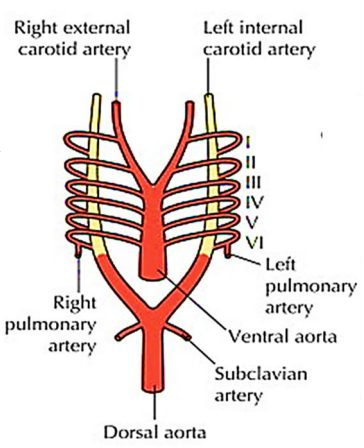
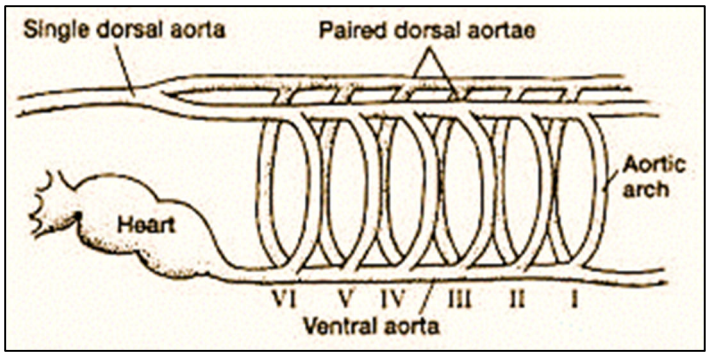
Aortic Arch Evolution



The aortic arches are the blood vessels that supply the pharyngeal arches, and they serve as a **communication between the ventral and dorsal aortae.** The **ventral aorta** is the main artery into which the truncus arteriosus leads. It bifurcates into left and right vessels which extend forward as the **paired external carotids**, whilst the **paired dorsal aortae** extend forward as the **internal carotids.** They are **paired,** serving the left and right pharyngeal regions which are basically similar in number and disposition in different vertebrates during the embryonic stages.

The appearance of six aortic arches during the embryonic development of living gnathostomes suggests that this is the ancestral pattern. However, as we have seen, the actual adult anatomy can be quite varied among different species.



Basic plan of Aortic arches

- Continuous vessels.
- Typical number 6 pairs (7 in primitive shark, many in cyclostome).
- Developed in a similar fashion (anterior to posterior).
- First (I): Mandibular arch (proceed upword on either side of pharynx).
- Second (II): Hyoid arch.

- Rest: III (1st branchial), IV (2nd branchial), V (3rd branchial), VI (4th branchial) aortic arch.

Modification of aortic arches in different vertebrates during evolution is based on following:

- The number of aortic arches is different in different adult vertebrates but they built on the same fundamental plan in embryonic life.
- The differences in number of aortic arches are due to the complexity of heart circulation in the mode of living from aquatic to terrestrial respiration.
- There is a progressive reduction of aortic arches in the vertebrate series during evolution.

Scheme of Evolution

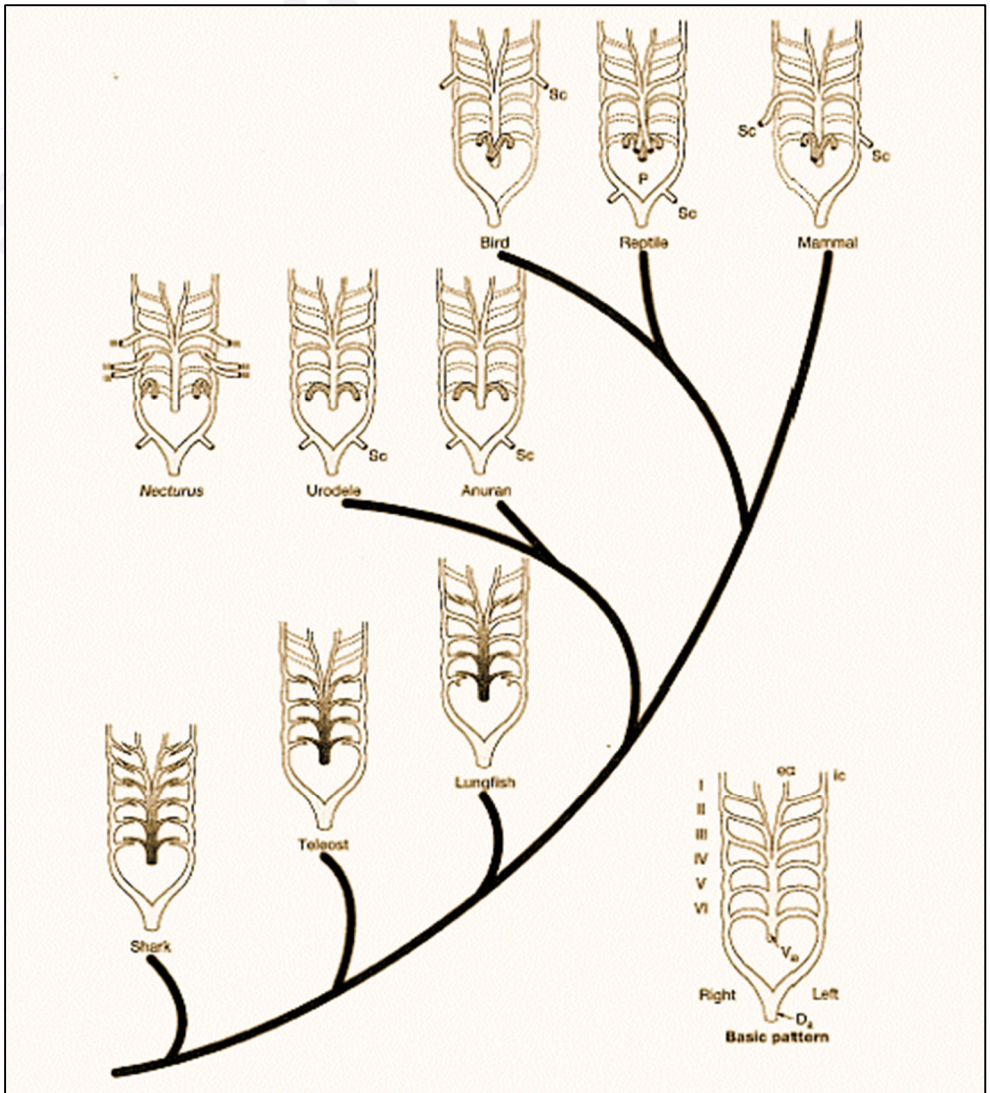
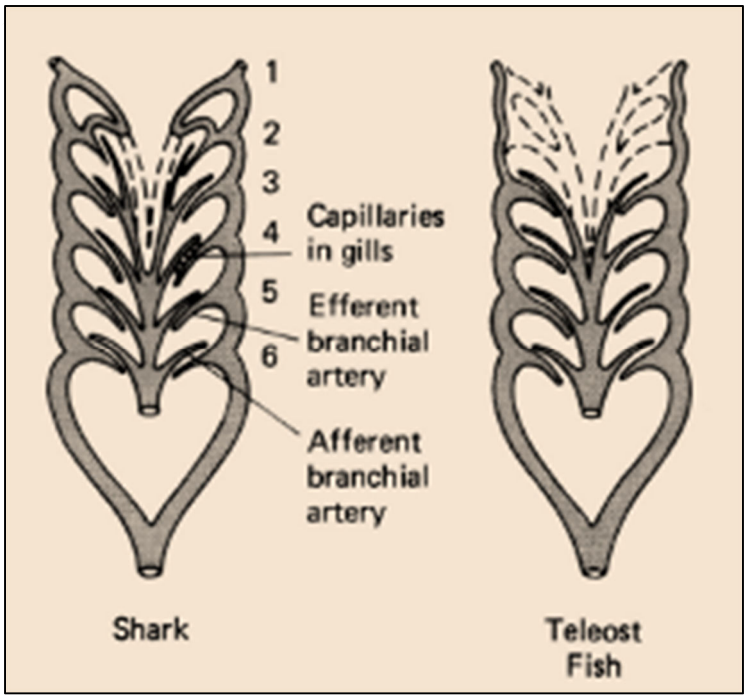


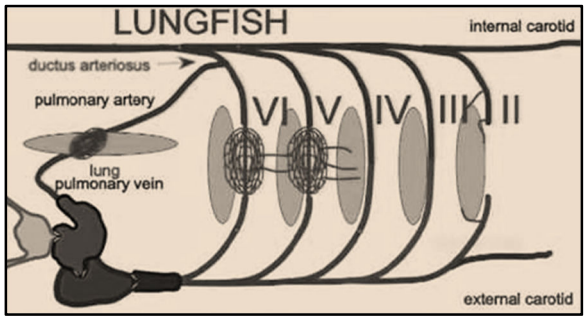
FIGURE 12.19 **Evolution of aortic arches.** Viewed from the ventral surface, the basic six-arch pattern includes a ventral aorta, paired aortic arches, and paired dorsal aortae. Selective loss or modification of this underlying pattern produces the derived aortic pattern of adult vertebrates. Vertical lines on the aortic arches represent gills. Dashed vessels are lost from the basic pattern in the adult. Abbreviations: dorsal aorta (D_a), external carotid (ec), internal carotid (ic), paired dorsal aorta (Pa), subclavian (Sc), ventral aorta (V_a).

In Petromyzon, there are 7 pairs of aortic arches. In other cyclostomes these vary from 6 pairs in Myxine and 15 pairs in Eptatretus.

Primitive fishes, represented by sharks, have six paired gill arches. In teleosts, the gill arch arteries are reduced to form four pairs in the caudal branchial arches. First pair (mandibular) and second pair (hyoidean) are lost. In most fishes, the aortic arches deliver deoxygenated blood to the respiratory surfaces of the gills and then distribute oxygenated blood to tissues of the head (via the carotids) and remainder of the body (via the dorsal aortae).



Among dipnoans there are four or five aor-tic arches that develop from the ventral aorta which supply blood to the gills. In the *Protopterus* the aortic arches retain second, third, fourth, fifth and sixth. The arches like the fish have afferent and efferent divisions. They have two pulmonary arteries which develop from the efferent division of the sixth arch.



In adult amphibians, the gill arches are lost and the aortic arch vasculature remains bilaterally symmetrical. Oxygenated and de-oxygenated blood enter the ventricle through the right and left atrium and leaves the heart through a single outflow tract containing a spiral valve. The aortic arches contribute to the pulmonary arch, the arterial circuit to the lungs, and the systemic arches, the arterial circuits to the rest of the body. The carotid arteries still bear the primary responsibility for supplying blood to the head, but now they usually branch from one of the major systemic arches.

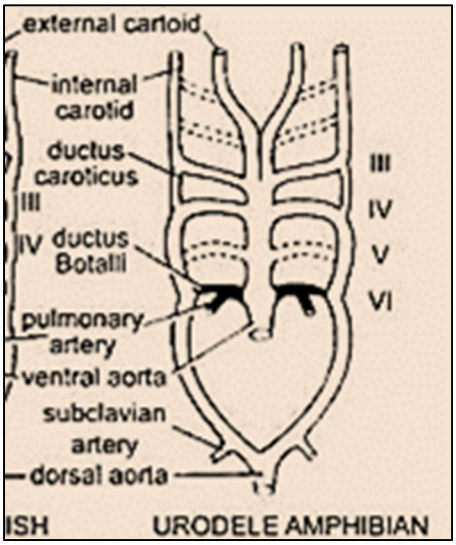
In Urodele

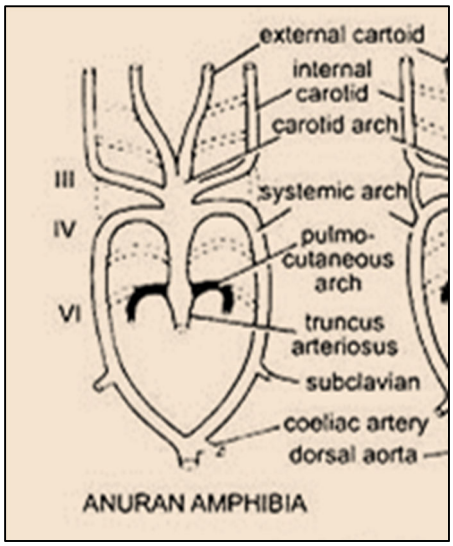
- Aortic arches show modification due to loss of gills and appearance of the lungs.
- In urodeles there are external gills present as respiratory organs in addition to lungs.
- The III, IV, V and VI aortic arches are present, though the fifth pair is much reduced in *Siren, Amphiuma and Necturus.*
- The lateral dorsal aortae between the III and IV aortic arches persist as a vascular connection, the **ductus caroticus.**
- The VI aortic arch forms the pulmo-cutaneous arch or artery on either side taking blood to the lung and skin.
- It also retains a connection with the lateral dorsal aorta known as a **ductus arteriosus (duct of Botalli).**

In Anuran

- In the larva of anuran (frog tadpole), arrangement of aortic arches is like an adult urodele due to presence of gills.
- At metamorphosis, with the loss of gills, I, II, and V aortic arches disappear completely, only the IIIrd, IVth and Vlth aortic arches are present.
- The lateral dorsal aorta between the third and fourth aortic arches (ductus caroticus) also disappears.

- Thus, the third aortic arch along with a part of the ventral aorta becomes the carotid arch carrying oxygenated blood to the head region.
- The fourth aortic arch along its lateral dorsal aorta forms the systemic arch.
- The sixth aortic arch becomes the pulmocutaneous arch supplying venous blood to lungs and skin.
- The ductus arteriosus disappears during metamorphosis. Thus, adult anurans have only III, IV and VI aortic arches. These are also retained by amniotes.

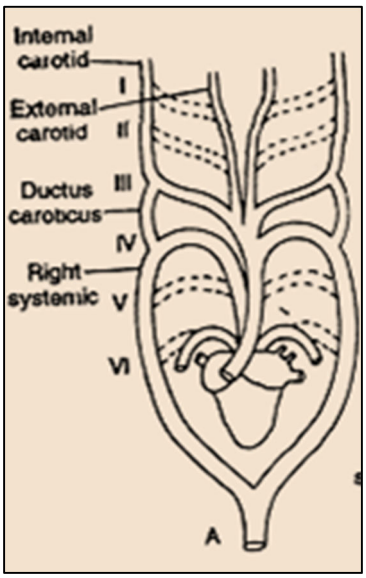




In reptiles, the gills are fully replaced by lungs. With the partial separation of the ventricle into two parts, the distal portion of the conus arteriosus and the entire ventral aorta are split into three vessels, i.e., two aortic or systemic and one pulmonary.

- Only III, IV and VI aortic arches are present.
- Right systemic arch (IV) arise from the left ventricle carrying oxygenated blood to the carotid arch (III).
- The left systemic (IV) and pulmonary aortae (VI) take their origin from the right ventricle.
- The left systemic carries deoxygenated or mixed blood to the body through dorsal aorta.
- While the pulmonary artery takes deoxygenated blood to the lungs.

- The ductus caroticus disappears, but it persists in snakes and some lizards (*Uromastix*).
- The ductus arteriosus disappears in most reptiles though it persists in a reduced form in Sphenodon and some turtles.



The double systemic arches (left and right) present in amphibians and reptiles become reduced to a single systemic arch— the right in birds, the left in mammals.

Although birds and mammals share many similarities, including endothermy, active lives, and diverse radiation, they arose out of different reptilian ancestries. Any similarities in their cardiovascular anatomies represent independent evolutionary innovations.

In Aves

- The III, IV and VI aortic arches are present.
- With the complete division of the ventricle into two parts, the conus arteriosus and ventral aorta have split to form two vessels, systemic aorta arising from the left ventricle and a pulmonary aorta from the right ventricle.
- Third aortic arch with remnants of lateral and ventral aortae forms the carotids which arise from systemic aorta.

- Fourth aortic arch forms the systemic aorta on the right side only. It unites with the lateral aorta of its own side and forms the dorsal aorta.
- Part of the fourth aortic arch of the left side forms the left subclavian artery, the rest along with its lateral dorsal aorta disappears.
- The sixth aortic arch forms the pulmonary aorta.
- Ductus caroticus and ductus arteriosus disappear.

In mammals

- The III, IV and VI aoric arches persist.
- The conus arteriosus and ventral aorta split to form two vessels:

  (i) A systemic aorta arising from the left ventricle, and

  (ii) A pulmonary aorta from the right ventricle. Third aortic arch with remnants of lateral and ventral aortae form the carotid arch.
- Fourth aortic arch forms the systemic aorta on the left side only, while on the right side its proximal portion forms an innominate and right subclavian artery, the rest along with its lateral dorsal aorta disappears.
- Sixth aortic arch forms the pulmonary aorta.
- The ductus arteriosus degenerates but it persists in some until hatching or birth in a reduced form on the left side as a thin ligamentum arteriosum.