Course material for 18.03.2020

# **EVOLUTION OF AORTIC ARCHES**

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# **BASIC EMBRYONIC PLAN**

- In typical vertebrate embryo, major arterial channels:
  - Ventral aorta
  - Dorsal aorta
  - 6 pairs of Aortic Arches: connecting Ventral & Dorsal aorta
- Blood leaves heart through ventral aorta → runs forward, midventrally, beneath the pharynx → branches anteriorly into a pair of External Carotid Arteries into head
- In b/w, the Ventral aorta gives off 6 pairs of aortic arches running through visceral arches
- Each aortic arch consists of a
- Ventral Afferent Branchial Artery carrying venous blood to capillaries in a gill
- Dorsal Efferent Branchial Artery taking arterial blood from the gill
- All efferent branchial arteries of the same side join dorsally to form a Lateral Dorsal Aorta/ Radix
- Radix extend into head as Internal Carotid Artery
- The two lateral dorsal aortae unite just behind the pharynx to form a single Median Dorsal Aorta which continues behind into tail region as Caudal artery.
- Branches from these main arterial channels supply all parts of the vertebrate body.



Fig. 3. Basic pattern of chief arterial channels of a typical vertebrate embryo.

- Although arterial system of different adult vertebrates shows major differences, but it is actually built according to the same basic architectural plan as seen in the vertebrate embryo
- The differences are due to increasing complexity of heart on account of a shift from gill respiration to lung respiration.
- The modifications mainly concern the aortic arches which undergo a progressive reduction in number from lower to higher vertebrates

# MODIFICATIONS IN AORTIC ACHES IN VERTEBRATE ADULTS



### **PRIMITIVE VERTEBRATES**

- Branchiostoma (Amphioxus): nearly 60 pairs of aortic arches are present, connecting the ventral and dorsal aortae
- *Petromyzon*: 7 pairs of aortic arches are found
- Other cyclostomes: varies from 6 (Myxine) to 15 pairs (*Eptatretus*)

### **FISHES**

- Embryos = primitive plan with 6 or more pairs of aortic arches, each passing through a gill
- Adults = the number is reduced to 4 or 5

### **Elasmobranchs**

- Sharks = only 5 pairs (II, III, IV, V, and VI) are functional
- 1<sup>st</sup> gill slit forms the spiracle (a non-functional gill)
  → 1<sup>st</sup> arch (mandibular) is absent or represented by an efferent pseudobranchial artery
- *Heptanchus* = 7 pairs of aortic arches
- Each arch forms one afferent and two efferent arteries (by splitting) in each gill

#### **Bony fishes**

- Teleosts = I and II arches disappear, so that only 4 pairs (III, IV, V and VI) remain functional
- Each gill has one afferent and one efferent artery

#### Lungfishes

- Polypterus and lungfishes (Dipnoi) = gills are poorly developed, so that a pulmonary artery arises from the efferent part of the VI arch on both sides and supplies blood to the developing air bladder or lung
- *Protopterus* = III and IV embryonic arches are uninterrupted by gill capillaries
- Each arch forms one afferent and two efferent arteries (by splitting) in each gill



## **TETRAPODS**

- No true internal gills → so aortic arches do not break up into afferent and efferent arteries
- I and II arches totally disappear in all tetrapods

### AMPHIBIANS

- Transition from gills to lungs
- **URODELES** live in water and retain external gills + lungs
- So, aortic system shows only partial shift w.r.t. fishes
- 4 pairs of arches (III to VI)
- Except Necturus, Siren, Amphiuma
  - V arch = incomplete, reduced or absent  $\rightarrow$  only 3 pairs of aortic arches
- III arch forms the carotid arches, IV the systemic arches
- The radix or lateral aorta between III & IV arches may persist as a vascular connection: *ductus caroticus*
- VI arch on either side becomes the *pulmocutaneous artery* or *arch*, supplying blood to skin and lungs
- it also retains connection with radix aorta called *ductus Botaili* or *ductus* arteriosus

#### ANURANS

- larvae- arrangement of aortic arches = adult urodele (gill respiration)
- At metamorphosis, with loss of gills, aortic arches I, II and V disappear
- Ductus caroticus disappears so that the III or carotid arch takes oxygenated blood only to head region
- IV or systemic arch on each side continues to dorsal aorta to distribute blood elsewhere except head and lungs
- *Ductus arteriosus disappears* so that VI or pulmocutaneous arch supplies venous blood exclusively to lungs and skin for purification
- Adults exhibit only 3 functional arches, (III, IV and VI) similar to amniotes



#### URODELE AMPHIBIAN



# REPTILES

- Fully terrestrial vertebrates, gills disappear altogether & are replaced by lungs
- Only 3 functional arches (in, IV and VI) present
- Elongation of neck, posterior shifting of heart and partial division of ventricle brings about certain innovations in the aortic system
- 1. Entire ventral aorta and Conus split: forming only 3 trunks-two aortic/systemic + one pulmonary
- 2. Right systemic arch (IV): arises from left ventricle carrying oxygenated blood to the carotid arch (III) to be sent into head
- 3. Left systemic arch (IV) leads from right ventricle carrying deoxygenated or mixed blood to the body through dorsal aorta
- 4. Pulmonary trunk (VI) also emerges from right ventricle carrying deoxygenated blood to the lungs for purification
- 5. Ductus caroticus and ductus arteriosus are absent. But, ductus caroticus is present in certain snakes and lizards (Uromasitx), ductus arteriosus in some turtles, and both in Sphenodon.

Reptiles also remain cold-blooded, like amphibians and fishes, due to mixing of blood.



## **BIRDS AND MAMMALS**

- Warm-blooded: ventricle is completely divided, no mixing of O2 and deO2 bloods
- As usual, 6 arches develop in the embryo, but only 3 (III, IV, VI) persist in the adult
- Other modifications include
- 1. Ventral aorta is replaced by two independent aortae or trunks-systemic & pulmonary
- 2. IV arch is represented by a single systemic aorta, right in birds and left in mammals, emerging from left ventricle and carrying oxygenated blood. Uniting with the radix aorta of its side it forms the dorsal aorta
- 3. The only remaining part of the other lost systemic arch is represented by a subclavian artery, on left side in birds and on right side in mammals
- 4. Arch III with remnants of lateral and ventral aortae represents carotid arteries, which arise from systemic aorta
- 5. Arch VI forms a single pulmonary trunk taking deoxygenated blood from right ventricle to the lungs
- 6. Embryonic ductus caroticus and ductus arteriosus also disappear. The latter closes but persists until hatching or birth in some cases as a thin ligament of Botalli or ligamentum arteriosum

