NAHEP

Institutional Development Plan (IDP),SKUAST Jammu

Strengthening Institutional Capacities for Delivering Competent Skilled Professionals

LECTURES DELIVERED IN REMEDIAL CLASSES

OF

FACULTY OF VETERINARY SCIENCES & ANIMAL HUSBANDRY

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VETERINARY ANATOMY

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CHAPTER-I

INTRODUCTION TO VETERINARY ANATOMY: SYSTEMIC AND REGIONAL

Anatomy is a branch of biological science, which deals with the study of forms and structures of the organisms. The term anatomy is of Greek origin and is formed of - Ana (up or apart) and tome (cutting). It signifies cutting apart or dissociating parts of animal body for study.

Veterinary Anatomy: Veterinary anatomy deals with the forms and structures of principal domestic animals (ox, horse, dog, fowl etc).

Special Anatomy: It deals with the study of forms and structures of a particular species of animal. e.g. bovine anatomy (anatomy of ox and buffalo), hippotomy (anatomy of horses), canine anatomy (anatomy of carnivores dog, cat), anthropotomy (anatomy of human beings) etc.

Comparative Anatomy: It deals with the description and comparison of forms and structures of different species of animals and thus forms the basis for their classification.

Branches of Anatomy:

Gross Anatomy: It is the branch of anatomy, which deals with the study of forms and structures of the organisms with naked eyes.

Histology: It is the branch of anatomy, which deals with the study of forms and structures of the organisms with the help of microscope, and hence, it is also called as microscopic anatomy.

Embryology: It is the branch of anatomy, which deals with the study of successive changes the organisms undergo during their development from the time of fertilization (zygote-formation) to the fully developed young one.

Radiological Anatomy: It is the branch of anatomy, which deals with the study of forms and structures of the organisms with the help irridations like X-rays, Ultrasound etc.

Methods of Study of Gross Anatomy

1. **Systemic Anatomy:** The systematic anatomy deals with the study of various systems of the animal body one after another.
2. **Regional Anatomy:** Regional (or topographical) anatomy is directly concerned with the form and relationships of all the organs present in particular parts or regions of the body (e.g. thorax region; includes study of muscles, bones, blood vessels, nerves and organs – heart, lungs, trachea, oesophagus of this region).

For the beginner, it is easier to understand systematic anatomy than regional anatomy. However, regional anatomy forms the foundations for clinical practice.

Applied Anatomy: The applied anatomy deals with the application of anatomical facts and knowledge in other practical subjects namely surgery, medicine and gynaecology (clinical subjects); diagnostic technique, pathology, livestock production and management, physiology, etc.

Branches of Systematic Anatomy:

Osteology: Study of bones **Myology**: Study of muscles **Arthrology**: Study of joints

Splanchnology: Study of visceral organs

Angiology: Study of cardio-vascular and lymphatic systems

Neurology: Study of nervous system

Aesthesiology: Study of sense organs

Language of Anatomy:

Topographic Terms: Those terms which are used to describe various organs or parts of body with respect to their location, directions, relations etc. It is assumed that the quadruped animal is in ordinary standing position.

Planes of body

Median plane: It is the plane of the body, which passes through the mid-longitudinal axis of the body (head, neck, trunk, tail) and divides the body into equal parts (left and right parts). It is also called as mid-sagittal plane.

Sagittal plane: The plane of the body that is parallel to the median plane is known as sagittal plane. It is also called as paramedian plane.

Transverse plane: The plane of the body that is perpendicular to the median plane is known as transverse plane. Transverse plane divides body into cranial (head-end) and caudal (tail-end) parts.

Dorsal or Horizontal plane: A plane at right angles to the median and transverse planes. It divides the body into dorsal and ventral parts that are not necessarily equal

Directional Terms:

Medial: The structure/ surface lie structures lie toward the median plane.

Lateral: The structure lie away from the median plane.

Cranial: The structure/ surface which is nearer to the head (cranium) of the animal body.

Caudal: The structure/ surface which is nearer to the tail (caudae) of the animal body.

Note: Within the head, structures toward the muzzle (rostrum) are said to be

Rostral: caudal remains appropriate.

Dorsal: Pertaining to the back area of the quadruped or denoting a position more toward the back (upward) than some other reference point.

Ventral: Pertaining to the belly or underside of a quadruped or denoting a position more toward the belly (downward) than some other reference point (body part).

Proximal (nearer to) and **distal** (farther away) are used to indicate relative distance from the long axis of body)

Modification of directional terms with respect to limbs:

Dorsal: The term dorsal denotes the cranial aspect in manus (from carpal joint in forelimb to the toe) and pes (from tarsal joint in hind limbs to the toe) regions is called as dorsal surface.

Palmer: The term palmer denotes the caudal aspect in manus (from carpal joint in forelimb to the toe) is known as palmer surface.

Planter: The term planter denotes the caudal aspect in manus (from carpal joint in forelimb to the toe) and pes (from tarsal joint in hind limbs to the toe) regions is called as planter surface.

Axial structures lie close to the axis of a central digit, close to the axis of the limb if this passes between two digits; Abaxial positions are at a distance from the reference axis.

Systemic Anatomy:

- Systemic anatomy looks at a group of structures that work together to perform a unique body function
- It focuses on whole organ systems, such as the respiratory, digestive, or nervous system
- The systemic approach of study allows you to focus on one type of material at a time, eg when learning about the skeletal system (osteology), you first understand the bone structure and then move on to study all the bones of an animal body, then we move on to another separate system like muscular system and so on
- This keeps the focus on one type of subject matter during the learning process
- On the downside, systemic approach makes it harder to understand the connections and relationships between multiple organ systems
    - One of the major functions of the skeletal system is to provide a rigid base for a lever system that produces movement, But the force for this comes from the muscular system, so one system is worthless without the other
    - The systemic approach makes students revisit a previously learned system every time a new system is studied

- When learning about the muscular system they must recall what they've learned about the skeletal system to know the muscular attachments
- When studying about the nervous system, they must recall what they've learned about the muscular system so that they know which muscles are innervated by which nerves

Regional Anatomy:

- Regional anatomy is directly concerned with the form and relationships of all the organs present in particular parts or regions of the body (e.g. thorax region; includes study of muscles, bones, blood vessels, nerves and organs – heart, lungs, trachea, oesophagus of this region)
- Regional anatomy forms the foundations for clinical practice and focus on the diagnosis and treatment of disease or injury in the particular region that is being studied
- In modern-day studies, the regional approach is used more commonly because it is easier to apply in a clinical setting than systemic anatomy

Advantages of Regional Anatomy:

- Students can focus on one region of the body at a time and thoroughly learn the muscles, nerves, vessels, etc. of the specific region
- Regional anatomy provides a better understanding of how a region functions as a unit by allowing us to explore the relationships of the various systems found there
- To compare it with the systemic approach, you are learning the bones of the region while also learning where the muscles of the region connect to these bones, at the same time, you are learning what nerves innervate the muscles of the region and what blood vessels supply the region
- The one challenge that comes with the regional approach is that it requires you to have some understanding of at least four different anatomical systems at the same time

Different Regions of Body:

- Head
- Neck
- Thorax
- Abdomen
- Pelvis
- Forelimb
- Hindlimb

Trunk:

- Part of the carcass that remains after the removal of head and neck, tail, forelimbs and hindlimbs; in common speech, it is the body of the animal
- Consists of three segments—thorax, abdomen, and pelvis
- Each is bounded by the body wall, and each contains a cavity, or a potential cavity, since, in life, the space is more or less obliterated by the close apposition of the walls and contents

Regional Vs Systemic Anatomy:

Anatomy:

The structure present in this region form part many different systems like

- Os coxae, vertebrae – Osteology
- Joints – arthrology
- Muscles – myology
- Lumbo-sacral plexus – neurology
- Organs present: Part of digestive system, Urinary system, reproductive system

Regional Anatomy:

- When studying the anatomy of the pelvic region, you would simultaneously learn about the bones, muscles, nerves, blood vessels, lymphatic tissues as well as the organs present in the pelvic region
- That is a lot to digest, so good learning materials that help you orient yourself in the wealth of information are essential
- The pelvic region consists of a sacrum, os coxae (3 bones), muscles like biceps femoris, gluteus medius, g profundus and many more
- In the same manner, you could then explore the innervation of these muscles, along with the veins and arteries that allow blood circulation in this region

VETERINARY EMBRYOLOGY: INTRODUCTION

Embryology: It is the study of successive changes that an organism undergo during their development from single fertilized egg (zygote) to a fully developed individual capable of independent life like it parents

DEVELOPMENTAL ANATOMY: Branch of anatomy which deals with study of Formative history (structural changes) of an individual from fertilization to maturity

1. Can be divided into: Prenatal and postnatal development

Embryo: Early stage of development before it has reached recognizable form (various types of tissues are developing)

Foetus: Unborn offspring in the uterus of animal after embryonic stage i.e. it has acquired its basic form(structural resemblance to adult)

Prenatal Development/ Embryology: It deals with prenatal stages of development from fertilization of ovum to birth (hatch in bird) of new individual

Prenatal Development can be divided:

1. **Period of ovum**: From fertilization to gastra
2. **Period of Embryo**:
    - Differentiation of body parts completed
    - Embryo resemble to parent
    - Placenta formed
3. **Period of fetus**: Growth and development of body part

Ontogeny: It is the development of individual from zygote formation to birth, maturity

Phylogeny: It is the development of a race (phylum)

- It is a evolutionary historical development of a species
  e.g. Fish → amphibia → reptiles birds → Mammals

GENERAL FEATURES OF DEVELOPMENT

A multicellular animal begins its development as a fertilized egg

Embryogenesis, the formation of body structures & organs (**organogenesis**), requires cell division (**proliferation**) and cell **differentiation** (specialization) to produce a variety of cell types and extracellular products

Cell proliferation: by mitosis **Growth**: by

synthesis of protoplasm

Differentiation : which includes

Morphogenesis: The modeling of the body and its organ into form/shape

Histogenesis: The specialization of embryonic cells into tissue

Organogenesis: Development of an organ by organization and arrangement of various fundamental tissues

Integration: by endocrine and nervous system

Scope of Embryology

Embryology helps:

- To provide a comprehensive and rational explanation of the many facts of anatomy which are otherwise meaningless or anomalous
- To interpretate rudimentary structures, variations, anomalies and monstorosities
- It throws light on how a single cell zygote gives rise to various systems in a creature

- It helps in better understanding of teratology
- Gives information about 4 dimensions of structures during development

Branches of Embryology:

Descriptive Embryology: Deals with morphological description of different embryonic stages in the ontogenic development of individuals of different species

Comparative Embryology: Deals comparative study of structural features of embryo in different animal groups

Experimental embryology: It involves all those studies that attempt to understand the various fundamental mechanism in the development of different animals, like fertilisation, embryonic induction, determination, differentiation etc

Chemical Embryology: Deals with all those studies which employ various biochemical, biophysical and physiological techniques for understanding embryological events at molecular level

Teratology: It is the branch of embryology concerned with the study of malformations or birth defects.

CHAPTER-II

SPLANCHNOLOGY

Digestive System:

1. Mouth (Os/oris): designated not only the cavity and its wall but also the accessory structure that projects (teeth, tongue) and drain (salivary glands) into it.

- Helps in prehension, mastication, insalivation.
- Elongated cavity at the beginning of alimentary canal divided by teeth and margin of gum into outer vestibular part and central mouth cavity proper.
- Roof – Hard palate, Floor – body of mandible and mylohyoideus muscle, Lateral walls – cheeks.
    - Vestibular part – bounded externally by lips and cheeks and internally by gums and teeth.
    - Mouth cavity proper – bounded in front and laterally by alveolar arches, gums and teeth and continuous with pharynx behind by oropharyngeal opening.
    - Both the cavity communicate by inter dental space and the space behind last molar teeth.

2. Lips: Upper & Lower

Thick rigid musculo membranous structure, situated at the orifice of the mouth.

- Covered by skin externally and lined by mucous membrane (pigmented epithelium) internally.
- Fibres of orbicularis oris muscle found between these two layers.
- Between mm and muscles of lip there are a no. of labial glands, the duct of which open on the buccal mucosa.
- Lower lip: - external surface present a prominence known as Chin
    - Free border present narrow area of skin devoid of hairs.
    - Mm of free edge present short and blunt horny papillae which become larger, longer and pointed towards angle.
- Upper lip: - middle part of external face between nostril is keratinous and smooth called muzzle or planum nasolabiale which is smooth, black and moist due to the secrection of nasolabial duct.

3. Cheeks

- Forms the lateral wall of the mouth and is continuous with lip infront. Composed externally of skin and internally mm, between these two layers are muscle (**buccinator**), glands, vessels, nerves etc.
- Skin is continuous with other part of face without any modification.
- Muscular layer – buccinator, levator, zygomaticus, depressor muscle of face.
- Buccal glands – arranged in 3 rows (superior, middle & inferior) within the musculature.
- Mm of cheek present a no. of thick long, pointed conical horny papillae directed backwardly. The largest and longest are found around the angle of mouth (commissure – where two lips meet).
- Mm present PAPILLA SALIVALIS at the level of/opposite to 5^{th} upper cheek teeth/ 2^{nd} molar where parotid duct open in mouth.
- Cheeks most capacious in herbivores and principal support is buccinator which has the important function of returning to the central cavity any food that has escaped into the vestibule.
- Buccal mucosa must be sufficiently loose to allow the occasional maximal opening of the mouth while avoiding large folds that would at other time invite injury from the teeth it tends. Therefore, to be tightly enchored here and there.

- Ruminants food dry & rough, additional protection is required, since a very thick and smooth cornified epithelium would limit flexibility, protection is provided by the papillae.

4. Gum/ Gingiva: composed of thick layer of fibrous tissue closely connected to the periosteum of the alveolar process and surround the neck of the teeth. The epithelium of the gum is reflected towards the alveoli and are attached with root of teeth.

Horse:

- Mouth cavity longer, narrower and less capacious.
- Angle at the level of first cheek teeth.
- Lips thinner and more mobile.
- Upper lip on its external surface doesnot present muzzle but a shallow median furrow the Philtrum.
- Free border of lip dense present short stiff hair, frenum labii superioris and inferioris more developed.
- Cheeks - less capacious, mm do not present any horny conical papillae, buccal gland in two rows – superior and inferior.
- Papilla salivalis opposite 3rd upper cheek teeth.

Dog:

- Rima oris more extensive.
- Lips thin, mobile and upper lip covers the lower lip.
- Angle at the level of 4th cheek teeth.
- Lateral part of free border of lower lip denticulated.
- Cheek loose enclosing large vestibule, mm smooth.
- Papilla salivalis opposite to 3rd upper cheek teeth.

Pig: upper lip modified to form snout contain Os rostrale (a visceral bone).

- Mucous membrane of cheek smooth, papilla salivalis at the level of 4th/ 5th upper cheek teeth.

Fowl: Vestibule absent, lips and cheeks replaced by beak.

- Soft palate absent

5. Palate

Divided into anterior hard palate and posterior soft palate.

Hard palate:

- Forms the roof of the mouth and is composed of dense connective tissue.
- It extends from the dental pad to the level of the 2nd molar tooth and continues behind as soft palate.
- Covered by mm which is pigmented and kept attached to periosteum of bony palate (formed by PALATINE, MAXILLA AND PREMAXILLA).
- Centrally there is a linear groove/ raphe which divides the surface into two equal halves and each half posses 15-19 transverse ridges the free margin of which are serrated. The ridges are straight anteriorly and few posterior ridges are backwardly concave.
- The DENTAL PAD or dental plate is a thick layer of dense, fibrous connective tissue covering the body of the premaxilla one on either side and covered by cornified epithelium. The dental pad occupy the position of upper incisor as it is absent in cattle.

- *PAPILLA INCISIVE* is an irregularly triangular structure placed in between the dental pad and the first transverse ridge on the median line. The oral opening of the naso-palatine canal (*Incisive duct*) open in the deep groove on either side of this papilla.

Soft palate:

- Posterior continuation of hard palate.
- It is the musculo-membranous structure forms the partition between mouth and pharynx.
- Suspend from the posterior border of the hard palate in a sloping manner downward and backwards towards pharynx.
- Present two surface and four borders.
- Pharyngeal surface convex the mucous membrane of this surface is continuous with the mm of the posterior nares.
- Oral surface concave and forms the posterior boundary of the mouth, it present numerous small openings of the ducts of the palatine glands. This surface is covered with oral mucosa which is continuous with mucosa of hard palate.
- A fold of mucous membrane (oral) detach laterally from each side of soft palate to the root of tongue called *ANTERIOR PILLAR/ PALATO GLOSSAL ARCH*. Another fold of mucosa detach laterally from each side of soft palate to lower lateral border of pharynx is POSTERIOR PILLAR/ PALATO PHARYNGEAL ARCH.
- The space between the anterior and posterior pillars called TONSILLAR SINUS which are occupied by bean shaped PALATINE *TONSIL* which projects outwards.
- The *superior* or *attached* border is continuous with the hard palate, while the *inferior* or *free border* is in contact with the epiglottis. It's lateral borders are adhered to the walls of the pharynx and lateral borders of the base of the tongue.

Horse:

- Hard palate- longer and narrower, whole surface is ridged but free edges not serrated.
- Dental pad absent, papilla incisive behind central incisor.
- Soft palate- longer so hangs down in front of epiglottis with its free margin in contact epiglottis and embrace it. So, oral breathing not possible and in case of vomiting the ejected matter escape through nose.
- Posterior pillar extensive and unite with each other over the beginning of oesophagus.
- Auditus pharyngis- smaller, less dilatable, kept closed by soft palate except during mastication.

Dog:

- Papilla incisive behind central incisor.
- Each half of hard palate present 8-9 transverse ridges.
- Soft palate shorter.
- Posterior pillar are double, superior one pass through roof of pharynx while inferior one reach sides of epiglottis.
- Auditus pharynges wider.
- Tonsillar sinus and tonsil better marked.

Fowl:

- hard palate narrow, soft palate absent

6. Floor of Mouth

Cattle:

- Mostly attached to the ventral surface of the tongue, small anterior part lies over the body of mandible is free and covered by oral mucosa.
- On either side behind the level of 3rd cheek teeth there is a wide hard papillae known as SUBLINGUAL CARUNCLE the free margin of which is serrated, mandibular and inferior sublingual salivary gland open at this papillae.
- Behind sublingual caruncle there is a row of conical pointed horny papillae where duct of superior sublingual salivary glands open.
- There is wide fold of mucous membrane behind caruncula sublingualis which connects the ventral surface of tongue with floor of mouth is known as FRENUM LINGUAE.

Horse:

- Caruncula sublingualis opposite to canine teeth on each side where only mandibular salivary gland opens.
- Linear conical horny papillae absent. Sublingual fold extends from either side of frenum linguae backward to the level of 4th lower cheek teeth/ 1st molar, a no. of small papillae found on the surface of the fold for opening of short small sublingual ducts.

Dog:

- Coruncula sublingualis opposite to 1st lower cheek teeth.
- Mandibular duct and duct from posterior division of sublingual gland open through this.

7. Isthmus faucium: aapparatus through which mouth communicates with pharynx

- Bounded above by soft palate, below by dorsum of tongue and laterally by anterior pillar of soft palate

8. Teeth

Hard dense white or yellowish white structures implanted in the alveoli and project into the muth.

Parts: The part of the teeth covered with enamel and seen above the gum is CROWN OR BODY. The implanted narrow part in the gum is ROOT OR FANG. The constricted line/junction between the root and crown is the NECK.

Surfaces: A teeth present total five surfaces

1. Surfaces towards adjacent teeth in the same dental arch are the CONTACT SURFACES (two for each tooth).
2. Surface which comes in contact with the tooth of opposite jaw/ that faces its antagonist is TABLE/ GRINDING/ OCCLUSAL SURFACE.
3. Surface towards lips/ cheeks is Vestibular/ Labial/ Buccal surface.
4. Surface towards tongue is Lingual surface.

Classification of Teeth:

1. **According to period of function**
    a. Temporary/ Milk/ Deciduous: Present in early life.
    b. Permanent: This replaces temporary one.
2. **According to period of growth**

a. **Brachydont**: Finite growth period and limited period of eruption i.e., completely formed at the time of eruption e.g. all teeth of Dog, Cat, Pig (except Pig's canine), Ruminant Incisors etc. These teeth are **short crowned** and have distinct root, body (crown) and neck.
b. **Hypsodont**: continuously erupt/ emerge through gingiva. These teeth consist only of root and body/crown, no neck.
    i. Some have finite growth period e.g., all teeth of horse, cheek teeth of ruminants.
    ii. Some continuously grow e.g., Boar (canine) and elephant tusk.

Dental formula: It is the way of expressing the number and position of the teeth in an animal's mouth.

- Complete dental formula 2 (I 3/3, C 1/1, Pm 4/4, M 3/3) = 22/22 = 44
- Of the domestic animals only pig have complete representation of all teeth. If any premolar is absent it is the first or rostral one absent and if any molar tooth is absent it is the caudal or posterior most molar.

Cattle:

2 x (0/4 0/0 3/3/ 3/3) = 12/20 = 32

- Upper incisors are absent and its position is occupied by DENTAL PADS. There is 8 lower incisors arranged in a curved line on the anterior part of the floor of the mouth which are loose in alveolar socket so permit some movement.
- Crown is short and wider and root is long and narrower and these two are separated by a distinct constriction the neck.
- Lingual surface – concave and labial one is convex. All the incisors are temporary and replaced by permanent teeth.
- Incisors are designated as central the first pair, one next to each central is intermediate, next one lateral and the outer most is the corner incisor according to their position.
- Canine teeth are absent. Premolar and molar together constitute CHEEK TEETH, which are 24 in number, 6 (Anterior 3 Pm, Posterior 3 M) on each side of each jaw. Crown of the cheek teeth is four sided with multiple root and distinct neck. First 3 cheek teeth have 3 root and the next 3 have 4 roots.

Horse:

2 x (3/3 1/1 3/3/ 3/3) = 20/20 = 40

- Incisor - Table of each Incisor present a mark/ infundibulum.
    - Roots firmly attached to the alveolus.
    - There is a longitudinal groove on the corner/ 3rd upper incisor on its labial surface – the Galvayne's groove.
- Vestigeal and inconstant 1st upper premolar if present is known as WOLF TOOTH
- Table of upper cheek teeth present double infundibulum.
- All teeth are hypsodont.

Dog:

2 x (3/3 1/1 4/4/ 2/3) = 20/22 = 42

- A horizontal ridge on the crown close to root is CINGULUM.
- Upper incisor more developed than the lower one.
- Canine large conical and curved.

- Upper 4th and lower 5th cheek teeth larger than the rest and is know as CARNASIAL/ SECTORIAL TEETH.

Pig:

- 2 (I 3/3, C 1/1, Pm 4/4, M 3/3) = 22/22 = 44
- Curved canine teeth (upper) is TUSK in boar, in saw it is smaller and donot project from mouth except tip.
- Table of molars more irregular by numerous tubercle ideal for crushing.
- Deciduous upper and lower third incisors and canine known as NEEDLE TEETH.

Fowl: teeth absent.

9. Tongue

Cattle:

- Highly movable protractile musculo-membranous structure situated on the floor of mouth between rami of mandible.
- Chief organ of prehension, mastication and deglutination.
- Three parts: an attached root/ base, body and free apex/ tip.
- Mobility achieved by the restricting the attachment to the more caudal part and leaving the apex free to roam within and beyond mouth.
- Shape corresponds to the shape of the oral cavity.

Root/ base:

- Most posterior or thickest part only dorsum is free.
- Attached to:
    - Hyoid bone and mandible by – hyoglossus and genioglossus.
    - Soft palate – anterior pillar/ palato glossal arch.
    - Epiglottis – glosso-epiglottic fold.

Body: middle attached part.

- Ventrally related to genihyoideus and myolohyoideus muscles.
- Present three surface two lateral and one dorsal
- Lateral surfaces flat and wide posteriorly but become narrow and rounded anteriorly.
- Dorsal surface known as dorsum linguae which is free.
- Posterior part of dorsal surface present an epithelial raised prominence (torus linguae) behind a transverse groove the lingual fossa.

Apex/ tip: thin pointed and narrow free part of the tongue.

- Highly protractile.
- Posterior part is wide and continuous with body.

Structure of Tongue:

- Composed of mm, glands, muscles, vessels and nerves. Mm present on dorsal dorsum linguae, sides of body and all parts of apex.

- Mm pigmented very thick and closely adherent to underlying structure on the dorsum, thin and loosely attached on the sides and under the surface of tip.

Lingual Papillae:

  - Mechanical – no taste bud present, keratinized eg. filliform, lenticular and conical
  - Gustatory – taste bud present eg. 1. fungiform, 2. Vallate and 3. foliate (horse).
- **Filliform papillae:** thin thread like projection on rostral 2/3rd of dorsum linguae and margin of tip
  - Backwardly directed and most numerous type.
- **Lenticular papillae –** large, lense shaped and present on torus linguae.
- **Conical papillae** – large, circular in shape, directed anteriorly or anterolaterally and present on the anterior aspect of torus linguae
- **Fungiform papillae –** larger in size, free end round and convex.
  - Scattered among filliform papillae and numerous on lateral aspect of tongue.
  - Due to its resembelance to tiny mushroom known as fungiform.
  - Taste buds located on the dorsal surface.
- **Vallate or Circum vallate papillae –** larger circular surrounded by a deep groove.
  - Arranged in two rows in a V manner at rostral border of root, **10-16** on each side.
  - Each papillae is encircled by a wall or depression called moat that is why called circum vallate.
  - Taste buds located on the lateral surfaces and open into the moat.

Horse:

- Root and body narrow, apex spatula shaped.
- Torus linguae absent.
- Folliate papillae – leaf like,
  - Parallel folds of lingual mucosa found in row at the lateral margin of tongue just rostral to palatoglossal arch, the folds are separated by furrow or gustatory sulci.
- Vallate papillae 2 in no. and placed one on either side of median line.

Dog:

- Very mobile, torus linguae absent.
- Dorsum present a median groove.
- Vallate papillae 3 on one side and 4 on other side.
- Ventral surface of tip present a thick fibromuscular cord like structure known as LYSSA.

Pig:

- 2 frenum linguae, apex round, torus linguae absent.
- Filliform papillae well developed, foliate papillae present.

Fowl:

- Tongue narrow and rigid
- Base attached to well developed hyoid bone.
- There is presence of a median groove on dorsal surface rostrally.
- Apex pointed, root crossed by a row of pointed horny papillae directed caudally.

10. Pharynx

- Musculo membranous structure common to both digestive and respiratory tract.

- It is in the form of a conical/ funnel shaped tube suspended obliquely downward and backward from the base of the cranium and is placed behind the soft palate.
- Attached by muscles to palatine, pterygoid and hyoid bonesuperiorly and to thyroid and cricoid cartilage of larynx inferiolaterally.

Relations:

- Dorsally – to the base of cranium and supra pharyngeal lymph node.
- Ventrally – larynx and root of tongue.
- Laterally – internal pterygoid muscle, great cornu of hyoid bone, mandibular salivary gland, external carotid artery, superior laryngeal, glossopharyngeal and hypoglossal nerves, pharyngeal lymph glands.

Parts of pharynx:

- **Nasopharynx**: Dorsal part/ compartment of the pharynx above the soft palate
- **Oropharynx**: The part between soft palate and root of tongue
- **Laryngopharynx**: The part dorsal and lateral to larynx

Openings: the pharynx communicates with the other structure by 7 openings.

- 2 opening superiolaterally with the nasal chamber is the posterior nares.
- 1 opening cranioventrally with the oral cavity is the by aditus pharynges.
- 1 opening ventrally with the laryngeal cavity by aditus larynges.
- 1 opening posteriorly behind the laryngeal opening with the oesophagus by aditus oesophagii.
- 2 openings caudolaterally with the Eustachian tube.

Horse:

- Longer and narrower.
- Posterior nares longer.
- Caudo-dorsal part of nasopharynx is the pharyngeal recess.
- Aditus oesophagii is smaller.
- The superior wall related to guttural pouch.

Guttural pouch:

- These are a pair of large mucous sac which is downward diverticulum of auditory tube and are situated on either side of the mandible above the pharynx.
- It lies between the base of the skull and atlas dorsally, pharynx and commencement of oesophagus ventrally, covered by pterygoid muscle laterally and medially by parotid and mandibular salivary glands.
- Capacity about 300 – 500 ml.

Viborg's triangle:

- Triangular area formed by caudal border of mandible, tendon of sternocephalicus and the linguofacial vein.
- This triangle used to approach guttural pouch for surgery

Dog:

- Auditory and oesophageal opening small.
- Pharynx is long and reaches the 2 cervical vertebra.

11. Salivary glands

There are three pairs of salivary glands i.e., parotid, mandibular (sub maxillary) and sublingual salivary glands, they pour their secretion the saliva into the mouth. Parotid glands are serous and others are mixed (both serous and mucous).

Parotid Glands:

- It is roughly quadrilateral, elongated gland located on the side of face, immediately below the base of the ear in between the posterior border of ramus of mandible and the wing of atlas.
- Extending from the zygomatic arch to the angle of mandible.
- Purely serous in nature.

Two surfaces and three borders

- Dorsal border - thick and embrace the base of the ear.
- Anterior border – irregulary convex and closely attached to the masseter.
- Posterior border – slightly convex in upper part and nearly straight in rest.
- Lateral surface – covered by parotid fascia, parotido-auricularis and facial cutaneous muscles. Upper part of this surface at the level of the base of the ear is related to the zygomatico-auricularis muscle.
- Medial surface – related to great cornu of hyoid bone, masseter muscle, parotid lymph gland, posterior border of ventral ramus of mandible, mandibular salivary gland, diagastricus muscle and superficial temporal and transfacial vessels.

It is lobulated gland; each lobule is composed of alveoli minute alveolar ducts emerging from the alveoli joins to form a lobular duct. Several lobular ducts unite to form Parotid or Stenson's duct.

The duct leaves the gland at the inferior part of its medial surface, passes forward on the medial side of the ventral border of the mandible between masseter muscle infront and external maxillary vein behind. The duct runs upward and forward between the anterior border of the masseter and facial vein, pierces the buccinator and opens on the Papilla salivalis in the buccal cavity at the level of 5th upper cheek teeth.

Mandibular or Submaxillary salivary glands:

- Largest salivary gland.
- It is pale yellow, lobulated, irregularly oval in shape and lies on the side of the root of the tongue
- Extend from fossa atlantis to the intermandibular space infront of the body of the hyoid bone.
- Posterior exterimity wide and thin, lies loosely attached to the fossa atlantis.
- Dorsal border – concave and middle part of which gives origing to Mandibular or Wharton's duct.
- Ventral border – convex and partly related to the external maxillary vein.
- Lateral surface – covered by parotid gland, diagastricus muscle, and medial pterygoid muscle.
- Medial surface – related to the atlantal lymph node, common carotid artery, larynx, last three cranial nerve and 1st cervical nerve.

Mandibular duct formed by union of alveolar and lobular duct. After its emergence at the middle dorsal border runs forward crossing the daigastricus between the myelohyoideus and hyoglossus then along the deep face of genioglossus. The duct then crosses the hypoglossal nerve and runs forward medial to the sublingual gland under the mucous membrane of the floor of mouth and open on the sublingual caruncle/ caruncula subligualis.

Sublingual glands:

- This gland is placed under the mucous membrane of the floor of the mouth between the horizontal ramus of mandible and the tongue.
- Has two parts – superior and inferior
    - Superior (polystomatic) –
        - Very extensive extending from the palatoglossal arch to the mandibular symphysis.
        - Very thin and yellowish gland discharges its secretion by numerous short duct which opens on the conical, pointed horny papillae linearly arranged on each side of the floor of the mouth.
        - Lateral surface is related to the myelohyoideus and medial to the styloglossus and genioglossus.
    - Inferior (monostomatic) – part is shorter and thicker and extends from the mandibular symphysis to the level of 3rd lower cheek teeth and placed below the superior one. The sublingual duct either join wharton's duct or open separately at the sublingual caruncle.

Salivary glands of Horse:

- Has three pair of salivary glands.
- Parotid – largest salivary glands, medial surface related to guttural pouch in additions.
- Parotid duct opens at papilla salivalis at the level of 3rd upper cheek teeth.
- Mandibular gland much samller and narrower.
- Sublingual caruncle opposite to canine teeth.
- Sublingual gland not divided into superior and inferior part i.e., inferior (monostomatic) part absent.
- Duct of sublingual glands open on the papillae situated on the sublingual fold.

Salivary glands of Dog:

- Has 4 pair of salivary glands.
- Parotid gland is smaller, triangular and dorsal border is notched.
- Stenson's duct leaves at the lower portion of the anterior border of the parotid gland.
- Papilla salivalis opposite to 3rd upper cheek teeth.
- Mandibular gland is larger that parotid gland and having rounded shape. The gland is superficially placed except at the proximal part which is covered by parotid gland.
- Sublingual caruncle opposite to 1st lower cheek teeth infront of the frenum linguae.
- Sublingual gland similar to ox.

Zygomatic/ Orbital salivary glands:

- This is the 4th pair of salivary glands.
- Situated under the zygomatic arch, and the masseter and temporalis muscles.
- Related medially to superior maxillary nerve, internal maxillary artery and the periorbita.
- Its 3-4 duct open into the mouth either singly or unitedly opposite to last upper cheek teeth.

Pig:

- Parotid gland is large and distinctly triangular

- The Stenson's duct arises from the deep face and opens on the cheek opposite to upper fourth or fifth cheek tooth.
- Mandibular gland is small reddish in colour and oval in outline, being covered by the parotid gland. It's superficial surface is marked by rounded prominences. The Whartson's duct opens near the frenum linguae, but there is no papilla.
- The caudal part of the sublingual gland is reddish yellow in colour. Most of the ducts from the caudal part join to form the major sublingual duct which opens near the Whartson's duct. The superior (rostral) part is much larger. From this part, 8-10 minor sublingual ducts convey the secretion to the floor of the mouth.

12. Oesophagus

- Musculomembranous tube extends from pharynx to stomach
- Length about 75 cm – 100 cm
- Divided into cervical and thoracic part (abdominal part absent due close apposition of stomach to diaphragm)
- Cervical part begins at the pharynx in the median line behind the aditus oesophageus above the anterior border of cricoid cartilage, passes backward and downward on the dorsal surface of trachea till 3rd or 4th cervical vertebra.
- At this level crosses the trachea obliquely, placing itself along left side, passes backward enter the thoracic cavity thorugh thoracic inlet and continues the course as thoracic part till the level of 3rd or 4th thoracic vertebra where it gains the dorsal surface of trachea
- Continues this relation till tracheal bifurcation
- As it passes through middle mediastinum, it pushed to the right of the aortic arch and lies to the right of median plane
- Then passes upward and backward in the mediastinum, inclines again to the left of median line and enters the hiatus oesophageus of the diaphragm
- Just after entering the abdominal cavity terminates at the dome shaped area of rumino-reticular wall, the atrium ventriculi.
- Muscle striated through out length
- Mucous membrane thrown into numerour longitudinal fold when the tube is empty

Relations:

- At the origin rectus capitis ventralis major (straight muscle of head) superiorly and cricoid cartilage inferiorly
- At the level of crossing to the left of trachea – longus coli superiorly and trachea inferiorly
- At the level of C_3 or C_4 – longus coli superiorly, vago-sympathetic trunk, carotid artery and external jugular vein externally and trachea internally
- Anterior mediastinal part – longus coli superiorly, trachea inferiorly, vagus right side, aortic arch and thoracic duct left side
- Posterior mediastinal part – superior and inferior division of oesophageal continuation of vagus nerve respectively, right and left lung on corresponding sides, bronchial and oesophageal artery left

Horse

- Longer, narrower and less dilatable, length about 1 – 1.2 m
- Have cervical, thoracic and abdominal part, the abdominal part is very small (about 2.5 cm)
- Also related to guttural pouch at origin

- Muscular coat striped upto the level of heart rest unstriped

Dog

- Wide and dilatable except at origin
- Constriction at the beginning due to the presence of submucosal gland on its ventral wall
- Small abdominal part
- Muscular fiber striped throughout

CHAPTER-III

NERVOUS TISSUE

Neuron & neuroglia

Neuron – structural & functional unit of nervous system

- Consist of large cell body containing nucleus & surrounded by cytoplasm known as perikaryon
- Two type of process, a single axon & one or more dendrite
- Cell body (Perikaryon) – located in CNS or Ganglia, not in nerve
    - Consist of nucleus, cytoplasm and plasma membrane surrounding nucleus
    - Axon arise from distinct conical portion of cell body known as Axon Hillock
- Cytoplasm with aniline dye present Nissle substance (aggregation of rER, free ribosome)
- Nissle substance extend into trunk of dendrite but absent from axon hillock
- Axon
    - Carry information away from cell body
- Dendrite – receive information
- Unipolar neuron – single axon only
- Pseudounipolar neuron – single dendrite & axon arise from common stem of cell body, eg. Sensory ganglia
- Bipolar neuron – usually sensory, eg. retina, olfactory epithelium
- Multipolar neuron – most coomon type, motor, integrator in nature

Nerve – bundle of axonal process of many neurons

Neuroglia – more than 90% of cell that make N. system, supportive, nourishing & protective function

- Neuroglia – more than 90% of cell that make N. system, supportive, nourishing & protective function
    - CNS – Astrocyte (most common)- form blood brain barrier, **Oligodendrocyte**, Microglial cell & Ependymal cell
    - PNS - neurolemocyte – **schwan cell** & Satellite cell
    - Unlike mature neurons, glial cells remain capable of mitosis, and thus they can give rise to tumors of the nervous system

Central Nervous Tissue

- Nervous tissue parenchyma consists of neurons and supportive cells called neuroglia
- Grey matter – neuronal cell body, glial cell & neuropil
    - Distinctive grey matter mass within CNS are designated as Nucleus
    - Grey matter on surface of cerebrum & Cerebellum is called – Cortex
- White Matter – dense accumulation of myelinated axon
- With silver stains, astrocytes exhibit numerous processes that contain glial fibrils
    - In gray matter, the processes appear shorter and highly branched
    - In white matter, the processes are long, slender, and moderately branched
    - Thus, white matter is said to contain fibrous astrocytes whereas gray matter contains protoplasmic astrocytes
- Adjacent astrocytes are joined by gap junctions
- Astrocyte processes terminate in expansions called **END FEET**
    - Collections of end feet form a glial-limiting membrane to which pia mater is attached at the CNS surface

- End feet cover vessels within the brain and spinal cord, and they are believed to be responsible for inducing formation of tight junctions between capillary endothelial cells (a basis for the blood brain barrier)
- BBB impedes diffusion of hydrophilic molecules from the blood stream to the CNS (polar molecules must be specifically transported into the CNS)

Oligodendrocytes

- Smaller than astrocytes, fewer processes and found in both gray and white matter
- In white matter, form the myelin sheaths that are around many axonsIn gray matter, synthesize defined growth factors which provide trophic signals to nearby neurons

Microglia

- Microglia are cells of mesodermal origin that invade the CNS when it is vascularized embryologically
- Small elongated cell body that is elongated with elongated mostly heterochromatin nucleus
  - Other glia have a spherical nucleus
- Under physiologic conditions, microglia synthesize and release trophic factors
  - In response to CNS injury, microglia react, proliferate, and express protective or, in some situations, cytotoxic properties

Ependymal Cells

- Ependymal cells form an epithelium that lines ventricular cavities within the brain and the central canal of the spinal cord
- They are typically cuboidal or columnar with numerous motile cilia on their apical surfaces
- Ciliary action acts to circulate cerebral spinal fluid
- Schwan Cells
- Neurolemmocytes (Schwann cells) are gliocytes of the PNS that sheathe and myelinate axons
- They provide a protected immediate environment for PNS neurons and are vital for axonal function and survival

Satellite Cells

- Ganglionic gliocytes (satellite cells) encapsulate neuron cell bodies in the PNS
- In cranial nerve and spinal (sensory) ganglia, a tight capsule is formed around each neuron cell body
- In autonomic ganglia, capsules formed by ganglionic gliocytes are incomplete and may enclose more than one postganglionic cell body

Nerve:

- Grossly visible anatomic structure and is bundle of axonal processes of many neurons
- Bundle of axonal processes of many neurons

CHAPTER-IV

CLASSIFICATION OF NERVOUS SYSTEM

1. Direction of Impulse Transmission

- Afferent: Carries impulse towards brain & spinal cord
  - Sensory
- Efferent: From brain and spinal cord to periphery (effector organ)
  - Motor

- Within spinal cord afferent/ sensory nerves are called Ascending whereas efferent Descending (because impulse from lower to higher or vice-versa)

2. Nature of information conveyed & activities that are directed:

- Somatic – concerened with those function that relationship of organism to outside
  - Communicate those stimulus from body to CNS & then provide output (locomotion)
  - Voluntary function
- Visceral: - functions that are related to internal environment eg. Regulation of heart rate, control of glandular activities
  - Central Nervous System
- When sectioned:
  - we find that two major areas of brain tissue may be defined on the basis of their color in fixed, unstained tissue
  - White matter – myelinated axon, oligodendrocytes
  - Gray matter – neuronal cell bodies, dendrites and glial cells
    - In living tissue gray matter is actually pink due to blood in the many capillaries coursing through this tissue
- In the brain, the gray matter forms an outer covering or cortex; the white matter forms an inner core or medulla
  - This arrangement is reverse in spinal cord where central part made by gray matter and peripheral part by white matter
- Cerebral cortex:
  - Peripheral part made by gray matter contains nerve cell bodies, axons, dendrites, and central glial cells, and it is the site of synapses

Brain:

Cerebellum: Cortex & Medulla

- Cerebellar cotex – 3 laye
  - Molecular layer –most superficial, basket cell
  - Purkinje cell layer – purkinje cell, (**purkinje fibre in heart**)
  - Granular Cell layer – adjascent to white matter

Cerebrum – Cortex & Medulla

- Cortex divided into six layer (outside to inside)
  - Molecular layer
  - External Granual layer
  - External Pyramidal layer
  - Internal granular layer
  - Internal pyramidal layer
  - Fusiform layer

- **CNS covered by 3 membranes**
  - Duramater:
    - Falx cerebri: sickle shaped vertical fold
    - Tentorium cerebelli: transverse fold between cerebellum andcerebrum
    - Diaphragm sellae: transversely across sella turcia (pituitary fossa) of?
    - Cranial durmater lines inner surface of cranium, no epidural space
    - Spinal duramater: foramen magnum – mid of sacrum
  - Arachnoid
  - Piamater
    - Delicate membrane of fine blood vessels and areolar tissues
    - Part invaginate deep to form choroid plexus

Spinal Cord:

- Centrally H-shaped grey mater surrounded by white mater
- From foramen magnum to mid of sacrum (cattle- S2/S3; Dog- L6/7, Fowl- pygostyle)
- 4 segments: cervical, thoracic, lumbar and sacral
- Cervical and lumbar enlargement for plexuses
- Caudal part terminate form conical structure, the **CONUS MEDULARIS**
- From tip of conus med. Thin delicate extension of piamater exten back as **FILUM TERMINALE**
- Filum terminale inside sacral canal surrounded by 2-3 sacral & 5 Cy nerve; and these arrangement of filum terminale the terminal spinal nerves give appearance of horse tail called **CAUDA EQUINA (absent in fowl)**
- **In fowl, two halves of sp. Cord separate at lumbar enlargement by an elliptical/ diamond shaped space (RHOMBOIDAL SINUS) and join again at sacral region**
- Spinal Cord
- A transverse section of the spinal cord has a central canal surrounded by an H-shaped profile of gray matter, which is in turn surrounded by white matter
- Spinal gray matter contains three categories of neurons:
  - interneurons (contained within the gray matter, connecting afferent and efferent neurons),
  - projection neurons (which project axons through white matter tracts to the brain)
  - efferent neurons (which send axons into ventral roots
- Spinal white matter is composed of fibers that form ascending and descending tracts plus fibers entering from dorsal roots or exiting to ventral roots

Cranial Nerves:

12 pairs:

- Name numerically according to the order in which they emerge from brain in rostro-caudal sequence and also according to function
- 1,2,8 (I, II, VIII) – sensory
- 3,4,6,11,12 – motor
- 5,7,9,10 - Mixed
- Cranial Nerver

No.	Name	Nature	Distribution
I	**Olfactory**	**Sensory**	**Nasal mucosa**
II	**Optic**	**Sensory**	**Retina**

III	**Occulomotor**	**Motor**	**All ext ocular except dorsal oblique & lat rectus**
IV	**Trochlear**	**Motor**	**Dorsal oblique**
V	**Trigeminal**	**Mixed**	**CLOT; maxillary; Mandibular**
VI	**Abducent**	**Motor**	**Lat rectus**
VII	**Facial**	**Mixed**	**Sensory – rostral 2/3rd of tongue; PNS**
VIII	**Cochleo-vestibular**	**Sensory**	**Ear**
IX	**Glossopharyngeal**	**Mixed**	**Caudal 1/3rd of tongue; PNS**
X	**Vagus**	**Mixed**	**Pharynx, larynx, thoracic & abdominal viscera; PNS**
XI	**Spinal accessory**	**Motor**	**Brachio-cephalicus, trapeziums etc**
XII	**Hypoglossal**	**Motor**	**Muscles of tongue**

Importat Points:

Trigeminal:

- Trigeminal: Largest cranial nerve (Sciatic: largest nerve of body)
  - Opthalmic branch sensory – to eye and dorsal part of head
  - Maxillary branch sensory – to upper teeth, palate, nasal cavity
  - Mandibular mixed – sensory to tongue, teeth and lower jaw
    - Motor to muscles of mastication (?)
- **Vagus: Pneumo-gastric**
  - Longest cranial nerve/ longest nerve of body
- **Smallest cranial nerve: TROCHLEAR**

Brachial Plexus

Formation:

- Ventral pr. Branch of last three cervical (?) & first, some time 2nd also thoracic spinal nerve
- Appear as thick wide band between two parts of scalenus muscle and is covered by ant deep pectoral and subscapularis muscles

Nerve	**Innervations**
Suprascapular	**Supra and infraspinatus**
Subscapular	**Subscapularis**
Radial	**Triceps brachii; extensor muscles; anconeus; flexor ulnaris lateralis** **Sensory/ cutaneous- fibers to cranio-lat aspect of forelimb**

Axillary	**Teres major, teres minor, deltoideus** **Sensory/ cutaneous- fibers to shoulder region, ant aspect of forelimb**
Thoraco-dorsal	**Latissimus dorsii**
Musculocutaneous	**Biceps brachii, coracho-brachialis;** **cutaneous- fibers to med aspect of antebrachium, carpus & cr. Lat aspect of metacarpus**
Median	**Brachialis, humeral head of DDF, pronator pteres, fl carp radialis**
Ulnar	**Ulnar & radial head of DDF; SDF, Fl carp ulnaris**
Long thoracic	**Serratus ventralis**
Ant thoracic/ pectoral	**Pectorals**
Ext thoracic	**Cutaneous trunci, deep pectoral**

Lumbo-sacral plexus:

Formation:

- Ventral pr. Branch of last three lumbar (?) & 1st two sacral sp nerve
- **First two branches: distributed inside/ through structure in pelvic cavity**
    1. Femoral
    2. Obturator
- Last 3 branches: emrge out of pelvic cavity through greater ischiatic foramen

3. Ant. Gluteal
4. Sciatic
5. Post gluteal

4. Epithelia:

- The epithelia (singular: epithelium) are a diverse group of tissues that include both surface epithelia and lining of organs.
- Surface epithelia cover or line all body surfaces, cavities and tubes and form the interface between different biological compartments. For instance, the epidermis of the skin is exposed to the external environment and the epithelial lining of the gastrointestinal tract is exposed to partially digested food and bacteria in the lumen of the gut.

Functions of epithelia

- Forming a protective barrier
- Regulation of the exchange of molecules between compartments (selective diffusion and absorption)
- Synthesis and secretion of glandular products.

- Many of these major functions may be exhibited at a single epithelial surface. For example, the epithelial lining of the small intestine is primarily involved in absorption of the products of digestion, but the epithelium also protects itself from noxious intestinal contents by secreting a surface coating of mucus.
- Surface epithelia form ***continuous sheets*** comprising one or more layers of cells.
- Epithelial cells are bound to adjacent cells by a variety of ***cell junctions*** that provide physical strength and mediate exchange of information and metabolites.
- All epithelia are ***supported by a basement membrane*** which separates the epithelium from underlying supporting tissues.
- Thus epithelial cells are ***polarised***, with one side facing the basement membrane and underlying supporting tissues (the basal surface) and the other facing outwards (the apical surface).

Classification of surface epithelia:

Number of cell layers	Types of cells	Special features	Examples
Simple (one layer)	**Squamous**		**Endothelium**
	Cuboidal		**Collecting tubules of kidneys**
		Microvilli	**PCT kidneys**
	Columnar		**Gall bladder**
		Microvilli	**Small intestine**
		Cilia	**Fallopian tube**

		Pseudostratification	**Respiratory tract**
		Goblet cells	**Small and large intestine**
		Stereocilia	**Vas deferens**
Stratified	**Squamous**		**Oral cavity**
		Keratinized	**Epidermis of skin**
	Cuboidal		**Exocrine gland ducts**
	Transitional		**Urinary bladder**

Glandular epithelia

- Epithelium that is primarily involved in secretion is often arranged into structures called glands.
- Glands are merely invaginations of epithelial surfaces which are formed during embryonic development by proliferation of epithelium into the underlying tissues.
- For example, glandular epithelium is characteristic of the lining of much of the gastrointestinal tract.
- However, some solid organs are composed largely of epithelial cells with a supporting tissue framework.
    - Some of these organs are connected to the surface epithelium of the gastrointestinal tract by a branching system of ducts and belong to the category of *exocrine glands* (e.g. salivary glands).
    - *Endocrine glands* on the other hand have lost their connection to the epithelial surface from which they developed and release their secretions directly into the blood (e.g. thyroid gland).

Simple Epithelia

- Simple epithelia are defined as surface epithelia consisting of a single layer of cells.
- Simple epithelia are almost always found at interfaces involved in selective diffusion, absorption and/or secretion.
- They provide little protection against mechanical abrasion and thus are not found on surfaces subject to such stresses.
- The cells comprising simple epithelia range in shape from flattened to tall columnar, depending on their function.
- For example, flattened simple epithelia are ideally suited to diffusion and are therefore found in the air sacs of the lung (alveoli), the lining of blood vessels (endothelium) and lining body cavities (mesothelium).

- In contrast, highly active epithelial cells, such as the cells lining the small intestine, are generally tall since they must accommodate the appropriate organelles.
- Simple epithelia may exhibit a variety of surface specialisations, such as microvilli and cilia, which facilitate their specific surface functions.

Simple squamous epithelium

- Simple squamous epithelium is composed of flattened, irregularly shaped cells forming a continuous surface that is sometimes called ***pavemented epithelium.***
- Simple squamous epithelium is found lining surfaces involved in passive transport (diffusion) of either gases (as in the lungs) or fluids (as in the walls of blood capillaries).
- Simple squamous epithelium also forms the delicate lining of the pleural, pericardial and peritoneal cavities where it allows passage of tissue fluid into and out of these cavities.

Simple cuboidal epithelium

- Represents an intermediate form between simple squamous and simple columnar epithelium;
- The distinction between tall cuboidal and low columnar is often arbitrary and is of descriptive value only.
- In the section perpendicular to the basement membrane BM, the epithelial cells appear square, leading to its traditional description as cuboidal epithelium; on surface view, however, the cells are actually polygonal in shape.
- The nucleus is usually round and located in the centre of the cell.
- Simple cuboidal epithelium usually lines small ducts and tubules that may have excretory, secretory or absorptive functions
- Examples are the collecting tubules of the kidney and the small excretory ducts of the salivary glands and pancreas

Simple columnar epithelium

- Similar to simple cuboidal epithelium except that the cells are taller and appear columnar in sections perpendicular to the basement membrane.
- The height of the cells may vary from low to tall columnar, depending on the site and/or degree of functional activity.
- The nuclei are elongated and may be located towards the base
- Found on absorptive surfaces such as in the small intestine, as well as at secretory surfaces such as that of the stomach.
- Some simple columnar epithelia have surface cilia **C** on the majority of the cells.
- Cilia are much larger than microvilli
- Simple columnar ciliated epithelium is found mainly in the ***female reproductive tract.***

Pseudostratified columnar ciliated epithelium

- The term pseudostratified is derived from the appearance of this epithelium in section, which conveys the erroneous impression that there is more than one layer of cells.

- In fact, this is a true simple epithelium, since all the cells rest on the basement membrane. The nuclei of these cells, however, are disposed at different levels, thus creating the illusion of cellular stratification.
- Pseudostratified epithelium is almost exclusively confined to the airways of the respiratory system in mammals and is therefore often referred to as ***respiratory epithelium***.
- Pseudostratified columnar ciliated epithelium may be distinguished from true stratified epithelia by two characteristics.
    - Firstly, the individual cells of the pseudostratified epithelium exhibit polarity, with nuclei being mainly confined to the basal two-thirds of the epithelium.
    - Secondly, cilia are never present on true stratified epithelia.

Stratified epithelia

- Stratified epithelium is defined as epithelium consisting of two or more layers of cells.
- Stratified epithelia have mainly a protective function and the degree and nature of the stratification are related to the kinds of physical stresses to which the surface is exposed.
- In general, stratified epithelia are poorly suited for absorption and secretion by virtue of their thickness, although some stratified surfaces are moderately permeable to water and other small molecules.
- The classification of stratified epithelia is based on the shape and structure of the surface cells, since cells of the basal layer are usually cuboidal in shape.
- Transitional epithelium is a stratified epithelium found only in the urinary outflow tract, with special features to make it waterproof as well as expansile.

Stratified squamous epithelium

- Consists of a variable number of cell layers that exhibit maturation from a cuboidal basal layer to a flattened surface layer.
- The basal cells include continuously dividing stem cells, their offspring migrating towards the surface where they are ultimately shed as anucleate squames.
- Stratified squamous epithelium is adapted to withstand abrasion, with plentiful cell junctions and a prominent intermediate filament (***keratin***) cytoskeleton.
- This type of epithelium lines the oral cavity, pharynx, oesophagus, anal canal, uterine cervix and vagina, sites which are subject to mechanical abrasion but which are kept moist by glandular secretions, such as the salivary glands of the mouth.
- There are five distinct layers with only superficial cell layer as squamous
- The deepest layer is stratified squamous epithelium next to basal lamina is stratum basale.
- Next layer is stratum spinosum composed of varying number of layers of polyhedral cells adhererd to each other by numerous desmosomes
- Then stratum spinosum or spiny layer, contain mitotic figures ,these are also present in stratum basale
- Both these layers are referred as stratum germinativum
- As the cell move towards surface they become flattened and accumulate keratohyaline granules in their cytoplasm and layer is called as stratum granulosum but not present in all st sq epithelia (absent in nonkeratinized epi and in hard keratinized layer like hoof and horn)
- Stratum lucidum occur only in non hairy skin region (contain eledin granule protein similar to keartin, it is transparent layer occur in between st granulosum and stratum corneum

- Stratum corneum is outermost layer consisted of dead keratinized cells resistant to environmental irritants
- During keratinization nuclei become pyknotic and subsequently disappear
- In nonkeratinized st epi top layer cells become flat and retain nuclei and kerain then grp of cells in outer most layer of str corneum become loose and separarate and called as stratum disjunction
- Keratinising stratified squamous epithelium constitutes the epithelial surface of the skin (the epidermis) and is adapted to withstand the constant abrasion and desiccation to which the body surface is exposed.
- During maturation, the epithelial cells accumulate ***keratin intermediate filaments*** which are cross-linked with proteins in a process called keratinisation. This results in the formation of a tough, non-living surface layer (***stratum corneum***) consisting of a compacted cross-linked keratin matrix interspersed with specialised lipids.
- The underlying granular cell layer consists of epithelial cells with extensive tight junctions, forming a waterproof barrier.
- The nuclei of the maturing epithelial cells become progressively condensed (pyknotic) and eventually disappear along with the other cellular organelles.

Stratified cuboidal epithelium

- Stratified cuboidal epithelium is a thin, stratified epithelium that usually consists of only 2-3 layers of cuboidal cells.
- This type of epithelium is usually confined to the lining of the larger excretory ducts of exocrine glands such as the salivary glands.
- Stratified cuboidal epithelium is probably not involved in significant absorptive or secretory activity but merely provides a more robust lining than would be afforded by a simple epithelium.

Transitional epithelium

- Transitional epithelium (or urothelium) is a form of stratified epithelium found only in the urinary tract in mammals, where it is highly specialised to accommodate a great degree of stretch and to withstand the toxicity of urine.
- This epithelial type is so named because it has some features intermediate (transitional) between stratified cuboidal and stratified squamous epithelia.
- In the non-distended state, transitional epithelium appears to be about four to five cell layers thick. The basal cells are roughly cuboidal, the intermediate cells are polygonal and the surface cells (umbrella or dome cells U) are large and rounded and may contain two nuclei.
- In the stretched state, transitional epithelium often appears only two or three cells thick (although the actual number of layers remains constant) and the intermediate and surface layers are extremely flattened.

Glands:

- **On the basis of number of cells**

1. Unicellular: eg Goblet cells.

Goblet cell is specialized columnar epithelial cell that produces and secrete mucus. They are scattered among the cells of many simple epithelial lining mainly GIT and respiratory system. Contents are released by exocytosis which when combines with water forms viscous material known as ***mucus.***

2. Multicellular: P/O more than 1 cell. Entire sheet of epithelium becomes secretory. eg. Lining of glandular stomach

- **Endocrine:** No duct system
- **Exocrine:** P/O duct system

- **On the basis of nature of secretion**

Serous:

- Secrete clear, watery secretion
- Nucleus central and spherical
- Apical cytoplasm filled with zymogen granules. These granules are precursor of enzymes.
- Deep stain with H&E due to presence of zymogen granules.
- Cytoplasm has 2 zones particularly in pancreas. Basal zone is basophilic due to presence of RER. Apical zone is acidophilic due to presence of zymogen granules.

Mucous:

- Produce thick, viscous secretion called **mucin** which contributes to protective coating over lining of hollow organs. The protective coating is called **mucus** (mucin + leucocytes + cast-off epithelial cells). ***To describe physiology, term mucous is used like mucous cell/mucous glands/mucous membrane.***
- Cells are filled with mucinogen (precursor of mucin)
- Nucleus flat, dark stained and towards periphery
- Basal area dark stained and lumen light stained
- Stain poorly with H&E because they contain little RER.

Mixed:

- In single gland, serous and mucous acini at different locations
- Consist mainly of mucous units with crescent-shaped serous cells located at the periphery of mucous secretory unit and is known as ***serous demilunes***.

- **On the basis of means/modes of secretion**

Secretion from exocrine glands may occur in one of three ways:

- **Merocrine (eccrine)** secretion involves the process of exocytosis and is the most common form of secretion; proteins are usually the major secretory product.
- **Apocrine secretion** involves the discharge of free, unbroken, membrane-bound vesicles containing secretory product; this is an unusual mode of secretion and applies to lipid secretory products in the breasts and some sweat glands.
- **Holocrine secretion** involves the discharge of whole secretory cells, with subsequent disintegration of the cells to release the secretory product. Holocrine secretion occurs principally in sebaceous glands.

- **On the basis of duct system**

The duct system may be unbranched (simple gland) or branched (compound gland).

- The secretory component may be tubular or acinar (roughly spherical).

- Both types of secretory component may also be coiled or branched.
- Almost any combination of duct and secretory component may occur

Simple tubular glands

- Example***: Large intestine***
- This type of gland has a single, straight tubular lumen into which the secretory products are discharged

Simple coiled tubular glands

- ***Sweat glands*** are almost the only example of simple coiled tubular glands.
- Each consists of a single tube that is tightly coiled in three dimensions; portions of the gland are thus seen in various planes of section.
- Sweat glands have a terminal secretory portion lined by simple cuboidal epithelium, which gives way to a non-secretory (excretory) duct lined by stratified cuboidal epithelium.

Simple branched tubular glands

- Simple branched tubular glands are found mainly in the **stomach.**
- The mucus-secreting glands of the pyloric part of the stomach are shown in this example. Each gland consists of several tubular secretory portions, which converge onto a single unbranched duct of wider diameter.
- Mucus-secreting cells also line the duct but, unlike those of the large intestine, these mucus cells do not have a goblet shape.

Simple acinar/alveolar

- Eg. Sebaceous glands, glands of skin of amphibians, glands in respiratory system of poultry

Simple branched acinar/alveolar

- Eg. Large sebaceous glands of skin of domestic animals.
- It is more common than unbranched form.

Compound glands

- They have elaborate duct system that branch repeatedly. It is composed of secretory units and ducts collectively known as ***parenchyma*** and the supportive or CT element comprises the ***stroma.***

Compound branched tubular gland: Brunner's glands of the duodenum
Compound acinar gland: Pancreas
Compound tubule-acinar gland: Major salivary glands

CHAPTER-V

HINDLIMB BONES

PELVIC LIMB BONES

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

OS COXAE

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

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

Ilium

- The *ilium* is the largest of the three parts.
- It is irregularly triangular being wide above narrow and prismatic at the middle and slightly expanded below.
- It presents *two surfaces, three borders and three angles*.
- The *lateral* or *gluteal surface* is directed dorso-laterally and backward. The inferior third of this surface presents rough lines for the origin of the *gluteus profundus.* This surface is traversed by the gluteal line running nearly parallel to the cotyloid edge from a little below the tuber coxae to become continuous with the ischiatic spine. This surface serves for the origin of the *gluteus medius.*
- The *medial* or *pelvic surface* presents a rough triangular medial part-the *sacral surface* and a smooth quadrilateral part -the *iliac surface*. The former presents an irregular facet, the articular surface for the sacrum. The iliac surface is directed forward and is covered by *iliacus*. The *ilio-pectineal* line, which separates these two surfaces, begins below the articular surface and joins the anterior border of pubis

and forms the lateral boundary of the pelvic inlet. It bears about the middle the *psoas tubercle* for the *psoas minor.*

- The *cotyloid border* leads to the acetabulum, little above and infront of which are two depressions (the lateral one is faint) for the origin of the *rectus femoris.*The *ischiatic border* is concave and forms the *greater isciatic notch.* The notch forms the greater ischiatic foramen which is covered by the sacro-sciatic ligament in life and serves for the passage of gluteal nerves and anterior gluteal vessels. In its lower part, it is convex, rough and is continuous with the ischiatic spine, which gives attachment to the sacro-sciatic ligament at its free edge and to the *gluteus profundus* on its lateral aspect. The *dorsal border* or *the crest* of the ilium is concave thick and rough for the attachment of the muscles of the loin.
- The *medial angle* or *tuber sacrale* is separated from its fellow and forms with it and the sacrale spines, the *point of the croup.* The *lateral angle* or *tuber coxae* is large and prominent, wide in the middle and smaller at either end and serves for the attachment of the iliacus, *obliquus abdominis internus, tensor fasciae latae, gluteus medius* etc. The *inferior* or *acetabular angle* is thick and meets the other two parts at the acetabulum.

Ishium

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

Pubis

- The *pubis* is the smallest of the three parts. It is irregularly triangular and has *two surfaces* and *three borders*.
- The *dorsal* or *pelvic surface* forms the anterior part of the pelvic floor and the urinary bladder rests on it in life. The *ventral surface* is rough for muscular attachment.
- The *anterior border* is thick. Laterally it bears the ilio-pectineal eminence and curves for the attachment of the prepubic tendon. The *posterior border* forms the anterior margin of the obturator foramen. The *medial border* meets the same border of its fellow at the pubic symphysis. The *acetabular angle* joins the ilium and the ischium at the acetabulum. The medial borders of the

pubis and the ischium meet the corresponding borders of their fellows to form the *pelvic symphysis / Ischio-pubic symphysis* and the pelvic floor is basin like.

Acetabulum

- *Acetabulum* is a cotyloid cavity formed on the ventro-lateral aspect of the os coxae by the meeting of its three components.
- It consists of an *articular* and a *non-articular part*.
    - The former is nearly circular and articulates with the head of the femur. The rim of the cavity presents on its postero-medial aspect the *acetabular notch*, which transmits the round ligament of the hip joint.
    - The non-articular part, the *acetabular fossa* is situated in the depth of the acetabulum.

Obturator foramen: The *obturator foramen* is a large, elliptical opening on the floor of the pelvis and is circumscribed by the ischium and the pubis. It is covered in life by the obturator muscles.

Sexual differences

- The ischial arch is wider and the outlet is larger in the female than in the male.
- The conjugate (vertical) and transverse diameters are greater in the female so that the cavity is roomier.
- The pubis and the ischium of the opposite sides meet at a more open angle in the female than in the male.

Horse

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

Pig

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

Dog

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

Fowl

- **The *ilium* is elongated** and extends over the entire length of the hipbone. **It is firmly fused to the transverse processes of the lumbo-sacral mass.** The **pelvic face is concave for the lodgment of kidney.** The lateral border is free in its anterior half but is fused with the ischium behind.
- The ***ischium* is smaller** and lies below and lateral to the **posterior part of the ilium is triangular.** The **sciatic foramen is formed by the adjacent borders of the ischium and ilium behind the acetabulum**. The **ventral border forms the obturator foramen with the pubis.**
- **The *pubis*** is a long and **slender rod running along the ventral border of the ischium**. The anterior end has a muscular process.
- The ***acetabulum* is large and perforated** and presents at its supero-posterior part process - ***anti-trochanter*** for articulation with the great trochanter of the femur.

BONY PELVIS / BONE OF HIP (PELVIC) REGION

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

A. Diameters of Pelvic inlet

1. **Sacro-pubic (Conjugate) diameter**: - It is measured from sacral promontory to the anterior margin of pubis symphysis.
2. **Transverse (Bis-iliac) diameter:** - Measured at its greatest width just above psoas tubercle.
3. **Vertical diameter of inlet**: - It is measured between anterior end of symphysis pubis and articulation of **sacral 3rd and 4th vertebra**.
4. **Oblique/sacro-iliac/ilio-sacral diameter of inlet**: - It is measured from sacro-iliac joint of one side through the center of pelvic cavity to the psoas tubercle of opposite side. It is intermediate between sacro-pubic and superior bis-iliac diameter.

FEMUR

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

Shaft:

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

Proximal extremity

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

Distal extremity

- The *distal extremity* is large and comprises of *trochlea* in front and *two condyle*s *behind.*
- The *trochlea* articulates with patella. The medial ridge of the trochlea is more prominent.
- The *condyles* are separated by the intercondyloid fossa and articulate with the condyles of the tibia through the medium of the *interarticular cartilages or menisci.*
- The *medial condyle* presents an eminence on its medial aspect for the medial ligament.
- The *lateral condyle* presents two depressions on its lateral aspect, the upper one for the lateral ligament of the stifle and the lower one for the *popliteus.*
- Between the lateral condyle and the lateral ridge of the trochlea is, the *extensor fossa* for the *complex* muscle.
- The inter-condyloid fossa lodges the spine of the tibia. Its anterior part is for the posterior crucial ligament. At its posterior part close to the medial condyle is a depression for the coronary ligament of the lateral meniscus and close to the lateral condyle is another depression for the anterior cruciate ligament.

Horse

- It is more massive.
- The posterior face bears in its proximal third a rough eminence for the *biceps femoris*.

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

Pig

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

Dog

- The shaft is proportionately large and strongly curved with the convexity forward.
- The **supra condyloid fossa is absent**.
- The **trochanteric fossa is rounded and deep**.
- The **ridges of the trochlea are sagittal and equal**.
- The **inter-condyloid fossa is wide**.
- On the posterior aspect of the distal extremity immediately above each condyle is a small facet for a sesamoid-the **fabella.** The *fabellae* are two small rounded sesamoid bones, located one each on the condyles of the femur on the posterior aspect. They are developed in the tendons of origin of the *gastrocnemius* muscle.

Fowl

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

PATELLA

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

Horse

- The base is wide and large.

- It looks **quadrilateral in shape** on their dorsal/anterior view.

Pig

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

Dog

- It is long and narrow.

Fowl

- It is wide and thin.

TIBIA

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

Shaft

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

Proximal extremity

- The proximal extremity is large and is made up of *two condyles*, a *tuberosity* and a *spine.*
- The *tuberosity* is anterior; it is continuous distally with the tibial crest and is for the straight ligaments of the patella. Between the tuberosity and the lateral condyle is the sulcus muscularis for the passage of the tendon of origin of the complex muscle.
- The condyles are *medial* and *lateral.* Each presents a saddle shaped articular surface above for the corresponding condyle of the femur and the meniscus. The condyles are separated behind the popliteal notch. The *lateral condyle* has the rudimentary fibula fused with it on its lateral aspect and serves for the attachment of the lateral ligament of the stifle.
- The *tibial spine* is placed between the condyles whose articular surfaces are continued on the spine.

Distal extremity

- The distal extremity is smaller than the proximal.
- The *articular surface* presents two deep sagittal grooves.
- The *malleoli* are bony prominences on the outer marigins of the sagittal grooves. The *medial* is smaller and fused with the distal extremity of the tibia. The medial groove is bounded on the medial aspect by the medial malleolus (which is fused to the tibia). The latter is rough medially for ligamentous

attachments and articulates laterally. Its anterior part is prolonged downward to end in a blunt point. The lateral groove is separated by a sharp ridge from an outer area, which is for the *lateral malleolus.* The latter completes the lateral groove.

Horse

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

Pig

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

Dog

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

Fowl

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

FIBULA

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

Horse

- It is better developed and placed along the lateral border of the tibia.
- The shaft is a slender rod, extends down to about the middle of the tibia with which it forms the tibio-fibular arch.

- The proximal extremity is large and flattened from side to side.
- The medial face has a facet for the lateral condyle of the tibia.
- The lateral face is slightly convex and rough.
- The anterior and posterior edges are blunt and rounded, the posterior being the thicker.
- The distal extremity -the lateral malleolus is fused to the tibia.

Pig

- It **extends the entire length of the tibia**.

Dog

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

Fowl

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

TARSAL BONES

Ox

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

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

Tibial tarsal (Talus)

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

Fibular tarsal (os calcis/calcaneus)

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

Fused central and fourth tarsal (scapho-cuboid)

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

First tarsal (cuneiform parvum)

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

Fused 2nd and 3rd tarsal (cuneiform magnum)

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

Horse

- It has six bones.

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

- In the *tibial tarsal*, the ridges of the trochlea curve obliquely downward and outward. The lateral face has no facets for the fibular tarsal.
- The *fibular tarsal* is short and thick. It does not articulate with the lateral malleolus. The medial process is larger.
- The *central tarsal (scaphoid)* is not fused to the fourth tarsal (cuboid). It is flat and irregularly quadrilateral. The proximal face is concave and articulates with the tibial tarsal. The distal face is

convex and articulates with the third tarsal and the fused 1st and 2nd tarsal. The dorsal and the medial borders are continuous and rough. The lateral border is oblique and has two faces for the cuboid.

- The *fused 1st and 2nd tarsal (cuneiform parvum)* is irregular in shape. The medial face is convex. The lateral face is concave. The proximal face is concave and has two facets for the central tarsal. The distal face articulates with the large and the medial small metatarsals. The plantar end is prolonged downward into a nodular projection.
- The *third tarsal (cuneiform magnum)* is triangular in outline. The proximal face is concave and articulates with central tarsal. The distal face is convex and is for the large metatarsal. The medial border has no facet for the fused 1st and 2nd tarsal and the lateral has two facets for the fourth tarsal.
- The *fourth tarsal (cuboid)* has six surfaces. It is not fused to the central tarsal. The proximal face is convex transversely and is for the fibular tarsal and the tibial tarsal. The distal face presents two facets separated by a sagittal ridge for the lateral small metatarsal bones. The medial face has facets for the central and the third tarsal. The dorsal, lateral and the plantar surfaces are convex and rough.

Pig

- It has seven bones

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

Dog

- It has seven bones

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

Fowl

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

METATARSAL BONES

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

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

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

Medial small metatarsal

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

Horse

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

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

Pig

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

Dog

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

Fowl

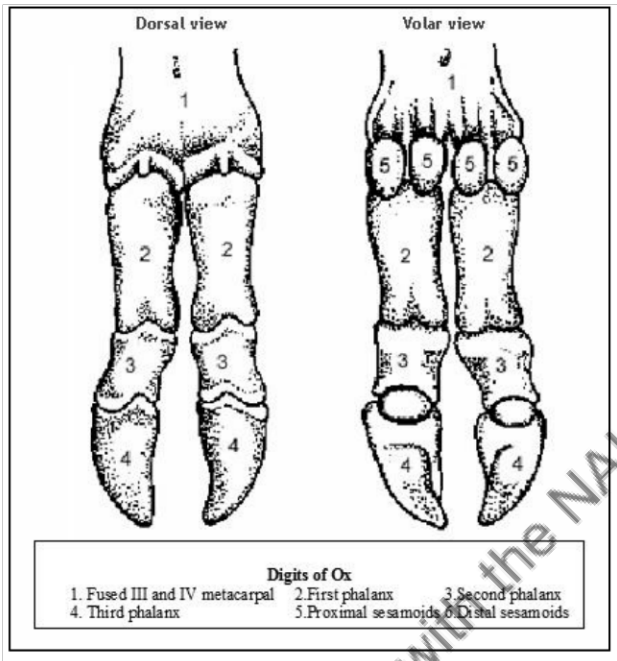
- The *tarso-metatarsus* is a single bone formed by the fusion of the distal row the tarsals with the second, third and fourth metatarsals.
- The proximal extremity presents two glenoid cavities for the distal end of the tibio-tarsus.
- The shaft is two-sided.

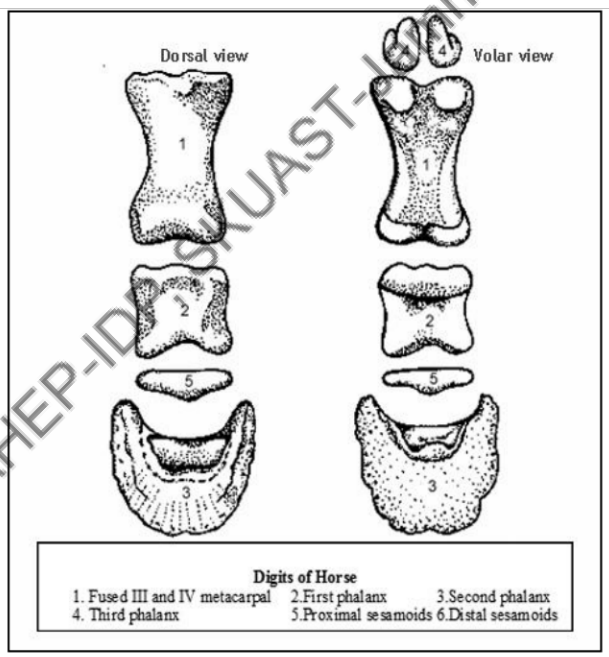
- The first metatarsal is attached by ligament to the postero-medial border of the large metatarsus. In the male, a conical projection arises from the medial aspect of the body of the metatarsus and serves as a core for the *horny spur* or *calcar.*
- The distal extremity divides into three processes.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

DIGITS

Ox

- Resemble those of the forelimb very closely.





Sheep and Goat

- Resembles that of Ox.

Horse

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

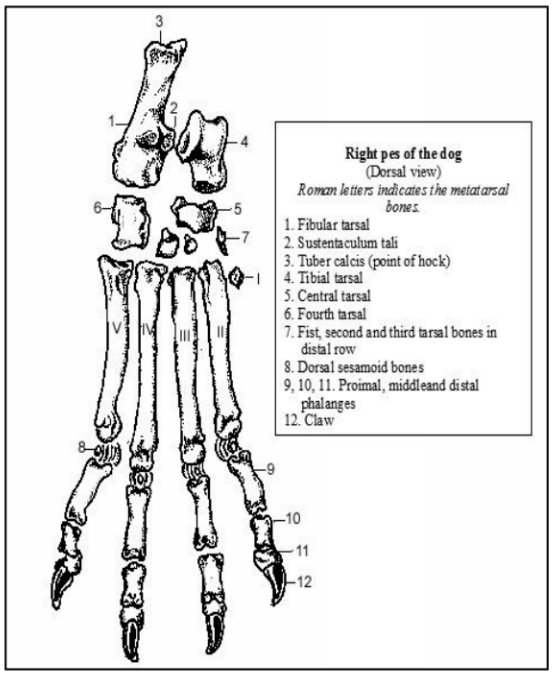
Pig

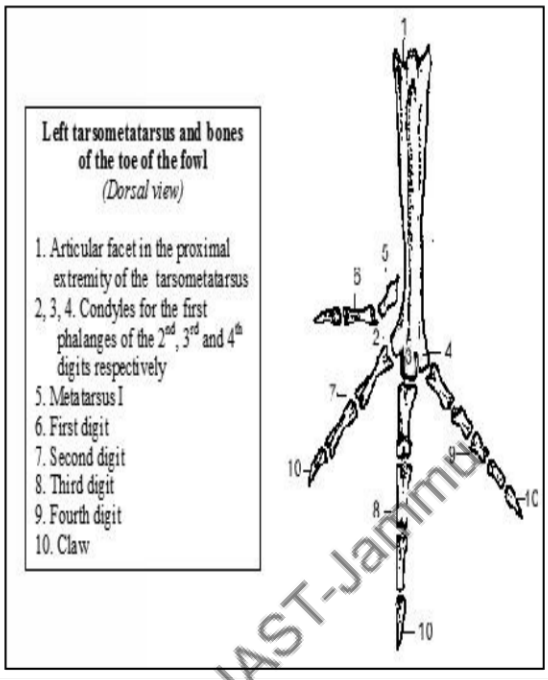
- Each chief digit comprises of three phalanges.

Dog

- Of the five digits the first is often absent.

- The other four digits constantly present and resemble those of the forelimb.





Fowl

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

CHAPTER-VI

INTRODUCTION TO MYOLOGY

Myology deals with the study of muscles 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.

There are three different types of muscles that make up the muscular system viz.,

- **Skeletal muscle**
- **Smooth muscle**
- **Cardiac muscle**

The accessory structures of the muscle are

- **Fascia:** Superficial fascia **&** Deep fascia
- **Synovial membranes:** Synovial bursa **&** Tendon sheath

Origin: Mainly from Mesoderm
Skeletal muscles from paraxial mesoderm
Smooth and cardiac muscles from visceral splanchnic mesoderm

Properties of muscles: Four properties of muscles enable them to perform their functions. These properties include

• **Excitability**: Sometimes called irritability. Muscle cells maintain a membrane potential and are able to respond to a stimulus such as a neurotransmitter by developing an electrical impulse.

• **Contractility**: When stimulated, the electrical impulse spreading across a muscle cell can cause the cell to contract.

• **Extensibility**: In addition to contraction, muscle cells can lengthen in response to stretch. This is more evident in smooth muscle compared to skeletal muscle.

• **Elasticity**: Once stretched, muscle fibers can recoil to their original resting length due to the elastic elements within the muscle.

Functions of muscles

• **Production of movement**. The action of skeletal muscle is responsible for moving joints and thus allowing locomotion. However, movement can be viewed more broadly than locomotion. An animal can change its posture or facial features as a result of muscle contraction. In addition, generally as a result of smooth or cardiac muscle contraction, materials can be relocated within the body. For example, contraction of the heart helps propel blood through the vessels; contraction of the bladder or gastrointestinal tract can also move materials.

• **Maintaining posture**. Maintaining a position is generally an active, rather than a passive, process. Through the actions of signals generated from sensors located in joints, tendons, and muscles, minute adjustments are automatically made to maintain the position of joints.

• **Stabilizing joints**. In addition to moving joints, muscles also stabilize the joints, thus minimizing dislocations.

• **Generating heat**. Endotherms maintain a relatively constant body temperature over a range of environmental temperature. Skeletal muscles are an important organ in heat production, such as through the process of shivering.

SKELETAL 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 **endomysium** surrounds each muscle fibre. Several muscle fibres grouped together to form fasciculus, which is covered by **perimysium.** A muscle as a whole is composed of many fasciculi and is surrounded by **epimysium,** 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 *tendon*. When a muscle contracts and shortens, one end of its attachments usually remains fixed and the other end 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.

Tendon: A narrow band of white fibrous tissue that attaches muscle to bone or cartilage or other tissues is known as **tendon.** Instead, some muscles are connected to bone or other muscles by a broad sheet of fibrous connective tissue called **aponeurosis.**

Blood and nerve supply

The muscle tissue is richly supplied with blood. Large arteries are accompanied by the veins and lymphatics. The lymph vessels are few. The nerve fiber reaches the muscle fibers and terminates into ramified expansions and is termed as **end plates**

Myofibrils

Muscle fibers are composed of functional subunits called **myofibrils**. Each muscle fiber contains hundreds to thousands of myofibrils that run longitudinally the length of the fiber. The myofibrils consist of bundles of myofilaments that are protein filaments composed primarily of actin and myosin, the two contractile proteins in muscle. Actin forms the bulk of the thin filaments, and myosin forms the bulk of the thick filaments. The myofibrils are packed tightly into the muscle fiber, forcing the mitochondria, nuclei, and other organelles to be squeezed toward the outer edge of the cell.

The myofibrils contain three types of proteins:

1. **Contractile proteins**. Contractile proteins generate the force during contraction. These proteins include myosin and actin.

2. **Regulatory protein**. Regulatory proteins help initiate and terminate the contraction process and include tropomyosin and troponin found on the thin filaments.

3. **Structural proteins**. Structural proteins help maintain the alignment of the thin and thick filaments, provide elasticity and extensibility, and attach the myofibrils to the sarcolemma. These proteins include titin, myomesin, and dystrophin.

Sarcoplasmic reticulum

Similar to the endoplasmic reticulum in nonmuscle cells, the sarcoplasmic reticulum (SR) forms a tubular network surrounding each myofibril. The terminal cisternae (end sacs) of the SR are always found in pairs, with an intervening T tubule. The combination of a terminal cisterna, a T tubule, and the adjacent terminal cisterna form a **triad**. The T tubule communicates with the extracellular space while the SR is intracellular. The terminal cisternae of the SR are the source of calcium for skeletal muscle contraction.

Sarcomeres

The functional unit of skeletal muscle is the **sarcomere**. A myofibril consists of thousands of sarcomeres. The sarcomere is composed of thick and thin filaments, proteins that stabilize those filaments, and proteins that regulate the interactions between thick and thin filaments. A sarcomere is the region between two adjacent Z discs (or Z-lines). It consists of one-half an I band, an A band, and one-half an I band. The A band is the length of the thick filament, and can contain both thick and thin filaments. In a muscle at rest, a lighter region can be found in the center of the A band called the H zone (from helle, meaning bright), which contains only myosin. This region disappears as skeletal muscle contracts and the actin filaments overlap, thus entering this area. The M-line, named for being in the middle of the sarcomere, transects the H zone and is composed of proteins that stabilize the position of the thick filaments.

Thin filaments

Thin filaments are 5–6 nm in diameter and 1 μm in length. Each thin filament is composed of:

1. **F actin**. Thin filaments are composed of two strands of F actin, also called filamentous actin, arranged in a double-stranded helix. Each strand of F actin is composed of polymers of G actin, or globular actin. Therefore, the F actin appears as two twisted strands of pearls, with each pearl being analogous to a molecule of G actin.
2. **Tropomyosin**. Strands of tropomyosin (trope = turning) wrap around the length of the F actin. Each tropomyosin molecule is a double-stranded protein that, at rest, covers seven myosin-binding sites on the actin filament.
3. **Troponin.** A globular protein, troponin consists of three subunits. One binds to tropomyosin (TnT), one to G actin (TnI), and the other to calcium ions (TnC). Therefore, troponin controls the structural

relationship between tropomyosin and F actin. At rest, troponin allows tropomyosin to be positioned such that it covers the myosin-binding sites. When a muscle is stimulated and intracellular calcium levels increase, calcium binds to troponin, causing a conformational change that allows the tropomyosin to slide into the grooves of the double helix of actin and thus uncover the myosin-binding sites.

Thick filaments

Thick filaments are 10–12 nm in diameter and 1.6 μm in length. Thick filaments consist of approximately 500 myosin molecules, each composed of two myosin subunits wrapped around each other. The long tails of the myosin molecules line up forming the thick filament, and the heads of the myosin molecules project off the filament toward the adjacent thin filaments. The head of the myosin molecule consists of two globular proteins, has ATPase activity, and is able to bind to the actin filament.

The myosin molecules are arranged so that their tails point toward the M-line. In the H zone, there are no myosin heads, only tails. Also within each thick filament is a molecule of titin extending from the M-line to the Z-line.

Types of Muscle Contraction: Isometric versus isotonic contraction

There are two major categories of muscle contraction: isotonic and isometric. During isotonic (iso = same; tonos = tension), the length of the muscle changes as force is generated, resulting in movement. During isometric (metric = measure) contraction, the length of the muscle does not change because the tension produced does not exceed the resistance. Isometric contraction is commonly observed in postural muscles that maintain a constant body position while opposing gravity.

Classification of skeletal muscle on the basis of arrangement of muscle fibres

Parallel (Fusiform) Muscles

Fibers are parallel to the long axis of muscle. Most skeletal muscles are arranged in this manner. Eg. Sartorius. If ends are tapering, then the term **fusiform muscle** is used. eg Biceps brachii

Convergent (Triangular) Muscles

In a convergent muscle, the fibers are based over a broad area, but all the fibers come together at a common attachment site. The fibers typically spread in a fan shape with tendon at apex. Origin is generally wider than insertion. Muscle fibers pull in different directions, depending on stimulation. Eg. Latissimus dorsi

Pennate Muscles (Pennate = “feather-like”)

Fibers are at an angle with the tendon. These muscles do not move as far as parallel muscles but since contain more myofibrils than parallel muscles, thus develops more tension than parallel muscles.

Unipennate: fibers angled on 1 side of tendon. e.g., peroneus

Bipennate: fibers angled on both sides of tendon. e.g., rectus femoris

Multipennate: tendon branches within muscle. e.g., deltoid

Circular muscles: Also called **sphincters.** There is concentric arrangement of fascicles. They open and close to guard entrances of body. e.g., obicularis oris

Cruciate muscles: in these muscles the fibres are arranged in superficial and deep plane, crossing like 'X'. E.g. masseter

Muscle Terminology Based on Function

Agonist (prime mover): produces a particular movement. *Biceps brachii* is the prime mover responsible for flexion of the elbow

Antagonist: opposes movement of a particular agonist. *Triceps brachii* are the antagonist to the bicep brachii, responsible for extending of the elbow)

Synergist: a smaller muscle that assists a larger agonist

Agonists and antagonists work in pairs: When 1 contracts, the other stretches. e.g., flexors–extensors, abductors–adductors.

Descriptive Names for Skeletal Muscles

1. Location in the Body: eg. Temporalis muscle
2. Origin and insertion: eg. Sternocephalicus muscle
3. Fascicle Organization: Describes fascicle orientation within muscle. Eg Rectus, oblique or transverse
4. Relative Position:
    a. Externus (superficialis): visible at body surface
    b. Internus (profundus): deep muscles
    c. Extrinsic: muscles outside an organ
    d. Intrinsic: muscles inside an organ
5. Structural Characteristics
    a. Number of tendons: Biceps, triceps or quadriceps
    b. Shape: Eg. Trapezius, deltoideus
    c. Size: Longus = long
        i. Longissimus = longest
        ii. Teres = long and round
        iii. Brevis = short
        iv. Magnus = large
        v. Major = larger
        vi. Maximus = largest
        vii. Minor = small
        viii. Minimus = smallest
6. Action: Flexor, extensor, dilator, levator, depressor

Accessory structures of muscle

- The accessory structures of the muscles are the fasciae and synovial structures

Fasciae

The connective tissue membranes separating muscles from each other and binding them in position are called **Fascia.** It is situated between the muscles and acts as a package material between the muscles. It provides pathways for passage of blood vessels and nerves. Fascia situated immediately beneath the skin is termed as **superficial fascia** and fascia lying between the muscles is called as **deep fascia**.

Superficial fascia is thinner and cannot be separated because it is intimately blended with the subcutaneous connective tissue whereas the *deep fascia* is thicker and tougher

Synovial Structures

These include joint capsule, bursae and synovial sheath. Their inner layer consists of CT membrane that produces synovial fluid to decrease friction.

Bursae are thin walled connective tissue sacs lined by synovial membrane and filled with synovial fluid. They are present where tendon rubs against bone, ligaments or other tendons or where the skin moves over a bony prominence. They facilitate the movement by minimizing the friction. Bursa gives adequate protection to structures that moves only a short distance in relation to each other. However, tendon that travels a long distance over a bone or other structure requires protection and friction free movement for their entire length. This is provided by ***synovial sheath/tendon sheath.*** They resemble an elongated bursa placed between tendon and underlying tissue, with edges of bursa reflected around tendon until they meet. This results in an inner layer of synovial membrane on surface of tendon and superficial layer outside tendon, forming a closed sac that contains fluid to reduce friction. The double fold of membrane formed where edges of sheet meet is called ***mesotendon.*** Vessels and nerves to tendon reach by passing through mesotendon.

Cardiac muscle

Cardiac muscle, composed of cardiac muscle cells called cardiocytes or cardiac myocytes, is found exclusively in the heart. It is considered as involuntary, striated muscle.

- Fibers are branched
- Adjacent cardiac cells are joined end to end by specialized structures known as **intercalated discs**
- Heart functions as a syncytium (Atrial syncytium and ventricular syncytium)
- Discs contain several gap junctions providing cytoplasmic continuity.
- Rapid transmission of impulse.
- When one cardiac cell undergoes an action potential, the electrical impulse spreads to all other cells that are joined by gap junctions

Autorhythmicity: The ability of the heart to initiate its beat continuously and regularly without external stimulation. Location of Autorhythmic cells:

- **Sinoatrial node (SA node)** Specialized region in right atrial wall near opening of superior vena cava.
- **Atrioventricular node (AV node)** Small bundle of specialized cardiac cells located at base of right atrium near septum
- **Bundle of His** (atrioventricular bundle) Cells originate at AV node and enters interventricular septum. Divides to form right and left bundle branches which travel down septum, curve around tip of ventricular chambers, travel back toward atria along outer walls
- **Purkinje fibers** Small, terminal fibers that extend from bundle of His and spread throughout ventricular myocardium

Cardiac muscle has several structural differences from skeletal muscle fibers:

1. Cardiocytes are smaller in diameter and length than skeletal muscle fibers.
2. Cardiocytes generally have a single, centrally located nucleus, although occasionally a cell may have two or more nuclei. In comparison, skeletal muscle fibers are multinucleated.
3. T tubules are shorter and broader, and they lack a triad. The T tubules encircle the sarcomere at the Z-line rather than at the overlap between thin and thick filaments.
4. The SR lacks terminal cisternae.
5. The sarcoplasm of cardiocytes contains a large number of mitochondria since cardiac muscle is almost exclusively dependent on aerobic metabolism.
6. Cardiocytes connect with each other at specialized junctions called intercalated (intercal = to insert between) discs.

Smooth muscle

Smooth muscle, also called nonstriated or involuntary muscle, can be found surrounding the blood vessels, digestive tract, urinary system, reproductive system, and respiratory system. It can be found in the form of bundles or sheets around other tissues.

Smooth muscle cells are long and slender, varying from 5 to 10 μm in diameter and 30–200 μm in length, with a single, centrally located nucleus. There are no T tubules, and the sarcoplasmic reticulum is not as well organized as in skeletal and cardiac muscle. The source of Ca^{2+} for smooth muscle contraction is mostly the extracellular space. To facilitate the entry of Ca^{2+}, the sarcolemma of smooth muscle has in-foldings called caveolae that increase the surface area.

Smooth muscle also lacks the well-organized connective tissue sheaths found in skeletal muscle. There is an endomysium found between smooth muscle cells that is secreted by the smooth muscle cells and that contains blood vessels and nerves.

While smooth muscle contains actin and myosin, it **lacks myofibrils** and sarcomeres that cardiac and skeletal muscles possess. As a result, smooth muscle lacks striations, hence the name smooth or nonstriated muscle.

Thick filaments are found throughout the smooth muscle cell. Cross bridges are more numerous in smooth muscle since they are found along the entire length of the myosin filament, which is also longer than in skeletal muscle. In addition, scattered throughout the sarcoplasm is a network of intermediate filaments composed of the protein desmin. Attached to the intermediate fibers are structures called **dense bodies**.

Types of smooth muscle

There are two types of smooth muscle: single-unit smooth muscle and multiunit smooth muscle.

1. **Single-unit smooth muscle**. Single-unit smooth muscle, also called visceral smooth muscle, is widely distributed throughout the body. The cells are electrically coupled by gap junctions, allowing an electrical impulse to move between cells. Since the cells are electrically connected, they function as a unit in which an entire sheet of cells are interconnected. Such muscle is found along the wall of the digestive tract, the gall bladder, the urinary bladder, and most other internal organs.

This type of muscle is often found as two layers: a longitudinal layer running parallel to the long axis of the organ and a circular layer in which the fibers encircle the organ.

2. **Multiunit smooth muscle.** In contrast to single-unit smooth muscle, individual cells are separated from one another in multiunit smooth muscle. Such cells generally lack gap junctions. This necessitates that each cell must be innervated by a nerve ending. Therefore, such muscle has a richer nerve supply than single-unit smooth muscle. This type of muscle is found in the iris of the eye, along portions of the male reproductive tract, surrounding the walls of large arteries, and in the arrector pili muscle of the skin.

CHAPTER-VII

MUSCULATURE OF HIND LIMB

Pelvis is firmly connected to the trunk by means of ilio-sacral joints and its ligament. Muscles of pelvic girdle are not so numerous and not so active as muscles of shoulder girdle

Muscles are divided into:

- **Girdle musculature**: Girdle muscles establish the connection between the limbs and the trunk and support the limb. Includes:
    - Psoas minor
    - Iliopsoas muscle (Iliacus and Psoas major)
    - Quadratus Lumborum muscle
- **Intrinsic musculature**: Unite only individual parts of the skeleton of the limb and accordingly they only move the joints of the extremities. They are divided into several functional groups as:
    - Muscles of Hip joint
        - Outer hip muscles
        - Muscles of Buttock
        - Medial muscles of thigh
        - Deep muscles of hip joint
    - Special muscles of Stifle joint
    - Muscles of Hock joint
        - Flexors and Extensors of Hock joint
    - Muscles of digits
        - Long muscles of digits (Extensors & Flexors)
        - Short muscles of digits

Psoas Minor: Originates ventrally from bodies of last 2-3 thoracic and first 4-5 lumbar vertebrae and insert over psoas tubercle of ilium. Ventral surface of this muscle is covered by caudal vena cava, abdominal aorta and external iliac artery. Ureter is applied to its lateral border

Iliopsoas muscle: Consist of lumbar part known as Psoas major and iliac part known as Iliacus muscle

- Psoas major originates ventro-laterally from bodies & transverse processes of lumbar vertebrae and last 2-3 thoracic vertebrae. Its tendon lies in groove between two bellies of Iliacus muscle which originates from ventral surface of wing of sacrum and shaft of ilium
- Insert on lesser trochanter of femur

Quadratus Lumborum: Originates ventrally from transverse processes of lumbar vertebrae and vertebral extremities of last rib and insert over wings of sacrum

Muscles acting on Hip Joint

Muscles acting on hip joint are very powerful. This is due to the fact that hip is very much more mobile than shoulder and hip has more important role of transmitting forward propulsive power into the trunk.

Outer Hip muscles

- Includes:
- Gluteus muscle (Extensor of Hip Joint)
  - Superficial
  - Middle
  - Deep
- Tensor Fasciae Latae (Flexor of Hip Joint)
- These muscles are innervated by cranial and caudal gluteal nerves

Gluteus Muscle

Superficial gluteal is separate structure only in carnivores. In ruminants and pigs, it is fused with the carnial part of biceps femoris muscle to form the **gluteobiceps muscle.** In equines, it is connected to caudal part of Tensor Fasciae Latae muscle.

The middle gluteal muscle lies on the proximal lateral hip region (gluteal surface of the ilium) between the tensor fasciae latae and superficial gluteal muscles. It consists of superficial part and a deep part known as **gluteus accessorius.**

- Origin: Tuber coxae, wing of the ilium, and lateral surface of the sacrosciatic ligament.
- Insertion: Greater trochanter
- Action: Extends the hip and abducts the limb

The deep gluteal muscle lies deep to the middle gluteal muscle and ventral to the course of the large sciatic nerve on the lateral surface of the sacrosciatic ligament. It has a fan-shaped appearance and is covered by a glistening aponeurosis.

- Origin: Tuber coxae, ischiatic spine, lateral and ventral surface of the body of the ilium.
- Insertion: Greater trochanter.
- Action: Extends the hip joint and abducts the limb.

Tensor Fasciae Latae Muscle

The tensor fasciae latae is triangular in shape. It is located laterally distal to the middle gluteal muscle and wraps around the proximal cranial thigh region. It fills the gap between the tuber coxae and the stifle joint.

- Origin: Tuber coxae and neighboring parts of the ventral surface of the ilium.
- Insertion: Patella and cranial surface of the tibia by the way of broad connective tissue sheet known as fascia lata and lateral femoral fascia.
- Action: Flexes the hip and tenses the lateral femoral fascia.

Muscles of Buttock/Hamstring Muscles

The hamstring muscles include the biceps femoris, semitendinosus and semimembranosus muscles. In ruminants, the superficial gluteal muscle fuses with the biceps femoris to form the **gluteobiceps muscle.**

Biceps femoris

Ruminants have no separate superficial gluteal muscle. The equivalent muscle fuses with the biceps femoris muscle to form the gluteobiceps muscle.

- Origin: Tuber ischii, gluteal fascia, and ventral surface of ischium.
- Insertion: Three sites: the lateral patellar ligament, cranial tibia, and common calcanean tendon.

- Action: Has multiple complex actions. In addition to extending the hip joint, this muscle can also extend or flex the stifle joint depending if the limb is fixed (bearing weight) or free. It also acts to extend the hock joint.

Semitendinosus

The semitendinosus muscle lies between the gluteobiceps muscle cranially, and semimembranosus muscle caudally. Its major action is to extend the hip. Additionally, it has flexor and extensor actions on the stifle and the hock joints, respectively. In ruminants, the semitendinosus has a pelvic head but the vertebral head is absent. In horses, the semitendinosus muscle has vertebral and pelvic heads that arise from caudal vertebrae and the ischiatic tuberosity, respectively.

- Origin: Ischiatic tuberosity (pelvic head).
- Insertion: Medial proximal tibia, and on the tuber calcaneus via the common calcanean tendon.
- Action: Extends the hip, flexes the stifle, and extends the hock.

Semimembranosus

The semimembranosus muscle lies between the semitendinosus cranially, and adductor muscle on the medial aspect of the thigh. On the medial thigh, it is covered by the gracilis muscle. The semimembranosus muscle is shorter than the semitendinosus and its prime action is to extend the hip.

- Origin: Ischiatic tuberosity (pelvic head).
- Insertion: Medial epicondyle of the femur, caudal to the medial collateral ligament of the stifle joint.
- Action: Extends the hip joint.

Medial Thigh Muscles

1. **Sartorius:** Long, relatively flat muscle in the cranio-medial thigh region. It has cranial and caudal heads that are separate at their origin but are fused distally. Only at its origin does it appear to have two heads. The sartorius muscle flexes the hip and helps to adduct the limb.
   Origin: Psoas minor tendon and iliac fascia (cranial head), and body of the ilium (caudal head).
   Insertion: Medial patellar ligament, and fascia on the medial aspect of the stifle joint.
   Action: Adducts the limb and flexes the hip joint.

2. **Gracilis:** Most superficial muscle on the medial thigh. It is a broad flat muscle that arises from the symphysial tendon. The symphysial tendon is a condensation of connective tissue on the ventral surface of the pelvic floor (pelvic symphysis). It is a caudal extension of the prepubic tendon, the primary insertion tendon for the rectus abdominis muscle. The symphysial tendon serves as the origin for the adductor muscles, and contributes to suspension of the udder in the female
   Insertion: Medial patellar ligament, medial and cranial proximal border of the tibia.
   Action: Adducts the limb (main action).

3. **Pectineus:** Thin muscle which lies between the sartorius muscle cranially, and the gracilis and adductor muscles caudally. The pectineus muscle forms the caudal boundary of the femoral triangle.
   Origin: Pectin and prepubic tendon.
   Insertion: Medial epicondyle of the femur.
   Action: Adducts the hind limb.

4. **Adductor:**
   Origin: Pelvic symphysis (by the symphysial tendon).
   Insertion: Medial proximal femur.
   Action: Adducts the limb (major action).

5. **External Obturator Muscle:** In ruminants, the external obturator muscle has intra-pelvic and extra-pelvic parts. It lies deep to the origin of the adductor muscle and covers the ventral and dorsal surfaces of the obturator foramen. In other domestic animals, the intra-pelvic portion of the external obturator is a separate muscle called the internal obturator muscle.

Muscles Acting on the Stifle Joint

1. **Quadriceps Femoris**

   The quadriceps femoris muscle is the largest muscle on the cranial surface of the femur. It comprises four heads: the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius. The three vastii (vastus lateralis, vastus medialis, and vastus intermedius) muscles of the quadriceps femoris muscle originates from the proximal femur but the rectus femoris originates from a location on the body of the ilium cranial to the acetabulum. The four heads of the quadriceps femoris fuse distally and insert by three patellar ligaments on the tibial tuberosity

   The quadriceps femoris is a prime and powerful extensor of the stifle joint. The rectus femoris is the only head of the quadriceps femoris muscle that has a flexor action on the hip joint.
   Origin: Proximal lateral and medial surface of the femur (vastus lateralis, vastus intermedius, and vastus medialis), and body of the ilium cranial to the acetabulum (rectus femoris).
   Insertion: Tibial tuberosity via three patellar ligaments.
   Action: Extends the stifle (all four heads) and flexes the hip (rectus femoris only).

2. **Popliteus**

   The popliteus muscle lies on the proximo-caudal surface of the tibia deep to the lateral and medial heads of gastrocnemius muscle
   Origin: Popliteal fossa and later condyle of the femur.
   Insertion: Caudo-medial surface of the tibia.
   Function: Flexes the stifle.

Muscles Acting on the Hock and Digits

The muscles are divided broadly into two groups. The cranio-lateral group includes muscles that only flex the hock, and others that flex the hock and extend the digits. The muscles in the cranio-lateral group are innervated by the common peroneal (fibular) nerve, the cranial division of the sciatic nerve.

The second group is the caudo-medial group that comprises muscles that extend the hock only, and others that extend the hock but also flex the digits. The muscles in the caudomedial group are innervated by the tibial nerve.

Flexors of hock

1. **Tibialis cranialis**

   The cranial tibial muscle lies on the dorsal (cranial) surface of the tibia deep to the fibularis tertius and long digital extensor muscles.
   Origin: Proximal lateral surface of the tibia and fibula.

Insertion: First tarsal bone, fused second and third tarsal bones, and proximo-medial surface of the large metatarsal bone

2. **Peronaeus/Fibularis tertius**

The belly of the fibularis (peroneus) tertius muscle is the largest and most superficial and cranial of the craniolateral group. Unlike the horse, in which the fibularis tertius is purely tendinous, in ruminants it is fleshy.

Origin: Extensor fossa of the femur

Insertion: The tendon of insertion has 2-3 branches. Lateral tendon inserts on the dorsal surface of the large metatarsal bone. The medial tendon inserts on the first tarsal and fused tarsal bones II and III, and the plantar aspect of the large metatarsal bone.

3. **Peronaeus Longus**

The fibularis (peroneus) longus is a triangular muscle lying caudal to the long digital extensor muscle.

Origin: From the lateral tibial condyle, rudimentary fibula, and the lateral collateral ligament of the stifle.

Insertion: Fourth tarsal bone, and plantar aspect of the large metatarsal bone.

Function: Flexes the hock.

Extensors of Hock

1. **Gastrocnemius muscle**

Large muscle that lies on the caudal aspect of the stifle joint and proximal tibial. It is known as the calf muscle in humans. The gastrocnemius has lateral and medial heads that join to form a common insertion tendon. The large tibial nerve courses distally between the two heads of the gastrocnemius muscle.

Origin: Lateral and medial supracondylar tuberosity.

Insertion: Calcanean tuber.

2. **Soleus muscle**

Small muscle that originates from the rudimentary fibula. The soleus is seen on the proximo-lateral surface of the lateral head of the gastrocnemius muscle.

Origin: Rudimentary fibula.

Insertion: Joins the calcanean tendon.

Function: Helps in extending the hock.

- Two heads of gastrocnemius and soleus are collectively known as *triceps surae.* Their common tendon is known as *Achilli's tendon or Calcanean tendon*

Extensors of Digits

1. **Long Digital Extensor**

The long digital extensor muscle fuses with the fibularis tertius and is partially covered by the fibularis (peroneus) tertius muscle. The long digital extensor muscle has medial (deep) and lateral (superficial) bellies that give medial and lateral digital extensor tendons.

Origin: Extensor fossa of the femur.

Insertion: Medial tendon (from the medial belly) inserts on the dorsal surface of the middle (P2) and distal (P3) phalanx of the medial digit. The lateral (middle) tendon (from the lateral belly) bifurcates into two thinner tendons that insert on the extensor processes of P3 on both the third (medial) and fourth (lateral) digits.
Function: Flexes the hock joints and extends the digital joints.

2. **Extensor brevis**

The short (brevis) digital extensor muscle is a small muscle situated on the dorsal surface of the hock. The tendon of the short digital extensor joins that of the long digital extensor

3. **Lateral Digital Extensor**

The lateral digital extensor muscle lies caudal to the fibularis longus muscle
Origin: Lateral collateral ligament of the stifle and by extension from the lateral epicondyle of the femur.
Insertion: Middle (P2) and distal phalanx (P3) of lateral digit (digit IV).
Function: Flexes the hock and extends digital joints of the lateral digit.

Flexors of Digits

1. **Superficial Digital Flexor**

In the proximal leg, the SDF muscle lies deep to the lateral and medial heads of the gastrocnemius muscle. The SDF in ruminants is fleshier than in the horse but has a tendinous band that courses within the muscle. It is very tendinous in the horse.
Origin: Supracondylar fossa
Insertion: Calcanean tuber proximally, and middle phalanges (P2) of digits III and IV distally.
Function: Extends the hock, and flexes the fetlock and pastern joints.

2. **Deep Digital Flexor**

DDF muscle has three heads designated

- Flexor Hallucis Longus: Applied directly to the caudal surface of tibia
- Tibialis Caudalis: Lies behind Flexor Hallucis
- Flexor Digitalis Longus: Towards medial aspect

Distally in the metatarsal region, the combined tendons of the DDF muscle lie deep to the SDF
Origin: Lateral and caudal proximal surface of the tibia.
Insertion: Distal phalanges (P3) of both digits III and IV.
Function: Flexes the digital joints of digits III and IV muscle

Common Calcanean Tendon: The common calcanean tendon is formed principally by the tendons of the gastrocnemius and SDF muscles with contribution from soleus, gluteobiceps, and semitendinosus muscles.

CHAPTER-VIII

BODY CAVITIES

Thoracic Cavity: Laterally compressed cone shaped

- **Roof:** Thoracic vertebrae with intervertebral discs, thoracic muscles (long. dorsii), proximal end of ribs
- **Lateral Walls:** Ribs and intercostal muscles
- **Floor:** Sternum, distal end of costal cartilage, muscles such as transverse thoracis, pectoral etc.
- **Thoracic Inlet:** small, oval vertically elongated anterior opening of thoracic cavity
- **Posterior wall:** Diaphragm
    - **`Three openings:** Hiatus aorticus, hiatus oesophagii and caval foramen
- **Contents:** Heart, lungs, thoracic part of oesophagus, trachea, beginning of large vessels, lymph nodes, nerve; Thoracic part of thymus in young

Abdominal Cavity: Largest body cavity, extends from diaphragm to pelvic inlet

- **Roof:** Lumbar vertebrae with intervertebral discs, sublumbar muscles, crura of diaphragm
- **Lateral Walls:** Abdominal muscles (Ob. Abd. externus, Ob. Abd. internus and tr. Abdominis)
- **Floor:** Two rectus abdominis muscles, linea alba and part of xiphoid cartilage
- **Openings:**
    - Diaphragm (3 openings)
    - Inguinal regions – femoral ring, inguinal opening, umbilical opening in fetus
- **Contents**: -Stomach, Intestines, Liver, Pancreas, Spleen, Gall bladder, Kidneys, adrenal, ureter, part of genital system
- **Paralumbar fossa**: Non osseus part of abdominal cavity
- **Flank**: triangular depresseion in in the upper part of lateral wall of abd cavity

Pelvic Cavity: Smallest body cavity, continue infront with abdominal cavity and pelvic brim

- **Roof:** Sacrum and 3-4 coccygeal vertebrae
- **Lateral Walls:** Shaft of ilium, sacro-sciatic ligament
- **Floor:** Pubis and ischium
- **Contents:** Part of intestines, int genital organs
- **Pelvic brim/ inlet:**
    - Base of sacrum above
    - Ilio-pectineal line laterally
    - Anterior border of pubis below
- **Pelvic outet:**
    - 3rd coccygeal vertebrae above
    - Sacro-sciatic ligament laterally
    - Ischial arch below

Lining of Body Cavities:

- Lined by serous membrane (mesothelium?), the **parietal layer** and the remainder of membrane is reflected over organs contained in the cavity (the **visceral layer**)
- **Pleura:**
    - **Lining serous membrane of thoracic cavity**
    - Two in number (right and left), so two distinct pleural sac

        - Each pleura lines one side of thorax and one half of diaphragm
    - Parietal and visceral pleura,
    - Apex of pleural sac is known as **Cupula pleurae**
    - Interpleural space or place between two pleural sac is called **Mediastinum**
        - **Cranial, Middle and Caudal mediastinum**
    - **Parietal pleura**: Lines wall of thoracic cavity
        - Costal pleura: Lines inside of lateral thoracic wall
        - Diaphragmatic pleura: reflected over thoracic surface of diaphragm
        - Mediastinal pleura: part covering structures in the mediastinum
        - Connecting pleura: double fold of pleura eg. Pulmonary ligaments
- **Peritoneum:**
    - Largest serous membrane
    - Lines abdominal and part of pelvic cavity
    - **Peritoneal cavity**: Space between parietal and visceral peritoneum
        - **Peritoneal cavity closed in male; but in female oviductal opening**
        - Although cavity is single but two sacs
            - Greater sac – main cavity
            - Lesser sac - diverticulum

        These two sacs communicate through ***Epiploic foramen*** or ***foramen of Winslow***

    - **Connecting folds of peritoneum:**
        - Connects different organs or parts to hold the organs in position and enclose vessels
        - **Omentum**: from stomach to other viscera
            - Greater omentum: greater curvature of stomach to dorsal abdominal wall
            - Lesser omentum: lesser curvature of stomach to liver
        - **Mesentery**: Different part of intestines dorsal abdominal wall
        - **Ligaments**: passed between viscera and connect to wall eg. Broad ligament,

Oesophagus

- Musculomembranous tube extends from pharynx to stomach
- Divided into cervical, thoracic part and abdominal part (abd part absent in cattle absent due close apposition of stomach to diaphragm)
- Cervical part begins at the pharynx in the median line behind the aditus oesophageus above the anterior border of cricoid cartilage, passes backward and downward on the dorsal surface of trachea till 3rd or 4th cervical vertebra.
- At this level crosses the trachea obliquely, placing itself along left side, passes backward enter the thoracic cavity thorugh thoracic inlet and continues the course as thoracic part till the level of 3rd or 4th thoracic vertebra where it gains the dorsal surface of trachea and continues till tracheal bifurcation
- As it passes through middle mediastinum, it pushed to the right of the aortic arch and lies to the right of median plane
- Then passes upward and backward in the mediastinum, inclines again to the left of median line and enters the hiatus oesophageus of the diaphragm
- Just after entering the abdominal cavity terminates at the **dome shaped area of rumino-reticular wall, the atrium ventriculi**.
- Muscle striated through out length
- Mucous membrane thrown into numerour longitudinal fold when the tube is empty

Horse

- Longer, narrower and less dilatable, length about 1 – 1.2 m
- Have cervical, thoracic and abdominal part, the abdominal part is very small (about 2.5 cm)
- Also related to guttural pouch at origin
- Muscular coat striped upto the level of heart rest unstriped

Dog

- Wide and dilatable except at origin
- Constriction at the beginning due to the presence of submucosal gland on its ventral wall
- Small abdominal part
- Muscular fiber striped throughout

STOMACH

- Most dilated part of alimentary canal and very capacious
- Lies between termination of oesophagus and beginning of small intestine
- Occupy almost 3/4th of abdominal cavity
- Four compratments: Rumen, reticulum, omsasum and abomasum
- Rumen, reticulum and omsasum: lined by stratified sq. epithelium (**Forestomach**)
- Abomasum: true stomach, lined by glandular epithelium
- Capacity of stomach about 125 – 200 liter
    - At birth: abomasum is the largest compartment
    - Adult: Rumen – 80%; reticulum – 5%; omasum and abomasum – 7-8% each

Rumen

- Occupy most of the left half of abdominal cavity except small space for spleen and part of right half of abdominal cavity
- Extends from lower part of 7th/8th intercostal space to pelvic inlet
- Present 2 surfaces, 2 border, 2 curvature and 2 extremities
- **Parietal (left) surface:**
    - Smooth, convex and marked by left longitudinal groove, which indicates division of rumen into dorsal and ventral sac
    - Related to spleen, liver and diaphragm
- **Visceral (right) surface:**
    - Irregularly smooth, concave and marked by right longitudinal groove
    - Some time right longitudinal groove is divided into dorsal and ventral branch and enclose an elongated swelling, the **INSULA RUMINIS**
    - Related to omasum, abomasum, intestines, liver, pancreas, left kidney, left adrenal, aorta, part of venacava etc.
- **Dorsal curvature:**
    - Convex, round and attached to left sublumbar muscles and crura of diaphragm by peritoneum
- **Ventral curvature:**
    - Convex, round and related to abdominal floor
- **Cranial extremity:**
    - Lies near diaphragm
    - Divided by anterior transverse groove into dorsal and ventral blind sac
    - Dorsal surface of dorsal blind sac with reticulum form a dome line rumino-reticular area, the atrium ventriculi where oesophagus open

- Remun and reticulum externally demarcated by rumino-reticular groove and internall by rumino-reticular fold

- **Caudal extremity:**
  - Lies near pelvic brim
  - Divided by posterior transverse groove into dorsal and ventral blind sacs, which are marked off from remainder of rumen by dorsal and ventral **coronary groove**
  - Rright and left longitudinal groove connected posteriorly by posterior transverse groove
- **Interior**:
  - Rumen is divided into dorsal and ventral sac by muscular fold called **PILLARS** which project into the cavity as shelf like process
  - Pillars corresponds to the groove on external surface
  - Anterior and posterior pillars are joined by left and right pillars, hence the circle of constriction is complete
  - Posterior pillar branches on either side to form dorsal and ventral coronary pillars, which mark off posterior blind sac from main cavity
  - Anterior dorsal sac communicate with the reticulum while the remaining 3 sacs are blind
  - Mucous membrane marked by papillae which are conical, rounded and gives appearance of **Turkish towel**
  - Papillae well developed in the region of blind sacs, whereas the pillars lack the papillae
- **Remino-reticular fold:**
  - Pillar partially separating the reticulum from the cranial sac of rum, and has ruminal papillae on the caudal face and reticular crest (honey comb) on cranial face

Reticulum:

- Smallest compartment, extends from 6^{th} to 8^{th} rib
- Placed between diaphragm & liver infront and cranial extremity of dorsal sac of rumen behind
- Present 2 surfaces, 2 curvature and 2 extremities
- **Parietal surface**: convex and related to diaphragm and liver
- **Visceral/ posterior surface**: flat, lies against cranial extremity of rumen; dorsally this surface continue with rumen
- Greater curvature: is ventral border which is convex and lies against diaphgram
- Lesser curvature: is dorsal, concave, towards right side and connected with omasum bu reticulo-omasal orifice
- Interior of reticulum divided by high folds of mucous membrane into polyhedral cells which gives the characteristic **honeycomb** appearance of reticulum
- The mucous membrane of rumino-reticular orifice present some claw like curved horny papillae called **UNGIFORM PAPILLAE**

Omasum:

- Roughly oval in shape and compressed from left to right
- Situated at the level between 7^{th} – 11^{th} rib at right side of median plane
- Present 2 surfaces, 2 curvature and 2 extremities
- **Parietal/ right surface**: related to diaphragm and live
- **Visceral or left surface**: related to rumen, reticulum and abomasum
  - Reticulo-omasal and omaso-abomasal orifice present at upper part of this surface
- Greater curvature: is superior and convex
- Lessser curvature: is inferior and concave, faces cranially and related to reticulum
- Reticular extremity: constricted and form neck of omasum through which communicate with reticulum
- Abomasal extremity: Continuous with abomasum

- Interior: interiors of omasum is occupied by about 100 longitudinal folds, the **OMASAL LAMINAE** which are attached to greater curvature
    - Free border of laminae are concave and look towards lesser curvature
    - About a dozen of the laminae are larger, in between these there are intermediate one and in between smaller and so (i.e primary, sec., tertiary and quarternary type)
    - The laminae are studded with rounded horny papillae

Abomasum

- True stomach
- Elongated, curved and lies mostly on the abdominal floor
- Anterior/ fundic part related to reticulum and lies between omasum and ventral sac of rumen
- Terminal part/ pylorus turns backward and upward to continue with duodenum
- Parietal surface related to abdominal floor while visceral surface is related to rumen and omasum
- Greater curvature faces downward and greater omentum attaches this surface
- Lesser curvature faces upward and related to omsaum and lesser omentum attaches this
- Interior: 3 glandular area
- Cardiac glands: narrow zone around omaso-abomasal orifice
- Fundic gland region: larger and present about a dozen oblique folds extended from lesser curvature to greater curvature in spiral manner
- Pyloric gland region: mucous membrane devoid of any fold but wrinkled in appearance
- **Torus pyloricus:** thick round prominence of mucous membrane at upper part of pyloric sphincter.

Sphincter: Ring like band of muscle, closing a natural orifice or constricting and controlling a passage.

- Formed by thickening of inner circular muscle fiber layer

Intestine

Small Intestine: Duodenumn, Jejunum and Ilium

Large Intestine: Caecum, colon and Rectum

Liver:

Ligaments

Surfaces

Lobes

CHAPTER-IX

DIGESTIVE SYSTEM OF FOWL

Mouth:

Triangular in shape, vestibule absent, lips and cheeks absent and replaced by beaks.

Teeth absent.

Hard palate is narrow and triangular which presents median ridge anteriorly and median slit posteriorly which communicates with the nasal cavity.

Saoft palate absent.

Mouth is directly continuous with pharynx.

Pharynx:

On the roof of pharynx there is common opening for left and right auditory tube.

Floor presents a median slit, the entrance to larynx.

Epiglottis absent.

Tongue:

Narrow, rigid and triangular, Base is attached to well developed hyoid bone.

There is presence of a median groove on dorsal surface rostrally.

Apex pointed, dorsal surface of root crossed by a row of pointed horny lingual papillae directed caudally.

Salivary Glands:

There area no. of salivary glands.

The duct of maxillary, palatine, cranial lingual, submandibular and angular salivary glands open into the mouth cavity where as the duct of spheno-pterygoid, caudal lingual, caudal submandibualr and laryngeal open into the pharynx.

Oesophagus:

Thin walled with wide lumen.

Dilates into a sac like structure on right side near the thoracic inlet called Crop or Inglu vilus which serves as temporary store house of food.

Secretory gland except mucous gland absent from crop.

The oesophagus has small abdominal part that terminate at proventriculus.

Stomach:

The stomach consists of two part glandular stomach the Proventriculus and muscular stomach the Gizard.

Proventriculus – thick walled ovoid or fusiform structure connected posteriorly with gizzard by a constriction the Isthmus. A no. of papillae project into the lumen where duct of submucosal glands open.

Gizard – thick walled, muscular and larger of the two.

Oval in form and look like biconvex disc.

Presents two orifices placed side by side for communication with the proventriculus and duodenum.

Mucous membrane lining thrown into ridges.

Small Intestines:

Duodenum:

Length 22 cm – 35 cm, diameter 0.8 – 1.2 cm.

Has ascending and descending part held together by fold of mesentery.

Pancrease is placed in the loop formed by ascending and descending part of duodenum.

Bile duct and pancreatic duct open near by each other in the ascending part at termination of duodenum.

Jejunum and Ileum:

85 cm – 120 cm long, arranged in coils on right side of body cavity.

In the middle of jejunum a short closed remnant of yolk sac is present which is known as Meckel's Diverticulum.

Large Intestines:

Consists of Caeca and colon.

Caeca:

Connected to GI tract at the junction between ileum and colo-rectum.

Each caeca about 15 cm long and extends cranially and caudally and divided into proximal, middle and distal part.

Proximal part is narrow and connected with instestine.

Middle part is wide and distal part terminates as apex.

Wall of proximal part dcontain lymphoid tissue known as Caecal tonsil.

Colo-rectum:

10 cm long, straight part of intestine extend from ileum to cloaca and situated in the left side of abdominal cavity.

Caudal part expands to form cloaca which opens outside through an opening the Vent.

Cloaca:

Tubular cavity common to digestive, urinary and genital tracts and open outside through vent.

Comprises of three compartments coprodeum, urodeum and proctodeum.

Coprodeum is the first compartment where colo-rectum opens and may be separated from colo-rectum by mucous membrane fold.

Urodeum is the 2nd and smallest compartment, ureter opens dorsally and genital ducts laterally in the urodeum.

Proctodeum is the last compartment, Bursa of Fabricius opens on its dorsal aspect.

CHAPTER-X

SYSTEMIC HISTOLOGY

Female Reproductive System

The ovaries, oviducts, uterus, vagina, and vulva are the major components of the mammalian female reproductive system.

Ovaries

A simple squamous or cuboidal epithelium, **germinal epithelium,** covers the **cortex** of the **ovary**. Beneath the epithelium is a layer of dense connective tissue, the **tunica albuginea**. A **cortical stroma,** containing ovarian **follicles** in various stages of development, lies internal to the tunica albuginea.

A **medulla** consisting of richly vascularized loose connective tissue lies internal to the ovarian cortex.In the mare, the medullary tissue is located external tothe cortex. Channels, lined by a cuboidal epithelium and called the **rete ovarii,** are conspicuous components of the medulla in carnivores & ruminants.

Primordial follicles are the least developed and most numerous follicles of the ovary. They lie just below the tunica albuginea. Each consists of a **primary oocyte** surrounded by a layer of simple squamous **follicle cells**. In response to periodic hormonal stimulation, growth is initiated in some of the primordial follicles. The earliest growing follicle, the **primary follicle,** consists of an enlarging oocyte surrounded by a layer of cuboidal cells.

Primary Follicles: The primary follicles consist of a large primary oocyte surrounded by a single layer of cuboidal follicular cells. The primary follicles are evenly distributed in ruminants and sow and occur in clusters in carnivores.

Secondary follicle: The secondary follicle consists of stratified follicular epithelium that surrounds primary oocyte and separated from it by **zona pellucida**. The stroma begins to surround the secondary follicle forming **theca folliculi**.

Mature (Graafian) Follicle: The mature follicle contains a large cavity or **antrum**, filled with follicular fluid. The primary oocyte is displaced eccentrically in a thickened area of granulosa cells called the **cumulus oophorus**. Follicular cells immediately surrounding the oocyte become columnar and radially disposed, they are termed **corona radiata**. The theca differentiates into two layers; **theca interna** and **theca externa**. The theca interna **contains an extensive blood and lymph capillary network**. The **theca externa** consists of loose connective tissue arranged around the theca interna.

Corpus Luteum

Following ovulation, the **granulosa cells** enlarge, luteinize and are transformed into the **large luteal** (lutein) **cell** of the corpus luteum. The **large lutein cells** are polygonal with spherical nuclei. **They produce progesterone**. The fibroblast-type **theca interna cells** become spherical and contribute to the **small luteal cell** of the corpus luteum. The **small lutein cells** are found peripherally or as septa like clusters. They have more lipids and fewer steroid cells type organelles than large luteal cell. The connective tissue scar remaining after regression of corpus luteum is called **corpus albicans.**

Uterine Tube (Oviduct)

The oviduct is divided into three histologically distinct regions; **infundibulum**, **ampulla** and **isthmus**. The wall of the uterine tube is formed of **mucosa-submucosa**, **tunica muscularis** and **serosa**.

The **mucosa** is highly folded with many primary longitudinal folds. The **epithelium is pseudostratified columnar with motile cilia**. Few non-ciliated secretory cells are also found among the ciliated cells.

The **lamina propria-submucosa** is a loose connective tissue layer with many plasma cells, mast cells and eosinophils.

The **tunica muscularis** consists chiefly of circular smooth muscle bundles but isolated longitudinal and oblique bundles also occur.

The **serosa** is a loose connective tissue with an outer mesothelium.

Uterus

The uterine wall is formed of mucosa-submucosa (**endometrium**), tunica muscularis (**myometrium**) and serosa (**perimetrium)**.

The **epithelium** is pseudostratified columnar and/or simple columnar. The **propria-submucosa** is highly vascular. Simple branched tubular **uterine glands** are present. The uterus of the ruminants characterized by the presence of dome-shaped prominences in the endometrium that are called **uterine caruncles**.

Uterine glands secrete uterine milk. In ewe, the caruncles are cup-shaped (i.e., dome with a central depression).

The **tunica muscularis** (myometrium) consists of a thick inner circular and an outer longitudinal layers of smooth muscle fiber, between the layers is a vascular layer consisting of large arteries, veins and lymph vessels called **stratum vasculare**.

The **perimetrium** is a loose connective tissue covered by mesothelium.

Cervix:

The cervical mucosa is highly folded. The **epithelium** is simple columnar with many mucigenous cells and goblet cells. The **lamina propria-submucosa** consists of dense irregular connective tissue containing simple tubular glands in small ruminants and sow.

The **tunica muscularis** is formed of inner circular and outer longitudinal smooth muscle layers. Elastic fibers are prominent in the circular layer.

The **serosa** is a loose connective tissue layer with an outer mesothelial covering.

Vagina

The **epithelium** is stratified squamous non-keratinized. In cow a surface layer of columnar cells and goblet cells is present in the stratified squamous epithelium. **Lamina propria-submucosa** is a loose or dense connective tissue rich in elastic fibers and lymphocytes.

Tunica muscularis consists of interlacing circular and longitudinal smooth muscle bundles. Longitudinally arranged bundles are more numerous.

Tunica adventitia is a loose connective tissue contains venous plexuses, nerve bundles and fat cells.

Vestibule and Vulva

The wall of the vestibule is similar to that of the caudal portion of the vagina. The mucosa contains both **major** and **minor vestibular glands**.

The **major vestibular glands** are compound tubuloalveolar mucous glands in the deep part of the mucosa. They occur in ruminants and queen. The glandular duct is lined by stratified squamous epithelium. The gland has no capsule and is enclosed and partly divided by the striated musculature. They produce mucous for lubrication.

The **minor vestibular glands** are scattered in the vestibular mucosa of most domestic animals. In cow, they are concentrated in the median groove cranial to the clitoris.

Clitoris

Located near the ventral commissar of the vulva. It is rich in elastic tissue. It consists of **corpus cavernosum clitoridis**, **glans clitoridis** and **preputium clitoridis**.

Corpus cavernosum clitoridis is similar in structure to the corpus cavernosum penis.

Present in ruminants and well developed in the mare.

The preputium clitoridis is a mucosal continuation.

Mammary Gland

- The mammary gland is a compound tubuloalveolar gland that is believed to be modified sweat gland. It consists of **udder** and **teats**. The udder consists of **stroma** and **parenchyma**.
- The **stroma** of the udder is formed of dense fibroelastic capsule, fibrous septa and intralobular fine connective tissue. The **parenchyma** is formed of secretory mammary alveoli and excretory lactiferous ducts.

Male Reproductive System

Testes

- **Testes** are compound tubular glands that are invested by a thick capsule of dense irregular connective tissue, the **tunica albuginea**. Capsule is rich in smooth muscle in the stallion. Surrounded by peritubular cells. The tunica albuginea is covered by peritoneum, **the visceral layer of the tunica vaginalis**.
- Septa of connective tissue extend from the tunica albuginea into the testis, partially or completely dividing the testis into lobules. These septa are thin in ruminants and thicker in the carnivore, stallion, and boar. Centrally, the septa may merge with the loose connective tissue of the **mediastinum testis**.
- Leydig cells are found in clusters or cords. Their number varies with age and species. The interstitial cells are acidophilic and irregularly polyhedral with spherical nucleus and a prominent nucleolus.
- Interstitial cells are characterised by large amounts of smooth ER and abundant, typically elongated mitochondria with tubular projections of the inner membrane. In the mitochondria, cholesterol is converted into pregnenolone. Production of androgens (testosterone) by interstitial cells is stimulated by luteinising hormone (LH) produced by the hypophysis.

- Sertoli cells (70–80 μm high) extend from the basement membrane to the tubular lumen. They are pyramidal in shape, tapering towards the lumen from a broad base resting on the basement membrane. Sustentacular cells lie between the differentiating germ cells with which they are in structural and functional contact through specialised intercellular. The ovoid to ellipsoid nucleus is euchromatic and is typically located basally. The nucleolus is reticulated (net-like).

Epididymis

- It has three macroscopically distinguishable components: the head (caput), body (corpus) and the tail (cauda). The epithelium of the epididymal duct is pseudostratified columnar (epithelium pseudostratificatum columnare). Distally the height of the epithelium decreases.

- The epithelium is surrounded by smooth muscle which becomes distinctly thicker in the tail. Adjacent segments of the duct wall are connected by loose connective tissue containing macrophages, leucocytes and abundant vessels and nerves. The density of capillary bundles increases markedly in the tail.

Urinary System

Kidneys

- Kidney is composed of stroma and parenchyma. The stroma is represented by outer capsule. Parenchyma is differentiated into an outer cortex and an inner medulla.

- The renal cortex comprises two distinct regions: **cortex proper** or **cortical labyrinth** and the **medullary rays**. The cortical labyrinth contains renal corpuscles, proximal and distal convoluted tubules and arched collecting ducts.

- The medullary rays are formed of descending and ascending limbs of nephron (loop of henle) loop and straight collecting tubules.

- The **medulla** is deep to the cortex in it there are no renal corpuscles, only tubules.

- The nephron is the structural and functional unit of the kidney

- **Renal corpuscle** (which encloses the glomerular tuft), the **proximal convoluted tubule**, the **loop of Henle**, a **distal convoluted tubule**, and a short **collecting tubule**.

- The renal corpuscle is the first part of the nephron. The corpuscle has two components: the tuft of capillaries constituting the glomerulus; and the outside wall, which creates a well-defined space around the tuft, the Bowman's space.

- Most of the cortical tissue around the renal corpuscles is proximal tubules. These are made of ***tall cuboidal epithelium*** with ill-defined cell boundaries and spherical nuclei located near the base. The luminal surface of the cells has a distinct and prominent ***microvillous brush border*** which almost completely fills the lumen.

- The walls of the DT, like those of the PCT, are of simple cuboidal epithelium, but **they *lack* a brush border**. They also tend to be ***larger in cross section than the PCT.***

- The loop of Henle is made of *simple squamous epithelium.* A loop can be identified fairly easily by its thin outer wall and empty lumen.
- The collecting tubule receives the filtrate from the DT and carries it down through the medulla and out to the world beyond. Collecting tubules are quite large, with walls formed of cuboidal epithelium. They're larger than the DT and the nuclei of their mural cells bulge somewhat into the lumen. *The cells themselves are rather pale staining* compared to those of the other tubules.

Ureter

- The wall of the ureter is formed of mucosa-submucosa, tunica muscularis and adventitia or serosa.
- The mucosa is folded and is lined with transitional epithelium that rests on fibro-elastic connective tissue propria-submucosa which in horse, donkey and mule contains simple branched tubuloalveolar seromucoid glands, the secretion of these glands impart a characteristic turbid appearance for the urine of these species.
- The tunica muscularis is formed of three ill-defined layers; inner and outer longitudinal and middle circular layers of smooth muscle fibers separated by loose connective tissue.
- Near the bladder, the middle layer disappears
- The outer coat of the ureter may be either adventitia or serosa depending on the level of the sections.

Urinary bladder: The wall of the bladder is similar to that of the ureter, but there are said to be three layers of smooth muscle: inner and outer layers are longitudinal, and the middle more or less circular.

- There is also a fair amount of elastic connective tissue in the wall to provide for elasticity and distensibility.
- The lining is urinary epithelium, extensively folded and puckered in the relaxed state.
- The mucosa of the urinary bladder is lined with transitional epithelium.
- The lamina propria-submucosa is loose fibro-elastic connective tissue layer.
- The muscularis mucosa is absent except ox.
- The tunica muscularis is formed of interwoven muscle bundles.

The final passageway, the **urethra**, which in males does dual duty as part of the urinary tract and the reproductive system.

- The end of penile urethra has a lining of stratified squamous epithelium; farther up in the pelvic urethra, nearer the bladder, the lining is still urinary epithelium.
- The female urethra is the part of the urinary passage and conducts the urine from the urinary bladder to the exterior.

- The urethral epithelium begins with transitional type that changes to stratified columnar and ends by non-keratinized stratified squamous epithelium.
- The urethral epithelium may show intraepithelial mucous secreting cells and subject to species variations.
- The fibro-elastic propria-submucosa is permeated by cavernous spaces with species differences.
- The tunica muscularis is represented by bundles of smooth muscles and striated fibers that form inner circular and outer longitudinal layers in the proximal part of the urethra

CHAPTER-XI

MUSCLES OF THORACIC LIMB

The muscles of the thoracic limb are divided into two groups: **extrinsic and intrinsic** muscles. **Extrinsic muscles** attaches thoracic limb to other parts of the body like head, neck, etc. eg. Trapezius. **Intrinscic muscles** have both the attachments on thoracic limb bones. Eg. Biceps brachii.

The forelimb is attached to the body by a group of muscles called **muscles of the shoulder girdle/ synsarcosis**. These muscles connect the forelimb with the head, neck and trunk. They are as follows:

1. Trapezius muscle (Thoracic and cervical parts)
2. Rhomboideus muscle (Cervical and thoracic part)
3. Brachiocephalicus (has two divisions, cleidocephalicus and cleidobrachialis muscles)
4. Latissimus dorsi
5. Superficial pectoral muscle
6. Deep pectoral muscle
7. Omotransversarius muscle
8. Serratus ventralis muscle (has two divisions, cervical and thoracic parts)

Trapezius muscle

It is a broad triangular muscle extending along the dorsal midline from the level of atlas to the end of the thoracic region, and covers a part of the shoulder. It consists of *cervical (trapezius cervicis)* and *dorsal (trapezus thoracis)* parts.

Origin: Funicular part of Ligamentum nuchae on the cervical region and supraspinous ligament on thoracic region.

Insertion*:* The tuberous part of the spine of the scapula and the scapular fascia.

Action*:* To elevate the shoulder as a whole.

Blood supply: Deep cervical, dorsal and intercostal arteries.

Nerve supply: Spinal accessory nerve.

Rhomboideus muscle

The rhomboideus muscle is located deep to the trapezius muscle.

Origin:

- Cervical part arises from the Ligamentum nuchae (Funicular part) and summit of 1st 3-4 thoracic spines.
- Thoracic part arises from 5^{th} – 9^{th} thoracic spines.

Insertion*:* Dorsal and medial surface of scapular cartilage.

Action*:* Cervical part draws shoulder forward and thoracic part upwards.

Blood supply: Deep cervical & dorsal branch of costo-cervical artery.

Nerve supply: Branches from 5^{th} to 7^{th} cervical spinal nerve

The hump present in some breeds of cattle is an enlargement of the rhomboideus muscle.

Brachiocephalicus muscle

The brachiocephalicus muscle is a compound muscle that extends cranio-dorsally from the distal cranial surface of the humerus to the dorsal lateral surface of the skull. In ruminants, it has three parts: the

cleido-brachialis, cleido-occipitalis, and cleido-mastoideus muscles. The cleidooccipitalis and cleidomastoideus form the **cleido-cephalicus muscle**.

The divisions of the brachiocephalicus originate from the **clavicular intersection** cranial to the shoulder region and course to brachium (**cleidobrachialis division**) or to the head (**cleidocephalicus division** that itself has cleidooccipitalis and cleidomastoideus parts). **Clavicular Intersection** is a clavicular remnant visible in front of the shoulder. In carnivores, it contains clavicle bone.

The **cleido-mastoideus forms the dorsal boundary of the external jugular groove** and is located ventral and medial to the cleido-occipitalis muscle. The ventral border is formed by the **sternomandibularis** muscle in cattle.

Origin: Clavicular intersection cranial to the shoulder joint.

Insertion: Brachium or crest of the humerus (**cleidobrachialis**), nuchal crest and funicular part of ligamentum nuchae (**cleidooccipitalis**), and mastoid process of the petrous division of the temporal bone (**cleidomastoideus**).

Actions: The brachiocephalicus muscle has complex actions that depend on several factors such as whether the limb is weight-bearing or in motion. During motion, it extends the shoulder joint. Contraction of ipsilateral muscle moves the neck and head laterally. When both left and right brachiocephalicus muscles contract they pull the head ventrally.

Blood supply: Inferior cervical, carotid and vertebral arteries.

Nerve supply: Cervical spinal and axillary nerves.

Latissimus dorsi

The latissimus dorsi (L. dorsi) is a large triangular muscle that lies dorsally caudal to the scapula and courses cranially medial to the proximal part of the humerus. ***It is FAN shaped in dogs.***

Origin: Thoraco-lumbar fascia, 11th and 12th ribs and fascia over the intercostal and external oblique muscles.

Insertion: The anterior part in common with the *teres major* to the medial (teres) tubercle of the humerus; the middle part to the aponeurosis on the deep face of the long head of triceps*;* the posterior part along with the deep pectoral to the medial tuberosity of the humerus.

The tensor fasciae antibrachii originates *from* the lateral surface of this muscle.

Action: To flex the shoulder joint

Blood supply: Thoraco-dorsal artery

Nerve supply: Thoraco-dorsal nerve

Superficial pectoral muscle

Pectoral muscles form a thick mass, which occupy the space between the lower part of the chest wall and the medial face of the shoulder and arm. They are divisible into two layers -superficial and deep. The superficial layer is again divisible into anterior and posterior muscles.

Superficial Pectoral (Pectoralis superficialis)

- **Anterior superficial pectoral** extends from the manubrium sterni to the antero-ventral part of the arm.
  - **Orgin**: Manubrium sterni.
  - **Insertion**: In common with the brachiocephalicus, to the anterior edge of the humerus (***crest of humerus***)
- **Posterior superficial pectoral:** This is closely blended with the preceding muscle and extending from the ventro-lateral aspect of the sternum to the medial side of the forearm.
  - **Origin**: The ventral and lateral aspects of the 2-6 sternebrae.
  - **Insertion**: To the crest of the humerus and fascia of the forearm.

Action: To prevent abduction of the fore-limbs when bearing weight. To adduct the forelimbs when not bearing weight.

Deep pectoral muscle

It is a large, fleshy muscle extending from the level of xiphoid cartilage forwards and upwards to the level of the shoulder joint. It is thicker than the superficial pectoral muscle.

Origin: The ventral surface of the sternum.

Insertion: Anterior part of ***Medial tuberosity of the humerus***.

Action: To adduct and retract the limb.

Blood supply: External thoracic artery.

Nerve supply: Pectoral nerves.

Omotransversarius muscle

This muscle extends from the level of the atlas to the shoulder and most part covered by brachiocephalicus except at the scapular portion where it is seen as a broad, flat muscular band. It covers pre-scapular lymph node. ***This muscle is absent in horses.***

Origin: Wing of atlas and transverse process of the axis.

Insertion*:* Scapular spine and scapular fascia.

Action*:* To pull the lower angle of the scapula forwards and upwards and to tense the scapular fascia.

Blood supply: Superior and inferior cervical arteries.

Nerve supply: Cervical spinal nerves.

Serratus Ventralis muscle

The serratus ventralis muscle is a large fleshy muscle located deep (medial) to the scapula. It has a critical role, along with other extrinsic muscles, in attaching the forelimb to the axial skeleton (ribs and cervical vertebrae). The left and right muscles act as a sling system to carry the weight of the body between the limbs along with the pectoral muscles.

Origin:

- **Serratus cervicis:** Transverse processes of last 4-5 cervical vertebrae
- **Serratus thoracis:** External surface of 4^{th} -9^{th} ribs

Insertion:

- **Serratus cervicis:** Triangular rough area at the dorso-anterior part of the ventral surface of the scapula.
- **Serratus thoracis:** Rough line at the dorso-posterior part of the ventral surface of the scapula.

Action: The two muscles act together as a sling to suspend the trunk between the two forelimbs.

Blood supply: Intercostal arteries.

Nerve supply: Long thoracic nerve.

Present below Latissimus dorsi muscle

Muscles of Shoulder

Medial group: Flex shoulder joint and adduct arm.

- Teres major
- Subscapularis
- Coraco brachialis

Lateral group: All are flexor of shoulder except supraspinatus (extend shoulder)

- Deltoideus
- Supraspinatus: Extend shoulder
- Infraspinatus: Abduct arm
- Teres minor

Teres Major

This is a flat, long muscle extends obliquely downwards and forwards between the dorsal angle of the scapula and the arm.

Origin*:* The dorsal angle of the scapula & the adjacent part of the posterior border of the scapula
Insertion*:* Teres tubercle of humerus along with Latissimus dorsi muscle
Action*:* To flex the shoulder and adduct the arm
Blood supply: Subscapular artery
Nerve supply: Nerve to teres major

Subscapularis

Origin: Subscapular fossa
Insertion: By a flat tendon to the posterior division of the medial tuberosity of the humerus. It is covered by the tendon of origin of coracobrachialis
Action: Stabilizes the shoulder joint on the medial side
Blood supply: Subscapular artery
Nerve supply: Nerves to Subscapularis

Coracobrachialis

The muscle lies partly on the medial face of the shoulder joint and the arm.

Origin: Coracoid process of scapula
Insertion:

- Medial surface of the humerus above the teres tubercle
- To the middle third of the anterior surface of the humerus

Action: To adduct the arm and flex the shoulder joint
Blood supply: Anterior circumflex artery
Nerve supply: Musculo-cutaneous nerve

Deltoideus

This muscle lies at the scapulo-humoral angle and consists of two parts, *acromial* and *scapular*. **In horse, the muscle lacks acromial head.**

Origin:

- Acromial part - Acromion process and scapular fascia
- Scapular part - The posterior border of the scapula

Insertion: To the deltoid tuberosity of the humerus. The scapular part is mostly inserted to the fascia covering the triceps
Action: To flex the shoulder and abduct the arm
Blood supply: Posterior circumflex artery
Nerve supply: Axillary nerve

Supraspinatus
Origin: The supraspinous fossa
Insertion: The muscle divides below the level of the acromion process into two divisions - *medial* and *lateral*. The lateral is inserted to the summit of the tuberosity and medial to the anterior division of the medial tuberosity of the humerus (**also deep pectoral muscle**)
Action: Main function is to stabilize shoulder joint. It also extend the shoulder
Blood supply: Suprascapular artery
*Nerve supply***:** Suprascapular nerve

Infraspinatus
Origin: Infraspinous fossa
Insertion: Two insertions as

- Circular rough area below the summit of the lateral tuberosity of the humerus
- Medial surface of the convexity of the lateral tuberosity of the humerus

Action: To stabilize the shoulder joint. To abduct the scapula and rotate it outwards
*Blood supply***:** Subscapular and suprascapular arteries
*Nerve supply***:** Suprascapular nerve
Teres minor
This is a small-elongated muscle under the deltoideus, infraspinatus.
Origin: The rough lines at the distal part of the infraspinous fossa and the posterior border of the scapula
Insertion: To the deltoid tuberosity and a small rough area above it
Action: To flex the shoulder joint and abduct the arm and rotate it outwards
*Blood supply***:** Subscapular and suprascapular arteries
*Nerve supply***:** Axillary nerve

MUSCLES OF THE ARM
This group consists of muscles, which are grouped around the humerus. They are as follows:

- Biceps brachii
- Triceps brachii
    - Long head (Caput longum tricipitis)
    - Lateral head (Caput parvum tricipitis)
    - Medial head (Caput medium tricipitis)
- Tensor fascia antibrachii
- Brachialis
- Anconeus

Biceps brachii and Brachialis flex elbow joint; other extend elbow joint.
Biceps brachii
It is a long, fusiform muscle situated on the cranial and medial surfaces of the humerus passing obliquely downwards, backwards and inwards.
Origin: Tuber scapulae
Insertion: Radial tuberosity
Action: To flex the elbow joint
Blood supply: Anterior circumflex and a direct branch from the brachial artery
Nerve supply: Musculo-cutaneous nerve
Triceps brachii

This is a large muscle, which fills up the space between the scapula and olecranon process of the ulna. In all domestic animals, the heads of the triceps brachii join distally to insert on the olecranon tuber. The long head is the only division of the triceps brachii that originates from the caudal border of the scapula with actions on two joints: the shoulder (flex) and elbow (extend) joints. The remaining heads originate from the proximal humerus. The triceps brachii is a major extensor of the elbow joint.

Long head (Caput longum tricipitis): It is the largest head and is visible on both the lateral and medial faces

- ***Origin*:** Posterior border of scapula and the humerus
- ***Insertion:*** The lateral, posterior and medial parts of the summit of the olecranon
- ***Action:*** Flex shoulder joint and extend elbow joint

Lateral head (Caput parvum tricipitis): It is quadrilateral in shape and lies on the lateral surface of the arm below the long head.

- ***Origin:*** The curved line extending from the deltoid tuberosity to the neck of the humerus.
- ***Insertion:*** Tendon of long head and lateral aspect of the olecranon.
- ***Action:*** To extend the elbow joint.

Medial head (Caput medium tricipitis): It is the smallest and is situated on the medial surface of the humerus below the insertion of coracobrachialis.

- ***Origin:*** The upper third of the medial face of the shaft of the humerus.
- ***Insertion:*** Anterior and medial parts of summit of the olecranon process.
- ***Action:*** To extend the elbow.

Blood supply: Posterior circumflex and deep brachial arteries.
Nerve supply: Radial nerve.

Tensor fascia antibrachii

Origin: Posterior border of scapula & Latissimus dorsi.
Insertion: Olecranon process of Ulna.
Action: To extend the elbow and tense the fascia of the forearm.
Blood supply: Posterior circumflex and deep brachial arteries.
Nerve supply: Radial nerve.

Brachialis

This is a curved muscle lodged in the musculo-spiral groove of the humerus.
Origin: Posterior surface of the humerus.
Insertion: Upper part of the medial surface of the radius below the insertion of biceps brachii.
Action: To flex the elbow joint.
Blood supply: Posterior circumflex and deep brachial arteries.
Nerve supply: Musculo-cutaneous branch of the median nerve.

Anconeus

Origin: The margins of the olecranon fossa.
Insertion: The anterior and lateral parts of the olecranon.
Action: To extend the elbow joint.
Blood supply: Deep brachial and posterior circumflex arteries.
Nerve supply: Radial nerve.

MUSCLES OF THE FOREARM AND MANUS

Muscles of the forearm and the manus consist of extensors and flexors. The **extensors of the carpus** and digit occupy the anterior and lateral aspects of the forearm region while the **flexors occupy the posterior or volar aspect.**

Extensor Group

Extensor Carpi Radialis

This is the largest of the extensor muscles and lies over the dorsal face of radius in a nearly vertical direction extending from the lower end of the humerus to the upper end of the large metacarpal bone.

Origin: Lateral supracodylar crest (A sharp ridge on the lateral epicondyle of the humerus) and radial fossa. The tendon **passes down the middle groove on the distal end of the radius** through a synovial sheath runs down over the dorsal capsular ligament of the carpus.

Insertion: By a wide flat tendon to the metacarpal tuberosity. Its tendon is crossed over by the tendon of extensor carpi obliquus.

Action: To extend the carpus, and flex the elbow.

Common Digital Extensor
(Medial & Lateral heads and three tendons)

The common digital extensor in ruminants has two bellies or heads (medial and lateral) and three insertion tendons. It is located caudal to the extensor carpi radialis muscle and cranial to the lateral digital extensor muscle.

The tendon of the medial head of the common digital extensor is sometimes called the **medial digital extensor tendon** or proper extensor tendon of digit III. The tendon of the lateral head is called the **common extensor tendon of digits III and IV.**

Origin: Lateral epicondyle of the humerus.

Insertion: Medial tendon inserts on P2 with extension to P3 (ox) of the medial digit (digit III); the lateral tendon splits into two thin tendons that insert on the extensor processes of P3 of digits III and IV.

Action: Extends the carpus and digital joints.

Medial digital extensor tendon and common extensor tendon runs in the **lateral groove on the dorsal aspects of the distal extremity of the radius.**

Lateral digital extensor

Origin: Lateral epicondyle of humerus and lateral collateral ligament of humerus

Insertion: The second and third phalanges of the lateral digit.

Action: To extend carpus and joints of the lateral digit

The tendon of the lateral digital extensor muscle to the lateral (IV) digit and the medial tendon of the common digital extensor muscle to the medial (III) digit are wider in size than the extensor tendons that course to the interdigital space. They are known as the **"proper" digital extensor tendons of digits IV and III,** respectively.

Extensor carpi obliquus

The belly of the extensor carpi obliquus muscle is located deep to the muscles of the cranio-lateral antebrachium group. Its tendon of insertion courses obliquely over that of the extensor carpi radialis muscle to insert on the proximal medial surface of the large metacarpal bone.

Origin: Lateral and dorsal faces of the radius and ulna.

- The muscle lies under the preceding muscles. The origin is wide and the muscle is succeeded by a flat tendon at the lower third of the forearm, crosses over the tendon of the extensor carpi radialis obliquely

inwards, and passes through a synovial sheath in the **medial groove on the dorso-medial aspect of the radius**.

Insertion: A tubercle on the postero-medial aspect of the upper extremity of the large metacarpal bone.
Action: To extent the carpus and rotate it outwards.
Blood supply to all extensors: Collateral radial artery.
Nerve supply: Radial nerve.

FLEXOR GROUP: These muscles are situated around the posterior and medial aspects of the forearm. They are arranged in two layers - superficial and deep.

- Superficial layer
  - Pronator teres
  - Flexor carpi radialis (Medial flexor of the carpus)
  - Flexor carpi ulnaris (Middle flexor of the carpus)
  - Ulnaris lateralis (Flexor metacarpi externus)
- Deep layer
  - Superficial digital flexor (Flexor pedis perforatus)
  - Deep digital flexor (Flexor pedis perforans)

Pronator teres

It is a very small and vestigeal muscle situated along the medial face of the elbow joint, closely blended with the medial lateral ligament.
Origin: Medial epicondyle of the humerus.
Insertion: Upper part of the medial border of the radius.
Action: Inappreciable as it is vestigeal.
Blood supply: Median artery.
Nerve supply: Median nerve.

Flexor carpi radialis (Medial flexor of the carpus)

The flexor carpi radialis muscle is located on the medial surface of the antebrachium directly caudal to the radius.
Origin: Medial epicondyle of the humerus.
Insertion: A tubercle on the postero-medial part of the upper extremity of the large metacarpal bone.
Action: To flex the carpus and extend the elbow.
Blood supply: Median artery.
Nerve supply: Median nerve

Flexor carpi ulnaris (Middle flexor of the carpus)

This is a wide muscle situated behind the preceding and covers the medial surface of the forearm. The flexor carpi ulnaris muscle lies caudal to ulnaris lateralis muscle on the caudo-medial side of the antebrachium. It has small **ulnar head** and large **humeral head**. It is one of two muscles that insert on the **accessory carpal bone**. The other muscle is ulnaris lateralis.
Origin: Has two heads of origin - **humeral head** from the medial epicondyle of the humerus and **ulnar head** from the medial face of the olecranon.
Insertion: The supero-medial half of the accessory carpal bone.
Action: To flex the carpus and extend the elbow.
Blood supply: Median artery.

Nerve supply: Ulnar nerve.

Ulnaris lateralis (Flexor metacarpi externus)
Origin: Lateral epicondyle of the humerus.
Insertion: Accessory carpal, lateral to Flexor Carpi Ulnaris.
Action: To flex the carpus and extend the elbow.
Blood supply: Collateral radial artery.
Nerve supply: Radial nerve.

Superficial digital flexor (Flexor pedis perforatus)
This muscle is under cover of flexor carpi ulnaris.
Origin: Medial epicondyle of humerus.

- Above the fetlock joint, the SDF tendon receives a band from the interosseus muscle. This band is similar to the distal check ligament of the SDF in the horse except that this band connects two muscles (SDF and interosseus) instead of bone and muscle (radius and SDF) as the case with the check ligament of the SDF in the horse. Additionally, this band is located in the metacarpus instead of the antebrachium where the check ligament of the SDF in the horse is located.
- The SDF and the band from the interosseus help form the **flexor manica**, a sleeve for the passage of the DDF tendon to palmar surface of P3.

Insertion: The palmer/volar face of the upper extremity of the second phalanges.
Action: To flex the digits and carpus and extend the elbow.
Blood supply: Median artery.
Nerve supply: Ulnar and median nerves.

Deep digital flexor (Flexor pedis perforans)
This is the largest of the flexor muscles and is partly under the cover of the preceding.
Origin: It has three heads of origin - humeral, radial and ulnar.

- The **humeral heads** are two, and arise from the medial epicondyle of the humerus.
- The **radial head** is the deepest and smallest and arises from the lateral part of the volar face of the radius at its upper half.
- The **ulnar head** is the most superficial and is situated between the flexor carpi ulnaris and ulnaris lateralis. It arises from both the faces of the olecranon.

Each head is succeeded by a tendon, which unite and form a common tendon just above the carpus. The common tendon passes through the carpal canal and in metacarpal region it passes between the suspensory ligament in front and the superficial digital flexor tendon behind. It divides above the fetlock into two divisions, which pass through the rings of the superficial flexor. The tendon of the muscle is provided with synovial sheaths in the carpal canal and the rings formed by the superficial flexor in the fetlock.
Insertion: The volar surfaces of the third phalanges of the two digits.
Action: To flex carpus and digits and extend elbow.
Blood supply: Median artery and common interosseous artery.
Nerve supply: Median and ulnar nerves.

Inter-osseous Muscle (Suspensory ligament)

The interosseus muscle (suspensory ligament) in ruminants is fused interosseus III and IV muscles. It is located on the palmar side of the large metacarpal bone (fused Mc III and Mc IV) deep to the deep digital flexor tendon.

The horse has a single interosseus III muscle (suspensory ligament). The suspensory ligament is very tendinous in horse compared to relatively fleshy muscles in ruminants.

In the distal palmar metacarpal region, the fused interosseus muscle in ruminants gives a band that joins the SDF and splits into five branches. Four of the five branches insert on the four axial and abaxial proximal sesamoid bones at the level of the fetlock joints. The fifth tendon courses in the interdigital space between the axial sesamoids and gives two axial extensor branches that join the "proper" extensor branches of the lateral and common digital extensor muscles on digits III and IV.

Origin: Distal row of carpal bones and palmar carpal ligament.

Insertion: Proximal sesamoids bones and by continuation join the proper digital extensor tendons by axial and abaxial extensor branches.

Action: Prevents overextension of the fetlock joints produced by pressure from the weight of the animal. The interosseus muscle opposes the flexor tension of the DDF tendon on the pastern and coffin joints.

CHAPTER-XII

HISTOLOGY OF DIGESTIVE SYSTEM

The digestive tract has a distinct structural pattern that typifies tubular organs in general. Although there are some minor variations from place to place, its structure usually includes **four** "tunics" or layers, a couple of which have subdivisions. From the innermost (i.e., closest to the lumen) to the outermost, these are:

1. **T. Mucosa**
   a. Epithelium
   b. Lamina Propria
   c. L. Muscularis Mucosae

2. **T. Submucosa**
   a. Submucosal plexus
      "Plexus of Meissner"

3. **T. Muscularis**
   a. Myenteric plexus
      "Plexus of Auerbach

4. **T. Serosa**

Organ	**Epithelium**
Mouth	Non-keratinized Stratified Squamous
Pharynx	Non-keratinized Stratified Squamous
Esophagus	Non-keratinized Stratified Squamous
Stomach	Simple Columnar
Small Intestine	Simple Columnar
Large Intestine	Simple Columnar
Anus	Non-keratinized Stratified Squamous

Organ	**Folds of the epithelium**
Esophagus	none
Stomach	L: Rugae, S: gastric pits
Small Intestine	L: Plicae circulares, Villi S: Crypts of Lieberkuhn, microvilli
Large Intestine	L: Haustra S: Intestinal glands

Organ	**Specialized structures**

Esophagus	Submucosal mucous glands
Stomach	None
Duodenum	Brunner's glands
Ileum	Peyer's Patches
Large Intestine	None

Organ	**Smooth muscle layers**
Esophagus	2, circular and longitudinal
Stomach	3, oblique, circular, and longitudinal
Small Intestine	2, circular and longitudinal
Large Intestine	2, circular and longitudinal

Organ	**Serosa**
Esophagus	Adventitia due to the fact that esophagus is not in a cavity
Stomach	Visceral Peritoneum
Small Intestine	Visceral Peritoneum
Large Intestine	Visceral Peritoneum
Anus	Adventitia

Tongue

- The tongue in mammals is an extremely muscular organ.
- Bulk of the tongue is skeletal muscle, arranged in three layers, all at right angles to each other. This provides for an amazing degree of flexibility and is vital to vocalization.
- The ventral surface of the tongue is smooth and is covered by thin non-keratinized stratified squamous epithelium continuous with that of the floor of the mouth.
- The dorsal surface is covered by stratified squamous keratinized epithelium and is raised into a series of elevations called **lingual papillae**. Lingual papillae are classified into two major groups: 1. **mechanical** and 2. **gustatory papillae**.
  - The **mechanical papillae** contain no taste buds and are principally concerned with movement of foods within and into the oral cavity. They include **filiform**, **conical** and **lenticular** papillae.
  - The **gustatory papillae** contain taste buds and are primary concerned with reception of taste sensation. They include, **vallate**, **fungiform** and **foliate papillae**.
- The **filiform papillae** are the most numerous types, forming a velvety covering on the tongue. Their shapes vary among different animal species. Ruminant filiform papillae are cone-shaped structure projecting above the surface and their connective tissue cores have several secondary papillae.
- Equine filiform papillae appear as thin cornified threads projecting above the surface and their connective tissue cores end at the bases of the cornified threads.
- Dog filiform papillae have two or more apices; the caudal one is larger and has a thicker stratum corneum than the others.
- **Conical Papillae** are cone-shaped structures, larger than **filiform papillae** and not highly keratinized. Their connective tissue cores have both primary and secondary papillae. They occur on the root of the tongue in dog, cat and pig. In other species, they occur on the inner side of the cheeks and floor of the oral cavity.
- **Lenticular papillae** are flattened lentil-shaped projections occur mainly in ruminants.
- **Vallate papillae** are the largest type, easily visible with the naked eye in most animals. They are paired and located near the back of the tongue. A vallate papilla is set into a deep pocket in the tongue's surface, and anchored at the bottom by a short broad stalk. It does not protrude above the general level of the surface. It's surrounded by a deep narrow epithelial-lined cleft called "**moat**". Vallate papillae

usually show **taste buds** which are located on the undersides of the papilla proper, and on the **tongue side of the "moat**." Aggregates of serous glands called **Von-Ebners glands** whose ducts open into the moat are located beneath the papilla. The serous secretions of these associated glands help to clean up the moat and thus facilitate taste reception.

- The **fungiform papillae** are scattered randomly among the filiform papillae on the dorsal tongue surface. As the name implies, they are fungus-like or mushroom shaped structures. They have thin **non-keratinized epithelium** and richly vascular connective tissue core. They rise above the general level of the filiform papillae, and they usually have taste buds. The taste buds are sparse in horse and cattle and **abundant in carnivores and goats**. They are found in the **upper epithelial surface.**

Oesophagus

The esophageal wall is formed of mucosa, submucosa, tunica muscularis and serosa or adventitia. The **mucosa** is formed of epithelium, lamina propria and lamina muscularis mucosa.

The **epithelium** is stratified squamous non-keratinized (dog, cat) slightly keratinized (pig) and highly keratinized (ruminants). The **lamina propria** is a dense irregular connective tissue layer rich in immune-competent cells, blood vessels and nerves. The l**amina muscularis** is formed of longitudinally arranged smooth muscles. In pig and dog, it is absent in the cranial end.

In cat, horse and ruminants, it is formed of isolated bundles at the cranial end and increase in number in the caudal part.

The **submucosa** is a loose connective tissue layer containing blood vessels, lymphatic, nerves and seromucoid **esophageal glands**. In dog, the glands extend throughout the entire length. In pig, they occur only in the cranial half. In cat, horse and ruminants, they occur at the pharyngeo-esophageal junction.

The **tunica muscularis** is formed of smooth and /or striated muscle fibers. In dog and ruminants, it is entirely striated muscle. In horse, it is striated in the cranial 2/3 and smooth in the caudal third. In pig, it is striated in the cranial 1/3, mixed in the middle 1/3 and smooth in the caudal third. In cat, it is striated in the cranial 4/5 and smooth in the caudal 1/5. At the cranial end, the muscles are spirally arranged while caudally, an inner circular and an outer longitudinal layer are clear.

The cervical esophagus is covered by **adventitia** that is a loose connective tissue layer contains blood & lymph vessels and nerves. The thoracic esophagus is covered by **serosa** that is a loose connective tissue layer with an outer mesothelial covering. The abdominal esophagus (beyond the diaphragm) is about 2.5 cm in horse and short- wedge-shaped in carnivores is covered by serosa.

Glandular Stomach

The lumen of the glandular stomach is lined with simple columnar mucus-secreting **epithelium**. There are **no goblet cells** in it (in which respect it differs from the intestines). Depressions in the "floor" representing **gastric pits** or **foveolae**, also lined with this simple columnar epithelium.

The **lamina propria** is a loose connective tissue layer rich in capillaries and lymphoid cells and is entirely occupied by glands, the **gastric glands**. There are three major categories of these glands, associated with different parts of the stomach: **cardiac**, **fundic** and **pyloric** regions. The glandular regions are wholly confined to the tunica mucosa. Unlike some other portions of the tract, submucosal glands are not found in the stomach at all.

Cardiac region

- These are found in the most proximal region of the stomach (*i.e.*, that part closest to the input of the esophagus), called the "cardiac region," because it's located close to the heart.
- **The gastric pits are wide and deep.** At the bottom of the gastric pits are the openings into the secretory portions of the glands.
- The glands are short, branched tubular, slightly coiled with wide lumen extending deep into the mucosa, and are lined with simple cuboidal mucous secreting cells.

- They are limited in their distribution to the region immediately adjacent the esophagus.

Fundic region

- The second and by far the most numerous type of gastric gland is the **fundic gland**. These are found underlying the bulk of the gastric mucosa. These glands produce the bulk of secretions in the stomach. They are deep, straight glands, with a mixed population of cells.
- The fundic glands open into the base of comparatively **shallow gastric pits.**
- Each gland consists of a neck, a long body and a dilated base or fundus.
- The fundic glands are lined by four cell types; **mucous neck cells**, **enzyme-producing cells**, **acid-producing cells** and scattered **endocrine cells**
- **Mucous Neck Cells:** They are found in the neck of the gland and are smaller than the surface mucous cells. They have basal nuclei and finely granular cytoplasm due to the presence of small mucus vacuoles that are distributed throughout the cytoplasm.
- **Enzyme-Producing Cells** are also called **chief** or **peptic** or **zymogen** cells. They are the most numerous cell types within the fundic glands, hence the name chief cells. The cells are cuboidal or pyramidal exhibiting all the criteria of **protein-secreting cells**: deep cytoplasmic basophilia, vesicular nucleus, and prominent nucleoli.
- The cell apices appear acidophilic due to the presence of eosinophilic refractile cytoplasmic granules called zymogen granules. The zymogen granules contain the inactive enzyme precursor **pepsinogen**, which is released into the lumen of the stomach where it is converted by the HCl into active enzyme **pepsin**.
- **Acid-Producing cells** are also called **parietal** or **oxyntic** cells. They are round or pyramidal-shaped with spherical central nuclei. They are much larger than chief cells, and **very strongly eosinophilic**. The base of the cell bulges outward and its narrow apex reaches the lumen of the gland. **The parietal cells make hydrochloric acid**, to keep the pH of stomach juice low (about 2.0 to 3.0 is typical). This pH is necessary to activate the gastric enzymes. Parietal cells are also thought to secrete the substance called **intrinsic factor** which is essential for the absorption of vitamin B_{12} in the ileum.
- **Enteroendocrine:** They are small spherical cells and are sited on the epithelial basement membrane. **In H&E sections**, they have a spherical, central dark-staining nucleus and a rim of clear cytoplasm. Some cells have an affinity for silver stains and are called **argentaffin cells**, others have an affinity for bichromate salts and are called **chromaffin cells.**

Pyloric region

- The third category of gastric glands is **pyloric glands**, found in the region of the **pylorus**, the junction with the first part of the intestine. Pyloric glands produce a mucous secretion. Structurally they closely resemble the glands of the cardiac region, though in the **pyloric stomach the gastric pits tend to be deeper and the glands larger and more obvious.**
- The **lamina muscularis** is made up of inner and outer circular and middle longitudinal layers of smooth muscle. **In the stomach of carnivores** an additional layer, **the subglandular layer**, is located between the base of the gastric glands and the underlying lamina muscularis. It is made up of an inner **stratum granulosum** (fibroblast-rich) and an outer **stratum compactum** of dense collagen fibers.
- The **tunica muscularis** of the stomach is generally considered to have three layers. The innermost layer is **obliquely** oriented with respect to the long axis of the organ. There is a **circularly** oriented layer next outward of that, and the outer layer is **longitudinal**.
- The outer surface of the stomach is covered by **serosa** consisting of loose connective tissue containing blood vessels, lymphatics and nerves and a single layer of mesothelial cells demarcates its outer limit.

Region	Epithelium	Glands	Muscle	Special features
Cardiac	Simple columnar epithelium, gastric pits	Tubular, branched mucous glands (cardiac glands), endocrine cells	Distinct lamina muscularis, tunica muscularis composed of circular, longitudinal and oblique smooth muscle fibres, cardiac sphincter	Extensive in the pig, smaller in the dog and horse
Body (and fundus in carnivores)	Simple columnar epithelium, gastric pits	Tubular glands with isthmus, mucous neck cells, chief and parietal cells (proper gastric or fundic glands), endocrine cells	Similar to cardiac region	Light and dark zones are observed in the dog
Pyloric	Simple columnar epithelium, gastric pits	Short, branched and unbranched tubular mucous glands (pyloric glands) emptying into deep gastric pits, endocrine cells	Similar to cardiac region, the middle layers of smooth muscle form the pyloric sphincter (sphincter pylori)	Torus pyloricus present in pigs and ruminants

Non-glandular stomach: The non-glandular region is lined by **stratified squamous keratinized epithelium** derived from that of the esophagus. It is entirely absent in carnivores, small in pigs, wide in horse and reaches its greatest development in ruminants where it is subdivided into three distinct compartments; **rumen**, **reticulum** and **omasum**. The structure of the other layers within the non-glandular are the same as seen for any tubular organ within the digestive tract.

Ruminants Stomach: The four divisions of the ruminant stomach are the **rumen**, the **reticulum**, the **omasum**, and the **abomasum**. The first three compartments are referred to as **forestomach**. The fourth compartment is referred to as **true stomach**.

Compartment	Epithelium	Glands	Muscles	Special features
Rumen	Keratinised stratified squamous	No glands	Lamina muscularis mucosae absent, circular and longitudinal layers of smooth muscle in tunica muscularis	Conical or elongated finger-like papillae, varying in length and morphology
Reticulum	Keratinised stratified squamous	No glands	Lamina muscularis mucosae present in upper portion of the primary reticular crests, tunica muscularis is weaker than in the rumen	Presence of papillae on surface of crests
Omasum	Keratinised stratified squamous	No glands	Lamina muscularis extends to varying degree into the higher order (I–III) omasal laminae	Prominent tunica muscularis, fibres of circular layer extend into higher-order omasal laminae
Abomasum	Simple columnar epithelium, gastric pits	Cardiac, proper gastric and pyloric glands	Inner circular layer, outer longitudinal layer	

Small Intestine

Segment	Epithelium	Glands	Muscle	Special features
Small intestine (villi present throughout in domestic mammals)				
Duodenum	Simple columnar with brush border, isolated goblet cells	Tubular, branched or unbranched glands (crypts of Lieberkühn), extend into the lamina propria, tubulo-alveolar glands (Brunner's glands) in submucosa, endocrine cells	Lamina muscularis mucosae present – sends smooth muscle cells into intestinal villi, inner circular and outer longitudinal tunica muscularis with plexus nervorum myentericus	Isolated lymphatic nodules (GALT), submucosal glands (mucous in dog and ruminant, may be mixed in the pig and horse).
Jejunum	Similar to duodenum, microvilli longer and finer	Similar to duodenum but no glands in submucosa	Similar to duodenum	Increasing numbers of lymphatic follicles
Ileum	Similar to jejunum	Similar to jejunum	Similar to duodenum	Well-developed GALT, Peyer's patches (all domestic mammals, particularly horse and calf)
Large intestine (villi absent in all domestic mammals)				
Caecum	Simple columnar with low brush border	Numerous goblet cells, simple tubular intestinal glands	Lamina muscularis mucosae present, inner circular and outer longitudinal smooth muscle layers	GALT near ileocaecal orifice in the dog, pig and ruminant, more developed in the colon in the cat and horse; taeniae (musculoelastic bands) and haustra in pig and horse
Colon	Simple columnar with low brush border	Marked increase in goblet cells, simple tubular intestinal glands	Similar to caecum	Taenia (musculoelastic bands) and haustra in pig and horse
Rectum	Similar to colon	Similar to colon	Muscle more prominent than in caecum and colon	

Liver

- The liver is the largest gland in the body
- The classic **hepatic lobule** is considered to be the functional unit of the organ. Each is a roughly hexagonally shaped, three dimensional unit, demarcated by connective tissue and constructed of the parenchymal cells of the liver, **hepatocytes**, in large numbers.
- **The pig's livers** have more connective tissue than most of the other animals; this abundance of connective tissue results in a very clear demarcation of hepatic lobes in these animals.
- At each corner of the liver lobule, there is **portal area** or **portal canal** or **hepatic triad**. The portal areas include at least one each of the following elements: 1) a branch of the **hepatic artery**; 2) a branch of the **portal vein**; and 3) a **bile ductule**.
- Within the limits that define each lobule, the hepatocytes are arrayed in long rows, the **hepatic laminae** and each lobule is organized around a so called **central vein**, really just an open space.
- Each lobule is supplied by blood from two sources: a branch of the **hepatic artery** and a branch of the **portal vein**.

- The **hepatocytes** are large polyhedral cells fairly uniform in size, which have variable cytoplasmic appearance depending on the nutritional status of the body. In well-nourished individual, their cytoplasm store significant quantities of glycogen and lipids hence appear vacuolated. The remaining cytoplasm is strongly eosinophilic due to a high content of organelles.
- The nuclei are large with peripherally dispersed chromatin and prominent nucleoli. As many as 25% of hepatocytes are binucleated. More than half of the hepatocytes contains twice the normal (diploid) complement of chromasomes within a single nucleus (i.e., tetraploid). Some contains four or even eight time (i.e., polyploid).
- Plates of hepatocytes are radially arranged around the central vein. These plates are usually one cell thick. The sinusoids are irregular vascular channels between the plates, with numerous blood cells in them.
- A narrow space known as the **space of Disse** is located between the sinusoidal lining cells and the hepatocyte surface. The sinusoidal lining cells are discontinuous and thus, the space of Dissue is continuous with the lumen of the sinusoids.
- The **Kupffer cells** are phagocytic cells, derived from the monocyte cell line. These liver-resident macrophages engulf particulate matter that passes through the sinusoids (especially bacteria and senescent blood cells).
- **Portal Lobule is the functional unit of the liver** based on the exocrine activity. It is triangular in shape and is made up of a portal tract and parts of the three adjacent hepatic lobules. The boundaries of the portal lobule are defined by lines joining three adjacent central veins.
- **Liver Acinus** is the functional unit of the liver based on the blood supply of the hepatic cells. It is a diamond or oval-shaped structure formed by the hepatocytes of two adjacent hepatic lobules. The liver acinus is subdivided into three zones: zone I, zone II and zone III. Zone I lies near the interlobular region and receives the best blood supply. Zone II is the intermediate zone and receives blood of moderate quality. Zone three lies close to the central vein and receives poor blood supply, therefore it is the first zone to die.

Gall bladder

- The gall bladder is absent in rats, camels and horses as well as pigeon. Its function is to concentrate and store bile produced in the live. The wall of the gall bladder is formed of mucosa, submucosa, tunica muscularis and serosa. The **mucosa** is covered by a very regular simple columnar **epithelium**, with no goblet cells or glands. There is a scanty **lamina propria**. There is no **muscularis mucosa**.
- The lamina **propria-submucosa** is formed of loose connective tissue containing solitary lymph nodules. The deep folds in the bottom of the mucosa, which are often cut in cross section, sometimes look like "glands," but they have no secretory activity and they are really parts of the lumen. In ruminants, true glands of seromucoid type are present.
- The **tunica muscularis** is thin and is formed of circular layers of smooth muscle fibers.
- The **serosal covering** (i.e., visceral peritoneum) covers the portion of the organ that's not nestled up to the liver.

Pancreas

- The pancreas synthesizes the bulk of the digestive enzymes needed in the intestines.
- The pancreas is a highly lobulated compound tubuloacinar gland with both exocrine and endocrine portions; digestive enzymes are conducted via a duct system to the duodenum, and the endocrine products enter the blood directly. The pancreas is invested by a loose connective tissue capsule which sends delicate septa demarcating the pancreas into lobules.
- Each lobule is formed of exocrine serous secreting units, ducts and endocrine islets of Langerhans. The bulk of the tissue in the pancreas is exocrine in nature. This is the pancreatic acinar tissue and its associated ducts.

Exocrine Pancreas

- The cells of the acinar tissue are arranged into **acini** formed of pyramidal-shaped cells with their apices projecting towards the lumen of a minute duct. The lumen of an acinus is small. The nuclei are spherical basally located and surrounded by basophilic cytoplasm. The apical region contains distinct granular material, the zymogen granules. The **zymogen granules** are eosinophilic and are precursor forms of digestive enzymes.
- The pancreatic duct begins from the lumen of each acinus.
- The **intercalated ducts** are short ducts. Each duct drains only one acinus. The duct lining cells are often seen in the lumen or the center of secretory acini, hence they are called **centro-acinar cells**, and are very characteristic to pancreatic ducts.
- Intercalated ducts of the adjacent acini merge with each other forming **intralobular duct**, so named because it is located inside the lobule. The pancreatic intralobular ducts are lined by simple cuboidal epithelium, and in contrast to intralobular ducts of the salivary glands they are not striated.
- The **intralobular ducts** fuse with each other and now they become larger and extended up to the level of the interlobular septa. These are **the interlobular ducts** which are lined with simple columnar epithelium instead of the cuboidal one.
- The secretions from the interlobular ducts are collected to a larger duct, **the main pancreatic duct** which drains into the duodenum. The **main duct** is lined by simple columnar epithelium with some goblet cells.

Endocrine Pancreas

- The endocrine portion is the **pancreatic islets of Langerhans** are regions of lighter staining tissue in the mass of the exocrine part. The islets are demarcated by a very fine investment of delicate CT fibrils. They're well vascularized. The cells produce the hormones **insulin** and **glucagon**.

ANIMAL GENETICS & BREEDING

CHAPTER-I

INTRODUCTION TO BIOSTATISTICS

Definition: Statistics is the branch of science that deals with methods of collection, classification, analysis and drawing influences from data, testing hypotheses and making recommendations is called Statistics.

The word 'statistics' is derived from a Latin word 'status' or an Italian word 'Statista' which means **'political state'.**

Statistical Method: Raw data obtained in biological experiments needs to be processed to get a correct result. The factors which influence the data are separated. The data then becomes suitable for classification, evaluation, comparison and interpretation. All these methods are put together and it constitute statistical method.

- **Steps or stages in statistical investigation:**

a) collection of data

b) organization of data

c) presentation of data

d) analysis of data

e) interpretation of data

- The use of statistics in biological science is called as **Biostatistics.**

It deals with the application of statistical data and methods to solve the problem of biological science.

- **Functions of Statistics:**

a) It presents facts in definite form.

b) It facilitates comparison.

c) It helps in formulating and testing the hypothesis.

d) It helps in prediction.

- **Limitations of Statistics:**

a) It doesn't deal with individual measurements.

b) It deals with quantitative characters.

c) It may be misused due to incomplete information.

CHAPTER-II

COLLECTION AND REPRESENTATION OF DATA:

Data: A set of values recorded for an event is called Data. The data in statistics is generally based on individual observation.

There are two types of data:

a) **Primary Data**: It is the first-hand data which has been collected by the person directly from the field.

b) **Secondary Data**: It is the data which has been already collected and which exists in published or unpublished form.

Specific aspects and significance of Statistical data:

- Collection of data: A data collected in original form is called Raw Data or Ungrouped Data.
- Presentation of Data: The collected data is presented in a particular order so that statistical method or techniques are used.
- Analysis of Data: Data is represented in table, diagram or graph are analysed as per requirement.
- Interpretation of Data: Here some conclusions are drawn from analysing data.

Classification of Data:

The process of arranging the collected material in groups and classes according to their resemblances or similarities is called as **Classification of Data.**

It is the process of condensation of raw data into systematic data that can be put for proper use.

Objectives of Classification:

- The data becomes simple and easy to interpret.
- It ensures an orderly arrangement of data.
- It helps in comparative studies.
- It helps in clarifying the points of similarities and dissimilarities.
- To put up the collected data to statistical treatment.
- It helps in drafting the final report.
- It ensures the proper use of collected data.

Methods of Classification:

Mass data is a large group of different types of elements collected through various modes and sources due to various types of characteristics data differs from one group to another.

- **Chronological classification:** Data related to a point of time or a period of time is chronological data. e.g; data related to growth of population.
- **Geographical classification:** If data is classified on the basis of area such as region, state or country. It is used to make a comparative analysis of two different areas.
- **Qualitative classification or Classification on the basis of attributes:** Data related to certain facts which cannot be measured directly in quantitative form. e.g; religion, occupation, etc.
- **Classification according to class interval:** when the classification of observations is done according to some measurable quantity such a classification is called as Quantitative classification or Numerical classification or **Frequency Distribution.**

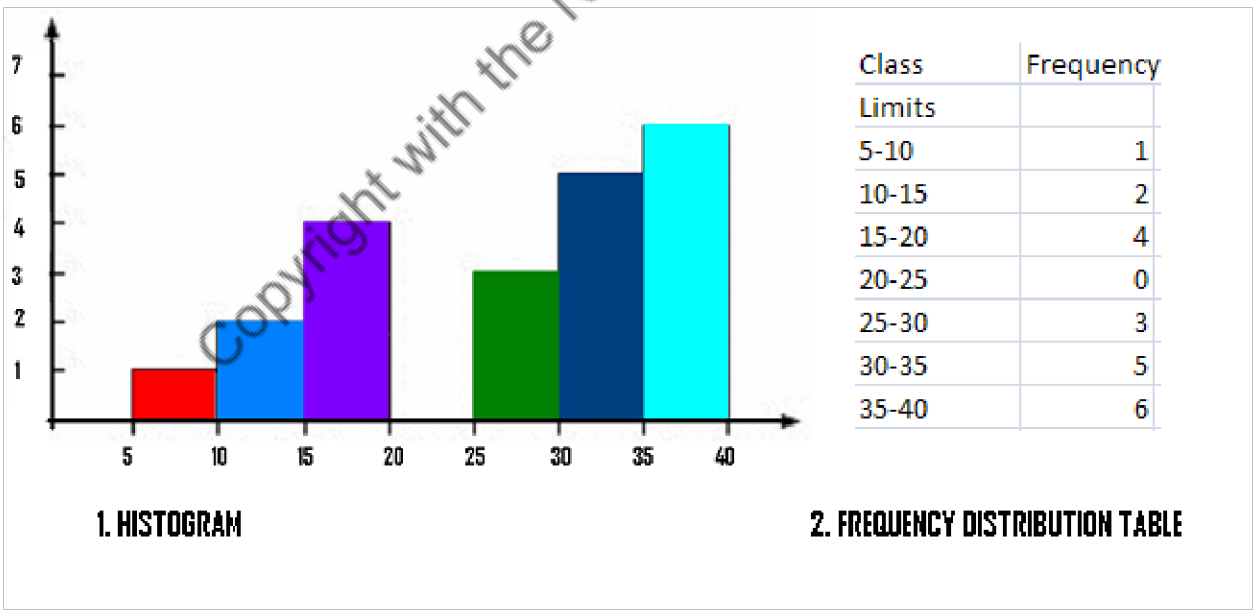
Construction of Frequency Distribution:

If there are repetitions in individual values or items of investigation suitable frequency table can be formed.

e.g; 21, 24, 11, 7, 6, 5, 12, 24,.

5-10	III
10-20	II
20-30	III

Cumulative Frequency: In statistics, cumulative frequency is found by adding up all successive frequencies in a frequency distribution table. e.g;

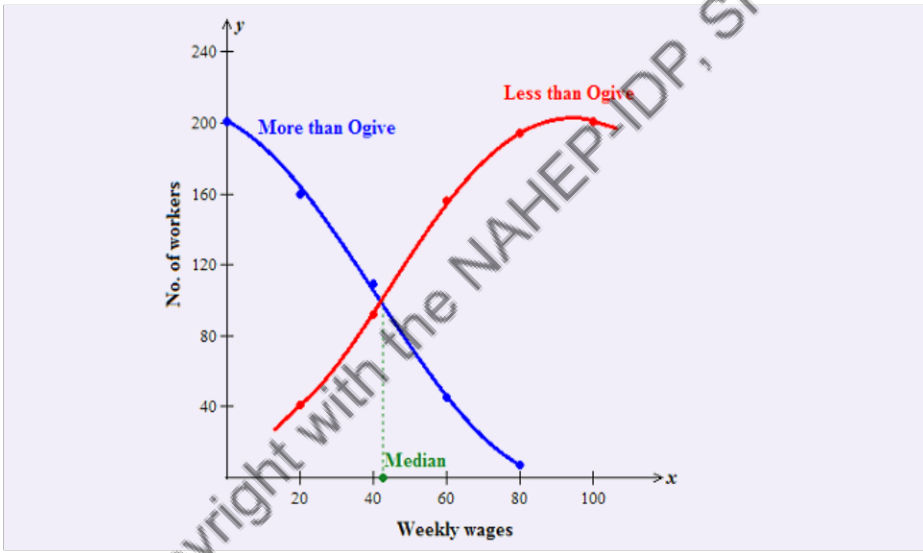


Class Limits	Frequency
5-10	1
10-15	2
15-20	4
20-25	0
25-30	3
30-35	5
35-40	6

Class interval	Frequency	Cummulative frequency
10-20	5	5
20-30	6	11
30-40	7	18

A cumulative frequency histogram is like a frequency histogram but uses the cumulative frequency column to graph the data. It looks like *steps going upwards*.

An **Ogive** is a line graph drawn on the cumulative frequency histogram. The line starts at bottom left corner of the first column and joins the top right corner of the successive column.



CHAPTER-III

MEASURE OF CENTRAL TENDENCY

Generally it is found that the values of variables try to or tend to concentrate around a particular value or central value which can be taken as representative of whole data. This tendency of distribution is called as **Central Tendency** and the measure design or devised to consider this tendency are called as **Measure of Central Tendency.**

- Measures of central tendency are also usually called as averages. They give us an idea about the concentration of the values in the central part of the distribution. It is a method of condensing whole data to a single value which is typical and representative of whole data.
- Types of Measure of Central Tendencies:

  a) **Mathematical average** : -Arithematic Mean

  -Geometric Mean

  -Harmonic Mean

  which can be simple or weighted.

  b) **Average of Position** : -Median

  -Mode

  c) **Measure of Partition value** : -Percentile

  -Decile

  -Quartile

- **Mean (Average):**

  Mean locate the centre of distribution.

  - Also known as **Arithmetic Mean.**

  - Most common measure.

  - The mean is simply the sum of the values divided by the total number of items in the set.

  Merits of Arithmetic Mean:

  - It is rightly defined and easy to calculate.

  - It covers all the observations.

  - It is least affected by sampling fluctuations.

Demerits of Arithmetic Mean:

- It is very much affected by extreme values.

- It can't be calculated by the inspection.

- **Geometric Mean:** It is another useful average defined as n^{th} root of product of 'n' variables.

It is used to find average of growth rate, prices, national income and compound interest.

Merits of Geometric Mean:

- It is most suitable technique to study the average of growth rates, growth ratios, price indices, etc.

- It is less affected by extreme values.

- Useful in finding the rate of change.

- It is highly useful in making index no.

Demerits of Geometric Mean:

- It is difficult to understand and calculate.

If a and b are postive numbers, then

$$\text{Arithmetic Mean (AM)} = \frac{a+b}{2}$$

$$\text{Geometric Mean (GM)} = \sqrt{ab}$$

$$\text{Harmonic Mean (HM)} = \frac{2ab}{a+b} = \frac{(GM)^2}{AM}$$

Harmonic Mean (A)

1. If a & b are two positive numbers.
⇒ Harmonic Mean (H) of a & b,

$$H = \frac{2ab}{a+b}$$

2. For $a_1, a_2, a_3, \ldots, a_n$ such that, $\forall\, i \in \{1, .., n\}, a_i > 0$
⇒ Harmonic Mean (H) of $a_1, a_2, a_3, \ldots, a_n$,

$$H = \frac{n}{\frac{1}{a_1} + \frac{1}{a_2} + \frac{1}{a_3} + \cdots + \frac{1}{a_n}}$$

It can't be calculated without log table.

It can't be calculated if a series has 0 or a negative value.

- **Harmonic Mean:** It is defined as reciprocal of Arithmetic Mean of reciprocal of given values.

It is mostly used in case of determination of speed or velocity, price index.

Merits of Harmonic Mean:

- It is rigidly defined.

- It is based on all observations.

- It is suitable in calculating average of the rates.

Demerits of Harmonic Mean:

- It is not easy to calculate.

- It can't be calculated if one or more observations are zero.

- **Relationship between AM, GM and HM :**

$AM > GM > HM \quad ; \quad AM.HM = (GM)^2$

➢ **Median:**

Median of a distribution is the value that divides it into two equal parts so that half of the data has value less than median and other half has value greater than median .

- Also defined as the **middle or central value** of the variables.

- It is most appropriate measure of central tendency.

Merits:

- It is rigidly defined

- It is easy to understand and easy to calculate.

- It is not at all affected by extreme values.

- It can be calculated for distributions with open-end classes.

- Median is the only average to be used while dealing with qualitative data.

- Can be determined graphically.

Demerits:

- In case of even number of observations median cannot be determined exactly.

- It is not based on all the observations.

- It is not capable of further mathematical treatment.

➢ **Mode**:

It is the value which occurs maximun number of times in a distribution. In another term, mode is the value which has greatest frequency.

Merits:

- Mode is readily comprehensible and easy to calculate.

- Mode is not at all affected by extreme values.

- Mode can be conveniently located even if the frequency distribution has class intervals of unequal magnitude

- Open-end classes also do not pose any problem in the location of mode.

- Mode is the average to be used to find the ideal size.

Demerits:

- Mode is ill defined.

- It is not based upon all the observations.

- It is not capable of further mathematical treatment.

- As compared with mean, mode is affected to a great extent by fluctuations of sampling.

$$\text{Mean} = \frac{\text{Sum of Observations}}{\text{Total Number of Observations}}$$

$$\text{If 'n' is odd:} \quad \text{Median} = \left(\frac{n+1}{2}\right)^{th} \text{term}$$

$$\text{If 'n' is even:} \quad \text{Median} = \frac{\left(\frac{n}{2}\right)^{th}\text{term} + \left(\frac{n}{2}+1\right)^{th}\text{term}}{2}$$

$$\text{Mode} = L + h\,\frac{(f_m - f_1)}{(f_m - f_1) + (f_m - f_2)}$$

CHAPTER-IV

MEASURE OF DISPERSION

Dispersion measures the extent to which the values are scattered from the average. Greater the variation amongst different items of series, the more will be the dispersion.

- Properties of Good Measure of Dispersion:

a) Easy to understand

b) Simple to calculate

c) Uniquely defined

d) Based on all observations

Capable of further algebraic treatment

- Different measures of dispersion are:
- Range
- Mean deviation
- Variance
- Standard deviation
- Standard Error

➢ **Range:** The difference between the maximum and minimum value of a given data is called Range. It is the simplest measure of dispersion.

- Since it is not based on all observations so it is not a suitable measure of dispersion.

Range = Max. - Min.

Coefficient of Range = $\frac{\text{Max. - Min.}}{\text{Max. + Min.}}$

Merits:

- Simple to understand.
- Easy to calculate.
- Widely used in statistical quality control.

Demerits:

- Can't be calculated in open-ended distributions.

- Not based on all the observations.
- Affected by sampling fluctuations.
- Affected by extreme values.

➢ **Mean Deviation:** It is also called **Average Deviation**.

- It is defined as the arithmetic average of the deviation of the various items of a series computed from measures of central tendency like mean or median.
- **M.D** = $\frac{\sum |X_i - M|}{N}$,

  where, M = mean ; X_i = 1,2,3,...

  Merits:

- Simple to understand ¢
- Easy to compute ¢
- Less effected by extreme items ¢
- Useful in fields like Economics, Commerce etc.
- Comparisons about formation of different series can be easily made as deviations are taken from a central value

  Demerits:

- Ignoring '±' signs are not appropriate
- Not accurate for Mode
- Difficult to calculate if value of Mean or Median comes in fractions
- Not capable of further algebraic treatment ¢
- Not used in statistical conclusions.

➢ **Variance:** It is sum of average of square deviation of individual measurement from the mean.

- It is the square of the Standard Deviation. i.e;

  Variance = $(SD)^2$

  $\sigma^2 = \frac{\Sigma(X_i - M)^2}{N}$

➢ **Standard Deviation:** also called as **Mean square Deviation**.

- It is defined as the square root of the arithmetic mean of the squares of the deviation of the values taken from the mean.
- It is the positive square root of the variance.
- **S.D** (σ) = +√Variance
- It is most important and widely used measure of dispersion. First used by Karl Pearson.

➢ **Coefficient of Variance**: It is the ratio of S.D and mean expressed in percentage. It was developed by Karl Pearson.

- It is used in comparing the variability, uniformity and consistency of two or more series.

$$C.V = \frac{S.D}{Mean} \times 100$$

➢ **Standard Error:** It is defined as the ratio of S.D and square root of total no of observations.

- $S.E = \frac{S.D}{\sqrt{N}}$

➢ **Probability**

Probability is defined as measure of relative chance of occurance of an event.

- Random experiment: It is an act which can be repeated under same given condition but the outcome can't be predicted.
- Event: The outcome of an experiment is called an Event.
- General explaination of Probability: if a particular event is certain to happen (sure event) then its probability is 1. On the other hand it is certain that the event will not happen (null event) then its probability is 0.

If an event can happen 'a' times and fails to happen 'b' times, then the probability of happening is written as

$$'p' = \frac{a}{a+b}$$

and the probability of not happening is **'q' =** $\frac{b}{a+b}$

then, **p+q = 1**

or, p = no. of occurrence of a particular event

Total no of trials

Rules of Probability:

a) **Addition Rule:** It mainly deals with mutually exclusive events that means both events can't occur together.

If the probability of occurrence of any event is denoted by E_1 and another event denoted by E_2, then for the mutually exclusive event the probability of **(E_1 or E_2) = P(E_1) + P(E_2).**

Multiplication Rule:

Independent Events: The probability of 2 or more independent events occuring together is the product of probabilities of independent events.

i.e, **P(E_1 and E_2)= P(E_1) × P(E_2)**

Dependent Events: If there are 2 events, E1 and E2 and the occurance of one is dependent on occurance of another, then P(E2/E1) denotes that probability of occurance of E2 is dependent on occurance of E1, which has already occured.

i.e; **P(E_1 and E_2) = P(E_1) x P(E_2/E_1)**

- **Importance of Probability:**

a) It is useful in making predictions and is used in construction of biometric models.

b) It is involved in observation of phenotype of an offspring.

Correlation

- It is the association or relationship between two or more variables.
- **Types of Co-relation :**
- **Based on direction of change:**
- **Positive co-relation:** when one variable increases then another variable also increases in positive direction or vice versa. Then this type of relation is called as Positive Co-relation. i.e; both variables moves in same direction.

e.g, growth and body weight, size of egg and weight of egg, etc.

- **Negative co-relation:** when one variable increases other tends to decrease and vice versa, then such type of relation is called as Negative Co-relation.

e.g; milk yield and fat percentage, etc.

- **Zero Co-relation:** There may be change in one variable while the other remains constant, then such relations are called Zero corelations.
- **Classification on the basis of no. of variables:**
- **Simple co-relation:** It is the association between two variables.

e.g; height and weight of animal.

- **Multiple co-relation:** In this type of co-relation it is estimated between 3 or more than 3 variables simultaneously.

e.g; milk yield, fat percentage and lactation length.

- **Partial co-relation:** Corelation is estimated among 3 or more variables but at one time corelation is estimated between 2 variables only and another is kept constant.
- **On the basis of change in ratio of variables:**
- **Linear co-relation:** Change in one variable tends to bring a constant ratio of change in another variable.
- **Non-linear co-relation:** Change in one variable doesn't maintain constant ratio to the change in another variable.
- **Coefficient of Co-relation:** It measures the degree of relationship or degree of association between 2 or more variables. It is denoted by **'r_{xy}'.**
- It ranges from **+1 to -1**, and can be written as $\mathbf{r_{xy} = r_{yx}}$.
- Coefficient of Co-relation is the ratio of co-variance between two variables and the product of standard deviation of two variables.

i.e; $r_{xy} = \frac{Cov_{xy}}{S.D_x \times S.D_y}$

Regression

- The concept of regression and term was given by **Francis Galton.**
- It measures the average relationship between two or more variables in terms of original unit of data.
- Regression is measured through regression coefficient denoted by '**b**'.

here, $\mathbf{b_{xy} \neq b_{yx}}$

and, $\mathbf{b_{xy} = \frac{Cov_{xy}}{Variance_x}}$

$\mathbf{b_{yx} = \frac{Cov_{xy}}{Variance_y}}$

- **Relationship between Co-relation coefficient and Regression coefficient:**

Corelation coefficient is the geometric mean of the two regression coefficient. i.e;

$$\mathbf{r_{xy} = \sqrt{b_{xy} \cdot b_{yx}}}$$

CHAPTER-V

DESIGN OF EXPERIMENT

Design of Experiment is the proper allotment of treatment to experimental unit.
Treatment means factor whose effect is to be determined or studied.
E.g-feed,medicine etc

Experimental unit-These are the unit which are subjected to experimentation or upon which the effect of treatment is being studied.
Ex-animals in farm.

Basic principles of Design of Experiment

- It should be easy to formulate or design.
- The comparison is to be made.

It should follow the principles of randomization, replication and local control**.**

Important considerations:

1. Objectives of the study
2. Types of experimental materials available
3. Characters to be studied
4. Treatments to be undertaken for comparison
5. Precision required

Randomization-
It is the process applied to avoid biasness in the proper allotment of treatment to experimental unit.
It is done by 2 ways
Lottery system
by using table random number
Replication-
it is the number of times the effect of treatment is measured by using replication.As replication increases, the accuracy increases.
Local Control -It is the logical grouping of experimental unit to control the variability among the experimental units.

Use of Replication:

i)For proper estimation of error component of variance.

ii) To reduce the magnitude of standard error, thereby to make the design of experiment efficient and precise.

iii)To decide the number of observations (replication) to be recorded under each treatment.

iv)To decide the number of treatments to be tested with the available experimental units.

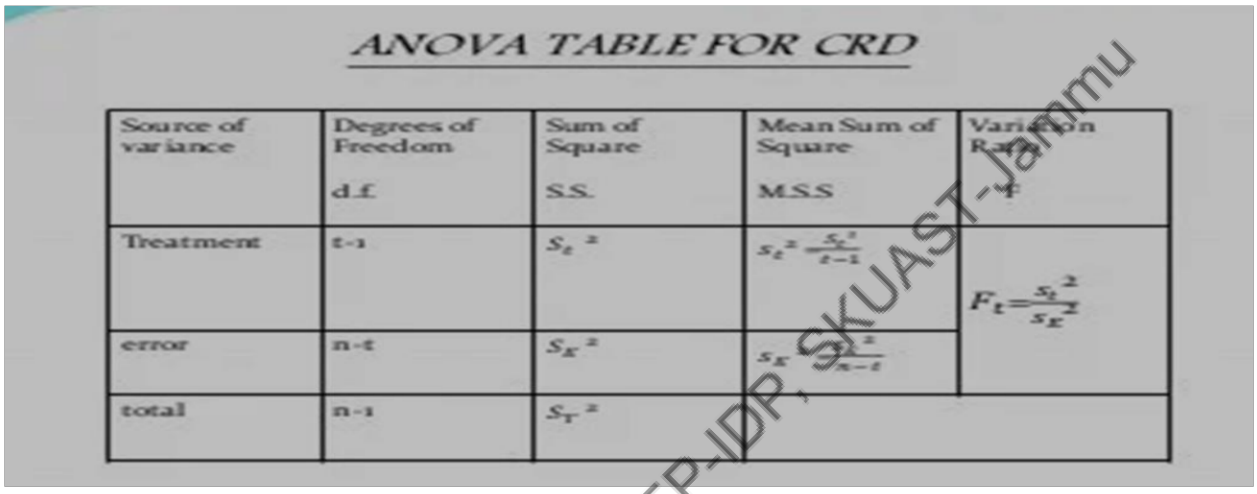
Completely Randomized Design(CRD)-

When the experimental units form the homogenous group,then the various treatment can be allotted in a completely random manner.

It is also called as One way ANOVA.

The random allotment can be done by Lottery system by using table random numbers.

It can be used to study the effect of feed on chicken growth etc.



ANOVA TABLE FOR CRD

Source of variance	Degrees of Freedom d.f	Sum of Square S.S.	Mean Sum of Square M.S.S	Variation Ratio F
Treatment	t-1	S_t^2	$s_t^2=\frac{S_t^2}{t-1}$	$F_t=\frac{s_t^2}{s_E^2}$
error	n-t	S_E^2	$s_E^2=\frac{S_E^2}{n-t}$	
total	n-1	S_T^2		

Advantage of CRD:

Easy to design

Analysis of data is simple & straightforward.

Statistical analysis do not become complicated if some of the experimental units fail to provide information.

If the calculated value of F is more than the tabulated value at a particular level of significance and degree of freedom, then it is significant.

Randomised Block Design
It is two way ANOVA.
It is an improvement over CRD. In this treatment or factors are not allotted randomly as in case of CRD. In this case ,homogeneous block are formed on basis of certain characters.like age wt etc.

All the experimental units are grouped into different homogeneous blocks according to variability.

Allotment of treatment is not completely at random like CRD but the allotment is completely at random within the homogeneous block.

The merit of RBD:

Most frequently used design. It is easy to design with one local control.

Statistical analysis of data is simple but little bit tricky than CRD.

It eliminates one assignable cause of variation among experimental units by using local control or blocking.

The error DF in RBD is lesser than that of CRD due to removal of DF for blocks.

Table 3.1 : ANOVA (Two-Way Layout) or RBD

Source of Variation	D.F.	S.S.	M.S.S.	F ratio
Replication	$r-1$	*RSS*	*RMS*	*RMS / EMS*
Treatment	$t-1$	*TSS*	*TMS*	*TMS / EMS*
Error	$(t-1)(r-1)$	*ESS*	*EMS*	
Total	$rt-1$	*Total S.S.*		

SKEWNESS AND KURTOSIS

Curves representing the data points in the data set may be

either symmetrical or skewed.

When the mean, mode and median do not have the same value in a distribution, then it is termed as skewed distribution

Shape of a Distribution

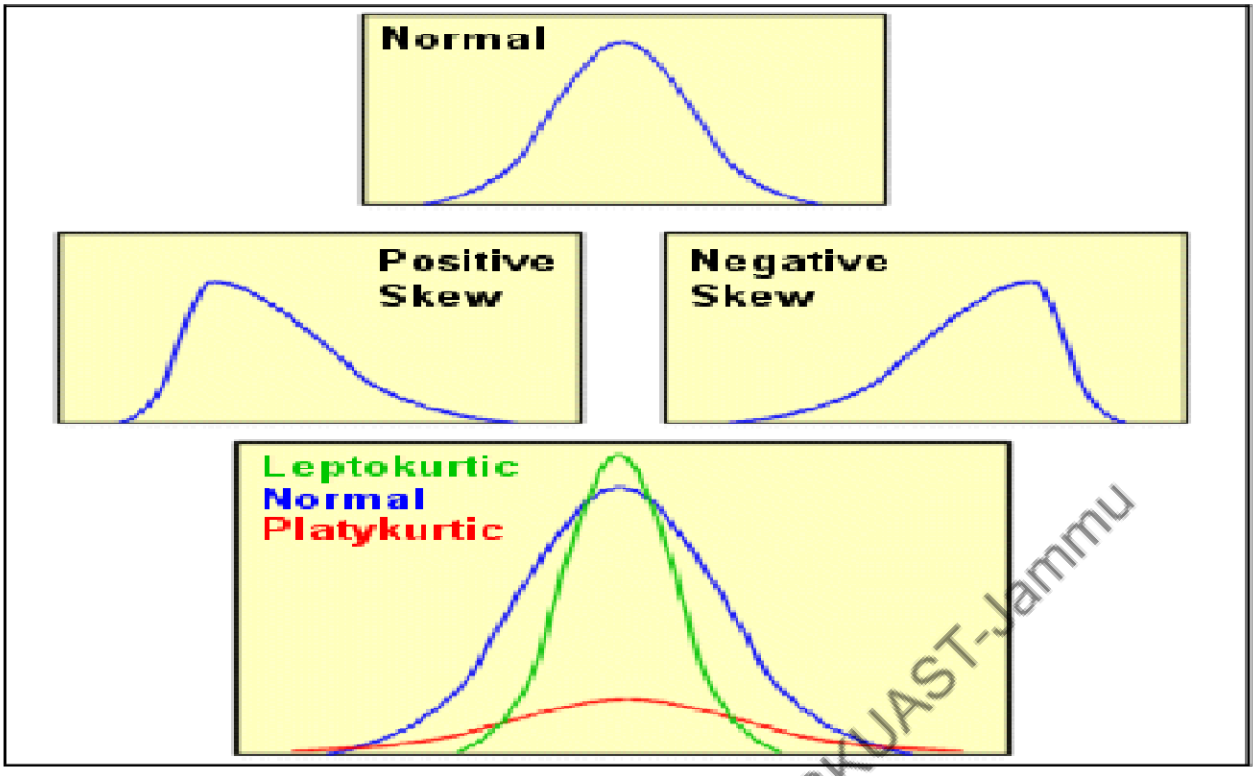
Describes how data is distributed

Measures of shape

Symmetric or skewed.

Kurtosis is another measure of the shape of a frequency curve.

While Skewness signifies the extent of Asymmetry, Kurtosis measures the degree of peakedness of a frequency distribution



CHAPTER-VI

SELECTION AND TYPES OF SELECTION

Selection:

Selection is a process of giving preference to certain individuals in a population to reproduce than other individuals which are denied the opportunity to produce next generation. Therefore selection is the choice of individuals to produce next generation. In genetic term, the selection is a process of differential reproduction and survival of genotypes which may be natural or artificial or both.

The selection, without creating any new gene, changes the genetic structure of the population by changing the frequency of genes and genotypes. The frequency of desired genes is increased in the population through selection at the expense of the frequency of undesirable or less desirable genes. This is the genetic effect of selection. The selection is more efficient for dominant genes at low frequency but it is relatively easy to select for the recessive gene. The characters are controlled by genes. Therefore, with the increase or change in the frequency of desirable genes, the phenotypic mean of the character of the progeny generation is also increased.

Selection is of two kinds namely, natural and artificial selection.

Natural selection:

The main force of natural selection is the survival of fittest in a particular environment. The survival is for the particular environment in which the population lives *e.g.,* wild animals. In nature, the animals best adapted to their environment survived and produced the largest number of offspring. This natural selection acts through the variations produced by mutations and recombination of genetic factors and eliminates unsuccessful genetic combination and allows nature's successful experiments to multiply.

Natural selection is a very complicated process and many factors determine the proportion of individuals that will reproduce. Those factors are:

- Differences in mortality in the population especially early in life,
- Differences in the duration of sexual activity,
- Degree of sexual activity and
- Differences in the degree of fertility of individuals in that population.

Natural selection operates through differences of fertility among the parents or of viability among the progeny. Therefore, in natural selection by means of survival of the fittest, there is a tendency towards elimination of the defective or detrimental genes that have arisen through mutation.

Artificial selection:

It is the selection practiced by man. This can also be defined as the efforts of man to increase the frequency of desirable genes or combination of genes in his herd or flock by locating or saving those individuals with superior performance or that have the ability to produce superior performing offspring when mated with individuals from other lines or breeds.

This can be classified as:

1. Automatic selection,
2. Deliberate selection and
3. Replacement selection and culling.

Replacement selection decides which animals will become parents for the first time *i.e.,* new animals to replace parents that have been culled. These new animals are called replacements.

Culling decides which parents will no longer remain parents. It is the removal of inferior animals rather than the more positive selection of good ones. While doing culling, decision should be firm that culling has been made for genetic or environmental reasons. It is easy to cull poor looking stock but genetically this achieves little if they are poor because of environmental reasons. Thus, selection and culling go together. The risks of this type of error are higher when animals examined after a period of high production such as lactation. *e.g.* In ewes, twin born will be thin and poor looking and barren ewes will be fatty. Similar observations can be seen in sows. Therefore, replacement selection and culling are really just different sides of the same coin. They involve different sets of animals, but their purposes are the same *i.e*., to determine which animals reproduce. Hence, both are integral parts of selection as a whole.

RESPONSE TO SELECTION AND FACTORS AFFECTING IT

The change produced by selection is the change of the population mean in the offspring. This is called as the response to selection, symbolized by "R". **The** response to selection **is the difference of** mean **phenotypic value between the** offspring **of the selected parents and the whole of the parental generation before** selection**.** The response to selection is also called as the expected genetic gain, symbolized by ê G.

R or ê G = h^2S

Where, h^2 = heritability and S = selection differential

R or ê G/ year = h^2S/GI

Where, GI = generation interval

FACTORS AFFECTING RESPONSE TO SELECTION (GENETIC GAIN)

The factors affecting the response are additive genetic variability (heritability), intensity of selection (selection differential), accuracy of selection, population size and generation interval. Maximum gain (response per year) will result when the selection differential (S) and the heritability (h^2) are high and the generation interval (GI) is low.

1. Heritability: The genetic gain depends on the h^2 of the character in the generation from which the parents are selected and if the h^2 is high, the genetic gain will also be more, because the environmental variation will be less. The high heritability depends on more additive genetic variability. Selection will not be affective to bring change if there is no genetic differences among animals.

2. Selection differential: The average superiority of the selected parents is called as selection differential, symbolized by "S". **It is defined as the difference between the** mean **phenotypic value of the individuals selected as parents and the** mean **phenotypic value of all the individuals in the parental generation before** selection.

S = (Ps - P) where, Ps = mean of the selected parents

P = mean of the population

The selection differential may also be expressed in terms of phenotypic standard deviation (standard deviation is the measure of variability) as,

S = i σ_p where i = **intensity of the** selection

σ_p = phenotypic standard deviation

Intensity of selection is defined as the standardized selection differential. The intensity of the selection is also called as selection pressure and it is the mean deviation of the selected individuals in units of standard deviation. The intensity of selection is symbolized by "i". It depends on the proportion of the individuals selected and it can be determined from the tables of properties of normal distribution.

i = Selection differential / Phenotypic standard deviation = S/ σ_p

FACTORS AFFECTING SELECTION DIFFERENTIAL

1. **Proportions of the animal selected for breeding**: Smaller the number larger the selection differential,
2. **Herd size**: Larger the herd size, smaller the proportions of animals selected,
3. **Reproductive rate**: in cattle selection differential will be less whereas in pigs, it will be more because of more litter size and
4. **AI**: Use of artificial insemination and frozen semen increases selection differential or selection intensity in case of males and in females, superovulation and embryo transfer increases the selection differential or selection intensity.

The following table gives the percentage of males and females to be selected for breeding to maintain a constant herd size for different species:

Species Percentage of animals to be selected

	Males	**Females**
Dairy cattle	4 - 5	50 - 60
Beef cattle	4 - 5	40 - 50
Sheep	2 - 4	45 - 55
Swine	1 - 2	10 - 15
Chicken	1 - 2	10 - 15
Horse	2 - 4	40 - 50

3. Generation interval:

It is the time interval between generations and **is defined as the average age of the parents when the** offspring **is born**. This varies between species and selection procedure. Management practices for early breeding in females reduces GI and breeding practices like progeny testing increases the GI. The average generation intervals for different species are:

Species Generation Interval (in years)

	Males	**Females**	**Average**
Dairy cattle	3 - 4	4.5 - 6.0	4 - 5
Beef cattle	3 - 4	4.5 - 6.0	4 - 5
Sheep	2 - 3	4.0 - 4.5	3 - 4
Swine	1.5 - 2	1.5 - 2.0	1.5 - 2.0
Chicken	1 - 1.5	1 - 1.5	1.0 - 1.5
Horse	8 - 12	8 - 12	8 - 12

The genetic gain per year is higher in the herd that bred with younger animals (at younger age) than the herd that bred comparatively at later age**.**

4. Accuracy of **selection**:

Accuracy of selection is the correlation of breeding value of an animal and its phenotype vale (source of information) which is denoted as r_{AP}. The correlation of breeding value and phenotype vale is equal to the square root of heritability (r_{AP} =h). Hence, the accuracy for selection is directly related to the heritability of the trait. If the heritability is high, the selection on phenotype will permit an average estimation of breeding value. If heritability is low, many errors will be made. Increased accuracy in selection can be obtained by comparing the animals in controlled environmental conditions. Correlation may be made for the age of the individual, age of the dam and sex to remove non-genetic variations. The techniques may increase the heritability of the trait by reducing the environmental variation. Selection will be more accurate when the heritability of the trait is high.

When the accuracy of selection on individual is low, accuracy can be increased by-

- Using additional measurements for the trait from the same individual,
- Using measurements of correlated traits and
- Using measurements of relatives.

5. Population size: The effect of population size on response to selection can be viewed in terms of inbreeding and genetic drift. The inbreeding is unavoidable in a population of small size. The Ne is the number of individuals that would give rise to the same rate of inbreeding, if they bred in the manner of an idealized population, in which the rate of inbreeding is $\Delta F = 1/(2N)$. The effect of inbreeding is to reduce the amount of genetic variability (V_A) and reduction in performance (inbreeding depression). This causes a decreases the response to selection. It is thus suggested that there should be sufficient Ne to reduce ΔF less than 1% per year. Genetic drift may cause the loss of favourable alleles from the population. This will reduce the response to selection and also the ultimate limit to selection will be less and will be reached more quickly.

Selection limit: When the selection is carried out continuously, the response to selection will be more for a few generations, and then it slows down and finally stops. When the response to selection has stopped, the population is said to be at "plateau" or "selection limit". The main cause for this is fixation of favourable genes. This causes reduction or absence of genetic variation. Therefore further improvement depends on introduction of new genetic variation. The new genetic variation can be introduced by cross breeding, mutation and genetic engineering.

Selection: Information from relatives

In our consideration of selection we have up to now suppose that individuals are measured for the character to be selected that the best of chosen to be parents in accordance with the individual phenotype values. An individual's on phenotypic value, however, is not the only source of information about its breathing value. Additional information is provided by the phenotypic values of relatives, particularly by those of full or half sibs. With some characters, indeed, the values of relatives provide the only available information. Milk-yield, to take an obvious example, cannot be measured in males, so the breeding value of a male can only be judged from the phenotypic values of its female relatives.

The use of information from relatives is of great importance in the application of selection of animal breeding, for two reasons.

1. The characters to be selected are often ones of low heritability, and with these the mean value of a number of relatives often provides a more reliable guide to breeding value than the individual's on phenotypic value.
2. When the outcome of selection is a matter of economic gain, even quite a small improvement of the response will repay the extra effort of applying the best technique.

In this chapter we shall outline the principles underlying the use of information from relatives and the choice of best method of selection.

If the family structure of the population is taken into account we can compute the main phenotypic value of each family; this is known as the ***family mean.*** Suppose, then, that we have a population in which the individuals are grouped in families, which may be full sibs or half sibs, and we have measurement of each individual and of the means of every family. How then is the additional information from the family means to be used? The problem may best be explained by reference to a specific example.

Table: Examples of individual values and family mean for selection (Explained in the text)

	Family			
Individual	A	B	C	D
1	13	11	7	9
2	10	9	7	5
3	8	6	6	3
4	5	6	4	3
Family mean	9	8	6	5
Overall mean	7			

Table above give some hypothetical but realistic values of litter size in mice. There are 16 individuals whose phenotypic values are entered in the body of the table. The individuals are grouped in 4 full sib families, A to D, with 4 individuals in each family. We have to choose the best 4 of these 16 individuals. Basing the choice on the individual phenotypic values we have no difficulty in choosing individuals A1, B1 and A2 with values, 13, 11, 10 respectively. But now there are two with values of 9, B2 in the good family and D1 in a bad family. Which do we choose? The decision rest on whether the differences between families are mainly genetic or mainly environmental. If they are genetic we choose B2 on the grounds that its better family means indicates a better breeding value. If, on the other hand, the differences between families are mainly environmental we would choose D1, on the grounds that its low family main indicates a poor environment and that it has performed well despite this disadvantage. The problem is not only in discriminating between individuals with the same phenotypic values, but is a matter of finding the right weight to be given to the family means. With the correct weighting we might be lead to choose A3 with 8 in place of B2 with 9. Application of the principal to be developed shows that this would in fact be the best procedure if these values were litter size of mice.

To calculate the best weighting of the family means, only three things need to be known:

1. The kind of family (whether full or half sibs).

2. The number of individuals in the families (the family size) and

3. The phenotypic correlation between members of the families with respect to the character.

The information needed to solve what seems a complex problem is thus surprisingly simple; but the explanation of the underlying principle is not so simple. The explanation will be presented in two ways. First we shall explain the concept of heritability as a determinant of the response to selection. This introduces no new principles and leads fairly easily to a solution of more complex problems found in practice. Then, under the heading of 'Index selection' a more general solution will be briefly explained. This allows information from different sorts of relatives to be combined, for example from parents as well as sibs. It also allows information from correlated characters to be used as an aid to selection.

The phenotypic vale of an individual, ***P***, measured as a deviation from the population mean, is the sum of two parts: the deviation of its family mean from the population mean, $\boldsymbol{P_f}$, and the deviation of the individual from the family mean, $\boldsymbol{P_w}$ (the within family deviation).

So, $P = P_f + P_w$

We may select on the basis of individual value only, giving equal weight to the two components P_f and P_w, this is known as ***individual selection***.

We may select on the basis of the family mean $\boldsymbol{P_f}$ only, giving zero weight to the within family deviation $\boldsymbol{P_w}$, is known as ***family selection***. Applied to the table above, all four individuals in family A would be selected.

We may select on the basis of the within family deviation $\boldsymbol{P_w}$ alone, giving zero weight to the family mean $\boldsymbol{P_f}$, is known as ***within-family selection***. Applied to the table above, the best individuals in each of the four families would be selected.

We may take account both the component giving different weight so as to make the best use of the two sources of information. This is known as selection by optimum combination or ***combined selection***.

Bases of selection

Various Bases for selection are:

1. Individual selection or mass selection
2. Pedigree selection
3. Family selection and sib selection
4. Progeny testing
5. Combined selection

INDIVIDUAL / MASS SELECTION

It is selection on the basis of individual's phenotype (appearance) and performance. Individuals are selected solely in accordance with their own phenotypic values. This is the simplest and yields more rapid response. It is the most commonly used method for selective improvement of livestock. Undoubtedly, most of the progress in livestock improvement can be credited to individual selection.

Indications: Individual selection is preferred-

- for traits expressed in both sexes,
- for traits with high heritability such as fleece weight, growth rate *etc.* and
- in the absence of pedigree and progeny records.

Advantages:

- The information on individuals to be selected are easily available.
- It can be applied earlier to progeny testing.
- This is used when pedigree information are not available.
- The generation interval is shorter by this method compared to progeny testing.
- This gives a direct estimate of breeding value and hence it is more accurate.
- This allows a greater selection differential.
- This method minimized the environmental effects (individuals are tested in the same environmental conditions).

Limitations:

- Not possible for sex-limited traits like egg production, milk production and litter size.
- Not efficient when traits are expressed in later life of the individual or after death (carcass traits) of the animal.
- Not efficient when heritability of a character is low such as reproductive characters.
- Not possible for traits expressed only after sexual maturity, because selection has to be delayed till maturity resulting in waste of time and money.

PEDIGREE SELECTION

A pedigree is a list or record of an individual's ancestors in the past few generations of the individual. The ancestors are the parents, grand parents, great grand parents, etc. Knowledge of the productivity of the ancestors is necessary if pedigree is said to be useful. Such pedigrees are known as performance pedigrees. Ancestors more closely related to the individual should receive most emphasis in pedigree appraisal. The basis of pedigree selection is the fact that an individual gets half of its inheritance from each of the parents and it is usual to expect offspring of outstanding parents to be of higher genetic value than the average of the individual in the herd. Pedigree should be used only as additional information to individual selection.

Indications:

Pedigree selection is helpful-

- When the trait is sex limited, *e.g*., milk production, egg production *etc*.
- When production performances of the individuals are not available.
- For making preliminary selection of sires in progeny testing.
- When the characters are expressed late in life.
- For traits with low heritability pedigree information can be combined with individual's record.
- Pedigrees do have the advantage that they are cheap to use.

Practical difficulties to use pedigree selection:

- The ancestor's records are not always available.
- The records may be faulty.
- The pedigree records are destroyed by the passage of time.
- Most of the economic characters have low heritability**.**

Merits:

- It is less costly

- It allows selection at younger age.
- It is helpful in multistage selection.
- It is useful in sex-limited traits and traits and traits expressed in later life or after death of the animal.
- It is helpful when two individuals have similar performance but one belongs to a better pedigree.

Limitations:

- When the phenotypic value of an individual is known not much is gained by the use of pedigree.
- The genetic make up of the parents can not be known definitely since the phenotype is not indicative of the genotype.
- The pedigree records are made in different environment and hence the accuracy of the ancestry may not be reliable.
- Unwanted favouritism towards the progeny of the favoured individual.

FAMILY SELECTION / SIB SELECTION

Family, in animal breeding, includes full-sib and half-sib families. In a random mating population, half-sibs have a relationship coefficient of 0.25 and full-sibs have a relationship coefficient of 0.5. Such family members are collaterally related not directly related. They are neither ancestors nor descendants. Because of their common ancestry, they would have some genes in common and thereby some performance in common.

If the records of the individual are included in the family average and used as a criterion for selection, it is known as family selection. The within family deviation is given zero weight. If the individuals' records are not included in arriving at the average, then it is known as sib selection. When selection is carried out for market weight in swine, the market weights of all males and females in the family are considered in the calculation of family average (family selection). But when selection is carried out for fertility traits and milk yield, the performance of males can not be included but they are selected on the basis of sibs' average (sib selection).

The families are ranked and based on this; the entire family is selected or rejected. Family/sib selection is used more frequently in swine and poultry where the number of progenies produced by females is high. The family selection does not increase generation interval. The information from family/sib is combined with individual information in the form of index and selection is based on the index.

The chief circumstance under which family selection is to be preferred are-

- When the characters selected has a low heritability.
- In larger family size.
- When there is little variation due to common environment.

The sib-selection is preferred for sex-limited traits and for carcass traits

Advantages:

- It can improve the characters of low heritability in species with high reproductive rates (pig, poultry) so as to get many sibs in a short time.
- The family selection does not allow the generation interval to increase.
- It is a support to individual selection because it is better to select an individual from a superior family.

Limitations:

- If selection intensity is more, then there may be an increase in inbreeding and there will be increase in cost and space in raising larger population.

- As a unit of selection results in inbreeding and thus limits genetic diversity because only few families represent the next generation.
- The family selection can only be applied in species with high reproductive rates to get large family size**.**

Precautions:

- Number of progeny in each family should be large.
- There should not be common environment between sibs.

WITHIN FAMILY SELECTION

The criterion of selection is the deviation of each individual from the mean value of the family to which it belongs, those individuals that exceed their family mean by the greatest amount being regarded as most desirable. This is the reverse of family selection, the individuals are selected based on within family deviation and the family means being given zero weight. In this method the best individuals from each family is selected.

The chief condition under which this method has an advantage over the others is a large component of environmental variance common to members of a family. For example: Pre-weaning growth of pigs or mice. An important practical advantage of selection within families, especially in laboratory experiments, is that it economizes breeding space, however in family selection it is costly of space. When selection within families is practiced, the breeding space required to keep the rate of inbreeding below a certain value is only half as great as would be required under individual selection.

PROGENY TESTING

Progeny testing is estimating the breeding value of a sire based on the average performance of its offspring. Each offspring receives a sample half of genes from the sire. Therefore, the performance of large number of daughters will indicate the breeding value of sire on progeny testing. Progeny testing is usually conducted for males as more number of progenies can be produced for males and also proven bulls can be extensively used for production of more number of progenies. The primary selection of the bulls is based on the sibs' average. The bulls with highest averages are selected and included in the progeny testing. Then the bulls are used on many females to produce many progenies. The performances of progenies are then studied to estimate the breeding value of each bull. It is the best way of determining the genetic make-up of an individual. It is a modified form of family selection because the progeny are also used as parent and await selection at the time of testing their own parent.

Indications:

- When the heritability of a trait is low.
- When the trait is sex-limited.
- For traits expressed after slaughter (carcass traits).
- For testing of animals for recessive characters.
- For selection of animals that nick well.

Methodology of Progeny Testing:

- In order to overcome the problem of population size the P.T. programme should be carried out in the associated herds.
- About 4-5 males should be kept under test for each required progeny tested bull for future breeding.
- About 50 progenies should be settled from each bull so as about 10 daughters of each bull must be performance recorded.

- It is better to complete one set of bulls within a period of 2 years.
- In each set of bulls, about 8-10 males should be tested so as atleast 2 top ranking bulls are selected on the basis of their B.V. estimated from their daughter's performance.
- Taking a set of 10 males, 2 tested and 8 under test, it will require 500 pregnancies in a period of 2 years. Considering that only 66% of the breeding females will calve each year, 250 pregnancies will be settled in one year from 375 breedable females.
- The 2 best proven bulls should be used on about 60 best yielding cows to get a set of young males for testing in a later batch and the remaining 8 which are the sons of 2 best proven bulls of an earlier batch should be used on the remaining bulls under test.
- The B.V. of the bull based on its progeny performance is estimated by multiplying the regression of B.V. of parent on the phenotypic performance of its progeny with the selection differential of the progeny of i^{th} sire from the mean of the contemporaries ($P_i - P_c$).

Thus the B.V.is estimated as-

$$\text{R.B.V.} = P_c + 2nh^2/ [4+ (n-1)h^2] (\overline{P}_i - \overline{P}_c)$$

Advantages:

- It is a better selection criterion for sex-limited traits, the traits with low heritability and slaughter traits in meat animals.
- It is useful to prove a sire whether he is free from any recessive gene. To identify the carrier sires for harmful gene, it is mated to its sibs or progeny.
- The main advantage is the increased selection intensity.
- Its accuracy increases with increase in progeny number.

Limitations:

- Increases the generation interval.
- Costly in terms of resources required.
- Time required is more.
- Sires can be selected only when the progenies come for production and by the time the sire may become old and useless. Therefore, the annual rate of genetic gain is lowered.

The genetic principle behind progeny testing is that the more the number of progeny are tested the greater the accuracy of assessment of the parents, since the errors in sampling are reduced. To get the best results from progeny testing, the following precautions should be borne in mind.

Precautions:

- Test as many sires as possible (usually 5 to 10).
- Females to which a sire is mated must be random sample of a population.
- There should not be any selection among the progeny.
- Environmental influences should be random
- Large number of progeny should be studied to eliminate sampling errors.
- Errors like effects of year, season and location should be eliminated as far as possible.

COMBINED SELECTION

The selection of individual on the basis of two or more sources of information is called combined selection or index selection. It is better to select on the basis of an index combining information from various relatives (dam, sibs and/or progeny) with or without individual's own record. This involves the **matrix method**

and is done by technique of multiple regressions of breeding values of all sources of information. These multiple regression coefficients are to be used as the weighting factors. All information available about each individual's breeding value combined into an index of merit is the optimal procedure for selection. Here the family mean (P_f) and within family deviations (P_w) are given different weights. $P = P_f + P_w$

The index so constrcured is the best linear prediction of an individual's B.V. The index can be represented as: $I = b_1P_1 + b_2P_2 + b_3P_3 + \ldots\ldots\ldots$

b = index weight (values are to be estimated so as there is maximum correlation between index and B.V. (r_{IA}).

P= Phenotypic values of different selection criteria.

METHODS OF SELECTION

The purpose of animal breeding is not to genetically improve individual animals but to improve future generation of the animal population. The method used by the breeder to make long-term change in animals is called selection. Selection is the process in which certain individuals in a population are given an opportunity to produce offspring while others are denied this opportunity. It also decides about how many offspring it should produce and how long they should remain in the breeding population. Selection is an important tool for changing gene frequencies to better-fit individuals for a particular purpose.

Breeders always tend to go for selection of several traits at a particular time. Because, the net value of an animal would depend on several traits that may not be equally economically important. The desirable trait will depend on the economic value but only of real importance may be considered. If too many traits selected for one time there will be less progress in improvement of any particular trait.

There are three methods of selection:

1. Tandem method
2. Independent culling level method
3. Selection index or total score method

TANDEM METHOD

In this method, selection is practiced for only one trait at a time until improvement has been made in that trait. Selection efforts for this trait are then relaxed and efforts are made towards the improvement of second, third, fourth, and so on. In general, the efficiency of this method is very low. The genetic progress per unit time is less and that too for great efforts. The average genetic improvement per generation in each of n traits (which are independent and equally important) would be only 1/n times. This method is less efficient than other methods of selection The efficiency depends on genetic correlation between traits. If there is a positive genetic correlation, then the results may be desirable in the other trait also. If there is a negative genetic correlation, the efforts will be undesirable. It requires more time for improvement in all the traits because while selection is being done for one trait, the other trait must wait. Since very long time would be involved in selection practice, the breeder may change one goal to another and discourage one trait.

INDEPENDENT CULLING LEVEL METHOD

In this method, selection may be practiced for two or more traits at a time. But for each trait, a minimum standard (culling level) is set, so that every animal must meet the standards to be selected for the breeding purposes. The failure to meet the minimum standard for any one trait makes the animal to be rejected. Therefore, in actual practice, it is possible to cull some genetically very superior animal when this method is used. The properties selected for each trait will depend up on the total number of animals screened for the breeding.

For example:

Traits	Standard set	Buffalo No.1	Buffalo No.2
AFC (months)	42	42	40
Milk yield (kg)	1900	1950	2100
Fat %	7.5	7.5	7

Under ICL method buffalo No.1 will be selected but buffalo No.2 will be rejected because it fails to meet the standard set for fat percentage, though it is superior in other traits.

This method reduces selection intensity of the traits to be selected. The negative correlation among the traits will make the further reduction in selection intensity. Selection based on independent culling method is easy to perform but becomes complicated when more traits are considered and if there is negative correlation between traits. Therefore, only few important traits should be considered in this method.

Advantages of ICL

1. This method is superior to tandem method because the selection is practiced for more than one trait at a time.
2. The practical and economic advantage of this method is that it allows culling the animals earlier which are inferior in early expressed traits.

Disadvantages of ICL

1. No compensation for other traits
2. Culling level- This method involves a tedious work to determine the optimum culling level.
3. More emphasis to early expressed traits
4. Selection intensity- Intensity of selection is reduced with increase in number of traits.

SELECTION INDEX OR TOTAL SCORE METHOD

Selection index is a single numerical value within the total scores given for each trait considered in the selection. Each trait is weighted, by giving score and an individual score is summed up to the total score for the each animal within the selection criteria. The selection index is a total score that includes all the advantages and disadvantages of an animal for those traits considered for selection. The amount of weightage given to each trait depends on their relative economic value, heritability of the character and genetic correlation between characters. A trait which is highly heritable can be given greater score than a trait which has a low heritability. The selection index method is the most efficient (best method) among these three methods because it results in more genetic improvement. The index is the best estimate of an animal's breeding value. The only disadvantage is that the traits vary in importance from time to time and the index built at one time will not be applicable for all times. The selection index has to be modified from time to time.

The index of an individual is given as

$$I = b_1P_1 + b_2P_2 + b_3P_3 + \ldots$$

In which the *b*'s are the factors by which each measurement is to be weighted. $P_1, P_2, P_3,$ etc.., each P is the phenotypic value of individual or a group of relatives taken as deviation from population mean.

The index weight (*b*) can be estimated as

$$\boldsymbol{b = P^{-1}Ga}$$

P is the phenotypic variance covariance matrix, G is the genotypic variance covariance matrix and a is the vector of relative economic values of the traits.

When two traits are considered:

$$\mathbf{P}=\begin{bmatrix}\sigma^2p_1 & \sigma p_{12}\\ \sigma p_{21} & \sigma^2p_2\end{bmatrix} \qquad \mathbf{G}=\begin{bmatrix}\sigma^2g_1 & \sigma g_{12}\\ \sigma g_{21} & \sigma^2g_2\end{bmatrix} \qquad \mathbf{a}=\begin{bmatrix}a_1\\ a_2\end{bmatrix}$$

Where,

σ^2p_1 = Phenotypic variance of first trait
σ^2p_2 = Phenotypic variance of second trait
σ^2g_1 = Genotypic variance of first trait
σ^2g_2 = Genotypic variance of second trait
$\sigma p_{12} = \sigma p_{21}$ = Phenotypic covariance of first and second trait
$\sigma g_{12} = \sigma g_{21}$ = Genotypic covariance of first and second trait
a_1 = Relative economic values of the first traits
a_2 = Relative economic values of the second traits

When three traits are considered:

$$\mathbf{P}=\begin{bmatrix}\sigma^2p_1 & \sigma p_{12} & \sigma p_{13}\\ \sigma p_{21} & \sigma^2p_2 & \sigma p_{23}\\ \sigma p_{31} & \sigma p_{32} & \sigma^2p_3\end{bmatrix} \quad \mathbf{G}=\begin{bmatrix}\sigma^2g_1 & \sigma g_{12} & \sigma g_{13}\\ \sigma g_{21} & \sigma^2g_2 & \sigma g_{23}\\ \sigma g_{31} & \sigma g_{32} & \sigma^2g_3\end{bmatrix} \quad \mathbf{a}=\begin{bmatrix}a_1\\ a_2\\ a_3\end{bmatrix}$$

Where,

σ^2p_1 = Phenotypic variance of first trait
σ^2p_2 = Phenotypic variance of second trait
σ^2p_3 = Phenotypic variance of firstthird trait
σ^2g_1 = Genotypic variance of first trait
σ^2g_2 = Genotypic variance of second trait
σ^3g_3 = Genotypic variance of third trait
$\sigma p_{12} = \sigma p_{21}$ = Phenotypic covariance of first and second trait
$\sigma p_{13} = \sigma p_{31}$ = Phenotypic covariance of first and third trait
$\sigma p_{23} = \sigma p_{32}$ = Phenotypic covariance of second and third trait.
$\sigma g_{12} = \sigma g_{21}$ = Genotypic covariance of first and second trait
$\sigma g_{13} = \sigma g_{31}$ = Genotypic covariance of first and third trait
$\sigma g_{23} = \sigma g_{32}$ = Genotypic covariance of first and second trait
a_1 = Relative economic values of the first traits

a_2 = Relative economic values of the second traits
a_3 = Relative economic values of the third traits

CHAPTER-VII

TESTS OF HYPOTHESIS OR TESTS OF SIGNIFICANCE

Tests of Hypothesis:

The tests used to ascertain whether the differences between estimator and the parameter or between two estimators are real or due to chance are called **tests of hypothesis** or **tests of significance**. In other words, the procedures, which enable us to decide whether to accept or reject hypothesis, are called **tests of hypothesis** or **tests of significance**. The following terms are commonly used in testing of hypothesis-

(i) Null hypothesis
(ii) Alternative hypothesis

1. Null hypothesis-

The hypothesis, which is tested for possible rejection under the assumption that it is true, called **null hypothesis**. It is denoted as H_0.

2. Alternative hypothesis-

Any hypothesis, which is complementary to the null hypothesis, is called an **alternative hypothesis**. It is denoted as H_1.

Example: If we want to test a null hypothesis that the average dry period of Hariana cows in a herd is 150 days, then these two hypothesis can be written as-

H_0: $\mu = 150$ (Null hypothesis)
H_1: $\mu \neq 150$ (Alternative hypothesis)
i.e. $\mu > 150$ or $\mu < 150$

Types of errors:

The decision to accept or reject the null hypothesis (H_0) is made on the basis of sample observations. There is always possibility of committing two kinds of error in testing of a hypothesis.

(i) Type-I error
(ii) Type-II error

Type-I error: Rejecting a null hypothesis (H_0) when it is true is called **type-I error**. It is denoted by '**α**'. Thus, α = P (Type-I error) = P (Rejecting H_0 when H_0 is true)

Type-II error: Accepting a null hypothesis (H_0) when it is false is called **type-II error**. It is denoted by '**β**'. Thus, β = P (Type-II error) = P (Accepting H_0 when H_0 is false)

The following gives an idea about the type-I and type-II errors:

	Accept H_0	**Reject H_0**
H_0 is true	Correct decision	type-I error
H_0 is false	type-II error	Correct decision

(1-β) is called the **power of a test**. In testing a hypothesis though efforts are made to reduce both Type-I error and Type-II errors. In testing a hypothesis it is desirable to keep both types of errors as minimum as possible. But these two types of error are so related that a reduction in one results an increase in other. Since,

type-II error is considered to be more serious than type-I error, we control α and minimize β. These two types of error can be clearly understood with the following example-

Example

Suppose an experimental ration is given to a group of animals to improve its growth. When the ration has a positive effect but it is considered of having adverse effect, it is **Type-I error**. When the ration has an adverse effect, but considered of having positive effect, it is **Type-II error**. If the type-I error is committed, these animals will be given another ration, which may or may not be effective, whereas in case of type-II error the ration is given continuously in spite of its adverse effect. Hence, it is likely that animals may die or have developed some complications. Thus it is obvious that type-II error is more serious than type-I error.

Level of significance:

In testing of hypothesis, we wish to minimize sizes of both types of errors. However, with fixed size testing procedure, both the errors cannot be minimized simultaneously. Thus, we keep the size or the probability of committing type-I error (α) fixed at certain level, called the **level of significance**. The level of significance is also known as the **size of rejection region** or the **size of the critical region**. The level of significance, which are usually employed in tests of significance are 5% and 1%. If the level of significance is chosen as 5 per cent, it means that the probability of accepting a true hypothesis is 95 per cent.

Critical region:

A region in the sample space S in which if the computed value of the test statistic lies, we reject the null hypothesis, are called the **critical region** or **rejected region**. When the rejection region consists of two regions each associated with probability $\alpha/2$, called two tailed test. On the other hand, when the rejection region consists of only one region, either on the right or left, associated with probability α, called **one tailed test**.

Degree of freedom:

It is the number of independent observation used in the making of the statistic. In general, the number of degree of freedom is the total number of observations minus the number of independent constrains imposed on the observations. Thus, if k is the number of independent constraints in a set of data of n observations, then the degree of freedom will be (n - k). The number of degree of freedom for a statistic is usually denoted by ν.

Procedure of Hypothesis Testing:

Following steps can carry out hypothesis testing-

1. Set up the null hypothesis (H_0)
2. Select the level of significance
3. Decide about an appropriate test statistic
4. Find out degree of freedom
5. Find the rejection region and locate the position of the computed test statistic in it. If the test statistic lies in the rejection region, H_0 is rejected otherwise it is not rejected and we conclude that the data do not provide sufficient evidence to cause rejection of null hypothesis.
6. Finally, we conclude the testing problem with a statistical decision stating clearly the level of significance.

Z-test (Large Sample Test)

When the samples are of size n >30, almost all distributions are closely approximated by normal distribution, therefore normal distribution form the statistical basis of all the large sample tests. Thus, in the

entire large sample test we compute the test statistic Z under H_0 where Z is a standard normal distribution with mean 0 and variance 1. Symbolically, we can Z ~ N (0, 1). The test is usually performed at 5% and 1% level of significance ($\alpha = 0.05$ and $\alpha = 0.01$) at which the critical values of Z are 1.96 and 2.58 respectively. We shall discus the following four large sample tests.

(i) Testing hypothesis about mean (population variances known)
(ii) Testing hypothesis about difference between means (population variances known)
(iii) Testing hypothesis of proportion
(iv) Testing hypothesis of difference between two proportions

1. Testing hypothesis about mean (population variances known)

Let $x_1, x_2, x_3, \ldots\ldots\ldots\ldots x_n$ be a random sample of size n drawn from a large population with mean μ and known variance σ^2. Then, we wish to test

$H_0: \mu = \mu_0$ (Population mean is μ_0)
$H_1: \mu \neq \mu_0$ (Population mean differ from μ_0)
Where, μ_0 is the specified value of mean.

Test statistic

Under H_0, the test statistic used is Z given by

$$Z = \frac{\bar{X} - \mu_0}{\sigma/\sqrt{n}}$$

Here, $\bar{X}$ = sample mean
μ_0 = population mean
σ = standard deviation of the population, and
n = sample size

Decision rule

After computing the value of the Z-statistic, the decision about H_0 is taken. If $|Z| < 1.96$, we accept H_0 and If $|Z| > 1.96$, we reject H_0, if calculated value of test statistic Z is either greater than 1.96 or less than -1.96 and conclude that the difference between $\bar{X}$ and μ_0 is significant.

2. Testing hypothesis about difference between means (population variances known)

Let $x_1, x_2, x_3, \ldots\ldots\ldots\ldots x_{n1}$ be a random sample of size n_1 drawn from a large population with mean μ_1 and known variance σ_1^2 and $y_1, y_2, y_3, \ldots\ldots\ldots\ldots y_{n2}$ be another random sample of size n_2 drawn from a large population with mean μ_2 and known variance σ_2^2. Then, we wish to test-

$H_0: \mu_1 = \mu_2$ (No difference between means)
$H_1: \mu_1 \neq \mu_2$ (Significance differ between means)

Test statistic

Under H_0, the test statistic used is Z given by

$$Z = \frac{\bar{X} - \bar{Y}}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

Where, $\bar{X}$ and $\bar{Y}$ are the means of samples X and Y, respectively.

Remark: If $\sigma_1^2 = \sigma_2^2 = \sigma^2$ i.e. if the samples have been drawn from the same population with common variance σ^2. Then

$$Z = \frac{\bar{X} - \bar{Y}}{\sigma\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Decision rule

After computing the value of the Z-statistic, the decision about H_0 is taken. If $|Z| < 1.96$, we accept H_0 and If $|Z| > 1.96$, we reject H_0, if calculated value of test statistic Z is either greater than 1.96 or less than -1.96 and conclude that the means of the two population are significant.

3. Testing hypothesis of proportion

Let p be the proportions of individuals possessing the given attribute in a sample drown from a large population. The null and alternative hypothesis are-

H_0: $p = p_0$ (population proportion is p_0)

H_1: $p \neq p_0$ (population proportion is not p_0)

Where, p_0 is a specific value of population proportion.

Test statistic

Under H_0, the test statistic is -

$$Z = \frac{p - p_0}{\sqrt{\left(\frac{p_0 q_0}{n}\right)}}$$

Where, $p = X/n$, p_0 = population proportion, $p_0 = 1 - q_0$ and X being the number of individuals possessing in a sample of size n.

Decision rule

After computing the value of the Z-statistic, the decision about H_0 is taken. If $|Z| < 1.96$, we accept H_0 and If $|Z| > 1.96$, we reject H_0, if calculated value of test statistic Z is either greater than 1.96 or less than -1.96 and conclude that the sample proportion of attribute in the sample are significant.

4. Testing hypothesis of difference between two proportions

Let p_1 and p_2 are the proportions of individuals possessing the given attribute in random samples of size n_1 and n_2 drown from two large populations. The null and alternative hypothesis are-

H_0: $p_1 = p_2$ (No difference between proportion)

H_1: $p_1 \neq p_2$ (Significant difference in proportion)

Test statistic

Under H_0, the test statistic is -

$$Z = \frac{p_1 - p_2}{\sqrt{\left\{pq\left(\frac{1}{n_1} + \frac{1}{n_2}\right)\right\}}}$$

Where, $p_1 = X_1/n_1$, $p_2 = X_2/n_2$, X_1 and X_2 being the number of individuals possessing the given attributes in the samples of size n_1 and n_2, respectively.

p = Combined estimate of proportion or

$$p = \frac{(n_1 p_1 + n_2 p_2)}{(n_1 + n_2)} = \frac{(X_1 + X_2)}{(n_1 + n_2)}$$

q = 1 - p

Decision rule

After computing the value of the Z-statistic, the decision about H_0 is taken. If $|Z| < 1.96$, we accept H_0 and If $|Z| > 1.96$, we reject H_0, if calculated value of test statistic Z is either greater than 1.96 or less than -1.96 and conclude that the difference between sample proportions are significant.

Questions:

1. A sample of 400 individuals is found to have mean height of 160.3 cms. Can it be reasonably regarded as a sample from a large population with mean height 160 cms with a standard deviation 3.0 cms?
2. In an experiment, two diets are compared on 40 and 50 calves. The average increase in weights due to two diets A and B are 6kg and 5kg with standard deviations 1.0kg and 1.3kg, respectively. Test whether there are significant differences in their mean weights.
3. In a survey of 240 people 105 were found to be regular smokers. Can we conclude from sample data that the proportion of smokers in the sample population is different from 50 percent?
4. In a random sample of 1000 persons from city-A, 400 are found to be consumers of meat. In another sample of 800 persons from city-B, 350 are found to be consumers of meat. Do these data reveal a significant difference between city-A and city-B, so far as the proportion of meat consumers is concerned?

Small Sample Tests (t-test)

When the samples are of size $n < 30$, the assumptions on which analysis of large samples is done generally do not hold well in case of small samples. In case of large samples we had presumed that the random sampling distributions of statistics are approximately normal and further that the values obtained by sampling study are close to the population values and can be used in their place for the calculation of the standard error of the estimate. These assumptions do not hold well if the size of the samples may or may not be normally distributed and similarly it is not possible to substitute the mean or the standard deviation of a small sample in place of the parameter mean or standard deviation for the calculation of standard errors. Under such circumstances the analysis of small samples has to be done by techniques which are different from those applicable in case of large samples.

Student's t-distribution

This distribution applicable to small samples was developed by **W. S. Gossett** who was employed by the Guinness & Son., Dublin bravery, Ireland. His employer did not permit him to get anything published in his name so he used a pen-name **Student** and get his work published. Therefore, the t-distribution is commonly called **Student's t-distribution**.

If $x_1, x_2, x_3, \ldots\ldots\ldots\ldots x_n$ is a random sample of size n drawn from a normal population with unknown mean μ and variance σ^2. The t-statistic is defined as-

$$t = \frac{\bar{x} - \mu}{S/\sqrt{n}} \sim t_{(n-1)\text{d.f.}}$$

Application of t-distribution

The t-distribution has a number of applications of which we will discuss the following:

(i) Testing the significance of sample mean (population variance is unknown)
(ii) Testing the significance of the difference between two sample means (Unpaired t-test)
(iii) Testing the significance of the difference between two means (Paired t-test)
(iv) Testing the significance of an observed sample correlation coefficient
(v) Testing the significance of an observed sample regression coefficient

Testing the significance of sample mean (population variance is unknown)

Let $x_1, x_2, x_3, \ldots\ldots\ldots\ldots x_n$ be a random sample of size n drawn from a normal population with a specified mean μ and variance σ^2. Then, we wish to test

$H_0: \mu = \mu_0$ (Difference between $\bar{x}$ and μ_0 do not differ significantly)

$H_1: \mu \neq \mu_0$ (Difference between $\bar{x}$ and μ_0 differ significantly)

Where, μ_0 is the specified value of mean.

Test statistic

Under H_0, the test statistic used is t given by

$$t = \frac{\bar{X} - \mu_0}{s/\sqrt{n}}$$

Here, $\bar{X}$ = sample mean

μ_0 = population mean

n = sample size

s = standard deviation of the sample estimated as

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n-1}}$$

$$= \sqrt{\{[\sum x^2 - (\sum x)^2/n] /n-1\}}$$

Decision rule

The test is usually performed at 5% i.e. (α=0.05) and 1% i.e. (α=0.01) level of significances for (n-1) degree of freedom. After calculating the value of the t-statistic, the decision about the acceptance or rejection of H_0 is taken in the following manner-

(i) If the calculated value of test statistic $|t| < t_{(n-1)d.f}$ (α=0.05), we accept H_0. Hence, we conclude that the difference between $\bar{x}$ and μ_0 do not differ significantly.

(ii) If the calculated value of test statistic $|t| > t_{(n-1)d.f}$ (α=0.05), we reject H_0 at 5% level of significance for (n-1) degree of freedom. Hence, we conclude that the difference between $\bar{x}$ and μ_0 differ significantly.

(iii) If the calculated value of test statistic $|t| > t_{(n-1)d.f}$ (α=0.01), we reject H_0 at 1% level of significance for (n-1) degree of freedom. Hence, we conclude that the difference between $\bar{x}$ and μ_0 **highly** differ significantly.

Questions:

1. Six buffaloes were randomly selected from a herd and the lactation yield (litre) was recorded as given below:

   Lactation yield (litre): 950 1100 1250 980 1280 1050

   Test whether the average lactation yields are significantly different from the population mean of 900 litres?

2. An experimental ration was given to 8 cows, after a certain period. The change in daily milk yield (litres) in comparison to normal ration as given earlier, was recorded as below:

   Daily milk yield (litres): 3.5 -1 1.5 0 0.5 -2 2.5 3

   Test whether the experimental ration had a significant effect in changing the milk yield?

3. Body weight of 10 heifers at 3-months of age was 63, 66, 63, 67, 68, 69, 70,70, 71 and 71 kg. Can we say that average body weight at 3 month old heifers is 66 kg ?

Testing the significance of the difference between two sample means (Unpaired t-test)

Let $x_1, x_2, x_3, \ldots\ldots\ldots\ldots x_{n1}$ be a random sample of size n_1 drawn from a normal population with mean μ_1 and unknown variance σ_1^2 and $y_1, y_2, y_3, \ldots\ldots\ldots\ldots y_{n2}$ be another random sample of size n_2 drawn from a normal population with mean μ_2 and unknown variance σ_2^2. Then, we wish to test-

$H_0: \mu_1 = \mu_2$ (No difference between means)

$H_1: \mu_1 \neq \mu_2$ (Significance difference between means)

Test statistic

Under H_0, the test statistic used is t given by

$$t = \frac{\bar{X} - \bar{Y}}{S\sqrt{\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

Where, $\bar{X}$ and $\bar{Y}$ are the means of samples X and Y, respectively.

$$S = \sqrt{\frac{\sum(x - \bar{x})^2 + \sum(y - \bar{y})^2}{(n_1 + n_2 - 2)}}$$

$$= \sqrt{\frac{s_1^2(n_1 - 1) + s_2^2(n_2 - 1)}{n_1 + n_2 - 2}}$$

Decision rule

The test is usually performed at 5% i.e. (α=0.05) and 1% i.e. (α=0.01) level of significances for (n_1+n_2-2) degree of freedom. After calculating the value of the t-statistic, the decision about the acceptance or rejection of H_0 is taken in the following manner-

(i) If the calculated value of test statistic $|t| < t_{(n1+n2-2)d.f}$ (α=0.05), we accept H_0. Hence, we conclude that the two sample means do not differ significantly.

(ii) If the calculated value of test statistic $|t| > t_{(n1+n2-2)d.f}$ (α=0.05), we reject H_0 at 5% level of significance for (n_1+n_2-2) degree of freedom. Hence, we conclude that the two sample means differ significantly.

(iii) If the calculated value of test statistic $|t| > t_{(n1+n2-2)d.f}$ (α=0.01), we reject H_0 at 1% level of significance for (n_1+n_2-2) degree of freedom. Hence, we conclude that the two sample means **highly** differ significantly.

Questions

1. Two new types of rations were fed to pigs. Five pigs were fed Type-A ration and another 7 pigs were fed Type-B ration. The gain in weight (kg) was recorded as given below:

   Type-A : 15 22 25 16 28

   Type-B : 18 21 20 15 22 25 16

   Test whether the effect of two rations differed significantly?

2. In a feeding trial, feed A was given to 10 animals and increase in body weight was recorded as 10, 6, 16, 17, 13, 12, 8, 14, 15, and 9 while feed B was given to 12 animals and increase in body weight was recorded

as 7, 13, 22, 15, 12, 14, 18, 8, 21, 23, 10 and 17. Test whether average increase in weight due to feed A is less than that due to feed B.

Testing the significance of the difference between two means (Paired t-test)

In the above case, we assumed that the samples have been randomly drawn from two normal populations and they are independent. However, in this situation, where two samples drawn are not independent, we use **paired t-test**. Here the paired observations are recorded on the same individuals or items. Therefore, the two samples will also be of the same size n in view of the paired character or observations and may be put down as-

Let (x_1, y_1), (x_2,y_2), ……, (x_n,y_n) be the n pairs of observations drawn from a normal population. Let $d_i = x_i - y_i$ represent the difference for each pair (mean difference). Then, we wish to test-

H_0: $\mu_d = 0$ (Mean difference is zero)

H_1: $\mu_d \neq 0$

Test statistic

Under H_0, the test statistic used is t given by

$$t = \frac{\bar{d}}{S/\sqrt{n}}$$

Here,

$$S = \sqrt{\frac{\sum(d - \bar{d})^2}{(n-1)}}$$

Where, d = x - y

Decision rule

The test is usually performed at 5% i.e. (α=0.05) and 1% i.e. (α=0.01) level of significances for (n-1) degree of freedom. After calculating the value of the t-statistic, the decision about the acceptance or rejection of H_0 is taken in the following manner-

(i) If the calculated value of test statistic $|t| < t_{(n-1)d.f}$ (α=0.05), we accept H_0. Hence, we conclude that the two sample means do not differ significantly.

(ii) If the calculated value of test statistic $|t| > t_{(n-1)d.f}$ (α=0.05), we reject H_0 at 5% level of significance for (n-1) degree of freedom. Hence, we conclude that the two sample means differ significantly.

(iii) If the calculated value of test statistic $|t| > t_{(n-1)d.f}$ (α=0.01), we reject H_0 at 1% level of significance for (n-1) degree of freedom. Hence, we conclude that the two sample means **highly** differ significantly.

Questions

1. The milk yield (litre) of six cows in first and second lactation are given below:

First Lactation (litre)	:	950	1100	1000	1200	900	1150
Second Lactation (litre)	:	970	1050	1075	1250	940	1200

Test whether there was significant difference in their milk yield of second lactation over first lactation?

2. Heart beat (in no./min.) of ten bullocks before and after ploughing are given below:

Before : 71, 69, 70, 72, 73, 70, 73, 73, 71, and 70 .
After : 75, 76, 78, 77, 79, 78, 80, 81, 79 and 80 .
Test whether there is increase in heart beat.

Testing the significance of an observed sample correlation coefficient

Let (x_1,y_1), (x_2,y_2), ……, (x_n,y_n) be the n pairs of observations drawn from a bivariate normal population. Then, we wish to test-

H_0: $\rho = 0$ (Sample correlation coefficient is zero)
H_1: $\rho \neq 0$

Test statistic

Under H_0, the test statistic used is t given by

$$t = \frac{r}{SE(r)}$$

Where,

$$SE(r) = \sqrt{\frac{(1-r^2)}{(n-2)}}$$

Here, r = correlation coefficient
and, n = number of pairs

Decision rule

The test is usually performed at 5% i.e. (α=0.05) and 1% i.e. (α=0.01) level of significances for (n-2) degree of freedom. After calculating the value of the t-statistic, the decision about the acceptance or rejection of H_0 is taken in the following manner-

(i) If the calculated value of test statistic $|t| < t_{(n-2)d.f}(\alpha=0.05)$, we accept H_0. Hence, we conclude that the correlation coefficient do not differ significantly.
(ii) If the calculated value of test statistic $|t| > t_{(n-2)d.f}(\alpha=0.05)$, we reject H_0 at 5% level of significance for (n-2) degree of freedom. Hence, we conclude that the correlation coefficient differ significantly.
(iii) If the calculated value of test statistic $|t| > t_{(n-2)d.f}(\alpha=0.01)$, we reject H_0 at 1% level of significance for (n-2) degree of freedom. Hence, we conclude that the correlation coefficient **highly** differ significantly.

Questions

1. From the data on milk yield (litre) and butter fat (%) of six buffaloes are given as follows:

Milk yield (litre)	:	8	12	7	5	2	15
Butter fat (%)	:	5.7	4.8	6.0	5.5	7.0	4.5

Test the significance of coefficient of correlation between milk yield and butter fat?

Chi-square (χ^2) Test for goodness of fit

Chi-square test is a **non-parametric test**. Such non-parametric tests have assumed great importance in statistical analysis and statistical inference because they are easy to compute and can be used without making assumptions about parameters as they are distribution-free tests. It is a test which describes the magnitude of difference between observed frequencies and the frequencies expected under certain assumptions. The chi-square test was first used by **Karl Pearson** in the year 1900. The Chi-square test is denoted by the Greek letter 'χ^2'. The quantity χ^2 describes the magnitude of the discrepancy between theory and observation.

Testing the goodness of fit:

The test for goodness of fit determines whether a population has a specified theoretical distribution. In other words, here our problem is to test the hypothesis of how closely the observed distribution approximates a particular theoretical distribution. Using the sample information, we wish to test

H_0: O = E (Provide good fit)

H_1: O ≠ E

Where, O = Observed frequencies

E = Expected frequencies

Test statistic-

Under H_0, the test statistic used is χ^2 given by-

$$\chi^2 = \sum \frac{(O - E)^2}{E} \sim \chi^2_{(n-1)d.f}$$

Decision rule:

The test is usually performed at 5% i.e. (α=0.05) and 1% i.e. (α=0.01) level of significances for (n-1) degree of freedom. After calculating the value of the χ^2-statistic, the decision about the acceptance or rejection of H_0 is taken in the following manner-

(i) If the calculated value of test statistic $\chi^2 < \chi^2_{(n-1)d.f}$ (α=0.05), we accept H_0. Hence, we conclude that the observed data follow the theory.

(ii) If the calculated value of test statistic $\chi^2 > \chi^2_{(n-1)d.f}$ (α=0.05), we reject H_0 at 5% level of significance for (n-1) degree of freedom. Hence, we conclude that the observed data not follow the theory.

(iii) If the calculated value of test statistic $\chi^2 > \chi^2_{(n-1)d.f}$ (α=0.01), we reject H_0 at 1% level of significance for (n-1) degree of freedom. Hence, we conclude that the observed data highly different to the theory.

Questions

1. A random sample of 140 persons was selected and blood group was recorded. The frequencies of different blood groups are given below. Test whether the frequencies are in the ratio 4: 10: 5: 1.

Blood group	O	A	B	AB
No. of persons	50	65	15	10

2. The theory predicts the proportion of beans, in the four groups A, B, C and D should be 9 : 3 : 3 : 1. In an experiment among 1600 beans, the numbers in the four groups were 882, 313, 287 and 118. Does the experimental result support the theory?

Chi-square (χ^2) test for independence of attributes

In this case, there are no definite expected values, the point is whether the results are dependent or independent of the conditions under which they have occurred. This test is called a **test for independence or contingency test**. The observed frequencies are indicated in various cells of the table for respective rows and columns. If there are 'm' rows and 'n' columns, the table is generally called "m x n" **contingency table**.

Suppose N observations in a sample are to be classified according to two attributes say A and B. Attribute A has m mutually exclusive categories say A_1, A_2, ……., A_m and the attribute B has categories namely B_1, B_2, ……., B_n. Then the sample observations may be classified as-

Contingency table of order m x n

B / A	**B_1**	**B_2**	--------	**B_j**	--------	**B_n**	**Total**
A_1	O_{11}	O_{12}	--------	O_{1j}	--------	O_{1n}	**(A_1)**
A_2	O_{21}	O_{22}	--------	O_{2j}	--------	O_{2n}	**(A_2)**
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
A_i	O_{i1}	O_{i2}	--------	O_{ij}	--------	O_{in}	**(A_i)**
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
A_m	O_{m1}	O_{m2}	--------	O_{mj}	--------	O_{mn}	**(A_m)**
Total	**(B_1)**	**(B_2)**	--------	**(B_j)**	--------	**(B_n)**	**N**

The above two-way table having m rows and n columns is called a **contingency table** of order (m x n). In this table-

A_i denotes the i^{th} category of the attribute A. (i = 1, 2, ……., m)

B_j denotes the j^{th} category of the attribute A. (j = 1, 2, ……., n)

(A_i) denotes the frequency of the attribute A_i.

(B_j) denotes the frequency of the attribute B_j.

$\sum_{i=1}^{m}(A_i) = \sum_{j=1}^{n}(B_j) = N$, the total number of observations.

(O_{ij}) is the observed frequency in (i, j) cell.

Suppose we are given a contingency table of order m x n in which N sample observations have been classified. Let O_{ij} be the observed frequency in $(i, j)^{th}$ cell. To test the null hypothesis that the two attributes are independent, we use chi-square test.

Using the sample information, we wish to test

H_0: Two attributes A and B are independent

H_1: Two attributes A and B are dependent.

Test statistic

Under H_0, the test statistic used is χ^2 given by-

$$\chi^2 = \sum_{i=1}^{m}\sum_{j=1}^{n}\frac{(O_{ij} - E_{ij})^2}{E_{ij}} \sim \chi^2_{(m-1)(n-1)\text{d.f.}}$$

Here, the χ^2 - distribution has (m-1)(n-1) degree of freedom. The expected frequency corresponding to $(i, j)^{th}$ cell observed frequency i.e. E_{ij} is obtained by -

$$E_{ij} = E(O_{ij}) = \frac{(A_i)(B_j)}{N} = \frac{\text{Sum of } i^{th} \text{ row} \times \text{Sum of } j^{th} \text{ column}}{\text{Sample size}}$$

Decision rule

The test is usually performed at 5% i.e. (α=0.05) and 1% i.e. (α=0.01) level of significances for (m-1)(n-1) degree of freedom. After calculating the value of the χ^2-statistic, the decision about the acceptance or rejection of H_0 is taken in the following manner-

(i) If the calculated value of test statistic $\chi^2 < \chi^2_{(m-1)(n-1)d.f}(\alpha=0.05)$, we accept H_0. Hence, we conclude that the two attributes are independent.

(ii) If the calculated value of test statistic $\chi^2 > \chi^2_{(m-1)(n-1)d.f}(\alpha=0.05)$, we reject H_0 at 5% level of significance for (m-1)(n-1) degree of freedom. Hence, we conclude that the two attributes are dependent or there is a significant relationship between the two variables.

(iii) If the calculated value of test statistic $\chi^2 > \chi^2_{(m-1)(n-1)d.f}(\alpha=0.01)$, we reject H_0 at 1% level of significance for (m-1)(n-1) degree of freedom. Hence, we conclude that there is a highly significant relationship between the two variables.

Testing the independence of attributes in a 2x2 contingency table

Sometimes the data are cross-classified in such a manner that there are only two categories. The contingency table containing such data which consist of two rows and two columns is often referred to as 2 x 2 table. Then the sample observations may be classified as-

Contingency table of order m x n

A \ B	B_1	B_2	Total
A_1	O_{11}(a)	O_{12} (b)	(A_1)
A_2	O_{21} (c)	O_{22} (d)	(A_2)
Total	(B_1)	(B_2)	N

The above two-way table having 2 rows and 2 columns is called a **contingency table** of order (2 x 2). Using the sample information, we wish to test

H_0: Two attributes A and B are independent

H_1: Two attributes A and B are dependent.

Test statistic

Under H_0, the test statistic used is χ^2 given by-

$$\chi^2 = \frac{(ad - bc)^2 \times N}{(a+b)(c+d)(a+c)(b+d)}$$

Here, the χ^2 - distribution has (2-1)(2-1) = 1 x 1 =1 degree of freedom.

Decision rule

The test is usually performed at 5% i.e. (α=0.05) and 1% i.e. (α=0.01) level of significances for **one** degree of freedom. After calculating the value of the χ^2-statistic, the decision about the acceptance or rejection of H_0 is taken in the following manner-

(i) If the calculated value of test statistic $\chi^2 < \chi^2_{1d.f}(\alpha=0.05)$, we accept H_0. Hence, we conclude that the two attributes are independent.

(ii) If the calculated value of test statistic $\chi^2 > \chi^2_{1d.f}(\alpha=0.05)$, we reject H_0 at 5% level of significance for 1 degree of freedom. Hence, we conclude that the two attributes are dependent or there is a significant relationship between the two variables.

(iii) If the calculated value of test statistic $\chi^2 > \chi^2_{1d.f}(\alpha=0.01)$, we reject H_0 at 1% level of significance for 1 degree of freedom. Hence, we conclude that there is a highly significant relationship between the two variables.

Yate's correction for continuity

If any of the observed cell frequency is less than 5, in a 2 x 2 contingency table. Yate's correction for continuity may be used. In this case, by utilizing the following formula-

$$\chi^2 = \frac{\left(|ad - bc| - \frac{N}{2}\right)^2 \times N}{(a+b)(c+d)(a+c)(b+d)}$$

It should be noted that this correction should not be used when m > 2 and n > 2.

Questions

1. Grading of 300 semen samples by two techniques 'A' and 'B' was done. The results are given below:

Techniques	Below Average	Average	Above Average
A	66	34	67
B	60	35	38

Would you say that the grading techniques are significantly different?

2. Can vaccination be regarded as preventive measure of small pox as evidenced by the following data:

Group	**Affected**	**Non-affected**
Vaccinated	12	13
Non-vaccinated	18	17

3. In an experiment on immunization of dogs against tuberculosis, the following results were obtained:

	Affected	Not affected
Inoculated	12	26
Not inoculated	16	4

Examine the effect of vaccine in controlling the incidence of disease?

F - Test

The name was coined by **George W. Snedecor**, in honour of **Sir Ronald A. Fisher**. The object of the F-test is to find out whether the two independent estimates of population variance differ significantly or whether the two samples may be regarded as drawn from the normal populations having the same variance. It is defined as-

$$F = \frac{S_1^2}{S_2^2} \sim F_{(n_1-1)(n_2-1)\text{d.f.}}$$

Where, $S_1^2 > S_2^2$ and

$$S_1^2 = \frac{\sum(x - \bar{x})^2}{(n_1 - 1)}$$

$$S_2^2 = \frac{\sum(y - \bar{y})^2}{(n_2 - 1)}$$

Here, the F-test has two degree of freedoms i.e. (n_1-1) degree of freedom for numerator and (n_2-1) degree of freedom for denominator.

Application of F-test

The F-test has a number of applications of which we will discuss the following:

(i) Testing the significance of ratio of two variance

(ii) Testing the homogeneity of several means.

1. Testing the significance of ratio of two variance

Suppose $x_1, x_2, \ldots\ldots\ldots, x_n$ be a random sample of size n_1 drawn from a normal population with mean μ_1 and variance σ_1^2 and another random sample of size n_2 drawn from a normal population with mean μ_2 and variance σ_2^2. The null and alternative hypothesis are-

$H_0: \sigma_1^2 = \sigma_2^2$

$H_1: \sigma_1^2 \neq \sigma_2^2$

Test statistic

Under H_0, the test statistic F is given by-

$$F = \frac{S_1^2}{S_2^2}$$

Where, $S_1^2 > S_2^2$ and

$$S_1^2 = \frac{\sum(x - \bar{x})^2}{(n_1 - 1)}$$

$$S_2^2 = \frac{\sum(y - \bar{y})^2}{(n_2 - 1)}$$

Decision rule

The test is usually performed at 5% i.e. (α=0.05) and 1% i.e. (α=0.01) level of significances for (n_1-1),(n_2-1) degree of freedom. After calculating the value of the F-test, the decision about the acceptance or rejection of H_0 is taken in the following manner-

(i) If the calculated value of test statistic $F \leq F_{(n_1-1),(n_2-1)d.f.}(\alpha = 0.05)$, we accept H_0. Hence, we conclude that the ratio of two variances do not differ significantly.

(ii) If the calculated value of test statistic $F > F_{(n_1-1),(n_2-1)d.f.}(\alpha = 0.05)$, we reject H_0 at 5% level of significance for (n_1-1),(n_2-1) degree of freedom. Hence, we conclude that the ratio of two variances differ significantly.

(iii) If the calculated value of test statistic $F > F_{(n_1-1),(n_2-1)d.f.}(\alpha = 0.01)$, we reject H_0 at 1% level of significance for (n_1-1),(n_2-1) degree of freedom. Hence, we conclude that the ratio of two variances **highly** differ significantly.

2. Testing the homogeneity of several means

In this case we should have a technique by which significance of the difference amongst more than two sample means is carried out at the same time. The **analysis of variance (ANOVA)** technique enables us to perform this simultaneous test.

Analysis of variance

The analysis of variance technique, developed by **R. A. Fisher** in 1920, is capable of fruitful application to a diversity of practical problems. The '**Analysis of Variance**' is a technique of partitioning or splitting the total variation i.e. assignable factors and the chance factors and then their comparison. The analysis of variance frequently referred to by the contraction ANOVA is a statistical technique specially designed to test whether the means of more than two sample means is carried out at the same time.

Classification of observations

The following criteria of classification of observations are used in the analysis of variance.

(i) One-way classification
(ii) Two-way classification

(i) One-way classification

In this case the observations are classified on the basis of a single criterion, so the classification is called **one-way classification**.

(ii) Two-way classification

If the observations in an experiment are classified in respect of two criteria, we get **two-way classification**.

One-way classification of analysis of variance

Suppose there are k normal populations with means $\mu_1, \mu_2, \ldots\ldots, \mu_k$ and common variance σ^2. Further, let k random samples, one from each population, are drawn from these populations. Let n_i (i = 1, 2, …..,k) be the size of the sample from i^{th} population. Using the sample information, we wish to test-

H_0: $\mu_1 = \mu_2 = \ldots\ldots\ldots = \mu_k$

H_1: $\mu_1 \neq \mu_2 \neq \ldots\ldots\ldots \neq \mu_k$

Let y_{ij} (i = 1, 2, ……., k; j = 1, 2, ……., n_i) be the j^{th} observation of i^{th} sample, then one-way classified data can be arranged as-

One way classification

Sample No.	**Observations**							**Sample Totals**	**Sample Means**
1	Y_{11}	Y_{12}	Y_{13}	…	…	…	y_{1n_1}	$T_{1.}$	$\bar{y}_{1.}$
2	Y_{21}	Y_{22}	Y_{23}	…	…	…	y_{2n_2}	$T_{2.}$	$\bar{y}_{2.}$
3	Y_{31}	Y_{32}	Y_{33}	…	…	…	y_{3n_3}	$T_{3.}$	$\bar{y}_{3.}$
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
k	y_{k_1}	y_{k_2}	y_{k_3}	…	…	…	y_{kn_k}	$T_{k.}$	$\bar{y}_{k.}$
Over all total								$T_{..}$	$\bar{y}_{..}$

Here,

$$T_{..} = \sum_{i=1}^{k} T_{i.}$$

and

$$\bar{y}_{..} = \sum_{i=1}^{k} \bar{y}_{i.}$$

also let

$$N = \sum_{i=1}^{k} n_{i.}$$

Now, for testing H_0, the steps in the analysis of variance procedure for one-way classification are-

(i) Calculate the correction factor (C.F.) as

$$C.F. = \frac{T_{..}^2}{N}, N = \sum_{i=1}^{k} n_i = (n_1 + n_2 + \cdots + n_k)$$

(ii) Find to total sum of squares (TSS)

$$\text{TSS} = \sum_i \sum_j (y_{ij} - \bar{y}_{..})^2 = \sum_i \sum_j y_{ij}^2 - \text{C.F.} = \left(y_{11}^2 + y_{12}^2 + \cdots + y_{1n_1}^2 + \cdots + y_{kn_k}^2\right) - \text{C.F.}$$

(iii) Find the between sample sum of squares (BSS)

$$\text{BSS} = \sum_i \sum_j (\bar{y}_{i.} - \bar{y}_{..})^2 = \sum_{i=1}^{n} \frac{T_{i.}^2}{n} - \text{C.F.}$$

(iv) Find error sum of squares (ESS) by subtraction. i.e. ESS = TSS - BSS

$$\sum_{i=1}^{k} \sum_{j=1}^{n_i} (y_{ij} - \bar{y}_{..})^2 = \sum_{i=1}^{k} \sum_{j=1}^{n_i} (\bar{y}_{i.} - \bar{y}_{..})^2 + \sum_{i=1}^{k} \sum_{j=1}^{n_i} (y_{ij} - \bar{y}_{i.})^2$$

(v) Prepare the ANOVA (Analysis of variance) table

ANOVA -table (One-way classification)

Sources of variations	**Degree of freedom (d.f.)**	**Sum of Squares (SS)**	**Mean Sum of Squares (MSS)**	**Calculated variance ration (F)**
Between Samples	k - 1	$\sum_i \sum_j (\bar{y}_{i.} - \bar{y}_{..})^2$	$\frac{\sum_i \sum_j (\bar{y}_{i.} - \bar{y}_{..})^2}{k-1} = V_1 (\text{say})$	$\frac{V_1}{V_2} = F$
Within Samples or Error	N - k	$\sum_i \sum_j (\bar{y}_{ij} - \bar{y}_{i.})^2$	$\frac{\sum_i \sum_j (\bar{y}_{ij} - \bar{y}_{i.})^2}{N-k} = V_2 (\text{say})$	
Total	N - 1	$\sum_i \sum_j (y_{ij} - \bar{y}_{..})^2$		

Decision rule

The test is usually performed at 5% i.e. (α=0.05) and 1% i.e. (α=0.01) level of significances for (k-1),(N-k) degree of freedom. After calculating the value of the F-test, the decision about the acceptance or rejection of H_0 is taken in the following manner-

(i) If the calculated value of test statistic $F \leq F_{(k-1),(N-k)\text{d.f.}}(\alpha = 0.05)$, we accept H_0. Hence, we conclude that the samples do not differ significantly.

(ii) If the calculated value of test statistic $F > F_{(k-1),(N-k)\text{d.f.}}(\alpha = 0.05)$, we reject H_0 at 5% level of significance for (k-1),(N-k) degree of freedom. Hence, we conclude that the samples differ significantly.

(iii) If the calculated value of test statistic $F > F_{(k-1),(N-k)\text{d.f.}}(\alpha = 0.01)$, we reject H_0 at 1% level of significance for (k-1),(N-k) degree of freedom. Hence, we conclude that the samples **highly** differ significantly.

Two-way classification of analysis of variance

Suppose there are k rows and n columns in the rectangular array representing a two-way classification. Let y_{ij} denotes a cell observation in i^{th} row and j^{th} column (i=1, 2, …….,k; j=1, 2, ……., n). Then, a two-way classification model can be represented as-

Two-way classification

Rows	**Columns**							**Total ($T_{i.}$)**	**Mean ($\bar{y}_{i.}$)**
	1	**2**	**3**	**…**	**j**	**…**	**n**		
1	Y_{11}	Y_{12}	Y_{13}	…	y_{ij}	…	y_{1n}	$T_{1.}$	$\bar{y}_{1.}$
2	Y_{21}	Y_{22}	Y_{23}	…	Y_{2j}	…	y_{2n}	$T_{2.}$	$\bar{y}_{2.}$
3	Y_{31}	Y_{32}	Y_{33}	…	Y_{3j}	…	y_{3n}	$T_{3.}$	$\bar{y}_{3.}$
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
i	Y_{i1}	Y_{i2}	Y_{i3}	…	y_{ij}	…	y_{in}	$T_{i.}$	$\bar{y}_{i.}$
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
k	y_{k1}	y_{k2}	y_{k3}	…	y_{kj}	…	y_{kn}	$T_{k.}$	$\bar{y}_{k.}$
Total ($T_{.j}$)	$T_{.1}$	$T_{.2}$	$T_{.3}$	…	$T_{.j}$	…	$T_{.n}$	$T_{..}$	
Mean ($\bar{y}_{.j}$)	$\bar{y}_{.1}$	$\bar{y}_{.2}$	$\bar{y}_{.3}$	…	$\bar{y}_{.j}$	…	$\bar{y}_{.n}$		$\bar{y}_{..}$

Here, $T_{i.}$ and $\bar{y}_{i.}$ respectively stand for total and mean of the i^{th} row (i = 1, 2, ……, k)
$T_{.j}$ and $\bar{y}_{.j}$ respectively stand for total and mean of the j^{th} column (j = 1, 2, ……, n) and
$T_{..}$ and $\bar{y}_{..}$ respectively stand for total and mean of all the nk observations.

Further, suppose the sample observations in i^{th} row be drawn from a normal population with mean $\mu_{i.}$ and variance σ^2. Similarly, the sample observations in j^{th} column are drawn from a normal population with mean $\mu_{.j}$ and variance σ^2. Using the sample information, we wish to set up the following two null hypotheses-

(a) H_{01}: $\mu_{1.}= \mu_{2.}=\ldots\ldots= \mu_{i.}=\ldots..= \mu_{k.}$ (i.e. rows means are equal)
H_{11}: $\mu_{1.}\neq \mu_{2.}\neq\ldots\ldots \neq \mu_{i.}\neq\ldots..\neq \mu_{k.}$ (i.e. rows means are not equal)

(b) H_{02}: $\mu_{.1}= \mu_{.2}=\ldots\ldots= \mu_{.j}=\ldots..= \mu_{.n}$ (i.e. column means are equal)
H_{12}: $\mu_{.1}\neq \mu_{.2}\neq\ldots\ldots \neq \mu_{.j}\neq\ldots..\neq \mu_{.n}$ (i.e. column means are not equal)

Now, for testing H_0, the steps in the analysis of variance procedure for two-way classification are-

(i) Calculate the correction factor (C.F.) as

$$C.F. = \frac{T_{..}^2}{nk},$$

(ii) Find to total sum of squares (TSS)

$$\text{TSS} = \sum_i \sum_j \left(y_{ij} - \bar{y}_{..}\right)^2 = \sum_i \sum_j y_{ij}^2 - \text{C. F.} = \left(y_{11}^2 + y_{12}^2 + \cdots + y_{1n}^2 + \cdots + y_{kn}^2\right) - \text{C. F.}$$

(iii) Find the rows sum of squares (RSS)

$$RSS = \sum_i \sum_j (\bar{y}_{i.} - \bar{y}_{..})^2 = \sum_{i=1}^{k} \frac{T_{i.}^2}{n} - C.F.$$

(iv) Find the column sum of squares (CSS)

$$CSS = \sum_i \sum_j (\bar{y}_{.j} - \bar{y}_{..})^2 = \sum_{i=1}^{k} \frac{T_{.j}^2}{k} - C.F.$$

(v) Find error sum of squares (ESS) by subtraction. i.e.

ESS = TSS - (RSS + CSS)

(vi) Prepare the ANOVA (Analysis of variance) table

ANOVA -table (Two-way classification)

Sources of variations	**Degree of freedom (d.f.)**	**Sum of Squares (SS)**	**Mean Sum of Squares (MSS)**	**Calculated (F)**	**Tabulated (F)**
Row	k - 1	RSS	$\frac{RSS}{k-1} = V_1(say)$	$\frac{V_1}{V_3} = F_1$	$F_{\nu_1,\nu_3}(\alpha)$
Column	n - 1	CSS	$\frac{CSS}{n-1} = V_2(say)$	$\frac{V_2}{V_3} = F_2$	$F_{\nu_2,\nu_3}(\alpha)$
Error	(k - 1)(n-1)	ESS	$\frac{ESS}{(k-1)(n-1)} = V_3(say)$		
Total	nk - 1	TSS			

Here, $\nu_1 = (k-1)$, $\nu_2 = (n-1)$ and $\nu_3 = (k-1)(n-1)$

Decision rule

After forming the above ANOVA table, the decisions regarding H_{01} and H_{02} are taken as-

(a) The test is usually performed at 5% i.e. (α=0.05) and 1% i.e. (α=0.01) level of significances for ν_1,ν_3 degree of freedom. After calculating the value of the F-test, the decision about the acceptance or rejection of H_{01} is taken in the following manner-

(i) If the calculated value of test statistic $F \leq F_{\nu_1,\nu_3\ d.f.}(\alpha = 0.05)$, we accept H_{01}. Hence, we conclude that the row samples do not differ significantly.

(ii) If the calculated value of test statistic $F > F_{\nu_1,\nu_3\ d.f.}(\alpha = 0.05)$, we reject H_{01} at 5% level of significance for ν_1,ν_3 degree of freedom. Hence, we conclude that the row samples differ significantly.

(iii) If the calculated value of test statistic $F > F_{\nu_1,\nu_3\ d.f.}(\alpha = 0.01)$, we reject H_{01} at 1% level of significance for ν_1,ν_3 degree of freedom. Hence, we conclude that the row samples **highly** differ significantly.

(b) The test is usually performed at 5% i.e. (α=0.05) and 1% i.e. (α=0.01) level of significances for ν_2,ν_3 degree of freedom. After calculating the value of the F-test, the decision about the acceptance or rejection of H_{02} is taken in the following manner-

(i) If the calculated value of test statistic $F \leq F_{\nu_2,\nu_3\ d.f.}(\alpha = 0.05)$, we accept H_{02}. Hence, we conclude that the column samples do not differ significantly.

(ii) If the calculated value of test statistic $F > F_{\nu_2,\nu_3\ d.f.}(\alpha = 0.05)$, we reject H_{02} at 5% level of significance for ν_2,ν_3 degree of freedom. Hence, we conclude that the column samples differ significantly.

(iii) If the calculated value of test statistic $F > F_{\nu_2,\nu_3\ d.f.}(\alpha = 0.01)$, we reject H_{02} at 1% level of significance for ν_2,ν_3 degree of freedom. Hence, we conclude that the column samples **highly** differ significantly.

Critical Difference Test (CD-test)

When values of F are found **significant** then **critical difference test (CD-test)** is applied. By this test, the different groups of assignable factors can be graded according to their magnitude i.e. superiority in some classes or groups can be established over other classes or groups.

Procedure of Critical Difference Test (CD-test)

i) For unequal no. of replications: This may occur in one way ANOVA:

$$\mathbf{CD_{1,2} = t_{[error\ df\ (0.05)]} \times \sqrt{[(1/r_1 + 1/r_2)\ EMSS]}}$$

ii) For equal no. of replications:

For calculating the value of critical difference, using following formula-

$$C.D. = t_{error\ d.f.}(0.05) \times \sqrt{\frac{2 \times EMSS}{r}}$$

Where,

t = table value of t-test with error degree of freedom mentioned in the ANOVA-table at 5% level of significance.

EMSS = error mean sum of square mentioned in the ANOVA-table

r = number of replications

The means of different classes of assignable factors are arranged either in ascending order or in descending order of their magnitude. Then, the actual difference between the different pairs will be compared with the value of critical difference (C.D.). If actual difference is found less than the value of C.D., it means that the two means do not differ significantly and they are connected with a **straight line**.

On the other hand, if actual difference is more or equal to the value of C.D. then the two means are said to be significantly different and they are **not** joined with the straight line. In this way, we can grade the means of different classes and the superiorities of some classes can be established over the other classes.

Questions

1. Compare the performance of four different types of cross bred cows on the basis of their daily milk yield (litre) as given below:

Breed					
A	11	8	14	12	15
B	17	15	18	19	20
C	22	24	28	26	30
D	14	19	21	24	25

2. Five breeds of cattle A, B, C, D and E were given on three different rations. Gains in weights (lb) over a given period were recorded.

		Breeds				
		A	B	C	D	E
	1	47	54	41	46	52
Ration	2	48	42	34	36	32
	3	50	48	38	36	44

Test whether there is significant difference between breeds and between rations?

……

CHAPTER-VIII

HARDY WEINBERG LAW

Population Genetics

Gene frequencies & genotype frequencies of a population for a given locus constitute the genetic structure of a population. Hence, the study of gene frequencies and genotype frequencies of a population in respect to a given locus is also known as Population genetics.

Genetic composition

1. The number of alleles at a locus
2. The frequency of alleles at a locus
3. The frequency of genotypes at a locus
4. Transmission of alleles from one generation to the next

Hardy Weinberg Law

Hardy-Weinberg law was proposed independently in 1908 by Wilhelm Weinberg, a German physician, and Godfrey Harold Hardy, a British mathematician.

"In a large random-mating population with no selection, mutation or migration, the gene and the genotypic frequencies remain constant from generation to generation".

When the gene frequency remains constant generations after generations, the population is in genetic equilibrium or Hardy-Weinberg equilibrium non-evolutionary model. When the population is in genetic equilibrium, the rate of evolution is zero. That is, when a population obeys, hardy-Weinberg law the population will not undergo evolution. So evolution occurs only when Hardy-Weinberg equilibrium is altered. The Hardy-Weinberg law is represented by a simple formula.

For 2 alleles (A1 and A2) of one gene p
= f(A) Frequency of 'A1' gene
q = f(a) Frequency of 'A2' gene

Then the next generation will have:

- The frequency of homozygotes is equal to the gene frequency squared
- The frequency of the A1A1 genotype = p2
- The frequency of the A2A2 genotype = q2
- The frequency of heterozygotes is equal to twice the product of the two gene frequencies
- The frequency of the A1A2 genotype = 2pq

For a dimorphic gene the Hardy-Weinberg equation is based on the binomial distribution:
p2 + 2pq + q2 = 1. This formula is used to find out the frequency of dominant gene and recessive gene in a population.

p = Frequency of dominant gene
q = Frequency of recessive gene
p2 = Frequency of dominant homozygote
2pq = Frequency of heterozygote
q2 = Frequency of recessive homozygote

Properties of equilibrium population

1. The genotype frequencies are determined by the square of the sum of the gene frequencies. This is also called **Square law.**

Frequency of A1= p, A2 = q, then

A1A1 A1A2 A2A2

$(p + q)^2 = p^2 + 2pq + q^2$

$(p + q + r)^2 = p^2 + q^2 + r^2 + 2pq + 2pr + 2qr$

2. The relationship between gene frequencies and genotype frequencies are applied to a single generation only.

3. Genotype frequencies in the progeny depend only on the gene frequencies of the parent, not on the genotype frequencies.

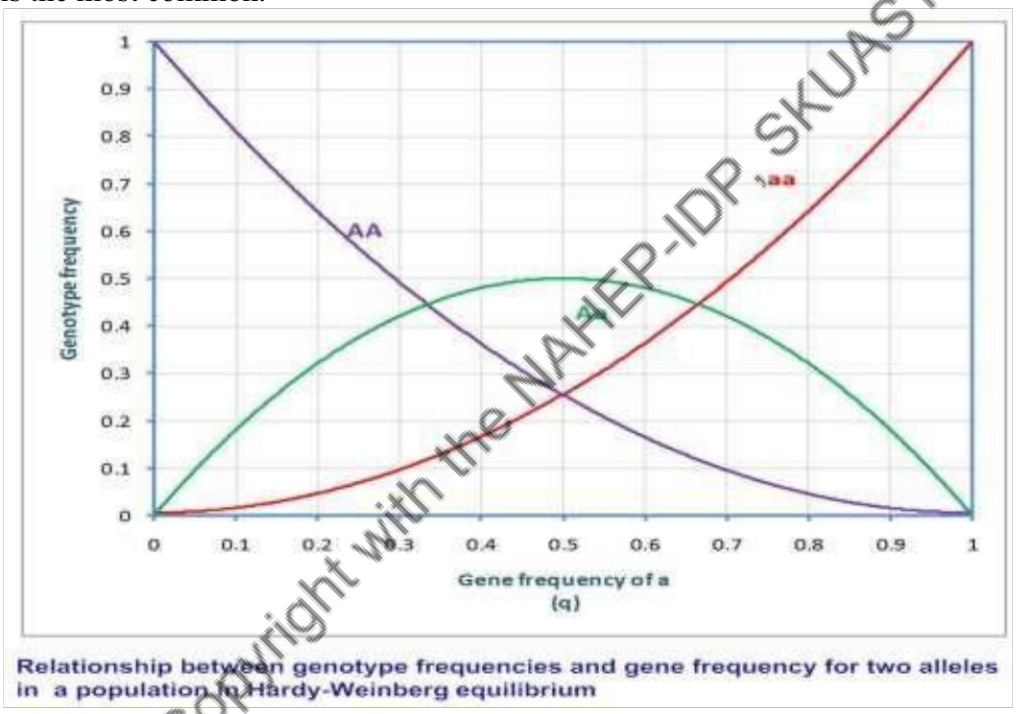
4. Maximum frequency of heterozygotes will be 50% at p = q = 0.5. and it never exceeds 50% for two alleles.

5. Frequency of rare allele occurs almost exclusively in the heterozygotes condition.

6. Proportion of heterozygotes is twice the square root of the product of frequency of two homozygotes.

7. Only ⅓ of the time when q is between ⅓ and ⅔, is the heterozygote the most common genotype

8. When q is between 0 and ⅓ A1A1 is the most common, and when q is between ⅔ and 1, A2A2 is the most common.



Relationship between genotype frequencies and gene frequency for two alleles in a population in Hardy-Weinberg equilibrium

PROOF OF HARDY-WEINBERG LAW

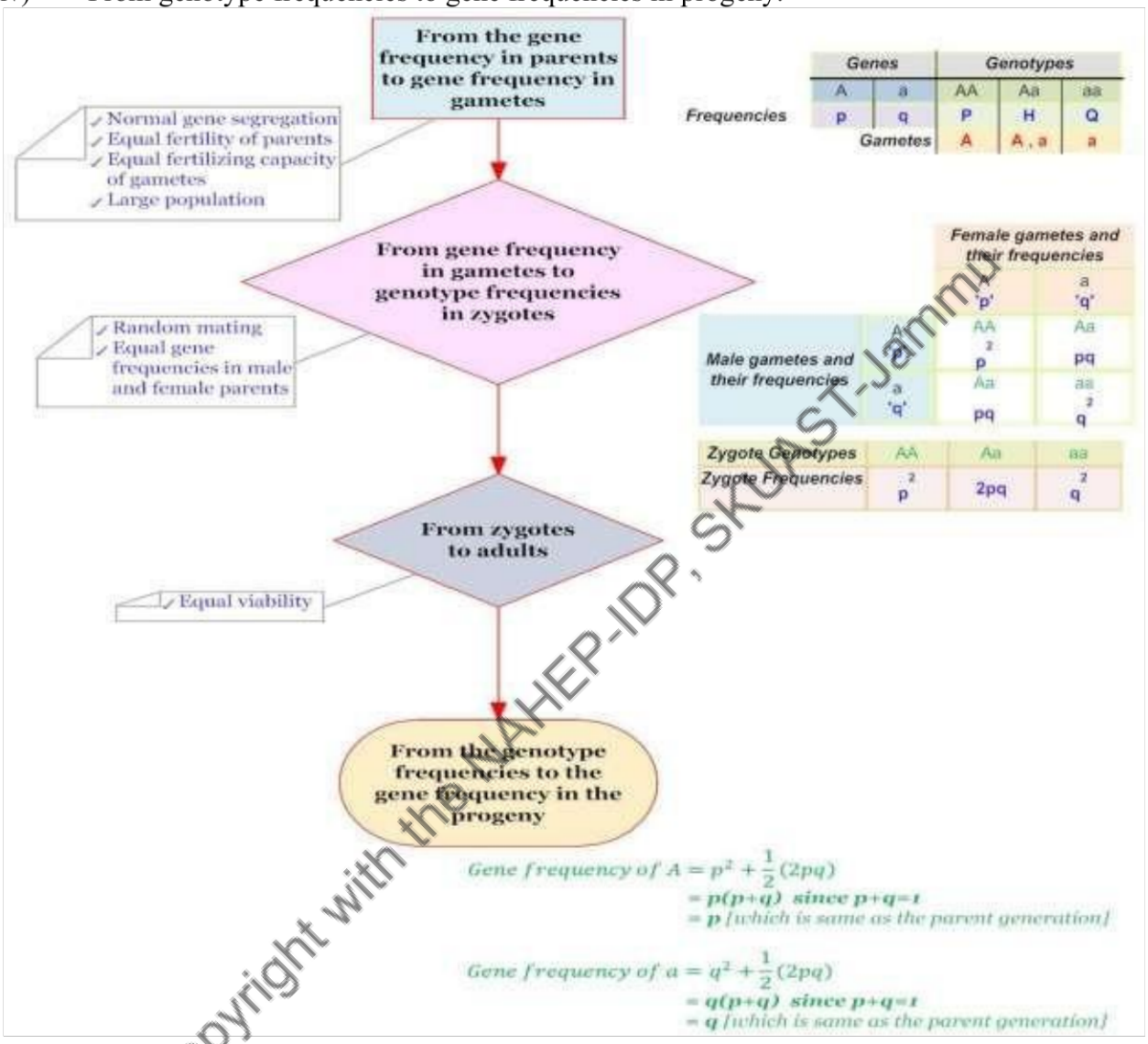
The H-W Law can be proved by two ways

1. **By random union of gametes**
2. **By random mating of genotypes**

1. By random union of gametes

It involves 4 steps:

i) From gene frequency in parents to gene frequency in gametes
ii) From gene frequency in gametics to genotype frequencies in zygotes
iii) From zygotes to adults
iv) From genotype frequencies to gene frequencies in progeny.



The gene frequency in the adult progeny can be found from the relationship between gene frequencies and genotype frequencies

Thus, the frequency of A1 is = p^2+1/2 (2pq)

= p^2+pq

= p(p + q)

= psince, p + q=1

Similarly, frequency of A2 is q^2+1/2 (2pq)

= q^2+pq

= q (q + p)

= q since, q + p=1

Hence, gene frequency in the progeny generation is the same as in the parent generation. This is proved HW law

2. By random mating of genotypes

Parents		Progeny genotype		
Mating type	Frequency	A1A1	A1A2	A2A2
A1A1 x A1A1	P^2	1	0	0
A1A1 x A1A2	PH	½	½	0
A1A1 x A2A2	PQ	0	1	0
A1A2 x A1A1	PH	½	½	0
A1A2 x A1A2	H^2	¼	½	½
A1A2 x A2A2	HQ	0	½	½
A2A2 x A1A1	QP	0	1	0
A2A2 x A1A2	QH	0	½	½
A2A2 x A2A2	Q^2	0	0	1

Mating Type	Frequency	Genotype & frequency of progeny A_1A_1	A_1A_2	A_2A_2
A1 A1 X A1A1	P^2	P^2		—
A_1A_1 X A_1A_2	2PH	PH	PH	
A_1A_1 X A_2A_2	2PQ		2PQ	—
A_1A_2 X A_1A_2	H^2	$1/4H^2$	$1/2H^2$	$1/4H^2$
A_1A_2 X A_2A_2	2HQ		HQ	HQ
A2 A2 X A2A2	Q^2			Q^2
	Sums =	$(P + 1/2\ H)^2$ p^2	$2\ (P + 1/2\ H)\ (Q + 1/2H)$ $2pq$	$(Q + 1/2H)^2$ q^2

APPLICATIONS OF HARDY-WEINBERG LAW

Hardy-Weinberg law has the following applications:

- Calculation of frequencies of recessive and dominant genes in a population
- Calculation of frequency of carriers or heterozygotes in a population Departure

from Hardy-Weinberg equilibrium can be tested from **Chi-Square test.**

HARDY-WEINBERG LAW-MULTIPLE ALLELES

If dominance is lacking, calculation of gene frequency is simple in multiple allelic systems. The best gene frequency estimate comes from simple gene counting. For example, in European cattle breeds, three transferrin alleles A, D and E occur. No dominance exists and so six genotypes can be

distinguished, i.e., AA, AD, AE, DD, DE and EE. If we let these symbols denote the numbers of each genotype and N denotes the total number, we may calculate the gene frequencies as follows:

$$f(A) = p = \frac{2AA + AD + AE}{2N} \qquad f(D) = q = \frac{2DD + DA + DE}{2N} \qquad f(E) = r = \frac{2EE + EA + ED}{2N}$$

For a three allele system, the equilibrium genotype frequencies can be expressed algebraically as $p + q + r = 1$.

- $(p + q + r)^2 = p^2 + q^2 + r^2 + 2pq + 2pr + 2qr = 1$
- The ABO blood groups in man are determined by a series of three multiple allelic genes: A, B and O alleles.

Allele frequency	A p	B q	O r
A p	AA p^2	AB pq	AO pr
B q	AB pq	BB q^2	BO qr
O r	AO pr	BO qr	OO r^2

Genotype	Frequency
AA	p^2
AB	pq+pq=2pq
AO	pr+pr=2pr
BB	q^2
BO	qr+qr=2qr
OO	r^2

HARDY-WEINBERG LAW: SEX-LINKED GENES

In mammals, the female is the homozygous sex, with two X chromosomes (XX), while the male is heterozygous, with one X and one Y chromosome (XY). Genes on the X chromosome are called sex linked genes. The relationship between gene frequency and genotype frequency in the homogametic sex is the same as with an autosomal gene; but the heterogametic sex has only two genotypes and carries only one gene instead of two. So, two-thirds of the sex- linked genes in the population are carried by the homogametic sex and one-third by the heterogametic sex.

Consider two alleles A and a with frequency *p and q*

	Female			Male	
Genotype	AA	Aa	aa	A	a
Genotype Frequency	*P*	*H*	*Q*	*R*	*S*

The frequency of A among the females is

$$p_f = P + \frac{1}{2}H$$

The frequency of A among the male is

$$p_m = R$$

The frequency of A in the whole populations is

$$\bar{p} = \frac{2}{3}p_f + \frac{1}{3}p_m$$

$$\bar{p} = \frac{1}{3}(2\,p_f + p_m)$$

$$\bar{p} = \frac{1}{3}(2P + H + R)$$

Hence, if gene frequencies among males and among females are different, the population will not be in equilibrium. The gene frequency in the population as a whole does not change; but its distribution between the two sexes oscillates as the population approaches equilibrium. This oscillation is because of getting sex linked genes in males only from their mother.

Males get their sex linked genes only from female parents

$$p'_m = p_f$$

Females get their sex linked genes equally from both parents

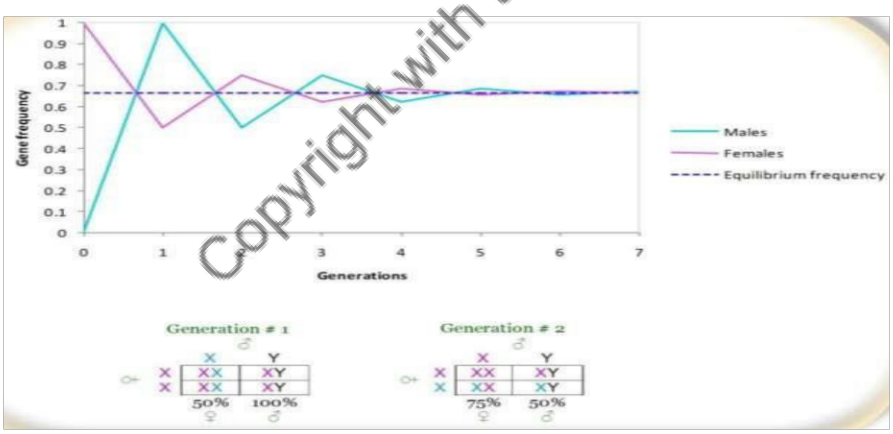
$$p'_f = \frac{1}{2}(p_f + p_m)$$

The difference between the frequencies in the two sexes is

$$p'_f - p'_m = \frac{1}{2}(p_f + p_m) - p_f$$

$$p'_f - p'_m = -\frac{1}{2}(p_f - p_m)$$

It is half the difference in the previous generation. Therefore, if the gene frequencies are different in males and females then one generation of random mating is not sufficient to achieve Hardy-Weinberg equilibrium. It may take several generations and the number of generations will depend on the magnitude of difference between the sexes in gene frequency. The difference in gene frequency between the sexes will be halved as compared to the previous generation and the sign will be opposite.



The most important implication is that sex-linked characters are expected to occur with different frequencies in males and females. This is relevant to the sex-linked recessive traits for which the frequency of the condition in males (q) is expected to be much higher than the frequency of the conditions in females (q2).

MORE THAN ONE LOCUS

The attainment of equilibrium in genotype frequencies after one generation of random mating is true of all autosomal loci considered individually. But it is not true of the genotypes considered jointly. Disequilibrium with respect to two or more loci is called gametic phase disequilibrium or linkage disequilibrium, irrespective of whether the loci are linked or not.Consider a population made up of equal numbers of AABB and aabb individuals of both sexes. The gene frequency at both loci is 0.5. If the individuals are mated at random the possible genotypes are:

AABB	**AaBB**	**aaBB**
AABb	**AaBb**	**aaBb**
AAbb	**Aabb**	**aabb**

Only three out of nine genotypes would appear in the progeny in the next generation i.e. the two original homozygotes (AABB and aabb) and the double heterozygote (AaBb). The genotype AAbb would be absent though its frequency in equilibrium population would be 1/16. The missing genotypes appear in subsequent generations but not immediately at their equilibrium frequency. Therefore, when two loci are considered together the genotype frequencies will reach equilibrium after several generations of random mating. If three loci are considered together, then the number of generations required to reach equilibrium genotype frequencies will be more than that required for two loci considered jointly.

Biometrical Techniques

Phenotypic variance & its components

Phenotypic value of an individual depends on its genotypic value and environment in which it is subjected as well as interaction between genotype and phenotype.

Thus, $P = G + E$

where, P = Phenotypic value,
G = Genotypic value,
E = Environmental deviation

Components of Genotypic Variance

$$\mathbf{G = A + D + I}$$

$$\mathbf{V_G = V_A + V_D + V_I}$$

Where,

V_A = Additive genetic variance or variance of Breeding Value
V_D = Dominance variance or variance due to Dominance Deviation V_I = Variance due to non-allelic gene interaction or epistasis
($V_D + V_I$) = Non-additive Genetic Variance

Components of Variance

$$V_P = V_G + V_E$$
$$= V_A + V_D + V_I + V_{EG} + V_{ET}$$

Variance component	Symbol	Value whose variance is measured
Phenotypic	V_P	Phenotypic value
Genotypic	V_G	Genotypic value
Additive	V_A	Breeding value/ Additive
Dominance	V_D	Dominance Deviation
Interaction	V_I	Interaction deviation
Environmental	V_E	Environmental deviation

Importance of partitioning the variance

- To understand the relative importance of each and every component of variance attributable to the different sources of variation
- To estimate the relative importance of various determinants of the phenotype, particularly the role of heredity and environment.
- To determine genetic determination, V_G/V_P.
- To estimate heritability of the character, V_A/V_P.
- To determine the degree of resemblance between relatives.
- To determine the repeatability of a character.

Heritability

The term heritability was introduced in Animal Breeding for the first time by **Prof. J. L. Lush**. Heritability is the most important characteristic feature of a metric character. In broad sense, it is the ratio of genetic variance to the phenotypic variance.

$$H^2 = V_G/V_P$$

In narrow sense, it is the ratio of additive genetic variance to the phenotypic variance.

$$h^2 = V_A/V_P$$

The fraction of total variation which is heritable is termed as coefficient of heritability in board sense. The extent to which individuals' phenotypes are determined by the genotypes is called **heritability in broad sense**. The extent to which individuals' phenotypes are determined by the genes transmitted from the parents is called **heritability in narrow sense.**

Properties of heritability

- It ranges from **0 to 1** or 0 to 100%
- Since, it is the ratio of variance components it **cannot be negative**.
- h^2 stands for heritability not square of h.

The symbol derives from **Prof. S. Wright's** (1921) terminology, **h** stands for ratio of σ_A / σ_V.

Low h^2 : 0 – 20% (0.00 -0.20)

Medium h^2 : 20 – 40% (0.20-040)

High h^2 : 40 – 100% (0.40-1.00)

Importance of heritability

1. It expresses the proportion of total variance which is attributable to the average effect of genes.
   $h^2=V_A/V_P$
2. Can be used for genetic determination of an individual.
   $H^2=V_G/V_P$
3. It determines the degree of resemblance between relatives
4. The most important function of h^2 is the prediction of breeding value on the basis of phenotypic value. **[BV=h^2 x P]**
5. It express the reliability of phenotypic value as a guide to the breeding value (b_{AP}).
6. It measures the correlation between breeding value and phenotypic value (r_{AP}).
7. It is used for prediction of genetic gain/response to selection.
   $R=h^2S$
8. It provides the estimation of accuracy of selection.
   $\sqrt{h^2} = h = r_{AP}$ = accuracy of selection.
9. It plays vital role in the formulation of breeding plan for genetic improvement of livestock and poultry.

Methods to Estimate Heritability

(A) Regression Method

(i) Regression of offspring on one parent
(ii) Regression of offspring on mid-Parent
(iii) Intra-sire regression of daughter on dam

(B) Correlation Method

(i) Half-sib correlation
(ii) Full-sib correlation

Heritability can also be estimated from selection experiment data
i.e. $R = h^2S$

$h^2 = R/S$

Where R = Response to selection and S = Selection differential

The heritability estimated by this way is called **Realized heritability**.

REPEATABILITY

Repeatability measures the **correlation between repeated measurements of a character** on the same individuals. When more than one measurement of a character is made on each individual, the phenotypic variance can be partitioned into two components, variance within individual and variance between individuals. The ratio of between individual variance component to the total phenotypic variance is called repeatability. It ranges from **0-1**.

The ratio of between individual variance component to the total phenotypic variance is intra- class correlation 'r'. It is the correlation between repeated measurements of the same individual and is known as **repeatability**.

$$\textbf{Repeatability, } r = (V_G + V_{Eg})/V_P$$

$$\textbf{or, } r \times V_P = V_G + V_{Eg}$$

Therefore, repeatability express the proportion of the variance of single measurements that is due to permanent or non localized differences between individuals to the total phenotypic variance. The special environmental variance component, V_{Es}, as a proportion of total is given by

$$V_{Es} / V_P = (1 - r)$$

$$\text{or } V_{Es} = (1 - r)V_P$$

Like heritability, repeatability is a population measure and is not a value associated with an individual animal. Like heritability, repeatability is not fixed, and varies from population to population and from environment to environment.

Uses of Repeatability

- Repeatability estimate sets upper limits to heritability in broad sense. Since repeatability is easier to estimate than heritability we can reasonably guess the probable value of heritability from the estimate of repeatability.
- Repeatability estimates are used to predict future performance from past records. When the repeatability for a trait is high, selection for the trait on the basis of the first record itself would be effective in improving the over-all performance of the herd in the next year.
- Repeatability indicates gain in accuracy expected from multiple measurements. If repeatability is high multiple measurements are not going to improve the accuracy of selection. If repeatability is low then two or more measurements will improve the accuracy of selection because increase in number of measurements reduces V_{Et} or V_{Es} that appears in the phenotype variance (VP), and thus the reduction of VP represents the gain in accuracy.
- Used to estimate the future performance of animals or **Most probable Producing Ability (MPPA).** *Lush* suggested the formula for estimating MPPA using repeatability estimate to adjust the records of cows with varying number of records / observations to uniform basis for comparison during selection programme.
- Repeatability estimate also throw light on the nature of environmental variance affecting the trait.

CHAPTER-IX

CORRELATION AND REGRESSION

Correlation is the strength of relationship or the intensity and the direction of association between two variables. If two variables vary in such a way that as one increases (or decreases), the other also increases (or decreases), then the correlation is said to be positive or direct. (eg.) feed intake and growth rate of animals. If two variables vary in such a way that as one increases, the other decreases and vice versa, then the correlation is said to be indirect or negative (eg.) litter size and birth weight of piglets. If there is no relationship between the two variables, they are said to be independent or uncorrelated.

Coefficient of correlation

A measure of correlation free from units of measurements is called **coefficient of correlation**. It is denoted by '**r**', r takes values from **–1 to +1**. When r = +1, the correlation is perfect and positive, r = -1, the correlation is perfect and negative, r = 0, there is no correlation. Correlation coefficient is independent of change of scale and origin of the variable x and y. Correlation coefficient is the geometric mean of the two regression coefficients

Types of Correlation

- Simple, partial and multiple
- Linear and Non-linear

It is based on the number of variables studied. When only two variables are involved in the study of correlation, it is called as the **simple correlation. Examples-** *feed intake and growth of animals; birth weight and number of piglets.*

When more than two variables are involved in the study, it is either multiple or partial correlation. In **multiple correlation**, we study the correlation of one dependant variable over all the other independent variables, (eg.) milk yield vs. first lactation period, food supplied, age etc. In **partial correlation** we study the relationship between two variables, assuming that the other variables are constant. (eg) correlation between the weight of broiler and feed intake assuming the other factors like area provided, labour used, medicinal cost etc. as constant .

On the basis of degree of covariation, correlation may be termed as linear or non-linear. When the correlation between two sets of variables is perfect of degree one or unity which means that the two variables have an exact functional relationship, the correlation is said to be **linear**. A perfect linear correlation may be positive or negative. Thus, its numerical coefficient will be either +1 or –1. These are the limits of correlation. Thus, coefficient of correlation cannot be greater than +1 or less than –1. If the correlation is imperfect, its graphic exposition will be **non- linear**. It will not form a straight line. Non-linear correlation will always be less than unity and it will lie between -1 and +1.

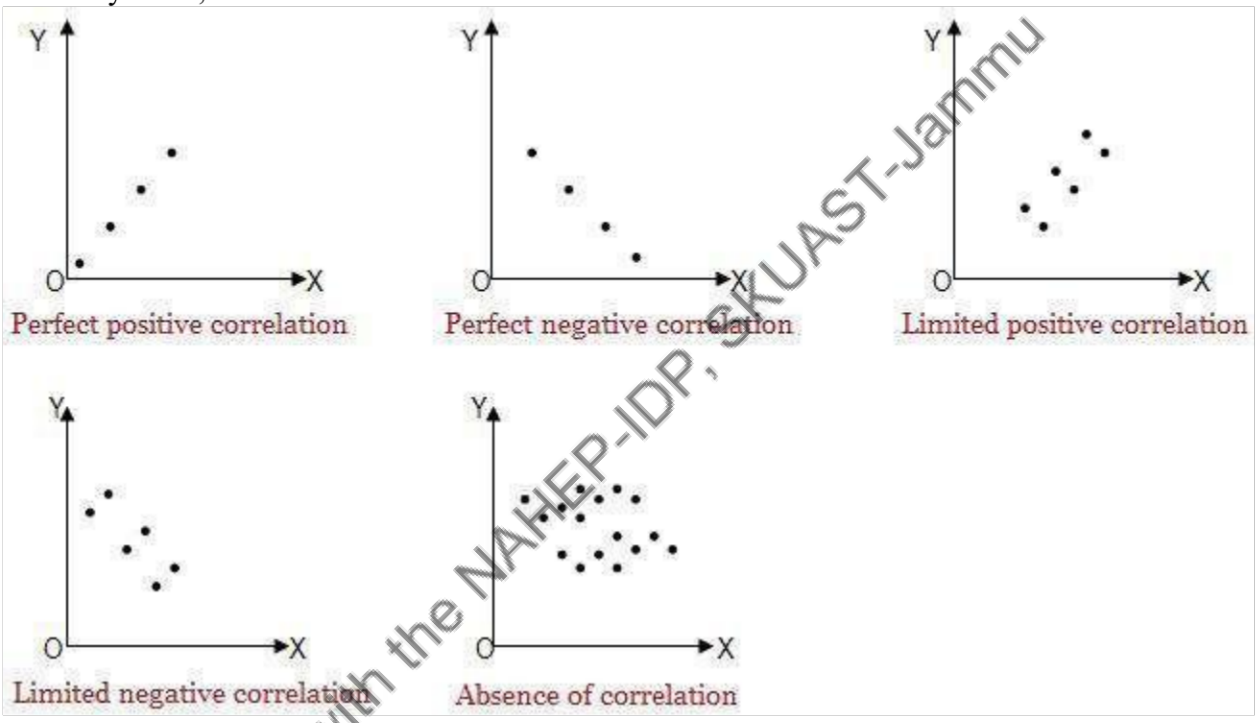
Methods of Studying Correlation

- Scatter diagram
- Correlation graph
- Karl pearson's coefficient of correlation
- Concurrent deviation method.

- Rank method

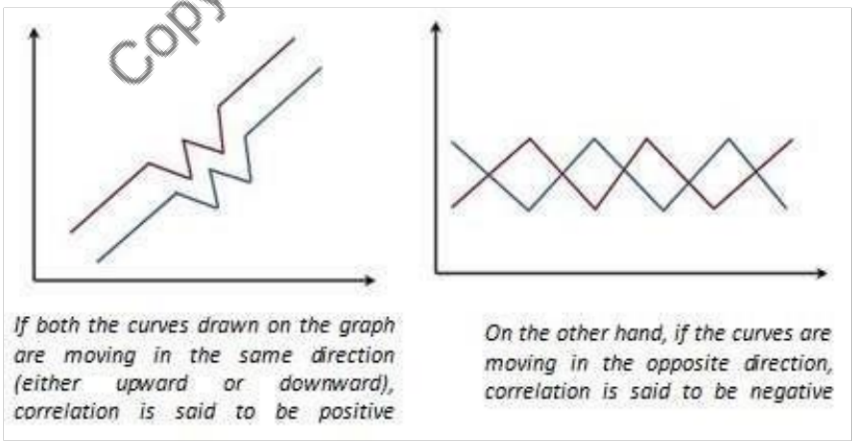
Scatter diagram

A scatter diagram or scatter gram or scatter plot or dot diagram is a chart prepared to represent graphically the relationship between two variables. Take one variable on the horizontal and another on the vertical axis and mark points corresponding to each pair of the given observations after taking suitable scale. Then, the figure which contains the collection of dots or points is called a **scatter diagram**. The way in which the dot lies on the scatter diagram shows the type of correlation. If these dots show some trend either upward or downward, then the two variables are correlated. If the dots do not show any trend, there is absence of correlation between the two variables.



Correlation graph

In this method, curves are plotted for the data on two variables. By examining the direction and closeness of the two curves so drawn, we can infer whether or not the variables are related.



This method is normally used for time series data. However, like scatter diagram, this method also does not offer any numerical value for coefficient of correlation.

Karl pearson's coefficient of correlation

Of the several mathematical methods of measuring correlation, the Karl Pearson's method, popularly known as Pearsonian coefficient of correlation is often used. It is denoted by r. It is also called product moment formula. It is given by

$$r = \frac{\Sigma XY - \frac{(\Sigma X)(\Sigma Y)}{n}}{\sqrt{\left[\left(\Sigma X^2 - \frac{(\Sigma X)^2}{n}\right)\left(\Sigma Y^2 - \frac{(\Sigma Y)^2}{n}\right)\right]}}$$

Concurrent deviation method

Find out the direction of change of x variable, i.e. as compared with the first value, whether the second value is increasing or decreasing or constant. If it is increasing, put a + sign, if it is decreasing, put a – sign and if it is constant, put zero. Similarly, as compared to second value, find out whether the third value is increasing, decreasing or constant. Repeat the same process for the other values also. Denote the column as Dx. In the same way, find out the direction of change of y variable and denote this column as Dy. Multiply Dx with Dy and determine the value of c, the number of concurrent deviations or the number of positive signs obtained after multiplying Dx with Dy. Then apply the formula

$$r = \pm\sqrt{\pm\left[\frac{2c - n}{n}\right]}$$ sign is taken as that of $(2c - n)$

Rank method

Sometimes we may not know the actual values, but their ranking may be known. In such occasions, this method would be of use. Even when the actual values are available, we can rank them and measure correlation using the formula:

$$r_s = 1 - (6\,\Sigma d^2) / n(n^2 - 1)$$

where 'd' is the difference in the ranking of the two series x and y, and n is the number of paired observations.

REGRESSION

Regression is the amount of dependence of one variable on the other. This gives the rate of change of one variable with respect to another. The meaning of regression is the act of returning or going back. This term was introduced by **Francis Galton**. We may be interested in estimating the value of one variable given the value of another. This is done with the help of regression. The problem of regression is to find out equations of the lines (or curves) with functional relationship between two variables, independent - x and dependent - y. The simple linear regression is of the form

$$y = a + bx$$

where 'b' represents the slope of the line (also called as regression coefficient) and 'a' the intercept of the line.

In a study where data on age and weight of animals are available, age could be considered as the independent variable, while weight as the dependent variable. It means that weight regresses on age.

Types of Regression

- Simple, partial and multiple
- Positive and negative and
- Linear and non-linear

Properties of Regression Coefficient

- It is generally denoted by 'b'.
- It is expressed in the form of an original unit of data.
- They are not independent of the change of scale.
- It ranges from - ∞ to + ∞
- Regression coefficient gives the rate of change in the value of dependent variable (y) for a unit change in the independent variable (x).
- Regression equation is useful in estimating the values of y by knowing the values of x i.e. prediction of dependent variable from independent variable.
- If two variables are there say x and y, two values of the regression coefficient are obtained. One will be obtained when x is independent and y is dependent and other when we consider y as independent and x as a dependent. The regression coefficient of y on x is represented by b_{yx} and x on y as b_{xy}.
- Both of the regression coefficients must have the same sign. If b_{yx} is positive, b_{xy} will also be positive and it is true for vice versa.
- If one regression coefficient is greater than unity, then others will be lesser than unity.
- Product of the regression coefficients is the square of correlation coefficient or The **geometric mean** between the two regression coefficients is equal to the correlation coefficient. **$r = \sqrt{(b_{yx} . b_{xy})}$**

Applications of regression

- It helps in finding out a cause and effect relationship between two or more characters.
- It is useful in determining the important yield contributing characters.
- It helps in the selection of elite genotypes by indirect selection for yield through independent characters.
- It also helps in predicting the performance of selected plants in the next generation

Comparison Between Correlation and Regression

Basis	**Correlation**	**Regression**
Meaning	A statistical measure that defines co-relationship or association of two variables.	Describes how an independent variable is associated with the dependent variable.
Dependent and Independent	No difference	Both variables are different.

variables		
Usage	To describe a linear relationship between two variables.	To fit the best line and estimate one variable based on another variable.
Objective	To find a value expressing the relationship between variables.	To estimate values of a random variable based on the values of a fixed variable.

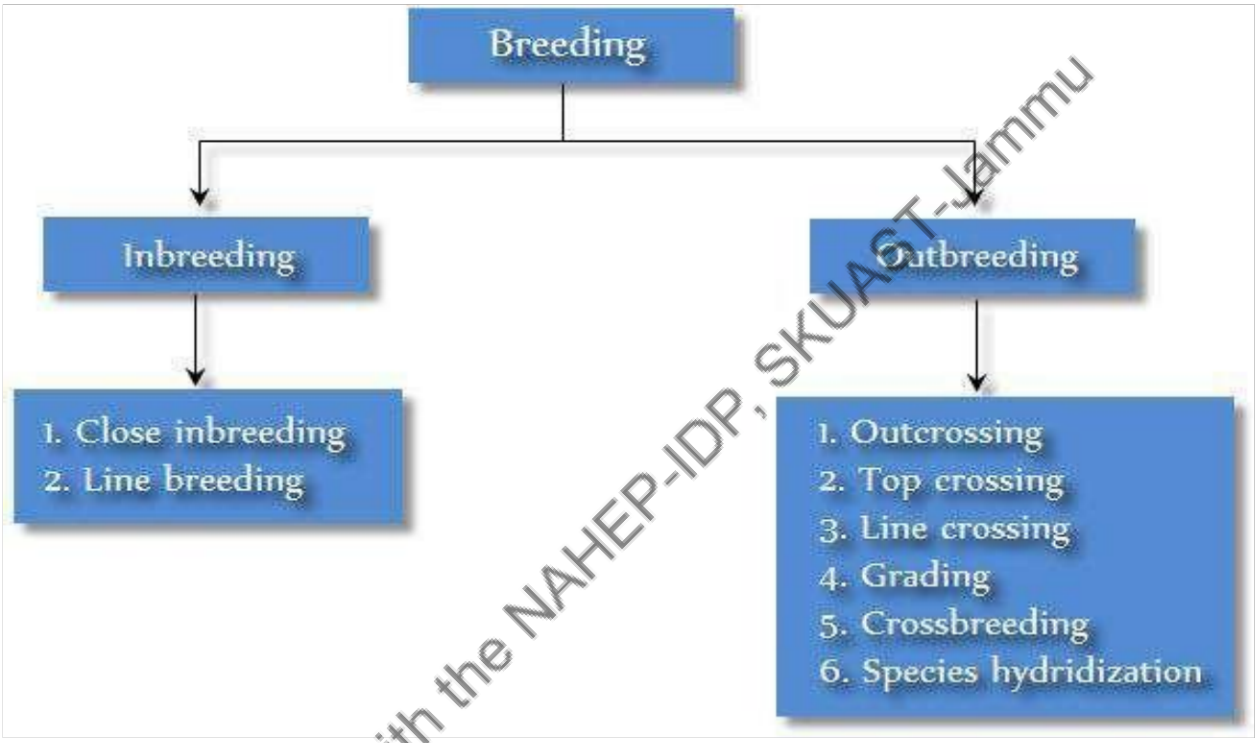
CHAPTER-X

SYSTEMS OF BREEDING

Mating system based on genetic relationship is divided into

1. Inbreeding
2. Out breeding

Inbreeding is defined as mating of animals more closely related to each other than the average relationship within the population concerned. Inbreeding includes matings like parent – offspring, brother –sister, eg. Brother, half sister and among cousins and other collateral relatives.



Inbreeding

Inbreeding is the mating between animals, which are more closely, related each other than the average relationship between all individuals in a population or inbreeding is mating between animals related by ancestors. When the animals are considered as closely related when they have one or more common ancestors in common, in the first 4 to 6 generations of their pedigree. Example: Sire-daughter, Son-daughter or Brother-sister. In general, inbreeding refers to close breeding. Inbreeding is classified into two types

Close Inbreeding: Such as mating between sibs or between parents and progeny in order to achieve inbred lines with relatively high degree of homogenisity. In most of the time we use full sib mating method. The same effect can be achieved by consistently back crossing the progeny to the younger parents. Half sib mating is much slower, rich in homozygosity but it is also less risky.

Line breeding: It is a system of mating in which the relationships of an individual or individuals are kept as close as possible to some ancestor. In general line breeding is a milder form of

inbreeding. As a general rule sire is not mated to its daughters but half sib matings are made among the offspring of the particular sire. Line breeding was used extensively in the past in development of British breeds of cattle such as Angus, Hereford and Shorthorn. The following points should be remembered while practicing line breeding,

- Line breeding should be practiced in purebred population of high degree of excellence, after identifying outstanding individuals.
- Line breeding is probably most useful when an out standing sire is dead or not available for breeding purpose.
- To form new breeds, line breeding can be advocated.

Genetic Effects of Inbreeding

Inbreeding makes more pairs of genes in the population homozygous irrespective of the type of gene action involved. The consequences of homozygosity are:

- Inbreeding does not increased the number of recessive alleles in a population; but merely brings to light through increased homozygosity.
- Inbreeding fixes characters in an inbred population through increased homozygosity whether the effects are favorable or unfavorable.
- As a result of homozygosity, the offsprings of inbred parents are more likely to receive the same genes from their parents than of offspring of non-inbred parents. This is another way of saying that inbred parents are more likely to be pre-potent than non-inbred parents.
- If overdominance exists (Aa is superior than AA or aa), inbreeding decreases the overdominance by changing the Aa genotype to AA and aa.
- Inbreeding doest not change gene frequencies.
- Inbreeding unmasks the recessive alleles

Phenotypic Effects of Inbreeding

When the animals are homozygous for a no. of traits, the regularity of inheritance is assured (i.e it fixes the characteristics). Inbreeding reduces vigour is called inbreeding depression. Increased inbreeding results in

- Reduced fertility,
- Reduced mothering ability,
- Reduced viability and growth rate
- Inbreeding if accompanied by selection may increase the phenotypic uniformity

Prepotency

Prepotency is the ability of the individual to stamp its characteristic on its offspring to such an extent that they resemble their parents more closely than in usual. It is the property of the characteristic and not the individual breed or sex. When two individuals are mated one may have more influence than the other on offspring. Similarly some lines and breeds are more pre-potent than others. However prepotency can't be passed on from one generation to another unless it is possessed by both sires and dams.

Uses of Inbreeding

In spite of certain obvious disadvantages of inbreeding, there are certain instances where it may be used as advantage of livestock production.

- The most practical use of inbreeding is to develop strains and lines that can be used for crossing purposes to exploit heterosis.

- Inbreeding may be used to determine the actual genetic worth of an individual, is done by mating to a sire with 25 to 35 daughters before it is used extensively in AI programme.
- Inbreeding could be used as a practical way to select against the recessive genes of economic importance. Such inbreeding brings out the hidden recessive genes both recessive homozygous and heterozygous parents can be identified and culled.
- Inbreeding may be used to form distinct families with in a breed especially the selection is practiced along with it.
- To maintain genetic purity and thereby to increase prepotency
- To eliminate undesirable recessives. When a sire is mated to 20 of its daughters and does not produce any recessive characters in the offspring, it may concluded that the sire is not heterozygous for recessive characters.
- To develop inbred lines.
- To regroup the genetic material
- To produce uniform progeny
- To determine the type of gene action. If inbreeding effects are large, the type of gene action is non – additive: if inbreeding effects are small , then the type of action is additive.

Disadvantages of Inbreeding

- Undesirable traits appear with increasing frequency as intensity of inbreeding increases (lethal and sub lethal).
- Growth rates in farm animals reduced by inbreeding.
- Inbreeding reduces the reproductive efficiency.
- Reduced vigour lower vitality due to inbreeding depression

Inbreeding depression

The most striking observed consequence of inbreeding is the inbreeding depression. It is the reduction in the mean phenotypic value shown by characters connected with reproductive capacity or physiological efficiency. In general inbreeding tends to reduce the fitness. Thus, characters that form an important component of fitness, such as litter size show reduction on inbreeding. Whereas characters that are not closely related with fitness show little or no change. Inbreeding depression for a single locus can be expressed as follows.

MF = Mo - 2dpqF and for all loci concerned

i.e, MF = Mo - 2 F pqd

Where,

Mo - Mean value of a population for a particular character before inbreeding. MF - Mean value of the population for a particular character after inbreeding.

F - Inbreeding co.efficient

d - dominance, i.e heterozygote does not have a value average to that of homozygote p - Frequency of one allele

q - Frequency of other allele

Therefore, inbreeding depression is – 2F pqd which depends on dominance (d), inbreeding coefficient (F) and relative frequencies of alleles (p & q). Genes are at intermediate frequency at the beginning of breeding show highest depression. Economic traits like reproductive viability, milk yield and growth rate show inbreeding depression. Characters like fat % and back fat thickness do not show much inbreeding depression.

Coefficient of Inbreeding

Inbreeding increases homozygosity and decreases heterozygosity. The average percentage increase in homozygosity or decrease in heterozygosity in an inbred animal in relation to an average animal of the same breed or population is known as coefficient of inbreeding symbolised by 'F'. It ranges from 0 to 100.

The degree of inbreeding inb any individual may be calculated by using the formula Wright 1921.

$$F_x = \sum[(1/2)^{n1+n2+1} (1+F_A)]$$

Where,

F_x = Coefficient of inbreeding of X.

$\sum$= Summation

n1 = No. of generation from the sire of X back to the same common ancestor n2 = No. of generation from the dam of X back to the same common ancestor F_A = Coefficient of inbreeding of the common ancestor

Out Breeding

Out breeding is the mating of animals which are less closely related to each other than the average of the population. Its general effects are the opposite of those of inbreeding. Out breeding increases the heterozygosity of the individual. The maximum practical usefulness of out breeding systems is the production of animals for market. Out breeding systems are broadly classified as follows:

1. Out crossing
2. Top crossing
3. Line crossing
4. Grading
5. Crossbreeding
6. Species hybridization

Out Crossing

Out crossing usually applies only to mating within a pure breed. If two lines or flocks within the same breed are separated for four or five generations and the sire from one herd is used in another herd that amounts to out crossing. The use of out crossing in purebreds are

- When there is lack of selection response due to reduced genetic variability.
- To reduce inbreeding in a closed population.
- To introduce new genes with reference - colour, horn type, etc.

Top Crossing

This is a system of crossing which is normally used within pure breeds. Top crossing refers to the use of highly inbred males to the females of the base population or non-inbred population. Top cross usually refers to the best sire in a pedigree. Top crossing also refers to the continued use of sires to different families within a pure bred, same breed or different breed.

Line crossing

Line crossing usually refers to crossing of inbred lines within a specific breed. Line crossing takes advantage of both increased homozygosity within a line and the difference between lines. Line crossing is mainly done to exploit heterosis or hybrid vigour.

Back Crossing

It is the mating of a cross bred animal back to one of the pure parent races, which were used to produce it. It is commonly used in genetic studies, but not widely used by breeders. When one of the parents possess all or most of the recessive traits, the back cross permits a surer analysis of the genetic situation than the F2 does.

A heterozygous individual of F1 when crossed with a homozygous recessive parent the offspring group themselves into a phenotypic ratio of 1:1. On the other hand if the F1 individual is crossed with the homozygous dominant parent then all the offspring will be phenotypically alike.

Grading Up

Grading up is the continual use of sires of one pure breed starting with foundation females which were of another breed or no particular breed at all (Non-descript or Mongrel). Marked improvement in crosses if sires from a particular breed (A) are repeatedly back crossed to another breed / non-descript animals (B). Five generations are sufficient to raise the level of inheritance of breed A to 96.9% (0.969) in the fifth generation. After five generations of repeated back crossing to a particular breed, the animals after the end of fifth generation become eligible to be registered as purebred.

Generation	**Level of pure bred blood of sire used %**
Foundation stock	0
First generation	50
Second generation	75
Third generation	87.5
Fourth generation	93.75
Fifh generation	96.875
Sixth generation	98.4375
Seventh generation	99.23875

Cross Breeding

Cross breeding is mating of two individuals from different breeds. Breed represents tremendous resources of varying genetic material. Cross breeding is done. Cross breeding is done to exploit hybrid vigor or heterosis and to sell the crossbred to market. Every time, the parental breeds have to be crossed for producing market animal. Crossbreeding has been used in recent years to establish a broad genetic base in the development of new breeds or synthetics: one or two crosses between the two or more populations are made in order to produce a single population of animals containing genes from each of the population involved. Once a synthetic has been formed then the main aim is to improve it as rapidly as possible by selection within it. For example: Santa Gertrudis, The Jamaica Hope, the Norwegian Red and White, the Australian Milking Zebu, Hissardale, Karan Swiss, Sunandhini, Taylor breed. The main guidelines to be followed in crossing to produce a synthetic are:

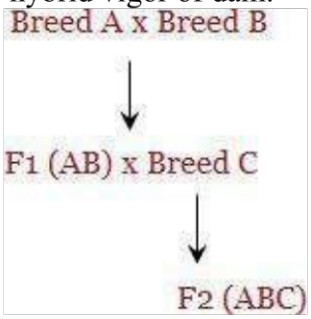
- Ensure that the animals used in the original crossings have been intensely selected in terms of relevant characters; it is of no use starting a synthetic with inferior animals.
- Maximise variance in breeding values amongst the foundation animals in the synthetics using as many unrelated animals as possible from each of the contributing populations

Single two way cross or Single cross

Two different breeds are crossed with each other to produce an F1 which is useful for production purposes and not for breeding.

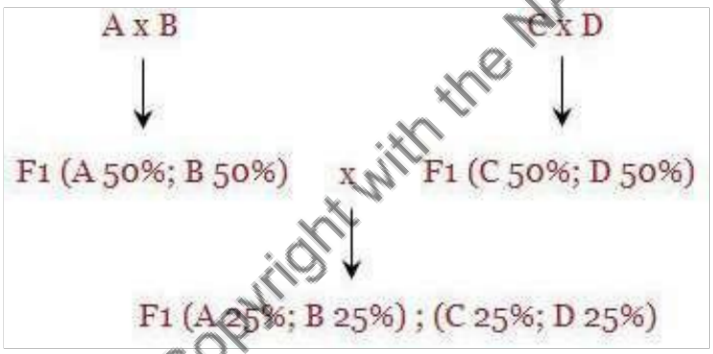
Three way crosses (A,B, C)

The first generation crossbred females are crossed with females of the third breed, then using the hybrid vigor of dam.



Double cross or Four way cross

There are four breeds are involved in this type of crossbreeding programme. First two breeds are crossed to get F1 and second two breeds are crossed for getting another F1 the both F1s are crossed to produce F2 which having 25% of genes each from four different breeds, so all the different characters are combines well. By inter-se mating the selected characters are fixed in the four way cross



Systematic cross breeding

Back cross (AB)

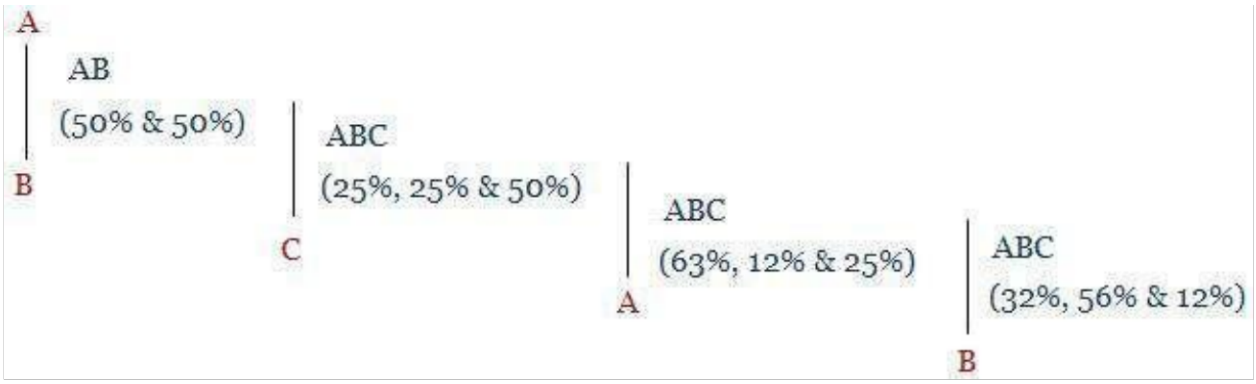
Usually the F1 females are back crossed to one of the parent breeds. In this cross, the maternal heterosis is exploited.

Criss crossing (Reciprocal back crossing)

Breeds A and B are crossed to produce F1 generation, then F1(AB) females are back crossed to B and F1 (AB) males back crossed to breed A and so on.

Three way rotational cross

Commercially used in pig industry. Breeds A, B, C are crossed in tradition.



Three way rotational crossing maintain a high degree of heterozygosity. For three way rotation, frozen semen/sire can be used without maintaining purebred population.

Species Hybridisation

Hybrids can occur where the species are closely related for the egg and sperm to result in a viable embryo. Where the two species are very closely related, the hybrids may even been partially or fully fertile. Some hybrids are bred for curiosity or public display, others are bred by researchers involved in genetic researcher and a few occur naturally. Chimeras are not the same as hybrids. Hybrids have intermediate features and each cell is a mix of chromosomes from the parental species. Chimeras are a mix of genetically different cells to form a mosaic animal.

Crossing the species boundary

Speciation (one species evolving into two) is usually a slow process. It is generally accepted that different species usually cannot mate and reproduce - this is called "**reproductive isolation**". The exception was closely related species which can produce hybrids, although those hybrids have reduced fertility.

Sometimes, one species can split into two through **behavioural isolation**. Some individuals develop behaviour patterns which limit their choice of mates e.g. they might be attracted to certain colours or might be active at different times of day. Though they are fully capable of interbreeding with the other group, their different behaviours keep them apart. If their habitat became permanently overcast, those behaviour barriers would break down and they would interbreed freely; their hybrids might become new species.

Another way reproductive isolation occurs is when fragments of DNA accidentally jump from one chromosome to another in an individual i.e., **chromosomal translocation**. The mutant individuals cannot reproduce except with other mutant individuals - not much good unless the individual has mutant siblings to mate with! There are also "**master genes**" which govern general body plan (**Hox genes**) and those which switch other genes on and off. A small mutation to a master gene can mean a sudden big change to the individuals that inherit that mutation. Sometimes, those radical mutations can "undo" generations of evolution so that two unrelated species can mate with each other and produce fertile young (only seen in micro-organisms).

In mammals, hybrid **White-Tail/Mule Deer** don't inherit either parent's escape strategy (White Deer dash. Mule Deer bound) and are easier prey than the pure-bred parents. Another example is seen in **Galapagos Finches**. Healthy Galapagos Finch hybrids are relatively common, but their beaks are intermediate in shape and less efficient feeding tools than the specialised beaks of the parental species so they lose out in the competition for food.

Several other species hybrids have been produced. Some of them are

S. No.	Hybrids	Sire	Dam	Remarks
1	Hinny	Stallion	Jennet	It is inferior to mule as a work animal and is also sterile
2	Zebroid	Zebra	Horse	Popular in tropics – docile – better disease and heat resistance
3	Cattalo	Cattle	Bison	Bison is known as American buffalo. Males are sterile and females are fertile. domestic bull/Bison cow crossings have a lower infant mortality rate (cow immune systems can reject hybrid calves)
4	Beefalo	American Bison	Domestic Cattle	Beefalo have been back-crossed to Bison and to domestic cattle; some of these resemble pied Bison with smooth coats and a maned hump. The aim is to produce high protein, low fat and low cholesterol beef on animals which have "less hump and more rump". Although Bison bull/domestic cow crossings are more usual,
5	Pien niu	Cattle	Yak	Found in Tibet.
6	Goep	Goat	Sheep	Sheep and goat are not so closely related. When crosses are made between them fertilization sometimes takes place. However the embroys die before parturition and are resorbed or aborted.
7	Zubron	Domestic cattle	Wisent (European Bison, *Bison bonasus*).	Zubron was considered as a possible replacement for domestic cattle as they were durable and resistant to many thrived on poor pasture, in harsh weather and with minimal husbandry. First generation Zubron males are infertile and cannot be used for breeding, but the females are fertile and may be bred back (back-crossed) to either Wisent or to domestic bulls. Males from these back- crosses are fertile.
8	Yakalo	Bison (American "Buffalo")	Domestic Tibetan Yak	In Nepal, Yak/Cow hybrids are bred using Yak bulls on domestic cows or, less often, domestic bulls on Yak cows. The Yak-Cow females are fertile, the males are sterile and the meat is considered superior to beef. In Nepalese, the hybrid is called a Khainag or Dzo (male)/Dzomo (female). A Dzomo crossed with either a domestic bull or yak bull results in an Ortoom (three-quarter-bred) and an Ortoom crossed with a domestic bull or yak bull results in a Usanguzee (one eighth bred).

9	Geep	Goat embryo	Sheep embryo	Although often cited as a hybrid, the famous "Geep" is not a true goat/sheep hybrid, but was a laboratory experiment which fused a sheep embryo with a goat embryo (a type of animal called a chimera). The geep is a mosaic of mismatched goat and sheep parts; the parts which grew from the sheep embryo are woolly while those which grew from the goat embryo are hairy. Each set of cells kept their own species identity instead of being intermediate in type. It could be fertile, but will produce either goats or sheep depending on whether its reproductive organs grew from the goat embryo or from the sheep embryo.
10	Cama	Camel	Llama	Llama is a hybrid
11	Iron Age Pigs	American wild hogs	Tamworth pigs	Resemble

Heterosis or Hybrid Vigour

Crosses of animals from different strains or lines of the same breed, from different breeds or from different species, result in offspring whose level of production is above that of the average of the parents. The increased production may be due to increased fertility, increased pre and post natal viability, faster and more efficient growth, improved mothering ability etc. The increased level of performance as compared to the average of the parents is known as heterosis or hybrid vigour. The heterosis can be either positive or negative. Heterosis is the phenomenon in which progeny of crosses between inbred lines or purebred populations exceed the average of the two parental populations.

It is just the opposite of inbreeding depression.

Heterosis can be measured by using the formula

Heterosis (H) = [(Mean of F1 offspring) - (Mean of parents) /Mean of Parents] x 100

Genetic basis of heterosis

The theories put forward to explain heterosis are

Dominance Theory : It postulates that the parental lines are homozygous dominant for different loci – when crossed produces progeny with dominant gene at all loci.

Overdominance Theory : It postulates that the heterozygote is superior to either homozygotes (parents).

Epistasis Theory: It postulates that gene interactions are responsible

But in practice the heterosis is due to combination of dominance, overdominance and epistasis in any proportion. However, the contribution of epistasis to heterosis is negligible in crossbred of domestic animals. Generally all the quantitative characters are governed by many genes and no animal is likely to carry all of them in homozygous dominant state. In living organisms, dominant genes are more often favourable than the recessive genes. Crossing of two

different lines or breeds has a greater chance of contributing different dominant genes to the progeny.

As the quantitative traits are polygenic in nature and the animals produce only a few offspring, it is not possible to produce animals with perfect combination even after many generations of selection. The chance is further reduced by other genetic factors like undesirable recessives, linkage between desirable and undesirable genes and by non-genetic factors like environment.

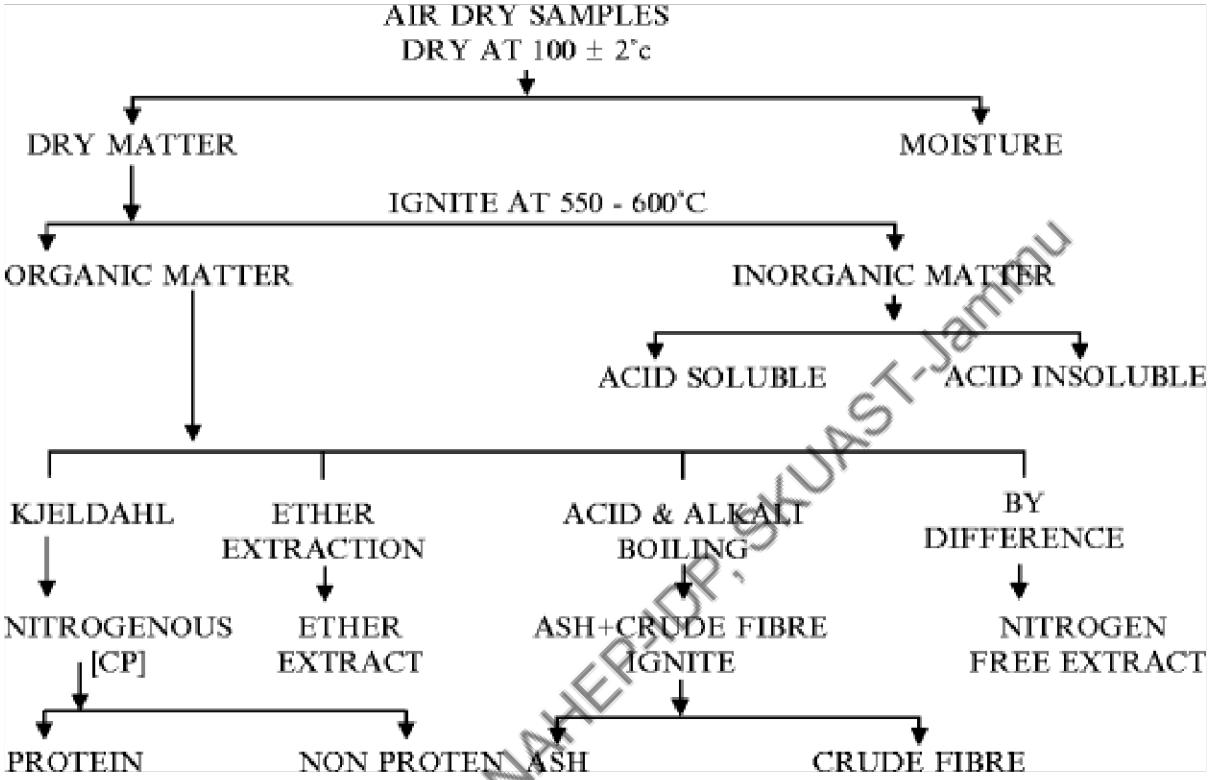
Formulae $HF_1 = dy^2$ and $HF_2 = ½\ dy^2$

Animal Nutrition

CHAPTER-I

MINERAL NUTRITION- MACRO MINERALS

Estimation of mineral matter:



Why is total ash estimated although it has no energy value?

- Gives an apparent idea about quantity of minerals
- Used to calculate NFE by difference
- Is of little value either for expressing mineral requirements or for indicating useful mineral content of feed
- May not be measure of total inorganic matter present
- AIA indicates regarding contamination of feed- the quantity silica and sand
- Soluble portion of total ash indicates micro and macro minerals
- AIA is estimated to know the quality of feed

About 3% of animal body consists of minerals. 30 – 40 elements occur in animal body, only few (nearly 15) are essential

Criteria of essentiality:

Essentiality is known from its metabolic role in animal body from the following criteria:

- It is present in all healthy tissues of animals

- Its conc. from one animal to the next is fairly constant
- Its withdrawal from body induces reproducibly the same structural and physiological abnormalities regardless of species studied
- Its addition either prevents or reverse these abnormalities
- Abnormalities induced by deficiency are always accompanied by pertinent, specific biochemical change
- These biochemical changes can be prevented or cured when the deficiencies are prevented or cured

Minerals and their functions:

❖ Inorganic elements needed by body for the following functions:

▶ 1. Structural and protective function of minerals- Ca, P, Mg, F, Si

Bones, teeth, hair, hooves, soft tissues

▶ 2. a. Regulatory functions of Minerals - Na, K, Ca, Mg, P, Cl

Maintenance of ionic equilibrium, Maintenance of osmotic pressure, Maintenance of acid base equilibrium

- b. Minerals and function of cell membranes

Transmission of nerve stimuli, intercellular signalling, perception of light odour taste, energy conversion in cell, changes in enzyme activities

▶ 3.Metabolic functions of Minerals

- a. Cofactors of enzymes: metalloenzymes and metal activated enzymes
- b. Minerals and hormones

Insulin, prolactin, oxytocin, thyroxin

- c. Minerals and symbiotic bacteria

Co serves as food for micro flora

- d. Minerals and milk

Cow milk contains 5.8% ash on DM basis

Classification of minerals:

▶ **Major minerals**

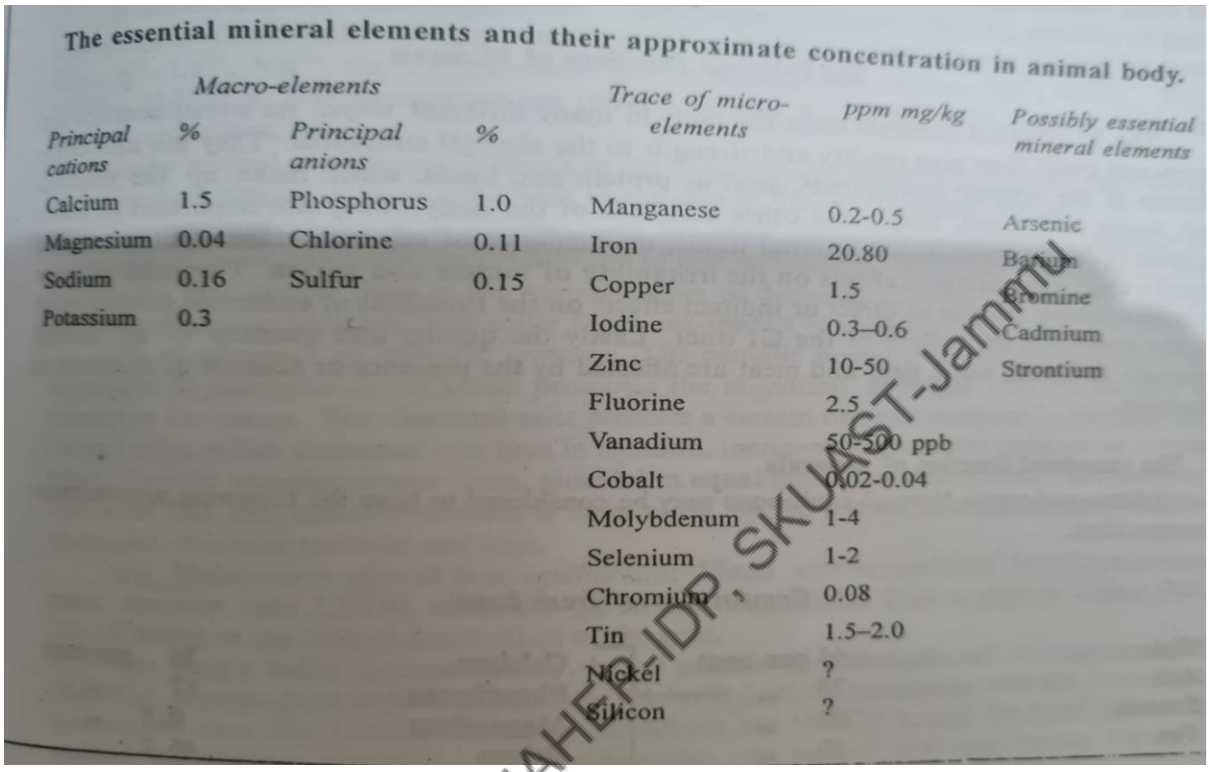
- required in amounts greater than 100mg a day
- Also called macrominerals
- Seven major essential minerals (in addition to C, H, O_2 and N)
- Usually expressed as percent of diet

▶ **Trace minerals**

-required in the diet in amounts less than 100mg a day

- Also called microminerals

-requirements are expressed in ppm or mg/Kg



The essential mineral elements and their approximate concentration in animal body.

Macro-elements				*Trace of micro-elements*	*ppm mg/kg*	*Possibly essential mineral elements*
Principal cations	*%*	*Principal anions*	*%*			
Calcium	1.5	Phosphorus	1.0	Manganese	0.2-0.5	Arsenic
Magnesium	0.04	Chlorine	0.11	Iron	20.80	Barium
Sodium	0.16	Sulfur	0.15	Copper	1.5	Bromine
Potassium	0.3			Iodine	0.3–0.6	Cadmium
				Zinc	10-50	Strontium
				Fluorine	2.5	
				Vanadium	50-500 ppb	
				Cobalt	0.02-0.04	
				Molybdenum	1-4	
				Selenium	1-2	
				Chromium	0.08	
				Tin	1.5–2.0	
				Nickel	?	
				Silicon	?	

Major minerals

Calcium and phosphorous

- Over 70% of body ash consists of Ca and P, Majority of which is present in bones and teeth
- Ratio of Ca:P in bones is 2:1
- Blood cells are devoid of Ca
- Bone: Noncrystalline phase(hydrated tricalcium phosphate) and crystalline phase resembling hydroxyapetite
- Normal adult bone has water 45%,ash 25%,protein 20%,fat 10%
- On fat and moisture free basis bone has 36% Ca, 17% P, 0.8%Mg
- Plasma Ca occurs in 2 forms: soluble ionised form and bound form (mainly albumin and plasma proteins
- Level of Ca in blood is 9-12mg/100ml
- Level of P IN blood is 4-12mg/100ml
- Ca and P is absorbed from SI
- Major portion of Ca is excreted through faeces
- P excretion occurs primarily through faces in herbivore, urine in carnivore
- Modern isotope technique (Ca^{45},P^{32}) is used to distinguish between faecal and metabolic fraction

  Functions

- Calcium:
  - Skeletal functions
  - Blood clotting
  - Myocardial function
  - Neuromuscular excitability
  - Enzyme activation
  - Sec of hormones and hormone releasing factors

Phosphorus
- Skeletal functions
-Bone matrix (organic)
- Body fluids and soft tissues
- Cell growth, energy utilization
- Acid: base balance
- Component of DNA, RNA

Calcium deficiency:

- Rickets in young animals

  Soft, bend easily and misshapen bones, enlarged joints often exhibit lameness
- Haemorrhages and tetany in rats
- Tibial dyschondroplasia in broilers
- Osteofibrosis in horse

  Adults:
- Osteomalacia- due to chronic Ca deficiency
- Osteoporosis- failure of normal bone metabolism
- Osteopenia- bone pathology which means too little bone
- Parturient paresis or milk fever or parturient hypocalcaemia

Phosphorus deficiency:

Most deficient mineral throughout world

- Pica- depraved appetite (Na and K def. also)
- Allotriophagia (generalised form)
- Osteophagia (craving for bones)
- Sarcophagia (craving for flesh)
- Reduced fertility, delayed conception
- Abnormal bones - Stiff gait, Arching of back, Fractures, Enlarged and Painful joints

High dietary Ca and P – interactions

- High dietary Ca without Zn leads to Parakeratosis in pigs
- Chronic high Ca intake leads to Osteopetrosis
- High dietary P with marginal Ca leads Nutritional secondary hyperparathyroidism
- Osteodystrophia fibrosa/Big head disease –horse, monkey
- Periodontal disease in dogs
- High dietary inorganic P, phytin P and Mg depress Ca absorption
- Oxalates and phytates decrease Ca absorption
- Lactose improves Ca absorption
- Ca binding protein – cadmolin and osteopontin

Sources

Sources of Ca: Green leafy vegetables especially leguminous grasses, Animal by-products like bones, Calcium and calcium phosphorous supplements

Sources of P: Grains, grain by-products, concentrates like oil cakes, brans, sterilized bone meal, milk products

Magnesium

- Blood serum conc. 1.7-4mg/100 ml

Functions:

- Constituent of bones (Ca:Mg 50:1)
- Activator and cofactor for various enzymes
- Constituent of chlorophyll
- Required for oxidative phosphorylation, β oxidation of fatty acids, transketolase rxn

Interactions:

- High Na and K depresses Mg absorption
- High P decreases Mg absorption and increases loss of endogenous Mg
- On low P diets Mg interferes with Ca absorptions

Deficiency

- Renal calculi
- Grass staggers/ grass tetany/ wheat staggers/ wheat poisoning

  Nervousness, muscle twitching, laboured breathing, rapid pulse, stiff gait, staggering, pricked ears, staring eyes, violent convulsions, pedalling of forelegs, jaws working, teeth grating, coma and death
- Lactation tetany/ hypomagnesaemic tetany

  Less than 1 mg%, muscle spasms, convulsions and death due to respiratory failure

  Prophylactic measure- 50g of MgO
- Young chicks – slow growth rate
- Peculiar stepping syndrome – pigs

Sources:

Green fodders, Pericarp of cereal grains, Brans, Cotton seed cake, Linseed cake

Sodium:

- Major cation of ECF
- Imp. For Amino acid and glucose uptake
- Reabsorption of Na - Aldosterone

Functions:

- Maintains body pH
- Regulates body fluid volume

- Nerve function and muscle contraction
- Functions in permeability and carrier of cells

Deficiency:

- Slow growth, softening of bones
- Keratinization of corneal epithelium
- Impotency in males, delayed sexual maturity, impaired estrus rhythm
- Decreased cardiac output, increased hematocrit
- Cannibalism, lowered production, loss of weight in laying hens

Sources:

- All animal products, esp. meat meals and foods of marine origin, commonest source is salt. Veg. origin has comparatively low Na

Chlorine:

- Major anion of ECF
- Requirement is half of that of Na

Function:

- For regulating pH and osmolarity
- Respiration is based on chloride shift
- Acid base balance
- Metabolism and requirement is related to Na and K
- Salt is the commonest source

Salt:

- As a condiment it stimulates saliva and promotes action of diastase enzyme
- Na is critically limiting element in sodium chloride salt
- Salt supplementation @ 1% in herbivores

Deficiency:

- Loss of appetite, decline in egg and milk production, retarded growth, lowered fertility, cannibalism
- Excess salt intake: salt poisoning in pigs and poultry, edema
- Ruminants have higher tolerance to salt poisoning

Potassium:

- Major cation in ICF, Mg 2nd
- Adrenal hormones increase K excretion
- Decreased use of hay and increased use of grain – K deficiency

Functions:

- Maintenance of Acid-base equilibrium
- Maintenance of osmotic balance
- Nerve transmission, heart beat relaxation
- Activates certain enzymes
- Imp. For CHO and protein metabolism, Uptake of AA by cell

Deficiency:

- Decreased growth rate
- General weakness
- Poor intestinal tone
- Cardiac weakness
- Weakness of respiratory muscles
- Tetany and death

Sources:

K content of plants is high, amount present in grass DM is frequently above 2.5%

Sulphur:

- Sulphur containing AA – cysteine, cystine and methionine
- Sulphur containing vitamins – Thiamine and Biotin
- Sulphur containing enzymes – Glutathione, oxytocin, lipoic acid, insulin
- Inorganic form – chondroitin sulphate (cartilage)
- Organic components - Heparin, fibrinogen and taurine
- Keratin, the hair protein is rich in S
- In Blood and saliva present as thiocyanate
- Excreted through faeces and urine
- Wool approx. contains 4% S
- N:S ratio of ruminant diets should be 10:1 to 15:1
- S in form of sulphate is used in Mo toxicity

Sources:

Fish meal, chicken eggs, hydrolysed feather meal etc.

CHAPTER-II

MINERAL NUTRITION- MICROMINERALS AND POULTRY DEFICIENCY DISEASE

Microminerals or trace minerals.

Iron

- Constituent of haemoglobin, myoglobin, cytochrome C, peroxidase, succinate dehydrogenase, NADH-dehydrogenase and catalase
- Storage form – ferritin and haemosiderin
- Transportation form – transferrin (siderophillin)
- Haemoglobin content – 11-12g per 100ml in pigs, poultry, cattle
- 10-11g per 100ml in sheep, goat and horses
- Iron absorption occurs mainly in SI, mostly duodenum
- Acidic condition in GI, ascorbic acid improves Fe absorption
- Phytic acid reduces Fe absorption

Iron deficiency

- In iron def. onset of anaemia is early in contrast to late anaemia in cobalt and copper deprivation
- Iron deficiency leads to hypochromic microcytic anaemia – pigs and chicken
- Microcytic normochromic anaemia in calves

Piglet anaemia –

- usually occurs 2-4 weeks of birth
- Low hb content (3-4g/100ml) , pale mucous membrane , poor growth rate , wrinkled skin and rough coat , laboured and spasmodic breathing(thumps)
- Dilated heart and oedematous lungs on post-mortem

Cause of piglet anaemia:

- Placental transfer of iron is poor with unusually small store of body iron
- Polycythaemia of birth seen in other species is absent in piglets
- Low levels of Fe in sow milk
- Rapid early growth rate compared to lambs or calf
- Large litter size

Treatment

- Drenching suckling pigs with saturated soln. of $FeSo_4$

- 100mg iron-dextran inj. I/M S/C at 4th and 14th day
- Other effects of Fe deficiency include reduced growth rate, elevated serum triglyceride levels, depressed folic acid levels
- Achromotrichia in chicken
- Cotton fur – mink

Iron toxicity:

- High iron decrease Po_4 and Cu absorption (Cu toxicity if S is low)
- Iron toxicity – deposition of storage forms in tissues – siderosis
- High plasma iron – hypersideremia , damage to intestinal mucosa cells
- $FeSO_4$ salts are used in gossypol toxicity in poultry

Sources

Green leafy materials, most leguminous plants, Seed coats, Bone meal, Glandular meal,

liver and meat meal

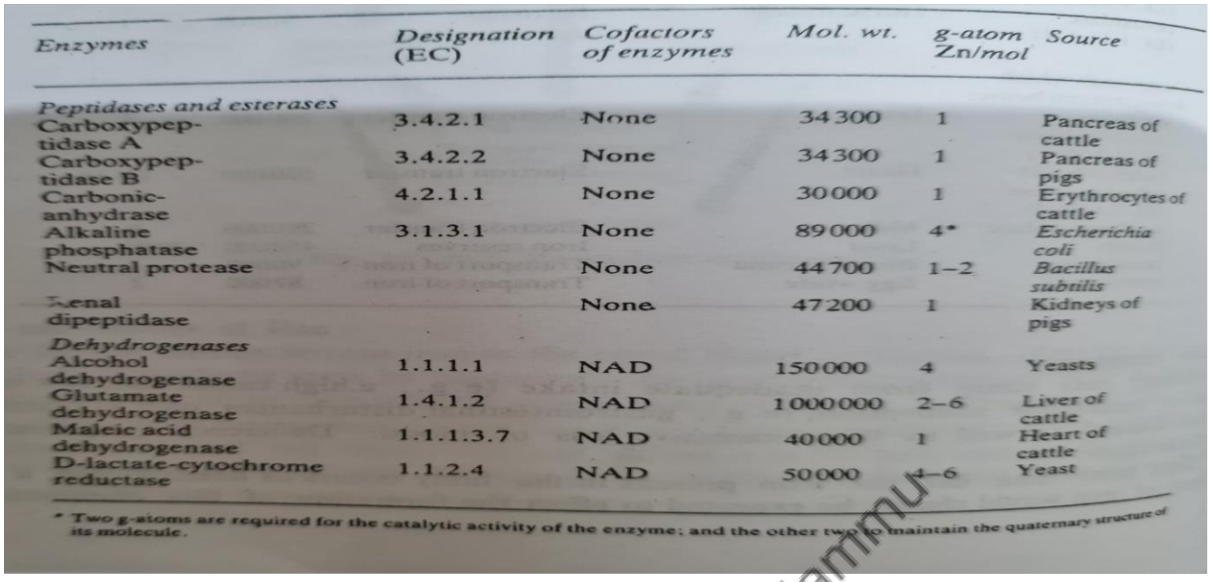
Zinc:

- Found in every animal tissue in animal body
- Bones are the main storage organs

Function:

- antioxidant role, required for normal immune function, proper skeletal dev. and growth
- Constituent of carbonic anhydrase, carboxypeptidase, alcohol dehydrogenase, alkaline phosphatase, nuclear poly (A) polymerase, lactic dehydrogenase
- Metallothionein a cysteine rich protein is synthesised in tissues in response to dietary Zn

❖ Zn is primarily excreted from faeces
❖ High Ca diets induce conditioned Zn deficiency



Enzymes	Designation (EC)	Cofactors of enzymes	Mol. wt.	g-atom Zn/mol	Source
Peptidases and esterases					
Carboxypeptidase A	3.4.2.1	None	34300	1	Pancreas of cattle
Carboxypeptidase B	3.4.2.2	None	34300	1	Pancreas of pigs
Carbonic-anhydrase	4.2.1.1	None	30000	1	Erythrocytes of cattle
Alkaline phosphatase	3.1.3.1	None	89000	4*	*Escherichia coli*
Neutral protease		None	44700	1–2	*Bacillus subtilis*
Renal dipeptidase		None	47200	1	Kidneys of pigs
Dehydrogenases					
Alcohol dehydrogenase	1.1.1.1	NAD	150000	4	Yeasts
Glutamate dehydrogenase	1.4.1.2	NAD	1000000	2–6	Liver of cattle
Maleic acid dehydrogenase	1.1.1.3.7	NAD	40000	1	Heart of cattle
D-lactate-cytochrome reductase	1.1.2.4	NAD	50000	4–6	Yeast

* Two g-atoms are required for the catalytic activity of the enzyme; and the other two to maintain the quaternary structure of its molecule.

Deficiency:

- Loss of appetite, reduced feed utilization, growth retardation
- Increased oxidative damage to cell membrane, decrease in cellular immunity
- Parakeratosis in pigs
- Delayed sexual maturity
- Leg abnormality in poultry

Sources:

- Wheat standard midlings, safflower seed oil, molasses, fish meal, yeast

Copper:

- Normal Cu in blood – 0.1mg/100ml
- Constituent of cytochrome oxidase, lysyl oxidase, ceruloplasmin, monoamine oxidase, uricase

Functions:

- Red cell maturation, essential for osteoblastic activity and normal collagen and elastin formation, occurs in certain pigments- haemocyanin and turacin, integral part of metalloenzymes, regulation of lipid metabolism
- Cu has bactericidal properties at intestinal levels

Deficiency:

- Microcytic and hypochromic anaemia – pigs, chicken
- Microcytic and normochromic anaemia – calves
- Depigmentation of coloured hair –reduced tyrosine activity
- Stringy or steely wool- loss of crimp
- Enzootic ataxia(Australia), swayback(England), Gingin rickets – myelin aplasia
- Falling disease (Australia)- atrophy of myocardium, macrocytic hypochromic anaemia

- Lechsucht (Holland) or scouring disease or peat scours (New Zealand) or copper pine-diarrhoea
- Lameness swelling of joints, decreased osteoblastic activity, decreased stability of bone collagen due to reduction in lysyl oxidase
- Dissecting aneurysm of the aorta due to efficiency of amine oxidase
- Impaired reproduction

Toxicity

- Sheep most susceptible. PKC feeding causes Cu toxicity in sheep
- Pigs highly tolerant, cattle and goat are less tolerant
- Humans – Wilson's disease
- Cu-Mo-S interaction
- High Mo and S – Cu def.(even when forage contains more than adequate levels of Cu) – conditional or induced deficiency
- High Zn and Cd depress Cu absorption

Sources:

- Liver and glandular meal, corn distillers dried solubles, dried whey, peanut meal, fish meal

Manganese:

- Blood contains 12-18 micrograms of Mn
- Absorption depends of formation of natural chelates

Function:

- Imp. constituent of enzymes: pyruvate carboxylase and glycosylaminotransferases
- AA metabolism- activation of hydrolysing enzymes and formation of chelates
- Activator in synthesis of fatty acids, mucopolysaccharides
- Direct effect on calcification
- Bone matrix cell maturation in chicks

Deficiency:

- Swine- slow skeletal growth, irregular estrus cycle reabsorption of foetus, poor udder dev., crooked legs and enlarged hock
- Poultry: perosis or slipped tendon, parrot beaks in embryo cheeks, reduced chondroitin sulphate in epiphyseal cartilage(biochemically)
- Rabbits- crooked front legs

Sources:

Whole rice, cereals except maize, most green foods

Iodine:

- Mature animal body contains <0.00004% I more than half of which is present in thyroid gland
- Thyroglobulin- main storage form of I in thyroid gland
- Thyroxin (3, 5, 3′, 5′ - tetraidothyronine) is most active form of thyroid sec. It contains 65% of I
- Thiourea and thiouracil supresses thyroid gland action

Function:

- Exercises control of the rate of energy metabolism
- Influences physical and mental growth
- Influences neuromuscular functioning and circulatory dynamics
- Affects other endocrine glands esp. hypothesis and gonads

Deficiency:

- Goitre (enlargement of thyroid gland)
- Hairlessness, thick skin and puffy necks- pigs
- Extreme weakness at birth, inability to stand – foals
- Infertility, decline in libido- sheep
- Molting and pigmentation affected in birds

Sources:

Foods of marine origin, fish meal, meat and bone meal, molasses

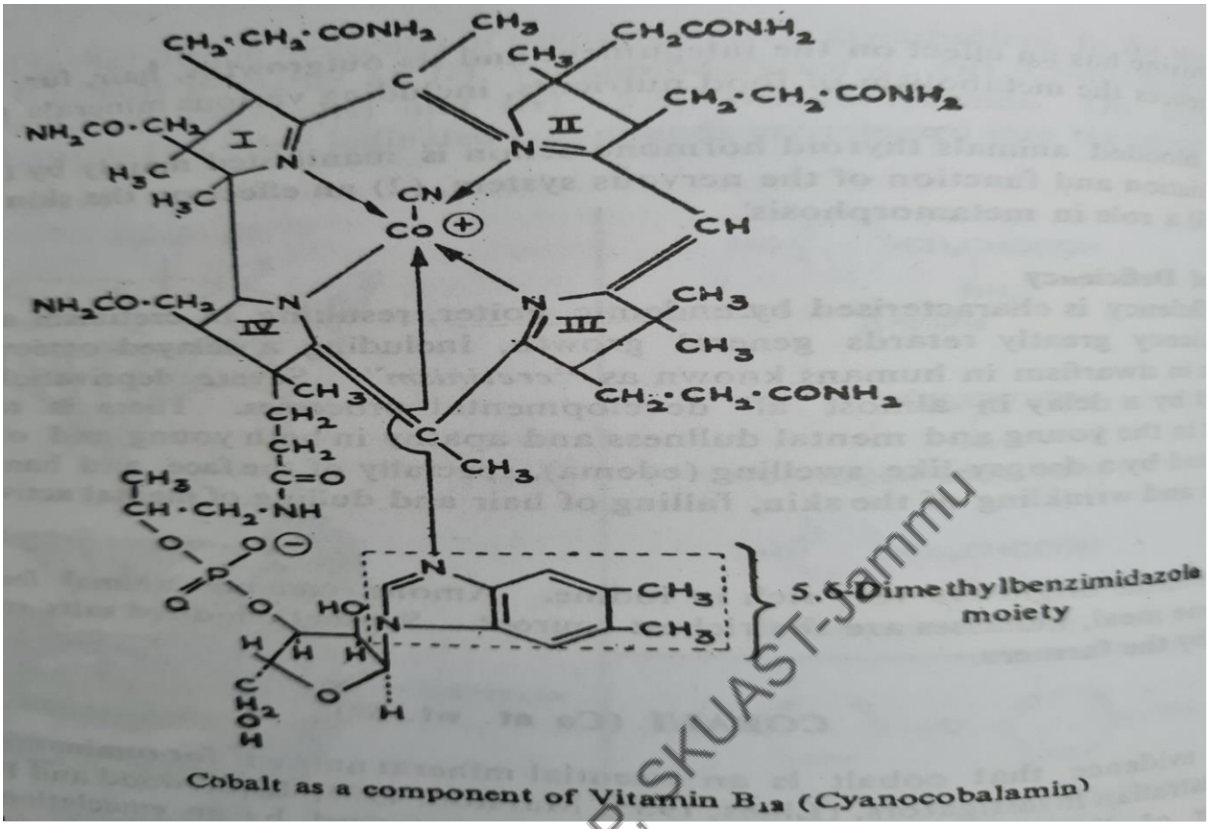
Cobalt:

- Requiremet-1/10th of Cu

Deficiency:

- Cattle- coast disease(South Australia) and wasting disease(Western Australia) or nakuruitis(Kenya), pining(Great Britain), most appropriately enzootic marasmus
- Normocytic and normochromic anaemia in animals, megaloblastic in humans
- Fatty degeneration of liver
- Wool growth is retarded , Co pine
- Lowering of vit B_{12} content of blood

❖ Rumen microbes partition Co – active (cobalamines) and physiologically inactive (corrinoids)



Cobalt as a component of Vitamin B_{12} (Cyanocobalamin)

Prevention and control:

Treatment of soils with cobalt-containing fertilizers, single dressings of Co sulphate@ 4oz to 8oz

per acre raises Co content from 0.04 to 0.19 and 0.39 respectively

- Salt licks containing 0.1 % Co

Sources:

- legumes, pastures

Molybdenum:

- Imp. Constituent of xanthine oxidase, sulphite oxidase, aldehyde oxidase

Toxicity:

- Mo >10 ppm in pastures leads to toxicity
- Cattle and sheep more susceptible, Horse and pigs more tolerant
- Teartness – cattle(England)
- Peat scours –(New Zealand and Canada) – extreme diarrhoea, weight loss

Sources:

- Cabbage, peas, liver and glandular meal, alfalfa meal, soyabean, cereals

MOLYBDENUM-CONTAINING ENZYMES

Enzyme	*Designation* (EC)	*Other cofactors*	*Substrate*	*Product*
Xanthine oxidase	1.2.3.1	FAD, Fe	Xanthine, purines	Uric acid
Aldehyde oxidase	1.2.3.1	FAD, Fe	RCHO	RCOOH
Assimilatory citrate reductase	1.9.6.1	FAD, cyto-chrome B	NO_3^-	NO_2^-
Respiratory nitrate reductase	1.9.6.1	FAD, cyto-chrome C	NO_3^-	O_2^-
Nitrogenase		?	N_2	NH_3

Chromium:

- Cr + 2 nicotinic acid molecules + AA - Glucose tolerance factor
- Cr reduces cortisol conc. during stress, promotes improved insulin and insulin like growth factors sensitivity – dairy cattle
- Increased muscle and decreased lipid deposition - pigs

Deficiency:

- Decreased sensitivity of peripheral nerves to insulin, diabetic like symptoms

Toxicity:

- Acute: inflammation and congestion of stomach and ulceration of rumen and abomasum
- Chronic: Skin contact dermatitis, irritation of respiratory passage, ulceration and perforation of nasal septum and lung cancer

❖ Cr decreases Zn absorption

Flourine:

- Occurs in bones and teeth @0.02-0.05 %

Function:

- Fluorine hardens tooth enamel
- Enhances growth in rats @ 2.5ppm
- Retards osteoporosis in adults

❖ Absorbed from SI

- Levels in diet above 20mg per kg of DM or from 8-9 mg per kilo of BW if given to cattle cause Fluorosis

Fluorine toxicity:

- Bones loose normal colour, mottled, thickened and softened and breaking strength is decreased, exosteoses
- Teeth become chalky and white, teeth become soft and worn out exposed up to pulp cavities in some (Geuvalgum or knocked knee in humans)
- Mottled teeth in children –drinking water contains F@1ppm
- Higher intakes interfere with food consumption, growth, and production

❖ BIS specified max F in bone meal and min mix – 0.05% - 0.07%

Selenium:

Function:

- Imp constituent of Glutathione peroxidase, Type I and II iodinases
- Acts as non specific antioxidant
- Protects against peroxidation
- Participates in biosynthesis of ubiquinone
- Participates in H transport along respiratory chain
- Prevents degeneration and fibrosis of pancreas in chicken
- Influences absorption and retention of vit E and of triglycerides
- Absorption in SI- Inorganic form(passive) and selenomthionine(active)
- Imp constituent of Glutathione peroxidase, Type I and II iodinases

Deficiency:

- Exudative diathesis in chicken, dystrophy of heart ad gizzard muscles in turkey
- White muscle disease, heart necrosis in lambs and calves
- Impaired reproductive performances in males (reduced viability) and females (cystic ovaries, metritis, erratic or silent heat, poor fertilization)

Toxicity:

- Dietary levels of 10 – 20ppm are toxic to most species
- Acute : Blind staggers
- Chronic : Alkali disease/ Degnala disease/ Saliman disease
- Grazing animals: Animals become unthrifty, dull listless, show decline in appetite, emaciated, loss of hair from tail
- Lameness, atrophy of hart, cirrhosis of the liver, anaemia
- Animals eventually die of starvation

- Pigs: Conception is low, higher percentage of dead and small pigs are born, loss of hair
- Horse: chronic cases – loss of hair from mane and tail, hoofs slough off, lameness, decrease in food consumption, death occurs by starvation

❖ Selenium toxicity – garlic order (dimethyl selenide)

Sources:

Fish meal, animal body parts (kidney cortex, pancreas, pituitary and liver)

Silicon:

- 2nd most abundant element in earths crust following O_2 (Quartz-most abundant mineral
- Blood serum conc. of farm animals- 1-2mgper100ml
- Relatively large amounts found in lungs – inspired
- Silica constitutes up to 77% ash of feathers, maintains there rigidity, essential for normal calcification of chick bones
- Involved in mucopolysaccharide synthesis
- Have been found in foetuses

Deficiency:

- Growth depression in chicks and rats
- Chicks- no wattles and small combs
- Mature plants – Si – opal phytoliths $(SiO_2.H_2O)$

Aluminium:

- 3rd most abundant element in earths crust

Sources:

Kaolin and bentonite (pellet binders), forages, Al utensils, sewage grown algae

Nickel:

- Present in high conc in RNA
- Essential for arginase and urease activity

Deficiency: impaired liver metabolism, decrease friability of liver, dermatitis, change in pigmentation of shank skin – chicks

Boron:

- Regulates paratharmone action, indirectly influences metabolism of Ca, P, Mg, Cholecalciferol
- B is needed for parathyroid hormone and prevents loss of Ca and bone demineralization in postmenopausal women

Toxicity: riboflavinuria – curled toe paralysis

Lithium:

- Used in manic – depressive psychosis, recovery of bovine spastic paresis

Tin:

- Oxidation reduction catalyst, functions at active site of mettalloenzymes

Arsenic:

- Found in small amounts in skin, hair, hoofs, thyroid gland

Toxicity: GIT damage, fatty infiltration and centrilobular necrosis of liver, renal tubular necrosis, bone marrow damage, rhabdomyolysis

Bromine:

- Found in blood and various glands
- No evidence to ascertain its role in body

Vanadium:

- Essential for chicks and rats
- Decreases incidence of carries in rats, hamsters and G. pigs

Deficiency:

Reduced body weight and feather growth, impaired reproduction, altered RBC and Fe metabolism, impaired bone tissue metabolism, altered blood lipid levels

❖ EDTA – antidote for V

Poultry deficiency disease

Mineral	Deficiency
Calcium and P	Poor egg shell quality, poor hatchability, rickets, soft, easily bent bones and beak, cage layer disease, tibial dyschondroplasia
Magnesium	Sudden death; hyperirritability in chicks, poults, ducks, lethargy
Manganese	Perosis, poor hatchability, , chondrodystrophy, thin shelled eggs
Iron	Anaemia (Microcytic hypochromic), depigmentation

Copper	Microcytic hypochromic anaemia, enlarged heart in chicks and poults
Iodine	Goitre, reduced hatchability, delayed yolk sac absorption
Zinc	Poor feathering, short bones, hock enlargement and bowing, scaliness in feet, frizzled and rough feathers
Cobalt	Slow growth, mortality, reduced hatchability
Selenium	Cardiac and gizzard myopathy, muscular dystrophy, depigmentation in turkey
Chloride	Fright reaction and tetanic spasms, decreased egg production

CHAPTER-III

MINERAL NUTRITION

Topics:

1. Chelated minerals
2. Bioavailability of minerals
3. Mineral Interactions
4. Purified diet experiment

Chelate

- Chelates are organic forms of essential minerals
- Chelate – Greek word – "Chele" meaning "claw"
- Used to describe the manner in which polyvalent cations are held by metal binding agents
- Prior to union with metal these organic substances are termed as "ligands" or chelator
- Ligand + mineral = chelate element

Chelator

Substance consisting of mol. that binds tightly to metal atoms, thus forcing the metal atoms to go wherever the chelator goes

- Chelates show exceptional stability
- Bond between metal atom and ligand – coordinate bond

Chelated Minerals

- Animals absorb, digest and use mineral chelates better than inorganic forms
- Animals fed chelated sources of essential trace minerals excrete lower amounts in their faeces - less environmental contamination

In biological system there are three types of chelates:

1. Type I. Chelates that aid in transport and storage of metal ions
   Behave as carrier for proper absorption, transportation in circulatory system and passing across cell membranes

a. AA- Cysteine, histidine, arginine
   Body is efficient in absorbing AAs. Dipeptides are especially well absorbed. When mineral

   atoms are strongly bonded to dipeptides they get dragged along.

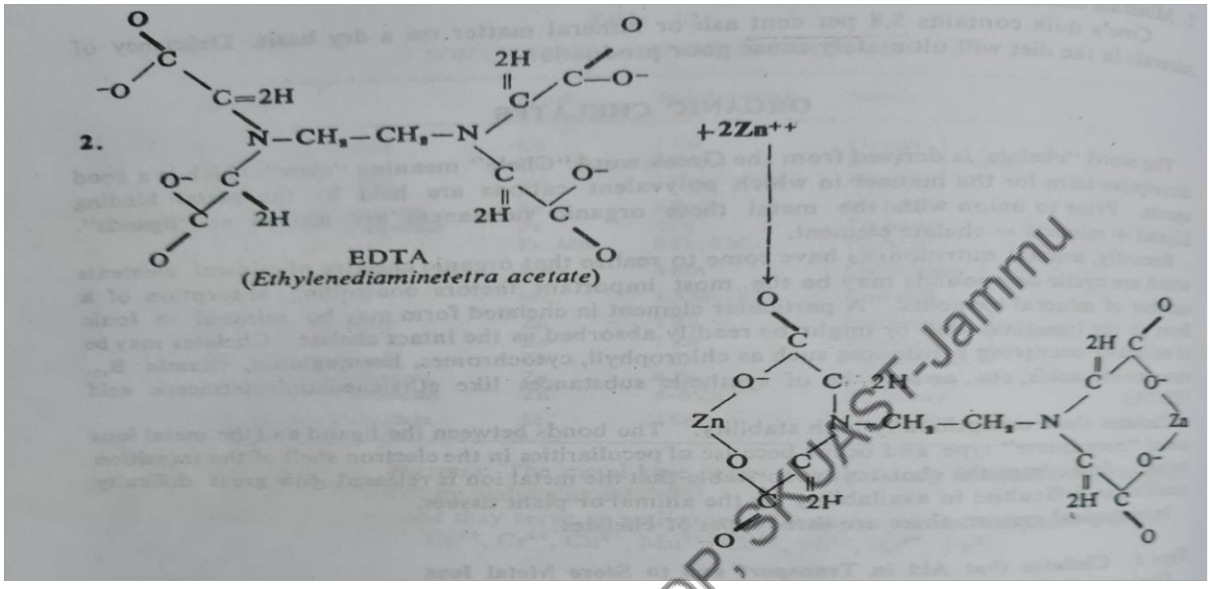
- AA chelation bypasses the competitive interactions that can occur between minerals when absorbed as salts
- Use of chelated minerals avoids this problem as they are absorbed through different mechanisms

b. EDTA and other synthetic ligands – improve availability of Zn and other minerals
c. Organic acids like Gluconate, lactate, citrate, succinate, picolinate

Gluconate – most widely used organic acid chelator, safe and effective

Frequently used to treat mineral deficiencies, treat inflammatory acne, regulate CD8 T cells

- Zn gluconate is used to supress hepatitis in dogs



- Bioavailability of Zn, Cu, Mg increases significantly when combined with picolinic acid

2. Type II. Chelates essential in metabolism

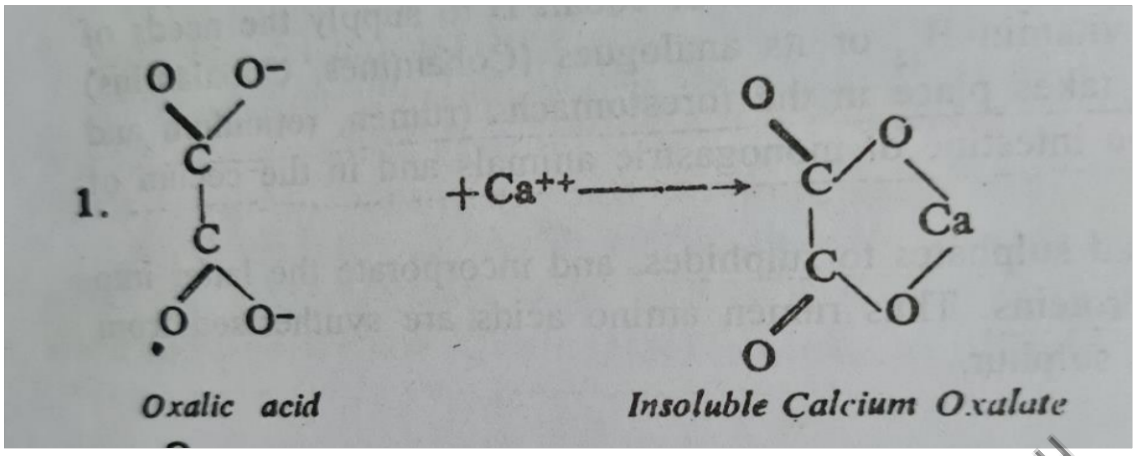
Many chelates hold metal atoms in such cyclic manner which is absolutely necessary to be in that form to perform metabolic function. Examples include Vit B_{12}, cytochrome enzymes and haemoglobin are some examples

- Haemoglobin molecule without Fe in ferrous form is of no use in transporting O_2

3. Type III. Chelates which interfere with utilization of essential cations

Some chelates are formed accidentally and are of no use to subject. They may rather be detrimental for proper utilization of element. Example

Phytic acid- Zn chelate, oxalic acid- Ca chelate



Bioavailability

Defined as proportion of nutrients in the feed that are absorbed from GIT and are available to the body to be utilised for various body functions

Factors affecting bioavailability:

1. Dietary factors
2. Host factors

Dietary factors:

- Bioavailability depends upon form in which minerals are supplemented, interaction with other minerals and chemical compounds
- Some elements decrease mineral availability by chemically binding to mineral- oxalate
- Excess of one mineral can influence the absorption and metabolism of other mineral – Zn decreases absorption of Fe and Cu, high Mo and S decreases Cu absorption
- Certain vitamins enhance the absorption of minerals from diet – Vit D aids in absorption of Ca, P, Mg
- Physical form also determines bioavailability – organic forms of mineral are more bioavailable than inorganic forms – Cu proteinate is more bioavailable than Cu sulphate
- Type of plant and forage – soya protein has inhibiting effect on Fe absorption, Although legumes are mineral matter than graminaceous sps bioavailability is poor – phytates – inh Fe and Zn absorption

Mechanisms of mineral interaction:

- Formation of insoluble complexes, which are unabsorbable by gut
- Competition between similar ions for absorption and metabolism
- Induction of non specific metal binding proteins

Host factors:

- Anatomy and physiology – age, sex, stage of growth, pregnancy, lactation

- Higher absorption occurs in animals that are deficient in a mineral
- Ruminants – interactions – Mg and K, Cu and S ; such interactions are absent in monogastrics
- Horse – Ca absorption is independent of Vit D
- Sex of animal – female reproduction creates high demand of some minerals
- Pregnancy and lactation
- Age – affects GIT absorption – foals don't have fully developed hindgut – higher demand of minerals
- Health and nutritional status
- Dehydration – diarrhoea – decreases absorptive capacity of gut

Mineral Interactions

Minerals interact both with each other and with other nutritive and non-nutritive factors

The interactions may be

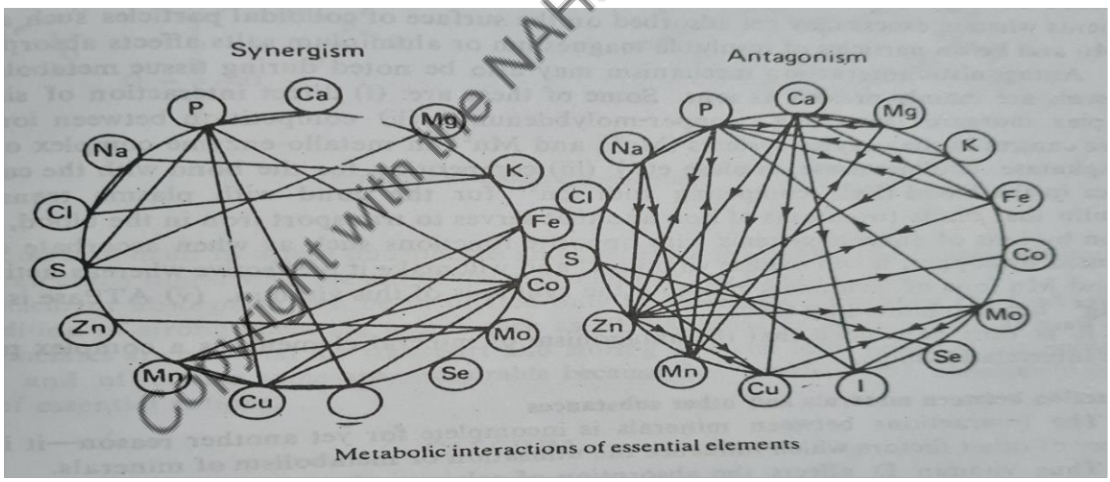
- Synergistic

  – Elements which mutually enhance their absorption in digestive tract

- Antagonistic

  – Elements which inhibit the absorption of each other in digestive tract

Interactions take place in feed itself, in the digestive tract and during tissue and cell metabolism



Metabolic interactions of essential elements

Synergism

Synergism of minerals in GIT and at tissue and cell metabolism renders following interactions:

1. At GIT:

a. Due to direct interaction between elements, the level of absorption enhances provided the elements are in proper ratio

– Ca with P; Na with Cl; Zn with Mo

b. Due to indirect interaction – stimulating the growth and activity of microflora in forestomachs and intestine

– Co causes intensification of microbial biosynthesis

2. At the tissue and cell metabolism level:

a. Direct interaction between elements in structural processes

- Ca and P in formation of hydroxyapatite, Fe and Cu in formation of Hb,

- Mn and Zn in conformation of RNA molecules in liver

b. Simultaneous participation of elements in the active centre of some enzymes eg

Fe and Mo in xanthine and aldehyde oxidases

Cu and Fe in cytochrome oxidase

Antagonism

Inhibition of absorption of some elements by others in digestive tract may proceed by following mechanisms:

a. Excess presence of an element in diet may form complex compound with another and affect the absorption

- excess Mg forms a complex Mg phosphate

- reaction between Cu and sulphate

- formation of triple Ca-P-Zn salt in presence of high Ca

b. Some elements when in excess may get adsorbed on the surface of colloidal particles

- fixation of Mn and Fe on particles of insoluble Mg and Al salts

Antagonistic interactions may also be noted during tissue metabolism where the minerals are present as ions

a. Direct interaction of simple and complex inorganic ions eg

Cu – Mo

b. Competition between ions for active centres in enzyme systems

Mg^{2+} and Mn^{2+} in metalloenzyme complex of alkaline phosphate, cholinesterase, enolase

c. Competition for the bond with the carrier substance in the blood

Fe^{2+} competing with Zn^{2+} for bond with plasma transferrin

d. Activation by ions of enzyme systems with opposite functions

- ascorbate oxidase is activated by Cu, it will oxidise Vit C making it ineffective ; activation by Zn and Mn ions of lactonase promote the synthesis of this Vit

- ATPase is activated by Mg^{2+} but is inhibited by Ca^{2+}

Interactions between minerals and other substances:

1. Other Substances may affect the absorption or requirement of minerals

- Vit D affects absorption of Ca ,P, Mg, Zn
- Fat affects the absorption of Mg and Ca
- Protein level and type of protein determines the degree of utilization of P, Mg, Zn, Cu and other minerals in pigs, ruminants and birds

2. Minerals may affect the absorption or requirement of other substances

- Mo stimulates the elimination of urea N, reduces biosynthesis of muscle protein and impairs flavour of meat
- Se decreases the requirement of Vit E and vice versa

Se and Vit E interaction

Se is integral part of enzyme glutathione peroxidase- converts reduced glutathione to oxidised glutathione and destroys peroxidases

$$2GSH + H_2O_2 \rightarrow GSSG + 2H_2O$$

It also destroys fatty acid peroxidases through reaction catalysed by glutathione peroxidase

$$2GSH + ROOH \rightarrow GSSG + ROH + H_2O$$

This prevention of attack by peroxidases upon PUFA of lipid membrane greatly decreases the requirement of Vit E

- Se also aids in retention of Vit E

Vit E reduces requirement of Se

- By maintain body Se in active form
- By preventing its loss from body
- By preventing chain reactive auto-oxidation of lipid membrane- inhibiting production of hydroperoxides - reducing the amount of Se containing glutathione peroxidase needed to destroy peroxides formed
- Vit E acts as an antioxidant by mechanisms not involving glutathione peroxidase

Interactions between minerals and other substances:

Complexed compounds – chelates – stimulate or inhibit absorption of minerals

Chelating agents like AA (glycine, cysteine, histidine), organic acids (citric acid, acetic acid, phytic acid, malic acid), polypeptides, proteins, prophyrins

- Some ligands improve absorption (arginine – Zn)
- Some form insoluble complexes and decrease absorption of minerals (phytate –Zn)

Purified Diet Experiment

Purified diet experiment is conducted to know the essentiality of any element

1. Animal is fed with ration made up of pure ingredients such as

   -for protein (purified uncontaminated casein)

   - for CHO (purified uncontaminated starch)

   -for oils or fats (purified stripped lard or purified oil of maize)

   - for mineral and Vit (individual purified items are added except the one about which we are

   interested to know the essentiality)

2. Thus due to absence of that element in that ration the experimental animal will develop some deficiency symptoms or disorder within reasonable period of feeding purified diet

3. If missing element is essential, upon addition of it in ration where it was missing the deficiency symptoms will be cured

CHAPTER-IV

FEEDING STANDARDS

Feeding standards are statements or quantitative descriptions of the amounts of one or more such nutrients needed by animals. Feedings standards are the tables, which indicate the quantities of nutrients to be fed to the various classes of livestock for different physiological functions like growth, maintenance, lactation, egg production and wool growth.

The nutrient requirements are generally expressed in

- quantities of nutrients required per day or
- percentage of diet.

(For dairy animals, nutrient requirements are generally expressed as separate body functions but in case of poultry and pigs, combined requirements of maintenance and other body functions are given.)

There are two terms, which has been used, in the feeding standards.

- Nutrient allowance
- Nutrient requirement.

Nutrient requirement gives the requirement for optimum production, however, nutrient allowance gives an extra allowance of nutrient over the requirement, which gives a margin of safety *(Remember: all individuals in a population and their conditions are not alike)*. This safety margin allow variations in requirement among the individual animals. Requirements may be expressed in quantities of nutrients or in dietary proportions. When the standard is set to represent the needs of the average in a population, many will require more than the figure stated, and many will require less. For this reason feeding standards should be considered as guides to feeding practice.

For convenience, all such feeding standards are grouped under major heading on the basis of principles of the standards such as

- Comparative type
- Digestible nutrient system
- Production value type.

The various feeding standards of the world which are available for feeding of different categories of livestock are given below:

Name of the country	Protein	Energy
NRC (USA)	CP, DCP	TDN, DE, NE
ARC/ AFRC (UK)	DCP, AP	DE, ME
SCANDINAVIA	DTP	FEED UNIT
GERMAN	DCP	SE
INDIA	DCP	TDN, ME

Where,

CP = Crude Protein

DCP = Digestible Crude Protein

DTP = Digestible True Protein

AP = Available Protein

TDN = Total Digestible Nutrient

SE = Starch Equivalent

DE = Digestible Energy

ME = Metabolizable Energy

NE = Net Energy

CLASSIFICATION OF FEEDING STANDARDS

1. Comparative type
   - Hay Equivalent standard
   - Scandinavian "feed Unit" Standard
2. Digestible-Nutrient system
   - Grouven's
   - Wolff's
   - Wolff's Lehmann
   - Haeckers's
   - Savage
   - Morrison
   - National Research Council
   - Indian
3. Production-value type
   - Kellner

- Armsby
- Agricultural and Food Research Council (AFRC, UK)

Some other feeding standards:

1. CSIRO: Australia
2. Kearl: Asia

Detailed description of feeding standards

A. COMPARATIVE TYPE

1. Hay standard

Given in 1810 by German scientist Thaer. In this standard, feeding value of different feeds was compared using meadow hay as a unit. Nothing was known of the chemical value of these feeds and the physiological requirements of the animals. The only measure was the practical feeding experience.

2. Scandinavian "feed unit" standard

In 1884, Professor Fjord formulated the Scandinavian feeding standard. In this system, value of one pound of barley, is given as one unit value and the value of all other foods is based upon this. According to this standard one feed unit is required for each 150 lbs. of body weight and an additional unit for every three pounds of milk production. As the grains are of different types in different countries, the feed units should also be different. Hence the Scandinavian units are not applicable universally.

B. DIGESTIBLE NUTRIENT SYSTEM

1. Grouven's Feeding standard

In 1859 Grouven, a German chemist published his feeding standard with **crude protein, carbohydrates and fat** contained in the feed as the basis of the standard.

Very soon after standard of Grouven; Henneberg and Stohmaan found that the total nutrient contained in a feed did not from an accurate guide to its value. The proportion of digestible parts varied with different feeds and hence the digestible nutrient would be more valuable. So due to this defect Grouven's feeding standard is now abandoned.

2. Wolff's feeding standard

In 1864 Dr. Emil Von Wolff proposed a standard on **digestible protein, digestible carbohydrates and digestible fats** contained in a feeding stuff. This standard does not consider the quantity and quality of milk produced.

3. Wolff's Lehmann feeding standard

Dr. Lehmann modified Wolff's standard in 1896. Till then Wolff's standard was in use. This standard was also based on **digestible protein, digestible carbohydrates and digestible fats**, **however,** it takes into account the **quantity of milk** produced, but he failed to take into account the quality of milk.

4. Haecker's feeding standard

Haecker, an American worker who for the first time considered **quality as well as the quality of milk (4% fat)** produced in formulating a milk standard. He was also the first to separate requirements for **maintenance** form the requirements of **production**. His standard included digestible crude protein, carbohydrates and fats.

5. Savage feeding standard

Another American scientist Savage came to the conclusion that the Haecker standard was too low especially in protein. He introduced dry matter partitioning (about two-thirds of the dry matter should be from the roughages and one-third from the concentrates). And also, increased the protein requirement was increased about 20 percent above the standard of Haecker. It was expressed in digestible crude protein and **total digestible nutrients**.

6. Morrison feeding standard

Morrison F.B. modified the Wolff and Lehmann standard expressed in terms of Dry Matter (D.M.), Digestible Protein (D.P.) and Total Digestible Nutrients (T.D.N.). These standards were first presented in the 15th edition of "Feeds and Feedings" published in 1915 and soon came to be known as the "Morrison Feeding Standard". These standards formed the basis of NRC and Indian feeding standards.

7. National Research Council (N.R.C.) standard

On animal nutrition of the National Research Council recommended a nutrient allowance. The standard includes digestible protein and total digestible nutrients and also includes the recommended requirements for calcium, phosphorus, carotene and vitamin D for
dairy cattle, beef cattle, pigs, poultry, sheep dogs, horses, laboratory animals etc. Today in a number of countries N.R.C. standards are followed where they use ME for poultry, DE for swine and horses, DE, ME and TDN for sheep, ME, TDN and NEm and NEg for beef cattle and for dairy cattle, values are given for DE, ME, TDN, NEm and NEg for growing animals with additional values as NEl for lactating cows. From time to time, the NRC revises these feeding standards in keeping with new information and changing feeding practices.

Last published NRC nutrient requirements revisions:

a. Beef cattle: 2016
b. Dairy cattle: 2001
c. Small ruminants: 007
d. Horses: 2007
e. Dogs and Cats: 2006
f. Swine: 2012

g. Poultry: 1994
h. Laboratory animals: 2000

9. Indian standards

Considering the fact that nutrient needs of livestock and poultry breeds under tropical environments are different from those developed in temperate climate, the Indian Council of Agricultural Research draw suitable feeding standards for the Indian livestock and poultry.

Dr. K. C. Sen and Dr. S.N. Ray in 1964 compiled the feeding standards for Zebu cattle and buffaloes, based on Morrison's recommendations, where they adopted the average of maximum and minimum values recommended by Morrison (**Mid-Morrison values**). It was known as **Sen and Ray standard and it was the first Indian feeding standard.**

Later on Sen, Ray and Ranjhan (1978) revised the Sen and Ray standard on the basis of experimental trials conducted in Indian animals. These modified values are still functioning in many of our established dairy farms. Later on, ICAR published standards in 1985 (by Dr Pradhan), which were updated in 1998 (by Dr Ranjhan) and further in 2013. The feeding standards are based on the experimental results and have been organized to contain information on daily DM, DCP, TDN, Calcium and Phosphorus intake.

C. PRODUCTION VALUE TYPE

1. Kellner feeding standard

In 1907 Kellner, a German scientist, investigated a feeding standard based upon "Starch equivalent" as the unit of measurement. He took into account not only the digestibility of the feeds as calculated from the amount lost in faeces and urine but also the entire loss from the body including energy expended in digestion and passing the food inside the body (chewing, etc.). For measuring the amount of energy lost from the body as heat, Kellner devised a respiration apparatus. Here heat in determined indirectly by finding the amount of carbon dioxide gas liberated or by measuring the amount of oxygen gas used up in oxidation which take place in the body. The animal breathes through an airtight mask placed over its nose and mouth.

2. Armsby feeding standard

Armsby standard is based on true protein and **net energy** values. By means of the respiration calorimeter, Armsby detemined the net energy required for mastication, digestion, assimilation and also the amount of heat and gases given off through the excretory channels. Thus after considering the various losses of energy such as in urine, faeces, gases and in the work of digestion, he was able to estimate the amount of net energy available for productive purposes. Armsby expresses his standard in two factors, that is true protein and therms of net energy.

3. Agricultural Research Council (A.R.C.) standard

The nutritive requirement of various livestock in the United Kingdom have been presented in Ministry of Agriculture's Bulletins. These are prepared by the Technical Committee of the Agricultural Research Council of Britain. Requirements are set forth in three separate reports dealing with poultry, ruminants and pigs, each of these reports extensive
summaries of the literature upon which the requirements are based. The most attractive feature of the British Feeding Standards is that the unit of energy requirements has been expressed in
terms of Starch equivalent instead of T.D.N. or ME of NE are in Morrison and in N.R.C. standards.

CHAPTER-V

SIALAGE MAKING

Livestock production makes an important contribution to economic development, rural livelihoods, poverty alleviation and meeting the fast growing demands of milk and milk products in India. Dairying in India has been and continues to be an important livelihood support activity. Feeding is the foundation of livestock system and accounts for more than 70% of the total cost of milk production. It directly or indirectly affects the entire livestock sector, including animal productivity, health and welfare (Makkar, 2016). To maximize profitability from the dairying, one need to ensure that the dairy animals receive required quantity of protein, energy, minerals and vitamins in a cost effective way, preferably from locally available feed resources such as local grasses, natural forages and green fodder. Green fodder is an important and economic source of nutrients and provides better option for costlier concentrate feed ingredients (Mohini et al., 2007). But the green fodder is not available throughout the year. In order to ensure the availability of fodder during lean season, the surplus fodder is to be conserved in the form of silage. Silage is the material produced by controlled fermentation of nutrients under an anaerobic condition. It is the green succulent roughage conserved mostly in its original condition, with minimum loss in respect of various nutritive constituents of fodder. The process of silage making is called ensiling.

Ensiling- Ensiling is a process by which fodder is stored in a silo in order to be converted into silage, a more succulent feed for livestock. The principle of ensiling involves the conversion of water-soluble carbohydrates (WSCs) into organic acids (mainly lactic acid) by lactic acid bacteria (LAB) under an anaerobic environment to rapidly reduce the silage pH. As a result, decomposition of the nutrients is inhibited and the storage time of the forage is extended through its preservation from spoilage microorganisms (Zhang et al., 2019). Ensilage has many advantages over the other methods for preservation of nutrients, particularly from forages. Ensiling of forage requires precautions for proper preservation of nutrients as lack of understanding of the factors associated with ensiling process may produce silage of poor quality leading to the poor animal performances.

For a rapid and extensive fermentation to occur, the forage must have high concentrations of fermentable carbohydrates, low buffering capacity, relatively low dry matter content (30-40 %) and adequate lactic acid bacteria present prior to ensiling. Forage crops such as maize has high concentrations of fermentable carbohydrates and relatively low buffering capacity; therefore, pH decline is rapid and final pH is usually 3.5-4.0. In general, the pH of silage at the final stage should be within the range of 3.5-4.3 (Roth and Heinrichs, 2001).

After chopping, plant respiration continues for several hours and plant enzymes (e.g., proteases) are active until air is used up. Rapid removal of air is important because it prevents the growth of unwanted aerobic bacteria, yeasts, and molds that compete with beneficial bacteria for substrate. If air is not removed quickly, high temperatures and prolonged heating are commonly observed. Air can be eliminated by wilting plant material to recommended dry matters (DM) for the specific crop and storage structure, chopping forage to a correct length, quick packing, good compacting, even distribution of forage in the storage structure, and immediately sealing the silo.

When air is removed lactic acid bacteria utilize water-soluble carbohydrates to produce

lactic acid, the primary acid, responsible for decreasing the pH in silage. A quick reduction in silage pH will help to limit the breakdown of protein in the silo by inactivating plant proteases. In addition, a rapid decrease in pH will inhibit the growth of undesirable anaerobic microorganisms such as enterobacteria and clostridia. Airtight silos and removal of sufficient silage during feed-out can help to prevent aerobic spoilage due to limitation of yeast. On other hand leguminous fodder like berseem and alfalfa has a high buffering capacity that leads to difficulty in lowering pH.

The dry matter content of the forage can also have major effects on the ensiling process. Proper dry matter in forage should be there so that it can be packed well and more lactic acid is produced. Clostridia tend to thrive in very wet silages and can result in excessive protein degradation, DM loss, and production of toxins. Delayed filling of silo pit results in excessive amounts of air trapped in the forage mass can have detrimental effects on the ensiling process. Longer filling time of chaffed fodder in silo might have not maintained anaerobic conditions properly leading to increased aflatoxins in silage (Brar et al., 2017). Rapid elimination of oxygen, is critical for the prevention of storage moulds, as subsequent aeration of silage can cause fungi to proliferate and if conditions are suitable, mycotoxin may be produced (Wittenberg, 2004). WSC decreases and DM losses increased when forage was not immediately packed into silos after chopping.

Time for harvesting the crop is crucial time for making good quality silage To prepare best quality silage, cereal green fodder like green fodder maize, fodder sorghum, bajra, Hybrid Napier, sugar cane tops and oat, etc are used. (Table 1) Preference for cereal green fodder (monocotyledons) is due to because of more sugar content than protein, as sugar is utilized in fermentation process to make lactic acid by microorganisms. Time of harvest has a major impact on the nutritive value of silage. With advancing crop maturity, protein content, available energy, daily nutrient intake and digestibility decrease while late cutting represents lower carbohydrate and more lignin.

Table 1: Time to Harvest crop for silage making

Crop	Proper Time to Harvest
Maize	Grains in 2.5 milk line stage (65-75 Days)
Bajra	Boot stage (45-55 DAS)
Sorghum	Flowering stage (75-85 DAS)
Oats	Flowering to milk stage (90-115days)
Guinea grass	Flowering stage (60-75 days)
Napier bajra hybrid	up to 1 meter heigh

Process of Ensiling

The first phase of the ensiling process is the residual respiration, which occurs due to intact plant cells. The initial microbial activity is mostly due to epiphytic aerobic microflora such as *Enterobacteria*, yeast and molds. At ensiling process, the facultative anaerobic bacteria carry out a heterolactic fermentation which slightly decrease the pH.

As the conditions becomes anerobic in the silo pit, fermentation phase starts. Decrease in the pH promotes the growth of acid tolerant lactic acid bacteria (LAB) species which converts the water soluble carbohydrates into lactic acid. This stage usually last for several days or weeks. In quality silage, LAB dominate the fermentation, rapidly producing the low pH conditions that help to preserve the silage.

The third phase is the storage phase. In this period the silage is sealed and it has anerobic conditions. This stage can last for several months and as long as the pH is sufficiently low and anaerobiosis is maintained.

The fourth phase is the unloading phase for animal feeding. Silos are opened and air penetrates into the silage depending on the density and porosity of the plant material and the rate of silage removal. Beside this Butyric acid fermentation (by **clostridia** or butyric acid bacteria) and aerobic deterioration (by **molds** and **yeast)** can also take place, which cause important loss of dry matter and forage quality in a silo.

From a practical view, the three most important things that must occur in order to make good silage are 1) the rapid removal of air, 2) the rapid production of lactic acid that results in a rapid drop in pH, and 3) continued exclusion of air from the silage mass during storage and feed out. Preventive measures, which should be taken care for quality silage production, are discussed below.

1. Timely harvest of crop –It Optimizes nutritive value (protein, fiber, energy, etc.) and DM content
2. Chop length- Chop material to correct length: about 5 to 7 cm ¾ Promotes good packing and elimination of oxygen ¾ Promotes cud chewing by animals
3. Equipment to be used should be in proper condition- Check that all equipment which are required for silage like Sharpen knives of the chaffer and Be sure that silos are free from leaks, breakage and holes
4. Wilt and chop during wet weather ¾ Prevents extensive DM losses from forage ¾ Helps in inhibiting the clostridia bacteria
5. If required additives can be added-Additives are generally added during the silage preparation to inhibit the growth of undesirable bacteria and toimprove the aerobic stability of silage. Commonly used additives are microbial inoculants and enzyme preparations. They are safe to handle and non -corrosive in nature. Addition of enzymes is more beneficial in low lignin feed stuffs.
6. Harvest, fill, and seal quickly – It will lead to Quick elimination of oxygen reduces DM losses from respiration and prevents growth of undesirable aerobic organisms and aid inestablishment of anaerobiosis. Sealing minimizes exposure to air, pack to proper density to eliminate air.
7. Allow silage to ferment for at least 45 days -Properly ensiled silage will minimize production losses during silage changeover

Advantages of silage making- Silage has many advantages over other methods of preservations, chiefly because of following reasons-

1. Less loss of essential nutrients- Lower field losses particularly of leafy portion which is relatively rich in protein and minerals. Lower probability of rain damage and thus leaching of nutrients
2. Day to day cutting, transporting and chaffing of fodder in traditional way requires more labour and time but in case of silage, fodder cutting, transport, chaffing is done at one time only, so it is less labour & time consuming practice
3. More crops from field- Land under fodder cultivation is emptied, and immediately it may be used for plantation of other crops. So farmers' can take more crops in same land in a year against traditional way where land is reserved for fodder until all crops is harvested.

4. No danger of fire - Silage is prepared in closed and air tight condition so there is no danger of fire
5. Increase digestibility- Due to lactic acid in silage, it is easily digestible to animals, so energy required for digestion is used for other purposes like milk production etc. Brar et al (2016) reported an increase in milk yield of HF crossbred cows by 15.47% (on an average) on replacing green fodder by maize silage.
6. More palatable and succlent- Silage is tasty and aromatic, so it increases appetite of dairy animals.
7. Increase Storage - If properly packed under optimal ensiling conditions it can be stored for longer period
8. Less moisture variation in diet:Silage stabilize moisture content in diet which helps in correct calculation of water requirement, supply of dry matter. As it occurs with different fresh crop feeding and their moisture variation due time, age and season.

Disadvantages of Silage Making:

1. Capital investment- Being mechanized technology it requires considerable inputs
2. Limits the preservation of high CP (leguminous) forages such as fodders e.g. cowpea, berseem, lucerne etc.
3. Losses of nutrients can be high if not properly preserved with exclusion of air and water. Clostridial fermentation spoils the quality of silage and its feeding value. Formation of butyric acid makes silage unpalatable.
4. Seepage losses are high if moisture content is high
5. Must be fed as soon as possible after removal from silo to avoid secondary fermentation
6. Need technical expertise

Types of Silos and method of silage making:

Silos : The container in which silage is made is of greatest importance and will determine to the large extent the nature and quality of final product. The dimension of container will generally depends on the number and kind of animals to be fed from itand the length of the feeding period. The most common type of silos are: Pit, Trench and Bunker silo. For small lot preparation silo can be a plastic container or a jumbo bags of different capacities.

One cubic meter space can store 5-6 quintals of green chopped fodder or one cubic feet pit can accommodate roughly 15 Kg of green fodder. The length and width of silo can vary depending on the number of animals and fodder available for making the silage. Generally a bunker of 10 m x 4 m x 1.5 m near the cattle shed can store 350-400 quintals of chopped green fodder. The pressing of the material may be carried out manually or mechanically by using a tractor. In case of pressing with tractor, the width of pit should be at least double the width of tractor i.e. 12-15 feet. Depth of pit should be 6-8 feet. Care should be taken that material on the sides and edges are properly compressed. The silo should be high spot so that rain water cannot stagnate near the silo pit. Silo pit should have slanting walls with narrow base and broad opening as such shape helps in maximum exclusion of the air. The process of silage making is as follows:

1. Harvested green fodder should be wilted to 65-70 % moisture. Or when harvested at properharvesting stage contains this much moisture.
2. Chop the fodder to make pieces of 2-3 inches so that material is packed well.

3. The walls of the silo pit should be plastered or lined with straw. The chopping should be donenear the silo so that the chopping of fodder and filling of silo pit is done simultaneously.
4. Filling should be done in layers and as soon as possible.
5. Pressing of the fodder in the pit should be done regularly to exclude the air.
6. The silo should be filled 1 meter above the ground level and arranged it in the semicirclewith dome shaped at top.
7. Cover the pit with plastic sheet and a thick layer of straw and plaster mixed mud mixed is applied to make it air tight and protect it from rains.
8. Silage will be ready within 45 days.
9. Open the silo pit from one side only and take out 25-30 kg silage per animal/day for feeding. The remaining silage kept covered stays good till used.

Conclusion: In order to ensure availability of fodder during lean season, preserving the fodder in the form of silage is the best practice available so far. However, the technical know-hows of quality silage making should be well known to prepare the quality silage that possess an efficiency to boost production and health of dairy animals in an economical way.

CHAPTER-VI

SHEEP AND GOAT NUTRITION

FEEDING OF GOAT:

Feeding may cost the highest expense in goat production. Goats need good quality feed and an optimum balance of many different nutrients to achieve maximum profit potential. Majority of the goats reared are hardly provided with any grain or good fodder. Goats respond readily to good management and proper feeding. Success in feeding can be achieved by formulating a nutritious and cheap ration. Preparation of balanced ration requires consideration of factors like nutritive value, bulk, palatability and digestibility, local availability and its cost. Dairy goats require more water as compared to meat goats.

Rearing systems

Goats are reared in three rearing systems these are Extensive, Semi Intensive, Intensive system.

Extensive system

Grazing in the entire pasture and leaving them there for the whole season. Due to open grazing the feed cost is reduced in this method of rearing.

Semi-intensive system

It is an intermediate compromise between extensive and intensive system followed in some flocks having limited grazing. It involves controlled grazing of fenced pasture therefore feed cost is somewhat increased. It involves stall feeding, shelter at night under shed and 3 to 5 hour daily grazing and browsing on pasture and range. It is easy to manage medium to large flock of 50 to 350 heads and above. There is profitable gain due to less labor input.

Intensive system-zero grazing-system

Goats under this system are kept under housing in confinement and are stall fed, so also called as zero grazing system. Intensive operation is of medium sized herd of 50 to 250 heads and is more oriented towards **commercial milk production** of dairy goats. It merits exploitation of the system of feeding agro-industrial by products. This system of management requires more labor and high cash input. There is close supervision and control over the animals. Dung is collected in one place and used as a good fertilizer. Less space is sufficient for more number of animals.

Goat Feeding Behavior

They are efficient browsers and prefer eating bushy, thorny shrubs and tree leaves. More selective and accept wide variety of feeds. Prefer to consume the most nutritious and palatable part of plants (top leafy portions). When stall-fed, goats have a preference for concentrates. Refuse to consume coarse, moldy or soiled forage. With mature forages the voluntary intake of goat will decrease. They relish eating aromatic herbs. Lesser exposed to worms load on pasture (not close grazer). Utilize well **cellulose rich**, **fibrous and nitrogen poor forages** as they have high concentration of cellulolytic bacteria in rumen, retain food for longer time in

gastrointestinal tract and efficiently recycle the blood urea. Goats are more capable than sheep for using fibre rich and nitrogen poor forages.

Nutrient requirement of adult goat for maintenance (ICAR, 1998)

Body weight (kg)	DM requirement (g/day)	DCP requirement (g/day)	TDN requirement (g/day)	Ca requirement (g/day)	P requirement (g/day)
15	500	23	240	1.1	0.7
20	615	29	295	1.3	0.9
25	730	34	350	1.6	1.1
30	830	39	400	1.8	1.2
35	940	44	450	2.1	1.4
40	1040	48	500	2.3	1.5
45	1125	53	540	2.5	1.7
50	1230	57	590	2.7	1.8
55	1315	62	630	2.9	1.9
60	1410	66	675	3.1	2.1

Nutrient requirement for growing kids (ICAR, 1998)

Body weight (kg)	Gain (g/day)	DM requirement (g/day)	DCP requirement (g/day)	TDN requirement (g/day)	Ca requirement (g/day)	P requirement (g/day)
10	50	380	27	265	2.0	1.4
	10	510	37	355	2.7	1.8
	150	635	47	445	3.4	2.3
15	50	510	33	330	2.7	1.8
	10	645	43	420	3.5	2.3
	150	785	53	510	4.2	2.8
20	50	640	39	385	3.3	2.2
	10	790	49	475	4.1	2.7
	150	985	59	590	5.1	3.4
25	50	760	44	440	3.8	2.5
	10	915	54	530	4.6	3.0
	150	1070	64	620	5.3	3.6

Feed intake and Energy requirement

Goats have a higher dry matter intake (DMI) compared to lactating dairy cattle. Average DMI is 5% of body weight compared to 3% in dairy cattle. A high producing doe will consume up to 7% of its body weight. This results in a faster rumen turnover rate and shorter retention time of ingested feed. There are also differences within breeds. DMI can also be affected by dietary energy and protein level. Higher protein levels will lead to increased DMI while increasing energy levels will decrease DMI. Energy deficiency will result in decreased production, reproductive failure, increased mortality, and increased susceptibility to diseases and parasitic infestation.

Maintenance ration

Goats have higher basal metabolic rate than cattle; therefore, their maintenance requirements are higher than those of cattle. For its size the goat can consume substantially more feed than cattle or sheep, viz. 6% of its BW in DM when compared with 2·5 to 3% for cattle/sheep. The requirements of Ca and P for maintenance are 6·5 and 3·5 g, respectively, per 50 kg body weight. Goats require slightly larger quantities of Ca ration at the rate of 0·2%.

Feeding of lactating doe

The nutritional requirements of a goat weighing 50 kg and yielding 2L of milk with 4% fat may be met by feeding 400 g of conc. mixture and 5 kg of Berseem or Lucerne. The ration should have 12 to 15% CP content, depending on the amount of protein in their hay and in the milk produced. Once a doe freshens, increase the amount of grain as rapidly as possible without pushing the doe because energy is the limiting factor for milk production. Concentrates should make up 50-60% of the diet. High quantity can cause digestive upsets. Feeding grain in smaller portions more frequently will help prevent does going off feed. Goats prefer coarsely ground or whole grains in their ration. Finely ground grains may lead to indigestion. However, with coarse/whole grains, there is more opportunity for selective feeding by does. Lactating does should have 1,000-9,000 IU of vitamin A, 100-500 IU of vitamin D and 15-40 IU of vitamin E per doe.

FEEDING OF SHEEP

Proper nutritional management is essential to exploit full genetic potential of the animal. Feed accounts for 55-60% in the total cost of rearing sheep.

Energy:

Insufficient energy in the diet may limit the performance of sheep. Energy deficiency may lead to reduced growth, Loss of weight, Reduced fertility and low production in terms of wool quantity and quality. There are many Factors which affects energy requirement like Size, age, growth, pregnancy, lactation, Environment, Shearing, parasitism, stress, transportation.

Protein

Protein deficiency may lead to Poor growth and muscular development. Low Reproductive efficiency, low Wool growth. Sulfur containing Amino acid Methionine is the first limiting Amino acid followed by lysine and threonine.

Fat

Addition of 5% tallow in sheep ration increase gain and reduce the cost of feed/kg gain. Minimum of 3% fat in sheep ration is essential.

Salt licks with minerals are kept in sheds as free choice it is added 0.5% of complete diet or 1% of concentrate mixture.

Nutrient Requirement for Maintenance:

DCP: 2.97g / kg $W^{0.75}$

TDN: 27.3 g / kg $W^{0.75}$

DM requirement- 3.0-3.5% Bwt, DMI decrease as the animal matures

Sheep are seasonal polyestrous/seasonal breeders, having more than one estrus cycle during specific time of year and can be divided into short day breeders as they are sexually active in fall or winter. Decreasing daylight stimulates cycling in ewes.

Flushing

It is a practice of increasing the nutrient intake of ewes and improving body condition prior to and during breeding. In this 25% more nutrients above maintenance needs has to be given 2-3 weeks prior to breeding season. The Purpose of flushing is to increase ovulation and lambing rate.

Pregnancy

Nutrient requirement slowly increases during first 15 weeks of pregnancy as embryo grows and requirement during final 6 weeks of pregnancy are elevated. Pregnant ewes (last 6 weeks) should be provided with 50% more nutrients than the maintenance needs.

Nutrient Requirement during Pregnancy

BW (kg)	DCP (g)	TDN (g)
25	80	580
45	135	903
60	155	1121

Milk Production

Although sheep's are not reared for milk production but it is essential for nutrition of lambs. Nutrient requirement is highest in first month of lactation. Lactating sheep needs twice the maintenance requirement during first 2 months and 1.5 times for the remaining period. Peak Milk Yield is achieved around 21 day of lactation and high Milk Yield are sustained for 6-8 wk of lactation.

BW (kg)	DCP (g)	TDN (g)
25	95	665
40	135	945

60 185 1280

Feeding of pregnant Ewes during last 6 weeks of gestation

Ewe need more energy, protein, mineral and vitamin. But excessive energy intake results in fattening. While low energy intake results in low birth weight, reduced viability of lambs, during pregnancy ewes should fed with sufficient good quality roughage like cereals fodder supplemented with concentrate mixture. To observe the nutrient intake of ewes body weight is the critical parameter if BW is increasing 100g/d in smaller breed and 150g/d in larger breed.

Feeding of Lactating/suckling ewes

After birth proper care of lamb and ewe should be taken. Only a little grain mixture is given for first 2-3 days along with good quality fodder. Gradually the feeding of ewes is increased upto 4% of BW (DMI). Feeding of supplemental feeding of concentrate mixture is gradually reduced at 8-10 weeks and can be stopped after 12-13 weeks of lambing i.e. at weaning. There after the ewes are maintained on grazing alone.

Wool production

For wool production there is requirement of energy, protein and sulphur. Wool protein is contains more than 20 amino acid along with Fat, calcium and sodium. Nutrition play role on growth and quality parameters of wool. Wool is composed entirely of protein. Wool growth requires high level of cysteine and serine. Small quantities of selenium, copper, cobalt, iodine, iron etc are also essential for wool growth.

CHAPTER-VII

FEEDING STRATEGIES OF HIGH YIELDING DAIRY ANIMALS

Milk yield of a dairy cow depends on four main factors these are, genetic ability, Nutrition, Management and health. The annual milk production of high yielding dairy cows has increased remarkably in the last few decades. To sustain this yield, dietary needs and all the nutrients should be given in required proportions. Feeding of such cows should be well planned for the last phase of gestation and the ensuing lactation. The aim should be not to loose more than one body condition score after calving. Due care should be taken to Maximize DM-intake during the early lactation phase. For enhancing the output from a high yielder start focussing the nutrition of cattle right from last stage of pregnancy.

In high yielding dairy animals following problems are observed during the transition period like Dry matter intake after calving is low and unsatisfactory, Cases of off feed are too high, especially in young cows, Metabolic disorders like fatty liver, ketosis, milk fever, hypocalcemia, and/or displaced abomasums are observed. Therefore, following factors should be considered while formulating ration of high yielder like Genetic potential of the cow, Ways to increase voluntary feed intake, increasing the Nutrient density of the diet, Availability of nutrients at cellular level.

Feed intake is the key factor in maintaining high milk production. Cows should be encouraged to maximize their intake during early lactation. Each additional kg of dry mater consumed can support 2-2.4 kg more milk. Feed intake by the dairy cow is influenced by many factors including level of production, forage quantity and quality, feed digestibility, stress and other environmental factors.

A protein level of **16-18%** CP can support 20 kg milk in cows and 15 kg in buffaloes. For those cows or buffaloes yielding more milk, the ideal protein content of the ration should be **19 % with 30-35 % RDP.** A cow can store only 20 kg of mobilizable protein in the body as against 100-200 kg of fat. Thus, during a period of need, animal can mobilize more fat than protein indicating that it's the *protein* content, which limits production. Since, the energy during this period comes from body reserves, there will be shortage of energy in the rumen and the microbes will not be able to utilize any additional rumen degradable protein (RDP). So, for the first 15- 20 weeks, the diet of such animals must contain at least 50-55% rumen un-degradable protein (UDP). The first service conception rate as well as pregnancy rate improves when the UDP level in diet increased from 38 to 56%.

The UDP level in the diet can be increased by Using Natural feeds like blood meal, meat meal, corn gluten meal coconut meal rich in Bypass protein in diet. It can also be increased by Using Protected protein feeds (roasted soybean meal or roasted full fat soya or formaldehyde treated oil seed meals). Feeding bypass protein will reduce NH_3 release in rumen, improves N utilization and lesser N excretion causing increase milk yield, fat and SNF levels.

Milk synthesis requires amino acids in grams, not protein in grams. Lysine, Methionine, Histidine are most essential for milk synthesis, these aa from natural feeds are degraded in rumen. The Rumen Microbial Protein is deficient in Lysine , Methionine & Histidine. So, there is a need to enhance bypass protein value of such feeds. Not only quantity of protein escaping ruminal destruction is important , but also the quality of amino acid content of that protein.

Ruminally protected methionine can increase fibre digestion, improve acetate levels and acetate: propionate ratios.

Energy

Energy is the first limiting nutrient in the diet of high yielder. Since the Feed intake DMI is the main constraint, due to depressed appetite and milk production is positively correlated with the intake of DM. In order to meet the energy demand the approach is to either to increase the energy density (by feeding additional maize or by adding fat) or by reducing Roughage: Concentrate ratio. For the best utilization of nutrients with minimum excretion in faeces, the grains shall be crushed and passed through the screen of 1 .5 -2.0 mm pore size. The total starch contents in the diet of high yielder should be between 20-25%.

Fat

Fat plays important role in the performance of lactating animals. The BIS specifications have recommended only 3.0 and 2.5% fat in type I and type II concentrate mixture, respectively whereas, NRC feeding standards have recommended 3.0% fat, in the complete feed for dairy cattle. Recent reports indicate that dietary fat up to 5% (complete feed) have direct positive impact on the quantity as well as quality of milk produced, but level beyond 5% depressed milk yield. The protected/prilled fat could be incorporated up to 9% in the diet without any deleterious effect on the productive performance of dairy cattle. The roasted full fat soya or roasted soyabean are rich blend of both bypass protein and bypass fat. The fat content should be 4-6% of the total diet of high yielders. One rule of thumb when high fat addition is required is that 1/3rd comes from natural feed ingredients, another 1/3rd should come from oilseeds or tallows and final 1/3rd should be come from bypass sources.

Roughage Intake:

Roughage quality is partly determined by fibre levels. Fibre content increases as the forage crop matures. High fibre forage has lower palatability, reduced protein levels, and is less digestible than high quality material. But care must be taken to ensure sufficient fiber in the diet in order to maintain normal rumen function, to promote rumination and to stimulate flow of saliva. The roughages should be of high quality with not more than 40- 45 % NDF, it should be chopped to a length of 2 inches or longer.

Complete feed of high yielding cow should not contain less than **21% ADF or 28% NDF,** because excessive levels of concentrates (>60 % of total DMI) fed during early lactation can cause acidosis and low milk fat percentage. More than **80% fibre** should come from lush green forage or quality silage and remaining from quality hay or naturally fermented straw. Underfeeding "effective" fibre causes off-feed problems and depression.Poor quality crop residues do not have any place in the diet of high yielder. However, straws/ stovers with improved quality after processing with urea could replace hay up to 25 % (DM basis), without any adverse effect on productive performance of such animals.

Molasses

Molasses is an easily fermentable source of energy. It is High in especially potassium and sulphur. It is included to increase the palatability as well as level of soluble sugars in the diet. The recommended level of molasses in high yielder is **5%.** At this level it has positive effect on the digestibility of nutrients. But at higher levels it increases the relative proportion of

butyrate and decreases that of propionate in the rumen, depresses utilization of nutrients and may cause ketosis. The level of sugar and starch beyond 35% in the diet depressed NDF digestibility.

Minerals and vitamins:

Milk is a good source of Calcium, Chloride, Potassium, Magnesium, Sodium, B-complex vitamins etc. Calcium is one of the crucial elements in the ration. At the beginning of lactation, the sudden demand of Calcium for milk production increases dramatically, leading to fall in blood calcium levels. This stimulates the secretion of PTH from parathyroid glands, resulting in activation of vit. D3 (25-OH vit D3 to 1, 25 (OH)2 D3), which increases absorption of Ca from intestine and mobilization of bone Ca. But this whole process requires 24-48h, and can't prevent animals from milk fever as more than 60% cases of milk fever occur within 24h of parturition. To avoid incidences of milk fever, the best feeding management practice is to provide low Ca (<50 g/day) during last 2-3 weeks of gestation and gradually increase to 100g/day two days before parturition. The diet, after parturition, should have sufficient Mg, essential for conversion of vit D3 to 25HD3 in liver.

Selenium and vitamin E play important role in lactating cows. Both help to maintain the immune system and reproductive efficiency. The supplementation in the diet reduced the number of cystic ovaries, eliminated retained placenta, and greater resistance to mastitis. The recommended dose is 0.4 - 0.6 g/day vitamin E and 0.3 ppm selenium/day.

Niacin (B-complex vitamin) being synthesized in the rumen is adequate for low yielders. It stimulate feed intake, prevent ketosis and improves milk production and increased fat content. Its effect is more pronounced especially in early lactation. Hence, Niacin is supplemented @ of 6 g/cowl/day. Anionic salts should be given@ 2 to 3 equivalents which bring the DCAD (dietary cation-anion difference) less than zero (-50 to -150 meq/kg). Use of low potassium diets and or adjusting the cation/anion relationship to near zero or slightly negative during 2-3 week prepartum will result in reducing hypocalcaemia and less depression in feed intake at parturition which will result in reducing the magnitude of negative energy balance in early postpartum. **Propylene glycol** is converted in the liver to glucose which can prevent ketosis and fatty liver formation. Supplementation of **Yeast cultures and yeast products** can stimulate fibre digesting bacteria, maintain rumen pH, and stimulate VFA production. The level of yeast cultures and products vary from 10 to 115 grams per cow per day.

Feeding management tips

Feed the cow in several small meals rather than two large ones, especially in hot weather. Increased feeding frequency reduces daily variations in rumen pH and thus helps stabilizing the rumen environment. The proper range and consistency of ruminal pH is critical in fiber digestion. Have fresh feed available in mangers after milking time. Allow cows access to feed for at least 22 hours of the day. Include high quality feed ingredients in the ration, analyze them periodically. Avoid drastic changes in the ration. If forage and concentrates are being fed separately, forages should be fed first in the morning followed by a portion of the concentrates.

Ingredient proportion in Con. Mix. for different physiological phases

Ingredients (%) in con. mix.	Maintenance	Moderate Prod.	High Prod.	Very high prod.
Grains	15-20	25-30	38-40	45-50
Bran	30-35	20-25	18-20	6-8
Oil cakes	15-20	20-25	25-30	32-35
Rice polish	15-20	10-15	5-8	3-5
Gram husk	8-12	5-8	3-5	-
Molasses	5	5-7	8-10	10
Urea	0.50	1	1.0	1.0
Mineral mix.	1	2	2	2
Common Salt	0.5	0.8	1	1
Calcite	-	-	1	2
Sod. bicarbonate	-	-	0.5	1
Bypass fat	-	-	0.5	1-1.5
Vitamin premix	-	-	0.1	0.01
Chelated trace min.	-	-	0.01	0.02
CP in con mix.(%)	**16-17**	**18-19**	**20-22**	**23-24(50-55% bypass)**
TDN in con mix (%)	**62-63**	**64-65**	**71-72**	**73-74**

CHAPTER-VIII

POULTRY NUTRITION

Poultry: The term poultry is applied to all domesticated birds used as food like chickens, ducks, quails, geese, turkey and pigeons, etc. Of these, chicken and turkey are most commonly used for their egg and meat. Poultry eat to acquire the energy and building materials that they need to live and grow. Poultry use energy to perform normal body functions such as breathing, walking, eating, digesting, and maintaining body temperature. They are considered as warm-blooded vertebrates; which means that their body temperature is relatively high and usually almost constant. They lay eggs that are incubated outside the body. During natural embryonic development, the eggs of the poultry are covered by the hen and they are maintained at a temperature close to her body temperature for the entire incubating period. An understanding of how various systems function within the body of the poultry makes it easier to know why certain practices are recommended time to time for feeding of various classes of poultry. From the structural standpoint, poultry is an interesting creature. It possesses feathers, has a breastbone and spur, but lacks teeth. Within poultry, chickens have a comb, which sets it apart from others birds. The comparison with most of the other domestic animals used for the production of food for mankind, the poultry is a short lived creature. It is a rapid breather and digests its food relatively quickly. The body temperature is higher than that of other domestic animals, averaging about 41°C or 106°F with variations between day and night temperatures.

Nutrition: The science of how the feeds birds/ poultry eat and affect their body functions.

Nutrients: Substances that nourish the body. **They** provide poultry the energy and material needed for the development of bone, flesh, feathers, and eggs. Each of these compounds is important in providing poultry the nutrients they need, and a deficit of even one can have serious health consequences for poultry. Feed has six major components such as Water, Carbohydrates, Fats & oils, Proteins and amino acids, Minerals and Vitamins.

Feed: Any material eaten by a bird as part of its daily ration.

Ration: Amount of feed given to bird at a time or in proportions at intervals in 24 hours.

Diet: Feed consumed by bird at a time to satisfy its appetite.

Mash: Mash is generally in the form of course powder and is a mixture of ingredients in meal form.

Meal: An ingredient which has been ground or otherwise reduced in particle size.

Cake: The mass resulting from the pressing of seeds, meat or fish in order to remove oils, fats or other liquids.

Poultry meat: Poultry meat has high protein content (about 25 percent) and is comparable in quality and nutritive value to other meats. It contains all the essential amino acids required for building body tissues. There is a little fat on the meat of young birds, but the fat content is influenced by age and species of poultry. Chicken fat is more unsaturated than the fat of red meat and this has nutritional advantage. Because of its high protein to fat ratio, poultry meat is advantageous to persons who must restrict the intake of fats. Like other animal tissues, poultry flesh is a good source of B complex group of vitamins and minerals.

Koilin: The sub-mucosa of the gizzard secretes a protein-polysacharides substance called koilin. The koilin solidified into short rods when it searches the acid conditions in the gizzard and the rods cross-link to form a mask around the gizzard wall. This protects the wall from the damage and provides an abrasive surface for the grinding process.

Essential amino acids: Some amino acids have to be provided in diet as the poultry cannot synthesize them or they do so inadequately. Such amino acids are called essential amino acids.

Critical amino acids: Among the essential amino acids, certain amino acids are likely to be low in practical feeds and these are known as critical amino acids.

Limiting amino acids: Among the critical amino acids, lysine and methionine are the most deficient amino acids in feed ingredients are known as limiting amino acids.

Importance of feeding poultry:

Proper nutrition of poultry is important for the following reasons:

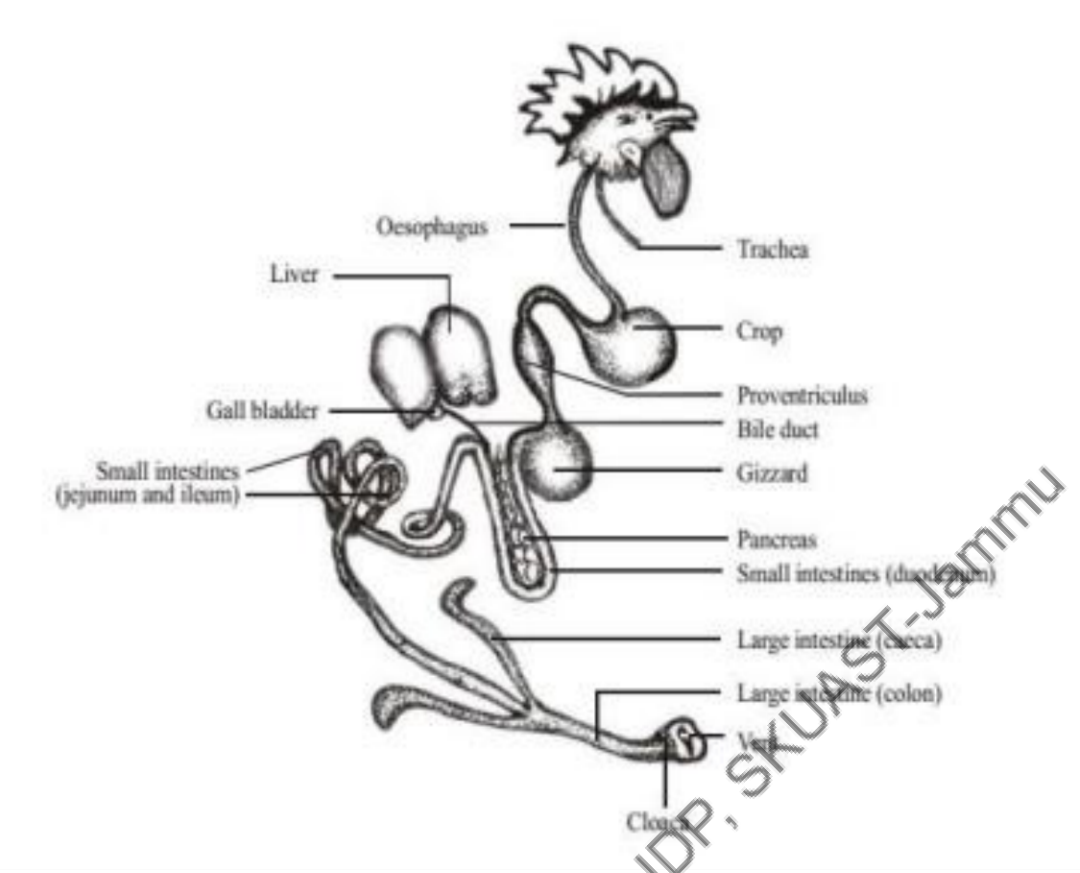
- Feed accounts for over 70% of the cost of producing poultry meat and over 60% of egg production costs.
- Poultry digestive system is relatively simple and short, but extremely efficient.
- Poor quality feed is not digested easily, causes ill health, retarded growth and development and reduced egg production.

- Intensive system of raising commercial poultry demands proper balanced feed mixtures.
- Day to day increase in price of feed ingredients, the feed value availability needs special attention in formulating balanced ration.
- Increased flock size and agro-industrial by-products in feeds.
- Formulation & preparation of feeds for specific purpose and for economic and efficient production ultimately provide more profit.

Principles of Feeding:

- Being simple stomach needs of poultry are very precise.
- Birds have no teeth hence more concentrated ration be supplied.
- They have higher metabolic rate and hence need more specific ration.
- Poultry must get all essential nutrients from balanced feed.
- Birds have no sweat glands hence they are quite sensitive to environmental effects.
- Poultry are fed better collectively rather individually.
- They cannot digest crude fibre and fat more than 6-7%.
- Clean and fresh drinking water be made available at all times.
- Feed compounded must be palatable, digestible and free from fungal infested ingredients.
- Optimum calorie (energy) and protein ration must be maintained for purpose it is intended.

Digestive system of poultry



A bird cannot be classified as a simple stomach animal, and yet its digestive system is somewhat similar. The organs related to digestion in poultry are described as under:

i) Mouth: The digestive system starts with a part visible from outside namely beak by which feed is picked up. The teeth and lips are absent in mouth. These parts are replaced by a horny mandible on each jaw, forming the beak. The tongue is shaped like the barbed head of an arrow. Saliva, with its enzyme amylase which is used to convert starches to sugar during digestion, is secreted by the glands in the mouth. Another function of saliva is as a lubricant to help with the transport of food particles.

ii) Oesophagus: It is characterized by enormous expansibility. Food passes from the mouth through the oesophagus to the crop and onwards.

iii) Crop: The crop is an enlargement of the oesophagus and is used for storing and softening the food. Little or no digestion takes place here except for that involved with the salivary secretion of the mouth, which continues its activity in the crop.

iv) Stomach:

a) ***Proventriculus:*** The oesophagus ends in a small dumbbell shaped organ called proventriculus, which has ample glands. It is here that gastric juices are produced and secreted. Pepsin, an enzyme needed for the digestion of protein, and hydrochloric acid are secreted by the glandular cell. Because the food passes quickly through the proventriculus, there is little digestion of food material here, but the secretions pass into the gizzard where the enzymatic action occurs.

b) Gizzard: The oesophagus is connected with a bulged dish type structured organ called gizzard. It has strong muscle and functions chiefly in crushing and grinding of food. The gizzard, sometimes is called as 'muscular stomach'. The gizzard is inactive when empty, but once food enters, the muscular contractions of its thick walls begin. The larger the particles of food, the more rapid will be the contraction of gizzard.

v) Small Intestine: The small intestine is comprised of two major sections, the duodenal loop and the ileum. Within the duodenal loop lies the pancreas that secretes pancreatic juices containing the enzymes amylase, lipase and trypsin. Other enzymes are produced by the walls of the small intestine, further aiding with the digestion of protein and sugars. The small intestine is the primary site of nutrient absorption.

vi) Caeca: Between the small and large intestine lie two blind pouches known as caeca. The exact function of the Caeca is not well defined, but it has been concluded that they have little to do with digestion and only minor functions associated with water absorption. A small amount of carbohydrate and protein digestion and the microbial fermentation of dietary fibre also take place in the caeca.

vii) Large intestine: The large intestine is a relatively short extension of the small intestine in the chicken. It is about twice the diameter of the small intestine. It extends from the end of the small intestine to the cloaca. The large intestine is involved in water resorption, and in doing so assists with maintaining the water balance in the bird.

viii) Cloaca: The bulbous area at the end of the alimentary tract (from the mouth to the vent) is known as the cloaca. Cloaca means "common sewer", and in the case of the chicken, the digestive, urinary and reproductive tracts all empty into the cloaca.

ix) Vent: The vent (anus) is the external opening of the cloaca. Its size varies greatly in the female depending on whether or not she is producing egg.

x) Pancreas: The pancreas lies within the duodenal loop of the small intestine. It is a gland that secrets enzymes into the duodenum by way of the pancreatic ducts. These

enzymes help in the digestion of starches, fats and protein. These enzymes, also known as pancreatic juices, neutralize the acid condition created in the proventriculus.

xi) Liver: This is a large, several lobed, dark red organ. It is the largest gland in the body. The liver secretes bile. Bile is stored in the gall bladder and helps in the digestion of fat.

xii) Gall bladder: While the chicken has a gallbladder, some bird's do not. The two bile ducts are used to transfer bile from the liver to the intestine. The right duct, through which most of the bile passes and is temporarily stored is enlarged forming the gall bladder. The left duct is smaller, therefore only a small amount of bile passes through it directly into the intestine.

Early nutrition and its impact on gut health and performance

Healthy gastrointestinal tract (GIT) is crucial for optimum performance, better feed efficiency, and overall health of poultry. In the past, antibiotic growth promoters (AGP) were commonly used to modulate the gut health of animals. However, considering the public health concern, the use of AGP in poultry feeding is banned or regulated in several jurisdictions around the world. This necessitates the need for alternative nutritional strategies to produce healthy poultry. For that, several alternatives to AGP have been attempted with some success. However, effective modulation of the gut health parameters depends on the methods and timing of the compound being available to various classes of poultry. Routinely, the alternatives to AGP and other nutrients are provided in feed or water to poultry. However, the GIT of the newly hatched poultry is functionally immature, despite going through significant morphological, cellular, and molecular changes toward the end of incubation.

Thus, early growth and development of GIT are of critical importance to enhance nutrients utilization and optimize the growth of poultry. Early nutrition programming using both *in ovo* and post-hatch feeding has been used as a means to modulate the early growth and development of GIT and found to be an effective strategy but with inconsistent results. This review summarizes the information on *in ovo* and post-hatch-feeding of different nutrients and feeds additives and their effects on gut development, histo-morphology, microbiology, and immunology.

Poultry production has increased at a faster rate than any other livestock animal globally. Among others, the nutritionally balanced-feeding program in poultry diets played a significant role in achieving this success. However, the poultry industry is under pressure to redefine its nutrition program to grow safe and quality meat in the light of public health concern

due to the use of AGP in poultry diets. Maintenance or improvement of gut health is essential for optimum growth, better feed efficiency, and overall health of poultry. Also, a healthy gut is critically important for the efficient conversion of feed into absorbable form for optimal nutrient utilization, thereby better growth performance of poultry.

Chicks have been shown to benefit from early access to feed and water. A healthy 1-day-old chick is a crucial link between the hatchery and the broiler farm. The delayed intake of water and nutrients to chicks could lead to a diminishing of their overall growth performance with adverse effects on breast meat. The most extreme consequence of delayed feeding is increased mortality. Early feeding strategies have been suggested and developed to diminish or possibly reverse the negative effects of delayed feeding. These strategies range from *in ovo* feeding to specially designed post-hatch diets. The importance of early nutrition and its effect on growth performance and different components of gut health (histo-morphology, microbiota, and immune system) have already been extensively studied in the last two decades. Some studies have gone in detail about specific nutrient supplementation and its effect on the poultry. For example, probiotics supplementation in early life prevent pathogenic infections, amino acids (L-arginine, L-lysine, L-histidine, threonine) are beneficial in growth performance, vitamin C and E boost immunity, carbohydrates increase glycogen stores, and creatine supplement promotes muscle growth. Also, the *in ovo* injection of sulfur-containing amino acids (methionine plus cysteine) in the embryonated eggs exposed to heat stress have positive effects on gene expression and antioxidant indices as well as reduce the lipid profile of newly hatched broiler chicks.

Nutrition involves providing a balance of nutrients that best meets the poultry needs for growth, maintenance, meat and egg production, etc. For economic reasons, this supply of nutrients should be at least cost, and so we must supply only enough for requirements, without there being any major excesses. It is very difficult and very expensive to supply all nutrients at the exact nutrient needs - rather we have to oversupply some nutrients in practical situations, in an attempt to meet the limiting nutrients. In poultry diets these limiting nutrients are usually energy and some of the essential/ limiting amino acids, such as methionine and lysine. In formulating diets the following nutrients are considered:

- Energy
- Protein
- Fat
- Vitamins
- Minerals

- Water

With the exception of water, these nutrients are provided by the ingredients that make up the diet. Ingredients are classified as:

- Cereals
- Animal Proteins
- Vegetables Proteins
- Vegetable Fats
- Animal Fats
- Micro Minerals
- Macro Minerals
- Vitamin Premixes

Each of these separate types of ingredient provides a specific quantity and quality of nutrients to the diet. Balancing these ingredients to produce the diet formulation (recipe) relies on the skill of the nutritionist. In order to produce a diet, the nutritionist must know the birds needs and the composition of the ingredients.

Formulation = Balance needs vs ingredients vs costs.

The following nutrients are considered both for the birds needs and for the composition of the various ingredients:

Protein

Measure as crude protein, which is simply nitrogen x 6.25

Component amino acids are the important part of protein. There are 11/12 amino acids that are essential to the bird:

Indispensable/ Essential amino acids

Ten AAs (AVHILLMPTT) are essential AAs but in poultry 11/12 AAs are essential (chicken can't synthesize in sufficient amount & need in the diet).

Alanine, Valine, Histidine, Isoleucine, Leucine, **Lysine**, **Methionine,** Phenylalanine, Threonine, Tryptpphane & **Arginine**.

Birds also require **Glycin**. It is needed for biosynthesis of uric acid

Lysine and methionine are limiting AAs.

These must be supplied as synthetic ingredients in order to achieve maximum production levels.

Lysine is supplied as Lysine hydrochlorideHCl) salt.

Methionine sources: DL methionine & methionine hydroxy analogue.

Protein and amino acids are supplied by ingredients such as:

Protein sources

Vegetable protein sources

Soybean meal (Full fat soya, SBM, solvent extracted SBM)

Groundnut cake (oiled and de-oiled)

Rapeseed and mustard meal (oiled and De-oiled)

Sunflower meal, Cotton seed meal, Coconut meal,

Sesame meal, Maize gluten meal and Guar meal

Animal protein sources

Fish meal, meat meal, meat cum bone meal,

De-oiled silkworm pupae meal, Hatchery by-product meal,

Poultry by-product meal, feather meal, and blood meal, etc.

All vegetable proteins sources contain some of the plant toxins that must be destroyed by various types of treatments/ processing such as heat treatment, drying, chemical treatment, etc. Other protein sources are obtained from animals, and are generally of better quality and/or better amino acid profiles, but are expensive:

Energy

The most expensive nutrient in a diet, but is difficult to measure and there is no guarantee with the feed. Energy is important because it governs feed intake.

- high energy ---> low feed intake
- low energy ---> high feed intake

Sources of energy - everything in the diet other than minerals, and Units of energy are Calorie, or Kilocalorie.

Metabolizable energy = Energy intake as feed minus energy appearing in urine and feces. Therefore can only measure with a chicken trial, therefore expensive ($1,000/assay).

Energy sources

- Cereal grains (Maize, Sorghum, Wheat, Rice, Barley and Millets),
- Grain by-products (Rice bran, De-oiled rice bran, Wheat bran, etc.),
- Industrial and forestry wastes (Molasses, De-oiled Sal seed meal, Mango seed kernel, Fats and oils),
- Miscellaneous materials (Tapioca meal or casava meal, Leucaena/ subabool leaf meal, Sweet potato tuber meal, etc.),
- Soybean seed
- Fat (vegetable and/ or animal fats)

Fiber largely indigestible - cecal microbes during fermentation can degraded to some extent.

- Influences manure consistency.
- Problem with some ingredients such as wheat, barley - enzymes.

Fats

Not really an essential nutrient, other than linoleic acid (essential fatty acid).

- Animal fats - hard, inexpensive. Problems with digestion by young birds.
- Vegetable oils - liquid, expensive

Fat can improve Pellet quality and reduce the dustiness of feed.

Vitamins

All supplied as synthetics.

- Fat soluble - A, D3, E, K.
- Water soluble - B vitamins eg. Riboflavin, biotin

Exception is choline, which is added separately.

Vitamin sources:

Feed ingredients contain vit A, carotenes, vit E, K and B complex group. But supplemental vitamins are required in poultry diets as the feed ingredients do not supply vitamins in required amounts. Therefore they are added from synthetic sources. Now they are commercially available in the market.

Vitamins	**Concentration**
Vitamin A, IU	500000/g
Vitamin D_3, IU	200000/g
Vitamin E, 50%, mg	500/g
Choline chloride 50%	500/g
Biotin/ folic acid/ niacin, pantothenate calcium/ pyridoxine/ riboflavin/ thiamin Hcl/ vitamin B_{12}	
Commercial preparation Vitamin AB2D3/ Vitamin AB_2D_3K	

Minerals

- Macro --> Calcium, Phosphorus, Magnesium, sodium, potassium, sulphur and chlorine
- Micro --> Copper, Zinc, Manganese, Iron, Iodine, Selenium
- Salt --> Sodium, Chloride

Mineral sources:

Compound	Source of Minerals (%)	
Bone meal	Ca (29)	P (12)
Calcium carbonate	Ca (38)	-
Di-calcium phosphate, DCP	Ca (22)	P (18)
Lime stone powder, LSP	Ca (38)	-
Meat cum bone meal, MBM	Ca (10)	P (5)
Shell grit	Ca (38)	-
Common salt	Na (39)	Cl (60)
Copper sulphate	Cu (35)	-
Cupric oxide	Cu (75)	-
Ferrous sulphate	Fe (43)	-
Potassium iodide	I (76)	-
Manganous sulphate	Mn (25)	-
Zinc sulphate	Zn (22)	-
Sodium selenite	Se (45)	-

Locally available feed ingredients and their nutrient profiles

Feed ingredients	Nutrients	Limitations
Maize	Principal energy source used in poultry diets, excellent source of linoleic acid, carotene & xanthphyll, ME-3350-3400 kcal/kg, CP-9-10%	Deficient in tryptophan and lysine
Sorghum	Slightly lower energy but more protein than maize, ME-3200 kcal/kg, CP-10-12%	Protein is deficit in lysine, methionine & arginine
Wheat	Good source of energy next to maize & sorghum, ME-3100 kcal/kg, CP-11-14%	Protein is deficient in methionine & threonine, contains indigestible NSPs (arabinosylans), reduce the performance of poultry.

Rice	Staple cereal food in many parts of country, CP=7-8%	Costly affair
Barley	ME-2900 kcal/kg, CP->10%	High fibre, Deficient in methionine and lysine, it contains β-D glucans, not digested & causes wet, sticky droppings due to increase viscosity of intestinal contents, need β-glucanase
Millets (Bajra, Korra, Ragi)	Used as sole source of energy ME-3000 kcal/kg, CP-10-12%	Protein is deficit in lysine
Rice bran/ Rice polish	Contains CP-13%, fat-13-16%, fibre-13%, ME-2900 kcal/kg, good source of B-complex group of vitamins, good AA profile compared to cereals	It is slightly deficient in lysine.
De-oiled rice bran (DORB)	CP-14%, ME-1400 kcal/kg, fat <1%	High fibre than RB (14%)
Wheat bran	ME-1300 kcal/kg, CP->12-15%	High fibre (11%), Deficient in methionine and lysine, it contains phytate (0.95%).
Animal fats (Tallow)	ME-7700-8000 kcal/kg, excellent source of energy, reduce dustiness, improve palatability & appearance.	Costly, limited use , tend to get rancid
Vegetable oils	ME-8000 kcal/kg, excellent source of energy, reduce dustiness, improve palatability & appearance, provide essential fatty acids.	Costly, limited use, tend to get rancid
Sweet potato tuber meal	Good source of energy, CP-6%, ME-3500 kcal/kg.	Contains anti-trypsin
Poultry manure (dried)	CP-20%, ME-1000 kcal/kg, Ca-4%	High in uric acid (10%)
Soybean meal	CP-38-45%, ME-2225-3275 kcal/kg. excellent source of lysine, trypt. & Threonine	Deficient in methionine, trypsin inhibitors.
Rapeseed and mustard oil cake	CP-30-36%, ME-2015-2300 kcal/kg, well balanced AAs	Uric acid, glucosinolates, increase iodine

		requirement, high CF.
Groundnut cake	CP-42-45%, ME-2000-2500 kcal/kg	Deficient in methionine, lysine and tryptophane, trypsin and othe protease inhibitors, problems of aflatoxins (B_1 level 250 ppb exert toxic effects).
Sunflower meal	CP- 30-35%, it is high in methionine	Low /deficient in lysine, high fibre, high in chlorogenic acid like tannins
Cotton seed meal	CP-35-38%, Gosypol-olive green yolk in stored eggs due to reaction with iron, & malvalic & sterculic acid results in pink discolourastion of egg albumin.	Deficient in lysine, methionine, trreonine & tryptophane, CF-11-13%, presence of gosypol and cyclopropenoid fatty acids.
Sesame meal / Til cake	CP-40%, fat-5%, Excellent source of methionine, cystine & tryptophane	Very low in lysine and threonine. High oxalic acid (35 mg/100g) and phytic acid (5%), they interfere with Ca, P, Mg, Zn and Iron metabolism.
Linseed meal	CP-30-32%, source of PUFA	Low in lysine and tryptophane, it contains linatin (an antipyridoxine) and linamarin (cyanogenic glucoside: HCN= 10-300mg/kg meal)
Maize gluten meal	CP-45-60%, high in methionine and S-containing AAs, good source of xanthphyll	Low in lysine and tryptophane.
Fish meal	CP- 40-60%, good source of lysine & methionine, Ca, available P, vitamin B12, Iodine & Selenium	Limited use, higher level more than 5% causes

		fishy flavour in eggs and meat.
Meat cum bone meal (MBM)	CP-56%, good source of Ca & P	Deficient in tryptophane, methionine & lysine,

Body weight and size

Body weight and body condition of the bird around the time of maturity, are perhaps the most important criteria that will ultimately influence breeder performance. Body weight and body condition should not really be considered in isolation, although at this time we do not have a good method of readily assessing body condition. Each strain of bird has a characteristic mature body weight that must be reached or surpassed for adequate egg production and egg mass output. In general, pre-lay diets should not be used in an attempt to manipulate mature body size. The reason for this is that with most flocks it is too late at this stage of rearing to meaningfully influence body weight - all too often pre-lay diets are used as a crutch for poor rearing management.

However, if birds are underweight when placed in the breeder house, then there is perhaps a need to manipulate body weight prior to maturity. Under controlled environment conditions, this can sometimes be achieved by delaying photo-stimulation. If pre-lay diets are then necessarily used in an attempt to correct rearing mismanagement it seems as though the bird is most responsive to energy. This fact likely fits in with the effect of estrogen on fat metabolism, and the significance of fat for liver and ovary development at this time. While such high nutrient density pre-lay diets may be useful in manipulating body weight, it must be remembered that this late growth spurt (if it occurs) will not be accompanied by any meaningful change in skeletal growth. This means that in extreme cases, where birds are very small in weight and stature at say, 16-18 weeks of age, the end result of using high-nutrient dense pre-lay diets may well be pullets of correct body weight, but of small stature. These short-shank length pullets seem more prone to prolapsed /pick-out, and so this is another example of the limitations in use of classical pre-lay diets.

Use of high-nutrient dense pre-lay diets to manipulate late growth of broiler breeder pullets does, however, seem somewhat redundant. The reason for this is that with restricted feeding programs, it is more logical to increase feed allowance than to add the complexity of introducing another diet. The only potential problem of this program is that in extreme cases feed intake is increased to a level that is in excess of the initial allowance of breeder diet at

start of lay i.e. ensure that breeders are not subjected to a step-down in feed allocation at time of first egg.

Body composition

While body composition at maturity may well be as important as body weight at this age, it is obviously a parameter that is difficult to measure. There is little doubt that energy is likely the limiting nutrient for egg production for all classes of birds, and that around peak production, feed may not be the sole source of such energy. Labile fat reserves at this time are, therefore, essential to augment feed sources. These labile fat reserves become critical during situations of heat stress or general hot-weather conditions. Once the bird starts to produce eggs, then its ability to deposit fat reserves is greatly limited. Obviously if labile fat reserves are to be of significance, then they must be deposited prior to maturity.

Egg weight and hatchability

It seems as though egg size is ultimately controlled by the size of the yolk that enters the oviduct. In large part this is influenced by body weight of the bird, and so factors described previously for body weight can also be applied to concerns with egg size. There is a general need for as large an early egg size as is possible. Most attempts at manipulating early egg size have met with limited success. Increased levels of linoleic acid in pre-lay diets may be of some use, although levels in excess of the regular 1% found in most diets produce only marginal effects on early egg size. From a nutritional standpoint, egg size can best be manipulated with diet protein, and especially methionine concentration. It is logical, therefore, to consider increasing the methionine levels in pre-lay diets.

For breeders we must also consider egg composition as it relates to early hatchability success. Eggs from young breeders seem to inherently have a hatchability problem, and perhaps this is one of the reasons that we wait for egg size to increase before sending eggs to the hatchery. The reason for this early hatch problem is not fully resolved, but most likely relates in some way to maturity and development of embryonic membranes and their effect on transfer of nutrients from the yolk to the embryo. However part of this problem may also elate to inadequate transfer of vitamins into the egg. For a number of critical B-vitamins, their concentration in successive eggs does not plateau until after 7-10 eggs have been laid. The effect of pre-lay nutrition on these factors probably warrants further study, but at this time these problems cannot be resolved by simply over-fortifying pre-breeder diets with vitamins or certain fatty acids.

Pre-breeder diets can successfully be used as part of a feeding program aimed at maximizing production potential in young breeders. However any desired increase in nutrient

intake prior to maturity can most easily be achieved by simply increasing the feed allowance of either grower or adult breeder diet at this time.

Energy in poultry diets

There are 4 main components that go together to make up a poultry diet. While protein, vitamins and minerals are referred to as nutrients, energy the 4th and most costly part of the diet is not a nutrient but the property of energy yielding nutrients. Dietary nutrients that yield energy are protein, fat and carbohydrates.

Protein is not commonly thought of as a source of dietary energy but it does result in a significant contribution to the energy requirement of the bird, and can, if fat and carbohydrate are in short supply, be used by the animal as it's main source of energy.

Dietary protein is a source of amino acids which are the building blocks for body tissue, hence growth, and the production of a product - eggs. Thus it's use as a source of energy must be kept to a minimum.

Protein, carbohydrate and fats all contain carbon, hydrogen and oxygen and thus can be burned as a source of energy in the body. While proteins and carbohydrates yield around 4 calories of energy per gram, fats yield 2 times as much or 9 calories per gram. Thus, when formulating for high energy diets it is usually necessary to add a source of fat to poultry diets.

Diets with high levels of energy are referred to as having a higher nutrient density. This means that the same amounts of nutrients are available in a smaller volume of with less weight. It follows that if the diet is more dense the bird will have to eat less of it to obtain it's nutrient requirements and thus feed: gain or feed: egg mass ratios are reduced. Hence, improved feed efficiency or improved feed utilization results.

Dietary energy level is the main factor influencing feed intake, as birds will, under normal circumstances, eats to satisfy their energy needs. Therefore the dietary nutrients, protein vitamins and minerals should vary in relation to the dietary energy content of the diet, if they are not to become deficient, with low feed intakes, or over-consumed, with low energy diets.

While there are a number of factors, such as level of protein, balance of essential amino acids and perhaps level of some of the other dietary nutrients, which can influence the cost of a diet, the level of dietary energy is usually the main factor influencing diet cost. Hence, by and large, the higher the level of energy the higher the diet cost and usually the lower is the feed consumption in relation to gain.

The energy content of a diet is usually given as so many calories per kilogram of diet. Thus diets are said to contain, for example, 2800 or 3200 kcal (a thousand small calories) per kilogram. Energy content of a feedstuff is measured by burning it in an oxygen saturated

environment and measuring the amount of heat or total, (gross energy) produced. However, all the energy, or heat produced from, for example, burning a gram of corn is not available to the bird. When the bird consumes corn, some of it is not digested and this undigested material is lost via the feces. Since birds excrete feces and urine together it is not possible to get a simple measure of fecal material. Thus for poultry the energy content of the feces and urine are measured together. Since this energy is unavailable to the bird it is subtracted from the gross or total energy value of the corn to yield what is referred to as a metabolizable energy value. This is the energy that is available to the bird for productive purposes, eg for growth, the production of eggs, for maintenance, activity, etc.

While the above is a simple explanation of energy and how it is utilized by the bird, there are many factors which can interact to influence dietary energy utilization. One of the main factors increasing energy requirements of the bird is pen temperature. Birds use dietary energy as a fuel to maintain body temperature. Hence, in cold pen situations a significant amount of dietary energy can be used to maintain body temperature rather than be used for more productive purposes like weight gain or egg production.

Feed manufactures are continually looking for ways to improve the energy utilization of ingredients. Such things as:

- The addition of fat to diets - which slows down the rate of food passage in the gut and thus allows enhanced digestion by digestive enzymes.
- Steam pelleting and conditioning - which through chemical and physical action improves the utilization of certain nutrients.
- The use of dietary enzymes to help break down some of the poorly digested dietary components.
- Mixing saturated and unsaturated fats together, in proper proportions, to enhance fatty acid absorption.
- The use of synthetic essential amino acids to give a better balanced lower protein diet and thus reduce nitrogen excretion - a high energy cost function.
- Precision grinding of cereal grains to increase surface area. This allows more efficient enzyme action resulting in enhanced nutrient availability.

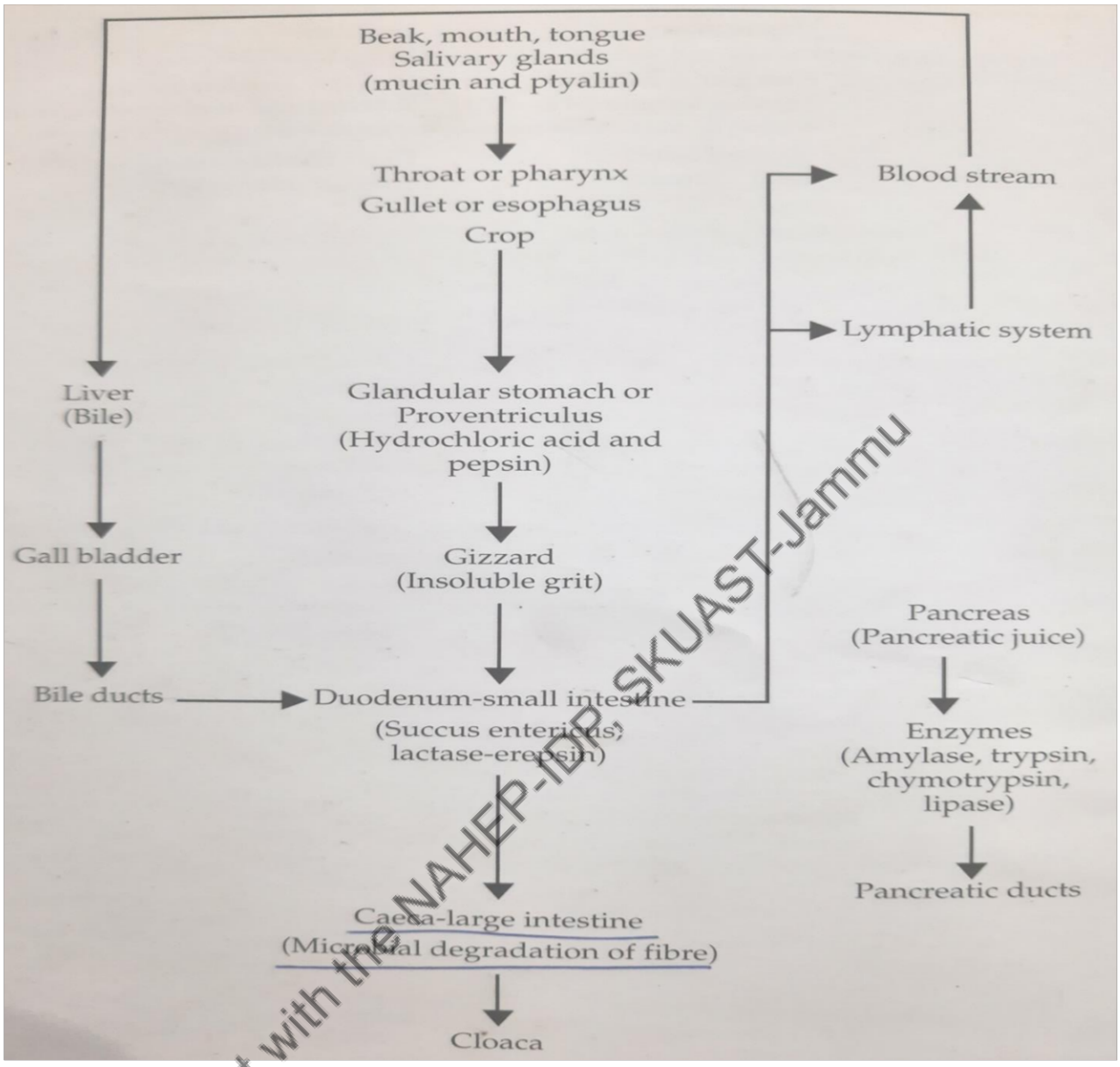
The above all help to improve feed utilization of the bird by making nutrients more available. Energy is the fuel that keeps the many different body functions operating, every minute of the day. It is a vital feed component, a costly feed component and the most wasted of the feed components. Hence, everything should be done to enhance the utilization of dietary

energy for productive body functions, as improvements readily show up in increased monetary returns which are readily apparent by improved feed: gain or egg mass ratios.

Nutrients, their end product of digestion and main site of nutrient absorption in the gastrointestinal tract:

Nutrient	End product of digestion	Main site of absorption
Carbohydrates (Starch and sugars)	Glucose	Small Intestine
Crude fibre		Not utilised
Fats	Monoglycerides, fatty acids and glycerol	Small intestine
Proteins	Amino acids	Small intestine
Minerals	As mineral elements	Small intestine
Vitamins	As vitamins	Small intestine

Different parts of digestive tract and their significance in digestion and absorption



Nutrient metabolism:

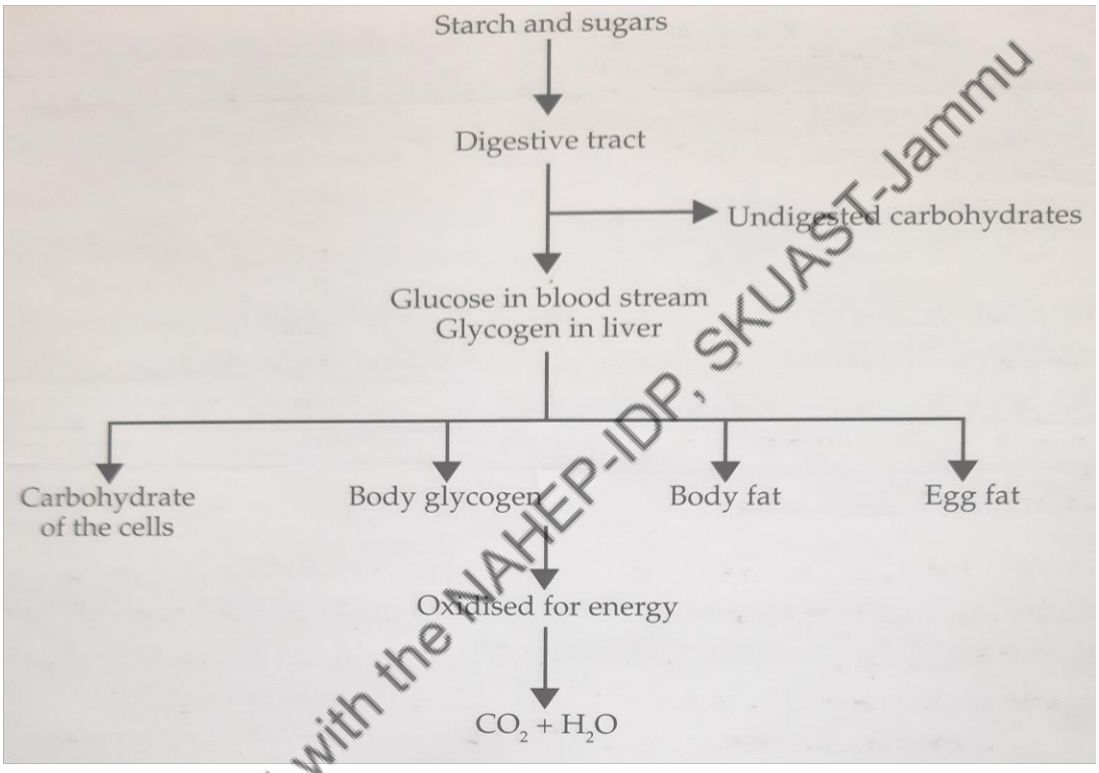
The absorbed nutrients are metabolized in the body to perform various functions like

- Maintenance of life,
- Body and feather growth ,
- Egg production,
- Fat deposition,
- Activity, etc.

- Excess carbohydrates and proteins are not deposited in the body as such.
- They are converted into fat and then deposited in the body.
- Minerals and vitamins after absorption perform various functions.

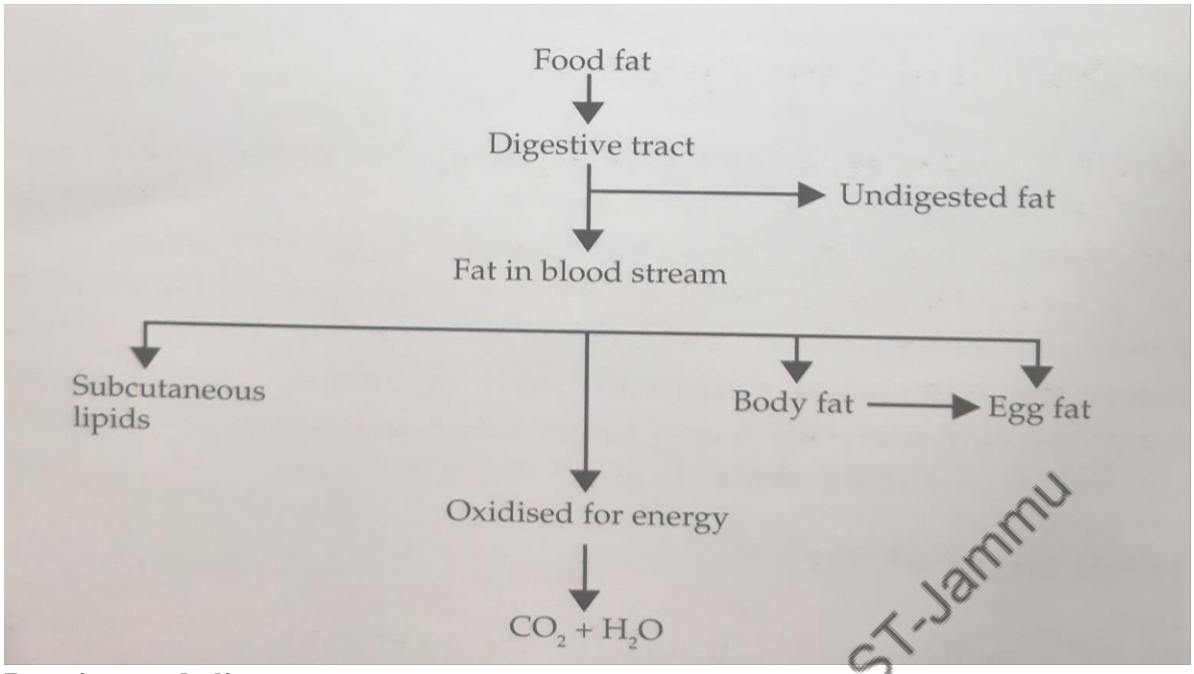
Carbohydrate metabolism:

- Glucose is used as available source of energy,
- Excess of glucose and few simple sugars are converted into glycogen (animal starch) by the liver and muscle.
- Storage capacity for glycogen is very limited (<1%),
- Excess glucose in blood stream is converted in to fat and deposited in the adipose tissue in the body,
- As and when more demand for energy the stored glycogen is converted back to glucose.



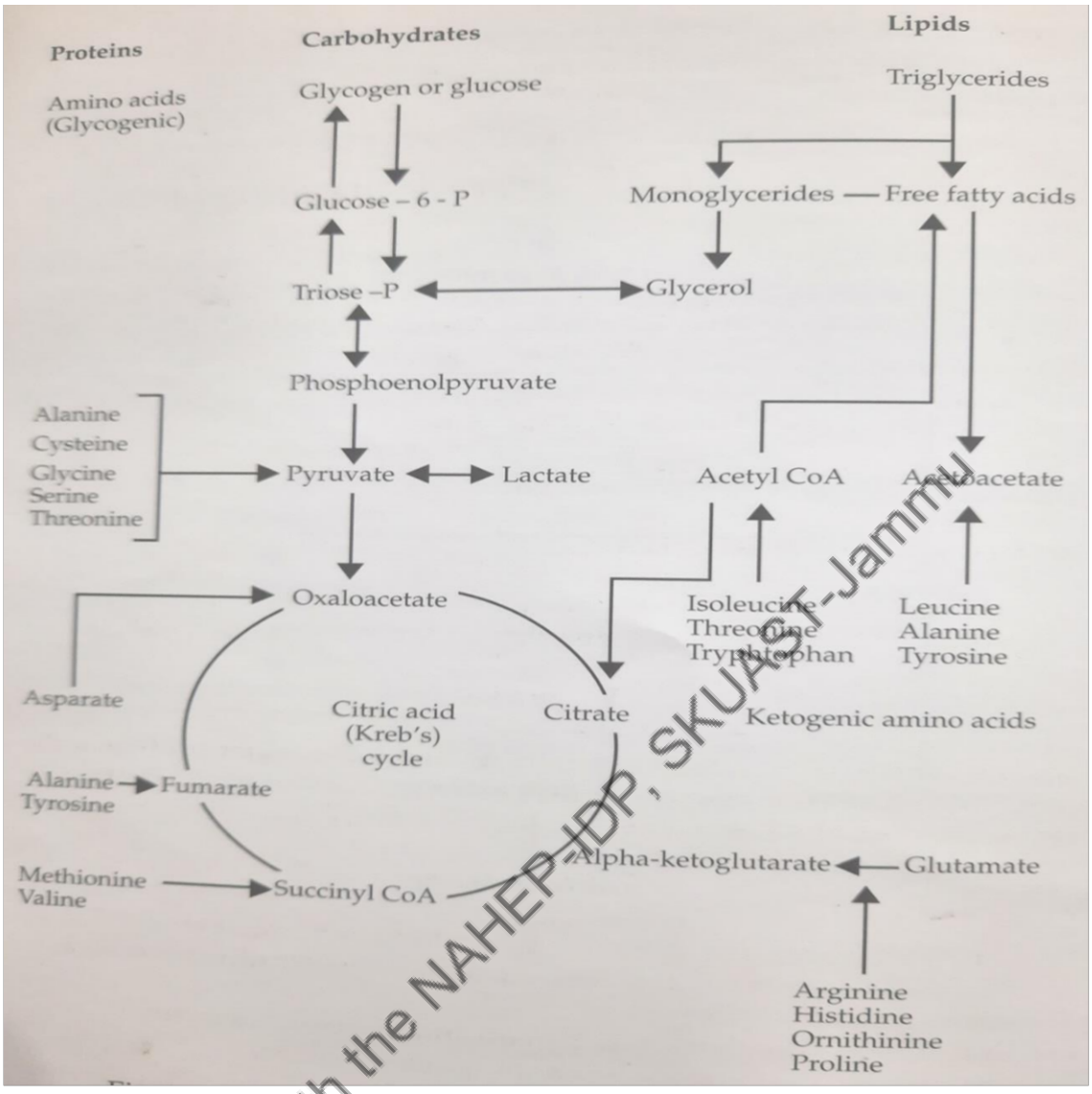
Fat metabolism:

- Fats are converted into fatty acids for energy, egg production, or stored as body fat,
- Fats are not excreted,
- Excess fat is deposited in the fat cells in the body,
- If CBHs, protein or fat consumed by bird is greater than required quantity, it gets deposited in body,
- If energy intake is lowered below requirement, stored fat is catabolized for energy.



Protein metabolism:

- Absorbed amino acids are used to form various tissues of body, for repair of tissue, egg production, etc.
- Excess intake of amino acids is used for energy through de-amination (removal of ammonia),
- Excess nitrogen derived from unutilized amino acids is excreted as uric acid through kidney.
- Excess protein intake is costly affair,
- Because protein feed supplements are costlier as well as its excretory product need energy for conversion.



Calcium metabolism

With egg-layers, pre-lay diets are used essentially to pre-condition the pullet for impending eggshell production. The very first egg represents a 1.5-2.0g loss in calcium from the body, the source of which is both feed and medullary bone reserve. Today breeder hens are capable of a sustained long clutch length which is necessary to achieve the 85-87% peak production that is now readily attainable. Calcium metabolism is, therefore, very important for the breeder. With Leghorn hens the consequence of inadequate early calcium balance is cage layer fatigue. Breeders do not show such signs, because they naturally have more exercise, and also have a readily available rich source of diet calcium in the form of their flock mates eggs. Hens have an innate ability to select out calcium, and so improperly fed breeders will eat litter and eggshells in an attempt to balance their diet. However inadequate calcium in the diet does lead to disruption of ovulation, and so these birds stop laying until their meagre calcium

reserves are replenished. In a breeder flock, it is the larger bodied, early maturing pullets that are disadvantaged in this manner.

Commercially, we see three different approaches used in pre-breeder calcium nutrition. Firstly, is the use of grower diets that contain just 0.9 - 1.0% calcium being fed up to 5% egg production. This is the system that was used many years ago, and unfortunately is still sometimes used today. At 5% egg production, we do not have 100% of the flock producing at 5% egg production - rather we have closer to 5% of the early maturing pullets producing at close to 100% production. Pullets can produce just 2-3 eggs with a diet containing 1% calcium. After this time they will eat litter/eggs as previously described, or more commonly simply shut down the ovary. With this approach, birds may in fact be at 10-15% production before the breeder diet is introduced, because no farm system allows for instantaneous change in feed supply as feed tanks are hopefully never completely empty. There is no justification, therefore, for this old system of feed management, because it will be very detrimental to life-time productivity of today's genetic stocks.

The second system involves the classical pre-breeder diet containing around 2% calcium, which is really a compromise situation. It allows for greater medullary bone reserves to develop, without having to resort to the 3.5% calcium as used in a breeder diet. However 2% calcium is still inadequate for sustained eggshell production - with this diet the breeder can produce 4-6 eggs before ovulation pattern is affected. If a pre-breeder diet is used, therefore, and a moderate calcium level is part of this program, then the diet must be replaced by the breeder diet before egg production starts. A good rule of thumb is to change from pre-breeder to breeder when the very first egg is noticed, because this occurs usually around 10 days before 1% egg production.

Methods of Feeding:

1. Whole grain feeding system
2. Grain and mash feeding system
3. All mash feeding system
4. Wet mash feeding system
5. Pellet / crumbs/ crumbles feeding system
6. Free choice feeding system
7. Restricted and controlled feeding

A well balanced ration improperly fed will not give the most satisfactory result unless a satisfactory method is followed.

1. **Whole grain feeding system**: by this method birds are allowed to have their required ingredients kept them in separate containers. The system though permit birds to balance their ration according to individual needs, however, it appears doubtful. This old and abandoned system offers no particular advantage. While it entails the use of several feed hoppers and a considerable amount of time to keep them filled.
2. **Grain and mash method**: this method is slightly better than the previous one. it involves feeding of grain mixture along with balanced mash. By this, one can increase or decrease the protein level as desired. Unless the poultry man is exceptionally skilled, the method will lead to bad performance.
3. **All mash method**: In this method of feeding, all the feed ingredients are ground, mixed in required proportion and feed as a single balanced mixture. This method is desirable for all types of poultry grown under litter and cage system. By this, birds cannot have the opportunity to have selective eating and more ever the quality of eggs produced are of uniform quality. However, ground feeds are not so palatable and do not retain their nutritive value so well as ungrounded feeds.
4. **Wet mash feeding system:** By this method, all the feed ingredients are ground, mixed in required proportion in single balanced mixture and then sprinkled some amount of water on mash before feed offered to poultry. This method is desirable for all types of poultry grown under deep litter and cage system and chances of fine feed ingredients like mineral and vitamin premixes leftover are minimized. By this, birds cannot have the opportunity to have selective eating and more ever the quality of eggs produced are of uniform quality. Avoid the dustiness of feed as well as less chances of respiratory problems.
5. **Free choice feeding system:** This type of feeding system is common in commercial broiler chickens for achieving fast growth and body weight gain. By this method, birds were fed *ad-libitum* according to their need either in deep litter or cage system of feeding,
6. **Pellet method**: Pellet are made of dry mash under high pressure. These are quite hard and cylindrical shape and are being extensively used in western countries. The greatest advantage in using pellets is that there is little waste in feeding. The disadvantage is that pellet are expensive- about 10% expensive than that of feed not pelleted.
7. **Restricted and controlled feeding:** The method involves restrictions of feeding pullets during 6-20 week of age instead of ad libitum feeding as is practiced at present in most poultry farm. Reduction in feed cost, delayed sexual maturity but improved egg production curve, along with a reduction in the number of small eggs laid are more advantages of this system. Feed restriction to birds can be made by a number of ways, viz.(1) Skip a-day programme: (2) alternate day feeding ,(3) restriction of feeding time, etc.

Important points regarding poultry feeds:

1) Commercial poultry diets are Corn and soybean meal based the most plentiful sources of energy and well-balanced protein,
2) Fish meals and meat meals - Good sources of protein, AAs and also minerals,
3) 30 to 40% of plant P is non-phytin P, which is available to poultry. Should either increase the availability or supplement with inorganic sources.
4) Salt - 0.4 to 0.5% is added to most poultry diets.
5) Supplemental lipids (up to 5% of the diet) - May increase energy utilization through a reduced passage rate, can reduce the heat increment.
6) Yellow pigmentation - Use as much yellow corn as possible plus good sources of xanthophyll, such as alfalfa meal or corn gluten meal, leaf meals for the yellow coloration of the shanks, feet, skin, and egg yolks?
7) Non-nutritive additives e.g., antibiotics (to stimulate growth & control diseases), arsenicals and nitrofurans (to improve performance), Antiparasitic compounds, antioxidative, and antifungal compounds.

Feed conversion ratio/ feed efficiency

The FCR/ feed efficiency is a useful measure of broiler performance. Together with growth rate, days to market and mortality, FCR/ feed efficiency has been considered as one of the important parameters in assessing the potential of bird strain or feeding program etc. The FCR is calculated by dividing feed intake by weight gain, and so values of around 1.6 are common for 42 days old broilers. However, the feed efficiency is calculated as weight gain divided by feed intake, and a corresponding value would be 0.53. Whatever system is used, measures of FCR or feed efficiency are useful in describing feed intake in relation to growth rate. Feed efficiency is, therefore, a useful measure of performance as long as all other factors affecting both growth and feed intake are either minor or do not vary from flock to flock.

Today, we have many factors affecting both growth rate and feed intake, because we have now moved from standardized growing programs to one tailored to meet specific local goals and economic conditions. The single largest factor affecting feed efficiency is energy level of the feed. Five to ten years ago, this was not a major concern because most broilers were fed on diets containing around 3000 kcal/kg in the pre-starter, 3050 kcal/kg in the starter and up to 3200 kcal/kg in the finisher. Now because of high energy prices, and other

management problems, we often see much lower energy values used in one or all diets of a feeding program, and so it is now more difficult to pin-point a standard energy level in the feed. We are also growing broiler chickens over a much more variable time frame, and this also affects feed efficiency. Similarly we now have broilers grown in most countries of the world, and so environmental temperature will affect maintenance energy need, and hence classical feed efficiency.

Diet energy level

It seems as though the broiler chicken is still eating to its energy requirement. It has been suggested that the bird eats to its maximum physical capacity, and that the birds' energy intake can easily be controlled by varying the energy density of the diet. This fact may be true to some extent with the young broiler, because we can temper early growth rate (ascites control programs, for example) by feeding lower energy diets. However as the broiler gets older it does seem to adjust its intake in relation to diet energy level.

As the nutrient level of the diet was reduced, so birds ate more feed. This means that the bird is not eating to physical capacity, because the bird was able to almost double its normal intake on the very low nutrient dense diet. This amazing ability to adjust feed intake resulted in no real difference in 42days' body weight.

As the birds eat more feed at constant growth rate, then feed efficiency starts to deteriorate. However, if we calculate energy efficiency, then the birds on the lowest energy feed were actually the most efficient in converting feed energy to weight gain. This is a good example of classical measures of feed efficiency being totally misleading. It is unlikely that the low energy levels used in Table 1 would be economical, because it is difficult to find low energy ingredients that are inexpensive per unit of energy. However these data do show that we can consider a range of energy levels for the broiler, without affecting growth rate too much, and so diet choice is simply a matter of allowing our formulation programs to select the most optimum solution.

Male vs female birds

The feed efficiency of female broilers will usually be higher (less efficient) than male birds of corresponding weight, after about 30 days of age. The reason for this is that female birds tend to deposit proportionally more fat in the carcass. Body fat takes nine times as much feed energy as required to produce muscle protein/weight. The reasons for this is that fat contains more energy than does protein per unit of weight, and more importantly, muscle is only about 20% protein by weight, the remainder being water. For this reason it is usually uneconomical to grow female broilers much beyond 42 days unless special emphasis is placed

on reducing fat deposition. Likewise with heavy male birds, feed efficiency is going to be greatly influenced by the growth of fat vs muscle.

Bird age

As birds get older, their feed efficiency will deteriorate. This situation is simply due to the fact that heavy birds use increasing quantities of feed to maintain their body mass, and less is used for growth. In the 7 days old bird, about 80% of feed is directed to growth and only 20% is needed to maintain the small body size - consequently feed is used very efficiently. In a 6-week old bird these numbers are reversed such that only 20% of feed is used for growth, and 80% is needed to maintain the ever-increasing body mass - feed efficiency, therefore, deteriorates.

Environmental temperature

The broilers' maintenance needs are greatly influenced by the temperature of its environments. After initial brooding, the bird must use some of its feed to maintain its body temperature. Under ideal conditions of around 20-25 degrees Celsius, the bird uses a minimum of feed to maintain body temperature. In cooler conditions, more diet energy must be used to maintain body heat, (and so less feed is used for growth) and consequently feed efficiency will deteriorate. Feed intake will increase by about 1% for each 1 degrees Celsius below 20 degrees Celsius. Between 20-25 degrees Celsius, the bird will eat about 1% less per 1 degrees Celsius increase in temperature, and so here feed efficiency will improve. Above 25 degrees Celsius (depending upon acclimatization), heat stress conditions can occur, and here feed efficiency will again deteriorate because now the bird is using energy to stay cool (panting, etc.). Under these conditions, efficiency of feed further deteriorates because the bird is reluctant to eat feed, and so proportionally more feed is directed towards maintenance, and less can be used for growth.

Bird health

Obviously an unhealthy bird is likely to have poor feed efficiency. The main reason for this is that feed intake is reduced, and so again proportionally more feed is directed towards maintenance. With enteric diseases there can be more subtle changes in feed utilization because various parasites and microbes can reduce the efficiency of digestion and absorption of nutrients. A bird with sub-clinical coccidiosis is not likely to absorb nutrients with optimum efficiency, because the oocytes will destroy some of the cells lining the gut. More recently the phenomenon of so-called feed passage has been observed in broilers. Undigested feed particles are seen in the excreta, and so consequently feed efficiency will be affected. The exact cause of this problem is unknown, but is most likely the consequences of microbial challenge.

Other measures of feed efficiency

The previous discussion suggests that feed efficiency is a moving target, and today striving for a low numerical value for feed efficiency may not always be the most economical situation. A much more useful measure will be feed cost/kg weight gain, or some further variation of this such as cost/kg deboned meat, etc. A very useful starting point in re-evaluating efficiency of feed use is to consider conversion of feed energy to live weight gain.

Feed efficiency of broilers is affected by bird age, sex, health and environmental temperature, although the major factor is usually diet energy concentration. With a very wide range of diet energy concentrations used worldwide today, classical measures of feed intake: weight gain (or weight gain: feed intake) become less meaningful. The lowest feed efficiency may not always be the most economical, because economics may dictate the optimum use of low rather than high diet energy levels. A more useful measure of feed usage is energy intake per unit of weight gain.

Pre-breeder diets

Using a pre-breeder or pre-lay diet is based on the assumption that the birds nutrient requirements change in this critical period of the birds' life. There are certainly major changes occurring in the birds' metabolism, hopefully related to ovary and oviduct development, and so this is the basis for a specialized diet at this time. With egg-laying stock, pre-lay diets most often involve a change in calcium nutrition, in order to establish the birds' calcium reserves necessary for rapid and sudden onset of eggshell production. The same situation can be applied to heavy breeders today, because with flocks of uniform body weight and with good light management, the subsequent synchronization of maturity leads to rapid increase in egg numbers up to peak production. However, most often pre-breeder diets are used in an attempt to condition or correct growth and/or body compositional problems that have arisen during the 14-18 week growing period. In these situations managers are perhaps ill-informed of the expectations of merely changing diet specifications at this time.

Pre-breeder period

Although there is no specific pre-breeder "period", most consider the 19-23 week period to be the major transition time for sexual development of the bird. During this time (4 weeks) the pullet is expected to increase in weight by about 570 g. This is somewhat more than the growth expectation of around 340 g for the previous 4 weeks (15-19 week) or growth of around 470 g for the 4 weeks from 23-27 weeks of age. It is expected that a significant proportion of this growth spurt will be as ovary and oviduct, which are developing in response to light stimulation. A practical complication of this

expected development is that it invariably coincides with move of the pullets from grower to breeder facilities. Under adverse conditions, such as transportation over long distances, heat stress, etc., then birds can lose up to 100 g of body weight at this critical time. If weight loss is characteristic of such transportation, then pullets should be given an extra feeding. Development of the ovary and oviduct require protein/amino acids and energy (fat) accretion. Nutrients of interest, therefore, are protein and energy, together with increase in calcium for early deposition of medullary bone. However it has never been clearly established that such nutrients need to come from a specially fortified diet versus simply increasing the feed allowance of the grower diet or breeder diet that is introduced prior to maturity.

Following are factors to consider in feeding the bird in the pre-breeder transition period.

Calorie: protein ratio

Calorie: protein ratio may be defined as the metabolizable energy (ME) in Kcal/kg divided by the percentage of crude protein (CP) in the ration of various classes of poultry, The energy: protein ratio varies with the age of the bird.

Calorie: protein ratio of Pre-starter= (3000/22)=136.37

Starter= (3050/21.50)=141.86,

Finisher= (3100/19.50)=158.97

Chicks= (2600/18,50)=140.54

Grower= (2600/15,50)=167.74

Layer= (2700/15,00)=180.00

Significance of calorie: protein ratio:

- Protein and energy are two important components of feed that generates a lot of interest and challenges to nutriationists,
- Because of the ability of poultry to adjust their feed intake to accommodate a wide range of diets with differing energy content.
- When feeding poultry, we have to look at what are some of the factors that can affect nutrient requirements.
- Genetic makeup of the birds are not the same.
- Broiler birds are raised for six weeks, maximum of 42-48 days, they are selected for maximum growth.
- Layer birds are raised for 70-72 weeks, selected for the egg production.
- When feeding these two classes of poultry energy content of the diet is very, very important.

- The most important thing about energy that you need to understand is birds eat to meet their energy requirement.
- Energy is needed to do the work. for broilers, is muscle growth. Work in layer is egg production, egg size.
- When we talk about energy, in poultry, we use the word ME or metabolizable energy. For example, ME of 2,600 kilocalories, the feed consumed will be around 102 grams. If you increase the ME to 2,800, feed consumption comes down to 98 grams.
- Thus the energy content or energy density of the diet goes up, total feed consumed comes down. This is a very important concept in nutrition. As the volume of the feed comes down, it has to be highly balanced to meet all the nutrient requirements.
- Dietary energy content must be specified to maintain the proper ratio of protein to energy so that birds can consume an adequate amount of protein.
- he protein requirement or amino acid requirements can be defined accurately only in relation to the energy density. Also, the degree of fat deposition in meat producing birds can be affected by the relationship.
- Methionine would be first-limiting AA in grain & soybean meal diets, but Lys is likely to become the first-limiting AA if SBM is replaced by another plant protein supplement such as cottonseed meal.
- Restricting protein/amino acids (& energy) to retard growth broiler strains grow at a rapid rate and also mature sexually at an early age)?
- Necessary to retard growth and delay the onset of sexual maturity to optimize the egg production and the production of viable chicks.

Feeding programme of broilers:

- Broiler chicks - Fed *ad-libitum* for 42 days to an average weight of 2-2.5 kg.
- Feed represent 60 to 75% of total production cost. Fed conversion - about 1.65.
- Use a 3-stage feeding program (Pre-starter, starter and finisher) - The pre-starter for the first 10 days, Starter 11 to 35 days, and the finisher for the remainder (36-42 days).
- Feed formulated and meet the nutrient requirements according to BIS, 2007 and/ or ICAR, 2013 feeding standards.

Feeding programme of Laying Hens:

- Higher concentrations of vitamins (A, D, E, riboflavin, pantothenic acid, niacin, and B12) and Mn & Zn would be required if eggs are to be used for hatching. Need about 18 g of protein/bird/d to support optimum egg production,
- 15% CP diet, must consume ≈ 11 kg of feed/100 birds/day.
- Met-first limiting AA and economical to use synthetic Met.
- Ca, P, and adequate Vitamin D - Important for egg shell formation

- Ca requirement - Varies with the age, ambient temperature, rate of lay, and egg size, generally 3.4 g Ca/d & 3.8 g Ca/d after 40 wk of age & 0.3 to 0.4% available P is needed.
- Grits - Can improve feed efficiency slightly, but not when finely ground feeds are fed.
- Phase feeding - To reduce the waste of nutrients caused by feeding more than necessary.

Nutrient requirements of poultry:

- Nutrient requirements are the amount of nutrients required by poultry to support normal function.
- Requirements may be expressed in quantities of nutrients or in dietary proportions.
- Statements or quantitative descriptions of the amounts of one or more nutrients needed by poultry have been provided by various agencies or organizations.
    - In India now days we usually follow BIS specification (2007) and ICAR (2013).
    - In USA and in many other nations the NRC specification is followed.
    - In UK the ARC specification is followed.
    - Some poultry industry also using Degussa (1996 and 2001) specification.
    - However certain commercial poultry farms follow their own standards.
- Poultry feeds must be formulated and prepared so that it provides all of the bird's nutrient requirements.

Nutrient requirements of poultry are affected by various factors:

- Genetics (the species, breed or strain of bird) - Different species, breeds or strains of bird have different average body sizes, growth rates and production levels and will also absorb and utilize nutrients from feed with different levels of efficiency, leading to different nutrient requirements.
- Age - Nutrient requirements are related to both body weight and the stage of maturity.
- Sex - Prior to sexual maturity the sexes have only small differences in their nutrient requirements. Differences in nutrient requirements are larger following the onset of sexual maturity.
- Reproductive state - The level of egg production in hens and sexual activity in males will affect nutrient requirements.
- Ambient temperature - Poultry have increased energy requirements to maintain normal body temperature in cold ambient temperatures and the opposite in hot ambient temperatures.
- Housing system - The type of housing system will influence the level of activity of the birds and therefore their energy requirements.
- Health status - Birds experiencing disease require an increase intake of some nutrients, commonly minerals and vitamins.

Nutrient requirements of chicken as per BIS (2007)

Nutrient	Requirements for various						
	Broiler feed			Layer feed			
	Pre-starter	Starter	Finisher	Chick	Grower	Layer Phase-1	Layer Phase-2
Moisture (%) Max.	11	11	11	11	11	11	11
CP (%) Min.	23	22	20	20	16	18	16
EE (%) Min	3	3.5	4	2	2	2	2
CF (%) Max.	5	5	5	7	9	9	10
AIA (%) Min.	2.5	2.5	2.5	4	4	4	4.5
ME (Kcal/kg) Min.	3000	3100	3200	2800	2500	2600	2400
Linoleic acid (%) Min	1.1	1.1	1.1	1	1	1	1
Lysine (%) Min.	1.3	1.2	1	1	0.7	0.7	0.65
Methionine (%) Min.	0.5	0.5	0.45	0.4	0.35	0.35	0.3
Meth + Cys (%) Min.	0.9	0.9	0.85	0.7	0.6	0.6	0.55
Salt (%) Max.	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Calcium (%) Min	1	1	1	1	1	3	3.5
Total P (%) Min.	0.7	0.7	0.7	0.7	0.65	0.65	0.65
Available P (%) Min.	0.45	0.45	0.45	0.45	0.4	0.4	0.4

Manganese (%) Min.	100	100	100	70	60	60	60
Copper (%) Min.	12	12	12	12	9	9	9
Zinc (%) Min.	80	80	80	60	60	60	60
Iron (%) Min.	80	80	80	70	60	60	60
Iodine (%) Min.	1.2	1.2	1.2	1	1	1	1
Selenium (%) Min.	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Vitamin A (IU/kg) Min	11000	11000	10000	9000	8000	8000	8000
Vitamin D_3 (IU/kg) Min.	3000	3000	3000	1800	1600	1600	1600
Vitamin E (mg/kg) Min.	30	30	30	15	10	10	10
Vitamin K (mg/kg) Min.	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Thiamine (mg/kg) Min.	2.5	2.5	2.5	2	1.5	1	1.5
Riboflavin (mg/kg) Min.	6	6	6	6	5	5	5
Niacin (mg/kg) Min.	40	40	40	40	20	20	20
Folic acid (mg/kg) Min.	1	1	1	1	0.5	0.5	0.5
Pantothenic acid (ppm) Min.	15	15	15	10	9	7	9
Biotin (mg/kg) Min.	0.15	0.15	0.15	0.10	0.10	0.10	0.10
Vitamin B_6 (mg/kg) Min.	5	5	5	3	3	3	3
Vitamin B_{12} (mg/kg) Min.	0.015	0.015	0.015	0.010	0.008	0.008	0.008
Choline (mg/kg) Min.	500	500	500	500	200	400	200
Aflatoxin B1 (ppb) Max.	20	20	20	20	20	20	20

Nutrient requirements of broilers as per ICAR (2013)

Nutrients	White (Age, Days)			Coloured (Age, Days)	
	0-14	14-21	21-42	0-21	21-42
Crude protein (%)	22.00	21.50	19.50	21.60	20.00
Metabolisable energy (Kcal/kg)	3000	3050	3100	2950	3050
Linoleic acid (%)	1.00	0.90	0.90	1.00	0.90
Lysine (%)	1.2	1.07	0.94	1.07	0.98
Methionine (%)	0.52	0.48	0.41	0.48	0.40
Methionine + Cysteine (%)	0.86	0.76	0.70	0.87	0.71
Threonine (%)	0.80	0.78	0.67	0.77	0.72
Tryptophan (%)	0.20	0.19	0.17	0.19	0.18
Arginine (%)	1.35	1.22	1.63	1.22	1.08
Isoleucine (%)	0.80	0.78	0.69	0.78	0.72
Calcium (%)	1.00	0.95	0.85	1.00	0.85
Available Phosphorus (%)	0.45	0.40	0.38	0.45	0.38

Daily requirement during starting (0-3 weeks) and finishing (4-6 or 7 weeks) periods

Nutrients	Type of activity	Requirements
Starting period (0-3 weeks)		
CP	Maintenance	2.403 g CP/kgW$^{0.75}$
	Gain	0.292 g CP/g gain
ME	Maintenance	43.25 kcal/kgW$^{0.75}$
	Gain	3.994 kcal/g gain
Lysine	Maintenance	117 mg/ kgW$^{0.75}$
	Gain	14.53 mg/g gain
Methionine	Maintenance	41.63 mg/kgW$^{0.75}$
	Gain	6.6 mg/g gain
Threonine	Maintenance	80.4 mg/kgW$^{0.75}$
	Gain	10.44 mg/g gain
Finishing period (3-6 or 7 weeks)		
CP	Maintenance	8.637 g CP/kgW$^{0.75}$
	Gain	0.195 g CP/g gain
ME	Maintenance	124.442 kcal/kgW$^{0.75}$
	Gain	3.06 kcal/g gain
Lysine	Maintenance	408 mg/ kgW$^{0.75}$
	Gain	9.632 mg/g gain
Methionine	Maintenance	173 mg/kgW$^{0.75}$
	Gain	3.81 mg/g gain
Threonine	Maintenance	307 mg/kgW$^{0.75}$
	Gain	6.923 mg/g gain

Nutrient requirements of Chicks & Growers (ICAR, 2013)

Nutrients	Laying pullets		
	0-8 wk	8-16 wk	16-18 wk
Crude protein (%)	18.50	15.50	15.00
Metabolisable energy (Kcal/kg)	2600	2600	2700
Linoleic acid (%)	1.00	0.80	0.80
Lysine (%)	0.85	0.65	0.50
Methionine (%)	0.32	0.29	0.27
Methionine + Cysteine (%)	0.65	0.59	0.54
Threonine (%)	0.68	0.58	0.50
Calcium (%)	1.00	0.80	2.00
Available Phosphorus (%)	0.40	0.35	0.32

Nutrient requirements of Layers as per ICAR (2013)

Description	Age (wk)		Age (wk)	
	18-30	18-30	>30	>30
Live wt (g)	1300	1400	1400	1500
Egg Mass (g)	42.5	45	45	50
Shed Temp (^{0}C)	25	25	25	25
Feed Intake (g)	90	100	100	110
Nutrient				
Crude protein (%)	20.00	18.00	16.50	15.00
Metabolisable energy (Kcal/kg)	2750	2600	2600	2550
Linoleic acid (%)	1.10	1.00	1.00	0.85
Lysine (%)	0.90	0.82	0.76	0.68
Methionine (%)	0.40	0.36	0.34	0.32
Methionine + Cysteine (%)	0.78	0.70	0.65	0.60
Threonine (%)	0.63	0.56	0.52	0.47
Arginine (%)	0.93	0.84	0.77	0.70
Tryptophane (%)	0.21	0.19	0.18	0.16
Calcium (%)	3.80	3.61	3.60	3.40
Available Phosphorus (%)	0.36	0.28	0.32	0.30

Feed additives for poultry:

Feed additive is an ingredient or a mixture of ingredients added to the basic feed mix or part thereof, usually in small quantities, to fulfill a specific function, nutritive or non-nutritive. The use of feed additives to improve the efficiency of growth and/or eggs production,

prevent disease and improve feed utilization is a strategy to improve the efficiency of the poultry industry. Now day synthetic feed additives may not enter the market unless authorization has been given following a scientific evaluation. The use and development of enzymes, phytogenics, prebiotics, postbiotics and probiotics has gained momentum in poultry feeding. The enzymes widely used by the industry are the non-starch polysaccharidases that cleave the non-starch polysaccharides in viscous cereals, microbial phytases that target the phytate-complexes in plant ingredients. Proteases are of interest to improve protein and amino acid digestibility, particularly in very young animals. Phytogenics are an alternative to in-feed antibiotics to prevent the risk of developing pathogens and also to satisfy consumer demand for a food chain free of drugs. Probiotic feed additives generally consist of one single strain or a combination of several strains of bacteria, Bacillus spores or yeasts species. Prebiotics are non-digestible food ingredients, such as fructo-oligo-saccharides, xylo-oligo-saccharides, mannan-oligo-saccharides and galacto-oligo- saccharides that are also used in feeds to protect poultry against pathogens. Future research needs to be directed towards understanding how combinations of these additives can be used to improve the efficiency of poultry production.

Various types of feed additives for poultry feeding

1. Antibiotics	2. Anti-oxidants	3. Aromatics/Flavourers
4. Anti-coccidials	5. Emulsifiers	6. Colouring agents
7. Pellet binders	8. Anti-caking agents	9. Herbal preparations
10. Hormones	11. Probiotics	12. Prebiotics
13. Mineral protionates	14. Arsenicals	15. Copper sulphate
16. Grits	17. Pigments	18. Adsorbants
19. Mould inhibitors	20. Enzymes	

Antibiotics:

- Several antibiotics are used as growth promotors or performance enhancers,
- Act by suppressing the microbial load in the gut,
- Thinning of intestinal walls, leading to improve efficiency in absorption of nutrients,
- Avilamycin, flavomycin, virginiamycin, zinc bacitracin, lincomycin, oxytetracycline and chlortetracycline,
- Now-a-days being discouraged due to AMR.

Anti-oxidants:

- These are the substances either natural or synthetic that may prevent or delay some types of cell damage,
- Natural: Beta carotene, vitamin C, vitamin E and selenium (inorganic or organic)
- Vitamin E- 15-30 g/ ton of feed,
- Vitamin C- 100-1000 g/ ton of feed,
- Se (inorganic/ organic) – 0.1 -0.15g/ton of feed,

- Synthetic: BHT/ BHA/ Ethoxyquin- 125 g/ ton of feed

Aromatics/ Flavouring agents:

- Flavouring agents, either in liquid or powder form, miscible with either water or oil, impart flavour or aroma to feed,
- They may be used to improve natural aroma or to mask the original flavour or to give new flavour.

Anti-coccidials:

- Coccidiosis is a major economic parasitic infestation,
- Development of resistance is a major problem
- Ionophores (salinomycin/ madhuramycin, monensin), herbal preparations, PSMs (CT), natural antioxidants are used for prevention of coccidiosis

Emulsifiers:

- Increase surface area of fat for digestion & absorption by dispersing it as droplets in water,
- Chicks in 1st wk of their life may not digest fat properly,
- Fat (animal/vegetable) is added @ 0.5-2% in finisher diets,
- These situations may require emulsification of fats,
- Soya lecithin is a good emulsifier.

Colouring agents:

- Colouring agents for poultry feeds are important to attract the customers,
- Some feed manufacturers now add colours to their feeds.

Pellet binders:

- Bentonites, lignin sulphonate and attapulgite may be used as pellet binders,
- Sodium bantonite has swelling properties, may be used @ < 2% in feed,
- Lignin sulphonate is derived from wood pulping industry and used @ 0.5 – 2.5% in feed,
- Attapulgite used @ < 0.25% in feed.

Anti-caking agents:

- Bentonites and attpulgite may be used as anti-caking agents, dose rate as above in pellet binders.

Herbal preparations:

Several herbal preparations are available, they may act differently and may be useful for several purposes viz.

- Protection of liver against mycotoxins,

- Improve performance,
- Protection against nephro-toxicity,
- Improve Ca & P utilization,
- Stimulate immune response

Hormones:

- Stilbesterol & somatotrophic hormone (STH) have been tried as performance enhancer but restricted their use due to residual effect and now banned as feed additives.

Probiotics/ Direct-fed Microbials (DFM):

Probiotics are live microorganisms/ mixture of live bacteria and/or yeast that are intended to have health benefits when consumed or applied to the body,

The most common bacteria that belong to groups are:

Lactobacillus, *Bifidobacterium*, *Streptococcus lactis, etc.*

Yeast: *Saccharomyces cerevisiae*,

- Stimulate immune response (10^9 to 10^{11}/g tract content).

Prebiotics:

Prebiotics are specific non-starch polysaccharides (MOS, FOS), not digested by chickens but act as a source of food for gut health positive bacteria/ probiotics and also help in improving intestinal health, provide favourable environment for gut health positive bacteria and unfavourable environment for gut health negative bacteria in the host GIT (Dose @ 0.2-0.5%, 0.1-0.2% of diets).

Mineral protionates:

- The absorption and availability of inorganic trace minerals varies depending upon the nature of minerals (sulphate, oxide, carbonate),
- Organic sources are more bioavailable to poultry and animals,
- Commercial preparations of proteinated selenium and chromium are used in poultry.

Arsenicals:

- Arsenicals (0.01% or less) are used for improvement in performance of poultry.

Copper sulphate:

- Copper (20 ppm) as copper sulphate is used in diets, especially for broiler diets.
- It may give beneficial response in health and can also be useful as a mould inhibitor.

Grits:

Stone grits when fed gets lodged in gizzard and help in grinding of feed particles, either stone grits or shell grits or marble grits can be added, they also contribute Calcium to the birds.

Pigments:

Naturally occurring xanthophylls pigments impart yellow colour to egg yolk, body fat, skin, shanks, feet and beak of birds. The most common xanthophylls are zeaxanthin in maize and lutin in alfalfa, they have no nutritive value.

Adsorbents:

Commonly used adsorbents are activated charcoal, zeolite, alumino silicate and bentonite, most commonly used adsorbent is HSCAS (hydrated sodium calcium alumino silicate), combination of HSCAS+Act. Charcol can be more beneficial.

Mould growth:

Stocking of feed ingredients is unavoidable, sometimes feed ingredients may contain more moisture. Fungal infestation and consequent mycotoxin production in stored grains can be inhibited with organic acids like propionic acid, formic acid, acetic acid and benzoic acid but they are corrosive. Copper sulphate may also be used to inhibit moulds.

Enzymes:

Non starch polysaccharides (NSPs) content of a typical maize-soya-DORB layer mash ranges between 20 and 25% and that of broiler from 10-20%. NSPs in feed are cellulose (9-11%), hemi-cellulose (10-12%), pectin, galactosides, B-glucans, etc. Plant ingredients contain nearly 2/3rd of P in phytate, which is unavailable to birds as they do not have phytase enzyme,

Feed Formulation for Poultry:

Ration can be defined as the total amount of feed given to the poultry on daily basis. Poultry feed formulation can be defined as the process by which different feed ingredients are combined in a proportion necessary to provide the poultry with proper amount of nutrients needed at a particular stage of production. There are about 5 conventional poultry feed formulation methods

1. Pearson Square method
2. Algebraic method
3. Two-By-Two Matrix Method
4. Trial and Error Method
5. Linear Programming (LP) Method

Pearson Square method

This method is relatively simple and easy to follow.

Advantages

1) Its simplicity of use and

2) Its usefulness for balancing protein requirement.

Disadvantages

1) Its usability for only two requirements at the same time,

2) Its reduced consideration given to other nutritive requirements especially, vitamins and minerals.

Simultaneous Equation Method/ Algebraic method

This is an alternative method for the square method using a simple algebraic equation. Here, a particular nutrient requirement is satisfied using a combination of two feed ingredients.

Advantages

1) The system is easy to use both by beginners and the experienced feed millers. It is used to introduce feed formulation to students in teaching classes.

2) Farmer can balance for both protein and energy.

3) It is useful in considering more than two feed ingredients at once when balancing more complex ration. Finally, as the requirement increases, the system of equation increases.

Disadvantages

1) It satisfies only one nutrient requirement and uses only two feed ingredients.

2) Level of the nutrient being computed should be intermediate between the nutrient concentrations of the two feed ingredients being used.

Two-By-Two Matrix Method

This method solves two nutrients requirement using two different feed ingredients. A 2 by 2 matrix is formed a set and a series of equations are solved to come up with the solution to the problem.

Trial and Error Method

This is the most popular method of formulating ration for the swine and poultry. It is a type of feed formulation used in many developing nations of the world.

Advantages

1) As the name implies, the formulation is manipulated until the nutrient requirements of the animal are met.

2) This method makes possible the formulation of a ration that meets all the nutrient requirements of the animal.

Disadvantages

1) In poultry feed formation, various cases of mineral deficiency such as osteomalacia, rickets and shellessness or soft shell formation may not be properly addressed.

2) If care is not taken to comprehensively analyze or calculate the level of calcium and phosphorus of the ration in question.

Imami Method

This is an educational way to describe and balance simple rations by a common calculator with a high accuracy for farmers who do not have access to the computer.

Linear Programming (LP) Method

This is otherwise called, least cost computerized feed formulation. This method of determining the least cost combination of ingredients using a series of equations which employs Linear Programming methods. This least cost can employed in feed formulation takes seven basic steps.

Advantages

1) Scientific Approach to Problem Solving: It is the application of scientific approach to problem solving. Hence it results in a better and true picture of the problems which can then be minutely analyzed and solution ascertained.

2) Quality of Decision: LP provides practical and better quality of decisions that reflect very precisely the limitation of the system i.e; the various restrictions under which the system must operate for the solution to be optimal. If it becomes necessary to deviate from the optimal path, LP can quite easily evaluate the associated costs or penalty It guaranteed the finding of optimal solution.

3) Evaluation of All Possible Alternatives: Majority of the problems in animal feed formulation are somehow complicated. LP method ensure that all possible solutions are generated, out of which the optimal solution is selected.

Disadvantages

1) Absence of risk

2) Linear Relationship: It can only be applied to situations where the given problem can be represented in the form of linear relationship. Hence it is based on implicit assumption that the objective as well as all the constraints or the limiting factors can be stated in the form of linear expression. Many practical problems like feed mix problem can be better expressed with a minimum of quadratic equation.

3) Constant Value of objective and Constraint Equations: Before a LP technique could be applied to any feed mix problem, the values or the coefficients of the objective and constraints functions must be completely known and be constant over a period of time. If the values changed during the period of study, the LP would loose its effectiveness and may fail to provide optimal solution to the problem. However, in practical sense it is not possible to determine the coefficients of objective function and the constraint equations with absolute certainty.

4) Fractional solutions often have no meaning: There is absolutely no certainty that the solution to a LP feed mix problem can always be quantified as an integer quite often. It can give fractional answers which are rounded off to the next integer. Hence, the solution would not be the optimal one.

5) Flexibility Limitation: Once a problem has been properly quantified in terms of objective function and constraint equations and the tools of Linear Programming are applied to it, it becomes very difficult to incorporate any changes in the system arising on account of any change in decision parameter. Hence, it lacks the desired operational flexibility. Reducing the world to a set of linear equations is usually very difficult.

6) Multiplicity of Goal: The long term objectives of any farm are not confined to a single goal. Any farm, at any point of time in its operations has a multiplicity of goals or the goals hierarchy- all of which must be attained on a priority wise basis for its long term growth.

A ration is the feed allowed for a given animal or bird during a period of 24 hours. The feed may be given at a time or in portions at intervals.

Ration formulation is a process by which different feed ingredients are combined in a proportion necessary to provide the animal or bird with proper amount of nutrients needed at a particular physiological stage or for stage of production. Ration formulation requires the knowledge about nutrients, feedstuffs and livestock including poultry.

The basic objective of ration formulation for different categories of poultry and swine is to provide the correct amount of nutrients and their intake at a lower possible cost. A mixture of 4-5 feed ingredients could probably meet all nutrient requirements for various classes of poultry and swine. Formulation of commercially prepared poultry and swine diets tend to low in fibre and are cereal based. Cereals and their by-products often comprises between 50-75 percent in poultry and swine diets. They supply high proportion of starch i.e. frequently the lowest cost form of available dietary energy. Animal fats or vegetable oils may also be used as a source of dietary energy up to their inclusion level. Cereals and their by-products may also contribute up to 50 % of the crude protein required in feed but this protein is usually deficient in essential amino acids. Lysine is particularly deficient in protein of cereals and their by-products. Concentrated source of protein must therefore, be used.

Basic inputs/ Prerequisites for Poultry Ration:

To know the nutrient requirements of various classes of livestock and poultry to which the ration is formulated.

2) To know the nutrient composition of feedstuffs/ feed ingredients used for ration formulation.

3) To know the current market price of selected feed ingredients.

4) Easy accessibility and availability of feed ingredients in local market.

5) Physical condition of the available feed ingredients

6) Acceptability and palatability of feed ingredients.

7) Knowledge about nutrient digestibility.

8) Maximum inclusion level of feed ingredients.

9) Interactions or interrelationship of various nutrients present in feed ingredients.

10) Presence of any anti-nutritional factors or toxins in the feed ingredients.

11) Knowledge about proper dose of feed additives / feed supplements in formulated rations.

Nutrient composition of various feed ingredients used for poultry rations

Feed ingredients	Crude protein (%)	ME (Kcal/kg)
Maize	10	3450
Wheat	10	3300
Barley	10	3000
Sorghum	10	3350
Pearl millet	12	3300

Finger millet	9.5	3000
Broken rice	7.5	3250
Rice bran	12	3400
De-oiled rice bran	14	2550
Wheat bran	13	2750
Cassava	2.5	3500
Sweet potato	6	3400
Banana fruit	5	3000
Mango kernel meal	7.5	2400
Sal seed meal	9	2400
Molasses	3	2480
Palm oil	-	8800
Coconut oil	-	8400
Animal fat	-	8800
De-oiled sal seed cake	45	2300
Soybean seed	38	3100
Soybean meal	45-48	2600
Groundnut cake	45	2800
Groundnut cake (solvent extracted)	48	2450
Cotton seed meal	38	2000
Rapeseed meal	40	2320
Sunflower meal	36	2130
Coconut meal	21	1900
Sesame meal	40	2000
Linseed meal	34	1660
Neem kernel meal	38	2550
Alfalfa meal	20	1600
Leucaena meal	22	900
Fish meal	45-50	2850
Blood meal	73	1420
Meat meal	56	2310
Meal cum bone meal	54	2110
Liver residue meal	65	3000
Silkworm pupae meal	48	2900
House fly pupae meal	60	2500
Earthworm meal	66	2400
Poultry feather meal	73	1850

Maximum level of inclusion of various conventional and un-conventional feed ingredients in poultry rations

Ingredients	**Chicks and Broilers**	**Growers and Layers**	**Remarks**
A. Energy Sources			
1. Maize	60-70	60-70	Susceptible to Mycotoxin contamination
2. Sorghum	30	50-60	Bird resistant variety may contain tannins

3. Wheat	20	30	Contains Arabinoxylans, Avidin
4. Rice	10	20	-
5. Broken Rice	10	20	Variable quality
6. Barley	10	20	Contains β-glucans
7. Bajra	30	60	-
8. Ragi	30	60	May not be used in broiler diet.
9. Rice bran	20	30	Susceptible for rancidity while storing.
10. Wheat bran	5	10	Low energy
11. Sal seed deoiled meal	3	6	Contains tannins
12. Cane molasses	2	5	Wet litter problems at higher levels.
13. Mango kernel meal	3	5	Contains tannins
14. Fats and oils	5	5	Cost limits inclusion
15. Tapioca tuber meal	20	30	Contains HCN
16. Leucaena leaf meal	5	10	Contains Mimosine
17. Alfalfa leaf meal	3-5	5-6	Good source of Carotenoides
18. Peanut leaf meal	3	5	Good source of Carotenes
19. Poultry manure meal	0	5	Problems of Pathogens
B. Veg. Protein Sources			
1. Soybean meal	35	25	Trypsin inhibitors
2. Peanut / Ground nut cake	35	25	Prone to contamination with Mycotoxins
3. Cotton seed meal	10	10	Iron suppl^{n} is required to bind Gosypol
4. Sunflower meal	10	20	High in fibre
5. Coconut meal	3	5	Prone to Mycotoxin contamination.
6. Rape seed/ Mustard cake	3	5	Erucic acid, tannins, glucosinolates
7. Safflower meal	5	10	High in fibre
8. Sesame/ Til cake	10	15	High in Phytate and Oxalate
9. Linseed meal	3	5	Linatin/Linamarin&indigestible mucilage.
10. Niger cake	5	10	High in fibre
11. Karanj cake	5	10	Contains Karanjin.
12. Ambadi cake	10	20	High in fibre
13. Maize gluten meal	10	20	Prone to Mycotoxin contamination.
14. Guar meal	3	5	Proper heat treatment is required, toasted.
C. Animal Protein Sources			
1. Fish meal	10	10	Rancidity, microbial contamination.
2. Meat meal	3-5	3-5	Pathogenic microbial contamination.
3. Meat cum bone meal	5	5	″
4. Silk worm pupae meal	2	3	Low in threonine
5. Hatchery by-product meal	2	3	Pathogenic microorganism, rancidity.
6. Poultry by-product meal	5	5	Source of microorganism, low in methionine.
7. Poultry offal meal	3	3	Source of microorganism, low in methionine.
8. Feather meal	2	2	Low in lysine, methionine, tryptophane

Important Anti-nutritional factors (Anti-nutrients) present in feed ingredients

Anti-nutritional factors/ Anti-nutrients	Occurrence in feed ingredients
1. Protease inhibitors eg. Trypsin inhibitors	Soybean seeds
2. Haemagglutins (Lectins)	Castor bean, kidney bean, soybean)
3. Glucosides	
a. Saponins	Soybean seeds, Lucerne leaf meal
b. Cyanogens	Cassava (Tapioca) root, Linseed meal

c. Glucosinolates	Rape and Mustard seed
d. Estrogens	Soybean seeds
4. Phenols	
a. Gossypol	Cotton seed meal
b. Tannins	Sorghum, meals of Rape and Mustard, Sal seed, Mango seed kernel, Leucaena and Tamarind seed
5. Phytate	All vegetable feed ingredients
6. Erucic acid	Rape and Mustard seed meal
7. Mimosine	Subabul (Leucaena) leaf meal
8. Nimbidines	Neem seed meal
9. Oxalates	Vegetable and animal feed sources
10. Anti-vitamins	
a. Anti-vitamin A	Lipoxygenase in Soybean seeds
b. Anti-vitamin D	Soybean seeds
c. Anti-vitamin E	Kidney bean
d. Anti-vitamin K (Dicumarol)	Sweet clover
e. Anti-vitamin B_6 (Linatin)	Lin seed meal
11. Non-starch Polysaccharides	Grains and vegetable protein sources.

Various important steps involved in ration formulation:

Ration formulation should be carried out in a step-wise manner.

For formulation/preparation of 100 Kg ration for broilers, the essential steps are as follows:

Steps I- Minor ingredients are fixed and or slack space may be left to include them later.

Fixed minor ingredients: Trace minerals, vitamins, feed additives

Slack space for – Fat, phosphorus source, calcium source, salt, amino acids and mineral mixture

Fixed minor ingredients and slack space – 5kg

Step II- The levels of animal protein sources are fixed as 8-10 kg.

Animal protein sources – Fish meal: 7 kg

Meat meal: 3 kg

Step III: The level cereal by-products like rice polish, rice bran/ deoiled rice bran, wheat bran if to be added may be fixed as 8-10 kg.

Cereal by-products – Rice polishing/ rice bran: 6-7 kg

De-oiled rice bran: 3-4 kg

Step VI: Vegetable protein sources and energy sources are added to provide the required amount of protein.

Step V: ME content of diet has to be balanced. Any shortfall of ME can be met by supplementation of animal fats.

Step VI: P content of diet is calculated in terms of available P from animal and inorganic sources

Step VII: Supplementation of limestone powder, di-calcium phosphate and bone meal as source of Ca & P.

Step VIII: Limiting amino acids in synthetic form can be supplemented to meet the requirement. Supplementation of synthetic amino acids is the question of economics. The requirement of these limiting amino acids can be met by increasing level of inclusion of animal protein sources.

Step IX: A check is made for the total of the ingredients and also for all the nutrients if desired. If the total is still below 100 kg, cereal or cereal by-products can be added to make the ration 100 kg.

Formulate a balanced ration for pre-starter chicks (CP: 23% amd ME 3000 Kcal) as per BIS (2007) by using **Algebraic method** from various feed ingredients and their nutrient composition given below:

S. No.	Feed ingredients	Crude protein (CP %)	Metabolizable energy (ME Kcal / kg)
1	Crushed maize	10	3450
2	Broken wheat	10	3300
3	Rice polish	12	3400
4	Wheat bran	15	2750
5	Soybean meal	45	2600
6	Ground nut cake	45	2800
7	Fish meal	45	2850
8	Meat meal	56	2310
9	Mineral mixture	-	-
10	DCP	-	-
11	LSP	-	-
12	Common salt	-	-
13	Vitamin premix	-	-
14	Feed additives	-	-
15	Animal/ vegetable fat	-	7600-8800

Solution;

Steps involved in feed formulation: Pre-starter chick feed

A 100 kg of least cost feed is formulated to provide the nutrients as per the specifications.

Step I: Fixed the minor ingredients and slack space: 5% or 5 kg

These include nutrient and non-nutrient feed additives and natural feed ingredients added at a later stage to balance the diet.

Step II: Fixed the animal protein source: 10 kg, These (Fish meal; 7 kg and meat meal; 3 kg) are added to the diets since they are rich source of limiting amino acids (lysine and methionine or methionine + cystine).

Animal protein sources	Parts	CP	ME
Fish meal	7	(45/100) x 7 = 3.15	(2850/100)x7=199.5 kcal
Meat meal	3	(56/100) x3 = 1.68	(2310/100)x3=69.3 kcal
Total	10	3.15 + 1.68 = 4.83	199.5 + 69.3 = 268.8 kcal

Step III: The level of cereal by-products may be fixed: 8-10 kg. Theses (here we use 8 kg) (Rice polish: 6 kg and wheat bran: 2 kg) are used as filler, cheaper sources of energy, protein and B complex group of vitamins.

Cereal by-products	Parts	CP	ME
Rice polish	6	(6/100) x 12 = 0.72	(3400/100) x 6 = 204 kcal
Wheat bran	2	(2/100) x 15 = 0.30	(2750/100) x 2 = 55. 0 kcal
Total	8	= 1.02	= 259 kcal

Step IV: Vegetable protein sources and energy sources are added to provide the required amount of protein.

Out of 100 kg total part fixed as slack space + animal protein sources + cereal by products

= 5 + 10 + 8 = 23 parts (fixed)

= 100 – 23 = 77 kg

Amount of protein from 23 fixed parts provide = 0 + 4.83 + 1.02 = 5.85 kg

That is the remaining 77 kg of ingredients are to provide (23 – 5.85) = 17.15 kg

Soybean meal and ground nut cake are considered as vegetable protein sources, while crushed maize and broken wheat are considered as vegetable energy sources.

Considered average protein value of vegetable protein source (soybean; SBM + ground nut cake; GNC)/ 2

= (45 + 45)/ 2 = 45

Average protein value of vegetable energy source (crushed maize + broken wheat)/ 2

= (10 + 10)/ 2 = 10

The required protein level can be calculated by algebraic equation

Algebraic equation: Total of ingredients = 77 kg

Protein = 17.15 kg

Let X represents the vegetable protein source (SBM + GNC) and Y represents vegetable energy source (Maize + Wheat). The average protein content of vegetable protein source (SBM + GNC) is 45 % and of vegetable energy source (maize + wheat) is 12.5%.

X + Y = 77 kg - (1)

0.45 X + 0.1 Y = 17.15 kg - (2)

Equation 1 is multiply with 0.10

0.10 X + 0.10 Y = 77 x 0.10 = 7.70 - (3)

Now equation 3 is subtracted from equation 2.

0.45 X + 0.10 Y = 17.15 kg - (2)

0.10 X + 0.10 Y = 7.70 - (3)

\- - = -

0.35 X = 9.47

Vegetable protein source (SBM +GNC), X = 9.47/ 0.35

= 27.06 kg

(SBM + GNC)/2 = 27.06/2 = 13.53 kg each i.e. 13.53 kg SBM and 13.53 kg GNC

Equation 1, X + Y = 77 kg

Here X value is = 27.06 kg

27.06 + Y = 77

Y = 77 – 27.06

Y = 49.94 kg

(crushed maize + broken wheat)/2 = 49.94 /2 = 24.97 kg each i.e. 24.97 kg maize and 26.93 kg wheat.

Feed ingredients	CP (%)	ME (Kcal/kg)	Parts	Calculated CP	Calculated ME
Crushed maize	10	3450	24.97	(10/100) x 24.97 = 2.497	(3450/100) x 24.97 = 861.465
Broken wheat	10	3300	24.97	(10/100) x 24.97 = 2.497	(3300/100) x 24.97 = 824.01
Rice polish	12	3400	6	(12/100) x 6 = 0.72	(3400/100) x 6 = 204
Wheat bran	15	2750	2	(15/100) x 2 = 0.30	(2750/100) x 2 = 55
Soybean meal	45	2600	13.53	(45/100) x 13.53 = 6.09	(2600/100) x 13.53 = 351.78
Groundnut cake	45	2800	13.53	(45/100) x 13.53 = 6.09	(2800/100) x 13.53 = 378.84
Fish meal	45	2850	7	(45/100) x 7 = 3.15	(2850/100) x 7 = 199.50
Meat meal	56	2310	3	(56/100) x 3 = 1.68	(2310/100) x 3 = 69.30
Mineral mixture	-	-	1	-	-
DCP	-	-	0.825		-
LSP	-	-	1.50		-
Common salt	-	-	0.5	-	-
Vitamin premix	-	-	0.025	-	-
Feed additives	-	-	0.5	-	-
Animal/veg. fat	-	8800	0.65	-	(8800/100) x 0.65 = 57.2
Total			**100**	**23.02**	**3001.095**

Requirement of CP = 23 % and ME 3000 Kcal for pre-starter chicks as per BIS (2007) and Formulated Ration provide CP = 23.02 % and ME 3001.1 Kcal.

Economizing feed cost:

- Economizing feed cost without impairing productive performance can be achieved by:
- Formulating least cost diets to meet the nutrient requirements/ nutrient need as per specifications
- Inclusion of unconventional feed ingredients
- Home feed mixing
- Avoiding feed wastage
- Increasing efficiency of feed utilization
- Stimulating feed intake in broilers

Feed Storage

Feed from the point of manufacturing until offered to birds has to be stored. During storage, following effects may occur:

- Moisture pickup from environment
- Nutrition destruction
- Oxidation of nutrients
- Insect infestation
- Fungal infestation
- Heat generation
- Combustion
- Rodent effects

Duration of Storage of Feed:

- Purchase and stock feed for 1-2 weeks during rainy season and 3-4 weeks during winter and summer season.
- Stack feed bags on wooden pallets.
- Fresh feed is always better than old one.
- Do not use fermented, damp/ wet feed under any condition.
- Never use infected or caked feed.

Latest Advances in Poultry Nutrition:

- Poultry is globally recognised as a vital aspect of animal agriculture,
- India is 2nd largest poultry market in world & 5th in duck and chickens population,
- It contributes greatly to supply of high-quality protein (meat and egg) for humans,

- Intensification and commercialization of poultry sector is accelerated and continues as a result of research discoveries in the field of nutrition, breeding, housing management and disease control,
- Explosion in poultry nutrition research has significant impact on the success of poultry production.
- Progress in nutritional advancement is made possible by use of several advanced techniques,
- Nutritional approaches are mainly geared towards improving knowledge on ingredients, good for the growth and health,
- Nutritional requirements for various types and classes of birds,
- Ability to match nutritional requirements of any type or class of bird for variable environmental conditions.
- Nutritional research efforts over the years in the 21st Century have been highlighted.

Latest advances in nutritional efforts are still ongoing in the light of new challenges facing poultry industry in terms of:

- Birds' welfare
- Issues of environmental pollution
- Consumers' concerns of food quality and safety

Goal of latest advances in poultry nutrition of include:

1) Select ingredients good for growth & health of bird,
2) Enabling conditions for bird to express its full genetic potential,
3) Eliminate certain disease conditions,
4) Reducing cost of production,
5) Maintaining product quality and allowing for partial alleviation of the adverse effects of environmental factors.
6) Advances in nutrition research are crucial for poulry sector because play a major role in animal protein food production in meeting the needs of ever-increasing world population.

Importance and Growth of Poultry Sector:

- Poultry meat and eggs are cherished worldwide and consumed in various forms.
- They are proteins and a source of essential micro-nutrients such as vitamin A, vitamin B_{12}, riboflavin, calcium, iron and zinc.
- They are important in human nutrition and health.
- Both the meat and eggs are produced in large quantities all over the world for food and income.

- Poultry sector is one of the leading suppliers of meat worldwide
- So much income can be derived from poultry products.
- Poultry sector has the potential to grow faster,
- Highly-productive strains of meat-and egg-type birds,
- Improvements in consumers' incomes,
- Modern technologies for processing feed/poultry products,

Overview of poultry nutrition research and advancement:

- Poultry research appeared in the early 1900's with limited scope (e.g. native birds) and unstructured,
- By the middle of 1900's, there began a surge in research with structured approach in all aspects of production with greater focus on nutrition,
- Realisation of genetic potential of birds, increased productivity, and decreased susceptibity to disease depend on appropriate nutrition,
- Hence the relevance of nutritional research.
- Nutritional research focus in 1950's to 1980's was on production efficiency with the whole bird in mind,
- There was a shift in research focus between 1990's and today to maximisation of biological and economical performance with regards to whole bird or selected organs and tissues,
- There has been more integration of nutrition with microbiology, nutrigenomics and nano-technology,
- Prevailing challenges in poultry sector suggest that future research focus will be more about efficiency of meat/egg production, meat/egg quality and safety for human consumption, feed efficiency to reduce environmental pollution and health and welfare of birds.

Advances in Nutritional Research:

- Advances made in poultry nutritional research with the aim of improving productivity and quality of meat/eggs, welfare of birds as well as environmental sustainability.

By applying:

Modern techniques for feed analysis and

Nutritional experimentation

- Involving novel feed ingredients and/or feed additives, chelated minerals, synthetic amino acids, nano-minerals, mineral toxicity as well as dietary management strategies to curtail problems and constraints of poultry health and environment.

Feed analysis:

- Surest way of meeting the nutrient requirements having adequate knowledge of nutrient contents of various feedstuffs available,
- Feed analysis required with regards to nutrient composition and anti-nutrient contents,
- It is performed by using latest techniques:
  - Automatic Kjeldahl Analyser for protein determination,
  - Soxflo method for fat determination
  - Amino Acid Analyser for amino acids/ protein estimation
  - Megazyme enzyme kit for starch determination in cereals,
  - Fibre Analyzers for determination of NDF and ADF,
  - AAS for mineral estimation, HPLC for nutrients & ANFs,
  - NIR for moisture, CP, ME, digested amino acids, etc.,
  - Aflatoxicometer / ELISA kit for Mycotoxins estimation.

Need based feed formulation:

- Feed formulation is crucial in meeting nutrient requirements of poultry and avoid excess nutrient supply or deficiency,
- Advances are made possible by computer operated feed formulation software/ Least-Cost formulation software.
- Use of advance technique in diet formulation greatly reduce the cost of feeding birds; which may account for affordability of poultry products,
- The most valuable advance technique is the use of NIRS
- this technology enables feed manufacturer to rapidly measure ME and DAA in real time,
- ME and DAA are the main dietary components considered in poultry feed formulation.

Efficiency of feed utilization:

Advances made with respect to determination of feed utilisation by using various latest techniques viz.

- Growth assay technique,
- In vivo and In vitro digest-ibility techniques,
- Inert marker technique,
- Caecetomy, Ileotomy and Ileal assay technique,

Advantages of these techniques among others are high precision data, reduction in duration and cost of experimentation, less labour intensive, use of small feed samples, avoid use of live birds for experiments, and rapid routine feed quality assessments.

Use of novel feed ingredients:

- Industrial processing of grains, a lot of by-products have been generated which are available for poultry feeding,
- Cereal offal's, oilseed meals, brewer's dried grains, distillers dried grain with solubles (DDGS), etc.
- Lesser used feedstuffs i.e. barley, rye, sorghum, cassava and grain legumes are increasingly being processed for feeding.
- Agro-forestry waste are being harnessed for feeding due to advances in feed processing technologies and analytical tools,
- The essence of using these novel feed ingredients is to serve as alternatives for conventional feed ingredients such as maize and animal proteins (fishmeal, meat and bone meal).
- This is aimed at reducing feed cost or curtailing dependency on these conventional feeds, particularly in developing economies.

Use of feed additives:

- They are employed in diets in order to improve digestive efficiency so that productivity is enhanced up to the mark,
- They include enzymes, synthetic amino acids, commercial preparations of vitamins/trace minerals, probiotics, prebiotics and toxin binders etc.,
- Commercial enzyme products aimed at augmenting the endogenous enzymes secreted in the gut of birds when fed in the diet so as to improve availability of nutrients,
- Researches on enzyme usage is necessitated by wide use of vegetable proteins (legumes and oilseed meals) and some cereal grains in poultry diets.

Enzymes:

- Phytate is also considered as anti-nutritional factors because it binds protein, amino acids and minerals like Ca, Mg, Mn, Zn, Cu and iron,
- Addition of external enzymes capable of breaking down NSPs and phytate will help in reducing anti-nutritional effects of NSPs and phytate and enhancing nutrient availability,
- Cocktail targeting the NSPs should be able to contribute:
- 200 units cellulase, 1000 units of xylanase, 400 units of pectinase for 1 kg of feed.
- Phytase is added in practical diets @ 500-700 FTU/ kg feed for broilers and 400-600 FTU/ kg feed for layers to substitute 0.1 to 0.12% phosphorus.

Probiotics:

Probiotics are live microorganisms/ mixture of live bacteria and/or yeast that are intended to have health benefits when consumed or applied to the body,

The most common bacteria that belong to groups are:

Lactobacillus, *Bifidobacterium*, *Streptococcus lactis, etc.*

Yeast: *Saccharomyces cerevisiae*,

They stimulate immune response (10^9 to 10^{11}/g tract content).

Prebiotics:

Prebiotics are specific non-starch polysaccharides (MOS, FOS), not digested by chickens but act as a source of food for gut health positive bacteria/ probiotics and also help in improving intestinal health, provide favourable environment for gut health positive bacteria and unfavourable environment for gut health negative bacteria in the host GIT (Dose @ 0.2-0.5%, 0.1-0.2% of diets).

Use of nano-minerals:

- Use of nano-minerals in poultry nutrition is a recent concept that is gaining importance as a result of varied application of nanotechnology in poultry production systems.
- This has to do with alteration of particle size to few nano meters (1–100 nm) and various studies proved that feeding of nanoparticle improved digestive efficiency, immunity, growth rate, performance, resistance to pathogens, quality of meat and eggs in birds.

Combating metal toxicity:

Several researches have highlighted the problems of metal toxicity in poultry which led to the establishment of nutritional guidelines on safety levels to protect both birds and humans from metal toxicity,

Nutritionally beneficial ones for good health but whose dietary excesses create health problems include Fe, Cu, Mn & Zn, etc., whereas poisonous ones which may contaminate feeds from the environment include arsenic, mercury, lead, cadmium, vanadium, etc.

Production of designer eggs/ meat:

- Dietary modification/ manipulation played a major role in the production of nutritionally-improved eggs/ meat referred to as “Designer Eggs/ meat”.
- By way of nutritional manipulations of the cholesterol content and its fractions, lipid profile, fatty acids, amino acids, minerals and vitamins can be modified to produce healthy eggs/ meat for human consumption,
- This can also be done through addition of therapeutic pharmaceutical compounds.

Nutritional management, GIT conditioning and poultry health:

- Some of these nutritional strategies with positive impact on poultry welfare:
- Manipulation of diet composition (dietary ME/CP as a way of controlling body composition to prevent body fatness of market broilers/fatty liver haemorrhagic syndrome in layers),
- Addition of linoleic acid and linolenic acid to prevent lesions or supplemental fats/oils to increase dietary ME values,
- Use of Ca & P (2: 1), or vitamin D to prevent bone problems,

- Use of supplemental mineral/vitamin boost normal health,
- Use of feed enzymes, probiotics improve feed efficiency with added advantage of less sticky excreta and control diseases,
- Dietary modifications to help birds cope with stress, particularly under hot climatic conditions
- Use of synthetic amino acids to increase amino acid intake,
- Use of fat to help decrease heat increment,
- Use of sodium supplement as bicarbonate for maintenance of blood electrolyte balance, use of vitamins such as vitamins C, E and A to help in heat and other types of stress.

Future nutritional research focus:

- Feed formulation soft wares and feeding programmes,
- Use of modern feed analysis techniques,
- Novel feed ingredients and feed additives,
- Gastro-intestinal conditioners for gut health, birds' welfare and food safety,
- Modern technologies for feed processing and feeding packages,
- Peri-natal nutrition and epigenetic programming.

Latest advances in poultry nutrition have contributed significantly to poultry production over the years. Progress in nutritional research is made possible by several advanced techniques that have been developed and tested by numerous researchers both in academia and industry. Appropriateness of any techniques to be used depends on the facilities available at the research site and the cost involved. In future, latest advances in poultry nutrition will require scientists to use extensive interdisciplinary approaches.

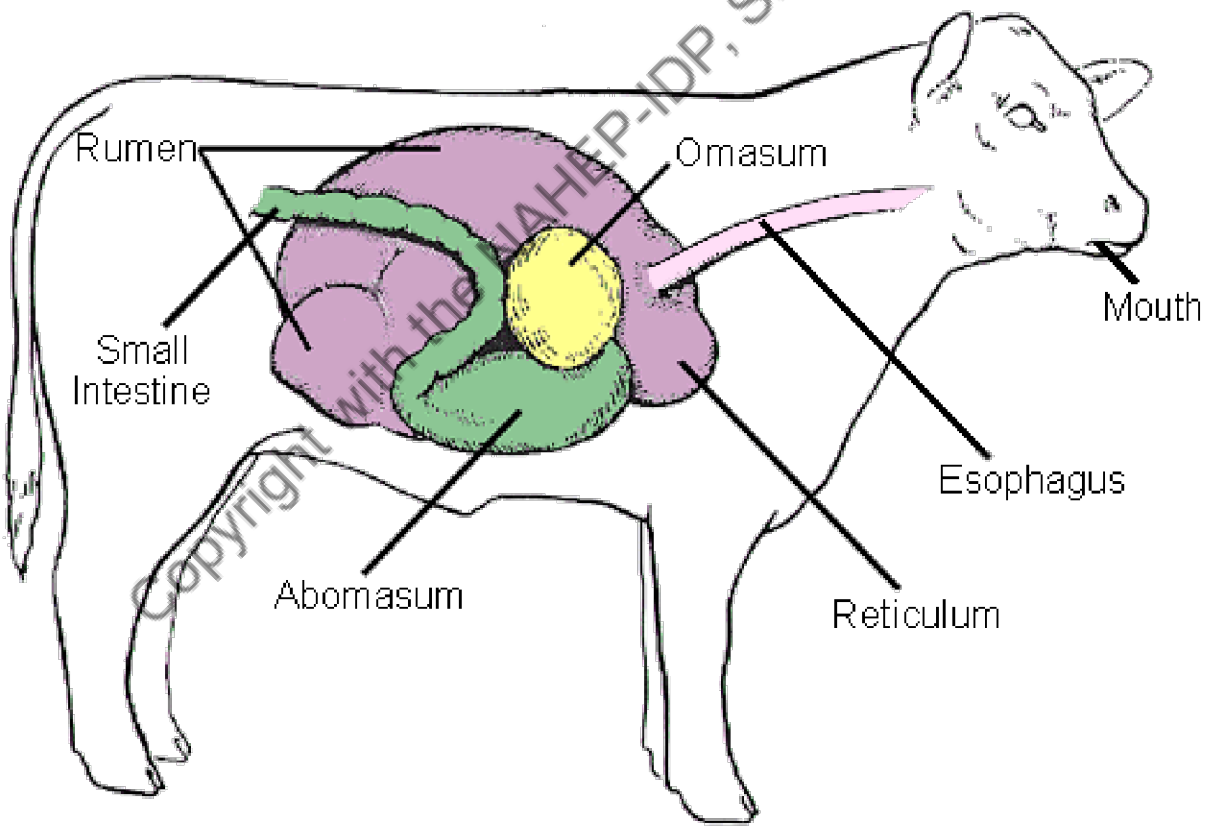
CHAPTER-IX

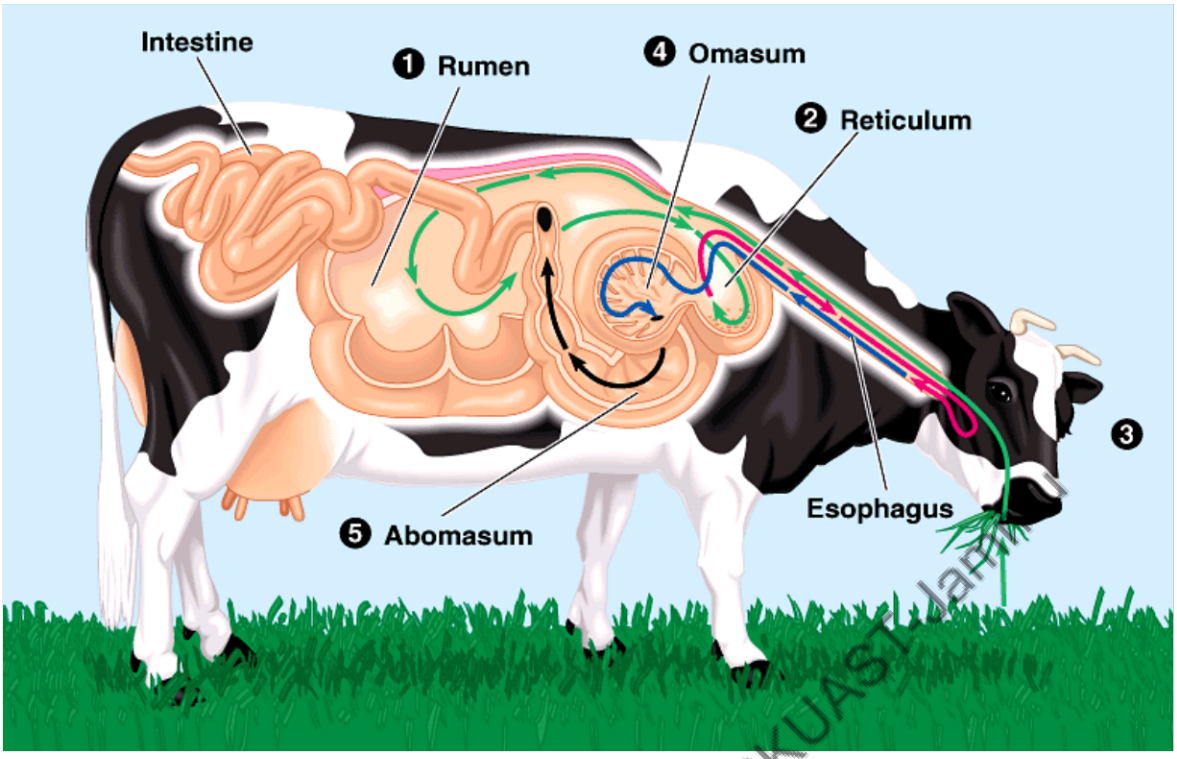
RUMINANT DIGESTION

Digestion in Ruminants:

- Ruminants are referred to the plant-eating mammals including Cattle, Buffaloes, Sheep, Goats, Deer, Bison, Giraffes, and Yaks, etc.
- Hoofed mammals
- Unique digestive system that allows better use of energy from fibrous plant material,
- Cud-chewing mammals have four chambers stomach (***polygastric***) used for their digestion.
- Obtain their nutrition from plant products by adapting to a certain process called **rumination**,
- Action of rumination, they ferment the feed, regurgitate and chew their feed before the main digestion process.

Ruminant Digestive Tract:





Ruminant Digestive Systems:

- Functions of the digestive system of animals include:
  - ingestion (eating)
  - chewing (mastication)
  - swallowing (deglutition)
  - absorption of nutrients
  - elimination of solid wastes (defecation)

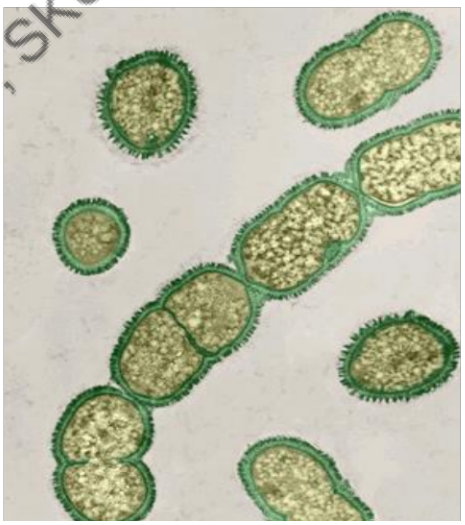
Stomach compartments:

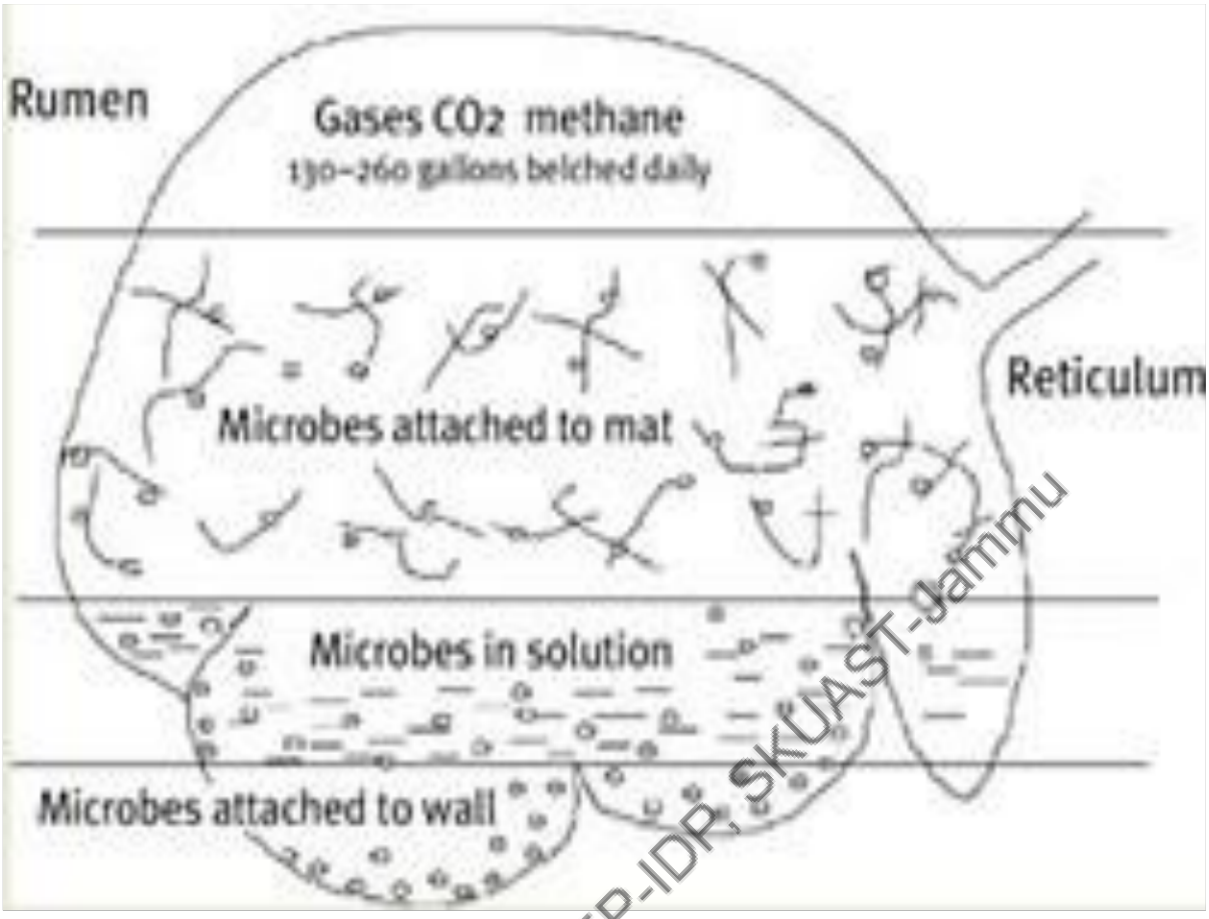
Rumen	(80% of capacity)
Reticulum	(5% of capacity)
Omasum	(7% of capacity)
Abomasum	(8% of capacity)

Rumen:

- Large fermentation vat
- Microorganisms break down cellulose
  - Bacteria, protozoa & Fungi
  - Creates lost of gases (methane)
  - Ruminants have to be able to eructate (belch)
- Roughages are reduced in size
- Rumen bacteria= 10^9 to 10^{11}
- Rumen protozoa=10^4 to 10^6
- Rumen fungi= 10^5 to 10^7
- Rumen archae=10^{10} to 10^{11}

Role of rumen microbes





Importance of rumen microbes

- Increasing the production of microbes in the rumen is the key to lifting milk production and composition.
- Microbes break down feed to produce volatile fatty acids, which are used by the cow as energy for maintenance and milk production.
- Rumen microbes are also digested and absorbed in the small intestine of the dairy cow as the main protein source for milk production, providing up to 70-90% of a cow´s protein requirements.

Reticulum:

- Collects objects that shouldn't be in the digestive system.
  - Nails
  - Screws
  - Baling wire
- Magnets are placed into many dairy animals reticulum.
- Honeycomb like structure

Omasum:

- Works to remove water from the food
- Absorbs fatty acids

Abomasum (True Stomach):

- Glandular Stomach (like yours)
- Secretes digestive juices.
- Breaks down food stuff further for absorption.
- Absorbs some nutrients.
- **Rumen** - the organ that allows for bacterial and chemical breakdown of fiber.
    - The rumen has a very thick, muscular wall
    - It fills most of the left-side of the abdomen
- Looks like carpet due to papillae lining it
- Fermentation vat
    - Primary digestion site for ruminants
    - Microbial digestion takes place here
    - Breakdown cellulose, simple sugars, and Nitrogen containing compounds like protein
- Physical mixing and breakdown
- Not active in the early stages of life

Reticulum holds approximately 5 gallons in the mature cow.

Rumen and reticulum are considered one organ because they have similar functions and are separated only by a small muscular fold of tissue thus collectively referred to as reticulo-rumen.

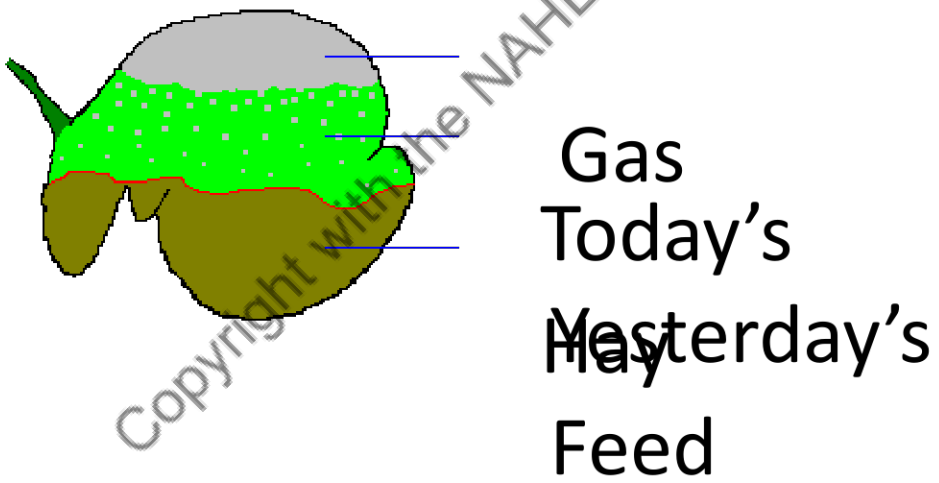
Omasum and abomasum hold up to 15 and 7 gallons, respectively, in mature cattle.

Reticulo-rumen is home to a population of microorganisms (microbes/rumen bugs) that include bacteria, protozoa, and fungi.

- Rumen is sometimes called paunch, it is lined with papillae for nutrient absorption and divided by muscular pillars into dorsal, ventral, caudodorsal, and caudoventral sacs.
- Rumen acts as a fermentation vat by hosting microbial fermentation.
- About 50-65% starch and soluble sugar consumed is digested in the rumen.
- Rumen microorganisms (primarily bacteria) digest cellulose from plant cell walls, digest complex starch, synthesize protein from NPN, and synthesize B vitamins and vitamin K.
- Rumen pH typically ranges from 6.5 to 6.9.
- Rumen environment is anaerobic (without oxygen).

- Gases produced in the rumen include CO_2, CH_4, and H_2S. The gas fraction rises to the top of the rumen above the liquid fraction.
- Omasum is spherical and connected to the reticulum by a short tunnel. It is called many piles or butcher's bible in reference to the many folds or leaves that resemble pages of a book.
- These folds increase the surface area, which increases the area that absorbs nutrients from feed and water. Water absorption occurs in the omasum. Cattle have a highly developed, large omasum.
- Abomasum is the true stomach of a ruminant.
- It is the compartment that is most similar to a stomach in a non-ruminant.
- Abomasum produces hydrochloric acid and digestive enzymes, such as pepsin (breaks down proteins), and receives digestive enzymes secreted from the pancreas, such as pancreatic lipase (breaks down fats).
- These secretions help prepare proteins for absorption in the intestines.
- The pH in the abomasum generally ranges from 3.5 to 4.0.
- The chief cells in the abomasum secrete mucous to protect the abomasal wall from acid damage.

Rumen Feed Storage



Ruminant Feeding Types

Based on the diets they prefer,

Ruminants can be classified into distinct feeding types:

1) Concentrate selectors,
2) Grass/roughage eaters, and

3) Intermediate types.

Concentrate selector's small reticulorumen and selectively browse trees and shrubs.

Example: Deer and giraffes

- Select plants and plant parts high in easily digestible, nutrient dense substances such as plant starch, protein, and fat.
- They are very limited in their ability to digest the fibers and cellulose in plant cell walls.

Grass/roughage eaters (bulk and roughage eaters) Example: Cattle, Bufalloes and sheep.

- Depend on diets of grasses and other fibrous plant material.
- They prefer diets of fresh grasses over legumes but can adequately manage rapidly fermenting feedstuffs.
- Grass/roughage eaters have much longer intestines relative to body length and a shorter proportion of large intestine to small intestine as compared with concentrate selectors.

Intermediate types they prefer forbs and browse such as woody, shrubby type plants.

- Example: Goats
- This group of ruminants has adaptations of both concentrate selectors and grass/roughage eaters.
- They have a fair though limited capacity to digest cellulose in plant cell walls.

Carbohydrate Digestion:

Forages:

On high-forage diets ruminants often ruminate or regurgitate ingested forage.

This allows them to "chew their cud" to reduce particle size and improve digestibility.

As ruminants are transitioned to higher concentrate (grain-based) diets, they ruminate less.

- Inside reticulo-rumen, forage is exposed to a unique population of microbes that begin to ferment and digest the plant cell wall components and break these components down into carbohydrates and sugars.
- Rumen microbes use carbohydrates along with ammonia and amino acids to grow.
- Microbes ferment sugars to produce VFAs (acetate, propionate, butyrate), methane, hydrogen sulfide, and carbon dioxide.
- VFAs are then absorbed across the rumen wall, where they go to the liver.
- Once at the liver, VFAs (propionates) are converted to glucose via gluconeogenesis. For higher milk production,
- Acetate is rezuired for milk fat synthesis as well as increase milk fat content,
- Butyrate is directly absorbed from rumen wall and converted into ketone bodies
- Plant cell walls are slow to digest, this acid production is very slow.

- Coupled with routine rumination (chewing and rechewing of the cud) that increases salivary flow, this makes for a rather stable pH environment (around 6).
- Relative concentrations of VFAs are also changed, with propionate being produced in the greatest quantity, followed by acetate and butyrate.
- Less methane and heat are produced as well.
- Increase in VFA production leads to more acidic environment (pH 5.5).
- Shift in microbial population by decreasing forage using microbial population and potentially leading to a decrease in digestibility of forages.
- Lactic acid is a by-product of starch fermentation.
- Lactic acid production, coupled with increased VFA production lead to metabolic acidosis.
- Acidic environment leads to tissue damage within the rumen and can lead to ulcerations of the rumen wall.

High-Concentrate Feedstuffs (Grains)

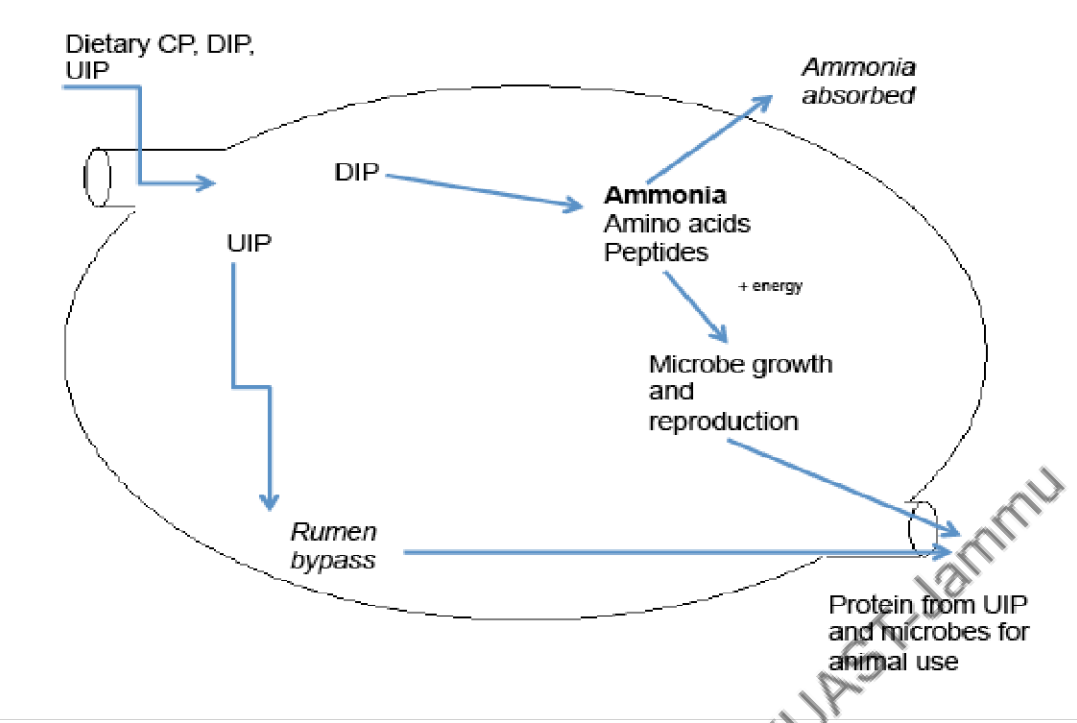
- On high-grain or concentrate rations, digestion process is similar to forage digestion, with a few exceptions.
- On a high-grain diet, there is less chewing and ruminating, which leads to less salivary production and buffering agents' being produced.
- Additionally, most grains have a high concentration of readily digestible carbohydrates, unlike the more structural carbohydrates found in plant cell walls.
- Readily digestible carbohydrate is rapidly digested, resulting in an increase in VFA production.

Two sources of protein are available for the ruminant to use:

1) Protein from feed and
2) Microbial protein from the microbes that inhabit its rumen.

- Ruminant is unique in that it has a symbiotic relationship with these microbes.
- Like other living creatures, these microbes have requirements for protein and energy to facilitate growth and reproduction.
- During digestive contractions, some of these microorganisms are "washed" out of the rumen into the abomasum where they are digested like other proteins, thereby creating a source of protein for the animal.

Protein Digestion



Rumen degradable Protein

- RDP = MCP (g/d) x 1.18
- When either RDP or energy is deficient relative to others
- Excess RDP relative to energy is lost as NH_3
- Excess energy relative to RDP results in less than optimal fermentation

Microbial Nitrogen

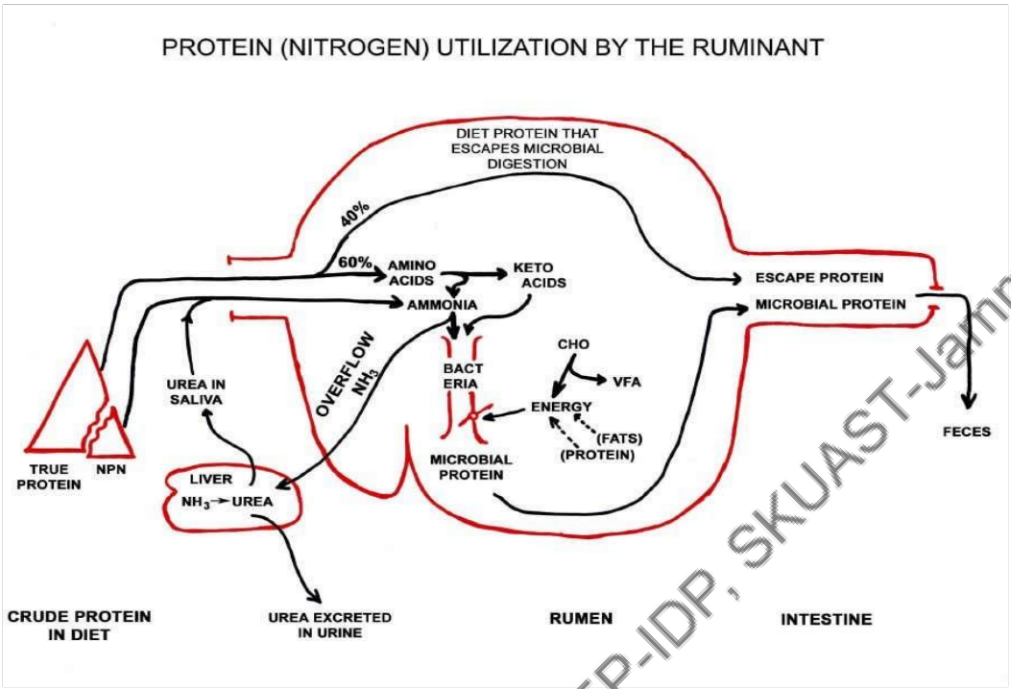
- Microbial N entering SI (%of Non-NH3-N)
- High protein diet-40%
- Low protein diet-60%
- Exclusive NPN diet-100%
- Limiting factors would include carbon and/or energy source.

Nutritive Value of Microbial Nitrogen

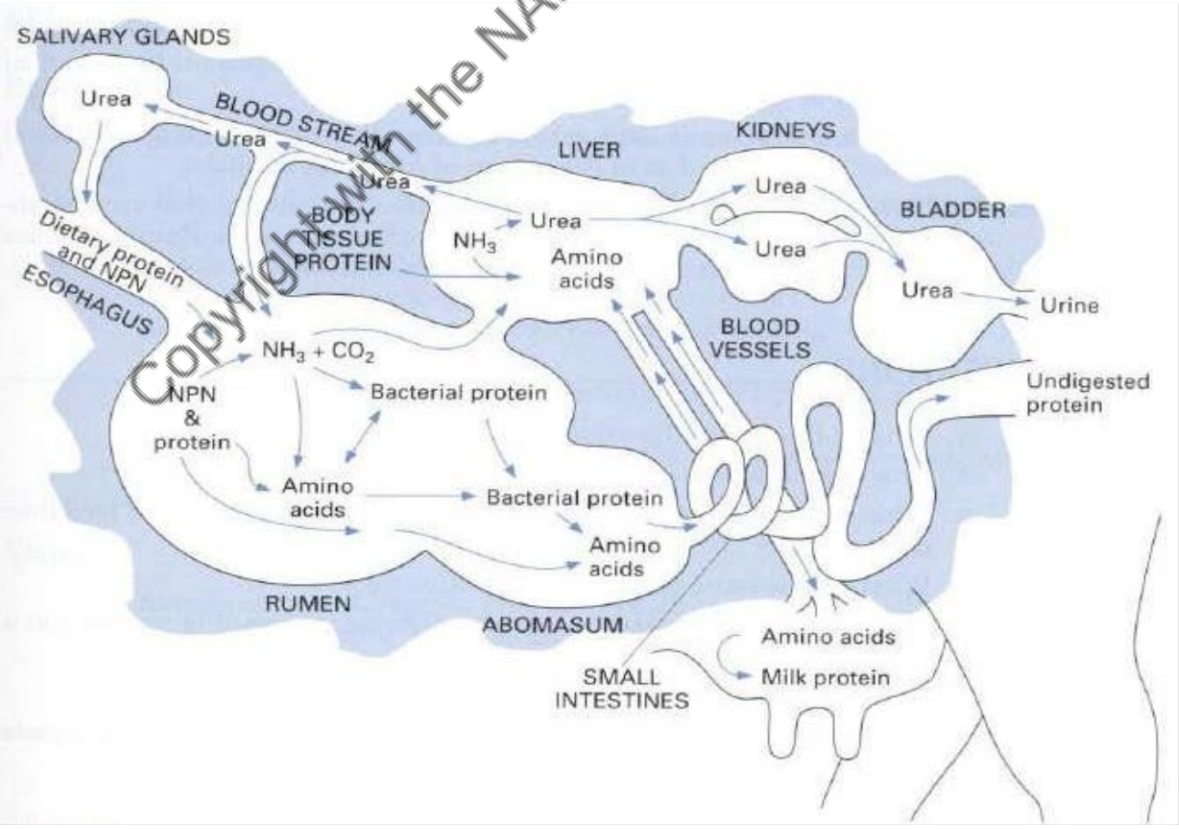
- Increases value of low quality feed N
- Decreases value of high quality feed N
- Animal can survive on NPN
- Can survive on low amount of recycled N

Microbial Protein Synthesis

- Microbial growth is dependent upon amount of carbohydrate fermented in the rumen,
- MCP (g/d) = 130 x kg TDN
- MCP is 80% true protein and 80% digestible
- 1 lb MCP provide 0.64 lb MP



Protein pathway in ruminants



Fat digestion in rumen:

Two major processes occur within the rumen:

- Composition and distribution of the lipid components of the digesta and their sub-sequent metabolism within the intestine. These processes, which are intrinsically bound together, are lipolysis of dietary lipids and hydrogénation of their unsaturated fatty acid constituents.
- Most important aspect of rumen function, namely the formation of short-chain (C2-C5) fatty acids.
- These make an immense contribution directly to the lipid metabolism of the host animal after absorption from rumen and also indirectly through their involvement in bacterial and protozoal lipid synthesis.
- Digestive system of ruminants optimizes use of rumen microbe fermentation products.
- This adaptation lets ruminants use resources (such as high-fiber forage) that cannot be used by or are not available to other animals.
- Ruminants are in a unique position of being able to use such resources that are not in demand by humans but in turn provide man with a vital food source.
- Ruminants are also useful in converting vast renewable resources from pasture into nutritious food products for human use and other inedible products (such as horns and bone), hides, fertilizer etc.

CHAPTER-X

VITAMIN NUTRITION

Vitamin Nutrition:

Researchers have made important advances in understanding the significance of vitamin adequacy to sound livestock and poultry nutrition. Vitamins are essential micronutrients, required for the optimum general health and physiological functions such as development, growth, maintenance and reproduction.

Vitamins exert catalytic functions that facilitate nutrient synthesis, thus controlling metabolism and affecting the performance and health of poultry. Vitamins in poultry feeds have two origins; they are natural components of the ingredients used to prepare the diet and they can be added as a supplement in a concentrated form.

There are many vitamins (fat-soluble vitamins: A, D, E and K; and water-soluble vitamins: B1,B2,B6,B12, folic acid, pantothenic acid, biotin, niacin and vitamin C) needed for optimal poultry health. The use of these nutrients in sufficient quantities can improve animal health. Most vitamins cannot be synthesized by birds and must be provided by feed, however, the feed alone is not sufficient to cover vitamin requirements. Diets supplemented with vitamins play an important role in disease treatment and prevention; because vitamins allow an animal to use proteins and energy for health improvement, FCR, growth, production and reproduction.

If vitamins are absent from the diet or improperly absorbed or utilized, specific diseases or deficiency syndromes occur. Deficiency of vitamins might cause disease states in poultry. Ruffled plumage, cessation of growth, incoordination, weakness, ataxia, xerophthalmia and blindness occur due to deficiency of vitamin A. Exudative diathesis and encephalomalacia are seen due to deficiency of vitamin E. Polyneuritis, perosis, impairment of food utilization and curled toe paralysis occur due to deficiency of vitamin B complex, and anaemia due to folic acid and vitamin B12 deficiency. There are some vitamins such as vitamin B12, folic acid, pantothenic acid and biotin, etc. which are essential for the normal development of the hemopoietic organs and erythropoiesis. Vitamins may be used with drinking water to get good results in BWG, hematological indices and biochemical profiles without any harmful effects on broiler chickens. Vitamins may improve the development of the intestinal mucosa and protect enterocytes from proapoptotic oxidant stress. The proper ratios of the fat-soluble vitamins and the combination of the four vitamins – A, D, E and C, as a vitamin emulsion

positively affected the performance of livestock and poultry. Vitamins improve the physiological and health status of livestock and poultry.

Vitamin A

Vitamin A is necessary for the visual development, growth, reproductive physiology, and maintenance of the integrity of epithelia and the skeleton. Also, it supports an optimum immune response and thus diminishes the susceptibility to infection. Supplementation of vitamin A at a level higher than recommended is preferable to aid normal development of the reproductive organs and membrane integrity of dairy animals and poultry hens under heat stress. The effectiveness of vitamin A @ 16,000 IU/kg diet can improve the productive performance parameters of livestock and poultry. Vitamin A addition to the diet can prevent inhibition of growth performance in poultry that may be deficient in this vitamin. Vitamin A levels required to maximize immunocompetence have been displayed to be much higher than that necessary for the feed efficiency and optimum growth. Dietary vitamin A at a high level of 12,000 IU/kg feed augmented the antibody titre against Newcastle disease virus of hens under heat stress. Vitamin A is necessary for the epithelial tissue integrity that represents the main defence against the entry of pathogens. Also, Vitamin A is useful in increasing antibody synthesis against pathogens that are able to get into the body. Vitamin A encourages antibody responses to T-cell–dependent antigens and induces protective antitumor immunity by some mechanisms such as enhancement of migration to lymph nodes and induction of cell differentiation. Additionally, vitamin A under heat stress is a vital antioxidant that minimizes lipid peroxidation. Its supplementation in female quail's diet improved the development and growth of the reproductive system accompanied by high levels of follicle-stimulating hormone. Generally, vitamin A improves the productive performance, immunity and reproductive system of livestock and poultry.

Vitamin D

Vitamin D3 is created naturally by the sunlight action on the skin of most mammals and all birds. Vitamin D3 is an important nutrient for bone growth and has a critical role in biological pathways such as immune function, calcium (Ca) homeostasis and cellular proliferation and differentiation. Also, vitamin D is associated with various physiological processes, including bone mobilization and mineralization and phosphorus (P) and calcium absorption. Supplementation of vitamin D induces the intestinal absorption of phosphorus and calcium, encouraging the production of calcium binding protein in the mucosa, activating the

calcium-activated tenderisation complex by the increase in the plasma calcium concentration. Also, it increases the re-absorption of Ca and P in the renal tubules and impacts the calcification process by boosting the uptake of minerals by bones. Higher levels of vitamin D in the diet increase absorption of Ca and P and improve bone strength and consequently leg health. Additionally, vitamin D regulates the parathyroid hormone secretion and stimulates many tissues with vitamin D receptors. Therefore, deficiency of this vitamin can lead to decrease in productivity and the appearance of metabolic disorders. The dietary addition of 25-hydroxyvitamin D (25(OH) D_3) decreased the incidence of tibial dyschondroplasia and had an affirmative influence on the quality of bone in broiler chicks. . Vitamin D3 addition alleviated the clinical signs of tibial dyschondroplasia disease by inducing maturation of chondrocytes. In laying hens, vitamin D plays a role in the optimal function of the skeletal system, strengthening the claws, beak and bones. It also has a positive impact on the quality of eggshells produced by layers. 1,25-dihydroxyvitamin D3 (1,25(OH)2D3) has an immunomodulatory property in chicken macrophages. Vitamin D induced upregulation in the expression of both pro- and anti-inflammatory cytokines.

Therefore, the presence of high doses of vitamin D3 or its derivative 25(OH)D3 above the recommended levels has a positive influence on the immune system particularly when dietary levels of calcium are low. Irrespective of form, the apparent total tract digestibility of calcium was higher in diets enriched with vitamin D. The apparent total tract digestibility of phosphorus was higher in 3,000 IU/kg feed of vitamin D2 compared to the other treatments. The utilization of calcium and phosphorus by laying birds can be enhanced by the addition of different sources of vitamin D in rations. Finally, the deficiency consequences of this vitamin are serious, including rickets, poor growth and immune response and also reduction of the production. Thus vitamin D can support bone growth and development, immunity and stabilize calcium-phosphorus metabolism in livestock, poultry and in human being.

Vitamin E

Vitamin E (a-tocopherol) is a biological antioxidant and contributes to the improvement of growth performance and physiological and immunological status of broiler chickens due to its ability to reduce lipid peroxidation and neutralize free radicals in both skeletal muscle and plasma. Vitamin E, selenium and carotenoids are the prime antioxidant components in poultry feed. The deficiency signs of clinical vitamin E include exudative diathesis, muscular myopathy and encephalomalacia in chicks (disturbance of the nervous system), as well as some subclinical vitamin E deficiency such as slow growth performance, diminished fertility and

frequent health problems. Therefore, the antioxidant properties of vitamin E were investigated regarding its vital role in the prevention of diseases that occur due to lipid peroxidation and protein oxidation via a free radical mechanism.

Moreover, vitamin E has a significant role in the improvement of health by boosting both humoral and cell-mediated immune functions. Vitamin E protects the phospholipids of sub-cellular and cellular membranes from the destruction by the lipid oxidation and therefore maintains the functionality and morphological integrity of tissues and cells of the organism. Vitamin E has been found to improve antioxidant defense, immune response and physiological functions of birds. It may have an effect on gene regulation e.g., glutathione peroxidase (GSH-Px) gene.

Dietary vitamin E supplementation for commercial broilers significantly improved the immune response and antioxidant concentrations in the liver. Also, a-tocopherol helps in the resistance and prevention of many diseases through its modulatory effect on the immune system by the macrophage activation and antibody production. The levels of dietary vitamin E (40 or 80 IU/kg feed) may alter the immune function, including the innate cellular oxidative immunity of broiler chickens. The direct impact of vitamin E on the immunological system is through inhibiting protein kinase C in the lymphocyte and monocyte cells, and decreasing the secretion of immunosuppressive factors such as hydrogen peroxide. Also, the improved immune response by supplementation of vitamin E in broiler chickens may be due to its antioxidant properties and ability to reduce concentrations of plasma corticosterone. Vitamin E-rich diet may reduce stress by suppressing the catabolic response in the body, causing improvement of the production indices, including increased BW revealed that the use of vitamin E in the diet decreased the mortality rate of male broiler chickens. As an important micronutrient, vitamin E optimizes the reproduction and performance of farm animals.

Moreover, it safeguards the ovarian follicles from oxidative damage and also has an important function in egg production by facilitating the yolk precursor (vitellogenin) release from the liver. Vitamin E (2 g a-tocopherol acetate/kg feed) augmented carcass mass and decreased the content of the abdominal fat of broilers. This form of vitamin E constitutes the second line of anti-oxidant defense in biological systems, and is the main lipid-soluble antioxidant, breaks the chain of lipid peroxidation in the membrane of cells and prevents the lipid hydroperoxides formation. There is a favorable influence of vitamin E on the sensory and technological quality of meat. Vitamin E addition in the diet had a significant influence on chicken meat quality by reducing juice drip and increasing the water-holding capacity of meat.

Improved meat quality is reflected in higher sensory grades. Finally, vitamin E plays a role in growth, immunity and the protection of biological systems against oxidative damage as well as in meat and meat products. Thus vitamin E acts as antioxidant, improves immunity, fertility, growth and development in livestock and poultry.

Vitamin K

Vitamin K regulates the production of some coagulation factors in the blood such as prothrombin and clotting factors (VII, IX and X) which are involved in stopping uncontrolled bleeding from wounds. Therefore, deficiency of this vitamin increases blood clotting time leading to hemorrhagic diseases in organs and tissues. Also, vitamin K is important in relation to bone formation and re-modeling which may be due to the fact that osteocalcin (one of the main bone proteins) depends on vitamin K. Vitamin K-dependent carboxylation of bone matrix proteins is regarded as important for bone matrix calcification.

Additional vitamin K3 (10mg/kg feed) in the diet led to higher proximal tarsometatarsus cancellous bone volumes of laying hens. A study conducted on male broiler birds for seven weeks to assess the effect of dietary vitamin K levels on bone quality and growth performance. The result of this experiment advocated the inclusion of 8mg/kg feed and 2mg/kg feed of vitamin K in the diet of starter and grower broilers, respectively. Vitamin K supplied in different concentrations improved the carboxylation of osteo-alcin and increased the hydroxyapatite binding ability of serum osteocalcin and therefore improved the bone quality. In contrast to this, some researchers have investigated the effect of vitamin K deficient diet supplied to the laying hens for a time period of 28weeks. Reduction in the concentration of skeletal/bone protein gamma-carboxyglutamic acid (Gla) and altered blood clotting was observed. But despite of the insufficient vitamin K level, no significant adverse effects on skeletal metabolism in laying hens, their growing progeny embryos and young chickens were noticed. The effect of vitamin K supplementation in hen's diet on hatchability was also studied. Thus, vitamin K improves bone development, growth performance, blood clotting and egg development in poultry and health and production performance in livestock.

B complex group of vitamins

B vitamins have very important functions in metabolism of poultry, as most of them represent coenzymes that fuse with larger enzyme molecules to accelerate many metabolic processes. Vitamins B1, B2, B6, biotin, pantothenic acid and niacin are involved in energy

metabolism, but folic acid and vitamin B12 exert their activity in the cell and growth maintenance.

Thiamin (vitamin B1) is actively and rapidly absorbed from the small intestine and then is transformed by phosphorylation into the active coenzyme – thiamin pyrophosphate that is involved in the oxidative decarboxylation of ketoglutaric acid and pyruvic acid. The reactions generate succinyl CoA and acetyl-coenzyme A (CoA) that are involved in proteins, lipids and carbohydrates metabolism. The deficiency symptoms of thiamin in poultry that included weight and appetite loss, weakness, heart failure (sudden death syndrome), fatty degeneration of the liver, mucosal inflammation, atrophied ovaries and reduced egg production.

Riboflavin is an essential constituent of two major coenzymes, flavin adenine dinucleotide (FAD) and flavin mononucleotide (riboflavin-50-phosphate). The coenzymes play major roles in the development, growth, cellular function and energy production and metabolism of steroids, fats, and drugs. This vitamin is phosphorylated in the mucosa of the intestine to flavin mononucleotide during absorption and then converted in the liver to FAD. Riboflavin is an essential factor of flavin enzymes (flavoproteins) that are involved in the transfer and transport of hydrogen inside the respiration chain and consequently contributes to energy production. Riboflavin supports the maintenance of the normal concentration of homocysteine in the blood. It is required for the proper functioning of the cellular antioxidant protection, metabolism, and nervous system in chickens. As such, riboflavin is a vitamin that is required for the growth and overall good health in poultry.

Vitamin B6 (pyridoxine) plays an important role in the metabolism of fatty acids, carbohydrates and amino acids and displays a critical function in the production of energy by the citric acid cycle. Pyridoxine is functionally important as pyrodoxal phosphate (co-factor of various enzymes) in the transformation of amino acids and assists in the synthesis of proteins required for immune responses. Some studies have reported the importance of vitamins during embryonic development. In ovo vitamin B6 administration (40, 60, 80 and 120 mg/egg) significantly augmented the hatchability percentage in Japanese quail. Also, in ovo injection of vitamin B6 (100 mg/egg) significantly increased BW at 28 days of age. Vitamin B6 is involved in the erythrocytes formation and the activities of growth hormone, insulin, thyroid, gonadotropic and adrenal hormones. Vitamin B6 is essential for brain development and function and benefits the body to synthesize serotonin, melatonin and norepinephrine hormones.

Vitamin B12 belongs to a specific group of cobalt containing coronoids with biological activity in animals and humans. It is available commercially for addition to the feed as cyanocobalamin. It is an essential constituent of some enzyme systems that carry out a number of basic metabolic functions in the body. This vitamin plays a central role in the homocysteine metabolism, energy metabolism, blood function and the immune system. Vitamin B12 works as a co-factor for methionine synthase and L-methylmalonyl-CoA mutase, and improved ducks hematological parameters such as white and red blood cells and their well-being. Vitamin B12 plays a central role in the normal functioning of the nervous system and brain as well as regulation and creation of nucleic acids (DNA and RNA). Moreover, it participates in fatty acid metabolism and energy generation. Erythrocytes require this vitamin for their proliferation and maturation, therefore, erythrocytes lacking vitamin B12 cannot be mature what can lead to hemolysis and hyperbilirubinemia, which may cause cardiovascular diseases and depress immunity.

Vitamin C

Vitamin C (ascorbic acid) increases disease resistance in birds by strengthening the immune system. It plays a significant role in the biosynthesis of corticosterone, a hormone that enhances energy supply during stress. Of note, poultry can produce vitamin C. Ascorbic acid is synthesized in the kidney in birds, and in the liver in some mammals. The endogenous production of this vitamin is usually considered as not sufficient for the biological demands in poultry, especially during severe environmental conditions. Therefore, classical deficiency of this vitamin does not take place in poultry, but it has been shown that additional ascorbic acid has positive effects under stressful conditions.

The concentration of vitamin C increased the performance and could improve carcass traits in birds reared under heat stress. Dietary vitamin C supplementation (200mg/kg feed) provided protection against the risk of high stocking density and improved final BW, reduced mortality percentage and down-regulated HSP70 expression level in the liver. Vitamin C (100 and 200mg/kg feed) exerted a positive influence on laying, egg fertilization and hatchability indices. Vitamin C improves the absorption of iron (Fe) leading to increase in the hemoglobin level and red blood cells. The supplementation of 200mg/kg feed of ascorbic acid was beneficial for improving immunity and performance and for exploiting the full genetic potential of the commercial broilers. Also, vitamin C plays a major role in cellular antioxidant defenses. Vitamin acts as an antioxidant by reacting with all oxygen species and the formation of dehydroascorbyl (a particular inert radical), as well as by transferring radical equivalents from lipid phases. Through regulation of gene expression like GSH-Px gene, vitamin C has been

found to prevent oxidative stress, improve immune response, and modulate physiological functions. Finally, the effectiveness of vitamin C is primarily due to its potent role as an antioxidant. Therefore, it is very important in poultry farms in high-temperature zones due to its important role in alleviating stress.

CHAPTER-XI

ADVANCES IN RUMINANT NUTRITION

A number of advances have been made with regard to the search of newer feed resources, feed additives, bypass nutrients and preparation of feed blocks.

AGRO-WASTES of JAMMU AS FEED RESOURCES

Global trends of increasing food production and processing has led to the generation of large quantities of food waste and by-products. The food waste is generated at every step of food production, processing and consumption. In developed countries, food waste generation amounts to 42%, 39%, 14% and 5% from households, industry, food service and in distribution channels respectively (HLPE, 2014).

Disposal of these food wastes and by-products is a management, economic and environmental problem. It has been estimated that for each ton of food waste there is an emission of about 2 tons of CO_2 (European Union, 2012). Many of these residues, however, have the potential to be recycled into other production systems.

In order to reduce waste generation, organizations around the world are strongly encouraging the agro-industrial sector to find alternate channels to use these residues (RedCorn *et al.*, 2018).

Approximately 1.81 million tonnes of fruit and vegetable wastes are generated in India and most of these are being disposed by dumping in the landfills and rivers, inflicting environmental pollution (Bakshi *et al.*, 2016).

The utilization of less traditional feeds may provide farmers with a variety of economically sound feeding options and conjointly contributes to alleviation of environmental issues related to their disposal (Ermgassen, 2015). By-product feed resources may impact traditional ruminant feeding practices by reducing the amount of concentrates fed to ruminants, providing feeding options when there is a scarcity of feed and reducing feed cost (Nkosi and Meeske, 2010).

Olive cake

Olive *(Olea europaea* L.*)* oil industry by-products are promising unconventional feedstuffs (Bashir, 2011; Ashraf, 2011 and Ahmad, 2011). Both cultivation of olive trees and olive oil extraction generate substantial amounts of by-products, which are potential pollutants. For 1000 kg of olives the three-phase procedure generates 550 kg of olive cake while the two-phase procedure produces 800 kg of olive cake (Molina Alcaide and Y´a˜nez Ruiz, 2008).

In India, Rajasthan, Punjab, Maharashtra, Himachal Pradesh and Jammu and Kashmir are taking keen interest in olive production. In Jammu and Kashmir about 423 ha of land is presently under olive plantation in Jammu province. Olive cake production is presently about 16.5 metric tons of olive cake, which is available at almost no cost from olive oil extraction mills.

The integration of olive cake in ruminant ration is limited. Main limiting factors are low crude protein; relatively high fat content; high fiber and lignin content all contributing to its poor digestibility. Depending upon the processing, crude protein in olive cake varies between 8 and 12% DM, but most the foreign workers have claimed that almost 80 to 90% of nitrogen is fixed on lignocellulose, thus not digestible (Sansoucy, 1985).

A series of experiments has been conducted at authors' laboratory regarding utilization of locally available olive cake in goat ration. In the pilot study, crude olive cake was included in the goat ration as a replacer of maize grain. It was found that on 25% replacement of maize by olive cake, the ration can sustain the maintenance requirement of adult goats, even though the dry matter and organic matter digestibility is slightly negatively impacted by the olive cake inclusion. However, balances of nitrogen, calcium and phosphorus and blood-biochemical parameters were not impacted by replacing maize with olive meal up to 25% in the ration. When replacement levels higher than 25% were tested *in vitro,* significant decline in dry matter degradability were noted (Bashir, 2011).

Various theories have been advanced to explain the reason for poor digestibility. High fat content, its composition and lingo-cellulosic nature of olive cake have been suggested as the incriminating factors. Buysse (1962) has shown that ruminants are sensitive to intake of fat above 5 per cent of dry matter in the ration. Further, Nefzaoui (1983) suggested that there is the same phenomenon of "protection" of carbohydrates related to lignin with olive cake as occurs with straw and when olive cake was treated with alkalis it's *in vitro* digestibility increased by almost four times.

Taking a cue from this, chemical treatment of olive cake was attempted in subsequent studies. Treatment with slaked lime {$Ca(OH)_2$} was employed to address both the factors that limit the utilization of olive cake. In principle, lime can help in weakening ligno-cellulosic structure of olive meal, as well as it can form calcium salts with the free fatty acids of olive, thereby alleviating their depressing action on digestibility and still maintaining their availability to the animal. Lime treatment caused significant decrease in OM, NFE, NDF, ADF and hemicellulose percentage and significant increase in total ash and calcium content in lime treated olive cake. Inclusion level of olive cake can be increased from 7.5% of concentrate mixture (25% maize replacement) by untreated crude olive cake to 12% of concentrate mixture (40% maize replacement) after treatment with slaked lime (Ashraf, 2011).

Urea treatment can also be used to improve utilization of olive cake by ruminants. Urea significantly increases the CP % of olive cake and IVDMD of the composite ration and was able to alleviate the digestibility depression caused by olive meal inclusion. 40% of maize in conventional concentrate mixture can be replaced by urea treated olive meal (12% olive meal in ration) without any effect on intake, nutrient digestibility and nitrogen balance of adult male goats (Ahmad, 2011).

It appears that olive cake is one of that feedstuff that blurs the demarcation between concentrate and roughage. Utilization of olive cake can be further increased in the ration by incorporating lime treated olive cake in complete feed on ADF replacement basis, where its high fibre content can act as roughage and high fat content can act as a replacer of carbonaceous concentrate feedstuffs. Study on this line in authors' laboratory revealed that olive cake can be included in complete feed at 30% level (w/w; 40% ADF replacement) for feeding of adult male goats without compromising nutrient intake, utilization and general performance of the animal (Ahmed, 2013).

In contrast to olive cake available in Europe, only a small percentage of nitrogen present in Indian olive cake was found to be lignin bound and thus unavailable to the animal. The acid detergent insoluble nitrogen (% total nitrogen) was 21.71%, whereas the neutral detergent insoluble nitrogen (% total nitrogen) was 38.86%. Around 78 % of nitrogen is likely to be available to the ruminant. Fraction A which gets instantaneously solubilised in rumen and is cent percent digested in the intestine was 33.69%. The protein fractions likely to be degraded in the rumen were 56% and undegradable dietary nitrogen component was 22.29% (Ahmed, 2013).

The olive cake incorporation in the ruminant ration can significantly improve economics of feeding and can effectively address the waste disposal problem that will increase dramatically with increase in Indian olive production.

Kinnow-Mandarin fruit waste

The development of citrus processing units in India has increased the problem of effective disposal of wastes. These fruits, after extraction of juice, produces significant amount of waste that consists of peel (flavedo and albedo), pulp (juice sac residue), rag (membranes and cores) and seeds. These components, either individually or in various combinations, are available for utilization as ruminant feedstuffs (Ensminger *et al.*, 1990). Citrus fruit by-product contains a relatively large amount of pectin and soluble carbohydrates, and for this reason can be used to replace cereal concentrates in ruminant diets.

'Kinnow,' a hybrid between king and willow mandarins (*Citrus nobilis* Lour x *Citrus deliciosa* Tenora) is one of the important citrus fruit crops in Northern Indian States (Sharma *et al.,* 2007). Jammu and Kashmir produces 19070 MT of citrus fruit (NHB, 2010), majority of which is produced in Jammu Division and out of which a considerable share is that of Kinnow-mandarins. Kinnow residues are rich in carbohydrates but poor in protein and account for approximately 55 to 60 % of the weight of the raw fruit (Kalra *et al.,* 1989). These residues can be a potential source of energy rich feed for livestock thereby reducing the cost of livestock feeding and simultaneously sparing a considerable amount of grains and grain byproducts for alternative use.

Kinnow mandarin waste (KMW) can be utilized in two forms. They can either be sun dried and then pulverized to form coarse powder and then can be used as an energy supplement in livestock ration or they can be preserved as silage with or without additives.

In the study conducted at authors; laboratory, KMW in dried form was incorporated up to 40% level in the concentrate mixture without any effect on intake, nutrient digestibility and nitrogen balance of adult male goats. However, Kinnow wastes are deficient in phosphorus and thus, KMW containing ration require additional phosphorus supplementation to maintain Ca:P ratio in the diet (Kour, 2012).

However, drying is not always the practical approach and thus, it would be convenient to develop economical and efficient method of preservation that would enable these perishable wastes to be utilized as animal feeds for longer periods of time. KMW can be ensiled after slight wilting (to 30% DM), if drying is not a practical alternative. In authors' laboratory, study was conducted to assess the ensilability of KMW and its utilization in goats. To cater for skewed calcium: phosphorus ratio of KMW, disodium hydrogen orthophosphate was added to KMW while ensiling at the rate of 2.5gm per kg. Colour of silage produced was yellowish without any discoloration or black/brownish spots. Odour of the silage was pleasant fruity and pH of silage was 3.8. Lactic acid concentration (% DM) was 8.14 in KMW silage and concentration of ammonia nitrogen (per cent of total nitrogen) was 3.3%. The soluble carbohydrate content was found to be 1.86% in KMW silage. There was significantly ($P<0.01$) lower pH and significantly ($P<0.01$) higher lactic acid concentration in KMW silage when compared to conventional oats silage prepared simultaneously. *In vivo* trial in the same study revealed that adult male goats can be maintained on the silage of Kinnow waste without affecting nutrient intake, utilization and general performance of animals (Malla, 2013).

Maize Cobs

Maize is one of the most important cereal crop grown in Jammu province of J&K. Maize harvesting leaves back large volume of maize cobs that are customarily burned or ploughed into the soil. Although, the energy digestibility and nitrogen content of these cobs are low (Alhassan and Aliyu, 1991) and digestible energy intake from these materials may not meet the maintenance requirements of ruminants (Fonseca *et al.,* 2001), like other lignocellulosic feedstuffs the nutritive value of maize cobs may be upgraded by applying different treatments.

Walnut cake

India stands seventh in walnut production with *85 thousand hectares as the total area under walnut in India and with an annual production of 107 thousand MT.* Jammu and Kashmir contributes around 98% of the country's output. The state produces about 86,263 tons from an area of 61,723 hectares. Walnut production is common in Badrawah, Poonch, Kupwara, Baramulla, Bandipora, Ganderbal, Budgam, Srinagar, Anantnag and other hilly areas of Jammu and Kashmir. Edible walnut kernels are used for producing edible oil which is used in medicines and cosmetics. Non-edible walnut kernels produce non edible oil which is used by soap industry for making soaps. About 40% of the weight of the kernels is oil and upon extraction almost 52% of the weight is yielded as walnut cake. The cakes produced from both types of kernels may be used for feeding of livestock.

Boiled potato peel waste

Potato (*Solanum tuberosum*) is one of the most important food crop in the world, with its increasing role in assuring food security and combating malnutrition programs. World production of potatoes in 2017 was 388.19 million metric tonnes with China as the lead producer followed by India (48.6 million metric tonnes; FAOSTAT, 2019).

Processing of potatoes generates large quantities of by-products that have huge potential as farm animal feedstuff (Bakshi *et al.*, 2016). The 4 main potato by-products are 1) potato peels; 2) screen solids (small potatoes and pieces); 3) fried product; and 4) material from the water recovery systems (oxidation ditch, belt solids, filter cake) (Dhingra *et al.*, 2013). There is huge variability in their nutrient content with their dry matter (DM) content (10 to 30%), CP (5 to 27% on DM basis), starch (3 to 56% on DM basis), NDF (4 to 41% on DM basis), and ether extract (3 to 37% on DM basis) (Nelson, 2010).

As all sorts of potato food processing starts with the step of peel removal, the generation of potato peel is unavoidable (Liang and McDonald, 2014). Industrial processing generates between 70 and 140 thousand tons of peels worldwide annually (Chang, 2011). Potato peels constitute a major waste of potato processing that ranges from 15 to 40% of the initial product's mass (Ajila *et al.*, 2012; Akyol *et al.,* 2016; and Gebrechristos and Chen 2018). Potato peelings and culled potatoes are attractive feedstuffs because of their availability, higher energy concentration and low cost (Monteils *et al.*, 2002).

Pressure cooking of potatoes prior to peeling is a routine processing method in India. This generates boiled potato peels with variable amount of attached pulp along with high

moisture content as waste. In addition to a significant loss of biomass (Nelson, 2010), disposal of this highly perishable waste (Waterer and Thomson, 2008) itself is very problematic.

Cooking renders the potato starch susceptible to enzyme attack and destroys the anti-nutritional factors, thereby increasing palatability and utilization (Whittemore, 1977). The major component of potato peel is suberin, an insoluble biopolyester, that is digestible by the ruminants (Brown and Kolattukudy, 1978). In raw potato protease inhibitors are present which are water soluble and heat labile (Whittemore 1977); boiling the potatoes helps in inactivation of such inhibitors (Nicholson *et al.*, 1988).

Traditionally potato peel waste has been reported to be used for producing low value animal feed (Nelson, 2010), fertilizer or as raw material for biogas production (Wu, 2016). These usages causes waste of abundant nutritive materials present in potato peels, which has been documented to possess antioxidant, antibacterial, apoptotic, chemo-preventive and anti-inflammatory activities (Liang *et al.,* 2014).

Potato by-products suffer from a similar limitation as green fodder. If it is not consumed, it often gets mouldy and sour, and therefore unlikely to be used as an animal feed (Nkosi and Meeske, 2010). Drying and ensiling are two options for preserving high moisture by-products (McDonald *et al.*, 2011). Drying process is costly and may not be affordable to the resource- poor farmers (Nkosi and Meeske, 2010).

Interest in conserving by-products by ensiling is steadily increasing, largely due to the increase in their use as animal feeds (Megias *et al.*, 1998; and Bakshi *et al.*, 2006). Properly ensiled silage from high moisture by-products can replace costly feeds such as maize silage in ruminant diets (Itavo *et al.*, 2000; Lallo *et al.*, 2003; and Pirmohammadi *et al.*, 2006). Utilization of potato by-products for animals feed may also eliminate a substantial pollution problem for the potato industry and provide a feedstuff which might be beneficial to cattle production (Pen *et al.*, 2006).

In authors laboratory boiled potato peel waste has been used in the form of silage and the results revealed that potato peel waste silage may be utilized as a component of adult goat ration without affecting nutrient intake, digestibility, plane of nutrition and nutrient balance (Raina, S., 2019).

Ram Lamb fattening-

Under the existing small ruminant production system the slaughter weight of lambs and kids in the country is lower and age at which usually achieved is much higher. The system of raising lambs for meat under grazing with supplementation although is cost effective, the procedure has not been largely adopted by the farmers due to their poor economical background and age old traditional practices. Grazing with supplementation has potential for still higher production. The major advantage of this programme is that the sheep owner can rear the animals only for six months and not for the whole year. He will get handsome profit after six months, which is at par with the lambs reared for 11-12 months under extensive grazing system. This technology would help the farmers in reducing the time period of rearing from 11-12 months and getting almost same profit per animal in addition to avoiding the mortality risk and unnecessary rearing of lambs for the whole year.

Objectives

• To rear the lambs with improved feeding for gaining desired body weight in a shorter period.

• To avoid the risk of high mortality in lambs

• Weaning age can be reduced from 90 to 60 days

Technical Feasibility

Scheme Area

This programme can be implemented in States having large population of sheep like Rajasthan, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and North and Sourashtra regions of Gujarat. The selected area should be nearer to veterinary aid, livestock market and bank branch.

Selection of lambs

Fat lamb production is a commercial programme. The profit earned after 6 months of rearing after weaning under semi intensive system is at par with or more than that earned after rearing lambs for 11-12 months under range condition. By selective breeding and intensive selection in some of the important indigenous sheep breeds of Malpura, Sonadi Muzafarnagari, Madras Red, Mandya, Nellori, Deccani, Marwari, Patanwadi and Dumba, lamb fattening programme can be successfully implemented in these breed tracts and in the States having large sheep population.

Housing

Normally sheep do not require elaborate housing facility. They should be protected against inclement weather and predators. Shelter should be provided with gunny bags or temporary removable protections made of thatching material and bamboo.

Feeding

In India sheep are traditionally maintained on extensive range management with supplementation of top feed resources during lean season. Due to progressive shrinkage of grazing land and market requirement of quality meat for local consumers as well as export market, fattening lambs are to be maintained on grazing / feeding on roughages with supplementation of concentrate feed on 80:20 basis.

Management of lambs

• The lamb should be taken care of to a maximum extent for better survival during the early period of life.

• Weaning can be done at two months of age.

• Lambs may be ear tagged or tattooed on the ear for identification.

• Use sterilized and clean knife for castration and docking and resort to proper legation and antiseptic dressing.

• During castration, keep the lambs on perfectly dry, clean and hygienic site so as to minimize the risk of loss from tetanus.

• The lamb should be protected against ecto and endo parasites by first month and vaccinated against enterotoxaemia and sheep pox. They should be protected against the vagaries of climate and predators.

• Intensive application of flock health technology to be followed instead of treating individual lamb

Marketing

Shepherds generally market their animals through rural agents or village weekly markets on rough estimates of weight or the appearance of the animal. The lambs can be marketed through Sheep Cooperative Societies, Meat Development Corporations of the State Government on weight basis wherever they exist and a regular marketing channel has to be established where sheep farmer can not be exploited.

CSWRI milk replacer

For lambs for higher gains and survivability.

Constituted milk feeding in lambs-

Skim milk powder, soya powder, peanut meal, different types of flour, variety of edible oils, citric and butyric acids, minerals and vitamins.
CP-12-18% and EE-10-12%
Age to start milk replacer feeding in lambs- 12-15 days and upto 90 days.
Amount of milk replacerto be fed daily (ml/lamb/day) 100 ml during first 10-15 days and upto 250 ml afterwards.

Densified feed blocks- Densifiction of feeds reduces the volume of feed which makes its handling, storage and transportation easy. Division of Animal Nutrition, SKUAST-Jammu has prepared densified condensed tannins enriched multinutrient and densified function complete feed blocks which contains herbal sources of condensed tannins.

Nano-form of minerals and chelated minerals have better availability than inorganic forms of minerals, so retention of minerals will be more in such forms of minerals rather than inorganic for of minerals have been prepared at national level for better mineral nutrition of livestock.

Bypass Nutrients:

- A nutrient fed in such a form that provides an increase in flow of nutrient unchanged to the abomasum, yet is available to intestine for absorption.
- Rumen has large number of microbes which degrade large amount of protein (60-70%) is broken into ammonia and this part of ammonia is converted into urea in liver and excreted through the urine.

Methods of Bypass Protein Preparation:

1. Naturally Protected Protein

2. Heat Treatment
3. Chemical Treatment
4. Esophageal Groove
5. Post Rumen Fistula
6. Amino acid analogs
7. Lowering Ruminal Protease activity
8. Decreasing Retention time in Rumen

Heat Treatment:

Heat treatment of feed decrease the degradation in rumen by denaturing protein and the formation protein carbohydrate cross links called as Maillard Reaction.

- Processing methods:

Roasting at 140,150,160,170C for 30 minutes.

Chemical Treatment:

1. Formaldehyde treatment
2. Lignosulfonate treatment
3. Xylose treatment
4. Tannic acid treatment

Formaldehyde treatment:

- Treatment of high quality protein result in the formation of cross-link with amino group makes the protein less susceptible to microbial attack.
- There is formation of Methylol group on terminal amino group of protein chain. These bridges are broken down in acidic medium of abomasum with liberation of formaldehyde.
- Formaldehyde treatment with 3.5gm HCHO/100gm of CP.

Lignosulfonate treatment:

- Lignosulfonate can bind and precipitate protein ,it was hypothesized that protein meal treated with lignosulfonate could be rendered less degradable in rumen.
- Treatment include:

Calcium lignosulfonate treatment at the rate of 0,5,6 and 7 percent with addition of 10% water and then heat treated at 95C 2 hr in hot air oven.

Tannin treatment

- The main effect of tannins on protein is based on their ability to form hydrogen bond with that are stable between pH 3.5 and 8.
- This complex is stable in rumen and dissociate when pH falls below 3.5(abomasum) or greater then 8(in Duodenum).

By Pass Fat:

Generally, ration of high yielding dairy animals during early lactation is energy deficient. The deficiency is further increased by decreased feed intake and higher quantity of milk production. Under field conditions, animals often shed around 80-100 kg body weight after calving. This leads to delayed conception in animals after calving resulting into longer inter-calving intervals. Such animals produce less milk during this period, thus, decreased lactation yield. At this stage of lactation, farmers usually supplement their animals with oil or ghee. But this is not economical and also hampers fibre digestion in the rumen.

Feeding bypass fat supplement to high yielders during advance pregnancy and early lactation helps in minimizing the energy deficiency. This in turn would help in improving milk production and reproduction. Use of the bypass fat should be in the ration of dairy animals for 10 days before and 90 days after calving. It can be supplemented in the ration of dairy animals @ 15-20 g per kg milk production or 100 -150 g per animal per day. Feeding bypass fat does not hamper fibre digestion and is always beneficial than feeding ghee/oi

Benefits of feeding bypass fat:

- Enhances peak milk production and persistency of lactation.
- Increase reproductive efficiency after calving
- Decreases metabolic disorders such as ketosis, acidosis & milk fever.
- Increases productivity and productive life of animals

NDDB has standardised the production process of bypass fat supplement on a pilot scale, using different methods of manufacturing and after conducted a large number of feeding trials.

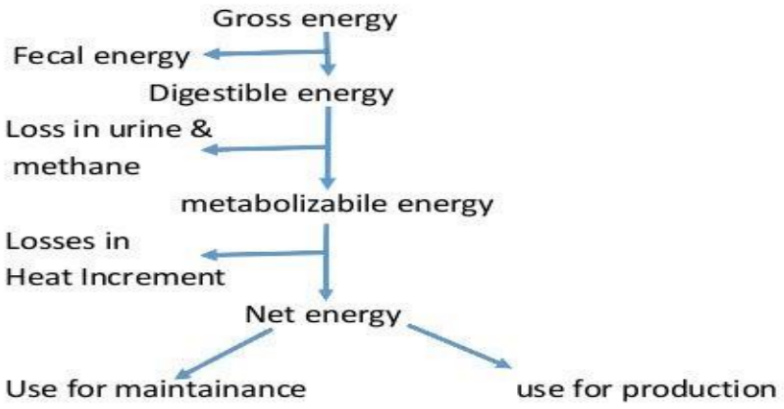
Silage Preparation

Division of Animal Nutrition, SKUAST-Jammu has prepared good quality silage by incorporation of Condensed Tannins containing tree leaves upto 25 % in conventional fodders.

A number of advances have also been made regarding the use of probiotics, prebiotics, synbiotics etc in the ration of ruminants and poultry for profitable livestock production.

CHAPTER-XII

ENERGY PARTITIONING



The schematic representation of partitioning of feed energy is presented as above. Gross energy is the **total heat of combustion** of a material which is determined in a bomb calorimeter-ordinarily expressed as kilocalories per kilogram of feed or mega joule/kg dry matter. Energy is expressed as digestible (DE), metabolizable (ME), or net energy (NE) by considering the loss of energy during digestion and metabolism from gross energy (GE) in the feed, as follows:

- **Gross energy (GE)**: the amount of energy in the feed.
- **Digestible energy (DE)**: the amount of energy in the feed minus the amount of energy lost in the feces.
- **Metabolizable energy (ME)**: the amount of energy in the feed minus the energy lost in the feces and urine.
- **Net energy (NE)**: the amount of energy in the feed minus the energy lost in the feces, urine, and in heat production through digestive and metabolic processes, i.e. heat increment.

Gross Energy (GE)

Gross energy is the **total heat of combustion** of a material which is determined in a bomb calorimeter-ordinarily expressed as kilocalories per kilogram of feed or mega joule/kg dry matter.

• Roughages have gross energy values comparable to concentrates, but the two differ greatly in digestible, metabolizable and net energy values.

• Fat, because of their greater proportion of carbon and hydrogen, yield 2.25 times more gross energy per kg than carbohydrates and protein

• Energy supplied by the food in excess of that needed for maintenance is used for the various forms of production. A young growing animal will store energy principally in the protein of its new tissues, a fattening animal stores energy in fat, and a lactating animal will transfer food energy into milk.

Digestible **Energy (DE)**

Digestible energy (DE) is the amount of **energy** in the feed minus the amount of **energy** lost in the faeces. The faecal losses represent a substantial part of GE intake. In cattle and sheep the losses are of the order of 40-50 percent in the case of roughages and 20-30 percent in case of concentrates. On commonly fed rations horses 35-40 percent of the GE intake.

Metabolizable Energy (ME)

It is the digestible energy less the energy lost in urine and combustible gases leaving the digestive tract, chiefly methane. It is the portion of energy available for metabolism.

Metabolizable energy = Energy in the food – (Energy lost in faeces + energy lost in combustible gases + energy lost in urine).

• Normally about 8 per cent of the gross energy intake is lost through the methane production. Metabolizable energy can also be calculated from the digestible energy by multiplying with 0.82 which means roughly about 18 per cent of the energy is lost through urine and methane.

ME = DE * 0.82

ME is commonly used to evaluate feedstuffs for poultry because the birds void urinary and faecal losses together. Urinary losses of energy are quite stable in a given species and is usually 2-3% of GE. The losses are more in ruminants.

Factors Affecting Metabolizable Energy Value of Feeds

- Species of animals
- Composition of feed (especially the fat content)
- Processing of feed
- Level of feeding

Net Energy (NE)

This is that portion of metabolizable energy which may be used as needed by the animals for work, growth, fattening, fetal development, milk production, and/or heat production. It differs from metabolizable energy in that net energy does not include the **heat of fermentation and nutrient metabolism** or the heat increment.

Net energy is obtained from ME by subtraction of heat increment. NE is that portion of energy that is completely useful to the animal for maintenance and production purpose. The portion of NE used for maintenance is the energy required to sustain life processes. The other portion of NE is used for tissue gain or milk or egg production. Heat increment is the amount of energy lost as a result of chemical and physical processes associated with digestion and metabolism. HI increases with the amount of feed consumed and may be used in animals reared in cold environment to warm the body otherwise. HI is also called as specific dynamic effect it **consists of the i)** Heat of nutrient metabolism and ii) Heat of fermentation.

Systems for expressing energy value of feeds

Food evaluation systems are based on digestible, metabolic and net energy.

1. Gross energy.
2. Digestible energy.
3. Metabolisable energy.
4. Net energy.
5. TDN.
6. Starch equivalent

Total Digestible Nutrients (TDN)

TDN is simply a figure which indicates the relative energy values of a feed to an animals. It is ordinarily expressed in kilogram's or in percent (kg of TDN per 100 kg of feed). TDN is the sum of digestible crude fiber, digestible crude protein, digestible fat multiplied by the factor 2.25, and digestible nitrogen-free-extract. The factors which affect TDN value of feed are:

- Percentage of dry matter

- Digestibility of dry matter
- Amount of mineral matter in the dry matter
- Digestibility of fat in the dry matter

Relationship of TDN with DE, ME and SE

TDN (%) = % dig. CP + % dig. NFE + % dig. CF + (% dig. EE x 2.25)

- **Relationship between TDN and Digestible Energy (DE)**
- 1 kg of TDN = 4400 kcal Digestible Energy

  = 4.4 kcal/ gram of TDN
- 1.87 TDN = 8228 Kcal
- **Relationship between TDN and Metabolizable Energy (ME)**
- I kg of TDN = 3520 kcal ME

  = 3.52 kcal / gram of TDN
- **Relationship between TDN and Starch Equivalent**
- 1 kg of TDN = 0.869 starch equivalent

Starch Equivalent (SE)

The concept of starch equivalent was given by Oscar Kellner. **Starch equivalent** is the number of kilograms of **starch** that would be required to produce the same amount of fat as that of 100 kg of feed. For example when we say starch equivalent of groundnut cake is 74 kg, it means that 100 kg of the groundnut cake, can produce as much animal fat as 74 kg of pure starch, when fed in addition to maintenance ration. In other words 100 kg of groundnut cake contains as much net or productive energy as 74 kg of the starch. The starch equivalent (SE) is essentially the same as net energy of the feedstuffs since both expressions aim at stating the **productive value of the feed**. The only difference being that, net energy is expressed as calories and starch equivalent is expressed in terms of starch, which is regarded to be a source of net energy to the animal.

1 Kg starch equivalent (SE) = 5.082 Mcal DE
= 4.167 Mcal ME
= 1.15 kg TDN
= 1.10 kg DOM
= 2.356 kcal NE

CHAPTER-XIII

FORMULATION OF RATION

- Ration: It is the feed allowed for a given animal during a period of 24 Hours.
- Balanced Ration: Balanced ration which provides essential nutrients to the animals in such proportion and amount that are required for the proper nourishment of the particular animal.

  In this write up formulation of ration for ruminants have been discussed.

Desirable characteristic of balanced ration

- Palatable & Variety: Ration should be palatable along with better and balanced mixture of protein, vitamins and other nutrients.
- Properly Balanced: Concentrate and roughage must be present in a balanced form. In green and dry roughages, both leguminous and non-leguminous fodder type must be included.
- Good and Sound: Low quality-unwholesome ingredients may contain toxic components while poor quality feed will reduce feed value of ration.
- Liberal feeding: Satisfy all the needs of an animal according to physiological status and also considers wastage during preparation & feeding. Over feeding must be avoided, as undoubted wastage of feed.
- Individual Feeding: It will avoid competition between animals. Adequate individual feeding is always better.
- Mineral Mixture: Milk consists of about 0.7% minerals. Diet deficit in minerals will lead minerals depletion causing different metabolic disease.
- Laxative: Ration should be laxative in nature otherwise food will be incompletely digested. It will cause digestive disorders, improper nutrient utilisation and finally reduction in production.
- Bulky: Capacious and satiety.
- Green Fodder: Source of vitamin-'A'-reproduction-Bulky- laxative-cost wise cheap unidentified factors-easily digestible.
- Avoid change in the diet: Microbial digestion will be according the feed ingredient present in the diet. If there is any sudden change in the diet, the microbes will not be able to perform their activity with full efficacy and may cause some digestive disorder.
- Maintain regularity: Balanced ration will maintain regularity in glandular secretion which is an essential component for digestion process.

- Properly Prepared: Ration prepared by using proper processing techniques will be utilized more efficiently. Eg; Hard grain - Coarsely ground; Cottonseed – soaking, coarse fodder – chaffing, sprinkled salt &molasses-increases consumption.
- Labour and cost: 70-75 % cost of production is attributed to feeding of animals.

General principles of computation of ration:

- Composition of ration involves translating the recommendations contained in feeding standard (ICAR , 2013) into actual formulation of feed mixture and feeding practices.
- In computing ration for ruminants main consideration is given to:
- DM (Dry matter)
- DCP (Digestible crude protein)

  TDN (Total digestible nutrients)

Ration formulation:

- A process by which different feed ingredients are combined in a proportion necessary to provide the animal with proper amount of nutrients needed at a particular stage of production.
- It requires
  - Knowledge about nutrients,
  - Knowledge about feedstuffs and
  - Knowledge about need of nutritionally adequate rations for the animal in the development process that will be eaten in sufficient amounts to provide the level of production at a reasonable cost.
  - The ration formulated should be palatable and will not cause any serious digestive disturbance or toxic effects to the animal.
  - The nutrient requirements can be arrived using feeding standards.
  - The list of commonly available feeds in that region is prepared.
  - The nutritional value of the feeds is obtained from any standard source such as ICAR or NRC.

Balancing Ration:

By Hand

1. Simple Arithmetic
2. Pearson square
3. Simultaneous algebraic equations

4. Two-by-two matrix method
5. Trial and error method

Using a computer

6. Standalone programs
7. Databases
8. Spreadsheets

Online applications

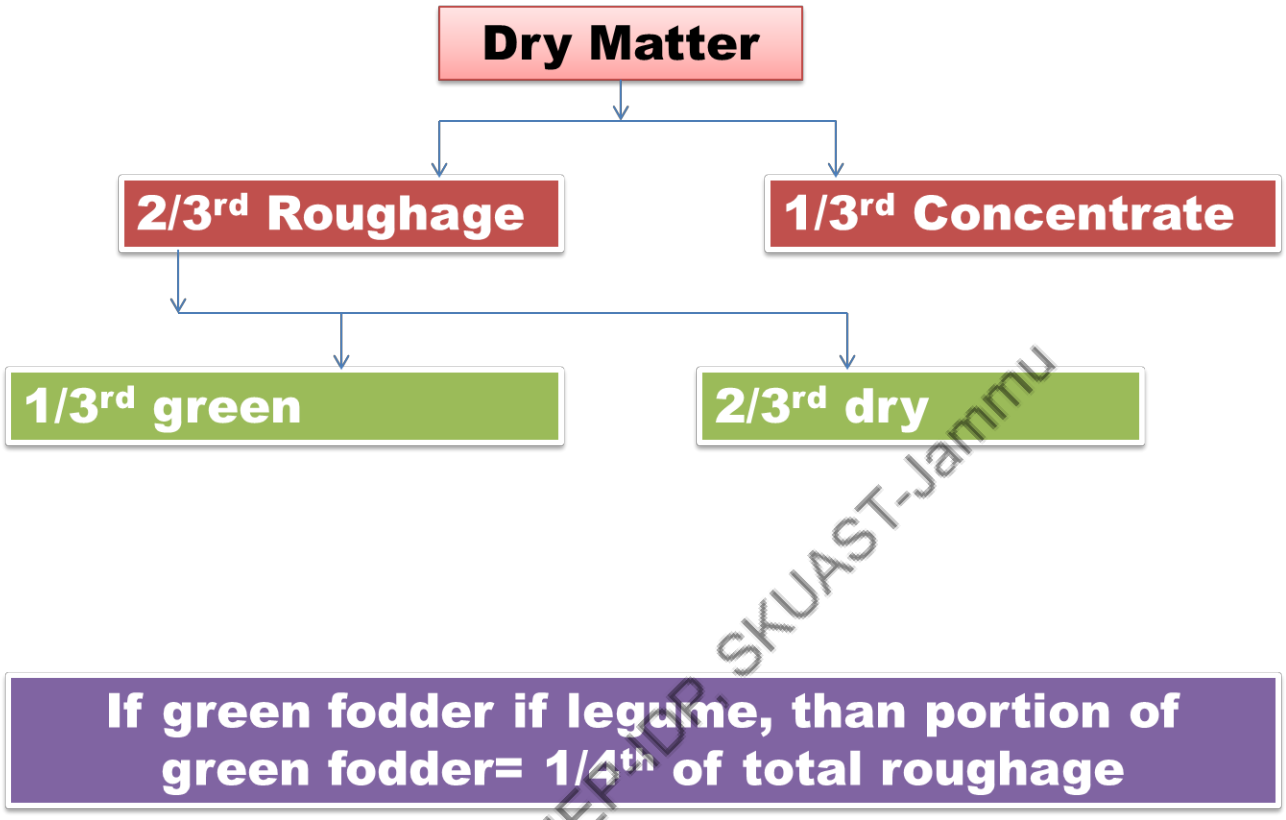
Steps in formulating ration:

- Calculate the DMI of the animal
- Calculate the nutrient requirements of the animal
- Determine the amounts of available ingredients that must be fed to fulfill the animal's nutrient requirements within its expected DMI limits.

Factors to be considered in ration formulations:

- Acceptability to the animal
- Digestibility
- Cost
- Anti-nutritional factors and toxins
- Other factors like; texture, moisture and the processing the feed has to undergo.

Partitioning of DM into roughages and concentrates for ruminants are given in the below schematic representation.



Partitioning of DM between Roughage and Concentrate:

- Calculation for a 400 kg cross bred cow
- DM = 2.5-3kg/100 body wt= 10 kg DM/day
- Roughage= 2/3 X 10= 6.7 kg
  - Green fodder (25% DM)= 1/3X6.7=2.3kg

    = 2.3/0.25= 9.2 kg
  - Dry fodder= 2/3 X 6.7=4.47 kg
- Concentrate= 1/3X10= 3.3 kg

Tips for feeding dairy cattle:

- Concentrate must be feed individually according to production requirements.
- Good quality roughage saves concentrates.

- Approximately 20 kg of grasses (guinea, napier, etc.) or 6-8 kg legume fodder (cowpea, lucerne) can replace 1 kg of concentrate mixture (0.14-0.16 kg of DCP) in terms of protein content.
- 1kg straw can replace 4-5 kg of grass on dry matter basis. In this case the deficiency of protein and other nutrients should be compensated by a suitable concentrate mixture.
- Regularity in feeding should be followed.
- Concentrate mixture can be fed at or preferably before milking – half in the morning and the other half in the evening – before the two milking.
- Half the roughage ration can be fed in the forenoon after watering and cleaning the animals. The other half is fed in the evening, after milking and watering.
- High yielding animals may be fed three times a day (both roughage and concentrate).
- Increasing the frequency of concentrate feeding will help maintain normal rumen motility and optimum milk fat levels.
- Over-feeding concentrates may result in off feed and indigestion.
- Abrupt change in the feed should be avoided.
- Grains should be ground to medium degree of fineness before being fed to cattle.
- Long and thick-stemmed fodders such as Napier may be chopped and fed.
- Highly moist and tender grasses may be wilted or mixed with straw before feeding.
- Legume fodders may be mixed with straw or other grasses to prevent the occurrence of bloat and indigestion.
- Silage and other feeds, which may impart flavour to milk, may be fed after milking.
- Concentrate mixture in the form of mash may be moistened with water and fed immediately. Pellets can be fed as such.
- All feeds must be stored properly in well-ventilated and dry places. Mouldy or otherwise damaged feed should not be fed.
- For high yielding animals, the optimum concentrate roughage ratio on dry matter basis should be 60:40.
- Buffalo need more green than cow.
- Requirement for concentrate is also more in buffaloes during early lactation.
- High lactating animal, concentrate mixture should contain 17-18% DCP & 75% TDN

CHAPTER-XIV

SYSTEM OF FEED ANALYSIS

The nutritive value of feed is evaluated by its chemical composition (Proximate system and Van Soest system of analysis) and by conduct of digestibility trials.

Proximate system of analysis of feed and fodder

This system is for approximating the nutritive composition of a feed and was given by Wilhelm Henneberg and Friedrich Stohmann in 1865 at village Weende in Germany and this system is also known as Weende system of analysis.

The principle of analysis is to separate feedstuffs into various fractions ie

1. Water
2. Ether extract
3. Crude fibre
4. Crude protein
5. Total ash
6. Nitrogen free extract

Importance of proximate analysis

- Basis for the description of feeds.
- Basis for feed purchasing.
- Basis for ration formulation.
- Starting point for detailed analysis of feed.
- Analysis of nutrients is required to find out the amount that can easily and sufficiently meet all the needs of an animal.

Moisture Determination

The methods for Moisture estimation of feed and fodder and silage are:

1. Oven drying
2. Toluene distillation
3. Freeze drying
4. Infra red moisture meter

The constant weight of a sample after complete removal of moisture or water is called dry matter

Oven drying method

Principle

- Moisture content of the sample is estimated by heating it in oven to a constant weight at 100-105°C under atmospheric pressure

- Moisture is removed as vapours.

Apparatus Required

1) Balance
2) Moisture cup/box
3) Hot air oven
4) Desiccator
5) Metal tongs

Procedure

- Dry the moisture cup in oven at 100°C.

-Cool it in a desiccator and record its weight.

-Take about 10 g of material in the moisture cup.

-Weight out to calculate actual amount of material taken.

- Dry it in a hot air oven at

-135°C for short period (around 2 h.).

-100°C for a longer period (8-24 h).

-Less than 100°C with forced air or under vacuum (till a constant weight is achieved).

-Remove the moisture cup from the oven and cool it in a desiccator.

-Repeat the process of heating and cooling till a constant weight is achieved.

-Record the constant weight of moisture cup with sample.

Calculations

- Moisture %= (Initial wt of cup + sample – Final wt after drying/ Wt of the sample) X 100
- Dry matter %= (Wt of dried sample/Wt of sample before drying) X 100
- Dry matter %= 100 - % Moisture

Precaution:

1) Weighing should be quick and accurate.

Total Ash (Mineral) Estimation

Principle

Total ash is the inorganic or mineral component of the sample left after complete ignition of the sample at 600°C in muffle furnace.

Apparatus Required

-Balance
-Silica crucible
-A pair of long tongs
- Muffle furnace
-Desiccator

Procedure
-Dry the crucible in an oven.
-Cool it in desiccator and record its weight.
-Weigh by difference about 5 g of oven dried sample in the crucible.
-Ignite the sample on a burner or on an electrical heater till the smoke ends up.
-Transfer the crucible to a muffle furnace with the help of a pair of long tongs.
-Keep it at 600 °C for two hours.
-All organic matter will be burnt leaving white ash.
-Remove the crucible from the furnace and cool it in a desiccator and weigh.
-Weight of empty crucible must be subtracted and weight of ash is thus determined.
-Preserve ash estimation of minerals.
Ash/Mineral matter %= Wt. of ash/ Original wt. of sample X 100

Precaution

2) Ash is highly hygroscopic and thus weighing should be done quickly.

Crude Protein Estimation

Crude protein is generally estimated by Micro-Kjeldahl Method or **Micro-Kjeldahl method**

Principle

Organic nitrogen when digested with concentrated H2SO4 in the presence of catalyst is converted into ammonium sulphate and ammonia liberated by making solution alkaline is distilled into a known volume of standard acid, which is then back titrated.

Crude protein content is obtained by multiplying the nitrogen value by 6.25.

Steps in CP estimation

Digestion

- Organic nitrogen + con $H_2SO4 \rightarrow (NH_4)_2SO4$

Distillation

- $(NH_4)_2SO4 + 2NaOH = 2NH_3 + Na_2SO4 + 2H_2O$

Titration

- $2NH3 + H_2SO4 = (NH_4)_2SO4$

Apparatus Required

- Kjeldahl's flask
- Balance
- Digestion bench
- Micro-Kjeldahl distillation assembly
- Volumetric flask
- Burette
- Pipette
- Beakers
- Conical flasks

Reagents and Chemicals required

- Digestion mixture (K_2SO4 and CuSO4 as 9:1)
- Nitrogen free concentrated H_2SO4
- 40% NaOH
- N/100 NaOH solution
- N/100 H_2SO4 solution
- Methyl red indicator (0.1 g of the indicator dissolved in 60 ml of alcohol and water added to make the volume 100 ml)

Procedure

Digestion

- Take 0.5-2.0 g of sample and transfer it to Kjeldahl flask.
- Add 20-30 ml concentrated H_2SO4.
- Add 2-5 g digestion mixture.
- Place the flask on digestion bench and heat till the solution becomes clear blue.
- Remove the flask and cool it.

Distillation

- Add 5-10 ml distilled water to the Kjeldahl flask.
- Transfer the solution to 100 ml volumetric flask with repeated washings till the volume is reached to 100 ml.
- Take 10 ml aliquot and transfer it to Micro-Kjeldahl assembly.
- Take 10 ml N/100 H2SO4 in a conical flask with the help of pipette.
- Add 2-3 drops of methyl red indicator.
- Set this flask under condenser.
- Add about 15-20 ml 40% NaOH solution to the distillation assembly to make content alkaline & immediately put stopper.
- Allow distillation for 10-15 minutes.

Titration

- Remove the conical flask after washing tip of the condenser with distilled water into the flask.
- Back titrate the flask content with standard alkali till the end point is reached (red to pink).
- Record the volume of alkali used in titration to calculate the volume of standard H_2SO4 used for ammonia absorption.

- *1 ml N/100 H_2SO4= 0.00014 g nitrogen*
- % Crude protein= V X 0.00014 x D x100 x 6.25

$$\frac{\text{V X 0.00014 x D x100 x 6.25}}{\text{W x A}}$$

V= Volume of N/100 H2SO4 taken- Volume of N/100 NaOH used for titration
D= Dilution factor (volume made in volumetric flask)
W= Weight of sample (g)
A= Aliquot taken
As average nitrogen content of most of the protein is 16%, so
1 g nitrogen = 100/16= 6.25 g protein

Precautions

- To avoid bumping during digestion glass beads should added in the flask.

- Incomplete digestion should be avoided.
- Set the conical flask containing N/100 H2SO4 before adding 40% NaOH.
- The tip of the condenser should be dipped in acid to avoid loss of ammonia.
- Potassium sulphate = to rise the boiling point for efficient oxidation.
- Copper sulphate= Catalyst to speed up the reaction.
- A blank must be run using all reagents except the sample to make correction for nitrogen present in the reagents used.

Conventional method

- Boric acid reagent may also be used to collect the evolved ammonia.
- The ammonia in boric acid can be then titrated directly against N/100 H_2SO4.
- For 2 % Boric acid reagent:
  - 20 g Boric acid + 500 ml hot distilled water
  - Add 200 ml absolute alcohol+ 12 ml methyl red (0.1%) + 6 ml bromocresol green (0.1%)
  - Make the volume to one litre with distilled water.
- No need to add indicator when boric acid is used.

Ether extract/ Crude fat Estimation

Principle

EE include all the proportions of a feed which are soluble in ether and this is estimated by extracting it with a fat solvent (petroleum ether, benzene, chloroform, diethyl ether, etc.). Ether is continuously volatilized at 55-60°C, condensed & allowed to pass through the sample in a Soxhlet's apparatus. Crude fat is a combination of simple fat, fatty acid esters, compound fat, neutral fat, sterols, waxes, vitamins (A,D,E,K), carotene, chlorophyll, etc.

Apparatus Required

- Soxhlet's apparatus
- Thimble with cotton swab
- Hot air oven
- Hot plate
- Balance and weight box
- Desiccator

Reagent

- Petroleum ether or any other fat solvent

Procedure

- Weight about 5 g of sample into a weighed extraction thimble having porosity permitting rapid passage of ether.
- Remove water from the sample by placing it overnight at 105°C in a drying oven.
- Cool in a desiccator and weigh.
- Place thimble in Soxhlet's apparatus in a straight direction so that the condensed ether may drop in it.
- Check the flask under the Soxhlet's apparatus to see if they are 3/4th full of petroleum ether.
- Make sure that water is running through all the condensers.
- Extraction period may vary from hours at a condensation rate of 3-6 drops per second to 16 hours at 2-3 drops per second.

- Take out the thimble.
- Keep it at room temperature for evaporation of ether and then keep overnight in the oven at 100°C.
- Remove the thimble and weigh after cooling in a desiccator.

Calculations

- Wt of sample= (Wt of thimble + Sample)- Wt of thimble
- Wt of fat= (Wt of thimble+ sample) – (Wt of thimble + sample after extraction)
- Ether extract (%)= Wt of fat/ Wt of sample X 100

Precautions

- While placing the thimble containing sample in the apparatus be sure that the top of the thimble is above the siphon tube.
- Put a cotton swab on the mouth of the condenser to avoid loss of ether vapours.

Important Note

- Preserve the ether extracted material for crude fibre estimation

Crude Fibre Estimation

Principle

Crude fibre consists of cellulose, variable portion of hemicellulose and highly variable portion of lignin along with some minerals. The estimation is based on treating the moisture and fat free sample successively with dilute (1.25%) acid and alkali.

Apparatus Required

- Tall spoutless beaker
- Round bottom condenser
- Measuring cylinder
- Sintered glass crucible
- Balance and weight box
- Muslin cloth
- Vacuum pump
- Hot plate
- Wash bottle
- Hot air oven
- Muffle furnace

Reagents

- 1.25% H2SO4 (W/V) solution
- 1.25% NaOH (W/V) solution

Procedure

- Weight about 2 g moisture and fat free sample and transfer it to the spoutless one litre beaker.
- Add 200 ml of 1.25% H_2SO4.
- Place on hot plate and allow to reflux for 30 min from onset of boiling.
- Shake after every five minutes.
- After boiling for 30 min, remove the beaker from hot plate and filter through a muslin cloth using suction.
- Wash the residue with hot water till it is free from acid.
- Transfer the material to the same beaker and add 200 ml of 1.25% NaOH.
- Again reflux for 30 minutes.
- Filter again through muslin cloth with the help of vacuum or suction pump.
- Wash the residue with hot water till it is free from alkali.
- Wash of residue on muslin cloth with dilute HCl before washing with hot water facilitates removal of alkali.
- Transfer the total residue to a crucible and place it in hot air oven, allow it to dry to a constant weight at 80-100°C and record its weight.
- Ignite the residue in muffle furnace at 550-600°C for 2-3 h.
- Cool and weigh again.
- The loss of weight due to ignition is the weight of crude fibre
- Crude fibre (%) = Wt of crude fibre/Original wt of sample x 100

Precautions

- During boiling keep the volume constant.
- To avoid foaming add a few drops of iso-amyl alcohol.
- Muslin cloth should have 18 threads to a centimetre.

Nitrogen Free Extract Calculation

NFE of a feed sample is not estimated in the laboratory but it is calculated from other proximate constituents.

NFE(%)= 100- (CP%+CF%+EE%+Total Ash)

Where, CP= Crude protein
CF= Crude fibre
EE= Ether extract

Demerits of Proximate analysis

- Proximate analysis is the starting point of chemical analysis, with certain limitations.
- Major limitation is in the estimation/relevence of Crude fibre and Nitrogen free extract.
- As CF= Total cellulose+ Hemicellulose + Lignin.

- But only some part of hemicellulose + lignin comes out in crude fibre.
- Remaining portion in NFE= consists of Highly digestible sugars and starch.
- Providing incorrect index regarding nutritive value of given feed.
- Overestimates NFE.
- Underestimates CF

Van Soest System of Forage Analysis

To overcome limitations of proximate system of anaysis, Van Soest developed a new scheme of analysis which is based of cell wall and cell constituents by using different detergents. This is applicable for forage fiber in ruminants.

Cell contents soluble in neutral detergent

Lipids, sugars, organic acids, starch, soluble proteins, non-protein nitrogenous compounds and other water soluble matter.

Insoluble in Neutral detergent (NDF)

Hemicellulose, cellulose, lignin, lignified nitrogenous compounds, heat damaged proteins, keratin and silica

NDF treated with acid detergent

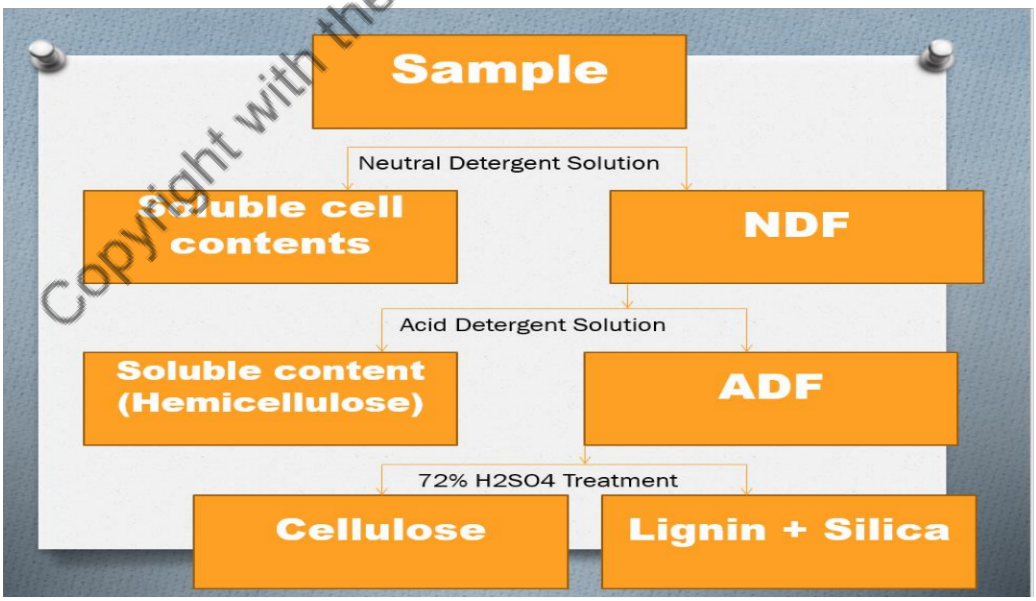
Solubles = Hemicellulose, some cell wall nitrogenous compound and acid soluble ash

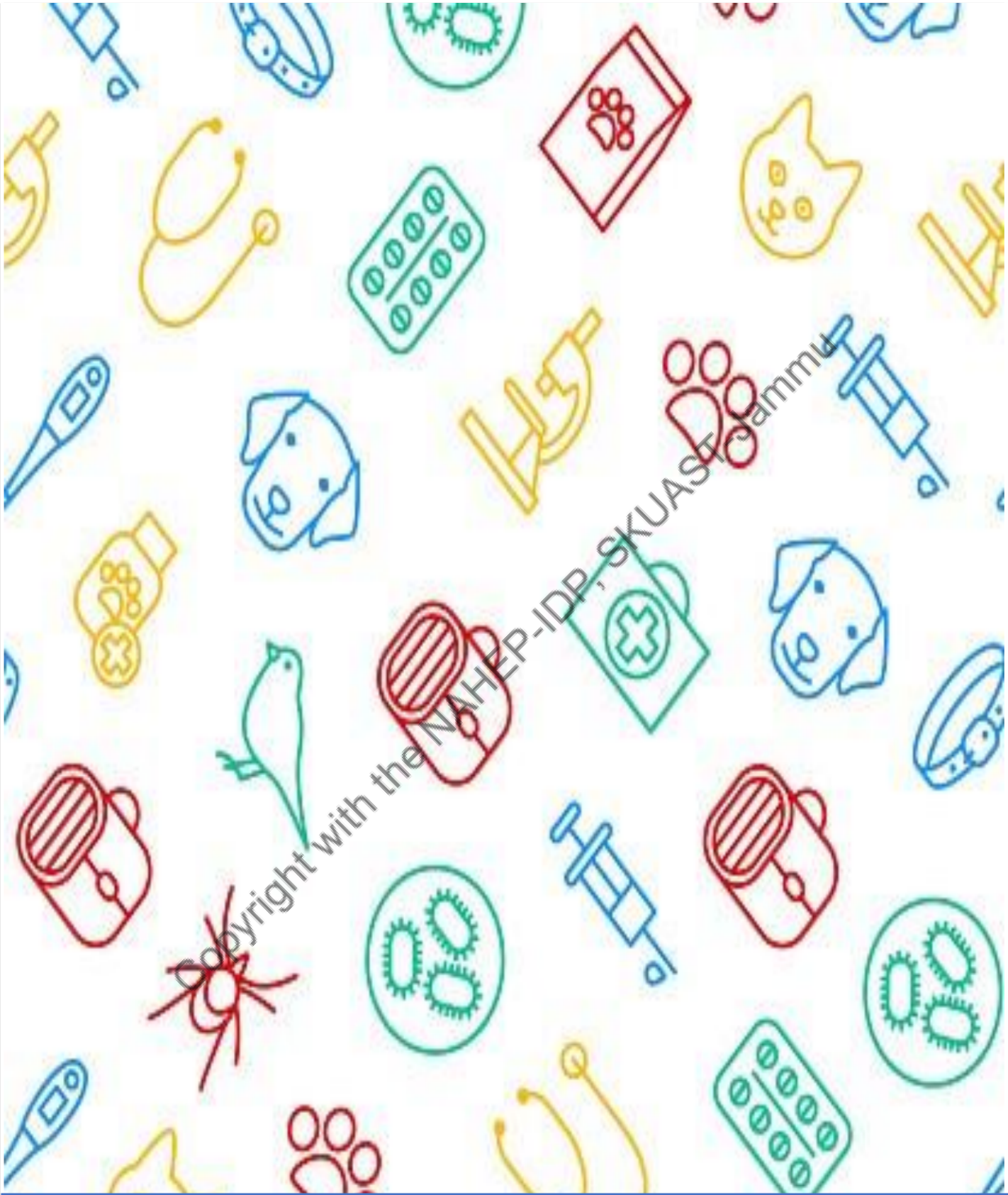
Insoluble fraction = ADF (Acid Detergent Fibre) or lignocellulose.

Ligno-cellulose + 72% H_2SO4→Disslove cellulose

- Insoluble part= Lignin + Silica.

Ignite the sample= Lignin is lost, remaining part is silica





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