INTRODUCTORY VETERINARY ANATOMY OF DOMECTIC ANIMALS

THEORY NOTES

FOR

VETERINARY AND LIVESTOCK DEVELOPMENT DIPLOMA (1st year)

BY

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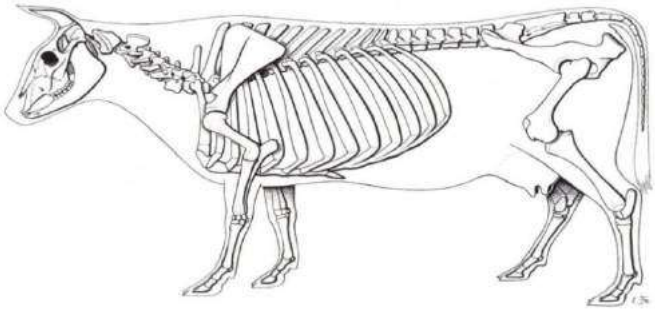

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INTRODUCTION TO VETERINARY ANATOMY

- The term **Anatomy** refers to that science which deals with the **form's** and **structures** of all organisms.

- Whereas the term **Veterinary Anatomy** refers to that branch of Veterinary Medicine which deals with the form's and structure of the principal domesticated animals.

- The study of anatomy usually involves dissection of animals in gross anatomy laboratory coupled with close observation of the shape, texture, location and relations of those structures visible to the naked eyes.

- The use of the microscope with properly prepared tissue section on slides is equally essential for an understanding of structures that are so small to be seen without optical assistance.

DIVISIONS OF ANATOMY

The science of anatomy has become so extensive that it is now divided into many specialized branches. However, the followings are of major interest to now.

1) **Gross (Macroscopic) Anatomy**: is the study of the form and relations (relative positions) of structures if the body that can be seen with the naked eye.

2) **Histology (Microscopic Anatomy**): involves study of those tissues and cells that can be seen only with the aid of a microscope.

3) **Comparative anatomy**: is a study of the structures of various species of animals, with particular emphasis on those characteristics that aid in classification.

4) **Embryology**: is the study of developmental anatomy, covering period from conception (fertilization of the egg with the female) to birth.

5) **Applied Anatomy**: Is the application of knowledge of anatomical landmarks in solving clinical problems.

DESCRIPTIVE TERMS

In order to indicate precisely the position and direction of part of the animal's body certain descriptive terms are used. These include –

(A) **Directional Terms:-**

1) The Longitudinal axis - This splits the body into equal left and right half (bilaterally symmetrical cut). This is also called longitudinal axis.

2) Sagittal plane or sagittal axis – This is a split that is parallel to the medianplane. If it is near the middle, it is the mid sagittal plane but if it is far from themiddle it is called lateral sagittal plane.

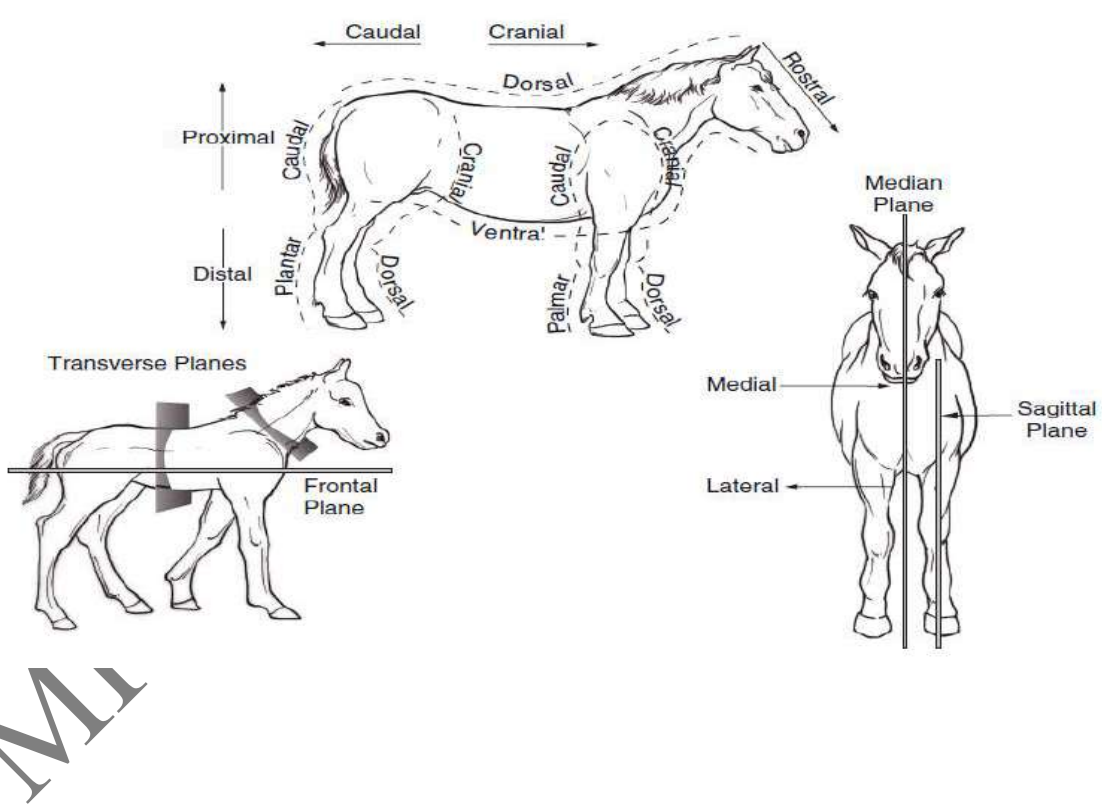
3) Transverse plane - Any point perpendicular to the median plane and at right angle to the longitudinal axis. It divides the body into a cranial and a caudal segment.

4) The fronal plane - Is at right angles to both the median plane and transverse plane. It divides the body into dorsal (upper) and ventral (Lower) segments.

(B) **Adjectives of Relative Position:-**

1. Medial - point closer to the median plane
2. Lateral - a point further away from the median plane

3. Dorsal - is toward the back or closer to the dorsum
4. Ventral - is closer to the lower position
5. Cranial - towards the head (cranium – the brain cavity) or it can be anterior.
6. Rostral - closer to the mouth region or rostrum
7. Deep - internal
8. Superficial – close to the surface. (external)
9. Caudal – towards tail
10. Proximal – toward the front or closer to the body
11. Distal – further away from the body (related to the limbs)
12. Palmar (volar) – the underside of the foot (fore limb)
13. Planter – the dorsal of the limbs
14. Pronation – the dorsal of the limbs
15. Supination – the ventral of the limb
16. Axial – closer to the longitudinal axis
17. Abaxial – away from the longitudinal axis
18. Inspiration – breathing – in
19 Expiration – breathing –out
20. Adduction – bringing together of limbs
21. - Abduction – Keeping apart of limbs



STRUCTURE & CLASSIFICATION OF CELL & TISSUE

THE CELL

- The cell is the basic building block of living organisms.
- Bacteria and the parasite that causes malaria consist of single cells, while plants and animals are made up of millions of cells.
- Most cells are spherical or cube shaped but some have different shapes. Most cells are so small that a microscope is needed to see them, although a few cells, e.g. the ostrich's egg, are so large that they could make a meal for several people.
- A normal cell is about 0.02 of a millimetre. When you look at a typical animal cell with a light microscope it seems quite simple with only a few structures visible.

➢ Three main parts can be seen:

- an outer cell membrane or plasma membrane
- an inner region called the cytoplasm
- the nucleus

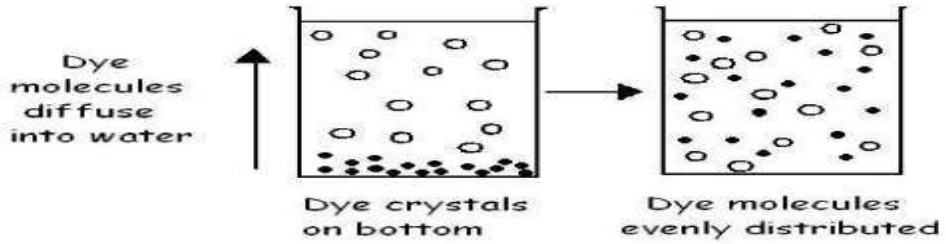
PLASMA MEMBRANE

- The thin plasma membrane surrounds the cell, separating its contents from the surroundings and controlling what enters and leaves the cell. The plasma membrane is composed of two main molecules, fats (phospholipids) and proteins.
- The fats are arranged in a double layer with the large protein molecules dotted about in the membrane. Some of the protein molecules form channels in the membrane while others help transport substances from one side of the membrane to the other.
- Substances need to pass through the membrane to enter or leave the cell and they do so in a number of ways. Some of these processes require no energy i.e. they are **passive**, while others require energy i.e. they are **active**.
- The processes include:

a) diffusion
b) osmosis
c) active transport
d) phagocytosis
e) pinocytosis
f) exocytosis

DIFFUSION

- In the body, diffusion causes molecules that are in a high concentration on one side of the cell membrane to move across the membrane until they are present in equal concentrations on both sides.
- It takes place because all molecules have an in-built vibration that causes them to move and collide until they are evenly distributed. It is an absolutely natural process that requires no added energy.
- Small molecules like oxygen, carbon dioxide, water and ammonia as well as fats, diffuse directly through the double fat layer of the membrane, variety of charged particles (ions) also diffuse through the protein-lined channels.
- Larger molecules like glucose attach to a carrier molecule that aids their diffusion through the membrane. This is called **facilitated diffusion**. In the animal's body diffusion is important for moving oxygen and carbon dioxide between the lungs and the blood, for moving digested food molecules from the gut into the blood and for the removal of waste products from the cell.



OSMOSIS

- Osmosis is in fact the diffusion of water across a membrane that allows water across but not larger molecules. This kind of membrane is called a **semi-permeable membrane**.It shows a container divided into two parts by an artificial semi-permeable membrane.

ACTIVE TRANSPORT

- When a substance is transported from a low concentration to a high concentration i.e. uphill against the concentration gradient, energy has to be used. This is called **active transport**.
- Active transport is important in maintaining different concentrations of the ions sodium and potassium on either side of the nerve cell membrane. It is also important for removing valuable molecules such as glucose, amino acids and sodium ions from the urine.

PHAGOCYTOSIS

- Phagocytosis is sometimes called "cell eating". It is a process that requires energy and is used by cells to move solid particles like bacteria across the plasma membrane. Finger-like projections from the plasma membrane surround the bacteria and engulf them.
- Once within the cell, enzymes produced by the lysosomes of the cell destroy the bacteria. The destruction of bacteria and other foreign substance by white blood cells by the process of phagocytosis is a vital part of the defense mechanisms of the body.

PINOCYTOSIS

- Pinocytosis or "cell drinking" is a very similar process to phagocytosis but is used by cells to move fluids across the plasma membrane.

EXOCYTOSIS

- Exocytosis is the process by means of which substances formed in the cell are moved through the plasma membrane into the fluid outside the cell (or extra-cellular fluid). It occurs in all cells but is most important in secretory cells (e.g. cells that produce digestive enzymes) and nerve cells.

CYTOPLASM

- Within the plasma membrane is the **cytoplasm**.
- It consists of a clear jelly-like fluid called the **cytosol** or **intracellular fluid** in which **cell inclusions**, **organelles, microfilaments** and **microtubules** are found.

- **Cytosol :-** The cytosol consists mainly of water in which various molecules are dissolved or suspended. These molecules include proteins, fats and carbohydrates as well as sodium, potassium, calcium and chloride ions. Many of the reactions that take place in the cell occur in the cytosol.
- **Cell inclusions :-** These are large particles of fat, glycogen and melanin that have been produced by the cell. They are often large enough to be seen with the light microscope. For example the cells of adipose tissue (as in the insulating fat layer under the skin) contain fat that takes up most of the cell
- **Organelles :- Organelles** are the "little organs" of the cell - like the heart, kidney and liver are the organs of the body. They are structures with characteristic appearances and specific "jobs" in the cell. The main organelles in the cell are the **ribosomes, endoplasmic reticulum, mitochondria, Golgi complex** and **lysosomes**.
- A cell containing these organelles as seen with the electron microscope R**ibosomes** are tiny spherical organelles that make proteins by joining amino acids together. Many ribosomes are found free in the cytosol, while others are attached to the rough endoplasmic reticulum.
- **Endoplasmic reticulum** The **endoplasmic reticulum (ER)** is a network of membranes that form channels throughout the cytoplasm from the nucleus to the plasma membrane. Various molecules are made in the ER and transported around the cell in its channels. There are two types of ER: smooth ER and rough ER. **Smooth ER** is where the fats in the cell are made and in some cells, where chemicals like alcohol, pesticides and carcinogenic molecules are inactivated. The **Rough ER** has ribosomes attached to its surface. The function of the Rough ER is therefore to make proteins that are modified stored and transported by the ER.
- **Mitochondria** (singular mitochondrion) are oval or rod shaped organelles scattered throughout the cytoplasm. They consist of two membranes, the inner one of which is folded to increase its surface area. Mitochondria are the "power stations" of the cell. They make energy by "burning" food molecules like glucose. This process is called **cellular respiration**. The reaction requires oxygen and produces carbon dioxide which is a waste product. The process is very complex and takes place in a large number of steps but the overall word equation for cellular respiration is-

  Glucose + oxygen = carbon dioxide + water + energy
- **C**ellular respiration is different from respiration or breathing. Breathing is the means by which air is drawn into and expelled from the lungs. Breathing is necessary to supply the cells with the oxygen required by the mitochondria and to remove the carbon dioxide produced as a waste product of cellular respiration. Active cells like muscle, liver, kidney and sperm cells have large numbers of mitochondria.
- The **Golgi bodies** in a cell together make up the **Golgi apparatus**. Golgi bodies are found near the nucleus and consist of flattened membranes stacked on top of each other rather like a pile of plates. The Golgi apparatus modifies and sorts the proteins and fats made by the ER, then surrounds them in a membrane as **vesicles** so they can be moved to other parts of the cell.
- **Lysosomes** are large vesicles that contain digestive enzymes. These break down bacteria and other substances that are brought into the cell by phagocytosis or pinocytosis. They also digest worn-out or damaged organelles, the components of which can then be recycled by the cell to make new structures.

Microfilaments And Microtubules

- Some cells can move and change shape and organelles and chemicals are moved around the cell. Thread like structures called **microfilaments** and **microtubules** that can contract are responsible for this movement. These structures also form the projections from the plasma membrane known as **flagella** (singular flagellum) as in the sperm tail, and **cilia** found lining the respiratory tract and used to remove mucus that has trapped dust particles. Microtubules also form the pair of cylindrical structures called **centrioles** found near the nucleus. These help organise the spindle used in cell division.

The Nucleus

- The **nucleus** is the largest structure in a cell and can be seen with the light microscope. It is a spherical or oval body that contains the **chromosomes**. The nucleus controls the development and activity of the cell. Most cells contain a nucleus although mature red blood cells have lost theirs during development and some muscle cells have several nuclei.
- A double membrane similar in structure to the plasma membrane surrounds the nucleus (now called the nuclear envelope). Pores in this nuclear membrane allow communication between the nucleus and the cytoplasm. Within the nucleus one or more spherical bodies of darker material can be seen, even with the light microscope. These are called **nucleoli** and are made of RNA. Their role is to make new ribosomes.

CHROMOSOMES

- Inside the nucleus are the chromosomes which:
  - contain DNA;
  - control the activity of the cell;
  - are transmitted from cell to cell when cells divide;
  - are passed to a new individual when sex cells fuse together in sexual reproduction.
- In cells that are not dividing the chromosomes are very long and thin and appear as dark grainy material. They become visible just before a cell divides when they shorten and thicken and can then be counted. The number of chromosomes in the cells of different species varies but is constant in the cells of any one species (e.g. horses have 64 chromosomes). Chromosomes occur in pairs (i.e. 32 pairs in the horse). Members of each pair are identical in length and shape.

CELL DIVISION

- Cells divide when an animal grows, when its body repairs an injury and when it produces sperm and eggs (or ova). There are two types of cell division:

1. **Mitosis**
2. **Meiosis**

1) **Mitosis**.
   - This is the cell division that occurs when an animal grows and when tissues are repaired or replaced.
   - It produces two new cells (daughter cells) each with a full set of chromosomes that are identical to each other and to the parent cell.
   - All the cells of an animal's body therefore contain identical DNA.

2) **Meiosis**.
   - This is the cell division that produces the ova and sperm necessary for sexual reproduction.
   - It only occurs in the ovary and testis. The most important function of meiosis it to halve the number of chromosomes so that when the spermfertilises the ovum the normal number is regained.
   - Body cells with the full set of chromosomes are called **diploid** cells, while **gametes** (sperm and ova) with half the chromosomes are called **haploid** cells.
   - Meiosis is a more complex process than mitosis as it involves two divisions one after the other and the four cells produced are all genetically different from each other and from the parent cell.
   - This fact that the cells formed by meiosis are all genetically different from each other and from the parent cell can be seen in litters of kittens where all the members of the litter are different

from each other as well as being different from the parents although they display characteristics of both.

ANIMAL TISSUES

- In complex animals, certain cells specialize in one or more the functions of the animal body. A group of specialized cells is a **tissue**.
- For example, cells that specialize in conducting impulses make up nerve tissue.
- Cells that specialize in holding structures together make up **connective tissue**. Various tissues are associated in functional groups called **organs**. The stomach is an organ that functions in digestion of food. A group of organs that participate in a commonenterprise make up a **system**. The stomach, liver, pancreas, and intestines are all part of the digestive system.

- The primary types of tissues include
  (1) **epithelial tissues**, which cover the surface of the body, line body cavities, and form glands;
  (2) **connective tissues**, which support and bind other tissues together and from which, in the case of bone marrow, the formed elements of the blood are derived;
  (3) **muscle tissues**, which specialize in contracting.
  (4) **nervous tissues**, which conduct impulses from one part of the body to another.

EPITHELIAL TISSUES

- In general the epithelial tissues are classified as **simple** (composed of a single layer) or **stratified** (many-layered). Each of these types is further subdivided according to the shape of the individual cells within it .
- **Simple epithelium** includes squamous (plate like) cells, cuboidal (cubic) cells, columnar (cylindrical) cells, and pseudo stratified columnar cells.
  1. **Simple squamous epithelium** consists of thin, platelike cells. They are much expanded in two directions but have little thickness. The edges are joined somewhat like mosaic tile covering a floor. A layer of simple squamous epithelium has little tensile strength and is found only as a covering layer for stronger tissues. Simple squamous epithelium is found where a smooth surface is required to reduce friction. The coverings of viscera and the linings of body cavities and blood vessels are all composed of simple squamous epithelium.
  2. **Cuboidal epithelial cells** are approximately equal in all dimensions. They are found in some ducts and in passageways in the kidneys. The active tissue of many glands is composed of cuboidal cells.
  3. **Columnar epithelial** cells are cylindrical. They are arranged somewhat like the cells in a honeycomb. Some columnar cells have whip like projections called **cilia** extending from the free extremity. **Pseudostratified columnar epithelium** is composed of columnar cells. However, they vary in length, giving the appearance of more than one layer or stratum. This type of epithelium is found in the upper respiratory tract, where the lining cells are ciliated.
- **Stratified epithelium** consists of more than one layer of epithelial cells and includes stratified squamous, stratified columnar, and transitional epithelia.
  1. **Stratified squamous epithelium** forms the outer layer of the skin and the lining of the first part of the digestive tract as far as the stomach.In ruminants, stratifi ed squamous epithelium also lines the forestomach (rumen, reticulum, and omasum).
     - Stratifi ed squamous epithelium is the thickest and toughest of the epithelia, consisting of many layers of cells. From deep to superfi cial, these layers include the **basal layer**

(**stratum basale**), the **parabasal layer** (**stratum spinosum**), **intermediate layer**(**stratum gra nulosum**), and **superficial layer**(**stratum corneum**).

2. **Stratifi ed columnar epithelium** is composed of more than one layer of columnar cells and is found lining part of the pharynx and salivary ducts.

3. Transitional epithelium lines the portions of the urinary system that are subjected to stretching. These areas include the urinary bladder and ureters. Transitional epithelium can pile up many cells thick when the bladder is small and empty and stretch out to a single layer when completely filled. Glandular epithelial cells are specialized for secretion or excretion of the

CONNECTIVE TISSUES

- **Connective tissues**, as the name implies, serve to connect other tissues. They give form and strength to many organs and often provide protection.
- Connective tissues include elastic tissue, collagenous (white fibrous) tissue, reticular (netlike) tissue, adipose (fat) tissue, cartilage, and bone.

- **Elastic tissue** contains fibers that tend to regain their original shape after being stretched. This tissue is found in the ligamentum nuchae, a strong band that helps to support the head, particularly in horses and cattle. Elastic tissue also is found in the abdominal tunic, in the ligament flava of the spinal canal, in elastic arteries, and mixed with other tissues wherever elasticity is needed.
- **Collagenous** (**white fibrous**) **tissue** is found throughout the body in various forms. Individual cells (fibroblasts) produce long proteinaceous fibers of collagen, which have remarkable tensile strength.
    - These fibers may be arranged in regular repeating units.
    - In **dense regular connective tissue** (the fibers are arranged in parallel bundles, forming cords or bands of considerable strength. These are the **tendons**, which connect muscles to bones, and the **ligaments**, which connect bones to bones.
    - The fibers of **dense irregular connective tissue** are arranged in a thick mat, with fibers running in all directions. The dermis of the skin, which may be tanned to make leather, consists of dense irregular connective tissue. This forms a strong covering that resists tearing and yet is flexible enough to move with the surface of the body.
    - **Areolar** (**loose**) **connective tissue** is found throughout the body wherever protectivecushioning and fl exibility are needed. For example, blood vessels are surrounded by a sheath of areolar connective tissue, which permits the vessels to move and yet protects them. Beneath the dermis is a layer of looselyarranged areolar connective tissue fibers that attaches the skin to underlying muscles. This attachment is fl exible enough to permit movement of the skin. It also permits the formation of a thick layer of fat between the skin and underlying muscles. Whenever the skin is adherent to bony prominences because of a lack of areolar tissue, the skin will not move, and no layer of fat can form. This feature is seen in beef cattle that have **ties**; in this case, the skin over the back shows large dimples where fat cannot fill in because the skin is adherent to the vertebrae.
- **Reticular connective tissue** consists of fine fibrils and cells.Reticular tissue makes up part of the framework of endocrine and lymphatic organs.
- **Adipose tissue** (fat) forms when connective tissue cells called **adipocytes** store fat as inclusions within the cytoplasm of the cell. As more fat is stored, the cell eventually becomes so filled with fat that the nucleus is pushed to one side of the cell, which, as a result, becomes spherical.
    - Most fat in the animal body is white, although it may have a yellow tinge in horses and some breeds of dairy cattle because of carotenoids in the feed. In contrast to this white fat, a small amount of **brown fat** may be found in domestic mammals, hibernating mammals, rodents, and human infants.

- The brown fat is found between the scapulae, in the axillae, in the mediastinum, and in association with mesenteries in the abdomen. Brown fat apparently generates heat to protect young mammals and hibernating mammals from extreme cold.

❖ **Cartilage** is a special type of connective tissue that is firmer than fibrous tissue but not as hard as bone. The nature of cartilage is due to the structure of the intercellular material found between the **chondrocytes** (cartilage cells).

- The three types of cartilage described are hyaline, elastic, and fibrous.
- **Hyaline cartilage** is the glasslike covering of bones within joints. This type of cartilage forms a smooth surface that reduces friction, so that one bone easily glides over another. The actively growing areas near the ends of long bones also consist of hyaline cartilage.
- **Elastic cartilage** consists of a mixture of cartilage substance and elastic fibers. This type of cartilage gives shape and rigidity to the external ear.
- **Fibrocartilage** consists of a mixture of cartilage and collagenous fi bers, which forms a semielastic cushion of great strength. The intervertebral disks between the bodies of adjacent vertebrae are composed of fi brocartilage.

❖ **Bone** is produced by bone-forming cells called **osteoblasts**. These cells produce **osteoid tissue**, which later becomes calcifi ed to form bone. The bone may be arranged in the form of spicules (small spikes) and fl at plates, forming a spongelike network called **cancellous bone** or **spongy bone**. Alternatively, it may be laid down in the form of laminated cylinders (**Haversian** or **osteonal systems**), closely packed together to form **compact bone** .

❖ **Blood** consists of a fluid matrix (liquid portion), the plasma, a variety of cells, proteins, monosaccharides (simple sugars), products of fat degradation, and other circulating nutrients, wastes, electrolytes, and chemical intermediates of cellular metabolism. It is sometimes considered to be a connective tissue becauseof the origin of some of its components.

MUSCLE TISSUES

➢ The three types of muscle tissue are skeletal, smooth, and cardiac. Both skeletal and cardiac muscle cells consist of fibers that under the microscope show characteristic cross-striations, so both are classified as **striated muscle**.

➢ Smooth muscle cells lack distinct cross-striations.

➢ Each skeletal muscle cell must have its own nerve supply, and when stimulated, the whole fiber contracts. This is the all-or-none law of muscle contraction. However, the force of contraction depends on the state of the fi ber at any one moment.Striated skeletal muscle tissue plus some connective tissue makes up the flesh of meat-producing animals.

➢ **Smooth muscle cells** are spindle-shaped cells that contain one centrally located nucleus per cell. Smooth muscle is found in the walls of the digestive tract, in the walls of blood vessels, and in the walls of urinary and reproductive organs. These cells contract more slowly than skeletal muscle and in response to a variety of stimuli, although they are not under voluntary control.

➢ **Cardiac muscle** is also known as involuntary striated muscle because it is not usually under conscious control, yet it does have crossstriations. The heart muscle is composed of a complex branched arrangement of cardiac muscle cells. Modified muscle cells called **Purkinje fibers** conduct impulses within the heart, much as nerve fibers do in other parts of the body.

NERVOUS TISSUES

- The essential cell of nervous tissue is the **neuron** (nerve cell). The neuron consists of a nerve cell body and two or more nerve processes (nerve fibers). The processes are called **axons** if they conduct impulses away from the cell body and **dendrites** if they conduct impulses toward the cell body.
- Bundles of axons in the spinal cord are called **tracts**, and those in the periphery are called **nerves**. A nerve fi ber may be covered by a **myelin sheath**, a specialized wrapping created by supportive cells called **Schwann cells** in nerves or by **oligodendrocytes** within the brain and spinal cord.
- The special connective tissues of nervous tissue are called **neuroglia** and are found only in the central nervous system. Outside the central nervous system, in addition to the Schwann cells, ordinary white fibrous tissue serves as the major protective covering for the nerves.

THE SKELETAL SYSTEM (OSTEOLOGY)

- The study of bones that collectively make up the skeleton or framework of the body is called **osteology**.
- The skeleton of a living animal is made up of bones that are themselves living structures. Theyhave blood vessels lymphatic vessels, and nerves. They are subject to disease, and adjust tochanges in stretch.
- The function of bones include providing protection, giving rigidity and form to the body,acting as levers, storing minerals, and providing a site for bloods formation.

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.They function to move, support, and protect the various organs of the body, produce red and white blood cells and store minerals.

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.

COVERINGS OF BONE

- **Periosteum**

  - It is the membrane, which covers the outer surface of the bone except at 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.

CLASSIFICATION OF BONES

According to the naked eye appearance, with regard to their size, bones are classified into following categories:-

1. **Long bones:-** These are LONG, HOLLOW, CYLINDRICAL types of bones, found in the LIMBS. These are weight bearing bones and act as lever. A long bone has a body/shaft and two extended ends. These have large medullary cavity called BONE MARROW, in which blood cells are produced. Eg. Femur, humerus.
2. **Modified long bones:-** Some bones are long, but they have no medullary cavity, are called modified long bones. Eg. Clavicle bones in dog, rabbit, fowl etc.

3. **Short bones:-** These are small pieces of bones with partially smooth surfaces found in joints. These help in the mobility of the joints. Most of these bones have six surfaces. These are composed of spongy substance with a thin layer of cortical compact bone. Eg. Carpal, tarsal.
4. **Flat bones:-** These are flat, irregular bony plates designed for enclosing cavities which contains some vital organs of the body. These bones are composed of two plates of compact bone. In between these plates there lies a spongy bone. Eg. Scapula,cranial bones of skull.
5. **Irregular bones:-** These are small bones with rough and irregular surfaces, found in the mid-line of the skeleton. These have so many projections. These projections help in attachment of various muscles. These bones are composed of spongy substance with thin covering of compact substance. E.g. Vertebrae.
6. **Pneumatic bones:-** Some long bones of birds having cavity inside their bones. These cavities accommodate. Air sacs through pneumatic foramina in living condition. Eg. Humerus of fowl.
   In mammals, bones situated close to the nasal cavity, which contain air filled cavities, also called pneumatic bones. Eg. Frontal bone, maxilla, ethmoid bone etc.
7. **Sesamoid bones:-** These are seed like small bones, called sesamoid bones. These work as pulley to avoid friction in the joints. These bones have no articulation with other bones of the skeleton. Eg. Patella, small bones found in fetlock and pastern joints.
8. **Visceral bones:-** These bones are found in the visceral organs of some animals and birds. Eg. Os penis in dogs, Oscordis in ruminants.

- **Ossification:** - The process of bone formation is called ossification.

SKELETAL SYSTEM

It consists of bones and some cartilage. Animal skeleton is made of living tissue. It has nerves and blood vessels. It can be broken and be repaired and can adjust to changes in stress and pressure.

Functions of skeleton system:-

1 Togive shape to the body.
2 To provide anchor points for muscles and therefore help in movement.
3 Reservoirs for minerals (Ca, Mg, P).
4 To produce red blood cells.
5 To protect vital organs (lung, heart etc.).

PARTS OF SKELETAL SYSTEM

(A) Axial Skeleton System.
(B) Appendicular Skeleton System.

AXIAL SKELETON SYSTEM

Axial skeleton system gives shape and support to the animal body. It consists of following bones:-

Skull				
Cranial Part	***Facial Part***	***Vertebrae***	***Ribs***	***Sternum***
Ethmoid	Incisive	Cervical	True (joined to sternum by cartilages)	Sternebrae
Frontal	Lacrimal	Thoracic		Manubrium
Interparietal	Mandible	Lumbar	False (not directly connected to sternum)	Xiphoid process
Occipital	Maxilla	Sacral		
Parietal	Palatine	Caudal	Floating (fixed only at vertebrae; last 1 or 2 pairs)	
Pterygoid	Nasal			
Sphenoid	Turbinates (conchae)			
Temporal	Zygomatic			
Vomer	Hyoid apparatus			

1) **SKULL: -** Skull is a bony frame work of head region which gives protection to brain and its associated structures. Except mandible all bones of skull are connecting by suture (Immoveable joint). Most of the bones of the skull are irregular and plate like in the shape. Skull bones are grouped in to two types:-

(a) Bones of Cranial cavity/ cranial bones:- Cranial bones make cranial cavity which accommodate the brains, eye balls and ears. These bones provide passage for spinal cord, cranial nerves, and blood vessels. Two types paired and un paired.

- Paired- Parietal, Interparietal, Occipital, Sphenoid, Ethmoid, Temporal, Frontal
- unpaired – occipital, sphenoid, ethmoid.

(b) Skeleton of face/ facial bones – make the face of anim

- Paired – maxilla, pre-maxilla, palatine, pterygoid, nasal, lacrimal, zygomatic,malar, turbinate
- unpaired – vomer, mandible, hyoid.

Bones of Skull:-

1. Parietal Bones (paired):- Each Parietal bone is situated at the lateral aspect of posterior part of skull.
2. Frontal Bones (paired):- Each bone situated at the anterolateral aspect and form the skeleton of forehead.
3. Temporal Bones (paired):- These bones form a part of lateral wall of skull.
4. Occipital Bone (unpaired):- This bone forms superior as well as posterior aspect of skull.
5. Sphenoid Bone (unpaired):- This bone forms the floor of cranial cavity. This bone form foramen Ovale and foramen orbitorotundum.
6. Ethmoid Bone (unpaired):- This bone form the anterior part of floor of cranial cavity and then make portion between cranial cavity and nasal cavity
7. Maxillae Bones (paired):- Largest bone of the skull and helps in formation of upper jaw, roof of oral cavity and floor of nasal cavity.
8. Premaxillae Bones (paired):- They form anterior part of upper jaw.
9. Palatine Bones (paired):- These bones takes part in formation of upper part of nasal cavity.
10. Nasal Bones (paired):- These bones remain side by side without fusion and form the roof of nasal cavity.
11. Lacrimal Bones (paired):-Each lacrimal bone is situated at the anterolateral portion of the skull. These bones makes the lacrimal fossa which lodge the lacrimal sac.
12. Molar Bones (paired):- Each molar bone is situated at lateral aspect of face, also called as Zygomatic bone.
13. Pterygoid Bones (paired):- Each bone is in the form of thin plate and make lateral wall of nasal cavity.
14. Vomer Bone (single):- It is a thin plate like bone situated at the median plane and takes part in formation of nasal septum.

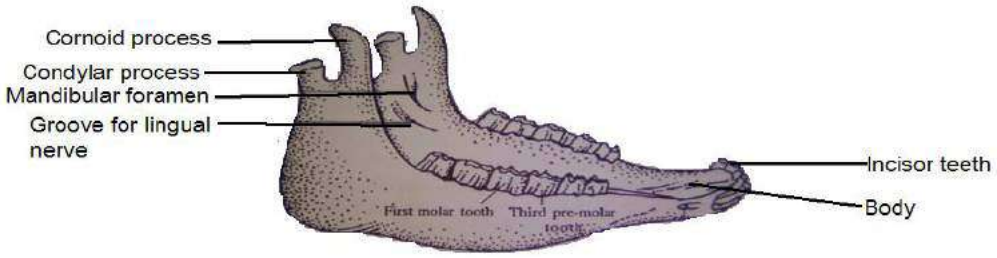
Mandible:- It forms the skeleton of lower jaw it comprises of two Rami. These two rami of mandible fused completely at the mandibular symphysis situated at the mid line with in the body of mandible.

Parts of mandible:-

1. Body:- It is horizontal part of the mandible. It has two parts:-

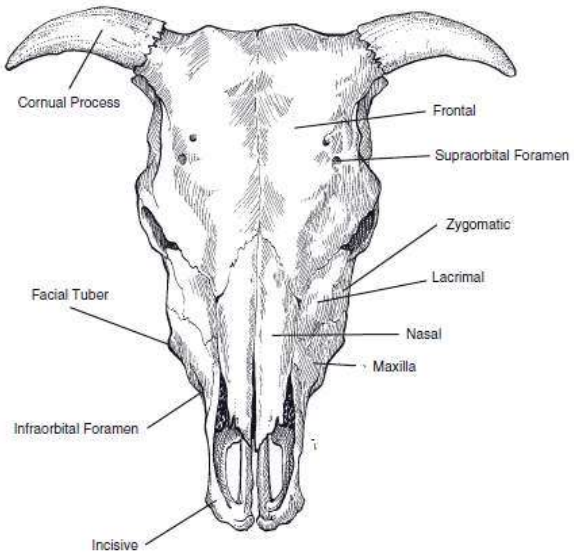
   (a). Anterior/incisival part
   (b). Posterior/Molar part

2. Rami of mandible:- The rami are the vertical part of the mandible. Each ramus has two surfaces, two border and two ends. Dorsal ends have coronoid process and condyle process.

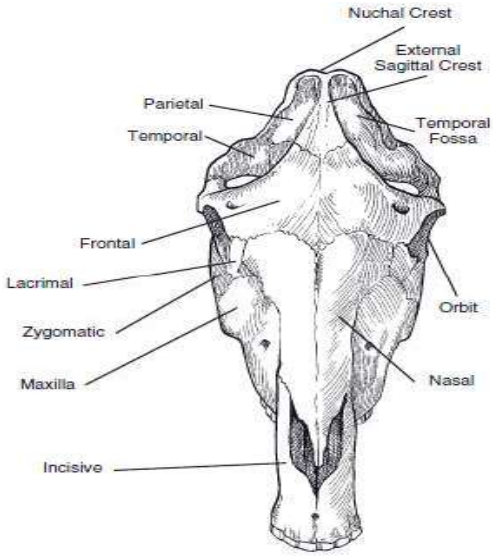


Skull of Horse with Ox:-

1. The skull is long and four sided.
2. Forman lacrum is extensive.
3. Fusion between two halves of mandible is complete.
4. Cornual process is absent.
5. Alveolar border of mandible are found for canine teeth.



SKULLL OF OX/CATTLE



SKULL OF HORSE

2) **VERTEBRAL COLUMN:-** It is defined as a series of bone articulating together to form a long column of axial skeleton called vertebral column. It is commonly called spine. There is a hollow canal in between the vertebral column for the protection of spinal cord. At the junctions of two vertebrae there is a intervertebral foramen on both side. These foramen give passage to the spinal nerve and vessels. There are 51 vertebrae in ox and horse. All vertebrae join with each other by a fibrous joint and there is a vertebral disc in between adjacent vertebrae which work as cushion.

- A typical vertebrae:- A typical vertebrae has a body, process and arch.

(a) Body:- It is a solid cylindrical rod which support other structure of vertebrae. The cranial end of the body is convex and the caudal end is concave.

(b) Process:- There are the three processes in the vertebrae i.e. spinous process, articular processes (cranial and caudal), transverse processes. The main functions of these processes are to prevent undesirable movement of vertebral column and to give the articulation to the bone and muscles.

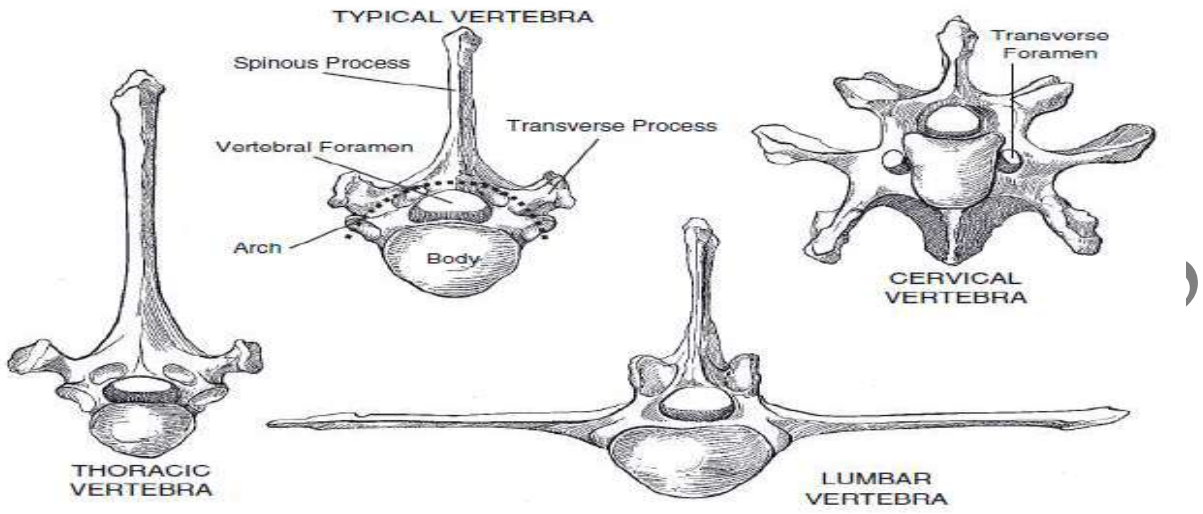
(c) Arches:- Each of the halves is composed of lamina and pedicle. Pedicle form the lateral wall of neural canal and lamina form the roof of neural canal. Intervertebral foramen are formed in pedicles.

Particulars	Cervical	Thoracic	Lumber	Sacral	coccygeal
No. of vertebrae	7	13 (18 in horse)	6	5	15-25 (16-27 in horse)
Supra Spinous Process	short,well developed inclinde forward	long and inclinde backwardly	in the form of quadrilateral plates	absent	these are under dvevlope vertebrae first have neural canal and rest are short rod type
Transverse process	short & well developed	short and thick	long in the form of bony plates	fused together	absent
Articular	short & well developed	not developed	well developed	to form a trian-gular bone called sacrum	absent
Function	make the skeleton of neck and help in the rotation of head. Ist bone is called Atlas on which head is placed & 2nd is called Axis which help in the rotation of head along with Atlas	these vertebrae make thoracic cavity with the help of ribs and sternum to protect the vital organs that is heart and lungs	these vertebrae make the roof of abdominal cavity and also help in respiration	make the roof of pelvic girdle	these make the tail of animal

The vertebral formula of common animals are as follows:

C = Cervical vertebra - neck region
T = Thoracic or dorsal chest region
L = Lumber – loin region
S = Sacral – in region of pelvis – Fused vertebrae
LS = Fused lumber and sacral (fowl)
Cy = Caudal (Coccygeal)

Species	C	T	L	S	Cy
Cattle	7	13	6	5	18-20
Sheep/Goat	7	13	6-7	4	12-18
Dog	7	13	7	3	20-23
Pig	7	14-15	6-7	4	20-23
Horse	7	18	6	5	15-21
Bird	16-17	5-6	15-	16	pygostyle
Camel	7	12	7	4	18-20



3) **STERNUM (breast bone):-** It is a long plate of osteocartiogenous structure placed at the mid line of the floor of thoracic cavity. It is composed of several sternal components called sternebrae. The caudal end of the sternum is formed by xiphoid cartilage which is attached with diaphragm.

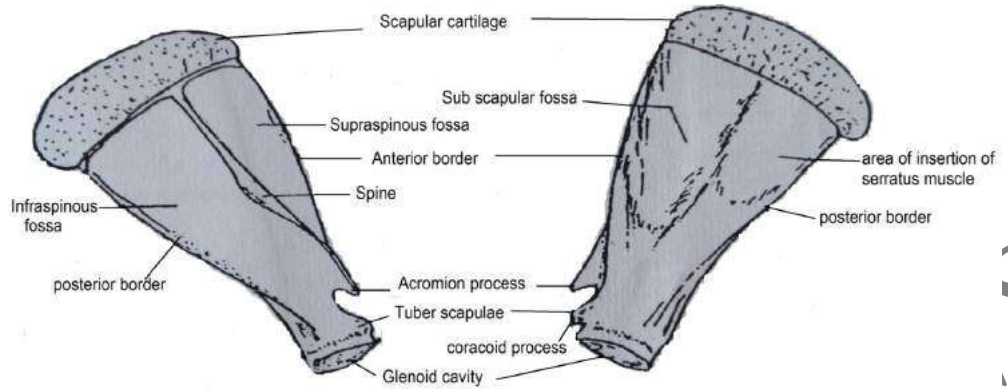
4) **RIBS:-** These are curved elongated bones arranged one after another on the both sides of vertebral column and form a cage. In ox there are 13 pairs of ribs. First 8 pairs are attached with sternum which are called sternal ribs or true ribs. Last 5 are asternal ribs or false ribs. These asternal ribs connected with each other. There are 18 pairs of ribs in horse, first 8 are sternal ribs and last 10 are asternal ribs.

- **Visceral bones: -** These are floating bones found in the viscera of animals. They have no connection with skeleton.
  i. Os-cordis:- Two small triangular bones embedded in the myocardium (upper layer of heart) on the either side of aortic ring of heart of cow.
  ii. Os-penis:- An elongated bone in the penis of dog.
  iii. Os-rostrale:- Small flat bone found in nasal septum of pigs.

APPENDICULAR SKELETON SYSTEM

It comprises of :-

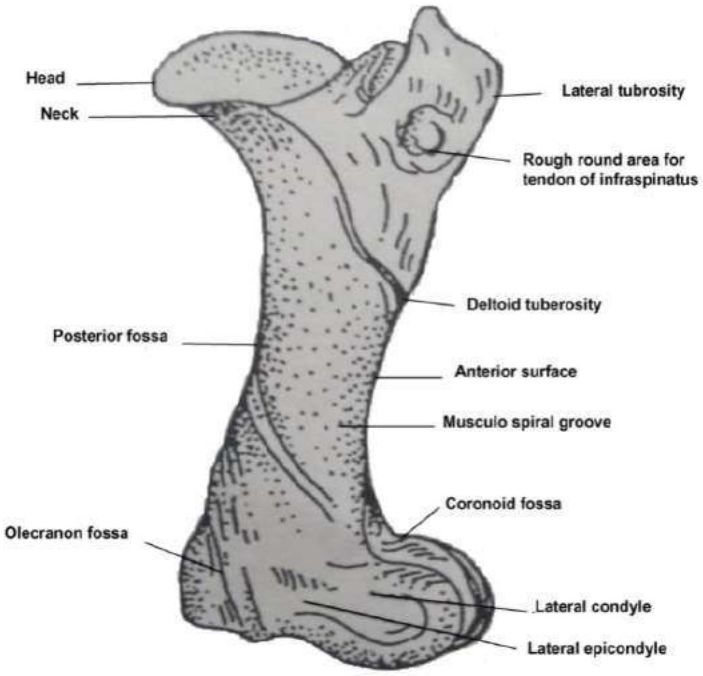
- **1.Fore limb (thoracic limb):-**it consist of the following bone's
  i. **Scapula: -** It is a flat triangular bone situated at cranio lateral aspect of the thorax. It has two surfaces, three angels and three borders. The dorsal border is rough for the articulation of scapular cartilage. The distal angle comprises of glenoid cavity which articulate the head of humerus.



A. Right scapula of ox (lateral veiw B. Right scapula of ox (medial veiw)

ii. **Humerus:-** It is a long bone situated obliquely downward and backwardly. It forms shoulder joint with the help of scapula above and below elbow joint with the help of radius and ulna. Proximal end of humerus is large and present head, neck and tuberosity. Head articulates with glenoid cavity of scapula and makes shoulder joint. The distal end of humerus has two condyle – medial and lateral. At distal end there are two fossae called-

a) Radial fossa/coronoid fossa which articulates with coronoid process of radius.
b) Olecranon fossa which articulates with olecranon process of ulna.

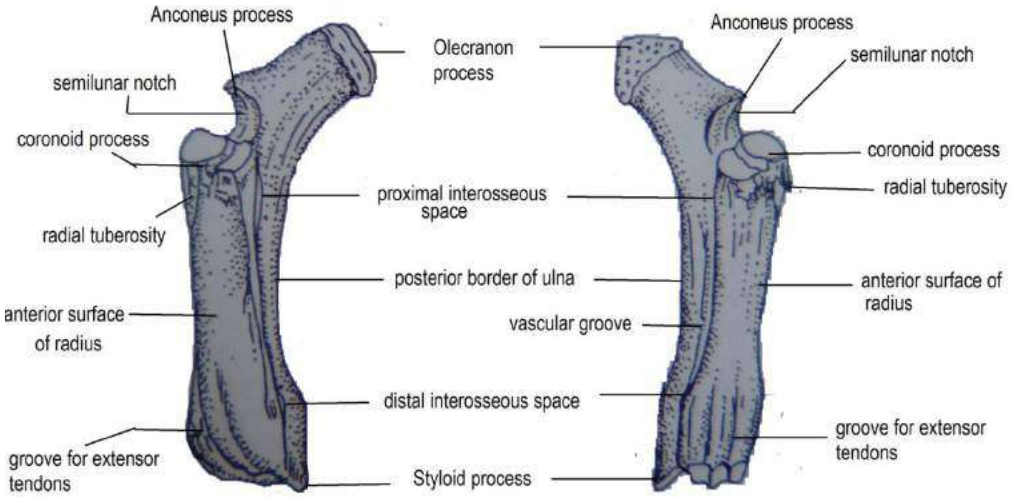


Humerus of ox (lateral view)

iii. **Radius & Ulna:-** These two bones are fused together in ox but described separately:-

a) Radius:- It is larger bone but no longer then ulna. It is situated in vertical direction in the forelimbs and forms elbow joint with humerus above and carpal joint with the help of carpal bones. It has coronoid process which articulates with coronoid fossa of humerus to form elbow joint.

b) Ulna:- This is ill developed bone fused with radius. Above its olecranon process articulates with olecranon fossa of radius to form elbow joint and similarly below makes carpal joint with the help of carpal bones.



Radius and ulna of ox (medial and Lateral View respectively)

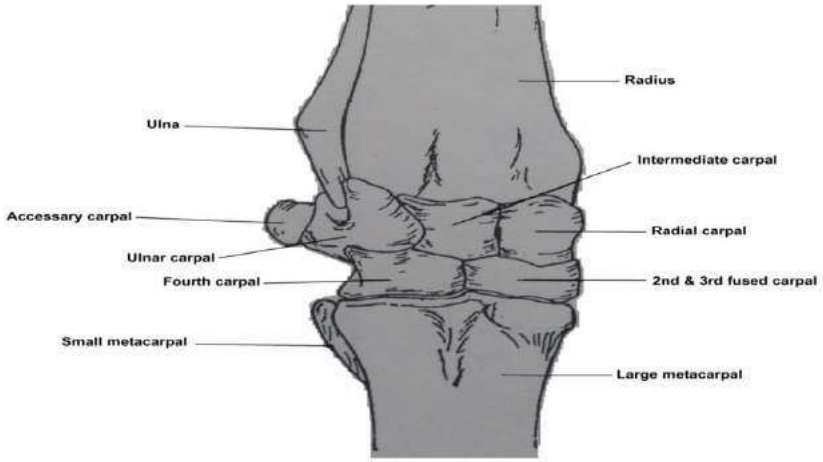
iv. **Carpal bones:-** These are six to eight short bones arranged in two rows.

1st row:-

a) Accessary carpal (Pisiform)
b) Ulnar form (Cuneiform)
c) Intermediate carpal (Semilunar)
d) Radial carpal (Scaphoid)

2nd row:-

a) 4th carpal (Unciform)
b) 2nd and 3rd (Osmagnus)



CARPAL

v. **Meta carpal bones:-** There are two metacarpal bones in the forelimb of ox. One is larger and one is small. Large metacarpal is made up of fusion of two metacarpal bones that is 3rd and 4th metacarpal bone.

3rd and 4th metacarpal:- The fusion is well marked by the groove present anteriorly and by the presence of double medullary cavity inside. The proximal end has two facets. One is medial which is articulates with second and third fused carpal and other is lateral which articulates with fourth carpal. The distal end of main metacarpal is divided into two articular areas by a sagittal notch and each area is subdivided into two condyles by a sagittal ridge. These condyles articulates with proximal ends of the 1st phalanx, at posterior aspect just above the condyles there are four depressions, each depression give accommodation to the corresponding sesamoid bones of proximal row.

Small metacarpal (Mc 5) – This is small elongated piece of bone situated at posterior-lateral aspect of large metacarpal. It remains fussed with large metacarpal bone.

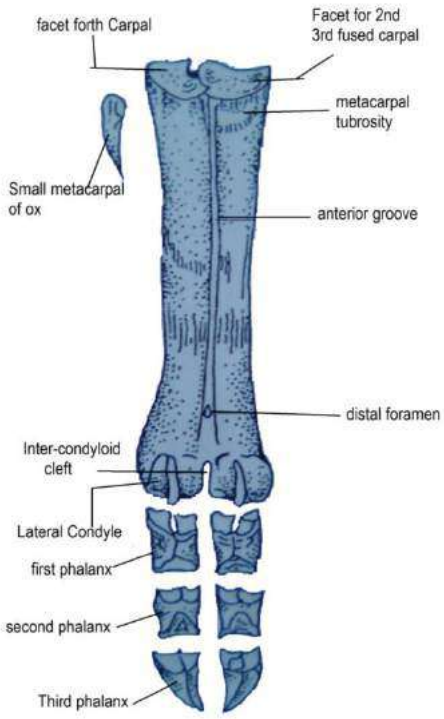
vi. **Digits :-** There are two fully developed digits (3rd and 4th) present in ox and second and fifth become rudimentary which are developed as dewclaw at the posterior aspect of fetlock joint. These digits/dewclaw make no articulation with any bone. Each developed digit has three phalanges.

- 1st phalanx:- these are elongated bones situated between metacarpal and second phalanx.
- 2nd phalanx :- shorter then 1st phalanx.
- 3rd phalanx:- it resemble the hoof in which whole bone is situated.

Sesamoid bones:- Seed like bones without any articulation with any bone. There are two rows of sesamoid bones 4 in 1st row and 2 in 2nd row.

1st row:- Proximal sesamoid bones are 4 in each limb (i.e. 2 in each digit).

2nd row:- 2 bones in each limb (i.e. 1 in each digit).

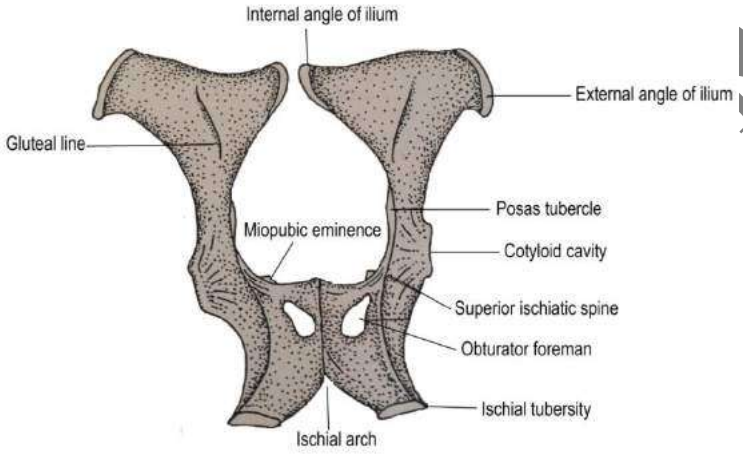


Metacarpal and phalanges

2. Hind Limb:- pelvic limb

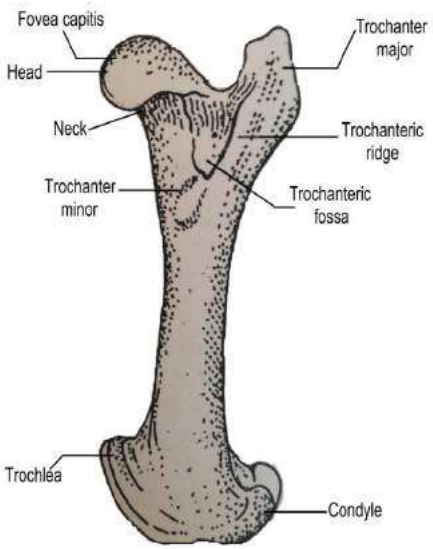
1. **Pelvic bones/ hip bones / os coxae:-** The pelvic is formed by right and left hip bones and sacrum and 1st two coccygeal bones. Each hip bone consists of three large plates like bones called ileum, ischium and pubis. These bones joint together to form a large cavity which articulates with Femur.

- ❖ Ileum:- This is a rectangular plate bone situated at the cranio-lateral aspect of pelvis.
- ❖ Ischium:- It is roughly a quadrilateral plate situated behind the pubic and makes the floor of pelvis.
- ❖ Pubic:- It is a small rectangular plate of bone situated at the anterio-medial aspect of pelvic floor.
- ❖ **Acetabulum or cotyloid cavity:-** this is formed by the corresponding angles of ilium, ischium and pubic. It accommodate the head of femur to form hip joint.



Pelvic bone

2. **Femur:-** It is a cylindrical and longest bone of the skeleton.it is directed downward and forward in oblique manner. This articulates with hip bones above to form **hip joint** and distally articulates with tibia and patella to form **stifle joint**.



Femur

3. **Patella:-**This is a triangular sesamoid bone placed in front of trochlea of femur.

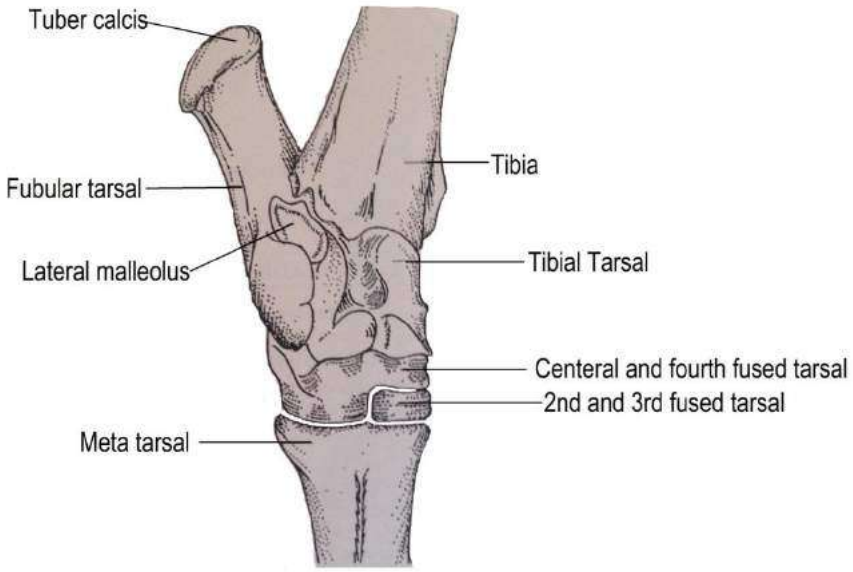
Patella

4. **Tibia:-** It is a strong and massive bone extend obliquely downward and backward. It forms stifle joint with the help of patella and femur above and at lower end make hock joint with tarsal bone.
5. **Fibula:-** This bone is highly rudimentary bone in ox. It's proximal end is fused with lateral condyle of tibia and the distal end & body of fibula remains as blunt prolongation called fibular tarsal.
6. **Tarsal bone:-**There are 5 tarsal bones in ox. Lateral malleolus remains as separate piece of bone in ox. These 5 tarsal bones are arranged in three rows-

a) Proximal row:- It consist two tarsal bones:-
   (i) Tibial tarsus (astragalus):- It articulates with tibia above and central and fourth fused tarsal below.
   (ii) Fibular tarsal (oscalcis):- It is a blunt elongated bonesituated obliquely latero-posterior aspect of tibial tarsal.

b) Central row:- Central and fourth fused tarsal:- This is a plate like bone extended throughout the hock joint.

c) Distal row:- It consist three tarsal bones:-
   (i) 2^{nd} and 3^{rd} fused tarsal:- It is a small bone placed under central and 4^{th} fused tarsal.
   (ii) 1^{st} tarsal:- Small nodule like bone placed below the central and fourth fused tarsal.

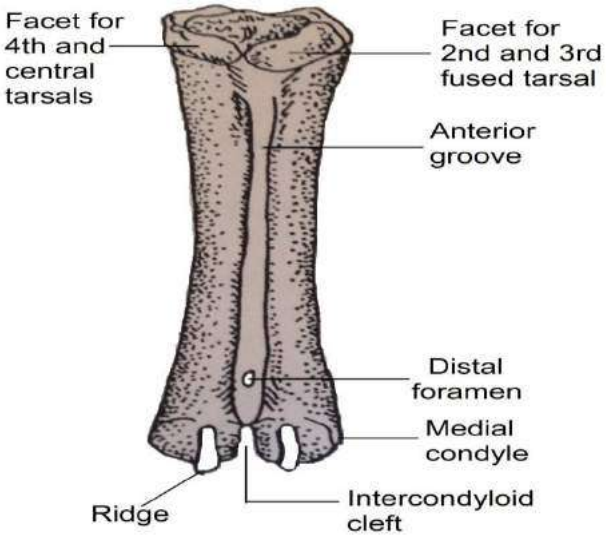


Tarsal's

7. **Metatarsal bones:-** Like metacarpal, metatarsal bones are two:-

i) Large metatarsal:- This is a large which is formed by fusion of two metatarsal bones i.e. 3rd and 4th.

ii) Small metatarsal:- It is a very small bone representing 2nd metatarsal.



Metatarsal

8. **Phalanx and sesamoid bones: -** They are almost similar in the hind limb and fore limb.

Difference b/w metacarpal and metatarsal:-

Metacarpal	Metatarsal
i) It is a shorter bone.	i) It is a longer bone.
ii) Shaft is irregular, cylindrical and presents two surfaces.	ii) Shaft is four sided.
iii) Proximal end has two facets.	iii) Proximal end has one facet.
iv) The anterior groove is not deep and wide.	iv) The anterior groove is more deep and wide.

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.

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.

ARTHROLOGY

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 bycartilage 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.

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.

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.

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.

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.

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)

- 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.

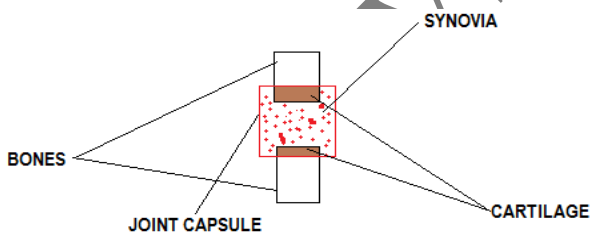
Classification of diarthrodial joints

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.



THE DIGESTIVE SYSTEM

Digestive system:- This consists of organs which are involved in the ingestion, mastication, digestion and absorption of food as well as the expulsion of the unabsorbed waste material.

Two parts of digestive system :-

1. Alimentary canal or GIT: -It is hollow irregular tube open at both ends, start from mouth and ends at anus. It has mouth, pharynx, esophagus, stomach, small intestine, large intestine and rectum.
2. Accessory digestive organs: - salivary glands,liver, pancreas.

Digestive organ of ruminants: -The alimentary canal of ruminants is more complex than non-ruminants. Stomach of ruminants has four compartments namely **RUMEN**, **RETICULUM**, **OMASUM**and **ABOMASUM.**

- **Parts of Alimentary canal:-**

1. Mouth :-

- It is the first segment of alimentary canal; it is bounded laterally by cheeks, ventrally by body of mandible and dorsally by hard palate and anteriorly by lipsand posteriorly by soft palate.
- Function of mouth is prehension or reception, mastication, salivation and rumination. There is no digestive enzyme in the mouth of ruminants. Only preliminary chewing or mastication and mixing of saliva are done in the mouthof ruminants.
- Mouth cavity is mostly occupied by tongue. The palate of mouth has dozen of transverse ridges/rogue. Lips of ruminants are less mobile but lips of horse are very mobile. Lips are the main organ of prehension of food. Tongue of ruminants is pointed and has small papillae and taste buds. These papillae of tongue give it roughness. Tongue also help in sounding in animals.

The entrance of mouth is closed by lips

- Lips: - these are two muscular folds which surrounds the mouth. Above the lips there is another structure known as muzzle.
- Cheeks: - are the lateral boundary of mouth and continuous with the lips in front of mouth
- Gums: - these are composed of dense fibrous tissue.
- Hard palate: - it is formed by premaxilla, maxilla, and palatine bones.it forms the roof of oral cavity.
- Soft palate: - it is a musculo-membranous partition, which separates the mouth from that of pharynx.

2. Tongue:-

- The **tongue** consists of a mass of muscle covered by mucous membrane. It is divided into a free **apex** at the rostral end, a meaty **body**, and a caudal **root** adjacent to the pharynx.
- The muscles of the tongue (**intrinsic muscles**) have fibers oriented in longitudinal, perpendicular, and transverse directions, permitting the tongue a wide range of movements. The surface is characterized by a large number of projections, the **papillae**, which are particularly well developed on the dorsal surface.
- Filiform, fungiform, and vallate papillae are found in all domestic animals, and foliate papillae are present in the horse, pig, and dog, but not in ruminants.

- The filiform and conical papillae do not bear taste buds, but all other types of papillae do. Taste buds may also be found on the epiglottis, larynx, pharynx, and soft palate.

3. **TEETH:-** Teeth are hard, white or yellowish white structures implanted in alveoli of jaw. They are organs of prehension, mastication or chewing. Domestic animals have two sets of teeth, temporary known as milk or deciduous teeth and permanent teeth

According to their position they are classified as,

- Incisors or cutting teeth
- Canines
- Premolars
- Molars or cheek teeth

DENTAL FORMULA OF DOMESTIC ANIMALS

- For Ruminants 2 (I 0/4, C 0/0, P 3/3, M 3/3) = 32
- For Horse 2 (I 3/3,C 1/1, P 3-4, M 3/3) = 40 or 42

4. **Pharynx:-**

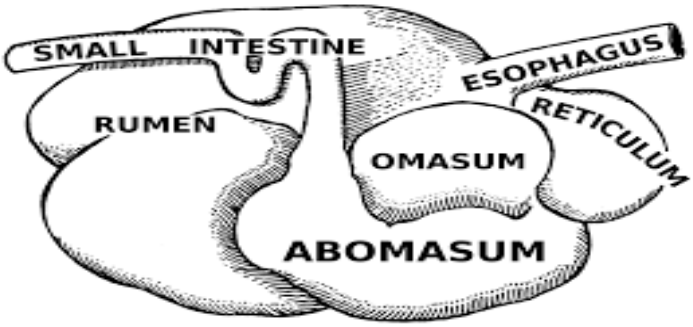
- It is roughly a funnel shaped space at the base of cranial cavity and behind posterior nasal aperture. Its walls are formed by muscle fibre and mucus membrane. The pharynx is common for digestive and respiratory passage. It connects mouth to the esophagus. The pharynx restricts the size of ingesta that can be swallowed by the animal. It receives and transmits to the mouth the regurgitated cuds in ruminants. Pharynx of horse is comparatively larger and narrow.

5. **Esophagus :-**

- It is a muscular tube extends from pharynx to rumen/stomach. The average length of esophagus is 90 cm in ruminants. In horse its length is 140 cm. The average thickness is about 4 cm. It lies dorsal lateral to the trachea on left side of neck. The muscles of esophagus are striated.
- The junction of esophagus to the stomach/rumen has a valve called Cardia.This cardia works as a valve, When Boli of food passes into or out of the rumen or gas escape from rumen.

6. **Rumen :-**

- It is the largest compartment of the stomach and has great significance in digestion in ruminants. It is a large sac extending from, Diaphragm to pelvis. It fills the left side of abdominal cavity. It is divided into two sub compartment. DORSAL PART and VENTRAL PART. The ventral sac is connected with reticulum.
- Rumen works as a store house of food which is ingested in hurry without proper mastication by the ruminants. Rumen has large number of micro flora which helps in digestion of feed, Microflora work by fermentation. Microflora in the rumen work to ferment the food to produce Microbial protein.



7. **Reticulum :-**
   - The reticulum is most cranial compartment. Its internal structure is like **honey comb**. The grooves present in reticulum work to pass the food material direct from esophagus to omasum. These grooves are functional in suckling animal and therefore non-functional in adult animal. Reticulum is present near the diaphragm and heart.
   - Any foreign object such as nail or wire etc. Swallowed by the animal may lodge in reticulum and penetrate through diaphragm making **diaphragmatic Hernia**. Then this foreign body may penetrate the heart which is very fatal condition like **T.P.**

8. **Omasum :-**
   - This is a spherical organ filled with muscular laminae bearing pointed papillae. These laminae arranged in such a manner that food moves from Reticulo-omasal orifice.The food material entering the omasum contains 90-95% water and thus main function of omasum is to remove water from this food up to 50%.

9. **Abomasum :-**
   - It is true stomach which has digestive gland; it is located ventral to the omasum and right side of rumen. The junction of abomasum to small intestine is called PYLORUS. Pylorus is a sphincter of circular smooth muscle.
   - The epithelial cell lining of abomasum secretes electrolytes , is specially hydrochloride, pepsin and mucus , pepsin is an enzyme which is responsible for the digestion of microbial protein in the abomasum hence true digestion starts from abomasum in ruminants.

PERITONEUM

- It is a serous membrane which lines the abdominal wall and reflected over the visceral organs. The lining portion is called parietal and the reflected portion is called visceral layer. The space between visceral and parietal layer called peritoneal cavity. This cavity has a fluid called peritoneal fluid. This fluid is helpful for free movement of visceral organs.
- The connecting fold of visceral layer is called mesentery. Mesentery transmits blood vessels and nerve to and from visceral organs.

➢ **Functions of Peritoneum:-**

1. It provides slippery space for the movement of abdominal viscera.

2. The phagocytic cells of peritoneum protect viscera against infections.

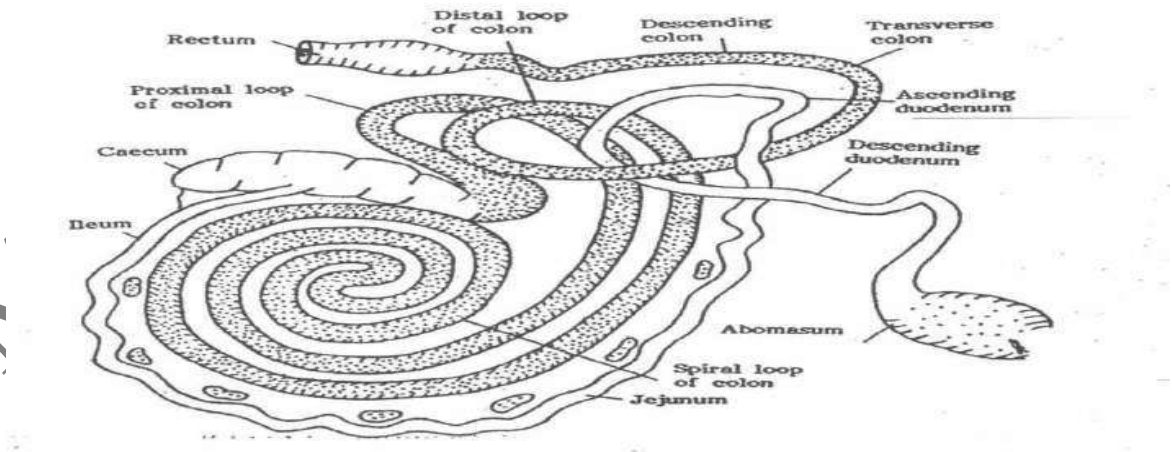
10. Small intestine:-

- Small intestine divided into three parts: -**(a)Duodenum**
  (b) Jejunum
  (c) Ileum

- These parts are **histologically** and **microscopically** different. **Duodenum** is the first segment of the small intestine. Ducts from pancreas and liver enter the first part of duodenum. Jejunum is the next segment of small intestine and ileum is the last segment. Ileum makes a junction with large intestine called ileo-caecal junction.
- Small intestine is the chief sight of absorption of digestive food. The mucus membrane of small intestine has numerous tiny projections known as **VILLI**.
- Each villus is further surrounded by numerous fingers like projections called **microvilli**. These villi and micro villi provide greater space for food absorption.
- The duodenum receives both bile's and pancreatic secretion from the gall bladder and pancreas respectively. The entry of both ducts into duodenum is at same point.
- Bile consists of bile acid and bile pigment which are responsible for the digestion of fats.
- Pancreatic secretion contains an enzyme called TRYPSIN. Trypsin with the help of pepsin secreted by abomasum, responsible for degradation of microbial proteins in small intestine, similarly lipids which have escape from ruminal fermentation also digested in small intestine with the bile juice.
- Length of small intestine in cow is about 145 ft.

11. Large intestine: -

- Size of large intestine of cow is about 35 ft. It has three parts –CAECUM and COLON AND RECTUM. The microbial fermentation as in rumen is also found in large intestine. The microbial degradation of polysaccharides and carbohydrates which escaped from rumen happens in large intestine.
- Water is also absorbed in large intestine. Rectum is the terminal part of large intestine which opens as anus.



G.I.T OF CATTLE

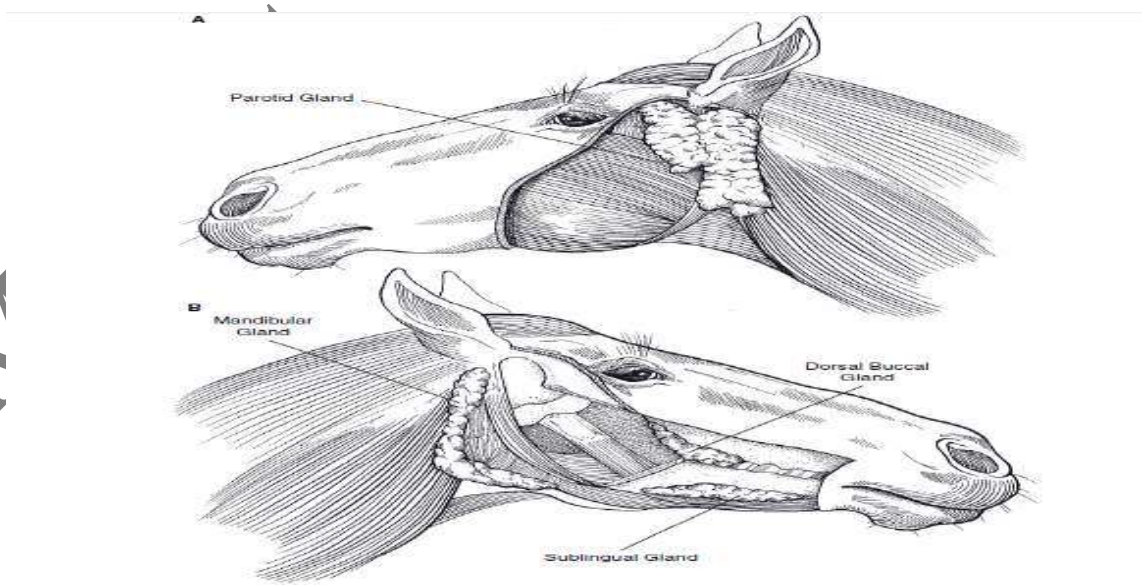
ACCESORY ORGAN OF DIGESTIVE SYSTEM

1. **Salivary gland :-** There are 3 pairs of salivary glands situated on sides of the face and adjacent of the neck,
   (a) Parotid: - Parotid salivary glandlocated below the each ear and to the caudal border of the mandible, its duct is known as Stenson's duct
   (b) Mandibular or Sub maxillary: - These glands are situated ventral to the parotid gland and largest among these.
   (c) Sublingual: -This Salivary Glandis located beneath the mucus membrane along the lateral surface to the tongue on the floor of mouth.

   - The other salivary glands include labial, buccal, lingual, palatine found in different species. The secretion of saliva in ruminants is continuous but rate is greatly increased by Stimuli associated with feeding, rumination and presence of coarse feed. In cattle total volume may range from 100 liter to 200 liter per day. The saliva of ruminant is slightly alkaline.

Uses / function of saliva: -

1. Lubrication: - Saliva keeps the mouth lubricated and wet.
2. Buffering capacity: - Large amount of bicarbonate present in saliva do the buffering of food.
3. Nutrients for microflora of rumen: - Saliva has good amount of urea, mucin, phosphate, magnesium and Chlorides which are the feed of the micro flora of rumen.
4. Prevention of bloat:-Gases accumulation in the rumen may cause bloat condition. Saliva acts as surfactant and thus prevents bloat.
5. Taste: - Saliva solubilizes a number of chemical present in food and hence help in realizing taste by taste buds presenting in the mouth.
6. Protection: - Saliva keeps the mouth wet/moist and hence protects the inner lining of mouth.
7. Source of digestive enzyme: - Saliva of ruminants has no digestive enzyme but saliva of dogs, pigs, horse, contain amylase enzyme which help in the digestion of starch.



2. **Pancreas :-**

Pancreas is the second main accessory digestive gland. In a cow its weight may range from 350gm to 500gm.Pancrease is a soft, lumpy organ with a large head, long body and tapering tail. The head of pancreas lies in the cavity of duodenum. It has two parts - the greater part is endocrine gland and exocrine gland.

- Endocrine part of pancreas: - Endocrine part of pancreas is just a tiny spherical mass.Endocrine gland of pancreas is made up of small cells which are called islets of Langerhans's. It produces insulin.
- Exocrine part of pancreas: - This is a compound gland of pancreas called interlobulargland.Acini are composed of cells contain granules of digestive enzyme. The acini are connected with small ducts which further make a single duct which entre in to duodenum. The main enzymes secreted by the pancreas are Trypsin, Amylase and Lipase etc. The pancreatic secretion is stimulated by vagus nerve.

3. **Liver and Billary system** :-

Liver is the largest gland of the body. It is solid and reddish brown in colour.Weight of liver is about 3-5kg in adult cattle. It is placed in right side of abdominal cavity.It has two surfaces – parietal and visceral. It is an important organ of intermediate metabolism. It has also an exocrine section which secrets bile. Bile is stored and concentrated in **gall bladder**. All domestic animals except horse have gall bladder. Gall bladder is situated at visceral surface of Liver. The bile duct is formed by the union of cystic duct and hepatic duct, it open in duodenum. Structure of liver shows no specific feature of importance. The liver is enclosed with in a tough fibrous capsule. Liver receives its blood through **hepatic artery** and **portal vein**. Blood leaves the liver through hepatic vein. The blood from hepatic artery and hepatic vein mixes and processes in the liver and return to general circulation. The functional tissue of liver is called hepatic sinusoids.

4. **The Spleen :-**

Spleen is a hemolymph organ. Spleen is eleptical in outline, has 2-3cm thickness, 50 cm length and 2.5 cm width and weight is about 900gm in adult cattle's. This organ is situated at craniodorsal part of the rumen against left half diaphragm and attached these two organs. Spleen is made of soft tissue and steel blue or reddish color. It is divided into red and white pulp. The main functions of spleen are phagocytosis, hemopoiesis, immune response and storage of RBCs.

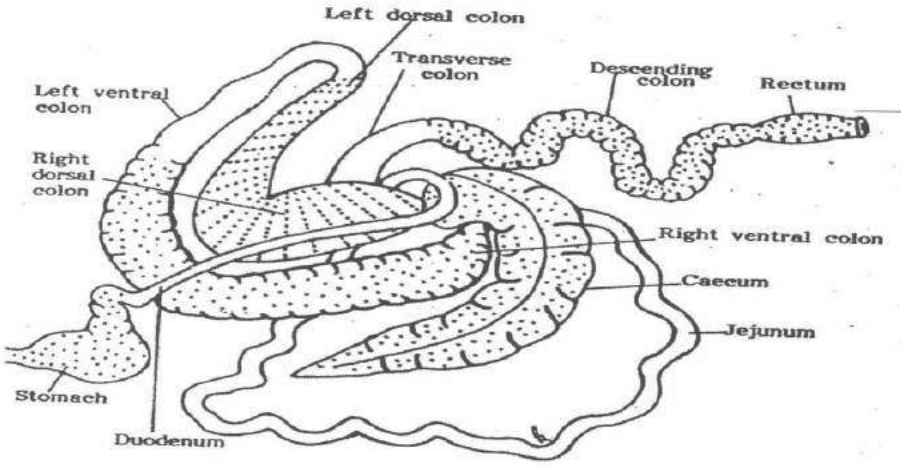
➢ **G.I.T of Horse:-**

1. Stomach: - The stomach of horse is in the form of a simple saccular structure. The capacity is about 12 liters in an adult horse. It is curved and 'J' shaped. The lesser curvature is short; pylorus and cardia are very close. The mucus membrane of stomach is divided into two parts-non glandular and glandular. The glandular part is divided into three parts:-

(a) Fundic
(b) Pyloric
(c) Cardiac

These portions are divided due to presence of different types of digestive glands.

2. Small intestine: - It is divided into three parts-Duodenum, Jejunum and Ilium. Total length is about 22 meters and diameter is about 6-7 cm.
3. Large intestine: - It has two parts- Cecum and colon. This is a wider tube ends into rectum and open as anus. Length about 10 metres.



G.I.T OF HORSE

There are four structural layers in the walls GIT:-

1. Mucosa: - It lines in the lumen and composed of epithelial cells.
2. Sub- mucosa: - It is the connective tissue between mucosa and tunica muscularis. This layer supports the mucosa. It is made of loose connective tissue.
3. Tunica muscularis: - It is composed of an inner circular layer and outer longitudinal layers. These muscles wrap the GIT in such a way that the GIT can propel the content in lumen of GIT.
4. Tunica serosa/Adventitia: - It is the outer most layer of GIT covered by serosa/adventitia which connects the GIT with peritoneum.

THE MUSCULAR SYSTEM (MYOLOGY)

MYOLOGY

- Myology deals with the study of muscles (musculi) and their accessory structures such as the fasciae and synovial membranes
- The muscles are highly specialized organs, which have the property of contracting under the influence of a stimulus

- This is termed as contractibility and this phenomenon helps them to move those parts of the body to which they are attached
- They are the active part of the locomotion. Sylvius is the anthropotomist, who first named the muscles
- There are three different types of muscles that make up the muscular system viz.,
    - Skeletal muscle
    - Smooth muscle
    - Cardiac muscle
- The accessory strucutres of the muscle are
    - Fascia
        - Superficial fascia
        - Deep fascia
    - Synovial membranes
        - Synovial bursa
        - Tendon sheath

CLASSIFICATION OF MUSCLES

- The muscles are classified based on the structure in to three types as
    - Skeletal muscle
    - Smooth muscle
    - Cardiac muscle
- The muscles are classified based on the function in to two types as
    - Voluntary muscle
    - Involuntary muscle

SKELETAL / STRIATED MUSCLES

- They are both directly or indirectly attached to the skeleton and hence often named as skeletal muscles
- Striated muscle is composed of long, unbranched muscle fibres, which shows cross striations under a microscope; hence it is called as striated muscle
- Contraction of this striated muscle occurs as per the will of the animal. Hence, they are also named as voluntary muscles
- Morphologically, each muscle is considered as individual organs made up of several muscle fibres. There are about 200-250 paired and few unpaired muscles present in the domestic mammals.
- A delicate connective tissue sheath, the endomycium surrounds each muscle fibre. Several muscle fibres grouped together to form fasciculus, which is covered by perimycium.
- A muscle as a whole is composed of many fasciculi and is surrounded by epimycium**,** which is closely associated with the fascia and sometimes fused with it.
- Each muscle consists of a central portion called belly and two ends
- Each end of the muscle is attached to bone or cartilage or to skin by means of either tendon or ligament

- When a muscle contracts and shortens, one end of its attachments usually remains fixed and the other end alone moves
- The fixed attachment is called origin; the movable one is called insertion. In the limbs, the more distal parts are usually mobile. Therefore, the distal attachment is usually called the insertion

SMOOTH MUSCLE

- Smooth muscle is also called as non-striated or involuntary muscle, because the contraction of the muscle is not controlled by the will of the animal
- The muscle fibres don't show cross striations under microscope. Hence, they get the name smooth muscle
- They make the bulk of the walls of the visceral organs and are also named as visceral muscles
- It is composed of fusiform or spindle shaped cells with a single nucleus at the centre
- The muscle fibres are generally arranged parallel to each other

CARDIAC MUSCLE

- Cardiac muscle is found only in the heart, the immediate proximal ends of aorta, pulmonary artery and pulmonary veins
- It is also known as involuntary and striated muscle. Since the contraction is not under the control of the animal and the muscle fibres also shows the cross striations under microscope as the skeletal muscle fibres, they can be called as involuntary and striated
- Unlike the skeletal muscle fibres they are single nucleated,smaller in size and often have multiple branches
- They are attached to the adjacent cells to form a branching network
- The firm end-to-end attachments between cardiac muscle cells are visible under the microscope as dark, transverse lines between the cells.These attachment sites are called intercalated discs

THE CIRCULATORY SYSTEM (ANGIOLOGY)

- The cardiovascular system consists of the **heart** and a system of vessels for distribution of the blood to the tissues of the body and to the lungs for exchange of gases. Vessels that carry blood away from the heart are called **arteries**, and vessels that carry blood toward the heart are called **veins**.
- Circulation to the lungs (**pulmonary circulation**) is functionally and anatomically separate from circulation to the rest of the body (**systemic circulation**).

HEART

- The heart is a cone-shaped hollow muscular structure. The **base** is directed dorsal or cranio dorsal and is attached to other thoracic structures by large arteries, veins, and the pericardial sac.
- The **apex** of the heart is directed ventrally.
- It consists of two atria (atrium) i.e. receiving chambers and two ventricles i.e. discharging chambers. Heart work as a double pump for pulmonary and systemic circulations.

PERICARDIUM

- The heart is partially surrounded by a serous membrane called the **pericardium**.
- The pericardium, like other serous tissues (the pleura and peritoneum), creates a closed cavity (**pericardial space**) that contains only a small amount of fluid for lubrication. The inner layer, which is adherent to the outer surface of the heart, is called **visceral pericardium** or **epicardium**.
- The outer layer called **parietal pericardium**.
- In cattle, the apex of the heart contacts the dome of the diaphragm and the reticulum in the abdominal cavity lies on the caudal side of the diaphragm. Sharp metallic objects (most commonly, bits of wire) that are swallowed often accumulate in the reticulum.
- The contractions of this organ can cause these foreign bodies to penetrate the adjacent diaphragm and the pericardial sac, resulting in an infection of the sac called **traumatic pericarditis**.

CARDIAC ANATOMY

- The heart wall consists of three layers: an outer serous covering called **epicardium**, an inner endothelial lining called **endocardium** and a thick muscular layer called **myocardium**.
- The epicardium is the same as the visceral layer of pericardium. The endocardium is a layer of simple squamous endothelial cells that lines the chambers of the heart, covers the heart valves, and is continuous with the lining of the blood vessels.
- The myocardium consists of cardiac muscle.
- The heart is divided into right and left sides, each side has two chambers: an **atrium**, which receives blood from veins, and a **ventricle** which pumps blood from the heart through a large artery.
- The atria are thin-walled chambers, the myocardium of the ventricles, which pump blood back into vascular beds, is much thicker than that of the atria.
- The wall of the left ventricle is also thicker than that of the right; blood ejected from the left side during its contraction is under higher pressure than that ejected from the right ventricle.
- The right ventricle does not reach the apex of the heart, as the apex is formed entirely by the more muscular left ventricle.
- The myocardium between the two ventricle chambers is the **ventricular septum**. Between the atrium and the ventricle of each side is an **atrioventricular valve**, or **A-V valve**.
- The left A-V valve is occasionally called the **bicuspid valve**, because in it has two distinct flaps or cusps. Another more commonly used synonym is **mitral valve**.

- The right A-V valve is also called the **tricuspid valve** because in it has three flaps or cusps. The thin valve leaflets are attached to the inner wall of the ventricle at the junction of atrium and ventricle.
- The free margins of the cusp are attached to the interior of the ventricular wall by fibrous cords called **chordae tendineae**. The chordae tendineae attach to small muscular protrusions called **papillary muscles** that project into the lumina of the ventricles.
- These chordae tendineae prevent the valve from everting into the atrium when the ventricle contracts and closes the A-V valve by forcing blood against the ventricular side of the valve.
- Each ventricle's outflow tract features a **semilunar valve** that ensures blood flows only from the ventricle into the artery and not in the opposite direction.
- The semilunar valves have three cuplike leaflets, with convex side facing the ventricle.
- The **aortic valve** lies at the junction of the left ventricle and aorta; the **pulmonary valve** is at the junction of the right ventricle and pulmonary trunk.
- Blood returning to the heart from the systemic circulation is delivered to the right atrium by the **cranial** and **caudal venae cavae** (singular **vena cava**) . From the right atrium, this deoxygenated blood passes through the right A-V valve into the right ventricle. From the right side, the right ventricle wraps around the cranial side of the heart and terminates as the funnel-shaped **conus arteriosus**.
- The conus arteriosus is the origin of the pulmonary trunk, from which it is divided by the pulmonary valve. Just distal to the pulmonary valve, the pulmonary trunk divides into right and left **pulmonary arteries**, carrying deoxygenated blood to the respective lungs.
- A variable number of **pulmonary veins** return blood from the lungs to the left atrium. From the left atrium, blood passes through the left A-V valve into the thick-walled left ventricle. The left ventricle pumps the blood past the aortic valve into the **aorta**. The aorta and its branches carry oxygenated blood to all parts of the body.

BLOOD VESSELS

- Blood vessels resemble the branching of a tree in that the arteries start as large vessels and divide into smaller and smaller branches.
- The smallest arteries are **arterioles**, which are continuous with the smallest blood vessels, **capillaries**.
- Capillaries again unite to form small **venules** that come together to form larger and larger veins. The largest veins empty into the atria of the heart.
- Arteries and arterioles are tubular structures that carry blood away from the heart. Like all blood vessels, they are lined with endothelium.
- The walls of arteries tend to be thick and elastic, properties that are important in maintaining blood pressure. Smooth muscle in the walls of smaller arteries controls the diameter of these vessels.
- Capillaries are tiny tubes composed almost entirely of endothelium, a continuation of the simple squamous epithelium that lines the heart and blood vessels.
- The wall acts as a selectively permeable membrane that permits water, oxygen, and nutrients to leave the blood for tissue cells and permits waste products from tissue cells to enter the blood. Much of the fluid that passes out of the capillaries into tissue spaces again returns to the blood by passing back through the capillary walls.
- Some fluid remains in the tissues, and excess fluid normally is removed by lymph vessels. Capillaries unite to form venules, which merge into larger and larger veins. Veins are larger in diameter than the arteries they parallel and have much thinner walls.

AORTA

Aortic Arch.

- The left ventricle receives oxygenated blood from the left atrium and pumps the blood through out the systemic circulation by way of the largest artery, the **aorta**.

- The aortic valve, at the junction of the left ventricle and aorta, prevents back flow of blood from the aorta into the left ventricle when the ventricle relaxes.
- Two large vessels arise from the aorta immediately distal to the aortic valve. These are the right and left **coronary arteries**, they are the arterial blood supply for the myocardium.
- Most of the venous blood from the myocardium is returned to the right atrium by way of the **coronary veins**, which empty directly into the right atrium by way of the **coronary sinus**, adjacent to the opening of the caudal vena cava.
- After emerging from the base of the heart, the **aortic arch** courses dorsaly and then caudaly, just ventral to the bodies of the thoracic vertebrae. The aorta continues as the **thoracic aorta** until it passes through the aortic hiatus of the diaphragm to become the **abdominal aorta**.
- Arteries that supply the head, neck, and thoracic limbs branch from the aortic arch. In horses and ruminants, the aortic arch gives rise to a single large **brachiocephalic trunk**, whose many branches distribute blood to the cranial half of the animal.
- The precise pattern of the main arterial branches is species dependent, but the following generalities can be made:
  (1) the main blood supply to the thoracic limbs arises as right and left **subclavian arteries**;
  (2) the right and left **costocervical trunks** provide arterial blood to regions of the neck and cranial thoracic wall.
  (3) right and left **common carotid arteries**, a main source of blood for the head and brain, arise together from a single **bicarotid trunk**.

Thoracic Aorta.

- The **thoracic aorta** passes caudaly just ventral to the vertebral bodies. As it does so, pairs of segmental arteries arise from its dorsal aspect to supply the thoracic wall and adjacent muscles. Each of these **intercostal arteries** enters the corresponding intercostal space, giving off a **spinal branch** that enters the vertebral canal to supply the spinal cord and spinal nerve roots.
- The continuation of the dorsal intercostal artery follows the caudal border of each rib ventrad. Other branches of the thoracic aorta supply parts of the esophagus, lungs, and diaphragm.

Abdominal Aorta.

- The aorta is called the **abdominal aorta** after it passes through the **aortic hiatus** of the diaphragm. Ventral to the last few lumbar vertebrae, it terminates by dividing into two **external iliac arteries** (supplying the pelvic limbs) and two **internal iliac arteries** (supplying the gluteal and perineal region). Some species have a **median sacral artery**, a small midline continuation of the aorta that continues ventral to caudal vertebrae as the **median caudal artery**.
- The accompanying **median caudal vein** (tail vein) at this site is often used for collection of blood from adult cattle. The abdominal aorta features paired **lumbar arteries** arising from its dorsal side, supplying the abdominal wall and epaxial muscles and giving off **spinal branches** that supply the spinal cord and spinal nerve roots of the lumbosacral region. Paired visceral branches provide arterial blood to the kidneys (**renal arteries**) and gonads (**testicular** or **ovarian arteries**).
- Three unpaired visceral branches supply nearly all the abdominal viscera. These are, from cranial to caudal, the **celiac, cranial mesenteric**, and **caudal mesenteric arteries**.
- **celiac artery** arises shortly after the aorta passes through the diaphragm. This is a large unpaired artery that supplies the stomach (**left gastric artery**), the spleen (**splenic artery**), and the liver (**hepatic artery**).
- The exact branching pattern of this artery depends to a great extent upon the type of stomach; the ruminant has a much more complex distribution of the celiac artery than do animals with a simple stomach. Immediately caudal to the celiac artery is the **cranial mesenteric artery**.
- This large, unpaired artery branches into a number of smaller arteries that supply blood to most of the small intestine and much of the large intestine. The number and distribution of the branches of the

cranial mesenteric artery vary among species. The caudal part of the large intestine and the rectum receive blood from a relatively small unpaired artery, the **caudal mesenteric artery**.

Arterial Distribution to the Head

- Most of the structures of the face, head, and cranial neck are supplied by the right and left **common carotid arteries**, each of which runs craniad in a connective tissue sheath with the vagosympathetic trunk of the same side.
- This **carotid sheath** lies in a groove dorsolateral to the trachea. Branches of the common carotid arteries supply the thyroid gland and larynx. In the region of the larynx, the common carotid artery gives off the **internal carotid artery**, a primary source of blood for the brain. The continuation of the common carotid artery is the **external carotid artery**, whose many branches supply the face, tongue, and structures of the oral and nasal cavities.
- The **facial artery** is convenient for taking a pulse as it passes across the mandible. The internal carotid arteries or their derivatives enter into an anastomotic ring of vessels on the base of the brain called the **cerebral arterial circle** (formerly circle of Willis).
- The cerebral arterial circle gives rise to arteries that supply the cerebral hemispheres and rostral parts of the brainstem. More caudal parts of the brainstem and the cerebellum receive most of their blood supply from branchesof the **basilar artery**. This single ventral artery is formed by the joining of right and left **vertebral arteries**.
- The robust vertebral arteries ascend from their origin in the thoracic inlet, run alongside the cervical vertebrae, enter the foramen magnum of the skull, and there coalesce into the basilar artery (coursing rostrad) and the **ventral spinal artery** (running caudad).

Arterial Distribution to the Thoracic Limb

- The right and left subclavian arteries follow the same course on each side of the body and each gives off similar branches. Within the thorax each subclavian artery gives off a number of branches that supply blood to the caudal part of the neck, much of the thoracic wall, and the dorsal part of the shoulder.
- The subclavian artery passes cranial to the fi rst rib on the respective side, passing into the axilla (armpit) of the thoracic limb, where it is called the **axillary artery**.
- The axillary artery enters the limb, becoming the **brachial artery** in the region of the brachium and then the **median artery** as it continues distal to the elbow.
- The largest terminal branch of the median artery in the horse is the **medial palmar artery**, which passes distad in the metacarpus to the fetlock, where it divides into medial and lateral **digital arteries**. In ruminants, the median artery is continued in the manus as the **palmar common digital artery**.

Arterial Distribution to the Pelvic Limb

- The abdominal aorta terminates near the lumbosacral junction in the two internal iliac arteries (and often a small, midline continuation called the median sacral artery). Each internal iliac artery and its many branches supply the region of the pelvis, the hip, and much of the genitalia. Just cranial to the internal iliac arteries, the external iliac arteries arise and give rise to branches serving caudoventral parts of the abdominal wall and structures of the inguinal region (prepuce, scrotum, and/or mammary gland).
- These large arteries then continue into the pelvic limbs as the **femoral arteries**. The femoral artery descends on the medial aspect of the limb, giving branches to the large thigh muscles, and continues in the region of the caudal stifl e as the **popliteal artery**. After a very short course, the popliteal artery divides into **cranial** and **caudal tibial arteries**.
- The small caudal tibial artery supplies the muscles of the crus, or true leg. The cranial tibial artery is larger; it passes craniad between the tibia and fi bula and descends on the cranial side of the crus to the hock. Where this vessel lies on the fl exor surface of the hock, it is referred to as the dorsal pedal artery. In horses, it continues distad as the dorsal (great) metatarsal a. III, running on the lateral side of the pes in the groove between the cannon bone and lateral splint. Ultimately, it passes to the plantar aspect of the distal cannon bone by crossing deep to the splint bone.

- At the equine fetlock it divides into medial and lateral **digital arteries**. In ruminants, the dorsal pedal artery continues distad on the dorsal aspect of the pes; the plantar side is supplied by a continuation of the **saphenous artery**, a medial branch of the femoral artery.

Veins

- With some notable exceptions, veins accompany arteries of the same name. These "satellite" veins are always larger than their respective arteries and frequently duplicated. For example, the brachial artery carrying blood to the forearm and digit may be accompanied by two or more brachial veins returning the blood to the heart.
- Some veins are superfi cial, visible in the subcutaneous tissues, and these are particularly of interest as they may be accessed via **venipuncture** (introducing a needle into a vein). As indicated earlier, nearly all systemic veins eventually drain into either the cranial vena cava or caudal vena cava.

Cranial Vena Cava

- The **cranial vena cava** drains the head, neck, thoracic limbs, and part of the thorax. Tributaries to the cranial vena cava include the **jugular veins** (internal and external), **subclavian veins**, and **vertebral veins**.
- The external jugular veinsdrain the face and much of the head, while the internal jugular veins, if present, along with the vertebral veins drain most of the blood from the brain. Each subclavian vein receives venous blood from the same areas that are supplied by the subclavian artery and its branches (shoulder, neck, and thoracic limbs).
- The **azygos vein** (the word azygos derives from the Greek word meaning "unpaired") lies adjacent to the vertebral column, receiving the segmentally arranged intercostal veins. In horses, the right azygos vein empties at the junction between cranial vena cava and right atrium. Ruminants sometimes have both right and left azygos veins, but more usually have a single left azygos vein, which empties directly into the right atrium with the coronary sinus. The pig possesses a left azygous vein, which empties into the coronarysinus.

Caudal Vena Cava

- The caudal vena cava is formed in the abdomen by the junction of the paired **internal** and **external iliac veins**. These drain the gluteal and perineal regions and the pelvic limbs, respectively.
- The caudal vena cava also receives **lumbar veins**, **testicular** or **ovarian veins**, **renal veins**, and various others from structures associated with the body walls. Just caudal to the point at which the caudal vena cava passes through the **caval foramen** of the diaphragm, it receives a number of short **hepatic veins** directly from the liver.

Portal System

- A **portal system** is one in which a vessel divides into capillaries, recombines to form anothervessel, and then redivides into a second capillary bed. In birds and in some reptiles and amphibians, part of the venous blood returning from the pelvic limbs enters the kidneys to form a renal portal system.
- In the **hepatic portal system**, blood that has perfused the capillary beds of the viscera is brought to the liver by a single large vein, the **portal vein**, and then is redistributed into a second capillary bed within the substance of the liver. Tributaries to the portal vein include the **gastric vein** from the stomach, the **splenic vein** from the spleen, the **mesenteric veins** from the intestines, and the **pancreatic veins** from the pancreas.
- The portal vein enters the liver and immediately breaks up into smaller and smaller branches there, fi nally ending in the **sinusoids** of the liver. Here the blood comes into direct contact with cells of the liver. After being acted upon by the liver cells, the blood passes from the sinusoids of the liver into the liver's venous system and eventually empties into the caudal vena cava.

Fetal Circulation

- Throughout gestation, the fetus depends on the dam for the nutrients, water, and oxygen needed for growth and for the elimination of carbon dioxide and other waste products of fetal metabolism.
- During fetal development, the lungs are collapsed and not aerated, and the pulmonary vascular beds have high resistance to blood flow.
- The fetal circulation therefore bypasses these pulmonary capillary beds. Immediately after birth, however, the newborn needs to direct its blood through the pulmonary vessels for oxygenation.
- The heart and circulatory system are arranged in such an ingenious way that the cardiopulmonary circulation just moments after birth is profoundly different from that exhibited just prior to the first breath . Because it is exchanging gas, supplying nutrients, and removing metabolic waste pro ducts, the placenta must necessarily receive a large proportion of the fetus's circulating blood. It does so via two large **umbilical arteries**, extending from the caudal end of the abdominal aorta through the umbilical cord to the placenta.
- After passing through the placental capillary bed, the blood is returned to the fetusby a single **umbilical vein**, which passes into the substance of the liver. Most of the highly oxygenated blood returning from the placenta in the umbilical vein is delivered directly into the caudal vena cava, bypassing the hepaticsinusoids via a fetal diversion, the **ductus venosus**.
- Two features of the fetal heart allow blood to bypass the pulmonary circulation. During cardiogenesis, the wall between the two atria develops a fl utter valve. This aperture is called the **foramen ovale**, and its structure is such that the blood entering the right atrium (well oxygenated, as a goodly portion of it is returning from the placenta) uses the one-way flutter valve of the foramen ovale as a convenient passageway from the right to the left atrium.
- This is one way blood bypasses the fetal lungs. Second, blood fl owing from the right ventricle into the pulmonary trunk bypasses the pulmonary arteries through the **ductus arteriosus**,which connects the pulmonary trunk and the aorta.
- In the fetus, the pressures in the right side of the heart are greater than those of the left side, since relatively little blood is returning from the lungs to the left side. As a result, thepressure is higher in the pulmonary trunk than the aorta, and blood therefore passes across the ductus arteriosus from the trunk to the aorta, bypassing the pulmonary circulation. At birth, when the neonate takes its first breath and inflates its lungs, the resistance in the pulmonary capillary bed falls precipitously.
- The increase in oxygenation of the newborn's blood constricts the ductus arteriosus. Within a few minutes, this formerly large vessel has shrunk drastically.
- Within the first week of life, it closes completely, becoming a fi brous band, the **ligamentum arteriosum**, identifi able grossly between the pulmonary trunk and the aorta. These changes abruptly increase blood flowto the now low-resistance pulmonary capillary beds. This abrupt increase in fl ow to the lungs produces a dramatic increase in blood returning to the left atrium, and as a consequence, pressures in the left side of the heart increase markedly.
- Greater blood pressure in the left atrium squeezes shut the foramen ovale, and blood no longer flows between the two atria.
- A ductus arteriosus that fails to close is a patent ductus arteriosus (PDA). In PDA, the conduit between the low-pressure pulmonary trunk and the high-pressure aorta persists, and blood passes from the aorta intothe pulmonary circulation.
- This overperfuses the pulmonary capillary beds and increases the amount of blood returning to the left atrium, which dilates (is stretched). The left A-V valve is often affected by left atrial dilation in such a way as to allow regurgitation of blood. The overdistension of the left atrium is compounded, and pulmonary congestion may result. Other modifications of circulation outside of the heart and great vessels take place at birth.
- One of the most obvious changes is that the placenta loses its role as oxygenator and provider of nutrients. The vasculature associated with it (umbilical arteries and veins) collapses and converts into fi brous cords (**round ligaments**) that are sometimes identifiable grossly in the adult.

- The ductus venosus undergoes constriction as well. If the ductus venosus fails to close completely, blood returning from the viscera via the portal vein may fi nd its way back to the systemic circulation (specifi cally, the caudal vena cava) without fi rst being processed in the liver.
- This abnormality constitutesa portosystemic shunt (sometimes called portocaval shunt) and can produce abnormalities of metabolism, growth, and neural function.

DIFFERENCE

	Arteries		Veins
1.	These carry blood from heart.	1.	These drain the blood to heart.
2.	These contain oxygenated blood except pulmonary arteries.	2.	These contains deoxygenated blood except pulmonary vein.
3.	These are thick walled and have no valve except aorta and pulmonary artery	3.	These have valves to prevent back flow of blood except vena cava & pulmonary vein.
4.	They have blood pressure.	4.	They have no blood pressure.
5.	These situated deeper in the body.	5.	These present superficially.
6.	Color of these vessels are reddish.	6.	Colors of these vessels are bluish.

- **Lymph, lymphatics and lymph nodes:-**

1. **Lymph:-** Lymph is a colorless tissue fluid made of excessive body fluids, lymphocytes and antibodies. Lymph is produced and filtered into lymph nodes.
2. **Lymphatics:-** These are the vessels other than blood vessels which drain lymph from lymph glands to the venous system. Lymphatics are distributed between mucosa, serous membrane and synovial membrane.
3. **Lymph nodes:-** These are oval, bean sized, nodular, brown or reddish black color structures. Their size may vary from very minute to lemon size. Lymph nodes are found in specific areas – axilla, inguinal region, mesentery, pre scapula region or sub-mammary region etc.

These all make the defensive mechanism of the body and remove excess fluids from body.

BLOOD

Blood is a specialized connective tissue composed of cells suspended in liquid. Blood circulates through a closed system of blood vessels due to pumping action of heart. When it is centrifuged before clotting, it separates into two parts :-

- A straw colored liquid called plasma.
- Less than half of the blood is packed with formed elements consisting of RBCs, WBCs and Platelets.

Serum and Plasma:- In plasma a proteinous substance called fibrinogen is present but in it is serum absent.

Fibrinogen is a protein (globulin, albumins) which helps in clotting with the help of platelets.

FUNCTIONS OF BLOOD

1. Blood carries nutrients which are absorbed in the GIT to the all tissues of body.
2. It carries oxygen from lungs to the tissue of body and carries carbon dioxide from tissue to lungs for excretion.
3. Waste products from various tissues carried to kidneys for excretion.
4. Hormones are carried from endocrine glands to various organ of the body.
5. Blood helps in temperature control of body.
6. Water balance of body is maintained by blood.
7. Clotting capability of blood helps in preventing excessive loss of blood during injuries.
8. Blood helps in maintaining tissue pH.
9. Blood contains antibodies which help in disease control.
10. Blood helps in circulation of drugs to all tissues during treatment and vaccination.

Volume of blood in animals:-

The percentage of blood present in animal body to the total weight of animal body, which vary with species.

- Blood percentage in various animals :-
  Cattle - 7.7 % of body weight
  Sheep - 8 % of body weight
  Dog - 5.5 % of body weight
  Horse- 8- 10% of body weight

COMPONENT OF BLOOD

1. **Plasma:-** When whole blood is centrifuged before clotting, the blood divided into two portions- one is a straw colored fluid which is about 55 % of whole blood is called plasma. Plasma consist of 92 % water and 8 % other substance 90 % non-protenecious is a protein called fibrinogen. Fibrinogen is made up of two proteins Albumins and Globulin. And 0.9 %inorganic matter and remain 9.1% other non-pro organic matters. The main function of fibrinogen is to make clots with platelets which prevent excessive bleeding during injuries.

2. **Serum :-** When blood is allowed to clot then it divides into two parts –one is solid mass and second is colorless fluid called serum. Serum contains antibodies. Therefore plasma – fibrinogen =serum
3. The formed elements :-

(a) **RBCs/Erythrocytes :-** RBCs make 32 % of blood.

- The red color of the blood is due to Haemoglobin. The shape of RBC is biconcave, disc like, flexible and having no nucleus shape of RBCs varies with species and breed of animal.
- The number of RBCs varies with different breed, nutritional status, physical activities, age and health conditions. RBCs are produced in bone marrow of long bones. They are also producing by ribs, sternum, vertebrae and pelvic bone.
- RBCs main function is to carry oxygen to body tissue and carbon dioxide back to lungs for excretion.
- Hb has a protein compound named globin and it is united with four non protein groups called hems. Each hem contain iron atom.
- The hems are able to combine one oxygen compound reversibly. Thus each Haemoglobin molecule is capable of combining for oxygen molecule. When Haemoglobin is combined with oxygen is called oxyhaemoglobin.
- When blood returns lungs from tissues then 25 % of Haemoglobin is not having oxygen molecule is as reduced Haemoglobin, carbon-dioxide is reversible combined with hem group of Haemoglobin which are called carboxy-haemoglobin.
- This process is continuous and oxygen is supplied to the body tissue for oxidation to produce energy for life and after oxidation a byproduct carbondioxid is carried back to lungs and excreted out.
- In some diseases such as poisoning, snake bite, blood parasitic infestation, hypotonic solutions ingestion, the Rbcs are ruptured and Haemoglobin comes out in plasma, this condition is called Haemoglobinemia and when this ruptured Haemoglobin excreted through urine, this condition is called Hematuria.
- If proper treatment is not given in time, the death of animal is sure. The average age of erythrocytes 50-120 days which is varies with species and breeds .
- Thus millions of RBCs are produced and degraded in every second .

(b) WBCs/ Leucocytes :-

- These are color less cells found along RBCs .They are larger than RBCs but fewer in numbers All WBCs have nuclei but no Hemoglobin. These are capable of independent movement. In addition to blood these WBCs are found into lymph glands, spleen and GIT.
- There are of two types:- GRANULOCYTES and AGRANULOCYTES.

Granulocytes are of three types :-

1. **Eosinophil**
2. **Basophil**
3. **Neutrophils**

Agranulocytes are of two types :-

1. **Monocytes**
2. **Lymphocytes**

- **Granulocytes :-**

These WBCs have granules in their cytoplasm but in agranulocytes these granules or fewer or absent.

(i) Neutrophils:-These WBCs make greatest part of White Blood. They have granules which not stain with basic dyes. The nucleus of neutrophils has 3 to 5 lobs , these have Phagocytic property.

(ii) Eosinophil's:- These also have granules and stain reddish with basic dyes. They are weekly phagocytic property. There number is about 5-10% of WBCs . There nuclei have 2 lobs . The main function of Eosinophil's is detoxification of toxins which are entre through lungs and GIT or produced by bacteria, viruses and parasites.

(iii) Basophils :- Their count is 0- 0.2 % of all WBCs . They stain blue in basic dyes . The nucleus has two lobs. They contain heparin which is anticoagulant .Therefore the main function of basophils is to help clotting of blood.

- **Agranulocytes :-**

(i) Monocytes :- They are largest WBCs . They have phagocytic properties and help in production of globulin.

(ii) Lymphocytes :-They are variables in size and appearance and having a big nucleus covering almost all the area of lymphocytes .Their main function is to make antibodies from antigens and they help in production of globulin.

- Percentage of leucocytes in blood of cattle :-

(1) Neutrophils	25-30%
(2) Lymphocytes	60-65%
(3) Eosinophil's	2-5 %
(4) Basophils	<1%
(5) Monocytes	5%

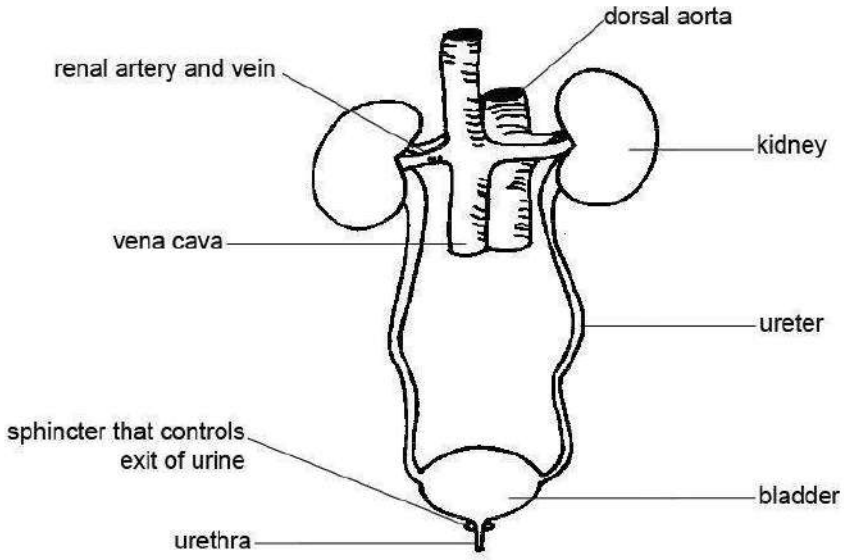
(c) **Platelets: -** These are the fragment of protoplasm found in blood. They help in clotting of blood with the help of globulin to prevent excessive bleeding during injury.

THE URINARY SYSTEM

This system excretes waste products from the blood and maintains alkalinity & chemical composition of blood, to a constant level.

This system composed of following organs:-

1. **Kidneys**
2. **Ureters**
3. **Urinary bladder**
4. **Urethra**



Urinary tract

➢ THE KIDNEY: -

- The kidneys are paired reddish-brown organs that filter plasma and plasma constituents from the blood and then selectively reabsorb water and useful constituents from the filtrate, ultimately excreting excesses and plasma waste products.
- The kidneys of most animals are roughly bean-shaped, with the exceptions among domestic animals of the heart-shaped right equine kidney and the distinctively lobulated kidneys of the ox.
- The kidneys are described as being **retroperitoneal** in location, reflecting their position outside the peritoneal cavity where they are more closely attached to the abdominal wall by fascia, vessels, and peritoneum than are most other abdominal organs.
- The position of right kidney is fixed but left kidney is variable in position. Right kidney is bean shape; left kidney has three surface, three borders, and two ends i.e. anterior and posterior. When rumen is full then left kidney slipped downward as compare to right kidney.

Structure of kidney:- Kidney is composed of capsule and cavity of kidney.

I. Capsule:- Capsule of kidney is made up of fibrous material and it covers the whole kidney this fibrous capsule can be easily separated from cavity of the whole kidney.

II. Cavity of kidney: - Kidney is composed of renal sinuses. The Structural and functional unit of kidney is nephron.

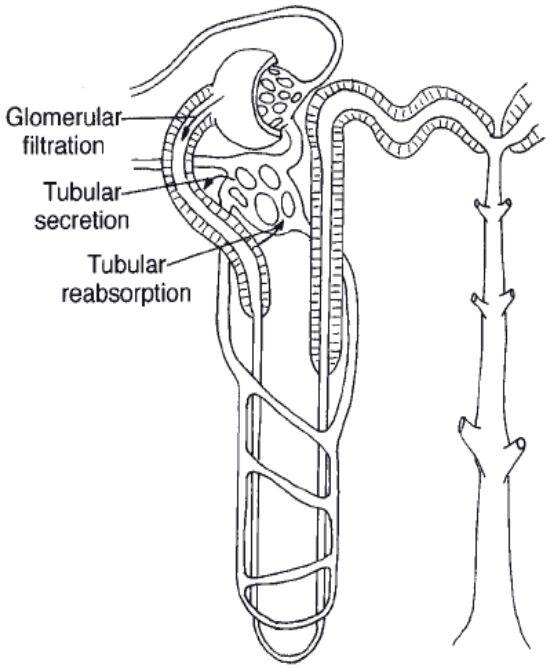
- Blood supply:- Blood is supplied to the kidney by the two arteries i.e. right renal artery and left renal artery. These both arteries originated from the abdominal aorta.
- Nerve supply:- Nerves are supplied from renal plexus.

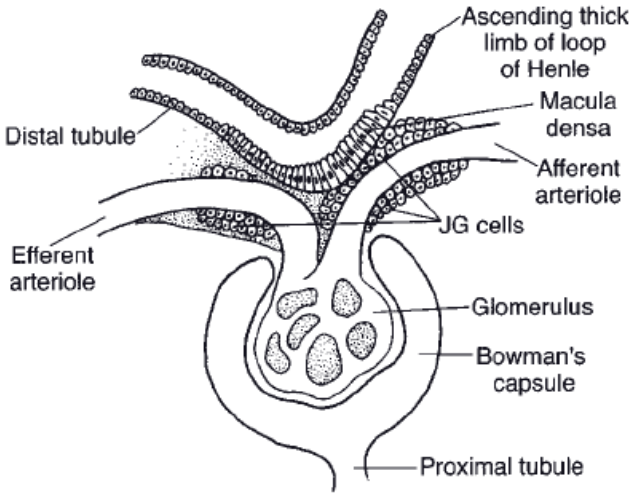
- **THE URETER:** -
  - These are the excretory ducts of the kidneys, one from each right and left kidney. They originate from renal pelvis of corresponding kidney, passes caudally and terminate into the urinary bladder.
  - At the point of termination/entry of ureter into the bladder, they become oblique which work as valve and stop the back flow of urine into the kidney. Diameter of ureters is 6-8 mm and length of right ureter is nearly 60 cm and left ureter is nearly 50 cm.

- **THE URINARY BLADDER:-**
  - It is a thick walled sac like structure which works as reservoir of the urine. The shape and size depend on the amount of urine it contains. When bladder is empty then it is placed in contracted form at the floor of pelvis. When it is full of urine then it is distended into the abdominal cavity.
  - In female the dorsal border of urinary bladder is related to the ventral side of vagina and uterus. In male the dorsal border of urinary bladder is related to rectum, vas deferens and seminal vesicle.
  - The caudal end of the urinary bladder is in the form of narrow tube which is called sphincter or neck of urinary bladder. This neck is continued as urethra. The epithelial lining of urinary bladder is transitional epithelium.

- **URETHRA:** -
  - In male it is a tube that extends from the neck of U.B to the glans penis. It is a common passage for urine and semen. It has two parts pelvic part and penile part.
  - In female it is 8-12 cm long narrow tube that extends from the neck of U.B to external urinary meatus. It travels along the vagina. The mucus layer of female urethra is rich in blood vessels and urethra open as urinary meatus.
- **Urination/micturition:-**
  - The periodic discharge of urine from the bladder is called urination. It is initiated by voluntary relaxation of muscle of neck of Urinary bladder and maintained by the involuntary reflex contraction of urinary bladder muscles. Therefore urination is both voluntary and involuntary.
  - Kidneys are composite organs that consist of thousands to millions of similar microscopic functional units, the **nephrons.** Nephrons in all mammalian kidneys are similar in basic structure and function, but the number of nephrons differs among mammals.
  - Large animals have more nephrons per kidney than small animalsNephrons consist of a spherical structure (**Bowman**'**scapsule**) that contains a capillary tuft (**glomerulus**) and a single long tubule connected to Bowman's capsule .

- A Bowman's capsule with its contained glomerulus is a **renal corpuscle.** The single tubule is divided into segments based on differences in histological appearance, location in the kidney, and function.
- These segments are named the **proximal** (**convoluted**) **tubule**, **loop of Henle**, and **distal** (**convoluted**) **tubule.** The distal tubules of numerous nephrons connect to another tubular structure found in the kidney, the **collecting duct** (tubule).
- Collecting ducts begin in the renal cortex, where they connect with distal tubules, and extend into and through the renal medulla.
- Three processes are involved in urine formation: - (1) **glomerular filtration**(2) **selective tubular reabsorption**(3) **selective tubular secretion**





STRUCURE OF NEPHRON AND BOWMAN'S CAPSULE

THE REPRODUCTIVE SYSTEM

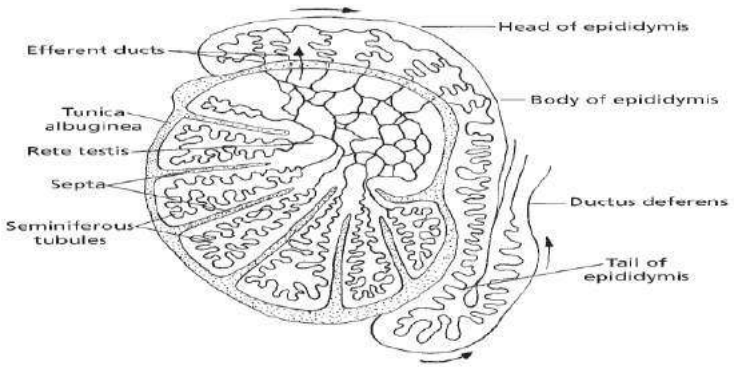
Male reproductive system:-

The organs and glands of the male reproductive tract manufacture the male gamete **spermatozoa** and deliver it to the female reproductive tract. In the male, the urethra is a passage common to the urinary system and the reproductive tract.

- The male reproductive system of mammals consists of two **testes** in the **scrotum,** accessory organs including ducts and glands, and the penis. The testes produce spermatozoa (also called **sperm**) and **testosterone** (the male sex hormone).
- The scrotum provides a favorable environment for the production and maturationof spermatozoa, related structures include the **epididymis** and **ductus deferens**, accessory sex glands (**ampullaryglands**, **vesicular glands**, **prostate**, and **bulbourethral glands**), the **urethra**, and the **penis**.

❖ TESTES

- Testes produce viable potentially fertile spermatozoa and male sex hormone called testosterone. Testes are the primary reproductive organ of male. These develop in the scrotum in mammals.
- There are 2 testes suspended in the scrotum. Descending and ascending mechanism of testes in the scrotum gives thermodynamic conditions for the development of viable and fertile spermatozoa. Size of testes in cow bull is about 10-16 cm long and 5-8 cm wide. The size of testes varies with age and weight of animal. Weight is about 250-300 gm.
- Histologically each testes is composed of several crypts enclosed in a serous membrane called tunica vaginalis. Each crypts has a number of seminiferous tubules.
- Seminiferous tubules have 2 layers, basement layer and multilayered sperm producing epithelium. This multilayered sperm producing epithelium produces spermatozoa. In the space between seminiferous tubules there are interstitial cells called as ley dig cells which produce male sex hormone called testosterone. Several seminiferous tubules combine to make the bigger tubule called vasa efferntia.



INTERNAL ANATOMY OF TESTES

❖ EPIDIDYMIS

- Vasa efferentia emerges from testicles and enters into epididymis. Epididymis is paired tube arising from the dorsal part of the testicle. The length of this tube is about 33-35 m in ox.
- There are three parts of this tube caput (head), corpus (body) and cauda (tail). Throughout the length of the epididymis lined with secretory cells. This secretion helps in nourishing, concentrating, storing and

transferring of spermatozoa. It takes 7-9 days for any sperm travel from germinal epithelium to the cauda of epididymis. The diluted spermatozoa produced from testes are concentrated and stored in epididymis.

❖ **VAS DEFERENS**

- This is also a paired tube arise from the cauda of epididymis. It is slender tube which is thick cord like. These tubes along with spermatic nerves, vessels and cremaster muscles surrounded by tunica vaginalis are also known as spermatic cord. Vas deferens is abundantly supplied by nerve. Vas deferens by involuntary contraction of musculature helps in ejaculation of semen. The vas deferens ends in urethra.

❖ **URETHRA**

- The urethra is a common passage of semen and urine. It extends through pelvic area & penis and ends at tip of penis i.e. glans penis. The outer end of urethra is called external urethral opening, in females it is called external urinary meatus.

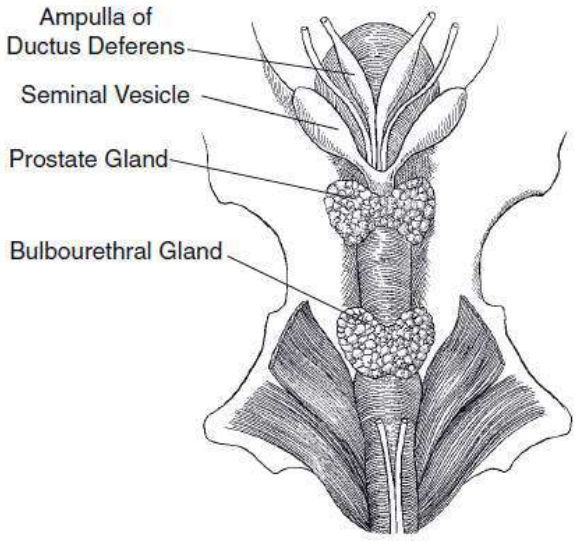
❖ **THE PENIS**

- Penis is the male copulatory organ and it is composed of erectile tissues. It is continuation of urethra through which urine and semen are discharged. The erectile tissue is called **corpus cavernosum** and **corpus spongiosum**.
- These tissues filled with blood and the penis becomes enlarged and rigid on sexual sensation. The semen can be ejaculated with erected penis only. In bull penis has an 'S' shaped flexure called **sigmoid flexure**. In normal condition this sigmoid flexure is situated behind the scrotal sac i.e. prescrotal.
- The tip of penis is called glans penis and this glans penis has maximum sex stimulating nerve endings just like clitoris in female. In bull length of penis is about 3 feet and diameter is 1 inch.

❖ **Accessory sex glands:-**

- The male accessory sex glands produce the bulk of the **ejaculate** or **semen**, the medium for transport of sperm. Semen provides favorableconditions for nutrition of sperm and acts as a buffer against the natural acidity of thefemale genital tract.
- The accessory sex glands include the ampulla of the ductus deferens, vesicular gland, prostate gland, and bulbourethral gland. Except for the prostate, these glands are paired. There is considerable variation in shape and size of the various accessory sex glands among species, but the relative location is similar in all animals

1. **Ampullae**
   - The **ampullae** are glandular enlargements associated with the terminal parts of the ductus deferentia. They are well developed in the stallion and bull; they empty into the ductus deferentia and contribute volume to the semen.
2. **Seminal vesicle's**
   - These are paired glands associated with thegenital fold. The vesicular glands of the stallion are hollow,pear-shaped sacs; those of the bull are lobulated glands of considerable size.
3. **Prostate gland**
   - The **prostate gland** is an unpaired gland that more or less surrounds the pelvic urethra. The prostate produces an alkaline secretion that gives semen its characteristic odor.
4. **Bulbourethral Gland**
   - The **bulbourethral** (Cowper's) **glands** are paired glands on either side of the pelvicurethra just cranial to the ischial arch but caudalto the other accessory glands.



ACCESSORY SEX GLANDS IN MALE

Male genital organs of horse:-

1. Scrotum is short and oval.
2. Color of scrotum is black.
3. Testes are smaller.
4. Penis is shorter and thicker.
5. Sigmoid flexure is absent.
6. At the base of glans penis there is a border called corona glandis.

Female reproductive system:-

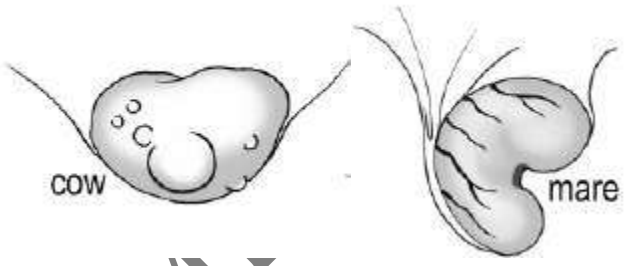
- The mammalian female reproductive tract produces the female gamete (**ovum**), delivers it to a site where it can be fertilized by the male gamete.
- Fertilization normally occurs within the uterine tube during passage of the ovum from the ovary to the uterus. Within the uterus, the fertilized ovum, now a **zygote,** develops into an **embryo** and then into a **fetus** and finally passes out of the uterus through the vagina and vulva as a newborn (**neonate**).

It consists of the following organs:-

1. The ovaries
2. Fallopian tubes or oviducts
3. The uterus
4. Vagina
5. The vulva

1. THE OVARIES:-

- The **ovaries,** like the testes in the male, are the primary organs of reproduction in the female. The ovaries are both endocrine and cytogenic (cell producing) as they produce hormones, which are released directly into the blood stream and ova, which are released from the surface of the ovary during **ovulation.**
- The ovaries are paired glands usually found in the lumbar region of the abdominal cavity, a short distance caudal to the kidneys. Like all abdominal organs, the ovaries are covered with peritoneum.
- They are suspended from the body wall by a reflection of this serous membrane, the **mesovarium,** the most cranial part of the peritoneal investments of the female genitaltract. In most species, the ovaries are somewhat ovoid, in the mare; however, the ovaries are bean shape and have **ovulation fossa.**
- When palpated through the wall of the rectum, an ovary feels solid because of the large amount of connective tissue that makes up the stroma of the gland.
- Normal size of the ovary varies considerably from species to species, and even within a species there is some variation. For example, the ovary of the mare may be less than 2.5 cm in diameter when no developing ova are present or as large as 10 cm with many developing ova.
- The ovary is invested in a dense connective tissue capsule, the **tunica albuginea.** The**medulla,** or central portion, of the ovary is the most vascular part, while the **cortex,** or outer portion, consists largely of dense, irregular connective tissue interspersed with follicles and **interstitial cells,** which have an endocrine function.



2. FALLOPIAN TUBE OR OVIDUCT: -

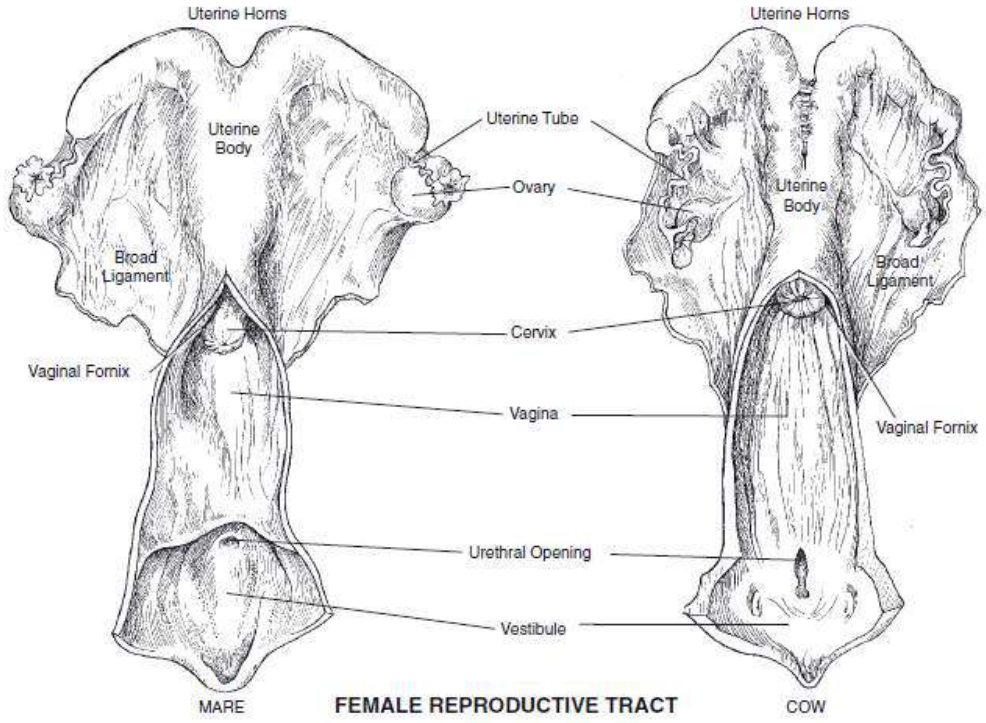
- The **uterine tubes** (also called **oviducts**) are paired, convoluted tubes that conduct the ova from each ovary to the respective horn of the uterus and are the usual site of fertilization of ova by the spermatozoa.
- The portion of the uterine tube adjacent to the ovary is expanded to form a funnel-shaped **infundibulum.** The infundibulum appears to take an active part in ovulation, at least to the extent of partially or completely enclosing the ovary and directing the ovum into the uterine tube.
- The lining of the uterine tube is a much folded mucous membrane covered primarilywith a simple columnar ciliated epithelium. Oviduct have 3 different portions as: -
  i. Isthmus:- it is also called uterine portion. It is narrow and thick walled.
  ii. Ampulla:- It has thick walled and little dilated.
  iii. Infundibulum:- It is also dilated and forms a funnel. Infundibulum is situated in such a position near the ovary which never fails to capture the ovum shed by the ovary.

  Fertilization generally occurs in ampullary part of oviduct.

3. THE UTERUS: -

- The **uterus** of the domesticmammal consists of a **body,** a **cervix** (neck), and two **horns**. The relative proportions of each vary considerably with the species, as do the shape and arrangement of the horns.Relative to the extent of the horns, the body of the uterus is largest in the mare.

- The uterus is suspended bilaterally from the body wall by the **mesometrium.** The mesometrium, mesosalpinx, and mesovarium collectivelyconstitute the **broad ligament.**
- **Caruncles** are mushroomlike projections fromthe inner surface of the uteri of ruminants; theyprovide a site of attachment for the fetal membrane. The **cervix** of the uterus projects caudally into the vagina. The cervix is a heavy, smooth muscle sphincter that is tightly closed except during estrus and parturition.
- During estrus thecervix relaxes slightly, permitting spermatozoa to enter the uterus. In ruminants, and to some extent in sows, the inner surface of the cervix It consists of three partsis arranged in a series of circular ridges or rings, sometimes called **annular folds**.
- The cervix of the mare is relatively smooth and projects prominently into the vagina,which surrounds the cervix as a deep **vaginal fornix.** The tunica muscularis is the muscularportion of the uterine wall, commonly calledthe **myometrium.**



FEMALE REPRODUCTIVE TRACT

4. THE VAGINA:-

- The **vagina** is the portion of the reproductive tract that lies within the pelvis between the uterus cranially and the vulva caudally. The vagina is the birth canal for delivery of the fetus at parturition and a sheath for the penis of the male during copulation.
- The mucous membrane of the vagina is glandless stratified squamous epithelium except in the cow, in which there are some mucous cells in the cranial part of the vagina adjacent to the cervix. The sub mucosa is loose, and the muscular layers consist of an inner circular and an outer longitudinal layer of smooth muscle.

5. THE VULVA: -

- It is the verticalopening of female genital tract. It lies just below the anus. Vulva has two labia – one is outer called labia majora and second is inner called labia minora. Labia majora has tactile hairs.
- The diameter of vulva is greater than the vagina. The vulvar wall is lined by mucus membrane which secrets mucus during copulation and sexual excitement. On the posterior floor of vulvathere lies clitoris.

- Clitoris is the counter part of male penis. It is a bud like structure. It is very sensatory and erectile in nature. Just below the clitoris external urinary meatus or urethral opening is presents. Clitoris is also called Pseudopenis.

❖ **Accessory female organs :-**

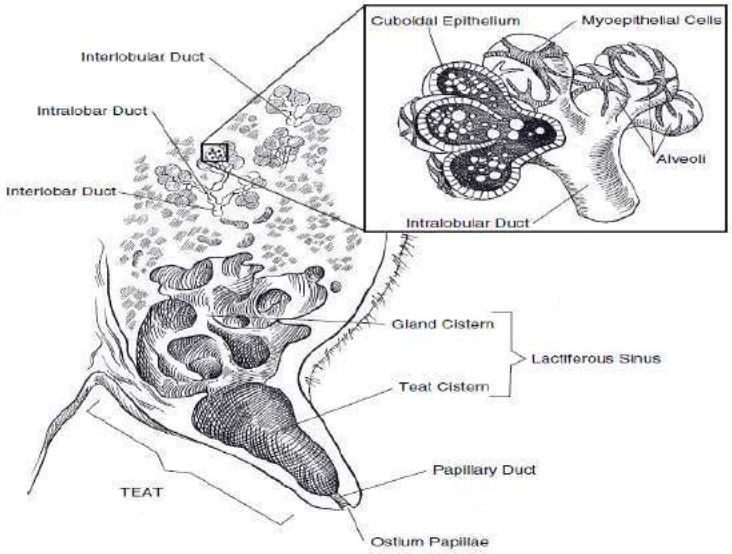
1. Placenta and extra embryonic membrane:- Placenta can be defined as an area where a close fusion takes place between uterine wall and the embryo. This fusion helps in the exchange of nutrients and oxygen from mother to embryo. The blood of mother and fetus never mixes with each other. Three germinal layers in the fetus :-
   i. Yolk sac:- It is very small in mammals and remains functional for a very short time. It provides nutrition to the embryo.
   ii. Amnion:- it is the inner most membrane enveloping the embryo. This membrane forms a cavity called Amniotic cavity. This amniotic cavity filled with a fluid which protects the embryo from mechanical injuries.
   iii. Allantois: - It contributes in the formation of placenta and umbilical cord. This layer comes in contact with chorion.

- Chorion: - It is outer most layer which makes contact with uterine wall through cotyledons.

2. Mammary glands: - The **mammary glands** are modified sudoriferous (sweat) glands that produce milk for the nourishment of offspring. They develops with the influence of hormones during puberty and starts functioning after conception (after the stage of pregnancy) and secreting milk after parturition. The development of mammary glands occurs by the action of estrogen and progesterone. These hormones cause –
   i. Deposition of fat.
   ii. Development of stroma.
   iii. Growth of lobules, alveoli and duct.

The gland of both side (right and left) are separated by a septum. Demarcation of glands of same side is not clear and has no connection or duct system. The udder is attached to the abdominal cavity with the help of suspensory apparatus and udder is situated in the inguinal region between the thighs.

Mammary glands are made up of epithelial component and connective tissue (stroma). Epithelial component has number of alveoli, which secret milk and collected in the teat system of the corresponding teat. There are 4 teats in cow. Teats are long tubular in shape and the distal end of teats is conical. Teats have muscular sphincter which prevent leakage of milk.



ANATOMY OF UDDER OF COW

THE RESPIRATORY SYSTEM

The respiratory system has two components:-

1. **The respiratory passage:-**

It includes:-

I. Nose and nasal cavity:-

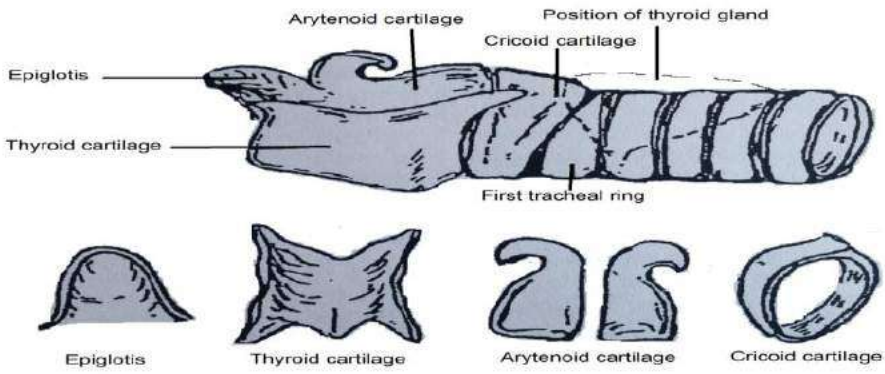
- It is the first part of the respiratory passage. It extends from exterior of the nose to the nasopharynx. This is bilateral, irregular tubular passage and this is enclosed by facial bones and cartilages.
- The external opening of nasal cavity is called nostrils. Nostrils are 'comma' shaped, oblique openings placed on the both sides of the muzzle. Both nostrils are separated by a cartilage called nasal septum.
- The nasal cavity is lined by mucus membrane. Nasal cavity in animals is hairless and kept moist by the secretion of mucus membrane. The posterior last 1/4th part of the nasal cavity works as olfactory organ.

II. Pharynx:-

- This is common organ of digestive system and respiratory system. Pharynx connects the nasal cavity to the larynx.

III. Larynx:-

- It is a musculo cartilage elongated compartment of respiratory passage. It is situated between pharynx and trachea.
- It is composed of four cartilages i.e. thyroid cartilage, epiglottis cartilage, arytenoid cartilage and cricoid cartilage.
- These 4 cartilages form laryngeal cavity extends from the entrance of larynx and the caudal borders.



Larynx of ox

IV. Trachea:-

- It is an elastic tube extends from larynx to the level of base of heart. It is made of cartilages and membranes. There are about 50-60 cartilages in the form incomplete rings in trachea of cattle. The open ends of the rings placed caudally.
- The rings are completed by connective tissue and smooth muscles of trachea. The length of trachea in cow is about 60 cm. Trachea bifurcates into two right and left bronchi at the lower terminal end.
- Trachea is divided into two parts i.e. cervical and thoracic. Before this bifurcation there originate and extra bronchus on the right side called apical bronchus.

❖ **Thoracic part of trachea:-** In thoracic part there is extra bronchus on the right side of trachea at level of thirds ribs in ruminants. It is called apical bronchus. This apical bronchus ventilates the apical lobe of the right lung. This is a peculiarity in the ruminants.

Composition of trachea:-

- Outer layer of fibrous adventitia.
- Cartilaginous rings – This is hyaline in nature.
- Sub-mucosa
- Mucus membrane.

2. The Lungs:-

- Lungs are in pair and these are main organs of respiration. They occupy most of the area of thoracic cavity. The two lungs are separated by mediastinum. Each lung is placed into the corresponding pleural cavity.
- Lungs are pink in color in fresh condition. Lungs are soft and spongy in appearance. They are crepitating to touch and float's in water. Lungs of new born calf are solid and do not float in water.
- Right lung is larger than left. Each lung is conical in shape and divided into lobes. Lungs have two surfaces, two borders, one base and one apex.

➢ **Lobes of the lungs:-** The lungs are divided into lobes by fissures.

Right lung has four lobes:-

i. Apical lobe
ii. Cardiac lobe
iii. Diaphragmatic lobe
iv. Accessory/intermediate lobe.

Left lung has three lobes:-

i. Apical lobe
ii. Cardiac lobe
iii. Diaphragmatic lobe

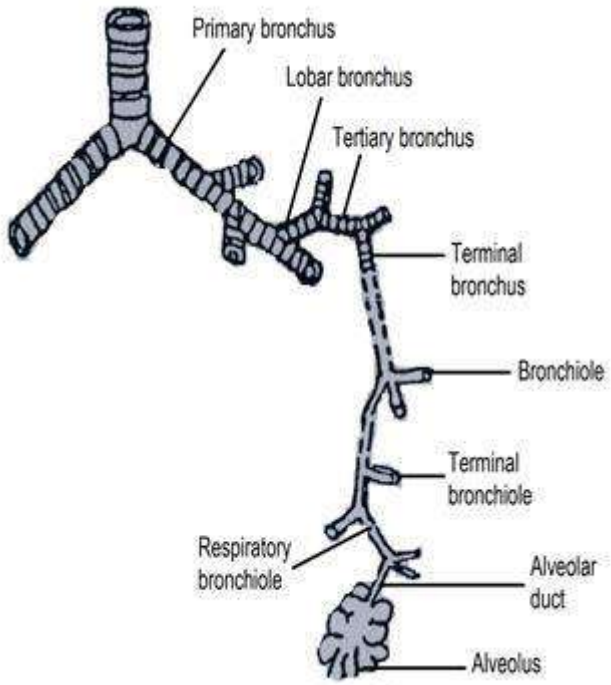
The apical lobe of right lung is larger than the apical lobe of left lung and it is ventilated by a special bronchus called apical bronchus.

➢ **Structure of lungs:-** Lungs are organ's which are enclosed space covered by external serous coat called pleura. Lungs have thousands of lobules and bronchioles. These lobules are the basic unit of respiration.

➢ **Bronchial tree:-**

- Trachea after giving of apical bronchus at the level of 3rd rib, bifurcates into right and left bronchi. These are called primary or pleural bronchi.
- Then these primary bronchi further bifurcate into secondary bronchi or lobular bronchi. The secondary/lobular bronchi ventilate each lobe.
- These secondary/lobular bronchi again sub-divided into tertiary bronchi which ventilate the specific area of the lobe. Then further divided into terminal bronchi. Terminal bronchus further divided into bronchioles.

- Bronchioles further divided into terminal bronchiole. This terminal bronchiole further divided into respiratory bronchioles and the respiratory bronchiole divided into alveolar duct. Alveoli are the basic unit of respiration.
- These are microscopic and exchange of oxygen and carbon dioxide takes place in the alveoli and there are thousands of alveoli in the lungs.



Bronchial tree

 # Pulmonary circulation:- Pulmonary circulation is of 2 types:-

1. The deoxygenated blood from the right ventricle is discharged into the lungs by 2 pulmonary arteries. After oxygenated, the blood is discharged into the left atrium via pulmonary veins.
2. Bronchiole artery from thoracic aorta supplies the oxygenated blood to the tissues of lungs. Nerve supply to the lungs is by pulmonary branch of vagus and sympathetic nervous system.

 # Respiratory organs of Horse:-

1. Nasal cavity is narrow and longer.
2. Thoracic cavity is larger.
3. Trachea is longer.
4. Apical bronchus is absent.
5. The apical lobe of right lung is not as large as compare to ox.

- **Pleura and pleural cavity:-** Pleura is a thin transparent serous membrane. This encloses the lungs and lines the interior of thoracic cavity. Pleura have 2 surfaces i.e. parietal and visceral.

Visceral:- It invest the surface of lungs. The space between these 2 layers is called pleural cavity.

THE NERVOUS SYSTEM (NEUROLOGY)

The nervous system consists of the **brain**, the **spinal cord**, and the **peripheral nerves**, which connect the various parts of the body to either the brain or spinal cord.

The basic functions of the nervous system are:-
1. Initiate and regulate movement of body parts by initiating and regulating the contraction of skeletal, cardiac, and smooth muscles.
2. Regulate secretions from glands.
3. Gather information about the external environment and about the status of the internal environment of the body, using senses (sight, hearing, touch, balance and taste) and mechanisms to detect pain, temperature, pressure, and certain chemicals, such as carbon dioxide, hydrogen, and oxygen.
4. Maintain an appropriate state of consciousness.
5. Stimulate thirst, hunger, fear, rage, and sexual behaviors appropriate for survival.

- All functions of the nervous system require the rapid transmission of information from one site within the body to another. This transmission is possible because neurons have the property of **excitability**.
- This property permits neurons to develop **actionpotentials** and rapidly propagate them along their individual cellular processes (**axons**). When an action potential reaches the end of an axon, the information encoded in the action potential is transmitted to another neuron or some other type of cell (notably, muscle cells). This transmission is accomplished at specializedjunctions known as **synapse.**

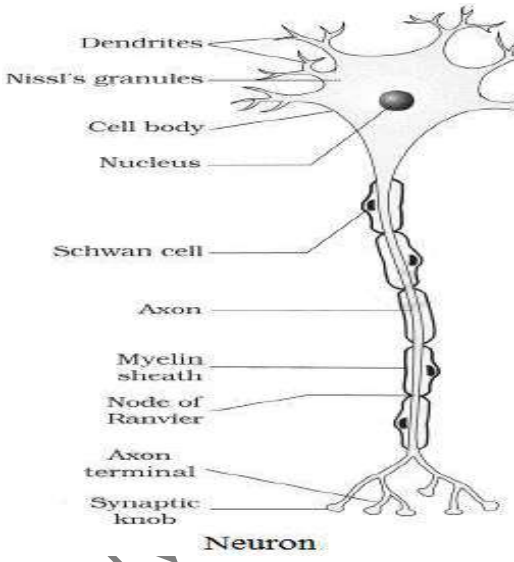
Nervous systemcan be divided into two parts:-
1. The **central nervous system (CNS)**, which includes the brain and spinal cord.
2. The **peripheral nervous system (PNS)**, which consists of cranial nerves and spinal nerves.

- A further distinction is the **autonomic nervous system(ANS)**, which coordinates activity of visceral structures (smooth muscle, cardiac muscle, andglands). The ANS has elements in both thecentral and peripheral nervous systems, and it features both sensory and motor components.
- In the PNS, **sensory (afferent) nerves** gatherinformation about the external and internal environments and relay this information to the CNS. The information is obtained by specialized organs, cells, or axon terminals that react to specific environmental energies and initiate action potentials in associated sensory axons.
- The specializedstructures that detect environmental stimuli are **sensory receptors**. The CNS receives information arriving via the PNS, integrates that information, and initiates appropriate movement of body parts, glandular secretion, or behavior in response. It may do this via voluntary or involuntary (i.e., autonomic or reflexive) processing. Communication between the CNS and the target muscles and glands in the periphery is accomplished via **motor (efferent) nerves** of the PNS.

NEURONS:-

- The individual nerve cell is called a **neuron**. Neurons possess the usual featuresof cells, but in keeping with their function ofcommunication over long distances, they alsoexhibit a number of specializations. Each neuronalcell body gives rise to one or more **nerve processes**, cytoplasmic extensions of the cell.
- The nerve processes are called **dendrites** if they transmit electrical signals toward the cell bodies; they are called **axons** if they conduct electrical signals away from the cell bodies.

- The junction between the axon of one neuron with another neuron or target cell is the **synapse**. The neuron belonging to the axon is the **presynaptic neuron**, and the one receivinginformation from the axon is the **postsynaptic neuron**.
- Nervous tissue consists of not only neuronsbut also supportive cells. Within the CNS,these supportive cells are the **neuroglia**, comprisinga variety of **glial cells**, whereas mostof the supporting tissue of the peripheralnerves is ordinary white fibrous connective. Nerve fibers may be **myelinated** or **unmyelinated**.
- In the PNS, the myelinating cell is the **Schwanncell** (**neurolemmocyte)**, whereas in the CNS,the **oligodendrocyte** fulfills this function.Groups of nerve cell bodies within the CNS are generally called **nuclei**, while groups of nerve cell bodies in the PNS are called **ganglia**. In general terms, aggregates of neuronal cell bodies form the **gray matter** of the CNS, whereas regions characterizedprimarily by tracts are **white matter**.

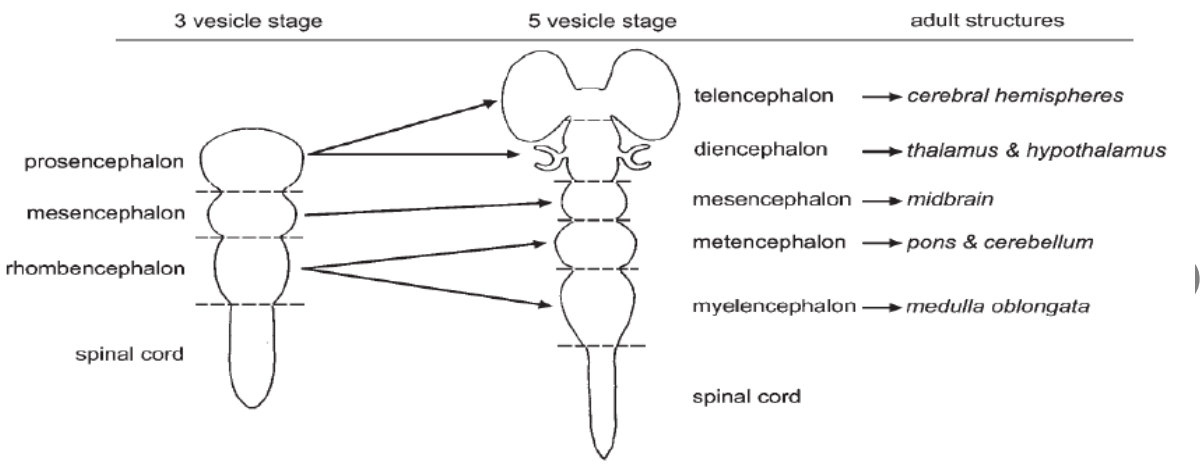


Neuron

THE BRAIN:-

Brain is the main part of CNS. It is situated into the cranial cavity of the skull.

- Development of the brain begins before the neural tube is fully closed caudally. It grows rapidly throughout embryonic and fetal life and into the neonatal period. The first gross subdivisions of the brain create the three vesicle stage. These subdivisions, which consist of three dilations of the presumptive brain, are the **prosencephalon** or forebrain,**mesencephalon** or midbrain and **rhombencephalon** or hindbrain.



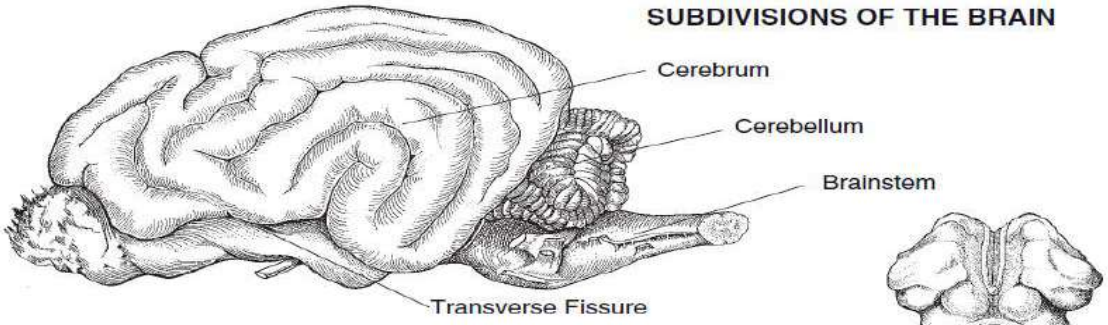
- The gross subdivisions of the adult brain include the **cerebrum, cerebellum**, and **brainstem**. The **cerebrum** develops from the embryonic **telencephalon**. The components of the brainstem include the **diencephalon**, **midbrain**, **pons**, and **medullaoblongata**.
- The **telencephalon** or **cerebrum**comprises the two **cerebral hemispheres**, including the **cerebral cortex**, the **basal nuclei**, and other subcortical nuclei, and an aggregate of functionally related structures called the **rhinencephalon**. The surface area of the cerebrum in domestic mammals is increased by numerous foldings to form convex ridges, called **gyri**, which are separated by furrows called **fissures** or **sulci**.
- A particularly prominent fissure, the **longitudinal fissure**, lies on the median plane and separates the cerebrum into its right and left hemispheres. Unlike the spinal cord, in the cerebrum most of the neuronal cell bodies i.e. gray matter is on the exterior. This layer of cerebral gray matter is called **cerebral cortex**.
- Deep to the cerebral cortex are aggregates of subcortical gray matter called the **basal nuclei**. The basal nuclei are important in initiation and maintenance of normal motor activity.

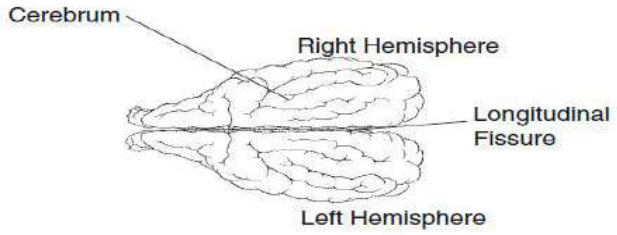
- The **diencephalon** is a derivative of the prosencephalon. The thalamus and hypothalamus are included in the diencephalon. The **thalamus** is an important relay center for nerve fibers connecting the cerebral hemispheres to the brainstem, cerebellum, and spinal cord. The **hypothalamus**, ventral to the thalamus, function in autonomic activities and behavior. Attached to the ventral part of the hypothalamus is the **hypophysis**, or **pituitary gland**, one of the most important endocrine glands.

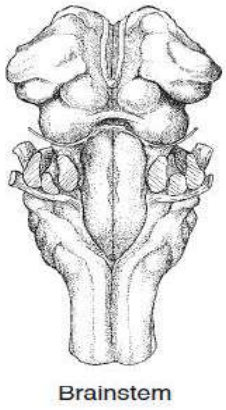
- The **mesencephalon**, or **midbrain**, lies between the diencephalon rostrally and the pons caudally. The two cerebral peduncles and four colliculi are the most prominent features of the midbrain. The two **cerebral peduncles**, also called **crura cerebri**, are large bundles of nerve fibers connecting the spinal cord and brainstem to the cerebral hemispheres.

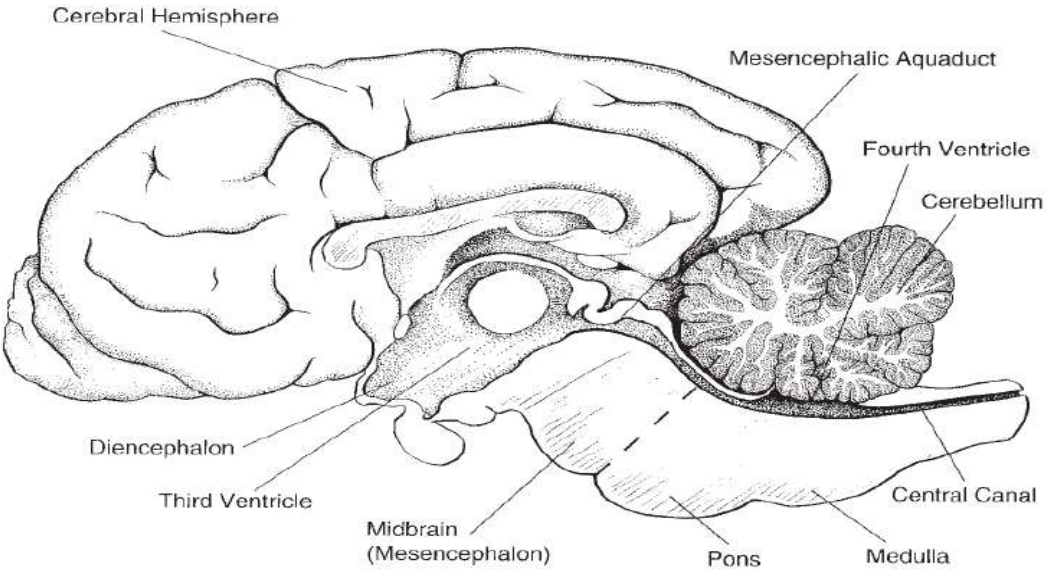
- The **metencephalon** includes the **cerebellum** dorsally and the **pons** ventrally.The cerebellum features two **lateral hemispheres.**

- The **myelencephalon** becomes the **medulla oblongata** in the adult. It is the cranial continuation of the spinal cord, from which it is distinguished at the foramen magnum. The medulla oblongata contains important autonomic centers and nuclei for cranial nerves.









MENINGES:-

- The connective tissue coverings of the brain and spinal cord are the **meninges**. They include, from deep to superficial, the **pia mater**, the **arachnoid** and the **duramater**.

  - ❖ The **pia mater**, the deepest of the meninges, is a delicate membrane that invests the brain and spinal cord, following the grooves and depressions closely. The pia mater forms a sheath around the blood vessels and follows them into the substance of the CNS.

- The **arachnoid**, middle meninx arises embryo logically from the same layer as the pia mater but separates from it during development so that a space forms between them. The space betweenthe two layers, bridged by arachnoid trabeculae,is the **subarachnoid space**. It is filled with CSF. **It is the space from which CSF is collected.**
- The **dura mater** is the tough fibrous outercovering of the CNS. Within the cranial vaultthe dura mater is intimately attached to theinside of the cranial bones and so fulfills therole of periosteum.The dura mater of the spinal meninges, however, is separated from the periosteum of the vertebral canal by a fat-filled space, the **epidural space**

SPINAL CORD:-

- The spinal cord is the caudal continuation of the medulla oblongata. Unlike that of the cerebrum, the spinal cord's gray matter is found at the center of the cord. Spinal nerves are formed by the conjoining of dorsal and ventral roots, which come together at the point where the axons exit and enter the vertebral canal.
- Sensory neuronal cell bodies are present in aggregates, called **dorsal root ganglia**. The **ventral root** of the spinal nerve consists of motor fibers that arise from the nerve cells primarily in the ventral horn of the spinal cord. The dorsal and ventral roots unite to form the spinal nerve close to the intervertebral foramen between adjacent vertebrae.

PERIPHERAL NERVOUS SYSTEM:-

The PNS includes the nerves and ganglia outside the CNS. Its purpose is to convey sensory information to the brain and spinal cord and to produce movement of muscle and secretion from glands via its motor nerves.

SPINAL NERVES:-

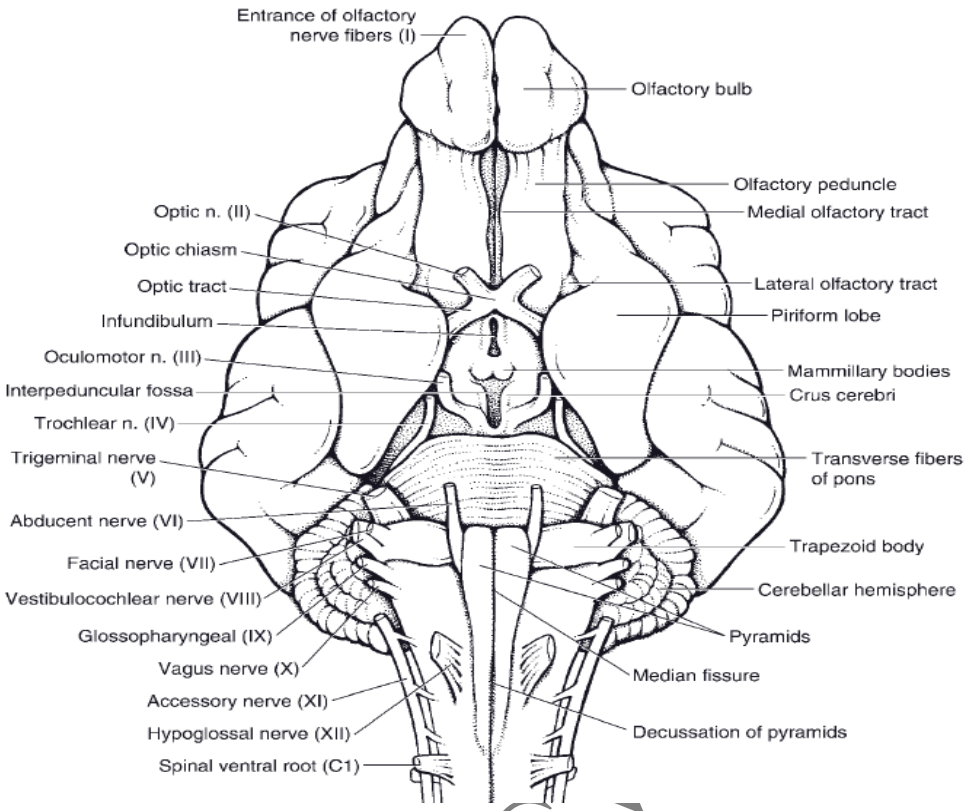
The spinal nerves tend to innervate the region of the body in the area adjacent to where they emerge from the vertebral column. The limbs, however, are supplied with sensory and motor fibers within tangled arrangements of spinal nerves known as **plexuses**.

- **Brachial Plexus.** Each thoracic limb is supplied by a **brachial plexus**, a network of nerves derived from the last three cervical and first one or two thoracic nerves

- **Lumbosacral Plexus.** The right and left **lumbosacral plexuses** supply nerves to the respective pelvic limbs. The lumbosacral plexuses are made up of the ventral branches of the last few lumbar and first two or three sacral nerves.

CRANIAL NERVES: -

Twelve pairs of **cranial nerves** arise from the brain. They are designated by Roman numerals, numbered from most rostral (I) to most caudal (XII). With the exception of cranial nerves I (olfactory) and II (optic), the cranial nerves arise from the midbrain, pons, and medulla oblongata.



CLASSIFICATION OF CRANIAL NERVES:-

No.	Name	Kind	Origin
1.	Olfactory nerve	Nerve of special sense (smell)	Fore Brain
2.	Optic nerve	Nerve of special sense (sight)	Fore Brain
3.	Oculo Motor Nerve	Motor nerve	Fore Brain
4.	Trochlear Nerve	Motor Nerve	Fore Brain
5.	Trigeminal Nerve	Mixed nerve	Mid Brain
6.	Abducent Nerve	Motor nerve	Mid Brain
7.	Facial nerve	Mixed nerve	Mid Brain
8.	Acoustic Nerve	Nerve of special sense (hearing & equilibrium)	Mid Brain
9.	Glosso pharyngeal	Mixed nerve	Hind Brain
10.	Vagus nerve	Mixed nerve	Hind Brain
11.	Spinal Accessory	Motor nerve	Hind Brain
12.	Hypoglossal nerve	Motor nerve	Hind Brain

AUTONOMIC NERVOUS SYSTEM:-

The ANS is the part of the nervous system that regulates activity in viscera and other structures not under voluntary control. ANS is functionally and anatomically divided into two parts:-

- The **sympathetic division** of the ANS prepares the organismto meet a stress by producing a combination of physiologic changes that increase available fuel molecules, blood flow to muscle, and cardiac output while simultaneously decreasing digestive processes.
- The **parasympathetic division** ofthe ANS is in many respects the opposite of the sympathetic division. Parasympathetic activity leads to digestion and storage of fuel molecules and acts to bring the organism to a state of rest

SENSORY SYSTEM (AESTHESIOLOGY)

Sensory or **afferent**, systems are the means by which the nervous system receives information about the external environment (**exteroception**), the internal environment (**interoception**), and the position and movement of the body (**proprioception**).

VISION (EYES):-

- The eye is an elaborate organ whose primary function is to collect and focus light upon the photo sensitive retina. It lies within a cone shaped cavity of the skull, the **orbit**, which houses the eyeball. Each eye ball is housed in the orbit within a soft atmosphere of surrounding fat and maintained in position by the action of extra ocular muscles.

Eyes have following parts:-

1. **Eye lids: -** Two mobile folds of haired skin protect the anterior aspect of the eyeball.
2. **Conjunctiva:-** This is a thin transparent membrane which covers the front portion of sclera and cornea.
3. **Orbit:-** This is bony cavity which accommodates the eye ball at the apex of the orbit there is an optic foramen through which optic nerve passes.
4. **Lacrimal apparatus:-** This is composed of lacrimal glands which produce tears.
5. **Ocular muscles:-** There are 7 ocular muscles which are responsible for the movement and holding of eye ball. These muscles are controlled by occulomotor cranial nerve.
6. **Eye ball: -** It is spherical in shape with a transverse diameter of 3-5 cm. the axial diameter is slightly longer due to forward bulging of cornea. This is composed of three coats:-
   i. Fibrous coat:- This is outer hard protective coat.
   ii. Vascular coat:- It has choroid, ciliary body and iris.
   iii. Nervous coat:- This is the inner most layer of the eye and has delicate membrane called retina. This retina is connected with optic nerve.
7. **Vitreous humour and Aqueous humour:-** These are two liquid and jelly like substance which fills the eye ball.
8. **Iris:-** It regulates the entry of light in eyes through pupil.

THE EAR

This is an organ associated with hearing and equilibrium. It is also called vestibulecohlear organ. It consists of three parts:-

1. **External ear:-** it is divided into two parts:-
   i. Auricle or Pinna:- Pinnae of animal, unlike to human beings. Can be moved in desired direction by muscles. These are elongated funnel shape structures made of elastic cartilage.
   ii. External acoustic meatus:- It is a canal leads medially towards the middle ear. It accommodates some sebaceous and sweat gland which produces cerumen, a wax type material. In between external and middle ear there lies tympanic membrane. This is oval type structure which seperates external and internal ear.
2. **Middle ear:-** It is an irregular biconcave small space between tympanic membrane and internal ear. This space is called tympanic cavity which contains three ear ossicles (small ear bones). These bones arranged in such a way in a chain which connects tympanic membrane to internal ear.

3. **Internal ear:-** This is the main portion of the organ of hearing. It is situated within temporal bone. It consists of a osseous labyrinth which has three parts:-
   i. Vestibule:- It is bony cavity placed middle to the tympanic cavity. It is continues with cochlea and semilunar canal.
   ii. Cochlea:- It is a bony spiral canal just like shell of snail.
   iii. Semilunar canal:- These are three tubes placed at right angle to each other.