

VIVEKANANDA COLLEGE

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KOLKATA-700063

NAAC ACCREDITED 'A' GRADE



Topic: SKELETAL SYSTEM
Course Title: COMPARATIVE ANATOMY OF VERTEBRATES
Paper: CC8 (ZOOA-CC4-8-TH)
Unit: 7
Semester: 4TH
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TABLE 42.1.

GENERAL DIVISIONS OF ENDOSKELETON IN A LAND VERTEBRATE.

<i>I. Axial skeleton (median)</i>			<i>II. Appendicular skeleton (lateral, paired)</i>	
Skull	Vertebral column	Thoracic basket	Girdles	Limb bones
A. Neurocranium 1. Cranium or brain box surrounding brain 2. Sense capsules <i>(i)</i> Olfactory-nose <i>(ii)</i> Optic-eyes <i>(iii)</i> Auditory ears B. Dermatocranium Membrane or dermal bones of skull C. Splanchnocranium Includes visceral arches or pharyngeal skeleton 1. Upper jaw 2. Lower jaw 3. Hyoid 4. Larynx	Vertebrae 1. Cervical-neck 2. Thoracic-chest 3. Lumbar-lower back 4. Sacral-hip 5. Caudal-tail	A. Ribs Paired; bony cartilaginous B. Sternum-Breast bone	A. Pectoral Anterior or shoulder girdle. Includes : 1. Scapula-dorsal 2. Clavicle-anterior 3. Coracoid-posterior B. Pelvic Posterior or hip girdle Includes : 1. Ilium-dorsal 2. Pubis-anterior 3. Ischium-posterior	A. Forelimb 1. Humerus -upper arm 2. Radius and ulna-forearm 3. Carpals-wrist 4. Metacarpals-palm 5. Phalanges-fingers B. Hind limb 1. Femur-thigh 2. Tibia & fibula-shank 3. Tarsals-ankle 4. Metatarsals-sole 5. Phalanges-toes

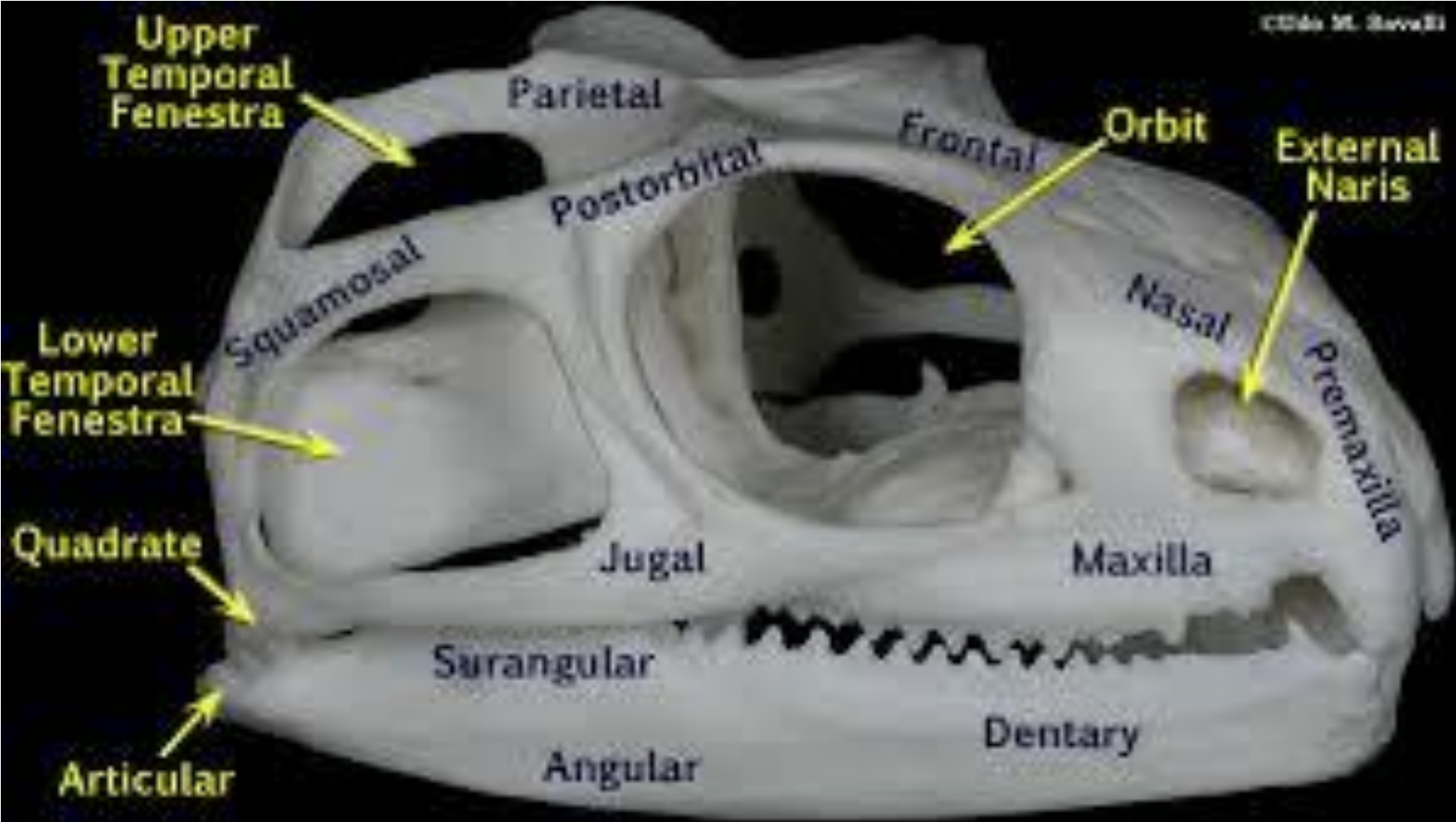


TABLE 42.2.

TYPES OF BONES IN SKULL OF VERTEBRATES.

Region of skull	Cartilage or replacement bones	Membrane or dermal bones	Bones of mixed origin
A. Chondrocranium			
1. Occipital	* Supraoccipital Exoccipital * Basioccipital	Parietal * Interparietal Postparietal	
2. Parietal	* Basisphenoid Pleurophenoid		
3. Frontal	Orbitosphenoid * Presphenoid	Frontal Postfrontal Lacrimal	Prefrontal
4. Olfactory capsule	* Mesethmoid Turbinals Cribriform Ectethmoid } (Ethmoid)	Nasal Vomer Septomaxillary	
5. Otic capsule	Epiotic Prootic Opisthotic	Squamosal Supratemporal	Sphenotic Pterotic
6. Optic capsule	Sclerotic		
7. Palate		* Parasphenoid Vomer (in mammals) Endopterygoid or Pterygoid, Ectopterygoid	Palatine
B. Splanchnocranium			
1. Upper jaw	Quadrate (incus) Epipterygoid Alisphenoid Metapterygoid	Premaxilla Maxilla Jugal Quadratojugal	
2. Lower jaw	Articular (malleus) Mentomeckelian	Dentary (mandible) Coronoid Splénial Angular Supraangular	
3. Hyoid arch	Hyomandibular Columella (stapes) Symplectic Inter-epi-, hypo-, cerato- * basihyal		
4. Gill-cover		Preopercular Opercular Subopercular Interopercular Gular	

N.B. – All bones are paired. Single bones are marked with an asterisk (*).

1. AXIAL SKELETON

A. SKULL

B. VERTEBRA

PARTS OF A TYPICAL VERTEBRA:

A typical vertebra consists of

- **Centrum** - a main body, bearing one or two arches and one or more attaching processes. The centrum develops as a ring of tissue around the noto-chord. The ring then fills in to become a disc or cylindrical mass.
- **Neural arch** - On the dorsal side of the centrum a neural arch becomes fused to enclose a **neural canal** through which the spinal cord passes.
- **Neural spine** - usually is developed from the mid-dorsal part of the neural arch.
- **Haemal arch** - A similar arch is present in the caudal region of many vertebrates on the ventral side of the centrum with haemal canal and haemal spine. Through the haemal canal the caudal artery and vein run.

Besides these structures, there are several outgrowths or processes arising from the centrum and at the basal regions of the neural arch, called **apophyses**. These processes are projected in different directions and offer surfaces for attachment of muscles or facilitate frictional contact of one vertebra upon others as sliding joints.

The most common apophyses are:

(a) Zygapophyses: usually two pairs of Zygapophyses help to articulate between successive vertebrae. The pair of zygapophyses projecting anteriorly are called prezygapophyses while the posterior pair, projecting at the basal region of the neural arch, called postzygapophyses. Prezygapophyses of the centrum face upward and postzygapophyses face downward. Zyga-pophyses are not common among fishes.

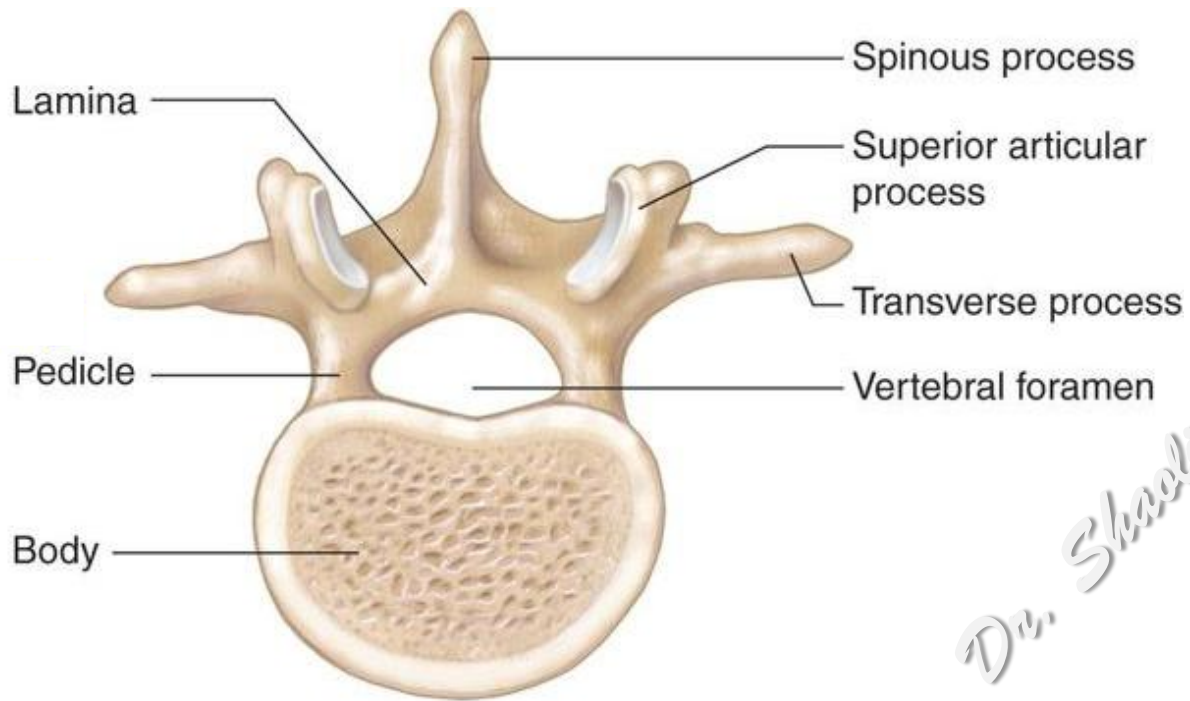
(b) Basapophyses: a pair of ventral projections of the centrum which represent the remains of the haemal arch.

(c) Diapophyses: A pair of lateral projections of the centrum; provide articulating surfaces for the dorsal head of the ribs, the tuberculum.

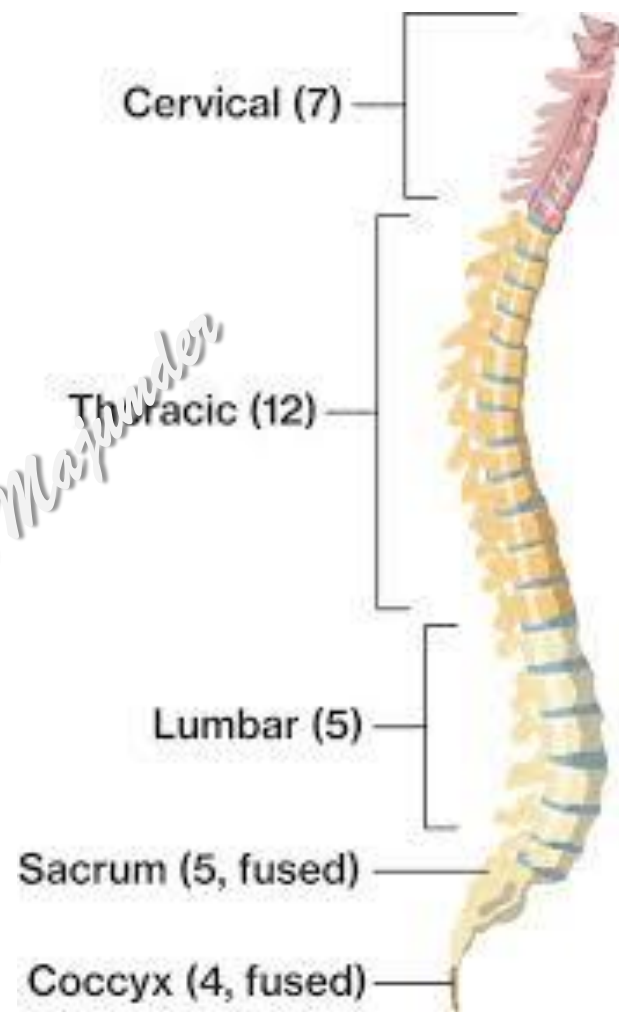
(d) Parapophyses: A pair of lateral projections of the centrum which are used for the attachment of the ventral head of the ribs, the capitulum.

(e) Transverse process: Laterally extended process which arises from the sides of the vertebra; ; common among tetrapods.

(f) Hypapophyses: ventral projections of the centrum which are found in reptiles, birds and mammals.



(c) Lumbar vertebra



TYPES OF VERTEBRAE IN LIVING VERTEBRATES:

Amphicoelous vertebra: (Gk. *amphi* = both, Gk. *coel* = cavity)

Both ends of centrum are concave and concavities are filled with connective tissue and cartilage. Eg: most fishes, some living amphibians (e.g., *Necturus*, *Proteus*) and living reptiles like *Sphenodon*, *Gecko*.

Procoelous vertebra: [Gk. *pro* = anterior, Gk. *coel* = concavity]

anterior end of centrum exhibits concavity and posterior end shows convexity. eg. some anurans (except sacral region of *Bufo* and *Rana*) and modern reptiles with a few exceptions.

Opisthocoelous vertebra: (Gk. *opisthe* = behind, Gk. *coel* = concavity)

centrum bears concavity at the posterior surface but the anterior surface shows convexity. Eg. *Lepidosteus* (a primitive of bony fishes), some anurans (*Discoglossidae*, *Pipidae*, etc.), 2nd and 3rd cervicals of turtles, penguin and parrots, cervical vertebrae of ungulates and dinosaurs.

Heterocoelous vertebra: (Gk. *hetero* = different, Gk. *coel* = concavity)

centrum of the anterior side of vertebra is convex dorsoventrally and concave from side to side, and the posterior face of the centrum is just reverse, having a transverse, saddle-shaped surface. e.g., cervical vertebrae of birds.

Acoelous: (Gk. *amphi* = both, Gk. *platys* = flat)

centrum of the vertebra is flat at both sides. Eg. Mammals.

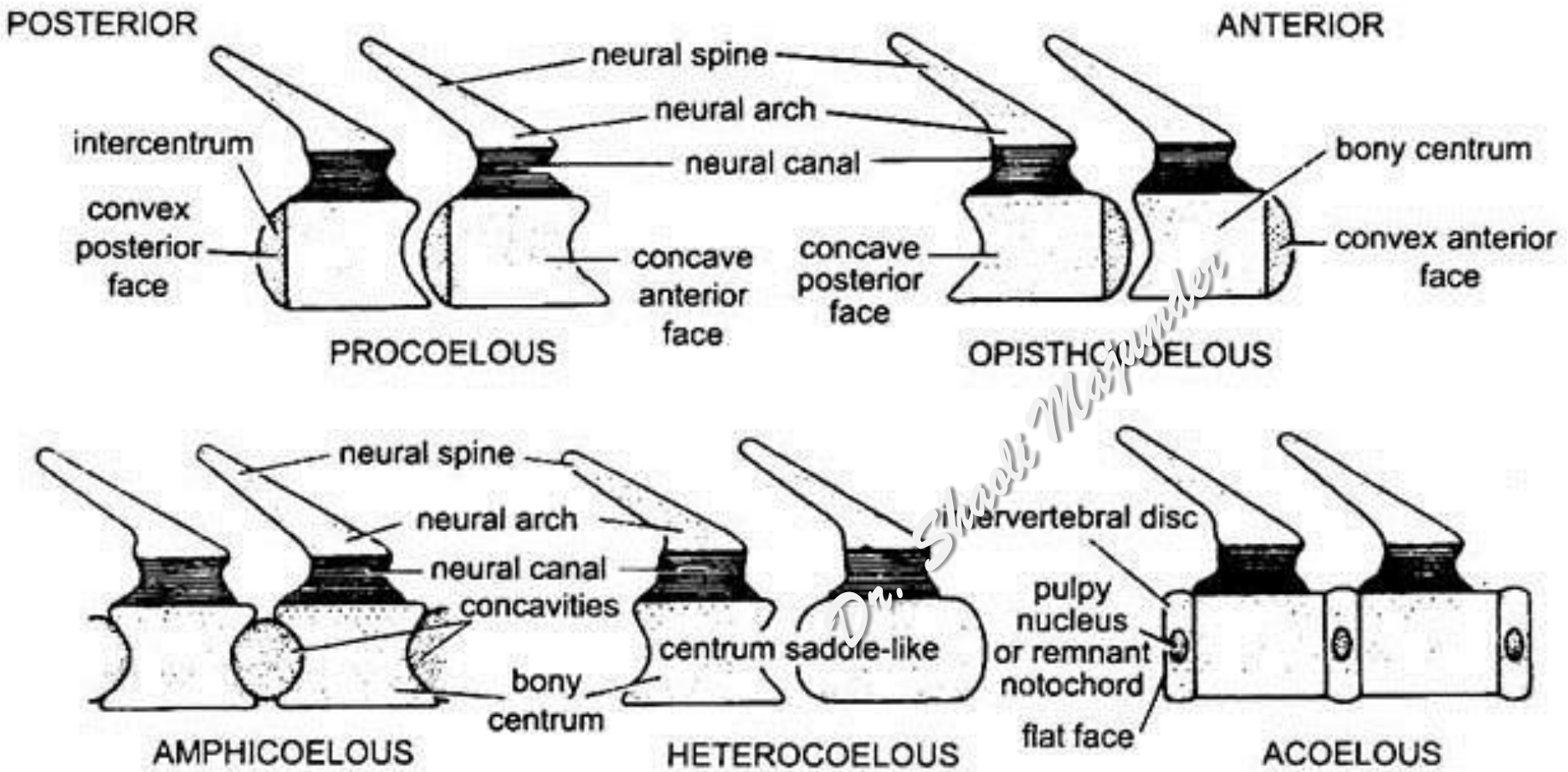


Fig. 42.12. Types of vertebrae based on shape of centra in sagittal section.

C. RIBS

Ribs are cartilaginous or bony structures, which are either fused to or articulated with vertebrae. Typically there is one pair of ribs to each vertebra.

☐ Fishes

- (i) Dorsal or intermuscular ribs extend from transverse processes into a skeletogenous septum between two successive myotomes.
- (ii) ventral or pleural ribs which arise from the centrum and lie between the body wall muscles and parietal peritoneum.

Most fishes have either dorsal or ventral ribs, but some have both kinds, e.g., *Polypterus* and many teleosts. In elasmobranchs only dorsal ribs are present, while most teleosts have only ventral ribs.

☐ Tetrapoda

- One pair of ribs to each vertebra; all ribs are short, except those in thorax.
- In amniotes ribs of the thoracic region unite ventrally with sternum and dorsally articulate with vertebrae by two heads. In these two-headed or bicipital ribs the tuberculum or upper head articulates with a process of neural arch called diapophysis, while the capitulum or lower head articulates with a process of centrum called parapophysis.
- In the cervical region ribs are fused with vertebrae.
- Abdominal ribs are also called gastralia or ventral ribs. present in some fossil amphibians, in *Sphenodon* and crocodilians. They are dermal elements, while true ribs are endoskeleton structures.

2. APPENDICULAR SKELETON (PIGEN)

A. GIRDLES

a. PECTORAL GIRDLE

(i) Coracoid:

It is a massive, rod-like strongly built bone. Each coracoid is placed on the dorsoventral axis and is attached to the broad end of the keel. Anterior end contains a process, called acrocoracoid process,

(ii) Scapula:

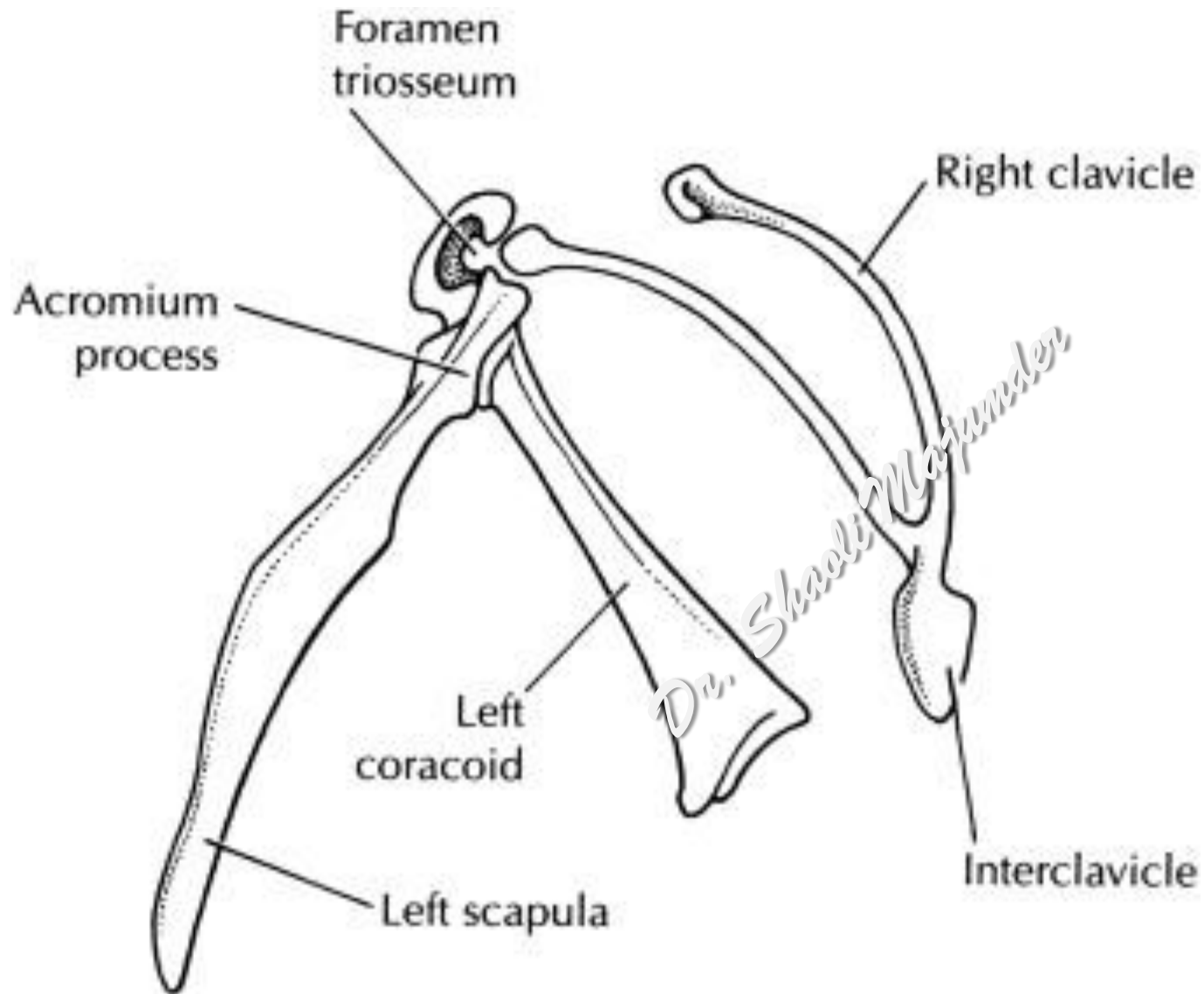
It is a sabre-shaped bone which extends anteroposteriorly over the ribs. At its anterior end, it is connected with the coracoid by a ligament. The coracoscapular angle is less than 90° . This is a characteristic feature of the flying birds.

(iii) Furcula or wish bone or Merry thought bone:

It represents the clavicles and interclavicles of pectoral girdle of other vertebrates. It forms a 'V'-shaped structure and hangs along the dorsoventral axis in front of the sternum. A small aperture (foramen triosseum) is left at the junction of the coracoid, scapular and furcula. Through this aperture, the tendon from the wing muscles passes for its attachment with the humerus.

(iv) Glenoid cavity:

It is the place where the head of the forelimb fits in. It is formed by both coracoid and scapula, the latter forms acromion process within it.



b. PELVIC GIRDLE:

The pelvic girdle is compact and ankylosed with the synsacrum. It contains the following skeletal parts on each side:

(i) Ilium:

It is a broad and large bone, fused with the synsacrum on its inner side. It is concave anteriorly and convex posteriorly,

(ii) Ischium:

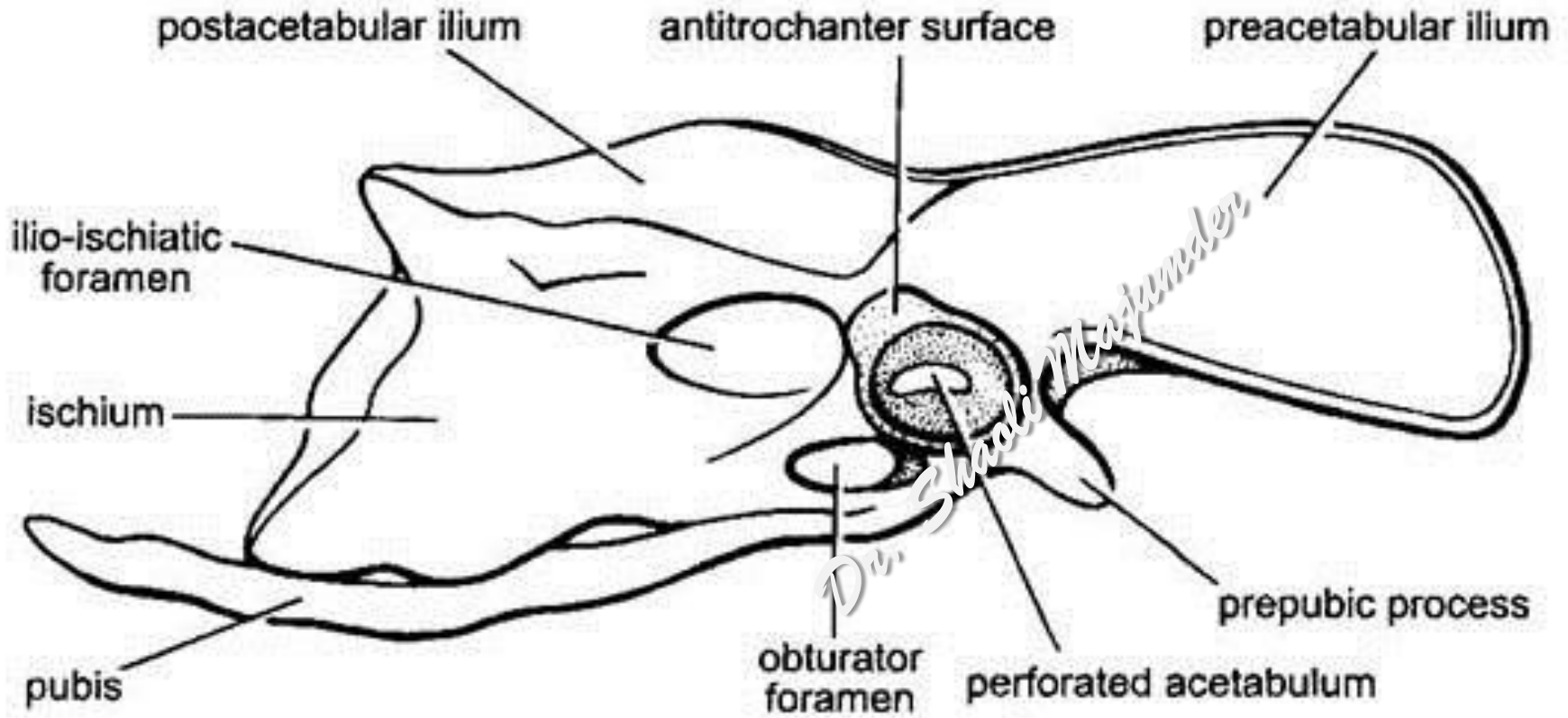
It is a broad bone, which is fused with the ilium at its posterior end. Anteriorly, an ischiatic foramen separates the ilium from ischium. No ischiatic symphysis is present.

(iii) Pubis:

It is a narrow, curved and elongated skeletal piece, which is placed parallel to the ischium and separated from it by obturator foramen. No pubic symphysis occurs in pigeon.

(iv) Acetabulum:

It is the cavity where the head of the femur fits in. Its dorsal side is formed by the ilium and the remaining part is formed by equal share from ischium and pubis. The edge of the cavity is drawn into a process, called anti-trochanter, which works against the trochanter of the femur of hind limb.



B. LIMBS

a. FORE LIMBS

(i) Humerus:

It is a strongly built bone with broad head. The head bears a number of prominent ridges and a pneumatic foramen.

(ii) Radius and Ulna:

Both bones are separated in the middle but remain closely approxed at two ends. Radius is a slender, straight skeletal piece, while ulna is curved and slightly bent.

(iii) Proximal carpals:

Two large skeletal pieces, radiale and ulnare —remain free

(iv) Carpometacarpus:

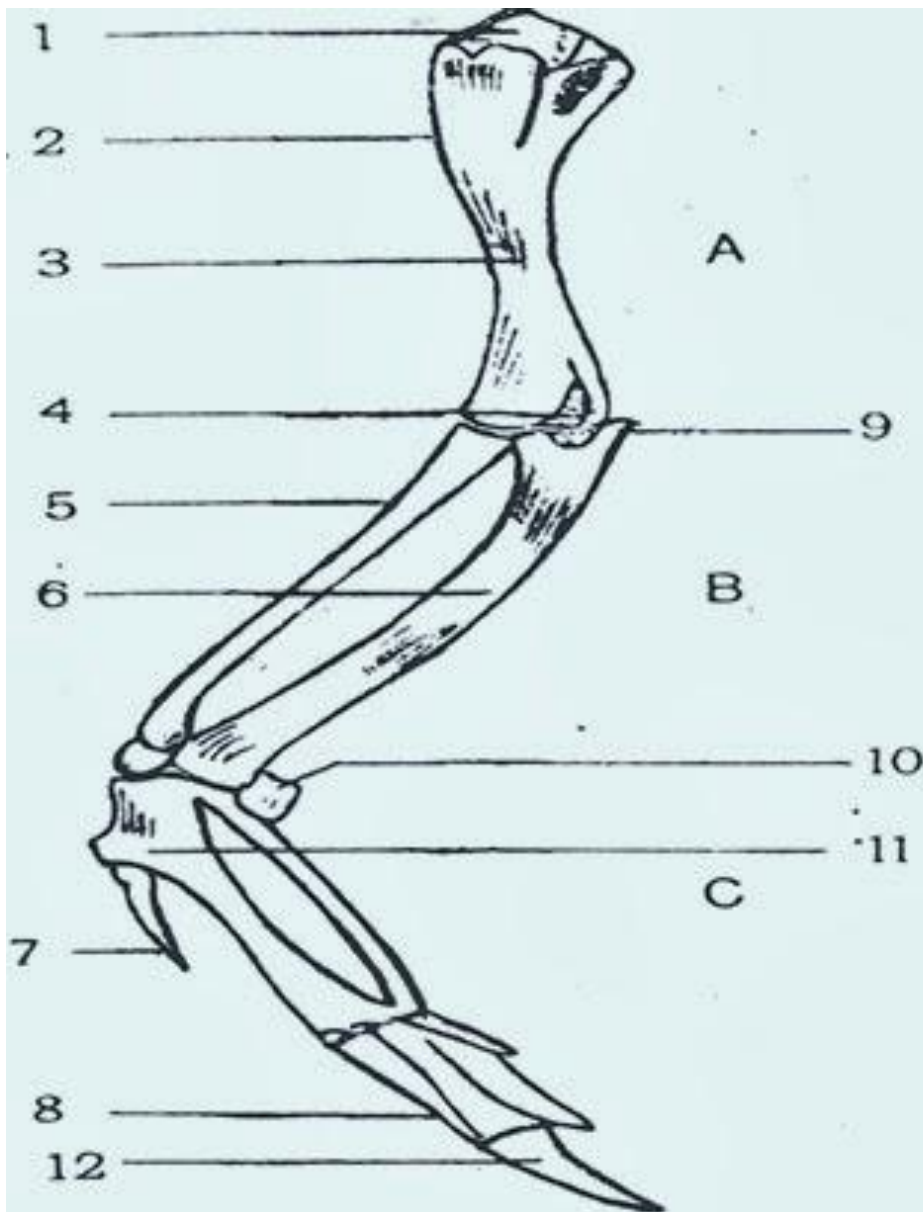
This small but compact bone formed by union of two distal carpals and three metacarpals, which are fused at both ends but remain separated in the middle. One piece is stout and straight, while the other piece is slender and curved.

(v) Phalanges:

Following phalanges are present in each limb, all of which are devoid of claws.

- One pointed phalanx is attached with the first metacarpal,
- Two phalanges remain attached with the second metacarpal, one of them is flange-like and the other is pointed.
- One pointed phalanx is attached with the third metacarpal.

Columba - Fore limb bones



- 1) Head of Humerus
- 2) Deltoid ridge
- 3) Shaft
4. Trochlea
- 5 Radius
- 6 Ulna
- 7 1st digit phalange
- 8, 9, 10, 11, 12) Phalanges of 2nd digit
9. Olecranon process
10. Ulnare
11. 1st metacarpal.

A. Humerus
B. Fore arm bones
C. Bones of palm

b. Hind Limb

(i) Femur:

It is a short and narrow skeletal piece. Its proximal end contains pointed trochanter and rounded head. The distal end is drawn into a pulley-like condyle, containing a patella as knee-joint.

(ii) Tibiotarsus:

It is a long bone formed of tibia with the fusion of two distal tarsals.

(iii) Fibula:

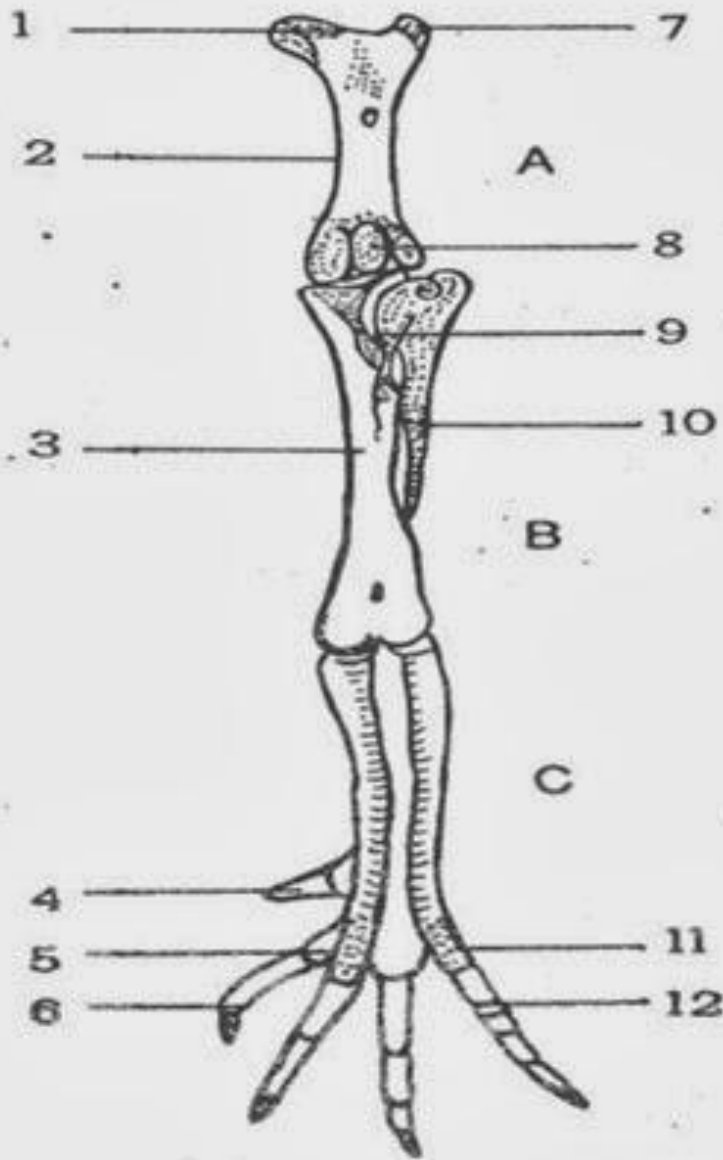
It is a small rudimentary bone situated on the lateral surface of the tibiotarsus.

(iv) Tarsometatarsus:

This bony segment is formed of some of the tarsals and the metatarsals of the second, third and fourth digits. A small vestige of the first metatarsus is located on the posterior side of the distal end of the tarsometatarsus.

(v) Phalanges:

Pigeon has four digits; the fifth one is lacking. The distal phalanges of all the toes are provided with sharp and pointed claws. The first toe or hallux has two phalanges and the second, third and fourth toes have three, four and five phalanges, respectively.



1. Head of femur
2. Shaft of femur

3. Tibio tarsus

4. Spur

5. 1 Meta tarsal

6. Phalanx

7. Trochanter

8. Patella

9. Cubit

10. Fibula

11. 4th Meta tarsal

12. Phalanx

A) Femur

B) Bones of shank

C) Bones of Foot

COLUMBA. BONES OF HIND LIMB

JAW SUSPENSION

- Jaws are the characteristic feature of the gnathostomes which are used for holding the prey, and chewing the food materials. In the course of vertebrate evolution, the appearance of jaws has profoundly changed the mode of living. Before the appearance of jaws, animals like protochordates are ciliary feeders.
- The mechanism by which the upper jaw (palatoquadrate) and lower jaw (Meckel's cartilage) are suspended from the neurocranium, is called jaw suspension.
- Amongst the visceral arches, the first (mandibular) arch consists of a dorsal palatopterygoquadrate bar forming the upper jaw, and ventral Meckel's cartilage forms the lower jaw.
- The second (hyoid) arch consists of a dorsal hyomandibular supporting and suspending the jaws with the cranium, and a ventral hyoid.
- The remaining visceral arches support the gills and are, hence, called branchial arches.
- Thus, splanchnocranium forms the jaws and suspends them with the chondrocranium.

Table 20 : A list of fates of the branchial arches in sharks, teleosts and tetrapods

NAME OF THE ARCH	SHARKS	TELEOSTS	AMPHIBIANS	REPTILES AND BIRDS	MAMMALS
1st or Mandibular arch	Palatoquadrate or Pterygoquadrate (upper part) Meckel's cartilage (lower part)	Quadrate Epipterygoid Articular	Quadrate Epipterygoid Articular	Quadrate Epipterygoid Articular	Quadrate Alisphenoid Malleus
2nd or Hyoid arch	Hyomandibula Ceratohyal Basihyal	Hyomandibula Ceratohyal Hypo-hyal Basihyal	Stapes (Columella) Ceratohyal Hypo-hyal	Stapes Ceratohyal Body of hyoid	Stapes Anterior horn of hyoid Body of hyoid
3rd or 1st branchial arch	{ Epibranchial Ceratobranchial Hypobranchial or 1st branchial arch }	{ Epibranchial Ceratobranchial Hypobranchial or 1st branchial gill arch }	Part of hyoid apparatus	Posterior horn of hyoid	Posterior horn of hyoid
4th or 2nd branchial arch	2nd branchial arch	—	Part of hyoid apparatus	Part of hyoid apparatus	Thyroid cartilages
5th or 3rd branchial arch	3rd branchial arch	3rd branchial arch	Laryngeal cartilages	Laryngeal cartilages	Laryngeal cartilages
6th or 4th branchial arch	4th branchial arch	Not found	Not found	Not found	Epiglottis (?)
7th or 5th branchial arch	5th branchial arch	—	—	—	—

TYPES OF JAW SUSPENSION

1. Autodiastylic:

jaws are attached by ligaments (anterior and posterior) to the chondrocranium. The hyoid arch does not support the jaws but remain completely free as the posterior branchial arches. The gill-cleft in front of the hyoid arch does not form a spiracle but forms a complete gill, e.g., early bony fishes (acanthodians).

2. Amphistylic:

both the pterygoquadrate and hyomandibular make direct articulation with the neurocranium. The upper jaw (mandibular arch) has basal and otic processes which are attached by ligaments to the chondrocranium. Thus, it is a double suspension in which both the mandibular and hyoid arches are attached to the chondrocranium. This type of suspensorium is the most primitive type and is found in Crossopterygii and in some primitive sharks *Heptanchus* and *Hexanchus*.

3. Hyostylic:

The upper jaw is (palatoquadrate) is loosely articulated with the cranium by anterior ethmopalatine ligament and posterior spiracular ligament. Both jaws are suspended from the hyomandibular which is attached to the otic region of the skull. Thus, only hyoid arch binds both the jaws with the cranium and, hence, it is called hyostylic. It is found in most elasmobranchs and bony fishes. These fishes are able to swallow large preys.

4. Autostylic:

The upper jaw (palatoquadrate) is completely fused by its processes to the bony skull and the articular of lower jaw is suspended from the quadrate of the upper jaw. The hyomandibular do not take part in suspensorium and modified into columella or stapes of the middle ear.

Some authorities use the term autosystylic for autostylic. It is found in extinct placoderms, chimaera, lung fishes and tetrapods. i.e, amphibians, reptiles and birds. In these, the quadrate of the upper jaw articulates with the articular of the lower jaw.

The autostylic suspension is divided into three varieties:

(a) Holostylic:

The upper jaw is fused to the skull and the lower jaw is suspended from it. The hyoid arch is complete and not attached to the skull, e.g., Holocephali (chimaera).

(b) Monimostylic:

In many tetrapoda, except mammals, hyomandibular forms columella (middle ear bone) and the articular of lower jaw articulates with the quadrate of the upper jaw. The quadrate becomes an immovable part of the skull.

(c) Streptostylic:

In lizards, snakes and birds the articulation is between quadrate and articular, but the quadrate is not firmly fused with the skull and is movable at both ends.

5. Crainostylic:

The upper jaw is fused with the cranium in its entire length. Hyomandibular forms the stapes of middle ear bone. The quadrate and articular also modified into malleus and incus respectively. Thus, squamosal of the skull and dentary of lower jaw articulate with each other and both are dermal bones. It is found in mammals. Some consider it as modification of autostylic type.

Dr. Shashi Wajankar

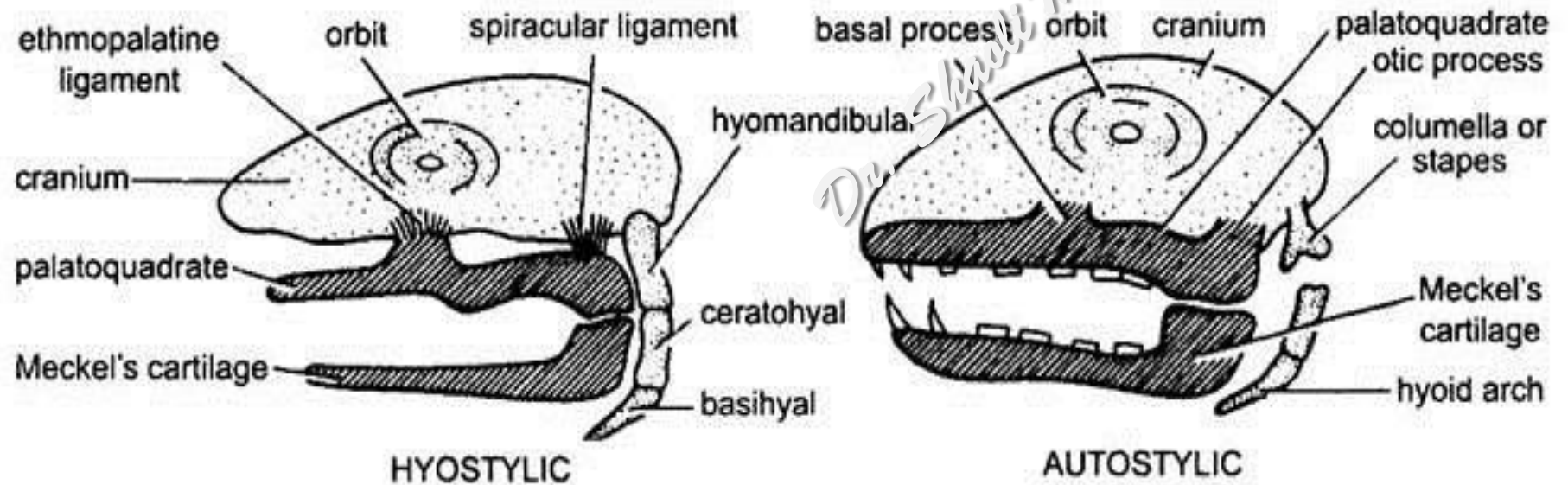
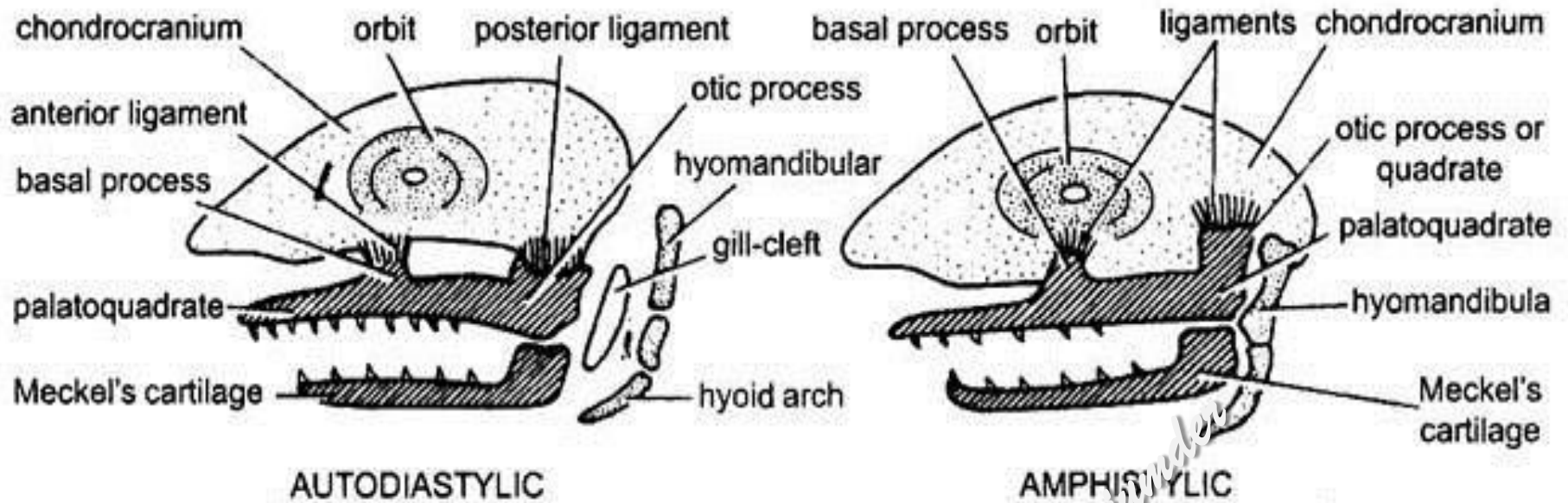


Fig. 42.7. Types of jaw suspensoria in vertebrates.