Comparative study of aortic arches of vertebrates :

In the vertebrate embryo, major arterial channels include three main channels – a dorsal aorta, a ventral aorta and six pairs of aortic arches connecting the dorsal and ventral aorta. Blood from the heart flows through the ventral aorta, running forward beneath the pharynx, and branches into two external carotid arteries to supply the head. Aortic arches, arising from this ventral aorta, consist of two parts – the part directing the deoxygenated blood to the gill is called afferent branchial artery and the part collecting the aerated blood from the gill is named as efferent branchial artery. Six efferent branchial arteries on each side are united to form a lateral dorsal aorta or radix. Both the lateral dorsal aortae from two sides again unite behind the pharynx and form a single median dorsal aorta. This dorsal aorta is continued up to the tail region as a caudal artery. Various arteries arise from this main dorsal aorta to distribute the aerated blood to different parts of the body (See Figure 1). Among the six aortic arches, first one is named as *Mandibular arch* and second one is *Hyoid arch*.

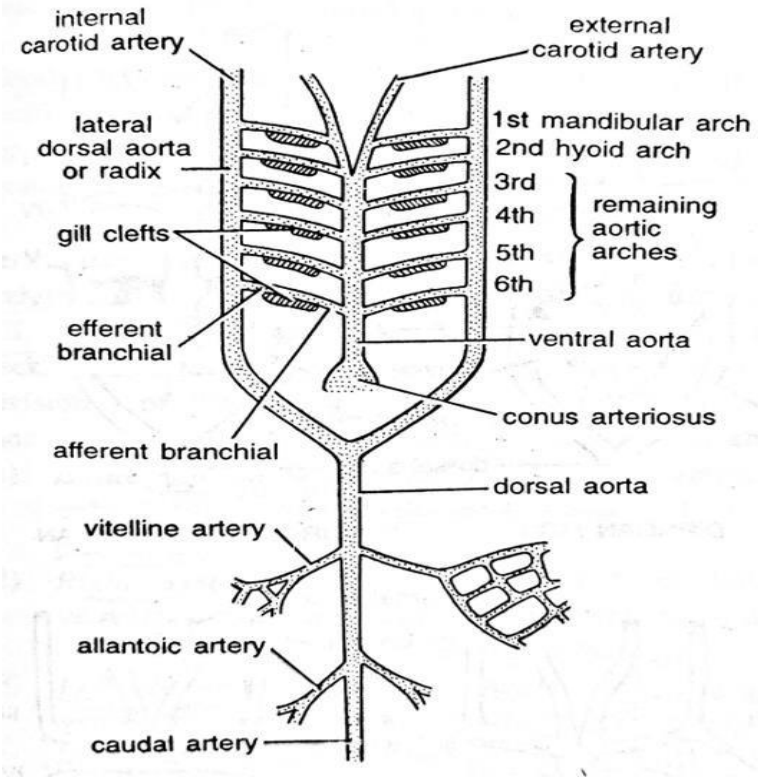

Figure 1. Basic pattern of chief arterial channels of a typical vertebrate embryo (Kotpal, 2010-11)

Modification of aortic arches

All the vertebrate embryos share a basic architectural plan in the structure of aortic arches (Figure 2). But, this architecture becomes modified in the adult animals of every vertebrate class starting from fish to mammals. The progressive decrease in the number of these arches and their structural modifications are correlated with the increased complexity of the heart due to the adaptation of lung respiration instead of gills by the animals in course of evolution.

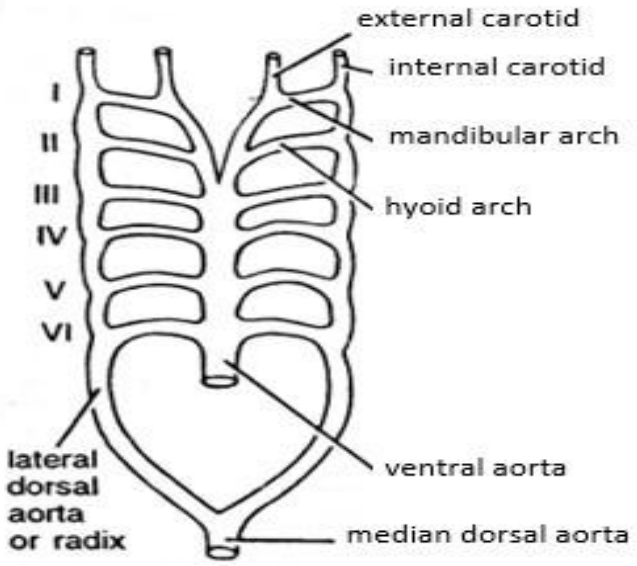

Figure 2. Basic pattern of aortic arches in primitive vertebrates (Kotpal, 2010-11)

A. **Primitive vertebrates:**

In primitive vertebrates, the number of aortic arches vary in adults. In cephalochordate Branchiostoma, the number of arches is 60 pairs. Even in different species of cyclostomes, the number of arches may vary. In *Petromyzon* and *Myxine*, the numbers are 7 and 6 pairs respectively, while in *Eptatretus,* it may reach up to 15 pairs.

***B*. <u>Superclass Pisces</u>:**

The most prominent modifications in aortic arches start from the fishes.

B.1. Elasmobranchs: Although a primitive elasmobranch *Heptanchus* possesses 7 pairs of aortic arches, most of the adult sharks have 5 pairs only starting from II up to VI arch. With the degeneration of first pair of aortic arch, first pair of gill-slits form the spiracle. One more specialization in elasmobranch aortic arches is the presence of two efferent branchial arteries arising from each aortic arch.

B.2. Teleosts: Adult bony fishes or teleosts have 4 pairs of aortic arches (from III to VI) and unlike the elasmobranchs, only one efferent branchial artery arises from each arch.

B.3. Dipnoans: In adult lungfishes or dipnoans, the number of aortic arches is same as that of teleosts (4 pairs: III to VI). But, due to the development of air bladder or lung, a pulmonary artery arises from VI arch carrying deoxygenated blood to that particular organ for aeration. Like elasmobranchs, the number of efferent branchial arteries arising from each aortic arch is two.

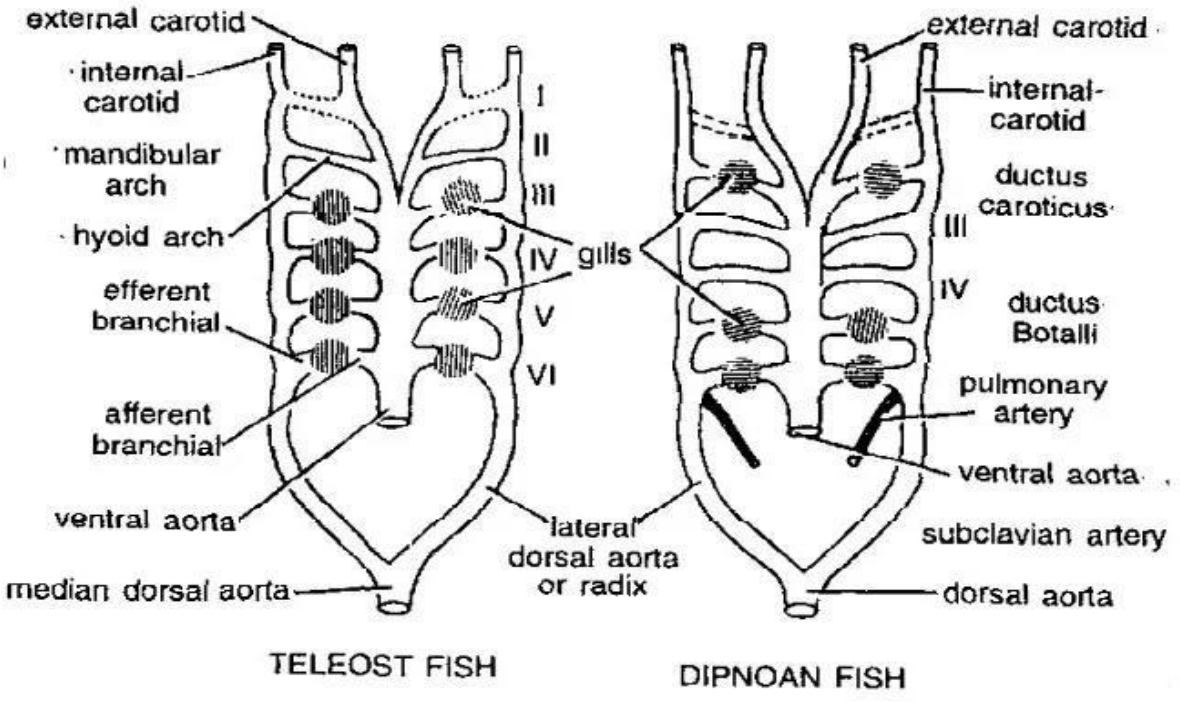

Figure3. Modification of aortic arches in fishes (Kotpal, 2010-11)

C. Class amphibia:

C.1. Urodeles: As the urodele amphibians are tailed aquatic amphibians, 4 pairs of arches (III to VI) are retained in their adult condition just like teleosts and dipnoans. But, some of the urodeles like *Necturus*, *Siren* show some advancement in having a more reduced number of aortic arches (3 pairs: IV to VI). In this way, urodeles exhibit a transitional state in shifting 4 pairs to 3 pairs of aortic arches. Third arch is named as carotid arch while the fourth one is systemic one. The connection between the III and IV arches is ductus caroticus, which is prominent in urodeles. The connection between VI arch and the lateral radix aorta named as ductus Botalli or ductus arteriosus is also evident. From the VI arch, a pulmonary artery arises.

Figure 4: Modification of aortic arches in urodeles (Kotpal, 2010-11)

C.2. Anurans: Being aquatic, the larval anurans exhibit the same pattern of aortic arches as the urodeles. But, as the adult anurans are completely terrestrial and possess lungs instead of gills, they have further modifications in the number and structure of aortic arches. In adult anurans, V arch is completely degenerated, leaving only 3 pairs of arches (III, IV and VI) in a functional condition. Ductus caroticus and ductus arteriosus are also lost.

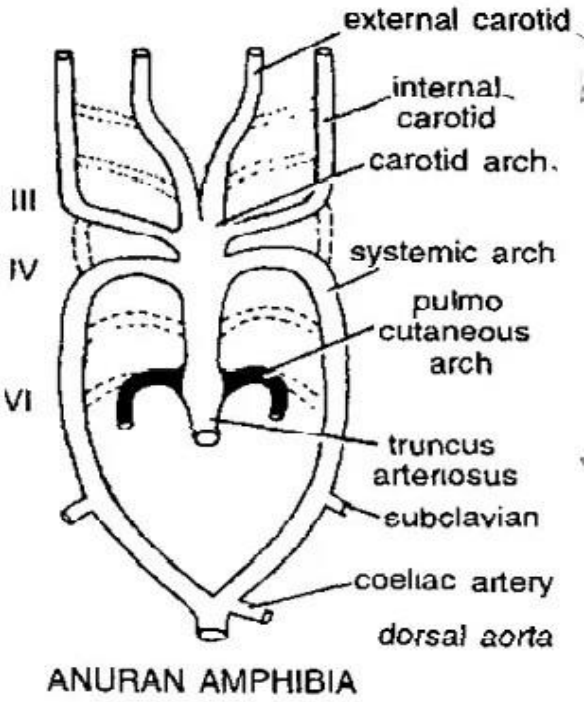

Figure 5: Modification of aortic arches in anurans (Kotpal, 2010-11)

D. **Class reptiliia:**

Being a terrestrial vertebrate, adult reptile possesses 3 pairs of functional aortic arches (III, IV and VI) like anurans. Generally, ductus caroticus and ductus arteriosus are also lost except in some snakes, lizards and turtles respectively. Notable reptilian modification in aortic arch is splitting of the systemic arch into two. Left systemic arch carries deoxygenated blood to the body while the right one directs oxygenated blood to the carotid arch for supplying into the head region. Again, pulmonary trunk (VI) carries deoxygenated blood to the lungs for purification.

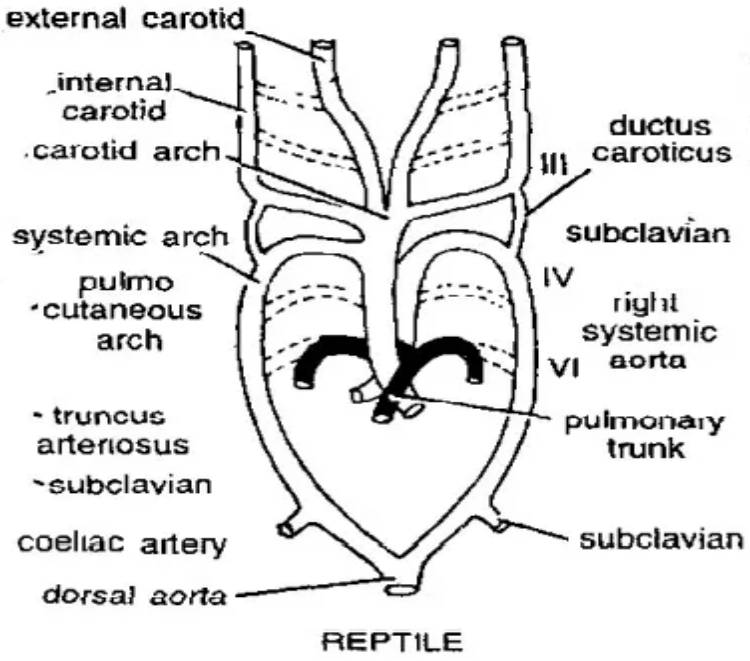

Figure 6: Modification of aortic arches in reptiles (Kotpal, 2010-11)

E. Class aves and mammalia:

Birds and mammals retain the same number of aortic arches in adult conditions (3 pairs: III, IV and VI). In both classes, ventral aorta is replaced by a pulmonary trunk and a systemic trunk. From the pulmonary trunk (VI), an artery supplies deoxygenated blood to the lungs for oxygenation. Ductus caroticus and ductus arteriosus are also absent in both classes. The IV arch shows structural modification over all the classes in having a single systemic half only. The striking difference in the structure of aortic arches between birds and mammals is the presence of right systemic arch in birds and left systemic arch in mammals. However, the remaining part of the other half of systemic arch is called subclavian artery.

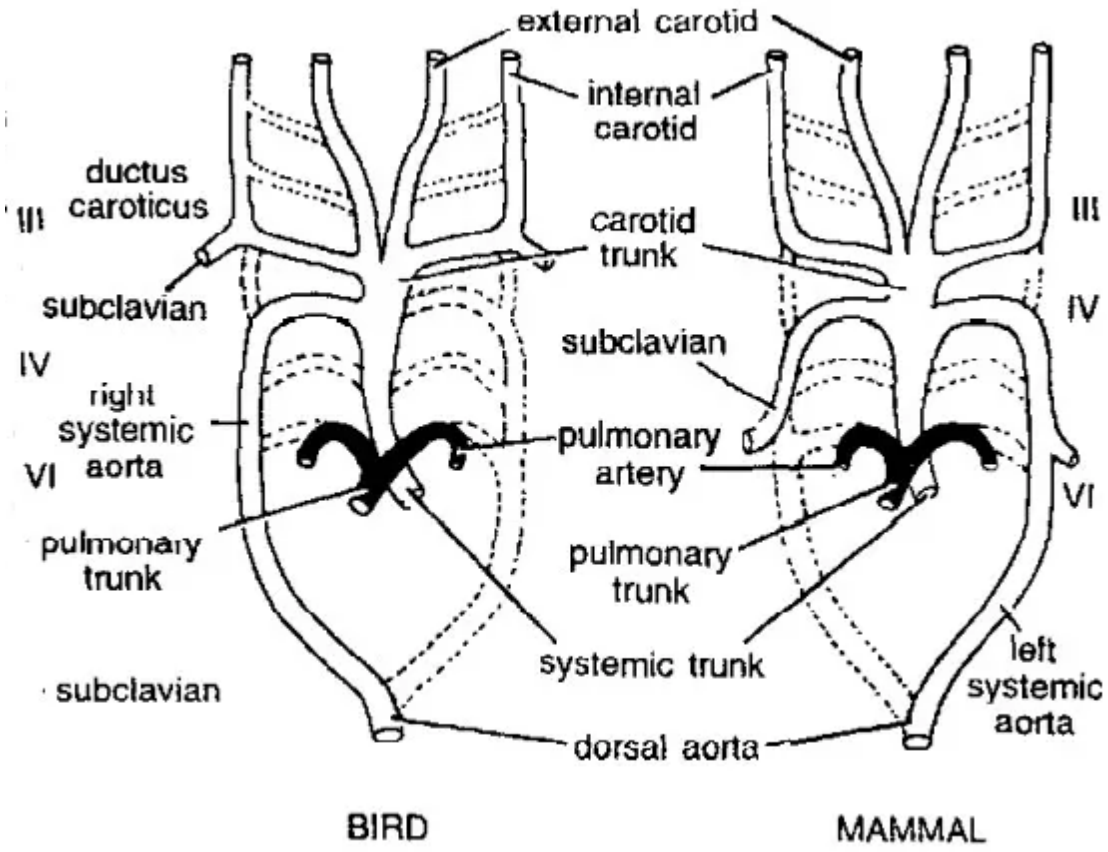

Figure 7: Modification of aortic arches in birds and mammals (Kotpal, 2010-11)

Table 1: Comparative account of aortic arches in lower and higher vertebrates

Embryonic aortic arch	Elasmobranch	Teleost	Urodela	Anura	Reptile	Bird	Mammal
Arch I	Lost	Lost	Lost	Lost	Lost	Lost	Lost
Arch II	Present	Lost	Lost	Lost	Lost	Lost	Lost
Arch III (carotid arch)	Present	Present	Present	Present	Present	Present	Present
Arch IV right systemic arch	Present	Present	Present	Present	Present	Only right systemic arch	Only left systemic arch
Arch V	Present	Present	Present	Lost	Lost	Lost	Lost
Arch VI	Present	Present	Present	Present	Present	Present	Present