ANIMAL GENETICS AND BREEDING

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Unit 1: Genetic Material

Topic 1: History of Animal Genetics and Breeding

Year	Scientist	Discovery
1677	Anton Van Leeuwenhock & Jonn Hamm	Observed sperms through a magnifying lens
1725-1795	Robert Bakewell	Began animal breeding with horses, sheep and cattle; known as Father of Animal Breeding
1744-1829	Lamarck	Explained use and disuse of organs and inheritance of acquired characters
1775-1849	Thomas Bates	Developed highly inbred herd of cattle
1780	L. Spallanzani	Conducted first scientific work on A.I.; obtained three pups by A.I. in dogs
1791	British Royalty	Encouraged horse breeding for races; resulted in English thoroughbred and general studbook
1809-1882	Charles Darwin	Proposed hypothesis of "pangenesis" and theory of survival of fittest
1822	Coats	First published a herd book for Shorthorn breed of cattle; American saddle horse developed
1866	Gregor Mendel	Published the law of heredity in Journal of Zoological Society of Austria
1899	E.I. Ivonoff	Practiced A.I. in many stud farms; first successful A.I. in cattle and sheep
1902	Hugo de Vries	Proposed "Mutation Theory" for species origin
1903	DeVeris, Von Tschermark, Correns	Rediscovered Mendel's principles
1907	Danish researchers	Studied growth rate, feed consumption, and carcass quality in swine

1908	G. H. Hardy and Weinberg	Formulated the Hardy-Weinberg law of population genetics
1939	Sampath Kumaran	Used A.I. for the first time in India
1942	P. Bhattacharya	First scientific work on A.I. in India
1953	J. D. Watson and F. H. C. Crick	Proposed the double-helix model for DNA
1980	Martin Cline and co-workers	Created a transgenic mouse
1990	International scientists	Formal launch of the Human Genome Project
1997	Ian Wilmut and team	Cloned "Dolly" the sheep from somatic cell of an adult ewe
1998	University of Hawaii scientists	Cloned a mouse using Wilmut's technique
1998	Kinki University scientists	Cloned eight identical calves from a single adult cow
1998	USA scientists	Created a cloned calf named "Jefferson"
2010	National Dairy Research Institute	Cloned buffalo calf named "Shresth"

Who coined these terms?

Year	Scientist/Breeder	Term/Concept Coined or Developed
1725-1795	Robert Bakewell	"Like begets like" principle; Systematic selective breeding of livestock
1858	Charles Darwin & Alfred Russel Wallace	Natural Selection
1866	Gregor Mendel	Laws of Heredity; Concept of "factors" (later called genes)

1871	Charles Darwin	Sexual Selection
1888	Heinrich Wilhelm Waldeyer	Chromosome
1901-1903	Hugo de Vries	Mutation; Mutation Theory
1905	William Bateson	Genetics; Allele; Zygote; Homozygote; Heterozygote
1908	G. H. Hardy & Wilhelm Weinberg	Hardy-Weinberg equilibrium
1909	Wilhelm Johannsen	Gene
Early 1900s	Thomas Hunt Morgan	Linkage
Early 1900s	Alfred Sturtevant	Linkage Map (Genetic Map)
Early 1900s	Thomas Hunt Morgan (honored)	Centimorgan
1976	Richard Dawkins	Replicator

Topic 2: Organisation of Nuclear Material – DNA and RNA

Chromosome Numbers of Livestock and Poultry

Haploid, Diploid

- Diploid cells (2N where N- chromosome number) have two homologous copies of each chromosome. The body cells of animals are diploid.
- Haploid cells (N) have only one copy of each chromosome. In animals, gametes (sperm and eggs) are haploid.

Animal	**Scientific Name**	**Chromosome Number**
Cattle	*Bos taurus*	60
Goat	*Capra aegagrus hircus*	60
Yak	*Bos grunniens*	60
Mithun	*Bos frontalis*	58

Elephant	*Elephus maximus*	56
River buffalo	*Bubalus bubalis*	50
Swamp buffalo	*Bubalus carabanensis*	48
Dog	*Canis lupus familiaris*	78
Cat	*Felis catus*	38
Sheep	*Ovis aries*	54
Horse	*Equus ferus caballus*	64
Mule	*Hybrid (Horse × Donkey)*	63
Donkey	*Equus asinus*	62
Human	*Homo sapiens*	46
Pig	*Sus scrofa domesticus*	38
Rabbit	*Oryctolagus cuniculus*	44
Chicken	*Gallus gallus*	78
Duck	*Anas platyrhynchos domestica*	80
Turkey	*Meleagris gallopavo*	76 (male), 77 (female)
Goose	*Anser anser domesticus*	80
Quail	*Coturnix coturnix japonica*	78
Ostrich	*Struthio camelus*	80
Emu	*Dromaius novaehollandiae*	80

Organisation of the Genome

Animal Cell:

- Fundamental structural and functional unit of life
- Comprised of different organelles including a central nucleus
- Nucleus contains the genetic material of the cell in the form of chains of deoxyribonucleic acid (DNA)

Genome: The complete set of DNA present inside the nucleus of an animal is called a genome

DNA:

- In humans and other higher forms of life, DNA consists of two polynucleotide strands coiled around one another in a spiral form (DNA double helix)
- DNA double helix structure was *discovered* by Watson & Crick by building on the work of Rosalind Franklin
- Repeating molecule of DNA – nucleotide
- One nucleotide = One nucleoside (1 deoxyribose (pentose) sugar + 1 Nitrogenous base) + 1 phosphate moiety
- Types of nitrogenous bases:
    - Purines – Adenine (A) and Guanine (G)
    - Pyrimidines – Thymine (T), Cytosine (C), Uracil (U)
    - Hydrogen bonds:
        - A = T
        - G ≡ C

**Thymine is present in DNA only, while Uracil is present in RNA instead of thymine*

- Back bone of DNA chain – phosphodiester bond – joins two nucleosides with each other
- Two chains of DNA running in antiparallel direction are joined together by hydrogen bonds (by the nitrogenous bases) to form DNA molecule
- Packaging of DNA:
    - DNA threads (chromatin) – negatively charged – is wrapped around an octamer of positively charged histone protein molecules

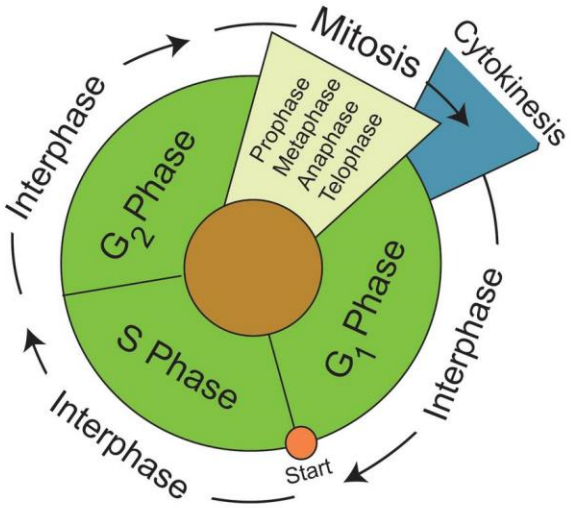
Types of DNA:

Characteristic	**B-DNA**	**A-DNA**	**Z-DNA**
Helical Sense	Right handed	Right-handed	Left-handed
Base pairs per turn	10.5	11	12
Rise per base pair	0.34 nm	0.23 nm	0.37 nm
Pitch (height) per turn	3.4 nm	2.55 nm	4.56 nm
Diameter	2.0 nm	2.3 nm	1.8 nm
Typical conditions	Normal physiological	Dehydrating conditions, DNA-RNA hybrids	High salt, alternating purine-pyrimidine sequences
Biological significance	Most common form in cells	Protects DNA during extreme conditions	Possible role in gene regulation

Topic 3: The Cell Cycle – Mitosis and Meiosis

Cell Cycle Overview

The cell cycle is a sequence of events that a cell undergoes as it grows and divides. It consists of two major phases: Interphase and the Mitotic (M) Phase. The cell cycle ensures that cells duplicate their DNA and organelles and divide correctly to produce two identical daughter cells.



Phases of cell cycle

Nucleus:

The nucleus is a membrane-bound organelle that houses most of the cell's genetic material and controls many aspects of cell function.

- **Genetic Material:**
  - The nucleus contains the cell's DNA and RNA. DNA holds the genetic blueprint for the cell, while RNA is involved in protein synthesis.
- **Nuclear Membrane:**
  - The nucleus is surrounded by a double membrane called the nuclear envelope. This envelope has pores (nuclear pores) that regulate the exchange of materials between the nucleus and the cytoplasm.
- **Nuclear Pores:**
  - RNA moves in and out of the nucleus through these pores. Proteins needed by the nucleus, such as those involved in DNA replication and transcription, also enter through these pores.
- **Role in Protein Synthesis:**
  - RNA synthesized in the nucleus (through transcription) is used in the cytoplasm for protein synthesis. The nucleolus plays a key role in ribosome assembly, which is crucial for protein synthesis.
- **Control Center:**
  - The nucleus controls the cell's activities by regulating gene expression and orchestrating the cell cycle. It is often referred to as the control center of the cell.
- **Nucleolus:**
  - The nucleolus is a dense region within the nucleus where ribosomal RNA (rRNA) is synthesized and ribosome assembly begins. It appears as a dark spot under a microscope.

1. Interphase:

Interphase is the longest phase of the cell cycle and is divided into three distinct sub-phases: G1, S, and G2.

**G_0 phase: Quiescence/Resting – Cell has stopped dividing. Its duration is highly variable, some cells are always G_0 phase (viz. nerve cells)*

G1 Phase (First Gap):

- Purpose: The cell grows and performs its normal functions. It synthesizes proteins, lipids, and other macromolecules needed for cell function and division.
- Key Events:
    - Increase in cell size.
    - Production of RNA and proteins required for DNA synthesis.
    - Preparation for DNA replication.
    - G1 check point – ensures cell is ready for DNA synthesis
- Duration: Varies greatly depending on the cell type and environmental conditions. It is often the longest phase.

S Phase (Synthesis):

- Purpose: DNA replication occurs ensuring that each daughter cell will have an identical set of chromosomes.
- Key Events:
    - Each chromosome is duplicated to form two sister chromatids connected at the centromere.
    - The centrosome, which organizes microtubules also duplicates.
- Duration: Typically lasts about 5-6 hours in most cells

G2 Phase (Second Gap):

- Purpose: The cell prepares for mitosis by synthesizing proteins and ensuring all DNA has been replicated accurately.
- Key Events:
    - Rapid cell growth.
    - Production of microtubules and other components needed for mitosis.
    - Repair of any DNA damage that occurred during the S phase.
    - G2 check point – cell is ready to start division
- Duration: Usually lasts 3-4 hours.

2. Mitotic (M) Phase:

The Mitotic Phase includes both mitosis and cytokinesis and is the process by which a cell divides to produce two daughter cells.

- Purpose: To ensure that each daughter cell receives an identical set of chromosomes.
- Key Events:

- Mitosis divides the nucleus and its contents.
- Cytokinesis divides the cytoplasm and organelles, resulting in two separate cells.

Mitosis

Mitosis is the process of nuclear division that results in two daughter nuclei, each with the same number of chromosomes as the parent cell. It is divided into several stages:

1. **Prophase:**
   Key Events:
   - Chromosome Condensation: Chromatin fibres condense into distinct chromosomes. Each chromosome is composed of two sister chromatids joined at the centromere.
   - Nucleolus Disappearance: The nucleolus fades as the chromosomes become more visible.
   - Mitotic Spindle Formation: The mitotic spindle begins to form. Microtubules extend from centrosomes at opposite poles of the cell.
   - Centrosome Movement: Centrioles move towards opposite poles, organizing microtubules into the spindle apparatus.
   - Nuclear Envelope Breakdown: The nuclear envelope disassembles, allowing spindle fibers to access the chromosomes.

2. **Metaphase:**
   Key Events:
   - **Chromosome Alignment**: Chromosomes align along the metaphase plate, an imaginary line equidistant from the two poles of the cell.
   - Metaphase chromosomes – most condensed and most distinctly visible under a microscope.
   - **Spindle Fiber Attachment**: Spindle fibers from each pole attach to the kinetochores at the centromere of each chromosome, ensuring proper alignment and tension.
   - Metaphase checkpoint – Ensures that cell is ready for complete division

3. **Anaphase:**
   Key Events:
   - Chromatid Separation: Centromeres split, and spindle fibers shorten, pulling the sister chromatids apart towards opposite poles.
   - Chromosome Movement: Each chromatid is now considered a separate chromosome and is moved to the poles of the cell.
   - Pole Formation: Each pole of the cell ends up with a complete set of chromosomes.

4. **Telophase:**
   Key Events:
   - Chromosome Decondensation: Chromosomes begin to decondense back into chromatin.
   - Nuclear Envelope Reformation: Two new nuclear envelopes form around the sets of chromosomes at each pole.

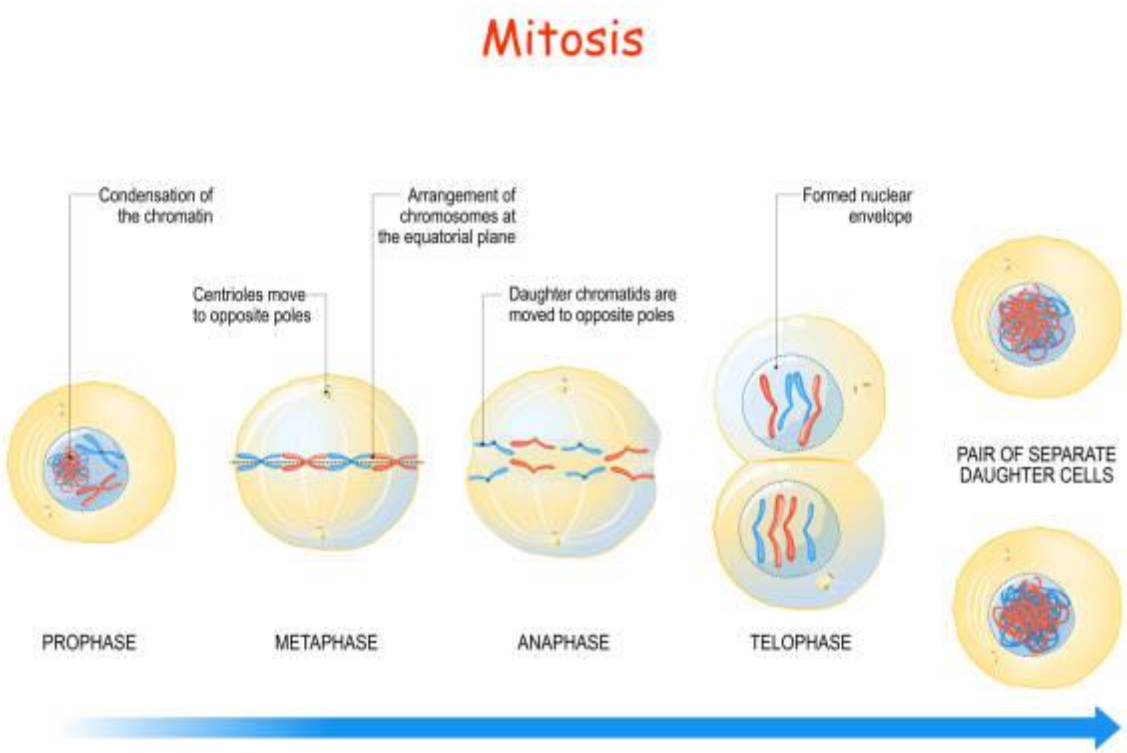
- Nucleolus Reappearance: The nucleolus reappears in each new nucleus.
- Spindle Disassembly: The mitotic spindle fibers disassemble.

Cytokinesis

- Purpose: Cytokinesis is the final step of cell division, where the cytoplasm and organelles of the parent cell are divided between the two daughter cells.
- *Key Events:*
    - Animal Cells: The cell membrane pinches inward, forming a cleavage furrow that deepens until the cell is pinched into two separate daughter cells.
    - Plant Cells: A cell plate forms in the centre of the cell, gradually expanding outward and eventually fusing with the cell membrane to separate the two daughter cells.

Key Terms and Concepts

- ✓ **Chromatid**: One of the two identical halves of a duplicated chromosome, connected by a centromere.
- ✓ **Centromere:** The central region of a chromosome where sister chromatids are joined.
- ✓ **Mitotic Spindle:** A structure composed of microtubules that segregates chromosomes during mitosis.
- ✓ **Nucleolus:** A dense region within the nucleus responsible for ribosome synthesis.
- ✓ **Generation Time:** The overall length of the cell cycle for a particular cell type; determines how long it takes for the population to double.



Meiosis

Purpose of Meiosis

- **Definition:** Meiosis is a specialized type of cell division that reduces the chromosome number by half, producing four genetically unique haploid gametes (sperm or egg cells) from a single diploid germ cell.
- **Importance:**
  - **Sexual Reproduction:** Essential for the formation of gametes, which combine during fertilization to restore the diploid chromosome number.
  - **Genetic Diversity:** Generates genetic variation through processes such as crossing over and independent assortment, contributing to evolutionary adaptation.

Stages of Meiosis

Meiosis consists of two sequential divisions: Meiosis I and Meiosis II, each with specific stages. The overall result is the formation of four non-identical haploid cells.

1. Meiosis I

Meiosis I is the reductional division, where homologous chromosomes are separated into two haploid cells.

1. **Prophase I:**

Stages of Prophase I

i. **Leptotene:**

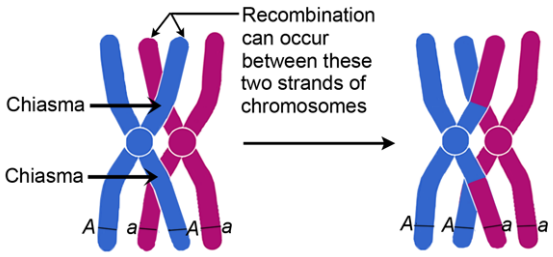
- **Key Features:**
  - **Chromosome Condensation:** Chromosomes begin to condense and become visible as long, thin threads.
  - **Chromosome Appearance:** Each chromosome consists of two sister chromatids connected by a centromere. All chromosomes are directed towards the centriole, making it appear like a bouquet – so it is also called the bouquet stage
- **Details:** Leptotene marks the initial phase of chromosome condensation, making the chromosomes easier to distinguish under a microscope.

ii. **Zygotene:**

- **Key Features:**
  - **Synapsis Initiates:** Homologous chromosomes start to pair up along their entire length, forming a close association known as the synaptonemal complex
  - **Formation of Tetrads:** Each homologous chromosome pair forms a tetrad (bivalent), consisting of four chromatids.
- **Details:** Synapsis is essential for accurate chromosome segregation and the establishment of physical connections between homologous chromosomes.

iii. **Pachytene:**

- **Key Features:**
  - **Thick thread: Increased attraction causes chromosomes to coil tightly around each other. Both chromatids (called sister chromatids) become distinct.**
  - **Crossing Over:** Genetic material is exchanged between non-sister chromatids of homologous chromosomes at specific points called chiasmata. The enzyme recombinase (endonuclease + ligase) is involved.
  - **Recombination nodules:** They are located on the synaptonemal complex (not visible as distinct structures). These form between non-sister chromatids of homologous chromosomes and facilitate the exchange of genetic material – they are involved in the biochemical process of crossing over.
  - **Formation of Chiasmata:** Chiasmata are the physical sites (or results of recombination) marking points where chromatids cross over and exchange segments of DNA. Chiasmata hold the homologous chromosomes linked together at the points of crossing over.
- **Details:** Crossing over during Pachytene creates genetic diversity by recombining genetic material between homologous chromosomes.



iv. **Diplotene:**

- **Key Features:**
  - **DNA recombination is complete**
  - **Chiasmata Become Visible:** The homologous chromosomes start to separate slightly, and the chiasmata, where crossing over occurred, become more visible as distinct cross shaped structures.
  - **Resolution of Synaptonemal Complex:** The synaptonemal complex dissolves, but homologous chromosomes remain connected at chiasmata. Terminalisation of chiasmata occurs as they tend to slip towards the end of the tetrads, as the meiotic prophase continues.
- **Details:** Diplotene is where the chromosomes begin to move apart, but the physical connections at chiasmata hold the homologous chromosomes together.

v. **Diakinesis:**

- **Key Features:**
  - **Chromosome Condensation Completes:** Chromosomes further condense and become even more visible and compact.
  - **Nuclear Envelope Breakdown:** The nuclear envelope disintegrates, allowing spindle fibers to interact with chromosomes.
- **Details:** Diakinesis prepares the chromosomes for alignment along the metaphase plate in Metaphase I by finalizing their condensation and spindle attachment.

Key Features of Prophase I

- ✓ **Synapsis:** Homologous chromosomes pair up to form tetrads (bivalents), which is crucial for proper chromosome segregation.
- ✓ **Crossing Over:** Exchange of genetic material occurs between non-sister chromatids at chiasmata, leading to genetic recombination and diversity.
- ✓ **Chiasmata Formation:** Physical connections between homologous chromosomes where crossing over occurs, ensuring proper segregation.
- ✓ **Chromosome Condensation:** Chromosomes become visible and compact, facilitating their movement during later stages of meiosis.

2. **Metaphase I:**

- **Alignment:** Tetrads align along the metaphase plate. Each homologous chromosome pair attaches to spindle fibers from opposite poles.
- **Key Features:** Random alignment of homologous pairs contributes to genetic variation, Spindle fibre attachment

3. **Anaphase I:**

    - **Separation:** Homologous chromosomes are pulled apart towards opposite poles. Each chromosome still consists of two sister chromatids.
    - **Key Features:** Chiasmata resolution, Separation of homologous chromosomes, Reduction in chromosome number from diploid to haploid.

4. **Telophase I and Cytokinesis:**

    - **Telophase I:** Chromosomes reach the poles, and the nuclear envelope may reform around each set of chromosomes – chromosome decondensation occurs here
    - **Cytokinesis:** The cytoplasm divides, resulting in two haploid daughter cells.
    - **Key Features:** Formation of two haploid cells, each with chromosomes still composed of two chromatids.

2. Meiosis II

Meiosis II is the equational division, similar to mitosis, where sister chromatids are separated.

1. **Prophase II:**
    - **Chromosome Re-condensation:** Chromosomes re-condense, and new spindle fibers form.
    - **Key Features:** Chromosomes are not paired with homologous chromosomes; each cell has one set of chromosomes.
2. **Metaphase II:**
    - **Alignment:** Chromosomes line up along the metaphase plate in each of the two haploid cells.
    - **Key Features:** Chromosomes are single, with two sister chromatids.
3. **Anaphase II:**
    - **Separation:** Sister chromatids are separated and pulled to opposite poles of the cell.
    - **Key Features:** Chromatids are now individual chromosomes.
4. **Telophase II and Cytokinesis:**
    - **Telophase II:** Chromosomes reach the poles, and nuclear envelopes reform around each set of chromosomes.
    - **Cytokinesis:** The cytoplasm divides, resulting in a total of four genetically unique haploid cells.
    - **Key Features:** Formation of four distinct haploid gametes.

Key Concepts and Terms of Meiosis

- ✓ **Homologous Chromosomes:** Chromosomes having the same genes at the same loci, but may have different alleles. An individual has a pair of homologous chromosomes, each coming from one of its parents.
- ✓ **Tetrad (Bivalent):** It is a structure formed by the pairing of two homologous chromosomes during Prophase I (Leptotene stage), via synapsis.
- ✓ **Crossing Over:** Exchange of genetic material between homologous chromosomes during Prophase I (Pachytene stage), increasing genetic diversity.

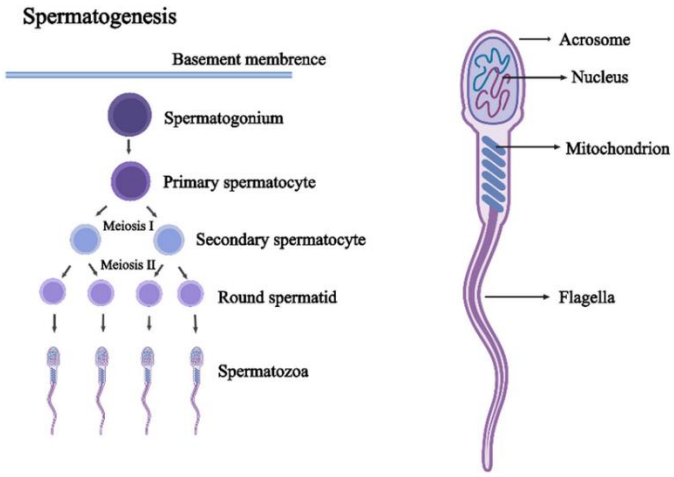
- ✓ **Independent Assortment:** The random distribution of homologous chromosomes into daughter cells during Metaphase I, contributing to genetic variation.
- ✓ **Gametes:** Haploid reproductive cells (sperm and egg) produced through meiosis.

Topic 4: Gametogenesis

Gametogenesis is the biological process by which specialized reproductive cells (gametes) are formed through meiosis and cellular differentiation from primordial germinal cells.

1. ***In Males (Spermatogenesis):***

- **Process:** Each primary spermatocyte (a diploid cell) undergoes meiosis to produce four haploid sperm cells.
- **Details:**
    - **Location:** Spermatogenesis occurs in the seminiferous tubules of the testes.
    - **Spermatogonia:** The process begins with spermatogonia, which are diploid stem cells located in the outermost layer of the seminiferous tubules.
    - **Mitosis:** Spermatogonia undergo mitotic divisions to produce primary spermatocytes, which are still diploid (having two sets of chromosomes).
    - **Meiosis I:** Each primary spermatocyte undergoes the first meiotic division to form two secondary spermatocytes. These cells are haploid (having one set of chromosomes).
    - **Meiosis II:** Each secondary spermatocyte undergoes a second meiotic division to produce a total of four haploid spermatids.
    - **Spermiogenesis:** Spermatid heads become embedded in Sertoli cells in the lumen of the seminiferous tubule. Spermatids undergo a series of morphological changes to become mature sperm cells (spermatozoa). This includes the development of a tail, condensation of the nucleus, and shedding of excess cytoplasm. Sertoli cells help in phagocytosing the excess cytoplasm and assist in final maturation of spermatozoa.
    - **Sperm Release:** The mature spermatozoa are released into the lumen of the seminiferous tubules and eventually transported to the epididymis for final maturation and storage.



2. ***In Females (Oogenesis):***

Process: Each primary oocyte (a diploid cell) undergoes meiosis to produce one ovum (egg cell) and three polar bodies.

Details:

- Oogonia Formation:
  - **Location:** Oogonia are formed in the ovaries of the developing fetus.
  - **Action**: Oogonia are diploid (2n) stem cells that undergo mitosis to increase their numbers.

- Primary Oocytes:

  - **Formation:** Before birth, oogonia enter meiosis I and become primary oocytes.
  - **Pause:** Primary oocytes are arrested in prophase I of meiosis and remain in this stage until puberty.

- Puberty Onset:

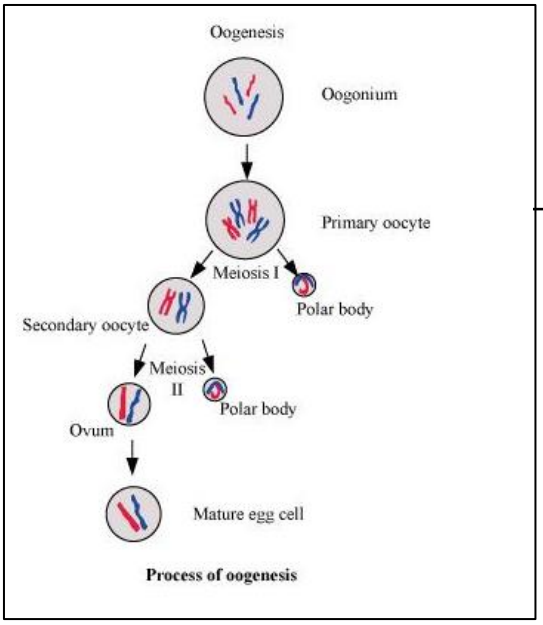
  - **Resumption:** During each menstrual cycle, some primary oocytes resume meiosis and complete the first meiotic division.
  - **Meiosis I:** This division produces one secondary oocyte and a smaller polar body (which typically degenerates). The secondary oocyte is haploid (n) and arrested in metaphase II of meiosis.

- Secondary Oocyte:

  - **Ovulation:** The secondary oocyte is released from the ovary during ovulation.
  - **Completion:** If fertilization occurs, the secondary oocyte completes meiosis II, resulting in the formation of an ovum (mature egg) and a

second polar body (which also usually degenerates). The polar bodies typically degrade, and the ovum is the functional gamete.

- Fertilization:
    - **Outcome:** The mature ovum, if fertilized by a sperm cell, combines with the sperm's genetic material to form a diploid zygote, beginning the development of a new organism.



Arrested at Prophase I; Completes Meiosis I at puberty

Arrested at Metaphase II; Resumes meiosis II after fertilisation

Arrest in Oogenesis:

- **Prophase I Arrest:**
    - **Stage:** Diplotene stage of Prophase I
    - **Details:** During fetal development, primary oocytes begin meiosis and are arrested in Prophase I of meiosis I. They remain in this arrested state until puberty. This arrest can last for many years, sometimes decades, until the female reaches reproductive maturity.
    - **Cause:** The arrest in Prophase I is due to the synthesis of regulatory proteins and the complex interactions of chromosomal pairing and recombination that need to be completed before the oocyte is released.
    - **Duration:** This arrest lasts from fetal development until puberty and can extend for several decades.
- **Metaphase II Arrest:**
    - **Stage:** Metaphase II of meiosis II
    - **Details:** Just before ovulation, the primary oocyte completes meiosis I, producing a secondary oocyte and a polar body. The secondary oocyte then enters meiosis II but is arrested in Metaphase II. It remains in this arrested state until fertilization occurs. If fertilization does not happen,

the secondary oocyte will not complete meiosis II and will eventually be expelled during menstruation.

- **Cause:** The arrest in Metaphase II ensures that the secondary oocyte is maintained in a state ready for fertilization. The oocyte is prepared to complete meiosis II upon sperm entry.
- **Duration:** This arrest lasts until fertilization. If the oocyte is not fertilized, it is discarded and does not complete meiosis II.

Topic 5: Gene Expression – Transcription and Translation

Gene expression is the process by which information from a gene is used to synthesize functional gene products, such as proteins or non-coding RNA.

Regulation of Gene Expression

- Gene expression can be regulated at multiple stages, including transcription, RNA splicing, translation, and post-translational modification.
- Regulation allows control over the timing, location, and amount of a gene product present in a cell.
- It is vital for cellular differentiation, development, morphogenesis and adaptability of organisms.
- Regulation of gene expression is the basis for cellular differentiation, development, morphogenesis and the versatility and adaptability of any organism.
- Gene regulation may serve as a substrate for evolutionary change.

Types of Genes Based on Regulation:

- Constitutive genes: Transcribed continually
- Facultative genes: Transcribed only when needed
- Housekeeping genes: Required to maintain basic cellular function, expressed in all cell types
- Inducible genes: Responsive to environmental changes or cell cycle dependent

DNA Replication

Overview

- DNA replication is the process by which DNA makes a copy of itself during cell division.
- It ensures that each new cell receives the same genetic information as the parent cell.
- DNA replication occurs in all living organisms and is the basis for biological inheritance.

Steps of DNA Replication

1. Initiation

- Replication begins at specific locations called origins of replication.
- Proteins called initiators recognize the origin and recruit other proteins to separate the two strands and initiate replication forks.
- Helicase unwinds and separates the double-stranded DNA by breaking the hydrogen bonds between complementary bases.
- Single-strand binding proteins stabilize the single-stranded DNA and prevent the strands from reannealing.

2. Elongation

- DNA synthesis occurs continuously on the leading strand and discontinuously on the lagging strand.
- RNA primase synthesizes an RNA primer on the template strands.
- DNA polymerase III extends the new DNA strand by adding nucleotides complementary to the template in the 5' to 3' direction.
- On the leading strand, DNA is synthesized continuously, whereas on the lagging strand, DNA is synthesized in short fragments called Okazaki fragments.
- DNA polymerase I replaces the RNA primers with DNA nucleotides.
- DNA ligase joins the Okazaki fragments together forming a continuous strand.

3. Termination

- DNA replication continues until the entire molecule is copied.
- In circular DNA (prokaryotes), termination occurs when the two replication forks meet.
- In linear DNA (eukaryotes), telomerase is required to replicate the ends of the chromosomes.

Key Enzymes Involved

1. **Helicase**: Unwinds the double helix at the replication fork
2. **Primase**: Synthesizes RNA primers complementary to the template strand
3. **DNA Polymerase III**: Adds nucleotides to the growing DNA chain
4. **DNA Polymerase I**: Replaces RNA primers with DNA nucleotides
5. **Ligase**: Joins Okazaki fragments together
6. **Topoisomerase**: Relieves the tension caused by unwinding
7. **Single-Strand Binding (SSB) Proteins**: Bind to single-stranded DNA to prevent reannealing

Replication Models

- **Semiconservative Replication**: Each strand in the double helix acts as a template for new DNA to be synthesized, resulting in two DNA molecules, each with one old and one new strand. This was proven by the Meselson-Stahl experiment.

Regulation of DNA Replication

- Ensures that the genome is replicated only once per cell cycle.
- Controlled by the cell cycle and checkpoint regulation.
- Licensing factors (e.g., ORC, CDC6, CDT1, MCM) restrict replication to once per cell cycle.

Significance

- DNA replication allows genetic information to be passed down to daughter cells.
- Accurate replication maintains the integrity of the genetic code and prevents harmful mutations.
- Errors during replication can lead to genetic disorders and diseases, including cancer.

Transcription

Overview

- Transcription is the process by which the genetic information in DNA is copied into a complementary RNA strand.
- It is the first step of gene expression, in which a particular segment of DNA is copied into RNA by the enzyme RNA polymerase.
- Transcription occurs in both prokaryotes and eukaryotes.

Key Enzymes and Components

1. **RNA Polymerase**: Catalyzes the synthesis of RNA from a DNA template
    - Prokaryotes have a single RNA polymerase for all RNA synthesis.
    - Eukaryotes have three types of RNA polymerase: I, II, and III, each transcribing a different class of RNA.
2. **Promoter**: A region of DNA that initiates transcription of a particular gene
    - Contains a TATA box in many eukaryotic genes
3. **Transcription Factors**: Proteins that bind to regulatory sequences and help recruit RNA polymerase to the promoter
4. **Terminator**: A sequence that signals the end of transcription

Stages of Transcription

1. Initiation

- RNA polymerase binds to the promoter region of the gene.
- General transcription factors help position RNA polymerase correctly at the promoter in eukaryotes.
- The DNA double helix is unwound and the two strands are separated, exposing the bases.
- One of the strands (template strand) acts as a template for RNA synthesis.

2. Elongation

- RNA polymerase moves along the template strand in the 3' to 5' direction, synthesizing the RNA strand in the 5' to 3' direction.
- Ribonucleotides are added to the 3' end of the growing RNA strand, complementary to the DNA template.
- Incoming ribonucleotides form phosphodiester bonds with the growing RNA chain.
- The RNA sugar-phosphate backbone forms with a release of pyrophosphate.
- A short stretch of RNA is synthesized before RNA polymerase clears the promoter and elongation begins.

3. Termination

- Transcription continues until RNA polymerase encounters a termination signal (terminator sequence).
- The newly synthesized RNA strand and RNA polymerase are released from the DNA template.
- The two DNA strands re-form the double helix.

Prokaryotic vs Eukaryotic Transcription

- In prokaryotes, transcription occurs in the cytoplasm and translation can begin immediately on the nascent RNA while it's still being transcribed.
- In eukaryotes, transcription occurs in the nucleus and the RNA needs to be processed and transported to the cytoplasm before translation can begin.
- Eukaryotic transcription is more complex, involving three RNA polymerases and additional transcription factors.

Regulation of Transcription

- Transcriptional regulation is a major point of control for gene expression.
- Transcription factors and other proteins interact with regulatory sequences on the DNA and with the transcription machinery to enhance or repress transcription.
- Eukaryotic transcription is also regulated by the accessibility of DNA, which is influenced by chromatin structure and modifications.

Processing of Eukaryotic RNA Transcripts

- Primary transcript (pre-mRNA) undergoes modifications before becoming mature mRNA:
    - 5' cap addition
    - 3' poly-A tail addition
    - Splicing to remove introns
- These modifications are important for mRNA stability, transport, and translation.

Translation

Overview

- Translation is the process by which the genetic code in mRNA is read to synthesize polypeptides.
- It is the second major step in gene expression, following transcription.
- Translation occurs in the cytoplasm of both prokaryotes and eukaryotes.

Key Components

1. **mRNA**: Messenger RNA, transcribed from DNA, carries the genetic information for protein synthesis.
2. **Ribosomes**: Molecular machines that catalyze protein synthesis by translating mRNA into polypeptides.
    - Composed of rRNA and proteins
    - Have two subunits: large and small
    - Prokaryotic ribosomes are 70S (30S + 50S), while eukaryotic ribosomes are 80S (40S + 60S)
3. **tRNAs**: Transfer RNAs, adapter molecules that carry amino acids to the ribosome and recognize codons in mRNA.
4. **Amino acids**: Building blocks of proteins, attached to tRNAs and incorporated into growing polypeptide chains.

Stages of Translation

1. Initiation

- Ribosomal subunits, mRNA, initiator tRNA, and initiation factors assemble to form the initiation complex.
- In prokaryotes, the small ribosomal subunit binds directly to the Shine-Dalgarno sequence on mRNA.

- In eukaryotes, multiple initiation factors and a 5' cap facilitate ribosome binding to mRNA.

2. Elongation

- The ribosome moves along the mRNA, reading codons and catalyzing peptide bond formation.
- Elongation factors (EF-Tu in prokaryotes, eEF-1 in eukaryotes) bring aminoacyl-tRNAs to the ribosome.
- Peptidyl transferase catalyzes peptide bond formation between the new amino acid and the growing polypeptide chain.
- Translocation moves the ribosome to the next codon, aided by elongation factors (EF-G in prokaryotes, eEF-2 in eukaryotes).

3. Termination

- Stop codons (UAA, UAG, UGA) signal the end of translation.
- Release factors (RF1, RF2 in prokaryotes; eRF1 in eukaryotes) recognize stop codons and trigger peptide release.
- The completed polypeptide is released, and the ribosomal subunits dissociate from the mRNA.

Differences Between Prokaryotic and Eukaryotic Translation

- In prokaryotes, transcription and translation are coupled, occurring simultaneously in the cytoplasm.
- In eukaryotes, transcription occurs in the nucleus, and the mRNA must be processed and exported to the cytoplasm for translation.
- Eukaryotic mRNAs have a 5' cap and a 3' poly(A) tail, which enhance translation initiation.
- Eukaryotic translation is more complex, involving more initiation factors and regulation steps.

Regulation of Translation

- Translation is a key control point for gene expression, allowing rapid changes in protein levels.
- Global regulation often targets initiation factors or ribosome availability.
- mRNA-specific regulation involves RNA-binding proteins or microRNAs that recognize elements in the UTRs.
- Dysregulation of translation contributes to diseases like cancer and neurological disorders.

Regulation of Gene Expression in Prokaryotes

Lac Operon

- Inducible operon in E. coli that regulates lactose metabolism
- Components: lacZ, lacY, lacA structural genes; promoter, operator, regulator (lacI) gene
- Regulation:
    - Repressor (product of lacI) binds operator in absence of lactose, blocking transcription
    - Presence of lactose inactivates repressor, allowing transcription
    - CAP-cAMP complex acts as positive regulator when glucose is low
- Key enzymes produced: β-galactosidase, permease, transacetylase
- Key concepts:
    - Inducible operon system
    - Negative regulation
    - Catabolite repression
- Definitions:
    - Operon: A cluster of genes under the control of a single promoter
    - Inducer: Molecule that triggers gene expression (lactose or allolactose)
    - Repressor: Protein that inhibits gene expression (LacI)
- Mechanisms:
    - Repression: LacI binds operator, blocking RNA polymerase
    - Induction: Lactose binds repressor, allowing transcription
    - Catabolite repression: CAP-cAMP complex enhances transcription in low glucose

Key differences of eukaryotic from prokaryotic regulation:

- Presence of chromatin structure
- Multiple regulatory elements for a single gene
- Interaction of distant regulatory elements through DNA looping
- Involvement of coactivators and corepressors

Unit 2: Mendelian and Modified Mendelian Inheritance Patterns

Topic 1: Mendelian Genetics

Gregor Johann Mendel:

- Known as the **'Father of Genetics'**
- Austrian Monk
- Worked with pure-line peas (*Pisum sativum*) – considered seven traits or characteristics of pea plants
- Published his paper "Experiment on pea hybridisation" in the *Natural Science Society*
- Could not repeat his work in hawk weeds as it is an asexually reproducing plant
- Work was largely ignored and eventually lost
- It was rediscovered independently by Hugo deVries, Carl Correns, and Erich von Tschermark
- Reasons for Mendel's success:
    - He considered one or two characters at a time.
    - He always selected true breeding varieties.
    - He kept complete records of breeding experiments.
    - He selected those characters which did not show linkage or interaction or incomplete dominance.
    - He was lucky in the fact that genes for the 7 characters selected by him were mostly present on separate homologous chromosomes.

Traits studied by Mendel and their alternative phenotypes in the pea plant:

Trait	**Phenotypes**
Height of the plant	Tall/Dwarf
Seed colour	Yellow/Green
Seed shape	Round/Wrinkled
Pod colour	Green/Yellow
Pod shape	Inflated/Constricted
Placement of flowers	Axial/Terminal
Colour of petals	Purple/White

Some genetics key words:

- ✓ **Gene:** The unit of heredity; functional unit of chromosome and a segment of DNA coding for a polypeptide
- ✓ **Genome:** The entire set of genes in an organism
- ✓ **Alleles:** Alternate forms of a gene (two or more), occupying the same position on homologous chromosomes and are responsible for the same trait

- ✓ **Locus:** A fixed location on a strand of DNA (chromosome) where a gene (or an allele) is located
- ✓ **Homozygous:** Having the same alleles for a gene on both of homologous chromosomes
- ✓ **Heterozygous:** Having different alleles of a gene on its homologous chromosomes
- ✓ **Dominant:** The allele that masks/suppresses the expression of another allele for a gene is said to be the dominant allele. Dominance is seen in a heterozygous condition
- ✓ **Recessive:** The allele whose expression is being masked/suppressed by another allele is said to be recessive. Recessive alleles can be expressed only when present in homozygous condition, otherwise their expression is masked.
- ✓ **Genotype:** The genetic composition of animals with respect to a particular trait. It is the specific combination of alleles an individual has for a given gene or genes.
- ✓ **Phenotype: -** The physical appearance of an organism is the phenotype. It refers to the observable physical characteristics, traits, or behaviors of an organism, resulting from the interaction between its genotype (genetic makeup) and the environment.
- ✓ **Monohybrid cross:** A genetic cross involving a single pair of genes (one trait); two parents differ by a single trait
- ✓ **P:** Parental generation
- ✓ **F_1:** First filial generation
- ✓ **F_2:** Second filial generation
- ✓ **Test Cross:** Crossing an individual with a dominant phenotype but an unknown genotype with its homozygous recessive parent is a test cross
- ✓ **Back cross:** Crossing a F1 progeny with either of its parental genotpes is called a back cross.

Mendel's Laws:

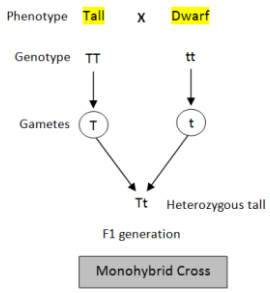
Mendel derived a total of three principles:

1. Law of dominance
2. Law of segregation
3. Law of independent assortment

The first two laws were derived from the monohybrid cross and the third from the dihybrid cross.

Monohybrid cross:

For stem length (height) of the pea plant:



Mating of F1 progeny:

F2 generation -

♂ Tt

Gametes	T	t
T	TT (Tall)	Tt (Tall)
t	Tt (Tall)	Tt (Dwarf)

♀ Tt

Monohybrid Ratios:

- Phenotypic Ratio - Tall:Dwarf = 3:1
- Genotypic Ratio - TT:Tt:tt = 1:2:1

Dihybrid Cross:

Phenotype of parents → Yellow Round × Green Wrinkled

Genotype → YYRR × yyrr

Gametes → YR × yr

F_1 generation → YyRr (Yellow round)

Selfing of F_1 generation → YyRr × YyRr

Gametes → YR Yr yR yr × YR Yr yR yr

F_2 generation →

♀ \ ♂	YR	Yr	yR	yr
YR	YYRR Yellow round	YYRr Yellow round	YyRR Yellow round	YyRr Yellow round
Yr	YYRr Yellow round	YYrr Yellow wrinkled	YyRr Yellow round	Yyrr Yellow wrinkled
yR	YyRR Yellow round	YyRr Yellow round	yyRR Green round	yyRr Green round
yr	YyRr Yellow round	Yyrr Yellow wrinkled	yyRr Green round	yyrr Green wrinkled

Dihybrid Ratios:

- Phenotypic Ratio:
  Yellow Round : Yellow Wrinkled : Green Round : Green Wrinkled = 9:3:3:1
- Genotypic Ratio:

  RRYY: RRYy: RRyy : RrYY : RrYy : Rryy : rrYY : rrYy : rryy = 1:2:1:2:4:2:1:2:1

The following laws of inheritance were derived by Mendel from these crosses:

1. Law of Dominance:

- It states that in a pair of alleles for a particular gene, one allele can suppress the expression of the other allele.
- In such a case, only the dominant allele will be expressed as the phenotype, and the recessive allele will be expressed only in the absence of the dominant allele.

2. Law of Segregation:

- It states that during the formation of gametes (sperm and eggs), the two alleles for a given gene separate, or segregate so that each gamete carries only one allele for each gene.
- It is a universal law

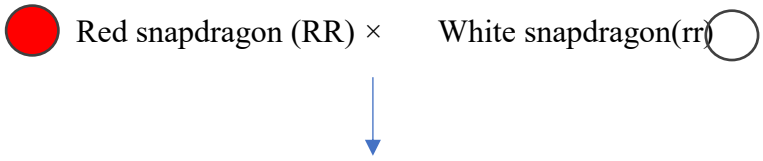
3. Law of Independent Assortment:

- During the formation of gametes, the segregation of one pair of alleles is independent of the segregation of another pair.
- As a result, different combinations of traits may be seen in the offspring as compared to the parent.

Topic 2: Modified Mendelian Inheritance

The genetic principles discovered after Mendel, which do not follow Mendel's laws of heredity are called non-Mendelian inheritance principles.

1. **Incomplete Dominance:**
   - The alleles of a gene do not show complete dominance over each other.
   - Rather, the phenotype produced in heterozygous indivduals is the result of a partial expression of both the alleles – it is intermediate to the two extremes of the trait.
   - E.g. snapdragon flowers (*Antirrhinum majus*)



Pink snapdragon flowers (Rr)

- Other examples : Flower colour in *Mirabilis jalapa* (4 o'clock plant), Feather colour of Andalusian chickens
- ∴ Phenotypic ratio = Red:Pink:White = 1:2:1

2. **Co-dominance/Mosaic Inheritance:**
   - No dominant allele
   - Both alleles expressed equally and independently – so no intermediate phenotype is seen here
   - E.g. ABO blood grouping in humans – the alleles for A & B antigens are co-dominant, and as a result, individuals with AB blood group have both antigens expressed on their RBCS.
   - Phenotypic ratio: Blood groups A:AB:B = 1:2:1
   - Another example is coat colour of shorthorn cattle (Red and white produce roan-coloured cattle, as both are expressed)
3. **Multiple Alleles:**
   - More than two alternate forms of a gene (alleles) exist for a single trait at the same locus within the homologous chromosomes
   - No crossing over in multiple alleles
   - Wild type allele is nearly always dominant over the mutant allele
   - More than two alleles exist for a particular gene within a population, contributing to genetic diversity
   - E.g.

     Blood groups in humans I^A (A antigen), I^B (B antigen), i (no antigen, recessive)
     - Coat colour in rabbits

       The alleles include:
       C (full color, dominant)
       c^ch (chinchilla, partial color)
       c^h (Himalayan, temperature-sensitive color)
       c (albino, recessive)

4. **Complementary gene action:**
   - Pair of genes working together to produce a particular phenotype
   - Only two phenotypes seen instead of 4
   - If:
     - Homozygous dominant - Dominant phenotype
     - Both genes heterozygous – Dominant phenotype
     - Heterozygous gene + homozygous recessive – Recessive phenotype
     - Both homozygous recessive - Recessive phenotype
   - Atleast one dominant allele should be present for each gene controlling the trait to get the dominant phenotype

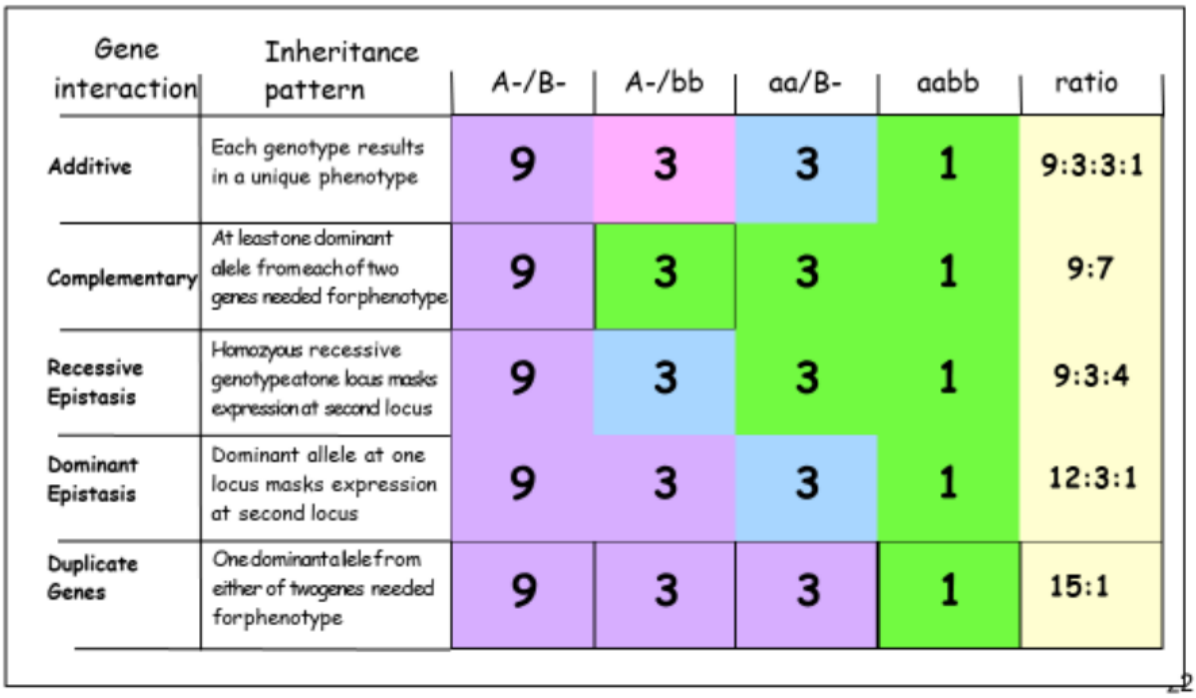
- In a dihybrid cross with complementary genes –
  - Phenotypic Ratio of F2 generation – Dominant:Recessive = 9:7
  - E.g. Flower colour in sweet pea
    - C_P_ - purple flowers
    - ccP_ / C_pp / ccpp – white flowers

5. **Epistasis:**
   - One gene (at one locus) masks or modifies the expression of another gene at a different locus
   - **Types of epistasis:**
     - **Dominant Epistasis:**
       - Description: A dominant allele at one locus masks the expression of alleles at another locus.
       - Phenotypic Ratio: 12:3:1
       - Example: In summer squash, the dominant allele for white color (W) masks the expression of alleles for yellow or green color.
     - **Recessive Epistasis:**
       - Description: A recessive allele at one locus masks the expression of alleles at another locus.
       - Phenotypic Ratio: 9:3:4
       - Example: In Labrador retrievers, the presence of two recessive alleles (ee) at one locus masks the expression of black or brown coat color, resulting in yellow coat.
     - **Duplicate Dominant Epistasis**:
       - Description: Either of two dominant alleles at different loci can produce the same phenotype.
       - Phenotypic Ratio: 15:1
       - Example: In some plants, if either of two genes has a dominant allele, the trait is expressed.
     - **Duplicate Recessive Epistasis:**
       - Description: Two recessive alleles at either of two loci can produce the same phenotype.
       - Phenotypic Ratio: 9:7
       - Example: In sweet peas, two recessive alleles at either of two loci result in white flowers, while having at least one dominant allele at both loci results in colored flowers.
     - **Dominant Inhibitory Epistasis:**
       - Description: A dominant allele at one locus inhibits the expression of alleles at another locus.
       - Phenotypic Ratio: 13:3
       - Example: In some plants, a dominant allele can suppress pigment production regardless of other gene expressions.
     - **Polymeric Gene Interaction:**
       - Description: Two dominant alleles at different loci intensify the phenotype or create a new variation.

        - Phenotypic Ratio: Varies depending on specific gene interactions.
    - **Examples of Epistasis:**
        - Coat Color in Mice: The agouti gene determines coat color patterns, but another gene can cause albinism, masking the agouti gene's effects.
        - Albinism in Humans: A gene mutation can prevent melanin production, overriding other genes that would determine hair or skin color.
        - Flower Color in Peas: Two genes are involved in pigment production; both must have dominant alleles for the color to be expressed.

Summary:

S. No.	Type	Phenotypic ratio in F2
1	Incomplete dominance	3:1
2	Codominance	1:2:1
3	Complementary gene action	9:7
4	Dominant Epistasis	12:3:1
5	Recessive Epistasis	9:3:4
6	Duplicate dominant	15:1
7	Duplicate recessive	9:7
8	Dominant Inhibitory	13:3
9	Supplementary genes	9:3:4



Topic 3: Pleiotropy, Penetrance and Expressivity

Pleiotropy:

Single gene influences multiple, seeminlgly unrelated traits. This occurs because the gene's product (typically a protein) has effects on various physiological processes or developmental pathways.

Examples:

1. Sickle Cell Anemia:

- **Gene Involved:** The *HBB* gene, which encodes beta-globin, a component of hemoglobin.
- **Traits Affected:** A mutation in the beta-globin gene affects the shape and function of red blood cells, leading to anemia, pain, and organ damage

2. Cystic Fibrosis:

- **Gene Involved:** The *CFTR* gene, which codes for the cystic fibrosis transmembrane conductance regulator protein.
- **Traits Affected:** This gene mutation leads to cystic fibrosis, affecting multiple organs. The protein malfunction causes thick mucus production, leading to respiratory issues (chronic lung infections), digestive problems (pancreatic insufficiency), and reproductive complications (infertility).

3. Phenylketonuria (PKU):

- **Gene Involved:** The *PAH* gene, which encodes phenylalanine hydroxylase.
- **Traits Affected:** Intellectual disability, developmental delays, and other neurological problems if the condition is not managed through dietary restrictions.

Penetrance

Penetrance refers to the proportion of individuals with a specific genotype who exhibit the associated phenotype. It is a measure of how consistently a gene expresses its traits.

Degrees of Penetrance

- **Complete Penetrance**: When 100% of individuals with a specific genotype express the associated trait. For example, neurofibromatosis type 1 (NF1) shows complete penetrance.
- **Reduced Penetrance**: When less than 100% of individuals with a specific genotype express the associated trait. Factors such as genetic background, environment, and lifestyle can influence reduced penetrance. For example, the BRCA1 gene mutation has a breast cancer penetrance of about 65% by age 70.

Factors Affecting Penetrance

- **Genetic Factors**: Modifier genes can influence the expression of the primary gene.
- **Environmental Factors**: Conditions such as diet, lifestyle, and exposure to toxins can affect gene expression.

- **Epigenetic Factors**: Changes in chromatin structure and DNA methylation can modify gene expression without altering the DNA sequence

Expressivity

Expressivity refers to the degree or intensity with which a particular genotype is expressed in the phenotype. Unlike penetrance, which is a qualitative measure, expressivity is quantitative and describes the range of phenotypic expression.

Variable Expressivity

Variable expressivity occurs when individuals with the same genotype exhibit different phenotypes. This can result in a spectrum of traits that vary in severity, size, color, etc.

Examples

- **Polydactyly in Cats**: The number of extra toes in Hemingway's cats varies due to variable expressivity of the ZRS gene.
- **Marfan Syndrome**: Individuals with this syndrome exhibit a range of symptoms, including variations in limb length and joint flexibility, due to variable expressivity

Topic 4: Lethal genes, Sex-linked, Sex-influenced and Sex-limited Traits

Lethal Genes

Definition:
Lethal genes are alleles that cause the death of an organism, either during prenatal development or shortly after birth. These genes can be either dominant or recessive and can lead to various genetic disorders or conditions.

Types of Lethal Genes:

1. **Recessive Lethal Genes:**
    - **Description:** These genes do not cause death unless an organism carries two copies of the lethal allele (homozygous recessive).
    - **Examples:**
        - **Cystic Fibrosis:** A genetic disorder affecting the lungs and digestive system.
        - **Sickle-Cell Anemia:** A condition where red blood cells become misshapen and can cause various health issues.
        - **"Amputated" Condition in Swedish Holstein Friesian Cattle:** Results in calves without legs and parrot jaws when homozygous.
2. **Dominant Lethal Genes:**

- **Description:** These genes are expressed in both homozygous and heterozygous states, often leading to rapid elimination from populations due to their severe effects.
- **Examples:**
    - **Huntington's Disease:** A neurodegenerative disorder that typically manifests in adulthood, leading to motor dysfunction and cognitive decline.

3. **Conditional Lethal Genes:**
    - **Description:** These genes cause death only under certain environmental conditions.
    - **Examples:**
        - **Favism:** A sex-linked condition caused by a deficiency in the enzyme glucose-6-phosphate dehydrogenase. Individuals with this condition can develop hemolytic anemia when they consume fava beans, which can lead to kidney failure and death.

Lethal Genes in Farm Animals:

- **"Amputated" Condition:** Found among Swedish Holstein Friesian cattle, leading to calves born without legs.
- **Hypotrichosis:** A congenital lethal condition found in Swedish Holsteins and Jerseys in the United States, characterized by a lack of hair.
- **Creeper Chickens:** A semi-dominant lethal factor in poultry, where birds have shortened wings and legs, giving them a squatty appearance.

Key Points:

- **Impact on Populations:** Lethal genes can significantly impact breeding programs and population genetics by reducing the number of viable offspring.
- **Genetic Counseling:** Understanding lethal genes is crucial for genetic counseling and managing breeding programs to avoid the propagation of these alleles.
- **Research and Management:** Ongoing research is essential to identify lethal genes and develop strategies to manage their effects in both human health and animal breeding.

Sex-linked, sex-limited and sex-influenced inheritance

Sex-Linked Inheritance

Types of Sex-Linked Inheritance:

1. **X-Linked Inheritance:**

- **Description:** Traits determined by genes located on the X chromosome. Since females have two X chromosomes (XX) and males have one X and one Y chromosome (XY), X-linked traits are more commonly expressed in males.
- **Examples:**

  1. X-linked recessive disorder

  - **Red-Green Color Blindness:** A recessive disorder where affected individuals have difficulty distinguishing between red and green colors.
  - **Hemophilia:** A recessive disorder that impairs blood clotting, leading to excessive bleeding.
  - **Duchenne Muscular Dystrophy:** A severe form of muscular dystrophy caused by mutations in the dystrophin gene on the X chromosome.

  2. X-linked dominant disorders:

  - **Incontinentia Pigmenti:** A disorder affecting the skin, hair, teeth, and central nervous system

2. **Y-Linked Inheritance:**
   - **Description:** Traits determined by genes located on the Y chromosome. These traits are only passed from father to son, as only males carry the Y chromosome.
   - **Examples:**
     - **Hypertrichosis (Hairy Ears):** A condition characterized by excessive hair growth on the ears.
     - **Spermatogenesis Genes:** Genes involved in the production of sperm, which are passed directly from father to son

Characteristics of Sex-Linked Inheritance

- **X-Linked Recessive Traits:**
  - More common in males because they have only one X chromosome. A single recessive allele on the X chromosome will result in the trait being expressed.
  - Females can be carriers if they have one recessive allele but typically do not express the trait unless they have two recessive alleles.
  - **Criss-Cross Inheritance:** X-linked recessive genes are transmitted from an affected male to all his daughters (carriers) and then to half of his grandsons through those daughters.
- **X-Linked Dominant Traits:**
  - Can be expressed in both males and females if they inherit the dominant allele.

    - Affected males will pass the trait to all their daughters but none of their sons.
- **Y-Linked Traits:**
    - Only affect males and are passed directly from father to son.
    - Traits include those related to male development and fertility.

Sex-Limited Inheritance

Definition:
Sex-limited inheritance refers to traits that are expressed in only one sex, even though the genes responsible for these traits are present in both sexes. These traits are typically influenced by the hormonal environment specific to one sex.

Examples:

- **Milk Production in Cattle:** Only female cattle produce milk, even though both males and females carry the genes for milk production.
- **Egg Production in Poultry:** Only hens lay eggs, although roosters also carry the genes for egg production.
- **Prolificacy in Rabbits, Swine, and Goats:** Traits related to reproductive efficiency are expressed only in females.
- **Plumage in Peacocks:** Males display elaborate tail feathers, while females do not.
- **Beard in Men:** Beard growth is a sex-limited trait expressed only in males.
- **Breast Development in Women:** Breast development is typically seen in females, although hormonal imbalances can cause breast development in males.

Key Points:

- Expressed in only one sex.
- Presence of genes in both sexes, but expression is limited to one due to hormonal differences.
- Examples include milk production, egg production, and secondary sexual characteristics like beard growth and breast development.

Sex-Influenced Inheritance

Definition:
Sex-influenced inheritance involves autosomal traits (not located on sex chromosomes) but are expressed differently in males and females. The expression of these traits is influenced by the sex of the individual, often due to hormonal differences.

Examples:

- **Baldness:** The gene for baldness is dominant in males but recessive in females. A male needs only one allele for baldness to express the trait, while a female needs two.
- **Horn Development in Sheep:** In the Dorset breed, both sexes are horned, while in the Suffolk breed, both sexes are hornless. The expression of horns is influenced by the genetic background and sex of the sheep.

Key Points:

- Autosomal traits that are expressed differently in males and females.
- Expression is influenced by the hormonal environment.
- Examples include baldness and horn development in sheep.

Topic 5: Sex Determination

Sex determination in animals is a fascinating and complex process that varies significantly across different species. Here are some detailed notes on the primary mechanisms of sex determination in animals:

Chromosomal Sex Determination

Chromosomal sex determination is one of the most common methods and involves specific combinations of sex chromosomes that determine an individual's sex.

- **XY System**: This is prevalent in mammals, including humans, where females have two X chromosomes (XX) and males have one X and one Y chromosome (XY). The presence of the Y chromosome, which carries the SRY gene, leads to the development of male characteristics.
- **ZW System**: Found in birds and some reptiles, this system is the opposite of the XY system. Females are ZW, and males are ZZ. The W chromosome plays a crucial role in determining female characteristics.
- **XO System**: Used by some insects like grasshoppers, where females are XX, and males are XO (having only one X chromosome and no Y).
- **Haplodiploidy**: Seen in species like bees and ants, where unfertilized eggs develop into males (haploid), and fertilized eggs develop into females (diploid).

Genic Balance Theory

- Given by C.B. Bridges
- Applicable under XX-XY system in *Drosophila*

Ratio (X:A)	Ratio	Sex
XX:AA	1.0	Normal female
XY:AA	0.5	Normal male

XXX:AA	1.5	Triple-X female
XO:AA	0.5	Meta-female

Unit 3: Population and Quantitative Genetics

Topic 1: Population, Gene and Genotype frequencies

Introduction to Population Genetics

- Population: A group of individuals of the same species occupying a given area that can freely interbreed and produce fertile offspring
- Gene pool: The sum total of genes of all individuals in a population, consisting of all alleles at all gene loci

Allele and Genotype Frequencies

- ***Allele frequency (a.k.a. Gene frequency)***: Proportion of an allele in the gene pool compared to other alleles at the same locus
    - p = frequency of dominant allele (A), q = frequency of recessive allele (a)
    - $p + q = 1$

- ***Genotype frequency***: Proportion of individuals with a specific genotype in the population
    - AA genotype frequency = p^2
    - Aa genotype frequency = 2pq
    - aa genotype frequency = q^2

  In a population with one-locus-two-alleles condition (A and a), three kinds of individuals will occur – AA, Aa, aa.

  - Therefore: If - N = Total no. of individuals in the population

    D = No. of dominant homozygous individuals

    H = No. of heterozygous individuals

    R = No. of homozygous recessive individuals

    Then, AA genotype frequency = D/N

    Aa genotype frequency = H/N

    aa genotype frequency = R/N
  - **genotype frequency** is obtained by dividing the number of individuals with that genotype by the total number of individuals in the population.

- ***Sample problem***: In a population of 100 individuals with 40 homozygous dominant (AA), 40 heterozygous (Aa), and 20 homozygous recessive (aa) individuals, then allele frequencies (using the allele counting method) will be as follows:
    - Frequency of A = ((2×40) + 40)/200 = 0.6
    - Frequency of a = (40+40)/200 = 0.4

Topic 2: Hardy Weinberg Equilibrium

- States that allele and genotype frequencies remain constant over generations in a large, randomly mating population when evolutionary forces (migration, mutation, selection) are absent.
- It describes the situation where the population is undergoing no evolutionary change
- Assumptions:
    - No mutation, selection, migration
    - Large population size
    - Random mating
    - Equal gamete production and random combination

- Genotype frequencies: p^2 (AA) + 2pq (Aa) + q^2 (aa) = 1

Factors Affecting Hardy-Weinberg Equilibrium

- Small population size: Genetic drift causes random fluctuations in allele frequencies
- Non-random mating: Inbreeding and assortative mating change genotype frequencies
- Mutation: Introduces new alleles, usually at low rates
- Migration: Gene flow between populations alters allele frequencies
- Selection: Different genotypes have different fitness, changing allele frequencies
    - Types: Directional, balancing, disruptive

Applications of HW Law

1. Calculation of frequencies of dominant and recessive genes in a population
    - Recessive homozygotes are phenotypically distinguishable, hence frequency can be calculated
    - Frequency of heterozygotes and dominant homozygotes can not be estimated based on phenotype alone
    - If population is in HW eq^m, knowledge of the frequency of the dominant allele can be estimated using that of the recessive allele, as p + q = 1
    - Introgression of genes in a population - testing frequency of the new genes – used as base for any breeder
2. Calculation of frequencies of carriers or heterozygotes in a population
    - Can be estimated if the gene frequency of one allele is known
    - Use: freq = 2pq = 2p(1-p) = 2(1-q)q
    - Important – to figure out the frequency of carriers of recessive genes or abnormalities in a population
    - Elimination of lethal genes from population – selection decisions
3. To test for agreement with a population in HW eq^m – (to test whether a population is evolving)
    - If gene frequencies are available – expected frequency of genotypes are calculated
    - Observed genotype frequency is estimated from the population
    - Using chi-square test on both observed and expected frequencies, significance of any discrepancy observed is tested

Example:

I. In a population of 1000 cats, coat color is determined by a single gene with two alleles. The dominant allele B produces black coat color, while the recessive allele b produces white coat color. After surveying the population, researchers found 490 black cats and 510 white cats.
Find the following:

1. Calculate the frequencies of the B and b alleles in this population.
2. Using the calculated allele frequencies, predict the expected genotype frequencies (BB, Bb, bb) in the next generation, assuming Hardy-Weinberg equilibrium.

Solutions:

Calculating allele frequencies:
Frequency of b allele (q): √(510/1000) = √0.51 = 0.714
Frequency of B allele (p): 1 - 0.714 = 0.286

Predicting genotype frequencies:
BB: p^2 = 0.286^2 = 0.082 or 8.2%
Bb: 2pq = 2(0.286)(0.714) = 0.408 or 40.8%
bb: q^2 = 0.714^2 = 0.51 or 51%

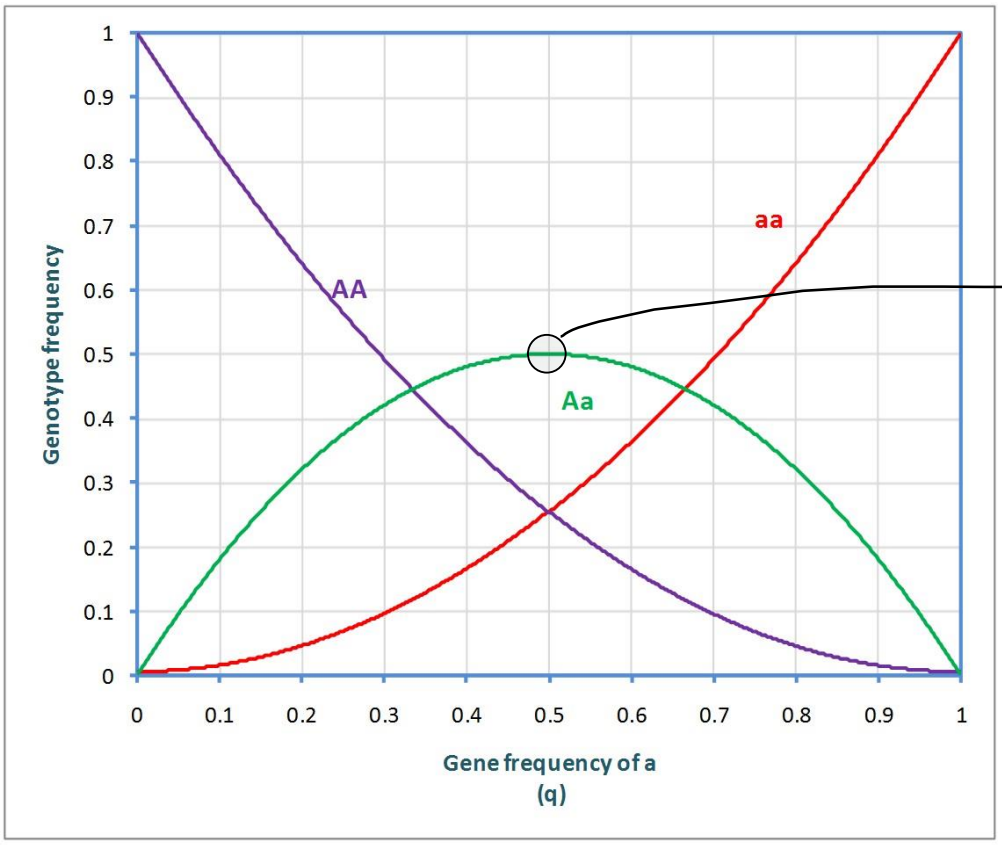
II. In a population of 500 cats, a recessive allele causes a genetic disorder. After testing, 36 cats were found to have the disorder. Calculate:
a) The frequency of the recessive allele (q)
b) The frequency of the dominant allele (p)
c) The expected number of heterozygous carriers in the population

Solution:
a) Calculating the frequency of the recessive allele (q):
- Number of affected cats (homozygous recessive) = 36
- Total population = 500
- Frequency of affected individuals = 36/500 = 0.072
- Since q^2 = 0.072 (frequency of homozygous recessive)
- q = √0.072 = 0.268 (rounded to three decimal places)

b) Calculating the frequency of the dominant allele (p):
- Since p + q = 1
- p = 1 - q = 1 - 0.268 = 0.732

c) Calculating the expected number of heterozygous carriers:
- Frequency of heterozygotes = 2pq
- 2pq = 2 × 0.732 × 0.268 = 0.392
- Expected number of heterozygotes = 0.392 × 500 = 196 cats

Therefore:
a) The frequency of the recessive allele (q) is 0.268 or 26.8%
b) The frequency of the dominant allele (p) is 0.732 or 73.2%
c) The expected number of heterozygous carriers in the population is 196 cats



Relationship between genotype frequencies and gene frequency for two alleles in a population in Hardy-Weinberg equilibrium

Changes in Gene Frequencies Due to Migration and Mutation

Migration (Gene Flow)

Migration introduces new alleles into a population or changes existing allele frequencies. The effect depends on:

- Migration rate (m): Proportion of population composed of migrants
- Allele frequency difference between migrant and resident populations

Change in allele frequency due to migration:

$$\Delta p = m(p_m - p)$$

Where:
Δp = Change in allele frequency
m = Migration rate
p_m = Allele frequency in migrant population
p = Initial allele frequency in resident population

Sample Problem:

A population has an allele frequency of 0.6 for allele A. Migrants with an allele frequency of 0.8 for A enter the population at a rate of 0.1 per generation. Calculate the new allele frequency after one generation of migration.

Solution:

$\Delta p = m(pm - p)$

$= 0.1(0.8 - 0.6)$

$= 0.1(0.2)$

$= 0.02$

New allele frequency = $p + \Delta p = 0.6 + 0.02 = 0.62$

Mutation

Mutation introduces new alleles or changes existing ones. The effect depends on:

- Mutation rate (μ): Probability of a gene mutating per generation
- Back mutation rate (ν): Probability of mutant allele reverting to original form

Change in allele frequency due to mutation:

$$\Delta p = \nu(1-p) - \mu p$$

Where:
Δp = Change in allele frequency
ν = Back mutation rate
μ = Forward mutation rate
p = Initial allele frequency

Sample Problems:

1. In a population, allele A mutates to allele a at a rate of 1×10^{-5} per generation. The back mutation rate from a to A is 2×10^{-5} per generation. If the initial frequency of A is 0.8, calculate the change in allele frequency due to mutation in one generation.

Solution:
$\Delta p = \nu(1-p) - \mu p$
$= (2 \times 10^{-5})(1-0.8) - (1 \times 10^{-5})(0.8)$
$= (2 \times 10^{-5})(0.2) - (8 \times 10^{-6})$
$= 4 \times 10^{-6} - 8 \times 10^{-6}$
$= -4 \times 10^{-6}$

The frequency of allele A will decrease by 0.000004 in one generation due to mutation.

2. A population has an initial frequency of 0.7 for allele B. It experiences migration from a population with a B frequency of 0.9 at a rate of 0.05 per generation. Additionally, B mutates to b at a rate of 2 × 10^-6 per generation, with no back mutation. Calculate the new allele frequency after one generation.

Solution:
Change due to migration: $\Delta p_m = m(p_m - p) = 0.05(0.9 - 0.7) = 0.01$
Change due to mutation: $\Delta p\mu = -\mu p = -(2 \times 10^{-6})(0.7) = -1.4 \times 10^{-6}$

Total change: $\Delta p = \Delta pm + \Delta p\mu = 0.01 - 0.0000014 = 0.0099986$

New allele frequency = 0.7 + 0.0099986 = 0.7099986

Factors Affecting HW Eq^m

1. **Mutations**

- Definition: Sudden, inheritable changes in genetic material
- Types and Examples:
    - Point mutations: Single nucleotide change (e.g., sickle cell anemia in humans)
    - Chromosomal mutations: Large-scale changes (e.g., Down syndrome in humans)
- Effects:
    - Introduce new alleles into the population
    - Can be beneficial, neutral, or deleterious
- Example: In cattle, a mutation in the myostatin gene leads to double-muscling, affecting meat production

2**. Gene Flow (Migration)**

- Definition: Transfer of genetic variation between populations due to movement of individuals or gametes
- Effects:
    - Alters allele frequencies in both source and recipient populations
    - Can introduce new alleles or change existing allele frequencies
- Example: Introduction of polled (hornless) cattle breeds into horned populations, altering the frequency of the polled allele

3**. Genetic Drift**

- Definition: Random changes in allele frequencies due to chance events
- Types and Examples:

        - Bottleneck effect: Drastic reduction in population size (e.g., near-extinction of American bison)
        - Founder effect: Establishment of a new population by a small number of individuals (e.g., Chillingham cattle in England)
    - Effects:
        - More pronounced in small populations
        - Can lead to loss of genetic variation
    - Example: Loss of genetic diversity in small, isolated populations of endangered breeds like the Florida Cracker cattle

4**. Non-random Mating**

- Definition: Mating patterns that deviate from random mating assumptions
- Types and Examples:
    - Inbreeding: Mating between closely related individuals (e.g., line breeding in pedigree dogs)
    - Assortative mating: Mating between individuals with similar phenotypes (e.g., selection for coat color in cattle)
- Effects:
    - Increases homozygosity in the population
    - Can lead to deviations from Hardy-Weinberg proportions
- Example: Increased incidence of genetic disorders in highly inbred dog breeds, such as hip dysplasia in German Shepherds

5**. Natural Selection**

- Definition: Differential survival and reproduction of individuals based on their genetic makeup
- Types and Examples:
    - Directional selection: Favors one extreme of a trait (e.g., artificial selection for milk yield in dairy cattle)
    - Stabilizing selection: Favors intermediate phenotypes (e.g., birth weight in most mammals)
    - Disruptive selection: Favors extreme phenotypes (e.g., beak size in Galápagos finches)
- Effects:
    - Changes allele frequencies over time
    - Can lead to adaptation and evolution

- Example: Development of antibiotic resistance in bacteria affecting livestock, such as Staphylococcus aureus in dairy cows

Topic 3: Quantitative Genetics Concepts – Heritability, Repeatability and Correlation

Traits:

- *Quantitative traits* – measurable, continuous, polygenic, environmentally affected
- *Qualitative traits* – fall into distinct categories, discontinuous traits, can't be measured, only graded.

From now on, we will be talking only about quantitative traits.

- Economic traits – characters of economic importance (related to the economic value/productivity/profitability of the animal production system)
  - *Production Traits* – milk yield, fat percentage, egg production traits
  - *Reproduction Traits* – Age at first calving, inter calving interval, conception rate etc.
  - *Growth Traits* – Birth weight, FCR, carcass traits etc.
  - Since economic traits are majorly controlled by quantitative genes, there is a great deal of variation observed in their expression (i.e. phenotype)
- The expression of a particular phenotype (P) for a particular trait is affected by both the genotype (G) of the individual and the environment (E) in which the individual is placed. Both genotype and environment contribute their effects separately, but they also interact with each other. This interaction also affects the expression of the trait.
- Explanation for G*E interaction:
  - For example, consider the growth of an apple tree. If you have two apple trees with the same genetic constitution (i.e. the same genotype), and if you plant one of them in Kashmir and one in Karnataka, which one do you think will grow better and give tasty apples? Answer is: the one in Kashmir. This is because the genes of that apple are better suited for that environment than the hot conditions of Karnataka. That means, production will be better in one environment and lesser in the other, even though the genotype is the same.

  ∴We can say that,

$$P = G + E + (G*E)$$

  - The 'G' can be further divided into additive genetic effect (A) and dominance effect (D).
    - Additive genetic effect (A) – In polygenic inheritance of quantitative traits, each of the genes has a small effect and the phenotype observed is the overall cumulative effect of all these genes, i.e., their additive

effect. This is the portion that will be transmitted to the offspring without change, i.e., determines the breeding value of the parent.

- Dominance effect (D) – This is the effect of the interaction between the two alleles for a gene, where the dominant allele influences the character.
- Interaction effect (I) – The influence of the inter-genic interaction (*viz.*, epistasis, complementary genes, etc.) on the expression of the phenotype.
- Dominance and interaction effects exist only in an individual and cannot be passed on to the next generation, as the combination of alleles and genes breaks during gamete formation.

Due to all these effects (G, E, and G*E), there is a range of various phenotypes observed for a trait. This is known as its 'variation' and to study it, we calculate the 'variance'

- **Components of Variance:**
  - Quantitative Variance of a population is of three types:
    - Phenotypic Variance (V_P)
    - Genotypic Variance (V_G)
    - Environmental Variance (V_E)
  - Genetic Variance is further divided into three components
    - Additive genetic Variance (V_A)
    - Dominance Variance (V_D)
    - Epistatic Variance (V_I)

$$V_P = V_G + V_E$$

$$V_P = (V_A + V_D + V_I) + (V_{Ep} + V_{El})$$

Breeding Value

- It is, the average effect of the parent's genes that determine the mean genotypic value of the progeny.
- The value of an individual is judged by the mean value of its progeny, which is called the **breeding value** of the individual.
- Thus, **Breeding value** of an individual is the mean phenotypic value of its progeny.

- If an individual is mated to a number of individuals taken at random from the population, then its **breeding value** is twice the mean deviation of the progeny from the population mean.
- Each parent contributes half of the genes to their offspring, so the mean deviation of the progeny reflects only half of the parent's genetic potential. To determine the true breeding value of a parent, we double the mean deviation of their progeny. Since the parent mates randomly with others in the population, the average genetic contribution from the other mates is zero relative to the population mean. Therefore, the **deviation has to be doubled because the parent in question provides only half of the genes of the progeny,** the other half is coming at random from the population.
- In terms of **average effect of gene**, the **breeding value** of an individual is equal to sum of the average effect of genes it carries, the summation being made over the pair of alleles at each locus and over all loci.

Heritability, Repeatability and Correlation

Heritability

Definition and Concept

- Heritability measures the degree to which offspring resemble their parents in trait performance.
- It represents the strength of the relationship between phenotypic values and breeding values for a trait in a population.
- Denoted by the symbol h^2.
- It is necessary for determining the breeding value of the individuals

Types of Heritability

- Broad sense heritability: $h^2 = V_G / V_P$
    - Represents the influence of the entire genotype on the phenotype.
    - Not very useful for selection: the whole genotype (including dominance & interaction effect) can't be transmitted to the progeny, only the additive genetic effect is transmitted.
- Narrow sense heritability: $h^2 = V_A / V_P$
    - More useful for breeding purposes.
    - Represents the additive genetic portion of phenotypic variance.

Characteristics of Heritability

- Estimable - Ranges from 0 to 1 or 0% to 100%
- Always positive in value

- Dimensionless – Pure ratio (ratio of variances – has no unit)
- Population parameter/measure

Heritability Categories

- Low heritability: $h^2 < 0.2$ (e.g., fertility, survivability traits)
- Moderate heritability: $h^2 = 0.2\text{-}0.4$ (e.g., production traits like milk production, growth rate)
- High heritability: $h^2 > 0.4$ (e.g., carcass traits, structural size, mature body weight)

Practical Implications

1. Selection
    - High heritability: Individual selection may yield better progeny.
    - Low heritability: Individual performance is not a reliable indicator of superior genotype.
2. Prediction
    - Low h^2: Difficult to predict if the animal will pass on the trait.
    - High h^2: Highly likely that the genetic potential of progeny will be similar to the parent.
3. Management
    - High heritability: Phenotype largely influenced by genetics, environment has less impact.
    - Low heritability: Environment plays a significant role, management can improve productivity.
4. Breeding Strategies
    - High narrow sense heritability: Characters governed by additive gene action, selection for improvement is rewarding.
    - Low narrow sense heritability: Non-additive gene action, heterosis breeding is beneficial.

Factors Affecting Heritability Estimates

- Sample size: Large samples necessary for accurate estimates.
- Sampling methods: Random sampling provides true estimates of genetic variance.
- Experimental design: Increasing plot size and replications can reduce experimental error.

Interesting Note

- Heritability for the number of legs in dogs is 0, despite being genetically determined, due to lack of variation in the trait within the population.

- This is because heritability exists for the variation observed in traits, not for the traits themselves, even though all traits are genetically determined.

Repeatability

i. Strength of relationship (Correlation) between repeated measurements for a trait in the population

1. It can only be determined for traits which have more than one measurement in the lifetime of an animal, e.g. milk yield, egg production, etc.
2. It can not be determined for traits which occur only once, *viz*, age at first calving, age at sexual maturity, carcass traits etc.

ii. It is denoted by 'r' and expressed as:

$$r = \frac{v_G}{v_P}$$

iii. It ranges from -1 to +1

1. Very rarely can it be -1
2. R=0 means there is no repetition of the performances for a particular trait
3. R=1 (or close to 1), there is a high chance that the performance for a trait will be repeated throughout the life of the individual
4. Ranges of repeatability:
    - $r < 0.2$ – low repeatability
    - $0.2 < r < 0.4$ – moderate repeatability
    - $r > 0.4$ – high repeatability

iv. Practical implications:

1. When repeatability is high, the first record is a good indicator of its subsequent records
2. Repeatability is the relationship between single performance record and producing abilities
3. When repeatability is high, differences in performance of individuals of a population are mainly due to differences in their producing abilities, not due to environment, and vice versa.
4. Repeatability is used to take culling decisions:
   If a trait is highly repeatable in a population, the first production records can be helpful in deciding which animals to cull.
5. Repeatability and Prediction:
   By calculation of MPPA, repeatability can help in predicting the performance of individuals in a population, therefore it is important for selection decisions as well.

v. Importance:

1. Sets upper limit for genetic determination and heritability
2. Determines gain from repeated measurements
3. Allows prediction of future performance
4. It is used in the calculation of Most Probable Producing Ability (MPPA)

Correlation

- Strength of relationship between two variables (either traits or values for the same trait)
- Three types:
    - Genetic correlation - Strength of relationship between breeding values for two traits
    - Phenotypic correlation - Strength of relationship between performances for two traits
    - Environmental correlation - Strength of relationship between effect of environment on two traits
- It ranges from -1 to +1, with 0 indicating no genetic relationship between traits.

Genetic Correlation:

- ✓ Correlation can be positive and negative:
    - A positive genetic correlation means selection for one trait will lead to improvement in the other trait as well., e.g. milk yield and mastitis incidence
    - A negative genetic correlation means selection for one trait will lead to a decline in the other trait., e.g. milk yield and milk fat percentage
- ✓ Genetic correlations are important for developing breeding programs and selection indices. They help predict correlated responses to selection.
- ✓ High genetic correlations allow indirect selection for difficult-to-measure traits.
- ✓ Common genetic correlations in livestock:
    - Positive correlation between milk yield and mastitis incidence in dairy cattle
    - Positive correlation between body weight and egg production in poultry
    - Negative correlation between growth rate and reproductive performance in pigs
- ✓ Genetic correlations can change over time due to selection.
- ✓ Environmental factors can mask true genetic correlations.
- ✓ Accurate estimation requires large datasets and pedigree information.
- ✓ Understanding genetic correlations helps avoid unintended consequences of selection.

- ✓ Genetic correlations are population-specific and may vary between breeds.
- ✓ Multi-trait selection indices account for genetic correlations between traits.

Topic 4: Selection Methods

Selection Differential (S)

- 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.

$$S = (P_s - P)$$

where,

  - P_s = 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,

$$S = i \times \sigma_P$$

Where,

- i = intensity of the selection
- σ_P= phenotypic standard deviation
- The intensity of the selection is also called as *selection* pressure. 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

- ***Factors Affection Selection Differential***
  - Proportions of the animal selected for breeding; smaller the number larger the selection differential
  - Herd size; larger the herd size, smaller the proportions of animals selected
  - Reproductive rate; in cattle selection differential will be less whereas in pigs, it will be more because of more litter size
  - Use of artificial insemination and frozen semen increases selection differential or selection intensity in case of males and in females, super ovulation and embryo transfer increases the selection differential or selection intensity.

Generation Interval

- Definition: The average age of parents when their offspring are born.
- Varies between species and selection procedures.

- Factors affecting Generation Interval:
    - Early breeding in females reduces GI.
    - Progeny testing increases GI.

Accuracy of Selection

- Directly related to the heritability of the trait.

High Heritability:

- Selection on phenotype provides a good estimation of breeding value.

Low Heritability:

- More errors in selection.
- Accuracy can be improved by:
    1. Comparing animals in controlled environmental conditions.
    2. Using techniques to reduce environmental variation, thus increasing heritability.

Improving Accuracy When Individual Selection is Low:

1. Using additional measurements for the trait from the same individual.
2. Using measurements of correlated traits.
3. Using measurements of relatives.

Relationship Between Heritability and Selection Methods

Heritability	Selection Method Effectiveness
High	Phenotypic selection effective
Low	Need additional information

<u>Selection Limit:</u>

- 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.

Response to selection (R)

- The change produced by selection is the change of the population mean in the offspring.
- Symbolized by "R"
- **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.**
- Also called as the expected genetic gain, symbolized by G.

$$R = h^2S$$

where,

- H^2 = heritability
- S = selection differential
- R / year = h^2S / GI where,
- GI = generation interval

Factors affecting genetic gain

- The factors affecting the response to selection are
- heritability
- selection differential and
- generation interval
- Maximum gain will result when the selection differential (S) and the heritability (h^2) are high and the Generation Interval is low.

Bases of Selection

The sources of information indicative of an animal's genetic value w.r.t. a particular phenotype, based on which selection is made, are known as bases of selection.

1. Individual selection
   - Selection of an individual based solely on its performance
   - Good for traits with high heritability – a good indicator of its breeding value for the phenotype
   - Not useful for lowly heritable traits, sex-limited traits and carcass traits

2. Pedigree Analysis
   - Pedigree: Record of an individual's ancestors through its parents.
   - Selection is based on the information from pedigree records
   - Useful for sex-limited traits
   - Closer the relation of the ancestors to the individual, better the selection
   - E.g. selection based on parents and grandparents is more accurate than that based on just its great-great-grand parents

3. Family Selection
   - Selection based upon the performance of collateral relatives (full-sibs, half-sibs, cousins)
   - Two types based on the criteria used for selection:
     a) Individual's records + family records – family selection
     b) Only records of siblings (individual's own records not used) – sib selection
   - Used more frequently in swine and poultry
   - Advantage:
     i. Does not increase generation interval
     ii. Useful for traits which are hard to measure (*viz.*, meat quality in live animals), sex limited traits and traits related to survival and disease resistance
   - ***Accuracy of Selection***
     Factors Affecting Selection Accuracy Based on Collateral Relatives
     - **Heritability**: Higher heritability increases accuracy.
     - **Relationship closeness**: Closer relatives provide better accuracy.
     - **Number of relatives**: More relatives used improves accuracy.
     - **Phenotypic correlation**: Lower correlation between relatives' phenotypes increases accuracy.

4. Progeny Testing
   - Individual selected as a parent based on the records of its progeny
   - High number of progenies is tested before making the decision
   - The production records of progeny are compared to its contemporaries
   - Useful especially for selection of sires for sex-limited traits (milk production)
   - The result of progeny testing for sires is expressed as sire index.
   - Advantage: High accuracy, identification of recessive genes in the sire
   - Disadvantage: Costly, time consuming (if generation interval is high)

Key Points

- Accuracy increases with more half-sibs and higher heritability.
- Accuracy using half-sibs never exceeds 0.5, regardless of number or heritability.
- Full-sibs can provide higher accuracy than half-sibs.
- Progeny testing offers higher accuracy but increases generation interval.

Methods of Selection

- The net economic value of an animal depends on performance of several characters
- Essential to estimate the total breeding worth (net merit) of an animal

- Multi trait selection: selection practiced for several traits simultaneously to improve overall merit

Requirements and efficiency of multi trait selection:

- Estimation of economic value of the traits
- Genetic significance of the animal in terms of h^2 of the traits and genetic correlations among the traits
- The methods of selection and number of traits to be included in the selection criteria

1. **Tandem Method**

- Multi trait selection practiced for improvement of several traits but at different times (one trait at a time)
- Selection continues for all traits one by one
- Efficiency depends on genetic correlation among traits
- Merits: easy to understand and conduct, positive genetic correlation leads to improvement in correlated traits
- Demerits: less efficient, requires more time, undesirable genetic correlation can neutralize progress

2. **Independent Culling Level (ICL) Method**

- Two or more traits taken at a time for selection
- Minimum standard (level) fixed for each trait
- Animal rejected if it fails to meet minimum standard for any one trait
- Efficiency depends on level fixed for each trait
- Advantages: superior to tandem method, culling can start at early age
- Disadvantages: inferior to selection index, no compensation for excellent traits, emphasis on early life traits, intensity reduced with more traits

3. **Selection Index**

- Numerical score assigned to estimate breeding value based on economic weight of traits
- Deficiency in some traits compensated by superiority in others
- Economic weight assigned to each trait based on h^2, economic value, genetic correlations
- Values of all traits added to get total score
- Animal with highest score selected for breeding

- Merits: superior to tandem and ICL, balanced approach, allows superior animals to be selected despite some inferior traits
- Requirements: economic value of traits, genetic and phenotypic variances and covariances of traits

Advances in Selection Methodologies: Marker Based Technologies

Molecular Markers: (Genetic/DNA Markers) –

- Any stable inheritable variation in the genetic sequence
- Can be detected with suitable techniques
- Helpful in identifying the presence of a specific genotype or phenotype other than itself (which is otherwise non-measurable or very difficult to detect)
- Examples: RFLP, DNA Fingerprinting, PCR base markers, AFLP, SNPs etc.

Marker Assisted Selection

1. ***Candidate Gene Approach*** – Gene affecting a trait may have variations, thus affecting the phenotype of a particular trait of interest. Identification of that gene and selection of animals possessing it is the basis of candidate gene approach.
   Disadvantage: Many candidate genes affect one character (polygenic inheritance) – difficult to map out
2. ***Gene Mapping Based Approach –*** Identification of quantitative trait loci (QTLs) – mapping of regions on a chromosome which comprise of one or more genes that influence a multi-factorial trait. The genes are mapped using linkage mapping approach, and selection is done based on the individuals who have inherited certain (linked alleles) QTLs.
3. ***Marker Assisted Introgression –***
   - Introgression is the introduction of favourable alleles/genes from a donor line to a recipient line that does not carry the allele.
   - Using molecular markers to identify the animals carrying the desired allele is called marker assisted introgression
   - Limited application in livestock due to long generation interval, low reproductive rates and greater rearing costs
4. ***Marker Assisted Selection (MAS)***
   - Indirect approach to selection (using genetic correlation)
   - Identification and selection of marker loci linked to QTLs of economic importance
   - Genes with significant effects are targeted for the selection of a particular trait with the help of markers
   - Useful for traits that are lowly heritable and difficult to measure.
5. ***Genome wide Association Studies (GWAS)***
   - Whole genome is screened to detect common genetic variants (like SNPs)
   - Many SNPs can be considered simultaneously and incorporated in the genomic selection process
6. ***Genomic Selection***

- Prediction of genomic breeding values (BV) of animals based on the presence of an assay of genomic markers (like SNPs) and their performance records and development of prediction equations for a population
- Then, selected candidates are genotyped for the presence of the marker and the data is used to estimate GeBVs on which their selection as parents is based.

Integration with Assisted Reproductive Technologies

AI, MOET, ovum pick up are technologies that are already being used. Additionally,

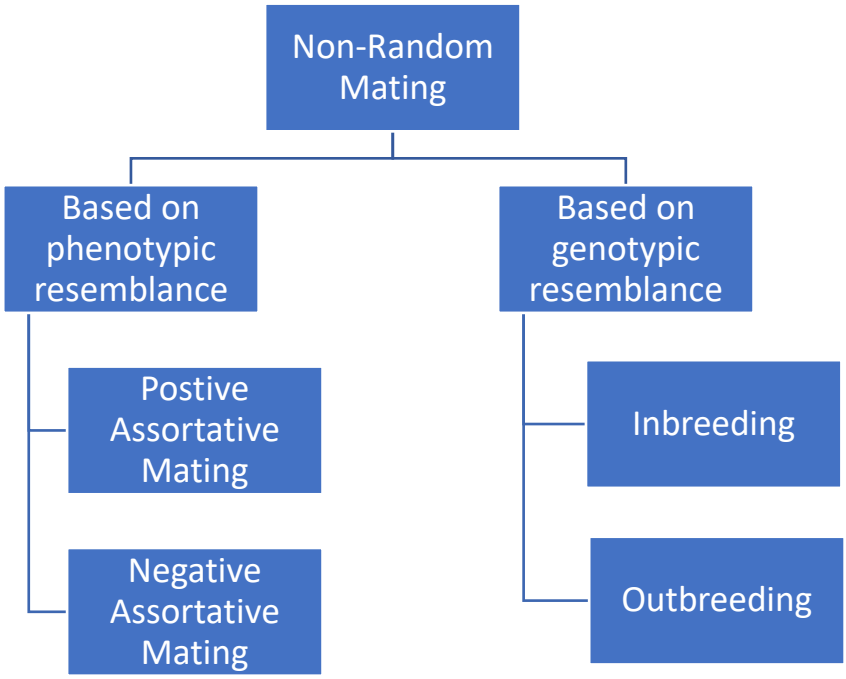
- Genotyping the embryos and selecting them before embryo transfer to get the best quality progeny
- Using ARTs on those animals which have been selected as parents will increase the rate of genetic improvement

Topic 5: Mating Systems

Random Mating (Panmixia):

- Every male has equal chance of mating with every female
- All individuals are fertile
- All individuals contribute an equal number of progeny to the next generation
- Simplest of all mating systems

Non-random Mating:



7. **Based on phenotypic resemblance:**

- Mating of either similar or dissimilar individuals – *assortative mating*

1.1 Positive assortative mating:

- Like to like mating
- Phenotypically similar animals are mated with each other
- Increases homozygosity in the population, reduces heterozygosity
- Increases genetic variance (distribution of genes) in the population
- Might lead to fixing of certain genes and creation of strains within breeds
- Leads to creation of extreme phenotypes in the population

1.2 Negative assortative mating:

- Mating of phenotypically dissimilar individuals
- Loss in homozygosity and gradual increase in heterozygosity
- The whole population starts showing the intermediate phenotype
- Leads to a decrease in genetic variance
- Maintains polymorphism in the population by maintaining different alleles in their heterozygous states

2. **Based on genetic resemblance**
   Introduced after the discovery of a measure of genetic relationship (coefficient of relationship)

2.1 Genetic Assortative Mating (Inbreeding)

- Mating of closely related animals
- Homozygosity increases
- Genetic variability reduces
- Expression of deleterious recessive alleles is prominenet

2.2 Outbreeding:

- Mating of unrelated individuals
- Increases heterozygosity
- Increases genetic variability
- Offers more opportunity for effective selection

Inbreeding:

- Mating of related individuals
- At least one or more common ancestors upto 4-6 generations in the pedigree
- Classification of inbreeding:
  i. Close inbreeding
  ii. Line breeding
  iii. Strain (breeding) formation

i. <u>Close inbreeding</u>

- Matings between sibs/parents and progeny
- Produces inbred lines with relatively high degree of homozygosity

- Most commonly used method – ‘full-sib mating’
- Same effect if continuous back crossing is done to the younger parent
- Purposes of close breeding:
  a) Developing highly inbred lines
  b) Discover undesirable recessive genes
  c) To get more uniform progeny

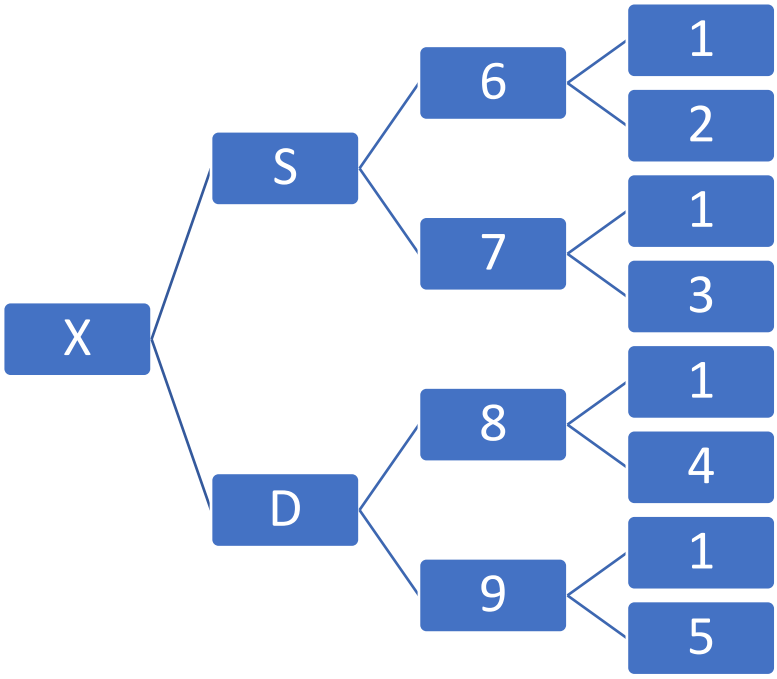
ii. Line breeding:

- Milder form of inbreeding
- Relationship of individuals is kept close to an outstanding ancestor (generally a male) in the pedigree
- Parents chosen – have high relationship to the admired ancestor but not much related to each other
- Reason: Concentrate the inheritance of one ancestor in the line bred offspring
- Practiced in a purebred population of a high degree of excellence after identifying outstanding individuals
- Application: Creation of families or lines within breeds
- Two ways:
  a) Half-sib mating/Cousin mating - lower rate of inbreeding
  b) Descendants mated to the outstanding ancestor directly for 3-4 generations – high rate of inbreeding

Consider the following pedigree:

Here, the pedigree has only one common ancestor between the sire and dam of ‘X’ – that is ‘1’

If there were no common ancestor between ‘S’ and ‘D’, ‘X’ would receive only 12.5% of genes of ‘1’. Instead, due to practice of line breeding, genes from ‘1’ are kept in the line-bred individuals and are passed on to ‘X’, which will have 50% inheritance from ‘1’, which is equivalent to what it would get from a single parent. Therefore, the inheritance of the outstanding ancestor ‘1’ remains concentrated in this pedigree or line.



*<u>*Strain formation*</u>: Breeding in a population without entry of new animals for atleast 3-5 generations; mildest form of inbreeding

Inbreeding Depression:

- Reduction in performance of progeny below the average of their parents
- Expression of unfavourable recessive alleles influencing polygenic traits
- Opposite to hybrid vigour
- Unfavourable gene combination value
- Performance level of inbred animals is low, and susceptibility to stress is high
- Noticeable in traits like fertility and survivability
- Inbreeding depression is not heritable

Outbreeding:

- Mating of unrelated individuals
- Increase in heterozygosity and variability of the population

Heterosis/Hybrid Vigour (H)

- Increased phenotypic value of the progeny over the average of its parents
- For polygenic traits, influenced by dominance
- Outbreeding – gain in gene combination value (due to non-additive dominance & interaction)
- The new combinations create high productivity
- Genetic basis of heterosis: Dominance theory, Over dominance theory, Epistatic theory

Different types of outbreeding systems:

1. Outcrossing:

- Mating of unrelated individuals within the same breed (generally purebred animals).
- No relationship between mates for 4-6 generations
- Exploitation of intra-herd or intra-breed variability

2. Crossbreeding

- Mating of animals from different breeds
- Progeny produced : crossbreds
- Most common form of outbreeding
- Widely practiced in swine, sheep and poultry; lesser in cattle and horses
- Reasons for crossbreeding:
  i. Use of heterosis
  ii. Breed complementarity
  iii. Introduce new genes in a closed population
  iv. Develop synthetic breeds
- Useful when *fertility is high*, *females can be kept for long*, and *cost of replacement is low*

3. Top crossing:

- Inbred male × non-inbred female of the same breed
- Females taken from base population
- The inbred male is the best or 'top' sire in the pedigree

4. Line crossing

- Inbred male of one line × Inbred female of another line
- Exploits heterosis by crossing of both homozygous lines
- Incrossing: Mating of inbred lines within the breed
- Incross breeding: Mating of inbred lines between different breeds

5. Grading up

- Continuous use of purebred sires on females of another breed or non-descript breed to raise them to the level of purebred sire.
- By 7^{th} generation, inheritance of the mongrel stock will reach that of the purebred line
- Normally done for buffaloes in India

6. Species hybridisation:

- Cross between two species
- Most extreme form of outbreeding
- Survivability of outbreds is very low
- Progeny are usually sterile

S. No.	Hybrid	Species Involved	
1.	Mule	Male donkey (Jack)	Female horse (Mare)

2.	Hinny	Female ass (Jennet)	Male horse (Stallion)
3.	Zebroid	Male zebra	Female horse
4.	Cattalo	Male American bison	*Bos taurus*
5.	Pien niu	Male cattle	Female yak
6.	Liger	Male lion	Female tiger
7.	Geep	Male sheep	Female goat

Combining Ability

General combining ability (GCA):

When a particular line is crossed with a number of other lines at random, the mean value of all the F1's in crosses with the other lines (i.e. the mean performance of the particular line) is known as the general combining ability of that line.

- Definition: The average performance of a parent in hybrid combinations.
- Represents the average value of an inbred line based on its behavior in crosses with other lines.
- Indicates the ability of a parent to transmit desirable genes to its offspring
- GCA effects are primarily due to additive gene action
- Used to identify superior parents for breeding programs

Specific Combining Ability (SCA):

The performance of a particular cross, as deviating from the average general combining ability of the two lines is called the specific/special combining ability (SCA) of the cross.

- Definition: The deviation in performance of a specific cross from what would be expected based on the GCA of the parents.
- Represents the unique combination effects that cannot be accounted for by GCA alone
- SCA effects are primarily due to non-additive gene actions (dominance, overdominance and epistasis)
- Used to identify superior specific cross combinations
- Important for traits showing heterosis or hybrid vigour

Key Points:

- GCA is useful for selecting parents, while SCA is useful for selecting specific crosses
- High GCA indicates a parent's ability to produce superior progeny when crossed with a variety of other parents
- SCA is important for identifying exceptional hybrid combinations that perform better than expected based on parental GCA

Recurrent Selection and Reciprocal Recurrent Selection

Recurrent Selection (RS)

- Highly inbred lines with good GCA employed to test a new line
- Test cross progeny are evaluated
- Males and females within the lines are selected based on the progeny testing and used in their own lines to produce the next generation
- Used for improving single lines
- Effective for traits with high heritability

Reciprocal recurrent selection (RRS)

- Two highly inbred lines used to produce progeny
- Each line acts both as a source material for selection and a tester for the other population
- Say two lines 'A' and 'B'
- Males of 'A' are mated with females of 'B' and vice versa
- Progeny produced are judged for their performance, further selection is done based on it within the lines
- Next, males of 'A' are mated with females of 'A' (similarly for 'B') to produce the next generation of parents to be tested.
- The test cross progeny and the individuals not selected as parents are discarded
- The lines 'A' and 'B' are assumed to have a high degree of homozygosity at all loci, but in opposite ways, such that application of RRS make the lines even more opposite w.r.t. the homozygous loci. Therefore, the progeny produced will have high degree of heterosis.
- Widely used in commercial poultry breeding
- Uses GCA of both lines and SCA of cross to produce superior progeny

Breeding Strategies for Improvement:

1. **Progeny Testing:**

- Best method for estimating breeding value or transmitting ability of an individual for a specific trait
- Principle:
  - **i.** Each parent contributes half the genes to its progeny
  - **ii.** Therefore, an average of many progenies will be more or less equal to its true genetic merit (breeding value)
- Generally done for sires (in cattle and buffalo) because number of progenies from sires is much more than from females, therefore the sire has a greater impact on the herd.
- In pleuriparous species – sheep, goat, pig – it can be used to estimate BV of both sire and dam
- Precautions/Requirements:

i. Sire is mated to a random sample of females
ii. Many progenies per sire
iii. Progenies should be maintained in a similar environmental condition
iv. Comparison of the progenies' performance is with its contemporary animals (born at the same time, in the same herd)

- PT is best for sex limited traits, low heritability traits, slaughter traits.]

2. Nucleus Breeding Schemes

Three tiered system – like a pyramid –

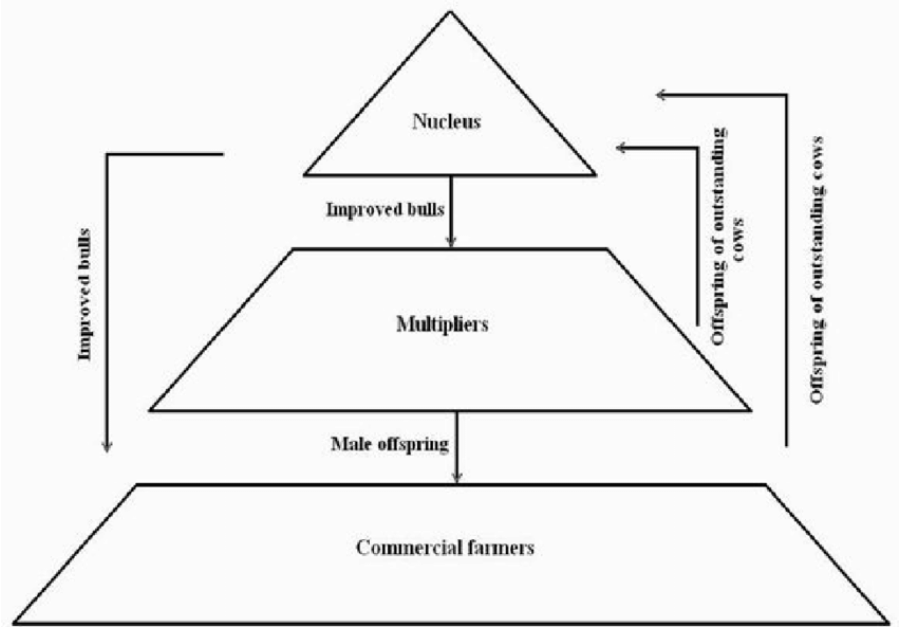
a) Nucleus herd –topmost and narrowest}
   - Males produced for breeding; Top ranking females (10-15%) of the total are included in this herd.
   - Genetic gain produced in the nucleus herd passes to the next herd
   - Male and female replacements for this herd are produced within the herd itself, and sometimes taken from other nucleus herds

b) Multiplier herd
   - Second tier of the NBS
   - Uses sires from nucleus herd
   - The genetic gain from nucleus herd is halved in the multiplier herd because sires pass only half their genes to the progeny
   - Its progeny serves as sires in the next herd
   - Genetic gain from multiplier herd passes to the commercial herd

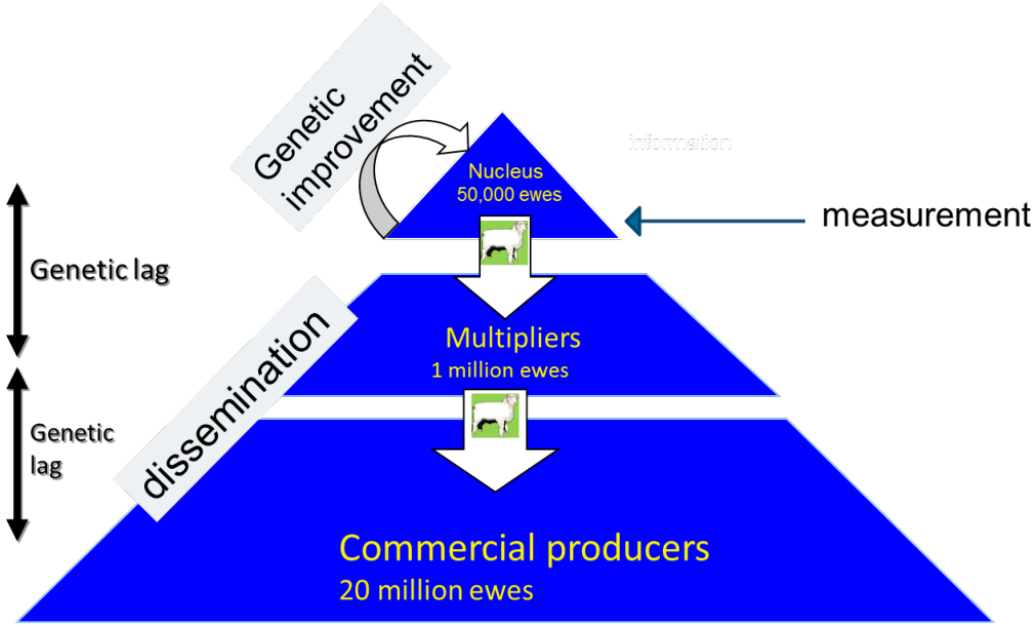
c) Commercial herd
   - Base herds with the farmers
   - It constitutes the broad base of the pyramid

Depending upon the gene flow, NBS is of two types – Open NBS and Closed NBS.

- **Open Nucleus Breeding Scheme**
  i. Gene flow is bidirectional
  ii. Animals can be sent downwards from the nucleus to commercial herds
  iii. They can be sent upwards from commercial to nucleus herds
  iv. Followed mostly in cattle, buffalo and sheep
  v. The central herd of ONBS is mainly under government control
  vi. Proper data recording and breeding practices should be carried out
  vii. The base population is the village herds which provide 10% replacement stock annually.
  viii. Farmers are in turn supplied with good quality bulls
  ix. Hence this is also called the *cooperative breeding scheme*.



- **Closed Nucleus Breeding System**
  - i. Unidirectional flow of genes
  - ii. Animals can be taken from nucleus herd to commercial herd
  - iii. No animals can be brought in from the commercial or multiplier herd into nucleus herd
  - iv. Mainly practiced in pig and poultry breeding programmes to avoid the risk of introducing diseases in the nucleus herd/flock



Unit 4: Breeds of Livestock Animals, Breeding Policies and Breeding Programmes

Topic 1: NBAGR Registered Breeds

Total – 220

Including 1 Synthetic Dairy Cattle breed (Frieswal)

Species	Number of Registered Breeds
Cattle	53
Buffaloes	20
Goat	39
Sheep	45
Chicken	20
Pig	14
Yak	1
Horse and pony	8
Camel	9
Donkey	3
Duck	3
Geese	1
Dog	3

Newly Registered Breeds:

Cattle Breeds	State
Poda Thurpu	Telangana
Dagri	Gujarat
Thutho	Nagaland
Shweta Kapila	Goa
Himachali Pahari	Himachal Pradesh
Purnea	Bihar
Nari	RJ & GJ
Kathani	Maharashtra
Sanchori	Rajasthan
Masilum	Meghalaya
Frieswal (synthetic)	UP & Uttarakhand

Buffalo Breeds	State
Gojri	Punjab and HP
Dharwadi	Karnataka
Manda	Odisha
Purnathadi	Maharashtra
Goat Breeds	**State**
Sojat	Rajasthan
Karauli	Rajasthan
Gujari	Rajasthan
Anjori	Chattisgarh
Andamani	Andaman & Nicobar

Sheep	State
Kajali	Punjab
Macherla	Andhra Pradesh

Chicken	State
Aravali	Gujarat
Donkey	**State**
Kacchhi	Gujarat
Horse	**State**
Bhimthadi	Maharashtra

Pigs	State
Mali	Tripura
Purnea	Bihar, Jharkhand
Banda	Jharkhand
Manipuri Black	Manipur
Wak chambil	Meghalaya
Andamani	Andaman & Nicobar

Special Names:

Species	Names
Buffalo	Black gold/Triple purpose breeds
Sheep	Poor man's mobile bank
Goat	Poor man's cow, shy breeder
Pig	Most intelligent animal
Yak	Ship of high hills
Mithun	Mountain cattle

Topic 2: Breeds of Indigenous and Exotic Cattle and Buffaloes

Indigenous Cattle

Classification based on Characteristics:

Group	Characteristics	Breeds
Group I	Broad face, lyre horns Flat dished forehead Western India	Kankrej, Kherigarh, Malvi, Tharparkar, Kenkatha, Ponwar, Dagri
Group II	Convex face, white/ light grey, short horn Coffin shaped skull	Hariana, Ongole, Bachaur, Gaolao, Krishna valley, Mewati, Nagori, Rathi
Group III	Heavy bull, even curled horn Pendulous sheath , Spotted red/white	Gir, Sahiwal, Red sindhi, Deoni, Dangi, Nimari
Group IV	Medium sized, Long horn up to back Mysore type cattle	Amritmahal, Deoni, Dangi, Nimari, Hallikar, Bargur
Group V	Heterogeneous mixture- north India	Siri , Ponwar
Group VI	Draft – tight naval sheath and dewlap	Dhani

Classification – Based on Utility

Specific Information:

Breed	Specification
Sahiwal, Red Sindhi, Gir, Rathi	Milch type, heat and drought tolerant
Hariana, Ongole	Dual purpose, Milch type, heat and drought tolerant
Nagori	Excellent draught animal for hot climate
Vechur	Miniature cattle (smallest cattle in the world)
Punganur	Dwarf cattle
Umblacherry	Excellent for wet ploughing
Siri	Dual purpose, high altitude breed

Exotic Cattle –

Milch Breeds:

Breed	**Origin**	**Characters**
Jersey	Isle of Jersey, British Channel Islands	High fat percentage (5.5%) Double dished forehead Long Lactation Period (365 days)
HF	Holland/Netherlands	High milk producer (6150 L/lactation) Low milk far percentage (3.5%)
Ayreshire	Scotland	Deep cherry red, Mahogany
Brown Swiss/Braunveih	Switzerland	Oldest High Milk Lactose (5%) Most heat tolerant exotic animal
Guernsey	Isle of Guernsey, British Channel Islands	Yellow milk

Beef Breeds:

Breed	**Origin**	**Characters**
Angus	Scotland	Black, polled, high dressing percentage
Brahman	India	Brought from India, tick resistant,
Hereford	Hereford, England	Red colour, white face, compact body
Charolais	France	White/cream coloured, good marbling
Devon	Southwest England	Red, hardiness, thrive on various types of forage
Beef Master	Texas, Colorado	Brahman X Shorthorn

Braford	Brazil	Brahman X Hereford
Brangus	United States	Angus X Brahman, Black/Red

Synthetic Cattle Breeds:

Breed	**Origin**	**Characters**
Taylor (1856)	Shorthorn & Jersey/Guernsey * Local cow	Patna
Jersind	Jersey * Red Sindhi	Allahabad, NIANI
Sunandini	Brown Swiss * ND	Munnar, Kerala (Indo Swiss Project)
Frieswal	HF * Sahiwal	Military Dairy Farms, ICAR
Karan Fries	HF * Tharparkar	NDRI, Karnal
Karan Swiss	Brown Swiss * Sahiwal/Red Sindhi	NDRI, Karnal
Jerthar	Jersey bull * Tharparkar cow	Bangalore
Vrindavani	HF/Jersey/Brown Swiss * Hariana	IVRI - AICRP
Brown Sind	Brown Swiss * Red Sindhi	

Best Breeds, Peculiarities and Special Horns

Peculiarities	Breed
High milk producing exotic cattle	HF
High fat producing exotic cattle	Jersey
Golden Milk	Guernsey

Traits	Breed
Economic Milk Producer	Red Sindhi
Best dairy breed	Sahiwal
Heaviest dairy breed/Spotted milch breed	Gir
Beef breed of India	Gir, Dangi
Disease Resistance breed	Tharparkar, Kosali, Malanad gidda
High Altitude Cattle	Siri
"Sawai Chal" Gait	Kankrej
Heaviest cattle	Kankrej
Lightest cattle	Punganur
Jalikattu breed	Pulikulam

Horns	Breed
Half Moon Shaped	Gir
Bow Shaped	Khillari
Lyre Shaped	Kankrej, Malvi, Ponwar
Crescent shaped	Punganur, Kangayam
Spiral horn	Nari (backward curl – females Forward curl – males)

Buffalo Breeds:

Classification

1. Murrah Group – Murrah, Nili Ravi, Godavari
2. Gujarat Group – Mehsana, Jaffarabadi, Surti
3. Uttar Pradesh Group – Bhadawari, Tarai
4. Central India Group – Nagpuri, Pandharpuri, Mandi, Jerangi, Kahaladi, Sambalpuri
5. South India Group – Toda, South Kanara

Other Breeds to Remember:

1. Odisha – Chilika, Kalahandi, Manda
2. Gujarat – Banni
3. Assam, Mizoram, Manipur (Brahmaputra valley) – Luit Buffalo (swamp)
4. Punjab, Himachal Pradesh – Gojri
5. Karnataka – Dharwadi

Breed Characteristics:

Breed	Origin	Characteristics	Specifics/Peculiarities	Remarks
Murrah (Kundi/Kali)	Rohtak, Hisar	Jet black, tail reaches fetlock	Most efficient milker, Tightly curled horns	1500-2000 kg milk with 7% fat
Nili Ravi (Panch Kalyani/ Panch Bhadra)	Punjab, Pakistan	Small horns, tightly coiled, White markings on body	Wall eyes Lowest fat (4%)	Milk yield: 1500-1850 kg/lactation
Jaffarabadi	Gir forest, Gujarat	Black in colour, Prominent forehead	Heaviest buffalo breed Long drooping 'J' shaped horns	Avg milk – 1000-1200 kg
Bhadawari	Uttar Pradesh & Gwalior	'Chevron' – two white lines on lower side of neck	Light copper coloured body Highest fat percentage	MY : 800-1000 kg Fat content: 6-12.5%

Breed	Origin	Characteristics	Specifics/Peculiarities	Remarks
Surti	Baroda, Gujarat	Colour: rusty brown to silver grey, Two white collars (jaw & brisket)	Sickle shaped horns	900-1300 kg MY 8-12% far (high fat percent)
Mehsana (Surti X Murrah)	Mehsana, Gujarat	Black/brown colour	Longest Lactation	MY: 1200-1500 kg Good lactation persistency 'Amul Milk'
Nagpuri	Maharashtra	Black with white patches (face, legs, tail) Long thin face, long neck	Sword shaped horns	MY: 700-1200 kg
Pandharpuri	Maharashtra		Sword Shaped horns	Longer letting down period
Toda	Nilgiri, Tamil Nadu	Fawn, ash grey colour, Long body, deep broad chest, strong legs	Most violent buffalo breed	Maintained by tribes
Bunni/Kutchi/Kundi	Gujarat	Black coloured, tightly coiled horns with single/double coiling		Night grazing on grasslands

Buffalo Specials

Feature	Breed
Buffalo used for crossbreeding	Murrah, Surti

Sword Shaped Horns	Nagpuri, Pandharpuri
Inverted coiling/Double coiling	Banni
Long horn upto pinbone	Pandharpuri
Half circle horn	Kalahandi
J-shaped horn	Jaffarabadi
Lightest breed	Nagpuri
Heaviest breed	Jaffarabadi
Long tail touching ground	Murrah, Nili ravi
Highest fat content	Bhadawari (6.5-12%)
Small size (deer buffalo)	Jerangi
Copper coloured buffalo	Bhadawari

Topic 3: Breeds of Indigenous and Exotic Sheep and Goats

Goat Breeds

Exotic Breeds

Goat Breed	Origin	Characteristics	Specials
Saanen	Switzerland	Sabre shaped horns Sensitive to sunlight 4-4.5 L milk/day 3-4% fat	"Milk Queen" of goat world
Toggenberg	Switzerland	Chocolate coloured body Hardy breed – milk producing	
Anglo-Nubian	Jamnapari/Malabari X English breed	Most outstanding dual purpose breed	"Jersey cow of goat world"
Alpine	Africa, France, Switzerland	Not suited to areas of high humidity	Scimitar shaped horns

Indigenous Breeds

- Milch Purpose
    - Beetal, Surti, Mehsana
- Meat purpose
    - Sirohi, Zalawadi, Black Bengal, Ganjam, Attapady Black, Berari, KanniAdu, Konkan kanyal,
- Meat + Milk
    - Jamnapari, Barbari, Marwari, Osmanabadi, Malabari, Gohilwadi
- Pashmina
    - Changthangi, Chegu

Breed	Purpose	State	Characteristics	Specific
Beetal	Milch	Punjab	Males possess beard Convex face, black lips Long pendulous ears	Males possess beard
Jamnapari	Dual (Milk/Meat)	Uttar Pradesh	White colour Both sexes horned Thick hair on buttocks (feathers)	"Most majestic breed" Parrot mouth Milk – 3.89 kg/day avg Butterfat (4.84%) - high
Barbari	Dual (Milk/meat)	Uttar Pradesh/ Rajasthan	Suitable for stall feeding Wedge shaped body City breed	Maximum milk fat (5%)
Jharkhana	Milk	Rajasthan	White spots on ear & muzzle Twisted horns in both sexes	Skin popular for "tanning" purpose
Sirohi	Dual purpose	Rajasthan	Coarse, short hair Brown/white/patched	
Kutchi	Milk, Meat, Hair	Gujarat		"Corkscrew horns" pointed upwards
Black Bengal	Meat, Hide	West Bengal	Black coloured Both sexes – small-med horns Beard in both sexes Hair coat- short & lustrous	"Best chevon breed" of India Skin – shoe making Highly prolific
Changthangi	Wool, Meat	J&K (Ladakh)	White + Brown Twisted horns in both sexes Small size	Pashmina breed – high quality Kashmiri rug/shawl (70-500 g/goat annually)
Chegu	Wool, Meat	Himachal Pradesh, Uttarakhand	Twisted horn in both sexes Long hair, fine downy undercoat White + greyish red mix	Pashmina producing breed

Points to Remember:

Aspect	**Breed**
Lightest goat breed	Changthangi
Tallest goat	Jamunapari
Shortest goat	Barbari
Sheep like goat	Angora
Goat like sheep	Nellore
Fine wool breed of India (goat)	Changthangi
High yielder	Jamunapari
Tender low fat meat and delicate skin	Black Bengal, Surti
Best chevon breed	Black Bengal

Short estrous cycle, high yielder	Barbari
Highly prolific	Black Bengal, Malabari
Long drooping ear	Jamnapari
High FCR	Jamnapari, Barbari
Minimum DM intake	Barbari, Black Bengal
Screw like horn	Zalawadi
Corkscrew horn	Kutchi, Changthangi, Marwari, Zalawadi
Scimitar Shaped horn	Boer, Alpine
Sabre shaped horn	Saanen
Cork shaped horn	Chegu
Goat used for upgrading	Anglo-Nubian

Sheep Breeds

Exotic Sheep Breeds

Breed	Origin	Characteristics	Specifics
Merino	Spain	Horned rams, polled ewes Head-leg – covered with wool	Most popular fine wool breed – Pashmina producing
Rambouillet	France	Horned rams, polled ewes Excellent fine wool fleece Heavy compact fleece	
Dorset	England	Hardy breed	Superior quality mutton
Southdown	England	Oldest English Breeds Mousey grey face Excellent mutton breed	Contributed to development of many sheep

Trait	Breed
Largest and heaviest sheep breed	Lincoln
Best pelt breed (good quality fur)	Karakul
Best mutton breed	Suffolk
Pashmina producing breed/most popular fine wool breed in the world	Merino
Largest fine wool breed/French Merino	Rambouillet

Indigenous Sheep Breeds

Trait	Breed
Indian Merino	Chokla
Yellow wool, Canary coloured wool	Nali
Highly disease & worm resistant	Marwari
Tallest sheep / Goat like sheep / Best mutton breed (India)	Nellore
Shortest, smallest sheep / Best mutton conformation	Mandya
Most prolific sheep	Garole
High quality skin	Mecheri
Best carpet wool	Chokla, Patanwadi
High quality palatable meat	Mandya
Lustrous carpet wool	Magra
Fine quality wool	Gaddi sheep
High quality skin	Mecheri
Best carpet wool	Chokla, Patanwadi
High quality palatable meat	Mandya
Lustrous carpet wool	Magra
Fine quality wool	Gaddi sheep

Synthetic Breeds of Sheep

Breed	Exotic Inheritance	Crosses	Character	Place of development
Bharat merino	75%	Chokla and Nali X Rambouillet Merino	Apparel wool	CSWRI, Avikanagar
Avivastra	50%	Chokla and Nali X Rambouillet Merino	Apparel wool	CSWRI, Avikanagar
Avikalin	50%	Malpura X Rambouillet	Meat & Carpet wool	CSWRI, Avikanagar
Avimans	50%	Malpura and Sonadi X Dorset and Sufflok	Mutton breed	CSWRI, Avikanagar
Indian Karakul	75%	Marwari, Malpura and Sonadi X Karakul	Pelt, Meat, Wool	CSWRI, Bikaner
Kashmir Merino	50-75%	Gaddi, Bhakarwal and Poonchi X Merino and Rambouillet	Apparel wool	J&K
Nilgiri synthetic	62.5-75%	Nilgiri X Merino and Rambouillet	Apparel wool	Sheep Breeding

				Research Station, Sandynallah
Patanwadi synthetic	50%	Patanwadi X Rambouillet and Merino	Wool	DAU, Dantiwada
Hissardale	75%	Bikaneri ewes X Merino rams	Fine wool	GLF, Hisar
Sandyno		Interse mated (Merino X Nilgiri)	Fine wool	

Who Produces Which Fibre??

Angora Rabbit – Angora

Angora Goat - Mohair

Changthangi Goat - Pashmina

Topic 4: Breeds of Indigenous and Exotic Pigs and Poultry

Exotic Pig Breeds

Species	Native	Character
Large white Yorkshire	England	• 1st grade bacon, Highly prolific • Black spot 'Freckles'. Good mother, good milker
Middle white Yorkshire	North England	• Large white X Small white • Excellent pork pig (high % lean meat to bone) • Dished face. Good walker- fast
Berkshire	England	• Descent of old English hog. Erect ears • Good quality pork – typical pork breed • South India for upgrading. Colour – 6 white points
Landrace	Denmark	• Excellent for cross breeding (India) - Loop ears • Highest quality bacon in world • Body has Freckles and Susceptible to sunburn
Hampshire	USA	• Black with white belt around chest
Tamworth	Central England	• Fine quality bacon. Excellent foragers • Colour: Golden red. Used for CB in south east Asia • Careful mother
Duroc	USA	• Jersey red X Duroc of New york • Excellent rate of gain and feed efficiency
Chester white	USA	• Very prolific sow • Foundation stock- English Yorkshire, Lincolnshire, Cheshire breed
Hereford	USA	• Small breed and 2/3rd red colour, white face
Saddle back	England	• Black colour with white forelegs. Very high FCR
Large black	Great Britain	• One of oldest in this area. Very good milker

Indigenous Pig Breeds

Breed	Origin	Characteristics
Ghungroo	North Bengal, Assam	Black colour, pendulous ear, Highly prolific – 6-10 piglets

Niang Megha	Meghalaya	Black, star shaped white patches on forehead 50-60 kg adult body weight
Andamani	Andaman & Nicobar	Adult body weight 68-70 kg, Black/rusty gray
Banda	Jharkhand	Pork, manure type; Adult body weight 27-28 kg, Litter size 4-7 piglets
Manipuri	Manipur	Adult body weight 96 kg (males), Litter size – 6-11 piglets Meat taste preferred by local people
Wak Chambil	Garo hills, Meghalaya	Round & pendulous belly Pork – unique flavour & taste Used for religious & ceremonial occasions
Angoda Goan	Goa	Adapted to coastal environment, few animals, white patches on leg and face
Tenyivo	Nagaland	Pot bellied (pendulous belly touching ground), sagging back, white switch markings, tail touches hock, white stockings
Nicobari	Andaman & Nicobar	Fast runners, No curling of tail
Doom	Assam	Black, large, flat belly type
Zovawk	Mizoram	

Aspect	Pig Breed
Pigs used for crossbreeding	Landrace
Pigs used for upgrading	Large White Yorkshire
Heart-shaped ear pig	Ghungroo
Best pig for show	Duroc
Smallest breed of pig	Kune-Kune pig
Best meat producers	Duroc, American Yorkshire
Bacon Pigs	Large White Yorkshire, Landrace, Tamworth
1st grade bacon	Large White Yorkshire
Pork Pigs	Middle white Yorkshire, Berkshire, Hampshire

Poultry Breeds

Classes of Poultry Birds:

1. American

- Clean Shanks
- Single/Pea comb
- Dual Purpose breeds
- E.g. Plymouth rock, New Hampshire, Rhode Island Red, Jersey Black Giant, Wyandotte

2. Asiatic
    - Feathered Shanks
    - Pea combs
    - Excellent for meat purpose
    - Ornamental purpose breeds
    - E.g. Brahma, Cochin/Shanghai, Langshan

3. English
    - Clean Shanks
    - Various Types of combs
    - Dual purpose breeds – Good meat, variable no. of eggs produced
    - Australorp, Cornish, Orpington, Sussex, Dorking

4. Mediterranean
    - Clean shanks
    - Yellow shanks
    - Single combs
    - Egg type breeds

Indigenous Poultry Breeds

Breed	Origin	Characteristics
Kadaknath/Kalamasi	Madhya Pradesh	Black pigmentation – external and internal surface Light brown eggs Purple comb, wattles and tongue
Aseel	Chattisgarh, Odisha, Andhra Pradesh	Fighting abilities – Game bird Majestic gait, high stamina Broody bird Close relationship with breed 'Ghagus'
Punjab brown	Punjab, Haryana	Meat quality
Chittagong/Malay	Northeast India	Game bird

Naked neck – no feathers around neck – helps with heat dissipation in hot, humid areas
*Naked neck is a genetic trait, not a breed.
- Major gene line developed for broiler production

Strains Developed at CARI

1. Desi/Backyard:
    1. CARI Nirbheek (Aseel cross)
    2. CARI Shyama (Kadaknath cross)
    3. Hitcari (Naked Neck cross)

4. Upcari (Frizzle feather cross)

2. Layers
    1. CARI Priya
    2. CARI Sonali
    3. CARI Debendra
    4. CARI Gold
3. Broilers
    1. CARI Vishal (Caribro-91)
    2. CARI-rainbro (B-77)
    3. CARIbro – Dhanraja
    4. Caribro – mritunjai (CARI Naked neck)

Strains developed at PDP, Hyderabad

Strain	**Cross**	**Purpose**
Vanaraja	Cornish male X Synthetic population	Dual
Gramapriya	Synthetic male X White leghorn female	Dual
Krishibro		Coloured Broiler

Specifics:

Trait	Breed
Disease resistant breed	Kadaknath – free range
Most susceptible to Marek's disease	Kadaknath – Intensive system
Best egg producer (Indian)	Nicobari
World No. 1 egg Producer	Leghorn
Excellent fleshing quality	Sussex
Best broiler breed	Cornish
Best brooder (India)	Brahma
Graceful bird	Langham
Poor mothering ability	Chittagong
Large egg producer	Hampshire
Blue eggs producing chicken	Araucana, Amerucana
Meat of medicinal value	Kadaknath, Telicherry
Convection ability	Naked Neck, Frizzle fowl
Improved adult fitness	Naked neck

Topic 5: Livestock Breeding Policy of India and Specific Policy for Indian States

National Livestock Policy 2013 (DAHD)

Breeding Policy for Cattle and Buffalo

Cattle:

- Selective breeding of indigenous high yielding and good draught cattle breeds in their home tracts
- Upgradation of non-descript cattle through crossbreeding with exotic cattle wherever the climate is supportive
  Breeds used: Jersey and Holstein Friesian
- Upgradation of non-descript cattle through crossbreeding with established indigenous breeds in resource-deficient areas (climate, feed and fodder)
  Breeds used: Sahiwal, Red Sindhi, Gir and Tharparkar

Buffalo:

- Selective breeding of major buffalo breeds in their breeding tracts for milk
- Grading-up of non-descript and minor breeds of buffaloes using high yielding buffaloes – Murrah and Surti

General:

- Production of breeding males of high genetic potential
- Formulation of breed associations with farmers for improvement of various indigenous breeds, with identification/registration of animals with good genetic potential
- Produce disease free high genetic merit bulls for natural service, focusing on the neglected natural mating system
- Use of semen of progeny tested bulls for crossbreeding

Sheep and Goat Breeding Policy

- Aims: Improve growth, body weight, reproductive efficiency, meat and wool quality/quantity, reduce mortality
- Approach: Area-specific for coarse and fine wool improvement
- Focus: Produce and distribute quality rams/bucks of indigenous breeds
- Methods:
  - Artificial insemination encouraged
  - Cross-breeding with high-yielding exotic and native goat breeds considered

- Sheep breed for:
    - Up-grading: Nali, Chokla, Patanwadi, Malpura
    - Crossbreeding: Suffolk, Dorset, Rambouillet, Soviet Merino
- Goat breeds for
    - Up-grading: Beetal, Jamnapari

Pig Breeding Policy

- Objectives: Improve growth, prolificacy, meat quality/quantity, survivability, and feed utilization
- Conservation: Preserve meritorious indigenous breeds in local tracts
- Cross-breeding: Encouraged with high-yielding, disease-resistant exotic breeds
- Exotic germplasm limit: Maximum 50% in crossbreeding
- Pigs for
    - Upgrading: Ghungroo, Dome (indigenous), Large white Yorkshire, Landrace (exotic)
    - Crossbreeding: Large white Yorkshire, Landrace, Hampshire, Duroc

Key points to remember:

1. Each species has specific breeding objectives
2. Indigenous breed conservation is emphasized
3. Cross-breeding is species and area-specific
4. Artificial insemination is promoted where applicable
5. Exotic germplasm use is limited and controlled

Poultry Breeding (The National Action Plan for Egg & Poultry-2022)

1. Low input technology chicken varieties:
    - Improve heat tolerance through feather modification genes (Na, F, Sc)
    - Reduce body size genes
    - Cross Aseel males with CARI red hens to produce CARI Nirbheek
2. Maintain high-yielding varieties:

- Focus on parent and grandparent stock

3. Advanced breeding technologies:
    - Use QTLs, CRISPR, transgenesis, RNAi
    - Identify and propagate robust, high-producing stocks
4. Immune competence:
    - Develop strains adaptable to changing farm conditions
5. Small-holder systems:
    - Implement creep-upgrading
    - Establish nucleus crossbreeding programs
    - Develop community-based breeding programs
    - Create strategies for replacement stock generation

Key points to remember:

- Emphasis on both indigenous and exotic breeds
- Focus on heat tolerance and disease resistance
- Use of advanced genetic technologies
- Tailored approaches for commercial and small-scale farming

State Breeding Policies and Breeding Programmes

Uttar Pradesh Breeding Policies:

- **Cattle Breeding Policy:**
    - Indigenous Breeds – Improvement of indigenous cattle breeds like Sahiwali, Gir, Kankrej, Tharparkar, Hariana
- **Buffalo Breeding Policy:**
    - Conservation and improvement of indigenous breeds like Murrah, Bhadawari and Jaffarabadi
    - Grading up for ND buffaloes
    - AI preferred for genetic improvement
- **Sheep Breeding Policy**
    - Improvement of sheep breeds like Muzzaffarnagari, Jalauni, Malpura
    - Crossbreeding with Corriedale and Rambouillet
    - Crossbreeding limit – 50% exotic inheritance
- **Goat Breeding Policy**
    - Indigenous Breeds – conservation and improvement of Jamunapari, Barbari and Sirohi
    - Natural service is the primary breeding method for goats
- **Pig Breeding Policy**

    - Indigenous breeds improvement – Gurrah
    - Crossbreeding – Large White Yorkshire, Landrace (75% exotic inheritance limit)

Madhya Pradesh – Breeding Policy

- **Cattle and Buffaloes**
    - Malvi, Nimari, Kenkatha and Gaolao – Selective breeding in home tract
    - Crossbreeding – Jersey/HF – 50% inheritance fixed
    - Crossbreeding for development of ND cattle
    - Upgrading with Sahiwal, Gir or Red Sindhi in areas unsuitable for crossbreeding
    - Encourage breeders' societies for breed improvements
- **Sheep**
    - Indigenous breeds –
        - Bharat Merino – selective breeding for meat and wool
        - Shahabadi – selective breeding for mutton production
    - Crossbreeding –
        - Exotic inheritance (75%) – Corriedale or Rambouillet breeds
    - Grading up of ND with Shahabadi breed
- **Goats**
    - Indigenous breeds (selective breeding)
        - Jamunapari: Chambal ravine area
        - Barbari: Gwalior and Bhind districts
        - Black Bengal: Rewa, Satna, and Sidhi districts
    - Grading up of non-descript goats with Jamunapari or Barbari breeds
    - Encourage formation of breeders' societies
- **Poultry**
    - Indigenous breeds:
        - Kadaknath: Conservation and improvement in its home tract (Jhabua district)

Rajasthan – Breeding Policy

- **Cattle and Buffaloes**
    - Upgrading of ND animals with high yielding animals
    - Selective breeding and conservation of Gir, Hariana, Malvi, Rathi, Kankrej, Nagauri, Sahiwal and Tharparkar cattle
    - Crossbreeding – exotic inheritance fixed to 50-62.5% - Exceeding the level only after ensuring enough resources for management
    - Castration of crub bulls and calves not used for breeding
    - Breed of choice for buffalo breeding
        - Murrah - Jaipur, Jodhpur, Kota, Ajmer, Bharatpur
        - Surti – Udaipur division
- **Goats –**
    - Selective breeding in their native tracts

        - Marwari - Osian block (Jodhpur dist.),
        - Sirohi - Sirohi, Udaipur and Chittorgarh dist
        - Jharkhana - Alwar dist.
            - Marwai and Sirohi bucks for upgrading (Buck to doe ratio 1:15 to 1:20)
            - ONBS for cluster areas to promote development

- **Sheep**
    - Indigenous breeds - Chokla, Nali, Marwari, Jaisalmeri, Sonadi, Malpuri, Pugal and Magra
    - Improvement by provision of superior rams to farmers
    - Genetic improvement:
        - Malpura – for mutton production (selective breeding)
        - Chokla – wool quality and quantity (selective breeding)
        - Rambouillet and Merino used for crossbreeding
            - Level of exotic inheritance – 75%
            - Specific Breeding Programmes:
        - Sheep breeding farm (Fatehpur, Sikar) – production and distribuition of superior breeding rams (Chokla, Nali, Marwari breeds) at subsidised rates
        - Central Sheep and Wool Research Institute (CSWRI)
- **Camels**
    - *In situ* conservation in their breeding tracts
    - Rajasthan Camel Act 2015 – bans evacuation or temporary migration of camels out of state
    - Four recognised camel breeds – Marwari, Bikaneri, Jaisalmeri, Kutchi
    - Emphasis on improving milk production in camels
    - Incentives for camel breeding to combat the declining population
    - Breeding programmes:
        - Ushtra Vikas Yojana (Camel Development Scheme) – 2016 – connservation and development

Punjab – Breeding Policy

- **Cattle**
    - Indigenous breeds:
        - Sahiwal: Selective breeding in home tract (Ferozepur, Amritsar, Tarn Taran)
        - Conservation of Red Sindhi and Tharparkar breeds
    - Crossbreeding:
        - Holstein Friesian (HF) preferred for crossbreeding
        - Maintain 62.5% HF inheritance (5/8 HF : 3/8 Indigenous)
        - Jersey crosses to be upgraded to HF crosses

- AI coverage to be increased from 20% to 50% in 5 years
- Embryo transfer technology to be used for faster genetic improvement

- **Buffalo**
    - Breed of choice: Nili-Ravi
    - Selective breeding within Nili-Ravi population
    - Murrah buffaloes to be graded up with Nili-Ravi
    - AI coverage to be increased from 20% to 50% in 5 years
    - Embryo transfer technology to be used for faster genetic improvement
- **Sheep**
    - Breeds: Nali, Lohi, Desi, and their crosses
    - Crossbreeding with exotic breeds not recommended
    - Focus on selective breeding within indigenous breeds
    - Emphasis on mutton production
    - Ram exchange program to avoid inbreeding
- **Goat**
    - Breeds: Beetal and Black Bengal
    - Selective breeding within Beetal breed
    - Black Bengal to be used for crossbreeding with Beetal for meat production
    - Emphasis on both milk and meat production
    - Buck exchange program to avoid inbreeding
- **Pigs**
    - Breeds: Large White Yorkshire, Landrace, and their crosses
    - Crossbreeding between Large White Yorkshire and Landrace
        - Maintain 50% inheritance of each breed in crossbreds
        - Focus on increasing litter size and growth rate

Topic 6: Current Livestock Breeding Programmes in India and Indian States

1. **<u>Rashtriya Gokul Mission (RGM):</u>**

- Implemented since December 2014
- Focuses on indigenous bovine breed development and conservation
- Continued under Rashtriya Pashudhan Vikas Yojna (2021-2026)
- Budget: Rs. 2400 crore

Objectives:

- Enhance bovine productivity and milk production
- Promote high genetic merit bulls for breeding
- Increase Artificial Insemination (AI) coverage
- Conserve indigenous cattle and buffalo

Funding:

- 100% grant-in-aid for most components
- Exceptions: IVF pregnancy subsidy, sex-sorted semen subsidy, breed multiplication farm subsidy

Key Components:

1. High genetic merit germplasm availability
2. Extension of AI network
3. Indigenous breed development and conservation
4. Skill development
5. Farmers awareness
6. Research and innovation

2. <u>Rashtriya Pashudhan Vikas Yojna:</u>

Sub-Missions:

1. Breed Development of Livestock & Poultry
2. Feed and Fodder Development
3. Extension and Innovation

3. <u>National Programme for Dairy Development (NPDD):</u>

Aims:

- Enhance milk and milk product quality
- Increase organized milk procurement

Components:
A. Infrastructure for quality testing and chilling
B. Dairying Through Cooperatives (JICA-aided project)

Implementation:

- Component A: Nationwide
- Component B: Pilot in Uttar Pradesh and Bihar

***Duration*:** 2021-22 to 2025-26

4. **ITC's Livestock Development Programme:**

- Focuses on artificial insemination services to improve milk yields
- These programmes collectively aim to improve breed quality, increase productivity, enhance infrastructure, control diseases, and support farmers and cooperatives in the livestock sector

5. **Animal Husbandry Infrastructure Development Fund (AHIDF)**

- *AHIDF Key Points*
    1. Announced by Prime Minister under Atma Nirbhar Bharat Abhiyan
    2. Fund size: Rs. 15,000 crore
    3. Incentivizes investments by entrepreneurs, private companies, MSMEs, FPOs, and Section 8 companies
- *Target Areas:*
    1. Dairy processing and value addition
    2. Meat processing and value addition
    3. Animal Feed Plants
- *Objectives:*
    1. Increase milk and meat processing capacity
    2. Improve market access for rural producers
    3. Increase price realization for producers
    4. Provide quality products to domestic consumers
    5. Address protein requirements and malnutrition
    6. Develop entrepreneurship and generate employment
    7. Promote exports in milk and meat sectors
    8. Provide affordable quality animal feed

6. **SDCFPO Scheme Key Points**

- Approved to provide working capital loans to State Cooperatives and Federations
- Budget: Rs. 500 crore (2021-22 to 2025-26)
- Implemented through National Dairy Development Board (NDDB)
- ***Objectives:***
    1. Assist State Dairy Cooperative Federations with soft loans
    2. Provide stable market access to dairy farmers
    3. Ensure timely payments to farmers

4. Enable cooperatives to procure milk at remunerative prices

- ***Key Features:***
    1. Interest subvention of 2% p.a. on working capital loans
    2. Additional 2% p.a. for prompt repayment
    3. Covers loans for SMP, WMP, White Butter, and Ghee
- ***Progress (as of 04.08.2022):***
    1. 2020-21: Rs. 155.78 crore released for 55 milk unions
    2. 2021-22: Rs. 107.11 crore released for 60 milk unions
    3. 2022-23: Rs. 50.63 crore sanctioned for 13 milk unions (no releases yet)

7. <u>National Programme for Bovine Breeding and Dairy Development (NPBBDD):</u>

Objectives:

1. Arrange quality Artificial Insemination services at farmers' doorstep
2. Bring all breedable females under organized breeding through AI or natural service using high genetic merit germplasm
3. Conserve, develop and proliferate selected indigenous bovine breeds
4. Provide quality breeding inputs in breeding tracts of important indigenous breeds
5. Integrate milk production and dairying activities scientifically and holistically
6. Increase milk production and productivity to meet growing demand

Key Points:

1. Launched in February 2014 by merging four existing schemes
2. Implemented with an allocation of Rs 1,800 crore during 12th Five Year Plan (2013-14 to 2016-17)
3. Has two main components:
   a) National Programme for Bovine Breeding (NPBB)
   b) National Programme for Dairy Development (NPDD)
4. Implemented on 100% grant-in-aid basis (with some exceptions)
5. Targets rural cattle and buffalo keepers irrespective of caste, class and gender
6. Aims to establish 5,000 MAITRI centers for delivering breeding inputs
7. Plans to organize 36,418 dairy cooperative societies with 2 million farmer members
8. Aims to create milk chilling capacity of 2.8 million liters/day and processing capacity of 3.01 million liters/day
9. Focuses on infrastructure development from grass-root level
10. Includes extension activities and training for farmers

8. **<u>All India Coordinated Research Project (AICRP)</u>**

- *AICRP on Cattle:*
    1. Aims to improve performance of cattle under farm and field conditions
    2. Includes projects like Frieswal, Indigenous Breeds Project (IBP), and Field Progeny Testing (FPT)
    3. Focuses on genetic improvement of both indigenous and crossbred cattle
    4. Evolved the "Frieswal" national milch breed (5/8 Holstein Friesian and 3/8 Sahiwal)
    5. Increased 300-day milk production from 2774 kg in 1989 to 3340 kg in 2019
- *AICRP on Goat Improvement:*
    1. Long-term program for genetic improvement and conservation of goat resources
    2. Covers 15 registered goat breeds and 3 local genotypes in 15 states
    3. 21 centers, including 9 partially Tribal Sub Plan (TSP) units
    4. Focuses on superior animal identification, performance recording, and breeding
- *AICRP on Buffaloes*:
    1. Expanded from a Murrah buffalo improvement program
    2. Part of the Network Project on Buffalo improvement
    3. Aims to improve productivity through selective breeding
- *AICRP on Pig:*
    1. While not explicitly mentioned in the search results, it's known to exist for pig improvement

These AICRPs play crucial roles in:

- Genetic improvement of livestock breeds
- Conservation of indigenous breeds
- Enhancing productivity
- Developing management practices and technologies
- Capacity building of farmers and keepers

Breeding Programs in Indian States:

State	Active Breeding Programmes	Important Highlights	Specific Details
Rajasthan	1. Livestock Research Station programs	- Improve and conserve Rathi cattle breed	- Selective breeding in closed herd system

	2. Sheep Breeding Programme	- Improve indigenous sheep breeds	- Sheep breeding farm at Fatehpur (Sikar)
	3. AICRP on Goat Improvement	- Genetic improvement of Marwari and Sirohi goats	- Focus on Marwari and Sirohi goat breeds
Punjab	1. National Programme for Bovine Breeding and Dairy Development (NPBBDD)	- Improve bovine breeding and dairy development	- Rs 9 billion allocated for livestock and dairy development (2024-25)
	2. Rashtriya Gokul Mission	- Conserve and develop indigenous cattle breeds	- Breed improvement of small ruminants
	3. Goat Breeding Farm, Kotkapura	- Improve Beetal goat breed	- Pure Beetal breed goats reared
Uttar Pradesh	1. National Programme for Bovine Breeding and Dairy Development (NPBBDD)	- Improve bovine breeding and dairy development	- Creation of Bull Mother Farm at Rauni village
	2. Rashtriya Gokul Mission	- Conserve and develop indigenous cattle breeds	- Specific details not provided
	3. Goat Development Scheme	- Promote goat rearing	- Aims to help 11,250 families in 3 years
	4. Animal Breeding Centre (ABC)	- Improve Murrah buffalo breed	- Progeny testing programme for Murrah buffaloes in Baghpat District
Madhya Pradesh	1. National Programme for Bovine Breeding and Dairy Development (NPBBDD)	- Improve bovine breeding and dairy development	-

	2. Rashtriya Gokul Mission	- Conserve and develop indigenous cattle breeds	-

Unit 5: Conservation of Animal Genetics Resources

Topic 1: Conservation and Preservation

Conservation:

- Definition: Management of human use of the biosphere
- Goal: Greatest sustainable benefit to present generation
- Maintains potential for future generations' needs and aspirations
- Positive approach that includes:
    - Preservation
    - Maintenance
    - Sustainable utilization
    - Restoration
    - Enhancement of natural environment

Preservation:

- Part of conservation
- Process: Designating a sample of animal genetic resource population
- Maintenance in isolated environment
- Environment free of human forces
- Purpose: Prevent genetic changes caused by human interference

Key differences:

- Conservation is broader, includes preservation
- Conservation allows sustainable use; preservation aims to keep resources untouched
- Conservation balances present and future needs; preservation focuses on maintaining current state

Reasons for Conservation:

6. Preservation of genetic variability
7. For future use of genes tolerant to certain environments
8. Conservation of culturally important animals

9. For research purposes
10. Aesthetic purposes

Remember:

- Conservation is active management
- Preservation is a more hands-off approach
- Both aim to protect resources, but with different methods and goals

Topic 2: Types of Conservation

1. *In-situ* conservation

• Definition: Conservation of live animals in their native environment
• Key points:
- Establishes live animal breeding farms within production systems and native ecology
- Emphasizes use of indigenous genetic resources
- Requires farmer participation and support
- Challenges: economic viability, maintaining effective population size
- Recommended population size: 5 males and 25 females (minimum), 50 males and 250 females (for low heritability traits)
- Advantages:
    1. Allows for evaluation and improvement over time
    2. Genetic defects can be eliminated
    3. Animals available for immediate use
    4. Produce can offset maintenance costs
- Disadvantages:
    1. Requires large number of animals
    2. Risk of inbreeding in small populations
    3. Costly infrastructure and maintenance

2. *Ex-situ* conservation

1. *Ex-situ in vivo* conservation

Definition: Conservation of live animals outside their native environment
• Examples: Herds in protected areas, farms, zoos
Key points:
- Removes breed from socio-economic considerations
- Useful for threatened or endangered breeds

2. *Ex-situ in vitro* conservation

Definition: Preservation of genetic material in frozen state

Materials preserved:

- Semen, oocytes, embryos (in vivo and in vitro)
- Somatic cells, DNA

Key points:

- For semen: 25 unrelated males recommended
- For embryos: 35 different matings recommende

Advantages:

- Economical and convenient
- Maintains genetic structure
- Supports in situ conservation efforts

Limitations:

- Delays breed restoration
- Environmental adaptation challenges upon restoration

Topic 3: Risk Status Categories

FAO's Role:

- Lead agency for global management of AnGR
- Maintains the Domestic Animal Diversity Information System (DAD-IS)
- Publishes the World Watch List for Domestic Animal Diversity (WWL-DAD)
-

Categories for Domestic Populations:

Risk Status Category	Number of Breeding Females	Number of Breeding Males
Extinct	0	0
Critical	≤ 100	≤ 5
Critical-Maintained	≤ 100	≤ 5
Endangered	100-1000	5-20
Endangered-Maintained	100-1000	5-20
Vulnerable	1000-5000	20-35
Not at Risk	> 5000	> 35

Effective Population Size (Ne):

- Definition: The number of individuals in an idealized population that would show the same amount of genetic drift as the actual population
- Formula: Ne = (4 x Nm x Nf) / (Nm + Nf)
- Where Nm = number of males, Nf = number of females

- Recommended minimum Ne for conservation: 50-100

Minimum Numbers for Conservation Programs:

- Cattle: 20 males, 1000 females
- Sheep/Goats: 20 males, 500 females
- Pigs: 20 males, 200 females
- Horses: 20 males, 1000 females

Global Plan of Action for AnGR:

- Adopted by FAO member countries in 2007
- Four strategic priority areas:
  - ✓ Characterization, inventory, and monitoring
  - ✓ Sustainable use and development
  - ✓ Conservation
  - ✓ Policies, institutions, and capacity building

Key Concepts:

- Genetic drift: Random changes in allele frequencies in small populations
- Inbreeding depression: Reduced fitness due to mating of related individuals
- Founder effect: Loss of genetic variation when a new population is established by few individuals

Unit 6: Basic Statistics

Topic 1: Basic Definitions in Statistics

3. **Statistical data** – Statistical data refers to quantitative information including facts, figures, observations, or measurements that are collected as a source of information for analysis.
2. **Statistical method** – A statistical method is a systematic approach for analyzing data based on probability theory. It includes the collection, classification, tabulation, presentation, analysis and interpretation of data
3. **Types of statistics:**
   - *Descriptive statistics* - Summarisation and description of data using mean, median, mode and standard deviation
   - *Inferential statistics* – Making prediction and inferences about a population based on a sample by using probability theory.

4. **Population**: The entire group of individuals, objects or events that are the subject of a statistical study
5. **Sample**: A representative subset of population selected for study
6. **Variables**: Characteristics or attributes that can be measured or observed
    - *Quantitative/Continuous variables*: Variables that can be measured numerically and take any value between any specified interval is a – height, weight, temperature
    - *Discrete/Discontinuous variables*: Represent clear categories/groups, or take only integral values – gender, blood type, no. of animals in a farm etc.
7. **Parameter and Statistic:**
    - Parameter – a statistical measure pertaining to the population
    - Statistic – a statistical measure pertaining to the sample

8. **Probability distributions**: Mathematical functions describing the likelihood of obtaining possible values of a random variable. Common distributions include:

Distribution	**Normal (Gaussian)**	**Binomial**	**Poisson**
Type	Continuous	Discrete	Discrete
Description	Symmetrical around mean	Dependent on Bernoulli's trials	Probability of events in fixed interval
Parameters	μ (mean), σ (standard deviation)	n (number of trials), p (probability of success)	λ (lambda), average number of events
Characteristics	- Mean, median, mode = μ - Symmetric bell-shaped curve - Unimodal (one peak) - Asymptotic (*graph approaches x-axis but doesn't touch it)* - 68-95-99.7 rule (68% data – 1σ 95% data - 2σ	- Fixed number of trials - Two possible outcomes per trial - Independent trials - Constant probability of success	- Events occur independently - Rate of occurrence is constant - Probability proportional to interval length

Distribution	Normal (Gaussian)	Binomial	Poisson
	99.7% data - 3σ		
Mean	M	np	λ
Variance	σ^2	np(1-p)	λ
Graph	Always symmetrical and bell shaped - Represented with a smooth line	Skewed or bell shaped (depending on the data) - Represented using bars \	Positively (right)skewed curve Has same mean and variance

9. **Hypothesis testing:**
   A statistical method used to make inferences about a population parameter based on sample data. It involves:
   - Formulating null and alternative hypotheses
   - Collecting sample data
   - Calculating a test statistic
   - Comparing the test statistic to a critical value
   - Making a decision to reject or fail to reject the null hypothesis

10. **Regression analysis:**
    - A statistical technique used to model the relationship between one or more independent variables and a dependent variable.
    - Range of regression coefficient (b): -1 to +1
    - It helps in predicting outcomes and understanding the strength of relationships between variables.

    - *Variables*:

Aspect	Independent Variable	Dependent Variable
Also called	Explanatory variable, Predictor variable	Response variable, Outcome variable
Definition	Factor manipulated or controlled in an experiment to study its effect on the dependent variable	Changes in response to the independent variable

Key Characteristics	- Not affected by other variables in the study - Presumed to be the cause/influencer of the study - Can be manipulated by researcher	- Measured to determine the effect of the independent variable - Cannot be manipulated - Observed in response to changes in the independent variable
Graph representation	Represented on the X-axis	Represented on the Y-axis
Examples	Temperature (studying effect on plant growth)	Plant growth rate
	Drug dosage (studying effect on recovery)	Recovery time
	Study time (studying effect on test scores)	. Test scores
	Exercise duration (studying effect on weight loss)	Weight loss

11. **Corrrelation**:
    - A measure of the strength and direction of the linear relationship between two variables. Correlation coefficients range from -1 to +1, where:
        - +1 indicates a perfect positive correlation
        - 0 indicates no linear correlation
        - -1 indicates a perfect negative correlation

Topic 2: Measures of Central Tendency

Indications of the values of observations around the central positions in a data set are the measures of central tendency.

1. **Arithmetic Mean:**
    - Obtained by dividing the sum of the values of the given items (of a variable) by the number of items
    - Denoted by $\bar{x}$
2. **Median:**
    - Value which has equal number of observations falling on either of its sides when all observations are arranged in ascending/descending order of magnitude
    - Median divides the observations into two parts – one part consisting of all variables less than the median, other containing all parts greater than the median
3. **Mode**
    - The value of the variable that occurs most often, *i.e.,* frequently repeats itself, in a set of observations is called a mode.

Some general properties:

- Arithmetic mean > Geometric mean > Harmonic mean - Generally
- When all the observations have the same value, then AM = GM = HM
- For a symmetrical (normal) distribution: AM = Median = Mode
- For positively skewed distribution – AM > Median > Mode
- For negatively skewed distribution – AM < Median < Mode

Topic 3: Measures of Dispersion

Measures of central tendency alone may not fully describe a data set
• Measures of dispersion indicate how values are scattered around the mean
• Dispersion is also known as scatter or spread
• Importance of dispersion:

- Shows if values are closely packed or widely scattered
- Makes averages more meaningful
- Indicates if an average truly represents the data set
- ***Definition****: Measurement of scattering of items in a distribution about the average*
- Uses of measures of dispersion:
    - Assess variability within a distribution
    - Compare variability between different distributions
        - Low dispersion: Average is more representative of the data
        - High dispersion: Average is less representative of the data
        - Dispersion measures complement central tendency measures for better data description
        - Essential for comparing consistency across distributions

Different Measures of Dispersion:

1. **Range**:
    1. Difference between highest (H) and lowest (L) value of a dataset
    2. Simplest of all measures of dispersion
2. **Quartile Deviation:**
    1. Divides the data set into four equal halves (Q_1, Q_2, Q_3, and Q_4)
    2. Interquartile range, QD = ($Q_3 - Q_1$)
    3. Coefficient of dispersion (QC) = $\frac{Q_3 - Q_1}{Q_3 + Q_1}$
    4. Used in the case of open end distribution
3. **Mean Deviation:**

1. Average of the deviations of the observations from the mean, taking all deviations as positive
2. Relative measure of mean deviation – *mean coefficient of dispersion/coefficient of mean deviation*

4. Standard Deviation (σ)

1. Most perfect and widely used measure of dispersion
2. It is the square root of the sum of square of deviations from mean divided by the total number of observations in a population

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}{n}} \quad \text{for raw data}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} f_i\left(x_i - \bar{x}\right)^2}{N}} \quad \text{for grouped data}$$

Coefficient of variation (CV/COV)

- Relative measure of standard deviation (expresses variability in relation to the mean)
- Expressed as ratio of standard deviation to the mean:

$$CV = \frac{\sigma}{x} \times 100$$

- Indicates how large the standard deviation is compared to the mean
    - Lower CV: Data is less dispersed relative to its mean
    - Higher CV: Data is more dispersed relative to its mean
- When to use:
    - Comparing variability between datasets with different units
    - Assessing relative variability when means are very different

5. Variance (σ^2)

- Square of standard deviation – mean square deviation

Standard Error (SE)

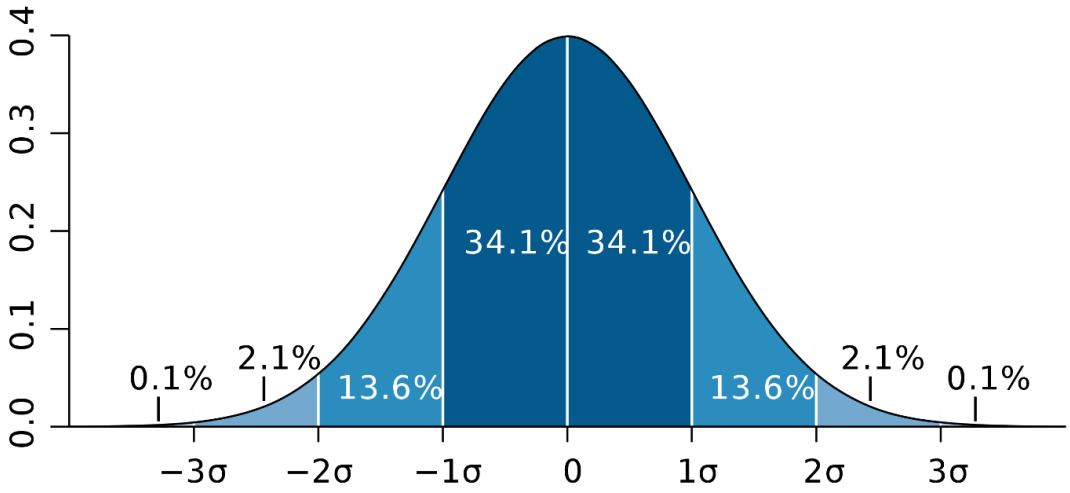
When a sample is collected from the population, the difference between the means of the samples and populations is known as standard error.

If only one sample is taken, then,

$\text{SE} = \frac{\sigma}{\sqrt{n}}$,

n is the sample size, and σ is sample mean

- ❖ ***Probable Error (PE) = 2/3 SD***
- ❖ Quartile deviation = 2/3 SD (approx.)
- ❖ Mean deviation = 4/5 SD (approx.)
- ❖ SD > MD > QD > PE



Topic 4: Tests of Significance

- **Hypothesis:** A statement made about any population
  - **Null Hypothesis:**
    - An assumption made about the population under test which can be either true or false
    - Denoted by H_o
  - **Alternate Hypothesis:**
    - Statement contrary to the null hypothesis which is denoted by H_1
    - If null hypothesis is rejected, alternate hypothesis will be accepted
- **Parametric tests:**
    - Distribution attached to the test
    - Testing means of two samples/populations
      - If sample size > 30 – Z-test
      - If sample size <30 – t-test
      - Types of t-tests: Paired and unpaired

Aspect	Paired t-test	Unpaired t-test
Sample relationship	Related or dependent samples	Independent or unrelated samples
Group composition	Same subjects in both groups	Different subjects in each group
Sample size	Equal sample sizes in both groups	Can have different sample sizes in each group
Variance assumption	Does not assume equal variance between groups	Assumes equal variance between groups (if unequal, Welch's test is used)
Application	Before-after studies, matched pairs, repeated measures	Comparing two independent groups or treatments
Data requirements	Requires naturally paired or matched observations	No natural pairing between observations in each sample

    - Testing variances of two samples/populations –
        - F-test
    - Comparing observed frequencies to expected frequencies –
        - Chi square test

- If test statistic < Table value for statistic – Accept H_o
- If test statistic > Table value for statistic – Reject H_o
- **Errors:**
    1. ***Type 1 error:***
        - Rejecting H_0 when it is true
        - Accepting H_1 when it is false
    2. ***Type 2 error:***
        - Accepting H_0 when it is false
        - Rejecting H_1 when it is true

MCQs

Unit 1: Genetic Material

1. Match the following diploid numbers of chromosomes with their species: MPSC 2019

a. Goat	i. 78
b. Sheep	ii. 54
c. Horse	iii. 60
d. Poultry	iv. 64

Answer options:

(1)a- i b-ii c-iii d-iv

(2) a-ii b-iii c-iv d-i

(3) **a-iii b-ii c-iv d-i**

(4) a-iii b-ii c-i d-iv

2. The Germplasm theory was proposed by MPSC 2019

(1) T.H. Morgan

(2) Jan Swammerdam

(3) **August Weismann**

(4) Wilhelm Johannsen

3. The science that deals with chromosomes are: UK VO 2024

a) Molecular genetics

b) Cytogenetics

c) Biochemical genetics

d) Developmental genetics

4. Genetic engineering is sometimes called as: UK VO 2024

a) Genetic drift

b) Genetic disassembly

c) Genetic mastication

d) Genetic modification

5. Regulated unit of genetic engineering is: JKPSC (2012)
   a. (A) Operator Gene
   b. (B) Promotor Gene
   c. (C) Regulator Gene
   d. (D**) Operon**
6. Enzyme useful in genetic engineering is: JKPSC (2012)
   a. (A) Lipase
   b. (B) DNAase
   c. (C) **Restriction endonuclease**
   d. (D) Amylase
7. Which is an example of chemical mutagen? JKPSC (2012)
   a. (A) Mustard gas
   b. (B) Nitrous acid
   c. (C) Morphine
   d. (D) **All of the above**
8. Smallest segment of genetic material affected by radiation is: JKPSC (2012)
   a. (A) Recon
   b. (B) Cistron
   c. (C) **Muton**
   d. (D) Exon
9. Hybridomas are result of fusion of: ZJKPSC (2012)
   a. (A) **Normal antibody producing cells with Myeloma cells**
   b. (B) Abnormal antibody producing cells with Myeloma cells
   c. (C) Male reproductive cell with Myeloma cells
   d. (D) Female reproductive cells with Myeloma cells
10. Which type of cell division is important for Animal Kingdom? JKPSC (2012)
    a. (A) Mitosis
    b. (B) Meiosis
    c. (C) **Both (A) and (B)**
    d. D) None of the above
11. Buffalo species having 48 chromosomes is known as: JKPSC(2012)
    a. (A) River buffalo
    b. (B) Water buffalo
    c. (C) African buffalo
    d. (D) **Swamp buffalo**
12. Arrange the different sub stages of first meiotic prophase in chronological order of their chromosome behavior and appearance. JKPSC 2012

    1) Pachynema
    2) Leptonema
    3) Diakinesis
    4) Zygonema
    5) Diplonema

    Arrange the sub stages in chronological order
    a. A) 1,2,3,4,5
    b. B) 2,4,1;5,3

c. C) 1,3,5,2,4
d. D) 3,5,4,2,1

13. The chromosome number of male sheep is: PPSC 2021
    a. a) 54, XX
    b. b) 54, XY
    c. c) 60, XX
    d. d) 60, XY
14. Chromosome number of cattle is PPSC 2021
    a. (A) 46
    b. (B) 48
    c. (C) 50
    d. (D) 60
15. The distance between two base pairs on DNA strand is MPPSC 2021
    a. (A) 3-6 Å
    b. (B) 3-4 Å
    c. (C) 4-3 Å
    d. (D) 3-2 Å
16. Which of the following acts as start codon during translation process? MPPSC 2021
    a. (A) UAG
    b. (B) UGA
    c. (C) AUG
    d. (D) GUA
17. During which phase of mitotic cell division, the nuclear membrane and nucleolus disappear? MPPSC 2023
    a. [A] Prophase
    b. [B] Metaphase
    c. [C] Anaphase
    d. [D] Telophase
18. Which of the following RNAs is involved in the selection of proteins for export? MPPSC 2023
    a. [A] Ribosomal RNA
    b. [B] Small nucleolar RNA
    c. [C] Small cytoplasmic RNA
    d. [D] Transfer RNA
19. Which of the following forms of double helical DNA, polynucleotide are in the form of right handed helix? MPPSC 2023
    a. [A] A-DNA and B-DNA
    b. [B] A-DNA and Z-DNA
    c. [C] B-DNA and Z-DNA
    d. [D] None of the above
20. The factor responsible for initiating cell division is: OPSC 2019
    a. (A) Cytoplasmic index
    b. (B) DNA
    c. (C) Karyoplasmic index
    d. (D) Nucleus

21. Crossing over takes place between: OPSC 2019
    a. (A) Sister cromatid
    b. (B) Non-sister cromatid
    c. (C) Chromosome
    d. (D) Chromonema
22. The type of cell division which takes place only once in cell's lifetime, is called: OPSC 2019
    a. (A) Amitosis
    b. (B) Meiosis
    c. (C) Mitosis
    d. (D) Free cell division
23. Crossing over takes place in: OPSC 2019
    a. (A) Mitosis
    b. (B) Meiosis I
    c. (C) Meiosis II
    d. (D) All of the above
24. 72. What happens in crossing over? OPSC 2019
    a. (A) Duplication of chromosome
    b. (B) Linkage in chromosome
    c. (C) Minimization in genetic material
    d. (D) Exchange of genetic material
25. Chromosome which do not have. centromere is called: OPSC 2019
    a. (A) Monocentric
    b. (B) Diacentric
    c. (C) Acentric
    d. (D) Polycentric
26. Diagrammatic representation of the karyotype is called: OPSC 2019
    a. (A) Cladogram
    b. (B) Cryptogram
    c. (C) Idiogram
    d. (D) All of the above
27. Mitosis can occur in which of the following? OPSC 2019
    a. (A) Haploid cells
    b. (B) Diploid cells
    c. (C) Polyploid cells
    d. (D) All of the above
28. The minimum number of chiasmata in a pair is: OPSC 2019
    a. (A) One
    b. (B) Two
    c. (C) Three
    d. (D) Four
29. During karyokinesis the chromosome exhibit minimum coiling at which phase? OPSC 2019
    a. (A) Prophase
    b. (B) Metaphase
    c. (C) Anaphase

d. (D) Interphase

30. H. J. Muller reported that the X-rays induces: OPSC 2019
    a. (A) Selection
    b. (B) Mutation
    c. (C) Migration
    d. (D) Aberration
31. Common wheat with 42 chromosomes is: OPSC 2019
    a. (A) Tetraploid
    b. (B) Triploid
    c. (C) Octaploid
    d. (D) Hexaploid
32. The sex chromosomes of females and males are respectively: OPSC 2019
    a. (A) XX in females and XY or (XO) in males
    b. (B) XY in females and XX in males
    c. (C) XO in females and XX in males
    d. (D) XX in females and XX in males
33. Dr. Hargobind Khurana has been awarded Nobel Prize for research on: OPSC 2019
    a. (A) Oral contraceptives
    b. (B) Hormones
    c. (C) Genetic code
    d. (D) Immunology
34. Who described the operon concept in E. coli ? OPSC 2019
    a. (A) Mendel, Darwin
    b. (B) Hugo de Varies, Muller
    c. (C) Miller, Muller
    d. (D) Francis Jacob and Jacques Monod
35. Extra chromosomal piece is known as: OPSC 2019
    a. (A) Cosmid
    b. (B) Epizome
    c. (C) Plasmid
    d. (D) Bacteriophage
36. In polymerase chain reaction which of the following is required essentially? OPSC 2019
    a. (A) DNA ligase
    b. (B) DNA primer
    c. (C) DNA polymerase
    d. (D) None of the above
37. The number of base pair units in a single turn of DNA is: OPSC 2019
    a. (A) 4
    b. (B) 6
    c. (C) 8
    d. (D) 10
38. The fragments of DNA attached to an RNA initiator component was discovered by: OPSC 2019
    a. (A) Watson and Crick

b. (B) Okazaki
c. (C) Peterson
d. (D) Nelson

39. The carbon atom at position 4 and 5 and the nitrogen atom at the position 7 of purine base are supplied from: OPSC 2019
a. (A) Valine
b. (B) Alanine
c. (C) Glycine
d. (D) Serine

40. Fragmentation of nucleus in a cell is termed as: OPSC 2021
a. (A) Pyknosis
b. (B) Karyorrhexis
c. (C) Karyolysis
d. (D) Chromatolysis

41. The nitrogenous base pair present in RNA but absent in DNA: OPSC 2021
a. (A) Adenine
b. (B) Thiamine
c. (C) Uracil
d. (D) Cytosine

42. The chromosomes with the centromere near one end are called: OPSC 2021
a. (A) Acrocentric
b. (B) Telocentric
c. (C) Metacentric
d. (D) Submetacentric

43. . The stage of cell division in which the chromosomes are most discrete and arranged in an equatorial plate? OPSC 2021
a. (A) Prophase
b. (B) Anaphase
c. (C) Metaphase
d. (D) Telophase

44. Which of the following species pairs possess equal number of chromosomes? OPSC 2021
a. (A) River buffalo and cattle
b. (B) Cattle and goat
c. (C) Sheep and goat
d. (D) Dog and poultry

45. In a Ram, DNA can be estimated from all of the following except: OPSC 2021
a. (A) WBC
b. (B) RBC
c. (C) Semen
d. (D) Root of hair follicles

46. Which of the following has maximum chromosome number? OPSC 2017
a. (A) Pig
b. (B) Horse
c. (C) Camel
d. (D) Dog

47. During which phase of the cell cycle does the centrosome duplicate in animal cells?

a. a) G1 phase
b. b) S phase
c. c) G2 phase
d. d) M phase

48. Which of the following statements about the G0 phase is incorrect?
    a. a) Cells in G0 have exited the cell cycle
    b. b) G0 cells can re-enter the cell cycle upon appropriate stimulation
    c. c) Terminally differentiated cells often remain in G0
    d. d) G0 cells have a higher metabolic rate than actively cycling cells
49. Which of the following statements about chromosome numbers in livestock species is correct?
    a. a) Sheep have a higher chromosome number than cattle
    b. b) Swine and cats have the same chromosome number
    c. c) River buffalo have fewer chromosomes than swamp buffalo
    d. d) Horses and donkeys have the same chromosome number
50. Match the following livestock species with their respective chromosome numbers:

Column A	**Column B**
Goat	78
Dog	60
Camel	74
Fowl	38

Options
    a. a) 1-A, 2-B, 3-C, 4-D
    b. b) 1-B, 2-A, 3-D, 4-C
    c. c) 1-B, 2-A, 3-C, 4-D
    d. d) 1-C, 2-B, 3-A, 4-D

Unit 2: Mendelian and Modified Mendelian Inheritance

1. If crossing over takes place in linked genes, the proportion of new/recombinant offsprings population is MPSC 2019

(1) **More than 50 percent**

(2) Less than 50 percent

(3) Less than 25 percent

(4) None of the above

2. The dihybrid F2 phenotypic ratio in case of dominance recessive epistasis is: UK VO 2024

a) 9 :3 :3 :1

b) 13:3

c) 15:1

d) 9:7

3. Hip dysplasia in German Shepherd dogs is due to Kerala PSC 2023
    a. An autosomal recessive gene
    b. Two pairs of alleles
    c. Multifactorial inheritance
    d. Sex linked recessive gene
4. Robertsonian Translocation in cattle is due to the fusion of the following chromosome. Kerala PSC 2023
    a. 1/29 acrocentric
    b. 1/29 telocentric
    c. 1/25 Submetacentric
    d. 1/D9 acrocentric
5. A delayed somatic effect of radiation is JKPSC 2019
    a. (A) Point mutation
    b. (B) Leukemia
    c. (C) Radiation sickness
    d. (D) Chromosome mutation
6. 21. In humans, trisomy of chromosome number 21 is responsible for (JKSPC 2019)
    a. (A) Haemophilia
    b. (B) Klinefelter syndrome
    c. (C) Turner syndrome
    d. (D) Down syndrome
7. Which of the following statements are true: JKPSC 2019
    1) Maximum diameter of chromosome was observed in anaphase
    2) The chromosome pairing occurs between homologous chromosomes
    3) The centromere divide chromosome into five equal halves
    4) Each chromosome has definite place in interphase
    Choose the correct answer:
    a. (A) 1 and 2 only
    b. (B) 2 and 3 only
    c. (C) 2 and 4
    d. (D) 2,3 and4 only
8. Match the following Species of animals with their Chromosomes (2n) JKPSC 2019

Species	Chromosomes (2n)
(a) Domestic cattle	(1) 60
(b) Domestic river buffalo	(2) 54
(c) Domestic sheep	(3) 38
(d) Domestic swine	(4) 50

    Select the correct answer using the code below:
    a. (A) a-1; b-3; c-1; d-4
    b. (B) a-2; b-4; c-3; d-1
    c. (C) a-1; b-4; c-2; d-3
    d. (D) a- 1; b-3; c-2; d-4

9. . Match the following JKPSC 2019

(a) Restriction endonucleases	(1) Small DNA segments used in DNA fingerprints
(b) Ligases	(2) Molecular scissors
(c) Probe	(3) Vector
(d) Cosmid	(4) Molecular stitchers

Choose the correct answer:

a. (A) a,2; b,4; c:1; d:3
b. (B) a:1; b:2; c:3; d:4
c. (C) a:3; b:4; c:1; d:2
d. (D) a:2; b:1; c:4; d:3

10. The Father of animal breeding is JKPSC 2019

a. (A) Gregor John Mendel
b. (B) T.H. Morgon
c. (C) Robert Bakewell
d. (D) Watson Crick

11. Milk production in cows is an example of: JKPSC (2012)

a. (A) Sex linked Inheritance
b. (B) Sex Influenced Inheritance
c. (C) Sex limited Inheritance
d. (D) None of the above

12. Sudden heritable change is: JKPSC (2012)

a. (A) Epistasis
b. B) Mutation
c. (C) Chromosomal aberration
d. (D) None of the above

13. Epistasis is JKPSC 2020

a. A) Inter allelic interaction
b. B) Intra allelic interaction
c. C) Intra and Inter allelic interaction
d. D) Genotype- Environment interaction

14. . Body coat comprising of large irregular patches of black and white with well defined line of demarcation between two colours is called: PPSC 2016

a. a) Pie bald
b. b) Skew bald
c. c) Whole coloured
d. d) Roan

15. Modified dihybrid ratio in duplicate dominant epistasis is RPSC 2019

a. (1) 9:6:1
b. (2) 9:7
c. (3) 12:3:1
d. (4) 15:1

16. Exchange of genetic material between non-homologous chromosomes is known as RPSC 2019

a. (1) Crossing over
b. (2) Duplication

c. (3) Translocation
d. (4) Inversion

17. Chromosome number (2N) of Bubalis bubalis is RPSC 2013
    a. (1) 60
    b. (2) 50
    c. (3) 48
    d. (4) 46
18. Modification of normal gene expression in which a particular gene at one locus masks the expression of at least one other gene at a different chromosomal location is termed RPSC 2013
    a. (1) Crossing over
    b. (2) Epistasis
    c. (3) Mutation
    d. (4) None of the above
19. 73. Two genes of two different traits located on the same chromosome are called RPSC 2013
    a. (1) Alleles
    b. (2) Linked
    c. (3) Segregated
    d. (4) Intermediate
20. Parents of one generation passes on the sex-linked characters to the opposite sex in the next generation. This process is known as RPSC 2013
    a. (1) Conjugation
    b. (2) Crossing over
    c. (3) Cross-over unit
    d. (4) Criss-cross inheritance
21. Reappearance of an ancestral but not parentral trait after several generations is called RPSC 2013
    a. (1) Atavism
    b. (2) Autogamy
    c. (3) Asynapsis
    d. (4) Amphidiploid
22. Which of the following term is used for replacement of a purine base by a pyrimidine base and vice versa? MPPSC 2021
    a. (A) Reversion
    b. (B) Transversion
    c. (C) Transition
    d. (D) Alteration
23. Which of the following term is used to explain Bar eye in Drosophila? MPPSC 2021
    a. (A) Linkage
    b. (B) Position effect
    c. (C) Multiple allele
    d. (D) Crossing over
24. Match the following theories with the scientist. MPPSC 2022

a. Germ plasm Theory	i. Hugo Devries

b. Mutation Theory — ii. Charles Darwin
c. Theory of evolution — iii. August Weismann
d. Preformation Theory — iv. Jan Swammerdam

Options:

	A	b	C	d
1.	III	II	I	IV
2.	II	II	I	III
3	**III**	**I**	**II**	**IV**
4	IV	I	II	III

25. Match the pair. MPPSC 2022

a. Monosomic — i. 2n-1
b. Triosomic — ii. 2n + 1
c. Tetrasomic — iii. 2n-2
d. Nullosomic — iv. 2n + 2

Options:

		A	B	C	D
a.	1.	III	II	I	II
b.	2.	III	II	IV	I
c.	3	I	II	III	IV
d.	4	**I**	**II**	**IV**	**III**

26. Who was the first to unravel the secret of biological reproduction and heredity? OPSC 2019

a. (A) Charles Darwin
b. (B) Thomas Hunt Morgan
c. (C) John Gregor Mendel
d. (D) James D. Watson

27. 28. The mahogany and red colors in cattle represent a good example to illustrate: OPSC 2019

a. (A) Sex-influenced inheritance
b. (B) Sex-limited inheritance
c. (C) Sex-linked inheritance
d. (D) None of the above

28. 29. The first case of mutation was discovered in: OPSC 2019

a. (A) Drosophila
b. (B) Garden pea
c. (C) Male lamb
d. (D) Neurospora

29. Manifold effects of a gene refer to: OPSC 2019

a. (A) Penetrance
b. (B) Expressivity
c. (C) Pleiotropy
d. (D) Epistasis

30. . Role of mutation in evolution is: OPSC 2019

a. (A) Reproductive isolation
b. (B) Genetic variation
c. (C) Genetic drift

d. (D) None of the above

31. Which is a tetrasomic condition? OPSC 2019
    a. (A) 2n-1
    b. (B) 2n+1+1
    c. (C) 2n+2
    d. (D) 2n +3
32. Mutation induced by 5-Bromouracil are: OPSC 2019
    a. (A) Transversional mutation
    b. (B) Transitional mutation
    c. (C) Frame shift mutation
    d. (D) Backward mutation
33. Daughter of colour blind father and normal mother marries a normal person. Colour blindness in the family shall be: OPSC 2019
    a. (A) 50% sons
    b. (B) 50% daughter
    c. (C) 50% offspring
    d. (D) 50% son and 50% daughter
34. Drones are: OPSC 2019
    a. (A) Sterile males
    b. (B) Sterile females
    c. (C) Fertile females
    d. (D) Fertile males
35. The lethal gene ratio is: OPSC 2019
    a. (A) 8:1
    b. (B) 2:1
    c. (C) 4:1
    d. (D) 1:1
36. . Skip generation inheritance is seen in: OPSC 2021
    a. (A) Sex-influenced traits
    b. (B) Sex-linked traits
    c. (C) Sex-limited traits
    d. (D) Autosomal inheritance
37. The condition in which a single gene influences more than one trait is referred to as: OPSC 2021
    a. (A) Polyploidy
    b. (B) Multiple alleles
    c. (C) Phenocopy
    d. (D) Pleiotropy
38. Parents having A and AB blood groups will not produce children having: OPSC 2021
    a. (A) A blood group
    b. (B) B blood group
    c. (C) O blood group
    d. (D) AB blood group
39. How many genetically different germ cells are produced by two pairs of chromosomes? OPSC 2021

a. (A) 1
b. (B) 4
c. (C) 2
d. (D) 8

40. A dominant expression that depends on the sex of the individual is called: OPSC 2021

a. (A) Simple dominance
b. (B) Co-dominance
c. (C) Sex-influenced dominance
d. (D) Sex-linked dominance

41. . If there are 3 alleles for the trait in a population, the total number of genotypes occurring in the population will be: OPSC 2021

a. (A) 3
b. (B) 4
c. (C) 5
d. (D) 6

42. . In a di-hybrid cross involving AaBb x AaBb, the fraction of progeny that will be homozygous for all four genes will be: OPSC 2021

a. (A) 1/16
b. (B) 3/16
c. (C) 1/4
d. (D) 9/16

43. Non allelic dominance is known as: OPSC 2021

a. (A) Over-dominance
b. (B) Co-dominance
c. (C) Partial dominance
d. (D) Epistasis

44. A measure of the intensity of natural selection action on the genotypes in the population: OPSC 2021

a. (A) Intensity of selection
b. (B) Relative fitness
c. (C) Survival of the fittest
d. (D) Selection coefficient

45. The criss-cross pattern of inheritance is seen in: OPSC 2021

a. (A) Sex limited trait
b. (B) Sex linked trait
c. (C) Sex influence trait
d. (D) None of these

46. The number of linkage groups in cattle are: OPSC 2012

a. (a) 20
b. (b) 30
c. (c) 18
d. (d) 25

47. In a cross between two heterozygous individuals for a trait showing incomplete dominance, what proportion of the offspring is expected to show the intermediate phenotype?

a. a) 1/4
b. b) 1/2
c. c) 3/4
d. d) 1/1

48. Which of the following best describes the phenomenon of epistasis?
    a. a) Interaction between alleles of the same gene
    b. b) Inheritance of traits linked to sex chromosomes
    c. c) Interaction between genes at different loci affecting a single trait
    d. d) Equal contribution of both alleles to the phenotype
49. In certain breeds of cattle, coat color is determined by multiple alleles at a single locus. If the dominance hierarchy is W > W^d > w, where W produces white coat, W^d produces dun, and w produces red, what would be the phenotype of a W^dw individual?
    a. a) White
    b. b) Dun
    c. c) Red
    d. d) Roan
50. In a certain breed of cattle, horn development is controlled by a single gene with two alleles. The polled condition (hornless) is dominant to the horned condition. A polled bull is mated to a horned cow, producing a horned calf. If this same bull is then mated to a large number of horned cows, what percentage of the offspring would be expected to be polled?
    a. a) 0%
    b. b) 25%
    c. c) 50%
    d. d) 100%

Unit 3: Population and Quantitative Genetics

1. Response to selection is the difference between mean phenotypic value of : MPSC 2017

(1) Offsprings and selected parents

(2) **Offsprings of selected parents and parental population before selection**

(3) Sire and dam

(4) Selected parents and base population before selection

2. Breeding system by which a few purebred sires can rather quickly transform a non-descript population into the purebred called : MPSC 2017

(1) Cross breeding **(2) Grading up**

(3) Back crossing (4) Criss crossing

3. The outcrossing within a herd by use of selected sire is called : MPSC 2017

(1) Upgrading (2) Line breeding

(3) Selective breeding *(4)* Back crossing

4. The most reliable and powerful Selection Index than conventional selection index for sire evaluation is: MPSC 2017

(1) Total score method

(2) Maximum likehood

(3) **BLUP (Best Linear Unbiased Prediction)**

(4) BLUE

5. Sunandini is a synthetic cattle breed developed by crossing : MPSC 2017

(1) Red Sindhi **X** Non-descript cattle (Kerla)

(2) Sahiwal X M.F.

(3) Tharparkar X Jersey

(4) **Brown Swiss X Non-descript cattle (Kerla)**

6. Method is used for selection when several traits are considered simultaneously:

(MPSC 2017)

(I) Individual selection (2) Independent culling level

(3) Selection Index (4) Tandom selection

7. The difference of mean phenotypic value between the offspring of the selected parents and the whole of the parental generation before MPSC 2019

(1) Selection differential

(2) Response to selection

(3) Phenotypic average

(4) Genetic gain

8. The index selection is efficient over other methods of selection because it takes account of: MPSC 2019

(1) Heritability of traits

(2) Relative economic weights of traits

(3) Genetic and phenotypic variances and covariance of all traits

(4) All of the above

9. Measures of the correlation between the repeated measurements of the same individual is known as MPSC 2019

(1) Repeatability

(2) Phenotypic correlation

(3) Genetic correlation

(4) Heritability

10. When two or more alleles of a gene are present in a gene pool the population is: UK VO 2024

    a. Polymorphic
    b. Evolving
    c. Drifting
    d. Somatic

11. Line breeding is traditionally practiced in UK VO 2024

    a) Pig

    b) Sheep

    c) Race horse

    d) Poultry

12. Which breeding is used to overcome inbreeding depression? UK VO 2024

    a) Out-crossing

    b) Cross-breeding

    c) Interspecific hybridization

    d) Inbreeding

13. Selection is effective for those traits which are governed by: UK VO 2024

    a) Additive genes

    b) Dominant genes

    c) Epistatic genes

    d) Recessive genes

14. The Expected Progeny Differences (EPD%) is used to select : UK VO 2024

    a. Young female animals

b. Young male animals
c. Adult bulls
d. Adult cows

15. The major cause of genetic correlation is UK VO 2024
a. Pleiotropy
b. Segregation
c. Heterozygosity
d. Homozygosity

16. Following is not a cause of heterosis: UK VO 2024
a. Overdominance
b. Dominance
c. Epistatic action
d. Additive gene action

17. Among the following species in which the high intensity of selection is not possible? UK VO 2024
a. Pig
b. Cattle
c. Poultry
d. Rabbit

18. The reproductive traits of livestock indicate heritability as: UK VO 2024
a. Low
b. Zero
c. Medium
d. High

19. Heritability estimate of a trait is higher when there is UK VO 2024
a. Uniform environment
b. Genetically uniform population
c. Small population
d. Dominance effect

20. The sun of average effect of all the alleles, is known as: UK VO 2024
a. Dominance effect
b. Transmitting ability
c. Breeding value
d. Genetic load

21. Movement of alleles from one population to another population is called: UK VO 2024
a. Selection
b. Mutation
c. Gene flow
d. Dominance

22. Osborne index is normally done for Kerala PSC 2023
a. High phenotypic variance
b. High environmental variance
c. Progeny evaluation
d. Parity evaluation

23. Maximum Production from livestock can be obtained from Kerala PSC 2023
    a. Superior herd with poor environment
    b. Poor genotype with best environment
    c. Superior genotype with best environment
    d. Poor genotype with poor environment
24. Hybrid vigour will result form Kerala PSC 2023
    a. Dominance
    b. Over dominance
    c. Epistasis
    d. All the above
25. Which of the following is not an assumption for Hardy Weinberg equilibrium: JKSPC 2019
    a. (A) Large population
    b. (B) Migration
    c. (C) Mutation
    d. (D) **Variation**
26. Proportion of phenotypic variance caused due to additive gene variance is JKSPC 2019
    a. (A) Heritability
    b. (B) Correlation
    c. (C) Regression
    d. (D) Response
27. 3. Correlation among different measurements on a character in the life of an animal is called JKPSC 2019
    a. (A) Repeatability
    b. (B) Heritability
    c. (C) Regression
    d. (D) Variance
28. In a random mating population, the maximum heterozygosity is expressed when one of the gene frequency is JKPSC 2019
    a. (A) 0.2
    b. (B) 0.7
    c. (C) 0.9
    d. (D) 0.5
29. 6. In h^2 value of a trait is 0.5; selection differential value is 2.5; generation interval is 2.5 years, then the response per year will be JKPSC 2019
    a. (A) 0.25
    b. (B) 0.50
    c. (C) 0.025
    d. (D) 0.80
30. General combining ability calculated in a diallel mating is indicative of JKPSC 2019
    a. (A) Overdominance
    b. (B) Epistasis

c. (C) Non-additive genetic effect
d. (D) Additive genetic effect

31. Traits having low h^2 can be improved through JKPSC 2019
a. (A) Family selection
b. (B) Individual selection
c. (C) Combined selection
d. (D) Tandem method of selection

32. Response to selection depends on JKPSC 2019
a. (A) Intensity
b. (B) Correlation
c. (C) Regression
d. (D) Inbreeding

33. 12. Inbreeding coefficient of an individual produced from parent offspring is
JKPSC 2019
a. (A) 0.25
b. (B) 0.50
c. (C) 0.025
d. (D) 0.80

34. The most important economic trait taken into account while selecting a dairy cow is
JKPSC 2019
a. (A) Age at first estrus
b. (B) Lactational yield
c. (C) Dry period
d. (D) Intercalving period

35. . The method of selection used when inadequate information is available about the individual is (JKPSC 2019)
a. (A) Performance testing
b. (B) Progeny testing
c. (C) Pedigree selection
d. (D) Show ring testing

36. Which of the following statement is correct regarding triple crossing for the improvement of milk production in dairy cattle?
JKPSC 2019
a. (A) Three breeds are crossed without rotation
b. (B) Crossbreds have 4/7 of inheritance in immediate sire
c. (C) 3/7 of inheritance from the breed of maternal grand sire
d. (D) 2/7 of heredity of pure breed

37. Continuous use of purebred sire on non- descript female is JKPSC 2019
a. (A) Cross breeding
b. (B) Top crossing
c. (C) lnter se mating
d. (D) Grading up

38. Cross-breeding increases: JKPSC (2012)
a. (A) Vigour
b. (B) Breeding merit

c. (C) Both (A) and (B)
d. (D) None

39. A new breed can be evolved by: JKPSC (2012)
a. (A) Grading up
b. (B) Out crossing
c. (C**) Cross-breeding**
d. (D) Inbreeding

40. Which type of mating should be preferred for the improvement of non-descript animals? JKPSC (2012)
a. (A) Inbreeding
b. (B) Line breeding
c. (C) Upgrading
d. (D) All of the above

41. Phenotype reflects genotype more precisely when heritability is JKPSC (2012)
a. (A) Low
b. (B) High
c. (C) Medium
d. (D) All of the above

42. Inbreeding coefficient measures: JKPSC (2012)
a. (A) Heterozygosity
b. (B) Homozygosity
c. (C) Cross-breeding
d. (D) None of the above

43. Closely related mating is: JKPSC (2012)
a. (A) Inbreeding
b. (B) Outbreeding
c. (C) Cross-breeding
d. (D) None of the above

44. The suitable selection aid for high heritable traits is JKPSC 2020
a. A) Sib selection
b. B) Pedigree selection
c. C) Family selection
d. D) Individual selection

45. The mean performance of line when expressed as the deviation from the mean of all crosses is: JKPSC 2020
a. A) General combining ability of line
b. B) Average effect of the line
c. C) General and Specific combing ability of line
d. D) Specific combing ability of line

46. Read the following statements JKPSC 2020
1) Progeny testing is useful for sex limited traits
2) Polled condition in cattle, is an example for lack of dominance
3) Mutation produces new genes in the population
4) In tandem selection, more number of traits selected at one time
Which of the following statements is / are correct?
a. A) 1 and 3

b. B) 3 and 2
c. C) 1 and 4
d. D) 2and 4

47. Consider the following statements JKPSC 2020

1) For comparing variance, F test is used
2) Additive genetic variance is the result of interaction of genes
3) covariance of the parents is equal to inbreeding coefficient of the progeny
4) Breeding of two different breeds is crossbreeding

Which of the following statements is / are correct?

a. A) 1and3
b. B) 3and2
c. C) 3and4
d. D) 1and4

48. Selection on the basis of individuality is most important, when h' of the trait is: PPSC 2016

a. a) Low
b. b) Medium
c. c) High
d. d) None of the above

49. Frequency of two alleles in parents is 'p' and 'q'; then proportion of heterozygotes in progeny will be: PPSC 2016

a. a) 2pq
b. b) p2
c. c) q2
d. d) p+q

50. Selection differential depends on all except: PPSC 2016

a. a) Sex of the animal
b. b) Proportion selected
c. c) Heritability
d. d) Phenotypic standard deviation

Unit 4: Breeds of Livestock Animals, Breeding Policies and Breeding Programmes

1. The number of registered native dog breeds in india is: UK VO 2024

a) 10

b) 21

c) 15

d) 3

2. Which animal would you find in Gir National Park only? UK VO 2024

a) Asiatic Lion

b) Bengal Tiger

c) Leopard

d) Bear

3. Captive breeding is performed in UK VO 2024
    a) Uncontrolled environment
    b) Controlled environment
    c) No importance of environment
    d) Between different species
4. Use of genetic technique in forensic science is also called:
    a. Genetic finger printing
    b. In vitro culture
    c. Hybridoma technology
    d. Gene therapy
5. Viable material of endangered species can be preserved by
    a. Gene bank
    b. Gene library
    c. Gene pool
    d. Herbarium
6. Rapid decrease of animal population numbers indicates the status of
    a. Extinct
    b. Endangered
    c. Vulnerable
    d. Insecure
7. Which of the following institute registers new breeds of animals in india? UK VO 2024
    a. NDRI, Karnal
    b. NBAGR, Karnal
    c. IVRI, Izatnagar
    d. NDDB, Anand
8. True swamp buffaloes are found where? UK VO 2024
    a. Haryana
    b. West Bengal
    c. Assam
    d. Goa
9. Sheep breed famous for mutton production is UK VO 2024
    a. Mandya
    b. Muzaffarnagri
    c. Nali
    d. Bikaneri
10. Which of the following is a dual breed of cattle JKPSC 2019
    a. (A) Red sindhi
    b. (B) Haryana
    c. (C) Sahiwal
    d. (D) Amritmahal
11. Malabari breed of goat originates in the state of JKPSC 2019
    a. A) Orissa
    b. (B) Jharkhand
    c. (C) Kerala

d. (D) Andhra Pradesh

12. The strain developed at CSWRI by crossing Rambouillet on Chokla and Nali sheep is JKPSC 2019

a. (A) Avivastra
b. (B) Abhimanas
c. (C) Abhikalin
d. (D) Kheri

13. 16. The original home tract of Sannen breed is JKPSC 2019

a. (A) USA
b. (B) Switzerland
c. (C) Turkey
d. (D) England

14. Which of the following is a milch breed of goat JKPSC 2019

a. (A) Beetal
b. (B) Chegu
c. (C) Ganjam
d. (D) Assam Hill

15. Match the following livestock & poultry breeds with their recognized number as per National Bureau of Animal Genetic Resources (NBAGR), Karnal:

JKPSC 2019)

Species	No of recognized breeds
(a) Cattle	(1) 20
(b) Buffalo	(2) 53
(c) Goat	(3) 20
(d) Chicken	(4) 39

Select the correct answer using the code below:

a. (A) a-1, b-2, c-3, d-4
b. (B) a-2, b-3, c-4, d-1
c. (C) a-2, b-4, c-1, d-3
d. (D) a-1, b-2, c-4, d-3

16. Newly recognized chicken breed UTTARA hails from the state of JKPSC 2019

a. (A) Jharkhand
b. (B) Chhattisgarh
c. (C) Uttarakhand
d. (D) Telangana

17. What is the J&K state breeding policy for sheep and goat JKPSC 2019

a. (A) Selective Breeding
b. (B) Cross breeding
c. (C) Line Breeding
d. (D) Upgrading

18. The first successful cloning of livestock was done in 1996 with JKPSC 2019

a. (A) cattle
b. (B) sheep
c. (C) swine
d. (D) goats

19. How many breeding farms for various species of animals and poultry are there in the J&K State?

JKPSC 2019

a. (A) 50
b. (B) 24
c. (C) 34
d. (D) 44

20. Which breed of cattle is known as milch breed? JKPSC (2012)

a. (A) Kankrej
b. (B) Haryana
c. (C) Gir
d. (D) Amrit Mahal

21. Best dairy breed of cattle in India is: (JKPSC 2012)

a. (A) Haryana
b. (B) Red Sindhi
c. (C) Sahiwal
d. (D) Tharparkar

22. The heaviest Indian cattle breed is: (JKPSC 2012)

a. (A) Rathi
b. (B) Ongole
c. (C) Sahiwal
d. (D) Kankrej

23. Corriedale sheep is native breed of JKPSC (2012)

a. (A) Australia
b. (B) Britain
c. (C) Switzerland
d. (D) New Zealand

24. Home tract of Nili-Ravi is JKPSC (2012)

a. (A) Rajasthan
b. (B) Gujarat
c. (C) Punjab
d. (D) Maharashtra

25. Cattle breeding policy of the state restricts exotic inheritance to % in temperate areas and % for plains of subtropical areas of Jammu JKPSC 2020

a. A) 75 and 50
b. B) 50 and 75
c. C) 62 and50
d. D) 50and 62

26. As per Olver (1938) which of the following cattle breed entered India along with Aryans

JKPSC 2020

a. A) Deoni
b. B) Hariana
c. C) Tharparkar
d. D) Punganur

27. Which of the following species was first domesticated by human beings? JKPSC 2020
    a. A) Cattle
    b. B) Sheep
    c. C) Dog
    d. D) Goat
28. Match the livestock and poultry breed as per the recognition by the National Bureau of Animal Genetic resources (JKPSC, 2020)

Species	No.of recognized breeds
i) Cattle	1) 7
ii) Sheep	2) 03
iii) Horses & Ponies	3) 53
iv) Ducks & Geese	4) 45

    Select the correct answer using the code below
    a. 1-2, ii- 3, iii-1, iv -4
    b. I-3, ii-4,iii-1.iv-2
    c. i-l, ii-3, iii-2, iv -4
    d. i-2,ii-4,iii-1,iv-3
29. Hissardale is evolved from: PPSC 2022
    a. a) Gaddi X Merino
    b. b) Nilgiri X Merino
    c. c) Bikaneri X Merino
    d. d) Nili-Ravi X Merino
30. 12. The Vrindavani cattle developed at a cross between: PPSC 2022
    a. a) Exotics (Holstein Friesian/Jersey/Brown Swiss) with native Sahiwal breed
    b. b) Exotics (Holstein Friesian/Jersey/Brown Swiss) with native Tharparkar breed
    c. (C) Exotics (Holstein Friesian/Jersey/Brown Swiss) with native Hariana breed
    d. (d) None of the above
31. . The coordinating unit of All India Coordinated Research Project (AICRP) on Goat Improvement is presently located at which of the following institutes? MPPSC 2023
    a. [A] NDRI, Karnal, Haryana
    b. [B] IVRI, Izzatnagar, Uttar Pradesh
    c. **[C] CIRG, Makhdoom, Mathura, (UP)**
    d. [D] CSWRI, Avikanagar, Rajasthan
32. Goat meat from which breed is more delicious: OPSC 2019
    a. (A) Black Bengal and Angora Chevon
    b. (B) Nubian
    c. (C) Chigu and Changthangi
    d. (D) Marwari and Beetal
33. Wall eye is the characteristic feature of the following breed OPSC 2012
    a. (a) Murrah
    b. (b) Surti
    c. (c) Pandarpuri
    d. (d) Nili Ravi

34. Lyre horns are the characteristics of the following breed of cattle OPSC 2012
    a. (a) Amrithmahal
    b. (b) Deoni
    c. (c) Tharparker
    d. (d) Kankrej
35. Wilmut et al. achieved the production of first cloned lamb from adult somatic cells in the year MPPSC 2019
    a. (A) 1986
    b. (B) 1992
    c. (C) 1996
    d. (D) 2000
36. Which is the draught purpose breed of cattle
    a. Sahiwal
    b. Nagori
    c. Gir
    d. Rathi
37. The copper-coloured skin is found in which breed of buffalo?
    a. Murrah
    b. Surti
    c. Bhadawari
    d. Toda
38. The finest wool producing breed of sheep in the world is
    a. Nellore
    b. Bellari
    c. Mandya
    d. Merino
39. Which of the following breeds evolved at Avikanagar for apparel purpose
    a. Avivastra
    b. Avikalin
    c. Both
    d. Hissardale
40. Best breed of layers is
    a. Leghorn
    b. RIR
    c. Brahma
    d. Sussex
41. Cross of Rambouillet and Chokla
    a. Karan Swiss
    b. Karan Fries
    c. Avikalin
    d. Avivastra
42. Cross of Brown Swiss and Sahiwal
    a. Khargoni
    b. Karan fries
    c. Kherigarh
    d. Karan Swiss

43. The swamp buffaloes distributed mostly in upper Brahmaputra valley of Assam is _____
    - **a. Luit**
    - b. Ghurrah
    - c. Toda
    - d. Chattisgarh
44. Which of the following breeds of class has feathered shanks?
    - a. American
    - b. English
    - **c. Asiatic**
    - d. Mediterranean
45. Name the smallest sheep breed with typical reversed ―U‖ shaped body conformation from rear side.
    - a. a) Nellore
    - b. b) Magra
    - **c. c) Mandya**
    - d. d) Hassan
46. Konkan Kapila cattle breed is native of _____
    - **a. Maharashtra and Goa**
    - b. Karnataka and Andhra Pradesh
    - c. Kerala and Karnataka
    - d. Maharashtra and Karnataka
47. _____is the fibre obtained from Angora goats.
    - **a. a) Pashmina**
    - b. b) Cashmere
    - c. c) Qiviut
    - d. d) Mohair
48. Minorca breed of poultry belongs to which class
    - a. Asiatic
    - b. English
    - **c. Mediterranean**
    - d. American
49. Which breed of buffalo is the heaviest among all breeds?
    - a. Mehsana
    - b. Surti
    - **c. Jaffrabadi**
    - d. Nilli ravi
50. The small dairy goat breed having red or brown spots is
    - **a. Barbari**
    - b. Beetal
    - c. Nellore
    - d. Kutchi

Unit 5: Conservation of Animal Genetic Resources

1. What is the primary goal of conserving animal genetic resources?
   a) Increasing farm profits
   b) Reducing biodiversity

c) Maintaining genetic diversity for future use
d) Promoting industrial farming

2. Which of the following is NOT a method of conserving animal genetic resources?
   a) In situ conservation
   b) Ex situ in vivo conservation
   c) Ex situ in vitro conservation
   d) Intensive selective breeding

3. The preservation of live animals in their native environment is known as:
   a) In situ conservation
   b) Ex situ conservation
   c) Cryoconservation
   d) Gene banking

4. Which international organization plays a key role in coordinating global efforts for animal genetic resource conservation?
   a) WHO
   b) UNEP
   c) FAO
   d) IUCN

5. The Global Plan of Action for Animal Genetic Resources was adopted in:
   a) 1992
   b) 2000
   c) 2007
   d) 2015

6. Which of the following is an example of ex situ in vitro conservation?
   a) Maintaining a herd of rare cattle breeds on a farm
   b) Keeping endangered chicken breeds in a zoo
   c) Storing semen samples in liquid nitrogen
   d) Raising native sheep breeds in their traditional habitat

7. The loss of genetic diversity within a breed is called:
   a) Speciation
   b) Mutation
   c) Genetic erosion
   d) Genetic drift

8. Which factor is NOT a major threat to animal genetic resources?
   a) Crossbreeding with exotic breeds
   b) Changes in production systems
   c) Natural disasters
   d) Increased use of artificial insemination

9. The Domestic Animal Diversity Information System (DAD-IS) is maintained by:
   a) IUCN
   b) UNEP

c) FAO
d) CBD

10. Which of the following is a key advantage of cryoconservation?
    a) It maintains natural animal behavior
    b) It allows for continued breed evolution
    c) It requires minimal space and resources for long-term storage
    d) It provides immediate access to live animals

11. The concept of "core collections" in animal genetic resource conservation refers to:
    a) The most profitable breeds
    b) Extinct breeds
    c) A representative sample of genetic diversity
    d) Wild ancestors of domestic animals

12. Which breeding method is most likely to contribute to the conservation of within-breed diversity?
    a) Intensive selection for production traits
    b) Crossbreeding with exotic breeds
    c) Rotational mating systems
    d) Cloning of top performers

13. The Convention on Biological Diversity (CBD) recognizes the importance of:
    a) Only wild animal species
    b) Only plant genetic resources
    c) Both wild and domesticated biodiversity
    d) Only marine genetic resources

14. Which of the following is NOT typically considered when prioritizing breeds for conservation?
    a) Genetic uniqueness
    b) Cultural importance
    c) Adaptive traits
    d) Current market value

15. The process of identifying and describing breed populations and their environments is called:
    a) Characterization
    b) Evaluation
    c) Cataloging
    d) Indexing

16. Which conservation strategy is most suitable for maintaining the adaptive potential of a breed?
    a) In situ conservation
    b) Cryoconservation of gametes
    c) Maintaining small populations in zoos
    d) Cloning individuals

17. The term "landrace" in animal genetic resources refers to:
    a) Highly selected commercial breeds
    b) Extinct wild ancestors
    c) Locally adapted, traditionally managed breeds
    d) Synthetic breeds created for specific environments

18. Which of the following is a limitation of ex situ in vitro conservation?
    a) It's too expensive
    b) It doesn't preserve genetic material
    c) It doesn't allow for continued adaptation to changing environments
    d) It requires too much land

19. The concept of Livestock Keepers' Rights is most closely associated with:
    a) Intellectual property protection
    b) Recognition of traditional knowledge and practices
    c) Animal welfare regulations
    d) Export restrictions on genetic material

20. Which approach is most likely to support the sustainable use of animal genetic resources?
    a) Replacing all local breeds with high-yielding exotic breeds
    b) Strict preservation of breeds without any utilization
    c) Integrating conservation with livestock development programs
    d) Focusing solely on ex situ conservation methods

21. Which conservation method involves maintaining animals in their natural habitat or traditional production systems?
    a) In situ conservation
    b) Ex situ conservation
    c) Cryoconservation
    d) Gene banking

22. The storage of genetic material in specialized facilities outside the animal's natural environment is known as:
    a) In situ conservation
    b) Ex situ conservation
    c) Ecosystem conservation
    d) Habitat preservation

23. Which of the following is an advantage of in situ conservation?
    a) Protection from disease outbreaks
    b) Controlled breeding environment
    c) Continued adaptation to local conditions
    d) Lower maintenance costs

24. Ex situ in vivo conservation refers to:
    a) Freezing embryos and semen
    b) Maintaining DNA libraries
    c) Keeping live animals in zoos or dedicated farms
    d) Preserving tissue samples in laboratories

25. Which conservation method is most effective for preserving the cultural and social aspects associated with a breed?
    a) In situ conservation
    b) Ex situ in vitro conservation
    c) Ex situ in vivo conservation
    d) Genome sequencing

26. The main advantage of ex situ in vitro conservation is:
    a) Allowing natural selection to continue
    b) Maintaining traditional farming practices
    c) Long-term storage with minimal genetic changes
    d) Immediate availability of live animals

27. Which of the following is NOT typically considered an in situ conservation method?
    a) Community-based breeding programs
    b) Protected area management
    c) Traditional pastoral systems
    d) Embryo transfer to surrogate mothers of different breeds

28. Ex situ conservation is particularly important for:
    a) Maintaining large population sizes
    b) Promoting genetic adaptation
    c) Safeguarding against catastrophic events
    d) Ensuring continued evolution of breeds

29. Which conservation approach is most likely to preserve the entire ecosystem associated with a breed?
    a) In situ conservation
    b) Ex situ in vivo conservation
    c) Cryoconservation
    d) DNA banking

30. The "Frozen Zoo" concept is an example of:
    a) In situ conservation
    b) Ecosystem restoration
    c) Ex situ in vitro conservation
    d) Sustainable use of genetic resources

Unit 6: Basic Statistics

1. Random allotment of treatments to different experimental units is called as
   UK VO 2024
    a. Replication
    b. Local control
    c. Randomization
    d. Experimental error
2. Which measure of dispersion is free from unit?

UK VO 2024

a. Range
b. Standard deviation
c. Coefficient of variation
d. Variance

3. The measure of variation that is least affected by extreme observation is:

UK VO 2024

a. Mean deviation
b. Quartile deviation
c. Standard deviation
d. Range

4. Numerical measures on the entire population are called: UK VO 2024

a. Statistics
b. Median
c. Parameter
d. Variable

5. . In a statistical hypothesis testing experiment, what type of error is committed by rejecting the null. hypothesis when it is true:

OPSC 2019

a. (A) Type-1
b. (B) Type-II
c. (C) Type-land Type-II
d. (D) None of the above

6. The variance ratio in case of 'F' test is ____ than one.

OPSC 2019

a. (A) Less
b. (B) More
c. (C) Equal
d. (D) None of the above

7. The probability that provides lines of demarcation between acceptance and rejection regions of null hypothesis is known as: OPSC 2021

a. (A) Confidence coefficient
b. (B) Power of test
c. (C) Level of significance
d. (D) Confidence interval

8. The approximate area covered between $\pm$1 S.D. under a normal distribution curve is:

OPSC 2021

a. (A) 68%
b. (B) 95%
c. (C) 99%
d. (D) 34%

9. . Which of the following errors is reduced by increasing the number of offspring in the progeny test?

OPSC 2021

a. (A) Systematic errors
b. (B) Non-sampling errors

c. **(C) Errors of Mendelian sampling**
d. (D) Type-Il errors

10. . In which of the following distributions the variance is always less than the mean? OPSC 2021
    a. (A) Normal distribution
    b. (B) Poisson distribution
    c. **(C) Binomial distribution**
    d. (D) Hyper geometric distribution

11. Which of the following best describes statistical data?
    a) Qualitative information about a population
    b) Theoretical models of probability
    c) **Quantitative information collected for analysis**
    d) Graphical representations of trends

12. What is the primary purpose of descriptive statistics?
    a) Making predictions about a population
    b) Testing hypotheses
    c) Analyzing probability distributions
    d) **Summarizing and describing data**

13. In statistics, what does a sample represent?
    a) The entire population under study
    b) A biased subset of the population
    c) **A representative subset of the population**
    d) A collection of outliers

14. Which of the following is an example of a discrete variable?
    a) Height
    b) Temperature
    c) Weight
    d) **Number of animals in a farm**

15. What is the main difference between a parameter and a statistic?
    a) Parameters are more accurate than statistics
    b) Statistics are always larger than parameters
    c) **Parameters pertain to populations, while statistics pertain to samples**
    d) Statistics are used in descriptive analysis, while parameters are used in inferential analysis

16. In a normal distribution, what percentage of data falls within one standard deviation of the mean?
    a) 95%
    b) 99.7%
    c) **68%**
    d) 50%

17. Which probability distribution is characterized by a fixed number of trials with two possible outcomes per trial?
    a) Normal distribution

b) **Binomial distribution**
c) Poisson distribution
d) Exponential distribution

18. What is the primary purpose of hypothesis testing in statistics?
    a) To describe the central tendency of a dataset
    b) To calculate correlation coefficients
    c) **To make inferences about a population parameter based on sample data**
    d) To determine the range of a dataset

19. In regression analysis, what does the regression coefficient (b) indicate?
    a) The sample size
    b) The standard deviation of the dependent variable
    c) **The strength and direction of the relationship between variables**
    d) The probability of Type I error

20. Which of the following is true about the correlation coefficient?
    a) It ranges from 0 to 1
    b) It indicates causation between variables
    c) **It ranges from -1 to +1**
    d) It is always positive for strong relationships

21. In a positively skewed distribution, how do the measures of central tendency typically relate to each other?
    a) Mean < Median < Mode
    b) Mean = Median = Mode
    c) **Mean > Median > Mode**
    d) Median > Mean > Mode

22. What is the primary purpose of measures of dispersion in statistics?
    a) To determine the average value of a dataset
    b) **To indicate how values are scattered around the mean**
    c) To test hypotheses about population parameters
    d) To classify data into categories

23. Which measure of dispersion is least affected by extreme values?
    a) Range
    b) Standard deviation
    c) **Interquartile range**
    d) Variance

24. What does the coefficient of variation (CV) represent?
    a) The absolute variability of a dataset
    b) The skewness of a distribution
    c) **The relative variability of a dataset in relation to its mean**
    d) The kurtosis of a distribution

25. Which of the following is true about the relationship between different measures of dispersion?
    a) Mean deviation > Standard deviation > Quartile deviation

b) **Standard deviation > Mean deviation > Quartile deviation**
c) Quartile deviation > Standard deviation > Mean deviation
d) All measures of dispersion are always equal

26. What is the primary difference between a paired t-test and an unpaired t-test?
a) Paired t-test is used for large sample sizes, while unpaired t-test is used for small sample sizes
b) Paired t-test assumes equal variance, while unpaired t-test does not
c) **Paired t-test is used for related samples, while unpaired t-test is used for independent samples**
d) Paired t-test is non-parametric, while unpaired t-test is parametric

27. Which statistical test is most appropriate for comparing the variances of two samples?
a) t-test
b) **F-test**
c) Chi-square test
d) Z-test

28. What is a Type I error in hypothesis testing?
a) Accepting the null hypothesis when it is false
b) **Rejecting the null hypothesis when it is true**
c) Failing to reject the null hypothesis when it is false
d) Accepting the alternative hypothesis when it is true

29. In a normal distribution, approximately what percentage of data falls within two standard deviations of the mean?
a) 68%
b) **95%**
c) 99.7%
d) 90%

30. Which of the following is a characteristic of the Poisson distribution?
a) It is always symmetrical
b) It has a fixed number of trials
c) **Its mean and variance are equal**
d) It is used for continuous variables

31. What is the primary purpose of inferential statistics?
a) To organize and summarize data
b) To calculate measures of central tendency
c) **To make predictions and inferences about a population based on a sample**
d) To graphically represent data

32. Which of the following is an example of a quantitative continuous variable?
a) Blood type
b) Gender
c) Number of offspring
d) **Body temperature**

33. In regression analysis, which variable is typically represented on the X-axis of a graph?
    a) **Independent variable**
    b) Dependent variable
    c) Confounding variable
    d) Control variable

34. What does a correlation coefficient of -0.8 indicate?
    a) A weak positive correlation
    b) No correlation
    c) A weak negative correlation
    d) **A strong negative correlation**

35. Which measure of central tendency is most affected by extreme values in a dataset?
    a) Median
    b) Mode
    c) **Arithmetic mean**
    d) Geometric mean

36. What is the primary advantage of using the interquartile range as a measure of dispersion?
    a) It uses all data points in its calculation
    b) **It is not affected by extreme outliers**
    c) It is always smaller than the standard deviation
    d) It is easier to calculate than other measures

37. When is the chi-square test typically used?
    a) To compare means of two samples
    b) To test for normality of a distribution
    c) **To compare observed frequencies to expected frequencies**
    d) To measure the strength of correlation between variables

38. What is the standard error primarily used for?
    a) Measuring the variability within a sample
    b) **Estimating the variability of a sample mean**
    c) Calculating the range of a dataset
    d) Determining the mode of a distribution

39. In a negatively skewed distribution, which of the following is typically true?
    a) Mean > Median > Mode
    b) Mean = Median = Mode
    c) **Mean < Median < Mode**
    d) Median > Mean > Mode

40. What does a low coefficient of variation (CV) indicate about a dataset?
    a) The data is highly dispersed relative to its mean
    b) The data has a large standard deviation
    c) **The data is less dispersed relative to its mean**
    d) The data has a small mean value

41. Which of the following best describes a discrete variable?
    a) It can take any value within a given range
    b) It is always measured on a continuous scale
    c) **It represents clear categories or takes only integral values**
    d) It is always represented by decimal numbers

42. What does the 68-95-99.7 rule refer to in a normal distribution?
    a) The percentage of data within 1, 2, and 3 standard deviations from the mean
    b) The probability of Type I and Type II errors
    c) The confidence intervals for hypothesis testing
    d) **The percentage of data within 1, 2, and 3 standard deviations from the mean, respectively**

43. Which of the following is a characteristic of the binomial distribution?
    a) It is always symmetrical
    b) It has a variable number of trials
    c) **It has a fixed number of trials with two possible outcomes per trial**
    d) It is used for continuous variables

44. What is the primary purpose of the coefficient of variation (CV)?
    a) To measure the absolute variability of a dataset
    b) To compare means of different populations
    c) **To compare variability between datasets with different units**
    d) To determine the median of a distribution

45. In a symmetrical distribution, how do the measures of central tendency typically relate to each other?
    a) Mean > Median > Mode
    b) Mean < Median < Mode
    c) **Mean = Median = Mode**
    d) Median > Mean > Mode

46. Which of the following is true about the geometric mean?
    a) It is always larger than the arithmetic mean
    b) **It is generally smaller than the arithmetic mean**
    c) It is equal to the harmonic mean
    d) It is not affected by extreme values

47. What is the main advantage of using the range as a measure of dispersion?
    a) It uses all data points in its calculation
    b) It is not affected by outliers
    c) **It is the simplest measure of dispersion to calculate**
    d) It provides the most accurate representation of variability

48. When is Welch's t-test typically used instead of a standard unpaired t-test?
    a) When sample sizes are equal
    b) When variances are assumed to be equal
    c) **When variances are unequal between groups**
    d) When dealing with paired samples

49. What does the probable error (PE) represent in relation to the standard deviation (SD)?
    a) PE = SD
    b) PE = 1/2 SD
    c) **PE = 2/3 SD**
    d) PE = 3/4 SD

50. Which of the following is true about the relationship between different measures of dispersion?
    a) Standard deviation < Mean deviation < Quartile deviation
    b) Quartile deviation < Mean deviation < Standard deviation
    c) Mean deviation < Quartile deviation < Standard deviation
    d) **Standard deviation > Mean deviation > Quartile deviation**