5. Development of circulatory system I. Embryonic and extraembryonic circulation. Aortic arches. Veins.

Blood vessels

- vasculogenesis = vessels arise from mesenchymal blood islands
  - in week 3, cells named angioblasts condense and form blood islands within extraembryonic mesenchyme in the wall of yolk sac, connecting stalk, and chorion
  - in the embryo, cells migrate mainly from the intraembryonic mesoderm to form undifferentiated embryonáic mesenchyme; in this mesenchyme, angioblasts condense into blood islands as well
  - the blood islands luminize, thus becoming primitive vascular canals lined with endothelial cells and containing primitive blood cells named erytroblasts
- angiogenesise = vessels sprout from existing vessels

Early bilateral circulation

- umbilical veins: these carry oxygenated blood from the chorionic villi → via the connecting stalk to the embryo → into the heart tube
- umbilical arteries: these carry blood from the dorsal aorta towards the chorionic villi
- vitelline artery: from the dorsal aorta → towards the extraembryonic vitelline circulation within the wall of yolk sac
- vitelline vein: from the vitelline circulation of the yolk sac → towards the heart
- segmental arteries arise from the dorsal aorta and pass between the body somites
- the venous drainage from the somites is collected via segmental veins which fuse into the anterior and posterior cardinal veins → these merge into the common cardinal vein
- the common cardinal vein finally collects the blood from the intersegmental veins and therefore from the body somites; the vein carries the blood to the heart

Unified circulation

- some parts of the early embryonic circulation, which consisted of paired blood vessels with bilateral symmetry, are reduced: either one of the paired vessels disappear, or the paired vessels merge to form a single vessel
- unified blood vessels:
  - single heart tube
  - single dorsal aorta
  - single vitelline artery and single vitelline vein (the left vitelline vein disappears)
  - single umbilical vein (the right umbilical vein disappears)

Embryonic and fetal circulation

- the umbilical vein carries blood saturated with oxygen and nutrients to the embryo
  - part of the blood mixes with the portal circulation, thus entering the liver sinusoids
  - part of the blood bypasses the liver via ductus venosus and enters the inferior vena cava
- the inferior vena cava enters the right atrium and the blood is mostly guided through the foramen ovale → from the right atrium to the left atrium
- the superior vena cava enters also the right atrium, but most of the blood goes to the right ventricle and then into the pulmonary trunk

- but the pulmonary arteries are collapsed, they have a great vascular resistence, as the lungs are collapsed
- → most of the blood goes from the pulmonary trunk via ductus arteriosus into the aortic arch

Aortic arches

- series of paired (left+right) arteries, each of these supplying their pharyngeal arches in the 4th and 5th week
- they connect the ventral aorta with the dorsal aorta
- they originate in cranio-caudal sequence (as do the pharyngeal arches)
- during week 6, the arches undergo significant remodelling, thus establishing final anatomy and architectonics of the vascular supply of head, heck and upper thoracic region
- some of the arches develop symmetrically, some of them are modified on the left side in a different way than on the right side
- derivatives of the aortic arches
  - 1st aortic arch → most of it disappears, a small portion persists as the maxillary artery
  - 2nd aortic arch → most of it disappears, a small portion persists as the hyoid artery and the stapedial artery
  - 3rd aortic arch → forms the common carotid artey and the first part of the internal carotid artery
  - 4th aortic arch →
    - right side: proximal portion of the right subclavian artery
    - left side: aortic arch from the left common carotid to the left subclavian arteries
  - 5th aortic arch: forms incompletely and regressed
  - 6th aortic arch →
    - right side: right pulmonary artery
    - left side: left pulmonary artery and ductus arteriosus

Derivatives of other embryonic arteries

- dorsal intersegmental arteries branching from the aorta→
  - intercostal arteries
  - lumbar arteries
  - common iliac arteries
  - part of vertebral, subclavian, sacral lateral arteries
- lateral segmental arteries branching from the aorta →
  - renal arteries
  - suprarenal arteries
  - testicular and ovarian arteries
- umbilical arteries → proximal part = superior vesical arteries; distal part obliterates into medial umbilical ligaments
- vitelline arteries →
  - coeliac trunk
  - superior mesenteric artery
  - inferior mesenteric artery

Veins

- vitelline veins = omphalomesenteric veins
- umbilical vein
- cardinal veins and their branches
  - subcardinal veins drain blood from kidneys
  - sacrocardinal veins drain blood from the lower extremities
  - supracardinal veins drain blood from the intercostal veins (from the thoracic wall)

Derivatives of embryonic/fetal veins

- left umbilical vein→ round ligament of liver (lig. teres hepatis)
- ductus venosus obliterates into the ligamentum venosum
- vitelline veins →
  - hepatic portal system, liver sinusoids, portal vein
  - hepatic vein
  - intrahepatic part of the inferior vena cava
  - superior mesenteric vein
- anterior cardinal vein →
  - superior vena cava (on the right side)
  - left brachiocephalic vein (on the left side)
  - interna ljugular vein
- posterior cardinal vein obliterates
- subcardinal veins (kidney region) →
  - inferior part of the inferior vena cava (on the right side)
  - renal veins, suprarenal vein
  - testicular veins/ovarian veins
- supracardinal veins
  - azygos vein (right side)
  - hemiazygos vein (left side)
  - part of the inferior vena cava between kidney and liver

Circulatory changes at birth

- respiration starts → expansion of lungs → the vascular resistence of pulmonary arteries drops → blood enters the pulmonary circulation instead of the ductus arteriosus → increased venous return into the left atrium → septum primum is compressed against the septum secundum → foramen ovale closes (it fuses during the 1st year in 80% individuals; it persists in 20% of individuals as a potential communication between the left and the right atrium (probe patent foramen ovale)
- smooth muscle in the ductus arteriosus contracts (due to an increase in PO_2, due to a drop in vasoactive prostaglandins and due to bradykinin released from lungs during the inflation); the ductus closes, its tunica intima proliferates and the ductus obliterates within 1-3 months
- arterial spasm (vasoconstriction) of umbilical arteries (due to a greater PO_2) → functional closure a few minutes after birth; anatomical obliteration within 2-3 months
- uterine contractions in the 3rd stage of the birth → most of the blood flows from the placenta into the fetal circulation → umbilical veins collapse

Arterial defects

- persisting ductus arteriosus
- coarctation (=narroed lumen) of aorta
  - preductal type = proximal to the ductus arteriosus; d. arteriosus persists
  - postductal type = distal to the ductus arteriosus; d. arteriosus obliterates and collateral circulation between the proximal and distal aorta develops to bridge the narrowed aorta; this collateral circulation is established by way of increased intercostal arteries and internal thoracic arteries
- abnormal origin of the right subclavian artery distally to the origin of the left subclavian artery
- double aortic arch: the right dorsal aorta persists and the double arch forms a vascular ring surrounding the trach and the oesophagus
- right aortic arch: left 4th aortic arch obliterates and the right 4th arch persists instead

Venous defects

- double inferior vena cava: the left sacrocardinal vein fails to lose its connection with the left subcardinal vein
- missing inferior vena cava: the right subcardinal vein does join hepatic circulation, but carries blood into the right supracardinal vein
- left superior vena cava: persisting left anterior cardinal vein