MODULE-1: VETERINARY ANATOMY - AN INTRODUCTION

Learning outcomes

At the end of this module, the learner will be able to know about

- the branches of anatomy
- directional terms
- zoological classification of domestic animals and
- the taxonomical position of the animals

DEFINITIONS AND DIVISIONS

- *Anatomy* is the branch of biological science, which deals with the form and structure of the body and its parts. The various parts of the body must work together in near-perfect harmony to maintain the life and well-being of an animal. The term anatomy strictly means *cutting open* or *dissociating the parts of the body*.

Branches of Anatomy

Gross anatomy / Macroscopic anatomy

- *Topographical /Regional Anatomy*
  - All the structures, present in the each regions or parts of the body are studied in the order, in which they should present themselves, in the course of dissection. For example, the anatomy of the neck region would include all the muscles, bones, organs, blood vessels and nerves present in the neck.
- *Systematic Anatomy*
  - The branch of anatomy deals with the different systems in the animal body are studied one after another. E.g. Skeletal system, muscular system etc.
    - Osteology (Bones)
    - Arthrology (Joints)
    - Myology (Muscles)
    - Splanchnology(Visceral organs)
    - Angiology (Cardio-vascular system)
    - Neurology (Nervous system)
    - Aesthesiology (Sense organs)

Histology and Cytology / Microscopic Anatomy

Developmental Anatomy / Embryology

The anatomy can also be classified as

- *Special Anatomy* which concerns with one species.
- *Comparative anatomy* compares with the other species.

Zoological classification of domestic animals

DIRECTIONAL TERMS

- Certain directional terms are used in anatomy for description of the various organs or parts of the body with regard to their position, direction etc. It is assumed that the animal is in the ordinary standing position.
- *Cranial* and *caudal* refers to the ends of the animal as it stands on four legs. *Cranial, cephalic* or *anterior* means direction towards the head. *Caudal* or *posterior* means direction towards the tail.
- *Rostral* is a special term used only to describe positions or directions on the head especially towards the tip of the nose.
- Dorsal and *ventral* refer to "up and down" directions with the animal in a standing position.
- *Dorsal* or *superior* means towards the back (top surface) of a standing animal and *ventral* or *inferior* means towards the belly (bottom) of a standing animal.

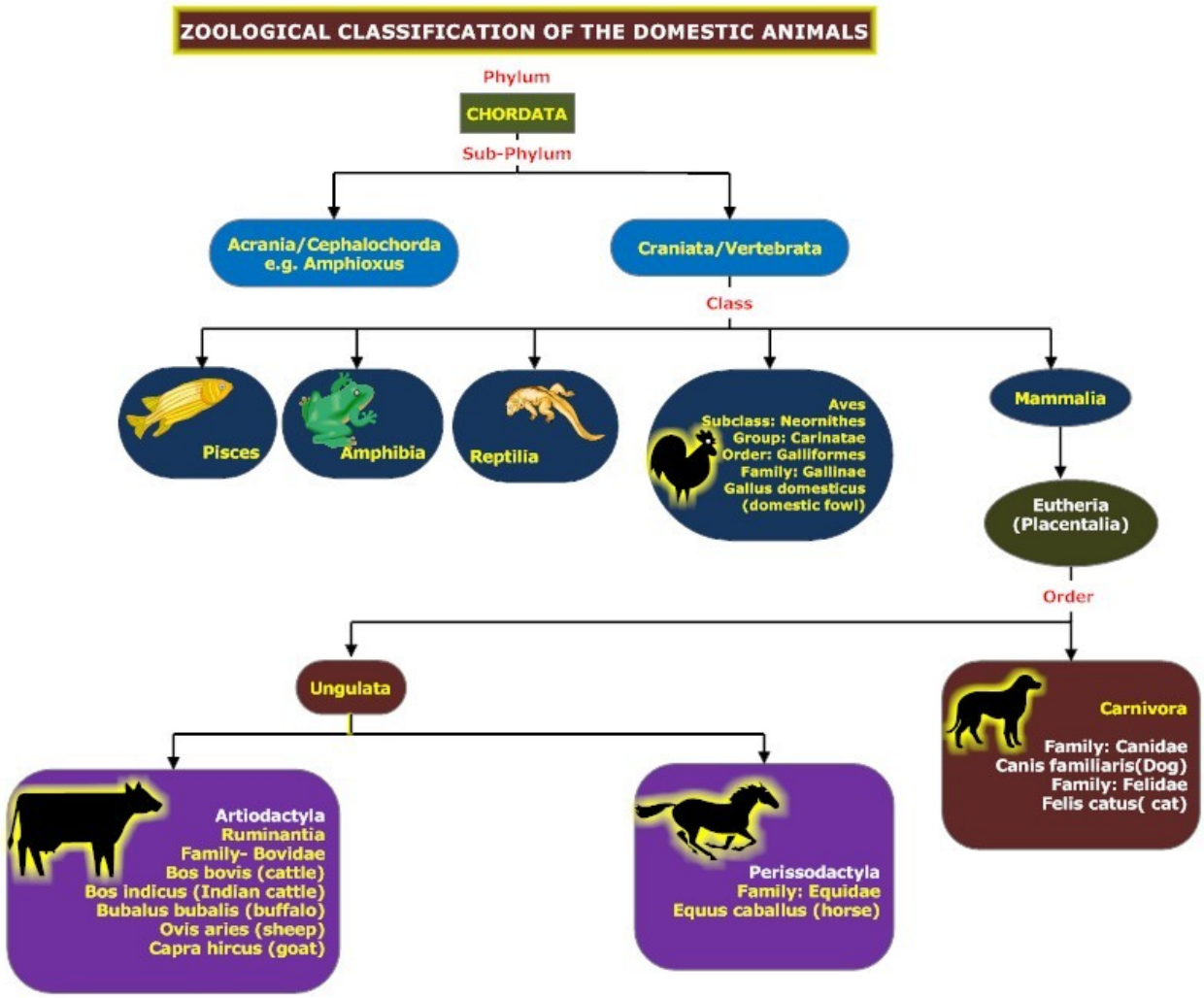
Medial and *lateral* refers to positions relative to the median plane. *Medial* means towards the median plane (toward the center line of the body) and *lateral* means away from the median plane.

- *Deep* and *superficial* refer to the position of the body parts relative to the center or surface of the body. *Deep* means towards the center of the body or body part. (Internal is sometimes used in place of deep). *Superficial* means towards the surface of the body. (External is sometimes used in place of superficial).
- *Proximal* and *distal* are used to describe positions only on extremities, such as leg, ear and tail, relative to the body. *Proximal* means towards the body and *distal* means away from the body.
- With respect to distal parts of limbs, the anterior and posterior faces are referred as *dorsal* and *volar* respectively in the case of the pectoral limb and *dorsal* and *plantar* in the pelvic limb. The *medial* and *lateral* aspects are referred as radial and ulnar respectively in the case of the pectoral limb and *tibial* and *fibular* in the pelvic limb. The terms *axial*and *abaxial* are used to denote the structures lying towards or away from the central axis of the limb.
- **Anterior/Cranial/Rostral:** The head end of the body.
- **Posterior/Caudal:** The tail end of the body.
- **Proximal:** Upper or superior
- **Distal:** Lower or inferior
- **Superior:** It is equivalent to upper or higher i.e. above.
- **Inferior:** It is equivalent to lower or under i.e. Below.
- **Volar:** The posterior face of the distal part of the fore limb.
- **Palmar:** The surface of the fore limb that contacts the ground in standing condition.
- **Plantar:** The contact surface of the hind limb in standing condition.
- **Axial:** Towards the central line of the body or any body part.
- **Abaxial:** Away from the axis.
- **Oral:** The structure towards the head.
- **Aboral:** The structure away from the head.
- **Central:** A part nearest the middle.
- **Peripheral:** A part nearest the surface.
- **Parietal:** The body wall or the wall of the cavity.
- **Visceral:** The viscera or organ in the cavity.
- **Somatic:** The part of the body other than viscera.

ANATOMICAL PLANES

- There are three anatomical planes of reference. Each plane is an imaginary "slice" through the body.

- Median or sagittal plane : A plane that runs down the centre of the body lengthwise and divides it into equal left and right halves. It is also known as midsagittal plane. Plane parallel to the sagittal plane but not on the median line is called Parasagittal plane.
- Transverse plane: A plane across the body that divides it into cranial (head-end) and caudal (tail-end), those are not necessarily equal.
- Dorsal or Horizontal plane: A plane at right angles to the sagittal and transverse planes. It divides the body into dorsal and ventral parts that are not necessarily equal



TAXONOMICAL POSITION OF THE ANIMALS

Kingdom : Animalia

Division : Vertebrata

Class : Mammalia

Sub-class : Theria

Inter-class : Eutheria

	Cattle / Buffalo	Sheep	Goat	Pig / Swine	Horse	Dog	Cat
Order	Artiodactyla				Periss-odactyla	Carnivora	
Sub-order	Ruminata			Suina	Hippo-morpha	Fissipedia	
Infra-order	Pecora			-	-	Arctoidea	Aeluroidea
Family	Bovidae			Suidae	Equidae	Canidae	Felidae
Sub-family	Bovinae	Caprinae		-	Equinae	-	-
Genus	*Bos / Bubalus*	*Ovis*	*Capra*	*Sus*	*Equus*	*Canis*	*Felis*
Species	*taurus & indicus / bubalus*	*aries*	*hircus*	*scrofa*	*caballus*	*domastica*	
Sub-species	-	-	-	*domest-icus*	-	-	-

Class : Aves

Sub-class : Neornithes

Super-order : Neognathae

	Fowl	Turkey	Duck	Goose	Pigeon
Order	Galliformes		Anseriformes		Columbiformes
Sub-order	Galli		Anseres		-
Super-family	Phasianoidea		-		-
Family	Phasianidae	Meleagridae	Anatidae		Columbidae
Sub-family	-	-	Anatinae	Anserinae	-
Tribe	-	-	Anatini	Anserini	-
Genus	*Gallus*	*Meleagris*	*Anas*	*Anser*	*Columba*
Species	*gallus*	*gallopova*	*platyrhychos*	*anser*	*livia*

Sub-species	*domesticus*	*gallopova*	-	-	-

MODULE-2: INTRODUCTION TO OSTEOLOGY

Learning outcomes

At the end of this module, the learner will be able to know about

- bone
- structure of bone
- classification of bone
- coverings of bone
- bone marrow
- development and growth of bone
- terminology
- blood and nerve supply of bone and
- skeleton of domestic animals

INTRODUCTION

- Osteology is the study of bones, the hardest structure in the body excepting teeth. Bones support and protect the tissues of the body and form the framework or skeleton of the body. They also act as levers to which muscle or their tendons are attached and serve as parts of loco-motor apparatus. It serves as a storehouse for calcium in the body. In addition, the bone marrow found inside the bones forms one of the important sources of blood corpuscles.
- The skeleton is generally classified as
    1. Exo-skeleton
    2. Endo-skeleton

Exo-skeleton:

Exo - skeleton found on the surface of the body. It is characteristic of invertebrates. In higher vertebrates, it is represented by nails on the digits, horns, hooves, etc., seen in some of the mammals and also shell of crab and tortoise.

Endo-skeleton:

Endo-skeleton found embedded in soft tissues within the body. It forms the supporting framework consists of two parts:

- *Axial skeleton:* Consisting of the skull, the vertebral column, ribs and sternum.
- *Appendicular skeleton:* Consisting of the bones in the pectoral (forelimb) and pelvic (hind limb) limbs.

In addition to this arrangement of bones, small bones occur in the tissues of an organ or other structures, which do not form a part of the regular skeleton. These small bones are called *Heterotropic bones* and occur only in particular sites in particular species of animals only.

The typical examples are

- *os cordis*. in the heart of cattle
- *os penis*, in the penis of the dog, also in bats, rodents and some primates
- *os rostri*, in the snout of pigs
- *os phrenic,* in the diaphragm in camels. (The term *splanchnic or visceral bone* is also used to refer to these heterotropic bones).

BONE

Bone is a hard structure, appears yellowish-white in colour in a fresh dead bone. While in the living animal, it appears bluish pink. It is hard and rigid in macerated and prepared bones, but in the living animals, the rigidity is combined with a certain degree of flexibility also.They function to move, support, and protect the various organs of the body, produce red and white blood cells and store minerals.

The details of the bone can be known by reading the following chapters.

- Chemical composition
- Structure of Bone
- Classification of Bones
- Coverings of Bones
- Bone marrow
- Development of bone
- Growth of Bones
- Terminology

COMPOSITION OF BONES

The bone is composed of *organic* and *inorganic matters*. Roughly it contains 30% organic and 70% inorganic matter and this proportion varies with the bones in different parts of the body.The proportion varies with the age and there is high percentage of organic matter In growing animals,which is slowly replaced by inorganic matter.

Organic matter

- It is present in the bone are bone cells, collagen fibres and matrix or the intercellular substance.

Inorganic matter

- The organic matter chiefly consists of the fibrous protein - collagen and ossein and chondroitin sulphate.
    - The organic part contributes to the flexibility.
    - It consists mostly of calcium phosphate (about 85%), and small amounts of calcium carbonate (10%), magnesium phosphate, sodium carbonate and sodium chloride.
    - The inorganic salts are responsible for the rigidity and hardness of bone.

STRUCTURE OF BONE

Microscopic structure

- The bone is one of the varieties of connective tissue, consisting of *bone cells* or *osteocytes*, parallel rows of *fine collagen fibres*, which are embedded in the *amorphous ground substance*.
- The ground substance or matrix is impregnated with regularly arranged crystals of calcium salts.
- The deposition of the mineral matter renders the intercellular substance hard and impermeable, forming thin plates or lamellae.

Macroscopical/Gross structure

- The gross structure of the bone shows differences in the arrangement of these bony lamellae, forming either *compact or cancellated bone*.

Compact bone

- It is dense, white and hard and forms the outer shell of a bone. It is found aggregated in portions where there is greatest strain on the bone is exerted.
- Bone is arranged in the form of concentric system called the *Haversian system or Osteone*.

Cancellated or Spongy bone

- It is made up of delicate plates, which intercross each other forming a meshwork with spaces containing marrow.
- Cancellated bone is found in the epiphyses of long bones and is always covered by a layer of compact bone.
- Haversian systems are absent.

CLASSFICATION OF BONES

Bones are classified based on their general shape and function as long bones, flat bones, short bones and irregular bones.

Long bones

- Have an elongated cylindrical part, the *shaft* or *diaphysis* and *two expanded extremities* or *epiphysis*.
- The shaft encloses the medullary cavity, which in life is occupied by yellow marrow.
- The wall consists of dense compact bone of considerable thickness in the middle part of the shaft but becoming thinner towards the extremities. Inside of the compact bone, there is a thin layer of spongy bone lining the *medullary cavity*.
- Each epiphysis consists of spongy bone covered by a thin layer of compact bone.
- The spaces in the cancellated bone of the epiphyses are occupied by red marrow.
- Long bones are found in the limbs and act as pillars for support and as levers. E.g. humerus, femur.
- Some long bones do not develop completely and their medullary cavity is very small or even absent which are called as *aborted long bones*. E.g. ulna of horse.
- Some bones though long they do not have a medullary cavity and are sometimes referred to as *elongated bones*. E.g. Ribs.

TOP

Flat bones

- They are expanded in two directions. They are plate like, affording large surface area for the attachment of muscles and protection of subjacent structures.
- The flat bones are made up of varying thickness of spongy bone between two layers of compact bone E.g. scapula, flat bones of skull like frontal, parietal.
- The flat bones of the cranial vault are composed of an outer layer of ordinary compact bone or lamina externa and an inner layer of very dense compact bone, lamina interna or tabula vitrea and between these is a variable amount of spongy bone called *diploe*.

TOP

Short bones

- They present similar dimensions in length, breadth and thickness. They are made up of a thin layer of compact bone outside and spongy bone inside.
- The *medullary cavity is absent*. This arrangement helps to diffuse concussion. E.g. carpals, tarsals.

Sesamoid bones

- They are short bones, which do not bear the weight of the body and they are developed in the capsules of joints or in tendons.
- They alter the direction of tendons and also give leverage to the tendons of muscles. E.g. patella.

TOP

Irregular bones

- They are irregular in shape and are usually placed on the median line. They resemble short bones in structure. E.g. vertebrae.

Pneumatic bones

- These bones contain *air spaces* within the compact substance instead of spongy bone and marrow. These cavities/spaces are lined by mucous membrane and are termed as*sinuses*. They communicate indirectly with the external air.
- In mammals, some flat bones of the skull (frontal, maxilla, palatine, etc.) enclose sinuses and communicate directly or indirectly with nasal cavity.
- In the fowl, many of the bones are pneumatic (vertebrae, sternum, humerus and femur) and these receive air through the medium of **air sacs**.

COVERINGS OF BONE

Periosteum

- It is the membrane, which invests the outer surface of the bone except its articular areas where it is covered by articular cartilage.

- The periosteum consists of *an outer protective fibrous layer* and *an inner cellular osteogenic layer*.

Endosteum

- It is a thin membrane lining the medullary cavity and larger haversian canals.
- It ia also called as medullary membrane.

BONE MARROW

There are two kinds of marrow - *red and yellow*.

Red marrow

- It occupies the interstices of spongy bone everywhere and medullary cavity of long bones at birth. After birth, the red marrow is gradually replaced by yellow marrow.
- Red marrow is an important blood forming substance and contains precursors of erythrocytes, granular leukocytes of the blood, giant cells, which give rise to platelets and a few fat cells.
- In the adult, red marrow is present only in the vertebrae, sternum, ribs, skull bones and epiphyses of long bones.

Yellow marrow

- It consists of ordinary adipose tissue especially in the medullary cavity of long bones and short bones.
- Yellow marrow fills the spaces of the spongy bone in short bones (carpals and tarsals) and medullary cavity of long bones.

DEVELOPMENT OF BONE

- In the embryonic life, the future elements of the skeleton are derived from the mesenchyme, which is derived from the mesoderm.
- Ossification is the process of development of bone from the mesenchyme.
- The formation of bone during the fetal stage of development occurs by two processes called
    - intramembranous and
    - endochondral ossification.

Intramembranous ossification

- The flat bones of the skull are developed by ossification in a membranous layer formed by the condensation of mesenchymal tissue. Hence, this process is being termed as intramembranous method of ossification.The bones developed by this method are termed as membranous bones.
- The steps in intramembranous ossification are
    1. Development of ossification centre
    2. Calcification
    3. Formation of trabeculae
    4. Development of periosteum
- At a point (centres of ossification), osteoblasts are differentiated from mesenchymal cells. A meshwork of collagen fibres produced by the osteoblasts appears between the cells. It becomes vascularised by capillary network. The osteoblasts produce other organic intercellular substances like mucoprotein, glycoprotein, mucopolysaccharides etc. This organic non-calcified matrix is known as *osteoid*. Now the matrix is calcified by the osteoblasts. Few osteoblasts become entrapped by the surrounding matrix

and are transformed into osteocytes. Simultaneously, other osteoblasts proliferate by division and are arranged in radiating manner from the centre. Thus trabeculae are formed between the cells. The trabeculae join each other to form cancellous bone. The osteoblasts surrounding the bony spicules deposit more bones to the free ends and sides and thus calcification is spread and the bone becomes compact. The periosteum is developed from the condensation of the mesenchyme.

TOP

Intra cartilagenous ossification /endochondral method of ossification

- The bones of appendicular skeleton, vertebral column, ribs etc, are developed by intracartilagenous or endochondral method of ossification . In this method, a cartilage model of future bone is formed at first and then it is replaced by bone. Bones developed by this method are termed as *cartilaginous bones*. The process of ossification does not take place simultaneously all over the cartilaginous or membranous representative of a future bone. It begins at one or more points known as centres of ossification, from which it extends until the central soft tissue is replaced by bone. In a long bone, there is a primary centre of ossification for the diaphysis and secondary centres appear for the epiphysis. Additional centres may appear in some bones for the various processes present in the bone. The number of centres is different for the various bones in the body, but the number for each bone is constant in a particular species.
- This process occurs in stages.
    - *Stage-I*
        - At the beginning, a cartilage model is formed by the condensation of the mesenchymal tissue. Perichondrium appears around the cartilage. The cartilage cells (chondroblasts) at the mid section of the model proliferate by mitosis and are arranged in rows towards the ends. They mature and hypertrophied. The hypertropic cells produce alkaline phosphatase and precipitate calcium salt at the matrix. The surrounding calcification cause death of the cartilage cells and thereby form spaces- the primary areolae . This zone is known as *primary ossification centre*. At the same time osteoblasts appear at the inner layer of perichondrium and form subperiosteal collarbone around the primary ossification centre.
    - *Stage-II*
        - At this stage the collar bone is eroded by the increased activity of the subperiosteal steoclasts and peroisteal buds containing osteoblasts, osteoclasts and blood vessels enter into the primary ossification centre. The osteoclasts absorb the irregular calcified mass and form secondary large areolae . These secondary areolae lead to the formation of marrow cavity, which subsequently becomes filled up by the bone marrow.
    - *Stage-III*
        - It is known as stage of true bone formation. Here the osteoblasts appear and lay down lamellated bone. Subsequently a number of longitudinal grooves proliferate and enclose a small blood vessel, which already developed along the periosteum and convert the grooves into tunnels. The lining osteoblasts of the tunnel convert the tunnel into Haversian system by proliferation and differentiation into osteocytes.
        - The whole process is repeated again and again and the ossification extends longitudinally. Simultaneously new bones are formed under the periosteum by appositional method.
          Secondary ossification centres appears at the ends of the cartilagenous model at birth. This zone is called epiphysis. Ossification occurs in the similar way in both directions.

GROWTH OF BONES

- Flat bones of the skull increase in size by continued marginal ossification from connective tissue at the site of later sutures.

- Both cartilage and membranous bones grow in thickness through further deposition of matrix at their outer surfaces.
- At the ends of a long bone a layer of cartilage does not ossify and remains as articular cartilage throughout life.
- In growth phase, a portion of the cartilagenous model remains as epiphyseal cartilage cartilage between the epiphysis and diaphysis.
- The epiphyseal cartilage helps in longitudinal growth of the bone and is replaced totally by bone when the growth is complete. Therefore the length of the bone increases with the growth of the epiphyseal cartilage. But with the advancement of the age, the growth of this metaphyseal cartilage slows down and the calcification becomes more rapid. So the whole epiphyseal cartilages become ossified and growth in length ceases.
- The width increases by the deposition of subperiosteal membrane bone.

Factors influencing the development and growth of bones

- They include calcium phosphorous, vitamin D, vitamin C, alkaline phosphatase, parathyroid hormone, growth hormone of pituitary, thyroid hormone and vitamin A.

TERMINOLOGY

- The surface of the bones presents a number of features in the form of prominences, depressions, perforations etc. These may be articular (forming joints with corresponding articular areas of another bone) or non-articular furnishing attachment to muscles, tendons and ligaments.

Some of the terms used to designate the features of bones are as below

Bone feature	Definition
Process	A general term for prominence.
Tubercle	A small blunt projection which, if more developed is called a tuberosity while a trochanter is the largest of these.
Spine	A pointed proection.
Crest	A sharp ridge.
Head	A rounded articular enlargement at the end of a bone; it may be joined to the shaft by the neck.
Condyle	A somewhat cylindrical articular eminence while an epicondyle is the non-articular projection in connection with it.
Protuberance, prominence, eminence, torus	A varieties of bony projections.

Trochlea	A pulley -lie articular area.
Glenoid cavity	A shallow cup-like articular depression
Cotyloid cavity	A deep cup like articular depression.
Line	A faint elongated elevation whereas a crest is an elongated elevation.
Facet	A flat articular surface.
Foramen	A perforation for the transmission of vessels, nerves etc.
Sinus	An air cavity within the bone lined by mucous membrane and communicates with the exterior.
Hiatus	A depression leading to two or more foramina. The terms fossa, fovea and sulcus denote various forms of depressions.
Cleft	A fissure in a bone.
Lamina	A thin plate of a bone.
Cornu or hamulus	A curved horn like process.
Canal	A bony tunnel (foramen of some length).
Meatus	A narrow passage.
Articular process	A projection that contacts an adjacent bone.
Articulation	The region where adjacent bones contact each other—a joint.
Canal	A long, tunnel-like foramen, usually a passage for notable nerves or blood vessels.
Eminence	A relatively small projection or bump.
Suture	Articulation between cranial bones.
Labyrinth	A cavity within a bone.
Malleolus	One of two specific protuberances of bones in the ankle.
Mamus	An arm-like branch off the body of a bone.

Angle	Corner of bone found between two borders
Articulation	A joint or union between two bones
Body (corpus)	The largest/pricipal part of a bone
Border	The edge of bone usually applied to flat bone
Condyloid cavity/Acetabulum	A deeper articular depression
Epicondyle	A non-articular projection in connection with or adjacent to condyle
Fissure	A narrow cleft in a bone
Fontanel	Unossified region between skull bone
Fossa	A concavity or depression, literally a ditch
Fovea	An articular surface in the form of a very small pit/depression
Groove	An elongated concavity between parallel ridges.
Incisura	A notch like depression
Linea	Narrow crest/ridge/line i.e. A very small line
Manubrium	A flat handle like projection
Notch	A deep or large indentation usually for articulation
Plexuses	It is a network or tangle of nerves.
Ridge	A narrow rounded elevation on the surface
Squama	The flat portion of the cranial bone
Styloid	Literally a pencil shaped pointed process
Symphysis	A union in which two similar bones are firmly connected by cartilage
Trochanter	A very large non-articular prominence.
Tuberosity	A large rounded uneven projection

Several terms are used to refer to specific features of long bones

Bone feature	Definition
Diaphysis	The long, relatively straight main body of a long bone; region of primary ossification. Also known as the *shaft*.
Epiphysis	The end regions of a long bone; regions of secondary ossification
Epiphyseal plate	Also known as the *growth plate* or *physis*. In a long bone it is a thin disc of hyaline cartilage that is positioned transversely between the epiphysis and metaphysis. In the long bones of humans, the epiphyseal plate disappears by twenty years of age.
Head	The proximal articular end of the bone.
metaphysis	The region of a long bone lying between the epiphysis and diaphysis.
Neck	The region of bone between the head and the shaft.

BLOOD AND NERVE SUPPLY OF BONE

Arteries

- The bones are highly vascular.
- The bone is supplied with blood externally on the surface and internally on the lining of the medullary cavity.
- The surface arteries ramify over the periosteum and large blood vessels gain entrance through the nutrient foramen and branches widely along the course and on the endosteal lining of the bone. Thus there is a network of blood vessels over the entire bone.

Veins

- They accompany the arteries ans mostly recurrent in nature.

Nerves

- They accompany the blood vesels. The periosteal branches are senosry.

Lymph vessels

- They run in company with blood vessels of the marrow, forming a network under the periosteum.

NUMBER OF SKELETAL SEGMENTS

- The number of bony segments are varies with the species.
- Some of the bones are laid down in the embryonic life, either fuse or disappear in adult life. So the young and adult animal of the same species will not have the same number of bones.

- The number of bones in the skeleton are given below

	Skull (Including hyoid and mandible)	Vertebral column (approx)	Ribs and Sternum	Fore limb	Hind limb	Visceral bone	
Ox	32	51	26+1+0	24 x 2	24 x 2	2 os cordis	208
Horse	32	51	36+1+0	20 x 2	20 x 2	-	200
Dog	32	51	26+1+2	44 x 2	45 x 2	1 os penis	291
Pig	30	52	28-30+1+0	40 x 2	40 x 2	1 os rostri	274
Rabbit	34	46	24-26+1+0	31 x 2	29 x 2	-	229
Fowl	40	41	14+1+1+2	13 x 2 (coracoid)	21 x 2	2 os opticus	169

MODULE-3: APPENDICULAR SKELETON - SCAPULA AND HUMERUS

Learning outcomes

At the end of this module, the learner will be able to know about

- pectoral limb
- pelvic limb
- scapula and
- humerus

APPENDICULAR SKELETON

- The appendicular skeleton consists of bones, which form the framework of the pectoral or forelimbs and the pelvic or hind limbs, including the elements, which serve to anchor or attach the limbs to the trunk of body, referred to as the pectoral and pelvic girdles respectively.
- The arrangement of the bones in the girdles and the rest of the regions of the limb are similar in the pectoral and pelvic limbs.
- The bones present in each species of animal represent modifications from a common pattern as part of evolutionary changes the species or group has undergone.
- The general designations for the different parts of the limbs and bones present in each are given below.

Pectoral limb

- *Pectoral girdle and shoulder region:* Scapula, Coracoid and Clavicle.
- *Arm:* Humerus
- *Forearm:* Radius and Ulna
- *Manus:* Consisting of
    - *Carpus:* A number of small bones called carpals arranged in the domestic mammals in two rows.
    - *Metacarpus:* Typically consisting of five bones designated only by numbers 1 to 5, but showing considerable modifications in different animals.
    - *Digits:* These form the terminal parts of the limbs and usually correspond to the number of the fully developed metacarpals. These are also designated by numbers 1 to 5. Each digit is composed of a number of bones arranged serially called the phalanges. The number of phalanges may vary (from 1 to 5) within the species and also in different digits of the same species.

Pelvic limb

- *Pelvic girdle and hip region:* Ilium, ischium, and pubis,
- *Thigh:* Femur
- *Leg:* Tibia & fibula
- *Pes:* Consisting of
    - *Tarsus* (3 rows)
    - *Metatarsus* : similar to the forelimb
    - *Digits*

BONES OF THE PECTORAL LIMB

- *Pectoral girdle and shoulder region :* Scapula, Coracoid and Clavicle.
- *Arm :* Humerus
- Forearm : Radius and Ulna
- *Manus :* Consisting of
    - *Carpus:* A number of small bones called carpals arranged in the domestic mammals in two rows.
    - *Metacarpus:* Typically consisting of five bones designated only by numbers 1 to 5, but showing considerable modifications in different animals.
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Modifications in different animals

It should be noted that in all animals, there are considerable modifications in the number present and the extent of development of the various bones as compared with the typical pattern. Significant modifications are noted in the domestic animals to be studied (i.e. *ox, sheep, goat, horse, pig, dog, rabbit* and fowl). They are

- The absence of a typical pectoral girdle and only scapula being well developed in all the mammals, (all three bones are present in the fowl).
- Ulna is being reduced and fused to radius in ox and horse.
- Extensive modifications in the bones of the manus, (i.e.) *carpus, metacarpus* and *digits*, with two well developed digits in the ox, sheep, goat, pig and only one in the horse but five (first reduced) in the dog and three in the fowl.

- For specific bones present in each species, refer details given in the descriptions of corresponding regions.

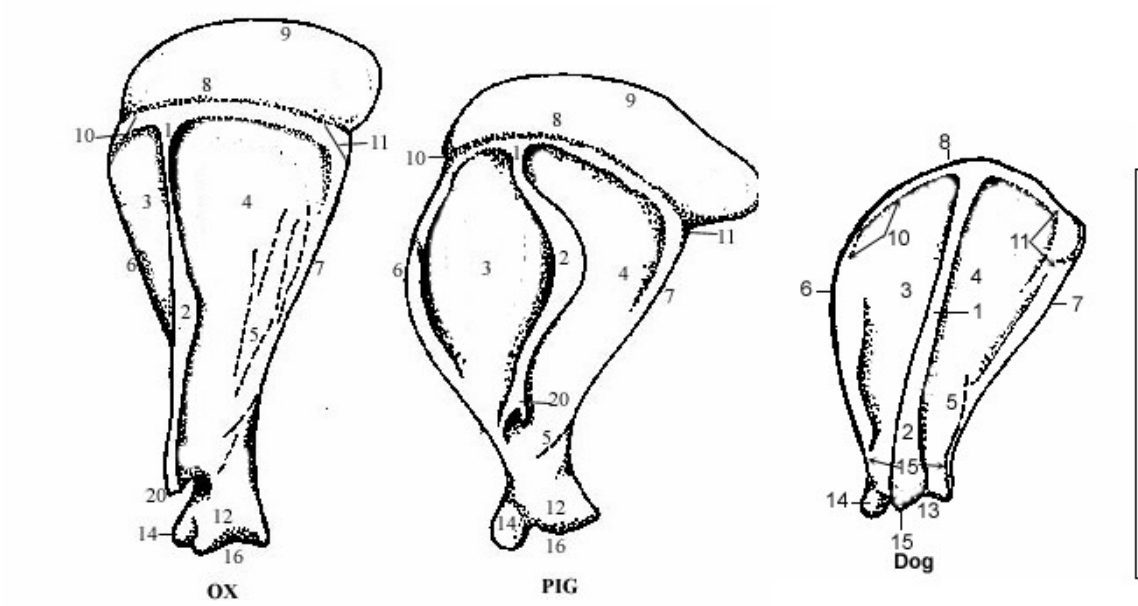
(***Note**: In this course, the anatomy of the ox, is given with significant differences and special features if any, are mentioned briefly for horse, pig, dog, rabbit and fowl.)*

SCAPULA

(Ox, Sheep and Goat, Horse, Dog, Pig, Rabbit, Fowl)

Ox

- It is flat, triangular bone, situated on the antero-lateral aspect of the thorax and directed obliquely downward and forward. The clavicle is absent. It is connected to the axial skeleton only by muscles.
- It has *two surfaces, three borders and three angles* .
- The *lateral surface* or the *dorsum* is wide above and narrow below.It is traversed by the *scapular spine*, which divides the lateral surface into an cranial supraspinous fossa and the caudal infraspinous fossa, the former being the smaller. The free edge of the spine is in great part subcutaneous, somewhat rough and tuberous in the middle for the attachment of *trapezius* and is prolonged downward to form the *acromion process* for the *deltoideus muscle*. The supraspinous fossa lodges the *supraspinatus muscle*. The infraspinous fossa is occupied by the *infraspinatus* and the muscular ridges at its lower part are for the origin of *teres minor*. The *costal* or *ventral surface* presents a shallow depression called *subscapular fossa* , which lodges the *subscapularis*. The upper third of this surface presents cranially a triangular rough area for the *serratus cervicis* and posteriorly a rough line for the *serratus thoracis*.
- The *cranial border* is thin, convex above and concave below. The *caudal border* is thick, presents the nutrient foramen in the lower third and is rough for *deltoideus*, *teres major* and *long head of triceps muscles*. The *vertebral border* is thick, pitted and carries in life the scapular cartilage, the unossified part of the fetal scapula. The *medial face* of the cartilage gives attachment to the *rhomboideus*.
- The *cranial* or *cervical angle* is thin. The *caudal* or *dorsal angle* is thick. The *ventral* or *glenoid angle* carries the glenoid cavity and cranial to it the *tuber scapulae*.The former meets the head of the humerus to form the shoulder joint. The rim of the cavity presents the *glenoid notch* on the craniolateral aspect. The tuber scapula is for the *biceps brachii*and presents the coracoid process on its medial aspect for the *coraco brachialis*.



TOP

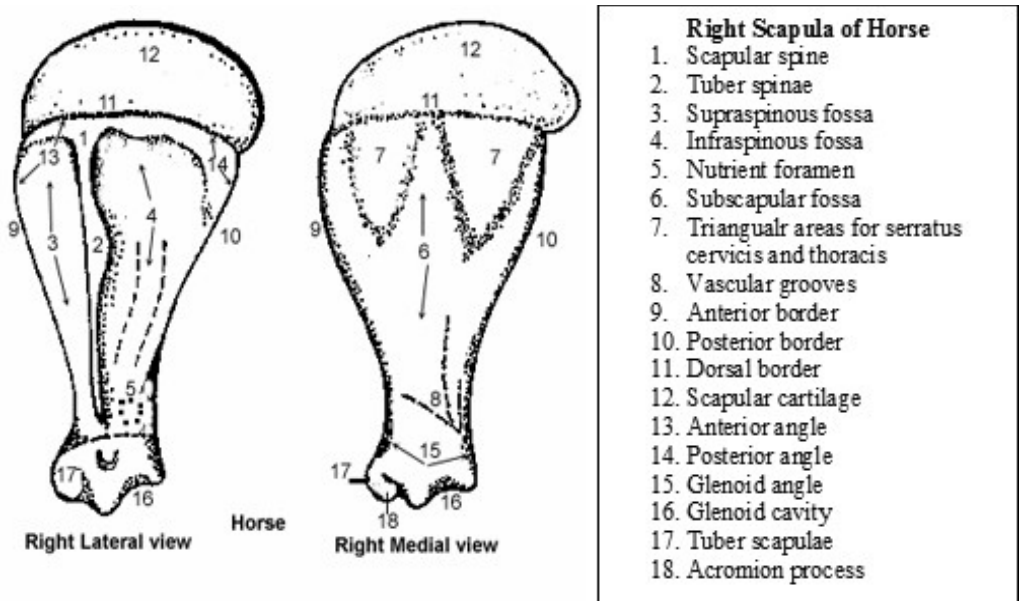
Sheep and Goat

- The vertebral border is longer and the neck is narrower.
- The scapular spine is less tuberous.
- The inferior or glenoid extremity is relatively longer, since the tuber scapula is connected with the rim of the glenoid cavity.
- Rim of the subscapular fossa is extensive.

TOP

Horse

- The acromion process is absent.
- The subscapular fossa is deeper and partly separates two triangular rough areas in the upper third.
- The glenoid notch is on the antero-medial aspect of the rim.
- On its postero-lateral aspect the rim presents a tubercle for *teres minor*.
- The tuber scapula is larger and placed further away from the glenoid cavity.



TOP

Pig

- Scapula of the pig is very wide.
- The scapular spine is triangular and is very wide in its middle, which curves backward over the infraspinous fossa and bears large tuberosity called tuber spine.
- Acromion process is rudimentary.
- The cranial border is slightly convex, thick and rough in its middle.
- The caudal border is wide and slightly concave.
- The vertebral border is convex and the scapular cartilage is not so extensive as in horse and ox.
- The cranial angle is thin and bent medially. The caudal angle is thick and is at right angle.
- The glenoid notch is absent.
- The tuber scapula is above the antero-medial part of the glenoid cavity.
- No distinct coracoid process and it unite with the rest of the bone at about one year.

TOP

Dog

- The Clavicle, when present, is a small cartilaginous or bony plate embedded in the *brachiocephalicus* muscle, in front of the shoulder joint and does not articulate with the rest of the skeleton.
- In the Scapula, the spine is placed in the middle of the dorsum and increases in height from above downward, to the level of the glenoid cavity where it terminates in the acromion process.
- The vertebral border is convex and the scapular cartilage is in the form of a thin band.
- The glenoid cavity extends to the inferior face of the tuber scapula.
- The coracoid process is absent.

TOP

Rabbit

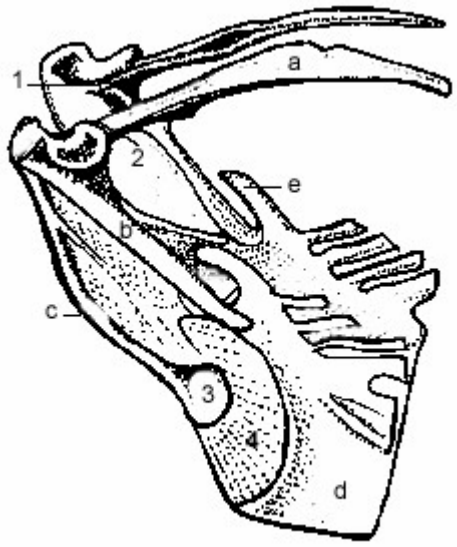
- The coracoid process appears as slight enlargement at the cranial part of the rim of the glenoid cavity.
- The scapular spine possesses distally an elongated caudal process, the *metacromion process* along with the acromion process.

TOP

Fowl

It has a clavicle, coracoid, and the scapula.

- The *clavicle* is a thin, bent rod directed downward and backward. The flat dorsal end rests against the scapula and the coracoid to form the *foramen triosseum* . The clavicles of two sides unite ventrally to form a flattened plate called *Hypocleidium,* which is attached to the rostrum of the sternum by a ligament. The two combined clavicles form the*furcula* and are also called *"wish bone"*.
- The *coracoid* is rod like, directed backward, downward and inward. The upper extremity is prolonged into a hook-like process medially. It presents a small articular surface -the glenoid cavity for articulation with humerus. Below this, there is another area for articulation with scapula. The lower extremity articulates with the sternum.
- The scapula is a narrow saber-shaped bone placed parallel to the vertebral column. The anterior end presents a depression laterally which forms part of the glenoid cavity for the reception of the head of the humerus and a projection cranially -the acromion process, which meets the clavicle and coracoid to form the foramen triosseum. the posterior end lies at the level of the sixth rib.



Skeleton of the shoulder girdle of fowl - Left view
a. Scapula
b. Corocoid
c. Clavicle (furcula)
d. Sternal crest
e. Anterolateral process of sternum
1. Clavicular process
2. Corocoid process of scapula
3. Hypocledium
4. Sternoclavicular membrane

HUMERUS

(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

- It is a long bone placed obliquely downward and backward between the shoulder joint above and the elbow joint below.
- It has a *shaft* and *two extremities.*

- *Shaft:*
  - It has a twisted appearance and has *four surfaces*.
  - The anterior face is triangular, wide and smooth above, narrow and rough below.
  - The posterior face blends with the medial and lateral faces. It presents the nutrient foramen about the middle.
  - The medial face is nearly straight in its length. Just above its middle it presents the teres tubercle for latissimus dorsi and teres major.
  - The lateral face is spirally curved and forming the *musculo-spiral groove*, which contains the brachialis muscle. The groove is continuous with the posterior face above and winds around towards the front. Lateral surface is separated from the anterior by a distinct border the crest of humerus, which bears above its middle the deltoid tuberosity. The crest is for the insertion of brachio-cephalicus and superficial pectoral and the deltoid tuberosity for the deltoideus muscle. A curved line extends upward from the deltoid tuberosity and is for the lateral head of triceps. At the upper part of the curved line is a nodule for the teres minor.
- *Proximal extremity:*
  - It consists of a *head, neck, two tuberosities* and the *intertuberal or bicipital groove*.
  - The head presents a circular articular surface, which articulates with the glenoid cavity of the scapula to form the shoulder joint.
  - The lateral tuberosity consists of two parts - an *anterior summit* arching medially and a *posterior convexity*. The former over-hangs the bicipital groove and gives attachment to the lateral tendon of the infraspinatus. The convexity gives attachment medially to the medial tendon of the infraspinatus.
  - The medial tuberosity is smaller and consists of *anterior* and *posterior parts*. The anterior part forms the medial boundary of the intertuberal groove and gives attachment to the medial tendon of supraspinatus and to the deep pectoral. The posterior part is for the subscapularis.
  - The intertuberal groove is bounded by the anterior divisions of the two tuberosities and in life, is covered by a fibro cartilage for the play of the tendon of origin of biceps brachii.
- *Distal extremity:*
  - It has an oblique surface, which is divided by a ridge into two condyles, the medial being the larger. The medial condyle is crossed by a groove, which extends into the olecranon fossa and articulates with the semilunar notch of the ulna.
  - This extremity presents anteriorly above the articular area, the *coronoid fossa,* which receives the coronoid process of the radius in extreme flexion of the elbow joint.
  - Behind and above the condyles are two thick ridges, the epicondyles. The medial epicondyle is more prominent and furnishes origin to flexor muscles of the carpus and digits and bears a tubercle for the attachment of medial ligament of the elbow joint. The margins of the olecranon fossa are for the origin of the anconeus. The lateral epicondyle bears laterally the condyloid crest in the form of a raised ridge, which gives origin to extensor carpi radialis. Between these two epicondyles is the deep olecranon fossa, which receives the anconeus process of ulna during extreme extension. The distal extremity also presents a rough depression laterally and a tubercle medially for the collateral ligaments of the elbow joint.

TOP

Sheep and Goat

- It is relatively longer and slender than that of ox.
- The deltoid tuberosity is closer to the proximal end and not as prominent.
- The lateral tuberosity is smaller and does not overhang the bicipital groove.
- Olecranon and coronoid fossa are shallower.

TOP

Horse

- The deltoid tuberosity is more prominent.
- The bicipital groove is divided by intermediate ridge.
- The summit of lateral tuberosity does not arch inward.
- The coronoid and the olecranon fossa are shallower.

TOP

Pig

- It has the appearance of italic letter '*f*' minus the cross bar.
- The shaft is laterally compressed and flat on the medial side.
- The musculo-spiral groove is shallow and the deltoid tuberosity is small and there is a larger rounded eminence midway between it and the lateral tuberosity.
- Teres tubercle is absent.
- The condyles are of equal size.
- The coronoid fossa is prominent.
- The olecranon fossa is narrow and deep.
- Occasionally the suprtrochlear foramen is found.

TOP

Dog

- The musculospiral groove is shallow.
- The deltoid tuberosity is in the form of a low ridge.
- The lateral tuberosity is undivided.
- The coronoid and the olecranon fossa communicate with each other through the supratrochlear foramen through which no soft structure passes.

TOP

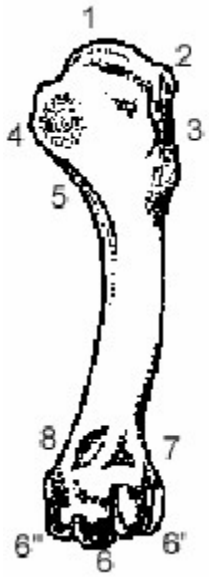
Rabbit

- The head is globose.
- In the distal extremity, the articular surface is double and is separated by a ridge.

TOP

Fowl

- The bone is directed parallel to thoracic vertebrae when the wing is at rest.
- The proximal extremity presents on the medial aspect, an opening leading into the air cavity in its shaft.



Left Humerus of Fowl
(Lateral view)
1. Head of humerus
2. Lateral tuberosity
3. Crest of humerus
4. Medial tubercle
5. Medial crest
6. Articular condyle of humerus

6'-condyle for radius
6''-condyle for ulna)
7 & 8. Epicondyles

RADIUS
(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

- The radius is the larger and shorter of the two bones of the forearm.
- It is a long bone placed obliquely downward between the elbow joint above and the carpal joint below.
- It consists of a *shaft* and *two extremities*.

- *Shaft*
  - It is flattened from before backwards.
  - It has *two surfaces* and *two borders*.
  - The *dorsal face* is convex in its length, smooth and covered by the extensors of the carpus and digits.
  - The *volar face* is concave in its length. It presents along its lateral border a narrow rough area where it is attached with the ulna by interosseous ligament. This rough area is interrupted above and below by two smooth areas which forms the proximal and distal *ra*dio-ulnar arches or interosseous space. These two arches are connected laterally by the *radio-ulnar groove* which is for the passage of the interosseous vessels.
  - The *medial border* is for the most part subcutaneous presents proximally, a rough area for the brachialis and the medial ligament of the elbow.
  - The *lateral border* is rounded in its proximal third, wide and flat below and is limited by the radio-ulnar groove. This border gives attachment to the lateral digital extensor and the extensor carpi obliquus.
- *Proximal extremity*

    - It presents an articular area, which is divided by a sagittal groove into two divisions, the medial being the larger.
    - It articulates with the distal extremity of the humerus and is surrounded by a rim, which carries the *coronoid process* about the middle of the anterior surface. The coronoid process is received into the coronoid fossa of the humerus during the extreme flexion of the elbow.
    - Posteriorly just below the articular surface are two facets for articulation with the like facets of the ulna and between these and the proximal interosseous space is a quadrilateral rough area to which the ulna is attached.
    - The medial aspect of the anterior face presents a *radial tuberosity* into which the biceps brachii is inserted. The *lateral tuberosity* is more prominent and gives attachmentto the lateral extensor of the digit.
- *Distal extremity*
    - It is wide.
    - It presents three oblique facets for the carpal bones viz., radial, intermediate and ulnar carpals from within outward.
    - The facet for the ulnar carpal is partly furnished by the ulna.
    - On the medial and lateral aspects are rough elevations for the collateral ligaments of the carpus.

TOP

Sheep and Goat

- It is relatively larger and more curved.
- Dorsal surface is more regularly rounded.

TOP

Horse

- Close to the medial border of the volar face, below the middle is a rough elevation for the radial check ligament.
- The lateral border presents only one smooth area to form the proximal radio-ulnar arch.
- The radial tuberosity is more prominent.
- The facets of the distal extremity are less oblique.
- The lateral face articulates with the ulnar carpal below and with the accessory carpal behind.

TOP

Pig

- It is short, thick and curved posteriorly.

TOP

Dog

- The radius and ulna are relatively long and articulate with each other at their extremities enclosing a narrow interosseous space and permit a certain degree of movement.

- The proximal extremity of radius is small and bears a concave surface for articulation with the humerus above and a convex marginal area posteriorly for the ulna.
- The distal extremity is wide and its medial border projects downward forming the styloid process of radius. Laterally there is a concave facet for the ulna.

TOP

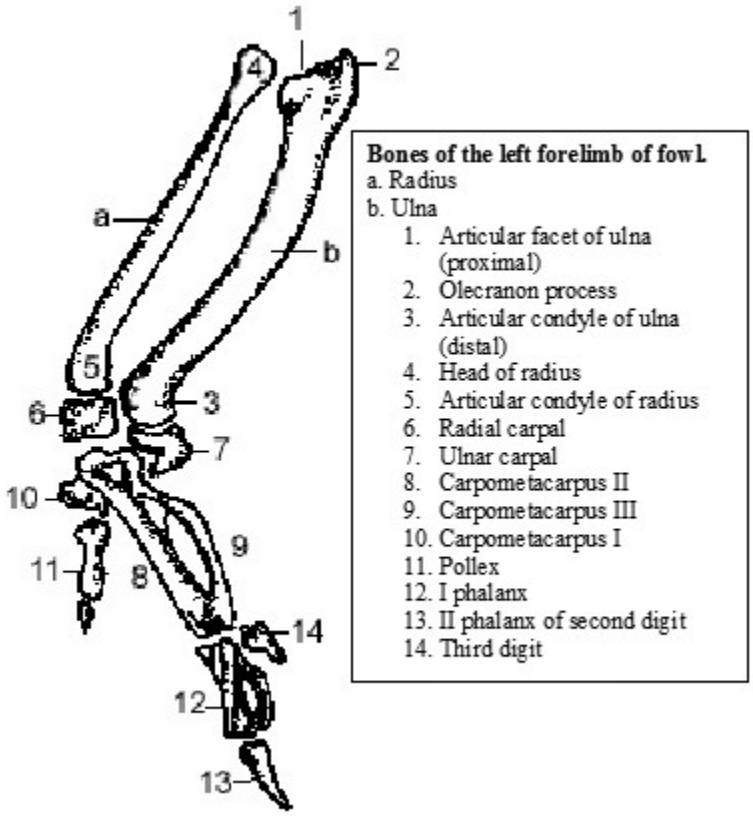
Rabbit

- Similar to that of dog.

TOP

Fowl

- The bones of forearm are nearly parallel to humerus.
- Of the two bones the radius is slender while the ulna is thicker and longer.
- They articulate at their ends and enclose a wide interosseous space.
- The proximal extremity of the radius presents a concave articular area while the distal extremity is flattened from side to side and articulates with the radial carpal.



Bones of the left forelimb of fowl.
a. Radius
b. Ulna
1. Articular facet of ulna (proximal)
2. Olecranon process
3. Articular condyle of ulna (distal)
4. Head of radius
5. Articular condyle of radius
6. Radial carpal
7. Ulnar carpal
8. Carpometacarpus II
9. Carpometacarpus III
10. Carpometacarpus I
11. Pollex
12. I phalanx
13. II phalanx of second digit
14. Third digit

ULNA

(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

- It is a long bone and longer than the radius.
- It situated on the posterolateral aspect of the radius.
- It is fused with the radius in the adult, except at the two inter-osseous spaces above and below. View image...
- *Shaft*
    - It is complete, *three sided* and strongly curved.
    - Its proximal part contains the medullary cavity, which extends somewhat into the proximal end.
    - The *dorsal face* is rough except at two places where it is smooth and is applied to the volar aspect of the radius.
    - The *medial face* is wide.
    - The *lateral face* presents the radio-ulnar groove between it and the radius.
- *Proximal extremity*
    - It forms the major part of the bone and is made up of the *semilunar notch* and the *olecranon process*.
    - The *olacranon process* is quadrilateral in shape directed upward and backward. The medial surface is concave and smooth while the lateral is convex and rough above. The anterior border bear on its middle a pointed projection the *anconeus process* that is for *anconeus* and during extreme extension of the elbow joint it passes into the olecranon fossa of the humerus. The posterior border is thick and concave. The summit of the olecranon process forms the *point of the elbow* and gives attachment to*triceps*.
    - The *semilunar notch* is placed below the anconeus process and articulates with the posterior part of the medial division of the articular area of the humerus. Below the notch are two facets for articulation with the like facets on the posterior face of the proximal extremity of the radius.
- *Distal extremity*
    - It is fused with the radius.
    - It projects below the level of the radius forming the styloid process of ulna, which furnishes a part of the facet for the ulnar carpal.

TOP

Sheep and Goat

- Shaft of the ulna is more slender especially in the distal half.
- Fusion with the radius occurs in the later part of the life and the fusion is much less extensive than the ox.

TOP

Horse

- It is shorter, reaching only the distal third of the radius. It forms only the proximal radio-ulnar arch.
- There is no articulation with the ulnar carpal.

TOP

Pig

- The proximal extremity is large and the olecranon process is prominent.
- The distal extremity is small and tapers to a blunt point. View image...

TOP

Dog

- It is well developed and crosses the volar face of the radius medio-laterally closing a narrow interosseous space.
- The olecranon is grooved and shows three prominences of which the posterior one is large and rounded.
- Below the semilunar notch is concave surface for the radius.
- The styloid process articulates dorso-medially with radius and low with ulnar and the accessory carpals.

TOP

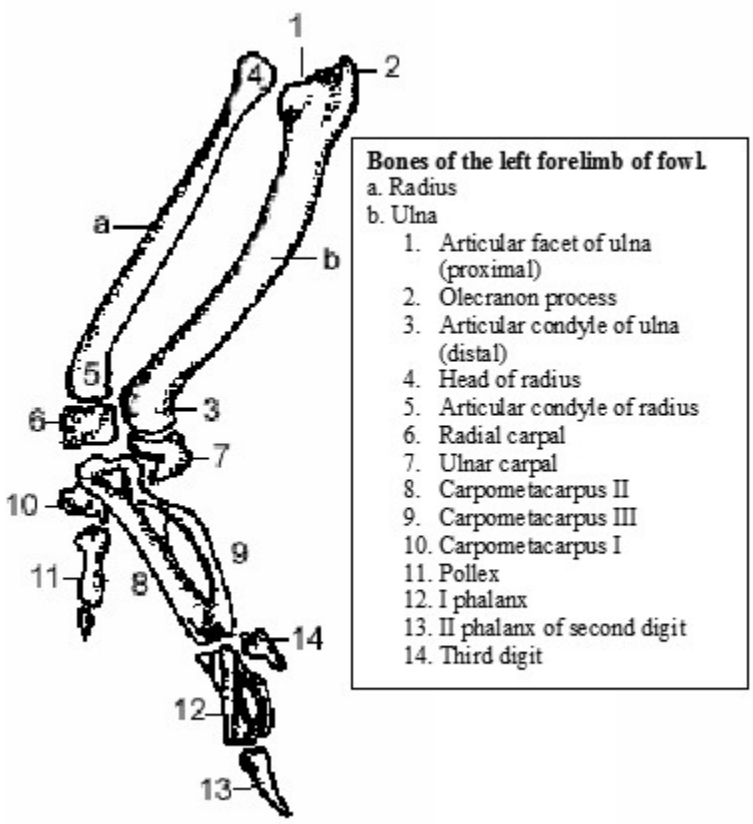
Rabbit

- Similar to that of dog.

TOP

Fowl

- It is larger and thicker than the radius.
- It is curved in its length.
- The proximal extremity has two concave articular areas.
- The olecranon process is short.
- The distal extremity is expanded and presents a trochlea and articulates with radial and ulnar carpal bones.

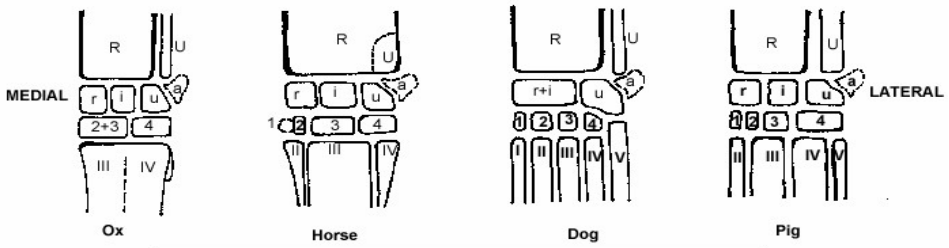


Bones of the left forelimb of fowl.
a. Radius
b. Ulna
1. Articular facet of ulna (proximal)
2. Olecranon process
3. Articular condyle of ulna (distal)
4. Head of radius
5. Articular condyle of radius
6. Radial carpal
7. Ulnar carpal
8. Carpometacarpus II
9. Carpometacarpus III
10. Carpometacarpus I
11. Pollex
12. I phalanx
13. II phalanx of second digit
14. Third digit

CARPAL BONES

(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

- The carpals are arranged in the following pattern in domestic animals.



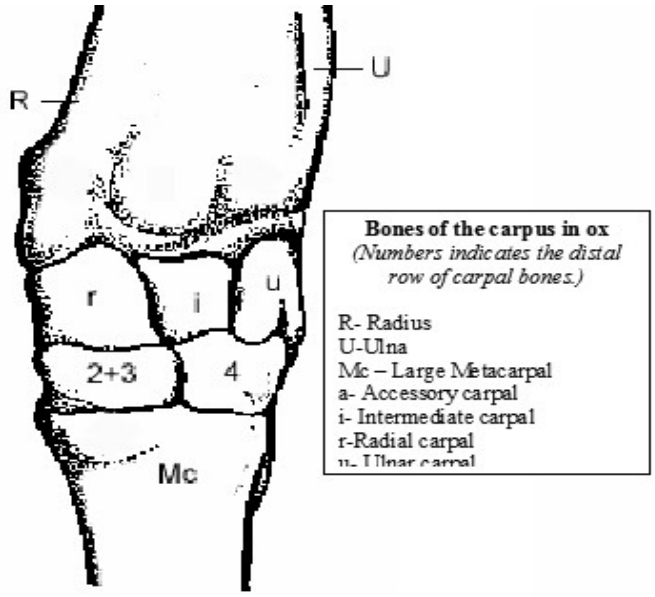
Bones of the carpus in domestic animals.
(Roman letters indicates the metacarpal bones. Numbers indicates the distal row of carpal bones.)

R- Radius U-Ulna Mc – Large Metacarpal a- Accessory carpal
i- Intermediate carpal r-Radial carpal u- Ulnar carpal

Ox

- The carpus consists of six bones arranged in two rows -*four in the proximal and two in the distal rows*. They are short bones arranged as noted below.

	Radial carpal	Intermediate carpal	Ulnar carpal	Accessory carpal
	Fused second and third carpal		Fourth carpal	



Radial carpal (scaphoid)

- It is the largest bone of the upper row.
- The *proximal surface* is convexo-concave from before backward and articulates with the radius.
- The *distal surface* articulates with the fused second and third carpal.
- The *lateral face* bears facets for the intermediate carpal.
- The *dorsal, medial* and *volar faces* are continuous and rough.

Intermediate carpal (lunar)

- It is wedge-shaped.
- The *dorsal face* is rough and forms the base.
- The *apex* is posterior, is prolonged medially.
- The *proximal face* is convexo- concave from before backward and articulates with the radius.
- The *distal face* is divided by a sagittal ridge into two facets for the second and third and the fourth carpals.
- The *medial face* has facets for the radial carpal.
- The *lateral face* articulates with the ulnar carpal.

Ulnar carpal (cuneiform)

- It is very irregular.

- The *proximal face* is oblique directed backward and downward, encroaches on the distal face and articulates with the fourth carpal.
- The *medial face* has facets for the intermediate carpal.
- The *dorsal face* is rough and convex
- The *volar face* has a facet for the accessory carpal.

Accessory carpal (pisiform)

- It is short, thick and rounded.
- It is a sesamoid bone situated behind the ulnar carpal.
- The *proximal face* is narrow and rough for *flexor ulnaris* and *ulnaris lateralis*.
- The *distal face* is broad and rough.
- The *dorsal face* has facet for the ulnar carpal.

Fused second and third carpal (os magnum)

- It is the largest of the carpals the medial one of the two bones of the distal row.
- The *proximal face* has two facets, medial larger for the radial carpal and the lateral smaller for the intermediate carpal.
- The *distal face* articulates with the large metacarpal.
- The *lateral face* has facets for the fourth carpal.
- The *medial* and *dorsal faces* are continuous rough and convex.

Fourth carpal (unciform)

- The *proximal face* has two facets for the intermediate and the ulnar carpals.
- The *distal face* articulates with the large metacarpal.
- The medi*al face* has facets for the fused second and third carpal.
- The *dorsal* and the *lateral faces* are continuous and rough.

TOP

Sheep and Goat

- Resembles that of ox.
- The accessory carpal is long and less tuberous.

TOP

Horse

Has *seven or eight bones*. They are:

- *Radial carpal:* Resembles that of the ox.
- *Intermediate carpal:* The lateral angle of its proximal face is more pointed.
- *Ulnar carpal:* The smallest bone of the proximal row. The proximal face articulates only with the radius.
- *Accessory carpal:* It is discoid. The *medial face* is concave and the lateral is convex and rough. A smooth groove for the long tendon of *ulnaris lateralis* crosses its anterior part obliquely downward

and slightly forward. The anterior border has two facets -the upper concave for the radius and the lower convex for the ulnar carpal.

- *First carpal (trapezium):* It is inconstant; when present it is situated behind the second.
- *Second carpal (trapezoid):* It is the smallest bone of the distal row. The proximal face has a convex facet for the radial carpal. The distal face is flat and articulates with the medial small and large metacarpals. The lateral face has two facets for the third carpal. The dorsal and the medial faces are continuous and rough.
- *Third carpal (os magnum):* It is the largest carpal. It is irregularly triangular with the base anterior. The proximal face articulates with the radial and the Intermediate carpals and distal with the large and medial small metacarpals. The medial border is more concave than the lateral. *Fourth carpal (unciform)* - It the proximal face is convex and articular and encroaches on the lateral face. The distal face articulates with the large and the lateral small metacarpals. The medial face has two facets for the third carpal.

TOP

Pig

- It has *eight bones* – four in each row.

	Medial		Lateral	
Proximal row				
Distal row				

The bones of the proximal row resembles that of an ox with the exception that accessory carpal is similar to that of horse but has no lateral groove. The first carpal is small, elongated from before backward, rounded and articulates in front with the second carpal.

TOP

Dog

- It has *seven bones* -Three in the proximal and four in the distal row. The radial and the intermediate are fused.

	Medial		Lateral	
Proximal row				
Distal row				

TOP

Rabbit

- It has nine bones arranged in 2 rows.

	Radial carpal	Intermediatecarpal	Ulnar carpal	Accessorycarpal	
	First carpal	Second carpal	Central carpal	Third carpal	Fourth carpal

TOP

Fowl

- There are only two free bones in the adult.
- The radial carpal is quadrilateral while the ulnar carpal is forked.
- The bones of the lower row fuse with those of the carpus during the development forming the *carpometacarpal bone*.

TOP

	Medial		Lateral	
Proximal row				
Distal row				

METACARPAL BONES

Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

The metacarpus consists of a *large metacarpal(fifth). (fused third and fourth)* , which carries the digit and a *lateral small metacarpal*

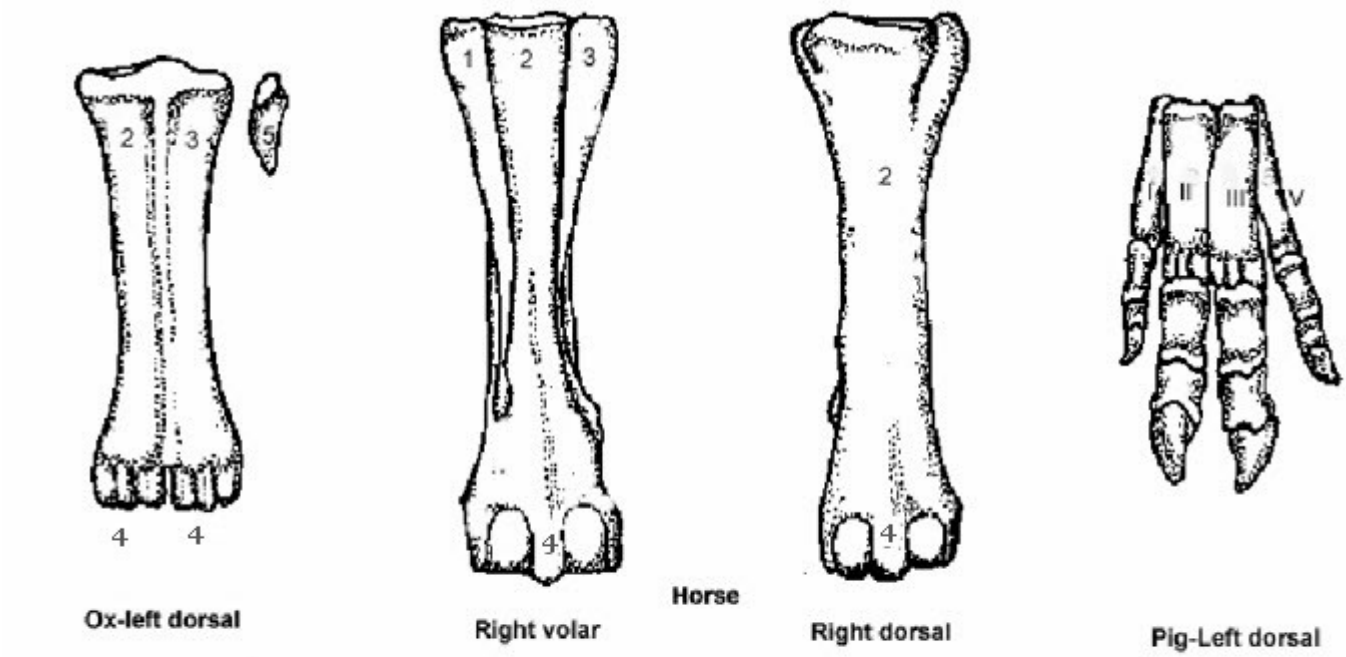
LARGE METACARPAL

It is a bone placed vertically between the carpus above and fetlock below. It results from the fusion of third and fourth metacarpals.It consists of a shaft and two extremities.

- *Shaft*
  - It is semi-cylindrical and as *two surfaces* and *two borders* .
  - The *dorsal surface* is convex transversely and is marked by a vertical vascular groove at either end (usually at the distal end) of which is a foramen, which traverses the thickness of the shaft.
  - The *volar surface* is flat from side to side and presents a shallow vertical groove, which communicates with the anterior groove through the foramina described above. This surface is in contact with the superior sesamoidean ligament.
  - The borders are *medial* and *lateral* and rounded. The latter, at its upper part has the lateral small metacarpal attached to it posteriorly.
- Proximal extremity
  - It has two facets separated by a ridge in front and a notch behind.
  - The medial facet is larger and corresponds to the second and third carpal and lateral to the fourth carpal. At the dorsal aspect of this extremity is the metacarpal tuberosity for the *extensor carpi radialis*. At the postero-medial aspect is a tubercle for the attachment of *extensor carpi obliquus*. The lateral aspect of the volar face bears a small facet for the lateral small metacarpal.
- Distal extremity
  - It is divided into two parts by a sagittal cleft.
  - Each part is made of two condyles separated by a sagittal ridge for articulation with the first phalanx below and two sesamoids behind.
  - The medial condyle is slightly larger than the lateral.
  - The abaxial aspects of each division are depressed for ligamentous attachment.

LATERAL SMALL METACARPAL (fifth metacarpal)

- It is an aborted long bone and is an inch and a half long.
- The bone is attached to the postero-lateral aspect of the proximal extremity of the large metacarpal.
- The proximal extremity is rounded and bears a small facet on the anterior face for the large metacarpal.
- The distal extremity is pointed.



Metacarpals of domestic animals.

1. I metacarpal 2.III metacarpal 3.IV metacarpal 4.V metacarpal
5. Sagittal ridge

TOP

Sheep and Goat

- Large metacarpal resembles that of an ox.
- The small metacarpal is usually absent.If present, it is in the form of a ridge on the large metacarpal bone.

TOP

Horse

The metacarpus consists of *one large metacarpal* (third) *two small metacarpals or splints* (second and fourth).

- *Large metacarapal*
  - The vascular grooves on the dorsal and volar faces are absent.
  - The volar face is roughened on either side in its proximal two thirds for attachment of the splints with which it forms a wide groove for the lodgment of suspensory ligament.
  - It articulates with the second, third and fourth carpals above and by means of small facets on either side, with the proximal extremities of the splints.
  - The distal extremity of the large metacarpal resembles one of the parts of the distal extremity of large metacarpal of the ox.
  - The medial condyle of the articular area for the first phalanx is slightly larger than that of the lateral.

- *Small metacarpals*
    - The shaft of each is three sided.
    - The dorsal face is rough for attachment to the large metacarpal.
    - The proximal extremity is relatively massive and has one or two facets dorso-laterally for the large metacarpal.
    - The medial bone bears two facets above for the second and the third carpals while the lateral presents one facet for the fourth.
    - The distal extremity is in the form of a small nodule and usually forms the '*button*' of the splint.

TOP

Pig

- Has four bones.
- The first is absent.
- Third and fourth metacarpals are large and carry the chief digits.
- The second and fifth are much smaller and bear the accessory digits.

TOP

Dog

- Has five bones.
- The first is the shortest.
- The third and the fourth are longest.
- The second is longer than the fifth.
- The lie close together above but diverges distally.
- The proximal ends articulate with each other and the first four with the corresponding carpals.
- The fifth also articulates with the fourth carpal.

TOP

Rabbit

- Has five bones in each.
- They are all cylindrical shape.
- First one is smallest and the third and fourth is longest.

TOP

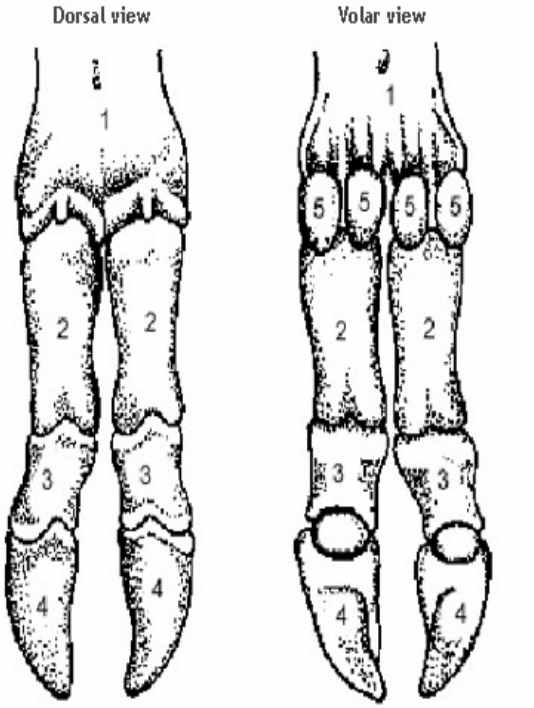
Fowl

- The metacarpus includes three bony elements, which fuse together with the lower row of carpal bones to form a single bone, **carpo-metacarpus**.
- The first i.e. most medial is in the form of a nodule projecting from the upper extremity of the second bone to which it is united.
- The second and third bones are united at their extremities; narrow interval separates their shafts.

DIGITS

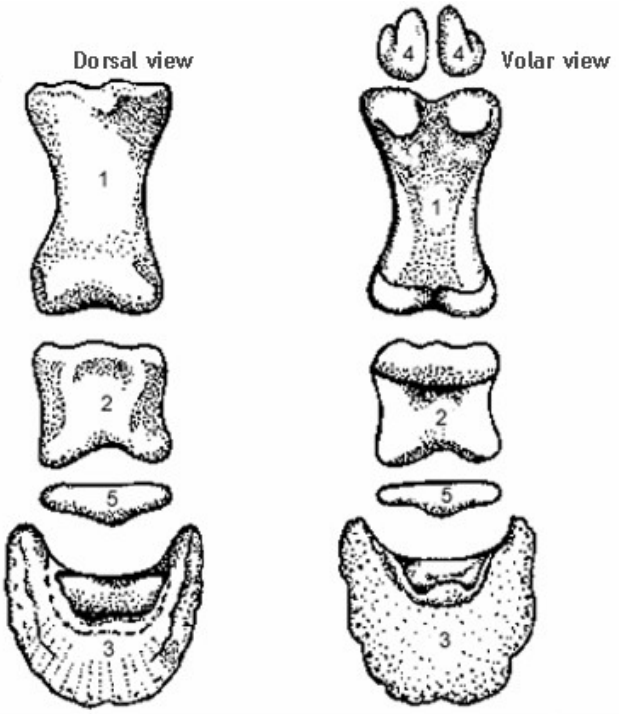
Ox

- It has two digits -the third and fourth are fully developed and have *three phalanges* and *three sesamoids* each.
- The second and the fifth are vestiges and are known as accessory digits or dew claws.
- These are placed behind the fetlock. Each accessory digit contains one or two small phalanges, which do not articulate with the rest of the skeleton



Digits of Ox

1. Fused III and IV metacarpal 2.First phalanx 3.Second phalanx
4. Third phalanx 5.Proximal sesamoids 6.Distal sesamoids



Digits of Horse

1. Fused III and IV metacarpal 2.First phalanx 3.Second phalanx
4. Third phalanx 5.Proximal sesamoids 6.Distal sesamoids

Sheep and Goat

- Resembles that of ox.
- The accessory digits have no phalanges.

Horse

- There is only one digit - the third and it consists of three phalanges and three sesamoids.

Pig

- Two chief digits (the third and fourth) consist of three phalanges each.
- There are two accessory digits and the numbers of phalanges in each are similar to that of the chief digits.

Dog

- There are five digits.
- The third and the fourth digits are the longest.
- The firstdigit has two phalanges and does not come in contact with the ground.

- The rest have three phalanges each.

Rabbit

- There are five digits.
- The first is the shortest and the third is the longest.
- The first digit has two phalanges and the rest have three each.

Fowl

- There are three digits.
- The first and the second digits have two phalanges each.
- The third digit has one phalanx.
- Sesamoids are absent.

PHALANGES

(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

First phalanx / os suffraginis

- It is a long bone placed obliquely downward and forward between the large metacarpal above and the second phalanx below.
- The *shaft* is four sided.
- The *dorsal face* is convex and blends with the abaxial.
- The *volar face* is flat and presents two tubercles, one on either side about the middle of its borders for ligamentous attachment.
- The *axial face* is flat.
- The *proximal extremity* is larger than the distal. Its articular surface is divided by a sagittal groove into two areas (the abaxial being the larger and higher), which respond to the distal end of the large metacarpal and behind these are two facets for the proximal sesamoids. On the volar aspect are two tubercles for ligamentous attachment.
- The *distal extremity* is smaller. Its articular surface is divided by a sagittal groove into two condyles (abaxial being the larger) which respond to the proximal extremity of the second phalanx.

Second phalanx /os coronae

- It is a long bone placed obliquely downward and forward between the first and third phalanges. The distal half of each is included within the hoof.
- The *shaft* is three sided.
- *The volar face* is encroached on by the distal articular surface.
- The *abaxial face* is rough while the *axial face* is flat.
- The *proximal extremity* is made up of two glenoid cavities, the abaxial of which is the larger. The volar aspect presents two tubercles for the attachment of the *superficial flexor tendon*.
- The *distal extremity* is smaller and is divided by sagittal groove into two condyles, the abaxial being the larger. It articulates with the superior face of the third phalanx below and the distal sesamoid behind.

Third phalanx / os pedis

- It is a short bone entirely enclosed in the hoof.
- It presents *four surfaces* and an *angle*.
- The *superior face* is articular and presents two areas for the distal extremity of the second phalanx and a small facet along the volar border for the distal sesamoid.
- The *inferior face* or *solar surface* is nearly flat, wide in the middle and narrowest in front. It is in contact with the sensitive sole in life.
- The *interdigital surface* is smooth and grooved below and rough and porous above. It presents a large foramen near the extensor process, the *volar foramen*.
- The *laminar surface* slopes from above downward and becomes steep posteriorly. Distally it is traversed by the preplantar groove with several foramina; the most posterior of these is the largest. The surface is covered by the sensitive lamina in life. At the extreme upper part of the dorsal border is the *extensor process* for the *common digital extensor*.The volar border is thick for the attachment of the deep flexor of the digit. The angle is a blunt process at the extreme posterior part of the laminar surface.

TOP

Sheep and Goat

- Similar to that of ox.

TOP

Horse

- Each phalanx appears like the combined corresponding phalanges of the ox.
- *First phalanx*, the volar face presents a "V" shaped area beginning from the proximal tuberosities and converging distally, which furnishes attachment to the distal sesamoidean ligament. The proximal face is articular and is divided by a sagittal groove into two concave areas, the medical being the larger. The lateral face bear tubercles.
- *Second phalanx is* a short bone being more wide than long.
- ***Third phalanx*** has *three surfaces*, *three borders* and *two angles*. The *superior articular surface* is adapted to the distal extremity of the second phalanx and distal sesamoid. The *volar face* is divided by the semilunar crest into a larger concave *solar surface* and smaller *semilunar flexor surface*. The latter presents a central prominent area on either side of which is the volar foramen, which leads into semilunar canal within the bone. The crest and the prominent area furnish attachment to the deep flexor tendon. The*antero-superior* or *coronary border* bears about its middle the extensor process or the pyramidal process for the common extensor tendon. The *postero-superior border* is nearly straight and forms the posterior limit of the superior articular surface. The *distal border* is irregularly notched with a wider notch in front. The *angles* or *wings* project backward and are divided into upper and lower parts by a notch or a foramen. The proximal border of the angle carries the cartilage of the third phalanx.

TOP

Pig

- Each digit has three phalanges.
- The phalanges of third and fourth are well developed.

- The phalanges of second and fifth digit are small and generally donot reach the ground.
- There are two proximal and distal sesamoid bones in each digit.

TOP

Dog

- The first digit has two phalanges and the other digits have three phalanges each.
- The first phalanges of the chief digits have four sided shafts and the second phalanges about two thirds of the length of the first phalanges and their distal extremities are wider and flatter than those of the first.
- The third phalanges correspond to the shape of the claws.
- The proximal face or base responds to the second phalanx.
- It is encircled by a collar of bone with which it forms a groove into which the proximal border of the claw is received.

TOP

Rabbit

- The first digit has two phalanges and the remaining four digits have three phalanges each.
- All the 3 rd phalanges bear horny claws.

TOP

Fowl

- The first and second digits have two phalanges each.
- The third has only one phalanx.

PROXIMAL SESAMOIDS

Ox

- The proximal sesamoids are a pair for each digit.
- They are situated behind the distal extremity of the large metacarpal and afford increased leverage to the flexors of the digits.
- Each bone has the form of a three-sided pyramid with the *base* below and the *apex* above. The **base** presents a facet for the first phalanx. The **dorsal surface** articulates with the distal extremity of the large metacarpal on its volar aspect.
- Each sesamoid also presents a facet for articulation with a similar facet of its fellow. The abaxial and axial sesamoids of each digit articulate with each other. The opposing faces of the axial sesamoids are covered in life by fibrocartilage and form a groove for the gliding of the *deep flexor tendon* of the digit.

Sheep and Goat

- The number similar to that of an ox.
- The abaxial ones are compressed from side to side and the axial ones are compressed from before backwards.

Horse

- There is only one digit (third) and hence one pair of proximal sesamoids.
- Each is much larger and distinctly pyramidal in shape.
- It articulates only with the large metacarpal but neither with the first phalanx nor with its fellow. The abaxial surface is concave.

Pig

- Similar to that of an ox.

Dog

- Nine proximal sesamoids are present; one for the first digit and two for each for the other digits.
- Besides, there is a dorsal sesamoid in the capsule of each metacarpo-phalangeal joint.

Rabbit

- Many proximal sesamoid bones on the metacarpo-phalangeal joints.

Fowl

- The sesamoids are absent.

DISTAL SESAMOID

Ox

- The distal sesamoid is otherwise called as *os navicularis*.
- It is placed behind the second inter-phalangeal articulation. It presents *two surfaces, two borders* and *two extremities* .
- The *dorsal face* is articular, faces upward and forward and presents two facets for the second phalanx.
- The *volar* or *flexor surface* is broader and in life is covered by fibro-cartilage for the play of the deep flexor tendon.
- The *proximal border* is grooved for ligamentous attachment.
- The *distal border* bears a small facet about its middle for the os pedis. The extremities are rounded.

Sheep and Goat

- The number similar to that of an ox.
- The flexor surface of the distal sesamoid forms a shallow groove not divided by a ridge.

Horse

- The distal sesamoid is shuttle shaped and longer, with narrow extremities.

Pig

- One distal sesamoid for each chief digit.
- Absent in accessory digits.

Dog

- The distal sesamoids are cartilaginous.

Rabbit

- Distal sesamoids are present in the inter-phalangeal joints.

Fowl

- They are absent

PELVIC LIMB BONES

The general designations for the different parts of the pelvic limb and bones present given below.

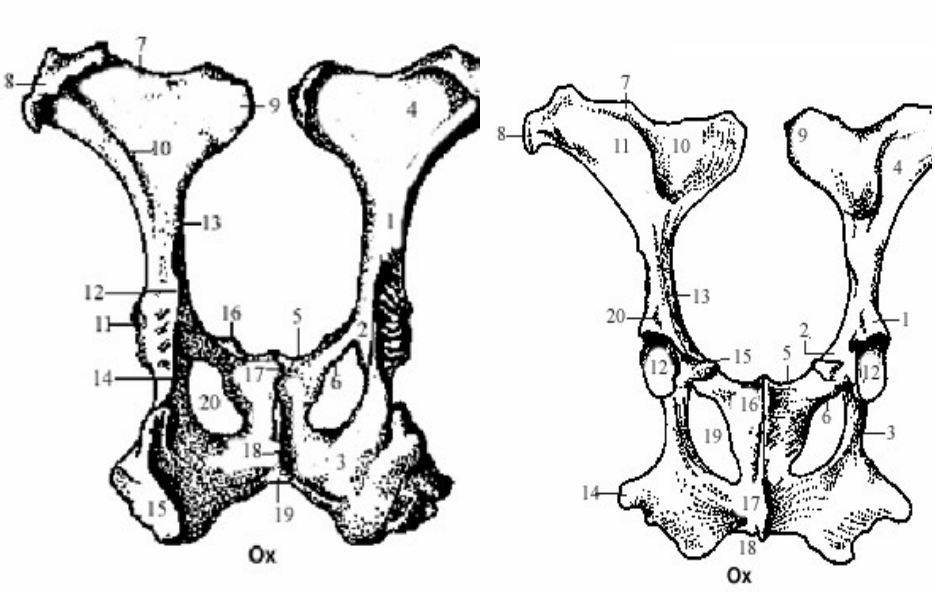
- Pelvic girdle and hip region : I*lium, ischium, and pubis*
- Thigh : *Femur*
- Leg : *Tibia & fibula*
- Pes : Consisting of
    - *Tarsus:* A number of small bones called tarsals arranged in the domestic mammals in three rows.
    - *Metatarsus:* Typically consisting of five bones designated only by numbers 1 to 5, but showing considerable modifications in different animals.
    - *Digits:* These form the terminal parts of the limbs and usually correspond to the number of the fully developed metacarpals. These are also designated by numbers 1 to 5. Each digit is composed of a number of bones arranged serially called the phalanges. The number of phalanges may vary (from 1 to 5) within the species and also in different digits of the same species.

OS COXAE
(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

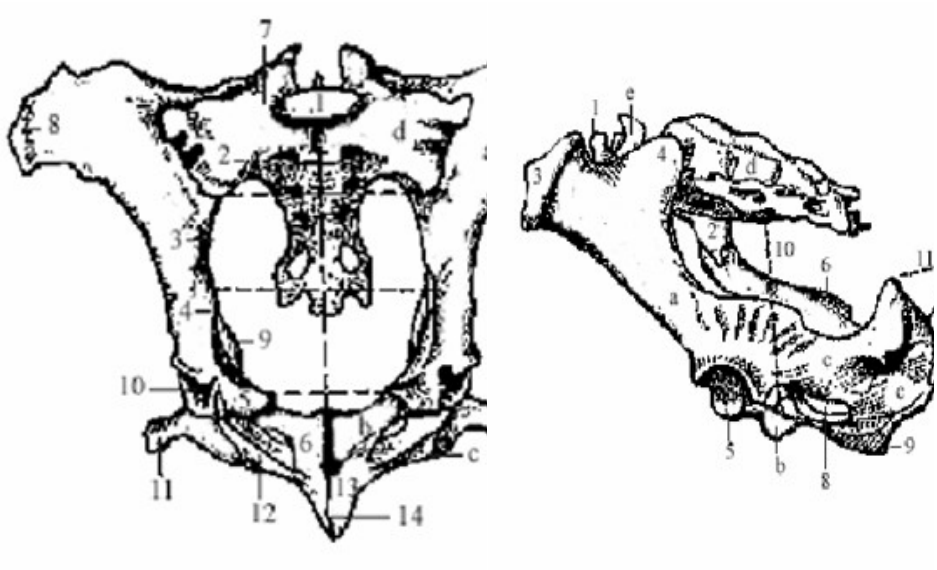
Ox

The *os coxae* or *hip bone* consists of three flat bones, ilium, ischium and pubis, which fuse together to form the *acetabulum*.

- The ilium extends from the acetabulum upwards forming the lateral wall of the pelvic cavity.
- The pubis and ischium extend medially and backward respectively and their medial borders fuse with those of the opposite side to form the *pelvic / ischio-pubic symphysis*.
- The pubis and ischium form the anterior and posterior parts respectively of the floor of the bony pelvis and enclose between them on each side, a large *obturator foramen*.



- *Ilium*
  - The *ilium* is the largest of the three parts.
  - It is irregularly triangular being wide above narrow and prismatic at the middle and slightly expanded below.
  - It presents *two surfaces, three borders and three angles*.
  - The *lateral* or *gluteal surface* is directed dorso-laterally and backward. The inferior third of this surface presents rough lines for the origin of the *gluteus profundus*. This surface is traversed by the gluteal line running nearly parallel to the cotyloid edge from a little below the tuber coxae to become continuous with the ischiatic spine. This surface serves for the origin of the *gluteus medius*.
  - The *medial* or *pelvic surface* presents a rough triangular medial part-the *sacral surface* and a smooth quadrilateral part -the *iliac surface*. The former presents an irregular facet, the articular surface for the sacrum. The iliac surface is directed forward and is covered by *iliacus*. The *ilio-pectineal* line, which separates these two surfaces, begins below the articular surface and joins the anterior border of the pubis and forms the lateral boundary of the pelvic inlet. It bears about the middle the *psoas tubercle* for the*psoas minor*.
  - The *cotyloid border* leads to the acetabulum, little above and infront of which are two depressions (the lateral one is faint) for the origin of the *rectus femoris*.
  - The *ischiatic border* is concave and forms the *greater isciatic notch*. The notch forms the greater ischiatic foramen which is covered by the sacro-sciatic ligament in life and serves for the passage of gluteal nerves and anterior gluteal vessels. In its lower part, it is convex, rough and is continuous with the ischiatic spine, which gives attachment to the sacro-sciatic ligament at its free edge and to the *gluteus profundus* on its lateral aspect.
  - The *dorsal border* or *the crest* of the ilium is concave thick and rough for the attachment of the muscles of the loin.
  - The *medial angle* or *tuber sacrale* is separated from its fellow and forms with it and the sacrale spines, the *point of the croup*.
  - The *lateral angle* or *tuber coxae* is large and prominent, wide in the middle and smaller at either end and serves for the attachment of the iliacus, *obliquus abdominis internus, tensor fasciae latae, gluteus medius* etc.
  - The *inferior* or *acetabular angle* is thick and meets the other two parts at the acetabulum.



TOP

- *Ishium*
  - The *ischium* is smaller than ilium.
  - It is irregularly quadrilateral and placed behind the ilium and the pubis.
  - It has *two surfaces* and *four borders*.
  - The *dorsal pelvic surface* is slightly concave transversely and forms the posterior part of the pelvic floor.
  - The *ventral surface* presents about its middle a rough ridge for the *biceps femoris*. It is roughened for the origin of the *adductor* muscles of the thigh. The anterior border is concave and forms the posterior boundary of the obturator foramen.
  - The *posterior border* slopes forward and downward and meets the same borders of its fellow to form the ischial arch, which constitutes the inferior boundary of the pelvic outlet.
  - The *medial border* with its fellow form the *ischiatic symphysis*, presents ventrally a ridge which gives attachment to the suspensory ligament of the penis in the male and that of the udder in the female.
  - The *lateral border* is concave and forms the *lesser isciatic notch* and is continuous with the ischiatic spine. The notch forms the lower boundary of the *lesser sciatic foramen*bordered above by the sacro-sciatic ligament (in life), which is for the passage of the posterior gluteal vessels.
  - The *antero-lateral angle* joins the ilium and the pubis at the acetabulum.
  - The *postero lateral angle-tuber ischii* is a trifid process and serves for the origin of the *biceps femoris, semitendinosus and semimembranosus.*

TOP

- *Pubis*
  - The *pubis* is the smallest of the three parts.
  - It is irregularly triangular and has *two surfaces* and *three borders*.
  - The *dorsal* or *pelvic surface* forms the anterior part of the pelvic floor and the urinary bladder rests on it in life.
  - The *ventral surface* is rough for muscular attachment.

    - The *anterior border* is thick. Laterally it bears the ilio-pectineal eminence and curves for the attachment of the prepubic tendon.
    - The *posterior border* forms the anterior margin of the obturator foramen.
    - The *medial border* meets the same border of its fellow at the pubic symphysis. The *acetabular angle* joins the ilium and the ischium at the acetabulum.
    - The medial borders of the pubis and the ischium meet the corresponding borders of their fellows to form the *pelvic symphysis / Ischio-pubic symphysis* and the pelvic floor is basin like.

TOP

- *Acetabulum*
    - *Acetabulum* is a cotyloid cavity formed on the ventro-lateral aspect of the os coxae by the meeting of its three components.
    - It consists of an *articular* and a *non-articular part*.
    - The former is nearly circular and articulates with the head of the femur. The rim of the cavity presents on its postero-medial spect the *acetabular notch*, which transmits the round ligament of the hip joint.
    - The non-articular part, the *acetabular fossa* is situated in the depth of the acetabulum.
    - Another small notch may be seen antero-medially, though sometimes it is replaced by a foramen or is absent.
- *Obturator foramen*
    - The *obturator foramen* is a large, elliptical opening on the floor of the pelvis and is circumscribed by the ischium and the pubis.
- It is covered in life by the obturator muscles.
- *Pelvic cavity*
    - The *pelvic cavity* is the smallest and the most posterior of the three visceral cavities of the body.
    - The bony pelvis composed of the os coxae laterally and ventrally. The sacrum and the first three coccygeal vertebrae dorsally. The lateral vacuities are closed up by the sciatic ligaments in life.
    - The pelvic inlet is bounded by the terminal line or brim which is composed of the base of the sacrum dorsally, ilio-pectineal lines laterally and the anterior borders of pubis ventrally.
    - The *pelvic outlet* is much smaller and is very incomplete in the skeleton. The third coccygeal vertebra bound it dorsally and ventrally by the ischial arch and the sacro-sciatic ligament and *semimembranosus* muscle completes it laterally.
- *Sexual differences*
    - The ischial arch is wider and the outlet is larger in the female than in the male.
    - The conjugate (vertical) and transverse diameters are greater in the female so that the cavity is roomier.
    - The pubis and the ischium of the opposite sides meet at a more open angle in the female than in the male.

TOP

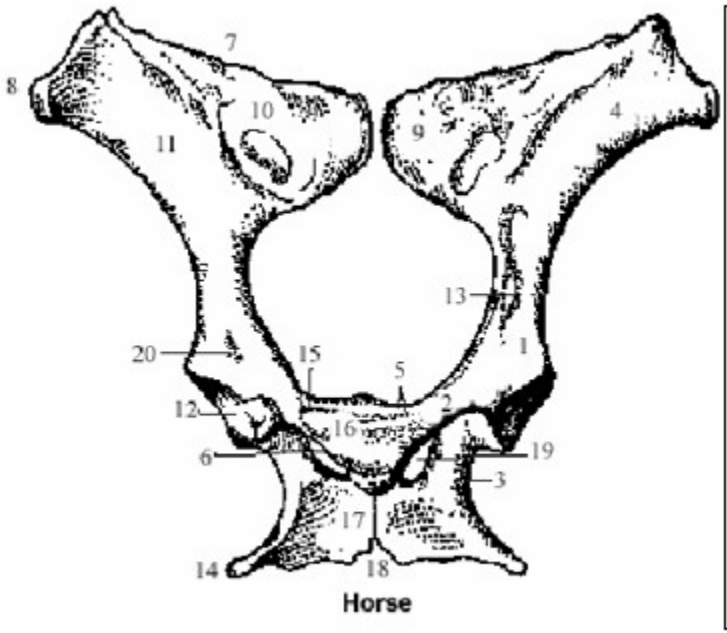
Sheep and Goat

- The long axis of the ilium is almost in straight line with that of ischium.
- Greater ischiatic spine is low and everted.
- Ischial symphysis is not ossified even in old animals.
- Acetabulum is large and deep.
- The pelvic brim is elliptical in outline.

TOP

Horse

- The gluteal line is very faint.
- The tuber coxae is large and compounded four tuberosities arranged in pairs.
- The pelvic surface of the ischium is less concave and meets its fellow at a more open angle.
- The ischial arch is wide and shallow.
- The ridge on the inferior face of the ischium is absent.
- The symphyseal ridge is also absent.
- The tuber ischii is not trifid and its lower border forms the ventral ischiatic spine.
- The ventral face of the pubis crossed near the anterior border by the pubic groove which leads to the acetabular notch which transmits the pubo-femoral or the accessory and round ligaments of the hip to femur.
- The acetabular notch is on the medial part of the rim.



Horse

Os coxae of Horse
(Ventral view)

1. Ilium
2. Pubis
3. Ischium
4. Medial surface of ilium
5. Anterior border of pubis
6. Posterior border of pubis
7. Iliac crest
8. Tuber coxae
9. Tuber sacrale
10. Sacral surface
11. Iliac surface
12. Acetabulum
13. Psoas tubercle
14. Tuber ischii
15. Iliopubic eminence
16. Pubic symphysis
17. Ischial symphysis
18. Ischial arch
19. Obturator foramen
20. Area for Rectus femoris

TOP

Pig

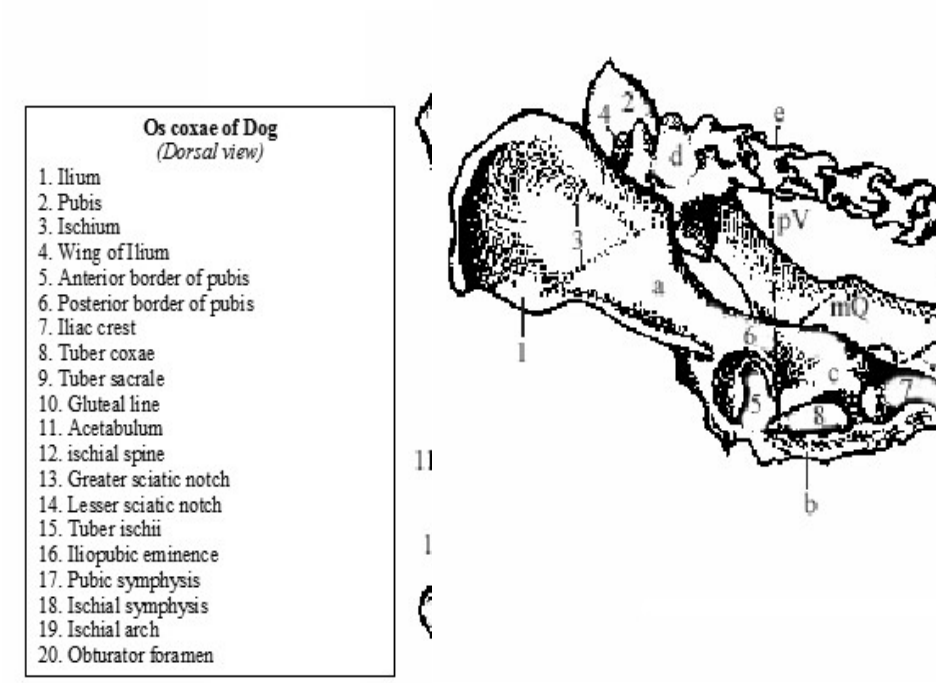
- Os coxae is long and narrow.
- The ilium and ischium are almost in line with each other.
- The gluteal surface is divided into two fossa by a ridge which is continuous with the greater ischiatic spine behind.
- The iliac crest forms the highest point of the bone.
- There is a crest or tubercle on the ventral surface of the ischium.
- The ilio-pectineal line is prominent and the psoas tubercle is well marked.

- Pelvic inlet is elliptical in outline.

TOP

Dog

- The ilium is nearly in a vertical plane.
- The gluteal surface is concave.
- The crest of the ilium is strongly convex.
- The ischium has a twisted appearance.
- The lesser ischiatic notch is absent.
- The acetabulum is deep.
- The symphyseal part of pubis is thick and fuses late with the opposite bone.

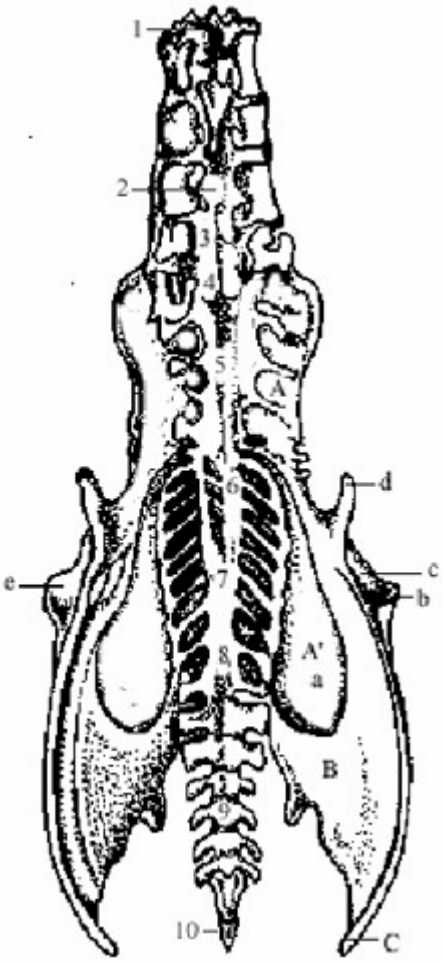


TOP

Fowl

- The *ilium* is elongated and extends over the entire length of the hipbone. It is firmly fused to the transverse processes of the lumbo-sacral mass. The pelvic face is concave for the lodgment of kidney. The lateral border is free in its anterior half but is fused with the ischium behind.

- The *ischium* is smaller and lies below and lateral to the posterior part of the ilium is triangular. The sciatic foramen is formed by the adjacent borders of the ischium and ilium behind the acetabulum. The ventral border forms the obturator foramen with the pubis.
- The *pubis* is a long and slender rod running along the ventral border of the ischium. The anterior end has a muscular process.
- The *acetabulum* is large and perforated and presents at its supero-posterior part process - *anti-trochanter* for articulation with the great trochanter of the femur.



Vertebral column and Pelvis of the Fowl
(*Ventral view*)

1. Second thoracic vertebrae
2. Fifth thoracic vertebrae
3. Sixth thoracic vertebrae
4. Seventh thoracic vertebrae
5. Sacrothoracic vertebrae
6. Sacrolumbar vertebrae
7. Primary sacral vertebrae
8. Synsacrocaudal vertebrae
9. Free coccygeal vertebra
10. Pygostyle

a. Renal fossa
b. Antitrochanter
c. Obturator foramen
d. Musular process
e. Acetabulum

A-Preacetabula
A' – Postactabular part of ilium
B- Ischium
C- Pubis

BONY PELVIS / BONE OF HIP (PELVIC) REGION

- Bony pelvis consist of sacrum, 1st three coccygeal vertebrae and two Os-coxae. Each formed by the ilium, ischium and pubis.

1. Sacrum

S. No.	Mare	Cow
1	It consist of 5 sacral segments, base and apex.	It consist of 5 sacral segments.

2	It is shorter than the cow.	It is longer than the mare.
3	It is triangular in shape.	It is roughly triangular in shape.
4	Dorsal surface presents 5 sacral spines which have tuberous summits and 4 pairs of dorsal sacral foramina.	Dorsal surface presents spines fuse to form median sacral crest. Articular processes fuse to form lateral sacral crest and 4 pairs of dorsal sacral foramina.
5	Ventral surface lodges 4 transverse lines.	Ventral surface presents 4 transverse groove and 4 pairs of foramina.
6	Pelvic surface presents transverse lines.	pelvic surface is concave in both directions and presents groove for middle sacral artery.
7	Smooth notches are present on either side of the body of 1st sacral segment.	No notches on either side of the body of 1st sacral segment.
8	Articular surface directed dorso-laterally which is slightly concave in its length. It is rough, irregular and articulates with ilium. Portion lateral to the foramina is formed by the fusion of the transverse processes.	Articular surfaces are concave and semicylindrical in curvature medially and process are large and widely separated.
9	Alae are the lateral part of the base (wing). Ventral margin of the base projects & form sacral promontory.	

S. No.	Buffalo	Sheep
1	I consist of 5 sacral segments.	It consist of 4 sacral segments.
2	No vascular groove on the ventral aspect.	No vascular groove on the ventral aspect.
3	Spines are fused.	Spines are not fused except 1st and 2nd which may be partially united.

4	Sacral promontory flattened dorso-ventrally more than the cow.	Sacral promontory is not much flattened dorso-ventrally.
5	4^{th} and 5^{th} sacral vertebrae are not fused but laterally attached.	The last segment may remain separate or undergo partial fusion.
6	Transverse processes of last segment are not distinct.	Transverse processes of last segment are distinct and outstanding.

S. No.	Sow	Bitch
1	It consist of 4 sacral segments.	It consist of 3 sacral segments.
2	Pelvic surface is less curved as compared to cow.	It is short, wide and quadrangular in shape.
3	Fusion of vertebrae is less complete.	Fusion of vertebrae is complete.
4	Spines are less developed & commonly absent.	Spines are fused to form median crest which is notched. On either side 2 tubercles are the vestiges of the fused articular processes.
5	Middle of the dorsal surface is flattened, smooth and presents opening.	Pelvic surface is deeply concave and has two pairs of foramina.
6	Anterior processes are very large.	Anterior processes are large and have extensive, slightly concave facets. Wings are prismatic and bear laterally, auricular surface on its lower part.
7	Transverse lines are distinct	Sacral canal is compressed dorso-ventrally
8	-	Transverse processes of last vertebrae project backward.

2. **Coccygeal vertebrae** : Each vertebra consist of body, spinous and transverse processes.

S. No.	Mare	Cow

1	These (Cy) are 15 to 21 (18) in number.	These (Cy) are 18 to 20 in number.
2	Spinous processes are short and have double summit.	-
3	1st vertebra presents groove on postero-medial aspect of the body.	It is longer and better developed than horse.
4	Ventral surface has a groove for coccygeal artery.	Ventrally, median sacral groove for median coccygeal artery.
5	These are ill developed.	First 5 to 6 vertebrae have complete arches and spinous processes.
6	Bodies of first 3 vertebrae are flattened dorso-ventrally and constricted in the middle.	In anterior part of series, anterior articulating processes do not articulate and ventral spines form a groove for middle coccygeal artery.

S. No.	Sheep	Sow
1	These (Cy) are 16 to 18 (3 - 24) in number.	These (Cy) are 20 to 23 in number.
2	Transverse processes are long and thin.	First 3 or 4 vertebrae are specially characterized by the presence of functional articular processes.
3	No haemal processes on the ventral surface of the body.	-

A. Diameters of Pelvic inlet

1. Sacro-pubic (Conjugate) diameter :- It is measured from sacral promontory to the anterior margin of pubis symphysis.
2. Transverse (Bis-iliac) diameter :- Measured at its greatest width just above psoas tubercle.
    - Superior bis-iliac diameter :- It is measured at upper 3rd of pelvic inlet and receives greatest width of the fetus at shoulder in anterior presentation and hip in the posterior presentation.
    - Inferior bis-iliac :- It is measured at the lower 4th of pelvic inlet at elbow of fetus in anterior presentation and stifle in posterior presentation.
3. Vertical diameter of inlet :- It is measured between anterior end of symphysis pubis and articulation of sacral 3rd and 4th vertebra.

4. Oblique / sacro-iliac / ilio-sacral diameter of inlet :- It is measured from sacro-iliac joint of one side through the center of pelvic cavity to the psoas tubercle of opposite side. It is intermediate between sacro-pubic and superior bis-iliac diameter.

B. Diameter of Pelvic outlet

- Superio-inferior (Vertical) diameter :- It is measured between the summit of ischial arch and articular of coccygeal 1st and 2nd vertebrae.
- Transverse diameter :- It is measured between two ischiatic spines (Chauveau).

FEMUR

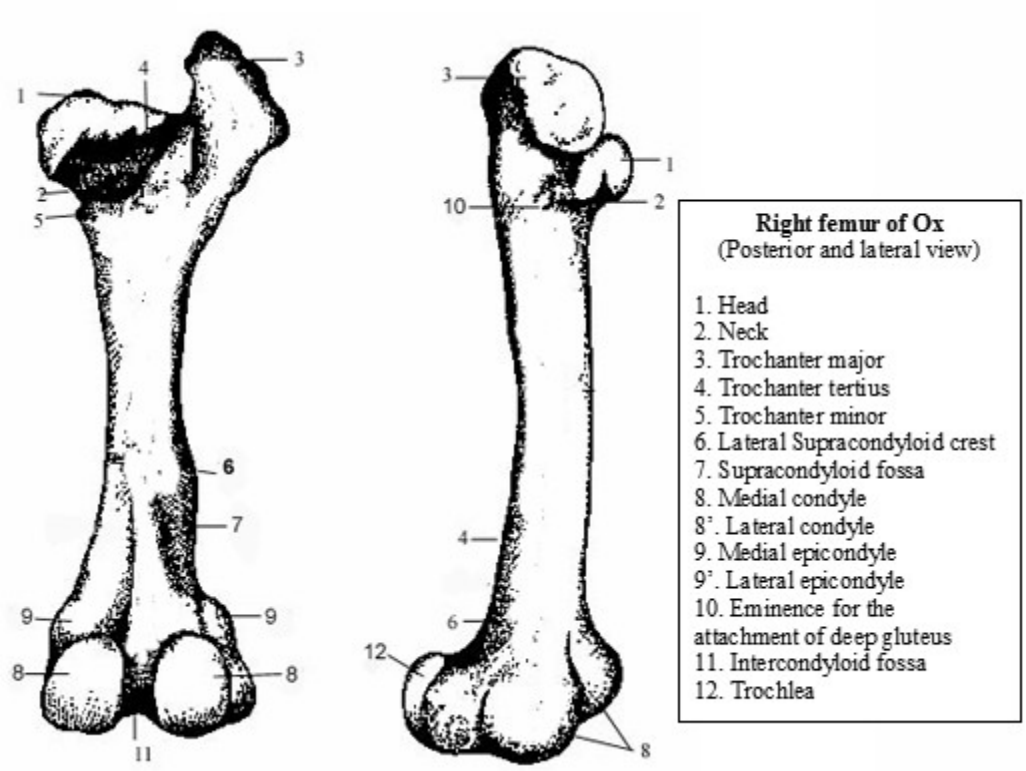
(Ox,Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

The femur, the most massive of the long bones, extends obliquely downward and forward between the hip and the stifle joints. It consists of a *shaft* and *two extremities*.

Shaft:

- The *shaft* posses four surfaces**.**
- The *anterior, medial* and *lateral surfaces* are continuous, convex from side to side and are covered in life by the *quadriceps femoris.*
- The *posterior face* is narrow in the middle where it is rough for the *adductor*. Below this is an oblique vascular impression running downward and outward marking the course of the femoral vessels.
- The medial border of posterior surface presents in its upper third the *trochanter minor*, which is for *quadratus femoris* and *ilio-psoas*. Extending from this trochanter obliquely and joining the *trochanter major* is *trochanteric ridge,* which forms the postero-lateral boundary of the *trochanteric fossa,* ridge is for the *gluteus medius* and fossa for*gemellus, obturator externus* and *obturator internus*.
- The distal third of this border carries above the medial condyle the *medial supra condyloid crest* for the medial head of the *gastrocnemius*. The rest of this border below the trochanter minor is for the *pectineus*.
- The *lateral border* presents in its distal third the *supracondyloid fossa,* which is bounded laterally by the lateral *supra-condyloid crest*. The fossa for the *superficial flexor of the digit* and the crest for the lateral head of the *gastrocnemius*.



Proximal extremity

- It composed of the *head* and the *trochanter major*.
- The *head* is medial and articulates with the acetabulum. The small non-articular sulcus, *fovea capitis,* on the middle of the head is for the round ligament of the hip joint.
- The *trochanter major* or *greater trochanter* is massive and is for the *gluteus medius*. The *lateral face* is convex. Below its base are two rough tubercles -the upper one for the*middle gluteus* and the lower one for the *deep gluteus*.

Distal extremity

- The *distal extremity* is large and comprises of *trochlea* in front and *two condyles behind.*
- The *trochlea* articulates with patella. The medial ridge of the trochlea is more prominent.
- The *condyles* are separated by the intercondyloid fossa and articulate with the condyles of the tibia through the medium of the *interarticular cartilages or menisci.*
- The *medial condyle* presents an eminence on its medial aspect for the medial ligament.
- The *lateral condyle* presents two depressions on its lateral aspect, the upper one for the lateral ligament of the stifle and the lower one for the *popliteus.*
- Between the lateral condyle and the lateral ridge of the trochlea is, the *extensor fossa* for the *complex* muscle.

- The inter-condyloid fossa lodges the spine of the tibia. Its anterior part is for the posterior crucial ligament. At its posterior part close to the medial condyle is a depression for the coronary ligament of the lateral meniscus and close to the lateral condyle is another depression for the anterior cruciate ligament.

TOP

Sheep and Goat

- A distinct line separates the lateral and posterior surfaces.
- The trochanter major is little higher than the head.
- Trochlear ridges are slightly oblique.

TOP

Horse

- It is more massive.
- The posterior face bears in its proximal third a rough eminence for the *biceps femoris*.
- The trochanter minor is in the form of a rough ridge.
- The lateral border bears the *trochanter tertius* in its proximal third for the *superficial gluteus*.
- The supracondyloid fossa and the lateral supra condyloid crest is better developed.
- The trochanteric ridge is vertical and extends from the proximal third to the great trochanter.
- The great trochanter is made up of a convexity a summit and a crest.
- The crest is below and lateral to the convexity

TOP

Pig

- The shaft is wide and relatively massive.
- A ridge extends from the trochanter major to the lateral supracondyloid crest and there is no supracondyloid fossa.
- The third trochanter is absent.

TOP

Dog

- The shaft is proportionately large and strongly curved with the convexity forward.
- The supra condyloid fossa is absent.
- The trochanteric fossa is rounded and deep.
- The ridges of the trochlea are sagittal and equal.

- The inter condyloid fossa is wide.
- On the posterior aspect of the distal extremity immediately above each condyle is a small facet for a sesamoid-the *fabella*.
- The *fabellae* are two small rounded sesamoid bones, located one each on the condyles of the femur on the posterior aspect.
- They are developed in the tendons of origin of the *gastrocnemius* muscle.

TOP

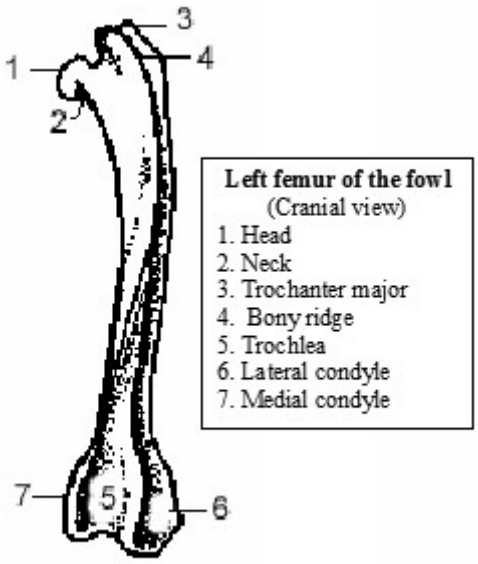
Rabbit

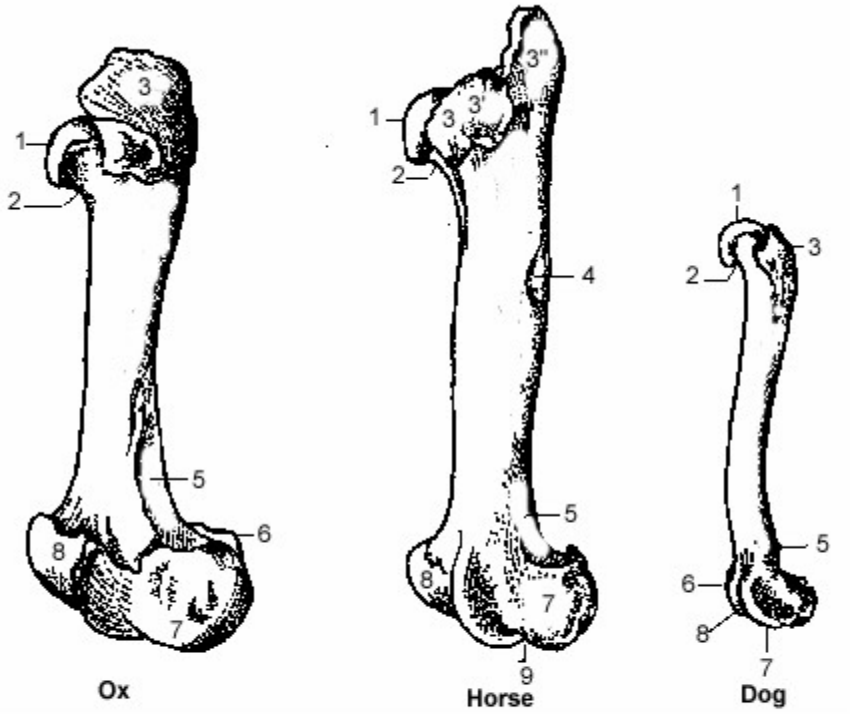
- Immediately below the head is the trochanter minor and lateral to it, a pair of projections, which form the greater trochanter and third trochanter.
- The distal extremity has medial and lateral condyles separated by a median patellar groove.

TOP

Fowl

- The head is prominent but smaller than the acetabulum and the articular surface extends on the trochanter and articulates with the acetabulum and the facet on its rim.
- The lateral condyle presents on its lateral aspect a groove for the head of fibula.





Left femur of domestic animals (Cranio-lateral view)

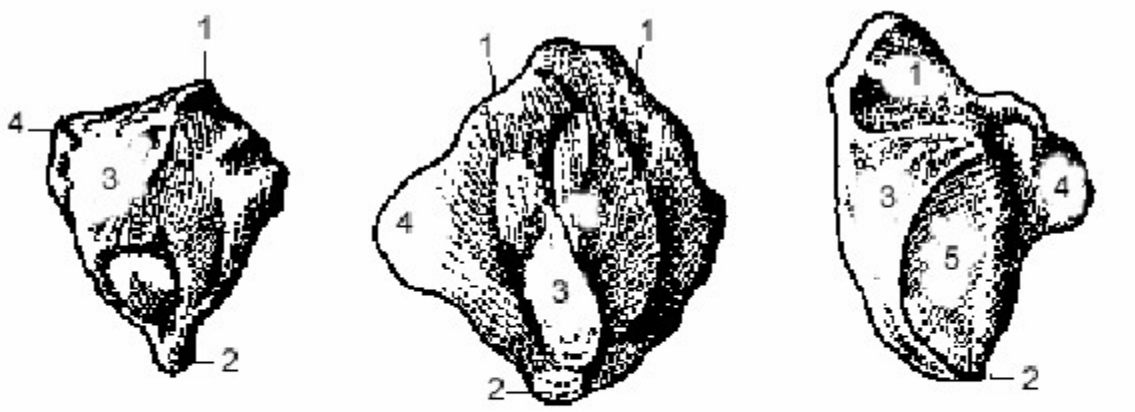
1. Head	2. Neck	3. Trochanter major	3'-Cranial part of 3
3'' Caudal part of 3	4. Trochanter tertius	5. Supracondyloid fossa	6. Medial condyle
7. Lateral condyle	8. Trochlea	9. Extensor fossa	

PATELLA

(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

- It is a large sesamoid bone placed on and articulating with the trochlea of the femur.
- It looks triangular in shape on their dorsal/anterior view.
- It gives increased leverage to the extensors of leg. It is irregularly triangular and presents *two surfaces, two borders*, a *base* and an *apex*.
- The *anterior surface* is convex and rough.
- The *posterior* or *articular surface* is divided by a vertical ridge into two concave areas of which the medial is larger.
- The two borders converge to the *apex* below.
- The *lateral border* is convex.
- The *medial border* is concave, forms an angle at the base and gives attachment to the fibro-cartilage of the patella.
- The *base* faces upward and is irregular and narrow.



Ox (left dorsal) Horse(Left dorsal) Horse(caudolateral)

Left patella of the domestic animals.

1. Base 2. Apex 3. Cranial surface 4. Cartilagenous process 5. Articular surface

Sheep and Goat

- It is relatively longer and narrower than that of ox.

Horse

- The base is wide and large.
- It looks quadrlateral in shape on their dorsal/anterior view.

Pig

- It is very much compressed transversely and presents 3 surfaces.

Dog

- It is long and narrow.

Rabbit

- Lies in the patellar groove.

Fowl

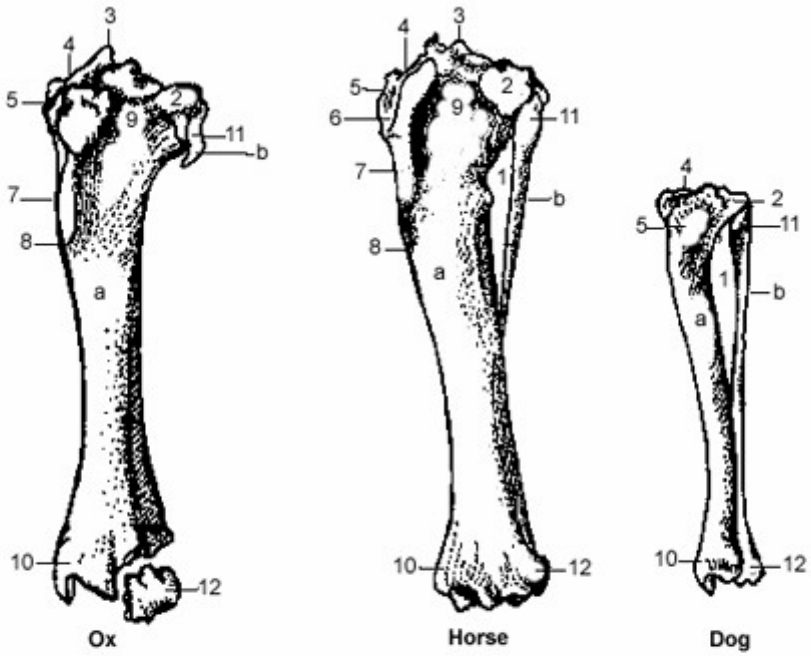
- It is wide and thin.

TIBIA

(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

The tibia is a long bone placed obliquely downward and backward between the stifle and the hock joints. It consists of a *shaft* and *two extremities*.



Left Tibia and Fibula of the domestic animals
(Cranioateral aspect)

1. Inteosseous space
2. Lateral condyle
3. Tibial spine
4. Medial condyle
5. Tibial tuberosity
6. Sulcus on tibial tuberosity
7. Tibial crest
8. Rough area for semitendinosus
9. Groove for extensors
10. Medial malleolus
11. Head of fibula
12. Lateral malleolus

Shaft

- The shaft is three sided above and becomes smaller and flattened below.
- It has *three surfaces* and *three borders*.
- The *lateral surface* is wide above and inclines gradually to the front of the bone distally. It is covered by the tibialis anterior.
- The *medial face* is subcutaneous, broad above and is slightly convex and rough for the medial ligament of the stifle, sartorius, gracilis and semimembranosus.
- The *posterior face* is flat. The upper fourth of this surface has a triangular area marked by the popliteal line for the popliteus. The rest of this surface is marked by rough lines for the deep flexor.
- The *anterior border* is prominent in its upper third forming the tibial crest. It presents on its medial aspect a rough prominence for the semitendinosus. The rest of its extent is rounded and indistinct.
- The *lateral border* is concave and has the fibrous part of fibula applied against it in life.
- The *medial border* is thick and rounded in its upper fourth for the popliteus.

Proximal extremity

- The proximal extremity is large and is made up of *two condyles*, a *tuberosity* and a *spine*.

- The *tuberosity* is anterior; it is continuous distally with the tibial crest and is for the straight ligaments of the patella. Between the tuberosity and the lateral condyle is the sulcus muscularis for the passage of the tendon of origin of the complex muscle.
- The condyles are *medial* and *lateral.* Each presents a saddle shaped articular surface above for the corresponding condyle of the femur and the meniscus. The condyles are separated behind the popliteal notch on the medial aspect of which is a tubercle for the posterior cruciate ligament. The *lateral condyle* has the rudimentary fibula fused with it on its lateral aspect and serves for the attachment of the lateral ligament of the stifle.
- The *tibial spine* is placed between the condyles whose articular surfaces are continued on the spine. It is bifid at the summit. Before and behind the spine are the depressions for ligaments.

Distal extremity

- The distal extremity is smaller than the proximal.
- The *articular surface* presents two deep sagittal grooves.
- The *malleoli* are bony prominences on the outer marigins of the sagittal grooves.The *medial* is smaller and fused with the distal extremity of the tibia. The medial groove is bounded on the medial aspect by the medial malleolus (which is fused to the tibia). The latter is rough medially for ligamentous attachments and articulates laterally. Its anterior part is prolonged downward to end in a blunt point. The lateral groove is separated by a sharp ridge from an outer area, which is for the *lateral malleolus*. The latter completes the lateral groove.

TOP

Sheep and Goat

- Resembles that of ox.

TOP

Horse

- The medial border presents at its upper part a small tubercle for the popliteus.
- The popliteal line is prominent.
- The anterior tuberosity is grooved vertically.
- Below the lateral margin of the lateral condyle is a facet for the fibula.
- The grooves on the distal extremity are oblique.
- The lateral malleolus is fused to the tibia.

TOP

Pig

- The shaft is slightly curve.
- Tibial tuberosity is grooved in front and a narrow sulcus separates it from the lateral condyle.
- Proximal part of the tibial crest is very prominent.

TOP

Dog

- The shaft forms a double curve, the proximal part is convex medially and the distal part convex laterally.
- The tibial crest is prominent.
- The facet for the fibula is on the postero-lateral aspect of the lateral condyle.
- The distal extremity presents laterally a facet for fibula.

TOP

Rabbit

- *Tibio-fibula* is formed by the fusion of tibia and fibula.
- Tibia is larger and the fibula is thin, rod like situated along the lateral side of the tibia.
- Fibula is not fused with the tibia in its proximal third. Hence, the tibia alone forms the proximal articular surface.
- Distally, both tibia and fibula share the articulation.
- Medial and lateral malleolus are in the form of small projections on the sides of the articular surface.

TOP

Fowl

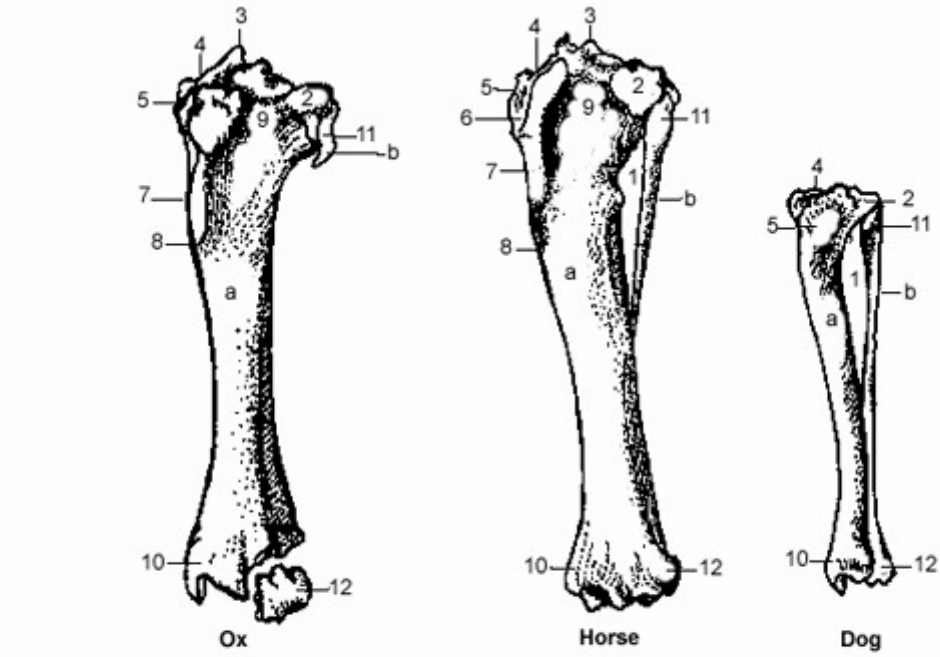
- The tibia fuses below with the upper row of tarsal bones and hence called tibio-tarsus.
- The tibio tarsus is the longest bone in the body.
- The proximal extremity is large and irregular.
- The distal extremity comprises of a trochlea behind and two condyles in front, representing the fused bones of the upper row of the tarsus.

FIBULA

(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

- The fibula is rudimentary.
- The *head* is fused to the tibia and is continued below by a small shaft.
- The *distal extremity* or *lateral-malleolus* is connected to the shaft in life by a fibrous cord. It is quadrilateral in outline and compressed from side.The *proximal articular face* is concave in front and convex behind. It articulates with the lateral facet of the distal extremity of tibia. The *distal face* has a concave facet for the fibular tarsal.The *medial face*presents a curved groove, which responds to the lateral ridge of the tibial tarsal. The *lateral face* is rough and irregular.



Left Tibia and Fibula of the domestic animals
(Cranioateral aspect)

1. Inteosseous space
2. Lateral condyle
3. Tibial spine
4. Medial condyle
5. Tibial tuberosity
6. Sulcus on tibial tuberosity
7. Tibial crest
8. Rough area for semitendinosus
9. Groove for extensors
10. Medial malleolus
11. Head of fibula
12. Lateral malleolus

TOP

Sheep and Goat

- The fibula has no shaft and its proximal end is represented by a small prominence below the lateral condyle of the tibia.
- The distal end forms the lateral malleolus as in the ox.

TOP

Horse

- It is better developed and placed along the lateral border of the tibia.
- The shaft is a slender rod, extends down to about the middle of the tibia with which it forms the tibio-fibular arch.
- The proximal extremity is large and flattened from side to side.
- The medial face has a facet for the lateral condyle of the tibia.
- The lateral face is slightly convex and rough.
- The anterior and posterior edges are blunt and rounded, the posterior being the thicker.
- The distal extremity -the lateral malleolus is fused to the tibia.

TOP

Pig

- It extends the entire length of the tibia.

TOP

Dog

- It is nearly as long as tibia.
- It is slender, somewhat twisted and enlarged at either end.
- The proximal extremity presents a facet on the medial aspect for the tibia.
- The distal extremity articulates with the tibia and the tibial tarsal medially and bears two tubercles laterally, the proximal being anterior.

TOP

Rabbit

- Tibio-fibula is formed by the fusion of tibia and fibula.
- Tibia is larger and the fibula is thin, rod like situated along the lateral side of the tibia.
- Fibula is not fused with the tibia in its proximal third. Hence, the tibia alone forms the proximal articular surface.
- Distally, both tibia and fibula share the articulation.
- Medial and lateral malleolus are in the form of small projections on the sides of the articular surface.

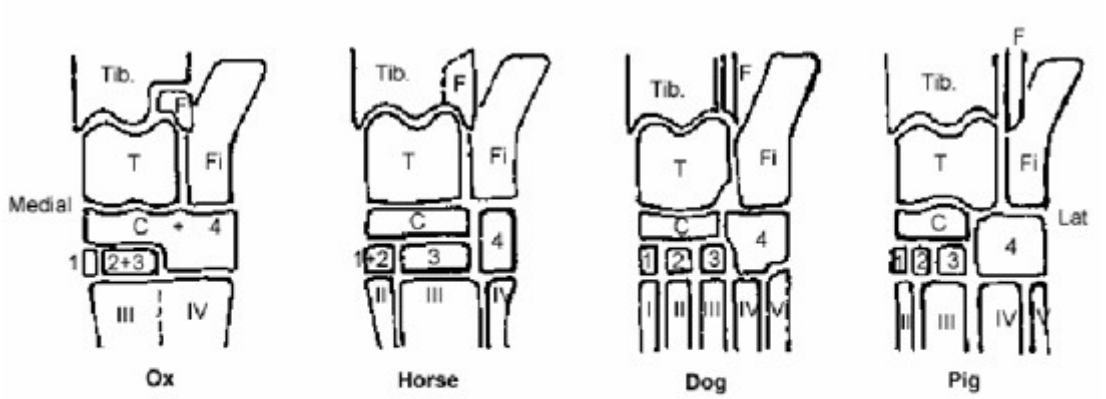
TOP

Fowl

- It is thin rod shaped bone.
- It is thick above and tapers to a point below reaching the lower third of tibia.
- The head is massive and articulates with the lateral condyle of the tibia and a presents a facet on its medial aspect for the lateral condyle of the femur.

TARSAL BONES

(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)



Bones of the tarsus in Ox, Horse, Dog and Fowl

(Roman letters indicates the metatarsal bones. Numbers indicates the distal row of tarsal bones)

Tib., Tibia F- Fibula t- Tibial tarsal Fi- Fibular tarsal C- Central tarsal

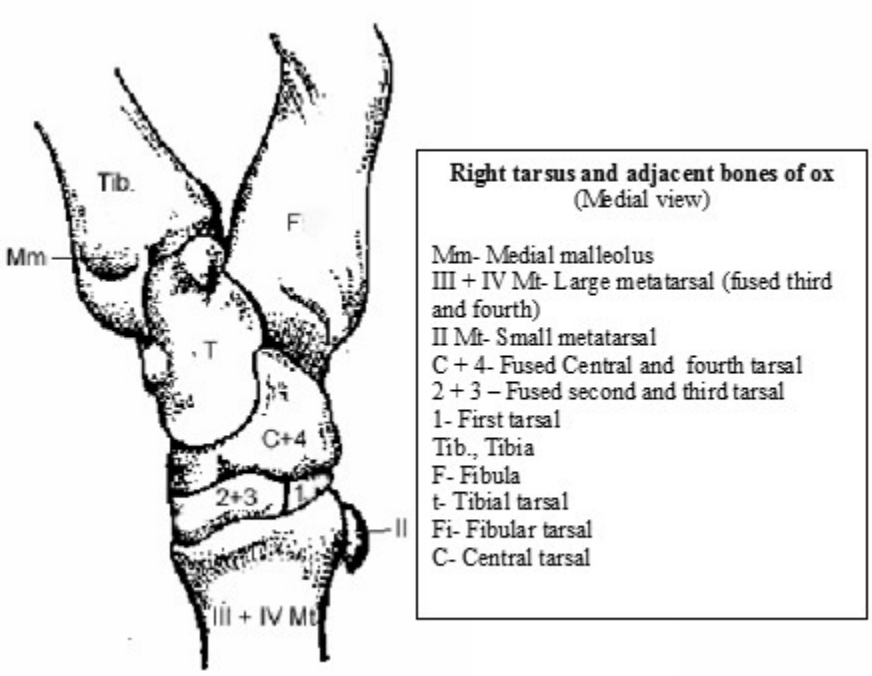
Ox

The tarsus is composed of five short bones arranged in below:

	Medial	Lateral
Proximal row	Tibial tarsal	Fibular tarsal
Central row	Fused Central and 4th tarsal	
Distal row	First tarsal	Fused second & third tarsal

Tibial tarsal (astragalus)

- It has **six surfaces**.
- The **proximal** and the **dorsal face** continuous and form a trochlea with vertical ridges for the tibia and the lateral malleolus.
- **Distal face** articulates with the fused central and 4th tarsal.
- The **plantar face** responds to fibular tarsal. A narrow elongated area on the medial aspect of the lower part of this face for the planter prolongation of the fused central and 4th tarsal.
- The **lateral face** is more depressed and shows two facets for the fibular tarsal.



Right tarsus and adjacent bones of ox
(Medial view)

Mm- Medial malleolus
III + IV Mt- Large metatarsal (fused third and fourth)
II Mt- Small metatarsal
C + 4- Fused Central and fourth tarsal
2 + 3 – Fused second and third tarsal
1- First tarsal
Tib., Tibia
F- Fibula
t- Tibial tarsal
Fi- Fibular tarsal
C- Central tarsal

Fibular tarsal (os calcis)

- It is the largest tarsal, is placed behind and lateral to tibial tarsal.
- It has **body** and **medial process** -the sustentaculum tali.
- The **lateral face** of the body is flat and rough while the **medial face** presents two facets for the tibial tarsal.
- The process the **sustentaculum tali**-projects medially and presents a facet dorsally for tibial tarsal. The body is prolonged above to form the tuber calcis.

Fused central and fourth tarsal (scapho-cuboid)

- The **proximal face** presents two concave areas for the tibial tarsal, a projection postero-medially for the narrow medial facet on the distal face of the tibial tarsal and a narrow facet on its lateral aspect for fibular tarsal.
- The **distal face** is uneven. The medial half is higher in level and presents a large facet in front for second and third tarsal and a small facet behind for the first tarsal. The lateral half presents two facets separated by a transverse groove and articulates with the large metatarsal bone.

First tarsal (cuneiform parvum)

- It is a small round piece of bone situated at the postero-medial aspect of the tarsus.
- The proximal face articulates with the fused central and 4th tarsal.
- The distal face with the large metatarsal and the dorsal face with the fused second and third tarsal.

Fused 2nd and 3rd tarsal (cuneiform magnum)

- It is placed beneath the fused central and 4th tarsal on its medial aspect.
- The proximal face is concavo-convex from before backward and articulates with the fused central and 4th tarsal.
- The distal face articulates with the large metatarsal.
- The plantar face has a facet for the first tarsal.
- The dorsal and medial faces are continuous, convex and rough.

TOP

Sheep and Goat

- Similar to that of ox.

TOP

Horse

- It has six bones.

	Medial	Lateral	
Proximal row	Tibial tarsal	Fibular tarsal	
Central row	Central tarsal		
Distal row	Fused 1st and 2nd tarsal	3rd tarsal	4th tarsal

- In the *tibial tarsal*,the ridges of the trochlea curve obliquely downward and outward. The lateral face has no facets for the fibular tarsal.
- The *fibular tarsal* is short and thick. It does not articulate with the lateral malleolus. The medial process is larger.
- The *central tarsal (scaphoid)* is not fused to the fourth tarsal (cuboid). It is flat and irregularly quadrilateral. The proximal face is concave and articulates with the tibial tarsal. The distal face is convex and articulates with the third tarsal and the fused 1st and 2nd tarsal. The dorsal and the medial borders are continuous and rough. The lateral border is oblique and has two faces for the cuboid.
- The *fused 1st and 2nd tarsal (cuneiform parvum)* is irregular in shape. The medial face is convex. The lateral face is concave. The proximal face is concave and has two facets for the central tarsal. The distal face articulates with the large and the medial small metatarsals. The plantar end is prolonged downward into a nodular projection.
- The *third tarsal (cuneiform magnum)* is triangular in outline. The proximal face is concave and articulates with central tarsal. The distal face is convex and is for the large metatarsal. The medial border has no facet for the fused 1st and 2nd tarsal and the lateral has two facets for the fourth tarsal.
- The *fourth tarsal (cuboid)* has six surfaces. It is not fused to the central tarsal. The proximal face is convex transversely and is for the fibular tarsal and the tibial tarsal. The distal face presents two facets separated by a sagittal ridge for the lateral small metatarsal bones. The medial face has

facets for the central and the third tarsal. The dorsal, lateral and the plantar surfaces are convex and rough.

TOP

Pig

- It has seven bones

	Medial	Lateral		
Proximal row	Tibial tarsal	Fibular tarsal		
Central row	Central tarsal			
Distal row	First	Second	Third	Fourth tarsals

TOP

Dog

- It has seven bones

	Medial	Lateral		
Proximal row	Tibial tarsal	Fibular tarsal		
Central row	Central tarsal			
Distal row	First	Second	Third	Fourth tarsals

TOP

Rabbit

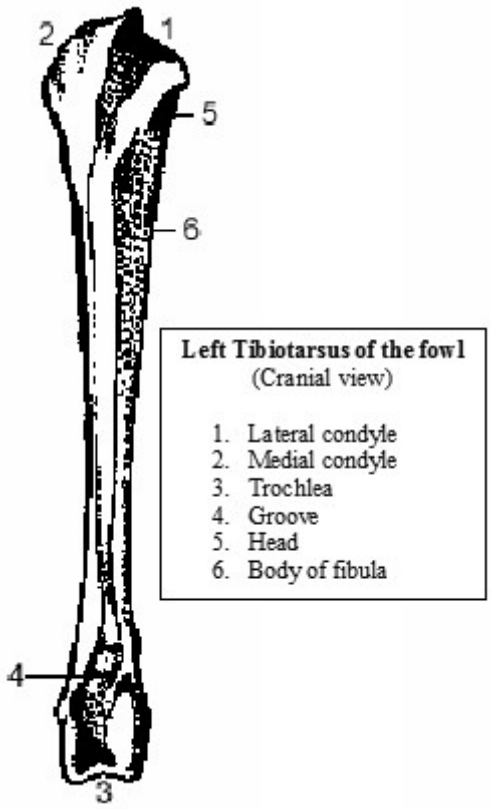
- It has six bones

	Medial	Lateral	
Proximal row	Tibial tarsal	Fibular tarsal	
Central row	Central tarsal		
Distal row		Second	Third Fourth tarsals

TOP

Fowl

- The tarsus is absent as such in the adult.
- In the proximal row the embryonic elements fuse with the tibia and in the distal row with the metatarsus.



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METATARSAL BONES
(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

The metatarsus has two bones -the *large* (*third and fourth*) and the medial *small* (second) *metatarsal bones*.

Large metatarsal bone (third and fourth)

- It resembles the large metacarpal except for the following differences
- The bone is longer than metacarpal.
- The shaft is four sided.
- The dorsal metatarsal groove is deeper.

- The *plantar face* presents a shallow groove. Commencing at the upper part of the groove is a vascular tunnel passing obliquely upward and forward through the proximal extremity to open on the articular face of the extremity behind and between the facets.
- The *proximal extremity* presents a flattened facet laterally for the fused central and 4th tarsal and a large facet on the medial aspect for the fused 2nd and third tarsal behind which is another small facet for the first tarsal. At its postero medial aspect, this extremity presents a facet for the small metatarsal bone.
- The dorso-medial aspect presents a tuberosity for the attachment of the tendon of the *peroneus tertius*.
- The *distal extremity* resembles that of the large metacarpal.

Medial small metatarsal

- The *medial small metatarsal* is disc shaped piece of bone situated at postero-medial aspect of the proximal extremity of the large metatarsal bone.
- It presents small facet on its dorsal face for the large metatarsal. The rest of the bone is rough.

TOP

Sheep and Goat

- Resembles that of Ox.

TOP

Horse

It has three metatarsal -one *large (third*) and *two small* (*second and fourth)* medial and lateral metatarsals.

- The large metatarsal resembles the large metacarpal.
- The vertical groove presents in the ox are absent.\
- The proximal extremity presents facets for the third tarsal, the fourth tarsal and sometimes the second tarsal. The shaft is cylindrical.
- The *small metatarsals,* each has two small facets in front for the large metatarsal.
- The *lateral (fourth) metatarsal* is relatively massive, especially in its upper part.
- The proximal extremity is large and outstanding and bears one facet above for the fourth tarsal.
- The *medial bone (second metatarsal)* is much more slender than the lateral especially in its proximal part, which bears two facets above for the first the second tarsal and sometimes one for the third tarsal.

TOP

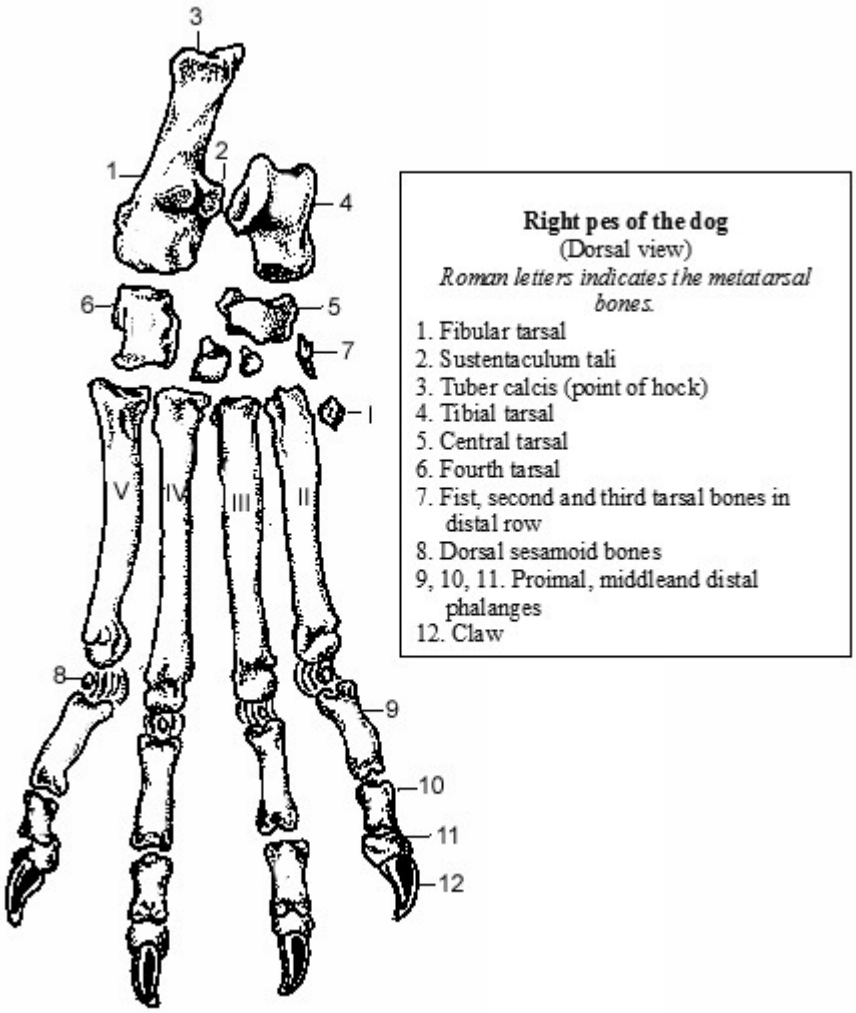
Pig

- Four in number and resembles that of the metacarpal of the forelimb.
- The second and fifth are placed more towards the plantar aspect of the large bones.

TOP

Dog

- Five metatarsals are present.
- The first is small and the other four are well developed and resemble the metacarpals.



Right pes of the dog
(Dorsal view)
Roman letters indicates the metatarsal bones.

1. Fibular tarsal
2. Sustentaculum tali
3. Tuber calcis (point of hock)
4. Tibial tarsal
5. Central tarsal
6. Fourth tarsal
7. Fist, second and third tarsal bones in distal row
8. Dorsal sesamoid bones
9, 10, 11. Proimal, middleand distal phalanges
12. Claw

TOP

Rabbit

- Four in number.
- They are very narrow rod shaped structures.

TOP

Fowl

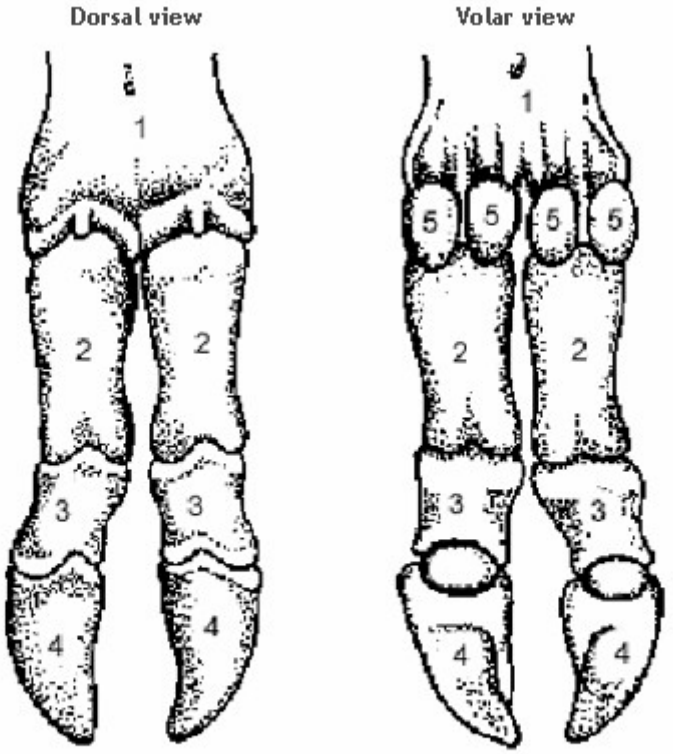
- The *tarso-metatarsus* is a single bone formed by the fusion of the distal row the tarsals with the second, third and fourth metatarsals.
- The proximal extremity presents two glenoid cavities for the distal end of the tibio-tarsus.
- The shaft is two-sided.

- The first metatarsal is attached by ligament to the postero-medial border of the large metatarsus. In the male, a conical projection arises from the medial aspect of the body of the metatarsus and serves as a core for the *horny spur* or *calcar*.
- The distal extremity divides into three processes.
- Each process is in the form of an articular convexity. The medial one is the shortest and articulates with the second digit.
- The middle one is the longest and articulates with the third-digit.
- The lateral one articulates with the fourth digit.

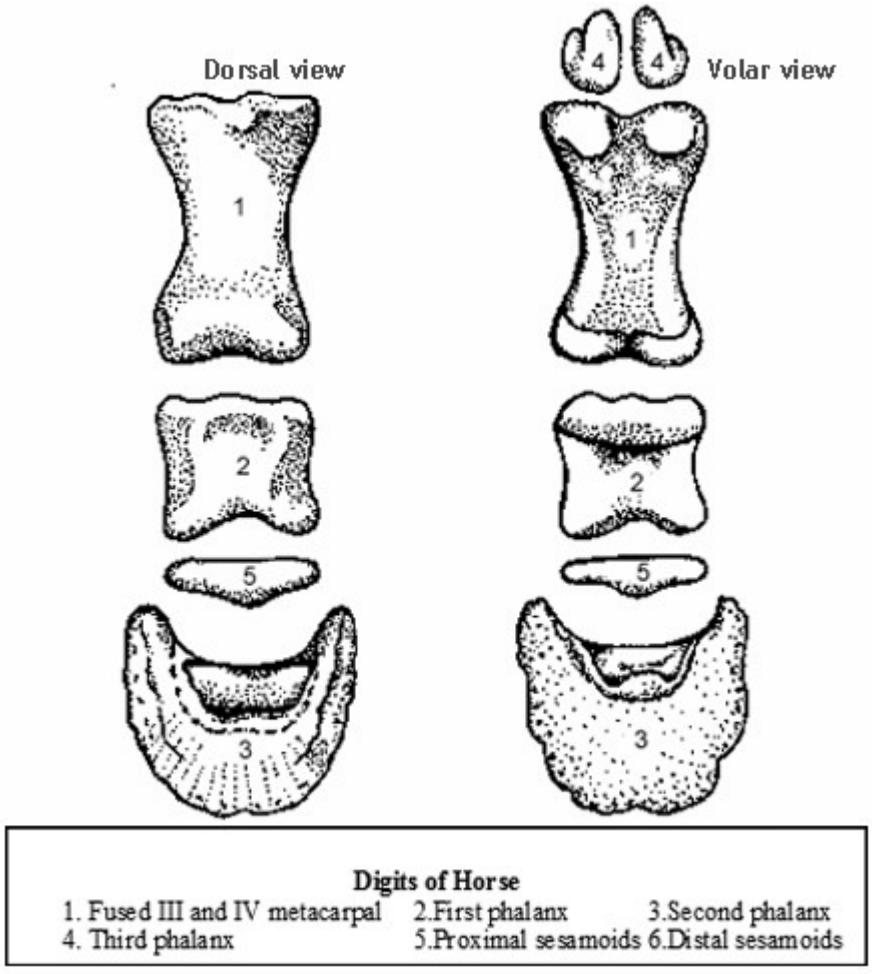
DIGITS
(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

- Resemble those of the forelimb very closely.



Digits of Ox
1. Fused III and IV metacarpal 2.First phalanx 3.Second phalanx
4. Third phalanx 5.Proximal sesamoids 6.Distal sesamoids



Digits of Horse

1. Fused III and IV metacarpal 2.First phalanx 3.Second phalanx
4. Third phalanx 5.Proximal sesamoids 6.Distal sesamoids

TOP

Sheep and Goat

- Resembles that of Ox.

TOP

Horse

- Compared with corresponding phalanges of the pectoral limb, the first phalanx is a little short, wider above and narrower below; the second is slightly longer and narrower, the third is narrower, the angle of inclination of the dorsal surface a little greater. The planter surface is more concave and the angles are less prominent and closer together.
- The proximal sesamoids are smaller and the distal shorter and narrower.

TOP

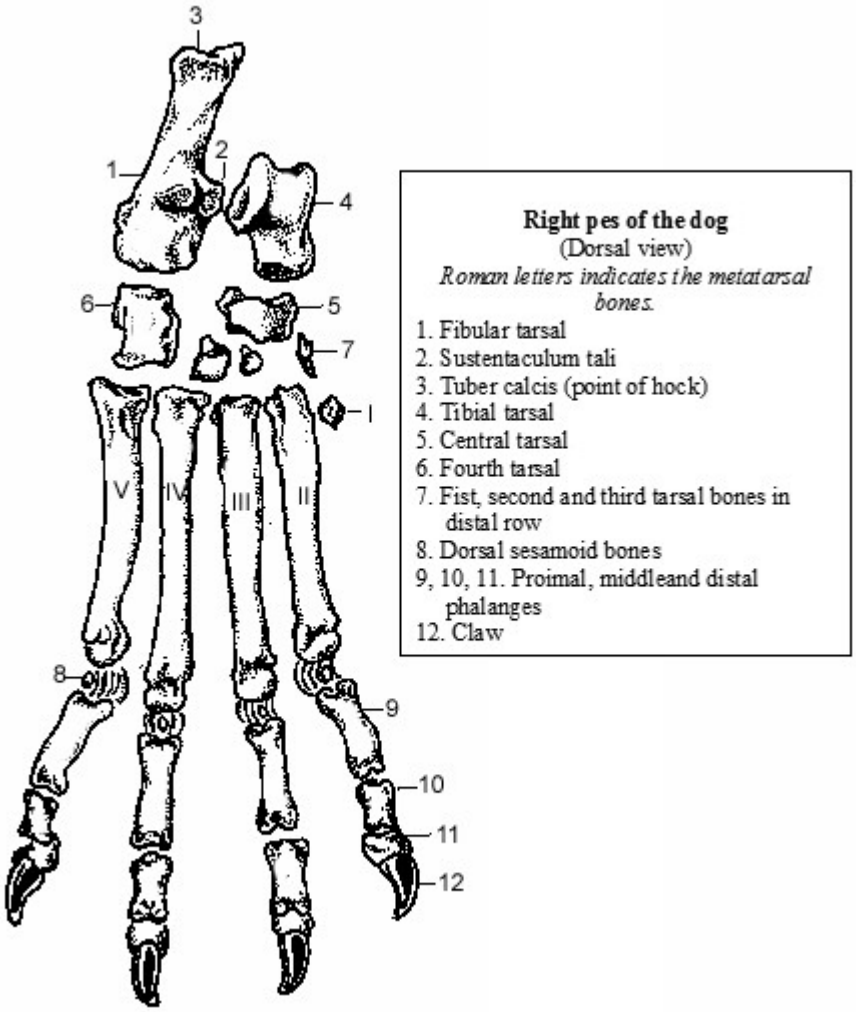
Pig

- Each chief digit comprises of three phalanges.

TOP

Dog

- Of the five digits the first is often absent.
- The other four digits constantly present and resemble those of the forelimb.



TOP

Rabbit

- There are five digits.
- The first is the shortest and the third is the longest.
- The first digit has two phalanges and the rest have three each.

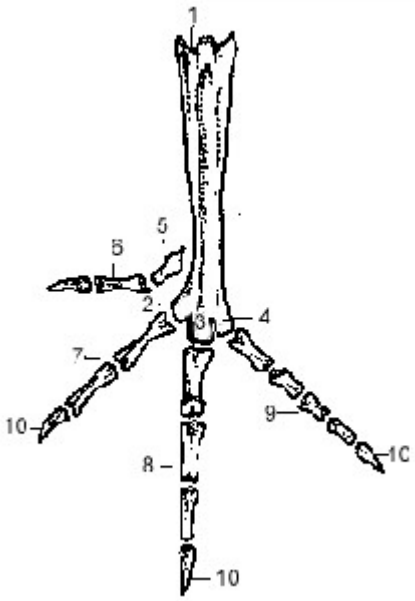
TOP

Fowl

- Four digits are usually present and the firth digit is absent.The number of phalanges in each digit is one more than the serial number of the digit.
- The phalanges of each digit diverge and enclose the inter-digital spaces.

Left tarsometatarsus and bones of the toe of the fowl
(Dorsal view)

1. Articular facet in the proximal extremity of the tarsometatarsus
2, 3, 4. Condyles for the first phalanges of the 2nd, 3rd and 4th digits respectively
5. Metatarsus I
6. First digit
7. Second digit
8. Third digit
9. Fourth digit
10. Claw



AXIAL SKELETON

- It consists of the skull, the vertebral column, ribs and sternum.

VERTEBRAL COLUMN

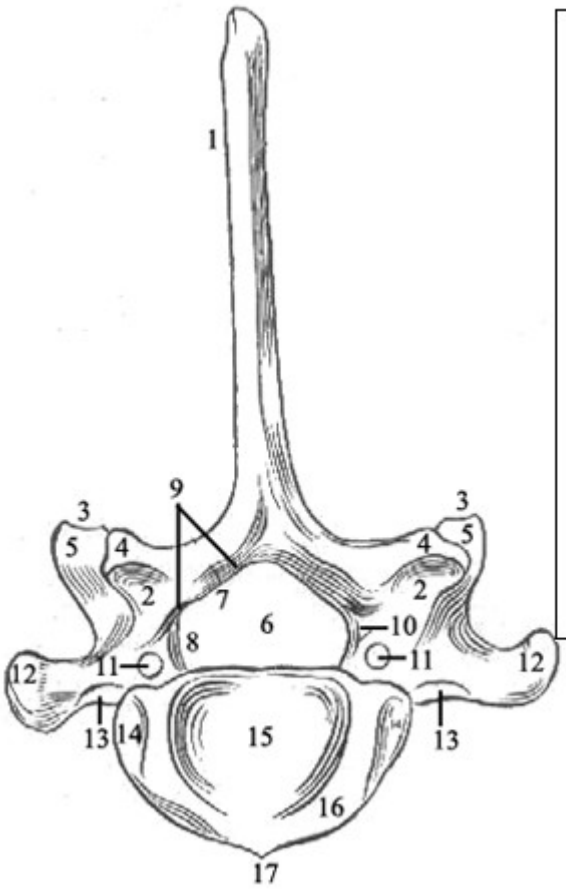
- Certain vertebrae remain free throughout life and are termed *movable* or *true vertebrae* and certain others get used together with the adjacent ones and are termed *fixed or false vertebrae*.
- The column as a whole may be divided for description into five regions - *cervical, thoracic, lumbar, sacral* and *coccygeal* accordingly as they form the skeleton of the *neck, back, loins, croup* and *tail* respectively.
- The number of bones in each region except the last is fairly constant in each species so that their number can be expressed as a formula called the vertebral formula.
- The vertebral formula in domestic animals is given below.

	Cervical vertebrae	Thoracic vertebrae	Lumbar vertebrae	Sacral vertebrae	Coccygeal vertebrae
Ox	C-7	T-13	L-6	S-5	Cy-18-20
Sheep	C-7	T-13	L-6-7	S-4	Cy-16-18
Horse	C-7	T-18	L-6	S-4	Cy-15-21

Pig	C-7	T-14-15	L-6-7	S-4	Cy-20-23
Dog	C-7	T-13	L-3	S-3	Cy-20-23
Rabbit	C-7	T-12	L-4	S-4	Cy-16
Fowl	C-13-14	T-7	LS-14	-	Cy-7

VERTEBRAE

- All the bones of the column which are constructed on the same general plan are termed *typical vertebrae*.Those that deviate from the general plan are atypical vertebra.
- The typical vertebrae presents a *body, an arch and processes.*



Typical cervical vertebra Ox

1. Dorsal spinous process
2. Posterior oblique process (articular part)
3. Anterior oblique process (articular part)
4. Posterior oblique process
5. Anterior oblique process
6. Neural ring
7. Horizontal lamina
8. Vertical pedicle
9. Neural arch
10. Posterior vertebral notches
11. Foramen transversarium
12. Transverse process
13. Tubercular facet
14. Demi facet
15. Concave articular surface on the body
16. Body / Centrum
17. Ventral spinous process

Body

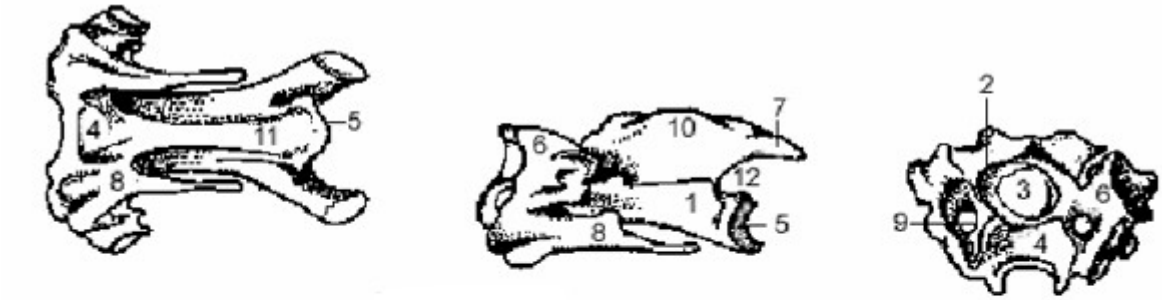
- It is the fundamental part of the vertebra around which the other parts are grouped.
- It is in the form of a solid rod.
- The anterior end is convex and the posterior end is correspondingly concave.
- The anterior end of one vertebra meets the posterior end of the preceding vertebra and between them is interposed a disc of fibrocartilage -the **intervertebral disc**.
- The dorsal surface of the body is flat and forms the floor of the vertebral foramen while the ventral face presents centrally the ventral spinous process for muscular and ligamentous attachments.

Neural arch

- The neural arch is situated on the superior face of the body and it forms with the body, a bony ring - the *vertebral foramen*.
- The entire series of these rings constitutes a canal called the spinal or *vertebral canal* for the lodgment of the spinal cord.
- Each half of the arch is made up of a vertical pedicle and a horizontal lamina.
- The anterior and posterior edges of the pedicles exhibit notches - the *vertebral notches* which when adjacent vertebrae are in position circumscribe the intervertebral foramina for the passage of vessels and spinal nerves.

Processes

- The processes of the vertebra are variable in size, development and shape in the different regions. They are:
- *Articular or Oblique Processes:* These are four in number two of which are placed on the anterior and two on the posterior edge arch. These present articular area, which face upward in the anterior and downward in the posterior processes. The anterior processes of one vertebra are overlapped by and articulate with the posterior processes of vertebra in front and form synovial joints. The non-articular area serves for muscular and ligamentous attachments.
- *Transverse Processes :* They are two in number for each vertebra, one on either side spring from the lateral aspect of the body or the lower part of the arch. These vary in size and shape in the different regions.
- *Spinous Processes (neural or superior spines):* They are single, projecting from the middle of the dorsal part of the neural arch. They vary greatly in size, form and direction in different vertebrae.
- *Ventral spinous processes:* These are also single and are situated on the ventral aspect of the bodies of the vertebrae.
- *Mamillary processes:* are those situated between the transverse and anterior articular processes or on the latter. *e.g*. lumbar vertebrae.
- *Accessory processes:* are situated between the transverse and posterior articular processes. *e.g*. lumbar vertebrae of dog.



Typical cervical vertebrae of the Fowl
(Ventral, Lateral and Caudal views)

1. Body	2. Neural arch	3. Vertebral foramen
4. Anterior articular surface	5.Caudal articular surface	6. Cranial articular process
7. Posterior articular process	8. Transverse process	9. Foramen transversarium
10. Spinous process	11. Ventral spinous process	12. Notch

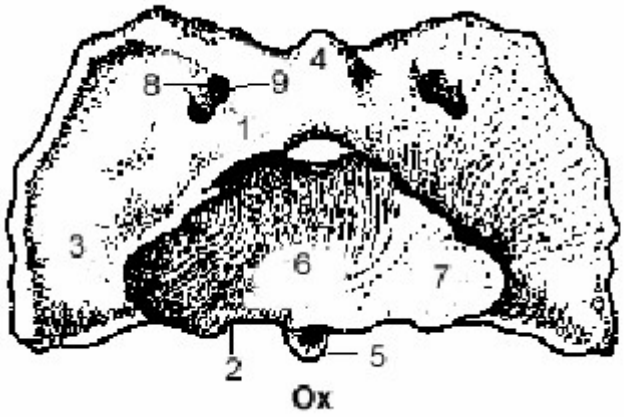
CERVICAL VERTEBRAE

- The cervical vertebrae form the skeleton of the neck. In the ox, horse and dog there are 7 cervical vertebrae.
- In all the animals including the fowl, the first and second cervical vertebrae named *atlas* and *axis* respectively and are *atypical vertebrae* .
- In the ox, horse and dog, the third, fourth and fifth cervical vertebrae are similar while the sixth and seventh, present some special features. The transverse process consists of two parts in the 3rd to the 6th vertebra, which in the 7th is undivided.
- In the fowl there are 14 cervical vertebrae. The third to 14th shows some special features when compared with the cervical vertebrae of mammals.
- The details of the following cervical vertebrae are given below:
    - Atlas
    - Axis
    - Third to seventh vertebrae

ATLAS
(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

This vertebra is atypical in form and structure.The body and spinous processes are absent. It has the form of a *ring* from which *two curved plates*, the *wings* project laterally.



Atlas ox
(Caudodorsal aspect)
1. Dorsal arch
2. Ventral arch
3. Alae / Wings
4. Dorsal tubercle
5. Ventral tubercle
6. Fovea dentis
7. Articular surface
8. Alar foramen
9. Intervertebral foramen

Ring

- The ring encloses a large vertebral foramen and consists of two lateral masses connected by dorsal and ventral arches.
- The lateral masses present two deep anterior articular cavities, which receive the occipital condyles; the cavities are partially divided into dorsal and ventral parts by a non- articular area and are separated by a narrow interval below.The posterior articular surfaces are confluent on the ventral arch, flattened behind and are continued into the vertebral canal forming an extensive area for the dens of the axis.
- The dorsal arch presents a median dorsal tuberosity and is concave ventrally. It is perforated on either side near its anterior margin by the intervertebral foramen, which is connected by a short groove -the alar groove, with another foramen-alar foramen, which perforates the wing. The anterior border of the dorsal arch is notched. The posterior is thin and shows a central and two lateral notches.

- The ventral arch is thicker and less curved than the dorsal. On its lower surface in the median plane is an obtuse eminence the ventral tubercle for the tendon of longus colli. The dorsal face has posteriorly a transversely flat articular surface the fovea dentis for the dens of the axis. In front of this a transverse rough area for the ligamentum dentis (odontoid ligament).

Wings

- The wings represent the transverse processes of the other vertebrae.
- Each is a horizontal plate of bone springing from the lateral aspect of the lateral masses and terminating outward in a rough thick edge. This edge furnishes attachment to the muscles of the head and neck.
- The dorsal surface is rough, between the ventral aspect of the wing and the lateral mass is a cavity - fossa atlantis. At the bottom of the fossa are two foramina, the anterior called alar foramen that perforates the wing and is for the passage of the ventral primary branch of the first spinal nerve and branches of vertebral vessels. The posterior foramen pierces the lateral mass and communicates with the spinal canal. The alar foramen is connected on the dorsal aspect by a short alar groove with the intervertebral foramen.

TOP

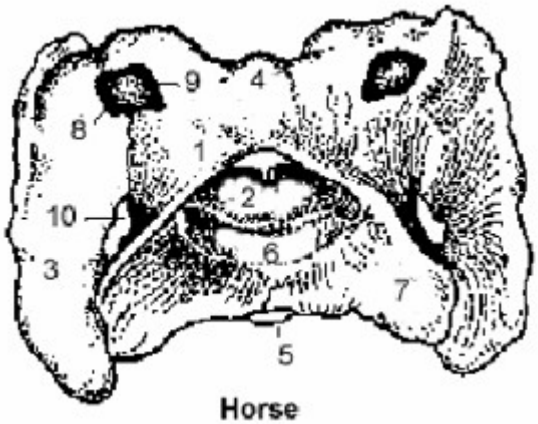
Sheep and Goat

- The atlas differs chiefly in that the prominence on the dorsal arch is much less developed.

TOP

Horse

- The wing slopes downwards and outwards
- Besides the alar and intervertebral foramina there is foramen transversarium at the posterior part of the wing.
- The posterior edge of the dorsal arch does not present the notches as in the ox.
- The posterior articular surfaces are saddle shaped.



Horse

Atlas-horse
(Caudodorsal aspect)
1. Dorsal arch
2. Ventral arch
3. Alae / Wings
4. Dorsal tubercle
5. Ventral tubercle
6. Fovea dentis
7. Articular surface
8. Alar foramen
9. Intervertebral foramen
10. Foramen transversarium

TOP

Pig

- The atlas has the large tuberosity.
- The wing is flattened and bears a posterior tuberosity.
- Foramen transversarium is small or absent.

TOP

Dog

- Ventral arch is narrower from before backward and bears a small tubercle posteriorly.
- Dorsal surface of dorsal arch is strongly convex and rough centrally.
- Wings are horizontal.
- An alar notch is present on the anterior border instead of alar foramen.
- Foramen transversarium is present.

TOP

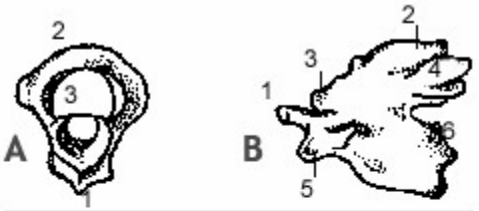
Rabbit

- Comparatively short.

TOP

Fowl

- It is ring like.
- The ventral arch presents anteriorly a concave articular area for the single occipital condyle.
- Posteriorly there are three facets for axis - one median on the ventral arch and two on the posterolateral aspects of the dorsal arch.



A. Atlas of Fowl (Cranial view)
1. Ventral arch with anterior articular process
2. Dorsal arch
3. Vertebral foramen

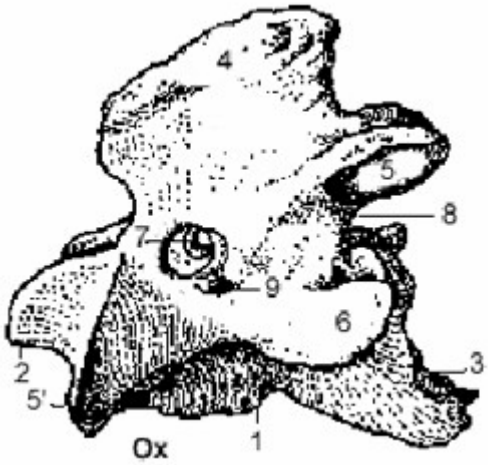
B. Axis of Fowl (Lateral view)
1. Dens
2. Spinous process
3&4. Anterior and posterior articular process
5. Anterior articular surface
6. Posterior articular surface

AXIS (EPISTROPHEUS)

(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

The axis is the longest of the vertebrae. Like the atlas, it is an atypical vertebra. It is also called vertebra dentata due to a tooth-like process called dens present on the anterior aspect of the centrum. The anterior articular processes are absent.



Axis -ox
(Lateral aspect)

1. Body
2. Dens
3. Posterior extremity
4. Spinous process
5. Posterior articular process
5'. Anterior articular Process
6. Transverse process
7. Intervertebral foramen
8. Notch on the posterior border
9 Foramen transversarium

- The body of the axis is the longest.
- The anterior end of the body presents centrally the dens or odontoid process.
- The dens represent the body of the atlas, which gets fused with the body of the axis during development.
- The process is spout-like, wide and has a convex articular surface below for articulation with the atlas.
- Its dorsal (superior) face is concave and rough for the attachment of the odontoid ligament (ligamentum dentis).
- The two surfaces are separated by a sharp convex edge, which may be notched in its centre. On each side of the root of this process, the anterior end of the body presents a nearly flat articular surface, which is continuous with on the ventral face of the dens and this articular area articulates with the posterior articular surface of the atlas. The posterior extremity the body presents the usual concavity for the anterior extremity of third cervical vertebra.The pedicles present the usual posterior notches but in the place of the anterior ones are large oval inter vertebral foramina for the exit of the second cervical spinal nerves.
- The anterior articular processes are absent and the posterior pair resembles those of the succeeding vertebrae.
- The transverse processes are small, undivided and project backwards.
- The foramen transversarium, when present, is in the form of an osseous canal passing through the root of the transverse process having anterior and posterior openings.
- The spine is a very large and strong process.Its summit is narrow in front but thickens and widens posteriorly and serves for the attachment of the lamellar portion of the ligamentum nuchae and muscles.
- The ventral spine is in the form of a ridge, becoming tuberculate at its posterior end.

TOP

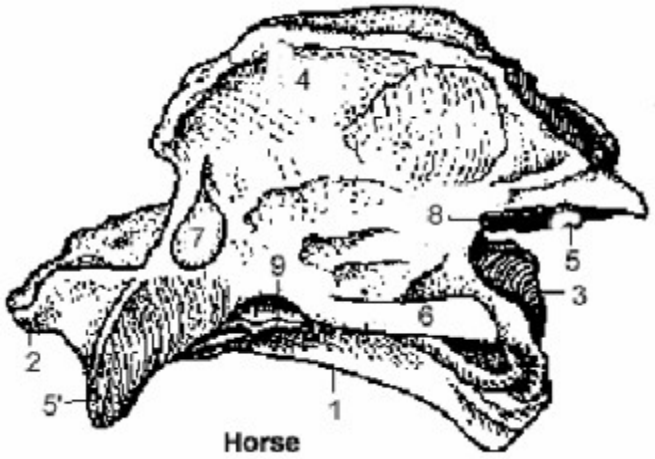
Sheep and Goat

- The spinous process of the axis is not enlarged posteriorly.

TOP

Horse

- The body is larger.
- The dens is longer narrower and more pointer (conical).
- The anterior extremity presents an undulating saddle-shaped articular area.
- The spine is more massive and divides posteriorly into two ridges, which terminate on the posterior articular processes.
- The transverse process is thinner.



Axis -Horse
(Lateral aspect)

1. Body
2. Dens
3. Posterior extremity
4. Spinous process
5. Posterior articular process

5'. Anterior articular Process

6. Transverse process
7. Intervertebral foramen
8. Notch on the posterior border

9 Foramen transversarium

TOP

Pig

- The dens is in the form of a thick cylindrical rod.
- The axis has a large spinous process directed upward and backward.

TOP

Dog

- The dens is rounded very long and reaches almost to the occipital bones.
- The anterior articular area, which flanks the dens, are condyloid and very oblique.
- The spine is of great size and it overhangs the dorsal arch of atlas.
- The anterior notches are large and are never converted into foramina.

TOP

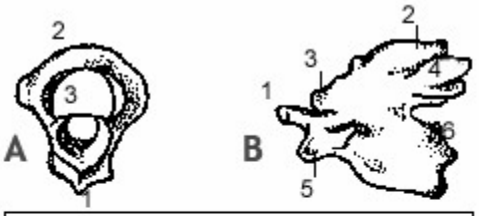
Rabbit

- Comparatively short.

TOP

Fowl

- The anterior articular processes are present and they articulate with the facets on the posterior aspects of the dorsal arch of atlas.
- The body presents below the dens a concave articular area for articulation with the ventral arch of atlas.
- The dens articulate with the occipital condyle.
- The dorsal and ventral spines are present.
- The transverse processes are absent.



A. Atlas of Fowl (Cranial view)
1. Ventral arch with anterior articular process
2. Dorsal arch
3. Vertebral foramen

B. Axis of Fowl (Lateral view)
1. Dens
2. Spinous process
3&4. Anterior and posterior articular process
5. Anterior articular surface
6. Posterior articular surface

THIRD TO SEVENTH CERVICAL VERTEBRAE
(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

- The bodies of these vertebrae are long. But the length decreases from 3rd to 7th.
- The ventral surface presents a median ventral spinous process, which is in the form of a sharp ridge becoming less prominent as it is traced behind and is tuberculate at its posterior end in the 3rd to 5th.
- The dorsal surface is flat for the attachment of the dorsal longitudinal ligament.
- The marked concavity and convexity of the ends of the bodies of vertebrae is a characteristic feature of this region.
- The facets on the *articular processes* are very large.A continuous plate of bone connects and anterior and posterior articular processes of the same side in the vertebra.
- The root of *transverse process* is perforated by the foramen transversarium except in the 7th.
- The aggregate of these foramina form the *canalis transversarius* for the passage of the vertebral vessels and nerve,hence called *Nervus transversarius.*

- Each transverse process divides into upper and lower parts, which are rough for muscular attachment.
- The *spinous process* is in the form of a low thick rod, which is directed upward and forwards.
- These spines gradually increase in height from third to the fifth. The spine of the third is often bifid at the summit.

Sixth cervical vertebra

- It presents the following distinctive features
- The body is the shorter and wider.
- The lower division of the transverse process is more developed and plate like and extends considerably below and behind the level of the body.
- The dorsal spine is longer than in the fifth.
- The ventral spine is absent.

Seventh Cervical vertebra

- The following character distinguishes this vertebra from the others.
- The body is the shortest of all the cervicals.
- The transverse process is single and undivided and foramen transversarium is absent.
- The spine is very well developed and inclines gently forwards and is a prominent plate of bone and hence the vertebra is also termed as *vertebra prominence*.
- On either side of the posterior end of body is a semicircular concave *costal (capitular)* facet which with a similar one on the anterior aspect of the first dorsal vertebra forms a cup-shaped *capitular cavity* for the head of the first rib.
- The ventral spine is absent.

TOP

Sheep and Goat

- The cervical vertebra is relatively longer than those of Ox.
- A central ridge separates the anterior articular processes.
- The ventral spines are rudimentary.

TOP

Horse

Third, fourth and fifth cervical vertebrae

- A continuous plate of bone unites the anterior and posterior oblique processes in the fifth but this plate extends only three-fourths the distance forwards from the posterior articular process in the fourth and only half way in the third.
- The spines are less developed.
- The articular processes are better developed.
- The transverse processes are bifid showing anterior and posterior division.

Sixth cervical

- The transverse process is trifid, the third part is plate like and spine back extends below the body.

Seventh cervical

- The spine is a flattened triangular process and much smaller than that of the ox.
- The body is larger.

TOP

Pig

- The cervical vertebra are short and wide.
- The bodies are elliptical in cross section.
- The ventral spinous process is absent.
- The pedicles are perforated by a foramen in addition to the intervertebral foramen.
- The transverse process is divided into two divisions from third to sixth.
- The spines increases in height from third to last and the last is the tallest.
- Usually two intervertebral foramen in each side of the arch.

TOP

Dog

- *The third, fourth and fifth cervicals:* The bodies are relatively longer and are compressed dorso-ventrally.
- The *sixth cervical:* The lower plate like division of the transverse process is extensive and is ridged on its medial face.

TOP

Rabbit

- Cervical vertebra is seven in number.

TOP

Fowl

Third to Fourteenth cervical vertebrae:

- The bodies of these vertebrae are rod like.
- The anterior extremity of each vertebra is concave from side to side and convex from above downward and the posterior extremity presents the reverse condition i.e. convex from side to side and concave from above downwards, which admits a great degree of movement in this region.
- The transverse processes arise from under the anterior articular process and are prolonged behind by *spicules of bone* - the *styloid process*. The latter represent *cervical ribs*.
- Foramen transversarium is present. No facets for the head of the first rib are present on the body of fourteenth.

THORACIC VERTEBRAE

(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

- They are 13 in number and the characteristic features of these vertebrae are the great development of neural spines, the presence of capitular facets on the body and tubercular facets on the transverse processes for articulation with the ribs.
- The bodies are shorter. On the sides of the articular ends of the body both before and behind are concave articular facets -the costal or capitular facets which with those of the adjacent vertebrae and the intervertebral disc form capitular or costal cavities for articulation with the heads of ribs. The anterior notches of the pedicle are shallower and the posterior ones are converted into foramina in the posterior series.
- The articular processes are small.The anterior ones are represented by small oval facets on the anterior part of the arch except in the first one where they surmount the transverse processes. The posterior ones spring from the base of the spinous process.
- The transverse processes though prominent do not always articulate with ribs.
- The spinous process is very long and of enormous size, which is characteristic of the vertebrae of this region. Each is a flattened plate, which serves for the attachment of the spinal muscles and ligaments.

Special Features:

- The anterior vertebrae in the series bear rounded mammillary processes.
- The spine of the first is very long and is usually pointed. The spines of the next two are the longest and behind these they gradually diminish in height. The backward slope, which is at first, slight and then increase to the tenth. The last dorsal has a vertical spine.
- The tubercular facets gradually decrease in size from before backwards.
- The last dorsal has no posterior capitular facets.

TOP

Sheep and Goat

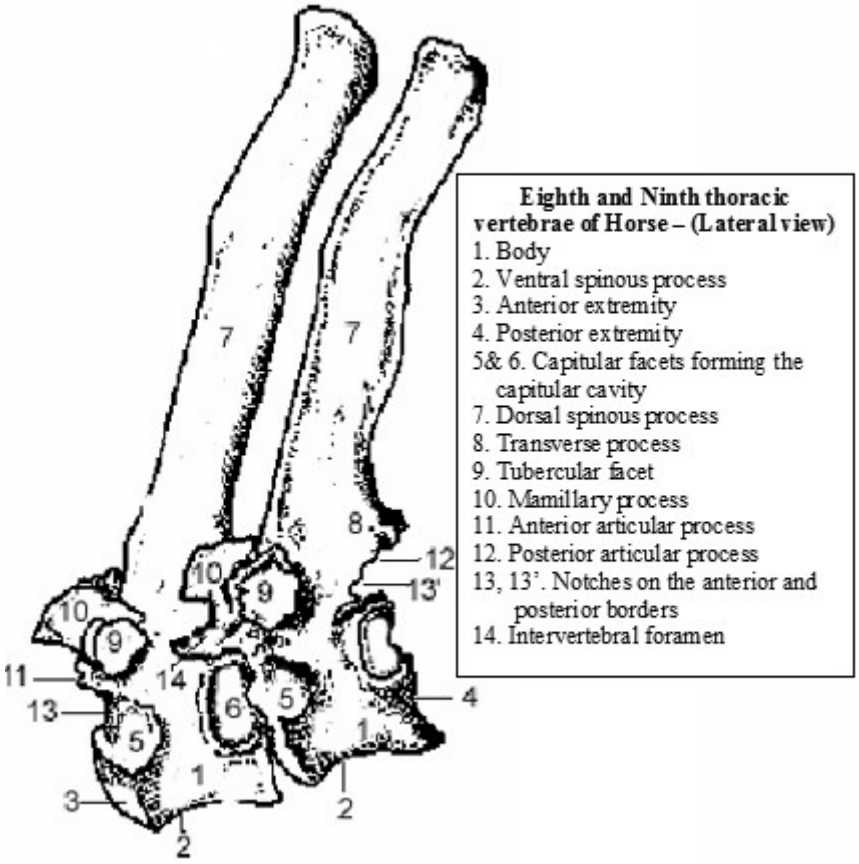
- They are usually 13 in number.
- The bodies are relatively wider and less constricted than those of the ox.
- The intervertebral foramina are relatively larger in correlation with the absence of foramen, which usually occur in the arches of these vertebras in ox.

TOP

Horse

- They are 18 in number.
- The bodies are shorter.
- The spine of the first is shorter and curved backward.
- The spinous processes increase in length to the third and fourth, then gradually diminish to the fifteenth beyond which they are about the same in height.

- The backward inclination of the superior spine is most pronounced in the second, the sixteenth is vertical and those of the last two are directed slightly forwards.
- The last four or five show a distinct mammillary process.



Eighth and Ninth thoracic vertebrae of Horse – (Lateral view)
1. Body
2. Ventral spinous process
3. Anterior extremity
4. Posterior extremity
5& 6. Capitular facets forming the capitular cavity
7. Dorsal spinous process
8. Transverse process
9. Tubercular facet
10. Mamillary process
11. Anterior articular process
12. Posterior articular process
13, 13'. Notches on the anterior and posterior borders
14. Intervertebral foramen

TOP

Pig

- The bodies are relatively long and constricted in the middle.
- The ventral spine is absent.
- Mamillary process is present except in the first two.
- The last transverse process is lumbar in character.
- Small accessory process occurs in the posterior part of the region.

TOP

Dog

- The bodies are wider and compressed dorso-ventrally.
- The transverse processes in the posterior of the series bear mamillary processes and in the last three accessory processes also.

- The posterior facets on the bodies for the heads of the ribs are absent on the last two or three, so that the head of each of the last three ribs articulates with only one corresponding centrum.

TOP

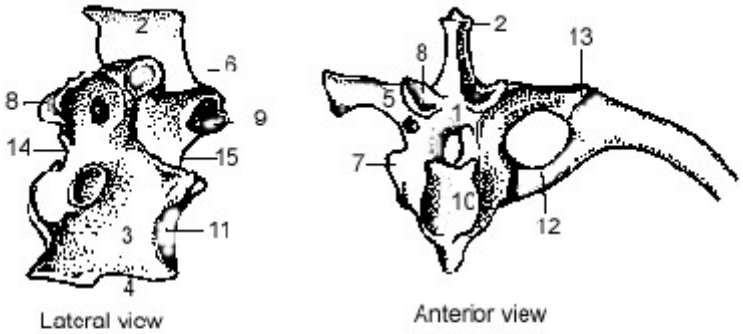
Rabbit

- 12 in number.

TOP

Fowl

- They are seven in number.
- The first and the sixth are free, second to the fifth are fused into one piece. The seventh is fused to the lumbo-sacral segment.
- Each vertebra presents a complete capitular cavity for the corresponding rib.
- The superior and inferior spines are well developed and are fused from the second to the fourth.
- The transverse processes are plate like and present tubercular facets, at their free ends. Thin plates of bone fill the gaps between the transverse processes.



Thoracic vertebrae of fowl (Lateral and Anterior view)

1. Neural arch	2. Spinous process	3. Body
4. Ventral crest	5. Transverse process	6. Tubercular facet
7. Capitular cavity	8. Anterior articular process	9. Posterior articular process
10. Anterior extremity	11. Posterior extremity	12. Head of rib
13. Tubercle of rib	14& 15. Anterior and posterior vertebral notches	

LUMBAR VERTEBRAE
(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

The lumbar vertebrae are six in number and are characterized by greatly *elongated transverse processes* and *strongly curved articular processes.*

Body

- The body is constricted in the middle, expanded at the extremities and much compressed from above downwards.
- The anterior extremity is less convex and the posterior less concave.
- The arches of the first three are about equal in size and similar to the last dorsal but behind, they gradually increase in breadth and height.
- The posterior notches are much deeper.
- The intervertebral foramina are often double in the anterior and are very-large further back.

Processes

- The articular processes are large.
- They are placed a little further apart and are strongly curved.
- The anterior articular processes are concave, directed medially and show the mammillary processes on their lateral aspect.
- The posterior articular processes are convex, directed outwards and project from the arch at the base of the superior spine.
- The transverse processes are elongated plates flattened from above downwards and project outwards at right angles to the body.
- The processes are all directed forwards. They are shortest in the first and the length gradually increases to the fifth and in the sixth they are shorter than those of the fifth. The inter-transverse spaces on either side are filled up by the inter transversales lumborum muscles in life.
- The spines are broad flattened plates, resemble the last thoracic and are of the same height as the last dorsal. That of the last is the narrowest of all.
- The ventral spines are rudimentary and afford attachment to the ventral longitudinal ligament.

TOP

Sheep and Goat

- Six or seven in number. In some cases there is an ambiguous vertebra at the junction of the thoracic and lumbar region.
- The anterior articular processes are strongly curved and overlap the posterior ones.
- The transverse processes curve forward and have expanded ends.

TOP

Horse

- They are six in number.
- The bodies are shorter.
- The first three have a distinct ventral spine, which subsides thereafter.
- The transverse process increases in length from the first to third or fourth and then diminishes. The first one or two slightly curve backwards and the last two or three curve forward and the third is at right angles.
- The posterior border of the transverse processes of the fifth at its medial part has an oval concave facet, which articulates with a convex facet on the anterior border of the sixth transverse process. Sometimes the fifth has small facet for the fourth also.
- The sixth transverse processes are thick at the base and thin and narrow elsewhere and curve forwards. It articulates by a large concave facet on its posterior border with corresponding facet of the sacrum.

TOP

Pig

- Six or seven in number.
- The bodies are longer and bear a ventral crest.
- The arches are deeply notched and are separated by an increasing space dorsally.
- The mamillary process project outward and backward.
- Transverse processes will not articulate with each other or with sacrum.
- The posterior edge of the root of the transverse process is marked by a notch in the anterior series and a foramen in the posterior part.
- The dorsal spines are broad and incline forward except the last, which is narrow and vertical.

TOP

Dog

- They are seven in number.
- Their bodies increase in width from first to last.
- The transverse processes are plate-like and are directed forward and downward. They do not form any joints with each other or with sacrum as in the horse.
- Accessory and mamillary processes are present.
- Spinous processes incline a little forward.

TOP

Rabbit

- They are seven in number.
- The transverse processes are long, projected anteriorly.

TOP

Fowl

- The lumbar and sacrum are fused and called as lumbosacrals.
- They are fourteen in number and these with the seventh dorsal and the first coccygeal-altogether 16 - are fused into one mass called synsacrum. This forms a rhomboid mass included between the two pelvic bones.
- The spines form a crest in the anterior third but absent posteriorly.
- The transverse ridges on the ventral face indicate the positions of the transverse processes. The extremities of all the transverse processes fuse with the medial border of the ilium.

MODULE-10: AXIAL SKELETON - SACRUM COCCYGEAL VERTEBRAE, RIBS AND STERNUM

Learning outcomes

At the end of this module, the learner will be able to know about

- sacrum
- coccygeal vertebrae
- ribs and
- sternum

SACRUM
(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

The sacrum is formed by the fusion of five sacral vertebrae. It is triangular in form and is wedged in between the ilia with which it articulates on each side.Its long axis is strongly curved and it presents two surfaces, two borders, a base and an apex.

- The dorsal surface is widest in front and shows along its median line a crest -the median sacral crest, which is formed by the fusion of spinous processes of the five sacral vertebrae. The summit of this crest is rough and tuberous. On either side of this crest is another crest -the lateral sacral crest, which results from the fusion of articular processes. The dorsal surface shows four dorsal sacral foramina for the passage of the dorsal primary branches of the sacral spinal nerves.
- The ventral surface is arched and forms the roof of the pelvis. This surface is marked centrally by a faint longitudinal groove for the middle sacral artery and also by four transverse lines, which indicate the lines of fusion of the bodies of the sacral vertebrae. There are four large ventral sacral foramina at the ends of the transverse lines on either side for the ventral primary branches of the sacral spinal nerves.
- The lateral borders are thin, concave and serve for the attachment of the sacro-sciatic ligament.
- The base or anterior extremity of the sacrum is infact the anterior end of the first sacral vertebrae. It shows centrally the body of the first sacral segment, which is wide flattened from above downwards and is elongated transversely. It articulates with the posterior end of the body of the sixth lumbar vertebra and the ventral margin projects slightly forming the promontory. The edge of the pedicles shows the usual anterior notches, which with the posterior notches of the last lumbar from the intervertebral foramina for the sixth lumbar spinal nerves. The anterior part of the sacral (vertebral) canal is triangular with its angles rounded off. Traced backward, its size diminishes and the posterior opening is small and triangular. On either side of the arch and above the notches are the anterior articular processes, which are very large and widely separated.
- The lateral parts of the base are the alae or wings. Each wing is quadrilateral compressed plate directed downwards and forwards. The anterior face is extensive, concave from side to side and non-articular. The posterior face is rough and in its lower part there is a triangular area -the articular surface for articulation with the ilium.
- The apex or posterior extremity of the sacrum is the posterior end of the fifth sacral vertebra. Centrally, it presents a small triangular neural ring and the posterior notches. Above these is the posterior extremity of the median sacral crest. Placed below the neural ring is the centrum of the last sacral segment, which is flat.

TOP

Sheep and Goat

- Consists of four segments ordinarily but the last vertebra may remain separate or undergo partial fusion.

- There is no vascular groove on the ventral surface.
- The dorsal spines are not fused with the exception of the first two.
- The transverse process of the last segment is distinct.

TOP

Horse

- The sacrum presents five separate dorsal spines, the bases of which are fused in old animals.
- On either side of the bases of the spines is a groove in which are the four dorsal foramina.
- The ventral surface is not so deeply arched as in the ox.
- The wings are prismatic with pointed ends. Each has a large oval convex facet in front, which articulates, with the facet on the posterior border of the transverse process of the last lumbar vertebra.

TOP

Pig

- Usually four vertebra.
- Fuse in the later part of the life.
- The spines are little developed.
- The anterior articular processes are very large.

TOP

Dog

- It is formed by three segments and is short wide and quadrangular
- The articular processes are vestigial and are represented on the side of the median crest as a pair of tubercles and lateral to these are the two dorsal sacral foramina.
- The pelvic face is deeply concave and presents two ventral sacral foramina.
- Wings are prismatic and very high. Their lateral faces are extensive, face almost directly inward and bear an auricular surface on the lower part.
- Promontory is distinct.
- The transverse processes of the last segment project backward and may articulate or fuse with those of the first coccygeal
- Spinal canal is compressed dorso-ventrally.

TOP

Rabbit

- It is a single bone in the adult animal formed by the fusion of four vertebra.
- The articulation with the pelvic girdle is primarily on the transverse process of the first sacral vertebra.

TOP

Fowl

- The lumbar and sacrum are fused and called as l umbosacrals.
- They are fourteen in number and these with the seventh dorsal and the first coccygeal -altogether 16 - are fused into one mass called synsacrum. This forms a rhomboid mass included between the two pelvic bones.
- The spines form a crest in the anterior third but absent posteriorly.
- The transverse ridges on the ventral face indicate the positions of the transverse processes. The extremities of all the transverse processes fuse with the medial border of the ilium.

COCCYGEAL VERTEBRAE

(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

- The coccygeal vertebrae vary considerably in number from 18 to 20.
- These gradually diminish in size from the first to the last.
- The first five or six are typical vertebrae but beyond the sixth the processes and the arches get gradually suppressed so that the posterior ones are made up of bodies only.
- The transverse processes are relatively large.
- The ventral surface presents a pair of processes -the *haemal processes* and between these is a groove – the *sulcus vasculosus* for the middle coccygeal artery.
- The articular processes do not carry facets.
- The arch disappears from the sixth backwards and the rudiments of the transverse processes disappear after the 9th or 10th.

TOP

Sheep and Goat

- Vary in number from three (in short tailed sheep) to twenty-four or more. No haemal process on the ventral surfce.

TOP

Horse

- 15-21 in number, An average is 18.
- The laminae fail to meet dorsally after the fourth so that the neural arch is incomplete.

TOP

Pig

- It is characterized by the presence of functional articular processes on the first four or five beyond which these become non-articular and smaller.
- The arches of the first four or five are complete.
- Fusion of the first coccygeal vertebra with the sacrum is not uncommon.

TOP

Dog

- 20 to 23 in number.
- Neural rings are present in the first six.
- The first three or four have articular processes which form joints.
- *Haemal arches* or *chevron bones* in the form of a V or Y occur ventrally at the inter-central junctions of the third, fourth and fifth usually.

TOP

Rabbit

- They are 16 in number.
- Neural arch is complete in the first seven vertebra.

TOP

Fowl

- They are seven in number. The first one is fused, with the lumbo-sacrals.The last is a three-sided pyramid called *pygostyle,* which results from the fusion of three or four vertebrae in the embryo and forms a foundation for the feathers of the tail and coccygeal glands. Its apex projects upward and backward
- The intermediate ones are typical vertebrae.
- The transverse processes of these are well developed and the spines are bifurcated.

VERTEBRAL COLUMN AS WHOLE

Curve

- The curve of the column is slight and concave above in the cervical region whereas in the dorsal and lumbar regions the curve is gently concave below and in the sacral region it is strongly convex above.
- The curvature varies in the coccygeal region.

Vertebral (Neural) canal

- The caliber is greatest in the atlas.
- It is reduced in the axis but becomes wider at the cervico-dorsal junction. From here it is once again reduced to about the terminal part of the dorsal region.
- It increases again in the lumbar region to about the middle of the sacrum. It thereafter diminishes and disappears altogether by about the fifth or sixth coccygeal.

Processes

- The *articular processes* are best developed in the cervical region. They are smaller in the dorsal region but again become larger and strongly curved in the lumbar region.

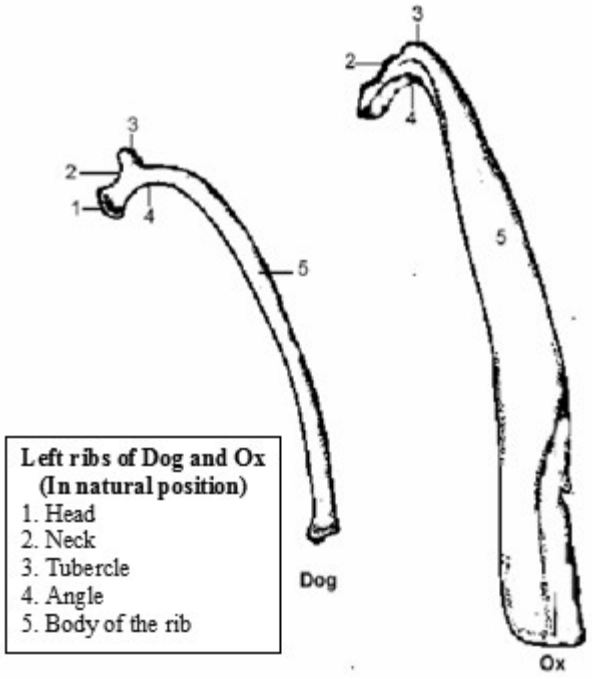
- The *spines* are best developed in the dorsal region. In the lumbar and sacral regions they are shorter but plate like. In the cervical region, they are shorter.
- The *ventral spines* are best developed in the cervical region.
- The *transverse processes* are large and plate like in the lumbar, thick and short in the dorsal but larger in the cervical region.

RIBS

(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

- The ribs are elongated curved bones, which form the skeleton of the lateral thoracic walls.
- They are arranged serially in pairs, which correspond in number to the thoracic vertebrae. Thus there are thirteen pairs of ribs.
- Each rib articulates dorsally with two vertebrae and is continued ventrally by a costal cartilage. Those that articulate with the sternum by means of their cartilage, (eight pairs) are termed sternal ribs; the remainder is asternal ribs.
- Ribs at the end of the series with free ventral ends not attached to adjacent cartilage are floating ribs.The intervals between ribs are intercostal spaces.
- A typical rib is an elongated, flat curved plate. It presents a shaft and two extremities.



Left ribs of Dog and Ox (In natural position)
1. Head
2. Neck
3. Tubercle
4. Angle
5. Body of the rib

Shaft

- The shaft is most curved at its upper part while its lower part is twisted and inclines inwards.

- The lateral surface is convex and is marked by a wide groove in its anterior part.The point at which a rib most curved is termed the angle and here it presents a rough area for the attachment of the longissimus dorsi muscle.
- The medial surface is smooth, concave and presents at its posterior part a distinct groove -the costal groove which turns downwards and disappears about the middle of the bone and lodges the intercostal vein.
- The borders serve for the attachment of the intercostal muscles.

Upper extremity

- The upper vertebral extremity is made up of a head, neck and a tubercle.
- The head presents an articular area which is composed of two convex facets -anterior and posterior, separated by a non-articular groove. The facets articulate with the capitular facets of two adjacent dorsal vertebrae and the intervertebral fibrocartilage between them and the groove serves for the attachment of the round conjugal ligament.
- The neck joints the head to the shaft and is roughened above and in front for ligamentous attachment.
- The tubercle is situated above and behind the head at the junction of the head and neck. Dorsally it presents a transversely placed concave facet for articulation with a tubercular facet of the posterior vertebra of the two with which the head articulates.
- The tubercular facet is small, flat or absent in the last two or three ribs.

Lower extremity

- The lower sternal extremity is smooth and articulate with its costal cartilage.
- The ventral ends of the second to the tenth or eleventh inclusive form diarthrodial joint (movable) with their cartilages.

Special Features

- The first rib is the shortest and least curved.The sternal end widens very greatly.The lateral surface and the anterior border present a rough area about their middle for the scalenus ventralis. At the lower part of anterior border is a smooth impression left by the dorsal roots of the brachial plexus.The groove on the lateral surface and the costal groove are absent.The head is divided by an oblique ridge into the two facets. The tubercle is larger than that of any other rib.
- The eighth, ninth and tenth ribs are the longest and widest. Both in front and behind these, the length and breadth diminish gradually. The first costal cartilage is the shortest.
- The costal cartilages are rods of hyaline cartilage and form diarthrodial joints with ribs (from) -2nd to tenth or eleventh). Those of sternal ribs articulate with the sternum by sternal cartilages. Those of asternal ribs overlap and are attached to each other by elastic tissue to form the costal arch. Except in the case of the first the cartilage does not continue the rib but forms with the later an angle, which is open in front and increases from the second to the last.

TOP

Sheep and Goat

- There are 13 pairs of ribs but the occurrence of 14 pair is common.
- The 13 th rib is often floating. 14 th rib when present is floating.
- The ribs are narrower and strongly curved in the anterior part of the series.
- The second to eleventh form diarthrodial joints with their cartilage.
- The 13 th rib may be more or less rudimentary on one side or both, may be fused with the corresponding vertebra, the latter therefore be ambiguous in character.

TOP

Horse

- There are 18 pairs of ribs. 8 sternal and 10 asternal, they are shorter, narrower, thicker, regular and more curved.
- The neck is shorter.
- The length increases upto the 10th and then diminishes.
- The anterior borders of the ribs from the 2nd to 8th are sharp and from 9th to 18th rounded and thick.
- The lower ends of ribs are s lightly enlarged and roughened at the junction with the costal cartilage.
- In regard to dorso-ventral direction, the first rib inclines a little forward the second is about vertical and others slope backwards in increasing degree.
- The two first costal cartilage articulate with each other and with sternum.
- The upper ends of cartilages form synarthrodial joints (immovable) with ribs.

TOP

Pig

- There are 14 or 15 pairs of ribs. Of which 7 are sternal and seven or eight are asternal.
- They are strongly curved with a distinct angle.
- The backward slope of the posterior rib is slight.
- The first rib is prismatic, has a large sternal end and a very short cartilage.
- The tubercle fuses with the head on the last five or six.
- The second to fifth form diarthrodial joints with their cartilages, which are wide and plate-like.
- The 15 th rib when present, may be fully developed and its cartilage enter into the formation of the costal arch.
- But in most cases it is floating and in some cases it is only about an inch in length.

TOP

Dog

- There are 13 pairs of ribs. 9 sternal and 4 asternal.
- They are strongly curved narrow and thick.
- The last rib is usually floating.
- The heads of the last two or three ribs articulate with only one vertebra.
- The costal cartilages are long and curve ventrally and forward. The length and curvature of the first pair are striking special features.

TOP

Rabbit

- There are 12 pairs in number. Of which 7 sternal and 5 asternal.
- Last pair is floating.

TOP

Fowl

- There are 7 pairs of ribs.
- Each rib is made up of an upper vertebral rib and a lower sternal rib.
- The first, second and sometimes seventh do not have sternal ribs: These are floating.
- The head of a rib articulates with the capitular cavity of a single dorsal vertebra.
- Except the first and seventh, the posterior border of each vertebral rib presents an uncinate process directed backward to overlap the succeeding rib.
- Sternal ribs are homologues of mammalian costal cartilage.

STERNUM OR BREAST - BONE
(Ox, Sheep and Goat, Horse, Pig, Dog, Rabbit, Fowl)

Ox

The sternum is a medially placed-segmented bone, forming the floor of the thorax.It is made up of the seven bony segments,sternebrae and is elongated from before backwards.The segments are connected by intervening cartilages. It is compressed laterally till about its middle and thereafter it is flattened from above downwards.It is directed obliquely downwards and backwards.

- It presents two surfaces, two borders and two extremities.
- The dorsal face is narrow in front but becomes gradually wider behind. This face gives attachment to the internal ligament in the middle and transverses thoracis muscle laterally.It forms the floor of the thorax.
- The ventral face is extensive and is strongly convex in front but more or less concave behind the second sternebrae.The surface affords attachments to the pectoral muscles and the recti abdominis muscles. The two surfaces are marked by transverse lines indicating the lines of fusion of the sternebrae.
- The lateral borders are thick in front but become thinner gradually behind.
- Each border presents eight articular cavities for articulation with the ventral extremities of the first eight costal cartilages.The first of these is on the anterior part of the dorso-lateral aspect of the first sternebrae. Excepting the first and the last two, the other cavities are between the sternebrae. The facets for the seventh and eighth costal cartilages often become confluent.
- The anterior extremity is the anterior end of the first sternebrae, which forms the manubrium sterni or presternum.The posterior end of this segment articulates with the anterior end of the second sternebrae to form a diarthrodial joint.The anterior extremity furnishes attachment to the sternocephalicus and sternothyro-hyoideus muscle.
- The posterior extremity or metasternum is formed by the xiphoid cartilage, which is thin, flexible and nearly circular. Between the pre and metasternum is the body or mesosternum.
- The diaphragm is attached across the upper concave face of xiphoid cartilage close to its junction with the last sternebrae.The part of the cartilage behind the line of attachment of the diaphragm forms the floor of the abdomen.The ventral face furnishes attachment to the transverse abdominis and linea alba.

TOP

Sheep and Goat

- Resembles in general that of ox.
- The number of segments may be reduced to six.
- The first segment is cylindrical with enlarged ends. The second and third are wide and flat.
- The last is long and narrow.

TOP

Horse

- It is composed of seven sternebrae.
- It is canoe or boat shaped and presents three surfaces, three borders and two extremities.
- The superior surface is narrow and triangular.
- The two lateral surfaces are convex above, slightly concave below and present costal cavities on their upper parts.
- The dorsolateral borders separate the dorsal and lateral surfaces.
- The inferior border is the keel.
- The anterior extremity presents a laterally compressed cariniform cartilage, which presents a deep notch superiorly for articulation with the two first costal cartilages
- The first sternebrae is fused with the second
- The manubrium is made up of the cariniform cartilage and the first sternebrae.

TOP

Pig

- The sternum consists of six segments and resembles that of Ox in general.
- The first segment is long and bears a blunt pointed cartilage at its anterior end, its posterior end forms a diarthrodial joint with the body.
- The last segment has a long, narrow part, which bears the xiphoid cartilage.

TOP

Dog

- The sternum is composed of eight sternebrae - all fused.
- Each sternebrae slightly compressed from side and constricted in its middle
- The anterior end bears a small presternal cartilage.
- The xiphoid cartilage is narrow.

TOP

Rabbit

- There are 6 sternebrae.
- Body of the sternum extends from 2 nd to 5 th sternebra.
- Xiphisternum is the last sternebra formed from the bony xiphoid process and the terminal spatulae - xiphoid cartilage.

TOP

Fowl

- The sternum differs from the corresponding structure of domestic mammals since it is formed entirely of bone in the adult. It results from the fusion of five pieces, which have separate centres of ossification in the chick.
- The central wide part forms the body of the bone. In front of this is the anterior process -the rostrum or manubrium and behind is the posterior process or metasternum.
- The dorsal surface of the body is concave and pierced by foramina, which permit air to enter the interior from the adjacent air sac. The ventral surface is encroached upon by the lower borders of anterior and posterior processes.
- The anterior process or rostrum is short and on either side of its root is an elongated facet for articulation with the coracoid bone.
- The posterior process or metasternum is very long being in fact more extensive than the body itself. It carries ventrally, a thin plate of bone called the keel or sternal crest, which affords attachment to the pectoral muscles.
- The keel is broad in front and fades out posteriorly. United to each lateral border of the body are the antero-lateral or costal process in front and the postero lateral process behind. The costal process projects upwards and forward. The postero-lateral process is short and divides into a medial and lateral xiphoid processes. The lateral division is broad, plate-like and covers the l ast two or three ribs. The medial division is longer and projects backward parallel to the lateral border of the metasternum. The deep notches between them and between the posterior division and metasternum are closed in life by tough membrane. Between the antero-lateral and postero-lateral process, the lateral border of the body shows four depressions for articulation with the third, fourth, fifth and sixth ribs. Occasionally the last rib also meets the sternum.

THORAX

Ox

- The thoracic cavity is the anterior of the three visceral cavities.
- It is compressed laterally and is narrow in front and wide behind.
- The *roof* is formed by the bodies of the dorsal vertebrae.
- The *lateral walls* are formed by the ribs and their cartilages.
- The *base* slopes obliquely downwards and forwards and is bounded superiorly by the last dorsal, inferiorly by the last sternebra and laterally by the last ribs and their cartilages.
- The *thoracic inlet* is oval and limited above by the first dorsal vertebra below by the first sternebra, and laterally by the two first ribs. In life, the inlet is closed by a number of structures, which enter and leave the thorax while the base is closed by the diaphragm.
- The intercostal muscles fill up the intercostal spaces between the ribs.

Sheep and Goat

- As in ox

Horse

- It is very much compressed laterally.
- It is longer than in ox.

Pig

- Relatively wide.

Dog

- It is barrel-shaped.

Rabbit

- It is short.

Fowl

- The thoracic cavity is continuous with abdominal cavity and relatively wide.

SKULL

- The bones of the skull are divided into cranial and facial groups.The former enter into the formation of the cranium,which lodges the brain and the essential organs of hearing while the latter form the boundaries of the oral and nasal cavities and also support the pharynx, larynx and tongue. The two sets together form the orbits.Some of the bones are also forming sinuses and they are called as paranasal sinuses.

- The *cranial bones* are parietal, interparietal, occipital, sphenoid, ethmoid, temporal and frontal. Of these, occipital, sphenoid, ethmoid are unpaired.
- The *Facial bones* are nasal, premaxilla, maxilla, palatine, pterygoid, lacrimal, malar, turbinates, vomer, mandible and hyoid.
- Most of the bones of the skull are flat bones developed in membrane. Those of the cranial base may be classified as irregular and are developed in cartilage. Occipital, sphenoid, ethmoid, petro-mastoid parts of temporal and turbinates develop in cartilage. Others develop in membrane.
- *Wormian* or *Sutural bones* are small irregular bones situated in the sutures of the cranial bones. They are developed after birth in the cranial, cranio-facial and facial sutures. Their number and position varies with the species of animals and even in the breeds of the same species.
- Cranial wormian bones are rare. When seen, they are at the junction of the petrous-temporal with the occipital bone. The wormian bones of the cranio-facial and facial sutures are more frequent. They are more particularly met with in the bovine species in the fronto-nasal, internasal, lacrymo-nasal, zygomatico-maxillary, orbital and maxillo-nasal incisive sutures.
- Skull of the pig and skull of the rabbit are described separately for the convenience.

CRANIAL BONES

The *cranial bones* form the cranial cavity which lodges the brain with its meninges,vessels and essential organ of hearing. They are named as follows:

- Parietal
- Interparietal
- Occipital
- Sphenoid
- Ethmoid
- Temporal
- Frontal

Of these, occipital, sphenoid, ethmoid are unpaired.

PARIETAL BONE

Ox

- They are placed on the posterior and lateral aspects of the cranium.
- They are fused to each other and with the inter-parietal and squamous part of occipital before birth.
- Each is made up of a posterior part and a lateral part.
- The posterior parts of the two sides form the posterior wall of the temporal fossa.
- The junction of the two parts is marked by a prominent parietal crest which is continuous with the temporal crest below and with the frontal crest anteriorly.
- The frontal sinus extends into the parietals.

Horse

- They are located on the dorsal aspect of the skull and form the roof of the cranium.
- The external parietal crest is median in position above but bifurcates below to join the frontal crest on either side.
- The internal face presents along its internal border, inter-parietal crest.
- The posterior border meets the occipital and curves inward and with the temporal forms the parieto-temporal canal. It is not excavated to form frontal sinus.

Dog

- It is rhomboid in outline and is located as in the horse.
- It is extensive and form the greater part of the roof of the cranial cavity.

Fowl

- It is situated on the posterior part of the skull and forms part of the roof of the cranium.
- It is included between the supra-occipital, frontal and temporal.

INTERPARIETAL BONE

Ox

- It is single bone located in the postero-superior part of the cranium.
- It is paired in the fetus; wedged in between the parietals above and the supra-occipital below and is fused with these bones before or shortly after birth.
- The frontal sinus is prolonged into it in the adult.

Horse

- It is located on dorsal aspect of the cranium.
- The external face is quadrilateral, smooth and presents the sagittal parietal crest.
- The internal aspect presents a three sided process-the *internal occipital protuberance* or *the ossific tentorium*.

Dog

- Its location is similar to that of the horse.
- It fuses with the occipital before birth.
- It bears the high posterior part of the parietal crest.
- The ossific tentorium is of great size.

Fowl

- It is absent.

OCCIPITAL BONE
(Ox, Horse, Dog, Fowl)

Ox

It is single bone situated on the lower part of the posterior surface of the skull. It consists of *lateral (ex-occipital), squamous (supra-occipital)* and *basilar (basi-occipital) parts*.

Lateral part

- Each consists of a *condyle* and a *paramastoid process*.
- The *condyles* articulate with the atlas. Placed lateral to the condyle is the paramastoid process, which serves for muscular attachment.
- The *paramastoid process* projects downward and backward and is curved medially. Between the root of the paramastoid process and the condyle is the *condyloid fossa*, in which a large foramen the *hypoglossal foramen* is present for the XII cranial nerve. Above this is another (often double) foramen which conducts a vein from the condyloid canal.
- The condyloid canal passes upward from a foramen on the medial side of the condyle and opens into the temporal canal.
- The canal lodges a vein which connects the transverse sinusof the duramater and basilar plexus of veins.

Basilar part

- It is a wide thick bar of bone which extends forward from the ventral margin of foramen magnum.
- Its ventral surface is rounded. It lodges the pons and medulla oblongata on its canal surface.
- The anterior end is fused to the body of post sphenoid. At its junction with the post-sphenoid it presents two tubercles (*basilar tubercles*) externally, which serve for muscular attachment.
- The lateral border form the medial margins of the *foramen lacerum* which is for the passage of IX, X and XI cranial nerves.
- The *lateral* and *basilar* parts enclose the large *foramen magnum* at which the cranial cavity and the vertebral canal join.

Squamous part

- It is quadrilateral plate of bone lying between the lateral parts below, squamous temporal laterally, the parietal and interparietal bones with which it fuse before birth.

- It presents externally, a central *external occipital protuberance* near its junction with the interparietal for the funicular part of the ligamentum nuchae.
- The *mastoid foramen* is situated on each side, at the junction of the occipital and squamous temporal bones. It communicates with the temporal and condyloid canals at their junction.
- The cerebral surface of the squamous part presents shallow median fossa for the vermis of the cerebellum and above this is a small eminence-the *internal occipital protruberance.*
- A groove on either side (lodging in life the transverse sinus) leads into the temporal canal.
- In the adult is excavated to form a part of the frontal sinus.

TOP

Horse

- The posterior surface of the skull is entirely by the occipital.
- The condyles in the lateral parts are obliquely placed.
- No other foramina besides the hypoglossal are and present in the condyloid fossa.
- The paramastoid process is longer narrower and less curved.
- The basilar part is longer and narrower and the basilar tubercles are smaller.
- The foramen lacerum is wider and appears as a large triangular gap in the dry skull but is covered to most of its extent by fibrous tissue in life, (refer sphenoid for the foramina formed here).
- The squamous part forms the supero-posterior part of the skull and is crossed externally by prominent transverse and horizontal ridge called *nuchal crest***.**
- Its cranial surface shows a deep central and two shallower lateral depressions for the cerebellum.

TOP

Dog

- Its situation is an in the horse.
- The nuchal crest is prominent, angular and directed backward.
- There is only one foramen in the condyloid fossa.
- Mastoid foramen and condyloid canal are as in the ox.
- The paramastoid processes are very short.
- The basilar part is wide and joins the bulla tympanica on either side.
- The basilar tubercles are at the junction with the bulla.

TOP

Fowl

- The bones of the cranium in the fowl lose their identity early after hatching as the sutures become ossified and the bones fuse together.
- The occipital condyle is in the basilar part and is single, placed below the foramen magnum and articulates with the atlas and axis.

SPHENOID BONE
(Ox, Horse, Dog, Fowl)

Ox

- The bone is placed at the base of the skull. In the calf at birth and some months after it consists of two pieces.
- The posterior part lies next to the basilar part of the occipital, being termed *post-sphenoid* and the anterior part *pre-sphenoid***.** Though the two parts fuse later in life it is convenient to describe them separately.

Post-sphenoid

- The *post-sphenoid* has a *body, two temporal wings* and *two pterygoid (subsphenoidal)processes.*
- The *external face* of the *body* presents close to its junction with the pterygoid a *vidian groove* for the nerve of the pterygoid canal (vidian nerve).
- The *internal surface* presents the *hypophyseal* or *pituitary fossa (sella turcica)* for the pituitary gland. The *dorsum sellae* is a transverse projection at the posterior end of the body and bears *posterior clinoid processes*.
- The *wings* diverge outward from the body.
- Each is perforated about its middle by *foramen ovale* for the mandibular nerve and middle meningeal artery.
- The *internal surface* presents a longitudinal groove leading to *foramen orbito rotundum***.**
- The *posterior border* forms the anterior margin of the foramen lacerum.
- The *anterior border* presents a notch medially which with a similar one on the wing of pre-sphenoid forms the foramen orbito-rotundum for III, IV, VI cranial nerves and maxillary and ophthalmic division of V cranial nerves.
- It is free antero-laterally to form the *pterygoid crest*.
- The *subspheniodal* or *pterygoid processes* spring from the anterior part of the wing and is directed downward and forward.
- It's medial face is covered by the pterygoid and the palatine bones.

Pre-sphenoid

- The *pre-sphenoid* lies at a higher level, has a *body* and *two orbital wings*.
- The anterior part of the external face of the *body* is concealed mostly by the vomer and laterally by the pterygoid bones.
- The vidian groove is continued by a vidian canal at the junction of the wing with the body and opens into the *pterygo-palatine fossa*.
- The cranial surface of the body presents anteriorly a median *ethmoid spine*, which joins the crista galli of the ethmoid. Posteriorly and at a lower level is the optic groove which supports the optic commissure in life and the groove on either side leads to the optic foramen.
- In the adult, the body of pre-sphenoid is slightly excavated to form the sphenoidal sinus.
- The *orbital wings* are larger than the temporal wings.
- They curve dorsolaterally from the sides of the body.
- *External surface* forms a part of the orbital wall. It is overlapped by the frontal in such a manner that it appears to divide into two branches.
- The anterior one of these joins the ethmoid and perpendicular part of palatine at the *spheno-palatine foramen*. At its junction with the body it is pierced by the *optic foramen.*
- The *posterior border* forms with the wings of post-sphenoid, the foramen orbito-rotundum.
  The *internal face* lodges the cerebrum.

TOP

Horse

- The posterior border of the wing of the post-sphenoid forms the anterior border of foramen lacerum and presents three notches -*carotid, oval* and *spinous* from within outward.
- The foramen lacerum is a large triangular gap in the dry skull and is largely closed in life by dense fibrous tissue with a posterior opening i.e. *foramen lacerum posterius* or*jugular foramen* for the IX, X and XI cranial nerves and anteriorly the notches referred to above are converted into the carotid artery, mandibular nerve and the middle meningeal artery respectively.
- The dorsum sellae and post clinoid processes are absent.
- The anterior border of the wing meets the wings of pre-sphenoid above and below it, free and forms the pterygoid crest, which is continued on the pterygoid process.
- On or under the upper part of the crest there is usually a small *trochlear parvum*, which communicates with the alar canal.
- The wing presents close to its anterior border the *foramen rotundum* (for the maxillary division of V cranial nerve) and with the pre-sphenoid wing, it forms the *foramen orbitale* which is separated from the foramen rotundum by a thin plate of bone.
- The foramen orbitale serves for the passage of III, VI cranial and ophthalmic division of V cranial nerves.
- The *pterygoid processes* project downward and forward and curve outward at its lower part. The root of the process is perforated by alar (*subsphenoidal)* canal for the passage of the internal maxillary artery.
- The *wings* of pre-sphenoid form the foramen orbitale with the wing of post-sphenoid. In front and above this is the optic foramen. Anteriorly, the wings meet the cribriform plate of ethmoid and orbital plates of frontal to form the *ethmoidal foramen***.** The sphenoidal sinus in the body of pre-sphenoid communicates with the palatine sinus in the vertical part of palatine bone.

TOP

Dog

- The body of both pre and post sphenoid is dorsoventrally flattened. Dorsum sellae and posterior clinoid processes are better developed.
- Anterior clinoid processes project from the roots of the orbital wings.
- Temporal wings are extensive and articulate with the parietals dorsally.
- Foramen orbitale is at the junction of the wings a little lower to the optic foramen.
- An alar canal is present and the foramen rotundum opens into it.
- Foramen ovale is as in the ox.
- The carotid notch with a similar notch on the temporal forms the carotid from the foramen.
- The sphenoidal sinus is absent.

TOP

Fowl

- The sphenoid is concealed largely by a large triangular basitemporal or *sub-sphenoid bone*.

ETHMOID BONE

(Ox, Horse, Dog, Fowl)

Ox

It is a single bone situated in front of the presphenoid and has a *cribriform plate*, a *perpendicular* part and *two lateral masses*.

Cribriform plate

- It is a sieve-like partition between the cranial and the nasal cavities.
- Its cranial surface is divided by the *ethmoidal crest (crista galli)* into two halves.
- Each half forms the deep *ethmoidal fossa* for the olfactory bulb. The plate is perforated by numerous small foramen for the passage of the olfactory nerve filaments and on either side is the *ethmoidal foramen* for the ethmoidal artery and nerve.
- The convex nasal surface has the lateral masses attached to it.

Perpendicular plate

- It forms he postero-dorsal part of the septum nasi and is covered by a mucous membrane.
- Its dorsal border joins the junction of the frontals.
- Its ventral border is received into the groove of the vomer.
- Its anterior border is continuous with the septal cartilage in life.

Lateral mass

- Each *lateral mass* is the posterior part of the nasal cavity above and behind the posterior nares.
- The perpendicular plate separates the two masses.
- Each has the shape of cone with the base attached to the nasal surface of the cribriform plates.Each is curved on its lateral face by a thin plate of bone; the *lamina lateralis*.
- The ventral part of this lamina is seen in the pterygo-palatine fossa forming the dorsal margin of the *sphenopalatine foramen*.
- The mass consists of delicate, scroll-like plates of bone termed *ethmo-turbinates*. They are attached to the lamina lateralis and are separated by narrow intervals termed*ethmoidal meatuses*, which communicate with the nasal cavity.
- In the fresh state, the ethmo-turbinates are covered with mucous membrane.
- The largest ethmo-turbinates is so extensive that it projects between the dorsal and central turbinates and is often called the *middle* or *third turbinate bone*.
- The mucous membrane covering the ethmo-turbinates is part of the olfactory mucous membrane.

TOP

Horse

- The great ethmo turbinate is less massive.

TOP

Dog

- The ethmoid bone is highly developed.
- The cribriform plate is extensive and the olfactory fossae are very deep.
- The ethmoidal crest is little developed and often incomplete.
- The perpendicular plate is long.

- The lateral masses are greatly developed and project into the frontal sinus.
- The lamina lateralis is extensive and forms the medial wall of the maxillary sinus.
- Its ventral border joins the palatine process of the maxilla and horizontal part of the palatine.
- A shelf-like plate extends inward from its lower part and connects with the similarly incurved part of the palatine bone and meets outcurving plates of vomer to form the *lamina transversalis*, which divides the olfactory fundus of the nasal cavity from the lower *nasopharyngeal meatus*.

TOP

Fowl

- The lateral masses and the horizontal part are absent.
- The perpendicular plates form the *interorbital septum* with the sphenoid.

TEMPORAL BONE
(Ox, Horse, Dog, Fowl)

Ox

- They form part of the lateral walls of the cranium. They are situated between the occipital and the parietal behind, and the frontal dorsally and sphenoid ventrally and medially. Each consists of *squamous* and *petrous parts*, which are fused completely at birth.

Squamous temporal

- It has a *body* and *zygomatic process*.
- The *external surface* of the *body* is divided by the temporal crest into two parts.
- The crest is continuous with the parietal crest above, turns forward below ending in a tubercle, above the external acoustic meatus. This corresponds to the *mastoid process* (on the petrous part of the horse). The area in front of the crest is the *temporal fossa* and presents two or three foramina leading into the temporal canal. The area behind the crest is smaller and meets the occipital bone.
- The *internal surface* is overlapped by the parietal and sphenoid.
- *The zygomatic process* is wide behind and narrow in front. The anterior part of zygomatic process meets the zygomatic process of the malar to form the *zygomatic arch*.
- At its upper part it forms dorsally part of the temporal fossa and ventrally it presents an articular area- a *condyle, a glenoid cavity* and a *postglenoid process*-for articulation with the mandible.
- Behind the postglenoid process is the *post glenoid foramen*-the external opening of the temporal canal.This canal is formed by the opposition of squamous and petrous-temporal bones.This canal is a continuation of the groove mentioned in the squamous part of the occipital and its internal opening lies above and behind the petrous part of the petrous temporal bone. It contains the dorsal cerebral vein the continuation of the transverse sinus of the duramater.

Petrous temporal

- The *petrous temporal* is situated between the occipital behind and the squamous temporal in front. It consists of *petrous* and *tympanic parts*.
- *Petrous part*
  - The *petrous part* contains internal ear.
  - The medial face is smooth and forms the lateral wall of the cerebellar compartment of the cranial cavity.
  - It presents the internal acoustic (auditory) meatus for the VII and VIII cranial nerves.

    - The fundus of the meatus is divided by a crest into two fossae. In the superior one is the origin of the facial canal (*aquaeductus Fallopius*), which curves through the bone and opens externally at the stylomastoid foramen, it transmits the seventh cranial nerve.
    - The inferior fossa presents small foramina for the passage of the fibres of the eighth cranial nerve.
    - Behind the meatus and near the posterior margin of the surface is the slit-like opening of *aquaeductus vestibuli* covered by a scale of bone. Below it forms part of the cerebral compartment.
    - The petrosal crest separates these two surfaces.
- *Tympanic part*
    - The *tympanic part* is external and presents the following:
    - The *external auditory process*-a curved plate of bone projecting through a notch in the squamous temporal and encloses the external acoustic meatus.
    - Blow the external auditory process is a rod of bone- the *hyoid process*. This is connected by a bar of cartilage to the styloid cornu of the hyoid bone.
    - Between the hyoid and the paramastoid processes is the *stylomastoid foramen*-the external opening of the facial canal.
    - The *bulla tympanica* (auditory bulla) whose cavity forms part of the middle ear.
    - The *muscular (styloid) process* of the petrous temporal springs from below the bulla for muscular attachment.
    - Lateral to the root of this process is the *petrotympanic (Glaserian) tissue* for the chorda tympani nerve and medially is a groove or semicanal-the *osseous eustachian tube (auditory tube)*.

TOP

Horse

- The squamous part is relatively larger. It presents a *zygomatic* and *posterior triangular process*.
- The *zygomatic process* meets not only the malar but also the supra-orbital process of the frontal.
- The *posterior process* springs from the posterior aspect of the body and presents a temporal crest on its lateral face. Its medial surface forms the outer boundary of the parieto-temporal canal.
- The parietal bone takes part in the formation of the temporal canal (parieto-temporal canal). There is a well developed mastoid process between the squamous-temporal and the paramastoid processes.
- The stylo mastoid foramen is between the hyoid and the mastoid processes. The auditory bulla is smaller.

TOP

Dog

- The parts of the temporal bone fuse early.
- The zygomatic process is strongly curved.
- Its anterior part is beveled ventrally and articulates extensively with the corresponding process of malar.
- The articular area is represented by a transverse groove and it extends upon the front of the large postglenoid process.
- A distinct mastoid process is present.
- The external acoustic meatus is very short and wide so that in the dry skull one can see into the tympanum.
- The bulla tympanica is very large and rounded and smooth, its medial side is united to the basilar part of the occipital bone.

- Above this junction and roofed in by the union of the petrous parts and the basioccipital is the petrobasilar canal; this transmits a vein from the floor of the cranium to the foramen lacerum posterius. The latter opens into a depression behind the tympanic bulla. It transmits the 9th, 10th and 11th cranial nerves.
- The carotid canal branches off from the petro-basilar, passes forward lateral to it through the medial part of the bulla tympanica and opens in front of the carotid foramen; it transmits the internal carotid artery. The eustachian opening is immediately lateral to the carotid foramen. The muscular and hyoid processes are very rudimentary.
- The petrosal crest is sharp and prominently projects into the cranial cavity. The medial surface presents a deep floccular fossa above the internal acoustic meatus. The anterior angle is perforated by a foramen for the trigeminal nerve.

TOP

Fowl

- The *squamous temporal* lies on the lateral aspect of the cranium. It presents the *supra orbital* and the *zygomatic process*.
- The former is fused to that of the frontal; it furnishes a facet for the quardrate bone.
- The *petrous temporal* is concealed by the adjacent bones. It forms the floor of the tympani cavity and a part of the facet for the quadrate bone.

FRONTAL BONE
(Ox, Horse, Dog, Fowl)

Ox

The frontal bones are situated on the dorsal aspect of the skull and form the entire roof of the cranium.They are the largest of cranial bones.The characteristic appearance of the skull is largely due to the shape and size of the frontal bones. Each has a *body* or *frontal part, an orbital plate and supra orbital processes*.

Body

- The *external surface* of the *body* presents the supra-orbital groove about the middle of which is foramen-the upper opening of the supra orbital canal.
- The supra orbital groove marks the course of frontal vein.
- The bone consists of two tables between which is large frontal sinus. The internal surface forms part of the cranial and nasal cavities.
- It meets the parietal and at the junction, forms a central prominence-the *frontal eminence (torus frontalis)*.
- At its posterolateral angle is a large conical process.
- The *horn core (flint or cornual process)* is excavated to form part of the frontal sinus. The horn core varies greatly in size, length curvature in different animals and different breeds.
- The anterior end with its fellow form notch to receive the two nasal bones.

Orbital plate

- It forms the medical wall of the orbit.
- It presents the orbital opening of the supra-orbital canal.
- Close to the posterior edge is the ethmoidal foramen.

- The medial surface meets the sphenoid and ethmoid.

Supra-orbital process

- It forms a part of the posterior rim of the orbit.
- Its medial face is related to the lacrimal gland.
- It meets below the frontal process of the malar.

TOP

Horse

- They are situated between the parietals behind and the nasals in front and are relatively smaller than in the ox.
- The supra orbital foramen perforates the root of the supra orbital process, which joins the zygomatic process of squamous temporal.
- The horn core is absent.
- The inferior borders of the two bones form a projection, which fits into the notch formed by the two nasal bones.

TOP

Dog

- Its location and extent resembles that of the horse.
- The external surface is crossed by a frontal crest which extends as a curve from the parietal crest to the supra orbital process.
- The frontal parts show central depression and slope downward and forward.
- In front, there is a narrow nasal part, which fits in between the nasal bone and maxilla.
- The supraorbital process is short and blunt and the orbital rim is incomplete.
- The supraorbital foramen is absent.
- Two ethmoidal foramina are present.

TOP

Fowl

- It is the largest bone of the cranium.
- It consists of a *body* and *orbital plate*.

CRANIAL CAVITY
(Ox, Horse, Dog)

Ox

- The cranial cavity encloses the brain with its membranes and blood vessels.
- The dorsal wall or roof is formed by the body of frontal bone.

- The lateral wall is formed by the lateral part of parietal and temporal behind and by the orbital plate of frontal and wings of the sphenoid in front.
- The ventral wall or floor is formed from before backwards by the presphenoid, postsphenoid and basi occipital.
- The posterior wall is formed above by the posterior parts of parietal and interparietal and below by squamous and lateral parts of occipital.
- The anterior wall is formed by the cribriform plates of the ethmoid bone.

Cranial cavity of ox opened dorsally
(Dorsolateral aspect)

1&2 Outer and inner layer of frontal 3. Septum 4. Frontal sinus 5. Supraorbital canal 6. Crita galli 7. Ehtmoidal fossa 8. Ethmoidal foramen 9. Orbitosphenoid crest 10. Chiasmatic sulcus 11. Entrance to optic canal 12. Olfactory compartment 13. Cerebral compartment14. Cerebellar compartment15. Hypophyseal foosa 16. Sella tursica 17. Foramen orbitorotundum19. Foramen ovale 20. Petrous part of occipital 21. Internal auditory meatus 22. Condyloid canal 24. Occipital condyle 25. Intercondyloid notch26. Paramastoid process 27. Tympanic process 28.Frontal process of zygomatic bone 29. Lacrimal bulla 30. Zygomatic process of frontal bone

The cranial cavity is divided into three compartments.

- The *olfactory compartment* lies at the anterior end and it is divided by the crista galli of the ethmoid into two oval olfactory or ethmoidal fossae. They accommodate the olfactory bulbs.
- The *cerebral compartment* greatly exceeds the other two in size. Its floor is formed by the sphenoids, the roof by the frontal and lateral wall by temporal. The internal occipital protuberance above and laterally the petrosal crests indicate the demarcation between the cerebral compartment and cerebellar compartment behind (to which the tentorium cerebelli is attached).
- The *cerebellar compartment* is enclosed by the basi occipital below, the squamous parts of the occipital above and behind and literally by petrous parts of petrous temporal bone.

TOP

Horse

- The dorsal wall is formed by the frontal, parietal and inter-parietal bones.
- The posterior wall is formed by the squamous and lateral parts of occipital.

TOP

Dog

- The boundaries of the cranial cavity are similar to that of the horse.

FACIAL BONES

The face is more extensive than the cranium in most of the domnestic animals.Sone of thses bones involved in the formation of nasal cavity.The facial bones are named as following;

- Nasal
- Premaxilla
- Maxilla
- Palatine
- Pterygoid
- Lacrimal
- Malar
- Turbinates
- Vomer
- Mandible
- Hyoid

The last three are single, the others are paired.

NASASL BONES

Ox

- They are elongated curved plates situated in front of the frontals and form the greater part of the roof of the nasal cavity.
- They do not fuse laterally with adjacent bones even in old age.
- The *dorsal facial surface* is convex.
- The *ventral nasal face* is concave.
- Its medial half forms the *dorsal meatus* and immediately below it, is the *dorsal turbinate crest* for the attachment of the dorsal turbinate, bone.
- The extreme *posterior part* is excavated to a small extent in old animals.
- The *lateral border* is free and forms the naso-maxillary notch with the premaxilla.
- The posterior extremities of the two bones together form a projection, which is received into the notch formed by the anterior ends of the frontals.

- The *anterior end* presents two processes separated by a notch and the anterior ends of the two bones together present a trifid appearance.

Horse

- The posterior ends of two bones together form a notch into which the pointed anterior ends of the two frontals are received and excavated to form part of the frontal sinus.
- The anterior end is pointed.

Dog

- It is long and wider in front than behind.
- The dorsal face is concave in its length and forms a central groove with its fellow.
- The medial borders project into the nasal cavity to form the internal nasal crest.
- The posterior ends resemble those of the ox.
- The anterior ends form a semicircular notch

Fowl

- It is small thin plate with a body and three processes-*frontal, premaxillary* and *maxillary*.
- These circumscribe the anterior nares with the premaxilla and the maxilla.

PREMAXILLA BONE

Ox

- The premaxilla forms the anterior part of the upper jaw and has a *body* and *two process* - *nasal* and *palatine*.
- The *lateral surface* of the *body* is convex and is related to the upper lip.
- The *buccal surface* is concave and related to the dental pad.
- The medial edge is concave and forms with its fellow the *incisive fissure*.
- The *nasal process* projects upward from the body and form the lateral wall of the nasal cavity. The lateral (facial) and medial nasal surfaces of this process are smooth. Its posterior two third fits into the groove on the anterior edge of the body of the maxilla.
- The *palatine process* is smaller than the nasal. It is a thin plate of bone, which forms the anterior part of the bony palate. Its nasal surface slopes medially and with its fellow forms a groove for the vomer and septum nasi. The lateral border of the palatine process is separated from the nasal process and the maxilla by a large oval opening, the *palatine fissure*.

Horse

- The bodies of the two bones are fused together.
- The body of each bone is thicker and presents three alveoli for the upper incisors.
- The medial surface is rough and joins the opposite bone; it presents a groove, which with a similar one of its fellow forms the *foramen incisivum*.
- The nasal process is longer and presents at its junction with the maxillary bone an alveolus for the canine tooth.
- The palatine process is wide and the palatine fissure narrow.

Dog

- The body presents three alveoli for the incisors and with the maxillary bone forms an alveolus for the canine tooth.
- Foramen incisivum is very small.
- The palatine fissure is short but wide.

Fowl

- The premaxilla forms the skeleton of the upper portion of the beak and fuse to form a solid bone before hatching.
- They form the anterior boundary of the external opening of the nasal cavity.
- They present three pairs of processes-the *palatine process* which meets the palatine, the *maxillary processes* which extend backward and meet the maxilla and the *nasal processes* which extends dorsally and backward along the median line and between the nasal bones and meet the frontals.

MAXILLA BONE
(Ox, Horse, Dog, Fowl)

Ox

Maxilla is the largest bone of the upper jaw and carries the upper cheek tooth. It is situated on the lateral aspect of the face. It is made up of a *body* and *two processes*-the*palatine* and *zygomatic*.

- The *external surface* of the body is convex and presents about the level of the first cheek tooth, the *infra orbital foramen*,the external opening of the infra orbital canal for infra orbital artery and maxillary nerve.
- About the level of the third cheek tooth is the *facial tuberosity* extending from which is the *facial crest*.
- The *internal surface* form the lateral walls of the nasal cavity and presents about the middle the *ventral turbinate crest* for the ventral turbinate bone.
- Immediately below this is the lacrimal groove for the membranous naso lacrimal duct.
- The *dorsal border* is irregular, scaly and articulates with the nasal process of premaxilla nasal, lacrimal and malar bones.
- The *ventral* or *alveolar border* shows six alveoli posterior and is free anteriorly.
- The anterior extremity is pointed and joins the premaxilla.
- Behind last alveolus is a rough mark-the *alveolar tuberosity*.
- The *maxillary tuberosity* forms posterior extremity of the bone and has the maxillary sinus prolonged into it.
- Medial to this is the *maxillary hiatus*, which presents the *spheno-palatine, maxillary* and *posterior palatine foramina* for nerves and vessels of the same name.
- The *zygomatic process* is small a projection from the posterior extremity and is overlapped by the malar.
- The *palatine process* forms a large part of the bony palate. Its oral surface shows the palatine groove for the greater palatine artery and nerve. It is excavated to form part of the palatine sinus.

TOP

Horse

- The facial crest is prominent.
- The infra-orbital foramen is at the level of the third cheek tooth and a small canal from this extends into the pre-maxilla.

- The palatine can is formed between the medial face of the body of the maxilla and the vertical part of the palatine bone.
- The medial borders of the palatine processes bear nasal crests in their nasal aspect and these form a groove for the vomer.
- At the junction of the maxilla and pre-maxilla is an alveolus for the canine tooth.

TOP

Dog

- The facial crest is absent.
- The infra-orbital foramen is as in the horse.
- Frontal process fits into a deep notch between nasal and orbital parts of frontal bone.
- Maxillary and alveolar tuberosities are absent, but behind the last alveolus is a pointed *pterygoid process*.
- There is a large alveolus for the canine tooth at the junction with premaxilla.

TOP

Fowl

- There is slender rod like bones placed on the sides and partly on the floor of the nasal cavity.
- The two palatine processes do not meet, but join the palatine and vomer posteriorly.
- The maxilla joins the pre-maxilla and nasal anteriorly while it is continuous with malar posteriorly.

PALATINE BONE
(Ox, Horse, Dog, Fowl)

Ox

The bones are situated on either side of the posterior nares and each consists of a *horizontal* and *perpendicular (vertical) part*.

- *Horizontal part*
  - It forms the posterior one-fourth of the bony palate.
  - Its *anterior border* joins the palatine process of maxilla.
  - The posterior border is free and gives attachment to the aponeurosis of soft palate.
  - Its medial border meets its fellow on the median palatine surface.
  - Its palatine surface is perforated about its middle by the *anterior palatine foramen* in continuation with which is the very faint palatine groove in front.
  - The palatine canal is formed entirely in this part, open behind at the maxillary hiatus- the *posterior palatine foramen*.
  - The horizontal part consists of two tables, which enclose a part of palatine sinus.

- *Vertical part*
  - It forms the posterior part of the lateral wall of the nasal cavity and in part bound the posterior nares.
  - It has the pterygoid articulating with it medially and the sub-sphenoidal process of the post sphenoid laterally.
  - It presents a notch along its upper edge which, with the ethmoid and the presphenoid forms *spheno-palatine foramen*.
  - Behind this it articulates with the presphenoid.

TOP

Horse

- The horizontal part is narrow and is not excavated to form the palatine sinus.
- Anterior palatine foramen is formed between the anterior border of the horizontal part and the palatine process of the maxilla.
- The palatine canal is formed between the maxilla and the vertical part.
- The perpendicular part is more extensive consists of two plates and is excavated to form the palatine part of the spheno-palatine sinus, behind the spheno palatine foramen.
- The inner plate curves medially to articulate with the vomer.
- The outer plate joins the maxilla frontal and the orbital wing of the sphenoid. It may join the lacrimal also.

TOP

Dog

- The horizontal part is extensive and forms the posterior one third of the bony palate.
- The palatine canal is sometimes formed entirely in the horizontal part.
- The perpendicular part is very extensive.
- Its lateral surface is free and forms most of the medial wall of the pterygo-palatine fossa.
- The maxillary foramen is situated in deep recess between this bone and the zygomatic process of the malar. Just above this is another foramen opening into the nasal cavity.
- The posterior palatine and spheno-palatine foramina are situated further back and a little lower.
- The former is ventral to the latter. A horizontal plate extends from the nasal surface, meets its fellow and the laminae of the vomer to complete the *lamina transversalis* that divides the olfactory and the respiratory parts of the nasal cavity.
- There is no palatine sinus.

TOP

Fowl

- It is wide behind and narrow in front. It forms lateral boundary of the posterior opening of the al cavity and part of the roof of mouth.
- It meets the pterygoid and the sphenoid posteriorly and the premaxilla and maxilla anteriorly.

PTERYGOID BONE

Ox

- They are thin plates of bones situated on either side of the posterior nares located over the perpendicular parts of the palatine bones.
- This medial face forms part of the lateral wall of the posterior nares.
- The lateral face meets the palatine and the subsphenoidal process of the sphenoid.
- The extreme upper part of this face forms the pterygoid or vidian canal with the sphenoid.
- The lower extremity is free and forms a curved process the *hamulus pterygoideus* around which the tendon of the *tensor palati* is reflected.

Horse

- Shorter and narrower.
- The lateral surface articulates with the palatine, vomer and sphenoid, concurring with last in the formation of the pterygoid canal.

Dog

- It is wide quadrilateral and short.

Fowl

- It is rod shaped and extends between the rostrum of the sphenoid medially and quadrate bone laterally.

LACRIMAL BONE

Ox

- They are situated at the anterior part of the orbits and extend forward on the face.
- The lateral surface is divided into *facial* and *orbital parts* by the orbital margin (orbito-facial crest).
- The *orbital part* forms the anterior part of the medial wall and floor of the orbit. Immediately behind the crest is the lacrimal fossa at the bottom of which is the posterior opening of the lacrimal canal. On the floor of the orbit is a large and thin walled protuberance-the *lacrimal bulla* into which the maxillary sinus extends.

- The *facial part* is extensive. The nasal (internal) face presents osseous naso-lacrimal canal, which divides it into two parts. Both the parts enter into the formation of the maxillary sinus.

Horse

- It is smaller.
- The facial part is less extensive and presents a small lacrimal tubercle about an inch from the orbital margin.
- Lacrimal bulla is absent.

Dog

- It is very small.
- Orbital face is small triangular and has lacrimal canal.
- The facial part does not extend beyond the orbital margin.

Fowl

- It is triangular plate of bone situated at the anterior margin of the orbit. Its medial edge meets the frontal.
- The apex, pointed downward, is continued by a long curved process.

MALAR BONE

Ox

- The *malar* or *zygomatic bone* is irregularly triangular and is situated between the lacrimal and maxilla.
- It presents *three surfaces-lateral, nasal (medial) and orbital*-and *a zygomatic process, which* divided into *frontal* and *temporal branches*.
- The *lateral* or *facial surface* is extensive and convex. The facial crest runs down the lateral face just below the rim of the orbit and is continued above on the temporal division of the upper extremity and below on the maxilla.
- The *orbital face* is narrow and forms part of the posterior wall, a part of the floor and anterior wall of the orbit. A ridge separates these two surfaces and forms part of orbital rim.
- The *nasal face* is free and forms part of the maxillary sinus.
- The posterior extremity is formed by the *zygomatic process* which divides into a temporal and frontal process.
- The *trontal process* meets the supra orbital process of frontal to form part of the posterior margin of the orbit.
- The *temporal process* is overlapped by the zygomatic process of the squamous temporal with which it completes the zygomatic arch.

Horse

- The facial surface is very small.
- The posterior extremity is not divided and is overlapped by the zygomatic process of the squamous temporal.

Dog

- The body consists of a *dorsal lacrimal process* and *ventral maxillary process*.
- The facial part is small and convex.
- The zygomatic process forms the bulk of the bone.
- The dorsal border of this process is free anteriorly and forms part of the orbital rim and behind it meets the zygomatic process of the temporal.
- It bears an eminence-*frontal process* for the attachment of the orbital ligament.

Fowl

- It is a slender rod of bone extending from the maxilla anteriorly and to the quadrate posteriorly.
- The anterior part of the bone is called the *jugal* and posterior part the *quadrato-jugal bone*.

TURBINATE BONE

Ox

- They are delicate scroll like bones two on either side, attached to the lateral walls of the nasal cavity.
- Each is a thin *cribriform lamina* covered on both sides by mucous membrane in the fresh state.
- The *dorsal turbinate* is the smaller of the two.
- The medial face is separated from the septum nasi by narrow space-the *common nasal meatus*.
- The lateral face is attached to the turbinate crest of the nasal bone.
- The posterior part joins the cribriform plate and the lateral mass of ethmoid. It communicates with the frontal sinus in the dry skull and this opening is closed by mucous membrane in fresh state.
- Between the dorsal turbinate bone and the roof of the nasal cavity (nasal bone) is the *dorsal nasal meatus*.
- Between the dorsal and ventral turbinate is the *middle nasal meatus*. The ventral turbinate is larger than the dorsal.
- It is attached to the turbinate of the maxilla by a basal lamella. The latter divides at its inner edge into two plates, which is rolled in opposite directions to enclose two cavities. The upper cavity opens into the middle nasal meatus while the lower opens into the *ventral nasal meatus*.

Horse

- The dorsal turbinate is longer and larger.
- Each turbinate has an anterior coiled part and posterior curved portion.
- The coiled parts of the two bones are rolled towards the septum and each other.

Dog

- The turbinates are richly convoluted. However, the anterior part of the dorsal bone form a simple curved plate overhang the ventral bone.
- The posterior part of the dorsal bone is not clearly separated from the lateral mass of ethmoid. The ventral bone is as in the ox; but has additional *tertiary lamellae*.

Fowl

- They are three in number-*anterior, middle* and *posterior*.
- The middle is the largest.
- The posterior is the smallest.

VOMER BONE

Ox

- It is a "U" or "V" shaped median bone, which forms the ventral part of the septum nasi.
- It is composed of a *thin lamina*, which is bent so as to form a groove to receive the perpendicular plate of the ethmoid and the septal cartilage.
- The lateral surfaces are covered by mucous membrane in life.
- The posterior part partly divides the posterior nares and is made up of two wings applied against the body of presphenoid to form the vidian or pterygoid canal.
- The ventral border lies in the groove formed by the palatine processes of the premaxillae and the maxillae and posteriorly is free and separated from the nasal floor by a considerable interval and hence the two posterior nares are separated only in the upper part.

Horse

- The ventral border is attached to the nasal crests of the maxillae and so the posterior nares are completely separated in the skull.

Dog

- Posteriorly it is not in contact with the floor of the nasal cavity and does not divide completely the posterior nares.
- Near the posterior nares the two plates of vomer curve outward and join the lamina lateralis of ethmoid and the palatine bones to form the lamina transversalis.

Fowl

- It is a slender rod extending forward from the rostrum of the sphenoid and is part of the nasal septum and is attached above to the septal cartilage in its anterior part.

NASAL CAVITY

Ox

- The nasal cavity is a longitudinal passage,which extends in life from the anterior nares or nostrils to the posterior nares, which open into the naso pharynx.
- It is divided into right and left halves by a median septum nasi.
- The turbinate bones divide each half of the cavity into three meatus nasi: *dorsal, middle* and *ventral.*
- The *dorsal wall* or *roof* of nasal cavity is formed by the nasal and frontal bone.
- The *lateral walls* are formed by pre-maxilla, maxilla, perpendicular part of palatine and turbinate bones.
- The *ventral wall* or *floor* is formed by the palatine process of premaxilla, palatine process of maxilla and the horizontal part of palatine bones.
- The *septum nasi* is formed above by the perpendicular palate of ethmoid continued in front by the septal cartilage and below by the vomer. The septum does not reach the floor posteriorly. So that the cavity here is incompletely divided.
- The *posterior nares* or *chonae* are narrow and bounded laterally by the pterygoid and perpendicular part of palatine and it is separated into two halves only in its upper part by vomer.

Horse

- The nasal cavity and the posterior nares are completely divided, as the vomer meets the nasal crests of the palatine and maxilla.

Dog

- The nasal cavity conforms to the shape of the face.
- The turbinates occupy the cavities to a large extent.
- The posterior part of the cavity is divided by the lamina transversalis into an upper olfactory region and a lower naso pharyngeal meatus.
- The posterior nares are undivided.

MANDIBLE OR LOWER JAW BONE
(Ox, Horse, Dog, Fowl)

Ox

It is a single bone. It is the largest bone of the face and is made up of two halves, which do not fuse completely so that a mandibular symphysis is present. It has a body and two rami.

- *Body*
  - The lingual surface of the body is covered in life by mucous membrane and tip of the tongue rests on it.
  - The mental surface is related to the lower lip.
  - The symphyseal surface/symphyseal border/serrated border/medial borders are rough and irregular.
  - The alveolar/anterior border presents alveoli for the lower incisor teeth.
- *Two rami*
  - The two rami diverge backward from the body and enclose the mandibular space.
  - Each ramus is bent to form a horizontal part and a vertical part. The most prominent part of the curve is the angle.
  - The lateral surface is widest at the angle and narrow at either end. It is smooth and convex in the horizontal part and is nearly flat in the vertical part. A rough elevation near the angle and the rough line are for the insertion of the masseter muscle. It presents a fossa at its junction with the body. Placed in this fossa is the mental foramen-the external opening of the mandibular (inferior dental) canal. A small incisor canal continues the mandibular canal into the body of the mandible.
  - The medial surface of the horizontal part gives attachment to the mylo-hyoid muscle. An its junction with the body is a fossa for the genio-hoyid and genio glossus muscle. On the vertical part, this surface presents rough lines inferiorly for the medial pterygoid. Placed about the middle of this surface is the mandibular foramen the posterior opening of the mandibular canal. From the foramen, a groove leads forward and downward-the lingual groove for the lingual nerve.
  - The dorsal or alveolar border of the ramus presents the inter-alveolar space in front and six alveoli for the lower cheek teeth behind. In the vertical part it serves for the attachment of muscles.
  - The ventral border of the horizontal part is convex, and presents a smooth impression in its posterior part left by the facial vessels and parotid duct. It is concave and thin in the vertical part.
  - The anterior extremity of each ramus joins the body. The posterior or articular extremity presents a coronoid process in front separated by the mandibular notch through which passes

the masseteric nerve. The coronoid process is long, curves backward into the temporal fossa and is for the temporalis.

- The condyle is elongated transversely, placed about two inches below the summit of the coronoid process and articulates with the condyle of the squamous temporal through the medium of an interarticular cartilage. The condyle projects inwards for the lateral pterygoid.

TOP

Horse

- The two halves of the mandible fuse completely.
- The alveolar border of the body presents six alveoli for the lower incisors and two for the canines.
- The lingual groove is absent.
- The antero-medal part of the condyle presents a depression.
- The fovea pterygoidea is for the lateral pterygoid muscle.
- Coronoid process is less prominent.
- The rami diverge less than in ox.

TOP

Dog

- The two halves do not fuse.
- The alveolar border of the body presents six alveoli for the incisors and two for canines.
- The horizontal part of ramus carries seven alveoli for the lower cheek teeth.
- The interalveolar space is very short or even absent.
- There are two or three mental foramina on either side.
- The vertical part is relatively small.
- The lateral face of the vertical part presents a deep masseteric fossa.
- The posterior border bears an angular process at the level of the mandibular foramen.
- This is the equivalent of the angle of other animals. The condyle is placed very low.
- The coronoid process is extensive and is bent slightly outwards and backward.

TOP

Fowl

- It is a single bone and each half is made up of five pieces in the embryo.
- The two halves fuse anteriorly. Posteriorly its articular part carries an articular area for the lower end of the quadrate bone. Behind this, the ventral border is carried upward and backward by a process.
- The quadrate bone articulates with the articular part of mandible below, above it articulates with the temporal, in front of the tympanic cavity, laterally with the quadrato jugal bone; medially with the pterygoid bone. It is irregularly four sided. Its anterio-medial angle projects into the orbit as a muscular process. The quadrate is the homologue of the mammalian incus (one of the middle ear ossicles). Its presence and the great mobility of the bone of the face permit extensive opening of the mouth. (See for details-under mandibular articulations in arthrology).

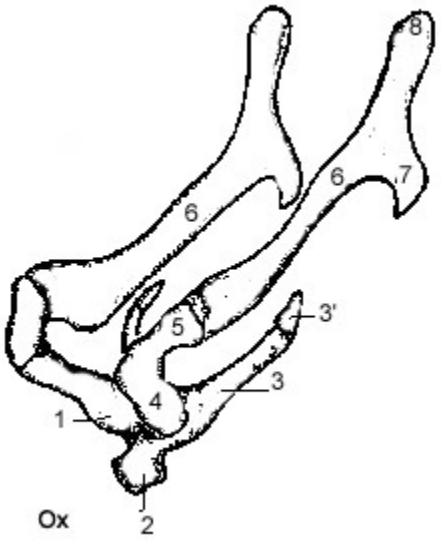
HYOID BONE

(Ox, Horse, Dog, Fowl)

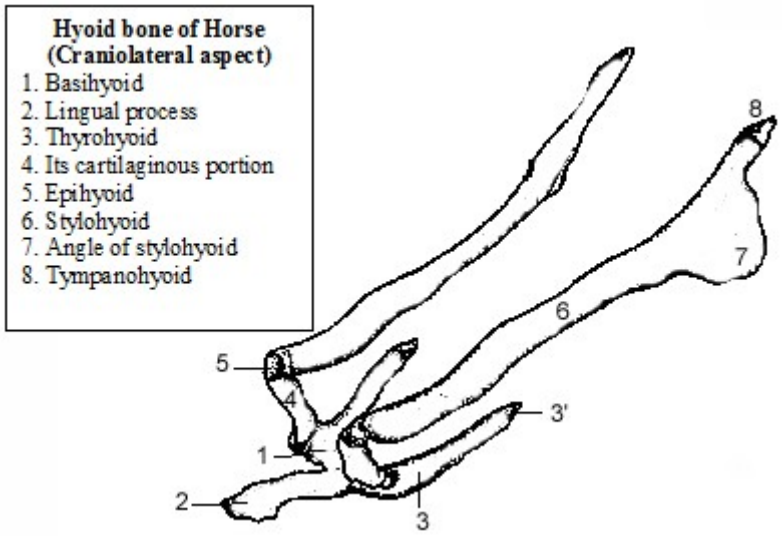
Ox

It is situated between the vertical parts of the rami of the mandible and extends obliquely downward and forward from the temporal above to the root of the tongue below. It consists of a *body*, a *lingual (glossal) process* and *four pairs of cornua (stylohyoid, epihyoid, keratohyoid and thyrohyoid).*

- The *body* or *basi-hyoid* is short rod of bone placed transversely. The anterior border, in its middle, carries the short blunt *glossal process*, which is embedded in the root of the tongue.
- The body is attached to the *thyroid cornua* of the thyro-hyoid by bars of cartilage on the postero - lateral aspects.
- The thyroid cornua extend backward and upward from the body and are attached to the anterior cornua of the thyroid cartilage of the larynx.
- The *ketato-hyoids (small cornua)* are directed upward and forward and articulate by the lower ends by concave facets with the cartilage uniting the body and thyroid cornua. Their upper ends are attached to the of lower ends of the *middle cornua* or *epihyoids* by short bars of cartilage.
- The epihyoid is a small curved rod attached to the small cornua below and the *great cornu* or *stylo-hyoid* above which is largest piece.
- The great cornu is directed upward and backward. Its lower end is attached to the upper end of the epihyoid. Its upper end resembles a human foot and has a heel-like part the*muscular angle* for muscular attachment and a toe-like part-the *articular angle,* which is connected by a short rod of cartilage to the hyoid process of the petrous temporal.



Hyoid bone of Ox
(Craniolateral aspect)
1. Basihyoid
2. Lingual process
3. Thyrohyoid
4. Its cartilaginous portion
5. Epihyoid
6. Stylohyoid
7. Angle of stylohyoid
8. Tympanohyoid



TOP

Horse

- The lingual process (glosso-hyoid) is longer with its free end pointed.
- The thyro-hyoid are fused with the body.
- The body of thro-hyoids and glosso-hyoid are fused and resemble spur or fork.
- The epihyoid is fused with the lower end of the stylo-hyoid.

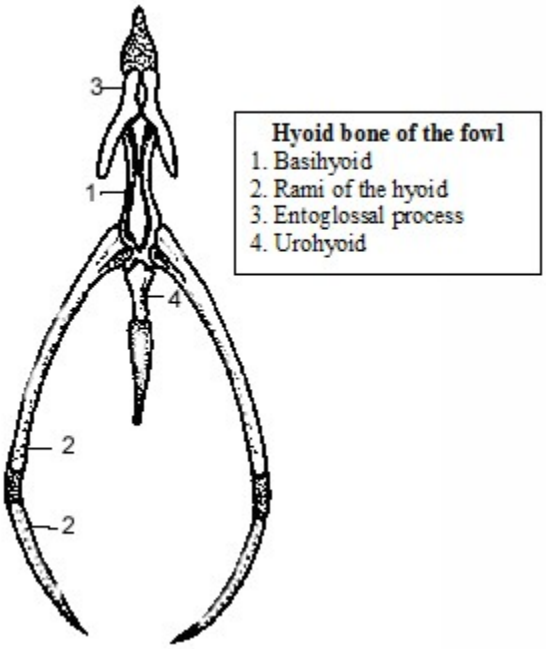
TOP

Dog

- The glosso-hyoid is absent.
- The epihyoid is longer than the stylo-hyoid.
- The stylo-hyoid is bent and twisted.
- The thyro-hyoid is permanently attached to the body by cartilage.

TOP

Fowl



Hyoid bone of the fowl
1. Basihyoid
2. Rami of the hyoid
3. Entoglossal process
4. Urohyoid

- It is composed of seven bony segments-three median and two lateral processes.
- The anterior median segment is the *entoglossal* and is embedded in the tongue.
- It articulates behind with the second or basi-hyoid.
- The *basi-hyoid (body)* is connected behind to the third segment of uro-hyoid at its middle and to the lateral processes by a bar of cartilage at either end.
- The *uro-hyoid* is partly bony and partly cartilaginous.
- Each *lateral process* consists of an anterior *basi-branchial* and a posterior *cerato-branchial* connected by cartilage. The lateral processes extend posteriorly upwards and towards the occipital bone.

SINUSES OF THE SKULL (PARANASAL SINUSES)

(Ox, Horse, Dog, Fowl)

Ox

The sinuses are air cavities in bones, which are lined by mucous membrane in the fresh state. They communicate with the nasal cavity directly or indirectly and hence are termed *diverticula of the nasal cavity*. The sinuses are *frontal, maxillary, palatine* and *sphenoid*.

- *Frontal sinus*
  - It is the largest of all the sinuses and is excavated in the frontal, parietal, interparietal and supraoccipital.
  - It extends from the posterior wall of the cranium down to the level of the anterior margins of the orbit and laterally to the frontal crests and supra-orbital process; medially it is separated from its fellow by an imperforate bony septum.
  - The cavity is divided into small spaces by partial septa.
  - This sinus communicates with the middle meatus by narrow apertures at the ethmoidal meatuses.
  - In the macerated skull, its communication with the cavity of the dorsal turbinate and the lacrimal part of the maxillary sinus is closed in life by the mucous membrane.
- *Maxillary sinus*

    - It is formed in the body of maxilla.
    - It extends forward to the level of the facial tuberosity and upward to a line joining the infra-orbital foramen to the upper margin of the orbit.
    - It extends behind into the maxillary protuberance and the lacrimal bulla to a point nearly opposite to the bifurcating of the zygomatic process of the malar.
    - It also extends upward and backward through a large opening into a cavity formed by the lacrimal frontal ethmoid and the roots of the last 3 or 4 check teeth project into the sinus covered by a plate of bone.
    - It communicates with the palatine sinus over the infra-orbital canal. Above this it communicates with the middle nasal meatus.
- *Palatine sinus*
    - It is formed in the palatine processes of maxilla, and horizontal part of palatine bones.
    - It is separated from its fellow by a bony septum.
    - It extends from posterior border of the palatine to about an inch in front of the level of the first cheek tooth.
    - It communicates with the maxillary sinus laterally and is separated from the ventral meatus medially by mucous membrane in life.
    - The palatine canal passes obliquely through the posterior part of the sinus.
- *Sphenoidal sinus*
    - It is excavated in the body of the presphenoid and extends into the orbital wing.
    - It is smallest of the four sinuses and communicates with the ventral ethmoidal meatuses.

TOP

Horse

The sinuses are *maxillary, frontal, spheno-palatine and ethmoidal*.

- *Maxillary sinus*
    - It is the largest and is formed by the maxilla, lacrimal malar, posterior turbinate and lateral masses of ethmoid.
    - It extends from the level of the supraorbital process behind to the level of a line joining the infraorbital foramen and the facial crest.
    - Its dorsal boundary is a line drawn from the infraorbital foramen backward parallel to the facial crest.
    - The ventral wall or floor is the alveolar part of the maxilla. It is divided into anterior and posterior part by an oblique septum directed inward, backward and upward from about two inches behind the anterior end of the facial crest.
    - The posterior end of the ventral turbinate forms the upper part of the septum.
    - The *anterior compartment (inferior maxillary sinus)* is partially divided by the infra-orbital canal into lateral and medial parts. The former is formed entirely in the maxillary bone and the root of the fourth cheek tooth and parts of third and fifth cheek teeth project into it, covered by a plate of bone. The medial or turbinate part communicates with the outer compartment and with the middle meatus.
    - The *posterior compartment (superior maxillary sinus)* is also divided into two parts by the infraorbital canal over which it freely communicates with spheno-palatine sinus. Dorsally it communicates with the frontal sinus through a large oval, *fronto-maxillary* opening. In front of this covered by a plate of bone is a narrow *naso-maxillary*opening by which the sinus opens into the posterior part of the middle meatus.
- *Frontal or Fronto-turbinate sinus*
    - It is formed in the frontal, lacrimal, ethmoid and dorsal turbinate bone. It consists of *frontal* and *turbinate parts*.
    - The *frontal part* extends forward to the anterior margins of the orbits, backwards to the temporal condyles and outwards into the roots of the supra-orbital processes.
    - A median septum is present as in the ox.

    - The *turbinate part* is situated in the posterior part of the dorsal turbinate bone, roofed in by the nasal and lacrimal bones.
    - It extends forward to a transverse plane about half way between the anterior margin of the orbit and the infra orbital foramen.
    - It is in free communication behind with the frontal part over the lateral mass of ethmoid.
    - It is separated form the nasal cavity by a thin turbinate plate.
- *Spheno-palatine sinus*
    - It is formed in the body of presphenoid and vertical part of the palatine bone.
    - It communicates with the medial part of the posterior compartment of the maxillary sinus.
- *Ethmoid sinus*
    - It is the largest cavity in the ethmo-turbinate.
    - It communicates with the maxillary sinus.

TOP

Dog

- The frontal sinus is confined to the frontal bone and opens into the ethmoidal meatuses.
- The maxillary sinus is small and communicates with the nasal cavity, very freely.
- There are no sphenoidal or palatine sinuses.

TOP

Fowl

- There are no sinuses in the skull.

ARTHROLOGY
(Bone, Cartilage, Ligament, Capsules, Synovial Membrane)

The study about joints is termed *arthrology* or *syndesmology*. A *joint* or *articulations* are the structures, where two or more bones of the skeleton meet one another by certain determined areas of their surface named *articular areas* with the help of certain binding materials.

- In immovable joints, the adjacent margins of the bones in contact, being separated merely by a thin layer of fibrous membrane called the sutural *ligament* eg. joints in the skull. In certain regions at the base of the skull this fibrous membrane is replaced by a layer of cartilage.
- Where slight movement combined with great strength is required, the osseous surfaces are united by tough and elastic *fibrocartilages* E.g. joints in the vertebral bodies.
- In freely movable joints, the surfaces are completely separated and the bones forming the joints are expanded for greater convenience of mutual connection are covered by*cartilage* and enveloped by *capsules* of fibrous tissue. The cells lining the interior of the fibrous capsule form an imperfect membrane—the *synovial membrane*—which secretes a lubricating fluid. The joints are strengthened by strong fibrous bands called *ligaments*, which extend between the bones forming the joint.

Bone

- Bone constitutes the fundamental element of all the joints.

- In the long bones, the extremities are the parts which form the articulations.They are generally enlargedand consist of spongy cancellous tissue with a thin coating of compact substance.
- In the flat bones, the articulations usually take place at the edges.
- In the short bones at various parts of their surfaces.
- The layer of compact bone which forms the joint surface where the articular cartilage is attached is called the *articular surface*. It differs from ordinary bone tissue in that it contains no Haversian canals, and its lacunæ are larger and have no canaliculi. The vessels of the cancellous tissue as they approach the articular surface, turn back in loops, and do not perforate it. This layer is consequently denser and firmer than ordinary bone, and is evidently designed to form an unyielding support for the articular cartilage.

TOP

Cartilage

- Cartilage is a non-vascular structure which is found in various parts of the body in adult life chiefly in the joints, in the parietes of the thorax, and in various tubes, such as the trachea and bronchi, nose, and ears, which require to be kept permanently open.
- In the early period of fetus, the greater part of the skeleton is cartilaginous and are replaced by bone.
- Cartilage is divided according to its structure into *hyaline cartilage, white fibrocartilage*, and *yellow* or *elastic fibrocartilage*.
    - *Hyaline Cartilage*
        - Hyaline cartilage consists of a gristly mass of a firm consistence, but of considerable elasticity and pearly bluish color. Except where it coats the articular ends of bones, it is covered externally by a fibrous membrane, the *perichondrium*.
        - It contains no nerves.
        - Microscopically it consist of cells of a rounded or bluntly angular form, lying in groups of two or more in a granular or almost homogeneous matrix.
        - *Articular cartilage, costal cartilage,* and *temporary cartilage* are all of the hyaline variety. They present differences in the size, shape, and arrangement of their cells.
    - *White Fibrocartilage*
        - White fibrocartilage consists of a mixture of white fibrous tissue and cartilaginous tissue in various proportions; to the former of these constituents it owes its flexibility and toughness, and to the latter its elasticity.
        - When examined under the microscope it is found to be made up of fibrous connective tissue arranged in bundles, with cartilage cells between the bundles; the cells to a certain extent resemble tendon cells, but may be distinguished from them by being surrounded by a concentrically striated area of cartilage matrix and by being less flattened.

TOP

Ligaments

- Ligaments are composed mainly of bundles of white fibrous tissue placed parallel closely interlaced with one another and present a white, shining, silvery appearance.
- They are pliant and flexible to allow perfect freedom of movement, but strong, tough, and inextensible to yield readily to applied force.
- Some ligaments consist entirely of *yellow elastic tissue*, as the ligamenta flava which connect together the laminæ of adjacent vertebræ. In these cases the elasticity of the ligament is intended to act as a substitute for muscular power.

TOP

Capsules

- *Articular Capsules*
  - The articular capsules form complete envelopes for the freely movable joints. Each capsule consists of two strata—an *external* (stratum fibrosum) composed of white fibrous tissue, and an *internal* (stratum synoviale) which is a secreting layer and is usually described separately as the synovial membrane.
- *Fibrous capsules*
  - It is attached to the whole circumference of the articular end of each bone entering into the joint, and thus entirely surrounds the articulation

TOP

Synovial membrane

- It invests the inner surface of the fibrous capsule and is reflected over any tendons passing through the joint cavity
- It is composed of a thin, delicate, connective tissue with branched connective-tissue corpuscles.
- Its secretion is thick, viscid, and glairy, like the white of an egg, and is hence termed synovia.
- They consist of connective tissue covered with endothelium and contain fat cells in variable quantities with isolated cartilage cells.
  - *Synovial sheath*
    - They serve to facilitate the gliding of tendons in fibroosseous canals.
    - Each sheath is arranged in the form of an elongated closed sac, one layer of which adheres to the wall of the canal and the other is reflected upon the surface of the enclosed tendon.
    - These sheaths are chiefly found surrounding the tendons of the Flexor and Extensor muscles of the fingers and toes as they pass through fibroosseous canals in or near the limb.
  - *Synovial bursae*
    - They are interposed between surfaces which glide upon each other.
    - They consist of closed sacs containing a minute quantity of clear viscid fluid.

DEVELOPMENT OF THE JOINTS

- The mesoderm from which the different parts of the skeleton are formed shows at first no differentiation into masses corresponding with the individual bones. Thus continuous cores of mesoderm form the axes of the limb-buds and a continuous column of mesoderm the future vertebral column.
- The *first indications of the bones and joints are circumscribed condensations of the mesoderm* and these condensed parts become chondrified and finally ossified to form the bones of the skeleton.
- The intervening non-condensed portions consist at first of undifferentiated mesoderm, which may develop in one of three directions. It may be converted into fibrous tissue as in the case of the skull bones, a synarthrodial joint being the result or it may become partly cartilaginous, in which case an amphiarthrodial joint is formed. Again, it may become looser in texture and a cavity ultimately appear in its midst; the cells lining the sides of this cavity form a synovial membrane and thus a diarthrodial joint is developed.
- The tissue surrounding the original mesodermal core forms fibrous sheaths for the developing bones, *i. e.,* periosteum and perichondrium, which are continued between the ends of the bones over the synovial membrane as the capsules of the joints. These capsules are not of uniform thickness, so that in them may be recognized especially strengthened bands which are described as ligaments.

- This, however, is not the only method of formation of ligaments. In some cases by modification of, or derivations from, the tendons surrounding the joint, additional ligamentous bands are provided to further strengthen the articulations.
- In several of the movable joints the mesoderm which originally existed between the ends of the bones does not become completely absorbed—a portion of it persists and forms an articular disk. These disks may be intimately associated in their development with the muscles surrounding the joint, *e. g.,* the menisci of the knee-joint, or with cartilaginous elements, representatives of skeletal structures, which are vestigial in human anatomy, *e. g.,* the articular disk of the sternoclavicular joint.

CLASSIFICATION OF JOINTS

- Joints are classified *anatomically* according to their *mode of development*, the *nature of uniting medium* and the *form of joint surfaces*.
- They can also classified *physiologically* base on the *amount* and *kind of movements* permitted or the absence of movement in them.
- These joints are classified *developmentally* as
    - Fibrous joints
    - Cartilaginous joints
    - Synovial joints
- Based on the *nature of uniting medium* and the *movements permitted*, they are classified as
    - Synarthroses (includes fibrous and primary cartilagenous joints)
    - Amphiarthroses (secondary cartilaginous joints)
    - Diarthroses (synovial joints)

FIBROUS JOINTS (SYNARTHROSES)

These are the temporary joints and subsequently the uniting medium i.e. white fibrous tissue is invaded by process of ossification. The fibrous tissue connecting the bones also undergoes ossification with advancing age and this process is known as *synostosis***.** These joints practically provide no movement and hence termed as *immovable joints*.

- These joints are of following type:
    - *Sutures*
        - These joints are mostly found in the skull. The opposing ends of bones are united by fibrous tissue, the *sutural ligament*. The sutures are classified according to the shape of the opposing edges of the bones.
            - *Sutura serrata* –the edges are serrated or like the tooth of the saw. E.g. frontal suture.
            - *Sutura squmosa*-one bone overlaps the other. E.g. suture between the parietal and temporal bone.
            - *Sutura harmonia* or *plane suture*-the edges are present no irregularities and are smooth and rounded or slightly roughened.E.g. nasal suture
    - *Syndesmoses*
        - The uniting medium is a mixture of fibrous and elastic tissue.
        - *E.g*. intermetacarpal articulations-horse.
    - *Schindylesis*
        - When a bone is fitted into a groove of another bone.
        - *E.g*. junction between the vomar and sphenoid bone.
    - *Gomphosis*
        - The articulation between the roots of the teeth in the alveolar sockets is termed as gomphosis.
        - Here the peg like roots of the teeth are implanted into the alveolar sockets.

CARTILAGINOUS JOINTS

- In this type,the bones are united by cartilage. The movement is a limited one.
- In *primary cartilaginous joints (synarthroses),* the uniting medium is hyaline cartilage and movement is absent. Synostosis usually follows in these joints.
- In *secondary cartilaginous joints (amphiarthroses)*, the opposing ends of bones connected by fibrocartilage. The chondrification appears secondarily in the membranous tissue between the zones (which are primary chondrified and then ossified) and there is limited range of movement permitted in these joints (intercentral articulations of vertebrae).
- These are of two types
    - *Synchondroses:* The opposing bones are connected by hyaline cartilage E.g. occipito-sphenoid.
    - *Symphyses:* These are the fibrocartilaginous articulations between the symmetrical bones. They are also called secondary cartilaginous joints and persist throughout the life. They permit certain amount of movement. These articulations are generally placed at the longitudinal median plane of the body. E.g.Symphysis mandibulae and symphysis pelvis.

SYNOVIAL JOINTS (DIARTHROSES)
(Classification)

- These are characterized by the presence of a *joint cavity*, a *synovial membrane* and the *joint capsule* and by their mobility.
- The opposing ends of bones are free and are enclosed by fibrous capsule with synovial membrane lining. These joints possess a *wide range of movement*.
- The following structures enter into the formation of a diarthrodial joint.
    - *Articular surfaces* are formed of especially dense bone and may present non-articular depressions known as *synovial fossae*. These may be facets, head, condyle, trochlea or concavities, glenoid cavity, cotyloid cavity etc.
    - *Articular cartilages* are hyaline in type and cover the articular surfaces. They diminish concussion, reduce friction and may accentuate the curvature of the bone. It is thicker in young ones and thinner in old animals. It is believed that this tissue derives its nutrition from the vascular network of synovial membrane, synovial fluid and from blood vessels of underlying marrow spaces.
    - Besides these articular cartilages, in some joints other varieties of cartilage such as interarticular cartilage, marginal cartilage, etc are present.
    - *Inter-articular cartilages* or *menisci* are fibrocartilaginous plates or disc interposed between the two articular surfaces to render the surface congruent. They minimize the pressure and friction, which are produced during the activity of the joint.
    - *Marginal* or *circumferential cartilages* are rings of fibro-cartilage encircle the rim of an articular cavity in some joints. They enlarge the cavity and tend to prevent the fracture of the margin.
- *Articular* or *joint capsule* consists of an *outer fibrous capsule* and *inner synovial membrane.*
    - The *fibrous capsule* or *capsular ligament* is composed of parallel and interlacing bundles of white connective tissue fibres. This capsule is perforated for the passage of blood vessels and nerves. Sometimes a portion of synovial membrane protrudes out through an aperture and forms a pouch. It encapsulates the joint and is attached around the articular ends of the concerned bones.
    - The *synovial membrane* lines the joint cavity, synovial bursa and synovial sheath. It is a thin membrane richly supplied with blood vessels and nerves and secretes *synovia*, which lubricates the joints.
    - *Synovia* resembles white of an egg in consistency but has a yellowish tinge. It contains albumen, mucin, and salts and is alkaline in nature. It also contains hyaluronic acid, which decides the viscosity of the fluid. *Articular joint cavity* is a potential space enclosed by synovial and articular cartilages.

- *Ligaments* are strong strands usually composed of white fibrous tissue, which bind the bones together. In some cases, they are made up of elastic tissue. They may be periarticular or intra-articular. The ligaments may be of following varieties:
    - *Capsular ligament* or *fibrous capsule*- already described.
    - *Collateral ligaments*- Present on either side of the joint.
    - *Intra-articular ligament*- these are the connecting bands remain within the joint cavity and is covered by synovial membrane.
    - *Interosseous ligaments* -The opposing surfaces of bones are connected by these ligaments.
    - *Annular ligaments*-These are in the form of rings or tunnels, over or near the joints for the passage and the protection of tendons.
- *Vessels and nerves:* The arteries form anastomoses around the larger joints and give branches to the extremities of the bones and joint capsule. Nerve fibres are numerous in and around the synovial membrane and specialized nerve endings (Pacinian corpuscles, articular end bulbs of Krause) are present.

Classification of diarthrodial joints

The diarthrodial joints are classified according to the axes of movement. This classification assumes the existence of three mutually perpendicular axes. They are

- *Uniaxial*-When a joint permits movement in one plane only. Hinge joints and pivot joints belong to this group. *E.g*. ginglymus, pivot and condyloid joints.
- *Biaxial*-These joints permit movement in two planes at right angles. *E.g* extension-flexion and abduction–adduction. A combined circumduction movement may also available.*E.g*. saddle and ellipsoidal joints.
- *Multiaxial*-These joints permit angular, rotation and circumduction movements. *E.g*. ball and socket joints.
    - Synovial joints may also be classified according to the shape of the articular surfaces of the constituent bones. These shapes determine the type of movement and are partly responsible for determining the range of movement. The more common types are gliding, hinge and condyloid. Ball and socket, ellipsoidal, pivot and saddle joints are less common.
        - *Arthrodia* or *Gliding joints:* The articular surfaces of bones are flat and admit only gliding movements.E.g. carpus, tarsus.
        - *Ginglymus* or *Hinge joints:* The condyles or convexities of one bone articulate with corresponding concavities of another and permit only extension and flexion.E.g. elbow.
        - *Condyloid* or *imperfect hinge joints:* The elliptical concavities of one bone atriculate with other and except rotation all movements are permitted to varying degrees. E.g. radio-carpal.
        - *Enarthroses* or *Ball and socket joint:* The head of one bone is received into a glenoid or cotyloid cavity and shows extensive and various movements including circumduction. E.g. hip.
        - *Trochoid* or *Pivot joints:* One segment rotates around another.E.g. atlanto-axial.
        - *Ellipsoidal joint* resembles the ball and socket joint; the articulating surfaces are much longer in one direction than in the direction at right angles. The circumference of the joint thus resembles ellipse. E.g. carpal joint.
        - *Saddle* or *Sellar joint:* The opposing surfaces are convexo-concave or saddle shaped. E.g. interphalangeal articulations of the dog.

MOVEMENTS OF SYNOVIAL JOINTS

Movements are determined chiefly by the form, extent of joint surfaces and the arrangements of ligaments. They are classified as

- *Translation* or *Gliding:* one bone moves or glides over another in the same plane (carpals and tarsals).
- *Angular:* During these movements, the angles between the two adjoining bones change. The angular movement as follows;
    - *Flexion* –The motion that diminishes the angle between the bones forming the joint.
    - *Extension*-The angle increase or the segment straightens (elbow).
    - *Adduction*-Inward movement of one segment from the central axis.
    - *Abduction*- Outward movement of one segment from the central axis.
    - The terms *depression, elevation* also refer to angular movements in a vertical place (temporo-mandibular joint).
- *Circumduction* - The distal end of the bones forming the joint describes a circle or segment of one (hip point).
- *Rotation:* One bone rotates around the longitudinal axis of another (atlanto-axial).
- *Pronation* and *Supination* refer to the position and movement of forearm and manus. In supination the volar (palmar in men) face of the manus is turned forward (or upward) and in pronation, it faces backwards (downwards).

ARTICULATIONS OF THE SKULL

- Most of the bones of the skull are united by *sutures*. A few are united by *cartilage* (synchondrosis) and one (temporomandibular) joint is a *synovial joint*.
- The *sutures* have been named according to the bones involved in their formation. E.g. interparietal suture, interfrontal suture, frontoparietal suture, temporoparietal suture etc.
- The principal *synchondroses* are between (1) basioccipital and post sphenoid (2) post sphenoid and presphenoid (3) parts of occipital. Most of these joints ossify in life.
- A *symphysis* occurs between the two halves of the ventral ends of the mandible at the median plane. This symphysis does not ossify even in adult life.
- The only movable articulations are the temporo-mandibular and hyoidean articulations.

TEMPORO - MANDIBULAR ARTICULATIONS

Ox

- It is a *diarthrosis* between the condyles of the ramus of the mandible and the squamous temporal.
    - *Ligaments*
        - *Capsular Ligament* attached round the articular areas. There are two synovial membranes one above and below the inter-articular cartilage.
        - *Lateral ligament*-which extends between the zygomatic process and the neck of the ramus.
        - An *inter-articular cartilage* or *meniscus* is interposed between the articular surfaces to bring about adoption of the articular areas.
    - *Motion*

        1. Gliding and angular movements as depression and elevation in opening and closing the mouth.
        2. Rotation on a vertical axis in transverse movements performed during mastication.

Horse

- There is in addition a posterior ligament of elastic tissue attached above to the post glenoid process and below to the next of the ramus.
- Lateral movements are restricted.

Dog

- The inter-articular disc is very thin.
- The posterior ligament is absent.
- There is no transverse movement.

Fowl

- The presence of the quadrate bone permits the mechanical elevation of the upper part of the beak whenever the mandible is depressed.
- This is rendered possible by the absence of rigidity in the neighborhood where the frontal, nasal and incisive bones meet and add materially to the freedom with which the fowl can widely open the mouth.
- The elevation of the upper beak is brought about in the following manner. Depression of the mandible causes a forward motion to the lower end of the quardrate and this is transmitted to the pterygoid, the inner end of which is movably articulated to the sphenoid.
- The palatine being joined to the pterygoid is necessarily pushed forwards at the same time; thus the movement is communicated to the upper beak with which the anterior end of the palatine is connected.

HYOIDEAN ARTICULATIONS

Ox

- In connection with the hyoid bone, five joints are formed on each side viz, (1) basicornual between the body and keratohyoid (2) and (3) intercornual between kerato and epihyoid and between epi and stylohyoid (4) temporo hyoidean between stylohyoid and hyoid process of petrous temporal and (5) thyro hyoidean between the thyroid cartilage of larynx and thyrohyoid.
    - The basicornual articulation is a diarthrodial joint between the shallow articular cup on the lower end of keratohyoid and a convex articular facet on the body. There is a joint capsule the movement is chiefly hinge like.
    - The intercornual and temporo-hyoidean articulations are amphiarthorses. The thyro-hyoidean articulation is syndesmoses.
        - *Motion*
            - The movements of hyoid bone are concerned chiefly in the acts of mastication and deglutition.
            - During deglutition, the ventral parts of the hyoid bone are moved forward and upward carrying the root of the tongue and larynx with them and then return to their former position.

Horse

- As the epihyoid is fused with the stylohyoid and is the only one intercornual articulation.

Dog

- No difference.

ARTICULATIONS OF THE VERTEBRAL COLUMN

- The bones of the vertebral column are serially articulated by their bodies and by the neural processes.
- Most of the joints are articulated by some common or common variety of ligaments and therefore called as *common vertebral articulations*.
- There are few joints in the vertebral column, which are not articulated by common ligaments, are called as *special vertebral articulations*.
- The *common vertebral articulations* are of two kinds:
    - *Intercentral*, those formed between the bodies of the vertebrae
    - *Interneural*, those formed between articular processes of adjacent vertebrae.
- Associated with these joints are ligaments, some of which extend the whole length of vertebral column- the *common ligaments* and some are restricted to a single joint-the*special ligaments*.
- The *special vertebral articulations* are the *occipito-atlantoaxial* and the *coccygeal articulations*.

COMMON VERTEBRAL ARTICULATIONS
(Intercentral, Interneural)

- The bones of the vertebral column are serially articulated by their bodies and by the neural processes. Most of the joints are articulated by some common or common variety of ligaments and therefore called as *common vertebral articulations*.
- The *common vertebral articulations* are of two kinds:
    - *Intercentral* - those formed between the bodies of the vertebrae
    - *Interneural* - those formed between articular processes of adjacent vertebrae.
- Associated with these joints are ligaments, some of which extend the whole length of vertebral column- the *common ligaments* and some are restricted to a single joint-the*special ligaments*.

Intercentral articulations

Ox

- These are *amphiarthroses* formed the bodies of adjacent vertebrae.
    - *Ligaments*
        - *Inter-vertebral discs*-Each of these is made up of fibro cartilage and is interposed between the bodies to which it is intimately attached. These discs are thinnest in the dorsal, thicker in the cervical and lumbar and thickest in the coccygeal region. Each consists of a peripheral fibrous (**annulus fibrosus**) and a soft central pulpy substance (nucleus pulposus). There are joint cavities in the cervical intercentral joints, in those between the last cervical and first thoracic and between last lumber and first sacral joints.
        - *The ventral longitudinal ligament:* It lies along the ventral faces of the bodies of vertebrae and the intervertebral discs to which it is firmly attached. It is strongest in the lumbar region where it is blended with the crura of the diaphragm. It begins from about the seventh dorsal as a thin band, becomes gradually thicker and wider behind and terminates on the pelvic face of the sacrum. In the anterior dorsal (in front of seventh dorsal) and the cervical regions, it is replaced by the *longus colli* muscle.
        - *The dorsal longitudinal ligament:* It is a ribbon like white fibrous band extending from the sacrum to the axis along the floor of the spinal canal intimately attached to

the superior faces of the intervertebral dics. In each vertebra, it is narrow in the middle and wider at the extremities.

TOP

Interneural articulations

- These are *diarthroses* formed between the articular processes. The articular surfaces are extensive flat and oval in the cervical region; small and flat in the thoracic region, while in the lumbar region the anterior ones are concave and the posterior convex. They are *arthrodia* in the neck and back and *trochoid* in the lumbar region.
    - *Ligament*
        - *Capsular ligament* surrounds the joint.
        - *Ligamenta flava* connects neural arches of the adjacent vertebrae.
        - *Interspinous* between the spines of the contiguous vertebrae.
        - *Intertransverse*-between the adjacent of the transverse processes in the lumbar region.
        - The *supraspinous ligament* is an elastic ligament extending from the sacrum to the occipital bone consists of a *dorso- lumbar* and a *cervical part*.
        - The dorso-lumbar part starts from the sacral spines where it is blended with the dorsal sacroiliac ligament and is attached all along its course to the summits and the first dorsal is continued by the cervical part.
        - The *cervical part* or *ligamentum nuchae* consists of right and left parts, which are continuous with the dorso-lumbar parts. Each division of the cervical part is made up of*dorsal funicular portion* and a *ventral lamellar portion*.
        - The *funicular parts* of the two sides run forwards and are inserted to the external occipital protuberance.
        - The *lamellar parts* is thick is made up of anterior and posterior divisions. The *anterior division* is paired (right &left), its fibres proceed from the funicular part and becomes inserted to the neural spine of second, third and fourth cervical vertebrae.
        - The *posterior division* is single and its fibres arise from the first dorsal and are inserted to the neural spines of the fifth, sixth and seventh cervical vertebrae. The ligamentum nuchae assists the extensors of the head and neck.
    - *Motion*
        - Dorsal, ventral and lateral flexion and rotation.
        - The range of movement in a single joint is small, but the sum of the movements is considerable.
        - The movements are free in the cervical and coccygeal regions whereas movement is restricted in the thoracic and lumbar regions.

Horse

- The dorso-lumbar part of supraspinous ligament is made up of white fibrous tissue. The ligamentum nuchae is less developed. The lamellar parts are undivided and are inserted to the neural spines of the second to the sixth cervical.
- *Intertransverse articulations* are present in the lumbar region. These are peculiar to equidae. These are *arthrodia* between the transverse processes of the sixth and wing of sacrum and also between the transverse processes of the sixth and the fifth. It may also be present between those of the fourth and fifth. There is a tight joint capsule reinforced ventrally by fibrous tissue.

Dog

- The ligamentum nuchae is narrow fibrous band and interspinous muscles replace interspinous ligaments.

SPECIAL VERTEBRAL ARTICULATIONS

There are few joints in the vertebral column, which are not articulated by common ligaments, are called as *special vertebral articulations*.

- The *special vertebral articulations* are
  - Occipito-atlantal articulation
  - Atlanto-axial articulation
  - Sacral and Coccygeal articulations

OCCIPITO - ATLANTAL ARTICULATION

Ox

- Is a *ginglymus* joint between the condyles of the occipital bone and the anterior articular cavities of the atlas.
  - *Ligaments*
    - *Capsular*
    - *Two lateral occipito*-atlantal ligaments attached to the paramastoid processes in front and the anterior margins of the wings of atlas behind.
    - The *dorsal occipito-atlantal ligament* consists of two fasciculi, which intercross and extends between the dorsal margin of the foramen magnum and wing of atlas
    - The *ventral occipito-atlantal ligament* extends from the ventral margin of the foramen magnum to the wing of atlas. Synovial membranes are two in number, one for each condyle**.**
  - *Motion*
    - Extension, flexion and slight lateral oblique motion.

Horse

- No difference.

Dog

- The synovial membrane communicates with that of the atlanto-axial joint.

ATLANTO - AXIAL ARTICULATION

Ox

- It is a *trochoid joint* formed between the atlas and the axis.
  - *Ligaments*
    - *Capsular ligament* is very loose.
    - The dorsal atlanto-axial is an elastic membranous ligament which extends from the posterior border of dorsal arch of atlas to anterior border of the arch of axis
    - The *ventral atlanto-axial ligament* is a thin fibrous band extending between the ventral tubercle of atlas and the ventral spine of axis.
    - The *odontoid ligament (Ligamentum dentis)* is attached to the dorsal face of the odontoid process of the axis behind and to the interior of the ring of atlas in front.
  - *Motion*

        - Rotation of the atlas in front, carrying the head with it.

Horse

- Since the dens is better developed, the dorsal cap between the axis and atlas is wide. Hence the ligaments covering the space are large and better developed.

Dog

- The *odontoid ligament* is replaced by *two alar* and one transverse ligament.
- The *two alar ligaments* arise on either side of the dens, diverge and end on either side of the foramen magnum.
- The *transverse ligament* is attached to lateral mass of atlas on either side. It stretches across the dorsal surface of the dens and binds it down on the ventral arch of atlas.

SACRAL AND COCCYGEAL ARTICULATIONS

- *Sacro-lumbar articulation*
    - It mostly resembles the intercentral articulations of the vertebral column except that the intervening fibrocartilage is very thick.
- *Inter-sacral articulations*
    - The articulations formed between the five sacral vertebrae in the embryo are obliterated by ossification of the intervertebral discs and fusion between the five vertebrae.
- *Sacro-coccygeal articulations*
    - The last segment of the sacrum articulates with the rudimentary first coccygeal vertebra. Only intercentral articulation is well developed.
- *Inter-coccygeal articulation*
    - *Ox*
        - The anterior three or four coccygeal vertebrae have the rudimentary neural canal and the rest are only bi-convex rods.
        - They are united by thick inter vertebral cartilages.
        - There are no spinal ligaments.
        - The coccygeal muscles encircle the body on all sides and acts as ligaments to produce movements.
        - The movements are extensive and varied owing to the smallness of the bodies and suppression of the arches and processes.
    - *Horse & Dog*
        - No difference.

THORACIC ARTICULATIONS

The thoracic articulations may be divided as

- *Extrinsic articulations*
    - *Costo-vertebral* articulations between the ribs and vertebrae.
- *Intrinsic articulations*
    - *Costo-chondral* articulations between the ribs and costal cartilages.
    - *Chondro-sternal* articulations between the costal cartilages and sternum.
    - *Sternal* articulations between the segment of sternum articulations.

EXTRINSIC / COSTO - VERTEBRAL ARTICULATIONS

This articulation is formed between the ribs and vertebrae. Each rib articulates with vertebra at the following two points

- Costo-central articulations
- Costo-transverse articulations

Costo-central articulations

Ox

They are *trochoid* formed between the heads of ribs and the capitular cavities formed by two adjacent dorsal vertebrae and the inter-vertebral disc in-between.

- *Ligaments*
  - *Capsular ligament*
  - *Radiate ligament* extends from the neck of the rib to the ventral part of the body and the intervertebral discs. It consists of three parts; of these, one becomes attached to the vertebrae in front, one to the intervertebral discs and other to the vertebra behind.
  - *Conjugal ligament* attached to the sulcus on head of a rib and enters the spinal canal, passes under dorsal longitudinal ligament attached itself to it and the vertebrae in front and the intervertebral disc and finally ends on the head of the corresponding rib of the opposite side. The first costo-central articulation has no conjugal ligament
  - *Ligament of the neck of the rib* is a strong, flat band which begins from the neck of the rib, crosses the joint superiorly and ends on the vertebra above the costal facet.
- *Motion*
  - Rotation.

TOP

Costo-transverse articulations

These are *gliding joints* formed between the facet on the tubercle of a rib and the tubercular facet on the transverse process of the corresponding dorsal vertebra.

- *Ligaments*
  - *Capsular* ligament
  - *Anterior costo-transverse ligament* lies in front of the joint and connects the neck of the rib to the anterio-ventral part of the transverse processes.
  - *Posterior costo-transverse ligament* is situated on the superio-posterior aspect of the joint connects the tubercle to the lateral part of the transverse process.
- *Motion*
  - Gliding movement.

Horse and Dog

- No difference.

INTRINSIC ARTICULATIONS

The intrinsic articulations are as follows

- Costo-chondral articulations between the ribs and costal cartilages.
- Chondro-sternal articulations between the costal cartilages and sternum.
- Sternal between articulations the segment of sternum.

COSTO-CHONDRAL ARTICULATIONS

- *Ox*
  - These are *diarthroses* (arthrodia). All the ribs except the first and last two articulate with the concerned costal cartilages. The roughened end of costal cartilage is inserted in the depression at the end of the concerned rib. The perichondrium and periosteum cover the junction.
  - *Ligaments :* Capsular ligament.
  - *Motion:* Gliding (inappreciable).
- *Horse*
  - The costo-chondral junctions are *synarthroses (gomphosis)*.
  - The periosteum and perichondrium of the ribs and their cartilages are continuous.
- *Dog*
  - No difference.

TOP

CHONDRO -STERNAL ARTICULATIONS

- *First chondro-sternal articulations*
  - *Ox*
    - They are *synchondrosis* between the ventral ends of the first pair of the ribs and the first segment of the sternum.
    - *Ligaments*
      - *Capsular ligament* is a common one for the first pair of joints
      - *Cruciate ligament*-the fibres are strong and extend diagonally from one joint to the opposite joint and cross at the middle.
    - *Motion:* Restricted.
- *Other chondro-sternal articulations*
  - *Ox*
    - They are diarthroses (*trochoid*) between the second to eighth cartilages of sternal ribs and the concerned concavity of the sternum.
    - *Ligaments*
      - *Capsular ligament*
      - *Dorsal* and *Ventral chondro-sternal* extending from the cartilage to the sternum on the dorsal and ventral aspect of the joint. The fibres of the dorsal ligament also called *radiate costo-sternal ligament* as they pass medially to blend with the internal sternal ligament**.**
      - *Costo-xiphoid ligament*-the cartilage of the eighth rib is connected with xiphoid cartilage by this ligament.
    - *Motion:* Rotation around the vertical axis.
- *Inter-chondral articulations*
  - *Ox*
    - The asternal cartilages and the last two cartilages are united together by their free ends to those infront by fibrous connective tissue called *interchondral ligament*. These are known as *interchondral articulations*.
  - *Horse*
    - The cartilages articulate with each other medially.

- *Movements of ribs*
  - The costal movements are of great importance in respiration.
  - During inspiration each rib is rotated laterally and forwards as if it was hinged in an axis passing through its head and sternal end of its cartilage.
  - There is thus a simultaneous rotation in the costo-central joints.
  - The effect being to move the midpoint of each ribs laterally and forwards from the corresponding point of the opposite ribs.
  - In this way the transverse diameter of the chest between any two opposite ribs is increased. During expiration each rib returns to its original position.
  - In each of these respiratory movements, the tubercle of rib glides on the facet of the transverse process moving in a circle whose centre is the costo central joint.
  - The ranges of motion are greater in the posterior series of ribs.

TOP

STERNAL ARTICULATIONS

- *Ox*
  - The first sternebra is articulated to the second forming a *diarthrosis*, which permits, limited movements.
  - The other sternal articulations are *synchondroses*.
  - The segments are connected to one another through discs of cartilages.
  - The different segments are connected on their dorsal aspect by a common *internal sternal ligament* which is narrow to start with from the first segment becomes wider posteriorly and ends on the last segment.
  - *Motion*
    - Limited lateral movement between the first and second sternebrae.
    - The remaining is immovable joint.
- *Horse*
  - There is no diarthrosis between the first and second segments and all joints are immovable. The internal sternal ligament consists of a central and two lateral bands.
- *Dog*
  - The internal sternal ligament divides into three bands.

MODULE-15: ARTICULATIONS OF THE PECTORAL LIMB

Learning outcomes

At the end of this module, the learner will be able to know about

- Shoulder joint
- Elbow / Cubital joint
- Knee joint
- Inter metacarpal joint
- Fetlock joint
- Pastern joint and
- Coffin joint

JOINTS OF THE FORELIMB

The joints of the forelimb are as follows

- Shoulder joint between the scapula and humerus.
- Elbow joint between humerus and radius and ulna.
- Carpal joint formed by the union of carpals bones with radius and ulna.
- Intermetacarpal articulation between the metacarpal bones.
- Fetlock joint between the metacarpal, first phalanx with proximal sesamoids.
- The *interphalangeal articulations* are
    - Pastern joint formed between the first and second phalanges
    - Coffin joint formed between the second and third phalanges and the distal sesamoid.

SHOULDER JOINT

Ox

(Click for image of Shoulder joint anterior view, posterior view and medial view)

- It is an *enarthrosis* formed between the glenoid cavity of the scapula and the head of the humerus.
    - *Ligaments*
        - Capsular ligament is the only ligament, which is loose and is protected by the several muscles of the shoulder around the joint.
        - The position of the joints not fixed because both the bones can move.
    - *Motion*
        - Polyaxial. Extension and flexion are best marked. Adduction and abduction and circumduction are also present.

Horse

- No difference.

Dog

- The rim of the glenoid cavity is raised by a marginal cartilage.

ELBOW / CUBITAL JOINT

This is a composite joint consisting of

- Humero-radio-unlar articulation
- Radio-ulnar articulation.

Humero-radio-unlar articulation

Ox

- It is a *ginglymus* formed between the distal extremity of humerus and the proximal ends of radius and ulna. The articular surfaces are the condyles of the humerus and concavities on the proximal extremity of radius and the semilunar notch of the ulna.
    - *Ligaments*
        1. *Capsular ligament* forms a pouch over the olecranon fossa

2. *Medial* and *Lateral collateral ligaments* attached above on the respective faces of the distal extremity of the humerus and the medial and lateral tuberosities of the upper extremity to the radius.
3. The medial ligament consists of a *superficial part* attached to the medial border of the radius below the radial tuberosity and a *deep part* attached to the medial tuberosity.

- *Motion*
    - Extension and flexion.

Horse

- No difference.

Dog

- The capsule is strengthened by two bands.
- One is in front, which is oblique and arising in front of the lateral condyle of humerus above the joint surface joins the terminal part of biceps and brachialis below:
- The other is on the postero medial aspect from the medial side of olecranon fossa (or the lateral aspect of medial epicondyle) to the ulna just above the anconeus process and the lateral ligaments are attached below to the radius and ulna.

TOP

Radio-ulnar articulation

Ox

- It is a *diarthrosis* and an *amphiarthrosis* formed between the radius and ulna.
- The *diarthrosis* is formed between the facets on the ulna and corresponding facets of the radius.
- *Ligaments*
    - *Capsular ligament*-continuous with that of the humero-radio articulation.
    - The *amphiarthrosis* is formed between the shafts of the radius and ulna. One above the proximal radio ulnar arch, second between the two radio ulnar arches and the third below the distal radio ulnar arch.
- *Ligaments*
    - *Three interosseous ligaments*, which ossify in the adult.
    - In addition, there are *two arciform ligaments*, lateral and medial which are attached to lateral aspect of the olecranon process of the ulna.
- *Motion*
    - Is inappreciable, the forearm being fixed in the position of pronation.

Horse

- There is only one inter-osseous ligament.
- Two bones above the proximal ulnar arch are not ossified till late in life.

Dog

- The joints between the radius and ulna at either end are *trochoid*. The proximal joint has in addition to the capsular ligament, an *annular ligament* that arises from the lateral condyle of the humerus and joins the terminal part of the brachialis and the biceps brachii.
- The distal joint has a tight capsular ligament.
- The shafts are united by interosseous ligaments.
    - *Motion*
        - Limited supination is possible with the lateral rotation of the radius carrying the paw with it.

KNEE JOINT

Ox

It is composite joint consisting of

- Radio-ulnar-carpal articulations
- Carpal articulations
    - Proximal carpal articulations
    - Intercarpal articulations
    - Distal carpal articulations
- Carpo-metacarpal articulations.

The joint as a whole is having *common ligaments* and *special ligaments*.

Common ligaments

- *Capsular ligament* is a loose sac. Its anterior part is called *dorsal carpal ligament*, which covers the joint in front and is adherent to the extensor tendons passing over it. The posterior part is called as *volar carpal ligament* covers the joint behind and its posterior face forms the anterior wall of the carpal sheath.
- *Lateral* and *Medial carpal ligaments* which arise from the distal extremity of the radius and ulna, pass down adherent to the carpal bones and are attached to the upper extremity of the large metacarpal below on the lateral and medial aspects of the joint.
- The *carpal sheath* or *canal* is formed by the volar capsular ligament in front and by the volar annular ligament behind, which extends from the posterior border of accessory carpal to the medial aspect, blending with the medial ligament of the carpus. The canal is lined by synovial membrane and serves for the passage of tendons of *flexor perforans*, deep division of *flexor perforatus*, median nerve, ulnar artery and vein.

Special ligaments

There are large number of special ligaments connecting the various bones of the carpal joint.

- *Radia-ulnar carpal articulation*
    - It is *diarthrosis* between the lower extremity of the radius, styloid process of ulna and upper row carpal bones. The radius articulates with all the three bones and the ulna articulate with ulnar carpal only.
    - *Ligaments*
        - *One oblique* and *three posterior ligaments*.
        - *Oblique ligament* connects the radius and ulnar carpal obliquely on the dorsal aspect.

        - *The three posterior ligaments* connects the (1) radius and radial carpal (2) radius and intermediate carpal (3) ulnar and accessory carpal on the volar aspect.
- *Carpal articulations*
    - *Proximal carpal articulations*
        - They are also *diarthroses* and between the bones of upper row.
        - *Ligaments*
            - There are *three anterior, two posterior* and *three interosseous ligaments*.
            - The *three anterior ligaments* are connecting viz., (1) radial carpal to intermediate carpal (2) intermediate to ulnar carpal (3) ulnar carpal to accessory carpal on the dorsal aspect.
            - The *posterioe ligaments connects* the (1) Intermediate to ulnar metacarpal (2) Ulnar carpal to accessory carpal on the volar aspect.
            - *Interosseous ligaments* that connect adjacent bones.
    - *Inter-carpal articulations*
        - They are *arthroid* and between the bones of proximal row and distal row.
        - *Ligaments*
            - There are *two oblique* and *three posterior ligaments*.
            - The *two oblique ligaments* are connecting on the dorsal aspect viz., (1)obliquely radial carpal and fourth carpal (2) ulnar carpal and fourth carpal fibres also extend below to the large and small connect metacarpal bones.
            - *The three posterior ligaments are connecting o*n the volar aspect (1) radial carpal to fused second and third carpal. (2) ulnar carpal to fourth carpal (3) accessory carpal to fourth carpal.
    - *Distal carpal articulations*
        - They are *arthroid* between the fused second and third carpal and fourth carpal.
        - *Ligaments*
            - A ligament connectssecond and third carpal to fourth carpal on dorsal aspect
            - An interosseous ligament.
- *Carpo-metacarpal articulation*
    - They are formed between the distal row of carpal bones and proximal extremity of the metacarpal bone.
    - *Ligaments*
        - There are *two anterior, two posterior* and *two interosseous ligaments*. However, these short ligaments are sometime weak or inconstant in number.
        - The *anterior ligaments* connects (1) second and third carpal to on large metacarpal (2) fourth carpal to large metacarpal on the dorsal aspect.
        - *The posterior ligaments connects* . (1) ulnar carpal to large metacarpal (postero lateral) (2) second and third carpal to large metacarpal (3) fourth carpal to large metacarpal on the volar aspect.
        - An *interosseous ligament* connects second and third carpal to large metacarpal. Two anterior and posterior ligaments hold the accessory carpal.
    - *Synovial membranes*
        - There are three large and one small synovial membrane.
    - *Motion*
        - Extension and flexion and to a small extent abduction and circumduction in the radio-ulnar carpal.
        - In the other joints motion is inappreciable.

Horse

- There is minor difference due to the increased number of the carpal bones.
- There are two other important ligaments peculiar to the horse called superior and inferior check ligaments.
- The *superior check ligament (supracarpal)* arises from the dorsal part of the medial border of the radius and is inserted to the tendon of the superficial flexor of the digit above the carpus.

- The *inferior check ligament (subcarpal)* is a continuation of the volar capsular ligament of the carpus. It joins the tendon of the deep flexor of the digit about midway down the metacarpus. The check ligaments assist the flexor tendons after severe exertion to keep them tight and prevent flexion.

Dog

- There are differences due to variation in the number of bones of the carpus.

INTER METACARPAL ARTICULATION

Ox

It is a diarthrosis and an amphiarthrosis formed between the large and small metacarpal bones, the former between the facets of their proximal extremities and the latter between their shafts.

- *Common Ligaments*
  - Dorsal capsular ligament of the carpus.
  - Lateral ligament of the carpus
  - Ligament connecting ulnar carpal and fourth carpal and large metacarpal and small metacarpal.
- *Special Ligaments*
  - Intermetacarpal ligament
  - An interosseous ligament connecting the shafts of the bones.
- *Motion*
  - Slight vertical gliding.

Horse

- Each small metacarpal is united through its length to the postero lateral face of the large metacarpal by syndesmosis.
- There is an interosseous ligament.
- The proximal extremities of each small metacarpal from synovial joints with the large metacarpal.

Dog

- Interosseous ligaments connect the various metacarpal bones.
- The proximal ends of second to fifth bone from synovial joints.
- The proximal ends of bones are connected on their dorsal aspect by the feeble bands.

FETLOCK JOINT OR METACARPO-PHALANGEAL ARTICULATION
(Ox, Horse, Dog)

Ox

There are two such joints for each limb. Each is a *ginglymus* formed between the distal extremity of the large metacarpal, the proximal extremity of the first phalanx below and the proximal sesamoids behind.

- *Ligaments*
  - The joint has a *capsular, collateral* and *sesamoidean ligaments*.
  - The *capsular ligaments* enclose the joints and adherent to the extensor tendons passing over the metacarpal.
  - The *collateral ligaments* are in the form of *axial* and *abaxial ligaments*.
  - The *abaxial ligaments* extend from the lateral aspects of the distal extremity of the large metacarpal to the abaxial sesamoids and the proximal extremity of the first phalanx below.
  - The *axial ligaments* arise common from the cleft of the large metacarpal bone and each spreads out on the cleft of the large metacarpal bone. It then spreads out and attached to the proximal part of the interdigital space of the first phalanx, where its fibres blend with the superior interdigital ligament.
  - The sesamoidean ligaments are *superior, inferior, collateral* and *inter sesamoidean*.
  - The *superior sesamoidean* or *suspensory ligament* (musculus interossei) arises from the volar face of the distal row of carpal bones and the proximal extremity of the large metacarpal descends on the volar face of the latter and divides about its middle into two branches- *anterior* and *posterior*.
    - The *posterior branch* soon bifurcates at the distal end of the large metacarpus and each unites with one the divisions of the tendon of the *superficial flexor of the digit*behind the fetlock to form a ring for the passage of the tendon of the *deep flexor of the digit*.
    - The *anterior branch* divides into six branches, which are in three pairs- *abaxial, middle* and *axial*.
      - The *abaxial* and *middle* slips are attached to the abaxial and axial sesamoids of each digit. The slips passing to the abaxial sesamoids detaches a slip which passes downwards the and forwards on the abaxial face of each digit to join the extensor tendon of the respective digit on the dorsal aspect.
      - The *two axial slips* pass into the cleft of the large metacarpal bone enter the inter-digital space and here join the same extensor tendons.
    - The suspensory ligament prevents extensive dorsal flexion of the fetlock joint and its slips prevent excessive volar flexion. In the young, the superior sesamoidean ligament is muscular while in the adult it becomes fibrous.
  - The *inter-sesamoidean ligaments* are three for each limb has three such ligament placed between four sesamoids.
  - The *collateral sesamoidean ligaments* extend between the corresponding faces of abaxial sesamoids to the proximal extremity of the first phalanx and the lateral aspects of the large metacarpal.
  - The *inferior sesamoidean* are *two straight* and *two oblique*.
    - The *straight ones* are vertical, connecting the bases of the sesamoids to the upper end of the first phalanx.
    - The *oblique ligaments* are placed deeper, also extended from the base of the sesamoids, they cross and get attached to joint the first phalanx.
- *Motion*
  - Extension and flexion.

TOP

Horse

- There is only one metacarpo phalangeal joint for each limb and hence there are only *two collateral* and *one inter-sesamoidean ligament* for the whole joint.
- The *inferior sesamoidean ligament* is made up of three parts-*superficial, middle and deep*.
  - *The superficial or straight* (Y-shaped) connects bases of two sesamoids to the first phalanx.
  - The *middle* one connects the sesamoids to the 'V' shaped area on the volar face of the second phalanx.
  - The *deep or cruciate* (X-shaped) ligament connects the base of each sesamoid to the phalanx. The *suspensory ligament* passes in the channel between the large and small metacarpal bones

and divides above the fetlock into two branches. Each of these is attached to the superior and lateral faces of each sesamoid and then passes obliquely forward and downward to the dorsal face of the first phalanx and joins the tendon of the extensor pedis to form broad ligament.

TOP

Dog

- There are five metacarpo-phalangeal joints in the dog.
- Each joint has its own capsule and indistinct collateral ligaments.
- A small dorsal sesamoid bone occurs in the anterior of each capsule over which the corresponding extensor tendon plays.
- The *cruciate inferior sesamoidean* ligaments are present on the volar aspect.
- The suspensory ligament is placed by interosseous muscles.

PASTERN JOINT

Ox

The proximal interphalangeal articulations are two for each limb. Each is *ginglymus* formed between the first and second phalanges.It has a glenoid fibro cartilage behind, kept in position by ligament and confounded with the tendon of the superficial flexor.

- *Ligaments*
  - *The capsular ligament*
  - *Abaxial collateral ligament* extends from axial face of distal extremity of first phalanx to abaxial face of proximal extremity of second phalanx
  - *Axial collateral ligaments* extend from the axial face of distal extremity of first phalanx to the interdigital or axial face of the proximal extremity of the second phalanx. Fibres also extend downwards to be attached to the interdigital face of third phalanx.
  - *Volar abaxial* and *volar axial ligaments* which extends from the first phalanx to the proximal extremity of the second phalanx on the corresponding aspects.
  - *Proximal* or *superior inter digital ligament* is a strong ligament of intercrossing fibres connects the axial faces of the shafts of the first phalanges in each limb.
  - A strong band of fibres unite the rudimentary digits of the second phalanx.
  - The *distal* or *inferior inter-digital ligament* (cruciate) consists of two strong bands attached above to the lateral tubercles at the proximal extremity of the second phalanx of each digit cross each other in the inter-digital spaces, behind and are inserted to the navicular bone of the other digit and axial face of the second phalanx and the navicular bone of the same digit to some extent.
  - The two *inter-digital ligaments* prevent excessive abduction of the digits.
- *Motion*
  - Extension and flexion.

Horse

- There is only one such joint in each limb.
- Inter-digital ligaments crossing the volar face of the first phalanges restrict apart of the digits.
- The 2nd & 3rd; 3rd & 4th; 4th & 5th are connected.

Dog

- It has the glenoid cartilage which is united on its posterior surface to the tendon of the superficial digital flexor and is kept attached to the first phalanx.
- It has one capsular ligament and two lateral ligaments.

COFFIN JOINT

Ox

The distal interphalangeal articulations are two for each limb. Each is a *ginglymus* formed between the second and third phalanges and the distal sesamoid.

- *Ligaments*
  - *Capsular ligament*
  - Anterior elastic ligament which is attached above to the distal ends of the first phalanx crosses the dorsal face of the second phalanx and is inserted to the extensor process of the third phalanx.
  - *The abaxial and axial collateral ligaments.*
    - The *abaxial collateral ligament* is closely adherent to the proper digital extensor tendon.
    - The *axial collateral ligament* extends from the distal extremity of first phalanx receives fibres from the second phalanx and is attached to the interdigital surface of the third phalanx.
  - *Volar collateral* or *Collateral sesamoidean ligaments*. The *volar abaxial ligament* arises from the distal extremity of the first phalanx receives fibres from the second phalanx and are attached to the *volar axial ligament* extends from the lower end of the phalanx to the interdigital face of the third phalanx.
  - The *superior navicular ligament* is formed by fibres from the two volar collateral and is attached to the upper border of the navicular bone.
  - The *inferior navicular ligament* or *phalango-sesamoidean ligament* extends from the distal border of the navicular to the flexor surface of the os pedis.

Horse

- There is only one joint for each limb.
- The dorsal elastic ligament is absent.
- In addition, it has three ligaments attaching the lateral cartilages to the phalanges.
- Lateral cartilages of the third phalanx are rhomboid plates of hyaline cartilage.
- The anterior end of each is attached to the distal extremity of the second phalanx by a short strong band.
- The lower border is thick and is attached by another band to the angle of third phalanx.
- The posterior end curves axially towards its fellow.

Dog

- Each joint has a capsular and two lateral ligaments.
- An elastic ligament attached above to the distal end of the second phalanx and below to the collar at the base of third phalanx aids in retracting the claw.

JOINTS OF THE HINDLIMB

The joints of the hindlimb are as follows

- Sacro-iliac joint between the articular surfaces of the ilium and sacrum.
- Pelvic symphysis formed between the pubis and ischium of the two sides.
- Hip joint between the acetabulum of os coxae and the head of the femur.
- Stifle joint between the femur,tibia and patella.
- Tibio-fibular joint between the tibia and fibula
- Hock joint formed by the union of tarsal bones with tibia.
- Fetlock joint between the metatarsal, first phalanx with proximal sesamoid.
- The *interphalangeal articulations* are
    - Pastern joint formed between the first and second phalanges.
    - Coffin joint formed between the second and third phalanges and the distal sesamoid.

SACRO - ILIAC ARTICULATIONS
(Ox, Horse, Dog)

Ox

It is *diarthrosis* between the articular surfaces of the ilium and sacrum.

- *Ligaments*
    - Capsular ligaments
    - *Dorsal sacro-iliac ligaments* –connects the dorsum of the sacral spines to the tuber sacrale. In t he spinal attachment it blends with supraspinous ligament.
    - *Lateral sacro-iliac ligament* is a thick, irregularly quadrilateral sheet, placed above the sacro-sciatic ligament and below the dorsal sacro-iliac ligament. It is attached anteriorly to the tuber sacrale and the medial border of the ilium above the greater sciatic foramen and ventrally to the lateral border of the sacrum. Its lateral surface is in contact with the *middle gluteus* and *biceps femoris* and *superficial gluteus* muscle. Its deep face is related to *dorsal* and *lateral coccygeal* muscles.
    - *Ilio -lumbar ligament* attaches the ilium to the transverse process of the lumbar vertebrae.
    - *Sacro-sciatic ligament* is a vast membranous expansion situated in the pelvis between the sacrum and the os coxae.
        - It is irregularly quadrilateral in shape and forms the lateral wall of the pelvis.
        - Its dorsal border is attached to the lateral surface of the sacrum and the first two or three coccygeal bones attaches it.
        - Its inferior is attached to ischiatic spine and tuber ischii.
        - It forms between these two attachments and the bones two foramina the greater and lesser sacro-sciatic foramina for the passage of structures out of the pelvic cavity.
        - Its posterior border forms the lateral boundary of the pelvic outlet.
        - The lateral face of this ligament is covered by the *gluteus medius* and *biceps femoris*, which derive part of their origin from it.
        - The posterior part of the medial face gives origin to the *retractor ani*.
- *Motion*
    - Is appreciable in this joint.

TOP

Horse

- The sacro-sciatic ligament is broader.
- The greater sciatic foramen transmits the posterior gluteal vessels and nerves and the lesser sciatic foramen transmits the tendon of the obturator internus and is pyriform.

TOP

Dog

- The sacro-sciatic ligament is a narrow thin band, which extends from the part of the lateral margin of the sacrum to the tuber ischii.

PELVIC SYMPHYSIS

Ox

- It is *amphiarthrosis* formed between the pubis and ischia of the two sides.
- The intervening cartilage gets ossified with increasing age.
- The obturator foramen is covered in life by the obturator membrane called *obturator ligament*, leaving a space in front for the passage of the tendon of the obturator internus muscle and the obturator nerve.

Horse & Dog

- No difference.

HIP JOINT

Ox

The coxo-femoral articulation is an *enarthrosis* formed between the acetabulum of os coxae and the head of the femur.

- *Ligaments*
  - *Capsular ligament*.
  - *Cotyloid ligament* is a marginal cartilage, which deepens the acetabulum.
  - That part of cotyloid ligament stretches across the cotyloid notch converting it into a foramen for the passage of structures and out of the joint is the transverse *acetabular ligament*.
  - Round ligament is attached to the lateral lip of acetabular notch and to the fovea capitis, on the head of femur.
- *Motion*
  - Gliding, circumduction, adduction and abduction are possible, extension and flexion are most marked.

Horse

- The cotyloid ligament is narrower.
- There is an additional ligament, the *accessory* or *pubic femoral ligament* which arises from the prepubic tendon, passes outwards and upwards and then backwards lodged in the pubic groove, the acetabular notch and is inserted to the fovea capitis behind the round ligament. This ligament is

peculiar to solipeds and it prevents abduction and limits side-kicking. The absence of the ligament in ruminants permits free abduction and this is the reason why ruminants can kick side ways, this movement being known as *'cow kick'*.

Dog

- Resembles that of the Ox.

STIFLE JOINT

The stifle joint is composite joint composed of

- Femoro-patellar articulation
- Femoro-tibial articulation

Femoro-Patellar joint

Ox

The femoro-patellar joint is *gliding joint* where the patella glides over the trochlea of the femur.

- *Ligaments*
  - The *capsular ligament* is loose. It forms a pouch under the insertion of the quadriceps muscle.
  - The *medial* and *lateral ligaments* which arise from corresponding faces of the condyles of the femur to the lateral and medial angles of the patella.
  - The *straight ligaments of the patella* are *lateral, middle* and *medial*, which extend from the patella and its fibrocartilage to the anterior tuberosity of the tibia.
  - *Bursae* of the patellar ligaments are two. One is interposed between the middle ligament and the upper part of the trochlea; a smaller one occurs between the upper part of the same ligament and the apex of the patella.The second is interposed between the lateral patellar ligament and the lateral condyle of the femur.
- *Motion*
  - The patella moves up and down the trochlea of femur.

Horse

- No difference.

Dog

- There is only one straight ligament.

TOP

Femoro-Tribial joint

Ox

The femoro-tibial joint is a *ginglymus* formed between the condyles of the femur and those of the tibia.

- *Ligaments*
  - The joint has a *capsular ligament*, *two inter-articular cartilages* called *menisci*, *two collateral ligaments*, *two crucial ligaments* and a *posterior ligament*.
  - The *capsular ligament* is attached to the margins of articular surfaces of femur and tibia and also to the convex borders of the menisci and to the cruciate ligaments. There are two synovial sacs, partially divided by the menisci into upper and lower compartments. The two synovial sacs communicate with each other and the medial sac also communicates with femoro patellar joint.
  - The *menisci (inter-articular cartilages)* are *medial* and *lateral*.
    - They are 'C' shaped plates of fibro-cartilage interposed between the condyles of the femur and tibia.
    - The lateral borders are thick and convex while their medial borders are thin and concave.
    - The proximal faces are hollowed out for the condyles of the femur and the distal faces are flattened for the condyles of the tibia. These cartilages bring about congruence of the articular surfaces and are kept in position by ligaments called *coronary ligaments*.
    - The *lateral meniscus* has three coronary ligaments one anterior and two posterior, of which one is superior attached to a depression on the medial aspect of inter-condyloid fossa of femur and other inferior attached to the tibia, lateral to the popliteal notch.
    - The *medial meniscus* has two coronary ligaments one anterior and one posterior. These are attached to the depression in front and behind the tibial spine.
  - The *collateral ligaments* arise from the corresponding condyles of the femur. The lateral ligament is attached to the fibula and the medial is to the medial condyle of the tibia.
  - The *posterior ligaments* are membranous, enclose the joint behind.
  - The *cruciate ligaments* are anterior and posterior. The *anterior* arises from the tibial spine, extends upwards and backwards and ends on the lateral part to the inter-condyloid fossa of femur. The *posterior* is attached below the tubercle medial to the popliteal notch, directed upwards and forwards and is attached to the anterior part of the inter-condyloid fossa of femur.
- *Motion*
  - Extension and flexion.

Horse & Dog

- No difference.

TIBIO - FIBULAR ARTICULATION

Ox

- The bony fibula is replaced by a ligament for most of its extent and thus the proper tibio-fibular articulation is absent.
- The upper end of the fibula fuses with the lateral tuberosity of the tibia.
- The lower end ossifies as a separate piece of bone and forms a diarthrosis with the lower end of the tibia.
- *Motion*
  - Inappreciable as two bones are closely united by strong short fibres.

Horse

- It forms a *diarthrosis* and an *amphiarthrosis*.
- The former is between the head of the fibula and the lateral condyle of the tibia.
- It has a tight capsular ligament.
- The amphiarthrosis is between the shafts of the bones and has an interosseous ligament.

Dog

- Diarthrodial joints are formed between the bones at either ends, the shafts are united by interosseous ligaments.

HOCK JOINT
(Common ligaments, Special ligaments)

Ox

This is a composite joint consisting of

- Tibio tarsal articulation
- Proximal tarsal articulations
- Inter tarsal articulations
- Distal tarsal articulations
- Tarso-metatarsal articulations.

The tibio tarsal articulation is a *ginglymus*. The rest are *arthrodia*. The joint has *common ligaments* and *special ligaments*.

Common ligaments

- *Capsular ligament* may be divided into two parts-*anterior* and *posterior*.
    - The *anterior capsular ligament* is membranous and encloses and tibio-tarsal joint in front.
    - The *posterior capsular ligament* is also membranous and is attached to the tibial tarsal above, metatarsal below and blends with the lateral ligaments.
- The *lateral* and *medial collateral* ligaments extending from the distal end of the tibia above, attached to the tarsal bones and the large metatarsal bone below.
- *Posterior ligament (calcaneo-metatarsal ligament)* is on the postero-lateral aspect from the posterior border of tuber calcis passes down and is attached to the central and fourth tarsal and to the large metatarsal below.
- *Dorsal oblique ligament* is a narrow band placed at the antero-internal aspect of the joint. It extends from the medial side of the tibial tarsal, passed obliquely downwards and attaches on the fused central, fourth tarsal and the large metatarsal bones.
- *Tarso- metatarsal ligament* is on the plantar aspect of the joint. It is blended in front with plantar oblique capsular ligament and is adherent to all the tarsal bones. It also blends medially with the medial (collateral) ligament and laterally with planter tarsal ligament. Its plantar face is lines by synovial membrane and forms anterior wall of the tarsal sheath.
- Besides these ligaments, there are certain *annular ligament* which serve to bind the tendons of the muscles.
    - On the dorsal aspect, there are two-*proximal* and *distal*.
    - The *proximal annular ligament* is large and thick running across from medial to lateral malleolus. It binds fascia down the tendons of complex muscle.
    - The *distal annular ligament* is thin, arises from fibular tarsal runs obliquely downwards inward is attached to the large metatarsal.

    - The *plantar* or *posterior annular ligament* extends from the fibular tarsal and plantar ligament to the medial collateral ligament. This from the posterior wall of the tarsal sheath.
- The *tarsal sheath* is formed in front by the tarso-metatarsal ligament (blended with plantar capsular ligament) and behind by the plantar annular ligament. The posterior and anterior faces respectively of these ligaments are lined by synovial membrane and this sheath for the tendon of the *deep flexor,* plantar arteries and nerves.

TOP

Special Ligaments

- *Tibio-tarsal articulations*
    - It is a ginglymus, between lower extremity of tibia and tibial and fibular tarsal bones. The common ligament of the hock joint serves to bind the tibia and tibial tarsal.
- *Proximal tarsal articulation*
    - Between tibial tarsal and fibular tarsal bones.
    - *Ligaments*
        - one extends from the supero-posterior margin of the trochlea of tibial tarsal to fibular tarsal
        - From sustentaculum tali to adjacent part of tibial tarsal on the medial aspect
        - A lateral band from trochlear process of fibular tarsal to lateral ridge of the trochlea of tibial tarsus.
        - An interosseous ligament.
- *Proximal inter-tarsal articulation*
    - Between tibial and fibular tarsals above and central & fourth tarsal below.
    - *Ligaments*
        - Interosseous between tibial and centrals
        - Interosseous between fibular and central tarsals.
- *Distal inter-tarsal articulation*
    - Between central & fourth tarsal above fused second and third tarsal and first tarsal below.
    - *Ligaments*
        - From central tarsal to fused second and third tarsal on the dorsal aspect.
        - Interosseous ligaments connecting fused central and fourth tarsal to fused second and third tarsal and to large metatarsal.
- *Distal tarsal articulation*
    - Between fused second and third tarsal and first tarsal
    - Interosseous ligament between fused second and third tarsal and first tarsal.
- *Tarsal metatarsal articulation*
    - Between central and fourth tarsal, second and third tarsal bones above and large metatarsal bone below.
    - On the dorsal aspect extending obliquely from medial aspect of tibial tarsal, down to large metatarsal. Synovial membranes are four in member.
    - *Motion*
        - Extension and flexion in the tibio-tarsal and gliding in other joints.

TOP

Horse

- Minor differences due to the variation in number of bones.
- Check ligaments are ill developed.
- The supra tarsal ligament is vestigial and is represented by deep tarsal fascia, attached to both sides of tendo-achilles.

- The sub tarsal ligament is the prolongation of the tarso-metatarsal ligament, which joins the deep flexor tendon.

Dog

- Differences are present due to variation in the number of bones.

FETLOCK JOINT / METATARSO - PHALANGEAL ARTICULATION
(Ox, Horse, Dog)

Ox

There are two such joints for each limb. Each is a *ginglymus* formed between the distal extremity of the large metacarpal, the proximal extremity of the first phalanx below and the proximal sesamoids behind.

- *Ligaments*
  - The joint has a *capsular, collateral* and *sesamoidean ligaments*.
  - The *capsular ligaments* enclose the joints and adherent to the extensor tendons passing over the metatarsal.
  - The *collateral ligaments* are in the form of *axial* and *abaxial ligaments*.
  - The *abaxial ligaments* extend from the lateral aspects of the distal extremity of the large metatarsal to the abaxial sesamoids and the proximal extremity of the first phalanx below.
  - The *axial ligaments* arise common from the cleft of the large metatarsal bone and each spreads out on the cleft of the large metatarsal bone. It then spreads out and attached to the proximal part of the interdigital space of the first phalanx, where its fibres blend with the superior interdigital ligament.
  - The sesamoidean ligaments are *superior, inferior, collateral* and *inter* sesamoidean.
  - The *superior sesamoidean* or *suspensory ligament* (musculus interossei) arises from the volar face of the distal row of tarsal bones and the proximal extremity of the large metatarsal descends on the volar face of the latter and divides about its middle into two branches- *anterior* and *posterior*.
    - The *posterior branch* soon bifurcates at the distal end of the large metatarsus and each unites with one the divisions of the tendon of the *superficial flexor of the digit*behind the fetlock to form a ring for the passage of the tendon of the *deep flexor of the digit*.
    - The *anterior branch* divides into six branches, which are in three pairs- *abaxial, middle* and *axial*.
      - The abaxial and *middle* slips are attached to the abaxial and axial sesamoids of each digit. The slips passing to the abaxial sesamoids detaches a slip which passes downwards the and forwards on the abaxial face of each digit to join the extensor tendon of the respective digit on the dorsal aspect.
      - The *two axial slips* pass into the cleft of the large metatarsal bone enter the inter-digital space and here join the same extensor tendons.
    - The suspensory ligament prevents extensive dorsal flexion of the fetlock joint and its slips prevent excessive volar flexion. In the young, the superior sesamoidean ligament is muscular while in the adult it becomes fibrous.
  - The *inter-sesamoidean ligaments* are three for each limb has three such ligament placed between four sesamoids.
  - The *collateral sesamoidean ligaments* extend between the corresponding faces of abaxial sesamoids to the proximal extremity of the first phalanx and the lateral aspects of the large metatarsal.
  - The *inferior sesamoidean* are *two straight* and *two oblique*.
    - The *straight ones* are vertical, connecting the bases of the sesamoids to the upper end of the first phalanx.

        - The *oblique ligaments* are placed deeper, also extended from the base of the sesamoids, they cross and get attached to joint the first phalanx.
- *Motion*
    - Extension and flexion.

TOP

Horse

- There is only one metatarso phalangeal joint for each limb and hence there are only *two collateral* and *one inter-sesamoidean ligament* for the whole joint.
- The *inferior sesamoidean ligament* is made up of three parts-*superficial, middle and deep*.
    - *The superficial or straight* (Y-shaped) connects bases of two sesamoids to the first phalanx.
    - The *middle* one connects the sesamoids to the 'V' shaped area on the volar face of the second phalanx.
    - The *deep or cruciate* (X-shaped) ligament connects the base of each sesamoid to the phalanx. The *suspensory ligament* passes in the channel between the large and small metatarsal bones and divides above the fetlock into two branches. Each of these is attached to the superior and lateral faces of each sesamoid and then passes obliquely forward and downward to the dorsal face of the first phalanx and joins the tendon of the extensor pedis to form broad ligament.

TOP

Dog

- There are five metatarso-phalangeal joints in the dog.
- Each joint has its own capsule and indistinct collateral ligaments.
- A small dorsal sesamoid bone occurs in the anterior of each capsule over which the corresponding extensor tendon plays.
- The *cruciate inferior sesamoidean* ligaments are present on the volar aspect.
- The suspensory ligament is placed by interosseous muscles.

PASTERN JOINT

Ox

The proximal interphalangeal articulations are two for each limb. Each is *ginglymus* formed between the first and second phalanges.It has a glenoid fibro cartilage behind, kept in position by ligament and confounded with the tendon of the superficial flexor.

- *Ligaments*
    - The capsular ligament
    - *Abaxial collateral ligament* extends from axial face of distal extremity of first phalanx to abaxial face of proximal extremity of second phalanx
    - *Axial collateral ligaments* extend from the axial face of distal extremity of first phalanx to the interdigital or axial face of the proximal extremity of the second phalanx. Fibres also extend downwards to be attached to the interdigital face of third phalanx.
    - *Volar abaxial* and *volar axial ligaments* which extends from the first phalanx to the proximal extremity of the second phalanx on the corresponding aspects.

    - *Proximal* or *superior inter digital ligament* is a strong ligament of intercrossing fibres connects the axial faces of the shafts of the first phalanges in each limb.
    - A strong band of fibres unite the rudimentary digits of the second phalanx.
    - The *distal* or *inferior inter-digital ligament* (cruciate) consists of two strong bands attached above to the lateral tubercles at the proximal extremity of the second phalanx of each digit cross each other in the inter-digital spaces, behind and are inserted to the navicular bone of the other digit and axial face of the second phalanx and the navicular bone of the same digit to some extent.
    - The two *inter-digital ligaments* prevent excessive abduction of the digits.
- *Motion*
    - Extension and flexion.

Horse

- There is only one such joint in each limb.
- Inter-digital ligaments crossing the volar face of the first phalanges restrict apart of the digits.
- The 2nd & 3rd; 3rd & 4th; 4th & 5th are connected.

Dog

- It has the glenoid cartilage which is united on its posterior surface to the tendon of the superficial digital flexor and is kept attached to the first phalanx.
- It has one capsular ligament and two lateral ligaments.

COFFIN JOINT

Ox

The distal interphalangeal articulations are two for each limb. Each is a ginglymus formed between the second and third phalanges and the distal sesamoid.

- *Ligaments*
    - Capsular ligament
    - Anterior elastic ligament which is attached above to the distal ends of the first phalanx crosses the dorsal face of the second phalanx and is inserted to the extensor process of the third phalanx.
    - The abaxial and axial collateral ligaments.
        - The *abaxial collateral ligament* is closely adherent to the proper digital extensor tendon.
        - The axial collateral ligament extends from the distal extremity of first phalanx receives fibres from the second phalanx and is attached to the interdigital surface of the third phalanx.
    - *Volar collateral* or *Collateral sesamoidean ligaments*. The *volar abaxial ligament* arises from the distal extremity of the first phalanx receives fibres from the second phalanx and are attached to the *volar axial ligament* extends from the lower end of the phalanx to the interdigital face of the third phalanx.
    - The *superior navicular ligament* is formed by fibres from the two volar collateral and is attached to the upper border of the navicular bone.
    - The *inferior navicular ligament* or *phalango-sesamoidean ligament* extends from the distal border of the navicular to the flexor surface of the os pedis.

Horse

- There is only one joint for each limb.
- The dorsal elastic ligament is absent.
- In addition, it has three ligaments attaching the lateral cartilages to the phalanges.
- Lateral cartilages of the third phalanx are rhomboid plates of hyaline cartilage.
- The anterior end of each is attached to the distal extremity of the second phalanx by a short strong band.
- The lower border is thick and is attached by another band to the angle of third phalanx.
- The posterior end curves axially towards its fellow.

Dog

- Each joint has a capsular and two lateral ligaments.
- An elastic ligament attached above to the distal end of the second phalanx and below to the collar at the base of third phalanx aids in retracting the claw.

DEFINITION

- **What is Biomechanics?**
- Biomechanics is the branch of science which deals with the application of mechanical principles to the biological systems like human, animals, plants, organs and cells. The word biomechanics developed during the early 1970s, describing the application of engineering mechanics to biological and medical systems.

HISTORY

- **Aristotle** wrote the first book on biomechanics, *De Motu Animalium*, or On the Movement of Animals . He not only saw animals' bodies as mechanical systems, but pursued questions such as the physiological difference between imagining performing an action and actually doing it.
- **Leonardo da Vinci** was recognized as the first true biomechanician, because he was the first to study anatomy in the context of mechanics. He analyzed muscle forces as acting along lines connecting origins and insertions and studied joint function. He also intended to mimic some animal features in his machines. For example, he studied the flight of birds in order to find means by which man could fly. Because horses were the principal source of mechanical power in that time, he studied their muscular system in order to design machines which would better benefit from the forces applied by this animal.
- In the 16th century, **Descartes** suggested a philosophic system whereby all living systems, including the animals and human body (but not the soul), are simply machines ruled by the same mechanical laws, an idea that did much to promote and sustain biomechanical study.
- **Giovanni Alfonso Borelli** embraced the idea of Descartes and studied walking, running, jumping, the flight of birds, the swimming of fish and even the piston action of the heart within a mechanical framework. He determined the position of the human center of gravity , calculated and measured inspired and expired air volumes, and showed that inspiration is muscle-driven and expiration is due to tissue elasticity. Borelli was the first to understand that the levers of the musculoskeletal system magnify motion rather than force, so that muscles must produce much larger forces than those resisting the motion. He had an intuitive understanding of static equilibrium in various joints of the human body well before Newton published the laws of motion.
- In the 19th century **Étienne-Jules Marey** used cinematography to scientifically investigate locomotion. He opened the field of modern 'motion analysis' by being the first to correlate ground reaction forces with movement. In Germany, the brothers **Ernst Heinrich**

Weber and **Wilhelm Eduard Weber** hypothesized a great deal about human gait, but it was **Christian Wilhelm Braune** who significantly advanced the science using recent advances in engineering mechanics. During the same period, the engineeringmechanics of materials began to flourish in France and Germany under the demands of the industrial revolution. This led to the rebirth of bone biomechanics when the railroad engineer **Karl Culmann** and the anatomist **Hermann von Meyer** compared the stress patterns in a human femur with those in a similarly shaped crane. Inspired by this finding **Julius Wolff** proposed the famous Wolff's law of bone remodeling .

STATICS AND DYNAMICS

- Biomechanics includes the principles of statics and dynamics.
- Statics is defined as the principles of construction of different body parts that result in maintaining the equilibrium of the body both during rest and in movement.
- Dynamics refers to the movement of the body parts during locomotion.
- The construction of different body parts vary between the species according to their living status in the environment. For example, carnivores, being predators, must run fast with a short period of time in order to catch their prey. Whereas the body parts of the herbivores are constructed in such a manner to bear the heavy weight of the contents of the body cavity (takes large quantity of poorly digestible food) and also enable continuous movement for long distances while grazing.
- However, though horse is an herbivore, it is able to run fast and carry heavy loads for a longer period of time without fatigue due to the development of passive support mechanisms. Whereas these supportive mechanisms have not developed in dog, because they have a lower body weight and takes highly digestible and high energy diet.

BIO MECHANICS OF THE TRUNK

Architecture of the trunk

- Construction of the body axis can be more accurately compared with the **"Bow and String"** theory.
- The thoracic and lumbar vertebrae, their articulations, epaxial muscles and ligaments associated with them constitute the "bow". The "string" is made up of abdominal muscles particularly the straight muscle (*rectus abdominis*) that extends from the thorax to pelvis and linea alba. The bow is connected with the string, laterally by ribs, cranially by sternum and caudally by the pelvic bones.
- Contraction of the abdominal muscles causes flexion of the bow, whereas contraction of the epaxial muscles straightens the bow. Further, the weight of the viscera attached to the vertebral column makes to straighten the bow, while at the same time the weight of the viscera on the abdominal muscles bends the bow.
- Flexion of the bow is assisted by the contraction of protractor muscles of the forelimb (*biceps brachii*) and the retractor muscles of the hind limb (b*iceps femoris*). Whereas, the bow is straightened by the contraction of retractor muscles of forelimb (*latissimus dorsi*) and protractor muscles of hind limb (p*soas major, psoas minor and ilio-pasoas*).
- Co-ordinated contraction of all these muscles resulted in elasticity to the trunk and thus maintains the equilibrium of the body. This is proved in the horse, when the rider sits over the back of the horse, it does not sag of bend under the rider; instead it is curved in a dorsal direction as a result of increased tension of the string muscles. The caudal part of the bow and string construction is attached to the sacrum in horse (sacro-transverse articulation).
- Excessive flexion of the bow is prevented by dorsal spinous process and their ligaments. Similarly, over-extension of the bow is prevented by the abdominal musculature and to some extend by the ventral longitudinal ligament of the vertebral column. Between these two extreme positions, the tension on the bow and string is constantly adjusted to the external circumstances.
- The same "bow and string" theory can be applied to the cervical region also. But the curve is in the opposite direction to that of thoraco-lumbar region. The cervical vertebrae and their articulations

constitute the bow, while the nuchal ligaments act as the string. The weight and active lowering of the head straightens the bow, while the nuchal ligament flexes it.

BIOMECHANICS OF FORE LIMBS

Architecture of thoracic/ pectoral/ forelimb

- In terrestrial mammals, the forelimbs bear the greater load both while rest and during locomotion. Their main function is to stabilise and support the trunk which is propelled from behind. To accomplish this basic function, the forelimb musculature is simply arranged but they are made stronger by tendinous insinuations. In many animals, the skeletal components of the fore limb is also reduced *i.e.* the scapula alone is well developed; the clavicle and corocoid are either absent or exist in vestigial form in certain species.
- The forelimb is attached to the cranial end of the bow and string apparatus *i.e.* the lateral wall of thorax only by muscles (Synsarcosis). This is done by the pectoral girdle muscles that join the forelimb to the trunk and named as synsarcosis which substitutes a conventional joint. The pectoral girdle muscles includes – *trapezius, rhomboideus, brachiocephalicus, omotransversarius, deep pectorals, latissimus dorsi and serratus ventralis*.
- When the animal is in standing position, some of the muscles of the pectoral girdle (*serratus ventralis and deep pectorals*) suspend the body between the fore limbs to which the weight of the head, neck and cranial part of the trunk is transmitted. The above said muscles form a cradle between the two scapulae which allows the thorax to raise and fall between the shoulders and to lean the animal towards one side without affecting the position of forelimb. These two muscles together with other pectoral girdle muscles stabilise the scapula against external forces and thereby prevent the rotation or displacement of scapula.
- During progression, the pectoral girdle muscles (*serratus ventralis, trapezius and pectoral muscles)* which are used to suspend the body between the forelimbs turn into antagonistic groups that control the swing of the limb; one group of muscles advances the limb (named as protractors) and the other group retracts the limb (named as retractors).
- In order to understand this, one must appreciate that the scapula is moving against the chest wall in two different ways. In one, the scapula is rotated around its transverse axis towards the proximal end. This movement is balanced by the opposing actions of *trapezius* and *rhomboideus* which are inserted on the lateral and medial surfaces of the scapula respectively. In the other movement, the whole scapula is moved on the thoracic wall. The scapula is moving downward and forward during protraction and upward and backward during retraction. This movement of the scapula on the lateral wall of the thorax is permitted by the looseness of the connective tissue between limb and trunk and also by the existence of the potential space, the axilla, corresponding to the human arm pit.
- When the animal is in standing position, the muscles of each limb helps to maintain the balance. Particularly in large animals, when the animal is standing for longer time, there is a possible chance that the muscles may become fatigue. To overcome this, in large animals the muscles are reinforced with adequate amount of fibrous tissue. For example, the thoracic portion of *serratus ventralis* is reinforced with more tendinous structure that provides great strength to the muscle.
- Apart from the muscles, the movement of the joint and ligaments associated with them also contribute in maintaining the equilibrium. In large animals, majority of the joint movement is restricted to flexion and extension except hip and shoulder joint. In some joints, presence of collateral ligaments restricts the movement.

Changes in forelimb during locomotion

- Stride: Stride is the fast walk. Each stride consists of three phases:
    - Thrust phase – this is initiated in the hind limb by the powerful contraction of all the hind limb muscles. This extends all the joints to create the thrust against the ground. Then the thrust is transmitted to the opposite forelimb via the trunk.
    - Swing phase – during this phase, the foot is off the ground by flexion of all the joints of the limb.

    - Stance phase – in this phase, the foot is in contact with the ground by the extension of the limb.
- During forward movement, the thoracic limb receives the thrust initiated by the opposite hind limb via the trunk. Subsequently the thoracic limb is raised off the ground from the starting point by the pectoral girdle muscles and the flexor muscle flexes all the joints of forelimb.
- The flexed limb is protracted by the *brachiocephalicus* muscle. At the same time, *trapezius* and *omotransversarius* rotates the distal end of the scapula cranio-dorsally and the caudal angle towards caudo-ventrally. Subsequently the stance phase begins, where all the forelimb joints are extended by the extensor muscles (*biceps brachii, triceps brachii*and extensors of forearm) of forelimb. Hence, the limb is straightened and moved forward from its starting point. Thus the limb becomes longer and reaches the ground further forward from its starting point.
- When one limb is under stance phase of the stride, the weight of the body is shifted to the other limb. Then the scapula is rotated in reverse direction by the contraction of rhomboideus and deep pectoral muscles.

BIOMECHANICS OF HIND LIMBS

Architecture of Pelvic limb

- Forward propulsion in locomotion is mainly brought about by the action of pelvic limbs. Hence, they are stronger, more muscular, particularly with regard to the development of hip and stifle joints. The sacrum and pelvis are attached by means of sacro-iliac joint (amphiarthrosis) i.e the sacrum is suspended on the medial surface of the wings of ilium. This helps in effective transmission of thrust of the hind limb to the trunk. From the trunk, the entire load is transmitted to the pectoral limbs.
- The principle muscle contraction in the hind limb during locomotion is similar to that of thoracic limb. The pelvic limb is raised off the ground by the flexion of all the joints of hind limb (swing phase). Then the flexed limb is moved forward by the contraction of *tensor fascia latae, superficial gluteus, sartorius and ilio-pasoas* muscles. During this time the limb is abducted. Then the limb is adducted by the adductor muscles on the medial aspect of thigh (*pectineus, gracillis and sartorius*).
- Then the stance phase begins by the extension of all the joints. During this pahse, the body is propelled forward by the contraction of extensors of hip (*middle gluteus*), stifle (*quadriceps femoris*) and the hock (*gastrocnemius*).
- Movement of the whole body of the animal results from the co-ordinated movement of the individual body parts. This may be forward, sideward or backward movement of the body. Some movement occur without change in location of the animal like sitting, lying down, rolling and rising.

CENTRE OF GRAVITY FOR ANIMALS

- The centre of gravity is the point where the maximum weight of the body is exerted. It varies in position static animal and during locomotion.
- Normally in a slow moving gait, there will be regular shifting of centre of gravity from left to the right of the midline resulted in forward movement. This will be accompanied by rhythmic sideward movement of the trunk, head and tail. These rhythmic movements of head and tail contribute much to the maintenance of equilibrium during locomotion.

TYPES OF MOVEMENT

- Movement is brought about by the co-ordinated movement of the different body parts. During locomotion, the limbs are moved in a repetitive and regular sequence.

Movement with change in location

- Movement with change in location of the animal is known as “locomotion”. The movement may be forward, backward or sideward. In principle, in all these type of movement, there is a shift in change of the position of centre of gravity forward, sideward or backward depending upon the type of movement. Generally in domestic animals, the most common form of locomotion is forward movement. Lateral and backward movements are occasionally performed in certain situations like playing, fighting or when they overcome any obstruction on their way.
- Forward movement is brought about by the extension of all the joints of one limb and it is pressed against the ground (thrust). If the extended limb does not slip, then the force directed against the ground will be converted into a forward thrust. This is in turn transmitted to the trunk via the pelvis. Form the trunk, the thrust is transmitted to the opposite forelimb, which is then lifted off the ground and swing forwards. Immediately afterwards, the hind limb which has initiated the thrust is also placed forwards. In the meantime, the joint of other limb has begun their extension, shifting the thrust to the opposite forelimb. Normally in a slow moving gait, there will be regular shifting of centre of gravity from left to the right of the midline resulted in forward movement. This will be accompanied by rhythmic sideward movement of the trunk, head and tail. These rhythmic movements of head and tail contribute much to the maintenance of equilibrium during locomotion.
- Walk: Walk is the slowest form of forward locomotion. It is four-beat gait. The sequence of hoof beat will be as follows: 1. Left hind → 2. Right fore → 3. Right hind → 4. Left fore limb. During walk, two feet are always in contact with the ground, there is no suspension period. Three types of walk are recognised: the quick walk, normal walk and shortened walk. In horse, the step length in walk is 1.3 to 1.8 meter and the speed is 6 – 7 Km/hour.
    - All domestic animals normally walk backwards with so much of reluctance. Because their locomotor apparatus is well suited only for forward walk and it has to spend more energy while walk backwards. A horse while walking backwards, spend 3 ½ of times more calories than it does when walking forward. To initiate backward walk, the thrust has to come from forelimb and it has to be transmitted to the hind limb via the trunk.
    - Factors that cause hindrance for backward walking are:
        - The forelimb musculature is poorly developed
        - The forelimb is attached to the trunk only by synsarcosis
        - The hind limb cantilever is rigidly attached with the trunk
        - The lumbar region is poorly developed
        - The position of centre of gravity of the body is not favourable for backward movement
- Trot: Trot is a two-beat gait in which fore and hind feet hit the ground together. The right forelimb and left hind limb move together as do the left forelimb and right hind limb.
    - Trot is a faster gait than the walk. It is used by the all domestic animals; particularly the horse and dog can trot for longer time. The step-length of the horse while trotting is 2 to 2.3 meter and the speed is 14 – 18 Km / hour. Eskimo dog can pull sledges at 4 meter / second over a distance of 75 Km and at 6.5 meter / second over 11 Km.
- Pace: Pace is a modified two-beat gait which produces a greater speed without alterations in the sequence of limb movements. It is seen only in some of the large ungulates like Giraffes and Camel. In elephants and large bears it is the natural form of gait during faster locomotion.
    - The characteristic feature of pace is simple “sagittal synchronism”. This means that the limbs of one side work together. Thus the movement of an animal in pace has been compared with that of two people walking in step, one behind the other.
- Gallop: The gallop is the fastest four-beat gait encountered in animals. In the horse, the step-length varies between 4.35 to 8 meters and the speed of 5 -9 meter / second at the middle gallop and 12 to 14 meter/ second at the racing gallop.

Movement with change in location

- Some movement occur without change in location of the animal like sitting, lying down, rolling and rising. In this type of movement, there may or may not be a shift in change of the position of centre of gravity.

APPLICATIONS OF BIOMECHANICS

- The study of biomechanics ranges from the function of a cell to the movement and development of limbs, to the mechanical properties of soft tissue, and bones. Hence, it helps to advance the field of tissue engineering, as well as develop improved treatments for a wide array of pathological conditions.
- Biomechanics is also applied in studying the musculo-skeletal systems. In recent years, research applied force platform to study the animal joint reaction forces, 3D movement. Motion is also captured through the Motion capture systems (e.g. Vicon systems) to study 3D motion with the help of force platform and vicon systems. It is possible to study the musculo-skeletal behavior, including joint reaction forces, postural control etc.
- Biomechanics is widely used in orthopaedic industry to design orthopedic implants for joints, dental parts, external fixations and other medical purposes. **Biotribology** is a very important part of it. It is a study of the performance and function of biomaterials used for orthopaedic implants. It plays a vital role in order to improve the design and produce successful biomaterials for medical and clinical purposes.
- Used in the treatment and management of lameness.
- Used as Index for draft power.
- Sire index in the selection of draft animals by a breeder.
- Helps in conservation of native germplasm of draft animals.