

CARDIOVASCULAR SYSTEM

SUBJECT : Anatomy

LEC NO. : Lecture 5

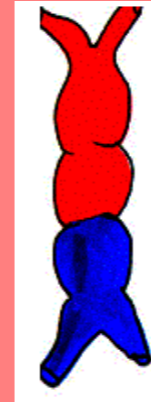
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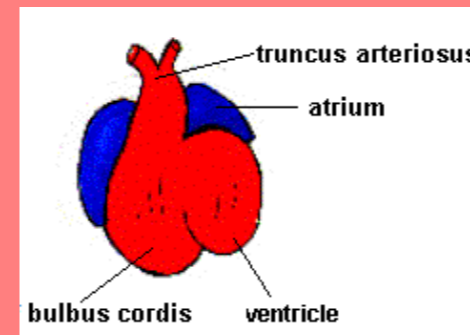
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SCAN ME!

Development of the Cardiovascular System



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(2024)



Highlights

❑ *The cardiovascular system is the first major system to function in the embryo.*

❑ The primordial heart and vascular system start to develop in the middle of the third week of development.

لما أقول ال adult forms معناها في form قبلها يعني القلب يأخذ أشكال مختلفة قبل ما يأخذ شكله الاعتيادي

❑ The heart begins to beat about day 22 or 23. The adult form of the heart is obtained by the 8th week.

Why dose the cardiovascular system get to development early ?

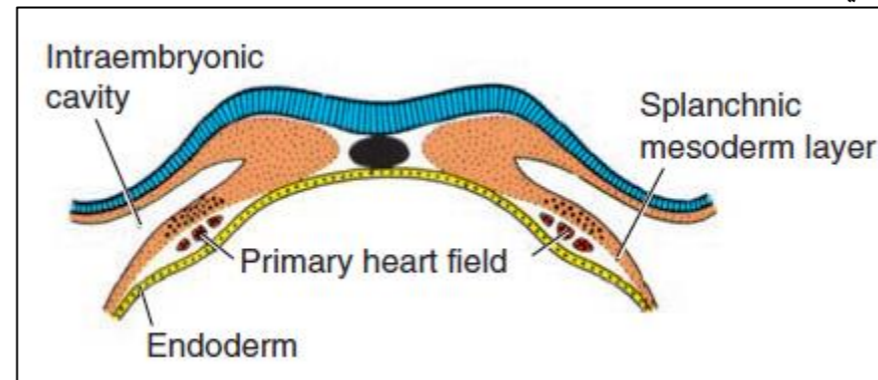
❑ *This early development is necessary because the rapidly growing embryo can no longer satisfy its nutritional and oxygen requirements by diffusion alone.*

Development of the Heart

- ❑ Mesodermal cells derived from the primitive streak form a crescent-shaped region in the splanchnic layer of the lateral mesoderm. This is called the *primary heart field*.
- ❑ Later in the third week, cells from the pharyngeal mesoderm and some cells from the neural crest will form the *secondary heart field* just medial to the primary.

الأزرق ال ectoderm
الأصفر ال endoderm
البنى ال mesoderm

Fig.1: Cross-section through embryo showing site of heart formation.



- ❑ Which part of the heart these cells will form is already determined at this early stage. In the embryo, this is controlled by *retinoic acid*. The right-left sidedness (laterality) is controlled by a complex pathway that involves *serotonin*.

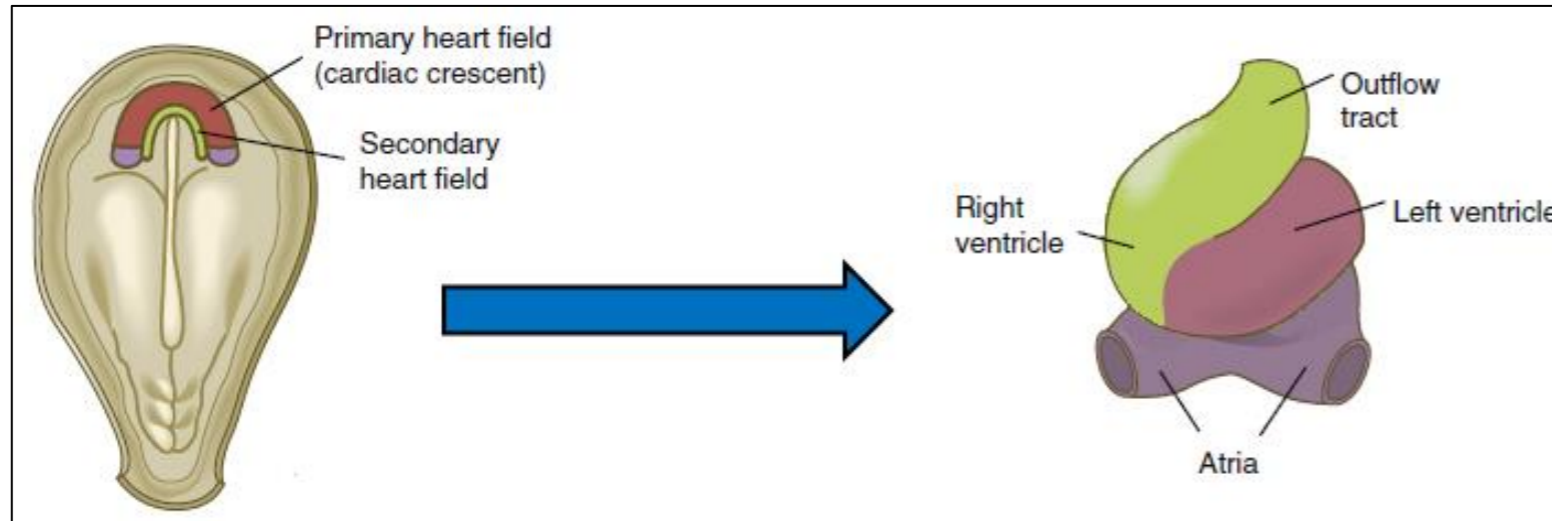


Fig.2: Heart fields and the parts of the heart they form.

Clinical Correlation

- Drugs based on retinoic acid (like some used for treating acne), may cause congenital heart disease if taken by a pregnant woman.

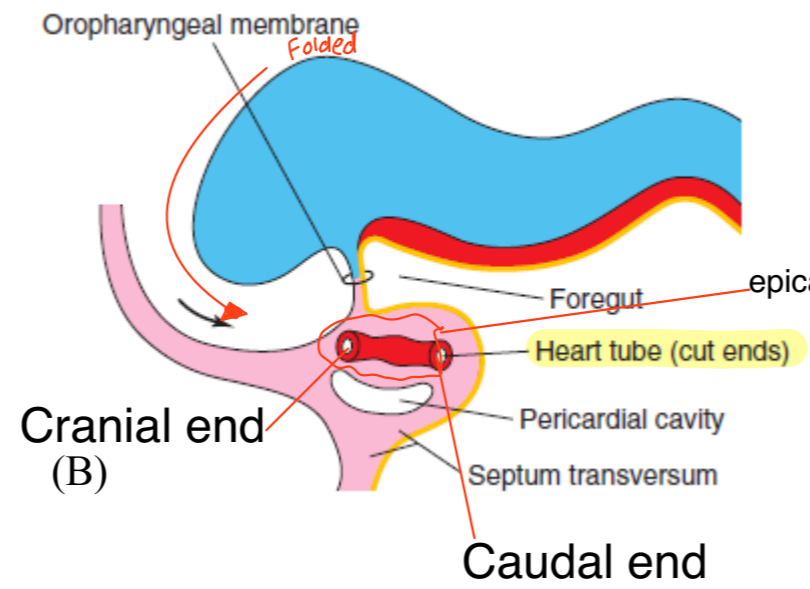
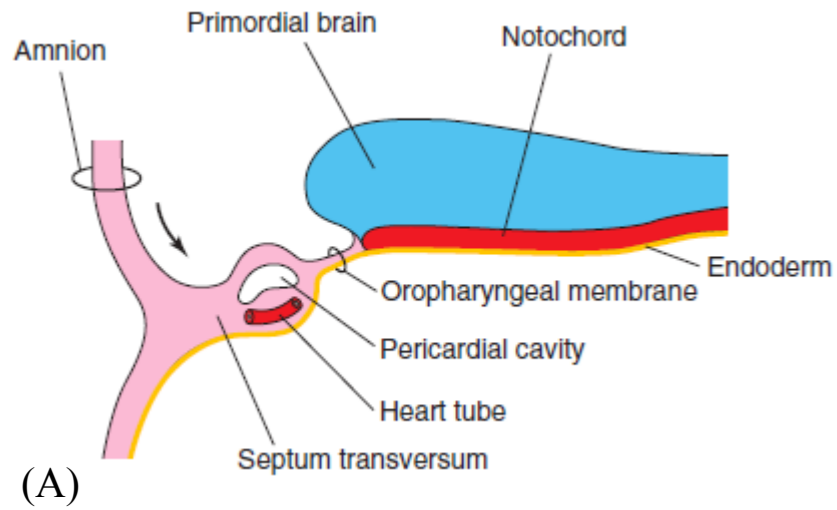
The Heart Tube

- ❑ By vasculogenesis, the heart field will be converted into two endothelial-lined tubes in the splanchnic layer of the lateral mesoderm, one on each side. These *heart tubes* will form the endocardium of the heart.
- ❑ Nearby mesodermal cells will form the *primordial myocardium* around the endothelial heart tubes. This myocardium will release a gelatinous-matrix connective tissue, the *cardiac jelly*, that separates it from the endothelial tube.
- ❑ Mesothelial cells covering the inflow and outflow tracts of the tubes move over the heart tubes to form the *epicardium*.
- ❑ Thus the heart wall is formed of three layers: endocardium, myocardium, and epicardium all derived from mesoderm.

في هاي الحالة اصبح جدار القلب يتكون من ثلاث طبقات endocardium and myocardium and epicardium كل هاي الطبقات من ال mesoderm

- ❑ The heart tube is initially located cranial to the neural tube and the oropharyngeal membrane. As the brain grows and the embryo folds, the heart tube will assume its position ventral to the foregut, caudal to the oropharyngeal membrane (Fig.3).
- ❑ Lateral folding of the embryo will bring the two heart tubes together ultimately resulting in their fusion (except the cranial ends). Thus a single heart tube is formed (Fig.4).
- ❑ The heart tube bulges more and more into the nearby intraembryonic cavity, the *pericardial cavity*. However, it remains attached posteriorly by a *dorsal mesocardium* (Figs.4d and 5a). Later on, this mesocardium disappears forming the *transverse pericardial sinus* (Fig.5). Thus the heart tube becomes suspended in the pericardial cavity by the vessels at its cranial and caudal ends.

القلب يكون فوق العقل والفم لكن في الأسبوع الرابع يحدث يصبير long two axes cranial and caudal and lateral
 This will move the heart becomes located ventral to the foregut and caudal to the oropharyngeal membrane
 الآن اصبح القلب أمام المريء وتحت الفم



حولين ال heart tube يوجد خلايا mesothelomas cells سوف تغطيه لتكوين ال epicardium

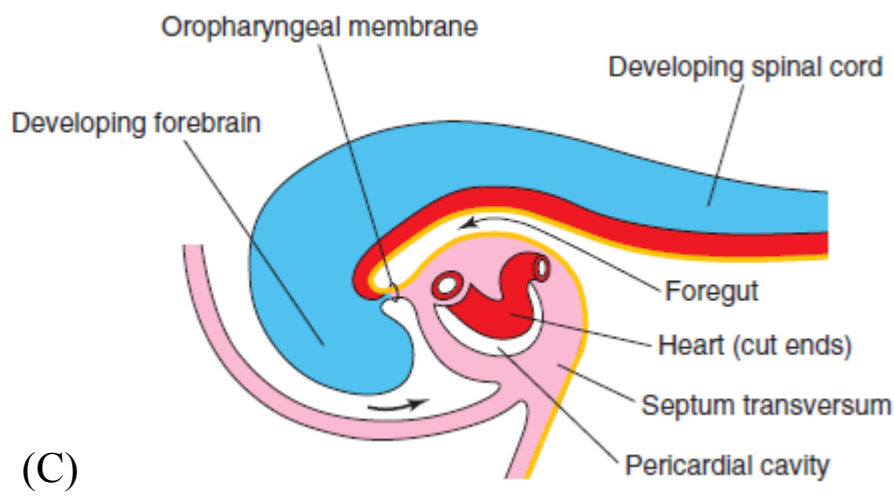
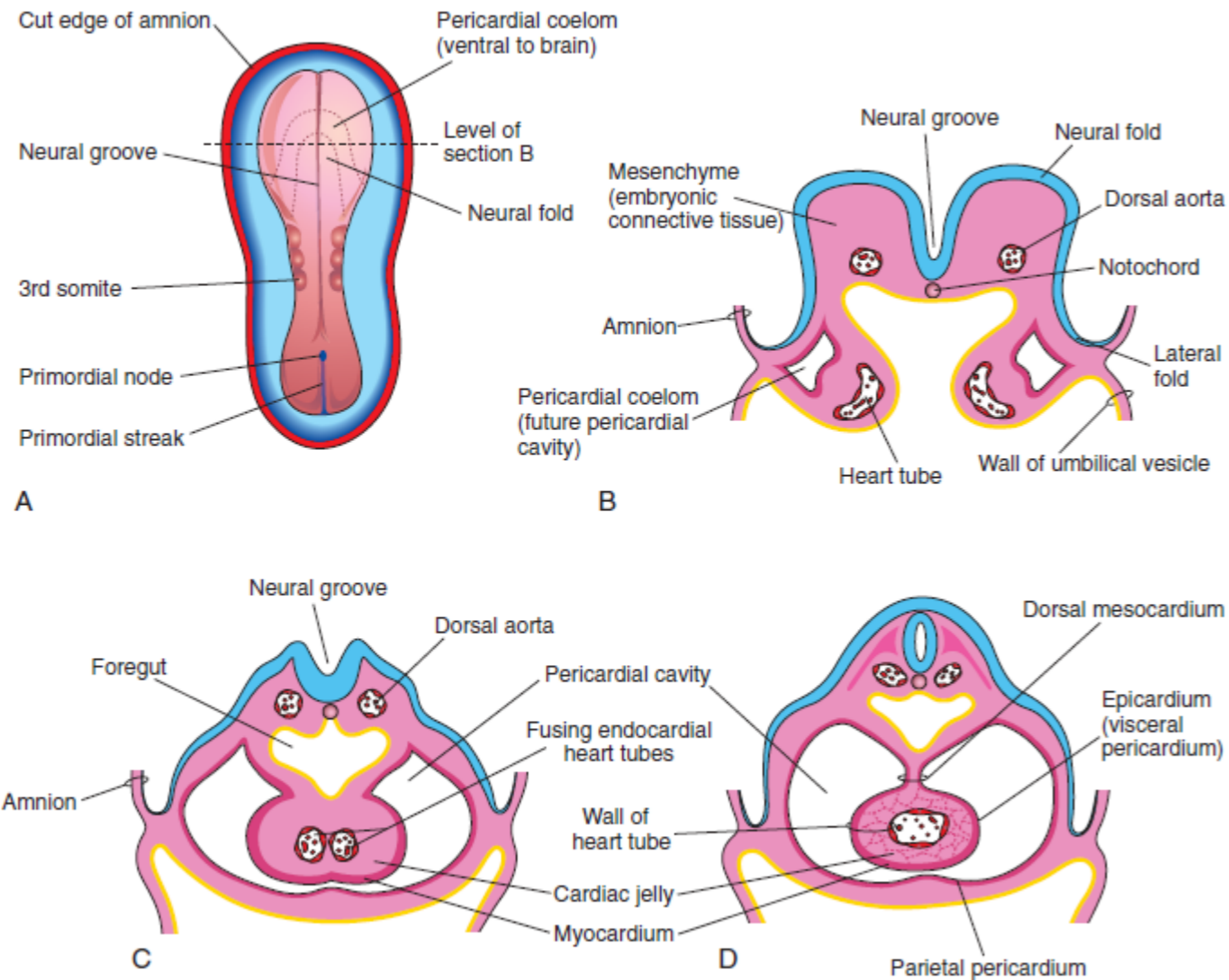


Fig.3: Longitudinal sections through the cranial part of the embryo during the fourth week, showing the effect of the head fold (arrows) on the position of the heart and other structures.



هذا جزء من intraembryonic coelom الذي هو
 pericardium cavity الذي بصير ال heart tube
 fusion and pericardial cavity fusion بعد ما
 يتحدوا القلب يدخل في داخل ال pericardium
 cavity ونلاحظ انه القلب معلق داخل ال
 pericardium cavity by dorsal
 mesocardium

Fig.4: A, dorsal view of embryo showing level of the sections. B-D, cross-sections through the embryo showing the effect of lateral folding on the development of heart tubes.

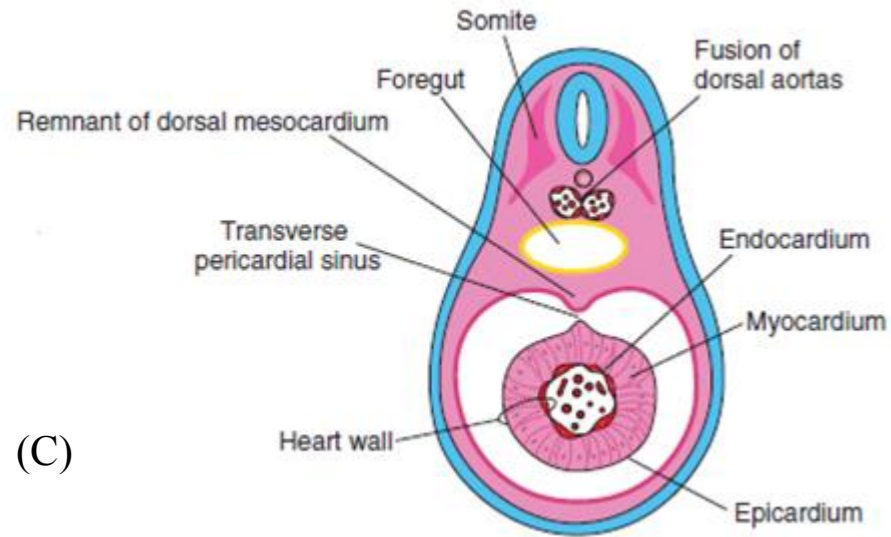
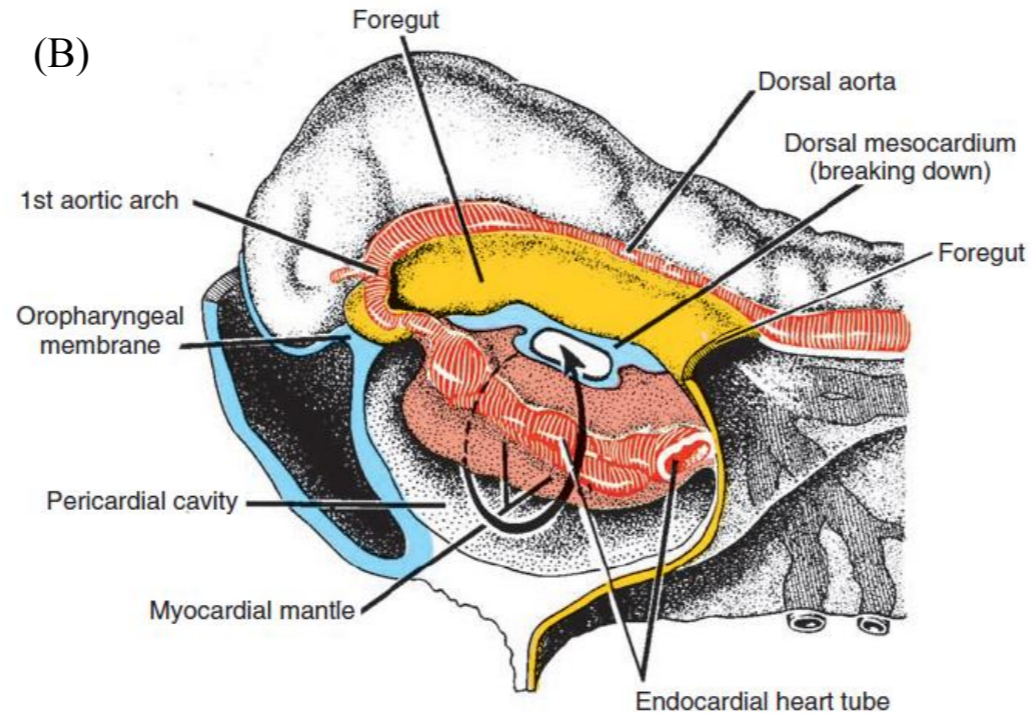
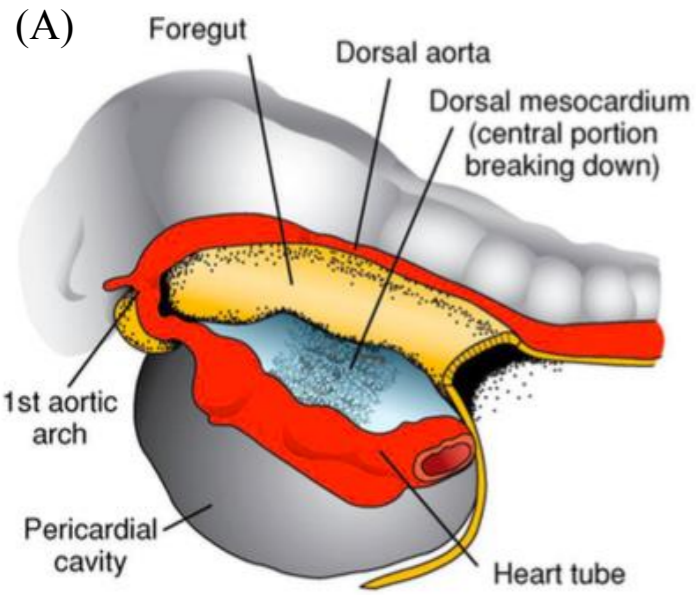


Fig.5: A and B, cranial part of the embryo showing the dorsal mesocardium and the transverse pericardial sinus. C, cross section through the embryo; note how the two halves of the pericardial cavity communicate through the transverse sinus.

□ The straight heart tube will elongate and develop a series of dilation and constrictions (Fig.6).

□ These dilations are (cranial → caudal):

1. Bulbus cordis (3 parts)
 - a. Truncus arteriosus
 - b. Conus cordis
 - c. Part of right ventricle
2. Ventricle
3. Atrium
4. Sinus venosus The most caudal

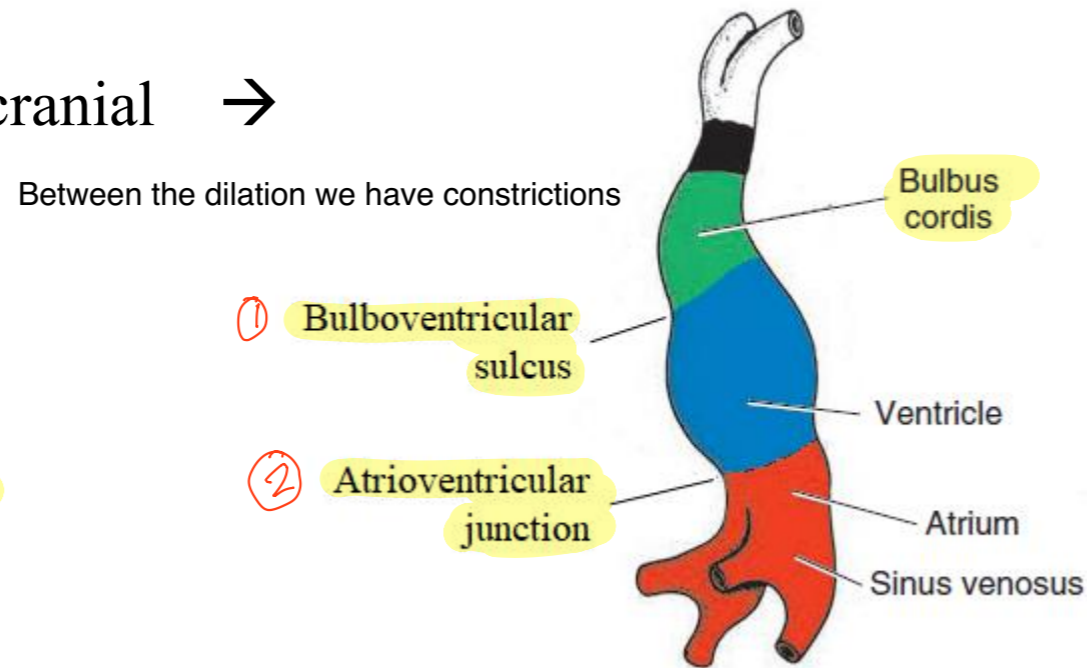


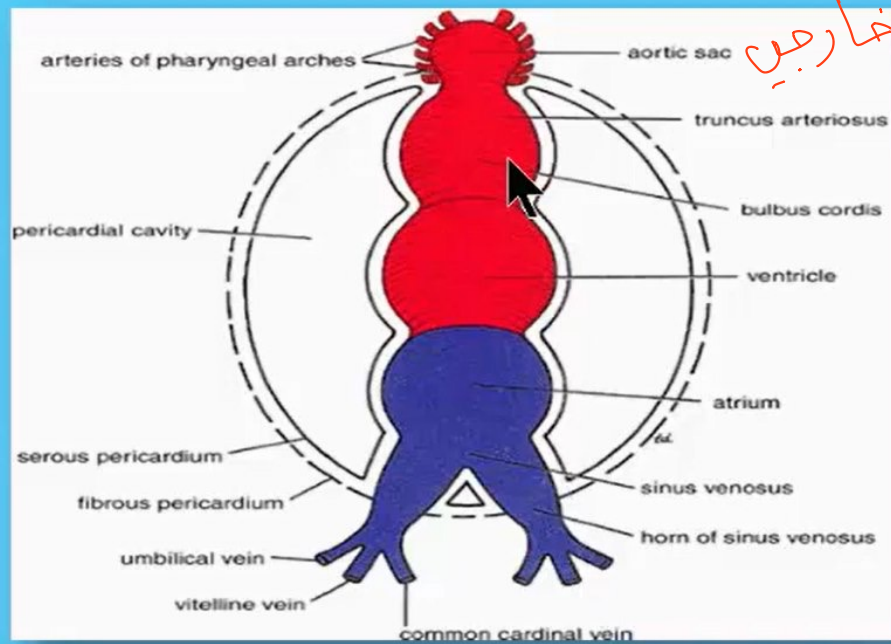
Fig.6: The heart tube and its parts.

□ The truncus arteriosus is attached to the *aortic sac* which gives rise to the pharyngeal arteries. The sinus venosus receives the common cardinal, vitelline, and umbilical veins.

Table 1: Derivatives of the various parts of the heart tube.

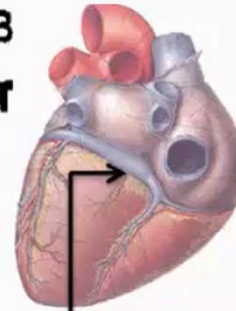
	Dilation		Derivative
1	Bulbus cordis	Truncus arteriosus	Proximal parts of the aorta and the pulmonary trunk
		Conus cordis	Outflow tracts of the right ventricle (RV) and left ventricle (LV)
		Proximal third of the bulbus	Trabeculated part of the right ventricle
2	Ventricle		Trabeculated part of the left ventricle
3	Atrium		Trabeculated part of the right atrium (RA) and left atrium (LA)
4	Sinus venosus		<ul style="list-style-type: none"> • Smooth part of the right atrium • Venous derivatives

Development Of the heart chambers



The heart tube shows 5 dilatations:

sinus venosus **S**
 Common atrium **A**
 common ventricle **V**
 Bulbus cordis **B**
 Truncus arteriosus **T**



Embryonic Dilatation	Adult Structure
Sinus venosus ↗ Rt. hom ↘ Lt. hom	-Smooth part of right atrium -Coronary sinus
Common atrium	-Rough part of right atrium (anterior wall + Rt. Auricle) -Rough part of left atrium (Lt. Auricle)
Common ventricle	-Rough part of right ventricle -Rough part of left ventricle
Bulbus cordis	-Smooth part of right ventricle (infundibulum) -Smooth part of left ventricle (vestibule)
Truncus arteriosus	-Ascending aorta -Pulmonary trunk

Looping of the Heart Tube

- ❑ The cranial (arterial) end of the heart is fixed to the pharyngeal arches and the caudal (venous) end is fixed to the septum transversum. The bulbus and the ventricle grow more rapidly than the other parts of the tube. Because of these reasons, the tube will bend on itself forming the U-shaped bulboventricular loop (Figs.7 and 8).

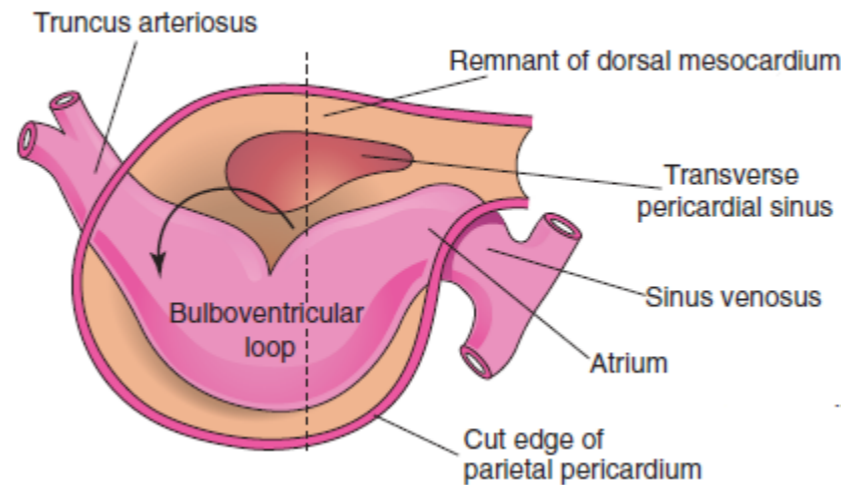


Fig.7: The bulboventricular loop.

cranial we have artery pass ال الجزء في heart tube ال في
structure تتكون في ال مجموعة من ال to pharyngeal arches
head and neck ال وهذول ال arches الها arteries الي هي
heart tube من الجزء العلوي من
caudal end receives veins these veins pass through ال
the diaphragm
شو يعني هذا الكلام انه الجزء العلوي والسفلي ثابتات في موقعهم

□ With further growth, the cranial part of the tube moves ventrocaudally and to the right; whereas the caudal part moves dorsocrainally (Fig.9). يعني الجزء العلوي ينمو للأمام ولأسفل ولليمين والجزء السفلي للخلف وللأعلى

□ The atrium is initially outside the pericardial cavity. With looping, it becomes inside. The sinus venosus develops two extensions, the *sinus horns*.

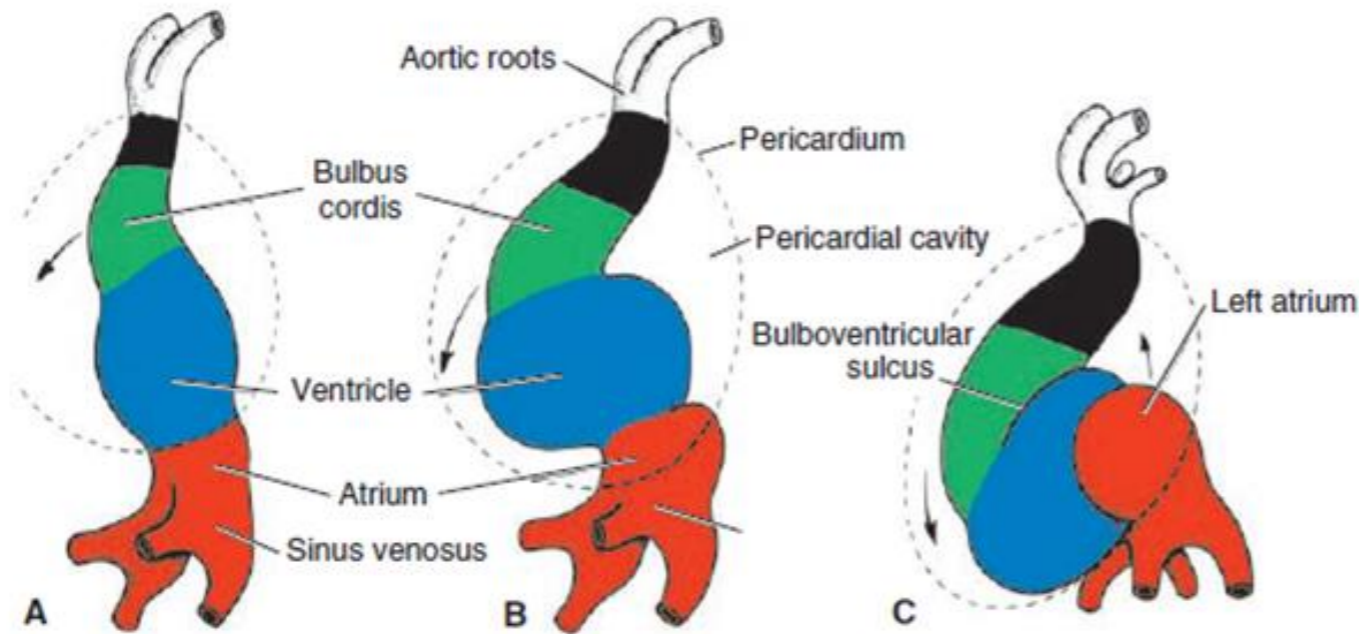


Fig.8: The looping of the heart tube.

When the heart was a simple straight tube it's started to beat

- ❑ Looping of the heart starts on day 23 and ends by day 28.
- ❑ Between the bulbus and the ventricle, there's a groove on the outside called the *bulboventricular sulcus* corresponding to a narrow *primary interventricular foramen*. The ventricular and atrial dilations are connected to each other by the narrow *atrioventricular (AV) canal*.
- ❑ After looping of the tube, trabeculae start to appear around the bulboventricular sulcus. The trabeculated ventricular dilation is now called the *primitive left ventricle*. Similarly, the trabeculated proximal third of the bulbus is now called the *primitive right ventricle* (Fig.9).

الي صار انه الأطراف ثابتة ما بقدر ينمو في الطول الي بصير إنها بتنمو وبتتحنى فال Bulbus cordis كانت في الأعلى فنزلت للأسفل وتحركت للأمام واتجهت لليمين إذا ال proximal part يمثل ال right ventricle بينما المجاور لها راح يكون ال left ventricle

ال caudal end هي تعتبر ال atrium راح تتحرك للأعلى وللخلف فالمحصلة النهائية ال atrium superior and the ventricles inferior هذا ال looping يصير تحت سيطرة ال serotonin

In dextrocardia, the heart is positioned on the right side of the chest instead of its normal position on the left side. Dextrocardia on its own does not usually cause problems, but it tends to occur with other conditions that can have serious effects on the heart

Situs inversus is a rare genetic condition in which the organs in your chest and abdomen are positioned in a mirror image of normal human anatomy

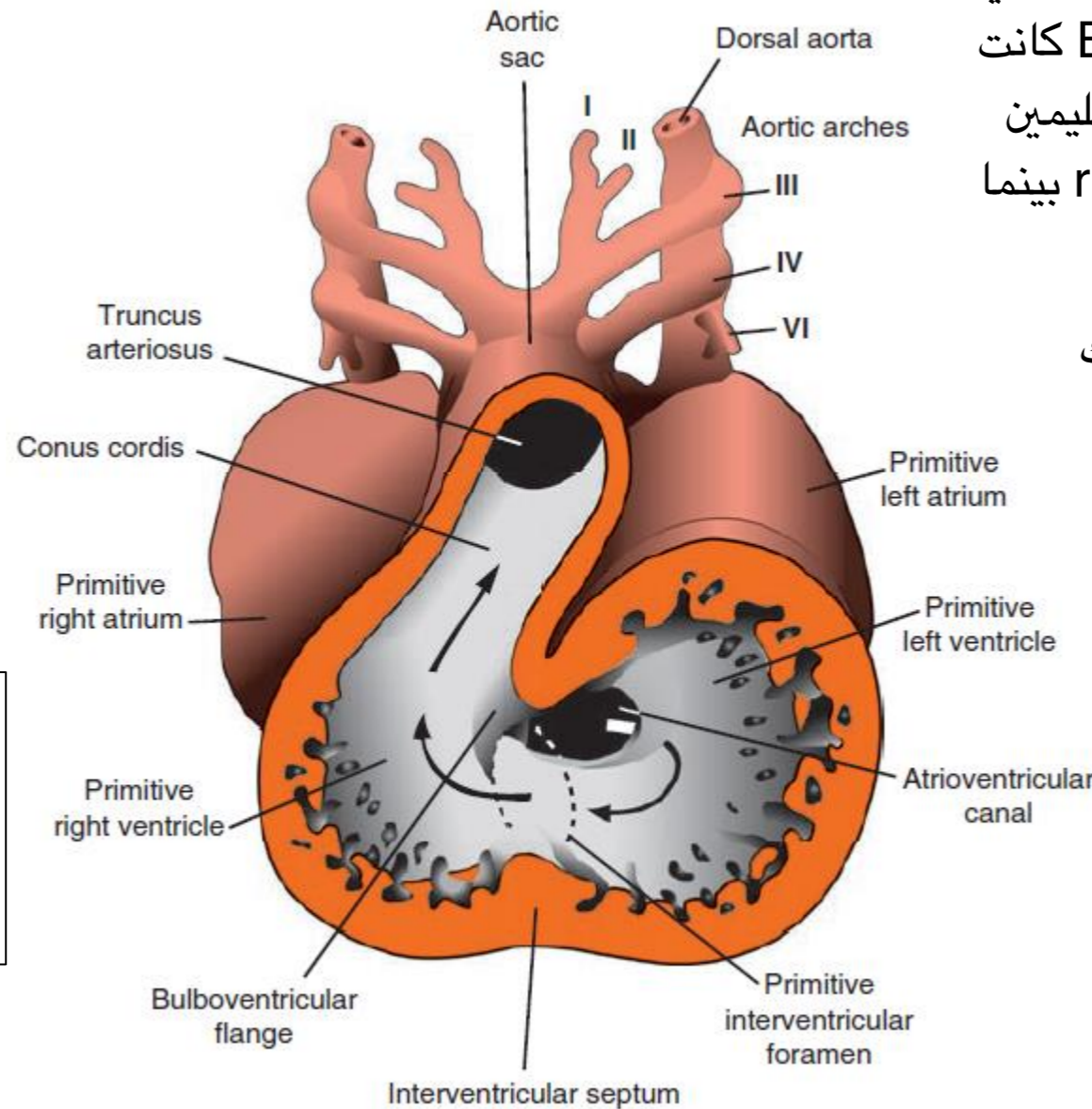
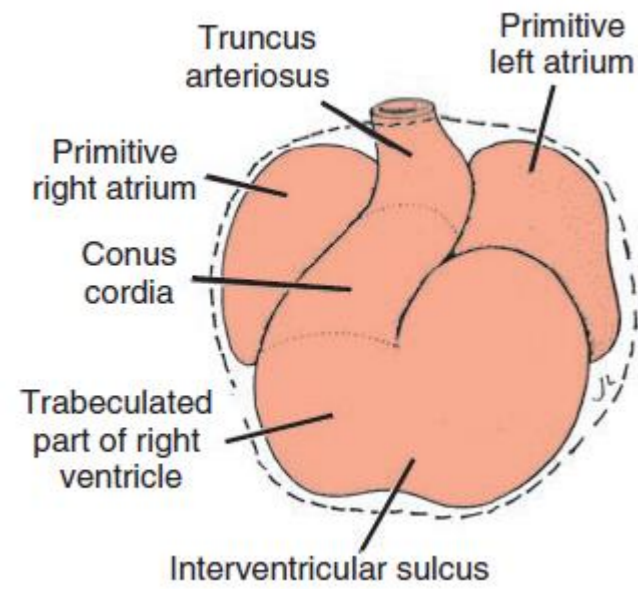


Fig.9: Above, the heart after looping. Note how the atria became posterior. Right, the same as above but sectioned to show the trabeculae in the ventricles.

Partitioning of the Atrioventricular Canal

- ❑ During the fourth week, atrioventricular endocardial cushions appear on the dorsal and ventral walls of the atrioventricular canal (Fig.10)
- ❑ These cushions meet and fuse with each other forming the *septum intermedium* dividing the atrioventricular canal into right and left halves.
- ❑ These cushions are made of extracellular matrix released by the myocardium (cardiac jelly) and neural crest and mesenchymal cells.

اول اشبي ال atrioventricular canal بتكون
 كبيرة وفاتحة بين ال atrium
 and ventricle

هسا في two cushions to out grow from
 ventral one from middle start to grow in
 atrioventricular canal and they grow to
 each other and tell fuse in the middle to
 form a complete septum in the middle of
 atrioventricular canal

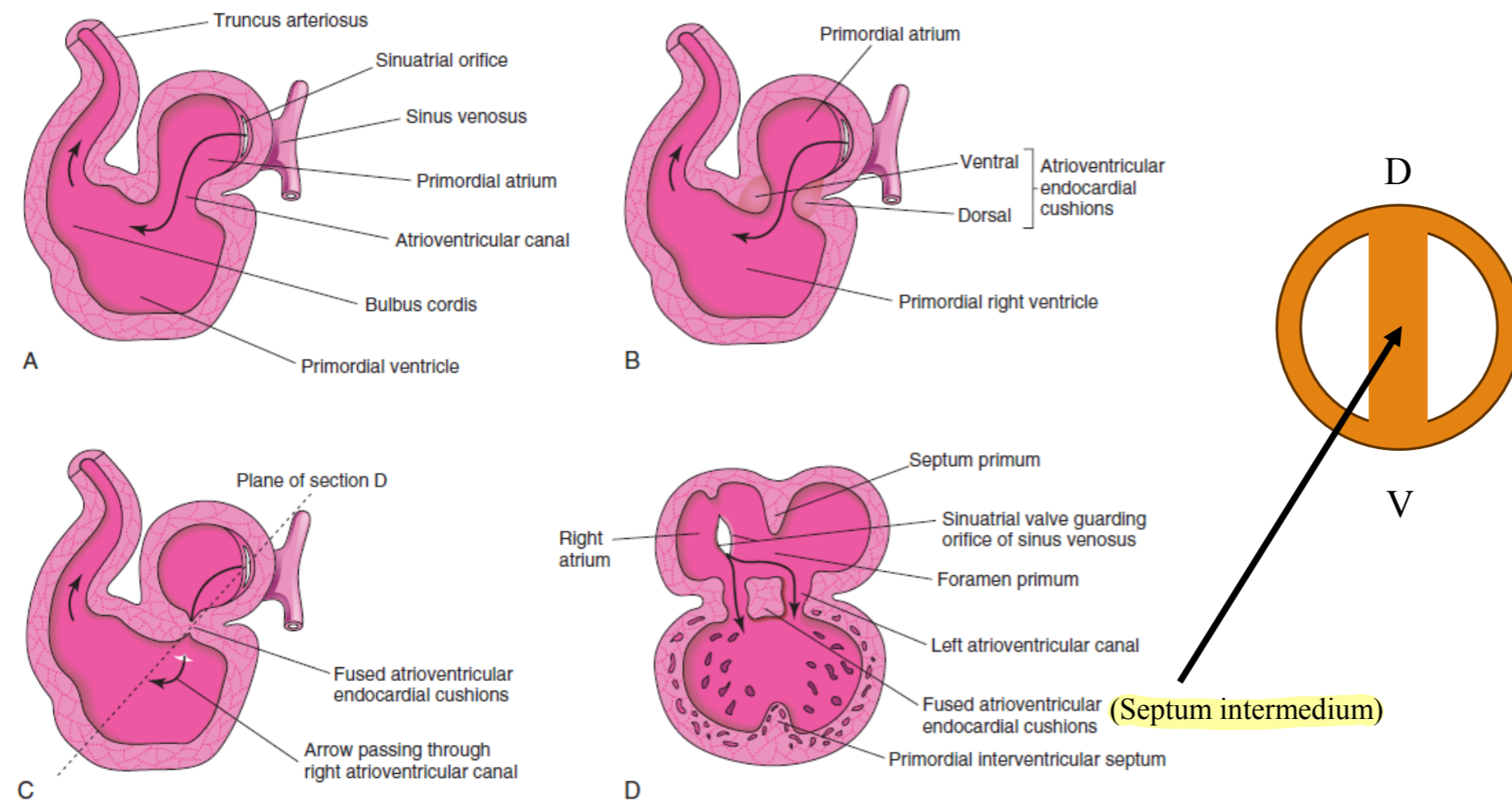


Fig.10: A-C, sagittal sections through the heart showing the partitioning of the atrioventricular canal. D, Coronal section through the heart showing the two atrioventricular orifices. The animated diagram to the right shows this process.

Formation of the Interatrial Septum

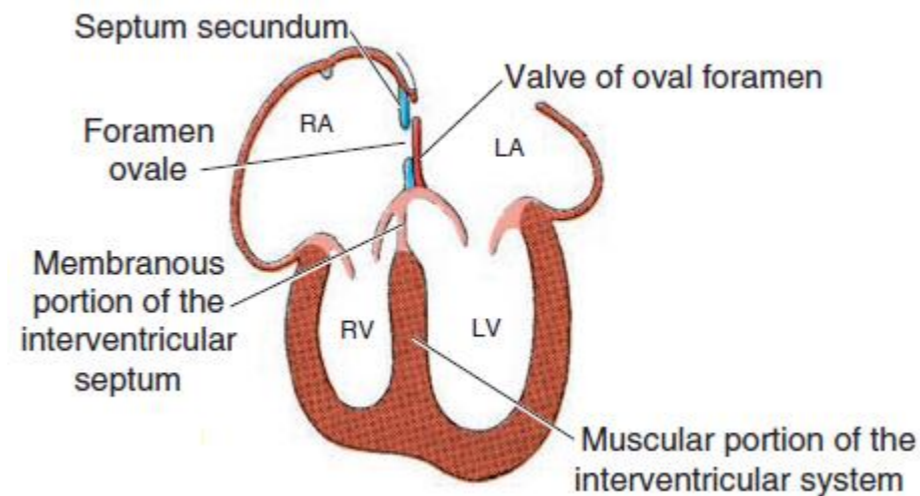
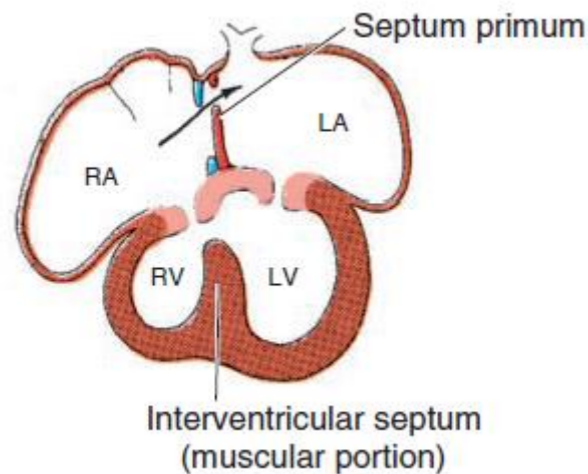
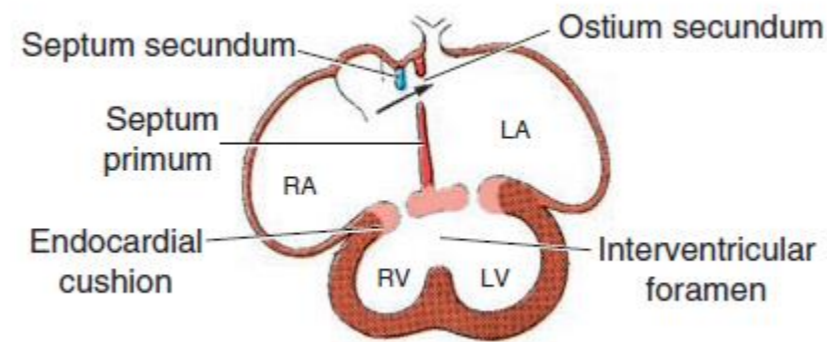
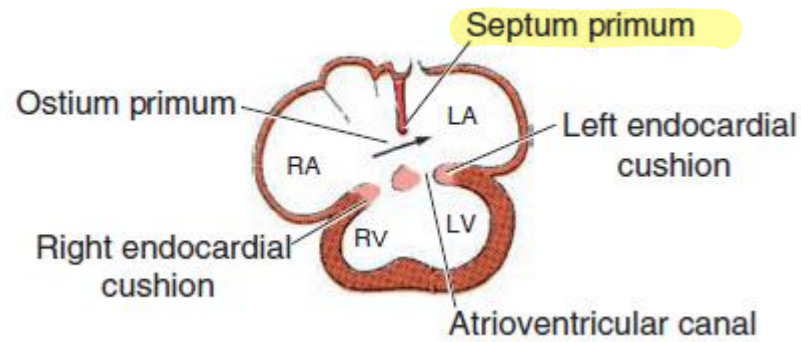
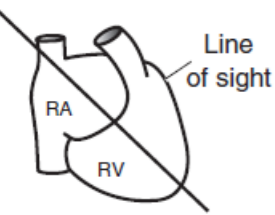
- ❑ The primordial atrium is divided into right and left atria by the formation, and subsequent modification and fusion, of two septa: the septum primum and septum secundum (Figs.11 and 12).
- ❑ The thin, crescent-shaped *septum primum* grows toward the fusing AV endocardial cushions from the roof of the primordial atrium.
- ❑ As the septum primum grows, a large opening, the *ostium primum*, is located between its free edge and the endocardial cushions. This foramen shunts oxygenated blood from the right to the left atrium. The foramen becomes progressively smaller and disappears as the septum primum fuses with the fused AV endocardial cushions.

- ❑ Before the ostium primum disappears, perforations appear in the central part of the septum primum. As the septum fuses with the endocardial cushions, these perforations fuse to form another opening in the septum primum, the *ostium secundum*, which ensures continued shunting of oxygenated blood from the right to the left atrium.

- ❑ The thick *septum secundum* grows from the the right atrium, immediately adjacent to the septum primum. As this septum grows, it gradually overlaps the ostium secundum in the septum primum. The septum secundum forms an incomplete partition between the atria leaving a foramen called the *foramen ovale*.

- ❑ The cranial part of the septum primum gradually disappears. The remaining part of this septum, attached to the fused endocardial cushions, acts as a valve for the foramen ovale.

Fig.11: stages of interatrial septum formation.



نلاحظ إلى حد الآن ما في عندي تقسيم ال atrium واحده وال ventricle وحدة بعدين يصير outgrowth from the roof of the primordial atrium towards AV cushions

نلاحظ ال septum primum من ما حد ما يتكون يوجد فراغ بين ال lower part of ال AV cushions وال primium اسميه ostium primum من خلال هذه الفراغ الدم ينتقل من الجهة اليمنى إلى اليسارى

بعدين ال septum primum continue to grow and fuse to AV cushions هاي الحالة ال ostium primum closed but before it closed it will appear a gap in septum primum it's called ostium secundum now the blood shunted through stium secundum

- ❑ Before birth, the foramen ovale shunts oxygenated blood from the right to the left atrium. The valve of the foramen (septum primum) prevents the returning of blood in the opposite direction.
- ❑ After birth, the pressure in the left atrium becomes higher pressing the septum primum against the septum secundum leading to their subsequent fusion and closure of the foramen ovale. The site of the foramen ovale is indicated in the heart by a depression called the *fossa ovalis*.

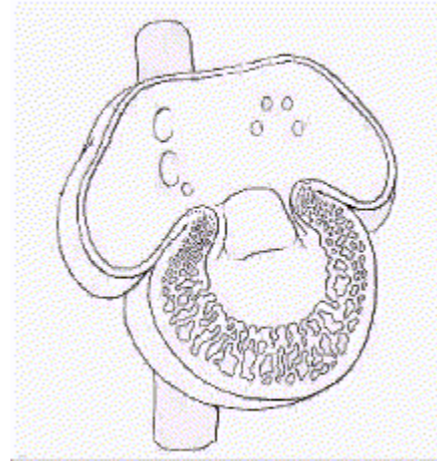


Fig.12: Animation showing interatrial septum formation.

Changes in the Sinus Venosus and Right Atrium

The most caudal

□ The sinus venosus has two extensions, the right and left sinus horns. On each side, they receive venous blood through the:

1. **Common cardinal vein** (formed by union of anterior and posterior cardinal veins) from the body of the embryo.
2. **Vitelline vein** from the umbilical vesicle.
3. **Umbilical vein** from the placenta. It's oxygenated blood

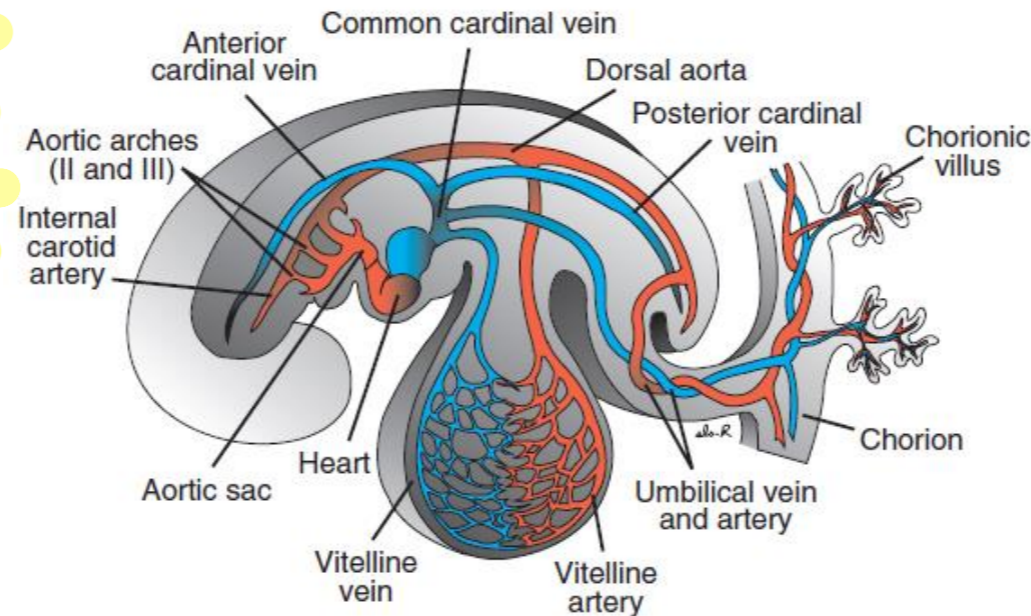


Fig.13: Veins draining into the heart of a 4-week old embryo.

تعرفون في جسم الإنسان ال
venous blood ينقلوا الدم الى ال
SVC AND IVC في الاذنين الأيمن
في الجنين يتكون في التساوي في
الجهة اليمنى و اليسارى لكن عملية
التطور ينتقل من اليسار إلى اليمين

- ❑ At first, communication between the sinus and the atrium is wide. Soon, however, this entrance shifts to the right. This is caused by left-to-right shift which occur in the venous system during development.
- ❑ As a result of this shift, the *left sinus horn* and its tributaries will lose their importance. Eventually, all that remains of the left sinus horn is the *oblique vein of the left atrium* and the *coronary sinus* (Fig.14).
- ❑ The *right sinus horn*, on the other hand, will enlarge and becomes incorporated into the right atrium forming its smooth-walled part, the *sinus venarum*, which is separated from the trabeculated part by a ridge called the *crista terminalis*.

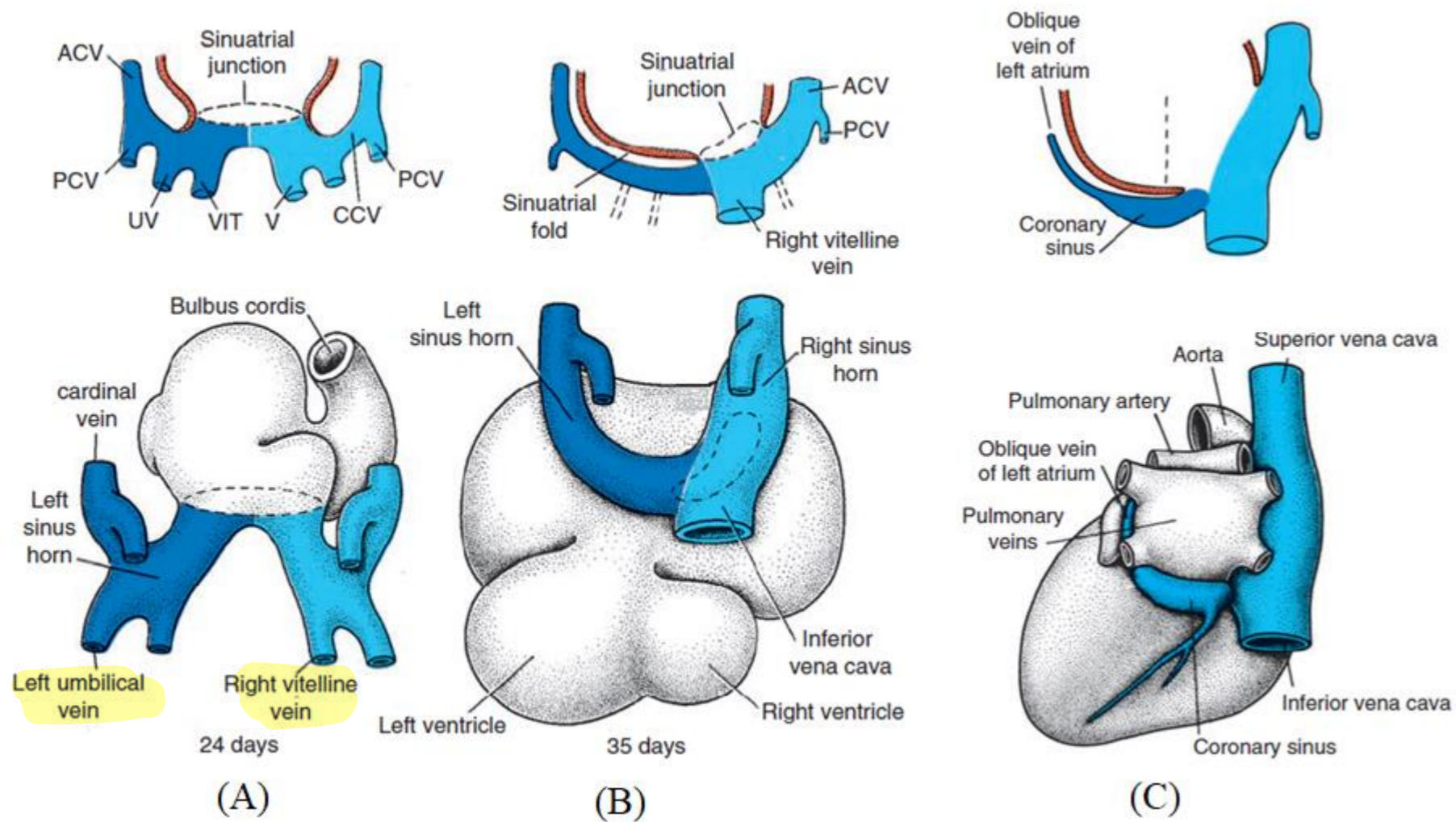


Fig.14: Dorsal view of various stages in the development of the sinus venosus. ACV, anterior cardinal vein; PCV, posterior cardinal vein; CCV, common cardinal vein; VIT V, vitelline vein; UV, umbilical vein.

نلاحظ انه ال left sinus horn راح يبدأ
 يصغر شوي شوي إلى ان
 all that remains
 of the left sinus horn a coronary
 sinus of the heart and oblique vein
 of the left atrium
 بالأول كانوا نفس الحجم لكن اليسار راح
 يختفي

- ❑ The opening of the right sinus horn into the atria, the *sinuatrial orifice*, is guarded by the right and left venous valves. Dorsocranially, the valves fuse forming a ridge known as the *septum spurium* (Fig.15a).
- ❑ Initially the valves are large, but when the right sinus horn is incorporated into the wall of the atrium, the left venous valve and the septum spurium fuse with the developing atrial septum.
- ❑ The superior portion of the right venous valve disappears entirely. The inferior portion develops into two parts: (1) the valve of the inferior vena cava and (2) the valve of the coronary sinus (Fig.15b).

Changes in the Left Atrium

- A single pulmonary vein arises from the dorsal wall of the atrium just to the left of the septum primum. As the atrium expands, the primordial pulmonary vein and its main branches are incorporated into the wall of the left atrium. As a result, four pulmonary veins and the smooth part of the left atrial wall are formed (Fig.16).

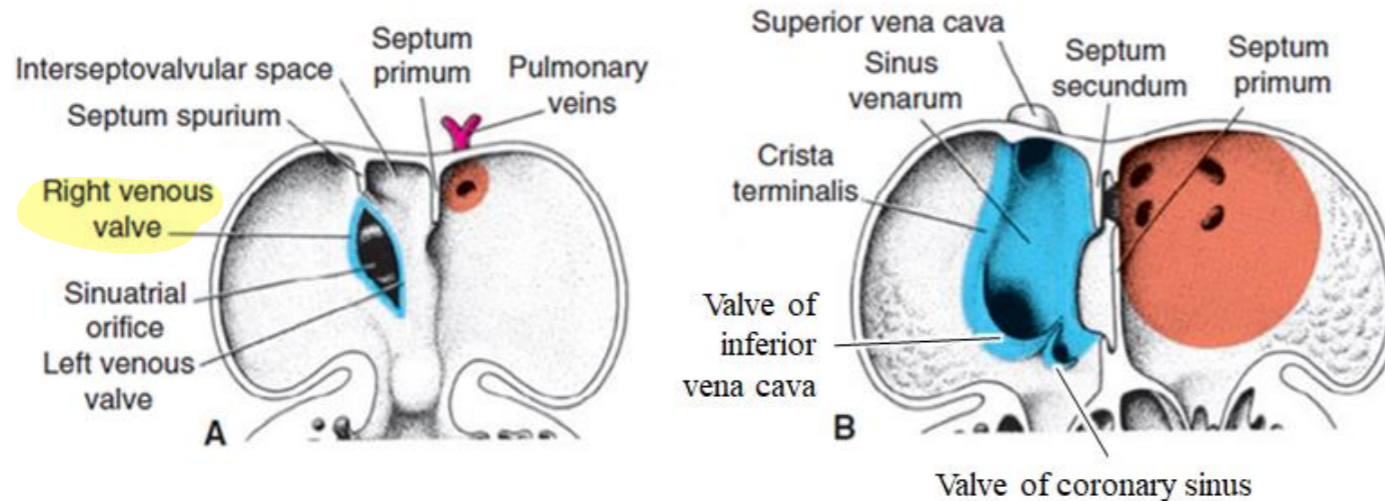


Fig.15: Coronal sections through the heart showing the development of the smooth-walled portions of the right and left atria.

فتحة في الجدار الخلفي للأذين الأيمن لها left valve and right valve the two valve meet each other cranially to form septum spurium
 اول اشئ كانت فتحة صغيرة لكن تدريجيا ال right sinus horn راح يدخل داخل ويصبح جزء من الاذين الأيمن

وريد واحد يدخل داخل ال left atrium هذا الوريد الواحد تجيله أربع أوردة اثنين من الين واثنين من اليسار to drain in a single pulmonary vein and this vein opens in left atrium however with growth of the left atrium more and more of this vein will be incorporated بعد ما دخلوا الأربعة كونوا الجزء الناعم

It is **vertical slit** like opening.

Its **right and left edges** are called (**sino-atrial valves**).

They **fuse superiorly** forming (**septum spurium**).

Upper part of the right valve = **crista terminalis**.

Lower part of right valve = **valve of both IVC and coronary sinus**.

Left valve = **part of inter-atrial septum**.

Pericardial Sinuses

ال transverse sinus هو الذي يفصل aorta عن الpulmonary veins

- The **transverse sinus** is formed when the arterial and venous ends of the heart tube come together after looping.
- The **oblique sinus** is formed as an expansion of the visceral pericardium due to the incorporation of the right sinus horn and the pulmonary veins into the atria.

هو الي يكون موجود في الbase of heart بسبب توسع

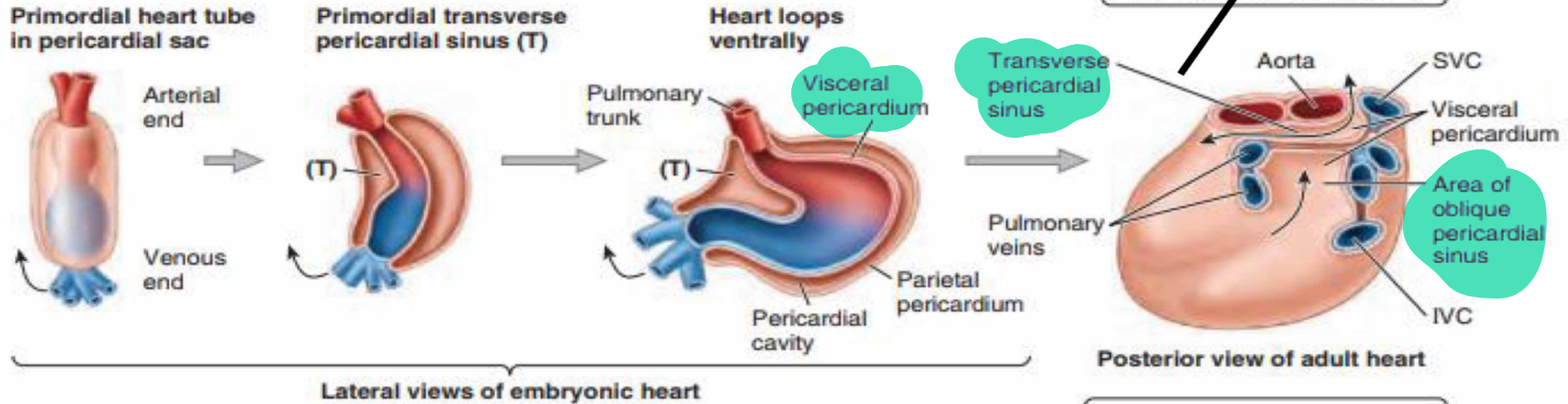


Fig.16: Formation of the pericardial sinuses.