Development of the Heart

Embryology

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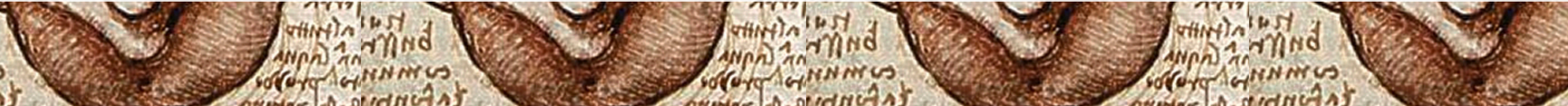
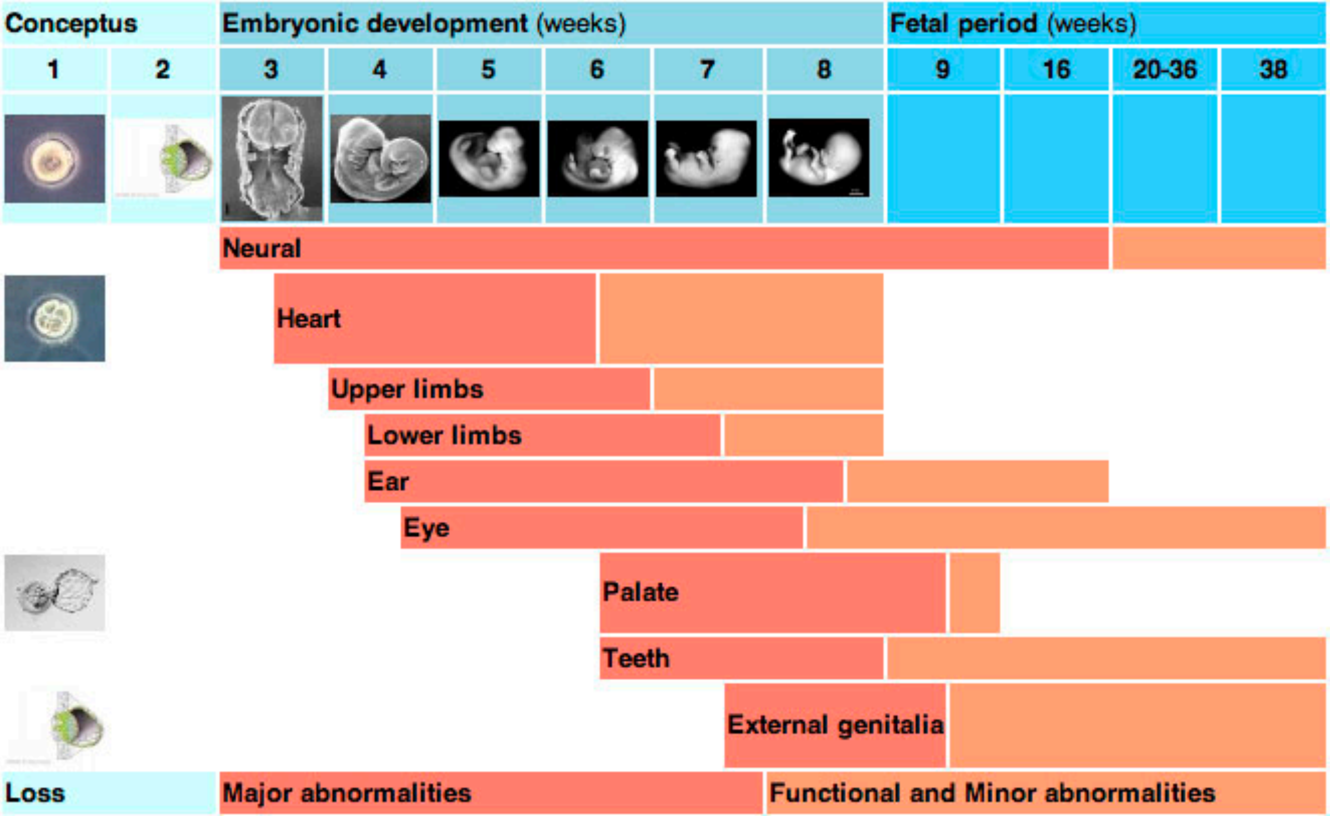


Overview

- Heart tube formation
- Cardiac looping
- Chamber septation
- Valve and outflow formation

Cardiovascular embryology: critical period

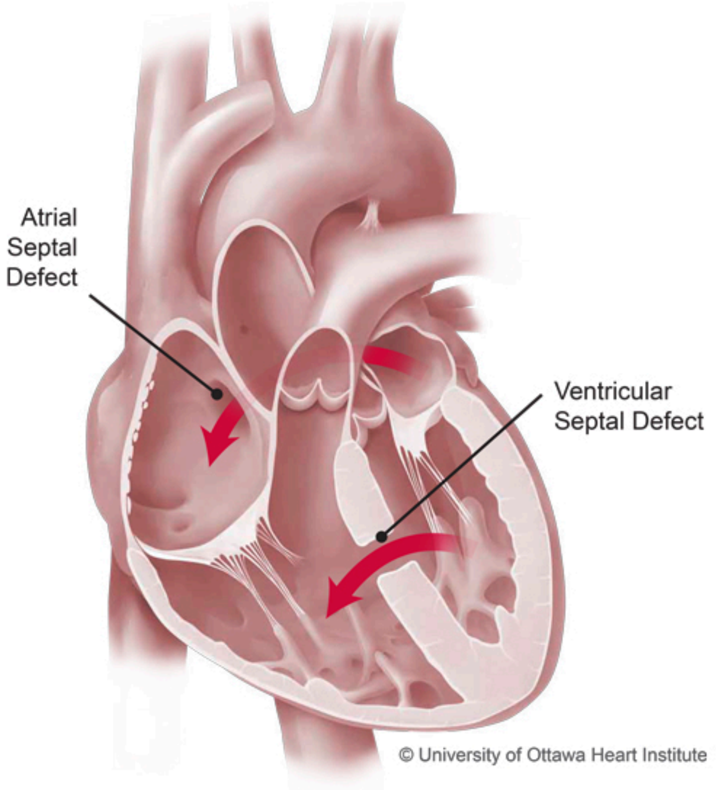
- Heart
- Vessels
- Lymphatic channels



Hill, M.A. (2019, May 26) **Embryology** *Human-critical periods of development.jpg*

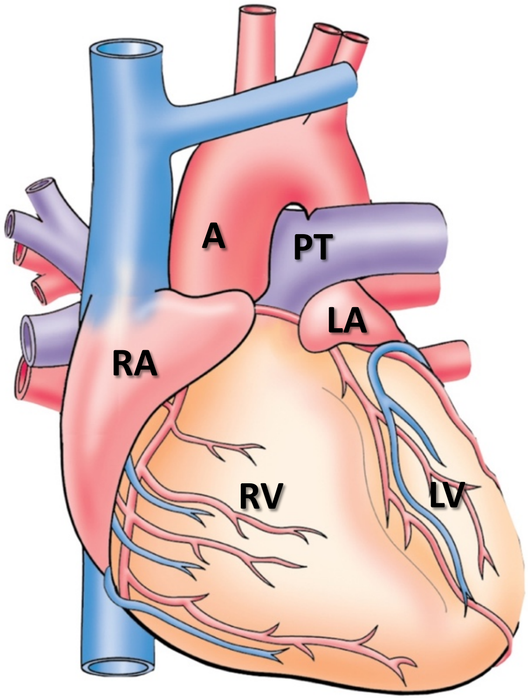
Congenital heart disease

- Relatively common
- Initiated by errors in early development
- ??exposure to teratogens
- Can originate with genetic defects

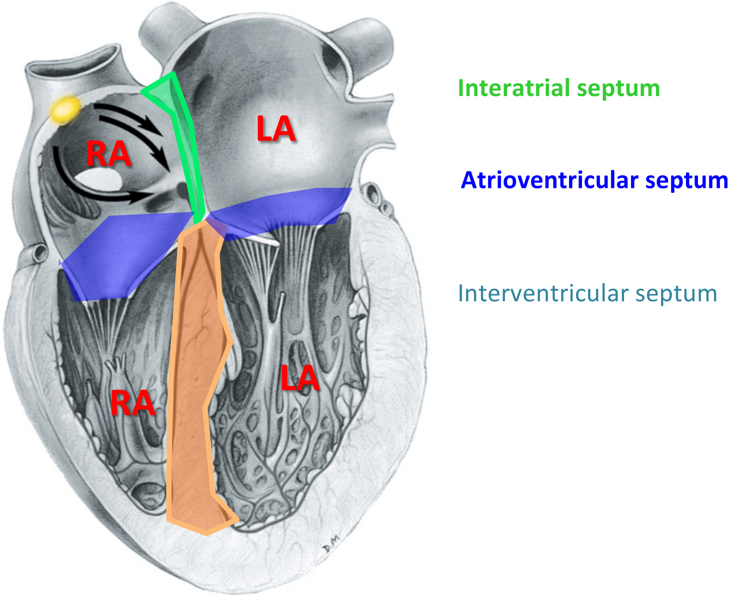


https://www.ottawaheart.ca/heart-condition/adult-congenital-heart-defects

What does the adult heart look like?



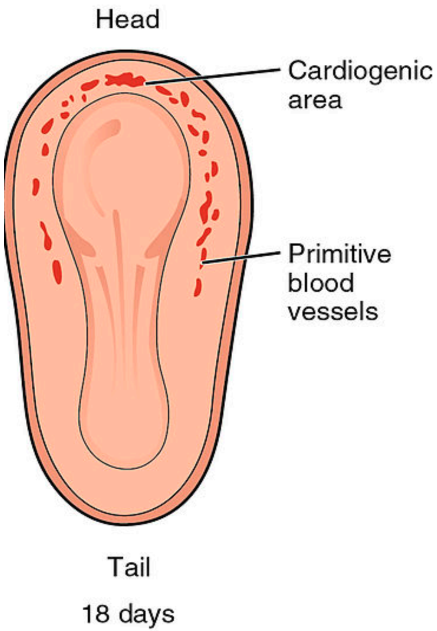
ANTERIOR VIEW



LONGITUDINAL SECTION

Heart tube formation

- Forms from lateral plate mesoderm - cardiogenic plate
- Cranial and lateral to neural plate (developing brain)



20 days→

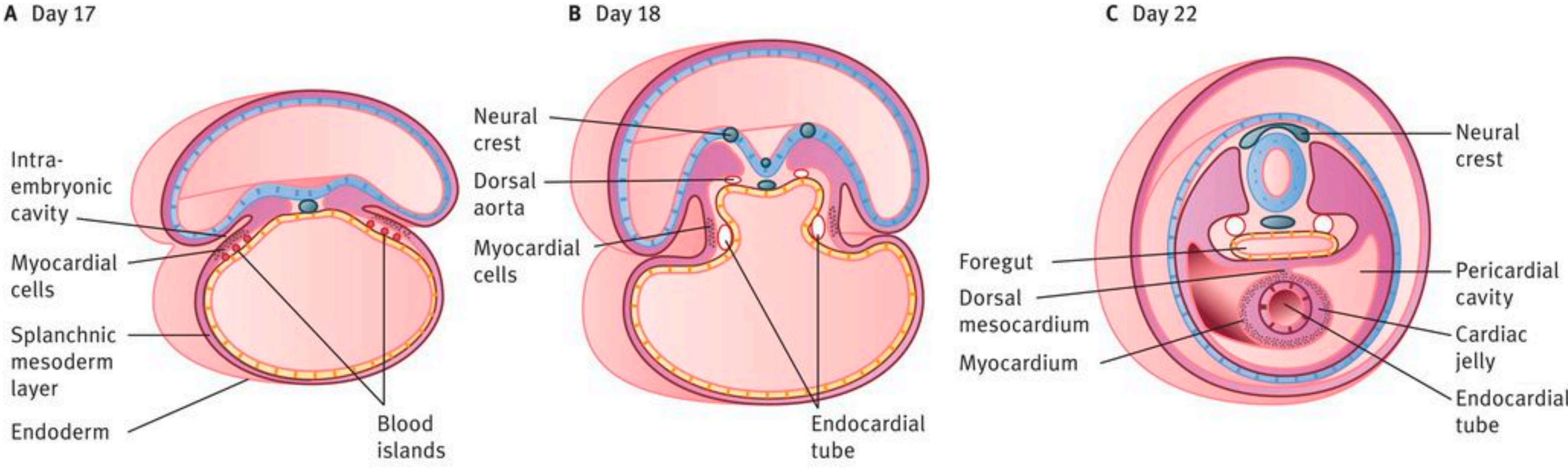
21 days→

22 days→

Illustration from Anatomy & Physiology, Connexions Web site. http://cnx.org/content/col11496/1.6/, Jun 19, 2013.

→ undergoes folding: laterally and cephalocaudally

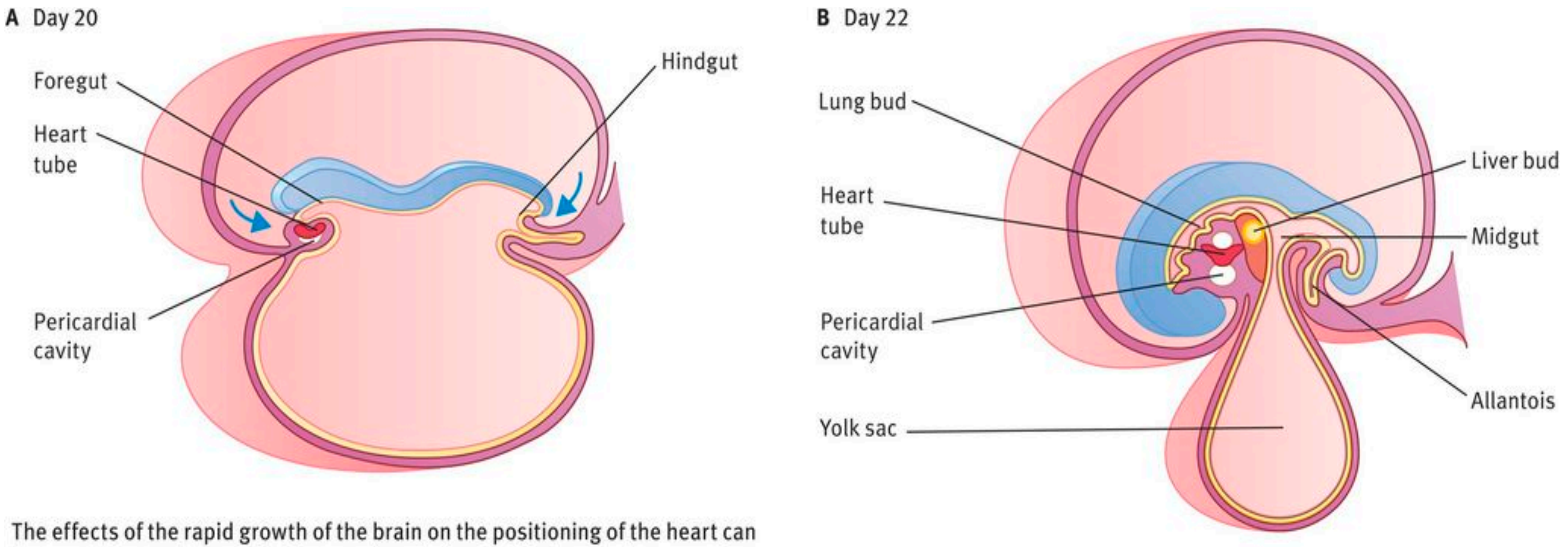
Lateral folding and cephalocaudal folding



The effect of the lateral folding of the embryo and the merging of the paired cardiac primordial to form the endocardial tube can be seen.

Obgyn Key, 2017 Development of the heart and the fetal circulation

Lateral folding and cephalocaudal folding

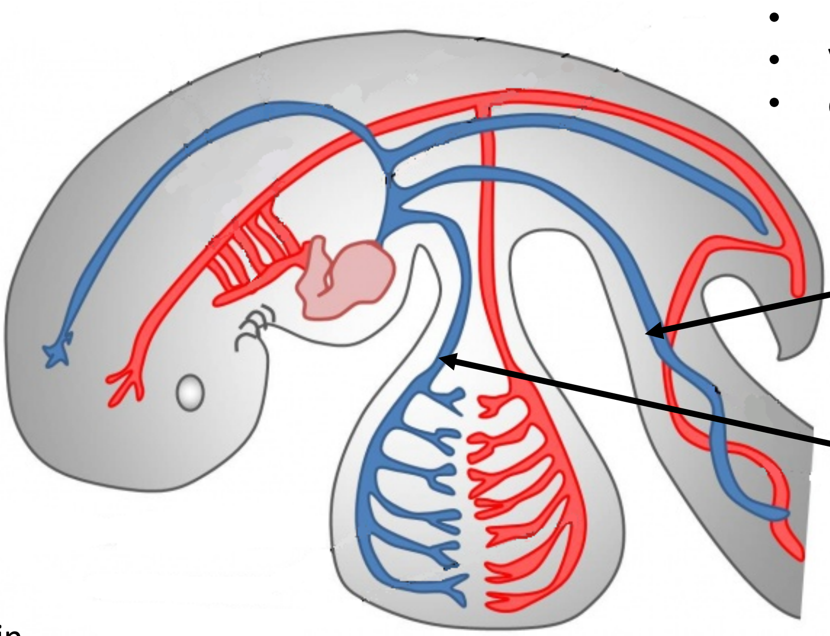


The effects of the rapid growth of the brain on the positioning of the heart can be seen. The cardiogenic field moves from in front of the buccopharyngeal membrane to the thorax.

Obgyn Key, 2017 Development of the heart and the fetal circulation

Heart tube connections and earliest blood vessels

- Umbilical veins→ chorion
- Vitelline veins → umbilical vesicle/yolk sac
- common cardinal veins →embryo



R&L umbilical veins

Network of vessels

Vitelline veins

Angioblasts

Haematocytoblasts

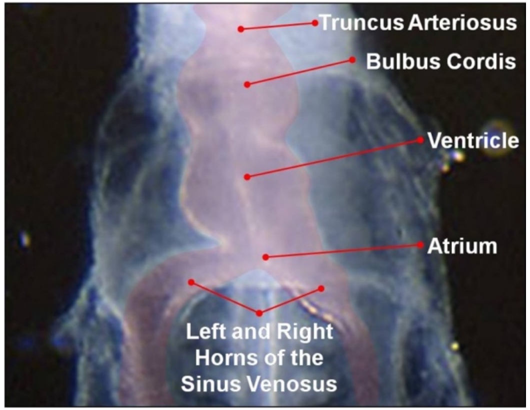
Haemangioblasts

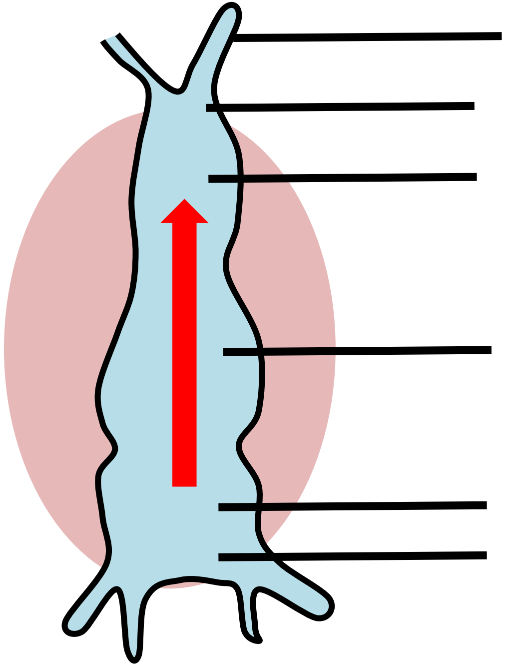
- Pharyngeal arches
- Dorsal aorta
- Common cardinal vein

Blood islands develop in EEM (yolk sac and body stalk)

Heart tube

- Heart is anchored at cranial and caudal ends to pericardium



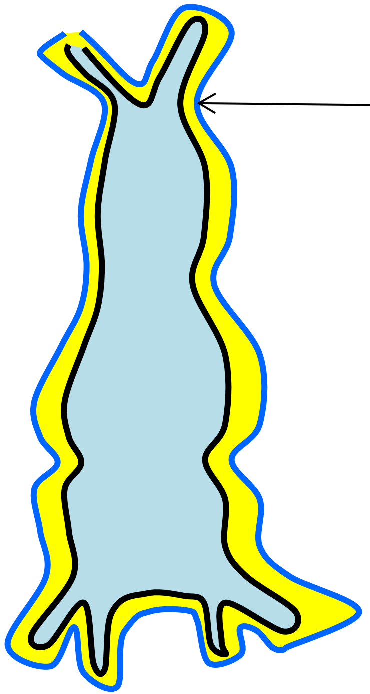


→ ***External and internal changes!***

External changes:

Heart wall

- Endothelial tube surrounded by visceral pericardium (epicardium)
- Space between layers fills with cardiac jelly



Invaded by cells from epicardium (myoblasts)

Cardiac muscle

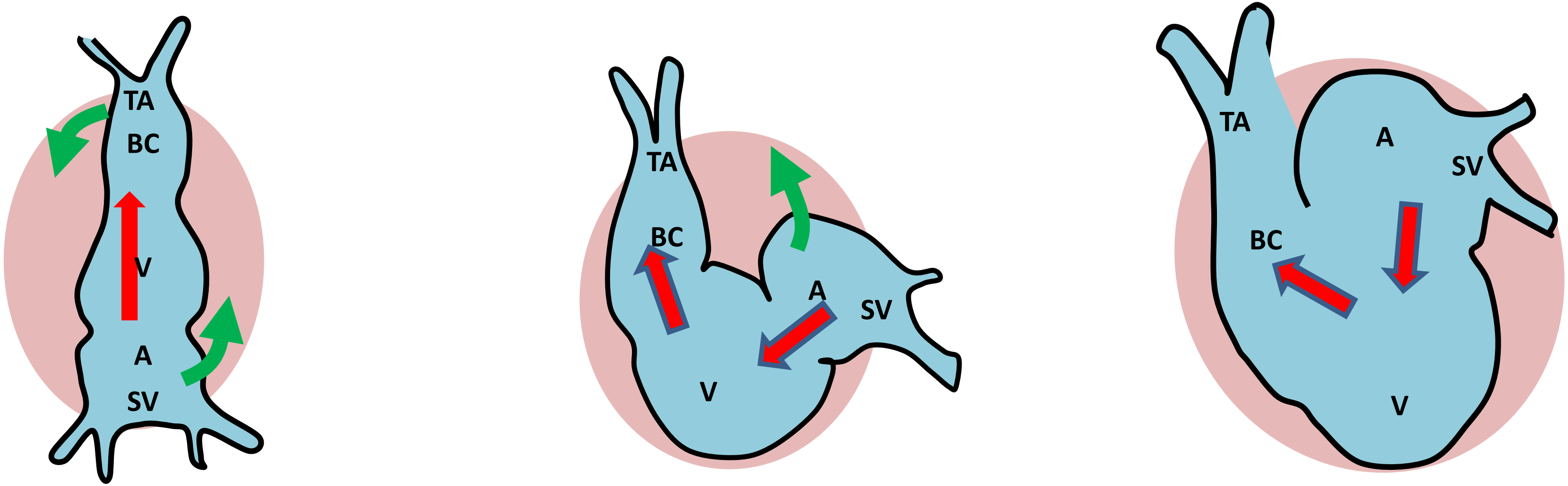
epicardium & invaded jelly = myoepicardial mantle

Blood islands form in epicardium = coronary arteries

External changes:

Cardiac looping due to rapid growth of heart

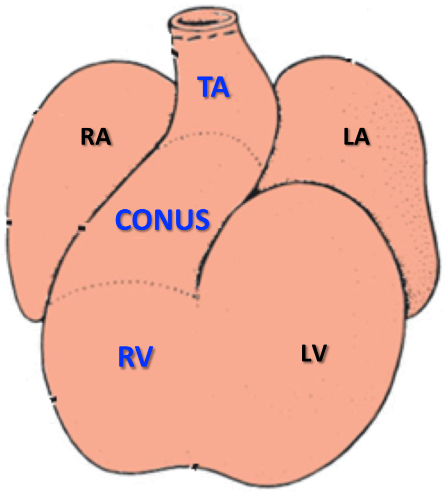
Buckling and Twisting

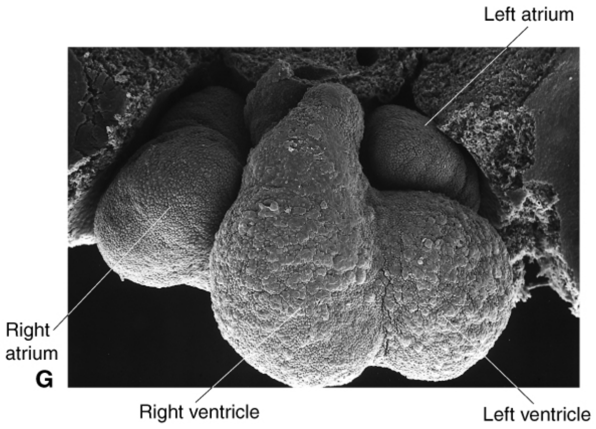


- Tube lengthens and develops dilatations and constrictions
- Ventricles absorb **BC** to form bulboventricular loop, which grows faster
- Heart buckles and twists to form a **S shaped loop**
- **A** & **SV** come to lie dorsal to **BC** &**TA** --- brings inflow up behind outflow
- Ventricles lie caudally.

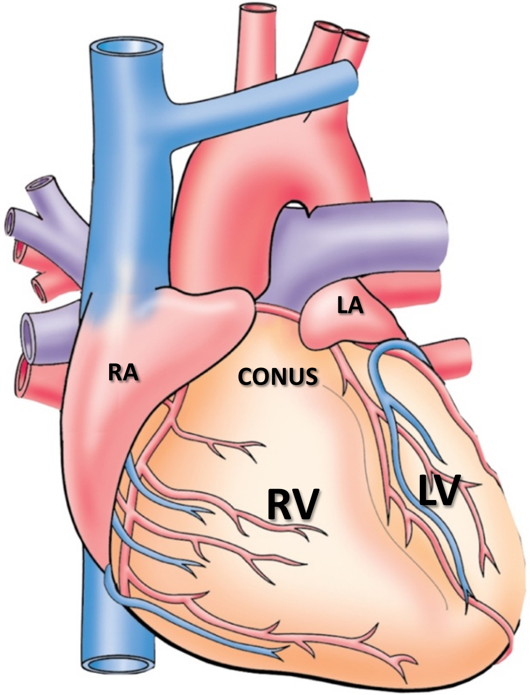
External changes:

cardiac looping establishes basic morphology at 28 days





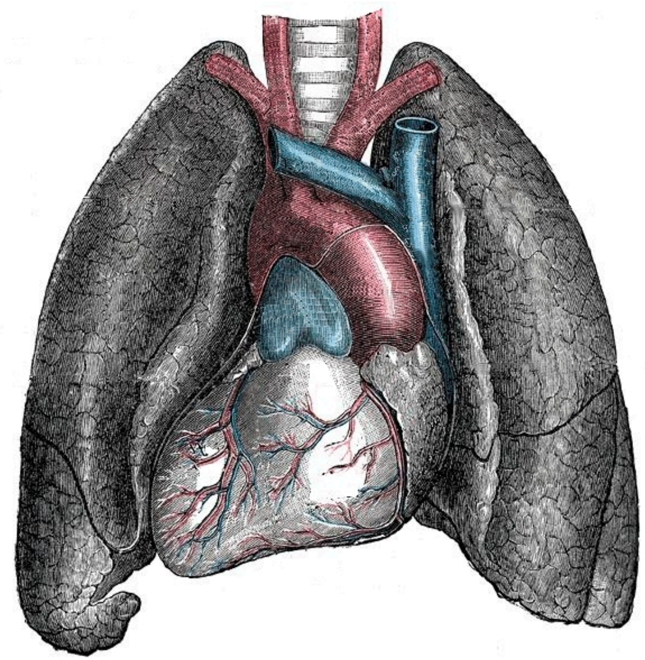
5-3G Heart looping



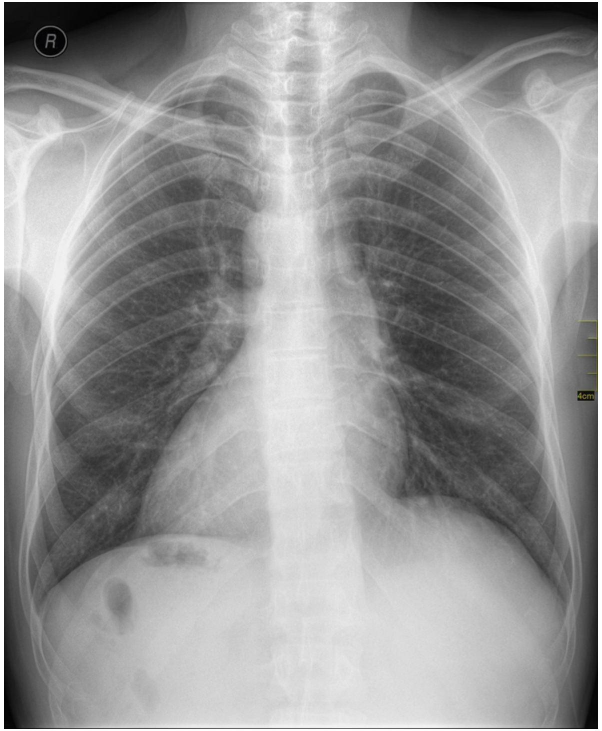
Bulbus cordis is divided into the truncus arteriosus, conus cordis and trabeculated part of the right ventricle

External changes:

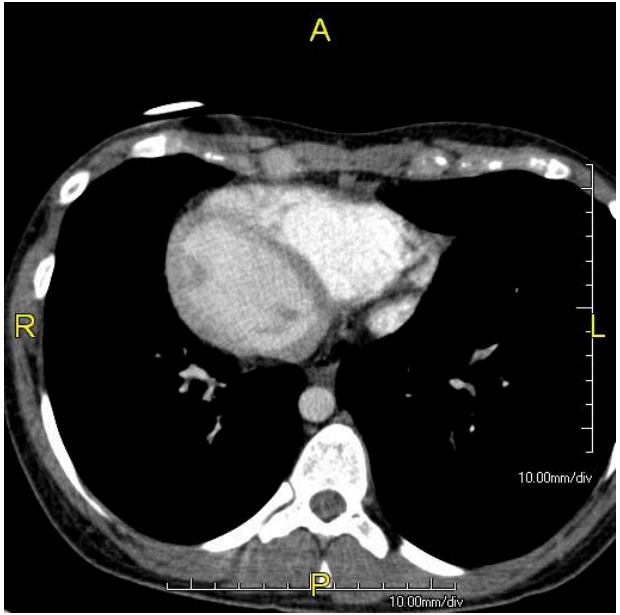
Anomalies: Dextrocardia & Situs Inversus



Gray's Anatomy, 1918



Situs inversus (Chest x-ray), Category:Nevit Dilmen Radiology Category:Situs inversus



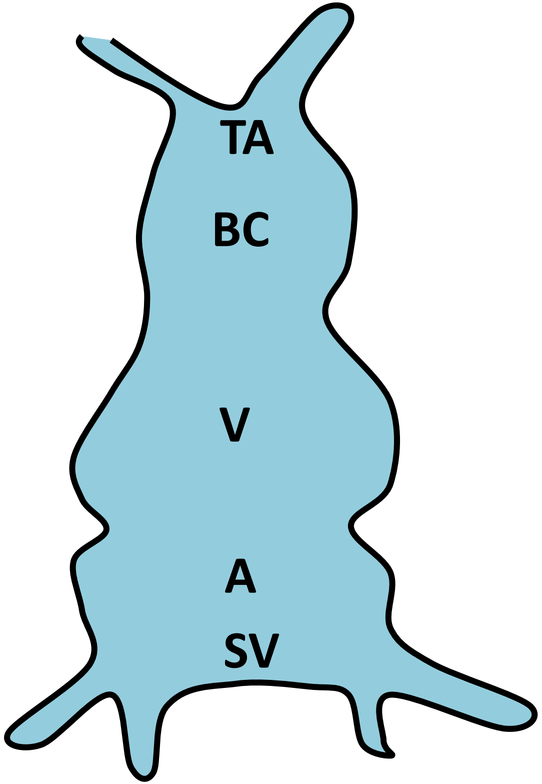
John To: Axial CT image showing dextrocardia and situs inversus in a patient with Kartagener syndrome.

Internal changes:

Partition into 4-chambers

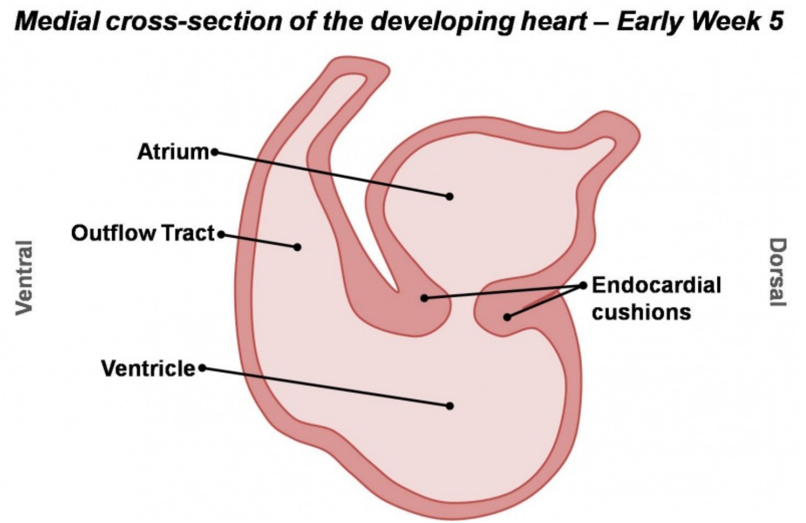
Internally – change from single pump to two pumps

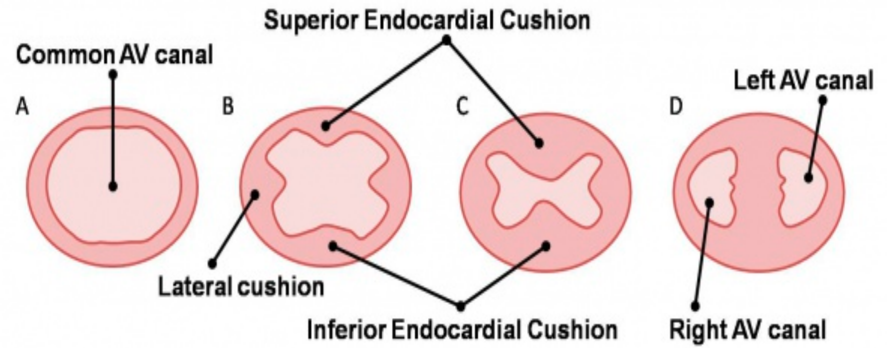
- Atrial septation
- Ventricular septation
- Atrioventricular valve formation to ensure unidirectional flow
- Division of the outflow tract



Internal changes:

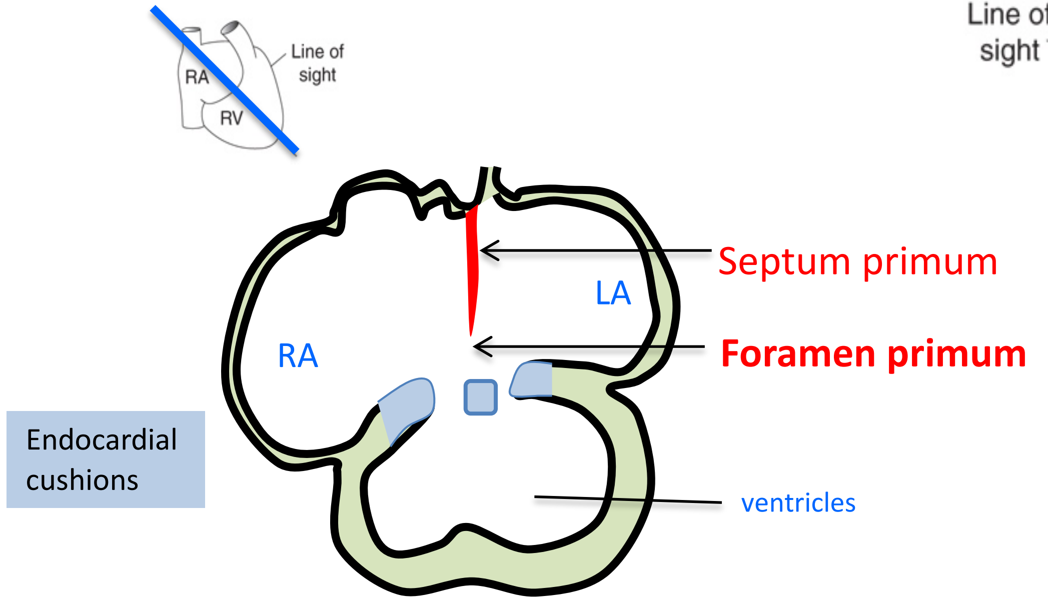
Formation of the AV canals

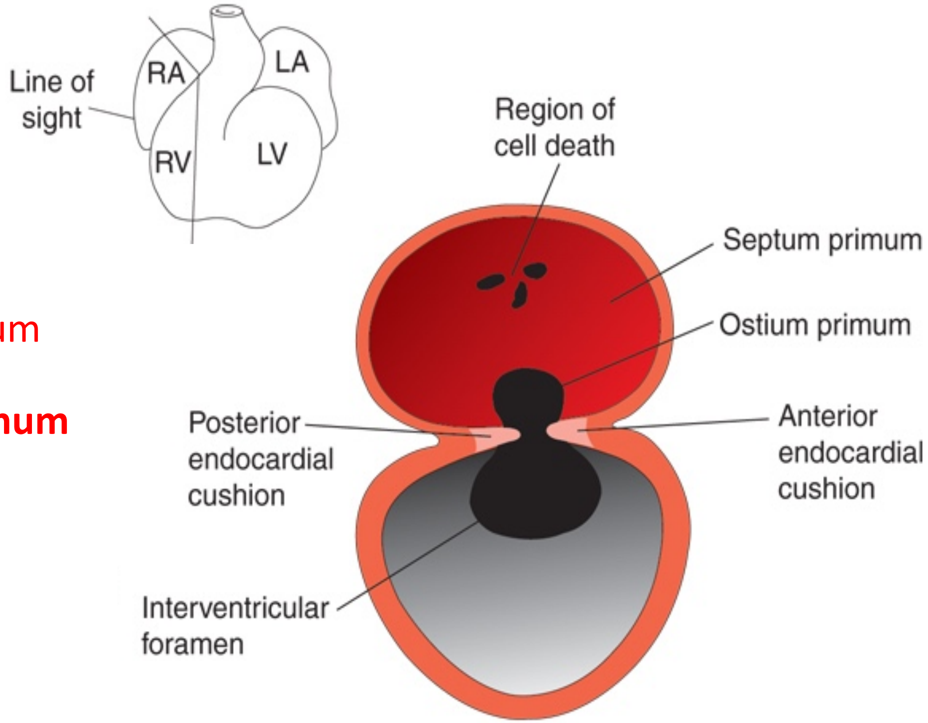




Atrial Septation: septum primum

- growth of 2 overlapping septa to create opening with a valve





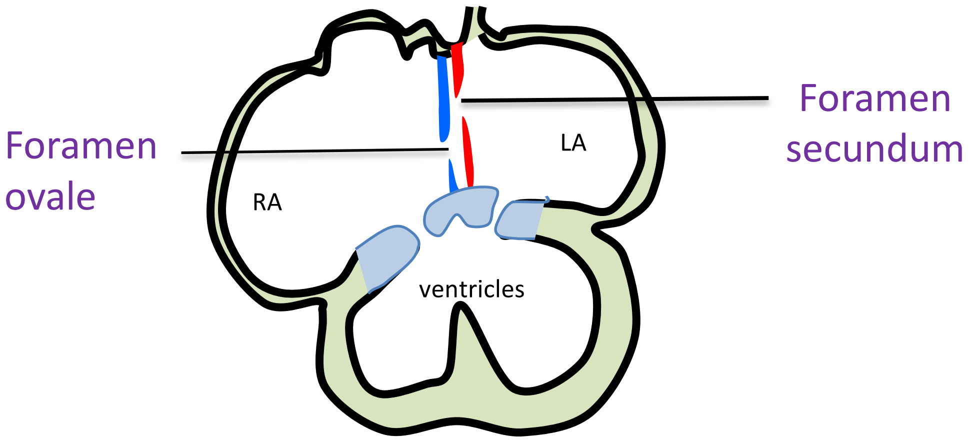
Heart septation: Atria and ventricles

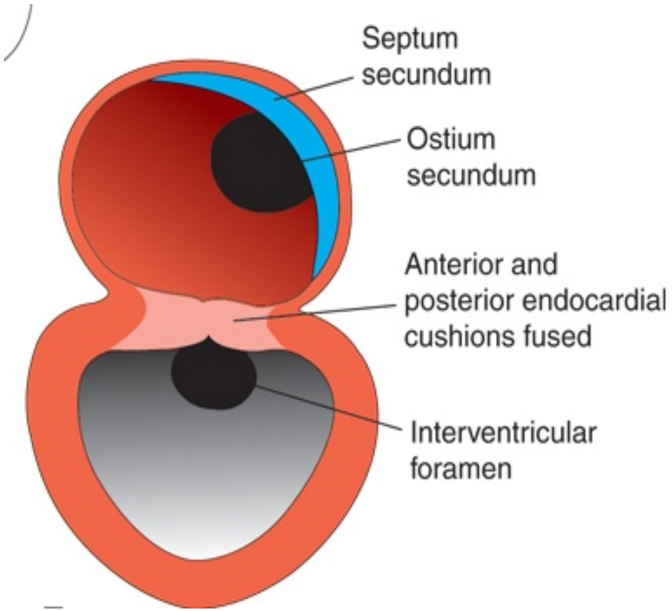
Week 4-6

Internal changes:

Atrial Septation: septum secundum

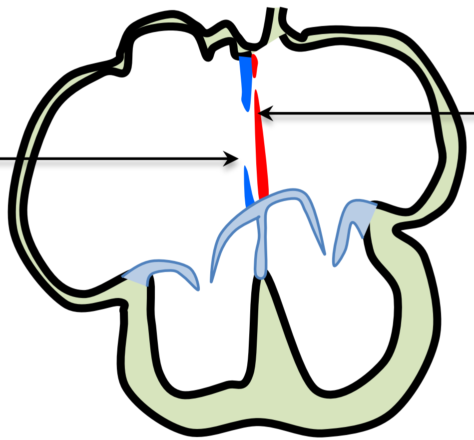
- growth of 2 overlapping septa to create opening with a valve





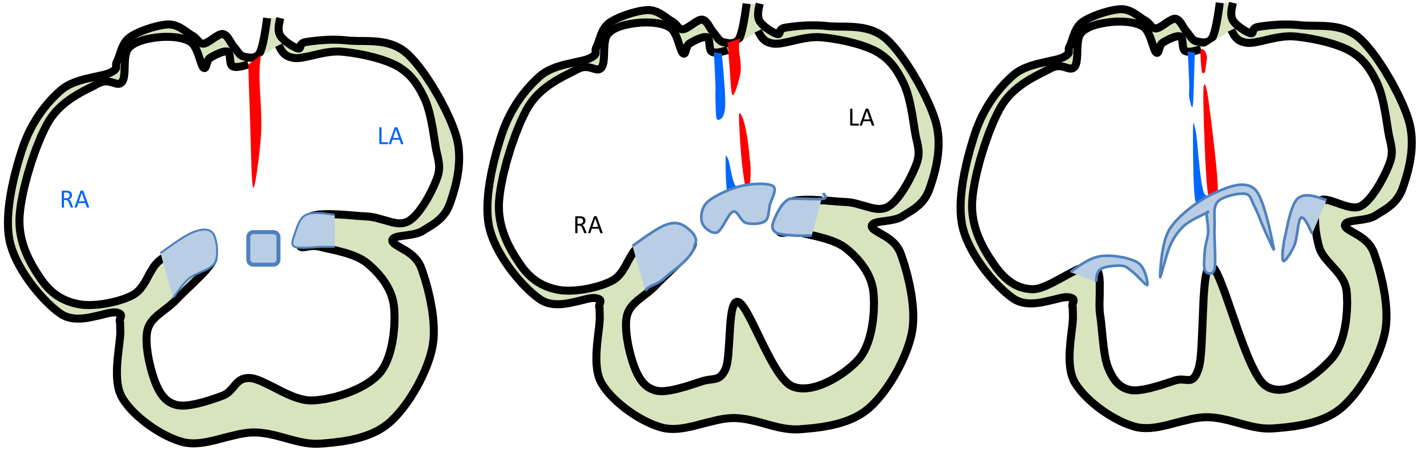
Sadler et al. 2005

Atrial Septation: Foramen Ovale



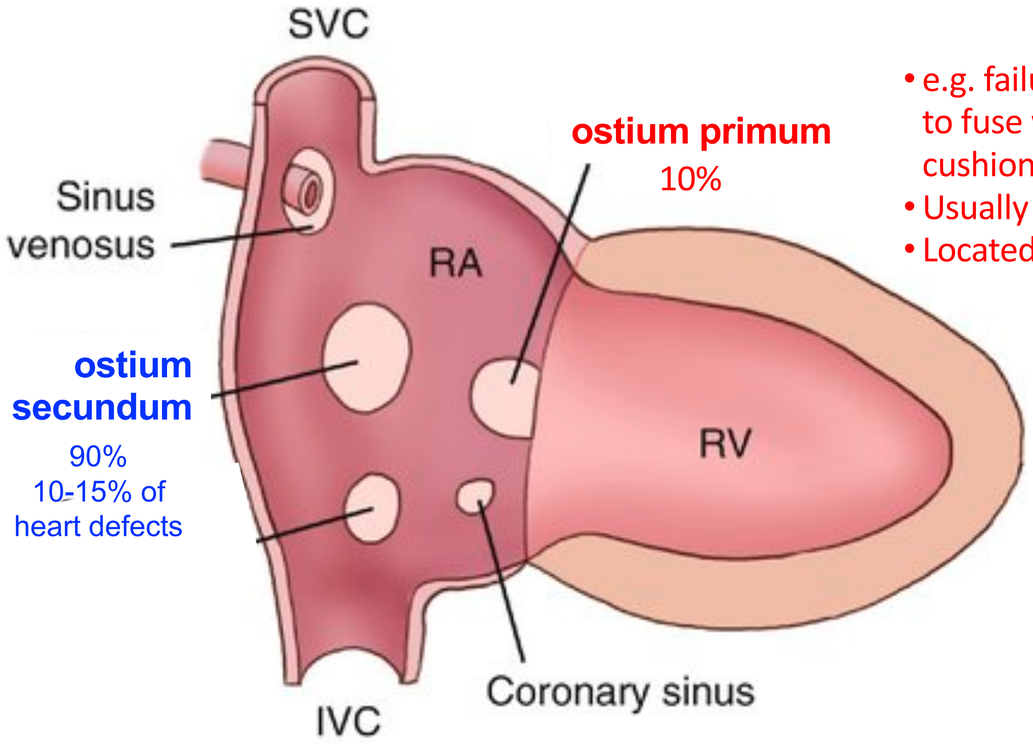
- Before birth – shunt for well oxygenated blood
- After birth – becomes fossa ovalis

Atrial Septation: summary



Atrial Septal Defect (ASD)

- 6.4/10 000 births
- 2:1 prevalence in females to males
- secundum, primum, sinus venosus



ostium primum
10%

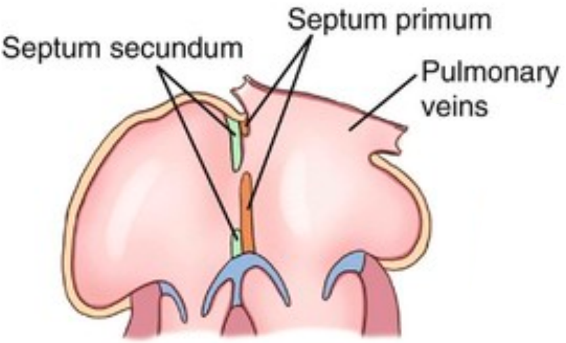
- e.g. failure of the septum primum to fuse with the endocardial cushions or excessive apoptosis
- Usually involves VSD
- Located near AV valve

ostium secundum
90%
10-15% of heart defects

- e.g. poor growth of the septum secundum or excessive absorption of the septum primum
- Usually located centrally on foramen ovale

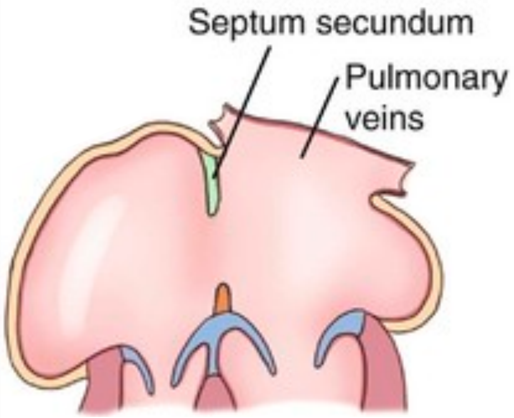
Stamm ER, Fetal Medicine, 2016

ASD types

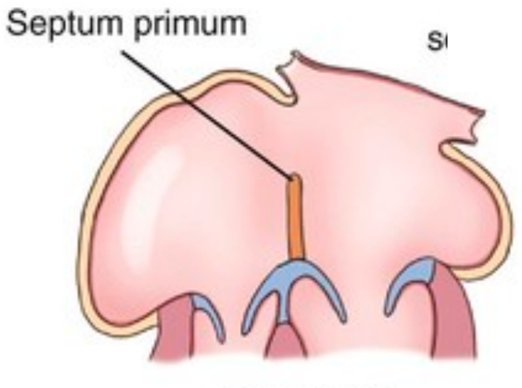


Normal atrial septum formation

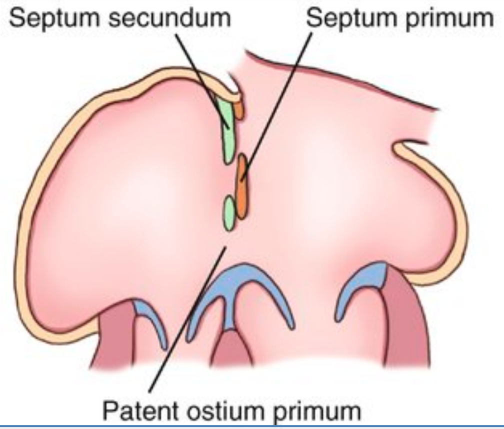
SEPTUM SECUNDUM



Excessive resorption of the septum primum



Failure of development of the septum secundum



OSTIUM PRIMUM ASD
caused by incomplete fusion of the endocardial cushions.

Stamm ER, Fetal Medicine, 2016

ASD types

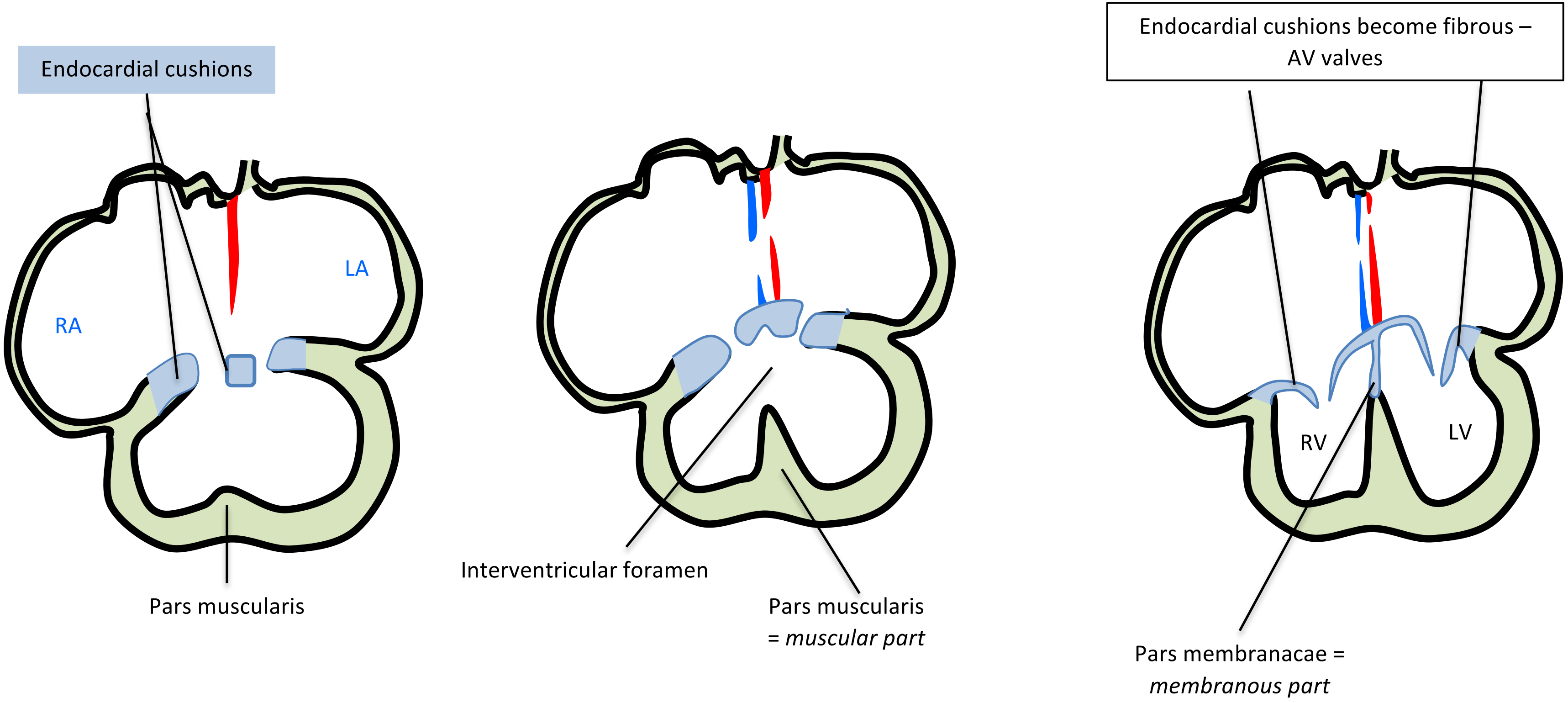
cor triloculare biventriculare:
complete failure of the septum primum and septum secundum to form

Most serious abnormality in this group

Stamm ER, Fetal Medicine, 2016

Internal changes:

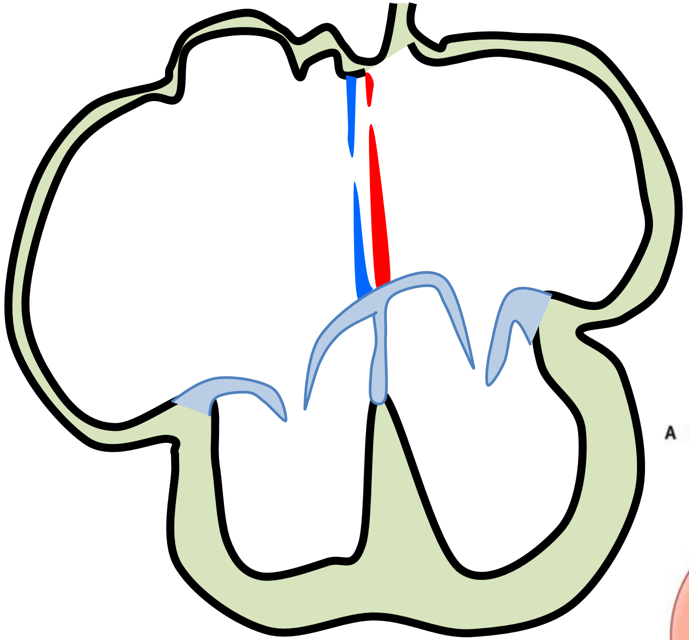
Septation of the ventricles



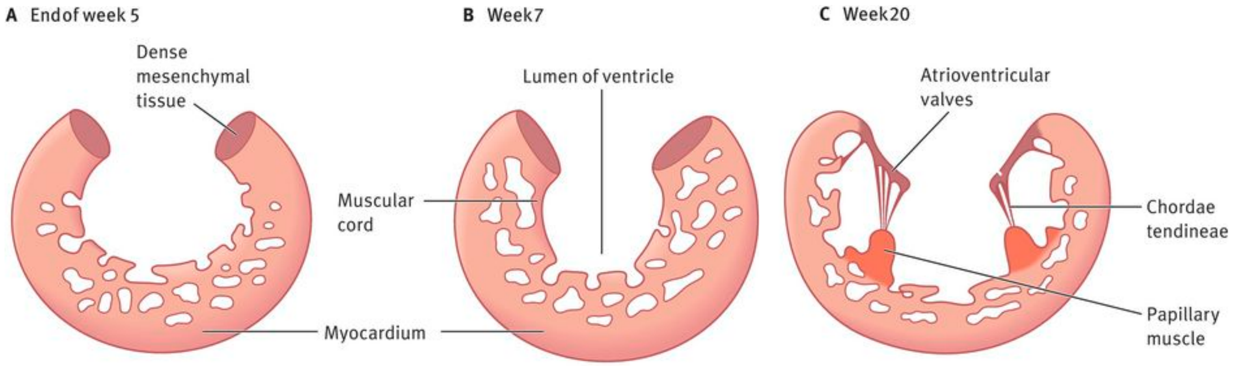
Neural crest cells in endocardial cushions

Internal changes:

Formation of AV valves

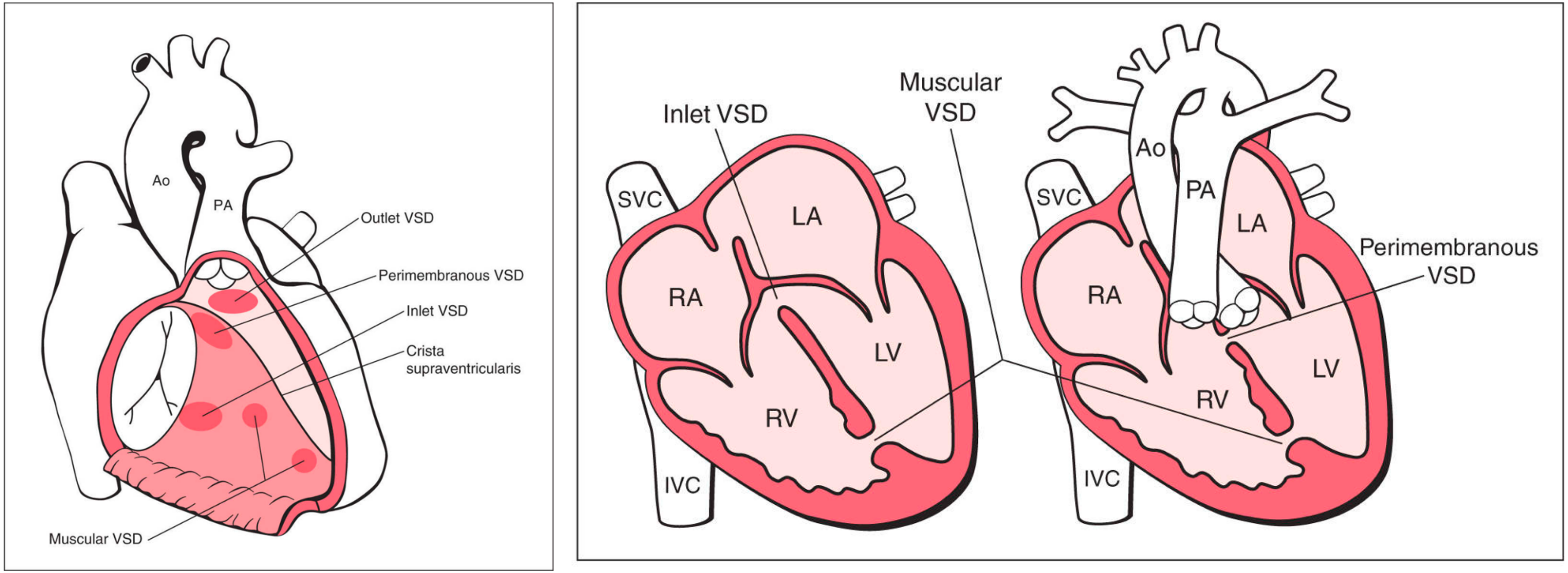


- Localised proliferation of mesenchymal tissue
- Tissue on ventricular surface ‘thins’ and forms valves
- Leaflets remain attached to ventricular wall by cords (week 20)



Ventricular septal defects (VSDs)

- Most common congenital cardiac malformation (12/10 000 births)
- 20% Membranous; 80% Muscular

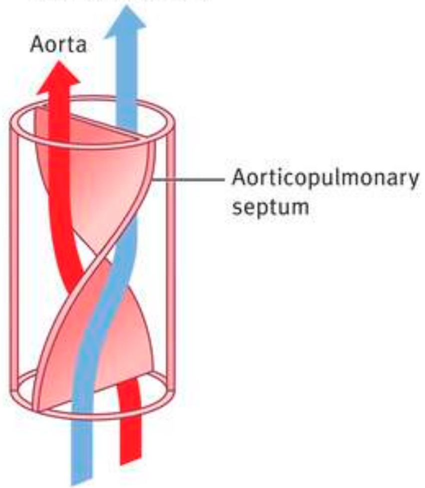


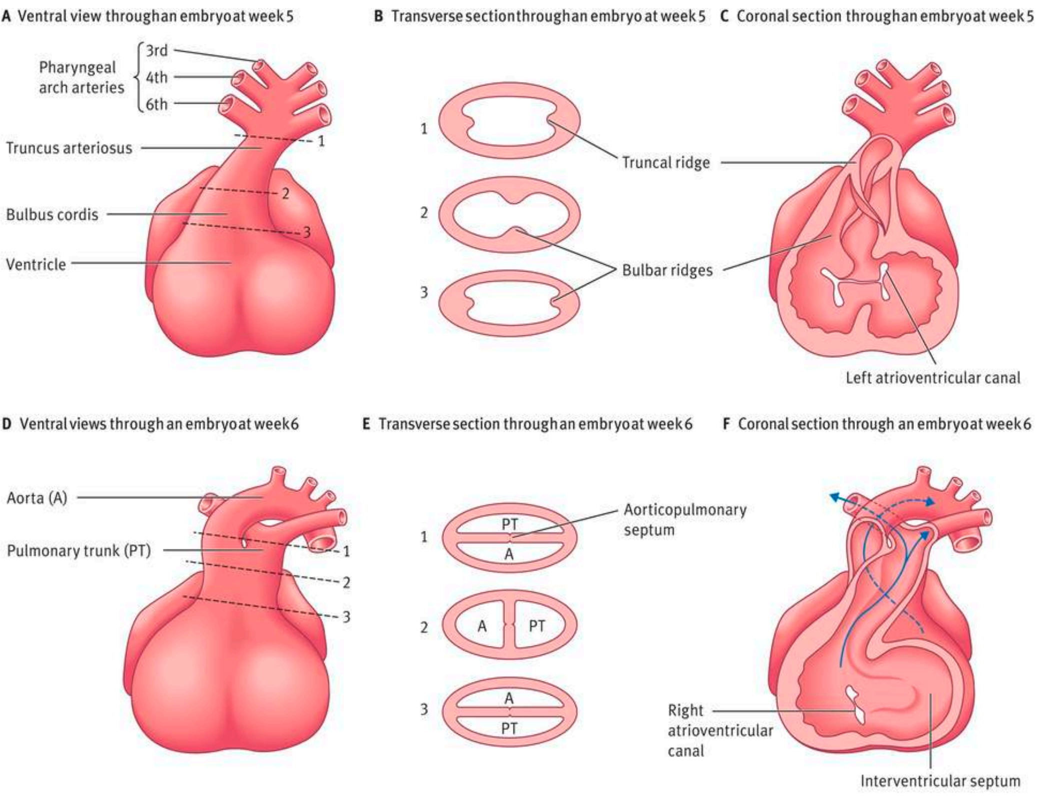
Schematic drawings of types and anatomic locations of ventricular septal defects (VSDs) as seen from the four-chamber and outflow tract views.

Internal changes:

Outflow septation

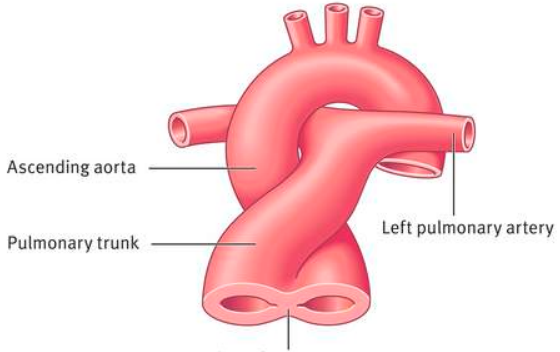
- 180° spiralling – aortico-pulmonary septum
  - Aorta
  - Pulmonary trunk





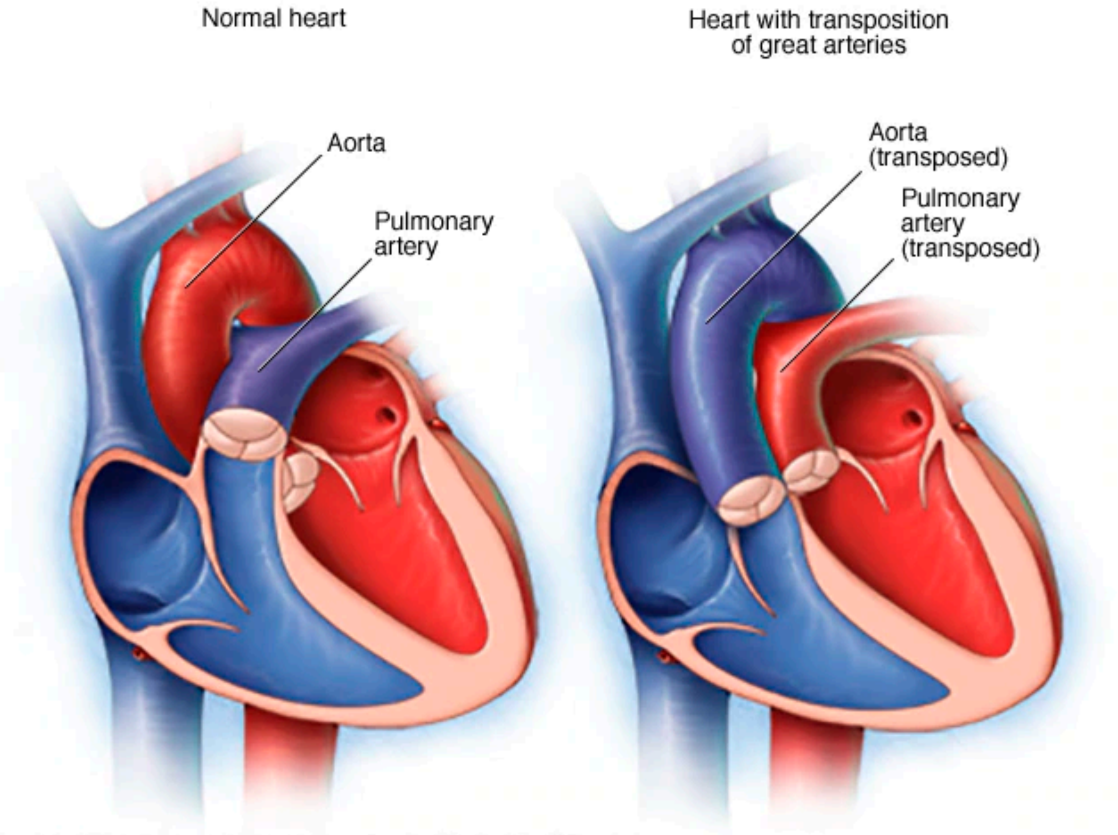
G Spiral form of the aorticopulmonary septum

(A–C) show the truncal and bulbar ridges at 5 weeks. (D), (E) and (F) show the aorticopulmonary septum at 6 weeks. (G) and (H) show the final position of the ascending aorta and pulmonary trunk at the end of 8 weeks, twisting around each other as they leave the heart.



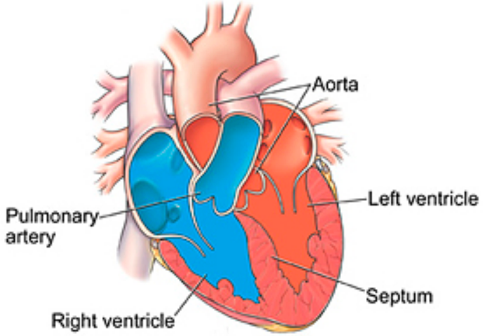
H Aorta and pulmonary trunk twisting around each other

Transposition of the Great Vessels

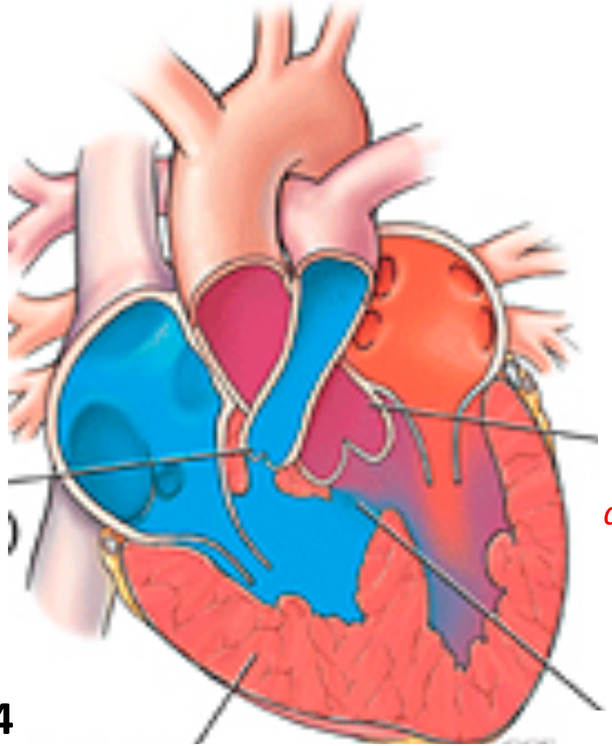


Tetralogy of Fallot

4 features!



normal



1

Pulmonary artery stenosis (narrowed valve)

abnormal outflow septation

2

overriding aorta

abnormal outflow septation

3

Large ventricular septal defect

abnormality in ventricular septation

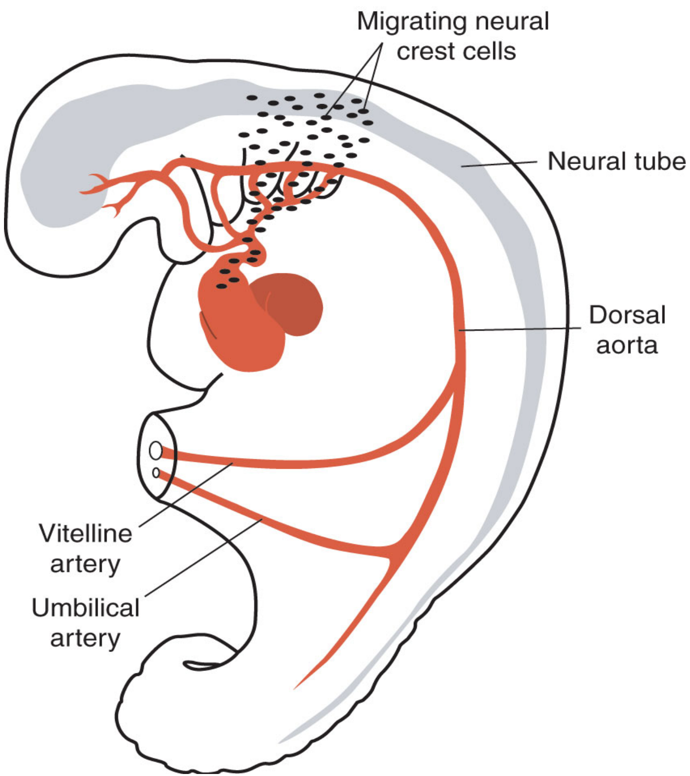
4

right ventricular hypertrophy

increase contractions

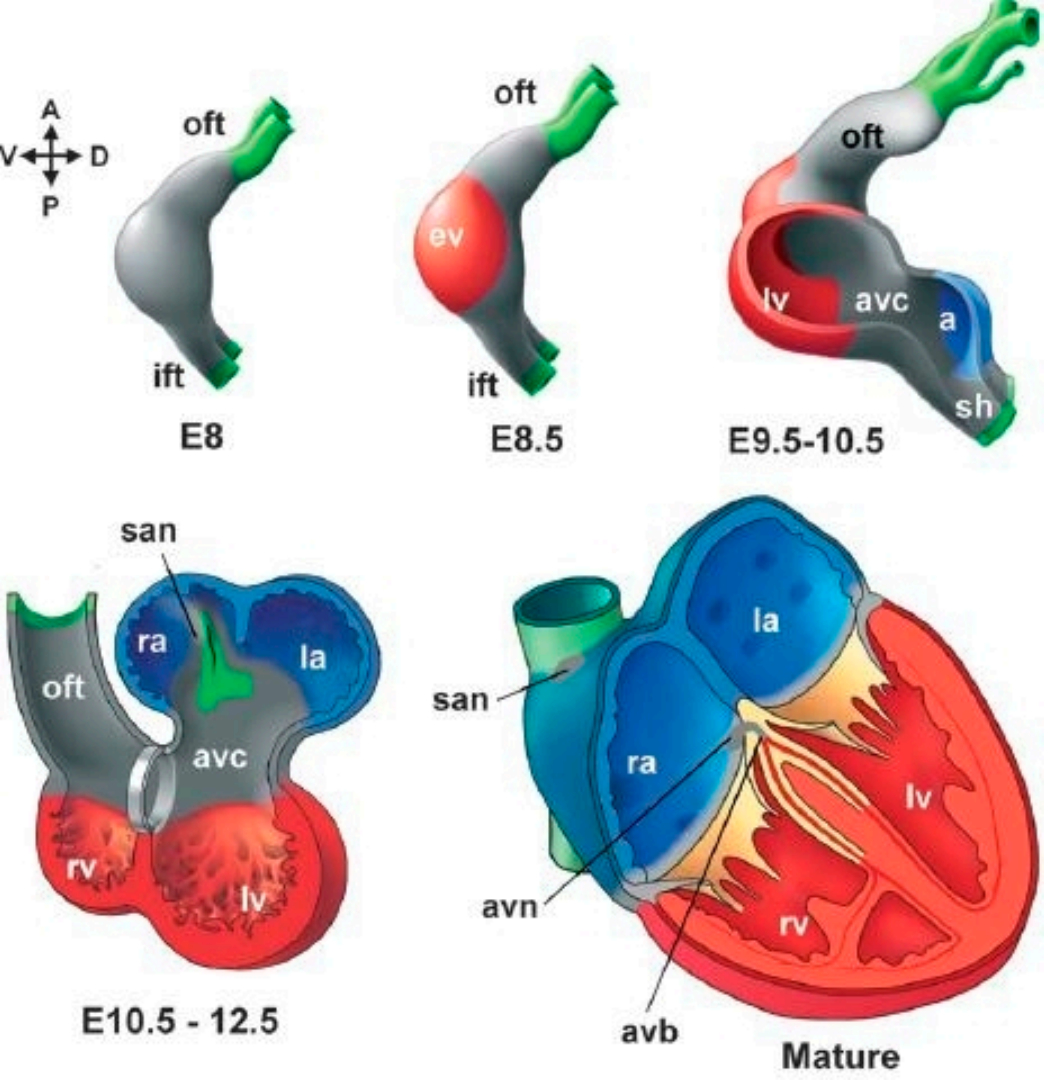
Cleveland Clinics

Migration of Cardiac Neural Crest Cells



3.5-4 Weeks

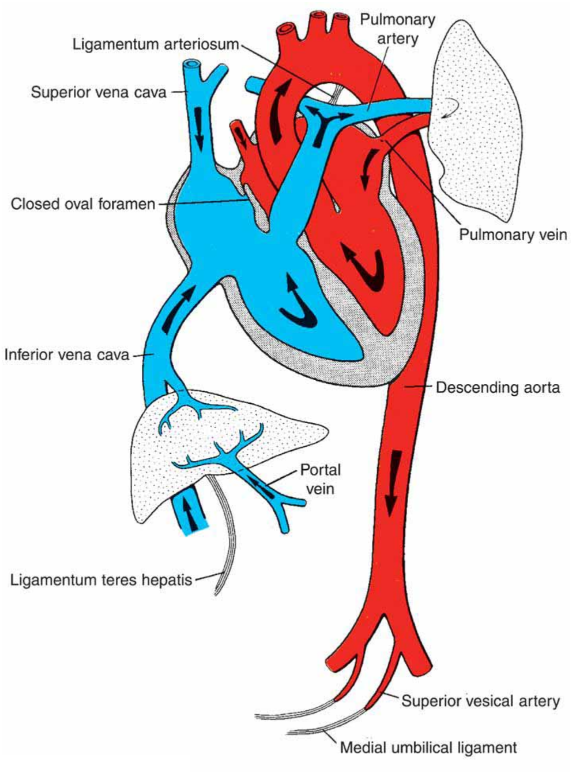
Regulation of cardiac development is complex and not fully understood



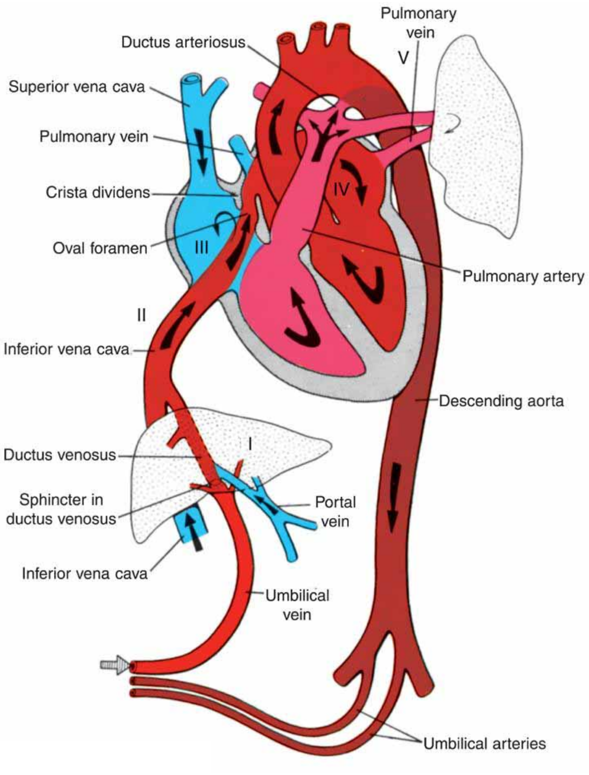
Bottom Line: Not surprisingly, a large number of regulating factors are involved in these processes that act in complex and intertwined pathways to regulate the activity of target genes responsible for morphogenesis and function.Functional and genetic analyses in a variety of divergent species has demonstrated the critical roles of multiple T-box factor gene family members, including Tbx11, -2, -3, -5, -18 and -20, in the patterning, recruitment, specification, differentiation and growth processes underlying formation and integration of the heart components.Insight into the roles of T-box factors in these processes will enhance our understanding of heart formation and the underlying molecular regulatory pathways.

Hoogars et al., CMLS, 2007

Postnatal and Prenatal Circulatory Patterns



Postnatal



Prenatal