B.Sc. (Hons). Part-II

Paper-IV

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AORTIC ARCHES IN VERTEBRATES 08

8.1. Introduction

In front of the heart is the **ventral aorta** which extends anteriorly and divides into two **aortic arches** (first pair of aortic arches). These two aortic arches pass upward on either side of the pharynx until they reach its dorsal side and then turn posteriorly as **radices aortae** or **lateral dorsal aortae** which finally join to form the **dorsal aorta**. During development additional pairs of aortic arches arise in a sequence between the first pair and the heart. The aortic arches connect the ventral aorta to the radices aortae.

8.2. Number

The maximum number of aortic arches was presumably high and variable in the ancestral vertebrates. In chordates the number of aortic arches is correlated with the number of visceral arches. *Amphioxus* has the largest number of aortic arches (19 pairs). Among vertebrates, the largest number of aortic arches is found in some species of cyclostomes (15 pairs in *Bdellostoma stouti*). However, in gnathostomes (jawed vertebrates) the maximum number of aortic arches is six pairs (Figure 8.1). This is the typical number which can be found in the embryos of all vertebrates. The first aortic arch is called **mandibular aortic arch**, the second is called **hyoid aortic arch** and the remaining ones are called **third, fourth, fifth** and **sixth** aortic arches.

8.3. Aim And Trend of Evolution

The aortic arches have undergone modification in different groups of vertebrates. This is mainly to develop a better type of arterial system by separating the venous and arterial blood. This has led to the loss or addition of certain basic arches. Moreover, the history of aortic arches differs greatly in different vertebrate classes and there is a gradual reduction in their number from lower to higher vertebrates. Some arch is completely lost whereas the others have undergone modification as a result of changes in the respiratory system.

8.4. Aortic Arches in Different Groups of Vertebrates (Figure 8.1)

The cyclostomes have more than six pairs of aortic arches. This is due to the presence of larger number of visceral clefts. In the Lamprey there are altogether eight pairs of aortic arches. The anteriormost arch is the hyoid, the second is the first branchial, and there is a gill pouch between these. Each aortic arch is divided into an **afferent** and an **efferent** portions in the gill

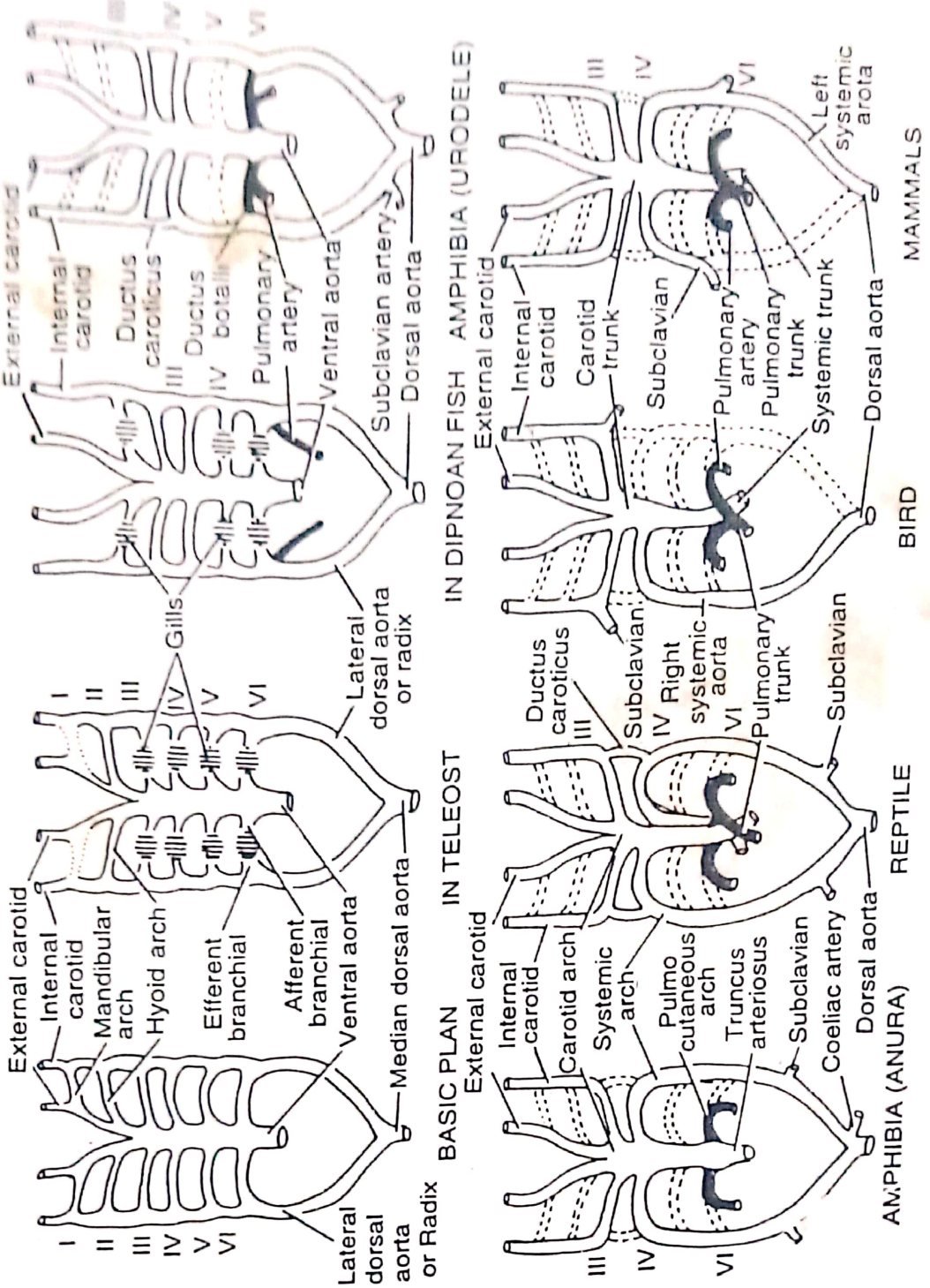

Fig. 8.1 Modifications of aortic arches in different groups of vertebrates

pouches. The afferent vessel supplies venous blood to the gill pouch while the efferent drains oxygenated blood.

As mentioned earlier, there are as many as 15 pairs in a mixinoid, *Bdellostoma stouti*.

8.5. In Fishes

Like cyclostomes, in fishes with the development of gills, each aortic arch

becomes divided into two portions—**an afferent branchial artery** and an **efferent branchial artery**. The afferent vessel carries deoxygenated blood from ventral aorta to the gills while the efferent vessel carries oxygenated blood from the gills to the radices aorta. The afferent and efferent vessels are connected by capillary loop in the gills. When the blood passes through this capillary loop it loses its CO_2 and takes up O_2 and thus it becomes changed from venous to arterial blood.

(A) In Elasmobranchs—In elasmobranchs there are five aortic arches. Since no gill is developed in the mandibular region only five pairs of aortic arches persist in the adult. These are **hyoid** (2nd), **third, fourth, fifth** and **sixth** pairs. The first or the mandibular aortic arches have disappeared.

(B) In Teleosts—Unlike elasmobranchs, in most bony fishes, the hyoid (second) aortic arch also disappears. This is because in teleosts the second gill slit is also nonfunctional. Therefore, only four pairs of aortic arches are retained in the adult. They are **third, fourth, fifth** and **sixth pairs.**

(C) In Dipnoi—In lungfishes the basic plan is similar to other bony fishes. However, in these fishes a pair of pulmonary artery is given off from the efferent portion of the sixth pair of aortic arches or the dorsal aorta taking blood to the air sac or the so-called lung. This is why the blood reaching the lung has already passed through the normal aerating device of the gill capillaries.

In *Protopterus* an interesting feature is noticed in the third and fourth aortic arches. These arches run without break past the gill region. This condition is associated with the reduced gills and developing lungs in this genus.

8.6. In Tetrapods

The fate of aortic arches in tetrapods affords material for studying the evolution of vertebrate structure. Some important factors which lead to gradual modification are as follows:

(i) Establishment of pulmonary and loss of branchial respiration

(ii) Increasing separation of venous and arterial blood in the heart

(iii) Differentiation of the neck

(iv) Shifting of heart to a more posterior position in the thoracic region

In general, there is a tendency of further reduction in the number of aortic arches in tetrapods. Since there is no internal gill, the aortic arches do not break up into afferent and efferent portions. The external gills of the larva or the adults (in amphibians) are supplied by accessory capillary loops. In the frog embryo, continuous aortic arches give rise to afferent and efferent arches as in the fish to enable larval gill breathing but finally the arches become continuous in the adult. Arches I and II disappear early in development of all

tetrapods and hence the maximum number of aortic arches to be found in the tetrapods is four pairs (only in urodela).

8.7. In Amphibia

As a result of the diminishing importance of the gills and the introduction of lungs as the main respiratory structures, the aortic arches of Amphibia have undergone modification. There are two different conditions in the amphibians—

(i) the aortic arches of those that remain permanently in water and retain the gills throughout the adult life such as urodeles and

(ii) the aortic arches of those in which gills are lost such as anurans.

(A) In Urodeles—In urodeles the **third, fourth, fifth** and **sixth** pair of aortic arches persist although the fifth arch is reduced. From the sixth aortic arch arises the pulmonary artery which carries venous blood to the lungs. The connection of the sixth aortic arch with the dorsal aorta is retained as the **ductus arteriosus** or **ductus Botalli**. The two lateral dorsal aortae (radices aortae) are still continuous with no break between the third and fourth arches.

(B) In Anurans—In anurans the fifth aortic arch also disappears and hence only three pairs of aortic arches perisist in the adult. These are the **third, fourth** and **sixth**. The third aortic arch along with a part of the ventral aorta becomes the carotid arch. The fourth aortic arch with its lateral dorsal aorta forms the systemic arch. A break in the continuity of the lateral dorsal aortae between third and fourth aortic arches (**ductus caroticus**) occurs by the disappearance of this part. The **ductus arteriosus** or **ductus Botalli** which connects the sixth arch with the lateral dorsal aorta also disappears.

(C) In Gymnophiona (Apoda)—In Apoda the aortic arches undergo the same changes as urodeles. Like urodeles, here also the ductus caroticus and ductus Botalli persist.

8.8. In Reptilia

With the total disappearance of gills, the arotic arches in Reptillia become fixed in pattern for a lung system. Here the first, second and fifth aortic arches disappear and only the **third, fourth** and **sixth** pairs persist in the adult. With the exception of a few such as *Sphenodon*, *Alligator* and many Lacertilia the ductus caroticus disappears. Similarly, with a few exceptions e.g., *Sphenodon*, *Alligator* and some Chelonia the *ductus Botalli* (ductus arteriosus) also disappears.

8.9. In Birds

In birds, like reptiles only the **third, fourth** and **sixth** aortic arches persist. The third aortic arch forms the carotid, the fourth becomes the systemic and the sixth is the pulmonary. **Ductus caroticus** which is retained in urodeles, apoda

and some reptiles is absent in birds. The ductus Botalli is also absent. Birds retain only the right systemic arch.

8.10. In Mammals

Like the reptiles and the birds in mammals also the first, the second and the fifth aortic arches disappear during development and only the **third** (carotid), **fourth** (systemic) and **sixth** (pulmonary) aortic arches persist. The right fourth systemic arch disappears except its base which remains connected with the subclavian artery (to the arm). The ductus arteriosus and ductus caroticus are absent.

8.11. Summary

(i) The basic number of aortic arches in vertebrates is six pairs. This number is found in the embryo of all craniates. Even the mammals during their embryonic development recapitulate to a considerable degree, the phylogenetic story outlined above.

(ii) In lower vertebrates, aortic arches are bilaterally symmetrical. However, in the amniotes asymmetry appears.

(iii) The fifth aortic arch disappears entirely in all adult tetrapods except the urodeles.

(iv) Among various factors which led to the gradual modification in the aortic arches of vertebrates, the tendency of separation of venous and oxygenated blood in the heart and resplacement of gill repiration by pulmonary respiration appear to be most important. The changes began in the Amphibia and completed when amniote grade of structure was reached.

(v) There is a slow and gradual reduction in the number of aortic arches from lower to higher vertebrate groups.

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