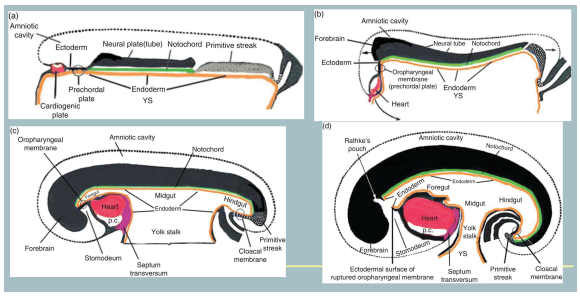
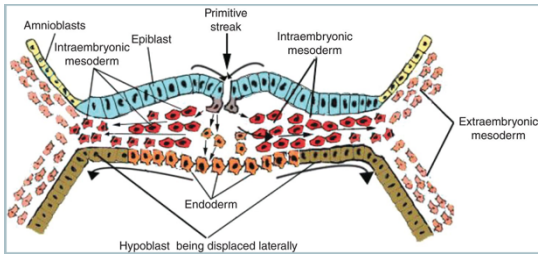
Formation of the cardiogenic field :

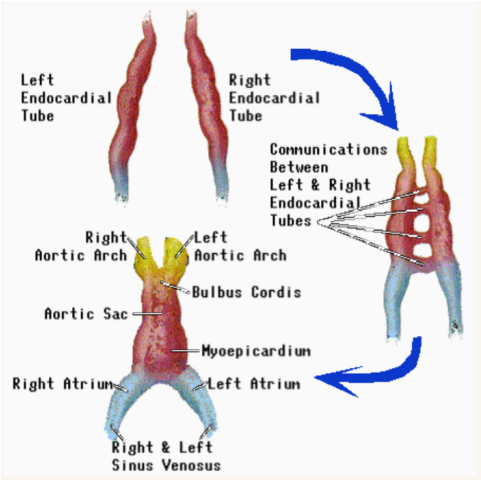
- The heart is the **first** functional organ.
- The heart development starts in the **middle of the third week** , before folding
- Migration of **cardiac progenitor cells** from the epiblast to the splanchnic part of lateral plate mesoderm which contain newly formed **blood islands.**
- The cardiac progenitor cells differentiate into the cardiac myoblasts and endothelial cell.
- The blood islands unite to form a **endocardial tube** lined by endothelial cells surrounded by the myoblasts
- Initially, the cardiogenic field lies cephalic to the **oropharyngeal membrane** and **neural plate**





2- Development of 2 endocardial tubes :

- **On 19th. Day , the endocardial tube** is changed into **2 endocardial tubes** which are connected to the 2 primitive aorta.
- Later on , the **pericardial cavity** is developed dorsal to the endocardial tubes from the surrounding **intra-embryonic coelomic** cavity which develops in the lateral plate mesoderm .
- At the beginning of **4th. week** , due to cephalic and lateral folding , the 2 endocardial tubes move towards the future thoracic cavity and meet in the middle line



3- Formation of single primary heart tube :

• The 2 endocardial tubes **fuse**, to form a **single primary heart tube ,**but remain separate in their cephalic and caudal ends to form **2 cranial horns and 2 caudal horns** of the primary heart tube .

- **The inflow to the primary heart tube:**

  Is through caudal horns which receives 3 pairs of veins (3 veins on each side) :

  A pair of common cardinal veins drain blood from the body of the embryo.

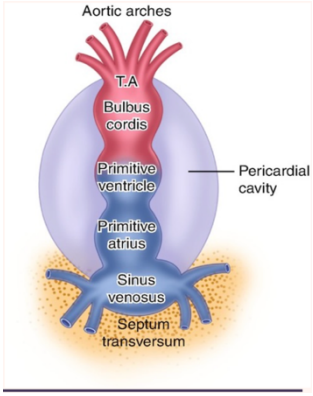
  A pair of vitelline veins drains the yolk sac.

  A pair of umbilical veins carries oxygenated blood from the placenta**.**

4- Formation of 3 constrictions

Subdivide the primary heart tube into four expansions which are (from caudal to cranial):

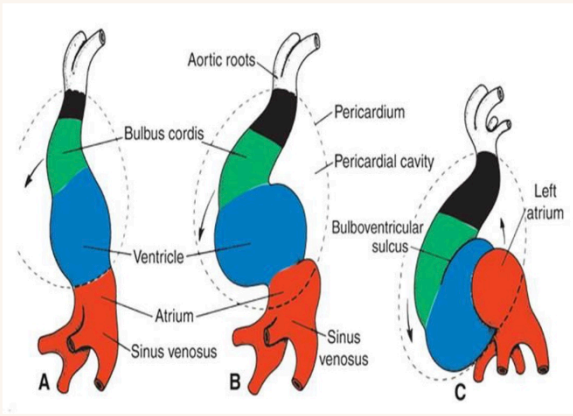
1. **Sinus venosus** consists of a small central part receiving 2 (left and right) sinus horns.
2. **Primitive atrium.**
3. **Primitive ventricle** separated from the atrium by the atrio-ventricular sulcus.
4. **Bulbus cordis** separated from the ventricle by the bulboventricular sulcus.

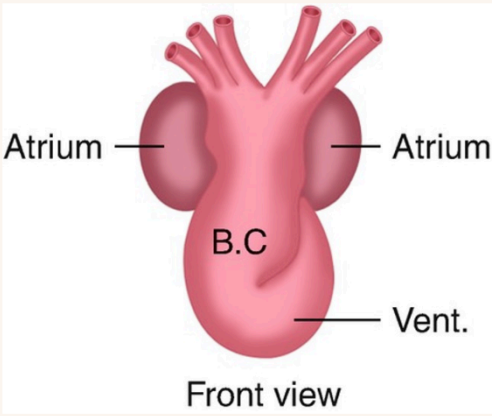


5- Formation of the cardiac loop :

Further elongation of primary heart tube results in its folding and formation of **S** shaped **cardiac loop** with displacement of cardiac chambers as follows :

- The bulbus cordis is displaced ventrally and to the right.
- The primitive ventricle is displaced ventrally and to the left of primitive atrium
- The primitive atrium becomes dorsal and cephalic





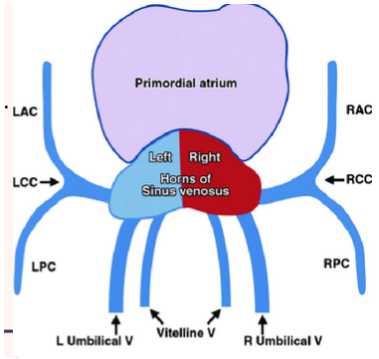
SINUS VENOSUS

It is the most caudal part of the primary heart tube and receives all the veins of the embryo.
It is formed of a small central median part and 2 lateral sinus horns (right and left).

Each horn receives the following veins:

- **Vitelline vein:** from the yolk sac.
- **Umbilical vein:** from the placenta.
- **Common cardinal vein:** from the body of the embryo itself.

It opens into to the primitive atrium by a **sino-atrial orifice guarded by right and left valves.**



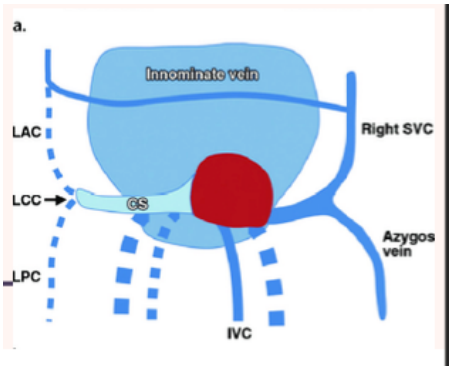
Fate of the sinus venosus :

1) The left sinus horn: It diminishes in size due to:

- Left vitelline and left umbilical veins lose their connection with the left sinus venosus.
- Shift of the venous blood to the right side due to the development of transverse anastomoses between the anterior cardinal veins and the posterior cardinal veins.

The left sinus horn becomes smaller and forms the **coronary sinus**.

2) The right sinus horn and central part of sinus venosus become absorbed into the right side of the primitive common atrium and will form the **sinus venarum** (the posterior smooth part of right atrium).



6) The right and left valves of the sino-atrial orifice:

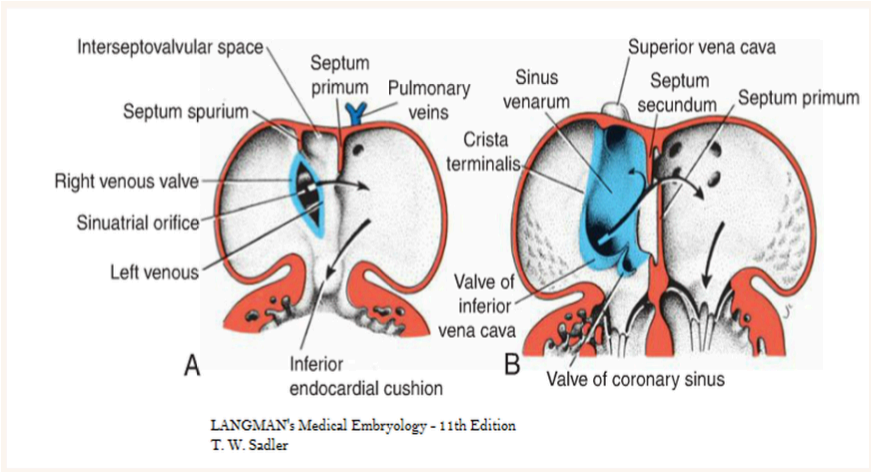
· These are two folds which appear at the sino-atrial orifice.

· They fuse cranially to form the **septum spurium** .

· **Left valve** and **septum spurium fuse with interatrial septum**.

· **Right valve:**

- Its **cranial** part forms **crista terminalis.**
- Its **caudal** part forms the **valves** of I.V.C. and coronary sinus

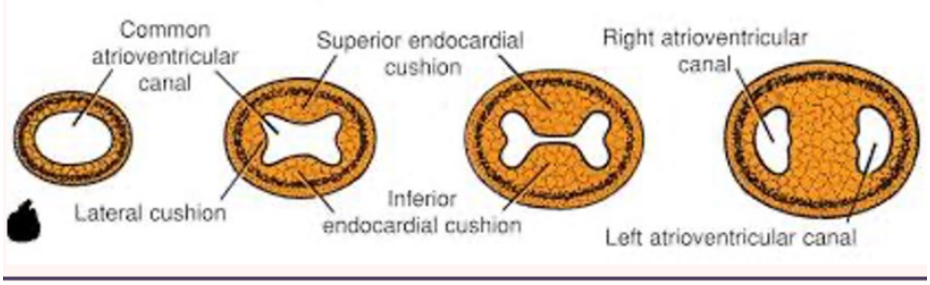


DEVELOPMENT OF THE ATRIA

Division of atrioventricular canal

Formation Septum intermedium in the atrio-ventricular (AV) canal :

1. Ventral and dorsal **endocardial cushions** appear in the walls of the atrio-ventricular canal.
2. The two cushions **approach** each other and **fuse** together forming the **septum intermedium** which **divides** the atrio-ventricular canal into **2 halves** (right and left).



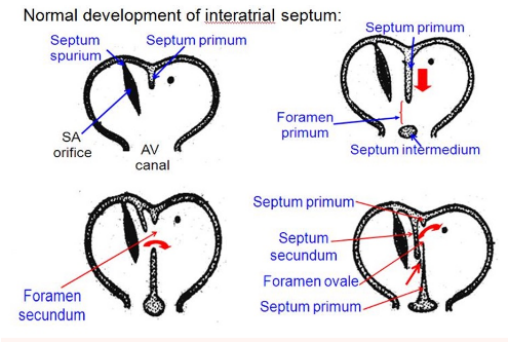
A. Septum primum :

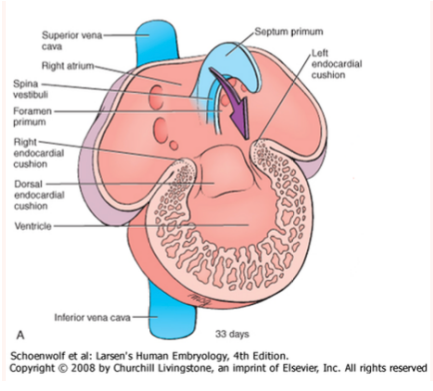
- **It is Sickle**-shaped having caudal **crescentic border** ending in ventral & dorsal **horns**.
- It arises from the **roof** of the common primitive atrium and **descends** in the direction of the **endocardial cushions** of the atrio-ventricular canal.
- The septum primum **divides** the cavity of the primitive atrium **incompletely** into right and left halves because its caudal border is still **separated** from the endocardial cushions by gap called the **ostium primum.**
- Ostium primum allows shunting oxygenated blood from right to left atrium

As development progress :

The ostium primum becomes **obliterated**.

A second foramen called **ostium secundum** appears as a result of **breaking** down of the **cephalic part** of the septum primum.





B.Septum Secundum :

- **It is Sickle**-shaped having a **caudal crescentic** edge with **2 horns** (ventral & dorsal).
- **It arises from the roof of the common primitive atrium** (just on the right side of the septum primum).
- **It descends caudally in the direction of the septum intermedium until its 2 horns fuse with the septum intermedium.**
- The septum secundum **overlaps** the ostium secundum but its caudal edge is still separated from the cephalic edge of septum primum by a gap called **foramen ovale.**The edge of the septum primum that forms the lower boundary of the foramen secundum is thin and mobile like a flap
- When blood tends to flow from the right to the left atrium, this thin flap moves away and there is no obstruction to blood flow.
- However, when there is a tendency for blood to flow from left to right this flap comes into apposition with the septum secundum and closes the opening.

Functional closure of the foramen ovale **at birth** due to firm apposition of septum primum and septum secundum due to low pressure in the right atrium due to arrest of placental circulation and high pressure in the left atrium due to increase pulmonary venous return .Later on life , **complete fusion** between the septum primum and septum secundum occur to form the **interatrial septum** which is formed of :

- **Septum primum :** form the lower part of interatrial septum with formation of **fossa ovalis .**
- **Septum secundum :** form the upper part of interatrial septum**.**
- **The free caudal edge** of the septum secundum form **annulus ovalis** .

2) Absorption of the atrio-ventericular canals into the atria:

The right and left atrio-ventericular canals becomes absorbed into the corresponding atrium.

3) Absorption of the pulmonary vein into the left atrium:

At first, a single common pulmonary vein opens into the dorsal wall of the left atrium.
This vein is the union of right and left veins, each of which is formed by 2 veins emerging from the lung.
Later on the stem of the common pulmonary vein and its 2 tributaries become absorbed into the posterior wall of the left atrium .
Thus the 4 pulmonary veins open separately into the left atrium.

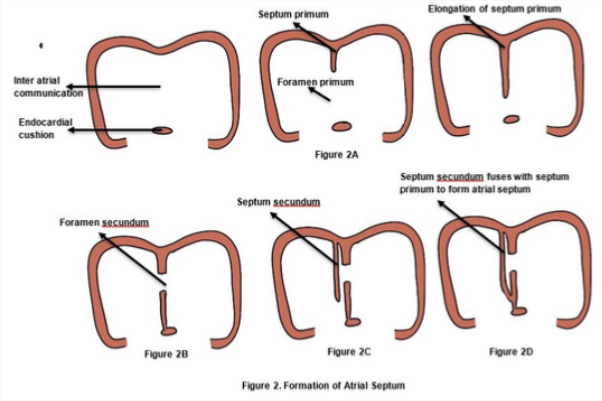
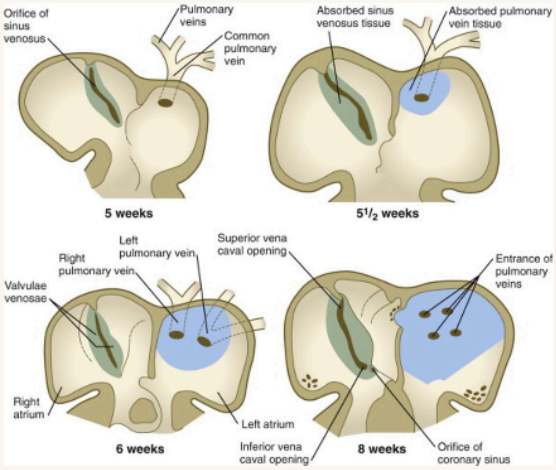


Figure 2. Formation of Atrial Septum



Absorption of the pulmonary vein into the left atrium

Embryological components of each atrium

Components of the right atrium	Components of the left atrium
(1) The right 1/2 of the common primitive atrium (forms the anterior rough part + Right auricle). (2) The absorbed central part & right horn of sinus venosus (forms the posterior smooth part). (3) The absorbed right atrioventricular canal	(1) The left 1/2 of the common primitive atrium (forms the left auricle). (2) The absorbed pulmonary vein and its tributaries (forms the posterior smooth part). (3) The absorbed left atrioventricular canal

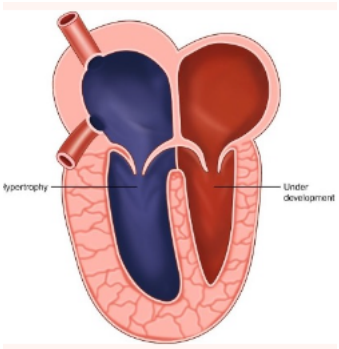
Postnatal Shunts

Right to left shunts are cyanotic
Left to right shunts are NON – cyanotic

Anomalies of the interatrial septum :

1- Premature closure of foramen ovale:

- **Character:** premature closure of foramen ovale in the intrauterine life due to excessive descend of septum secundum and fusion with septum intermedium .
- **Results:** hypertrophy of right atrium and right ventricle with underdevelopment of left atrium & left ventricle. It leads to the death.



2-Atrial Septal Defects Atrial septal defect (ASD)

- It is more common in female than in male ASDs result in **left -to-right shunting** and are **non-cyanotic conditions**.
- This ASD results in variable openings between the right and left atria in the central part of the atrial septum **above the** limbus.
- Secundum-type ASD is the most common ASD It is caused by either an excessive resorption of the Septum primum or an underdevelopment and reduced size of the Septum Secundum or both.
- If the ASD is small, clinical symptoms may be delayed as late as age 30

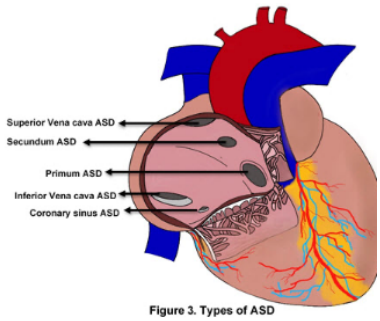
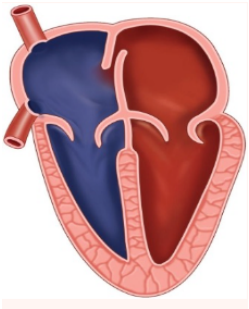


Figure 3. Types of ASD

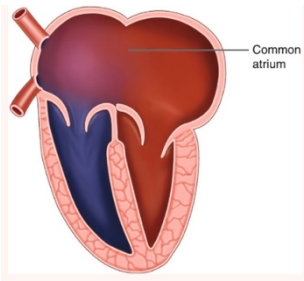
3- Probe patent foramen ovale:

- Normally, the foramen ovale closes completely at birth.
- In 25 % of people, a probe can be passed through the foramen ovale.
- The defect is often so small that blood cannot pass between the two atria, but in larger defects, surgery may be required.



4- Complete failure of formation of the interatrial septum:

- The heart is formed of 3 chambers (common atrium and 2 ventricles).
- **Cause:** it is due to failure of separation of the 2 atria.



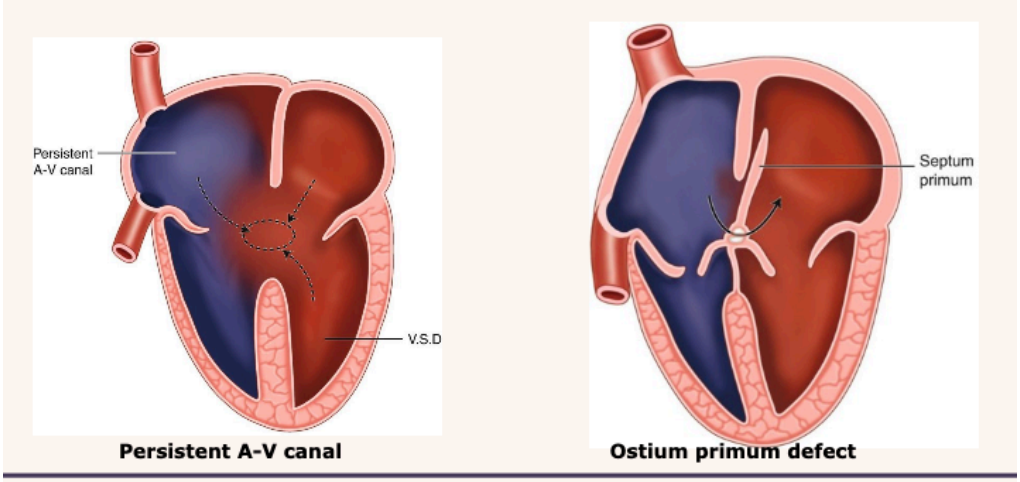
Anomalies of the atrio-ventricular canal :

1- Persistent A-V canal:

- This anomaly is usually accompanied by atrial septal defect and ventricular septal defect.
- **Cause:** complete failure of fusion of the ventral and dorsal endocardial cushions in the A-V Canal

2- Tricuspid atresia :

- **Cause:** fusion of the cusps of the tricuspid valve leading to its narrowing.
- This anomaly is usually accompanied by patent foramen ovale, hypertrophy of left ventricle, patent interventricular foramen and underdevelopment of right ventricle.

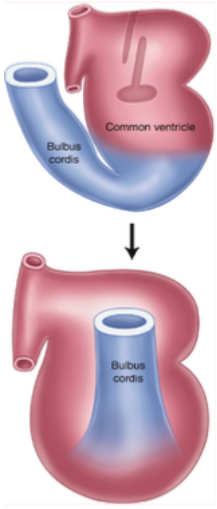


Persistent A-V canal **Ostium primum defect**

Development of the ventricles

I) Formation of common bulboventricular chamber :

- The bulbus cordis lies to the right side of the primitive common ventricle with a deep sulcus separating the two structures.
- The sulcus gradually becomes obliterated and the bulbus cordis moves to the left to lie in front of the common ventricle .
- The proximal part of the bulbus cordis becomes absorbed inside the primitive ventricle to form the common bulboventricular chamber.A ridges developed in the lumen **of the bulbus cordis** after their fusion are called **bulbar septum**
- This septum is divided into ; the Distal bulbar septum and the proximal bulbar septum



Function of The proximal bulbar septum

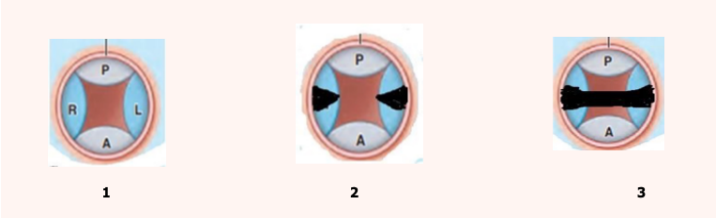
1-Share in closing interventricular foramen (Membranous part of interventricular septum)
2- Incorporated into the walls of the definitive ventricles to form smooth outflow parts Infundibulum (conus arteriosus) on the right ventricle OR aortic vestibule of the left ventricle

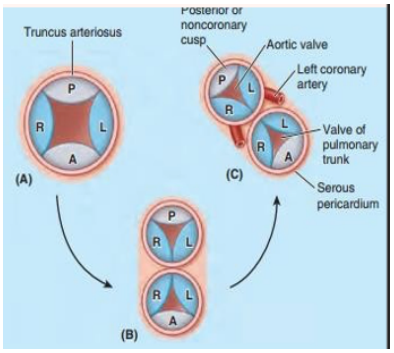
The distal bulbar septum

1- Four endocardinal cushions (one anterior, one posterior, and two lateral right and left) are developed in the distal part of the bulbus cordis.
2- A ridge is developed in the middle of each of the two lateral cushions which divide each of them into two.
3- These ridges will fuse to form a complete septum called the distal bulbar septum.
4- The distal bulbar septum will divide the cranial end of bulbus cordis into into two orifices: The pulmonary orifice **anteriorly** and The aortic orifice **posteriorly**

5- The cusps of the pulmonary valve are one anterior and two posterior but as a result of rotation of the vessels the two cusps become one anterior , right and left cusps

6- The cusps of the aortic valve are two anterior and one posterior but as a result of rotation of the vessels one cusp becomes one anterior posterior right and left cusps





II) Formation of the interventricular (IV) septum :

A) Development of the muscular part of the interventricular septum:

1. The muscular part of the interventricular septum develops from the floor of the bulboventricular chamber as a crescent-shaped ridge with a concave free cranial border with ventral and dorsal horns.

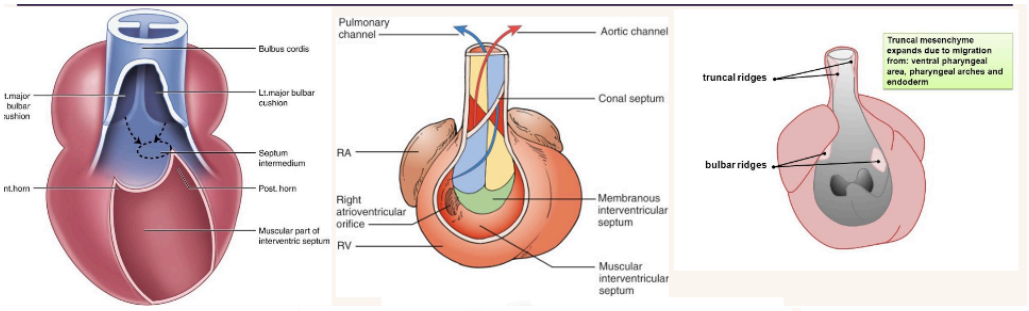
2. This ridge grows cranially towards the atrio-ventricular cushions .

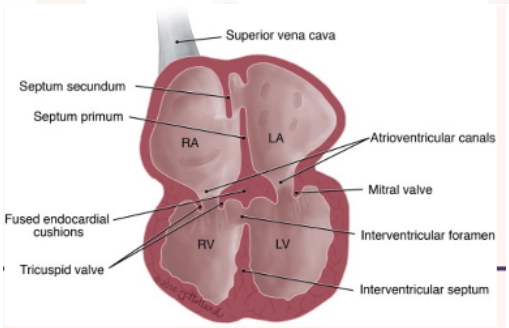
3. There is a crescent-shaped ***interventricular foramen*** between the free edge of the interventricular septum and the septum intermedium.

B) Development of the membranous part of the interventricular septum:

- This part develops by the end of the 7th week to close the interventricular foramen.
- It is developed from 3 structures surrounding the interventricular foramen :

1- **The muscular ventricular septum**
2- **Atrio-ventricular endocardial cushion.**
3- **Right and left bulbar ridges**.





III) Absorption of the proximal portion of bulbus cordis (conus cordis)

The conus cordis is absorbed into the ventricles forming the **outflow tracts of the both ventricles**:
The part absorbed into the Right ventricle will form *the* ***infundibulum of pulmonary trunk*** **.**
The part absorbed into the left ventricle will form *the* ***vestibule of the aorta.***

SOURCES OF THE VENTRICLES :

1. **Primitive ventricle:** It gives rise to
    a. Trabeculated part of the right ventricle.
    b. Trabeculated part of the left ventricle.
2. **Bulbus cordis:**

The proximal-portion part (conus cordis) forms the outflow tracts of both ventricles
Infundibulum (conus arteriosus) on the right ventricle OR aortic vestibule of the left ventricle

Anomalies of the interventricular septum :

Ventricular septal defect :

- More common **in males than in females**
- A defect may occur in the membranous as well as the muscular part of the IV septum.
- It may occur isolated or with other abnormalities.
- The whole IV septum may be absent.
- It results in **left-to-right shunting** of blood **through the IV foramen.**
- Patients with left-to-right shunting complain of excessive fatigue upon exertion.
- Left-to-right shunting of blood is noncyanotic, But causes increased blood flow and pressure to the lungs (pulmonary hypertension).
- Pulmonary hypertension causes marked proliferation of the tunica intima and media of pulmonary muscular arteries and arterioles.
- Ultimately, the pulmonary resistance becomes higher than systemic resistance and causes right-to-left shunting of blood and late cyanosis.
- At this stage, the condition is called **Eisenmenger complex**