Evolution of Visceral Arches

Visceral arches are pieces of cartilages or bones that support the pharyngeal region of vertebrates and also help attach the jaws with the skull. The visceral arches are also known as **pharyngeal arches.** These structures are seen in the embryonic development of vertebrates which are recognisable precursors for many structures. There are typically 7 pairs of visceral arches in vertebrates which modify in different groups depending upon the presence or absence of gills and type of jaw suspension.

The splanchnocranium (or visceral skeleton) is the name given to the gill arches and their derivatives. These include the jaws. The splanchnocranium is formed from the splanchnic mesoderm in the wall of the pharynx between gill-clefts for their support. It consists of series of a paired visceral bars of cartilage which become united with one another ventrally by an unpaired cartilage to form visceral arches, the visceral arches are horse-shoe-shaped and encircle the pharynx all round except dorsally. Those visceral arches which contribute to the formation of the skull constitute the splanchnocranium.

Evolution: The splanchnoderm is an ancient chordate characteristic. Its forerunner was associated with supporting the filter feeding structures of cephalochordates and urochordates.

Typically there are 7 visceral arches in fishes, though this number varies from 4 to 9 in different groups. The first visceral arch is known as **mandibular arch** having two cartilaginous pieces called **pterygoquadrate** and **meckel'scartilage**. In fish the pharyngeal arch is called **gill arch**. It is the first of six pharyngeal arches that develops during the fourth week of development. It is located between the stomodeum and the first pharyngeal groove. This arch divides into a maxillary process and a mandibular process, giving rise to structures including the bones of the lower two-thirds of the face and the jaw. The maxillary process becomes the maxilla (or **upper jaw**), and palate while the

mandibular process becomes the mandible or **lower jaw**. This arch also gives rise to the muscles of mastication. Meckel's cartilage forms in the mesoderm of the mandibular process and eventually regresses to form the incus and malleus of the middle ear, the anterior ligament of the malleus and the sphenomandibular ligament. The mandible or lower jaw forms by perichondral ossification using Meckel's cartilage as a 'template', but the maxillary does *not* arise from direct ossification of Meckel's cartilage. The skeletal elements and muscles are derived from mesoderm of the pharyngeal arches.

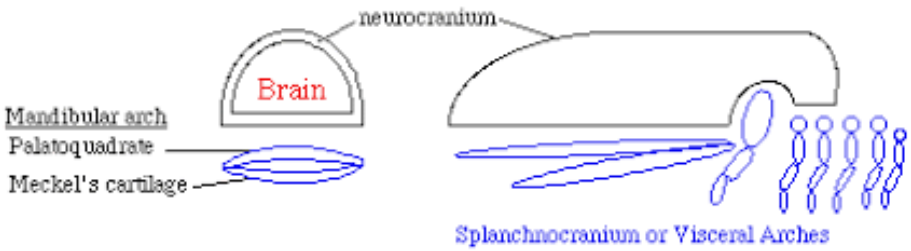
Second visceral arch, called hyoid arch, consists of hyomandibular, ceratohyal and basihyal. The hyomandibular cartilage articulates with the chondrocranium. It is the second of six pharyngeal arches that develops in fetal life during the fourth week of development and assists in forming the side and front of the neck. Cartilage in the second pharyngeal arch is referred to as **Reichert's cartilage** and contributes to many structures in the fully developed adult. It is composed of two distinct cartilaginous segments joined by a faint layer of mesenchyme. Dorsal ends of Reichert's cartilage ossify during development to form the stapes of the middle ear before being incorporated into the middle ear cavity, while the ventral portion ossifies to form the lesser cornu and upper part of the body of the hyoid bone. Caudal to what will eventually become the stapes, Reichert's cartilage also forms the styloid process of the temporal bone. The cartilage between the hyoid bone and styloid process will not remain as development continues, but its perichondrium will eventually form the stylohyoid ligament.

From 3rd to 7th visceral arches are called **branchial arches**, since they support gills and typically consist of 4 pieces of cartilages, namely, pharyngobranchial, epibranchial, certobranchial and hypobranchial. These branchial arches do not contribute to the formation of skull.

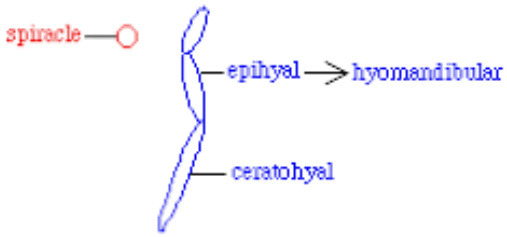
Cyclostomes

There is no resemblance with the typical pattern but cyclostomes possess a splanchnocranium in which usual cartilages are not identifiable. The whole pharyngeal skeleton fuses to form a branchial basket to support gills.

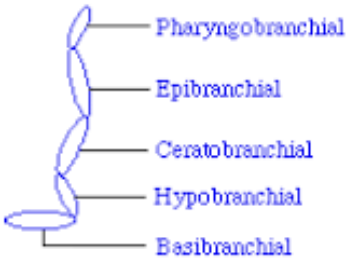
Chondrocranium Shark
(=Neurocranium, Endocranium, Primary Brain Case)

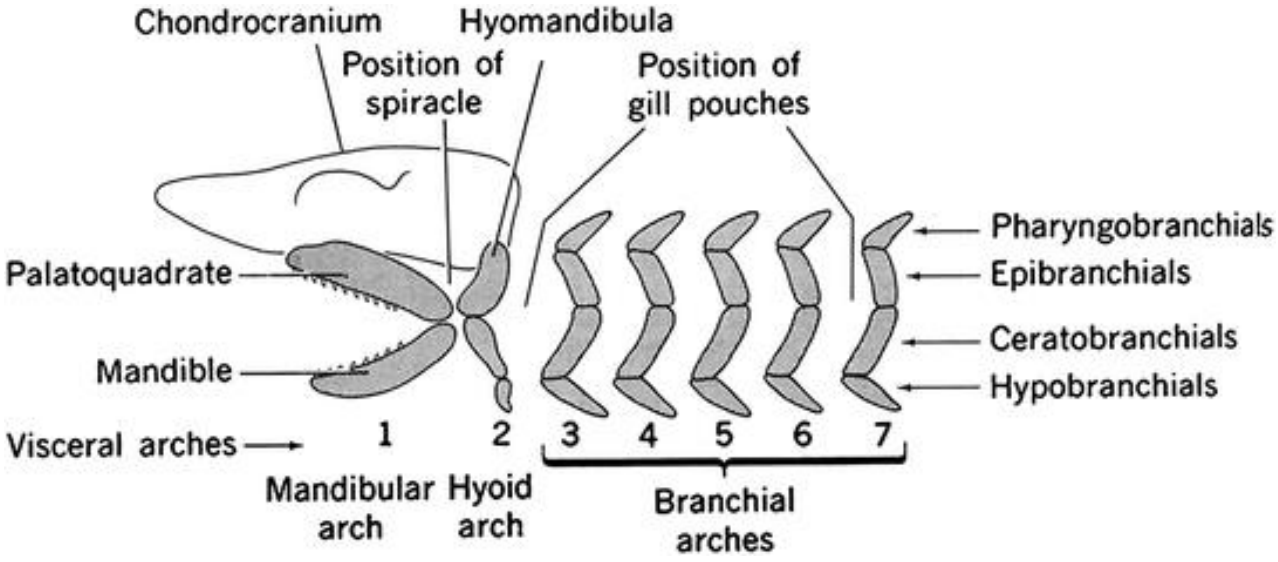


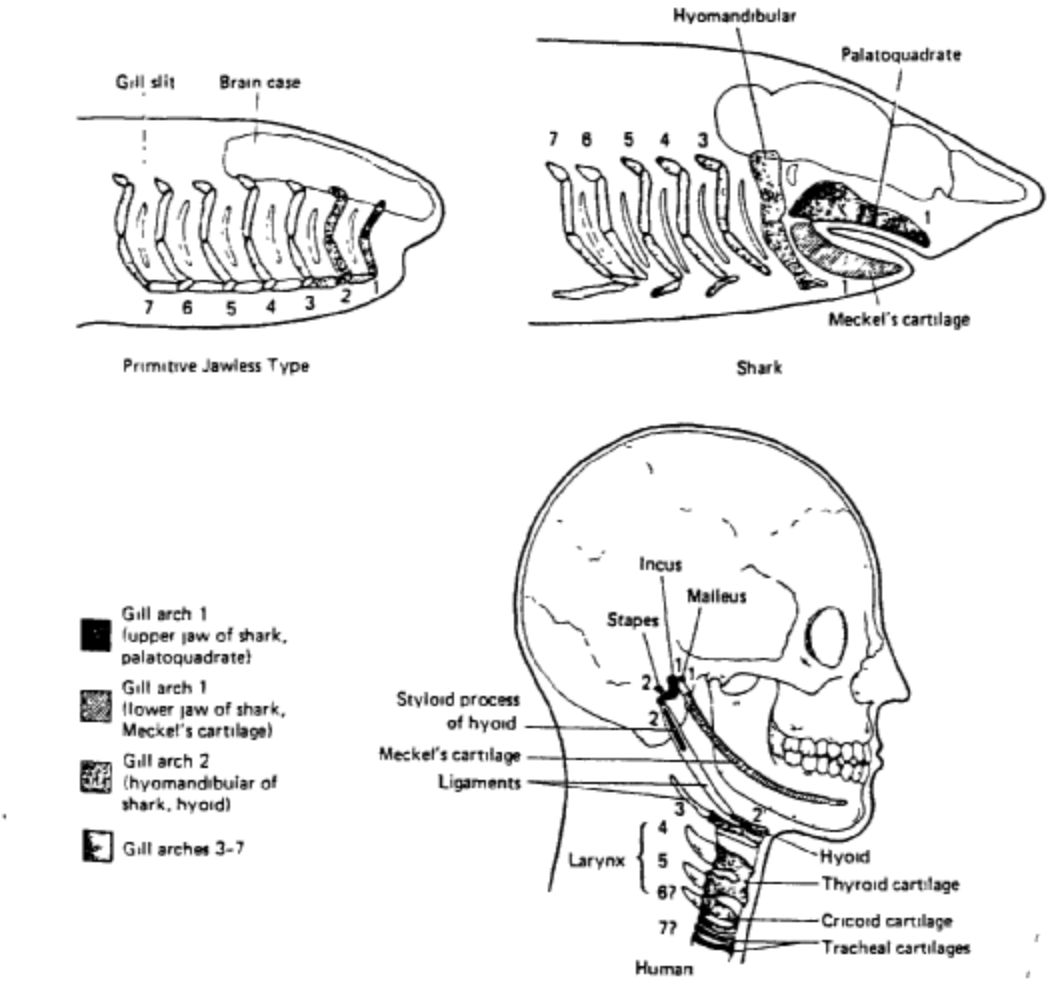
The hyoid arch consists of:



A typical branchial arch consists of:







Elasmobranchs

They contain full set of visceral arches and three unpaired branchial cartilages called basibranchials. The arrangement is close to basic pattern as they have 5 pairs of functional gills and skeleton is all cartilaginous.

Bony fishes

Meckel's cartilage forms articular and becomes part of the lower jaw. Hyoid arch is modified for the movement of operculum and functioning of the lower jaw. **Symplectic** helps in jaw suspension. Last branchial arch shows sign of degeneration as the number of gills is reduced to 4 pairs.

Amphibia

Larval frogs have 6 visceral arches and the last 3 bear gills. In urodeles having gills third, fourth and fifth epibranchials support gills while their basibranchials and ceratobranchials are reduced to two pairs. Hyomandibular modifies as **columella** of the middle ear cavity in frogs and toads. The air breathing hyobranchial apparatus of frogs and toads is made by the fusion of 2^{nd}, 3^{rd} and 4^{th} visceral arches.

Reptiles

Quadrate and epipterygoid bones of the skull are modifications of pterygoquadrate, and articular of the lower jaw is a modified meckel's cartilage. Hyoid arch forms a small hyoid plate that also extends forward to support the tongue. One of two ceratobranchials may form the posterior cornu of the hyoid plate.

Birds

Modification is similar to reptiles except that there is only one cornu of the hyoid plate that is modified from the third visceral arch.

Mammals

Petrygoquadrate breaks into **alisphenoid** and **incus**, the former becomes part of the skull and the latter joins the ear ossicles. Meckel's cartilage modifies into **malleus** and hyomandibular into **stapes** of the middle ear cavity. Larynx of mammals evolved from the fourth and fifth visceral arches. Thyroid cartilage is a modification of 4^{th} and 5^{th} visceral arches while **arytenoid** and **cricoid** cartilages are modified fifth visceral arch.

These arches work together in different ways to create jaw movement, based on the ways in which these arches articulate with the chondrocranium these are divided into the following three types -

Amphistylic (primitive cartilaginous fishes) - jaw is supported both by the hyomandibular and by a direct connection between the jaw and the chondrocranium

Hyostylic (elasmobranchs and most bony fishes) - upper jaw loses any major direct connection with the chondrocranium and the upper and lower jaws are supported solely by the hyomandibular

Autostylic (lungfishes and in tetrapod ancestors) - upper jaw (pterygoquadrate cartilage) articulates or is fused with the chondrocranium, lower jaw forms from the mandibular cartilage, and the jaw remains unsupported by the hyomandibular