**Skeletal System**

What is skeletal system?

The framework of the body, consisting of bones and other connective tissues, which protects and supports the body tissues and internal organs is called skeletal system. It is of two types namely exoskelatal system and endoskeletal system. The former includes nail, hair teeth etc. which are seen externally. The main framework is made by endoskeletal system, internally.

What do you mean by the word skeleton?

The **skeleton** refers to the frames of support of animal bodies (Encyclopedia Britannica, 2020).

Literally, the word 'skeleton' means the supporting framework, basic structure, or essential part of something, may be living or even may be non living (like a building).

In biology it is an internal or external framework of bone, cartilage, or other rigid material supporting or containing the body of an animal or plant.

Types of Skeleton

According to Barnes et al. (2003), there are two major types of skeletons: **solid** and **fluid**. Solid skeletons can be internal, called an **endoskeleton** or external, called an **exoskeleton**, and may be further classified as **pliant** (elastic/movable) or **rigid** (hard/non-movable). Fluid skeletons are always internal.

A] Exoskeletons are external and they enclose and protect the soft tissues and organs of the body. It is found in both invertebrate and vertebrates.

B] The endoskeleton is the internal support structure of an animal, composed of mineralized tissue and is typical of vertebrates. Bone, cartilage, ligament and tendon are the chief parts.

C] Pliant skeletons are capable of movement; thus, when stress is applied to the skeletal structure, it deforms and then reverts to its original shape. This skeletal structure is used in some invertebrates, for instance in the hinge of bivalve shells or the mesoglea of cnidarians such as jellyfish. Most pliant skeletons are formed from a mixture of proteins, polysaccharides and water.

D] Rigid skeletons are not capable of movement when stressed, creating a strong support system and most common in terrestrial animals. Rigid skeletons are formed from materials including chitin (in arthropods), calcium compounds such as calcium carbonate (in stony corals and mollusks) and silicate (for diatoms and radiolarians) and mineralized tissues in vertebrates.

E] The cytoskeleton (Greekr. *kytos* = cell) is used to stabilize and preserve the form of the cells. It is a dynamic structure that maintains cell shape, protects the cell, enables cellular motion (using structures such as flagella, cilia and lamellipodia), and plays important roles in both

intracellular transport (the movement of vesicles and organelles, for example) and cellular division.

F] Fluid skeletons are also known as hydrostatic skeleton or hydroskeleton. A hydrostatic skeleton is a semi-rigid, soft tissue structure filled with liquid under pressure, surrounded by muscles. Longitudinal and circular muscles around their body sectors allow movement by alternate lengthening and contractions along their lengths. A common example of this is the earthworm.

What are axial and appendicular skeleton?

The axial skeleton is the part of the skeleton that consists of the bones of the head and trunk of a vertebrate. The axial skeleton consists of skull, vertebral column and thoracic cage.

The appendicular skeleton is the part of the skeleton comprised of the upper and lower extremities, including the shoulder girdle and pelvis. The appendicular skeleton consists of bones of upper and lower limbs and girdles.

The skeleton of man (206)

Axial (80) + Appendicular (126)

Axial- Skull(22)+ Vertebral column (33)+ Thoracic cage (25)

Appendicular- Pectoral girdle (4) + Pelvic girdle (2) + Hand bone (60) + Leg bone (60)

Skull- total 22 bones of which cranium is the semicircular chamber consists of 8 bones ( 2 temporal, 2 parital, 1 frontal, 1 sphenoid, 1 occipetal and 1 ethmoid). Facial bones 14 of which zygometic, lacremal, maxilla, nasal, palatine and inferior nasal 2 eac i.e. total 12, and mandible and vomer 1 each.

Vertebral column- consists of 33 bones, each unit is called vertebra. 7 cervical, 12 thoracic, 5 lumber, 5 sacral and 4 coccigeal, the last are degenerative, combinedly called sacrum.

Thoracic cage consists of 12 pair of ribls i.e. 24 and 1 starnum.

Hand bone- humerus, radius, ulna, 8 carpal, 5 meta carpal and 14 phalanges.

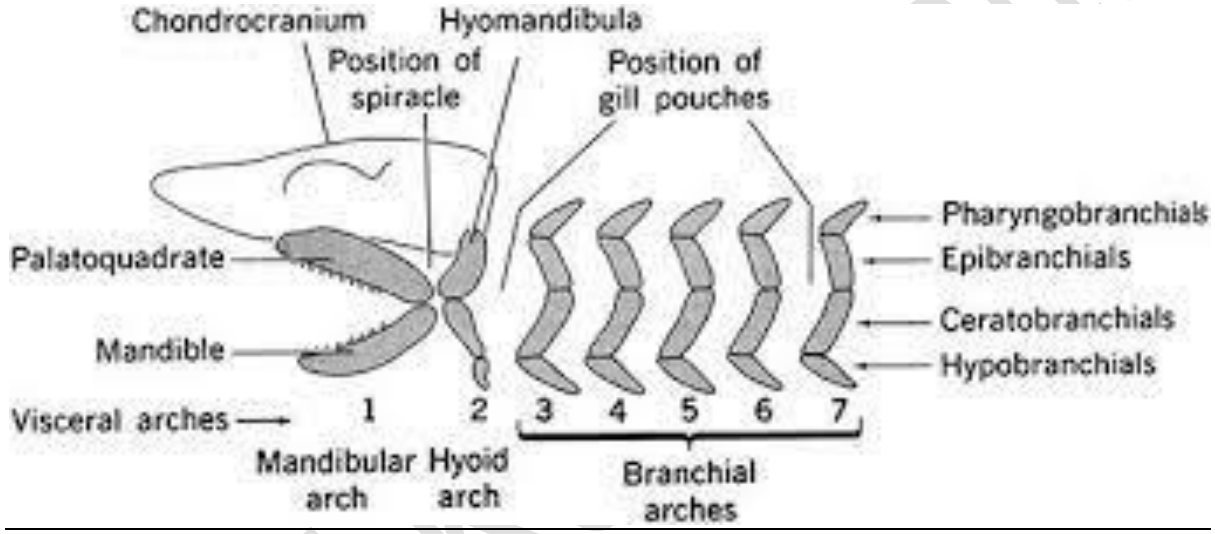
Leg bone- Femur, tibia, fibula, patella, 7 tarsal, 5 meta tarsal and 14 phalanges.

What are neurocranium and splanchnocranium?

The part of skull that remains attached with brain is called neurocranium. The jaw and hyoid apparatus constitute splanchnocranium.

# The Visceral arches

The splanchnocranium part is also known as visceral skeleton, which consists of a series of segmented cartilaginous rods which form incomplete or half hoops in the walls of the buccal cavity and the pharynx. In lower vertebrates, *these horse shoe-shaped structures lie in space between the gill slits and are known as* **gill arches** or **visceral arches**. In the beginning each gill arch is a continuous structure but as the pharynx grows, each breaks up into a number of pieces, which articulate with one another. So, these arches are not a part of cranium proper but a related structure.




There are seven cartilaginous gill arches namely : [1] mandibular arch [2] hyoid arch [3] 1st branchial arch [4] 2nd branchial arch [5] 3rd branchial arch [6] 4th branchial arch [7] 5th brancial arch. The first two are modified to form jaws and the rest are the branchial arches.

The primitive arrangement is 7 (possibly 8) arches, each consisting of the same series of paired (left and right) elements. In order from dorsal-most to ventral-most, these are the pharyngobranchial, epibranchial, ceratobranchial, hypobranchial, and basibranchial. The pharyngobranchials may articulate with the neurocranium, while the left and right basibranchials connect to each other (often fusing into a single bone). When part of the hyoid system, the names of the bones are altered by replacing "-branchial" with "-hyal", thus "ceratobranchial" becomes "ceratohyal" (Pradel et al., 2014).

- The **Basihyal** and **Basibranchials** lie at the midline of the lower edge of the throat. Almost all modern chondrichthyans have a single midline basihyal, as do many teleosts & lungfish. In tetrapods, the basihyal is known as the hyoid bone. Basibranchials, which are most common in osteichthyans, have the form of one or more rod-like bones projecting backwards along the throat.
- The **Ceratohyals** and **Ceratobranchials** lie above their respective basi- components, slanting backwards and upwards. They are often the largest bony components of the gill

system, as well as the most essential and abundant components. Small connecting bones known as **Hypophyals** or **Hypobranchials** may link the basi- and cerato- components. Paired hypophyals are characteristic of living osteichthyans. Living chondrichthyans lack hypohyals, though several extinct forms are known to have had them.

- The **Epihyals** and **Epibranchials** lie above their respective cerato- components, slanting forwards, upwards, and often inwards. They are also essential components of the gill system, found in every fish. The epihyal is more commonly known as the hyomandibula, which is homologous to the stapes (sometimes known as the columnella) of tetrapods. In filter-feeding fish, the epibranchials often host gill rakers, specialized spines projecting backwards to trap plankton.
- The **Pharhyngobranchials** are the most dorsal bony elements of the gill system, connecting to the upper extent of the epibranchials. Living chondrichthyans have large pharyngobranchials which lean backwards and upwards. Osteichthyans, on the other hand, have two different types of pharyngobranchials: **Suprapharyngobranchials** are toothless structures similar to those of chondrichthyans, while **Infrapharyngobranchials** often possess teeth and lean inwards and forwards, forming the roof of the throat. A hyoid equivalent of the pharyngobranchial, the **Pharyngohyal**, is only found in living holocephalans, also known as chimaeras.

I. Mandibular Arch

i) It is the first visceral arch & consists of two bars of cartilage namely (a) **Palatoquadrate** & (b) **Meckel's cartilage**. They form upper jaw & lower jaw respectively in cartilaginous fishes i.e. elasmobranchs & ganoid fishes i.e. superorders Chondrostei and Holostei. Both of these meet at the opposite side medially in front of the mouth.

ii) In bony fishes, these become ossified & invested by bones to form jaws. The paltoquadrate becomes ossified into **palatine, pterygoid & quadrate** bones and finally invested by **premaxilla** & **maxilla.** The Meckel's cartilage or lower jaw is ossified into **articluar** and invested by **dentary, angular, supra angular** & **coronoid**.

iii) In higher vertebrates reduction of bones in lower jaw occurs. In mammals, the mandible is formed of **dentary** bones only. The quadrate in upper jaw takes part in the jaw suspension and in mammals it forms the ear ossicle – **incus**. The articular bone forms **malleus**.

II. Hyoid arch

i) It is the second visceral arch and consists of two parts namely (a) **Hyomandibular** (also known as hyomandibula by some author- modified epihyal actually) & (b) **Hyoid** (also called hyoid proper), representing upper & lower part respectively. In the cartilaginous fishes, these two are closely connected and lies between the spiracle & first gill arch. Hyoid proper gives support to tongue.

ii) In the higher fishes, both of them are separated and hyomandibular acts as suspensor of jaws. In bony fishes, hyoid forms the hyoid cornu and is divided into segments known as **basihyal,**

**hypohyal, ceratohyal** & **epihyal** and becomes intimately connected with branchial arches behind.

iii) In higher vertebrates, the hyomandibular is reduced to form **columella** in amphibia and reptilia and **stapes** – the ear ossicle- in mammals. The hyoid proper contributes to the hypobranchial apparatus in amphibia, reptilia & birds. In mammals, it forms external ear cartilage, styloid process & anterior horn of hyoid.

III. Branchial arches

(i) In all lower vertebrates, all the branchial arches are similar. In fishes, they support the gills. They have four parts from upper to lower, namely **pharyngobrancheal, epibranchial, ceratobranchial** & **basibranchial.**

(ii) In higher vertebrates, due to suspension of gill respiration, these become greatly reduced, modified or even disappeared. In Amphibia, the first four branchial arches become part of hyoid apparatus where as the fifth one becomes Laryngotracheal cartilage. In mammals, first branchial arch forms posterior horn of hyoid. Second and fifth branchial arches become thyroid & arytenoids cartilages respectively. Most probably, the epiglottis of mammals is derived from fourth branchial arch.

Evolutionary significance

Visceral or gill arches, are a series of bony "loops" present in vertebrates. As gills are the primitive condition of vertebrates, all vertebrate embryos develop pharyngeal arches, though the eventual fate of these arches varies between taxa. In jawed fish, the first arch develops into the jaws, the second into the hyomandibular complex, with the posterior arches, i.e. gill or branchial arches supporting gills. In amphibians and reptiles, many elements are lost including the gill arches, resulting in only the oral jaws and a hyoid apparatus remaining. In mammals and birds, the hyoid is still more simplified.

In contrast to the external branchial basket of agnathan, branchial skeleton are internal to gills. Although it was long believed that the gill filaments were ectodermal in gnathostomes and endodermal in lampreys, Gillis and Tidswell, 2017 have demonstrated that they are endodermal so they are homologous in all vertebrates.

## JAW SUSPENSION

Jaw suspension means attachment of the lower jaw with the upper jaw or the skull for efficient biting and chewing.

There are different ways in which these attachments are attained depending upon the modifications in visceral arches in vertebrates. These are described in brief as follows:

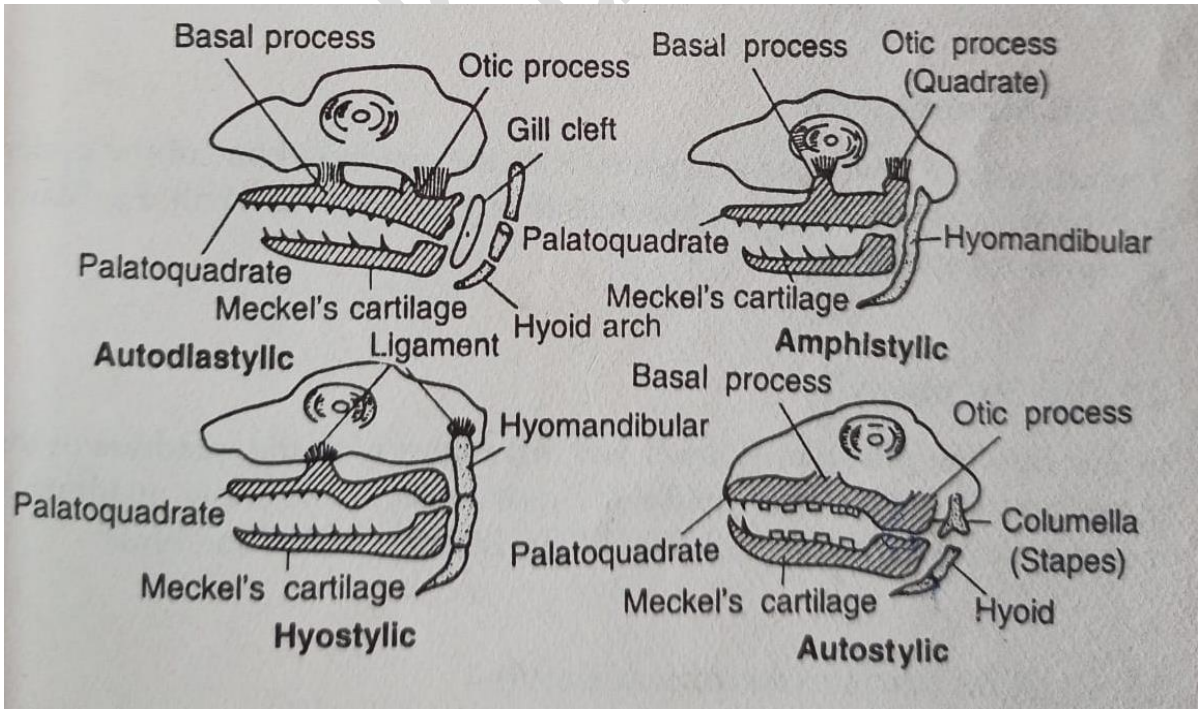
I. Amphistylic - In primitive elasmobranchs there is no modification of visceral arches and they are made of cartilage. Here, pterygoqadrate makes the upper jaw and Meckel's cartilage makes lower jaw and they are highly flexible. Hyoid arch is also unchanged in this type. Lower jaw is attached to both pterygoqadrate and hyoid arch and hence it is called amphistylic.

II. Autodiastylic – here, upper jaw is attached with the skull and lower jaw is directly attached to the upper jaw. The second arch is a branchial arch and does not take part in jaw suspension. It is found in Chimera (a cartilaginous fish, also spelled as Chimaera, the rabbit fish or ghost shark), in some amphibian & in other higher vertebrates.

III. Hyostylic - In modern sharks, lower jaw is attached to pterygoquadrate which is in turn attached to hyomandibular cartilage of the 2nd arch. It is the hyoid arch which braces the jaw by ligament attachment and hence it is called hyostylic.

IV. Autostylic - In this type, the pterygoquadrate is modified to form epipterygoid and quadrate, the latter braces the lower jaw with the skull. Hyomandibular of the second arch transforms into columella bone of the middle ear cavity and hence not available for jaw suspension. This type of jaw suspension is found in lungfish & in many tetrapod.

V. Craniostylic - This type is seen in mammals. here the pterygoqodrate transforms into incus and alisphenoid. Meckle's cartilage transforms into malleus. This is not available to act as jaw suspension hence it directly attaches to the skull i.e known as squamosal.



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