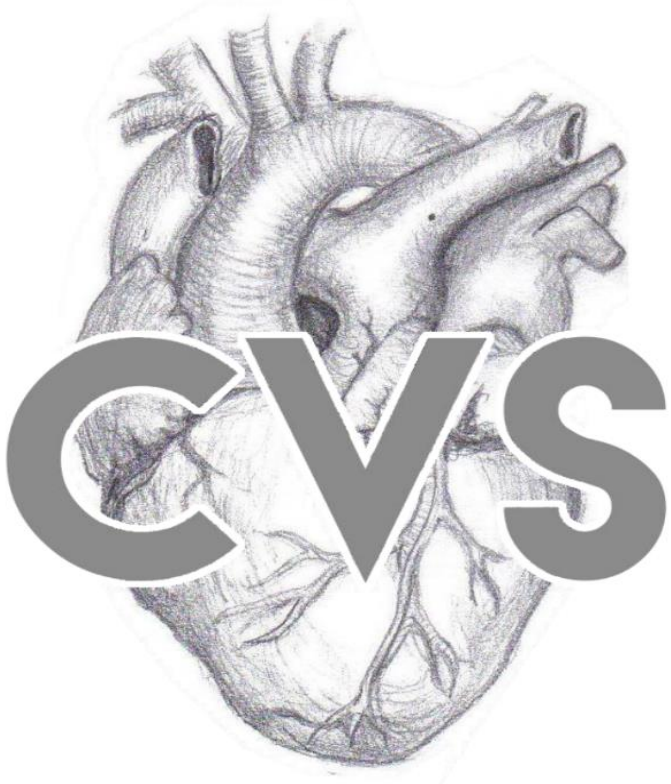

CVS

ANATOMY / HISTOLOGY

☑ Sheet ○ Slide ○ Handout

Number

7

Subject

Embryology

Done By

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Date: **25/10/2016**

Price:

Some points from the previous lecture:

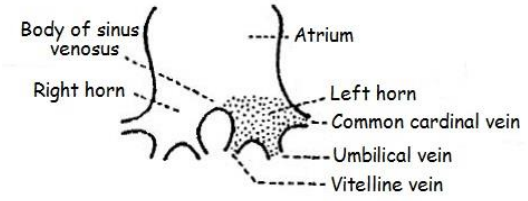
The right atrium has a rough anterior part which is derived from primitive atrium, and a smooth posterior part derived from the right horn of sinus venosus, hence it is called *sinus venerum*.

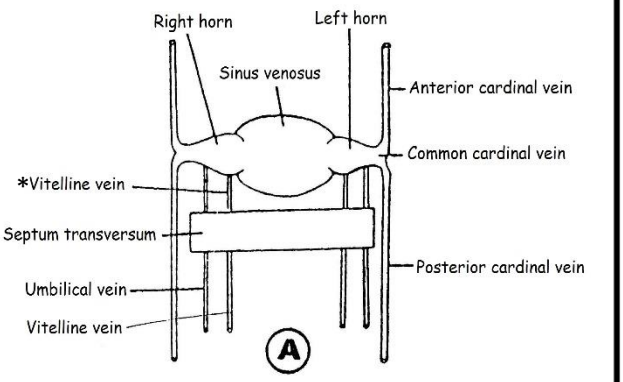
- In the picture we can see sinus venosus, with its right and left horns, each horn receives blood from three sources (3 veins open in each horn) which are the:

  1- **Common cardinal vein** that is formed by anterior and posterior cardinal veins bringing blood from the body wall.

  2- **Vitelline vein** bringing blood from the yolk sac.

  3- **Umbilical vein** bringing blood from the placenta.





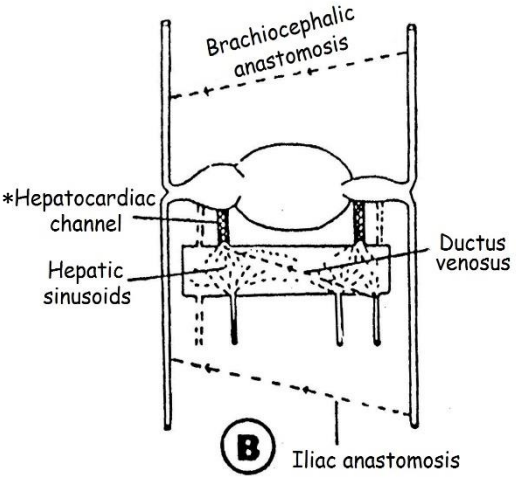
- The right horn will give rise to the **smooth posterior** part of the **right atrium**, but how does that occur?

  Right horn of sinus venosus will enlarge at the expense of the left horn, and that will happen by shunting the blood from the left to the right, when blood moves from the left to the right horn, the right horn will enlarge and the left one will shrink.

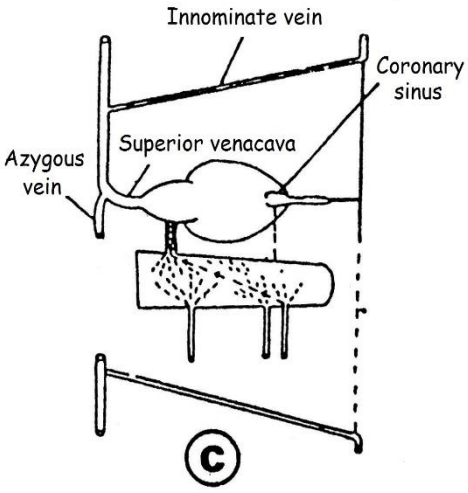
  But now, how was the blood of the left horn shunted to the right horn?

  - First of all we said that inferior to the heart tube in the fetus we have *septum transversum*, where the liver will develop in later stages of development. So, for the **umbilical** and **vitelline** veins to reach the horns they have to cross septum transversum.
  - Thus, the upper parts of both -the vitelline and umbilical veins- which are located above the liver are called **rostral** (means upper) and the parts below it are called the **caudal** parts.

- Now, let's start explaining the shunts system; we have two shunts:
  - The first one will connect the *anterior cardinal vein* on the left with the anterior cardinal vein on the right through a duct which will later give the **left brachiocephalic vein**. If things will go like this then the part of right anterior cardinal vein that meets this duct will give later the right brachiocephalic vein then they unite to give superior venacava (right common cardinal vein represent the SVC in fetus).



  - The second shunt is represented by the disappearance of some veins or parts of them on the left side, but which parts of the veins will exactly disappear?



  1- Vitelline veins:
  - The caudal parts of the two vitelline veins - left and right- will unite to form the portal vein (vein of the liver).
  - The rostral parts of vitelline veins; on the right side it will remain giving the terminal part of the inferior vena cava (IVC). But it will disappear on the left side.

  2- Umbilical veins:
  - All the right umbilical vein will disappear (both rostral and caudal ends will disappear).
  - Left umbilical vein; the rostral part disappears, but the caudal part remains to receive highly oxygenated blood from the placenta.

- Now, there are parts of the vitelline and umbilical vein which remain across the liver, these parts will give **liver sinusoids**, and that's because we don't want the highly oxygenated blood that is coming from the placenta -through the caudal part of the left umbilical vein- to pass through the liver and its sinusoids, so it will bypass the liver by a duct that shunts blood from left umbilical vein directly to the IVC. This duct is called **ductus venosus** although it contains highly oxygenated blood, not venous blood.

- After these shunts blood will be going to the right horn only and won't reach the left horn of the sinus venosus anymore, and that, as we've seen, happens because most of the veins on the left side disappeared except for the caudal part of umbilical vein which is already linked to the IVC through ductus venosus, and the left anterior cardinal vein which is connected to the right one through a duct which will later on give the left brachiocephalic vein.

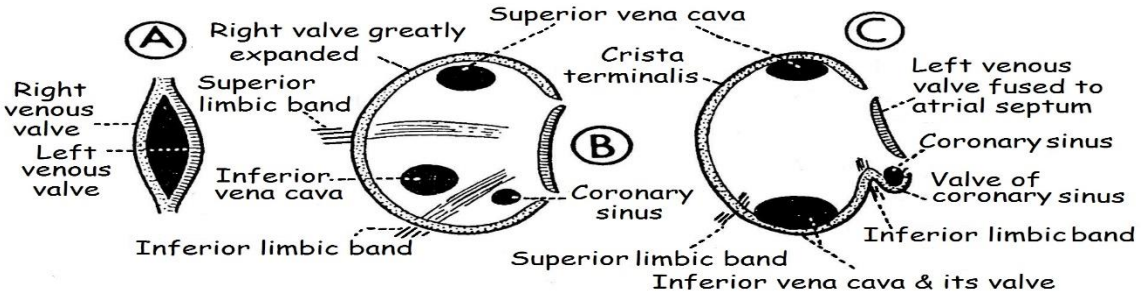
- So, when all blood have been shunted to the right horn, it will enlarge and ultimately give the smooth *posterior part* of the right atrium. on the other hand, the left horn will shrink because no blood is reaching it, and it will ultimately give coronary sinus on the posterior aspect of the heart bringing venous blood from cardiac muscle to the right atrium.

- So for now, what opens in the right horn of sinus venosus?
  1) **Right anterior cardinal vein** which will give later on *right brachiocephalic vein* that unite with the *left brachiocephalic vein* (which was the duct that connects the left anterior cardinal with right one) to finally give the *SVC.*
  2) *Rostral part* of **right vitelline vein** which will give the terminal part of *IVC*.

- The right horn opens into the atrium by two valves, then the big part of right horn wall will be absorbed to the wall of the atrium, and that's why we said that the right horn will give the smooth posterior part of the right atrium (behind crista terminalis).

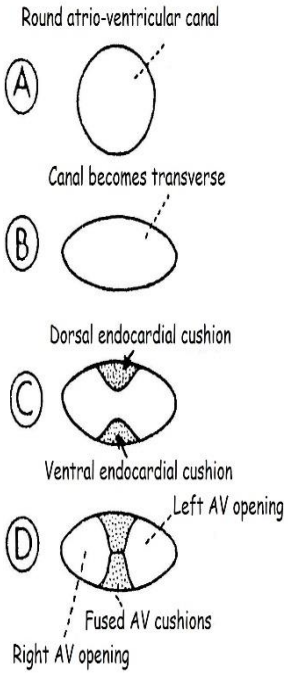
Remember: Crista terminalis;
a structure that separates the smooth from the rough part in the right atrium, as the rough part is anterior to it, and to its posterior comes the smooth part of the right atrium. In the posterior part of right atrium opens the SVC, IVC and coronary sinus.

Note: Most of the coronary sinuses developed from the left horn, and a small part only from the left common cardinal vein.
*That is how the **right atrium** formed.*



- Alright, so we said that right horn opens in the right atrium by two valves, which are the right and left valves. The *left* one will stick with the interatrial septum and disappear, but the *right* valve will give rise to certain structures which are:
  1. Valve of IVC (this valve is functioning only in fetal life and not after birth).
  2. Valve of coronary sinus.
  3. Crista terminalis.

- How will the two AV valves form?
  We will talk about this step by step;
  - Between the primitive atrium and the primitive ventricle there is one opening, this opening has to give a *right* AV canal which will give the **tricuspid** valve, and a *left* AV canal which will give **bicuspid** valve.
  - In the early stage this opening will be rounded, then it becomes transverse, and there are two projections that rise in the anterior and posterior walls, each projection is called an endocardial cushion.
  - These two projections will approach each other then unite, and because one of them is situated on the anterior wall and the other on the posterior wall, when they unite they will divide the opening into two openings; a left one, which becomes the opening between the *left* atrium and the *left* ventricle, and a right opening, which becomes the opening between the *right* atrium and the *right* ventricle.



  - This union of the two endocardial cushions will give a septum called **septum intermedium** which divides this one canal into two canals (openings) as discussed above.

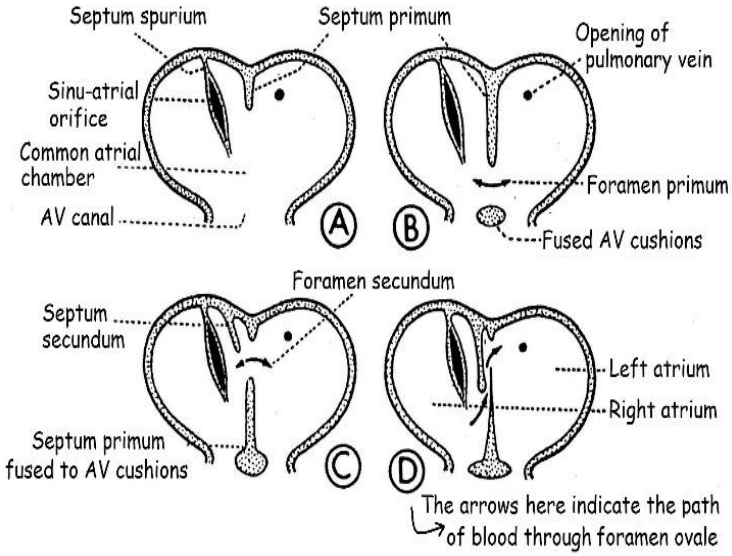
    Remember: The atrium in the fetus is above and behind the ventricle.

  To sum up
  Sinus venosus has two horns; right and left. The right horn will enlarge giving smooth posterior part of the right atrium, and the left horn will shrink giving most of the coronary sinus.

- But how does the primitive atrium divide into the right and left atria?
  (Remember that the anterior rough part of the right atrium is given by primitive atrium)

There is a septum called **septum primum** which descends from the roof of the primitive atrium to **septum intermedium** (the septum formed by the union of the two endocardial cushions to give right and left AV valves), but before septum primum unites with septum intermedium the posterior part of septum primum will break down. Why so?
Because in the fetus there must be a connection (opening) between the right and the left atria, and if septum primum united totally with septum intermedium then the atria can't communicate with each other. (This connection is a must because as we will see blood in the fetus will flow from the right atrium to the left atrium.)

After that, and to the right of septum primum there is another septum that will be formed which is called **septum secundum**, this one, unlike septum primum, doesn't reach septum intermedium.
- Between septum primum and secundum there is an opening which is called **foramen ovale** this opening remains during fetal life and doesn't close until birth.



- Nature of the two septa; primum and secundum:
  Septum primum is thin and can move to the right and left, for this it is called **flap valve** (because it moves in two directions), but septum secundum is thick. Why?
  - The ability of moving to right and left in septum primum is useful because in the fetus the blood will move from right atrium to the left atrium through foramen ovale, in this case septum primum won't resist the blood flow from the right to the left. After birth pressure in the left atrium becomes very high so it will push foramen primum to the right making it stick to septum secundum and therefore closing foramen ovale.
  - It is said that the valve of inferior venacava assists in the flowing of blood from the right atrium to left atrium through foramen ovale.
  - The lower end of septum secundum is called **crista dividens**.

- **Blood flow in the atria of the fetus:**
  From the placenta (highly oxygenated blood) → *Umbilical vein* → *Inferior vena cava* → Right atrium → *Foramen ovale* → *Left atrium* → *Left ventricle* → to the head and neck through the *aorta and its arches*
  Small amounts of blood mix with venous blood in the superior vena cava and flow from the right atrium to the right ventricle.

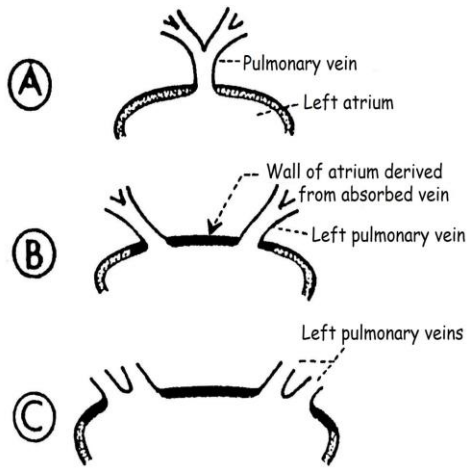
- **Summary of the formation of the right atrium:**
  Rough anterior part → from primitive atrium
  Smooth posterior part → from the right horn of sinus venosus

  What about left horn? It'll shrink and give most of the coronary sinus which opens in the right horn (in the right atrium later on).

Left atrium formation:

only the auricle is rough walled in the left atrium, which was formed from the primitive atrium. Notice that all the rough wall of both atria are formed by primitive atrium.

Now, the formation of the smooth part of left atrium:



- A **single pulmonary** vein rises from the wall of the left atrium then it will bifurcate into two branches, each one of these two branches will give another two branches, so now we have 4 terminal branches to the pulmonary vein. Now the single pulmonary vein and its bifurcation of veins will be reabsorbed in the wall of the left atrium making the main part of the left atrium, and only the 4 terminal branches will remain out of the wall.
  So, the smooth part of left atrium is formed by reabsorption of the pulmonary veins, except the terminal branches of it. In other words the pulmonary vein rises from wall of the left atrium then goes back to the same wall in which it arose from.

Ventricles formation:

- Bulbus cordis and the primitive ventricle are the two parts of the heart tube that participate in the formation of ventricles.

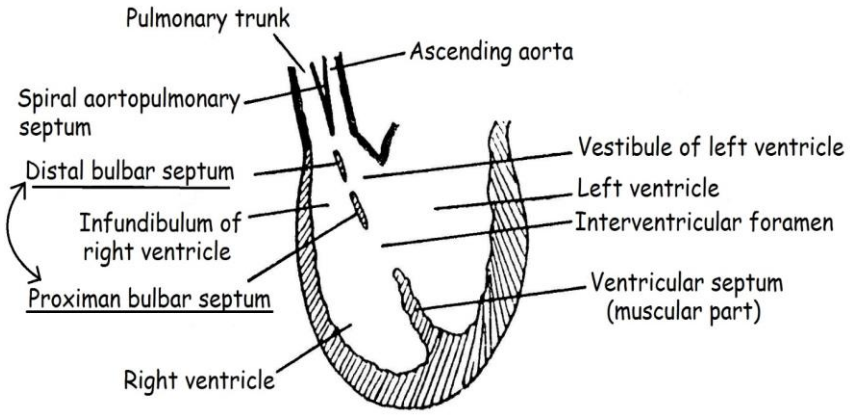
Initially, there is a sulcus separating bulbus cordis from the primitive ventricle, and bulbus cordis connects cranially (from above) with truncus arteriosus.

So, from caudal end to cranial end we have in order:
primitive ventricle → bulbus cordis → truncus arteriosus (which will later on give ascending aorta and pulmonary trunk)

- Now, a little bit later the sulcus between the primitive ventricle and ductus arteriosus disappears and they become a single chamber called *bulbo-ventricular chamber*. How does this chamber divide to give the two ventricles?

  - By seeing the coronal and sagittal sections –the picture in this page and the following one-, we can say that the first structure that appears to start the dividing process of ventricles is a *muscular* interventricular septum which arises from the floor of the primitive ventricle and ascends above (**ventricular septum**). This interventricular septum does not close totally, it will leave a small opening called the *interventricular foramen*. How is this foramen going to be closed?
    By two things, which are:
    1) **Septum intermedium** (endocardial cushions)
       This septum will be of the *membranous* part of the interventricular septum.
    2) **Proximal bulbar septum** (We will talk about it in a little bit)

- The membranous part of interventricular septum has two sides; anterior *interventricular* membranous septum, which separates the two ventricles, and the posterior *atrioventricular* septum, which separates the right atrium from the left ventricle.



- Why is this membranous part not purely interventricular?

- **1st** the septum primum and the membranous part do not attach to septum intermedium at the same level.
- **2nd** because septum primum is pulling septum intermedium upwards and the interventricular septum is pulling downwards these two septa will become on the same level, so when the septal cusp (cusp of tricuspid valve) attaches to the membranous interventricular septum its posterior part above the septal cusp becomes atrioventricular.

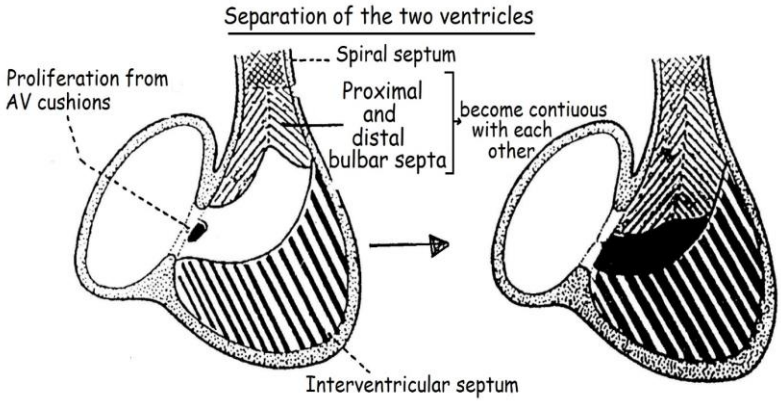
- Notice that the interventecular foramen closes before birth, unlike foramen ovale which closes after birth due to the high pressure in the left atrium.

- After the sulcus between the primitive ventricle and bulbus cordis disappear, distally in the bulbo-ventricular chamber the **proximal bulbus septum** will rise (which was 2 bulbus ridges that fused) and distal bulbus septum. The proximal bulbus septum participates in closing interventricular foramen. And also, this septum will divide the middle part of bulbus cordis into an *infundibulum* on right side, and *aortic vestibule* on the left side.

  What about the **distal bulbar septum**?
  It will divide the upper part of bulbus cordis into *pulmonary valve* on the right side and *aortic valve* on left side.

- But how is the rough part of left ventricle is formed?
  From the primitive ventricle.

To sum up in one sentence:
Bulbus cordis forms the whole two ventricles except for the lower rough part of the left ventricle which is formed by the primitive ventricle.



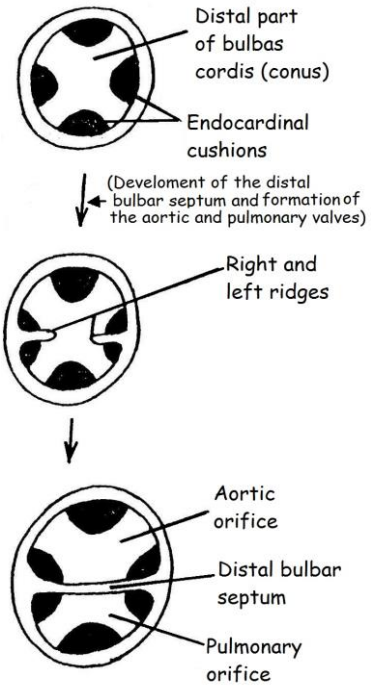
- Why does the membranous part of the interventricular septum has a greater chance to have congenital defects (openings) than the muscular part?
  As we said, membranous part of interventricular septum is formed by the

proliferation of two structures: septum intermedium as well as the proximal bulbus septum, so if any of these two structures does not proliferate in the right way there will be a defect in the membranous part of this septum. Unlike the muscular part that rises from one place, which is the floor of primitive ventricle.

- Note: any part of the body that is formed from more than one source will have a higher tendency to have any kind of defects than other body parts.
- Remember: the AV bundle is situated behind the membranous part of the interventricular septum.

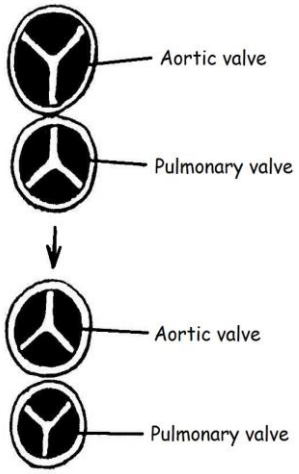
- **What happens if there is an opening in the membranous interventricular septum?**
  If the opening is small it will not pass blood between the two ventricles, but if it is a big opening it will pass blood from the left ventricle to the right ventricle (from the higher pressure to lower pressure), but this happens only during systole, why?
  Because during *systole* blood pressure in the left ventricle is 120 mmHg, and in the right ventricle it is 25 mmHg, so blood will pass from the high pressure to the lower pressure. While during *diastole* no blood will pass between ventricles even if there is an opening in the membranous part because during diastole the blood pressure in both ventricles is 0 mmHg (atmospheric), so there is no pressure gradient to push blood between the two ventricles.

- **How are the aortic and pulmonary valves formed?**
  - We said that these two valves formed by distal bulbar septum, but how?
    The distal bulbar septum will give rise to 4 endocardial cushions; anterior, posterior and two lateral cushions as you see in the picture to the right.
    Now the 2 lateral cushions will develop ridges in the middle of each one making a septum which divides the distal part of bulbus cordis into two orifices, one of them will become aortic valve and the other will become pulmonary valve. Each orifice has 3 cushions and will give semilunar valve (each cushion will give a cusp).



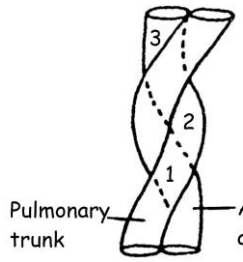
- As you can see, the pulmonary valve is situated anterior to the aortic valve in the fetus, and if you notice the positions of these two valves in a cadaver you will see that the beginning of the pulmonary trunk is anterior to the ascending aorta, then it will deviate to the left and then bifurcate under the arch of aorta (triple relation between pulmonary trunk and aorta).

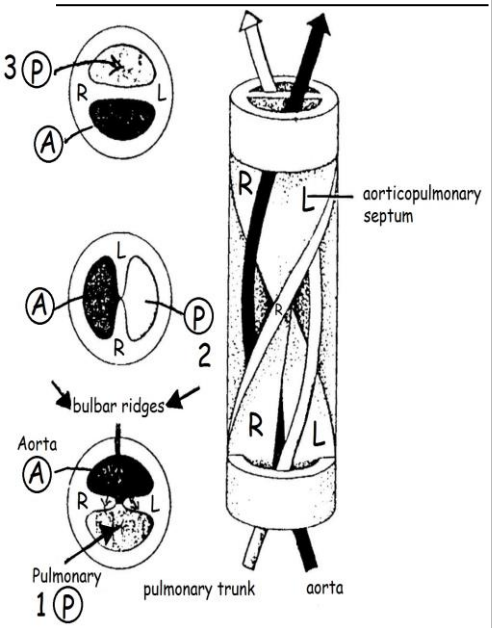
- **The order of cusps in each valve in the fetus:**
  In the *pulmonary* valve there are 2 posterior cusps and 1 anterior cusp, while the *aortic* has 1 posterior and 2 anterior cusps. This is in the early stage of fetal life, but later rotation of this part of the heart tube will take place so the picture will interchange resulting in a *pulmonary* valve with 1 posterior cusp and 2 anterior cusps and an *aortic* valve with 2 posterior cusps and 1 anterior.
  Each cusp of these has a bulge called **sinus**, these sinuses have a clinical importance since:
  - From the anterior aortic sinus the *right coronary artery* rises.
  - From the left posterior aortic sinus the *left coronary artery* will arise.



Truncus arteriosus:

Truncus arteriosus is the uppermost part of the heart tube. Initially, there are two projections rising in the wall of truncus arteriosus making a septum that separates the pulmonary trunk from the aorta, we will follow these projections from the lower part of truncus arteriosus to its upper part as follows:





I. In the lower part these two projections rise on left and right sides and they stick with each other making a septum, which is called **aorticopulmonary septum** (the septum in this region is transverse).

II. In the middle part they rotate, so the right one becomes anterior and the left one becomes posterior (the septum becomes longitudinal).

III. Then in the upper part they return again as they were in the lower part as left and right

(the septum becomes transverse again).
So, the septum of truncus arteriosus is spiral and never straight.

This is logical somehow because as you know, the *pulmonary trunk* arises from the **right ventricle**, and the *aorta* from the **left ventricle**. So, if the septum is straight (*transposition of great vessels*) then the pulmonary will rise from the left ventricle and the aorta from the right ventricle, and this condition is incompatible with life, unless there is an opening between the two ventricles to mix the arterial with the venous blood as this will interfere with the gas exchange and oxygen tension in the blood, in this way the oxygenated blood from the left ventricle will go to the lungs through pulmonary trunk, and deoxygenated blood from the right ventricle will go to the peripheral tissues through the aorta and its branches.
Also, this spiral form explains the *triple relation* between the aorta and the pulmonary trunk which we talked about previously.

THE END
I apologize for any mistake
hope the best for all of you ☺

This sheet has been corrected and edited