

AORTIC ARCHES IN VERTEBRATES

(1) Introduction

The aortic arches or pharyngeal arch arteries (= previously referred as branchial arches in human embryos) are a series of six paired embryological vascular structures which give rise to the great arteries of the neck and head. They are ventral to the dorsal aorta and arise from the aortic sac.

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.

(2) Number

The maximum number of aortic arches was presumably high and variable in the ancestral vertebrates. In chordates the no. of aortic arches is correlated with the no. of visceral arches.

In Amphioxys - 19 pairs - largest.

Some sps of Cyclostomes (in vertebrates) - 15 pairs.

Jawed vertebrates - 6 pairs

The first aortic arch is called - Mandibular aortic arch
second - hyoid aortic arch, and the remaining are called third, fourth, fifth and sixth aortic arch.

(3) Any and Trend of Evolution

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 arches are completely lost whereas the others have undergone modification as a result of change in the respiratory system.

Aortic arches in different groups of vertebrates

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 them. Each aortic arch is divided into an afferent and efferent portion in the gill pouches. The

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

(1) In Fishes

Like cyclostomes, each aortic arch in fishes becomes divided into two portions - an afferent branchial artery and an efferent branchial artery.

Afferent carries - deoxygenated blood. Ventral aorta to gill
Efferent carries - oxygenated blood - Gill to the radial aorta
The afferent and efferent are connected by capillary loop in the gills.

(A) In Elasmobranchs - 5 aortic arches; no gill is developed in the mandibular region. The first or the mandibular aortic arches have disappeared.

(B) In Teleosts - Unlike elasmobranchs, in cart-bony fishes the ligand (second) aortic arch also disappears. Only 4 pairs of aortic arches are retained in the adult. (They are 2nd, 4th, 5th and 6th)

(C) In Dipnoi - Similar to other bony fishes. However in these fishes, a pair of pulmonary artery is given off from the efferent portion of the 6th pair of aortic arches.

In protopterys, the third and fourth aortic arches run without break past the gill region. This condition is associated with the reduced gills at developing stage in this group.

(2) In Tetrapods - Some gradual modifications can be seen.

- (i) Establishment of pulmonary as 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 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 larvae or the adults 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 lateral gill breathing but finally the arches become continuous in the adult. Arches 2 and 3 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).

③ In Amphibia - Due to introduction of lungs the aortic arches have gone modifications in Amphibia.

a) the aortic arches of those that remain permanently in water and retain the gill tissues up to the adult life (= Urodela)

b) the aortic arches of those in which gills are lost (Amphibia)

a) Urodela - 3rd, 4th, 5th, 6th pairs of aortic arches persist although 5th arch is reduced. From the 6th aortic arch arises the pulmonary artery which carries venous blood to the lungs. The connection of the 6th aortic arch with the dorsal aorta is retained as the ductus arteriosus. The two lateral dorsal 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 persist in the adult, (3rd, 4th and 6th), the third arch with a part of ventral aorta becomes the caudal arch with its lateral dorsal aorta from the systemic arch. A break in the continuity of the lateral dorsal aortae between 3rd and 4th aortic arch (ductus caudalis) occurs by the disappearance of this part, the ductus arteriosus 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 Urodela.

④ In Reptilia - with the total disappearance of gills it becomes fixed in pattern for a lung system. Here the first, second and fifth aortic arches disappear and only the 3rd, 4th and 6th 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 as sphenodon, Alligator and some Chelonis the ductus arteriosus also disappears.

(5) In Birds - In birds, like reptiles only the 3rd, 4th and 6th aortic arches persist, the 11th aortic arch forms the caudal, the fourth becomes the systemic and the sixth is the pulmonary. Ductus caroticus which is retained in urodels, apoda and some reptiles is absent in birds. The ductus Botalli is also absent. Birds retain only the right systemic arch.

(6) In Mammals - Like the reptiles and the birds, in mammals also the 1st, 2nd and the 5th aortic arches disappear during development and only the 3rd (carotid) 4th (systemic) and 6th (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.

Summary

- (1) Aortic arches in vertebrates - 6 pairs. (found in embryos of all coelomates)
- (2) In lower vertebrates, bilaterally symmetrical. (In amniotes - asymmetry)
- (3) In tetrapods - fifth disappears in all tetrapods except the urodels.
- (4) Change began in the Amphibia and completed when amniote grade of structure was reached.
- (5) Slow and gradual reduction in the number of aortic arches from lower to higher vertebrate groups.