The Cardiovascular System
(Part II)

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Aortic arch derivatives

Aortic sac

Cut edge of pericardium

Right atrium

Bulbus cordis

Bulboventricular groove (sulcus)

Dorsal aorta

1st
2nd
3rd
4th
5th
6th

Truncus arteriosus

Left atrium

Ventricle
Pharyngeal and aortic arches

4th week
3rd, 4th, and 6th aortic arches (1st, 2nd pairs disappeared)

Midbrain

Spinal cord

Pulmonary artery

Dorsal aorta

Yolk stalk

Yolk sac

6th week (37 days)
8th week: transformed into the final fetal arterial arrangement

6th week

A

Left dorsal aorta

Aortic arches

Truncus arteriosus (partly divided into aortic and pulmonary arteries)

7th intersegmental artery

B

Left dorsal aorta

Internal carotid artery

Aortic sac

Ductus arteriosus

Right subclavian artery

Pulmonary arteries

7th intersegmental artery

6th month

C

Left common carotid artery

Internal carotid arteries

External carotid arteries

Brachiocephalic artery

Subclavian arteries

Ascending aorta

D

Right pulmonary artery

Arch of aorta

Ligamentum arteriosum

Left subclavian artery

Left pulmonary artery

Descending aorta

Pulmonary trunk

8th week
Derivatives of 1st pair aortic arches

- Maxillary arteries
  - Ears, teeth, muscles of eyes and face

- External carotid arteries
Derivatives of 2nd pair aortic arches

Stems of the stapedial arteries

2nd pair of aortic arch (dorsal part)
Derivatives of 3rd pair aortic arches

6 weeks

- Left dorsal aorta
- Aortic arches
- Truncus arteriosus (partly divided into aortic and pulmonary arteries)
- Aortic sac

7 weeks

- External carotid artery
- Right subclavian artery
- Ductus arteriosus
- Pulmonary arteries
- Left subclavian artery
- Left dorsal aorta
- Aortic sac

Legend:
- Red: 3rd aortic arch
- Pink: 4th aortic arch
- Pink: 6th aortic arch
- Light blue: Truncus arteriosus
- Dark blue: Dorsal aortae
Derivatives of 4th pair aortic arches

1. Right: proximal part of right subclavian artery
2. Left: part of arch of aorta
Fate of 5th pair aortic arches

- **50% embryos**: rudimentary vessels
  - no vascular derivatives

- **50% embryos**: no 5th pair arteries develop
Derivatives of 6th pair aortic arches

**Right:**
Proximal: right pulmonary artery (proximal)
Distal: degeneration

**Left:**
Proximal: left pulmonary artery (proximal)
Distal: ductus arteriosus
Left recurrent laryngeal nerve hooks around the ligamentum arteriosum and aortic arch
Why the course of the recurrent laryngeal nerves differs?

6 weeks

8 weeks

Child
Aortic Arch Anomalies

- Coarctation of Aorta: 10% of CHD
- Double Aortic Arch
- Right Arch of Aorta
- Anomalous Right Subclavian Artery
Coarctation of Aorta

\[ \text{Male : Female} \approx 2:1 \]
\[ 70\% \text{ cases} : \text{bicuspid aortic valve} \]

- Juxtaductal coarctation: 90%
- Postductal coarctation
- Preductal coarctation

[Image of anatomical diagrams showing coarctation of the aorta with labeled parts such as Ductus arteriosus, Postductal coarctation, and Preductal coarctation.]
Collateral circulation during the fetal period in postductal coarctation
Closure of DA in infant results in hypoprofusion and rapid deterioration

Treatment: infusion of prostaglandin $E_2$ to reopen the ductus arteriosus
Embryological basis of aortic coarctation

1. Abnormal involution of a small segment of left dorsal aorta
2. Muscle tissue of ductus arteriosus migrates into aortic wall.
3. The narrow area between left subclavian artery and DA does not enlarge.
Double Aortic Arch

Vascular ring around the trachea and esophagus

Large right arch of aorta
Small left arch of aorta

Normally involutes
**Right arch of aorta**

- **A**
  - Ductus arteriosus
  - Left dorsal aorta
  - Left subclavian artery
  - Area of abnormal involution

- **B**
  - Right subclavian artery
  - Trachea
  - Esophagus
  - Left subclavian artery
  - Ligamentum arteriosum
  - Descending aorta

- **C**
  - Ligamentum arteriosum
  - Pulmonary artery
  - Descending aorta

**Retroesophageal right arch of aorta**
Anomalous Right Subclavian Artery

Abnormal involution

Persistent portion of right dorsal aorta

Right subclavian artery

Common carotid arteries

Trachea

Esophagus

Left subclavian artery

Arch of aorta

Ascending aorta

Descending aorta
Disorders implicated in cardiac neural crest development

Fetal and Neonatal Circulation

Foramen ovale

Ductus arteriosus

Ductus venosus
Fetal circulation

- Ductus arteriosus
- Ductus venosus
- Foramen ovale
- Sphincter

Oxygen saturation of blood:
- Red: High oxygen content
- Purple: Medium oxygen content
- Blue: Poor oxygen content
Transitional Neonatal Circulation

1. Alteration of the lungs
   - Fall in pulmonary vascular resistance
   - Increase pulmonary blood flow
   - Thinning of walls of pulmonary arteries

2. The oval foramen closes.
   - Higher left atrium pressure
   - Thicker left ventricular wall by the end of 1st month

3. The ductus arteriosus constricts.
   - Oxygen, bradykinin, indomethacin
   - Hypoxia, PGE$_2$, prostacyclin (PGI2)

4. The umbilical arteries constrict.
Ligamentum teres (umbilical vein)

Oval fossa (Foramen ovale)

Ligamentum teres (umbilical vein)

Superior vesical artery (umbilical artery, proximal)

Medial umbilical ligament (umbilical artery, distal)

Ligamentum venosum (ductus venosus)

Ligamentum arteriosum (Ductus arteriosus)
Six primary lymph sacs at the end of embryonic period

- Internal jugular vein
- Jugular lymph sac
- Inferior vena cava
- Retroperitoneal lymph sac
- Cisterna chyli
- Iliac vein
- Iliac lymph sac

Head, neck, upper limbs
Primordial gut
Lower trunk, lower limbs
Right lymphatic duct

Thoracic duct

Chyle cistern (cisterna chyli)

Internal jugular vein

Subclavian vein

Superior vena cava

Anastomosis

Retroperitoneal lymph sac

Iliac lymph sac

Lymph node
Integumentary system
Integumentary system

Skin

Epidermis
Dermis

Appendages

Sebaceous gland
Sweat gland
Mammary gland
Hair
Development of skin: overview

4 weeks

- **Embryonic skin**: begins from embryo of 4-5 weeks
- **Epidermis**: surface ectoderm
  - **Dermis**: mesoderm

Mutual inductive mechanism for ectodermal/mesenchymal interactions (epidermal/dermal interactions)
Development of epidermis: early stage

• **4 weeks:** primordial skin from surface ectoderm

• **7 weeks:**
  - **Periderm:** single layer of squamous epithelium
    - Continue keratinization, desquamation
    - Exfoliated cells form part of vernix caseosa
  - **Basal layer:** proliferation
Development of Epidermis at 11 weeks

- **Stratum germinativum**
  - Epidermal ridges: begin at 10 weeks, permanently established at 17th week; Genetically determined (fingerprint), Dermatographics
- **Intermediate layer**: from stratum germinativum
- **Migration of neural crest cells**: to developing dermis (melanoblast), later melanocyte (as early as 40-50 days) in stratum germinativum
Development of epidermis: 21st week forward

- **Stratum corneum**: originally periderm
- Appearance of stratum lucidum, granulosum, spinosum

Melanocytes fail to produce melanin:
1. Generalized albinism
2. Localized albinism (piebaldism)

Ichthyosis: severe keratinization
Development of Dermis

- **Mesenchyme from mesoderm**: (major) somatic layer of lateral mesoderm & (minor) dermatomes of somites
- **By 11 weeks**: collagenous & elastic connective tissues fibers
- **Dermal ridge**: with capillary loops & sensory nerve endings
- **Capillary-like vessels**: begin at the end of 5th week
Development of sebaceous glands

- Glandular buds from sides of developing epithelial root sheaths of hair follicles, branch to form primordium of alveoli & ducts
- Central cells of alveoli: break down, release into hair follicle, mix with desquamated peridermal cells (vernix caseosa)
- Sebaceous glands independent of hair follicles: in external genital organs
Development of eccrine sweat gland

- **Epidermal downgrowth** into dermis by elongation, and coiling
- **End:** primordium of secretory part; (1) myoepithelial cells, (2) secretory cells
- **Epithelial attachment:** primordium of duct, central cells degenerate

20 weeks
Development of apocrine sweat gland

- Axilla, pubic, perineal regions, areolae of the nipples
- Downgrowths of stratum germinativum giving rise to hair follicles
- Open into the upper part of hair follicles superficial to the openings of sebaceous glands
- Secrete during puberty
- Pheromone
Development of hair (1/2)

• Hair follicle: stratum germinativum into dermis

• Hair bud

• **Hair bulb** (primordium of hair root)
  – germinal matrix, with mesenchymal hair papilla
  – Hair shaft: keratinized portion
Development of hair (2/2)

- **Epithelial root sheath**: from peripheral cells of hair follicles
- **Dermal root sheath**: from mesenchymal cells
- **Lanugo**: the first hair, end of 12th week, replaced during perinatal period
- **Melanocyte in hair bulb**: from migrating melanoblast
- **Arrector pili muscles**: from mesenchyme, goose bumps
Hypertrichosis
Folliculogenesis

Hair cycling
Hair follicle stem cells in bulge region
Hair follicle stem cells

• Hair follicles
• Schwann cells
• Neurons
• Glial cells
• Keratinocytes/sebaceous glands
• Smooth muscle cells
• Blood vessels
• Adipocytes
• Hematopoietic cells
Development of mammary glands

• Mammary ridges: 4th week; thickened strips of ectoderm from axillary to inguinal regions
• Mammary buds: downgrowth of epidermis at 6th week
Supernumerary breasts and nipples

1% of the female
Development of mammary glands

- **Mammary buds**: primary bud → secondary buds → lactiferous ducts/branches: canalization by placental sex hormones
- **Mammary pits**: depressed epidermis → nipples rise by proliferation of connective tissues (areola)

6 weeks

Flat or Inverted nipples (10-20%)