.

So there are two tubes> single heart tube> surrounded by myocardium and epicardium > outside them there's a pericardial cavity.

And the heart with its cavity is ventral to the foregut.

Again, two tubes form a single tube; in this single tube differential growth will take place and form 5 segments from caudal to cephalic ends (or according to the blood flow direction):

Sinus venosus > primitive atrium (Single) > primitive ventricle (Single)> bulbus cordis (conus)> truncus arteriosus

Sinus venosus represent the **venous** end of the primitive heart tube and has two horns, right and left, each horn formed by the joining of three veins:

1- **Common cardinal v.,** drains the body wall.
2- **Umbilical v.** from placenta.
3- **Vitelline v.** from yolk sac.

Truncus arteriosus represents the **arterial** end of the primitive heart tube.

You should know that at the earliest stages, the sinus venosus and the atrium lie outside the pericardial cavity.
In this early stage we should know what are the derivatives of each region, if we started from the cranial end – the highest segment in the tube- bulbus cordis and truncus arteriosus.
(In the past they used to call the proximal part conus and distal truncus but now the proximal part is bulbus cordis and distal is truncus arteriosus)

These are the derivatives:

1. Truncus arteriosus → forms → ascending aorta
   ↘ pulmonary trunk
2. Bulbus cordis (conus) ⊕ Ventricle → bulbo-ventricular chamber
   ↘ forms the trabeculated part of lt ventricle
   - infundibulum of Rt. ventricle
   - aortic vestibule of lt. ventricle
   - trabeculated part of Rt. ventricle
3. A-V canal → divided by the A-V (endocardial) cushions into Rt. & lt. A-V canals
   the A-V(endocardial) cushions form SEPTUM INTERMEDIUM
4. Atrium → forms → rough - walled ant. part of Rt. atrium including its auricle
   lt. auricle
5. Smooth parts of → Rt. atrium (formed by the Rt. horn of sinus venosus)
   ↘ lt. atrium (formed by absorption of pulmonary veins).

- Bulboventricular chamber (ventricle+bulbus cordis) gives us all the right ventricle and most of the left ventricle, and will be divided into left and right ventricles.

    - Primitive ventricle part > trabeculated part of the left ventricle
    - Bulbus cordis part > Trabeculated lower part and the smooth upper part and infundibulum of right ventricle (all right ventricle) and upper smoother aortic vestibule part of the left ventricle.

- Atrium will be divided into left and right atria.
- Primitive atrium will form the anterior rough part of the right atrium.
- Posterior smooth part where superior and inferior vena cava's open formed by the right horn of sinus venosus.
- Left atrium formation is a bit difficult now; we'll talk about it later on.

This was the primary description of the heart.

- How we will form two atria and two ventricles? Page 4, 5a and 5b.
  By head fold.
  This is the embryonic disc before head fold; here you can see the buccopharyngeal and anal membrane
- Before folding: The most anterior –cranical- part of the embryonic disc is called septum transversum and it lacks mesoderm, then posterior to it we have pericardium and beneath it the heart tube (after the joining of the two tubes), more posterior is the buccopharyngeal membrane

- Why does head folding happen? Because of the rapid growth of brain.

- After folding: Septum transversum become the most posterior, followed by the pericardium and heart tube and the most anterior now is the buccopharyngeal membrane which will break down and form the mouth opening.
  {Buccopharyngeal membrane> pericardium> heart tube> septum transversum}
- Septum transversum, here where the liver is formed (recall from GI)

- **Heart tube and pericardial cavity relationship:**
  After head fold, yolk sac will form gut(foregut, midgut and hindgut) amd as a result of the fold, they arrange in their normal position. Dorsal to heart will be a part of the foregut (esophagus).

  Firstly the two heart tubes were beneath (ventral) pericardial cavity (from intraembryonic coelom), then after head fold, the two heart tubes become dorsal to the pericardial cavity and more dorsal to them is the foregut part of the yolk sac, then

the two heart tubes unite and they're now embedded in the pericardial cavity –which they took from its wall something called myoepicardial mantle; which forms myocardium and epicardium-.

The final picture now: one tube inside the cavity hanged by a mesentery called dorsal mesocardium, this mesentery will later degenerate and be replaced by transverse sinus of pericardium.

So the two ends the heart are still hanging from the arterial and venous ends, but in the middle it became transverse sinus.

Further steps: Page 6 and 7a.

What happens? Why does the heart tube fold and loop?
Initially the pericardium contains only the ventricle and bulbus cordis with truncus arteriosus. Then the bulbus cordis and the ventricle grow faster so they form U shaped loop.
Later, the atrium and sinus venousus enter the pericardial cavity (after being within the septum transverum), so it becomes an S shaped loop.
The atrium now is behind and above the ventricle. (When you see the heart, the atria are located behind and above the ventricles) until they reach their final position, but until now the arterial end (ascending aorta and polmunary trunk) is away from the venous end (Atria). (In the heart, behind the pulmonary trunk and ascending aorta you find the atria) so they should get closer, how?
The picture shows the bulbus cordis and the ventricle, in between them you find a groove. This groove disappears forming bulbo ventricular chamber.

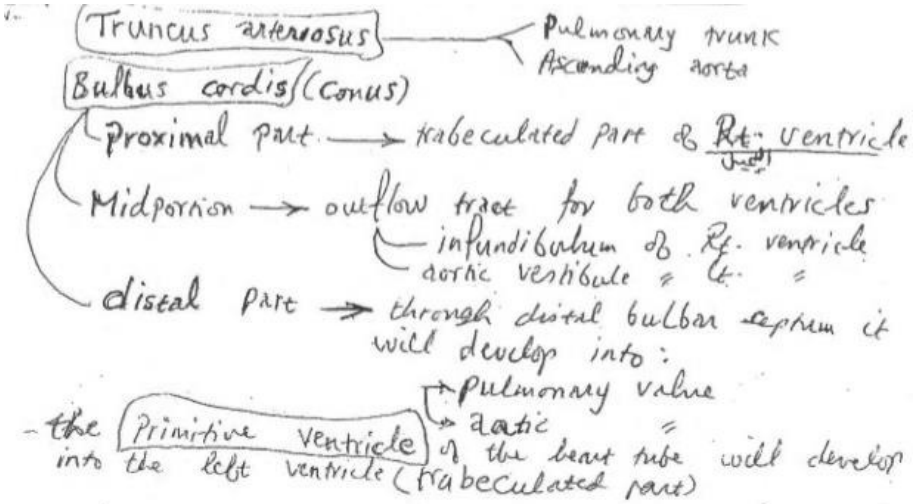
The atrium was outside, when it enters the cavity it became above and behind the ventricle, and starts to develop horizontally on the sides of the pulmonary trunk and aorta.

15.7 - C,B: the heart took its final shape; the arterial end represented by the pulmonary trunk and aorta near the venous end (left and right atria).

So let's say everything again:
The growth of bulbus and ventricles was faster than pericardium so it became U shaped loop then S shape when the atrium and sinus venosum joined.
Atrium grew horizontally and divided into right and left, they became behind and above the ventricle. And finally the arterial end of the heart tube is near to the venous end.

Derivatives:

Go back to the first figure in the sheet; they're the same in addition to these:



Polmunary valve is above the infundibulum and the aortic valve is above the vestibule due to their embryonic development.

Page 8:

- The <u>U shaped loop</u> bending is toward the right, so bending of bulbus corids and ventricles are to the right.

  In dexocardia (when the apex is found on the right) this binding is to the left!

- <u>Right atrium</u>, its anterior part is rough walled and posterior part is smooth, so the origins are different.
  - The anterior part (cristea terminalis and pectinate muscles) is from primitive atrium.
  - The smooth posterior part (where the openings of SVC, IVC and coronary sinus) from the right horn of sinus venosus.

- <u>Septum transverum</u> where the liver will be formed, before the umbilical and vetelline vein go to right horn of sinus venosus they pass through the liver, and this part of them is described as cranial part of the vein, which are located between septum transversum and sinus venosus, the caudal end is below the level of septum transversum

  What are the changes that make the right horn larger the left horn? And the left horn becomes smaller?

  Two left-to-right shunts, the left part stops receiving blood. How they are formed?

- Changes in umbilical vein and vetelline vein

  1st: Umbilical V.

  The right umbilical, all of it- the cranial and caudal parts- obliterates and whats left is the left, the left umbilical vein persists, bringing oxygenated blood from placenta and

becomes connected to the IVC through the ductus venosus, which develops in the liver.

2nd : Vitelline V.
The two caudal parts of vitelline veins form the portal vein.
The cranial part of the right vitelline vein forms the ending of IVC. And the left end disappears.

Finally: the left. umbilical vein brings blood from placenta to septum transversm (where liver will be formed).
The blood from placenta along the left umbilical vein goes to liver, and the liver is for metabolism, but this blood is already metabolized in the placenta so it should bypass the liver.
How? In the liver there will be a shunt (ducuts venousus) that connects umbilical vein with inferior vena cava (right horn). – and this is the first shunt-
Most of the left sided veins disappear (left. vetelline and left common cardinal vein and umbilical obliterate) so the left horn gets smaller.

- Other changes:
  When the left horn become smaller, all the blood goes to the right horn, so it enlarges and forms the posterior smooth wall of right atrium, and left horn is smaller now and forms coronary sinus.

  - Second shunt between two anterior cardinal viens, this shunt will persist in the fetus forming the left brachiocephalic vein, and the left brachiocephalic vein should unite with right forming the SVC, the SVC will open in the right horn which will enlarge and form the posterior part of right atrium.

- Sinus venosus:
  Right horn> receives all placental blood > large > form post wall of right atrium.
  Left horn > most of veins disappear > small > supporter for right horn> coronary sinus and opens in right horn.

- Primitive atrium is divided into right and left by interatrial septum, the anterior part of right atrium is rough walled (crista and pectinate) is from primitive atrium. The posterior smooth from right horn of sinus venousus.
  In the posterior surface, there are 3 openings:
  1- SVC which was common cardincal vien
  2- IVC which was the right vitelline vein
  3- Coronary sinus which is formed by the left horn of sinus venosus

This venous part which opens between sinus venosus and right atrium, forms right venous valve and left venous valve:

1- Right: forms crista terminalis , IVC's valve (this valve is only important in fetus) and the coronary sinus valveseparates sinus venosus from the right atrium.
2- Left: disappears and unites with the interatrialseptum.

Crista terminalis seperates the posterior smooth part from the right horn and anterior rough one.

Now the atrium is above and behind the ventricle, what is between the primitive atrium and primitive ventricle? An opening called AV canal divided into right AV canal and left AV canal (will be later tricuspid and bicuspid valves).

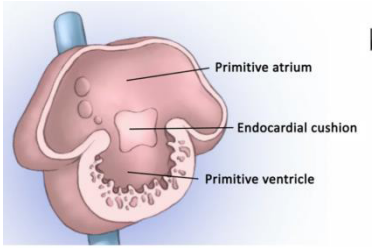
Page 12: This is the primitive atrioventricular canal, appears in the dorsal wall and ventral wall a growth called cushions, dorsal endocardial cushion and ventral endocardial cushion, they come in contact to each other forming septum intermedium which divides the AV canal between the atrium and ventricle into right and left AV canal.

Coronal Section: Shows that septum intermedium results from the joining of the dorsal endocardial cushion with the ventral cushion, this one divides the AV canal into right and left, and here the bicuspid and tricuspid valves will be formed.

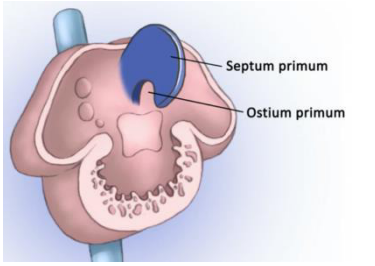
In this stage the premititve atrium and ventricle start to divide into two, notice that any septum between the two atria will eventually join septum intermedium, and the same story for ventricles. So any defect in septum intermedium will be reflected as a defect in the interatrial and inter ventricular septa.

- How is the interatrial septum formed?

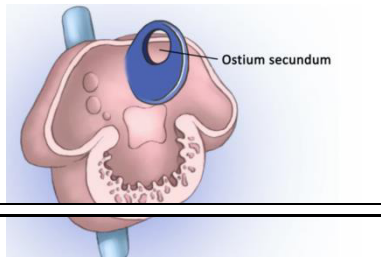
Two stages: the first one: the septum is formed from the roof of the primitive atrium, this septum goes down to join the septum intermedium, and it's called septum primum.



Since we already know that in the fetus there must be a connection between the right and left atrium and the blood should directly pass from the right to left atrium so we need an opening between them. And that's why, before the septum primum reaches down, it's upper



part breaks down to form the foramen secundum.



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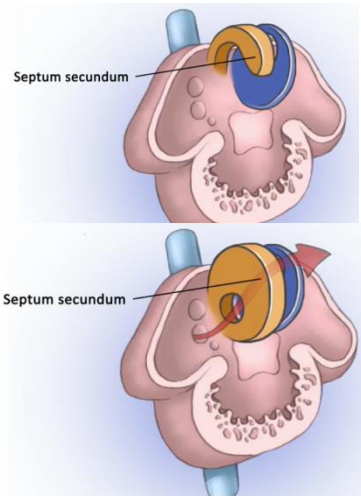
Septum secodum is incomplete, and doesn't reach the septum intermedium so there will be an opening between septum secondum and primum which is foramen ovale.

There is always a communication between right and left atrium, what is the communication? Foramen ovale.



- How does the blood in the embryo run from right atrium to the left atrium? Through foramen ovale.
- What are the mechanisms?
  - First one – IVC valve- : the blood which will reach the right atrium is originally from placenta (left umbilical vein> liver forming ductus venousus > IVC) when the blood reaches from placenta to IVC, valve of the IVC directs the blood to foramen ovale.
  - Second one and the most important one –**pressure gradient**: the blood pressure in the fetus' right atrium is higher than left atrium, because little blood reaches left atrium –lungs are not functioning, they're collapsed, so there will be not much blood to left atrium-. So the blood will easily pass from the high pressure area (Right atrium) to the low pressure area (Left atrium).
- And the lower edge of septum secondum is thick and firm called crista dividens, which lets most of the blood coming from IVC to right atrium and the remainder joined by venous blood from SVC and coronary sinus passes from right atrium into the right ventricle.

- **Foramen ovale**, closes after birth, why?
  Simply, after birth the lungs will expand, at the moment of birth the baby will take a breath and the lungs will expand therefore the pulmonary circulation starts to work. The blood will then go back from lungs to the left atrium, more and more to the left atrium which will increase the pressure there after birth until it becomes higher than the right atrium, that will approximate septum primum to secondum and they will eventually join each other and the foramen is closed now!

Atria Formation

- How the right atrium is formed?
  Anterior rough part from primitive atrium.

  Posterior smooth part from right horn of sinus venousus (openings of SVC,IVC, coronary sinus)

- How the left atrium is formed? Page 14

All is smooth except from auricle

Auricle: primitive atrium.

The large remainder smooth part of the left atrium: initially, it was a single pulmonary vein, this vein is divided into two branches, each branch gives two other branches. This pulmonary vein grew from the wall and then reabsorbed into it.

So most of the left atrium is derived from the pulmonary vein.

Ventricles formation

Initially there was a bulbus cordis and a ventricle, and a septum between them.

This septum gradually disappear forming bulboventricular chamber, this chamber will later on form the two ventricles.

Bulbus cordis >> most of the right and left ventricle. (Aortic vestibule, infundibulum, lower trabeculated rough part of right ventricle)

Primitive ventricle>> the lower rough part of the left ventricle.

Sorry for any mistakes.

Good luck ☺