Embriology of the heart

Please don't miss a single word of the handout , these extra notes are just to make the figures clearer !

the number of the page is the number you find on the upper right side of the handout .

Page 1A , figure (A, right):

Embryonic disk :

-lies between the amniotic cavity (above) and the yolk sac (below) .

-in the third week it becomes trilaminar (was bilaminar in second week):

*__ectoderm__ will develop to form the neural tube which will give the nervous system (brain and spinal cord) .

*__endoderm.__

*__intraembryonic mesoderm.__

-Two parts of the embryonic disk do not have mesoderm (or mesenchyme) :

1. buccopharyngeal membrane also called prechordal plate (future mouth) in the cranial end.

2.anal membrane (Future anus).

Any part of the embryonic disc that doesn't have mesoderm will break down and open at certain stage.(forming the mouth opening and anal opening).

A,left:

Intraembryonic mesoderm :

-consists of (if you look through the ectoderm) :

*paraxial mesoderm: will give somites which will give rise to muscles of the body.

*intermediate cell mass: will give rise to different parts of urogenital system (kidney for example).

* lateral plate.

B,left :

You can see paraxial mesoderm that gives muscular segments(somites).

We'll discuss the intermediate mesoderm in the urogenital system enshallah.

B,right :

The ectoderm differentiates to neural groove which will give neural tube then brain and spinal cord.

Figure C :

Formation of small cavities in the lateral plate , these cavities will fuse later to form a single cavity, the intra-embryonic coelom .

At this stage the lateral plate is divided by the cavity into :

*splanchnic layer (or splanchnopleuric) close to the endoderm .

* somatic layer (or somatopleuric) close to the ectoderm.

The **intra-embryonic coelom** is the future pericardial, pleural and peritoneal cavities.

******

In the splanchnic mesoderm , the **primitive endothelial heart tube** will develop in both sides **ventral** to the pericardial cavity . By the "primitive heart tube" we mean endothelium.
Other parts of the heart (myocardium and epicardium) will develop from the surrounding mesoderm.

Ventral to the pericardial cavity at the cranial end of embryonic disc there is a mass of mesoderm , **septum transversum,** from which the future liver will develop**. [**You can see it in page 4, figure.19,C]

******

Pages 4, 5A,5B:

Before folding the embryo from cranial to caudal :

-Septum transversum(most cranial/anterior part).
-primitive heart tube **ventral** to the pericardial cavity.
-buccopharyngeal membrane (prechordal plate in the figure): does not have a mesoderm and will form the future mouth.

Folding

During development of the embryo, two types of folding occur:
*lateral folding : to form a cylindrical embryo (with cavities).
*cephalocaudal folding: head fold and tail fold.

Why does folding occur ?
Because of the rapid growth of the brain as a part of the nervous system ,forming brain vesicle (forebrain, midbrain, hindbrain).
[the brain moving forword,pushing the other structures behind]. >> **head folding**

After head folding , from cranial to caudal :

-buccopharyngeal membrane (prechordal plate).
-primitive heart tube : lies **dorsal** to the pericardial cavity and starts to invaginate it.
- septum transversum.

***** During lateral folding the right and left heart tubes become close to each other and fuse to form the primitive heart tube .the pericardial cavities also fuse, which gives a single heart tube surrounded by a single pericardial cavity.
***** Forgut has developed from the yolk sac and it is dorsal to the pericardium , obviously that does not interfere with anatomy since the esophagus, which is a part of the foregut, is behind the heart.
***** The primitive heart tube is originally endothelium. Its myocardium and epicardium are derived from the splanchnic mesoderm that surrounds the pericardial cavity, forming a **myoepicardial mantle**.[page 5B, figure 15.4]

***** The primitive heart tube is suspended from the dorsal wall of the pericardial cavity by dorsal mesentery that soon disappears and gets replaced by the transverse pericardial sinus.

Note : liver is an endodermal bud of the foregut but the stroma and capsule are derived from the mesoderm of septum transversum.

Page2, figure15.1

*classical illustration.
A: two heart tubes , right and left.
B,C: fused to form a single heart tube , except caudally they remain separated.
D: five segments of primitive heart tube are defined, from cranial to caudal :
Truncus arteriosus →Bulbus cordis →primitive ventricle→primitive atrium →sinus venosus.

*sinus venosus divides into two horns , each horn receives 3 veins :
1.common cardinal vein : carry deoxygenated blood from the body wall of the embryo; formed by the union of anterior and posterior cardinal veins.
2. umbilical vein : carry oxygenated blood from the placenta. The source of blood in the fetus is the placenta, not the lungs.
3. vitelline vein : drain deoxygenated blood from the yolk sac.

Figure in Page 3:
you can see sinus venosus with its two horns , single atrium , single ventricle , single A-V canal (single A-V opening will develop to right and left A-V openings), bulbus cordis and truncus arteriosus .

Note : some books describe the proximal part/caudal part of the bulbus cordis (close to the ventricle) as **conus or bulbus cordis** and the distal part as **truncus arteriosus.**

In the early stages, the atrium and sinus venosus (caudal part of heart tube) were **outside** the pericardial cavity within the septum transversum .while the bulbus cordis (bulbus cordis and truncus arteriosus) and the ventricle were inside.

The Dr said there is something inaccurate in this figure which is the description of the whole structure as it is inside the pericardial cavity. This is true only in later stages .
[read the comment below the figure].

These parts of heart tube will differentiate to form different structures of the heart ,this is fully explained in the hand out
Note that the Lt horn of sinus venosus doesn't form any part of Lt atrium while the Rt horn form the smooth part of Rt atrium.

Page 6, figure15.5

A: heart tube inside pericardial cavity suspended to mesentery that will form the transverse sinus .
B: the bulbus cordis and ventricle are inside the peritoneal cavity , but the atrium and sinus venosus are caudal (outside) within the septum transversum .
C: the heart tube grows faster than the pericardial cavity so it starts to fold on its self forming a loop (U shaped).
D: pulling the atrium and sinus venosus into the pericardial cavity . the heart tube now is S-shaped.
Notice the sulcus between bulbus cordis and ventricle .

Figure 15.7:
A: the bulbo-ventricular sulcus disappears so that the bulbus cordis and ventricle come to form one chamber.
The atrium is behind and above the ventricle.
-truncus arteriosus is the most cranial.
-Remember that truncus arteriosus represents the arterial end of the heart and the atrium and sinus venosus are the venous end.
B,C: primitive atrium is expanding in both sides of truncus arteriosus to form the left auricle and rough part of right atrium .
D: the final state of the heart which involves making the arterial end closer to venous end and the atria so that the upper part of the atria will be behind the ascending aorta and pulmonary trunk .also from the final state we can say that the right atrium is **anterior and to the right** of left atrium, and right ventricle is **anterior and to the right** of the left ventricle as well.

Notes:
-the interatrial and interventricular septum are not quite sagittal, dividing the heart into right and left. Instead, the septum tends to be more coronal than sagittal.
- The heart tube undergoes looping (bending to the right). If it bent to the left, the heart would form on the right side of the chest (dextrochardia).

Figure in Page 8 :
A: we can see the sinus venosus and its two horns, each horn receives blood from 3 viens (mentioned before).
-**common cardinal vein** is formed by anterior and posterior cardinal veins:
Anterior : brings blood from the upper half of body wall.
Posterior: brings blood from the lower half of body wall.
B: notice that the **vitelline vein** and **umbilical vien** have crossed the septum transversum (future liver) before reaching the sinus venosus and each of them is divided into cranial part (between septum transversum and sinus venosus) and caudal part (below septum transversum).
Also notice that the left horn becomes smaller than the right horn . why ?
due to the shunt formation where the blood is shunted from left to right .

There are two shunts formed :
1. the first shunt is due to the changes in umbilical and vitellin veins.
2. the second shunt is innominate (brachiocephalic) shunt : between the two anterior cardinal veins.

** The changes/transformations are found in details in page 9.*
And just a note in point A2 :
" The left is left " : the caudal part of left umbilical vein is left, bringing highly oxygenated blood from the placenta (although it is called "vein").

* what is left after the first left-right shunt is :
-cephalic(cranial/proximal part) of right vitelline→ terminal part of inferior vena cava (hepatic cardiac channel).
- caudal part of left umbilical vein.

left umbilical vein →carries highly oxygenated blood from the placenta then reaches septum transversum (liver) .
There is no need for the liver to filter that blood since the placenta has already done this (the placenta performs the functions of the liver and lungs). So the blood bypass the liver through **Ductus venosus**.
[Ductus venosus is a shunt inside the liver brings the blood from the placenta through left umbilical vein to inferior vena cava].

*After birth the left umbilical vein becomes legamentum teres , whereas the ductus venosus gives rise to ligamentum venosum of the liver.

*these changes finally lead to :
Obliteration of proximal part of Lt vitelline, proximal part of Lt umbilical vein and Lt common cardinal vein.

****

*because of the obliteration of left common cardinal vein, the amount of blood supplying the left horn decreases so the left horn decrease in size and contribute in the formation of coronary sinus .
[some books say that the coronary sinus is derived from left horn only , other books say that the left horn and left common cardinal vein together contribute in it's formation].

* **Oblique vein of marshal** is the remnants of the left common cardinal vein, and may form the *left superior vena cava* .

****

The fate of sinus venosus is well illustrated in the handout page 11

Notes:

*the right venous valve forms the crista terminalis and the valve of IVC (lower figure B) , so if you examine a heart very well you will find that crista terminalis is continous with the valve of IVC.

****

Page 12

Remember when we said that in the primitive heart tube there is a single A-V canal .this canal is divided into two sides by the fusion of dorsal and ventral A-V cushions .Their fusion to septum intermedium is shown in the 3rd figure (coronal section).

Septum intermedium devides the canal into right and left A-V openings which will develop to tricuspid and mitral valves.

Congenital malformation of the septum intermedium is accompanied by anomalies in both tricuspid and mitral valves , as well as interatrial and interventricular septa . but it's effect on intervenrtricular septum is much greater. Why ?

the muscular part of ventricular septum is growing upward leaving a small defect (intervintricular foramen) must be closed by the developing septum intermedium before birth and then form the membranous part of the septum . while interatrial foramen remains open till birth , closes after birth in a mechanism illustrated in page 13 " formation of interatrial septum".

Page13

Another way of illustration so that it might become clearer:

- During fetal circulation, right atrial pressure is higher than left due to the large amount of blood coming from the placenta into the right atrium, and to the high pulmonary resistance, because lungs are collapsed in the fetus.
- The foramen ovale remains open during fetal life, in order to shunt blood from right to left atrium.

**Structures involved in the septation:*

- The **septum primum** grows inferiorly from the roof of the atrium toward the endocardial cushions, but it doesn't fuse with it.
- The **foramen primum (ostium premium)** is located between the inferior edge of septum primum and the endocardial cushions.
- The **foramen secundum (ostium secundum)** forms within septum primum just before the foramen primum closes to maintain the right to left shunting of blood.(if this foramen doesn't close, it will become the high atrial septal defect.)
- The septum primum fuses with the endocardial cushions, obliterating the foramen primum.(if it doesn't obliterate it will form low atrial septal defect)

- The thick **septum secundum** forms to the right of the septum primum from the roof of the atrium. It descends and partially covers the foramen secundum, but doesn't fuse with the endocardial cushions.
- The foramen ovale is the opening between septum primum and septum secundum.
- The part of septum primum that forms the lower edge of foramen secundum is mobile allows blood flowing . So, when blood tends to flow from right to left before birth, it moves away and there's no obstruction of blood flow.
- **After birth**, closure of foramen ovale immediately occurs due to decreased atrial pressure caused by closure of umbilical vein, and decreased pulmonary resistance. Blood now tends to move from left to right, but this blood faces septum secundum that closes foramen secundum, which prevents it from moving to the right atrium; septum primum adheres with septum secondum due to high pressure, which closes the foramen ovale, forming fossa ovalis.
- **Floor of fossa ovalis** is formed of the septum premium while it's boundary , the **annulus ovalis** (limbus of fossa ovalis), is derived from the lower margin of septum secondum .

Lower end of septum secondum is thick and strong, called **crista dividens**.It devides the oxygenated fetal blood **upon reaching the foramen ovale into two volumes. The greater volume enters the left atrium and lesser volume remains in Rt atrium and mixed with the deoxygenated blood from SVC.

Two mechanisms keeps the blood flow from Rt to Lt atrium :
1. crista dividens is important in directing the blood from IVC to foramen oval then to left atrium.
2.blood pressure in the Rt atrium is higher than the Lt atrium .

** the blood flow :
placenta...left umbilical vein...ductus venosus...IVC..right atrium.

* * *

Good luck ☺
Raeda Manasra