Cardiovascular System
Heart Development

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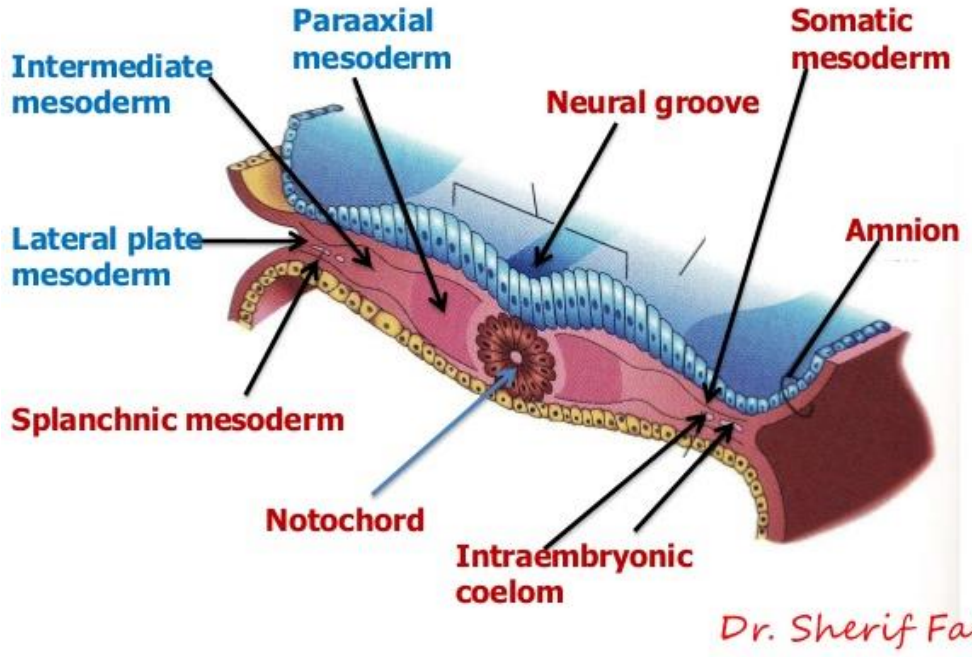
In human embryos, the heart begins to beat at approximately 22-23 days, with blood flow beginning in the 4th week. The heart is one of the earliest differentiating and functioning organs.

- This emphasizes the critical nature of the heart in distributing blood through the vessels and the vital exchange of nutrients, oxygen, and wastes between the developing baby and the mother.
- Therefore, the first system that completes its development in the embryo is called cardiovascular system.



https://www.slideshare.net/DrSherifFahmy/intraembryonic-mesoderm-general-embryology

- Connective tissue
- Smooth and striated muscle
- Cardiovascular System
- Kidneys
- Spleen
- Genital organs, ducts
- Adrenal gland cortex

Mesoderm is one of the three primary germ layers that differentiates early in development that collectively gives rise to all subsequent tissues and organs.

The cardiovascular system begins to develop in the third week of gestation. Blood islands develop in the newly formed mesoderm, and consist of (a) a central group of haemoblasts, the embryonic precursors of blood cells; (b) endothelial cells.

Development of the heart and vascular system is often described together as the cardiovascular system.

Development begins very early in mesoderm both within (embryonic) and outside (extra embryonic, vitelline, umblical and placental) the embryo. Vascular development occurs in many places.

- Blood islands coalesce to form a vascular plexus. Preferential channels form arteries and veins.
- Day 17 - Blood islands form first in the extra-embryonic mesoderm
- Day 18 - Blood islands form next in the intra-embryonic mesoderm
- Day 19 - Blood islands form in the cardiogenic mesoderm and coalesce to form a pair of endothelial heart tubes

Development of a circulation

- A circulation is established during the 4th week after the myocardium is differentiated.
- The cranial end communicates with the paired branchial arches that open into paired dorsal aortae. These fuse into a single dorsal aorta. At this stage three main pairs of arteries are present:
- (i) to the head,
- (ii) vitelline arteries to the yolk sac
- (iii) paired umbilical arteries to the placenta .

Three corresponding veins drain into the sinus venosus.

Formation of the Primitive Heart Tube

- At the start of its development, the cardiovascular system exists as two regions near the cranial end of the embryo.
- These regions are called cardiogenic fields and they are derived from the mesoderm layer of the embryo.

- The development of the heart begins with the formation of the primitive heart tube following the folding of the embryo during the end of the third week.
- The cardiogenic fields consist of blood islands which are primitive tissues, and mark the beginning of blood, vessel and heart development.

On either side of the neural plate, a horseshoe shaped area develops as the cardiogenic region
This is formed from cardiac myoblasts and blood islands.

By day 19, an endocardial tube begins to develop in each side of this region.
These areas develop further and fuse to form two tubes, which are called endocardial tubes, one on each side of the embryo (Day 19-20).

- The embryo folds in two directions:

- **Cephalo-caudal folding** brings the cardiogenic fields from the cranial end towards the centre of the embryo to sit in thoracic region where the heart will be.
- **Lateral folding** fuses the two lateral sides of the embryo. This brings to two cardiogenic fields into the midline so they can fuse and form the primitive heart tube.

Primordial Myocardium

- As the heart tubes fuse, an external layer of heart the primordial myocardium is formed from mesoderm.
- At this stage the developing heart is composed of a thin endothelial tube, separated from thick muscular tube by **cardiac jelly**.

During the fusion of the endocardial tubes, the myocardium secretes an extracellular (acellular) matrix (enriched in chondroitin sulfate, versican, heparan sulfate, hyaluronic acid, hyaluronan, and proteoglycans), forming the cardiac jelly layer separating the myocardium and endocardium

This primitive heart tube is formed at around day 25 of gestation.
It is divided into six parts:

1. Aortic roots (arterial poles):
Form the arteries of the aortic arch

2.Truncus arteriosus:

Involved in the formation of the pulmonary trunk and aorta (outflow

from the heart)

3.Bulbus cordis:

Involved in the formation of the pulmonary trunk and aorta (outflow

from the heart)

4.Primitive ventricle:

Forms the ventricles

5.Primitive atrium:

Forms the atria

6.Sinus venosus (venous poles):

Forms part of the right atrium and vena cava

In the fourth week of development the embryo begins to fold, which will put the heart tissue in the correct position to form the primitive heart tube surrounded by the pericardial sac.

Cardiac Looping

As the heart tube grows and elongates, it gets too long for the sac.

The heart tube continues to elongate, and begins looping at around day 23 of development.
The primitive ventricle moves ventrally and to the right.
The primitive atrium moves dorsally and to the left.

- This looping creates a space behind the arteries (aorta and pulmonary trunk) and in front of the superior vena cava.
- It is complete by day 28.
- When folding is finished, the primitive ventricle is sitting at the bottom of the cavity, with the primitive atrium behind it.

Embryonic structure	Adult structure
Truncus arteriosus	Ascending aorta Pulmonary trunk
Bulbus cordis	Smooth part of left and right ventricle
Primitive ventricle	Trabeculated part of left and right ventricle
Primitive atria	Trabeculated part of left and right atrium
Sinus venosus	Coronary sinus Smooth part of right atrium
Right common and right anterior cardinal vein	SVC

Development of the sinus venosus

- In the middle of the fourth week, the sinus venosus receives venous blood from the poles of right and left sinus. Each pole receives blood from three major veins: the vitelline vein, the umbilical vein and the common cardinal vein.

The right sinus horn is partially absorbed by the primitive atrium as it grows. This forms the superior and inferior vena cava. When the left common cardinal vein disappears in the tenth week only the oblique vein of the left atrium and the coronary sinus remain. The left sinus horn becomes the coronary sinus which drains venous blood from the coronary vessels into the right atrium.

The sinus opening moves clockwise. This movement is caused mainly by the left to right shunt of blood, which occurs in the venous system during the fourth and fifth week of development.

- During development of the heart, the orifice of the sinus venosus lies obliquely, and is guarded by two valves, the right and left venous valves; above the opening these unite with each other and are continuous with a fold named the septum spurium.

Development of the Pulmoner vein

The pulmonary veins begin as a single vein entering the left atrium. This vein is formed from four branches which converge to form one vein draining into the developing left atrium.

As the left atrium grows, it absorbs the single pulmonary vein, absorbing all the way to the four branches. This means that when the left atrium has finished growing, it is receiving blood from four pulmonary veins.

Endocardial cushions

Endocardial cushions, or atrioventricular cushions, refer to a subset of cells in the development of the heart that play a vital role in the proper formation of the heart septa.

They play;
In the formation of the central parts of the atrial and ventricular septa,
In the formation of aortic and pulmonary canals,
In the development of AV valves.

Development of Atria

- At the end of the fourth week, a crest grows that leaves the cephalic part. This crest is the first part of the septum primum.
- The two ends of the septum extend into the interior of the endocardial cushions in the atrioventricular canal.
- The opening between the bottom edge of the septum primum and endocardial cushions is the ostium primum (first opening).

- Just before the septum primum meets the endocardial cushions and the ostium primum is closed, a hole forms in the middle of the septum. This is the ostium secundum.
- The ostium secundum allows blood to continue to move from the right atrium to the left.

- Another septum grows down from the top of the atria, called the septum secundum.
- As the septum secundum grows down, it leaves another hole just below the ostium secundum.

- The foramen ovale forms in the late fourth week of gestation, as a small passageway between the septum secundum the ostium secundum.
- Blood then only passes from the right to left atrium by way of a small passageway in the septum secundum and then through the ostium secundum.

Development of Venticles

The formation of the ventricular septum take place in two steps.

First, a muscular portion of heart tissue grows upwards from the floor of the primitive ventricle towards the endocardial cushions. It doesn't quite reach the cushions, forming the primary interventricular foramen.

A membranous portion then grows down from the endocardial cushions to meet the membranous portion and close the foramen.

The fifth and eighth weeks of embryonic development, this meshwork compacts, proceeding from the epicardium to the endocardium and from the base of the heart to the apex.

The heart valves form between the atria and ventricles (mitral valve, tricuspid valve) and between the atria and blood vessels (aortic valve, pulmonary valve). The cardiac cushions in the atrioventricular (AV) canal contain cells that are the primordia of the cardiac valves. The atrioventricular valves are attached to papillary muscles by chordae tendineae.

Septum formation in the outflow tracts of heart

The bulbus cordis and truncus arteriosus form one tube allowing outflow from the heart. This tube needs to be spilt in order to form the aorta and pulmonary trunk.

Septum formation in the outflow tracts of heart

In the fifth week a pair of ridges appears opposite each other within the conus cordis and truncus arteriosus, the rigth and left truncoconal swellings.

The two ridges aproach one another and form the aorticopulmonary septum, seperating the two major outflow tracts of the two ventricles.

The septum develops as a spiral structure, which accounts for the spiralling around each other of the pulmonary trunk and ascending aorta.

Development of the Atrioventricular canal

- Atrioventricular valves form during the 5 to 8 week of development.
- Initially, endocardial cushion tissue forms bulges at the atrioventricular junction.
- These two masses will meet in the middle, thus dividing the common atrioventricular canal into right and left atrioventricular orifices.

- The endocardial cushions are thought to arise from a subset of endothelial cells that undergo epithelial-mesenchymal transition, a process whereby these cells break cell-to-cell contacts and migrate into the cardiac jelly (towards the interior of the heart tube). These migrated cells form the "swellings" called the endocardial cushions seen in the heart tube.

- Upon sectioning of the heart the atrioventricular endocardial cushions can be observed in the lumen of the atrial canal as two thickenings, one on its dorsal and another on its ventral wall. These thickenings will go on to fuse and remodel to eventually form the valves and septa of the mature adult heart.

Septum formation within the atrioventricular canal occurs when two large endocardial cushions fuse, resulting in a right (tricuspid) and left (mitral) atrioventricular orifice. This usually occurs by day 33 of development.

The interventricular septum is formed by the end of the seventh week of development. It results from the dilation of the two primitive ventricles (right and left conus swellings), which causes the medial walls to become apposed and fuse together. This forms the muscular portion of the interventricular septum. Formation of the membranous portion follows.

Development of the Arterial System

The dorsal aortae develop at the same time as the early heart tubes.
These connect to the heart tubes prior to fusion via the first aortic arch arteries.
Other arches develop, which go on to form the arteries of the head and neck.
The dorsal aorta gives off branches which supply blood to the rest of the embryo.

Development of the Arterial System

Vessels arise from the truncus arteriosus as aortic arches.

There are five pairs of arches, numbered I, II, III, IV, VI (arch V doesn't form in humans, so there are 5 arches numbered between 1-6 without a number 5). These arches, along with the truncus arteriosus, contribute to the formation of large arteries.

- The 1st Arch and 2nd Arch start to regress by approximately day 27, however portions of each persist as the maxillary artery, and the hyoid and stapedial arteries, respectively.
- By day 29 both these arches completely disappear.

- 3rd Arch : forms common carotid artery, first (cervical) part of internal carotid artery (rest of internal carotid arises from dorsal aorta), and external carotid artery.
- 4th Arch: on LEFT – forms part of arch of aorta
- On RIGHT – forms proximal part of right subclavian artery,
- 5th Arch: either never forms or regresses after incomplete formation.
- 6th Arch: forms Pulmonary Arch.

Development of the Venous System

There are three paired veins which form to drain into the sinus venosus:

Vitelline veins - return poorly oxygenated blood from the yolk sac

Umbilical veins - carry well-oxygenated blood from the primordial placenta

Common cardinal veins - return poorly oxygenated blood from the body of the embryo

Systemic venous system:

- At first, the sinus venosus communicates with the common atrium
- At 8 weeks, the distal end of the left cardinal vein degenerates, and the more proximal portion forms the common connection between left brachiocephalic vein and right anterior cardinal vein or right brachiocephalic vein, thus forming the superior vena cava
- The left posterior cardinal vein also degenerates, and the left sinus horn becomes the coronary sinus
- The right vitelline vein becomes the inferior vena cava, and the right posterior cardinal vein becomes the azygos vein
- The left umbilical vein degenerates and the right umbilical vein connects to the vitelline system through the ductus venosus.

Development of the lymphatic system

- The lymphatic system begins to develop at the end of week 5, approximately 2 weeks later than the cardiovascular system.
- One view states that the lymphatics develop as diverticulae of the endothelium of veins; whereas another states that like other blood vessels they develop from clefts in the mesenchyme that connect with the venous system secondarily.
- Thus, the cells lining the mesenchymal clefts assume an endothelial shape, and subsequent sprouting of these cells causes the clefts to fuse and form the lymphatic channels.

IN WEEKS 6-9,
LOCAL DILATATIONS of the lymphatic channels form 6 primary lymph sacs

- Two jugular lymph sacs near the junction of the subclavian veins with the anterior cardinals. (future internal jugular vein)
- Two iliac lymph sacs near the junction of the iliac veins with the posterior cardinal veins.
- One retroperitoneal lymph sac in the root of the mesentery on the posterior abdominal wall.
- One so-called cisterna chyli dorsal to the retroperitoneal lymph sac, at the level of the adrenal glands.

- Lymphatic vessels soon connect to the lymph sacs and pass along main veins;
- Two large channels (right and left thoracic ducts) connect the jugular lymph sacs with this cistern.

Congenital Heart Defects

Heart defects and preterm birth are the most common causes of neonatal and infant death. The long-term development of the heart combined with extensive remodelling and post-natal changes in circulation lead to an abundance of abnormalities associated with this system.

The atrial septal defects (ASD) are a group of common (1% of cardiac) congenital anomolies defects occuring in a number of different forms and more often in females.

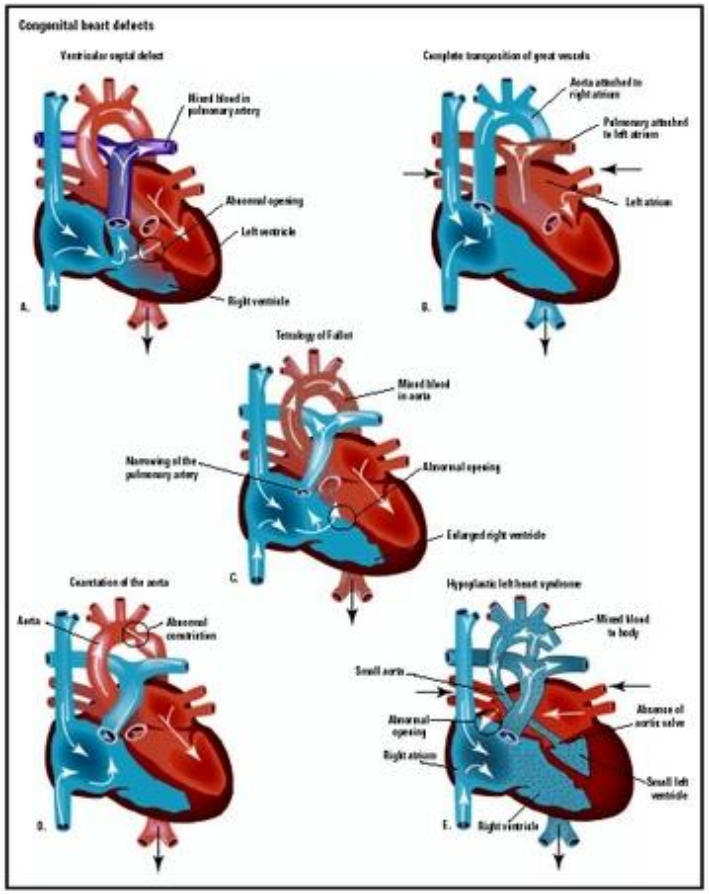
Patent Ductus Arteriosus

Patent ductus arteriosus (PDA), or Patent arterial duct (PAD), or common truncus, occurs commonly in preterm infants, and at approximately 1 in 2000 full term infants and more common in females (to male ratio is 2:1).

Tetralogy of Fallot named after Etienne-Louis Arthur Fallot (1888) who described it as "la maladie blue" and is a common developmental cardiac defect.

1.Ventricular septal defect.
obstruction of the right
2.Ventricular outflow tract.
3.Override of the ventricular septum by the aortic root
4.Right ventricular hypertrophy.

The ventricular septal defect (VSD) is one of the common forms of congenital cardiovascular anomaly, occurring in nearly 50% of all infants with a congenital heart defect. Usually occurs in the membranous (perimembranous) rather than muscular interventricular septum, and is more frequent in males that females.



The most common types of congenital heart defects are ventricular septal defect (A), complete transposition of the great vessels (B), tetralogy of Fallot (C), coarctation of the aorta (D), and hypoplastic left heart syndrome (E).

http://www.healthofchildren.com/C/Congenital-Heart-Disease.html#ixzz6IUXjyQRi

Sources

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Thank You