Stages of Neurulation and Development of the Heart

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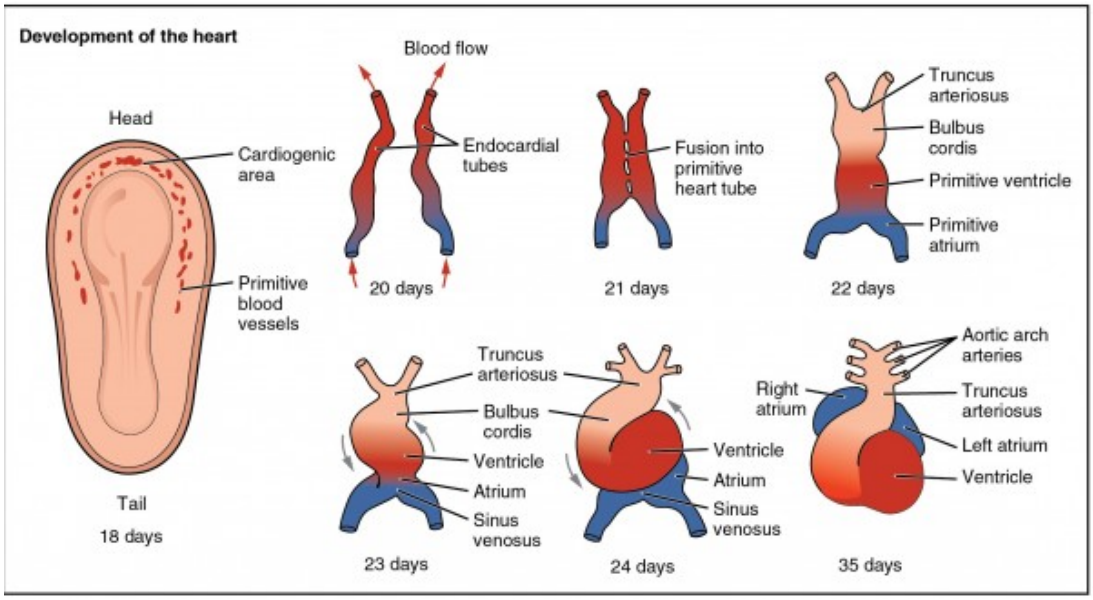
In the 3rd week of embryonic development, both the neurulation and development of the cardiovascular system begin. The neurulation denotes the formation of the neural tube in the development of the central nervous system. These complex processes are a combination of numerous factors and interactions.



The Stages of Neurulation

1st Stage: induction

At the beginning of the 3rd week of embryonic development, the induction of neurulation begins. The notochord and paraxial mesoderm secrete signaling molecules, resulting in the differentiation of the overlying ectoderm into neuroectoderm.

2nd Stage: formation of the neural plate

The neural plate originates from the neuroectoderm, an area with compressed and increased epithelial cells. It begins at the cranial end and grows toward the caudal. The cranial end initially increases rapidly in size and is, therefore, wider than the caudal end. The brain will develop from this histoid.

3rd Stage: formation of the neural tube

On approximately the 18th day of embryonic development, the neural plate deepens and forms the neural groove. Its margins are increased by the so-called convergent extension. This means that the cell rows shift into one another and form the neural folds. The neural folds then merge, cut off the neural groove, and form the neural tube. This is the basis for the central nervous system.

4th Stage: closing of the front and rear neuropore

The neural tube resembles a channel that is open at both ends. The end of the head is called the anterior neuropore. The brain will develop in this region. The caudal end, the posterior neuropore, will form the spinal cord. The cavity of the neural tube later forms the ventricular system of the central nervous system.

On the 25th day of embryonic development, the end of the head joins the anterior neuropore. Two days later, the posterior neuropore closes. The neural tube now ends approximately at the height of the later S2 segment. If the closing of the neural tube is disturbed, neural tube defects or dysraphic disorders can occur.

5th Stage: cells of the ceural crest

The neural crests separate at the closed neural folds. The cells of the neural crest are very important in embryonic development. Although they originate at the ectoderm, they are sometimes referred to as the fourth cotyledon. These cells have the ability to move around and diversify into numerous cell types. They form the glial and nerve cells, melanocytes of the skin, calcitonin cells of the thyroid gland, cells of the adrenal medulla, and many of the connective tissue cells and bone cells of the skull.

Many cell types of the central nervous system are formed from the neural tube. Numerous cells of the peripheral nervous system also emerge from the neural crest cells.

Primary vs. secondary neurulation

Primary neurulation refers to the development of the neural tube under the influence of the notochord and the mesoderm. It ends in the 4th week of embryonic development with the closure of the posterior neuropore. This is followed by secondary neurulation. The caudal end of the neural tube then develops into the neural notochord and is canalized. This process ends in the 6th week.

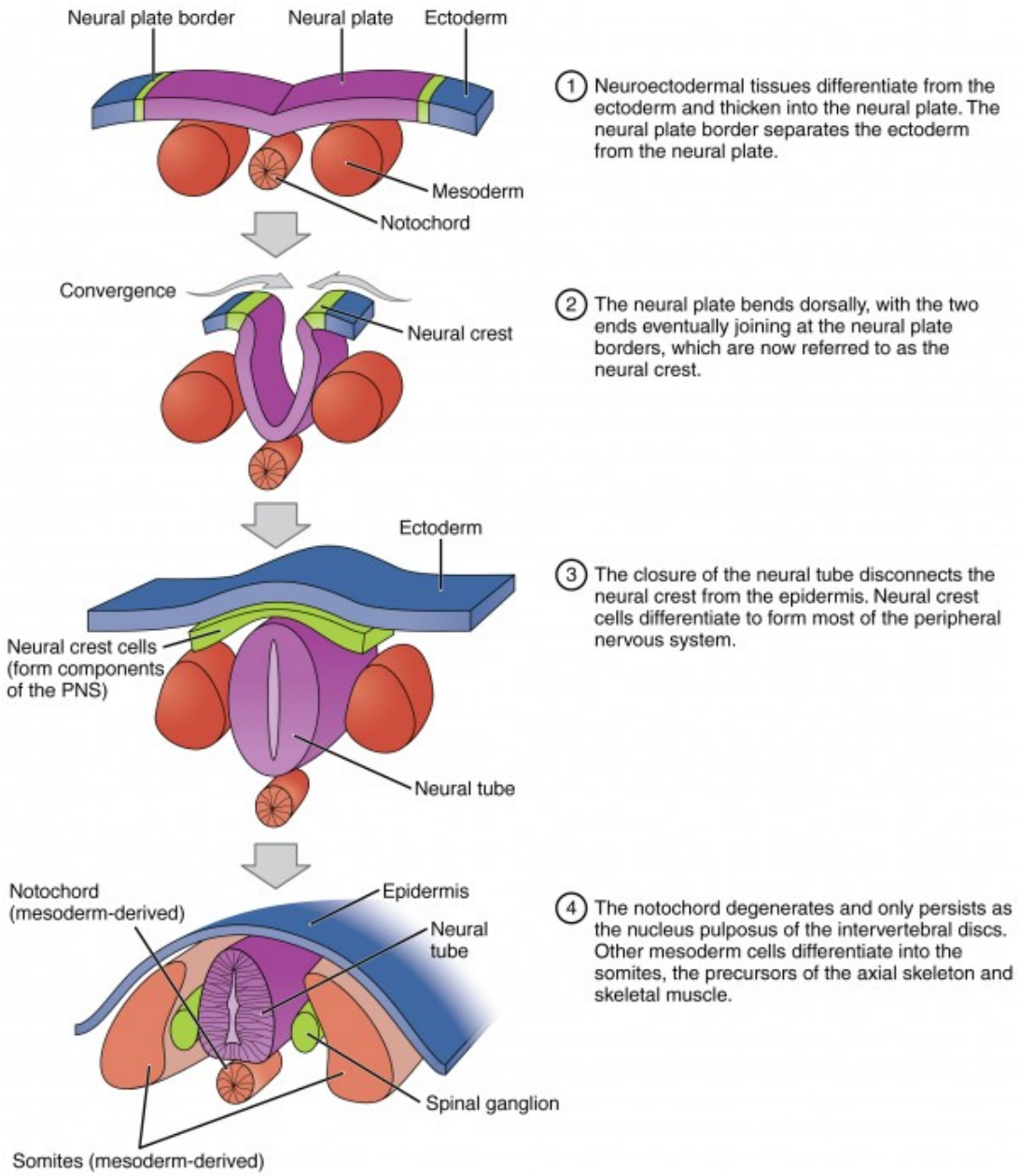


Image: Neurulation, by Phil Schatz. License: CC BY 4.0

Neural Tube Defects

Dysraphism roughly translates to ‘abnormal suture’. This condition disrupts the closure of the neural tube, either on the neuropore anterior or posterior, resulting in the following defects:

- **Anencephaly:** In this condition, the anterior neuropore does not close. As a result, significant portions of the skullcap, cerebrum, and diencephalon, are missing. Anencephaly usually results in fetal death.
- **Spina bifida:** In this condition, the neuropore caudalis does not close. The vertebral arches also remain open. There are different degrees of severity. This defect is compatible with life; however, paralysis often occurs.

Development of the Heart

Like neurulation, the development of the heart begins in the 3rd week of embryonic development. The heart's first contractions can be identified with an ultrasound device during the 4th week.

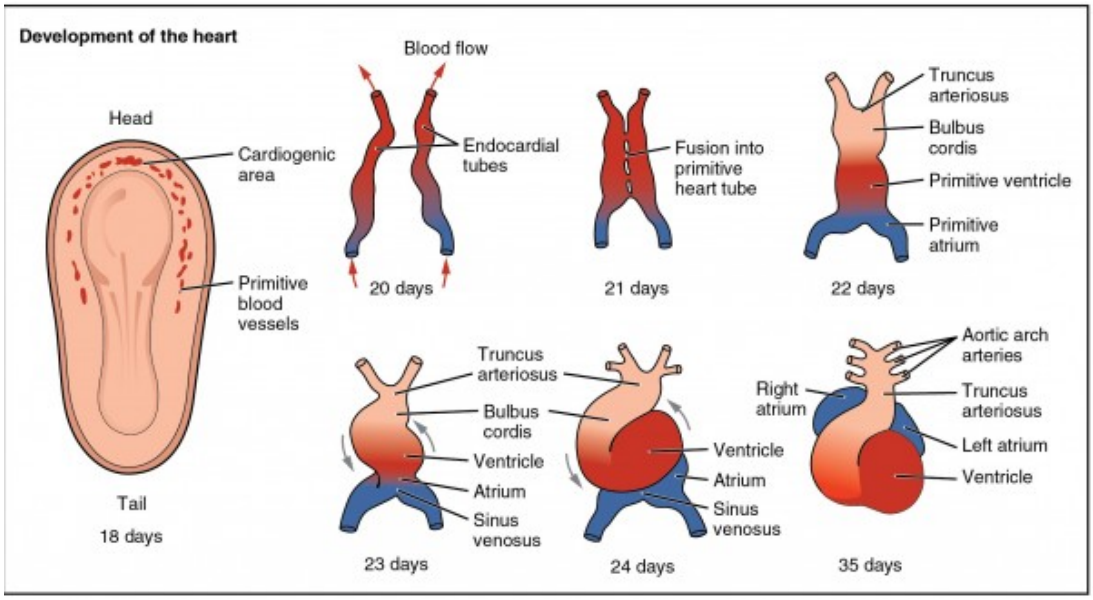


Image: Development of the human heart, by Phil Schatz. License: CC BY 4.0

Cardiogenic plate

The development of the cardiovascular system begins approximately on the 18th day of embryonic development. A horseshoe-shaped region of the splanchnopleura which lies cranial to the neural plate forms the cell groups. The cardiogenic plate originates from these cells. It consists of endothelium strands (endocardium), coelomic epithelium (myocardium), and coelom pockets (pericardium).

Cardiac tube

At the end of the 3rd week, a tubular structure, the cardiac tube, differentiates itself from the cardiogenic plate. It lies ventrally, partly due to the folding of the embryo. The following structures shape the heart tube through protuberances and constrictions from the cranial to the caudal end:

- **Truncus arteriosus:** The cardiac outflow tract of the heart tube is connected to the aortic sac.
- **Bulbus cordis:** This structure connects the truncus aorticus. The septum aorticopulmonary develops from the cells of the neural crest. Through a 180-degree spiral rotation of the septum, the aorta and the pulmonary truncus are separated from each other.
- **Primitive ventricle**
- **Primitives atrium**
- **Sinus venosus:** The blood of the vitelline veins, umbilical vein, and cardinal anterior and posterior veins flows through the influx path and into two sinus horns.

Cardiac loop

The cardiac loop forms when the sinus venosus cranial pushes behind the bulbus cordis. The result is an S-shaped structure, also known as the cor sigmoideum. The primitive ventricle lies caudally.

Atrioventricular canals

The four endocardial cushions are formed from the subendocardial connective tissues during constriction between the primitive atrium and the primitive ventricle. Two pairs of endocardial cushions grow toward each other and combine, and one pair forms the atrioventricular canals. The remaining two tissue cushions are part of the subsequent mitral and tricuspid valves. These valves monitor the blood flow between the atria and the ventricles once.

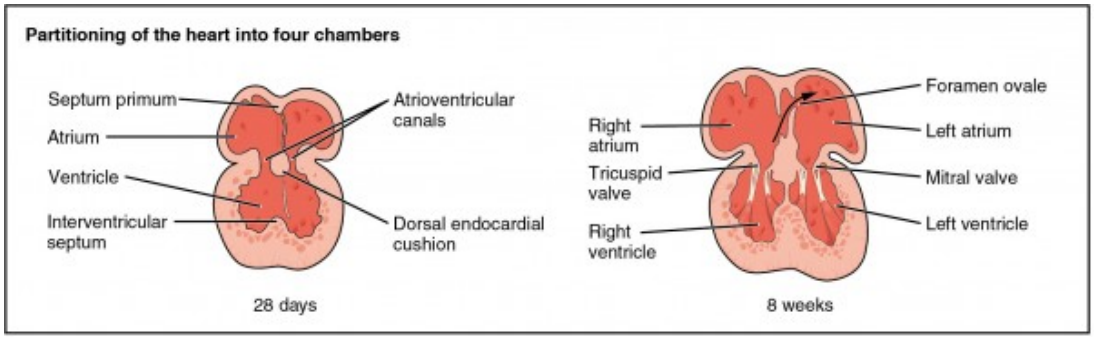
Division of the atrium

The primitive atrium divides at the end of the 4th week of embryonic development. In order to form the right and left atria, the septum primum grows from the roof of the atrium toward the endocardial cushion. This closes as a falcate and thereby leaves behind the ostium primum and provides communication between the right and left atrium. Finally, the ostium primum also disappears.

Small perforations also form in the cranial part of the septum. They join together to create the ostium secundum. A second septum, the septum secundum, also grows from top to bottom, closing the ostium secundum. There remains a slot-shaped opening between the septa and the endocardial cushion. The foramen ovale remains open until birth.

Division of the ventricle

The division of the ventricles occurs from the cardiac apex to the atrioventricular canals. The muscular septum is formed by the migration of myoblasts. The interventricular foramen between the right and left ventricles remains in the cranial portion up to the 7th week of embryonic development. This opening is finally closed via a thin membrane, the membranous part.



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Congenital Malformations of the Heart

If due to a defect of the septa a connection between the atria or the ventricles is made, the result is a mixing of oxygen-rich and oxygen-poor blood.

Atrial septal defect

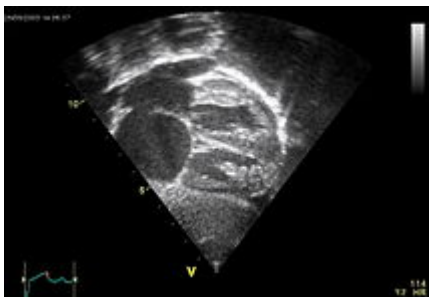

Image: Atrial septal defect

This defect results in, most commonly, a patent foramen ovale. Ostium primum or secundum defects are less common.

Ventricular Septal Defect

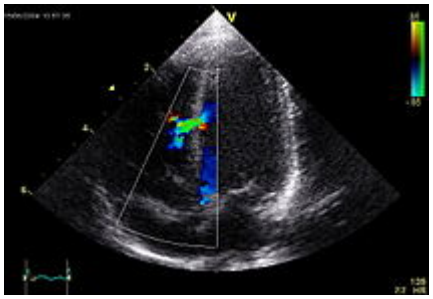

Image: Ventricular septal defect

This is the most common congenital heart defect. The membranous part does not form and an imperfect septum develops between the ventricles.

The Tetralogy of Fallot

This syndrome is a combination of four specific congenital malformations of the heart and the great vessels:

1. Ventricular septal defect
2. Pulmonary stenosis
3. Hypertrophy of the right ventricle
4. Overriding aorta

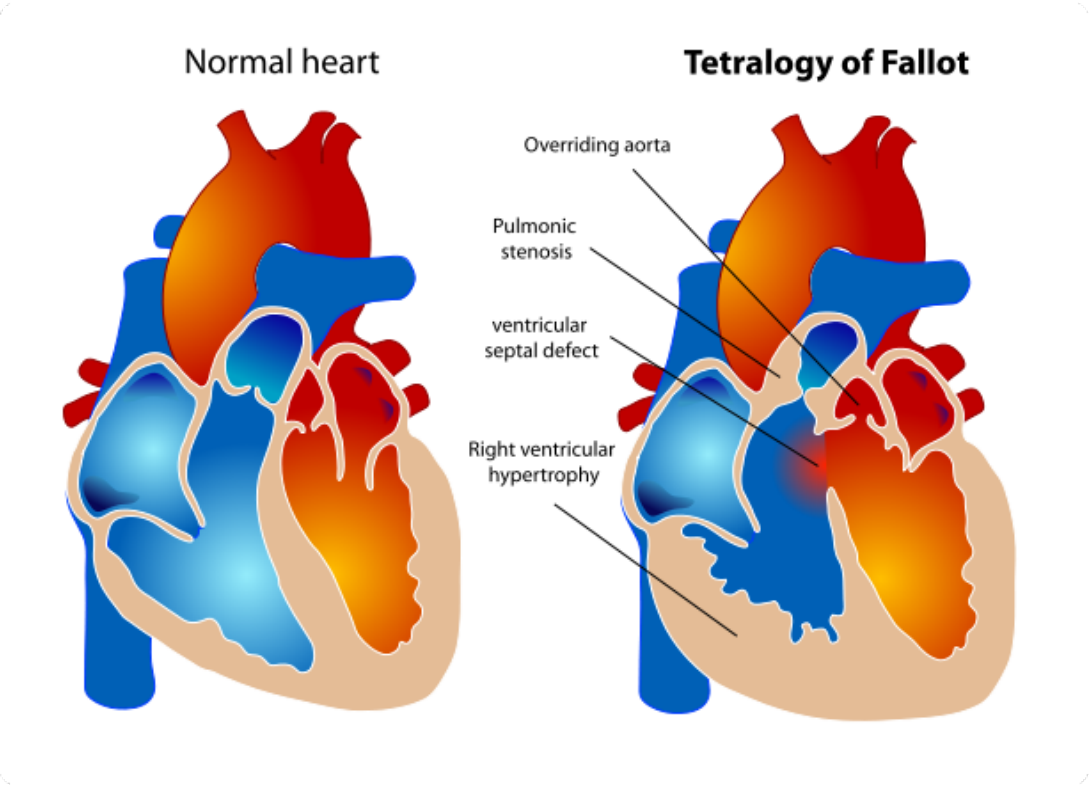

Image: Tetralogy of Fallot

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Notes