Endoskeleton in vertebrates:

Hardened tissues of body make skeleton and in vertebrates this skeleton develops underneath the body surface, it is called endoskeleton and is a living component.

Vertebrate endoskeleton is mesodermal in origin.

In early stages of the embryonic development, endoskeleton is composed of cartilages and is replaced by bones in most of the adult vertebrates.

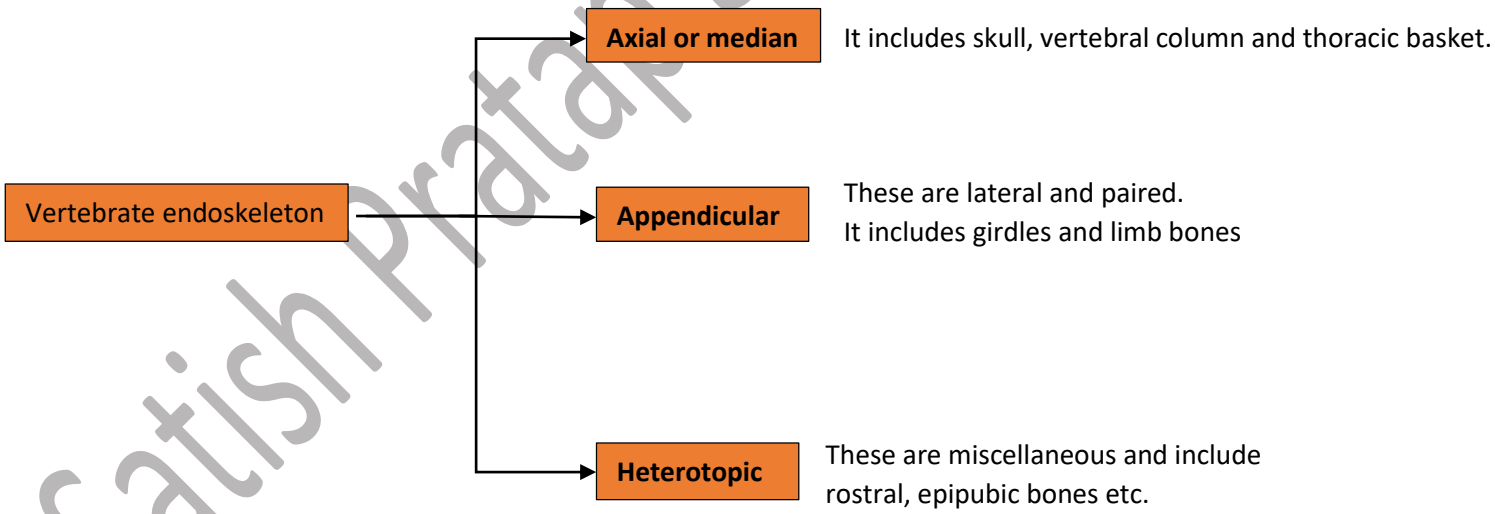
Bones are of two types:

1. **Replacement bones:** These are deposited in place of the cartilages, thus, are also called as cartilage bones.
2. **Dermal bones:** They form directly in the dermis without any pre-existing cartilage, thus, also called as dermal bones.

Functions of the endoskeleton are listed below:

1. To provide physical support to body by forming a firm and rigid internal framework.
2. To provide definite shape and form to body.
3. To protect delicate internal organs (brain, lungs etc.) by surrounding them.
4. To permit growth of large body size (elephants etc.) since it is live and growing.
5. To provide a surface for muscle attachment and serve as levers on which muscles can act.
6. To perform hematopoiesis in the bone marrow in most mammals.
7. To aid in hearing (ear ossicles) and breathing (ribs)

Division of vertebrate endoskeleton: Generally, vertebrate endoskeleton is divided in 3 broad categories:



Skull in vertebrates: The skeletal structure forming the framework of the vertebrate head is called skull. It is derived from three major embryonic components as is given below:

1. **Neurocranium:** It gives rise to cranium or brain box and three pairs of sense capsules i.e. olfactory, optic and otic.
2. **Dermatocranium:** It gives rise to dermal bones attached to neurocranium and splanchnocranium.
3. **Splanchnocranium:** It gives rise to pharyngeal skeleton such as jaws, hyoid apparatus etc.

Variations in the skull design among vertebrates is discussed below.

1. **Cyclostomata (Agnatha):** In this, skull is most primitive. It retains cartilaginous embryonic neurocranium with an imperfect fibrous roof that has no dermal bones.
2. **Superclass Pisces:** In chondrichthyes, neurocranium is cartilaginous and brain is completely roofed. Olfactory and otic capsules are fused with neurocranium. Optic capsules are free and dermal bones are absent.

   In osteichthyes, neurocranium is part cartilaginous and part ossified, completely roofed and flat.
   Cartilaginous splanchnocranium is replaced by dermal bones and replacement bones.
   Premaxilla and maxilla forming upper jaw are dermal bones while bones of the lower jaw are replacement bones.
3. **Amphibia:** Skull shows drastic modification from fishes and it is due to land dwelling evolution related needs. Amphibian skull is platybasic, flattened with far less bones. Absent bones are basioccipital, supraoccipital, basisphenoid and presphenoid.

   Hyomandibular becomes columella of middle ears and assists in auditory process.

   Skull has two occipital condyles for communication with first vertebra.
4. **Reptilia:** Skull is tropibasic and most of them have a single occipital condyle for communication with the first vertebra. Neurocranium is extensively modified except in naso – ethanoidal region.
   Dermal bones are more than Amphibia.
   Hyomandibular is modified into columella of middle ear for help with hearing.
   Lower jaw shows large toothed dentary, angular, supraangular, splenial, coronoid and articular bones.
5. **Aves:** Neurocranium is well ossified and there is single occipital condyle for vertebral connection. It shows modifications associated with flight and altered feeding habits.
   Skull is pneumatic, light, has very thin dermal bones and no sutures.
   Premaxillary and dentary are elongated to form toothless beak. Columella in middle ear is present and is a modification of Hyomandibular.
6. **Mammalia:** A mammalian skull shows two occipital condyles for vertebral connection. This is also indicative of synapsid phylogeny of the mammals.
   Absent bones are pre- and post – frontals, supra and post – orbitals, transpalatines, parasphenoid and quadratojugal and jugal.
   In lower jaw all bones except dentary are absent.
   Occipital bones fuse into a single piece enclosing the foramen of Magnum.
   Otic bones fuse to form a periotic.
   Middle ear cavity has three ossicles derived from the bones of jaw.
   Malleus from articular, incus from quadrate and stapes from columella or Hyomandibular bone.

Thus, we can conclude that skulls have evolved variously among the classes of vertebrates.

Suspensoria or jaw suspension in vertebrates

In gnathostomes, splanchnocranium gives rise to jaw apparatus. The first or mandibular arch consists of a dorsal palatopterygoquadrate bar forming the upper jaw and ventral Meckel`s cartilage forming lower jaw.

The second or hyoid arch consists of a dorsal Hyomandibular which supports and suspends jaws to the cranium and a ventral hyoid proper.

Thus, splanchnocranium plays an important role in the formation of jaw in the gnathostomes and in their suspension with the chondrocranium.

This method of attachment or suspension of jaws from the chondrocranium is termed jaw suspension or suspensorium.

There are five principal types of Suspensoria and are discussed below.

1. **Autodiastylic:** In this:
    - jaws are attached to cranium by anterior and posterior ligaments.
    - Hyoid arch does not support the jaws.
    - Gill cleft without spiracle is found between the jaw and hyoid arch.

    E.g. Early gnathostomes.

2. **Amphistylic:** In this:
    - upper jaw is attached to chondrocranium and so is upper end of Hyomandibular of hyoid arch.
    - lower end of hyomandibular supports the two jaws in their suspension to chondrocranium.
    - Thus, we see double suspension support by ligament and hyomandibular. This is the reason it is called as Amphistylic.

    E.g. Primitive sharks.

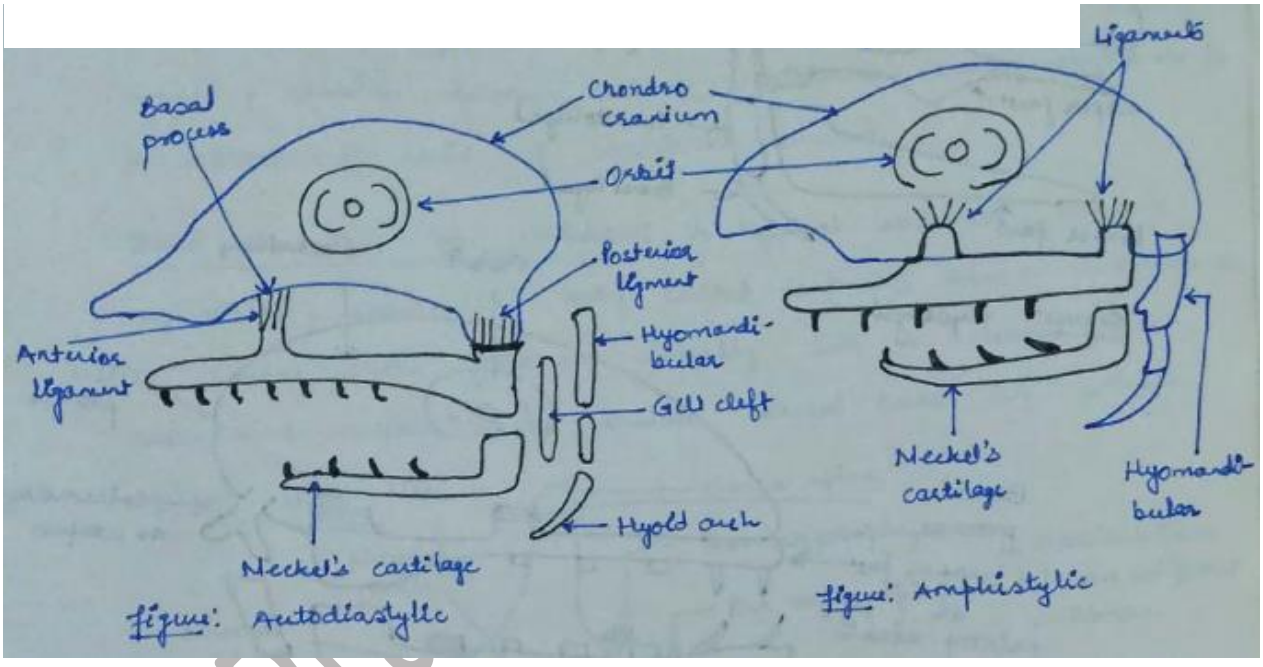


Figure: Autodiastylic and Amphistylic suspensorium types

3. **Hyostylic:** In this:
    - upper jaw is loosely attached to cranium by anterior ligament.
    - upper end of hyomandibular fits the auditory region of skull and both the jaws are braced against remaining part of hyomandibular.
    - as only hyoid arch braces the two jaws against cranium the jaws are capable of wider movement and it helps in swallowing larger prey.

    E.g. Bony fishes.

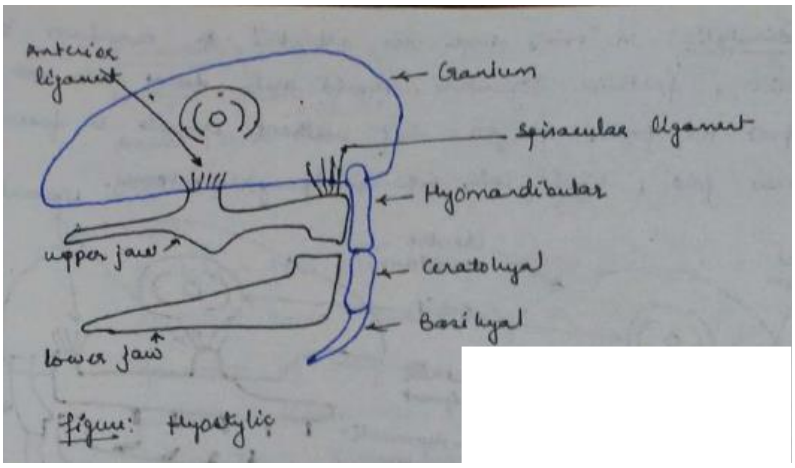
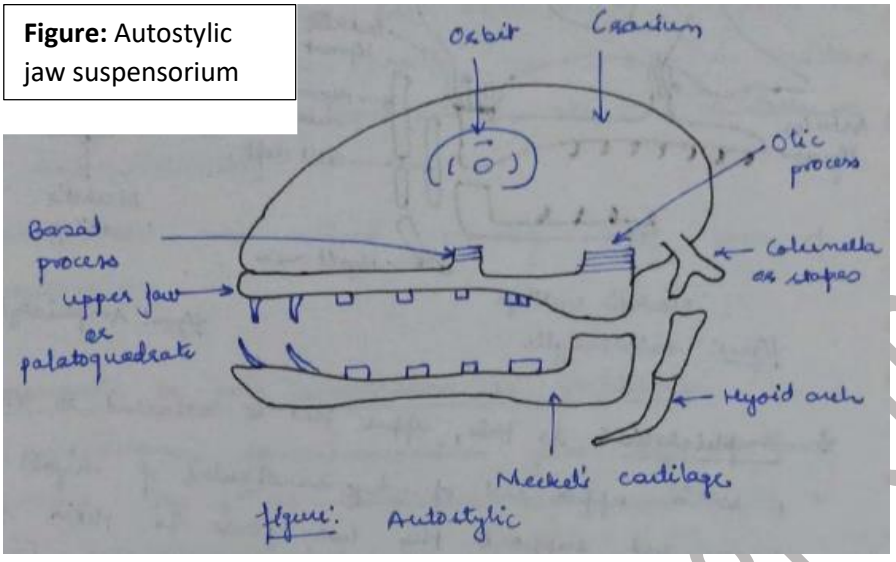


Figure: Hyostylic suspensorium type.

4. **Autostylic:** In this:
    - upper jaw is directly bound to cranium.
    - the articular bone in lower jaw articulates with quadrate bone of upper jaw.
    - hyomandibular is modified into columella and does not participate in suspension.
    - 3 subtypes i.e. holostylic, monimostylic and streptostylic.

    E.g. Most tetrapods such as amphibians and lizards etc.

Figure: Autostylic jaw suspensorium



5. **Craniostylic:** It is a modification of Autostylic suspension and in this:
    - upper jaw along its total fuses with the cranium.
    - hyomandibular forms stapes, articular forms malleus and quadrate forms incus of the middle ear.
    - articulation between jaws is provided by dentary of lower jaw and squamosal of skull.

    E.g. Mammals.

Vertebral column, vertebrae and its types in chordates:

In gnathostomes, embryonic notochord is covered by a bony column in adults. This column is called vertebral column. This column is formed of a metameric series of many small and similar pieces, called as vertebrae. Thus, vertebrae is a unit of vertebral column.

Basic structure of vertebra:

A typical vertebra has a cylindrical, spool – like body called centrum. Above the centrum is a neural arch produced dorsally into a neural spine. Successive neural arches enclose neural canal in which spinal cord lies.

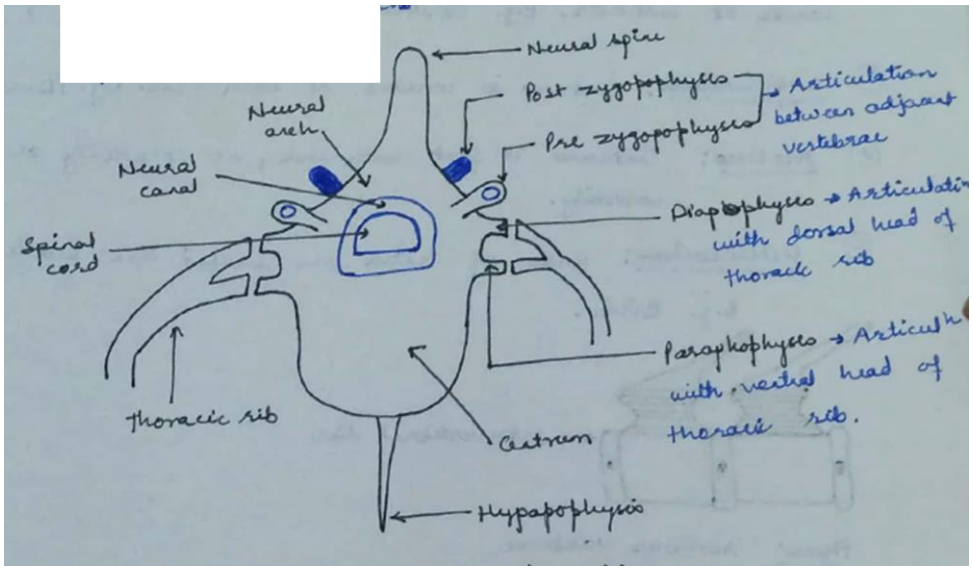


Figure:

Typical tetrapod vertebrae

Types of Centra and Vertebrae: An intercentrum is present between centra of successive vertebrae in embryo. These may fuse with anterior or posterior side of centra, changing its shape. This shape of centra is basis to identify following vertebrae types:

1. **Procoelous:** Anterior face of centrum is concave and posterior face convex. E.g. Frog and reptiles.
2. **Opisthocoelus:** Centrum is concave at posterior and convex at anterior. E.g. Cervical vertebrae in large ungulates.

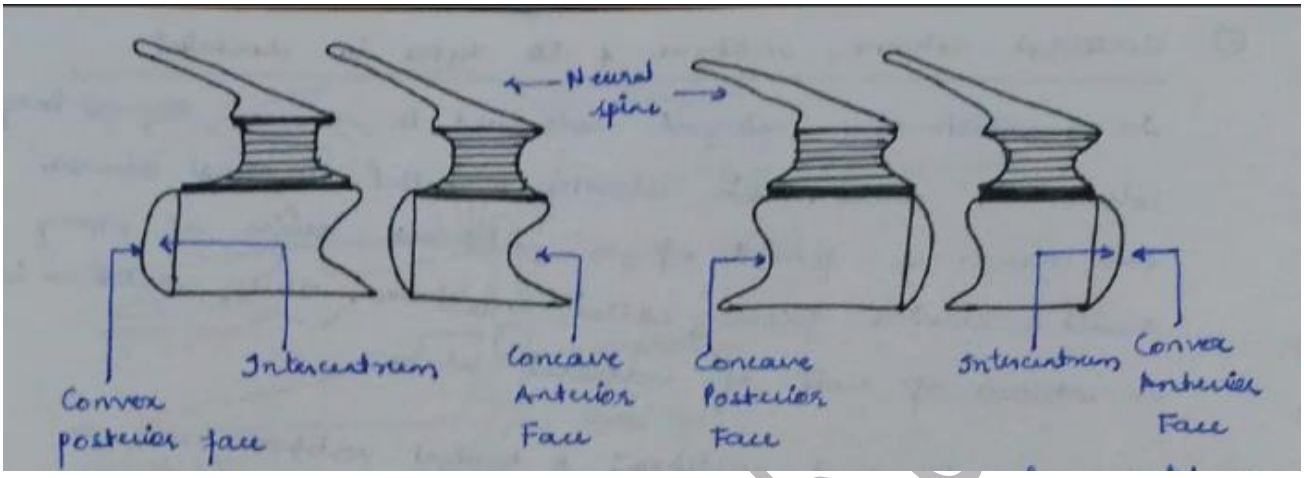


Figure: Procoelous vertebrae

Figure: Opisthocoelous vertebrae

3. **Amphicoelous:** Centrum is concave at both the ends. E.g. Fishes.
4. **Acoelous:** Centrum is flat at both ends, no concavity or convexity and vertebrae are separated by intervertebral disc. E.g. Mammals.
5. **Heterocoelous:** Ends of centra are shaped like saddle. E.g. Birds.

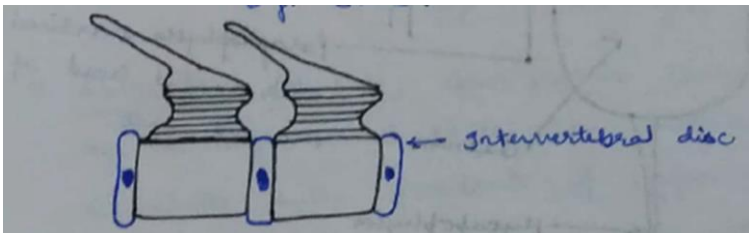


Figure: Acoelous vertebrae. Compare with figures of other vertebrae for better understanding.

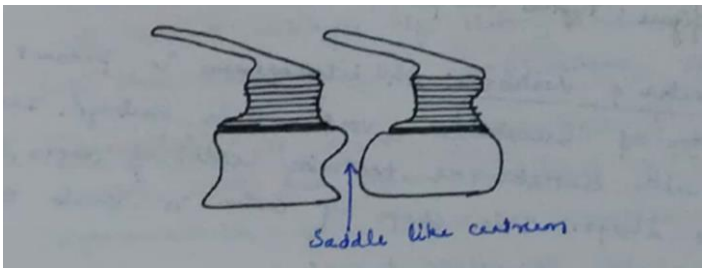


Figure: Heterocoelous vertebrae.

Compare with figures of other vertebrae for better understanding.