Development of the Great Vessels and Conduction Tissue
Development of the heart fields

Looking at a sagittal section of the heart early in development the bulbus cordis is continuous with the ventricle which is continuous with the atria. As the AV canal shifts to the right the bulbus move to the right as well.
The next three slides make the point via cross sections that the aorta and pulmonary arteries rotate around each other. This means the septum between them changes position from superior to inferior as well.
Septation of the Bulbus Cordis
Septation of the Bulbus Cordis
Migration of neural crest cells

Neural crest cells migrate from the 3rd, 4th and 6th pharyngeal arches to form some of the population of cells forming the aorticopulmonary septum.
Septation of the Bulbus Cordis

The cardiac jelly in the region of the truncus and conus adds the neural crest cells and expands as truncal swellings.
Septation of the Bulbus Cordis

These swellings grow toward each other to meet and form the septum between the aorta and pulmonary artery.
Septation of the Bulbus Cordis

The aorticopulmonary septum then rotates as it moves inferiorly. However, the exact mechanism for that rotation remains unclear.
Septation of the Bulbus Cordis

However, the aorticopulmonary septum must form properly for the IV septum to be completed.
Blood leaves the truncus and moves to the aortic arches. There is an aortic arch for each pharyngeal arch.
Development of the Arteries

They can be depicted this way for descriptive purposes explaining the fate of the arches.
The first arch degenerates shortly after the second arch develops.
Development of the Arteries

The second arch degenerates shortly after the third arch develops.
The distal third arch and the distal dorsal aorta form the internal carotid artery on both sides of the body.
The proximal third arch and the ventral aorta between the 3rd and 4th arches forms the common carotid artery on both sides of the body.
New vessels arise in the middle of the 3rd arch and form the external carotid arteries.
The truncus and the fourth arch on the left along with the dorsal aorta form the ascending aorta, the arch of the aorta and the descending aorta respectively.
ON the right the 4th arch and the dorsal aorta and 7th intersegmental artery form the right subclavian artery.
Development of the Arteries

The 7th intersegmental artery gives rise to the left subclavian artery.
The right ventral aorta between the 4th and 6th arches forms the brachiocephalic artery. Which then connects the aorta to the right common carotid artery and the right subclavian artery.
The proximal sixth arch forms the right and left pulmonary arteries along with some of the main pulmonary trunk.
On the right the distal sixth arch degenerates while on the right it remains as a shunt to take blood from the pulmonary system to the systemic system in the fetus.
Embryonic Circulation

- Dorsal Aorta
- Anterior Cardinal Vein
- Aortic Arches
- Ventricle
- Atria
- Yolk Sac
- Vitelline Artery & Vein
- Common Cardinal Vein
- Brain and Spinal Cord
- Posterior Cardinal Vein
- Umbilical Artery
- Umbilical Vein
In terms of the veins there are the systemic veins initially. They are the common cardinal veins, the anterior cardinal veins and the posterior cardinal veins.
The brachiocephalic veins form from the anterior cardinal on the right and a new system of veins called the thymicothyroid anastomosis on the left which then drains all the blood from the left side of the head and neck to the superior vena cava.
The superior vena cava develops from the right anterior cardinal vein and the right common cardinal vein.
The azygos vein develops from the right posterior cardinal vein and runs posterior to the lung root before arching anteriorly to enter the SVC.
The coronary sinus develops from the left common cardinal vein.
Because of the development of many abdominal organs several new vessels appear. Initially there is a posterior cardinal vein. Then there appears a set of subcardinal veins and supracardinal veins. These all contribute to the abdominal and pelvic vasculature.
Development of Inferior Vena Cava

The inferior vena cava develops from several sources. The renal segment develops from the right subcardinal vein (purple).
Development of Inferior Vena Cava

The inferior vena cava develops from several sources. The hepatic segment develops from a new vessel called the hepato-subcardinal anastomosis (yellow).

- anterior cardinal v.
- 7th intersegmental v.
- right vitelline v.
- right umbilical v.
- right subcardinal v.
- subcardinal anastomosis
- supracardinal v.
- posterior cardinal anastomosis
- sinus venosus
- right brachiocephalic
- internal jugular v.
- external jugular v.
- subclavian v.
- left brachiocephalic
- SVC
- hepatic IVC
- azygos v.
- suprarenal v.
- renal v.
- renal IVC
- postrenal IVC
- common iliac veins
- gonadal veins
Development of Inferior Vena Cava

The most proximal portion of the inferior vena cava develops from the right vitelline vein (red).

Diagram showing various veins and their anastomoses, including:
- anterior cardinal v.
- 7th intersegmental v.
- right vitelline v.
- right umbilical v.
- right subcardinal v.
- subcardinal anastomosis
- supracardinal v.
- posterior cardinal anastomosis
- sinus venosus
- right brachiocephalic
- internal jugular v.
- external jugular v.
- subclavian v.
- left brachiocephalic
- hepatic IVC
- azygos v.
- suprarenal v.
- renal IVC
- renal v.
- postrenal IVC
- common iliac veins
- gonadal veins
- hemiazygos v.
- renal v.
- SVC
- hepatic IVC
- suprarenal v.
Development of Inferior Vena Cava

The distal portion of the inferior vena cava develops from the distal supracardinal vein and perhaps the distal posterior subcardinal vein (navy blue).
The vitelline and umbilical veins are relocated on either side of the foregut (yellow).
The distal vitelline veins are going to develop anastomoses between the vessels and eventually form the portal vein (and perhaps the superior mesenteric vein) (green).
The proximal vitelline veins will form the main hepatic veins that empty into the inferior vena cava (orange).
The proximal part of the inferior vena cava was derived from the right vitelline vein (red).
Development of Veins

As the liver and kidneys grow they obliterate the right umbilical vein. It degenerates and blood from the placenta flows through the left umbilical vein. However, as the liver enlarges a new vessel develops so that placental blood will bypass the liver. This is the ductus venosus (blue).
Developments of Veins

A birth, the umbilical vein and the ductus venosus are no longer patent and become connective tissue cords called the ligamentum teres (purple) and the ligamentum venosum (blue) respectively.
Conversion of fetal circulation to newborn circulation

Fetal Circulation

- Umbilical vein
- Ductus venosus
- Inferior vena cava
- Right atrium
- Right ventricle
- Pulmonary artery
- R & L Pulmonary A

Newborn circulation

- Inferior vena cava
- Right atrium
- Right ventricle
- Pulmonary artery
- Lungs
- Pulmonary Veins
- Left atrium
- Left ventricle
- Aorta
At birth there is:

• Closure of the umbilical vein
• Closure of the ductus venosus
• Closure of the foramen ovale
• Closure of the ductus arteriosus.

– Increased $O_2$ partial pressure.
– Bradykinins are released from the lungs.
– Prior to birth prostaglandins keep fetal vasculature dialated.
Conduction tissue

The initial myocardial mantle gives rise to three rings of tissue.
SA Node
SA node cells develop from mesenchymal cells that are precursors of the sinus venosus tissue.
Cells Tbx18 positive.
Then Tbx3 positive
Leads to activation of
  CX40
  Cx43
  Nppa
  Scn5a
All SA node genes
AV Node and bundle

• AV Node cells
  • Cx45 positive
  • Cx30 positive
  • Tbx3 positive
• AV ring gives rise to AV node cells
• AV bundle develops from crest of muscular IV septum
• Rest of AV canal tissue becomes annulus fibrosus.
  • Insulates atria from ventricles
  • Otherwise accessory pathways.
• Mesoderm – gives rise to cardiac muscle cells and endocardial cells.
• Neural crest cells – develop into smooth muscle of outflow tract and cardiac ganglia.
• Proepicardium – epicardium and coronary vessels.
**TABLE 1**  
Mean Heart Rates for Embryos at 6–8 Weeks’ Gestation

<table>
<thead>
<tr>
<th>Group</th>
<th>Gestational Age (days)</th>
<th>Mean Heart Rate ±SD (beats/min)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (n = 456)</td>
<td>42–45</td>
<td>111 ± 14</td>
</tr>
<tr>
<td>2 (n = 522)</td>
<td>46–49</td>
<td>125 ± 15</td>
</tr>
<tr>
<td>3 (n = 558)</td>
<td>50–52</td>
<td>145 ± 14</td>
</tr>
<tr>
<td>4 (n = 628)</td>
<td>53–56</td>
<td>157 ± 13</td>
</tr>
</tbody>
</table>

**Embryonic heart rate in early pregnancy.**  
Stefos TI, Lolis DE, Sotiriadis AJ, Ziakas GV.
# Early Fetal Heart Rates

<table>
<thead>
<tr>
<th></th>
<th>6 weeks</th>
<th>7 weeks</th>
<th>8 weeks</th>
<th>9 weeks</th>
<th>10 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHR (bpm)</td>
<td>117 ± 6</td>
<td>129 ± 18</td>
<td>154 ± 16</td>
<td>169 ± 12</td>
<td>171 ± 6</td>
</tr>
</tbody>
</table>

• Normal fetal heart rate is between 110 and 160 beats per minute (bpm) throughout pregnancy.
• Later in pregnancy the heart rate may slow as the vagal innervation matures.