*Section: Genetics*

# Overview of the Section

**L1: The Cell Cycle – Mitosis, Meiosis, and Gametogenesis**
MCQs 1: The Cell Cycle

**L2: Basic Genetics: Mendelian, Non-Mendelian, Advanced Genetics Concepts**
MCQs 2: Basic Genetics

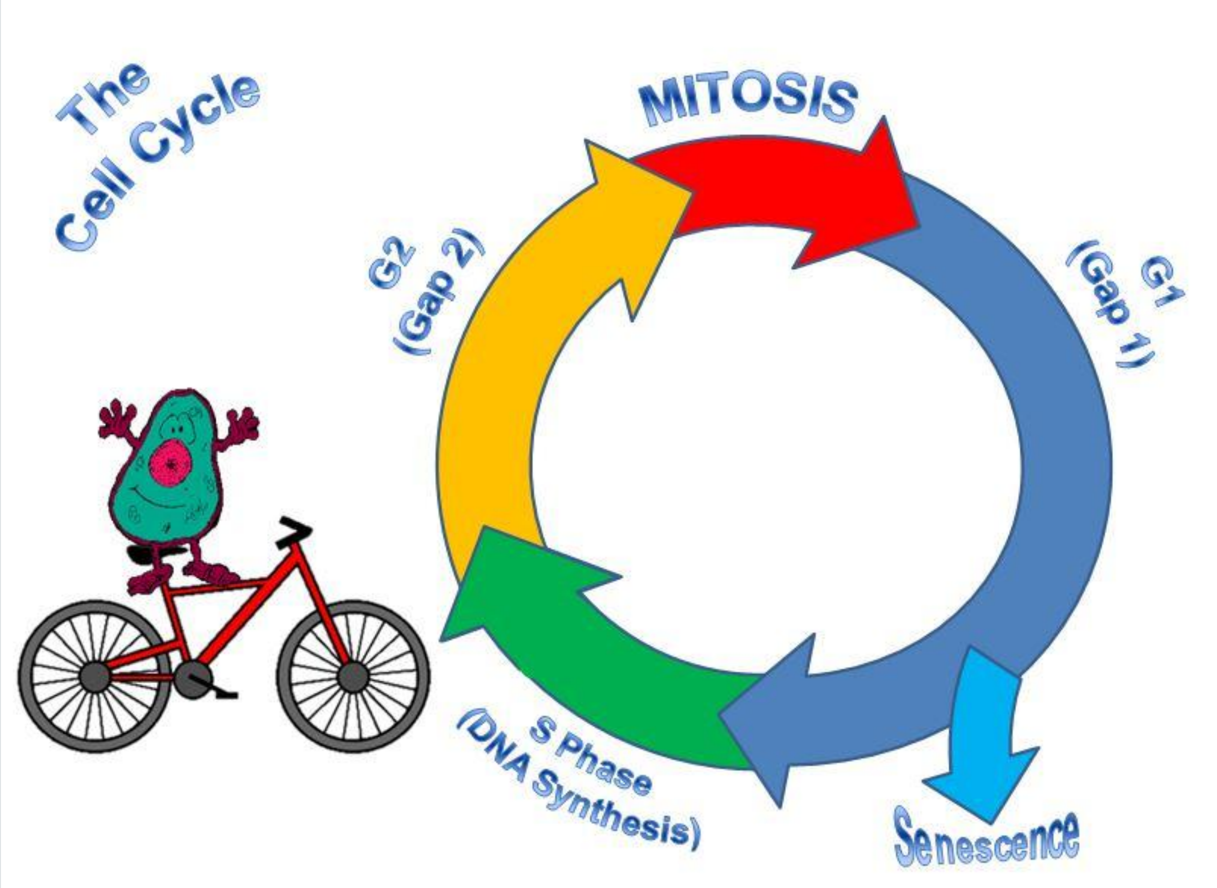
**L3: Population Genetics: Gene frequencies & Hardy Weinberg Equilibrium**
MCQs 3: Population Genetics

**L4: Quantitative Genetics: Heritability, Repeatability, Correlation**
MCQs 4: Quantitative Genetics

*Section: Genetics (Unit II)*

## Overview of the Section

# THE CELL CYCLE




The sequence of events a cell undergoes as it grows and divides.

Two main phases:

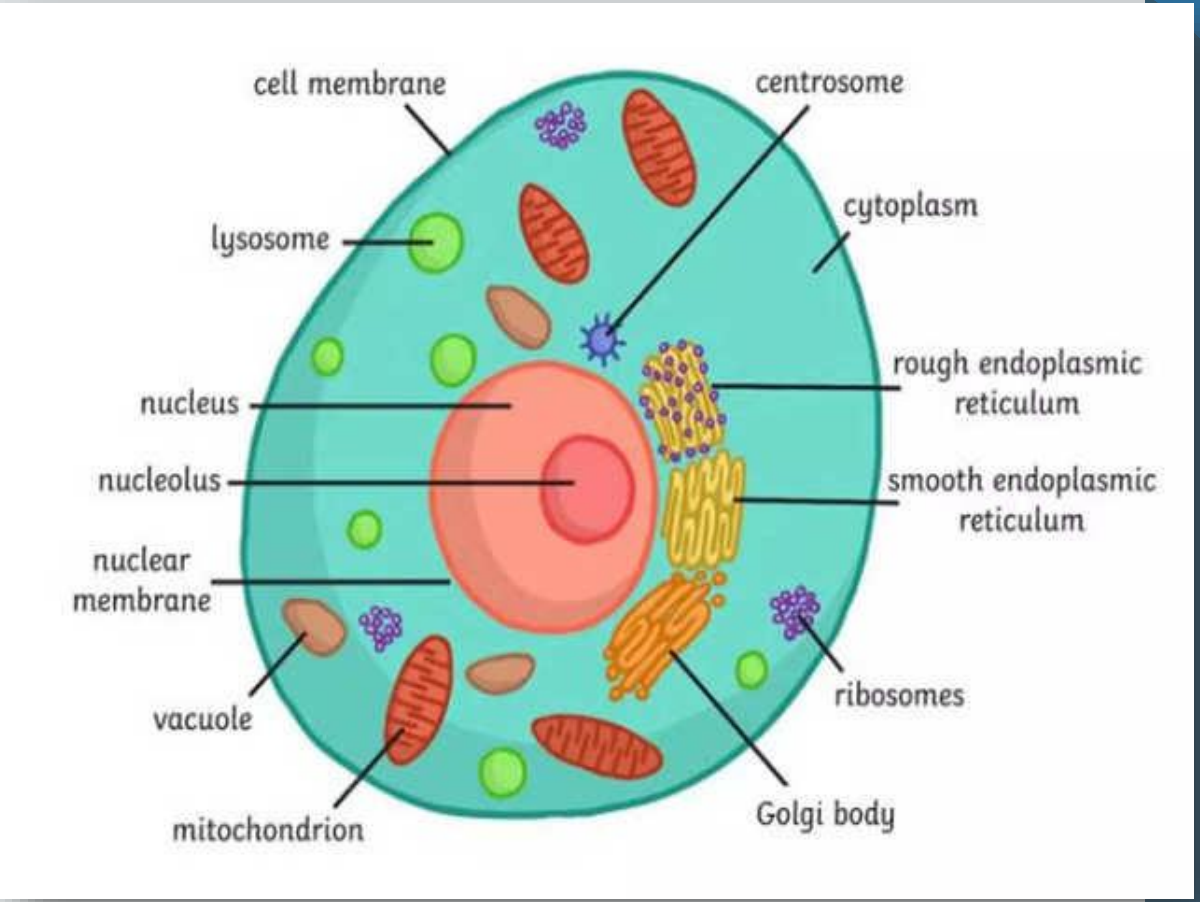
1. Interphase
2. Mitosis

# THE CELL CYCLE

## CELL

Cell – Basic structural and functional unit of life

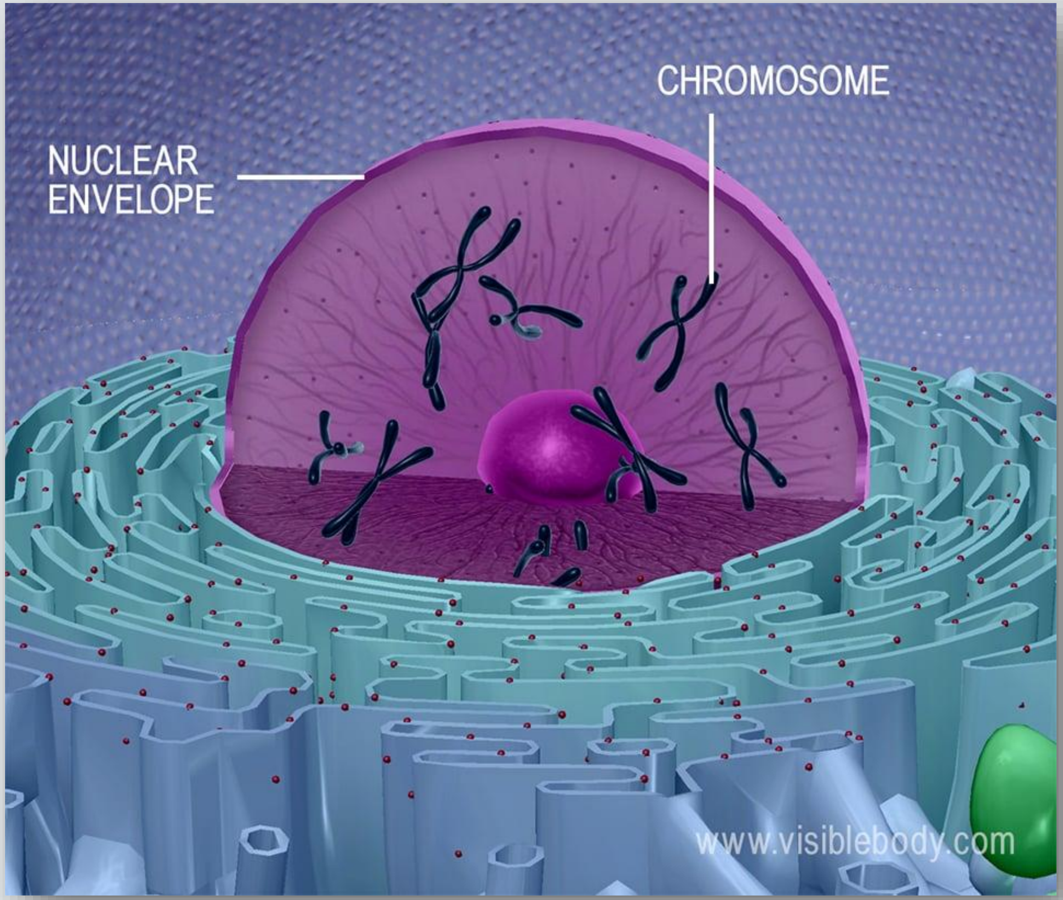
- Cell contents – called protoplasm
- Contains organelles – req. for functioning
- Cytoplasm = cytosol + suspended organelles
- Centriole – Barrel shaped self-replicating organelles – Involved in organization of mitotic spindle and completion of cytokinesis during cell division



# THE CELL CYCLE

## NUCLEUS

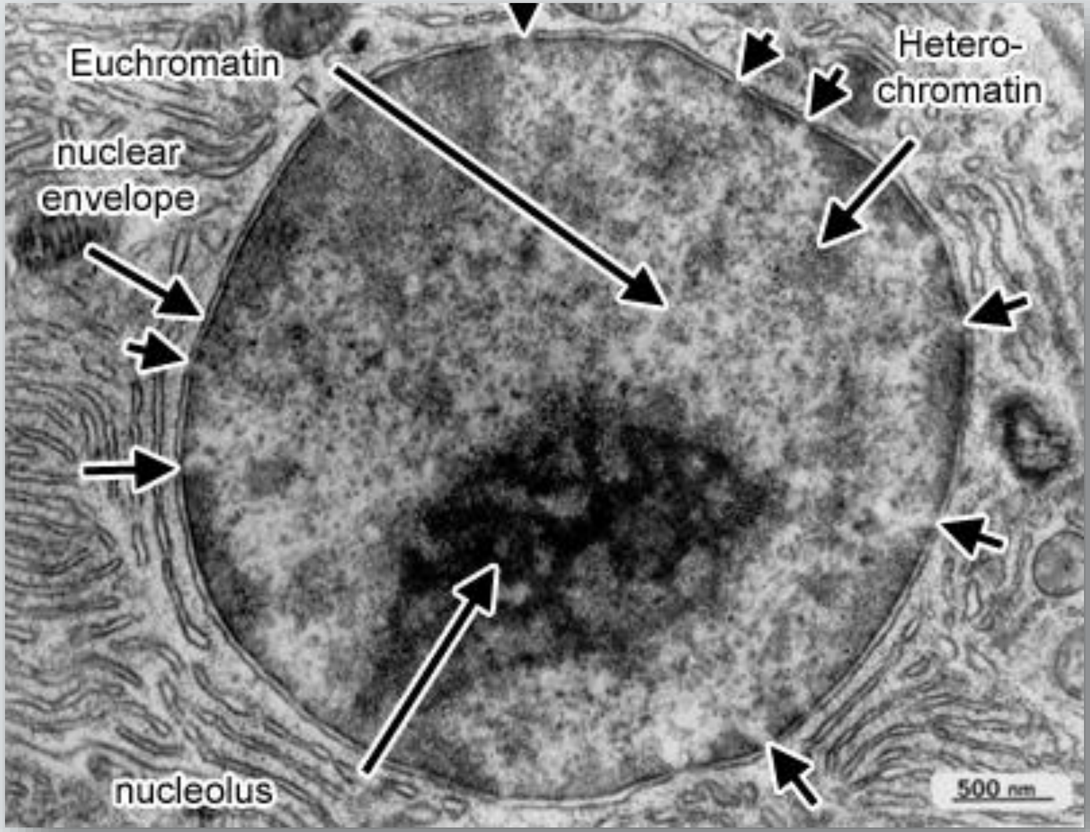
- Enclosed by nuclear envelope
- Contains nucleolus & nucleoplasm
- Contains the cell's genetic material (DNA) in a complex with histones – in the form of chromosomes
- Similar DNA present in all body cells – but depending on cell type, certain genes are turned 'on' or 'off' – creating differences within two different types of cells



# THE CELL CYCLE

## NUCLEUS

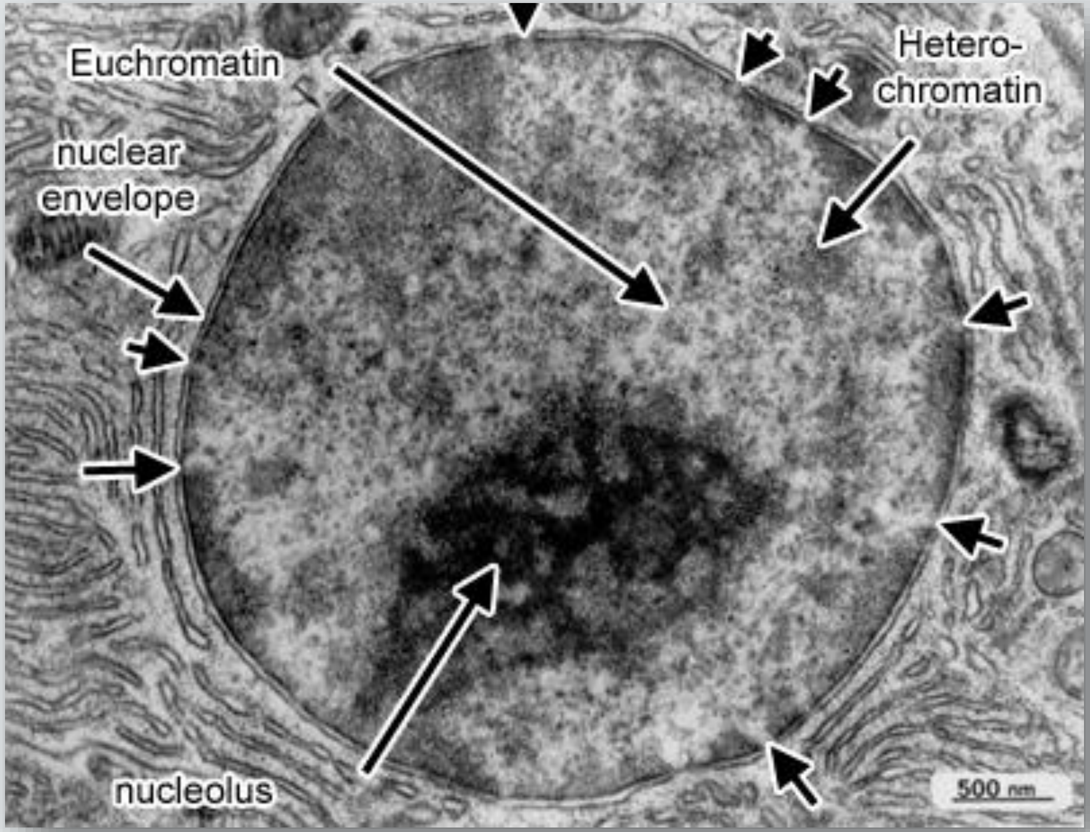
- Nuclear envelope –
  - Perinuclear envelope/ nucleolemma / karyotheca
  - Double membrane
  - Separates DNA from cytosol
  - Outer membrane continuous with RER
  - Space between two nuclear membranes – perinuclear space / cisterna
- Nucleolus – no membrane – involved in ribosome biogenesis and assembly



# THE CELL CYCLE

## CHROMOSOMES

- Thread-like self-replicating genetic structure in the nucleus
- One chromosome = One DNA molecule
- Two types –
  - autosomes
  - sex chromosomes (gynosomes)
- Chromosome number – remains constant for each species



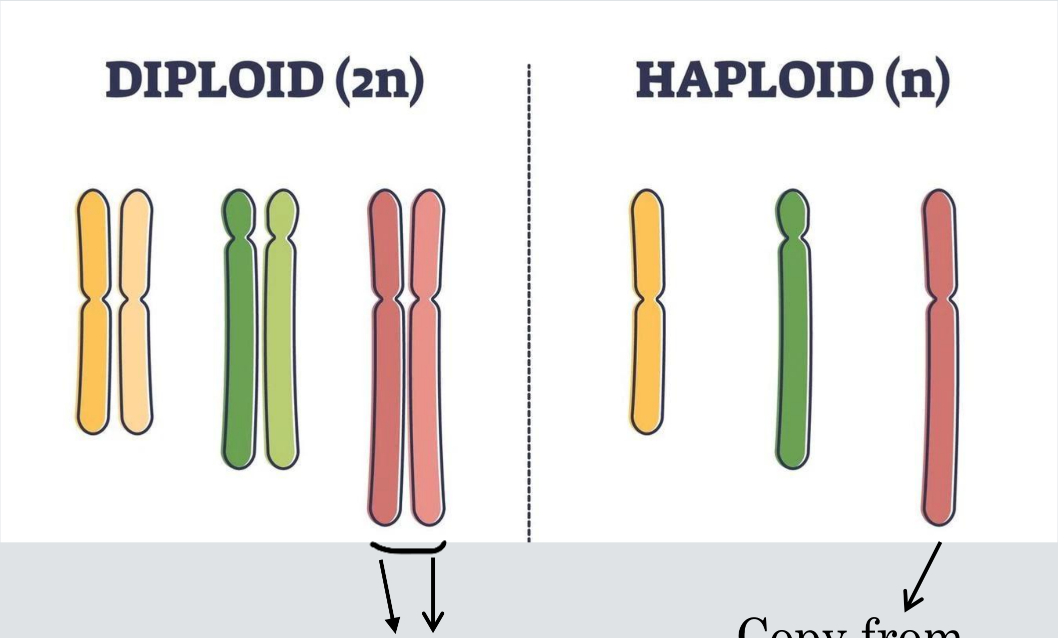
# THE CELL CYCLE

## CHROMOSOMES

### Chromosome numbers

*Haploid vs Diploid*

| | |
|---|---|
| Normal cell state | Diploid chromosome number (2n) |
| Gametes | Haploid chromosomes (n) |




Homologous chromosomes

Copy from one parent

# THE CELL CYCLE

## CHROMOSOMES

**Chromatid**

During replication –

One chromosome – duplicates into two

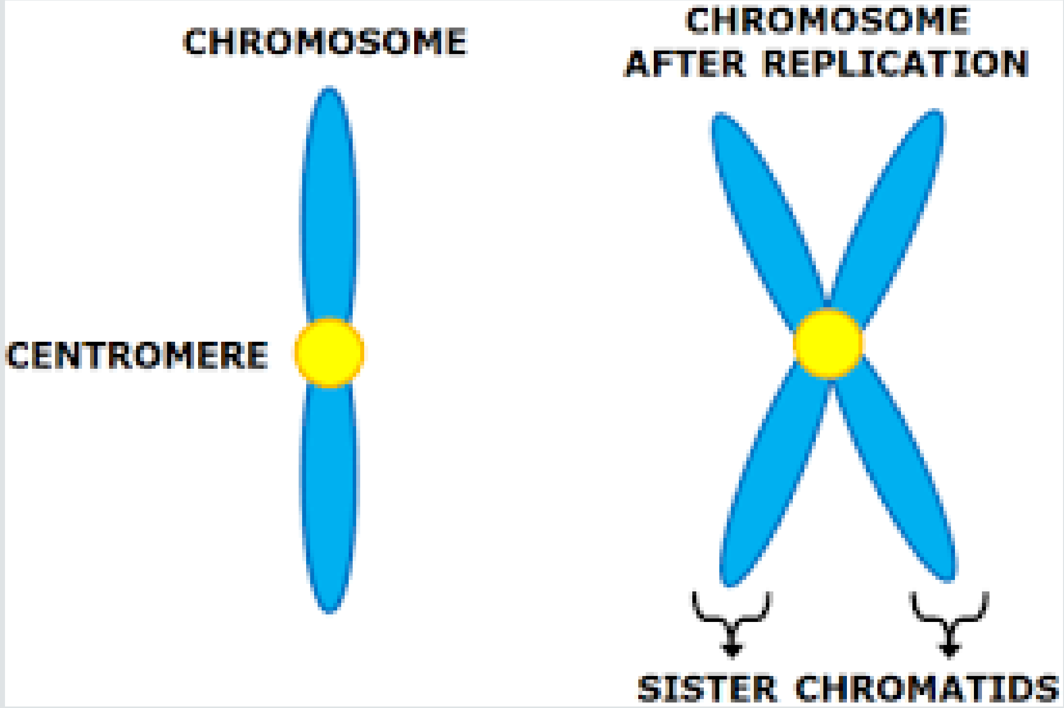
↓

These two are identical copies

↓

Remain connected at the centromere

- These are called sister chromatids (single copy – chromatid)

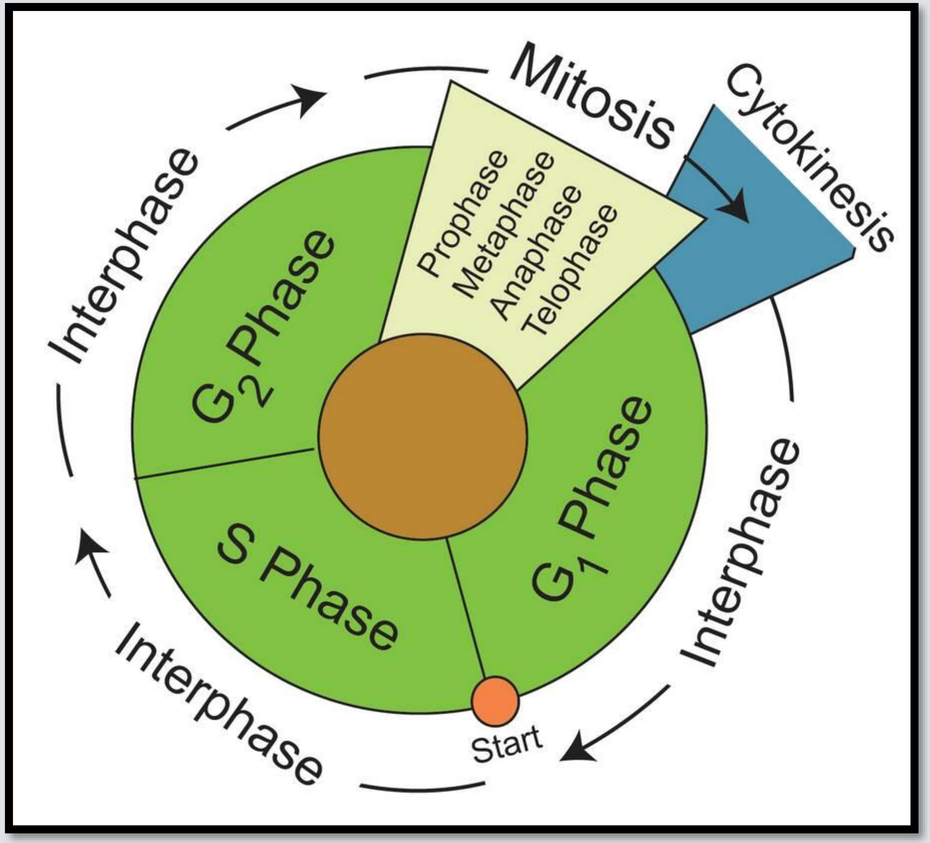


# THE CELL CYCLE

## PHASES OF THE CELL CYCLE

Phase I - Interphase

1. G1 Phase –
    1. Increase cell size
    2. Produce RNA & proteins needed for DNA synthesis
    3. Prepare to replicate DNA
    4. Longest phase

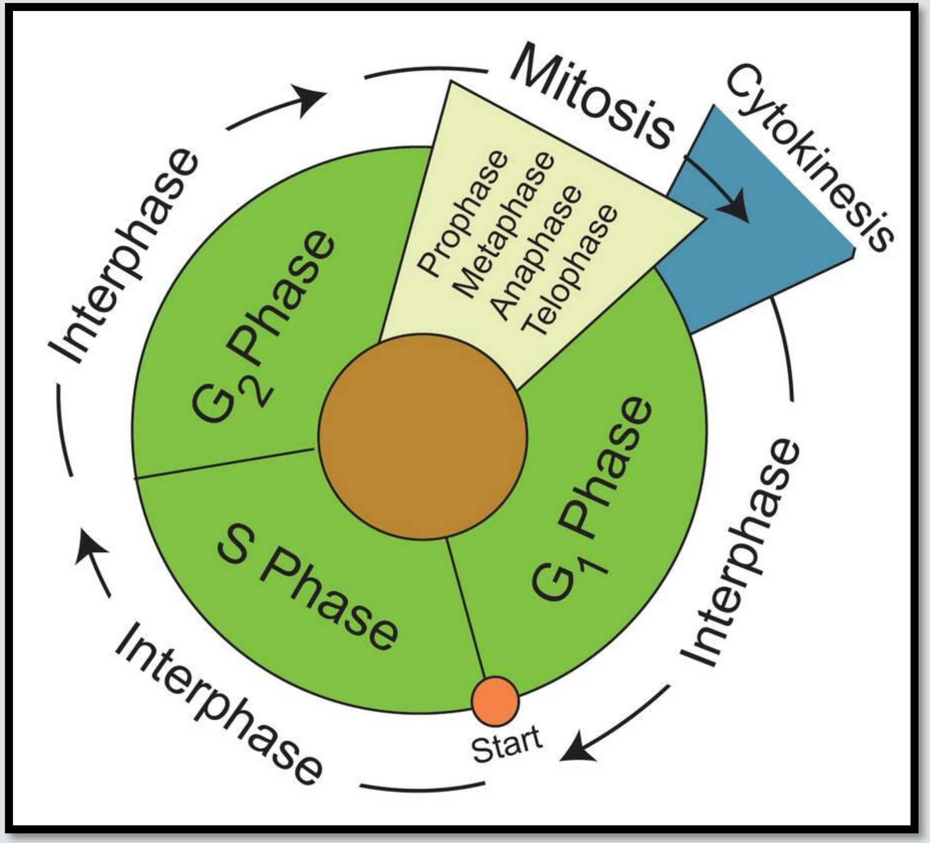


# THE CELL CYCLE

## PHASES OF THE CELL CYCLE

Phase I - Interphase

2. S Phase –
    1. Duplication of chromosomes
    2. One chromosome – two sister chromatids
    3. Sister chromatids remain connected at centromere
    4. Duplication of centrosome

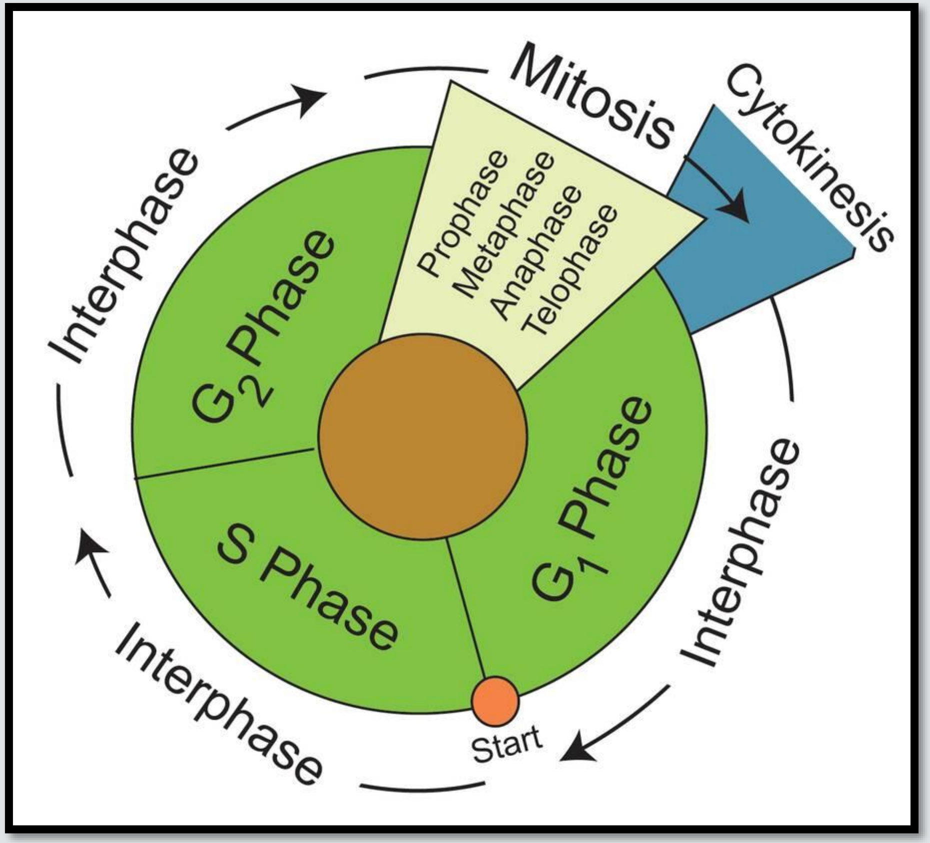


# THE CELL CYCLE

## PHASES OF THE CELL CYCLE

Phase I - Interphase

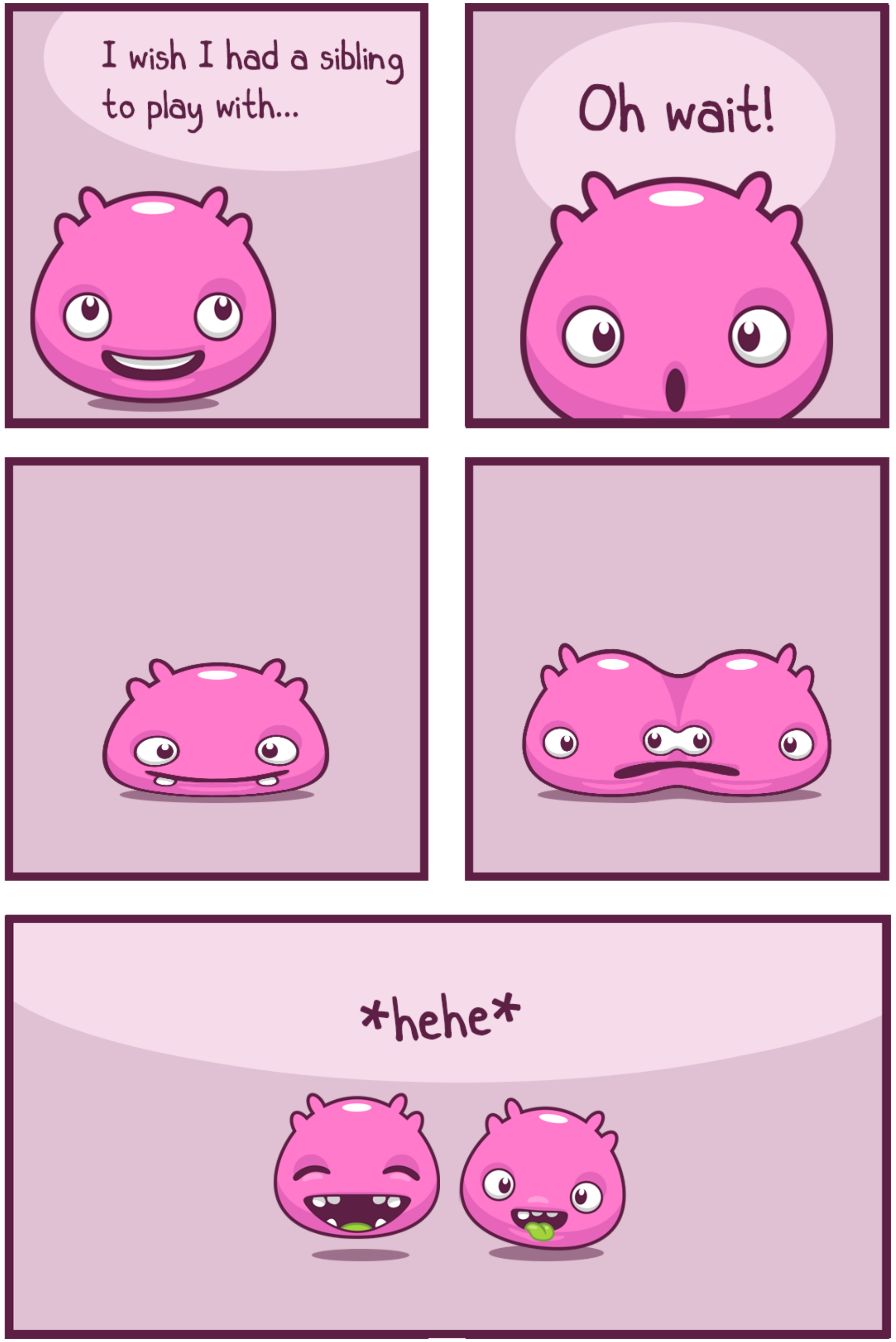
3. G2 Phase–
   1. Rapid cell growth
   2. Microtubule production
   3. Damaged, replicated DNA is repaired
   4. G2 check point – cell is ready for division



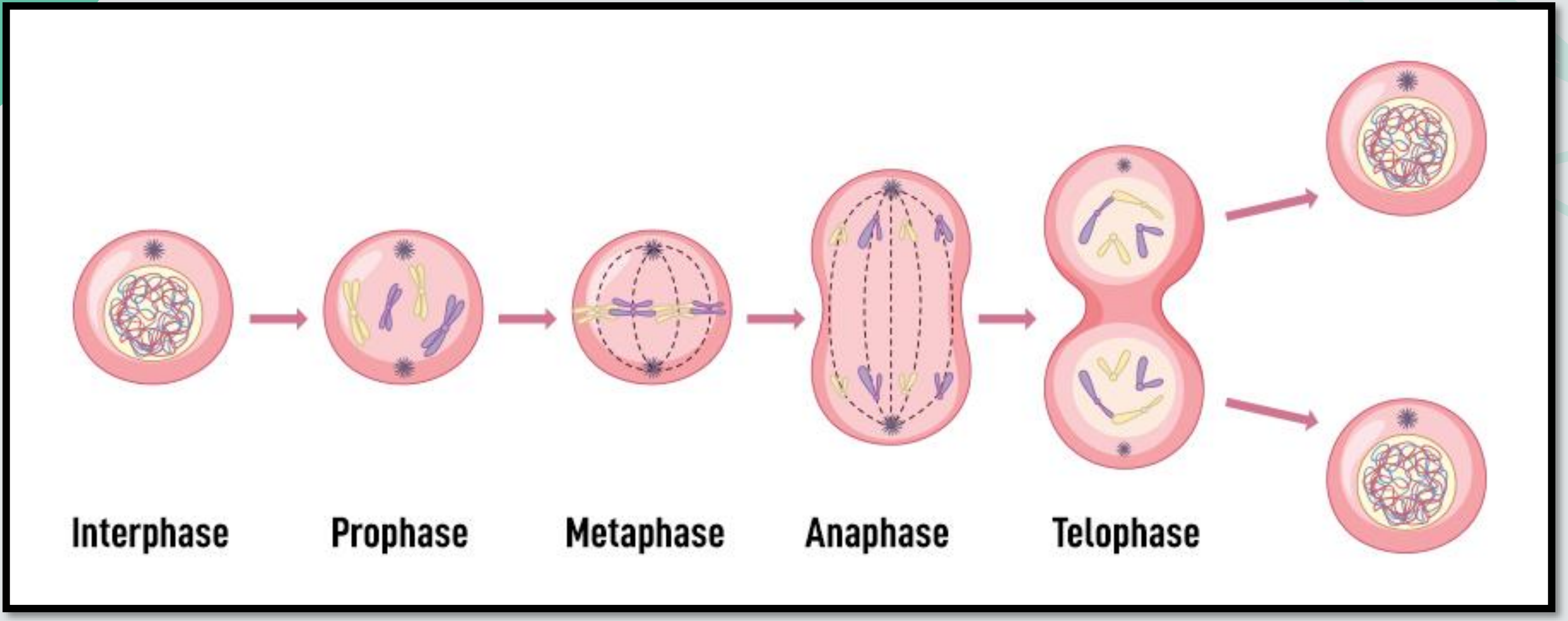
# Phase II: Mitosis

Equational Division

Happens in All Cells



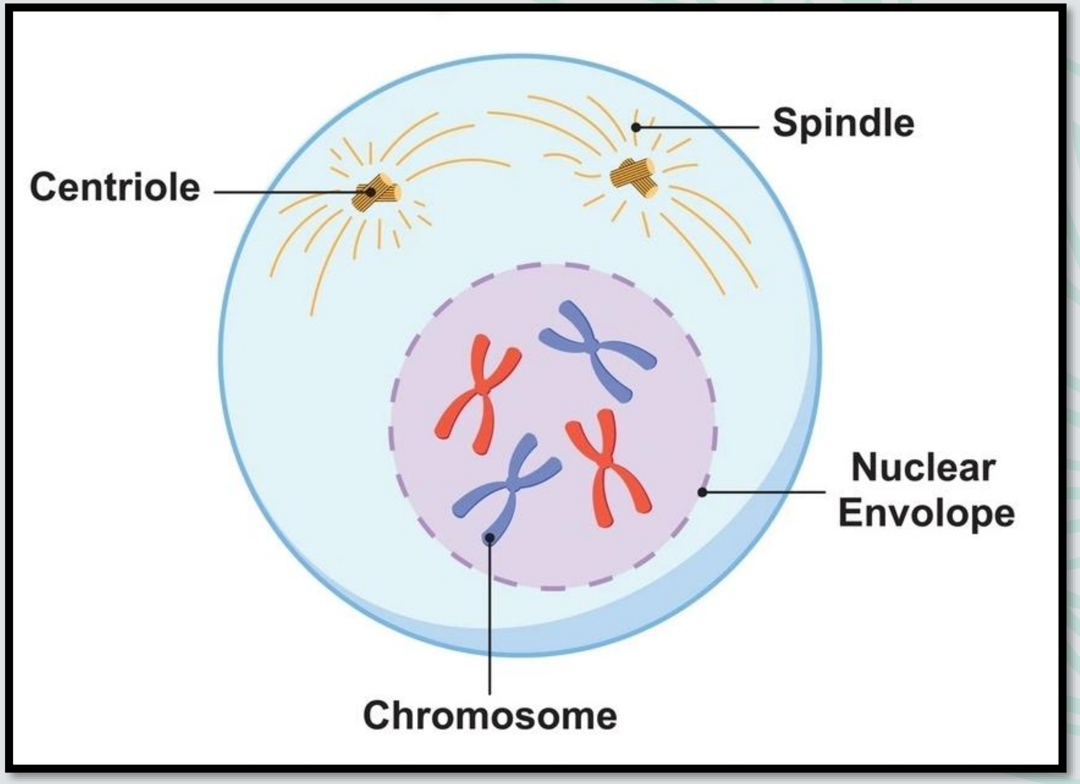
# Stages of Mitosis



# Stages of Mitosis:

# 1. Prophase

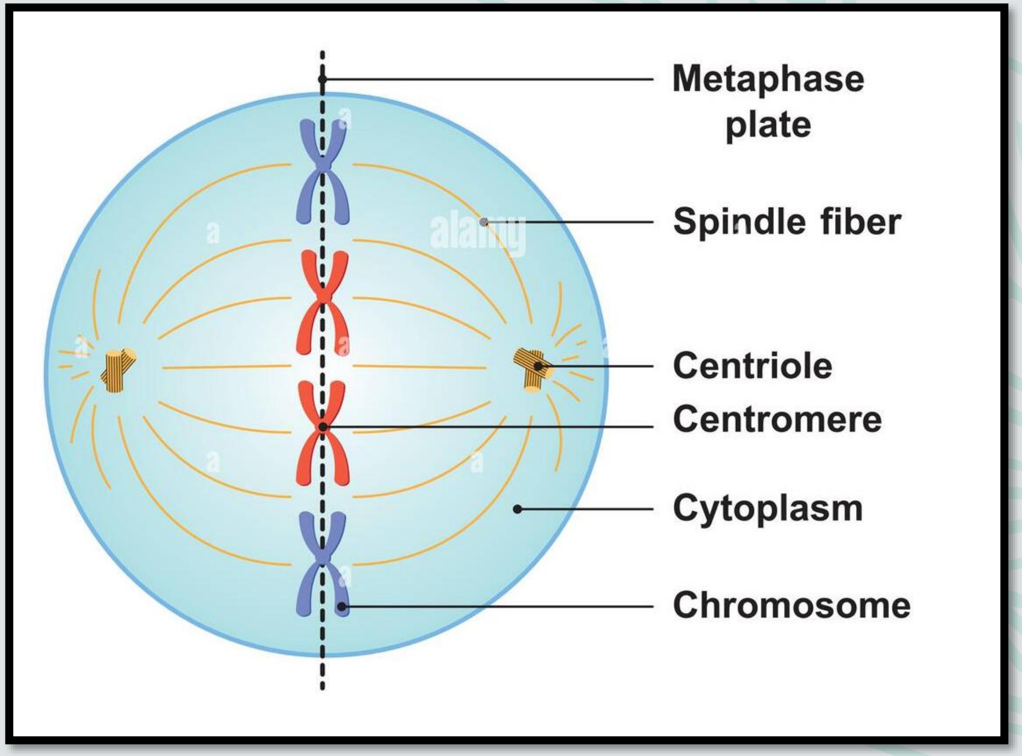
- Chromosome Condensation
- Nucleolus disappears
- Nuclear envelope breaks down
- Centrosomes start moving



# Stages of Mitosis:

# 2. Metaphase

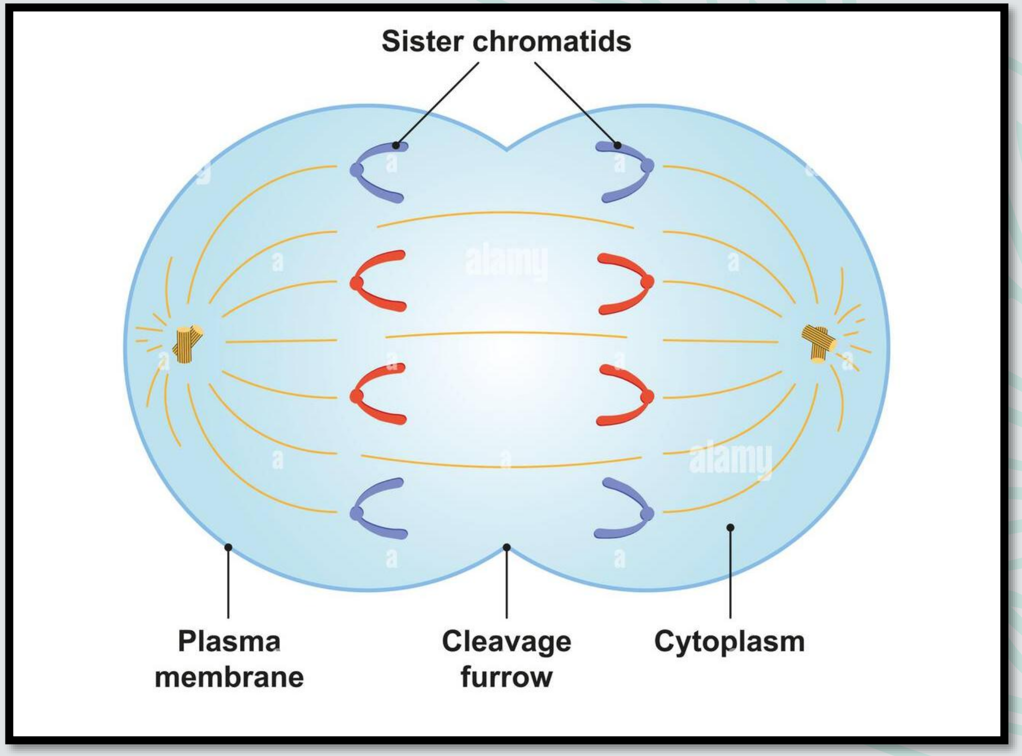
- Chromosomes alignment
- Spindle fibre attachment
- Metaphase check-point



# Stages of Mitosis:

# 3. Anaphase

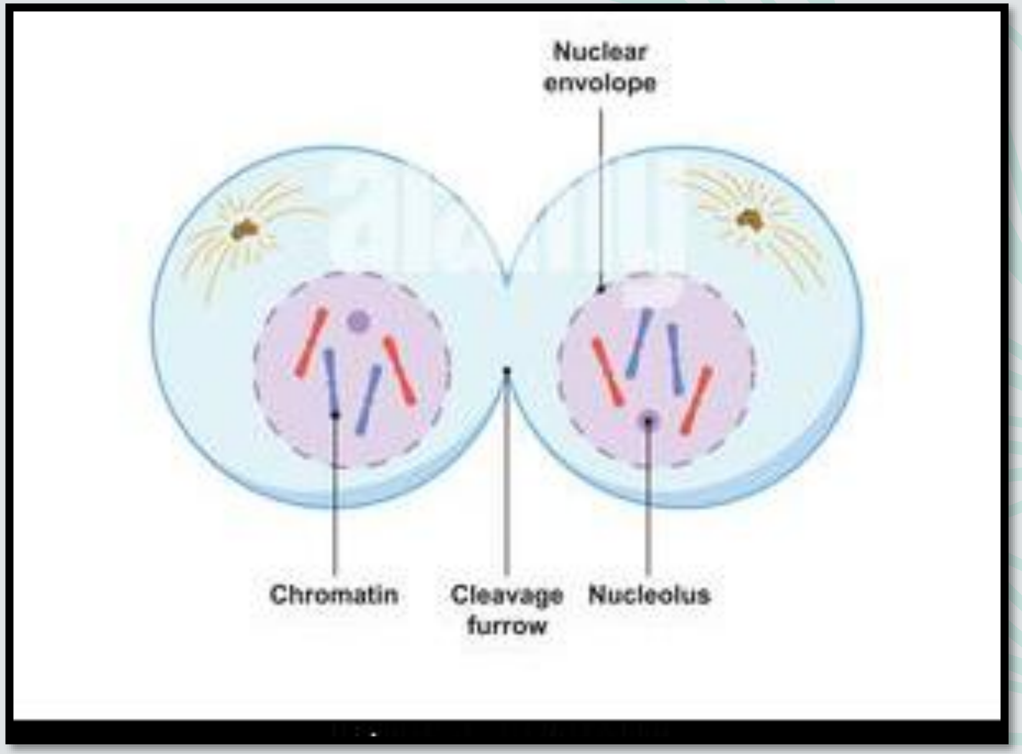
- Chromatid separation
- Chromosome movement
- Pole formation



# Stages of Mitosis:

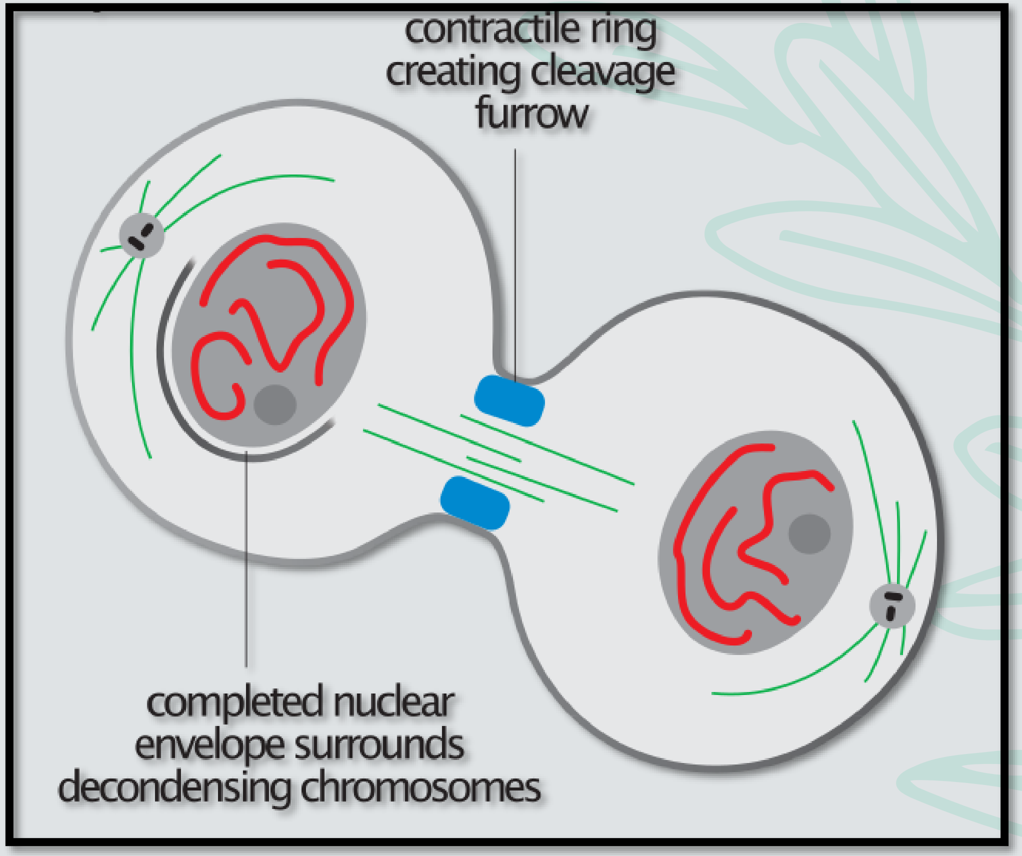
# 4. Telophase

- Chromosome decondensation
- Nuclear envelope reforms
- Nucleolus reappears
- Spindle dis-assembles



# Cytokinesis

- Final step in cell division
- One cell – Two daughter cells



# Key terms before starting Meiosis

1. Tetrad/Bivalent

   A pair of homologous chromosomes (containing four sister chromatids in total)

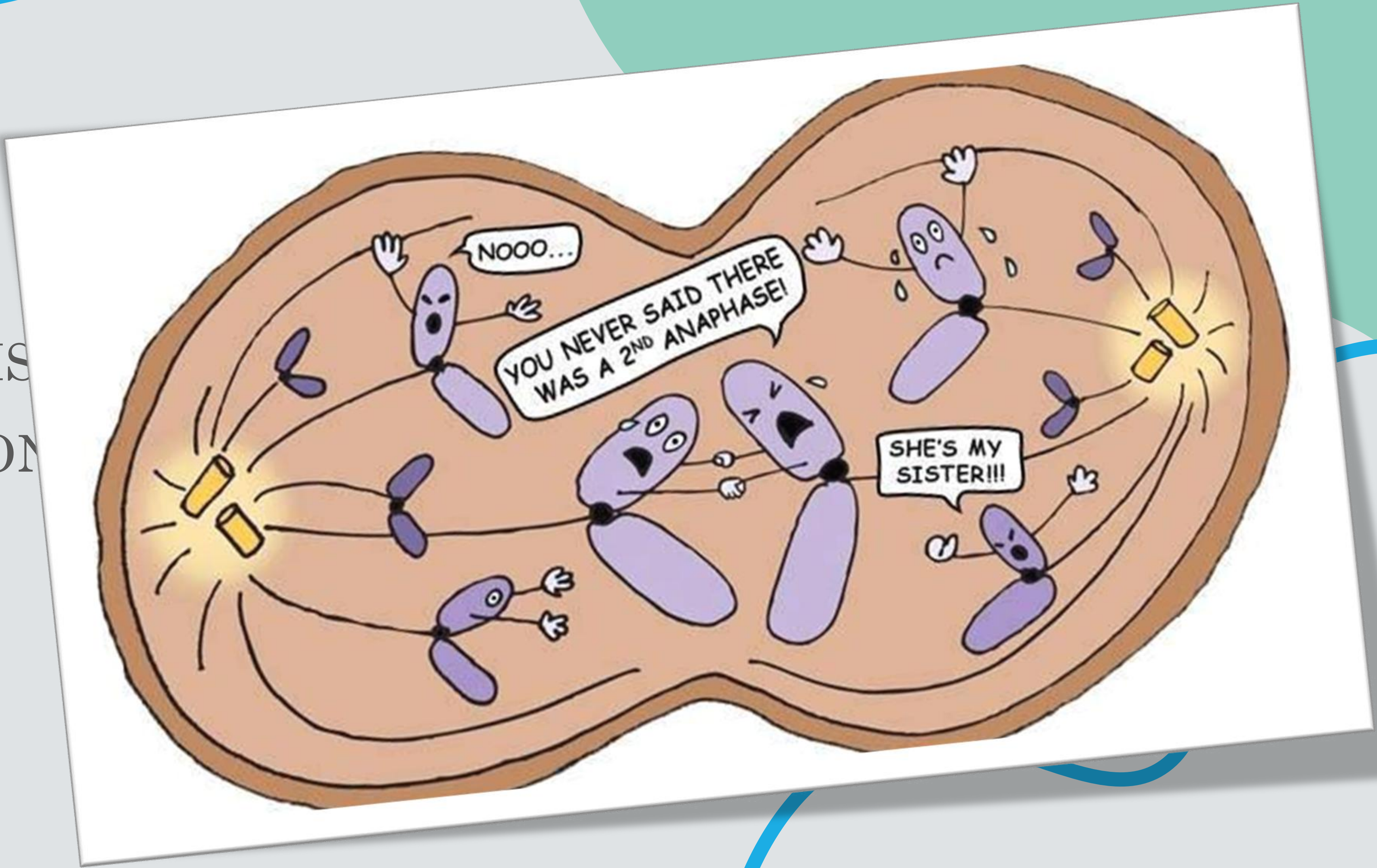
2. Crossing Over –

   Exchange of genetic material between homologous chromosomes

# MEIOSIS

REDUCTIONAL DIVIS

TAKES PLACE IN GON



# MEIOSIS

Has two stages –

Meiosis I

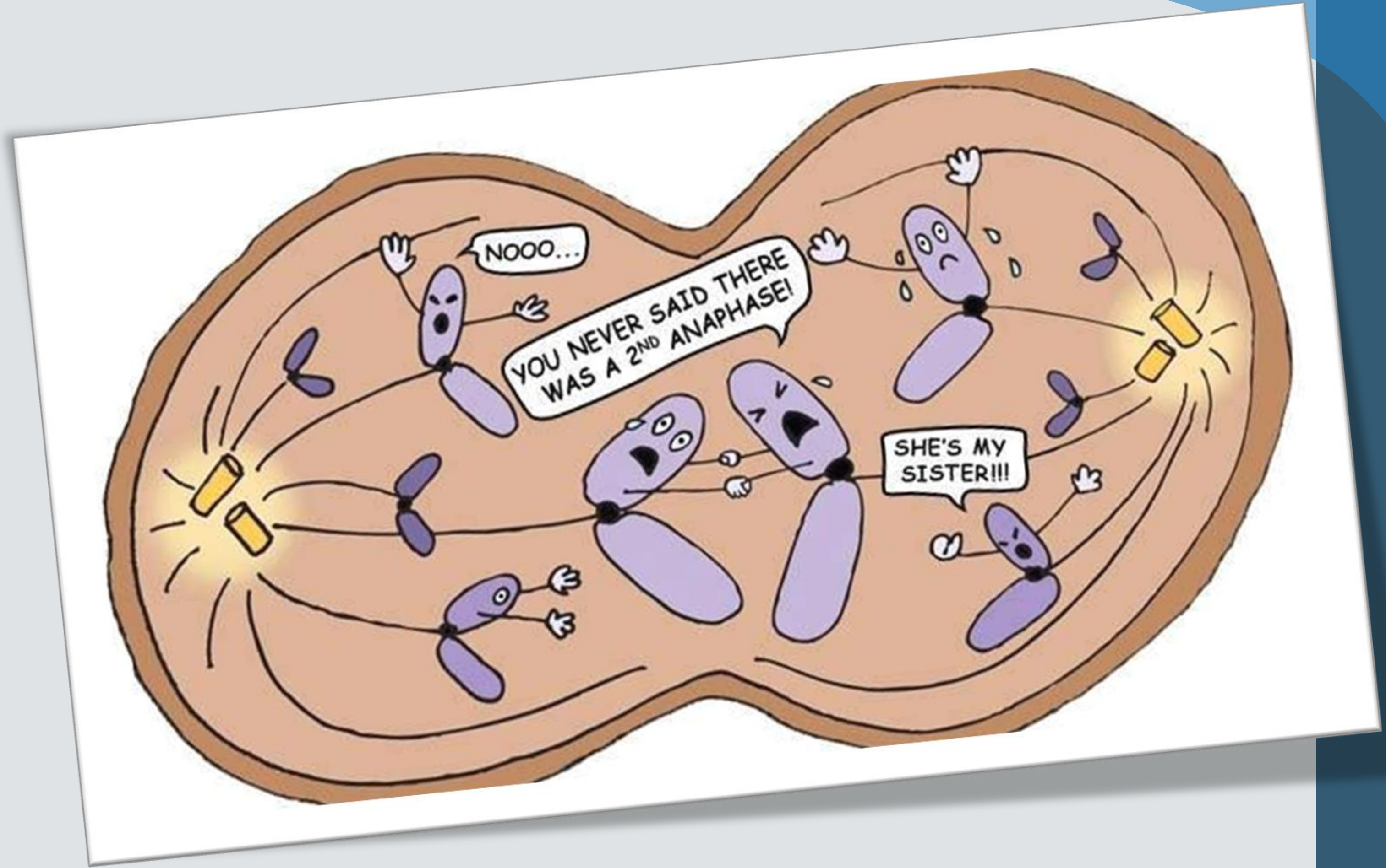
- Reductional division

Meiosis II

- Equational division like mitosis

Both divisions have all four phases –

Prophase, Metaphase, Anaphase and Telophase



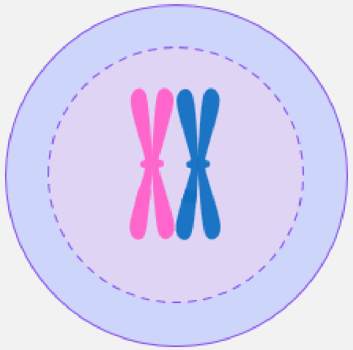
# Meiosis I

Four Phases:

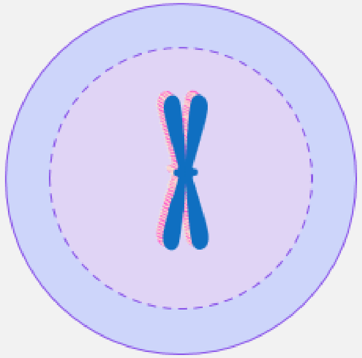
1. Prophase I
    1. Leptotene
    2. Zygotene
    3. Pachytene
    4. Diplotene
    5. Diakinesis
2. Metaphase I
3. Anaphase I
4. Telophase I

# Meiosis I

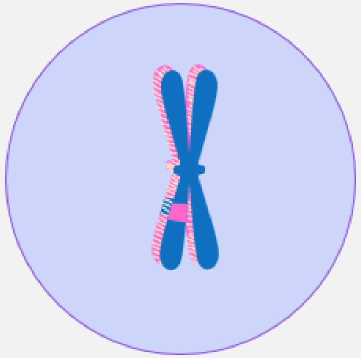
## Prophase I



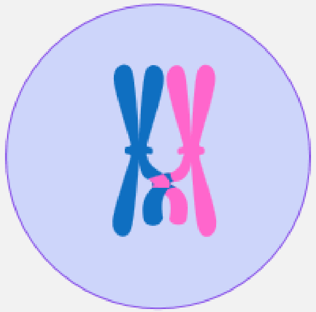
**Leptotene**
- Chromatin condense to form chromosomes



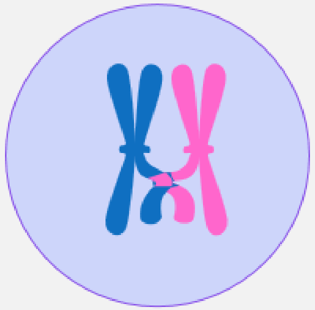
**Zygotene**
- *Homologous chromosomes come close*
- ***Synaptonemal*** *complex begins to form*



**Pachytene**
- **Crossing over** occurs

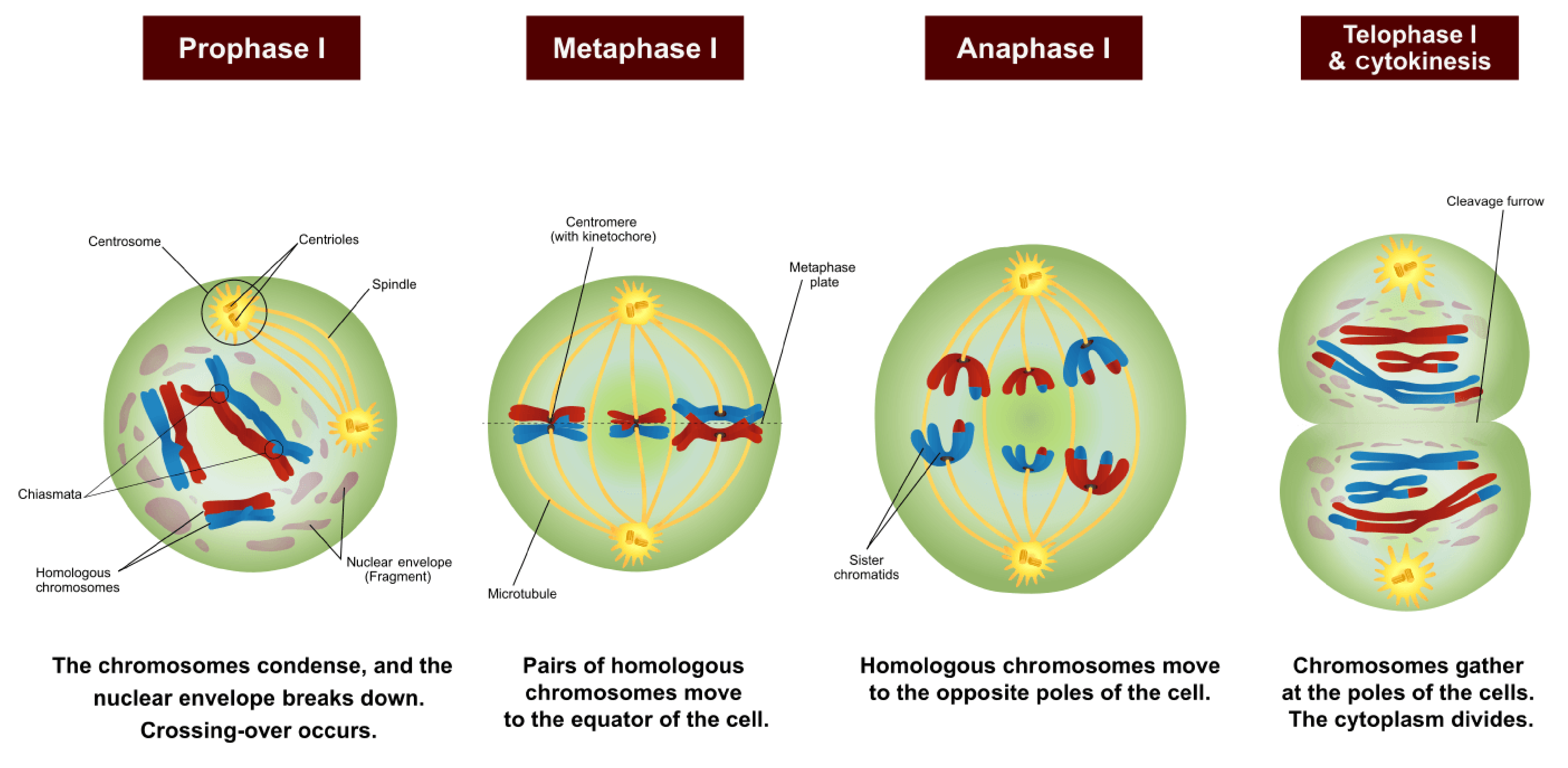


**Diplotene**
- **Synaptonemal complex** disintegrates
- Chiasma appears



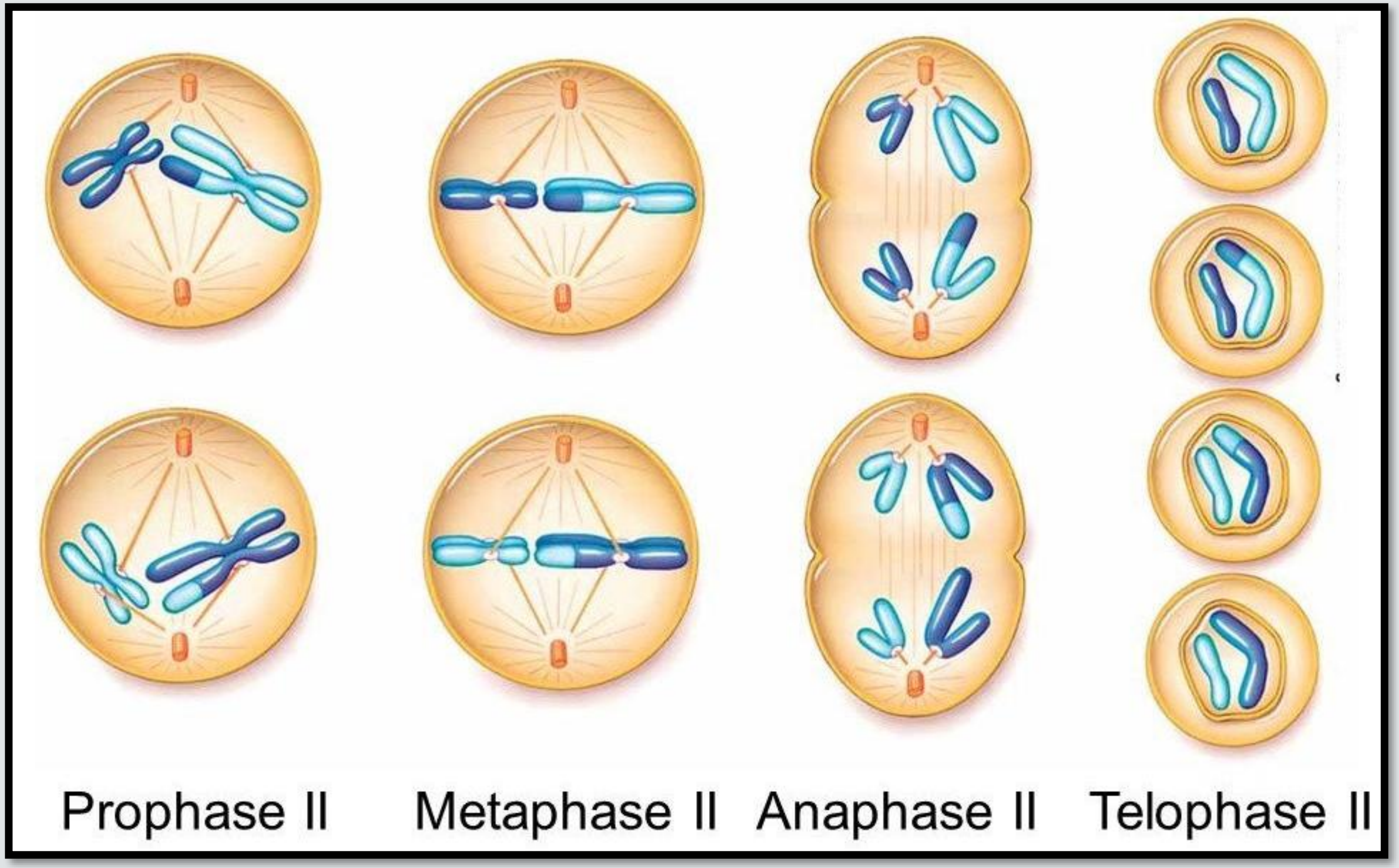
**Diakinesis**
- Homologous chromosomes **move farther**
- Chiasma becomes more prominent
- Nuclear membrane disappears

# Meiosis I



Prophase I
Metaphase I
Anaphase I
Telophase I & cytokinesis
Centrosome
Centrioles
Spindle
Chiasmata
Homologous chromosomes
Nuclear envelope (Fragment)
Centromere (with kinetochore)
Metaphase plate
Microtubule
Sister chromatids
Cleavage furrow
The chromosomes condense, and the nuclear envelope breaks down. Crossing-over occurs.
Pairs of homologous chromosomes move to the equator of the cell.
Homologous chromosomes move to the opposite poles of the cell.
Chromosomes gather at the poles of the cells. The cytoplasm divides.

# Meiosis II



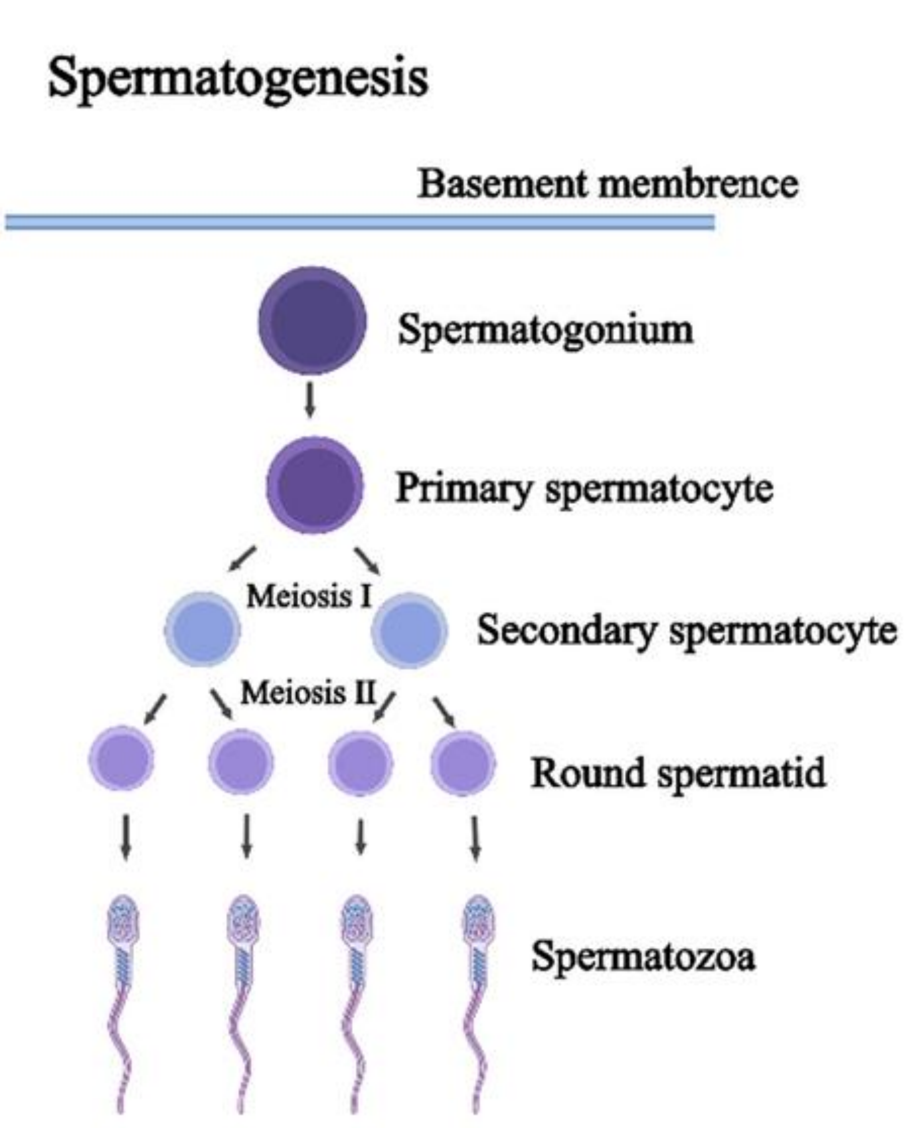
# GAMETOGENESIS

- SPERMATOGENESIS
- OOGENESIS

# Spermatogenesis

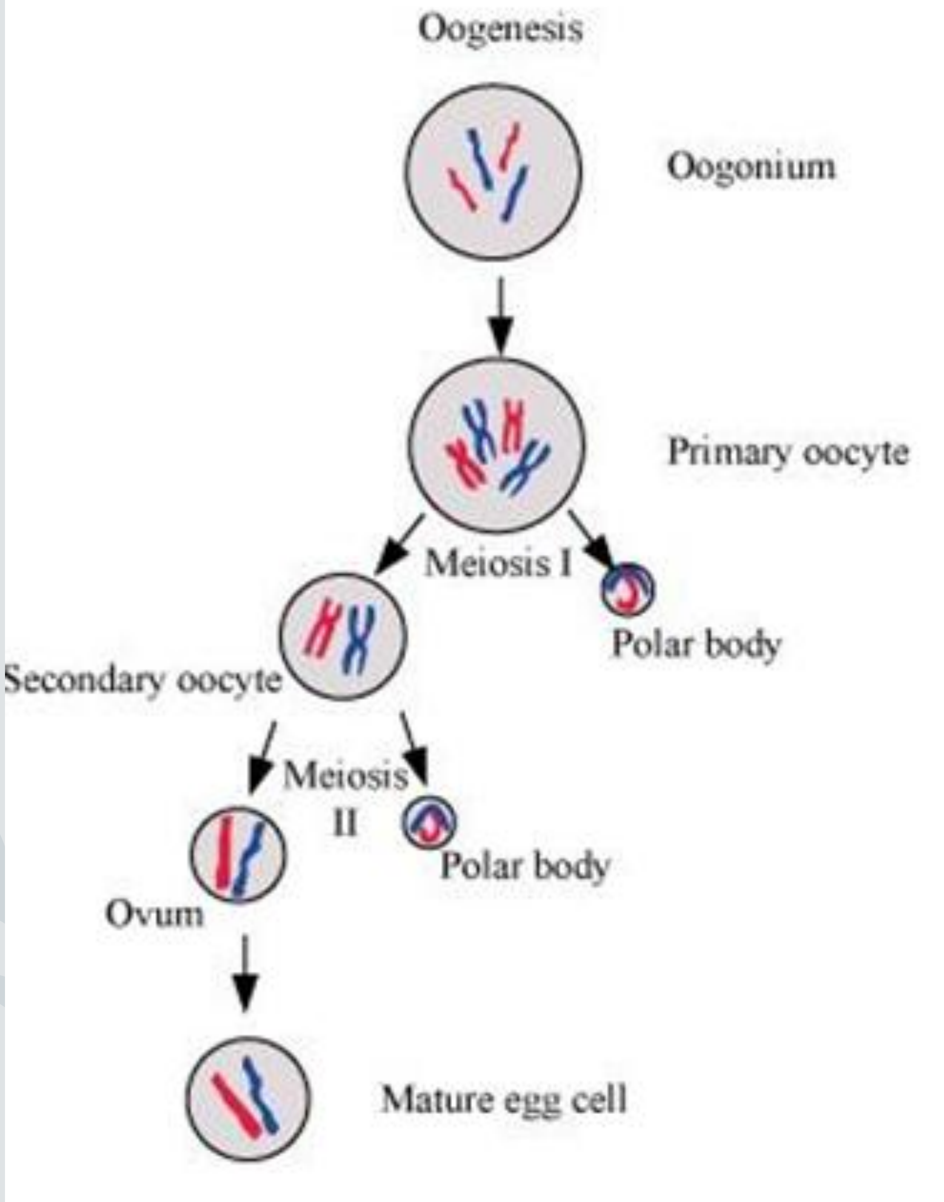
- Spermatogenesis begins at puberty
- Haploid sperms produced from spermatogonia
- Spermiogenesis –

Spermatid heads embedded in Sertoli cells – become matured to spermatozoa



# Oogenesis

- Oogonia – formed in the developing foetus
- Primary oocytes –
  - ✓ Oogonia enter meiosis I before birth
  - ✓ Become arrested at prophase I
- Restart of oogenesis at puberty
  - ✓ Meiosis I is completed
  - ✓ Meiosis II begins
  - ✓ Secondary oocyte – arrested at Meiosis II
- Meiosis II is completed after fertilisation



Process of oogenesis

# MCQs – The Cell Cycle

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

a) Molecular genetics

b) Cytogenetics

c) Biochemical genetics

d) Developmental genetics

# MCQs – The Cell Cycle

1. What is the number of chromosomes in riverine buffaloes? UK VO 2024

a) 54

b) 52

c) 50

d) 48

# MCQs – The Cell Cycle

- 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) 1 and 2 only
- (B) 2 and 3 only
- (C) 2 and 4
- (D) 2,3 and4 only

# MCQs – The Cell Cycle

- 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-1; b-3; c-1; d-4
- (B) a-2; b-4; c-3; d-1
- (C) a-1; b-4; c-2; d-3
- (D) a- 1; b-3; c-2; d-4

# MCQs – The Cell Cycle

- During which phase of mitotic cell division, the nuclear membrane and nucleolus disappear?
- [A] Prophase
- [B] Metaphase
- [C] Anaphase
- [D] Telophase

MPPSC 2013

# MCQs – The Cell Cycle

- . Crossing over takes place between:
- (A) Sister cromatid
- (B) Non-sister cromatid
- (C) Chromosome
- (D) Chromonema

MPPSC 2022

# MCQs – The Cell Cycle

- During karyokinesis the chromosome exhibit minimum coiling at which phase?
- (A) Prophase
- (B) Metaphase
- (C) Anaphase
- (D) Interphase

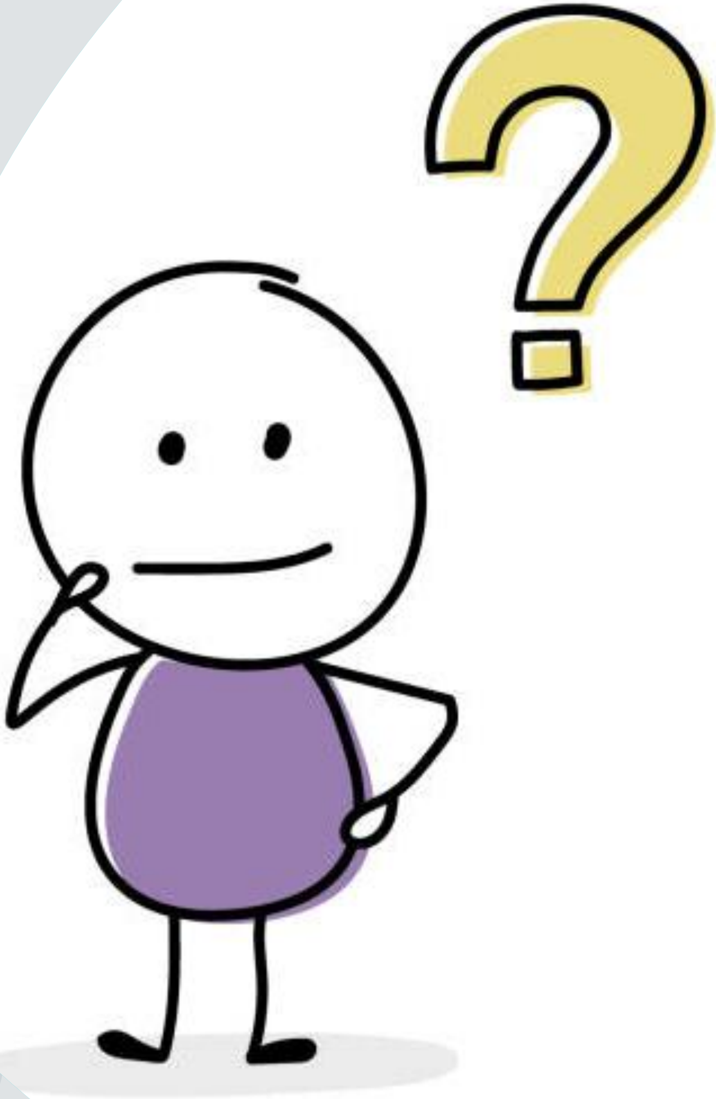
MPPSC 2022

# MCQs – The Cell Cycle

- The stage of cell division in which the chromosomes are most discrete and arranged in an equatorial plate?
- (A) Prophase
- (B) Anaphase
- (C) Metaphase
- (D) Telophase

OPSC

# ANY QUESTIONS?



# Lecture 2
# Topic - 1

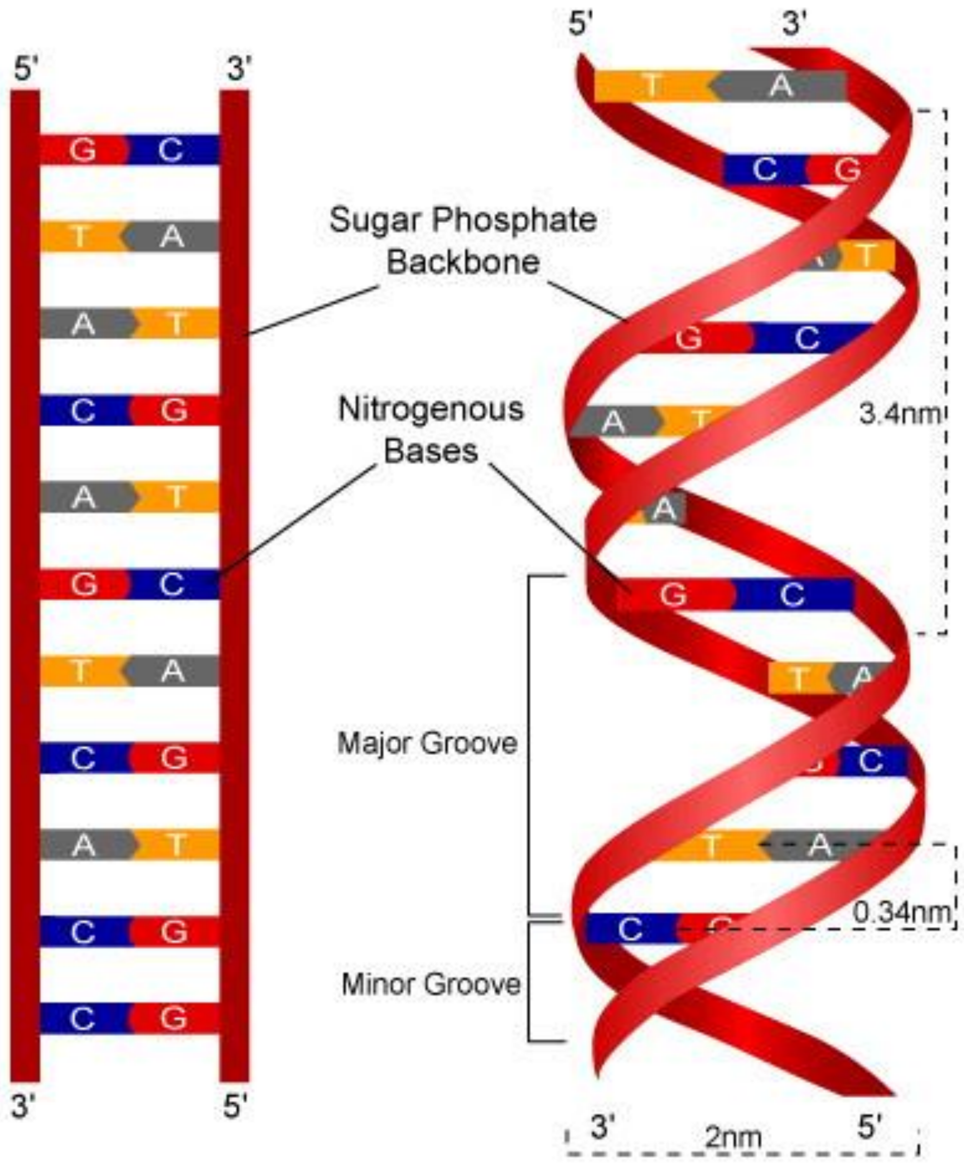
# Mendelian Genetics

- Some Basic Concepts
- Who was Mendel?
- Monohybrid Cross
- Dihybrid Cross
- Mendel's Laws of Inheritance
- MCQs

# Some Basic Concepts

# Structure of DNA

- Distance between 2 bp = 0.34 nm
- 1 turn = 10 bp
- Pitch of DNA = 0.34 × 10 = 3.4 nm



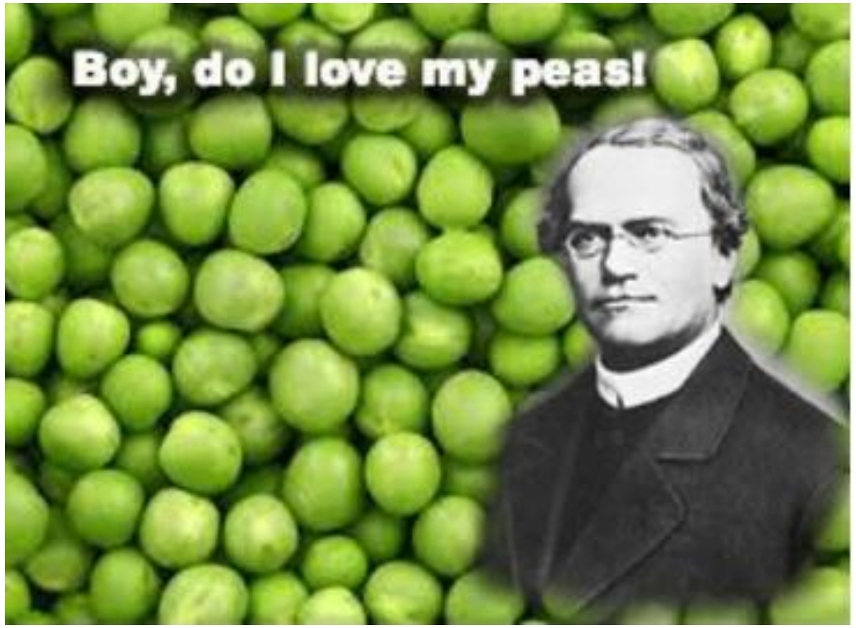
# Some Basic Concepts

| S. No. | Term | Definition/Explanation |
|---|---|---|
| 1. | DNA | chain of nucleotides (comprising of a specific nucleotide sequence – i.e. the genetic information) |
| 2. | Gene | The functional unit of heredity, gene is the segment of DNA which codes for a polypeptide. |
| 3. | Genome | The entire set of genes in an organism is called its genome |
| 4. | Chromosome | Composed of DNA in a supercoiled state<br>(1 chromosome = 1 DNA molecule) |
| 5. | Allele | The alternative forms of a gene (coding for the alternative forms of a trait) are called alleles |
| 6. | Locus | The physical position of a gene on a chromosome is called its locus |
| 7. | Homozygous | When an individual has the same allele for a gene in both its homologous chromosomes, it is said to be homozygous for that trait. |

# Some Basic Concepts

| S. No. | Term | Definition/Explanation |
|---|---|---|
| 8. | Heterozygous | When an individual has different alleles for a gene in both its homologous chromosomes, it is said to be heterozygous for that trait. |
| 9. | Dominant allele | When one allele, in a heterozygous condition, does not allow the expression of the other allele, it is said to be dominant. |
| 10. | Recessive allele | The allele unable to express itself is the recessive allele |
| 11. | Genotype | the genetic constitution of an individual with respect to a particular set of gene(s) (or the whole genome) is said to be its genotype |
| 12. | Phenotype | The observable characteristics of individuals which are produced as a result of its genotype is called its phenotype. |

# Who was Mendel?




- Austrian Monk
- Father of Genetics
- Experimented with Peas
- Mendel first presented his findings at the Brunn Society for Natural Science - 1865
- Published findings in a paper – "Experiments on Plant Hybridisation" – 1866
- His work was lost – later rediscovered by Hugo de Vries, Carl Correns, and Erich von Tschermak. (1900)
- Laid groundwork for the field of genetics

# Why so famous Mendel?

Reasons for his success:

- Focused on one or two traits at a time.
- Used true-breeding plant varieties.
- Maintained meticulous records of his experiments.
- Selected traits that did not show linkage or incomplete dominance.
- Benefited from the fact that the genes for the traits he studied were mostly on separate homologous chromosomes.

# Traits Studied

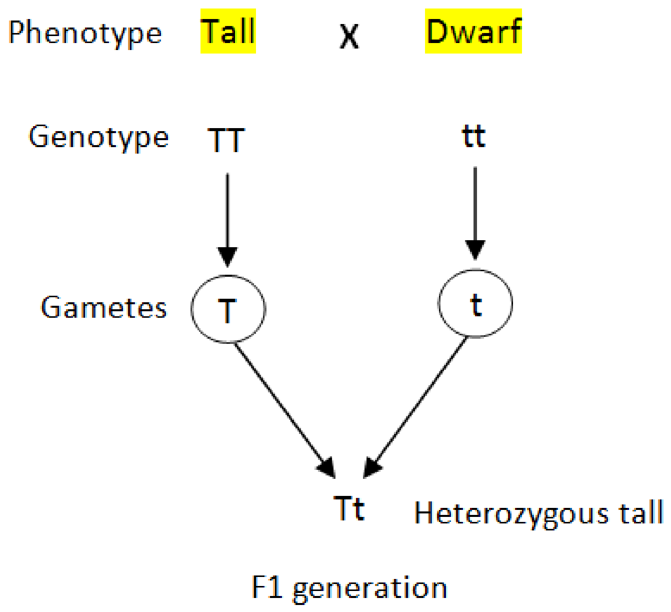
**Pea Plant Traits**

| Seed Shape | Seed Color | Pod Shape | Pod Color | Flower Color | Flower Location | Plant Size |
|---|---|---|---|---|---|---|
| Round | Yellow | Inflated | Green | Purple | Axial | Tall |
| Wrinkled | Green | Constricted | Yellow | White | Terminal | Short (Dwarf) |

# Monohybrid Cross

# Monohybrid cross

- Involves one trait at a time

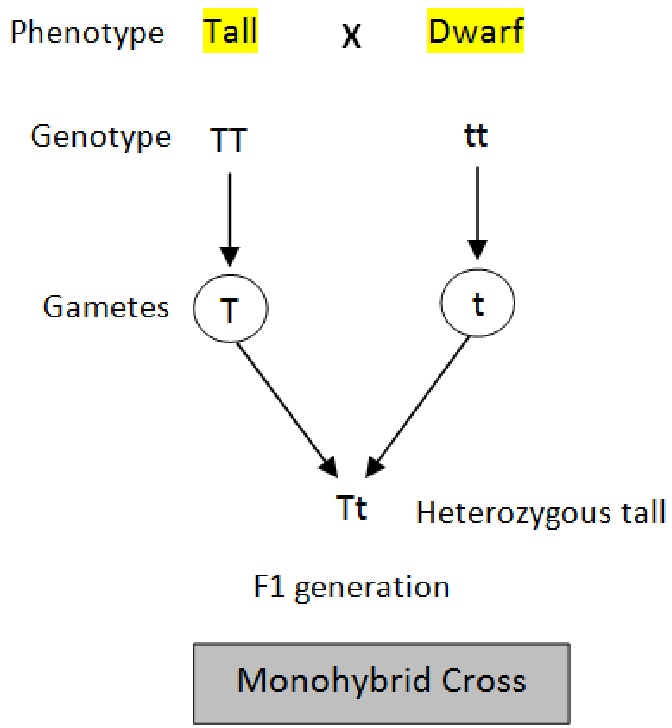



Monohybrid Cross

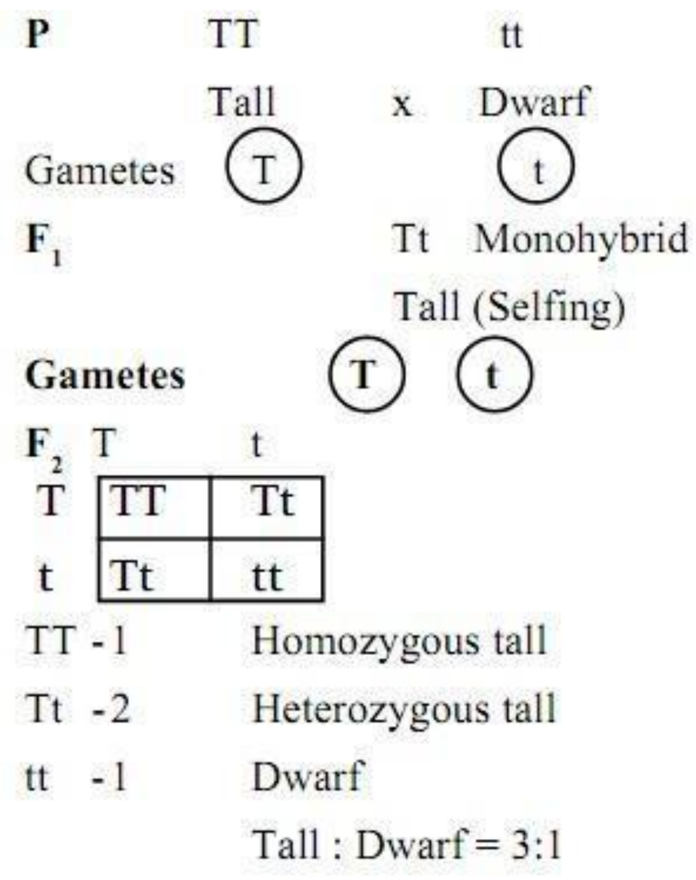
# Monohybrid cross

- Involves one trait at a time

F$_2$: Tt × Tt



# Monohybrid cross




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

# Monohybrid cross

- Homework:

Draw up monohybrid crosses for all Mendel's traits

# Dihybrid cross

- Two traits considered at a time
- E.g. seed is:

Round Yellow (RRYY) × Wrinkled green (rryy)

# Dihybrid cross

$F_1$ Gen :

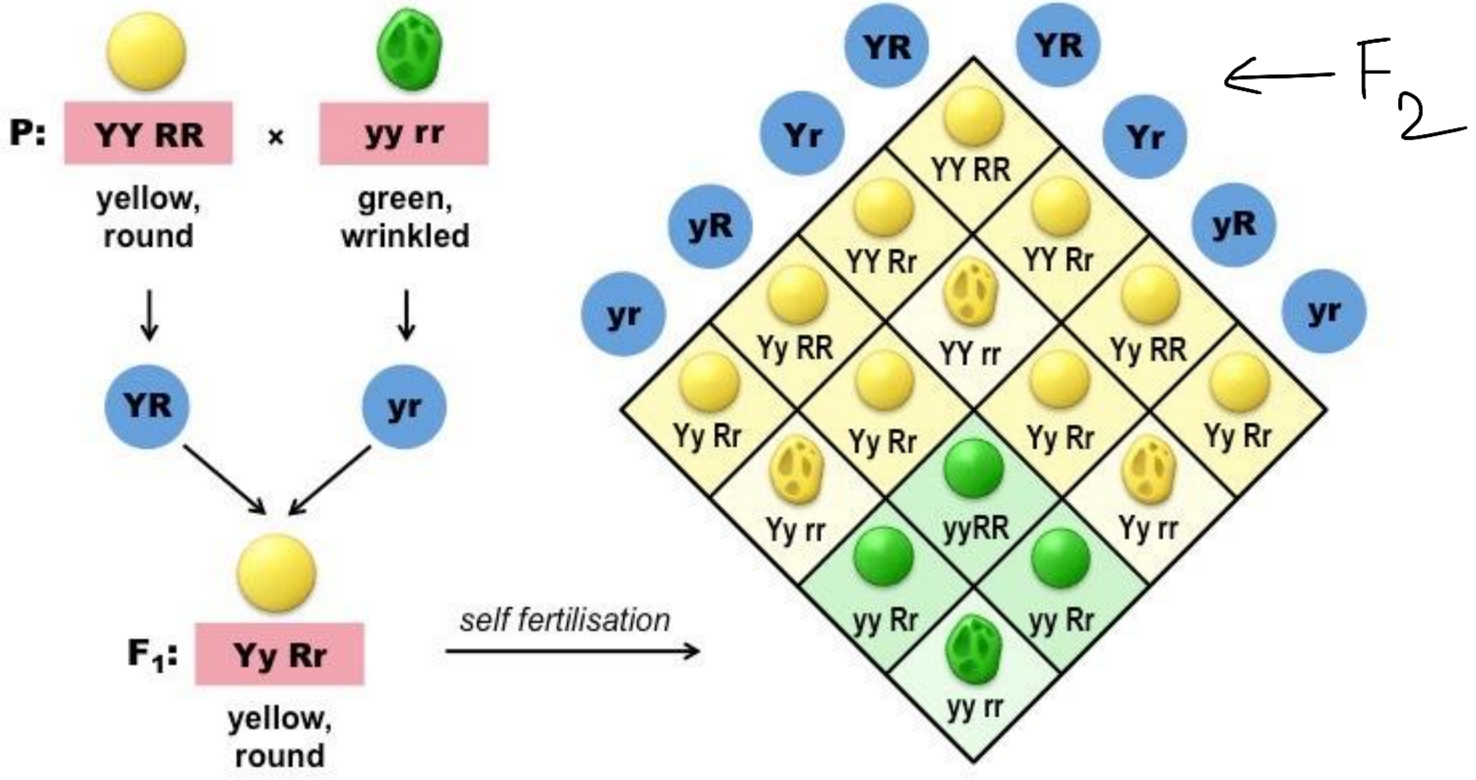
**Cross of Parent Generation**

round, yellow

wrinkled, green

| | RY | RY |
|---|---|---|
| ry | RrYy | RrYy |
| ry | RrYy | RrYy |

# Dihybrid cross




**Ratios**

Genotypic:

1:2:1:2:4:2:1:2:1

Phenotypic:

9:3:3:1

# Mendel's laws of Inheritance

**Law of Dominance:**

- In a pair of alleles, one allele can mask the expression of the other. The dominant allele is expressed in the phenotype, while the recessive allele is not, unless in a homozygous state.

**Law of Segregation:**

- During gamete formation, the two alleles for a gene segregate, so each gamete carries only one allele. This law was demonstrated through monohybrid crosses, showing a 3:1 phenotypic ratio in the F2 generation.

**Law of Independent Assortment:**

- Alleles for different traits segregate independently of each other during gamete formation, leading to genetic variation. This law was derived from dihybrid crosses, resulting in a 9:3:3:1 phenotypic ratio.

# MCQs on Mendelian Inheritance

- Mendel's law of segregation states that:
  a) Alleles segregate during gamete formation
  b) Genes are located on chromosomes
  c) Traits are inherited independently
  d) Dominant alleles mask recessive alleles

- A test cross involves crossing an individual with:
  a) Homozygous dominant genotype
  b) Heterozygous genotype
  c) Homozygous recessive genotype
  d) Another individual with unknown genotype

# MCQs on Mendelian Inheritance

- The genotypic ratio of a monohybrid cross is:
  a) 1:2:1
  b) 9:3:3:1
  c) 3:1
  d) 1:1:1:1

- Independent assortment of genes occurs during:
  a) Mitosis
  b) Meiosis
  c) Fertilization
  d) Mutation

# MCQs on Mendelian Inheritance

- Alleles are:
  a) Different forms of a gene
  b) Genes located on different chromosomes
  c) Mutations in genes
  d) Proteins coded by genes

- Mendel's law of independent assortment holds true for genes located on:
  a) The same chromosome
  b) Different chromosomes
  c) Sex chromosomes
  d) Mitochondrial DNA

# MCQs on Mendelian Inheritance

- A backcross involves crossing the F1 generation with:
  a) One of the parents
  b) F2 generation
  c) An unrelated individual
  d) Itself (self-pollination)

- Mendel's law of dominance states that:
  a) Recessive alleles are always expressed
  b) Dominant alleles mask the effect of recessive alleles
  c) Alleles blend in the offspring
  d) Genes assort independently

# MCQs on Mendelian Inheritance

- Mendel's principles of inheritance were rediscovered in the early 20th century by:
  a) Watson and Crick
  b) Darwin and Wallace
  c) deVries, Correns, and Tschermak
  d) Lamarck and Lysenko

- In guinea pigs, black coat color (B) is dominant over white (b), and short hair (S) is dominant over long hair (s). If two guinea pigs with genotypes BbSs are crossed, what proportion of their offspring will have a white coat and long hair?
  a) 1/16
  b) 1/8
  c) 3/16
  d) 1/4

# *Lecture 3 – Topic 2*

# *Modified Mendelian Inheritance*

*Modified mendelian ratios*

*Sex-linked, sex-limited, sex-influenced traits*

*Sex-determination*

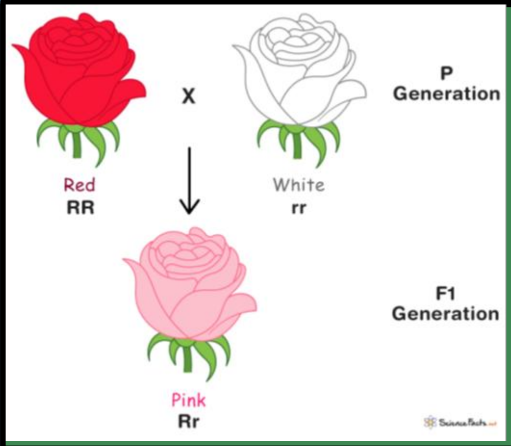
# Modified Mendelian Inheritance

- a.k.a. Modified Mendelian Ratios/Deviation from Mendelian Inheritance
- Deviates from Mendel's laws
- Can be divided based on Monohybrid and Dihybrid crosses

# Modified Mendelian Inheritance

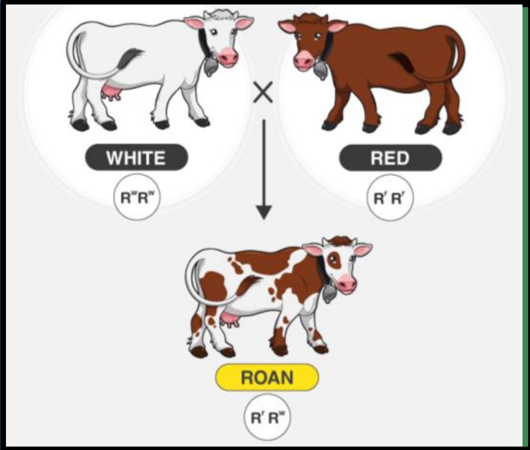
| Pattern | Phenotypic F2 ratio |
|---|---|
| Incomplete dominance | 3:1 |
| Co-dominance/Mosaic Inheritance | 1:2:1 |
| Multiple allelism | 1:2:1 |
| Complementary genes | 9:7 |
| Dominant Epistasis | 12:3:1 |
| Recessive Epistasis | 9:3:4 |
| Duplicate dominant | 15:1 |
| Duplicate recessive | 9:7 |

# Based on Monohybrid Cross



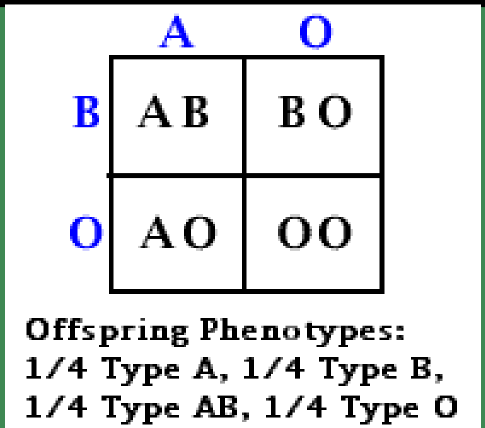

Incomplete Dominance

*Antirrhinum majus*



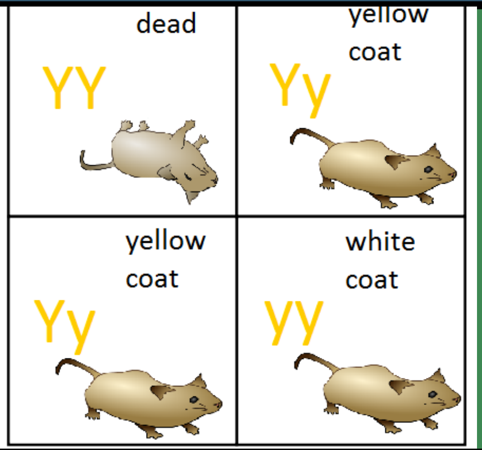

Co-dominance

Shorthorn Cattle coat colour
ABO Blood group




Multiple allelism

ABO Blood group

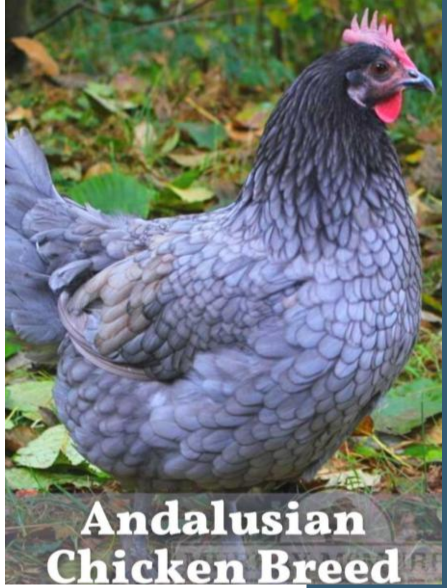



Lethal Genes

Yellow coat colour in mice

# 1. Incomplete Dominance

- Alleles do not show complete dominance
- Examples:
  - 4 o'clock plant (*Mirabilis jalapa*) – flower colour – red and white flowered plants produce progeny with pink coloured flowers
  - Feather colour of Andalusian chickens
- Phenotypic ratio in F2 generation – 1:2:1




# 2. Codominance

- There is no dominant allele
- Both alleles are expressed equally
- Examples:
  - AB Blood group in humans
  - Shorthorn cattle – coat colour

# 3. Multiple Allelism

- More than two alleles exist for a trait
- Can occur due to mutations
- Examples:
  - ABO blood groups in humans
  - Coat colour in rabbits
- Phenotypic Ratio (F2) – 1:2:1

# Lethal Genes

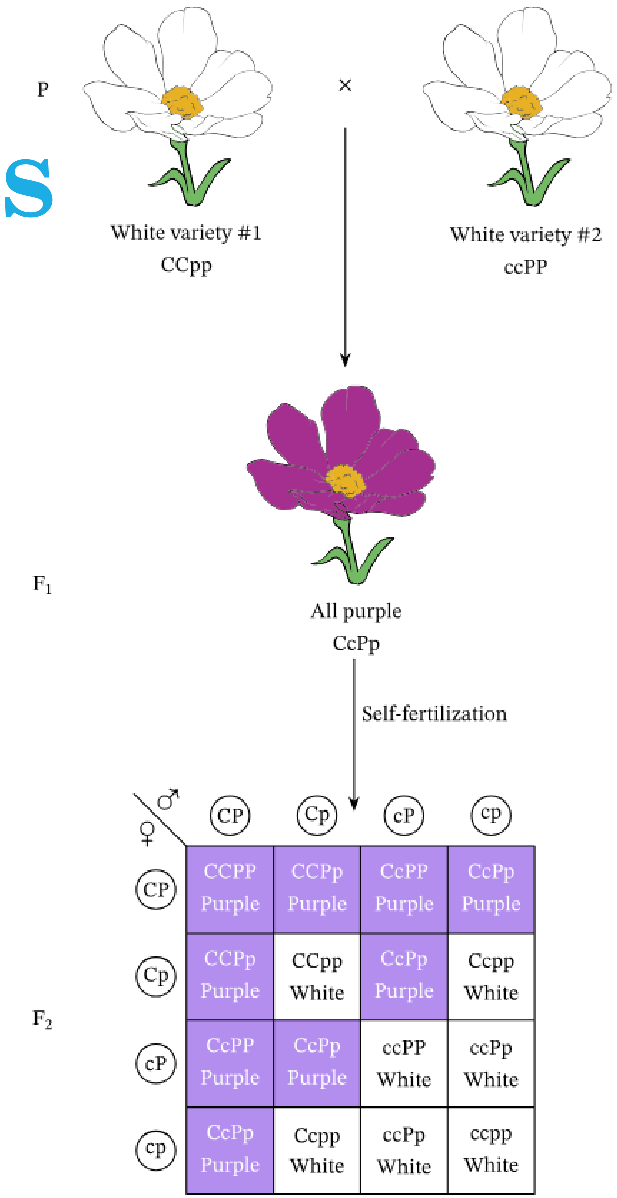
Cause death – either during the prenatal period or after birth

Types:

- Recessive Lethal – lethal in homozygous recessive condition
  - E.g. cystic fibrosis, sickle cell anaemia
- Dominant Lethal – LL/Ll = Death
  - E.g. Huntington's disease
- Conditional Lethal Genes
  - Cause death only under certain condition
  - E.g. favism

# 4. Complementary Genes

- A pair of genes work together (complement each other) to produce a particular phenotype
- Instead of having 4 phenotypes (like in Mendelian dihybrid cross), only 2 phenotypes are observed here
- Both dominant alleles needed for dominant phenotype expression
- F2 Phenotypic Ratio –
  Dominant : Recessive phenotype = 9:7
- Example:
  - Flower colour in sweet pea
  - C_P_ - purple flowers
  - ccP_ / C_pp / ccpp – white flowers

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# 5. Epistasis

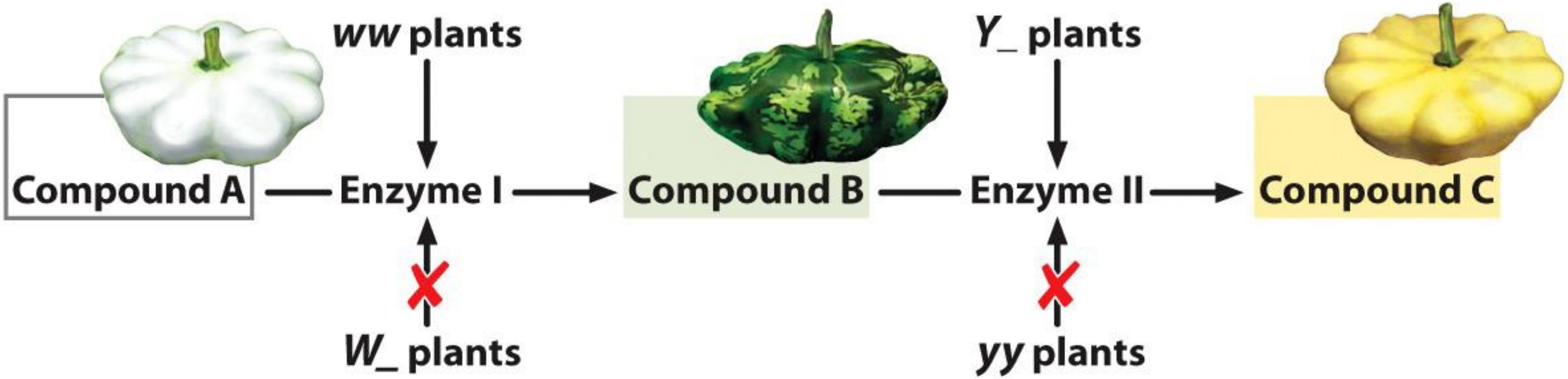
One gene (at one locus) affects the expression of another gene (at a different locus)

**Types of Epistasis:**

- Dominant
  - 12:3:1
- Recessive
  - 9:3:4
- Duplicate dominant
  - 15:1
- Duplicate Recessive
  - 9:7

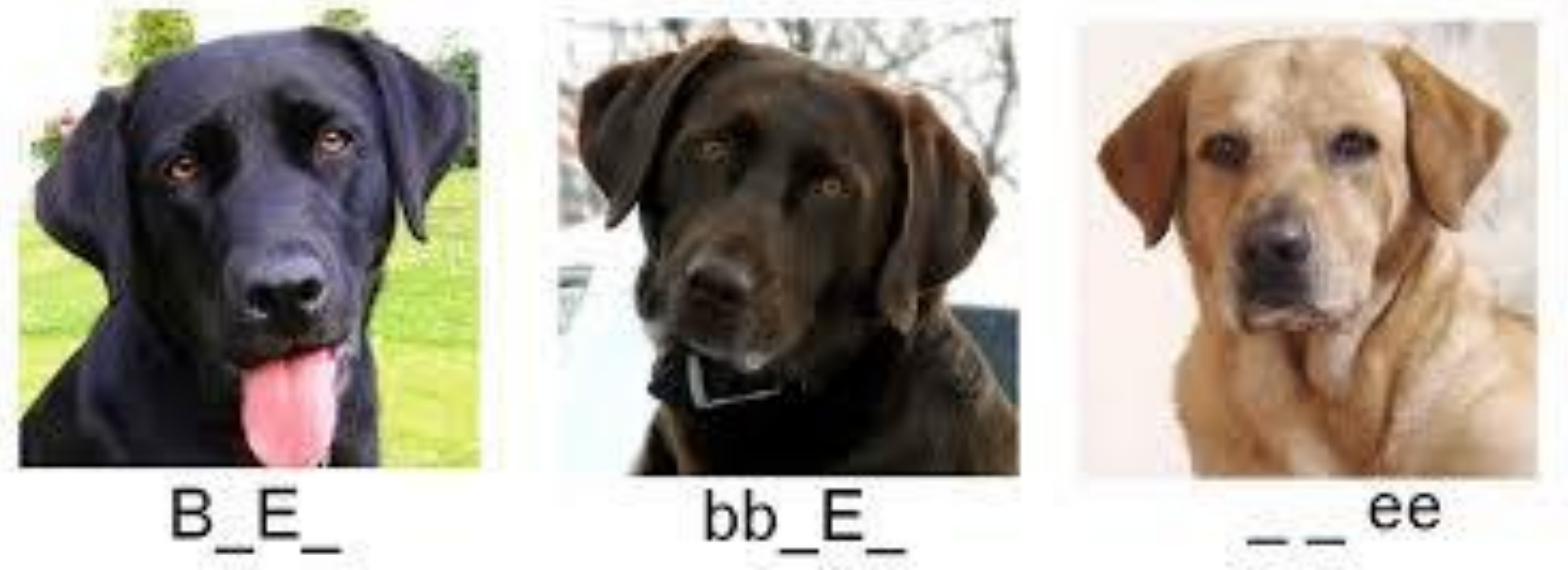
# 5. Epistasis

- Dominant Epistasis
  - Example: Summer squash – colour
  - F2 Ratio – 12:3:1



# 5. Epistasis

- Recessive Epistasis
  - Example: Labrador retrievers – coat colour
  - B – determines coat colour
  - E – affects pigment deposition (E allows deposition, e prevents it)
  - F2 Ratio – 9:3:4



# 5. Epistasis

- Duplicate Dominant Epistasis
  - Example: awn development (bristle like extension) in rice
  - Presence of one dominant allele masks the expression of the other recessive allele
  - Dominant allele A or B – awn present
  - Recessive state – aabb – awnless condition
  - F2 ratio – 15:1

# 5. Epistasis

- Duplicate Recessive Epistasis
  - Example: flower colour in some plants
  - Two genes – A and B
  - Presence of recessive allele at either of the two genes can mask the dominant phenotype

- Purple Flowers: A_B (A or B is dominant)

- White Flowers: aa__ or __bb (both recessive)

- Either gene has two recessive alleles – dominant phenotype is masked

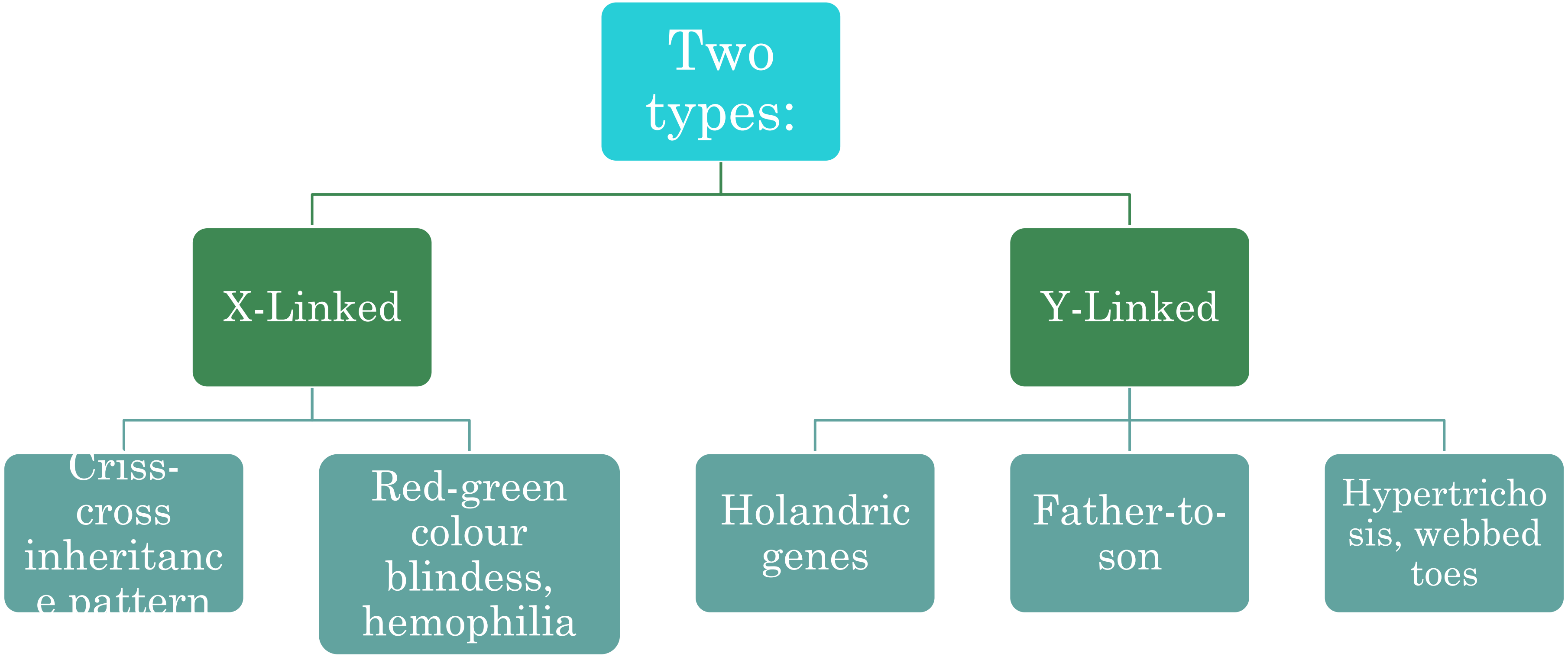
# Reasons for the deviation

1. Linkage
2. Crossing over
3. Inter-genic interactions
4. Environment

# Sex Linked, Sex Limited, Sex Influenced Inheritance

# Sex-Linked Inheritance

(Genes transmitted through sex chromosomes)



# Sex-Influenced Inheritance

- Autosomal traits
- Genes present in both sexes
- Expression influenced by sex hormone
- Dominant in one sex and recessive in another

E.g. Male pattern baldness, Index finger length,

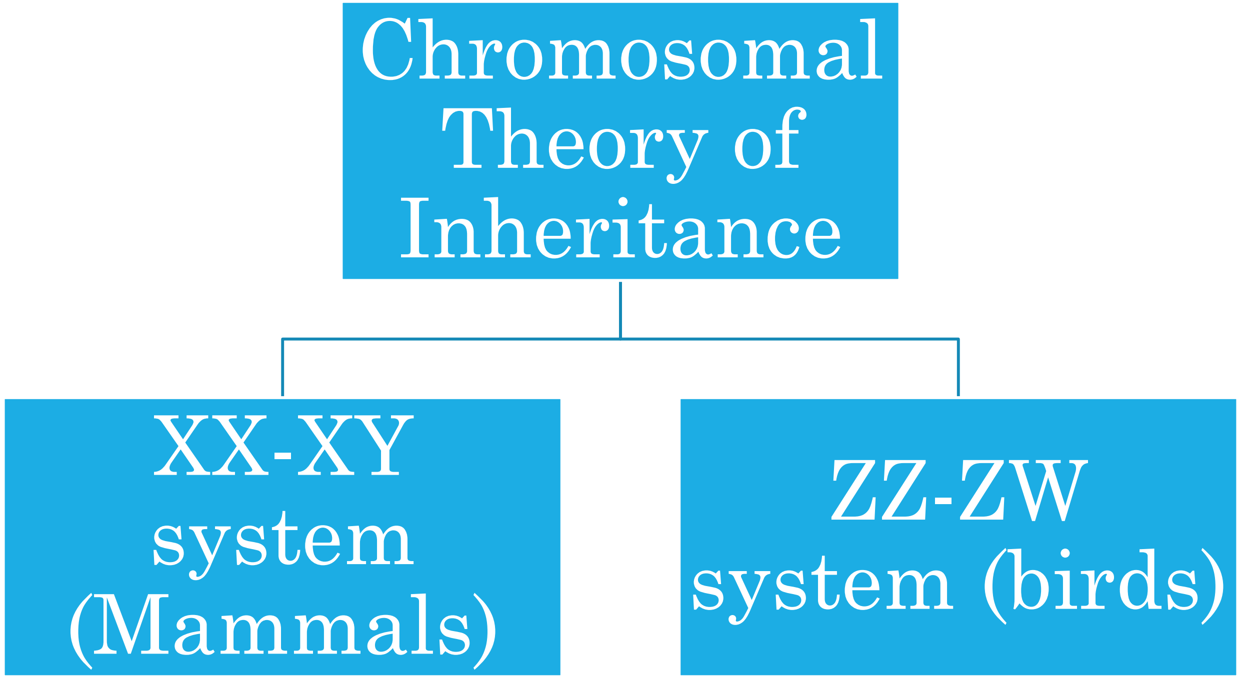
- ❖Horn development in sheep – Dorset & Suffolk
- ❖ Mahogany & Red colour in Ayreshire cattle
  - ❖Aa genotype
  - ❖ mahogany in males
  - ❖red in females)

# Sex-Limited Traits

- Genes present on autosomes
- Expressed in one trait and not in another due to
  - Hormonal influence
  - Anatomical differences
- E.g.
  - Milk production in females
  - Egg production in poultry
  - Plumage in peacocks
  - Breast-development in women

# Sex-Determination

# Sex-Determination



# MCQs – Modified Mendelian Genetics

- In incomplete dominance, the phenotype of the heterozygous individual is:
  a) Same as the dominant parent
  b) Same as the recessive parent
  c) Intermediate between the two parents
  d) Not expressed at all

- Which of the following is an example of co-dominance?
  a) ABO blood grouping in humans
  b) Flower color in snapdragons
  c) Coat color in Labrador retrievers
  d) Feather color in Andalusian chickens

# MCQs – Modified Mendelian Genetics

- In complementary gene action, the phenotypic ratio of the F2 generation in a dihybrid cross is:
  a) 3:1
  b) 1:2:1
  c) 9:7
  d) 15:1

- Which type of epistasis results in a phenotypic ratio of 12:3:1 in the F2 generation?
  a) Dominant epistasis
  b) Recessive epistasis
  c) Duplicate dominant epistasis
  d) Duplicate recessive epistasis

# MCQs – Modified Mendelian Genetics

- 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. This is an example of:
  a) Dominant epistasis
  b) Recessive epistasis
  c) Duplicate dominant epistasis
  d) Duplicate recessive epistasis

- Which of the following is an example of Y-linked inheritance?
  a) Red-green color blindness
  b) Hemophilia
  c) Hypertrichosis (hairy ears)
  d) Duchenne muscular dystrophy

# MCQs – Modified Mendelian Genetics

- In X-linked recessive traits, the condition is more common in:
  a) Males
  b) Females
  c) Both males and females equally
  d) Neither males nor females

- Which of the following is an example of a sex-limited trait?
  a) Milk production in cattle
  b) Baldness in humans
  c) Horn development in sheep
  d) Sickle cell anemia

# MCQs – Modified Mendelian Genetics

- In sex-influenced inheritance, the expression of traits is influenced by:
  a) The presence of sex chromosomes
  b) The hormonal environment
  c) The age of the individual
  d) The diet of the individual

- The ZW system of chromosomal sex determination is found in:
  a) Birds
  b) Mammals
  c) Bees
  d) Grasshoppers

# MCQs – Modified Mendelian Genetics

- In a cross between a red-flowered snapdragon (RR) and a white-flowered snapdragon (rr), the F1 generation will have:
  a) All red flowers
  b) All white flowers
  c) All pink flowers
  d) A 3:1 ratio of red to white flowers

- Which of the following coat colors in shorthorn cattle is an example of co-dominance?
  a) Red
  b) White
  c) Roan
  d) Black

# MCQs – Modified Mendelian Genetics

- In a dihybrid cross involving two complementary genes, if both parents are heterozygous for both genes, the proportion of offspring with the recessive phenotype will be:
  a) 1/16
  b) 3/16
  c) 9/16
  d) 7/16

- Which type of epistasis results in a phenotypic ratio of 9:3:4 in the F2 generation?
  a) Dominant epistasis
  b) Recessive epistasis
  c) Duplicate dominant epistasis
  d) Duplicate recessive epistasis

# MCQs – Modified Mendelian Genetics

- Epistasis is:
  a) Inter allelic interaction
  b) Intra allelic interaction
  c) Inter and intra allelic interaction
  d) Genotype – Environment interaction

- Which type of epistasis results in a phenotypic ratio of 9:3:4 in the F2 generation?
  a) Dominant epistasis
  b) Recessive epistasis
  c) Duplicate dominant epistasis
  d) Duplicate recessive epistasis

- Parents of one generation passes on the sex-linked characters to the opposite sex in the next generation. This process is known as
  a) Conjugation
  b) Crossing over
  c) Cross-over unit
  d) Criss-cross inheritance


THANK YOU!

# L2:

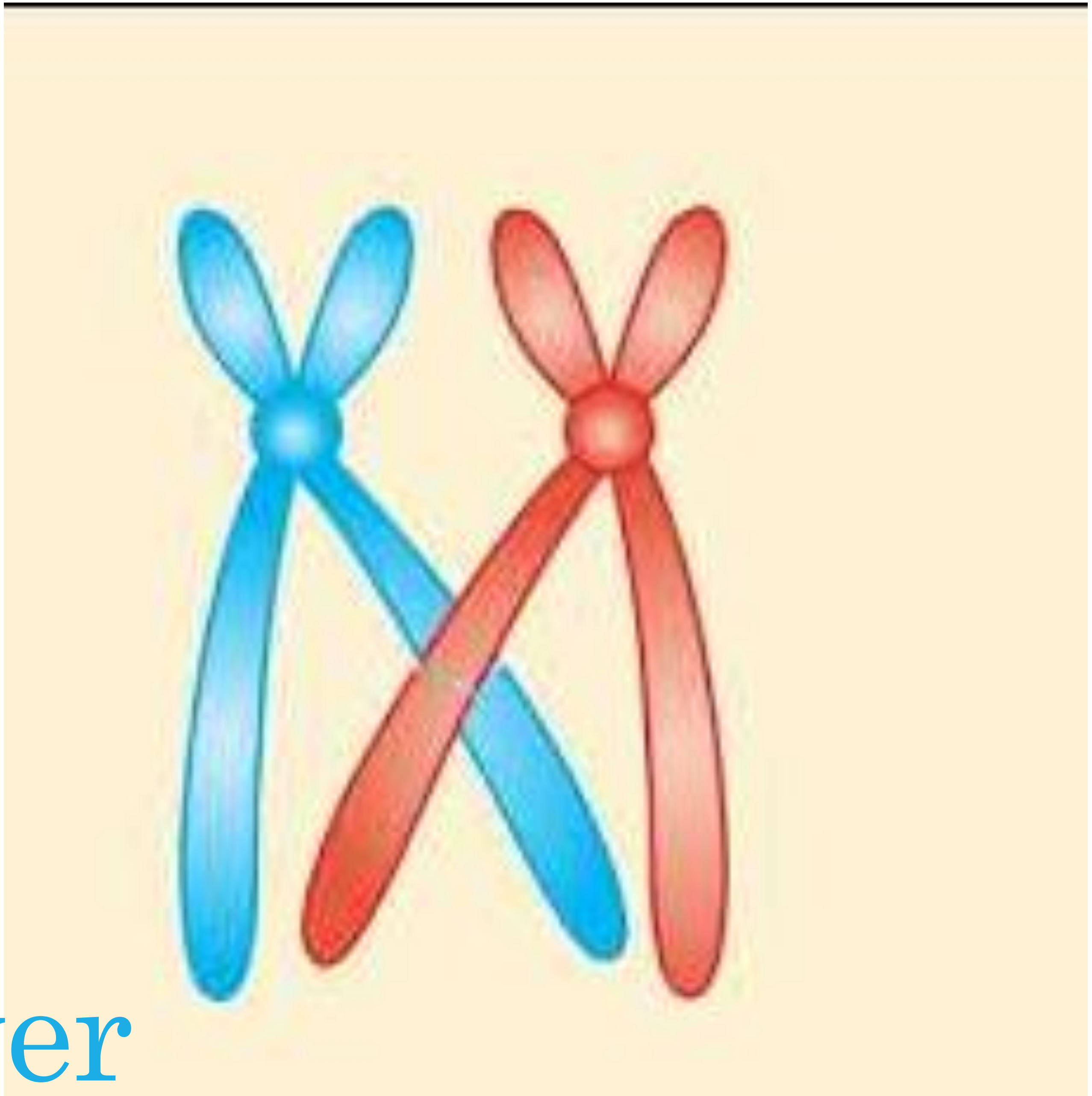
# *Topic 1: Advanced Genetics Concepts*

*Linkage*

*Crossing Over*

*Mutations*

# Linkage & Crossing Over



# Linkage

- Genes located close to each other on chromosome are inherited together
- No independent assortment
- Higher recombination frequency
- Linkage Map – relative position/distance between genes on a chromosome
  - Expressed in unit cM (centiMorgan)

# Linkage

- Linkage Groups:
  - All genes located on a given pair of chromosomes form a linkage group
  - So,

| Number of Linkage groups for a species = Haploid number of chromosomes |
|---|

Example:
No. of Linkage groups for cattle = 60/2 = 30

No. of Linkage groups for dog =

No. of Linkage groups for cat =

No. of Linkage groups for river buffalo =

# Linkage

Important Facts about Linkage

- Reduces Genetic Variability
- Strength of linkage depends on the distance between genes
- Linkage can be determined by test cross
- T.H. Morgan studied linkage in *Drosophila melanogaster* – concluded that it has two phases (coupling and uncoupling)

# Linkage

- Classification of Linkage
  - On the basis of crossing over
    - Complete linkage
    - Incomplete linkage
  - On the basis of genes involved
    - Coupling phase
    - Repulsion phase
  - On the basis of chromosomes
    - Autosomal linkage
    - Sex linkage

# Crossing over

- Exchange of genetic segments between non-sister chromatids of homologous chromosomes
- Occurs in Prophase I (pachytene) of meiosis I
- Leads to more genetic diversity in sexual reproduction

# Crossing Over

## Key Concepts

- Recombination
- Chiasmata
- Synapsis/Synaptonemal Complex
- Interference
- Parental/Non-crossover/Non-recombinant Types
- Non-parental/Crossover/Recombinant types

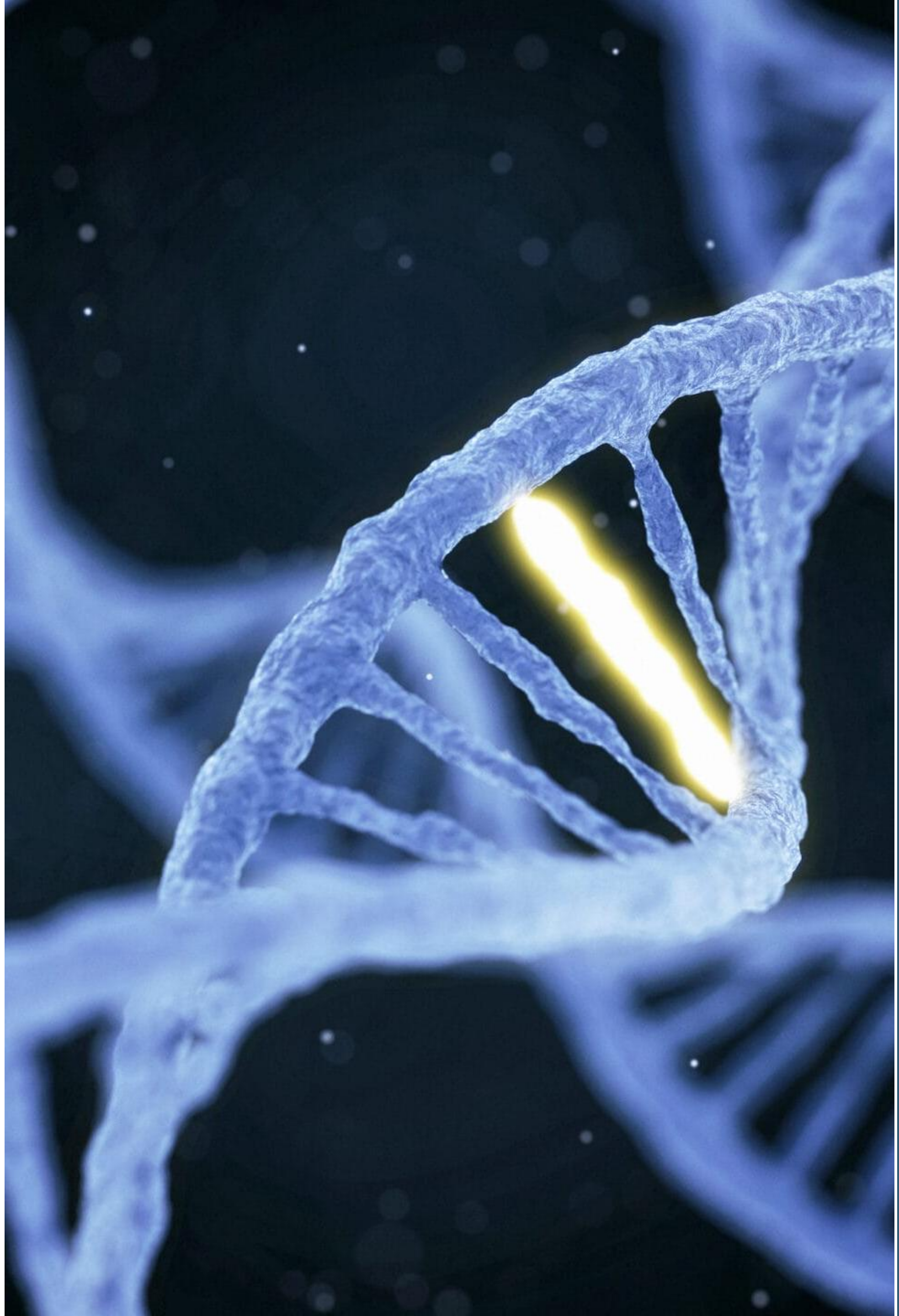
# Crossing Over

- Types of Crossing Over
  - Single Cross Over
  - Double Cross Over
  - Multiple Cross Over

# Linkage *vs* Crossing Over

| Linkage | Crossing Over |
|---|---|
| Keeps genes together | Separates genes from each other |
| Produces parental combinations | Produces recombinant combinations |
| Happens between genes placed close together | Happens between genes located away from each other |

# Mutation



# Mutation

- Sudden heritable change in DNA is known as mutation
- Types:
  - Gene Mutations
  - Chromosomal Mutations
  - Numerical Aberrations

# Mutation

- Gene Mutations:

- Point Mutation
  - Substitution – One base substituted by another
    - Transition – Purine substituted by purine, pyrimidine by pyrimidine
    - Transversion – Purine substituted by pyrimidine
  - Insertion – Addition of one or more bp
  - Deletion – Removal of one or more bp
- Frame Shift Mutation

# Mutation

- **Point Mutations:**
  - **Non-Sense Mutations** – Premature stop codon appearance & termination of peptide chain – protein is often non-functional.
    - E.g. cystic fibrosis – CFTR gene (Glycine>X) due to GGA>TGA (premature stop codon)
  - **Mis-sense Mutations** – Sickle cell anaemia – change in one nucleotide (A>T) causes change in amino acid coded – (glutamic acid to valine)
  - **Silent Mutations** – Change in base doesn't cause amino acid to be changed (e.g. CCA>CCG – both code for proline – no change in a.a.)

# Mutation

| Chromosomal Mutations | | |
| --- | --- | --- |
| | Deletion | |
| | Duplication | |
| | Inversion | |
| | Translocation | Robertsonian Translocation – fusion of two acrocentric chromosomes to form one single metacentric chromosome |

# Mutation

Numerical Aberrations of Chromosomes

- Numerical Aberrations of Chromosomes
  - Euploidy
    - Haploidy
    - Polyploidy
  - Aneuploidy
    - Monosomy (2n-1)
    - Nullisomy (2n-2)
    - Trisomy (2n+1)
    - Tetrasomy (2n+2)

# Mutation

Numerical Aberrations of Chromosomes - Disorders

| Turner Syndrome | Klinefelter's Syndrome | Down's Syndrome | Edward's Syndrome | Patau Syndrome |
|---|---|---|---|---|
| Monosomy of Sex Chromosome (XO) | Trisomy of Sex Chromsome (XXY) | Trisomy of Chromosome 21 | Trisomy of Chromosome 18 | Trisomy of Chromosome 13 |
| 2n-1=45 | 2n+1=47 | | | |

# MCQs – Advanced Genetics Concepts

- What is the maximum number of linkage groups in a species?
  a) Equal to the diploid number of chromosomes
  b) Equal to the haploid number of chromosomes
  c) Double the haploid number of chromosomes
  d) Independent of the chromosome number

- Which of the following is true about the frequency of recombination?
  a) It is inversely proportional to the distance between two genes
  b) It is directly proportional to the distance between two genes
  c) It always exceeds 50%
  d) It is independent of the distance between two genes

- In the linked genes, recombinant gametes are:
  a) More than 50%
  b) 50%
  c) Less than 50%
  d) none of the above

# MCQs – Advanced Genetics Concepts

- Which of the following is NOT a type of gene mutation?
  a) Transition
  b) Transversion
  c) Frame shift mutation
  d) Inversion

- Germline mutations are present in:
  a) Somatic cells only
  b) Egg or sperm cells
  c) All body cells
  d) None of the above

- Which of the following term is used for replacement of a purine base by a pyrimidine base and vice versa?
  a) Reversion
  b) Transversion
  c) Transition
  d) Alteration

# MCQs – Advanced Genetics Concepts

- Which of the following is an example of a chromosomal aberration?
  a) Point mutation
  b) Transition
  c) Deletion
  d) Frame shift mutation

- Monosomy is characterized by:
  a) One extra chromosome
  b) One missing chromosome
  c) Two extra chromosomes
  d) Two missing chromosomes

# MCQs – Advanced Genetics Concepts

- Klinefelter's syndrome is an example of:
  a) Monosomy
  b) Trisomy
  c) Tetrasomy
  d) Nullisomy

- Robertsonian translocations involve:
  a) Metacentric chromosomes
  b) Acrocentric chromosomes
  c) Telocentric chromosomes
  d) Submetacentric chromosomes

# MCQs – Advanced Genetics Concepts

- Which of the following is an example of aneuploidy?
  a) Haploidy
  b) Autotriploid in maize
  c) Turner's syndrome
  d) Wheat allopolyploidy

- The maximum frequency of recombination between two genes is:
  a) 25%
  b) 50%
  c) 75%
  d) 100%

- Sudden heritable change is :
  a) Epistasis
  b) Mutation
  c) Chromosomal aberration
  d) None of the above

# L3

# Topic 1:

# *Hardy Weinberg Equilibrium and Gene Frequencies*

# Population Genetics

- Population:
  - Group of individuals
  - In a given geographical area at a particular time
  - Free interbreeding & produce fertile offspring

- Gene pool
  - total of all genes (at all loci) of all individuals in a populations

# Population Genetics

- Allele (Gene) frequency
  - Proportion of one allele in a gene pool compared to other alleles at the same locus
  - p – frequency of dominant allele (A)
  - q- frequency of recessive allele (a)

- Genotype frequency
  - The proportion of individuals of a particular genotype (for a trait) in a population
  - Obtained by dividing the number of individuals with that genotype by the total number of individuals in the population

# Population Genetics

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:

# Hardy Weinberg Equilibrium

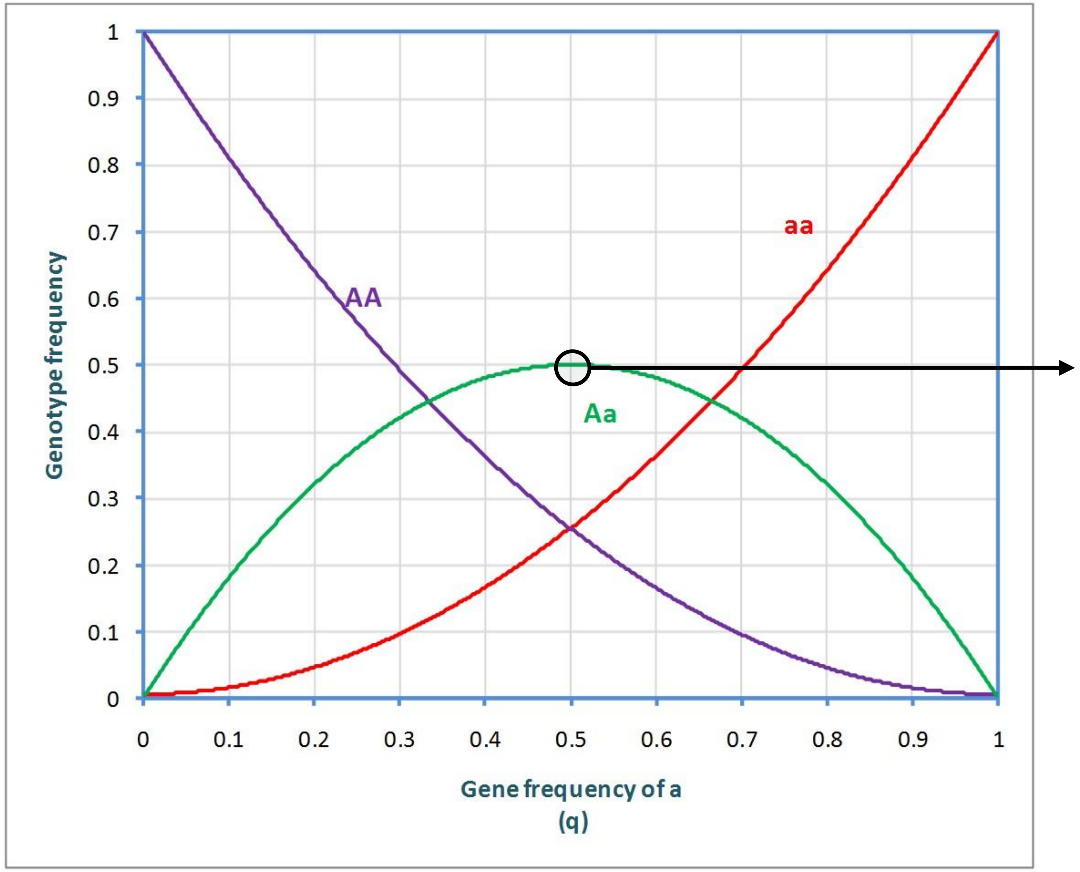
- Independently formulated by G. H. Hardy and Wilhelm Weinberg (1908)
- Describes a situation where a population is undergoing no evolutionary change
- States that:
  - The allele and genotype frequencies remain constant over generations in a large, randomly mating population when evolutionary forces (migration, mutation, selection) are absent.

# Hardy Weinberg Equilibrium

- Assumptions:
  - No mutation, selection, migration
  - Large population size
  - Random mating
  - Equal gamete production and random combination

- Gene and Genotype frequencies:
  - $p+q = 1$
  - $P^2 + 2pq + q^2 = 1$

# Relationship between gene & genotype frequencies




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

p=q=0.5

Max. gene frequency of any allele

# Applications of HW

- Calculation of frequencies of dominant and recessive genes in a population
- Introgression of new genes in a population – testing the frequency of new genes (used as a base by breeders)
- Calculation of frequency of carriers (heterozygotes) in a population
- To test for agreement of a population with HW equilibrium

# Attaining HW Equilibrium

- Assuming other conditions are met, HW equilibrium in population is attained for:
  - Autosomal traits – 1 generation of random mating
  - Sex-linked traits – 8-10 generations of random mating

- Key feature of HW Eq$^{m}$ – rapid attainment of equilibrium in one generation of random mating
  - Serves as a null model for population genetics

# Sample Questions

- 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.

# Sample Questions

*Solution:*

- **Calculating allele frequencies:**
- Frequency of b allele (q): $\sqrt{(510/1000)} = \sqrt{0.51} = 0.714$
- 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%

# Sample Questions

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

# Sample Questions

- *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)

# Sample Questions

**b) Calculating the frequency of the dominant allele (p):**

- Since $p + q = 1$
- $p = 1 - q = 1 - 0.268 = 0.73$

**c) Calculating the expected number of heterozygous carriers:**

- Frequency of heterozygotes = 2pq
- $2pq = 2 \times 0.732 \times 0.268 = 0.392$
- Expected number of heterozygotes = $0.392 \times 500 = 196$ cats

# Sample Questions

- 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.

# Sample Questions

Solution:

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

- $= 0.1(0.8 - 0.6)$
- $= 0.1(0.2)$
- $= 0.02$
- New allele frequency = $p + \Delta p = 0.6 + 0.02 = 0.62$

# Sample Questions

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

$$\Delta p = \nu q - \mu p$$

# Sample Questions

*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.

# Sample Questions

- 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 $2 \times 10^{-6}$ per generation, with no back mutation. Calculate the new allele frequency after one generation.

# Sample Questions

*Solution:*

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

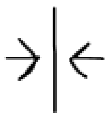
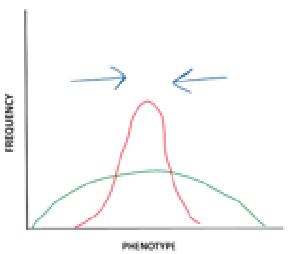
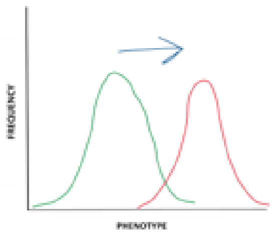
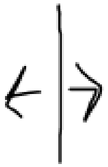
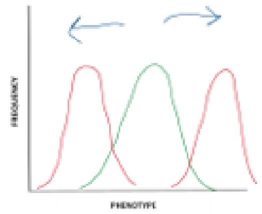
- Total change: $\Delta p = \Delta pm + \Delta p\mu = 0.01 - 0.0000014 = 0.0099986$

- New allele frequency = 0.7 + 0.0099986 = 0.7099986

# Factors Affecting Gene Frequency

- Mutations
- Migration (Gene Flow)
- Non-random mating
  - Assortative mating
- Natural Selection
  - Directional Selection – favours one extreme
  - Stabilising selection – favours the intermediate phenotype
  - Disruptive Selection – favours both extremes

# Factors Affecting Gene Frequency

| SELECTION TYPE | CHANGE IN MEAN | CHANGE IN VARIANCE | DIRECTION OF SELECTION | GRAPH |
|---|---|---|---|---|
| STABILIZING | No change in mean value | Mean frequency increases, changing overall variance |  |   |
| DIRECTIONAL | Mean value changes | Change in mean decreases variance, allele frequency changes |  OR  |   |
| DISRUPTIVE | Mean value changes | Mean favors extreme phenotypes, increasing variability |  |   |

# Factors Affecting Gene Frequency

- Genetic Drift –
  - Bottleneck effect –
    - Population size is drastically reduced for atleast 1 generation
    - Environmental effects/Human activities
    - E.g. Overhunting of northern elephant seals (1800s) – population came down to 20
    - E.g. Cheetahs – 12000 years ago – low genetic diversity
  - Founder effect –
    - New population established by a small section of a larger population
    - Non-random sample of genes
    - low genetic variation
    - E.g. Afrikaner population (South Africa) (came from Dutch) – higher prevalence of Huntington's
    - E.g. Amish community – higher prevalence of Ellis van Creveld syndrome

# MCQs

- What is a population in the context of population genetics?
  a) A group of different species occupying a given area
  b) A group of individuals of the same species that cannot interbreed
  c) A group of individuals of the same species occupying a given area that can freely interbreed and produce fertile offspring
  d) A group of individuals with different genotypes

- The sum total of genes of all individuals in a population is called:
  a) Genotype frequency
  b) Allele frequency
  c) Gene pool
  d) Phenotype frequency

# MCQs

- Which of the following is NOT an assumption of the Hardy-Weinberg equilibrium?
  a) No mutation
  b) Large population size
  c) Random mating
  d) Presence of selection

- The maximum gene frequency for heterozygotes in a one-locus-two-allele situation is achieved when:
  a) $p = 0.25$ and $q = 0.75$
  b) $p = 0.75$ and $q = 0.25$
  c) $p = q = 0.5$
  d) $p = 1$ and $q = 0$

# MCQs

- In a population of 1000 individuals, 160 are found to have a recessive genetic disorder. What is the frequency of the recessive allele (q)?
  a) 0.16
  b) 0.32
  c) 0.4
  d) 0.8

- In a population of cats, the dominant allele B produces black coat color, while the recessive allele b produces white coat color. If the frequency of the B allele is 0.6, what is the expected frequency of heterozygous (Bb) cats?
  a) 0.24
  b) 0.36
  c) 0.48
  d) 0.64

# MCQs

- In a population of 800 individuals, 128 are found to have a recessive genetic disorder. Assuming the population is in Hardy-Weinberg equilibrium, what is the frequency of the dominant allele (p)?
  a) 0.2
  b) 0.4
  c) 0.6
  d) 0.8

- The change in allele frequency due to mutation is represented by the equation:
  a) $\Delta p = \nu(1-p) + \mu p$
  b) $\Delta p = \nu(1-p) - \mu p$
  c) $\Delta p = \mu(1-p) - \nu p$
  d) $\Delta p = \mu(1-p) + \nu p$

# MCQs

- Hardy-Weinberg equilibrium is not attained in a single generation of random mating in case of (OPSC 2022)
  a) Sex-linked genes
  b) Multiple alleles
  c) Two autosomal alleles
  d) Polyploids

- The direction of change in the allelic frequencies cannot be predicted in: (OPSC 2022)
  (A) Mutation
  (B) Migration
  (C) Selection
  (D) Genetic drift

# MCQs

- 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

- The change in allele frequency due to mutation is represented by the equation:
  a) $\Delta p = \nu(1-p) + \mu p$
  b) $\Delta p = \nu(1-p) - \mu p$
  c) $\Delta p = \mu(1-p) - \nu p$
  d) $\Delta p = \mu(1-p) + \nu p$

# MCQs

- . Frequency of two alleles in parents is 'p' and 'q'; then proportion of heterozygotes in progeny will be:
  a) 2pq
  b) p2
  c) q2
  d) p+q


THANK YOU!

# L3:
# *Quantitative Genetics Concepts*

*Heritability*

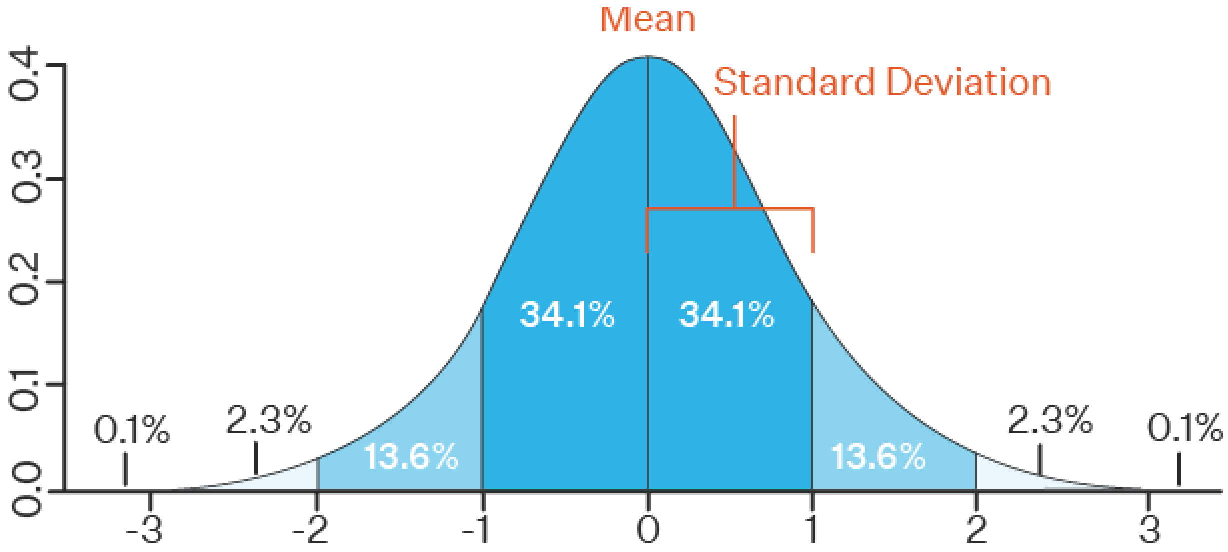
*Repeatability*

*Correlation*

# Some Basic Concepts

### Standard Deviation (S.D./$\sigma$)

- It measures how far data points tend to deviate from the mean on average
- Low $\sigma$ - values tend to be close to the mean
- High $\sigma$ – values spread out over wide range from the mean




$$\sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{N}}$$

# Some Basic Concepts

- Imagine you're a teacher, and you've just given a math test to a class of five students. Here are their scores out of 100:
  75, 80, 85, 90, 95

# Some Basic Concepts

- Variance ($\sigma^2$)
- Square of standard deviation
- Used to calculate heritability, repeatability, covariance, correlation.

# Economic Traits

- Selection of traits – market demand and parameters
- Trait = character
- Phenotype = alternate forms of a trait/specific measurements made on a trait

Different Phenotypes of coat colour in labrador retrievers

# Economic Traits

- These are traits of economic importance –
  - Related to economic value/productivity/profitability

Related to

- **Production**: Milk, meat, wool, skin, manure
- **Reproduction**: AFI, ICI, prolificacy, conception rate, service period
- **Growth**: Birth wt., yearling wt., FCR

# Quantitative Genetics

- Quantity --→ measurement

- *Quantitative Trait* –

  polygenic, measurable, continuous, and environmentally affected/controlled

- Then, the phenotype 'P' can be written as,

$$P = G + E$$

$$P = (A+D+I) + (E_P + E_T)$$

# Quantitative Genetics

- Then, the phenotype 'P' can be written as,

$$P = G + E$$

$$P = (A+D+I) + (E_P + E_T)$$

Also, the variability in the measured phenotype can be written as,

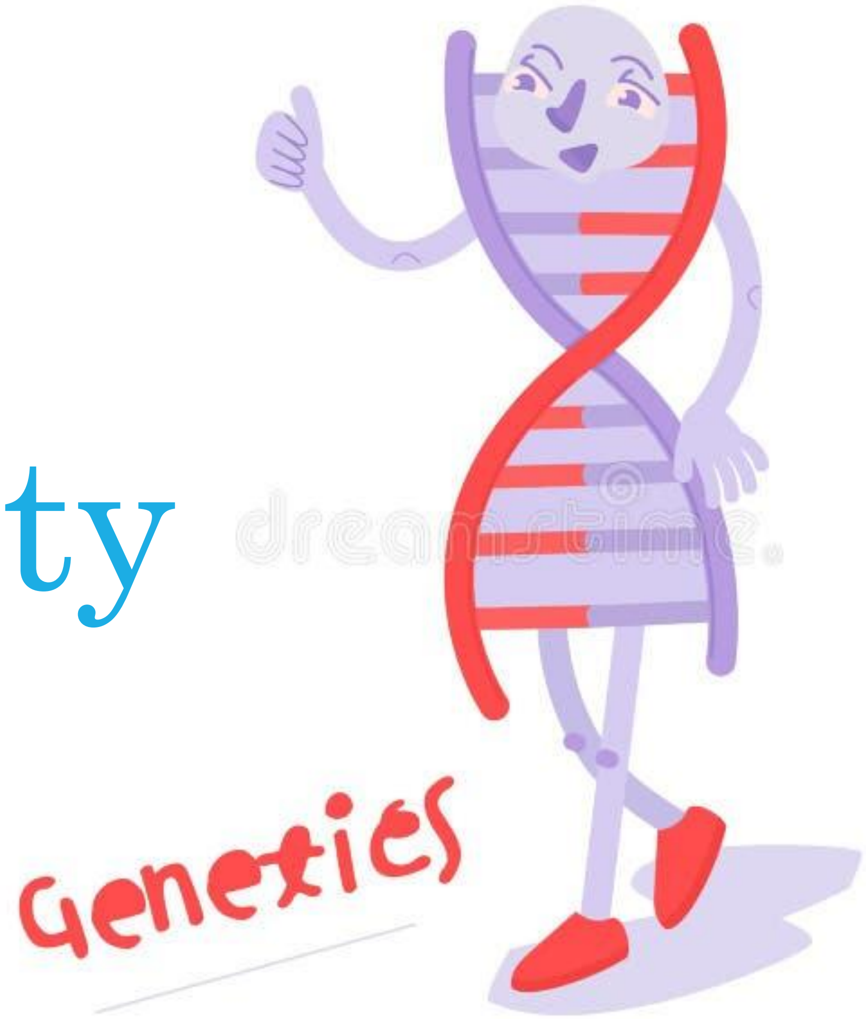
$$V_P = V_G + V_E$$

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

# Quantitative Genetics

- Selection for improvement of economic traits is necessary
- Phenotype is affected by genotype
- Measure genetic parameters for selecting the best animals (parents)
- Genetic parameters include – heritability, repeatability and genetic correlation

# Heritability



# Heritability

- Heritability measures the degree to which offspring resemble their parents in trait performance.
- It represents the strength of the relationship (consistency) between phenotypic values and breeding values for a trait in a population.
- Denoted by the symbol $h^2$.
- Heritability is dimensionless, estimable, and a population parameter.
- Heritability is necessary to predict breeding values

# Heritability - Types

$H^2$

**Broad sense:**

- $H^2 = V_G / V_P$
- Represents the influence of the entire genotype on the phenotype.

$h^2$

**Narrow Sense:**

- $h^2 = V_A / V_P$
- Represents the additive genetic portion of phenotypic variance.
- More useful for breeding purposes.

# Characteristics of heritability

- Ranges from 0 to 1 or 0% to 100%.
- Always a positive value mathematically.
- Population measure.
- A pure ratio

# Heritability

- When we say,
  - $h^2$ is high & production is high – so, a large proportion of the $V_P$ comes from $V_A$
  - $h^2$ is low & production is high – that means, $V_A$ is less

In which of the above cases will the phenotype of an individual give a higher indication of its breeding value?

# Example

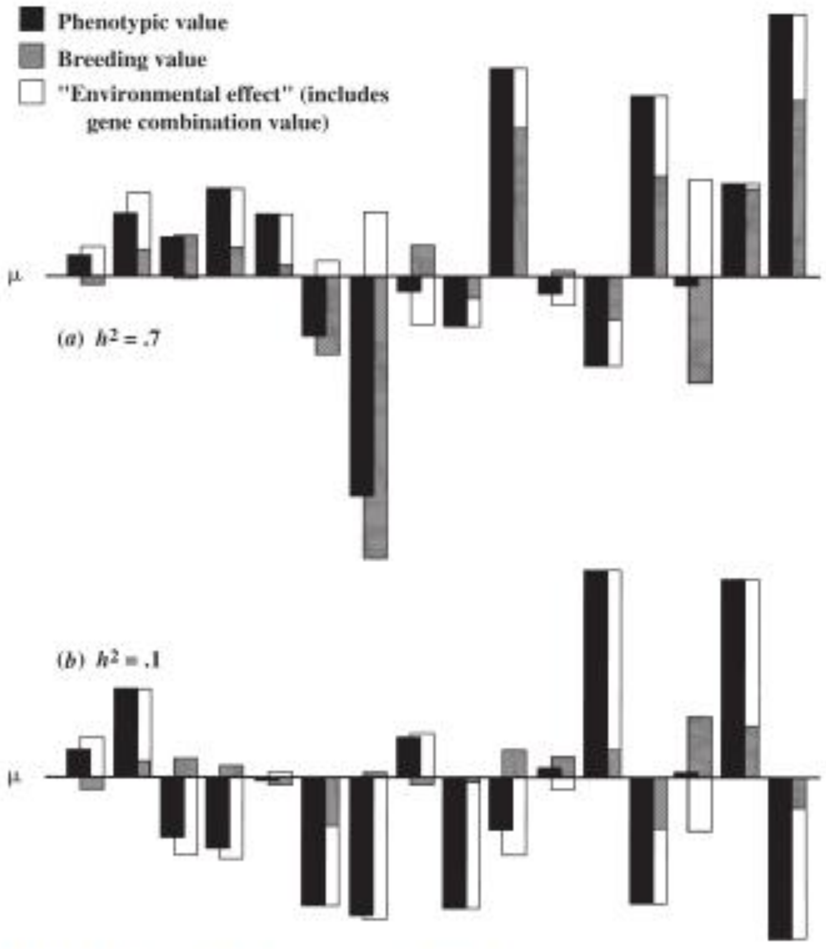



**FIGURE 9.1** Schematic representation of animal performance for two traits that differ in heritability. Records for a sample of 16 animals are shown for each trait. Contributions of breeding values and "environmental effects" (environmental effects and gene combination values combined) are shown in the background. Heritabilities ($h^2$) for the traits depicted in the upper (a) and lower (b) diagrams are .7 and .1, respectively.

- Fig. (a) –
  - Positive BV – above avg performance
  - Negative BV – below avg performance
  - Larger the BV, higher the deviation from mean
  - ∴ strong consistent relationship b/w BV and P
- Fig (b):
  - Cases with negative BV – higher P
  - Cases with less BV – higher P
  - Cases with high BV – lower P
  - Phenotype influenced by environment
  - Animal's own performance not a good indicator of BV

# Questions

- **What is the heritability for the number of legs in a dog?**
- **What is the heritability for the length of legs in a dog?**

Fun Fact

Temperament is a heritable trait. Make sure that donor cows are docile and easy to handle to ensure the calf crop is too!

# Estimation of heritability

In terms of correlation/regression, an alternative form for heritability is given as,

$$h^2 = b/r \quad \text{or} \quad h^2 = t/r$$

Where 'b' → regression of parent on offspring

't' → correlation between full sibs/half sibs

'r' → coefficient of additive variance in covariance (theoretical correlation)

# Heritability Range

- **Low heritability**: $h^2 < 0.2$ (e.g., reproduction & fitness traits – fertility)
- **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., growth traits, carcass traits, structural size, mature body weight)

# Estimation of heritability

When the contributions of epistatic interactions and environment are ignored, heritability can be estimated as given below,

| Relatives | Heritability (in terms of b or t) |
|---|---|
| Offspring and one parent | $h^2 = 2b$ |
| Offspring and mid-parent | $h^2 = b$ |
| Full sibs | $h^2 \leq 2t$ |
| Half sibs | $h^2 = 4t$ |

# KEY TAKEAWAYS SO FAR

Population parameter – depends on population size too

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Estimated for a trait in a population

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Narrow sense $h^2$ ($V_A/V_P$) used in breeding

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Population parameter – depends on population size too

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Narrow sense $h^2$ ($V_A/V_P$) used in breeding

When $h^2$ is high, P is a good indicator of animal's BV

# KEY TAKEAWAYS SO FAR

Population parameter – depends on population size too

Estimated for a trait in a population

Narrow sense $h^2$ ($V_A/V_P$) used in breeding

When $h^2$ is high, P is a good indicator of animal's BV

∴ Heritability - particular population; specific environment; particular time

# Practical Implications of $h^2$

## Selection

- Only phenotypic value available, but selection is for breeding value therefore, use $h^2$
- High $h^2$ – individual selection
- Low $h^2$ – Individual performance not a good indicator of genotype – other types of selection

## Prediction

- High $h^2$ – Highly likely that progeny is similar to parent in production

## Management

- High $h^2$ – Phenotype influenced by genetics – environment has low impact
- Low $h^2$ – Phenotype mostly influenced by enviroment

## Breeding Strategies

- High $V_A/V_P$ – Selection will be fruitful in a few generations
- Low $V_A/V_P$ , but high $V_G/V_P$ – Non additive gene action is dominant – heterosis breeding is beneficial

# Factors affecting heritability estimates

- Sample Size
- Data Collection
- Sampling Methods
- Environment
- Experimental Design – decides all these factors


# Repeatability

# Repeatability

- Strength of relationship (correlation) between repeated records (measurements) for a trait in a population
- Can be determined for traits which have more than one measurement
- $r = V_G/V_P$
- Population parameter
- Ranges from -1 to +1 (it is a correlation), but repeatabilities are rarely negative
- r=0 – trait is hardly repeatable, r close to 1 – trait is extremely repeatable
- Examples – Lactation yield, litter size, wool production etc.

# Repeatability

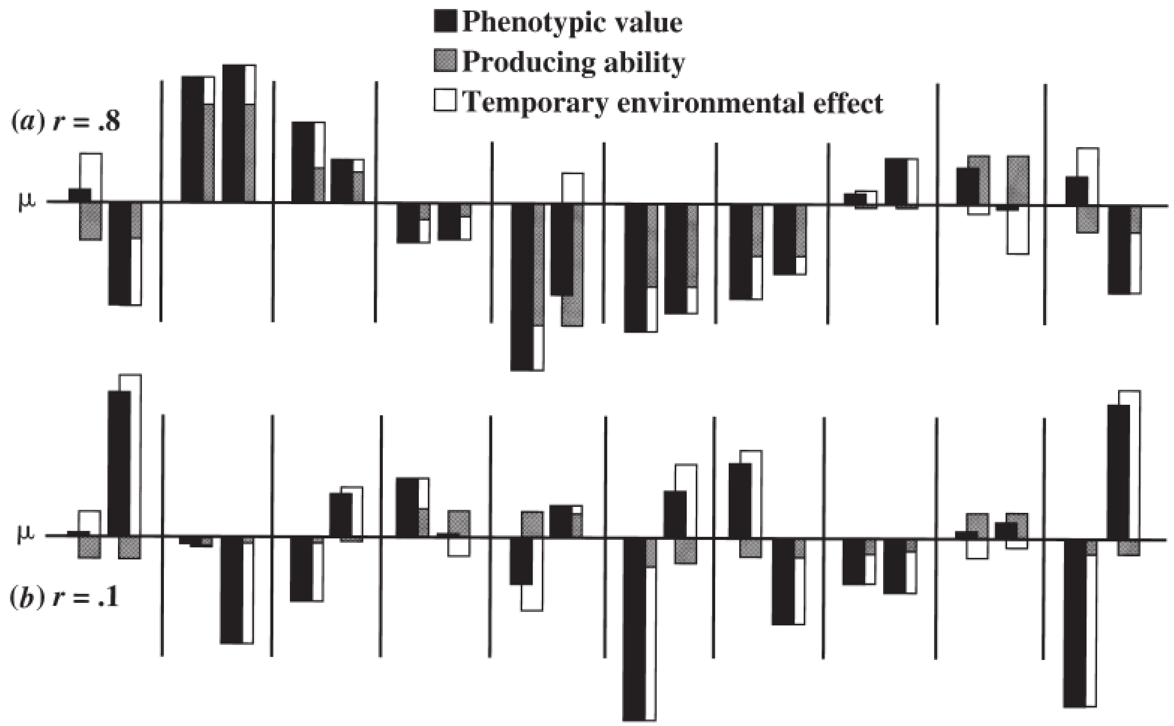



**Figure 9.4** Schematic representation of animal performance for two traits that differ in repeatability. For each trait, pairs of repeated records from a sample of 10 animals are illustrated. (For clarity, vertical lines separate each pair.) Contributions of producing abilities and temporary environmental effects are shown in the background. Repeatabilities (*r*) for the traits depicted in the upper (*a*) and lower (*b*) diagrams are .8 and .1, respectively.

- Trait (a) – high ‘r’ value
- Trait (b) – low ‘r’ value

# Repeatability

Practical implications:

- When repeatability is high, first record is a good indicator of its second record

OR

- Repeatability is the strength of relationship between single performance records and producing abilities.

- *When repeatability is high – differences in animal performances are largely attributable to differences in producing ability, not among environmental effects and vice versa.*

# Some repeatability estimates

***Repeatability range:***

- R < 0.2 – lowly repeatable
- 0.2 < r < 0.4 – moderately repeatable
- R > 0.4 – highly repeatable

| Species | Trait | *r* |
|---|---|---|
| Cattle (beef) | Calving date (trait of the dam) | .35 |
| | Birth weight (trait of the dam) | .20 |
| | Weaning weight (trait of the dam) | .40 |
| | Body measurements | .80 |
| Cattle (dairy) | Services per conception | .15 |
| | Calving interval | .15 |
| | Milk yield | .50 |
| | % fat | .60 |
| | Udder support | .50 |
| | Teat placement | .55 |
| | Rear leg set | .30 |
| | Stature | .75 |
| Poultry | Egg weight | .90 |
| | Egg shape | .95 |
| | Shell thickness | .65 |
| | Shell weight | .70 |

# Characteristics of Repeatability

- Repeatability is a population measure – not determined for an individual
- It is not fixed – varies between populations and environments
- Upper Limit of $h^2$
- Determines gain from repeated measurements
- Allows prediction of future performance

# Importance of Repeatability

- Repeatability and Culling

  Two cows:
  Ruby – Decent milker, but slow to breed back
  Emerald – Poor milker, but quick to breed back
  Whom would you cull?

  When repeatability is high –
  When repeatability is low –

- Repeatability and Prediction

# Importance of Repeatability

- Repeatability and Prediction

Calculation of MPPA – Most Probable Producing Ability

Repeatability is necessary to predict producing abilities

# Some concepts

- Higher the $h^2$ for a trait – one record is a good indicator of animal's BV
- Higher the r for a trait – one record is a good indicator of its producing ability
- Both $h^2$ and r are not constant – they can be increased for a population
  - Use common environments while determining
  - Accurate measurement

# Correlation

# Correlation

- **Correlation coefficient** – measure of strength of relationship between two variables
  - Variables can be two traits or two values for the same trait

- **Types:**
  - ***Genetic correlation –***
    strength of relationship between breeding values of two traits
  - ***Environmental correlation –***
    Relationship b/w environmental effects of one trait and another
  - ***Phenotypic correlation –***
    Strength of relationship between performance in one trait and performance in another

# Correlation

It's a population measure, denoted by the letter 'r'
Correlation range: -1 to +1

Range : -1 to +1

**r = 0**

no relationship between traits

**r>1**

Selection for one trait leads to improvement in another

E.g. Milk yield and mastitis incidence

(0.15-0.68)

**r<1**

Selection for one trait leads to decline in another

E.g. – milk yield and milk fat percentage

# Correlated Response to Selection

- Selection for one trait leads to selection of another
- Causes of correlated response:
  - Pleiotropy – major cause – one gene influences more than one trait

    e.g. halothane gene in swine – increased lean yield, feed efficiency, decreased litter size, survival rate and meat quality

    HYPP gene – horses – increased muscling and decreasing survival
  - Linkage – Selection for one trait increases frequency of the other

# Correlated Response to Selection

- Genetic correlations –
- Positive –
  - Keel length and body weight in turkeys (r=0.5)
- Negative correlation:
  - Milk yield and milk fat in dairy cows (-0.3)

# MCQs - $h^2$, r, and correlation ($r_{xy}$)

1. 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

2. The major cause of genetic correlation is (UK VO – 2024)
   a) Pleiotropy
   b) Segregation
   c) Heterozygosity
   d) Homozygosity

# MCQs - $h^2$, r, and correlation ($r_{xy}$)

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

- 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

# MCQs - $h^2$, r, and correlation ($r_{xy}$)

- The sum 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

- Proportion of phenotypic variance caused due to additive gene variance is (JKPSC 2019)
  a) Heritability
  b) Correlation
  c) Regression
  d) Response

# MCQs - $h^2$, r, and correlation ($r_{xy}$)

- Correlation among different measurements on a character in the life of an animal is called (JKPSC 2019)

  a) Repeatability
  b) Heritability
  c) Regression
  d) Variance

- Selection on the basis of individuality is most important, when $h^2$ of the trait is: (PPSC 2016)
  a) Low
  b) Medium
  c) High
  d) None of the above

# MCQs - $h^2$, r, and correlation ($r_{xy}$)

- Which of the following is used to predict future performance of individual ?

  (RPSC 2019)

  a) Genetic Correlation
  b) Heritability
  c) Repeatability
  d) Phenotypic correlation

- Which of the following is a heritable and fixable component of phenotypic variance? (MPPSC 2021)
  a) Environmental variation
  b) Additive variation.
  c) Both of the above
  d) None of the above

# MCQs - $h^2$, r, and correlation ($r_{xy}$)

- Which of the following statements indicates about narrow-sense heritability?
  (MPPSC 2023)

  a) It is the ratio of genetic variance to total phenotypic variance
  b) It is the ratio of environmental variance to total phenotypic variance
  c) It is the ratio of additive genetic variance to total phenotypic variance
  d) It is the ratio of phenotypic variance to total environmental variance

- What will be the heritability range for wool quality traits like fiber diameter, staple length, crimp frequency etc.? (MPPSC 2023)
  a) Less than 0-3
  b) More than 0.5
  c) Between 0-1 and 0-2
  d) None of the above

# MCQs - $h^2$, r, and correlation ($r_{xy}$)

- The causes which are responsible for the genetic correlation between two characters are (MPPSC 2022)

  a) Pleiotropy and linkage between genes
  b) Dominance and lethal genes
  c) Heterosis and pleotrophy
  d) Linkage and multiple alleles

- Family selection of the method of choice for traits with: (MPPSC 2022)
  a) High heritability
  b) Low heritability
  c) Expression in one sex only
  d) Large families

# MCQs - $h^2$, r, and correlation ($r_{xy}$)

- Intra-class correlation between repeated measurements of the same individual is a measure of (OPSC 2022)

  a) Genetic correlation
  b) Heritability
  c) Phenotypic correlation
  d) Repeatability

- Which of the following variances is fully transmitted to the next generation? (OPSC 2022)
  a) Dominance variance
  b) Epistatic variance
  c) ) Additive genetic variance
  d) Phenotypic variance


THANK YOU!

# L5: *Quantitative Genetics Concepts: Selection*

*Selection Differential*

*Response to Selection*

*Intensity of Selection*

*Bases of Selection*

*Methods of Selection*

# Selection & Mating Systems

- Selection –
  - Which individuals will become parents?
  - How many progenies will they produce?
  - How long will these individuals remain in the breeding population?

- Mating –
  - Which of the selected male will mate with which female?
  - Controls how the parents are mated to produce the next generation

- Breeding Plan = Selection + Mating System

# Selection

- Giving preference to certain individuals to reproduce
- Differential reproduction
- No creation of new genes
- Genetic structure of the population changes
- Two types of selection:
  - Natural Selection – "survival of the fittest"
  - Artificial Selection – intentional selection done by the breeder

# Artificial Selection

- Concerned with increasing the frequency of desirable genes in the herd or flock
- Sorts the genes - keep the desired genes, cull the undesired

# Selection Differential / Reach

- Phenotypic superiority of parents over population (before selection)
- For a particular phenotype:
- $P_b$ – Population mean
- $P_s$ – Mean of the selected parents
- Then selection differential (S):

$$S = P_s - P_b$$

Question:

Will the entire 'S' be transmitted to the next generation as it is?

Will a portion be transmitted to the next generation?

# Selection Differential / Reach

**Depends on:**

- Size of the selected population
- Large litter bearing animals – S.D. is large (Swine > Cattle)
- Herd size
- Use of AI, ETT and superovulation
- Standard deviation of base population

# Response to Selection/Genetic Gain

- Change in performance of progeny generation due to artificial selection is known as response to selection/genetic gain
- Symbol: R
- How much change has been seen in the population after selection?

$$R = P_o - P_b$$

**Annual Genetic Gain ($\Delta G$):**

$$\Delta G = \frac{R}{Generation\ Interval}$$

# Response to Selection/Genetic Gain

R is also estimated from 'S' – ***Expected Genetic Gain***

- We know that only $h^2$ portion of 'S' is transmitted to next generation, so,

$$R = h^2 S$$

Then, $h^2 = R/S$,

This is called *realised heritability* (what is actually passed on to the next generation

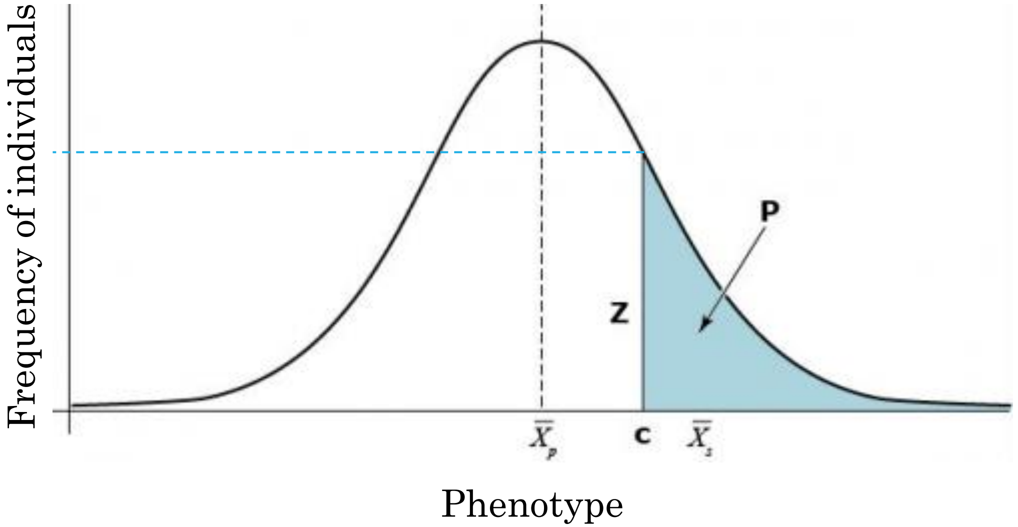
- Easily estimated
- Not as valid an estimate as the other formula

***Selection Plateau / Selection Limit***

# Selection Intensity (i)

$$i = \frac{S}{\sigma_P}$$

- Pure ratio
- If '*i*' is high – selection process is good
- In truncation selection:
- $i = z/p$



# Example question

- (population) Post weaning average dairy weight gain = 1.8 lb/day
- Selected females – 2.3 lb/day
- Calculate S, R, $h^2$, and i

# Response to Selection/Genetic Gain

**Factors Affecting R**

- $h^2$ ($V_A$) $\propto$ R
- S $\propto$ R
- i $\propto$ R
- Generation Interval – average age of parent when offspring is born
  - GI $\propto$ 1/R
- Genetic correlation
- Proportion of selected parents
- Accuracy of selection – sources of information (closer the relationship, more accurate the info, more accuracy of selection)

# Combined Selection

- Selection of individuals based on 2 or more sources of information
- Index selection – combining information from various relatives
- Osborne index (used in poultry) – gives weightage to each trait according to its importance, and helps in selection of multiple traits at a time

# Bases of Selection

# Bases of Selection

Choosing the source of information based on which we will select the animal

- **Individual Selection**
  - Not for – sex limited traits, slaughter traits, traits with low $h^2$
- **Progeny Selection**
- **Pedigree Performance**
  - 4-6 generations of ancestral records
- **Relatives' Performance**

# Bases of Selection

1. **Individual Selection:**

- Easiest, quickest, most common
- Best way when $h^2$ is high
- Generation interval is very low
- Minimum environmental effect – individuals will be in same environment
- If systematic records absent – best way

Multitrait selection – Considering whole individual instead of one trait

# Bases of Selection

## 1. Individual Selection:

Methods of individual selection:

1. Tandem Selection
2. Independent Culling Level
3. Selection Index

$$I = \sum b_i x_i$$

$b$ is the weightage (depends on $h^2$, economic value & genetic correlation)

# Bases of Selection

## 2. Pedigree Selection:

- Ancestral records – increase accuracy
- Useful for lowly heritable traits
- Performance of close relatives – better indicator than its own performance

Advantage:

- Less costly
- Selection at younger age
- Sex limited traits
- 2 individual – same performance, whom would you select?

# Bases of Selection

## 2. Pedigree Selection:

*Factors affecting pedigree selection:*

- Generation Interval
- Environmental variance
- Selection intensity

# Bases of Selection

3. **Family Selection**

- Traits : sex limited, slaughter traits, low $h^2$, disease resistance
- E.g. full sibs, half sibs, cousins, aunts
- Collateral relatives receive common genes
- Individuals which exceed the family means are selected (not the entire family)

# Bases of Selection

4. **Progeny Selection**

- Evaluating individuals based on their progeny performance
- Progenies compared to their contemporaries (born in same herd, same season, calved in the same time)
- Accuracy $\propto$ No. of progenies tested
- Mostly done for sires than females – why?
- Result of progeny testing is expressed as '*sire index*'.

# Bases of Selection

4. **Progeny Selection**

- *Advantages:*
  - Sex-limited, Slaughter traits can be selected
  - High selection intensity (S>>>)
  - Correct method to evaluate genotype
  - Prove that sire is free from recessive genes

# Bases of Selection

4. **Progeny Selection**

- *Disadvantages:*
  - High generation interval (in cattle)
  - Cost
  - $\Delta G/year$ –
  - Need to compare many sires
  - Only few males are progeny tested

# Correlated Response to Selection

**Indirect Selection:**

- When selection for one trait affects the phenotype of another trait, it is called correlated response to selection
- Can go two ways:
  - *Positive genetic correlation* –
    - halothane sensitivity gene in pigs is correlated with poor quality of meat
    - Egg weight and egg dimensions
  - *Negative genetic correlation* –
    - Milk yield and milk fat

# MCQs – Selection

1. Response to selection is the difference between mean phenotypic value of : (MPSC 2017)
   a) Offsprings and selected parents
   b) Offsprings of selected parents and parental population before selection
   c) Sire and dam
   d) Selected parents and base population before selection

2. Method is used for selection when several traits are considered simultaneously : (MPSC 2017)
   a) Individual selection
   b) Independent Culling Level
   c) Selection Index
   d) Tandom Selection

# MCQs – Selection

1. The difference of mean phenotypic value between the offspring of the selected parents and the whole of the parental generation before (MPSC 2019)
   a) Selection differential
   b) Response to selection
   c) Phenotypic average
   d) Genetic gain

2. The index selection is efficient over other methods of selection because it takes account of : (MPSC 2019)
   a) Heritability of traits
   b) Relative economic weights of traits
   c) Genetic and phenotypic variances and covariance of all traits
   d) All of the above

# MCQs – Selection

1. 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

2. 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

# MCQs – Selection

1. Osborne index (Kerala PSC 2023)
   a) High phenotypic variance
   b) High environmental variance
   c) Progeny evaluation
   d) Parity evaluation

2. 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

# MCQs – Selection

1. Traits having low $h^2$ can be improved through (JKPSC 2019)
   a) Family selection
   b) Individual selection
   c) Combined selection
   d) Tandem selection

2. Response to selection depends on (JKPSC 2019)
   a) Intensity of selection
   b) Correlation
   c) Regression
   d) Inbreeding

# MCQs – Selection

1. The method of selection used when inadequate information is available about the individual is (JKPSC 2019)

   a) Performance testing
   b) Progeny testing
   c) Pedigree selection
   d) Show ring testing

2. Selection differential depends on all except:

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

Q.6) Read the following statements

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) 1 and3

B) 3and2

C) 1 and4

D) 2and4 (JKPSC 2020)


THANK YOU!

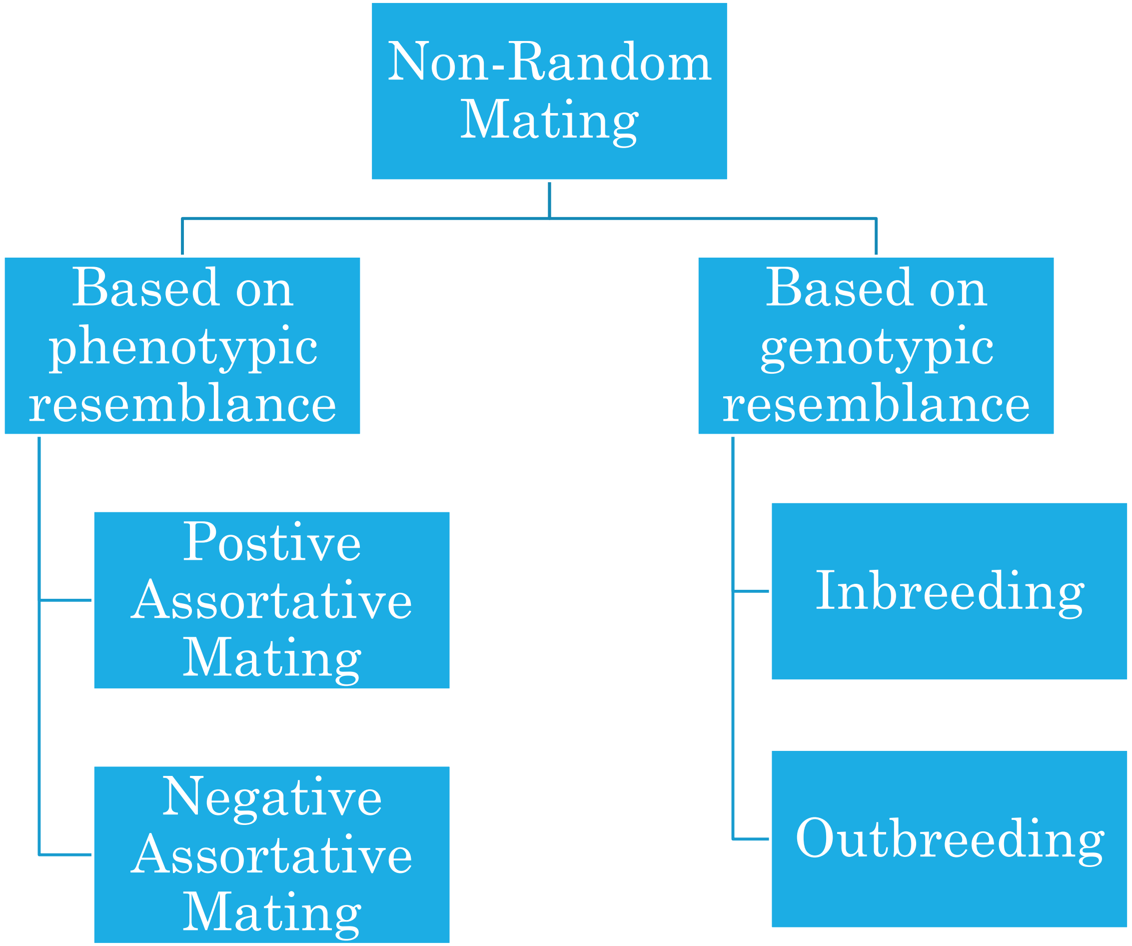
# L6:
# *Quantitative Genetics Concepts: Mating Systems*

*Inbreeding*

*Outbreeding*

# Mating Systems:

- Random Mating (Panmixia)
- Non-Random/Artificial Mating



# Inbreeding

- Mating of related individuals, having common ancestors in the pedigree upto 4-6 generations
- Classification:
  - Close inbreeding
  - Line breeding
  - Strain breeding

# Inbreeding

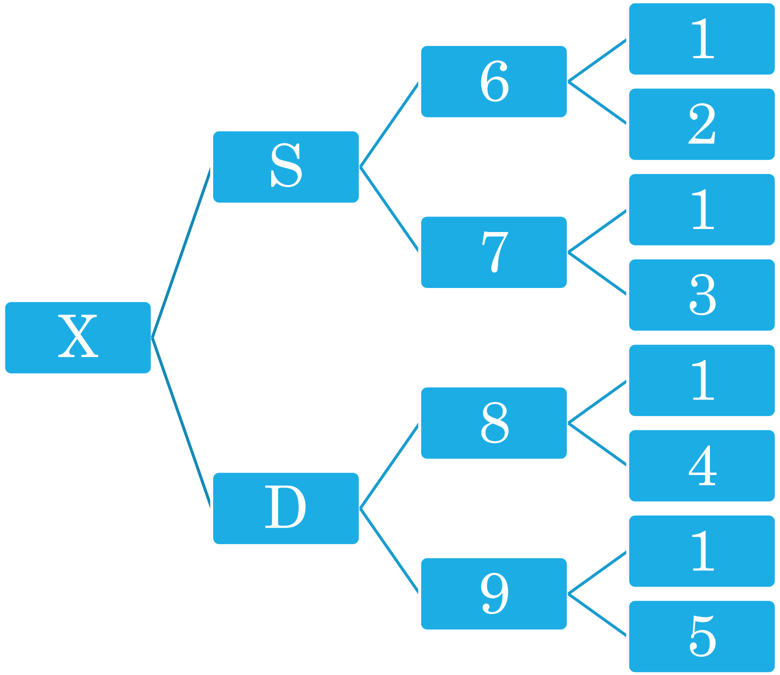
- ***Close inbreeding***
  - Mating between very close relatives – Full-sibs/parents-progeny
  - High homozygosity
  - Commonly used method 'full-sib mating'
  - Purpose:
    - Highly inbred lines
    - Discover undesirable genes
    - Get more uniform progeny

- ***Strain breeding***
  - Breeding within a population
  - No entry of new individuals for atleast 3-5 generations

# Inbreeding

- ***Line Breeding***
  - Milder form
  - Individuals within the line are related to one outstanding ancestor
  - Either mate with the ancestor, or with individuals who are related to the ancestor

Pedigree




Arrow Diagram

# Inbreeding

***Inbreeding Depression***

- Reduction in the performance of the progeny below the average of their parents
- Unfavourable gene combination influencing polygenic traits
- Opposite to hybrid vigour
- Noticeable for fitness traits especially

Question:

Is inbreeding depression heritable?

# Outbreeding

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

# Outbreeding

Hybrid Vigour/Heterosis

- Increased phenotypic value of progeny over the average of its parents is called heterosis
- Favourable gene combination value (non-additive dominance & interaction)
- Genetic basis: Dominance, Overdominance, Epistatic theory

# Outbreeding

Types of Outbreeding:

1. Outcrossing
2. Crossbreeding
3. Top crossing
4. Line crossing
5. Grading up
6. Species hybridisation

# Outbreeding

***Crossbreeding:***

- Crossbreeding
  - Regular/Systematic Crossing
    - Specific Crossing
      - Two breed cross
        - Purebred
        - Inter se mating
        - Back crossing
      - Three breed cross
      - Four breed cross
    - Rotational Crossing
      - Rotational criss crossing
      - Three way rotational crossing
      - Four-way rotational crossing
  - Composite Crossing (produces synthetic breeds)

# Outbreeding

***Crossbreeding – Systematic Crossing:***

1**. Specific Crossing:**

1. Two breed cross
   - Pure breds:
     $A \times B \rightarrow AB$ ; progenies are heterozygous, show 100% heterosis
   - *Inter se* mating:
     $F_1 \times F_1$ - creation of new genetic groups
   - Back crossing – $F_1 \times Parent$ $(P1$ or P2)
     Utilisation of maternal or paternal heterosis
2. Three breed cross
3. Four breed cross

# Outbreeding

***Crossbreeding – Systematic Crossing:***

**Specific Crossing:**

1. Two breed cross
2. Three breed cross:
   - $A \times B \rightarrow AB \times C \rightarrow ABC$
   - F1 female crossed with another breed
   - Full utilisation of maternal and individual heterosis in F2
3. Four breed cross

# Outbreeding

***Crossbreeding – Systematic Crossing:***

**Specific Crossing:**

1. Two breed cross
2. Three breed cross
3. Four breed cross/Double two breed cross
    1. Crossbred females from two breeds × Crossbred males from two other breeds
    2. $AB \times \mathrm{CD} \rightarrow ABCD$
    3. Full exploitation of both maternal and paternal heterosis

*Demerit of specific crossing:*

*Separate pure bred population of animals needs to be maintained to generate heterosis in progeny*

# Outbreeding

***Crossbreeding – Systematic Crossing:***

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*Demerit of specific crossing:*

*Separate pure bred population of animals needs to be maintained to generate heterosis in progeny*

# Outbreeding

***Crossbreeding – Systematic Crossing:***

## Rotational Crossing:

Males of two or three breeds used in regular sequence in successive generations on crossbred females of previous generations

*Advantage : All female crossbreds obtained from the programme itself*

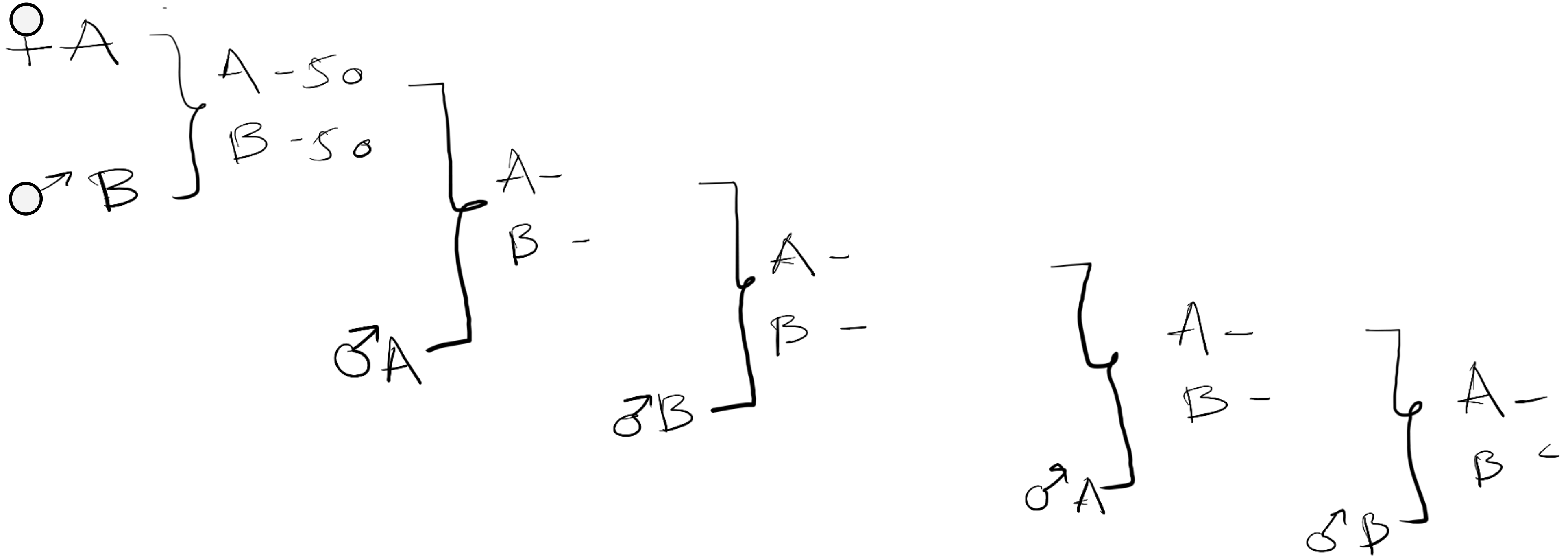
- Used in pig breeding for producing hybrids for sale
- No exploitation of complementarity
- Used for populations: less complementarity but high heterosis

# Outbreeding

***Crossbreeding – Systematic Crossing:***

## Rotational Crossing:

1. Rotational criss-crossing –
2. At equilibrium – 2/3rd inheritance from immediate sire's breed, 1/3rd from the other breed



# Outbreeding

***Crossbreeding – Systematic Crossing:***

**Three way rotational Crossing:**

- Rotational criss-crossing  with three breeds
- First generation of female crossbreds with male of third breed

# Outbreeding

***Crossbreeding – Systematic Crossing:***

**Three way rotational Crossing:**

- Rotational criss-crossing  with three breeds
- First generation of female crossbreds with male of third breed
- At equilibrium –
  - 4/7 inheritance from breed of immediate sire
  - 2/7 inheritance from breed of maternal grandsire
  - 1/7 inheritance from the third breed

# Outbreeding

***Composite breeds***

| S.No. | Synthetic Breed | Breeds Used | | Remarks |
|---|---|---|---|---|
| 1 | Karan Swiss | Brown Swiss | Red Sindhi, Sahiwal | Developed at NDRI, Karnal |
| 2 | Karan Fries | HF | Tharparkar | Developed at NDRI, Karnal |
| 3 | Frieswal | HF | Sahiwal | Developed at Military Dairy Farms |
| 4 | Jerthar | Jersey bulls | Tharparkar cows | Developed at Bangalore |
| 5 | Jersind | Jersry | Red Sindhi | Developed at Allahabad Agriculture institute |
| 6 | Santa Gertrudis | Shorthorn | Brahman | |

# Outbreeding

Species hybridisation:

| S. No. | Hybrid | Species Involved | |
|---|---|---|---|
| 1. | Mule | | |
| 2. | Hinny | | |
| 3. | Zebroid | | |
| 4. | Cattalo | | |
| 5. | Pien niu | | |
| 6. | Liger | | |
| 7. | Geep | | |

# Outbreeding

Species hybridisation:

| 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* cow |
| 5. | Pien niu | Male cattle | Female yak |
| 6. | Liger | Male lion | Female tiger |
| 7. | Geep | Male sheep | Female goat |

# Combining ability

- Animals with same genotype can produce different phenotypes in the same environment
- Reason: Type of gene action – Additive / Non-additive
- We know that,

$$V_P = V_A + V_D + V_I + V_E$$

# Combining ability

- Animals with same genotype can produce different phenotypes in the same environment
- Reason: Type of gene action – Additive / Non-additive
- We know that,

$$V_P = V_A + V_D + V_I + V_E$$

Continuous selection – $V_A$ gets exhausted – selection response declines

Some traits – $V_D$ and $V_I$ induce variation

# Combining Ability

## *General Combining Ability (GCA)*

- The average performance of a parent in hybrid combinations
- Indicative of the ability of the parent to transmit desirable genes to its offspring
- Used to identify superior parents in breeding programmes
- GCA effects – due to additive gene action
- High GCA – Parents' ability to produce superior progeny when crossed with another variety

# Combining Ability

***Specific Combining Ability (SCA)***

- The performance of a particular cross, as deviating from the average GCA of the two lines
- SCA effects due to non-additive gene action
- Used to identify superior cross/hybrid combinations
- Important for traits which show heterosis

# Combining Ability

***Diallel Mating***

- All possible mating combinations between several genotypes
- Greek. *Diallelos* – crossing each other
- Calculation of GCA and SCA effects

# RS and RRS

**Recurrent Selection (RS)**

- Highly inbred line × Tester Line
- Evaluate the test cross progeny and select parents from the tester line
- Used for improving single lines
- Effective for traits with high $h^2$
- Focuses on either GCA or SCA

# RS and RRS

# RS and RRS

**Reciprocal Recurrent Selection (RRS)**

- Two highly inbred lines crossed
- Progeny evaluated to select parents from both lines
- Improves GCA of each population and SCA between two populations

# People who coined terms

| Term | Scientist |
|---|---|
| GCA | Sprague and Tatum (1942) |
| SCA | Sprague and Tatum (1942) |
| Heterosis | G.H.Shull (1914) |
| Recurrent Selection | Hull (1945) |
| Reciprocal Recurrent Selection | Comstock *et al.* (1949) |

# MCQ – Mating Systems

- General combining ability calculated in a diallel mating is indicative of

(A) Overdominance

(B) Epistasis

(C) Non-additive genetic effect

(D) Additive genetic effect

# MCQ – Mating Systems

- General combining ability calculated in a diallel mating is indicative of

(A) Overdominance

(B) Epistasis

(C) Non-additive genetic effect

(D) Additive genetic effect

# MCQ – Mating Systems

- Continuous use of purebred sire on non- descript female is

(A) Cross breeding

(B) Top crossing

(C) lnter se mating

(D) Grading up

# MCQ – Mating Systems

- The Father of animal breeding is

(A) Gregor John Mendel

(B) T.H. Morgon

(C) Robert Bakewell

(D) Watson Crick

# MCQ – Mating Systems

1. A new breed can be evolved by:

(A) Grading up

(B) Out crossing

(C) Cross-breeding

(D) Inbreeding

# MCQ – Mating Systems

1. As inbreeding progresses, proportion of heterozygote will:

(A) Increase

(B) Decrease

(C) Both

(D) None

# MCQ – Mating Systems

1. Which type of mating should be preferred for the improvement of non-descript animals?

- (A) Inbreeding
- (B) Line breeding
- (C) Upgrading
- (D) All of the above

# MCQ – Mating Systems

1. Inbreeding coefficient measures:

- (A) Heterozygosity
- (B) Homozygosity
- (C) Cross-breeding
- (D) None of the above

# MCQ – Mating Systems

- The mean performance of line when expressed as the deviation from the mean of all crosses is:

A) General combining ability of line

B) Average effect of the line

C) General and Specific combing ability of line

D) Specific combing ability of line

# MCQ – Mating Systems

- Which of the following species was first domesticated by human beings?

A) Cattle

B) Sheep

C) Dog

D) Goat

# MCQ – Mating Systems

- Which of the following about heterosis is not true?

a) Term coined by G H Shull

b) Depends on difference of gene frequency

c) Might be caused by Overdominance

d) Independent of degree of dominance

# MCQ – Mating Systems

- . Maximum heterosis is observed in

(1) base population

(2) F1 generation

(3) F2 generation

(4) F3 generation

# MCQ – Mating Systems

- Diallele crossing is usually practiced in

(1) Cattle

(2) Sheep

(3) Camel

(4) Poultry

# MCQ – Mating Systems

- Full sib and half sib mating in poultry and parent offspring or uncle- cousin mating in swine is most commonly used in
- (1) Outcrossing
- (2) Inbreeding
- (3) Pure breeding
- (4) Strain crossing

# MCQ – Mating Systems

- Which of the following system of breeding enlightens the less desirable recessive genes?

(A) Cross breeding

(B) Grading up

(C) Inbreeding

(D) Species hybridization

# MCQ – Mating Systems

The outcrossing within a herd by use of selected sire is called :

(1) Upgrading

(2) (2) Line breeding

(3) (3) Selective breeding

*(4)* *(4)* Back crossing

# MCQ – Mating Systems

1. Which breeding is used to overcome inbreeding depression?

a) Out-crossing

b) Cross-breeding

c) Interspecific hybridization

d) Inbreeding

# MCQ – Mating Systems

. In a random mating population, the maximum heterozygosity is expressed when one of the gene frequency is

(A) 0.2

(B) 0.7

(C) 0.9

(D) 0.5


THANK YOU!

# AGB
# Lecture – 7
# *Breeds of Livestock Species*

*Cattle*

*Buffalo*

*Sheep*

*Goat*

*Pigs*

*Poultry*

# NBAGR Registered Breeds

| Species | Number of Registered Breeds |
|---|---|
| Cattle | 54 |
| Buffaloes | 21 |
| Goat | 41 |
| Sheep | 46 |
| Chicken | 20 |
| Pig | 15 |
| Yak | 2 |
| Horse and pony | 8 |
| Camel | 9 |
| Donkey | 4 |
| Duck | 4 |
| Geese | 1 |
| Dog | 5 |

Total - 230

Including 1 synthetic dairy cattle

# 10 Newly Registered Breeds 2025 -

| Species | Breed | Native Tract | Characteristics |
|---|---|---|---|
| Buffalo | Manah | Assam | Dual purpose – Daily milk yield 1.75 kg (avg) |
| Dog | Gaddi | Himachal Pradesh | Named after the Gaddi tribe, guarding dog |
| | Changakhi | Ladakh | Guarding dog for livestock from snow leopards, other predators |
| Donkey | Ladakhi | Ladakh | High altitude transportation; Adults: male (82 kg), female (78 kg) |
| Duck | Tripureshwari | Tripura | Egg & meat purpose; Avg body wt: 1.999 (12 m), egg prod. 70-101/yr |
| Goat | Chaugarkha | Uttarakhand | Kumaoni goat – Almora, Nainital, Champawat areas<br>- Mutton purpose |
| | Bundelkhandi | UP & MP | Meat purpose, black coloured, adapted to cover long distances while grazing |
| Sheep | Kheri | Rajasthan | Tall, majestic look; walk long distances, survive in fodder scarcity |
| Pig | Karkambi | Maharashtra | Pune, Satara, Solapur; scavenging system; litter size (2-10) |
| Yak | Ladakhi | Ladakh | Medium size (250 kg male, 183 kg female – adult body wt.) |

# Newly Registered Breeds - 2025

Manah Buffalo

Gaddi Dog

# Newly Registered Breeds - 2025

Changakhi Dog

Tripureshwari Duck

# Newly Registered Breeds - 2025

Chaugarkha Goat

Bundelkhandi Goat

# Newly Registered Breeds - 2025

Kheri Sheep

Karkambi Pig

# Newly Registered Breeds - 2025

Ladakhi Yak

Ladakhi Donkey

# Newly Registered Breeds – 2022

- Ten Breeds:

| Species | Breed | State |
|---|---|---|
| Cattle | Kathani | Maharashtra |
| | Sanchori | Rajasthan |
| | Masilum | Meghalaya |
| Buffalo | Purnathadi | Maharashtra |
| Goat | Sojat | Rajasthan |
| | Karauli | Rajasthan |
| | Gujari | Rajasthan |
| Pig | Banda | Jharkhand |
| | Manipuri Black | Manipur |
| | Wak Chambil | Meghalaya |

# Newly Registered Breeds – 2023

- Eight Breeds:

| Species | Breed | State |
|---|---|---|
| Chicken | Aravali | Gujarat |
| Duck | Andamani | Andaman & Nicobar |
| Goat | Anjori | Chattisgarh |
| | Andamani | Andaman & Nicobar |
| Horse | Bhimthadi | Maharashtra |
| Pig | Andamani | Andaman & Nicobar |
| Sheep | Macherla | Andhra Pradesh |
| Synthetic Cattle | Frieswal | Uttar Pradesh, Uttarakhand |

# 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 |

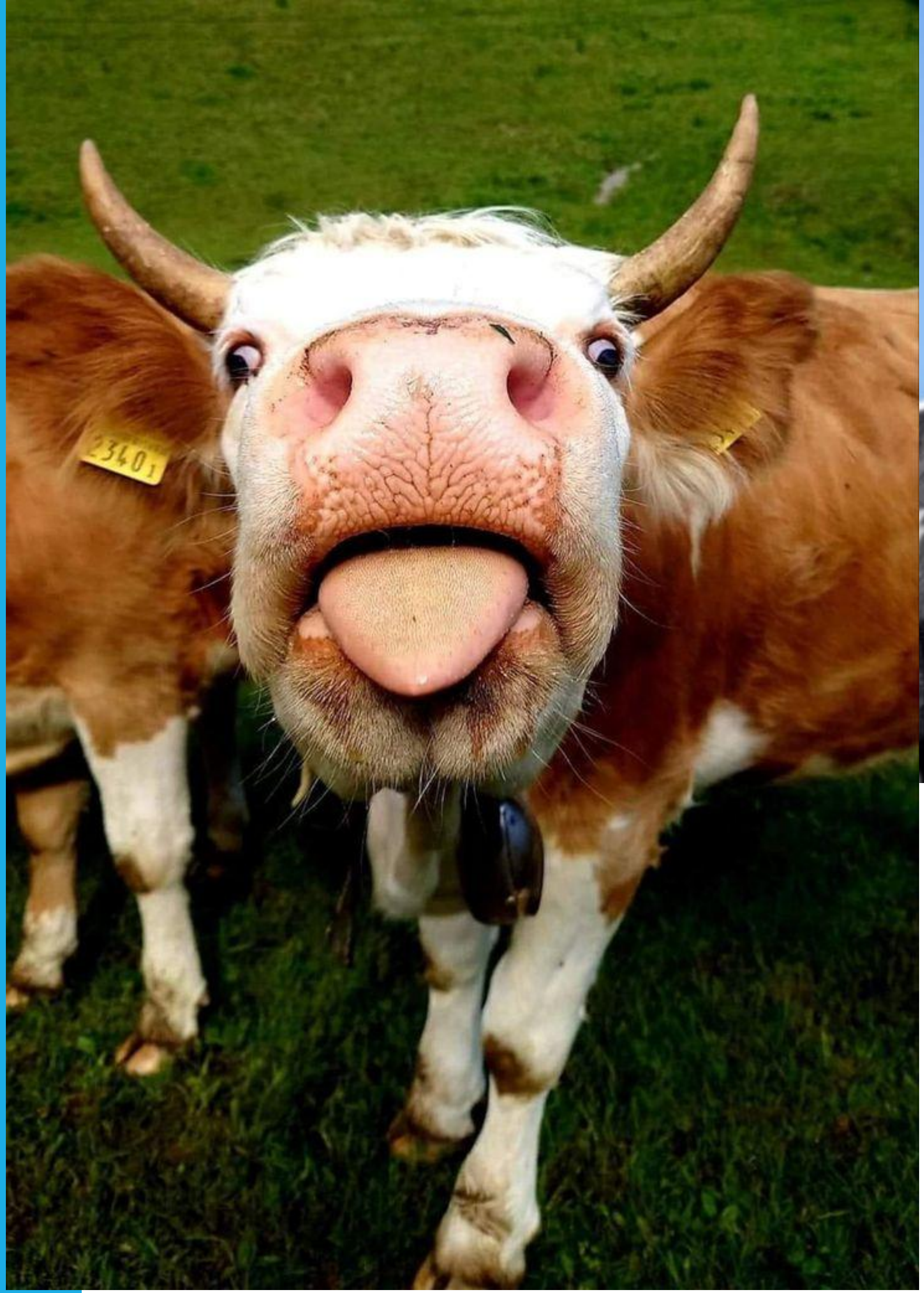
# Newly Registered Breeds

| Sheep | State |
|---|---|
| Kajali | Punjab |
| Macherla | Andhra Pradesh |
| **Pigs** | **State** |
| Mali | Tripura |
| Purnea | Bihar, Jharkhand |
| Banda | Jharkhand |
| Manipuri Black | Manipur |
| Wak chambil | Meghalaya |
| Andamani | Andaman & Nicobar |

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

# Species 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 |



# Cattle Breeds

# Indigenous Cattle – Classification

| Group | Characteristics | Breeds |
| --- | --- | --- |
| Group I | Broad face, lyre horns<br>Flat dished forehead<br>Western India | Kankrej, Kherigarh, Malvi, Tharparkar, Kenkatha, Ponwar, Dagri |
| Group II | Convex face, white/ light grey, short horn<br>Coffin shaped skull | Hariana, Ongole, Bachaur, Gaolao, Krishna valley, Mewati, Nagori, Rathi |
| Group III | Heavy bull, even curled horn<br>Pendulous sheath , Spotted red/white | Gir, Sahiwal, Red sindhi, Deoni, Dangi, Nimari |
| Group IV | Medium sized, Long horn up to back<br>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 |

# Indigenous Cattle – Classification

| | |
|---|---|
| Milch (1500-2000 L) | • Gir, Sahiwal, Red Sindhi, Rathi, Tharparkar |
| Dual Purpose (1200-1500 L) | • Hariana, Kankrej, Ongole, Deoni, Nimari, Dangi, Mewati, Rathi, Red Kandhari, Kathani |
| Draught (<500 L) | • Hallikar, Kenkatha, Amritmahal, Bargur, Nagori, Bachur, Malvi, Kherigarh, Kangayam, Ponwar, Siri, Gaolao, Krishna Valley, Umblacherry, Pulikulam |

# Indigenous Cattle – Specifics

| 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 |
| Punganur | Dwarf cattle |
| Umblacherry | Excellent for wet ploughing |
| Siri | Dual purpose, high altitude breed |

# Exotic Cattle Breeds – Milch Breeds

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

# Exotic Cattle Breeds – 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 | Composition | Origin |
|---|---|---|
| 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 | |

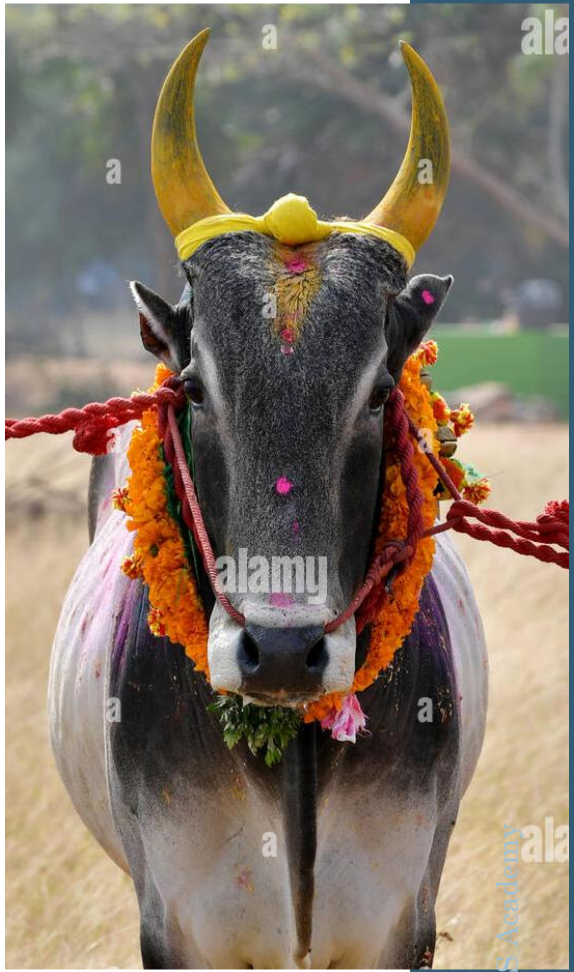
# Best breeds, Peculiarities and Special horns

| 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 |

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

# Special ho

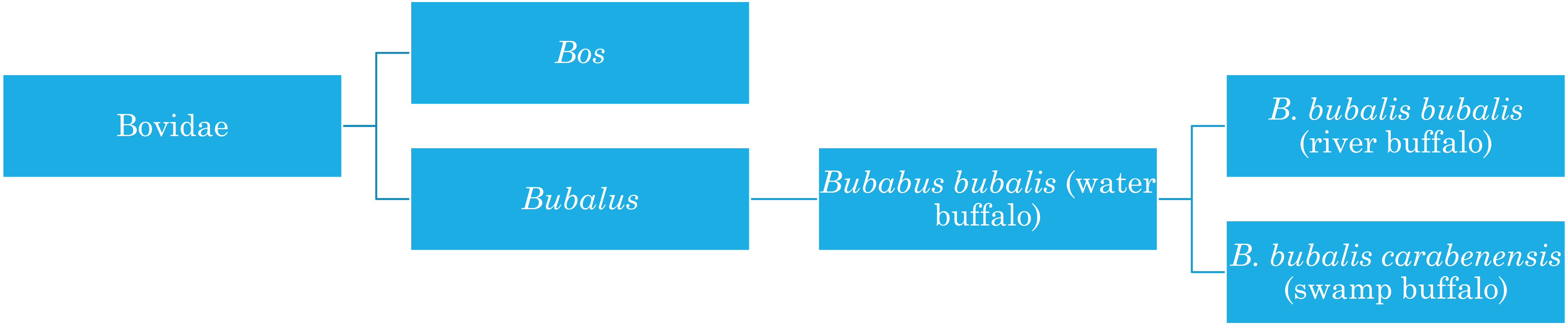
| Horns | Breed |
| --- | --- |
| Half Moon Shaped | Gir |
| Bow Shaped | Khillari |
| Lyre Shaped | Kankrej, Malvi, Ponwar |
| Crescent shaped | Punganur, Kangayam |
| Spiral horn | Nari<br>(backward curl – females<br>Forward curl – males) |

Long drooping ear – Red Kandhari
Leaf like ear – Gir

# Buffalo Breeds

# Buffalo Breeds



# Buffalo Breeds

20 registered breeds with NBAGR

1. Banni (Gujarat)
2. Bargur (Tamil Nadu)
3. Bhadawari (Uttar Pradesh and Madhya Pradesh)
4. Chhattisgarhi (Chhattisgarh)
5. Chilika (Odisha)
6. Dharwadi (Karnataka)
7. Gojri (Punjab and Himachal Pradesh)
8. Jaffarabadi (Gujarat)
9. Kalahandi (Odisha)
10. Luit (Swamp) (Assam)
11. Manda (Odisha)
12. Marathwadi (Maharashtra)
13. Mehsana (Gujarat)
14. Murrah (Haryana and Delhi)
15. Nagpuri (Maharashtra)
16. Nili Ravi (Punjab)
17. Pandharpuri (Maharashtra)
18. Purnathadi (Maharashtra)
19. Surti (Gujarat)
20. Toda (Tamil Nadu)

# Classification

| Group | Breed |
| --- | --- |
| Murrah Group | Murrah, Nili Ravi, Godavari |
| Gujarat Group | Surti, Jaffrabadi, Mehsana, Banni |
| Uttar Pradesh Group | Bhadawari, Tarai |
| Central India Group | Nagpuri, Pandharpuri, Mandi, Jerangi, Kalahandi, Sambalpuri |
| South India Group | Toda, South Kanara |

# Classification

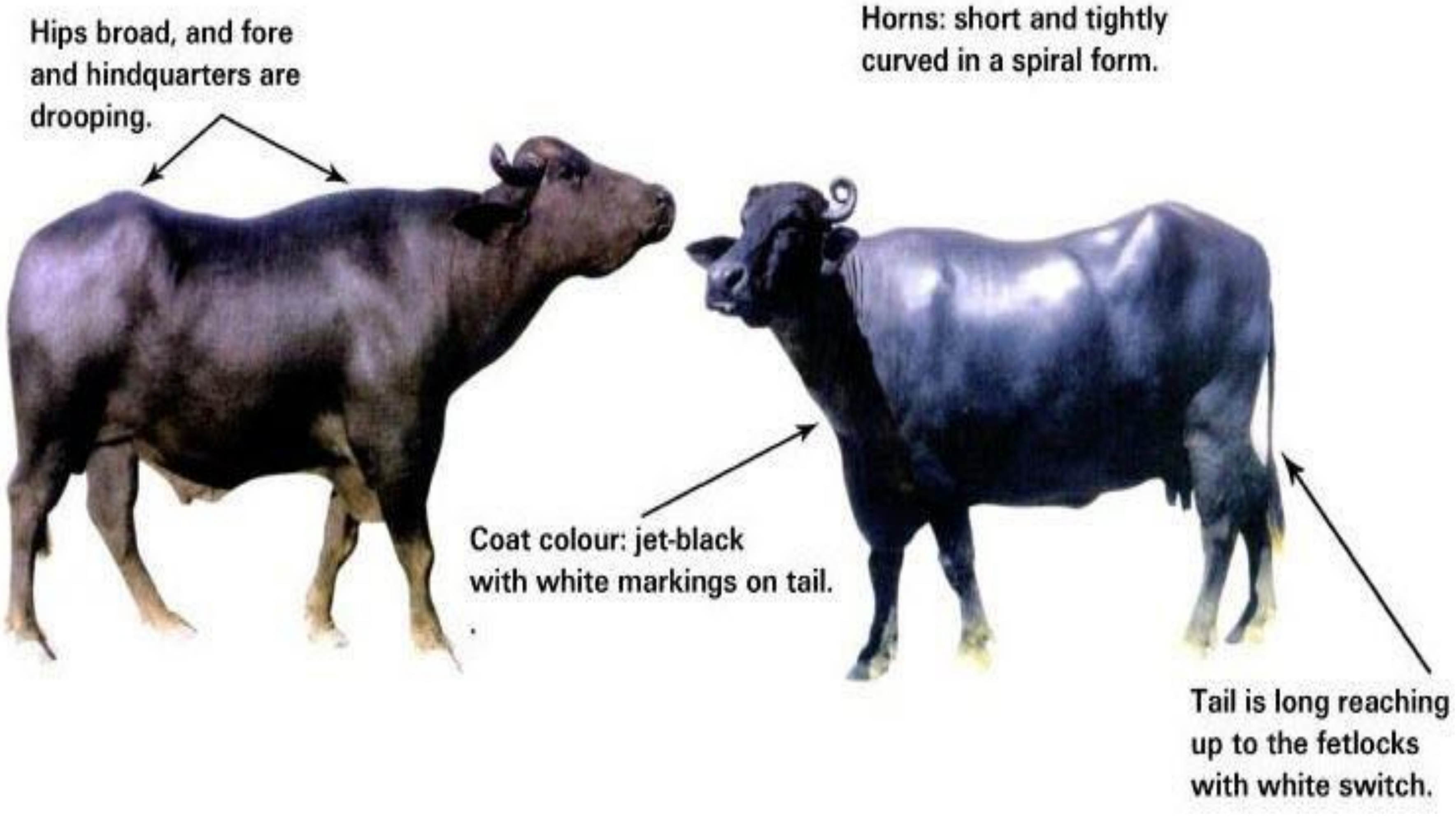
| Group | Breed |
| --- | --- |
| Murrah Group | Murrah, Nili Ravi |
| Gujarat Group | Surti, Jaffrabadi, Mehsana, Banni |
| Uttar Pradesh Group | Bhadawari, Tarai |
| Central India Group | Nagpuri, Pandharpuri, Manda, Jerangi, Kalahandi, Chattisgarhi |
| South India Group | Toda, South Kanara |

| State | Breed |
| --- | --- |
| Odisha | Chilika<br>Kalahandi<br>Manda |
| Gujarat | Banni |
| Assam, Mizoram, Manipur (Brahmaputra valley) | Luit Buffalo (Swamp) |
| Punjab, Himachal Pradesh (Gujjar community) | Gojri |
| Karnataka | Dharwadi |

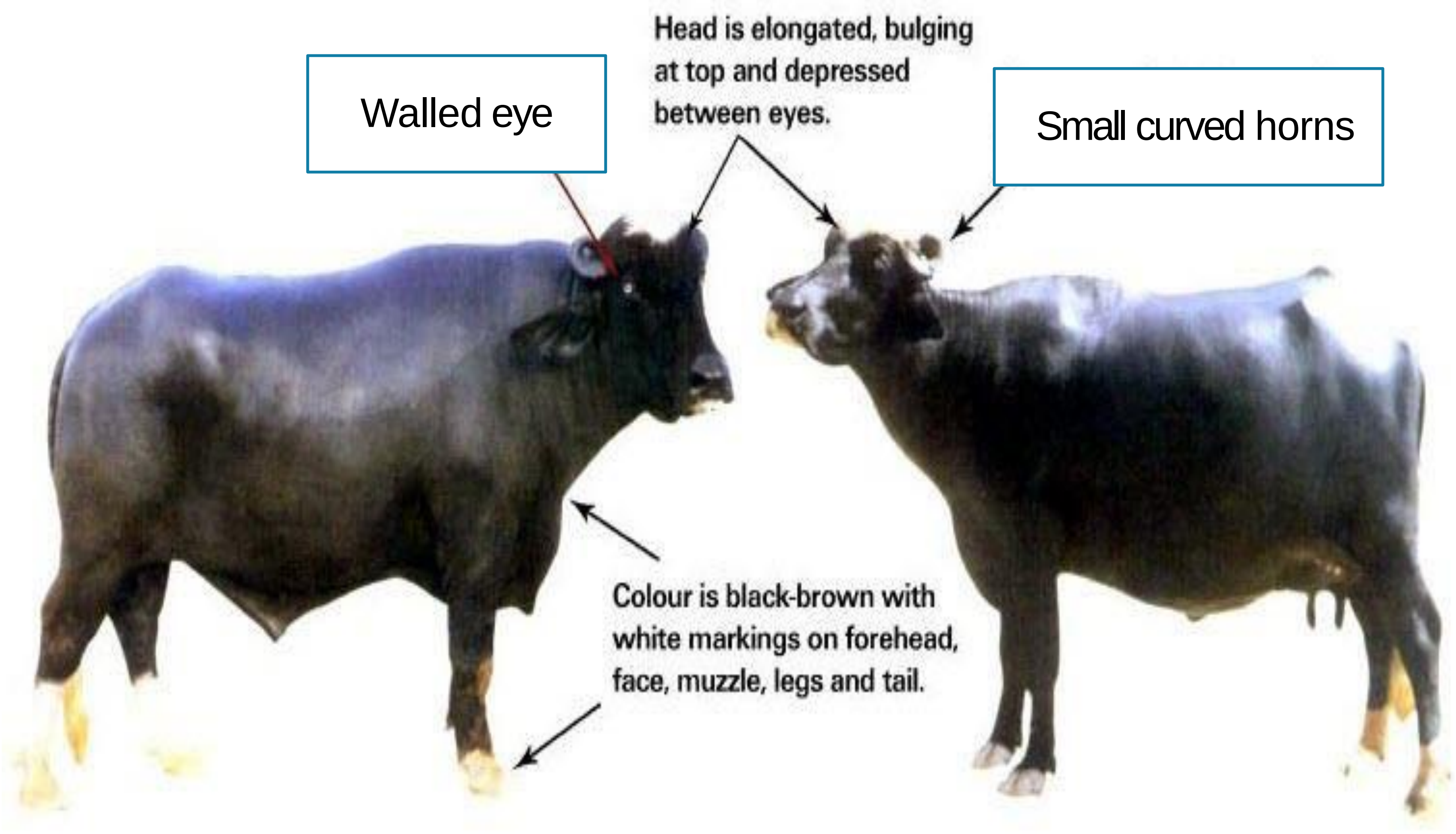
# Breed Characteristics

| Breed | Origin | Characteristics | Specifics/Peculiarities | Remarks |
| --- | --- | --- | --- | --- |
| Murrah (Kundi/Kali) | Rohtak, Hisar | Jet black, tail reaches fetlock | Most efficient milker,<br>Tightly curled horns | 1500-2000 kg milk with 7% fat |
| Nili Ravi<br><br>(Panch Kalyani/ Panch Bhadra) | Punjab, Pakistan | Small horns, tightly coiled,<br>White markings on body | Wall eyes<br>Lowest fat (4%) | Milk yield: 1500-1850 kg/lactation |
| Jaffarabadi | Gir forest, Gujarat | Black in colour,<br>Prominent forehead | Heaviest buffalo breed<br>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<br>Highest fat percentage | MY : 800-1000 kg<br>Fat content: 6-12.5% |

# MURRAH

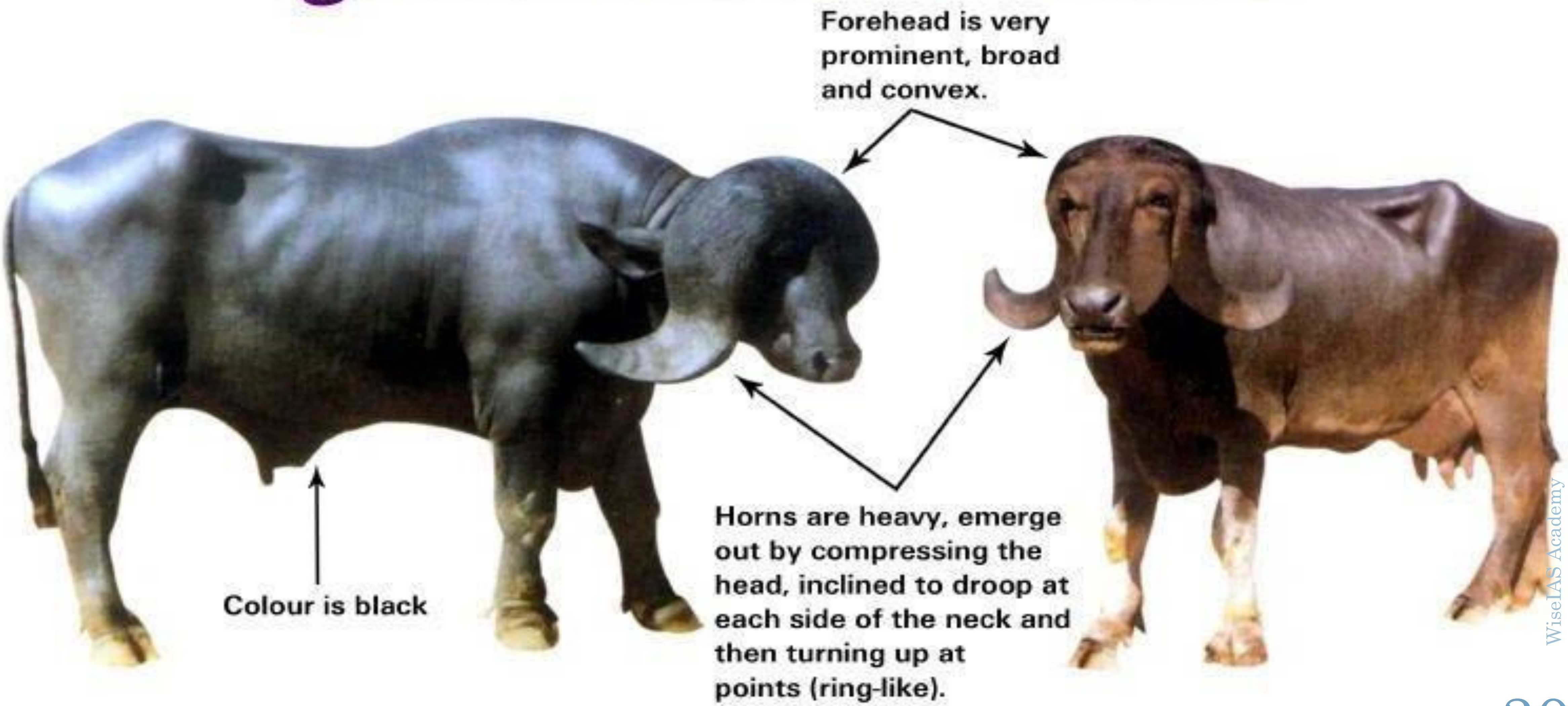

Hips broad, and fore and hindquarters are drooping.
Horns: short and tightly curved in a spiral form.
Coat colour: jet-black with white markings on tail.
Tail is long reaching up to the fetlocks with white switch.

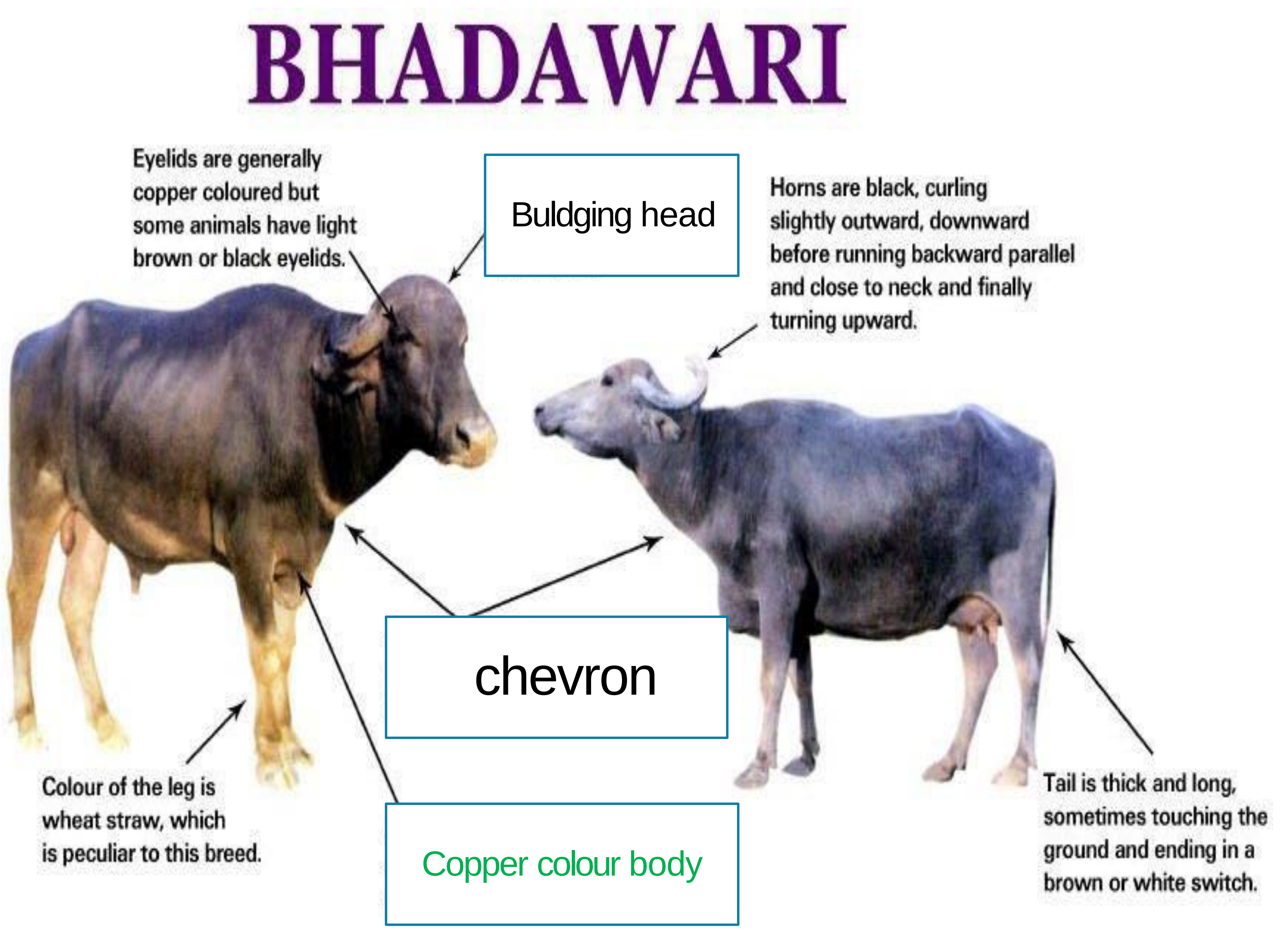
# NILI-RAVI



Walled eye
Head is elongated, bulging at top and depressed between eyes.
Small curved horns
Colour is black-brown with white markings on forehead, face, muzzle, legs and tail.

# JAFFARABADI

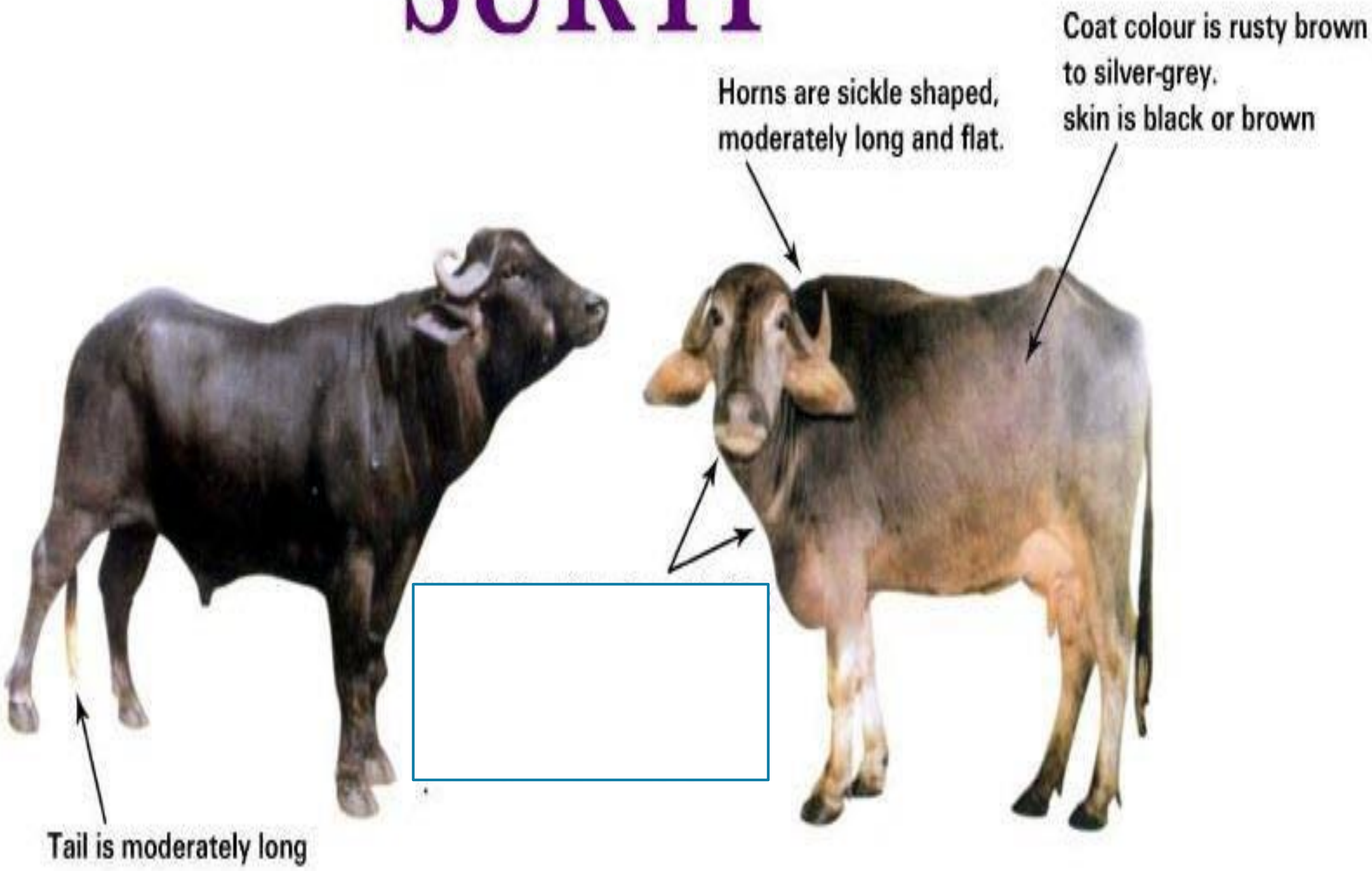



BHADAWARI
Eyelids are generally copper coloured but some animals have light brown or black eyelids.
Buldging head
Horns are black, curling slightly outward, downward before running backward parallel and close to neck and finally turning upward.
chevron
Colour of the leg is wheat straw, which is peculiar to this breed.
Copper colour body
Tail is thick and long, sometimes touching the ground and ending in a brown or white switch.

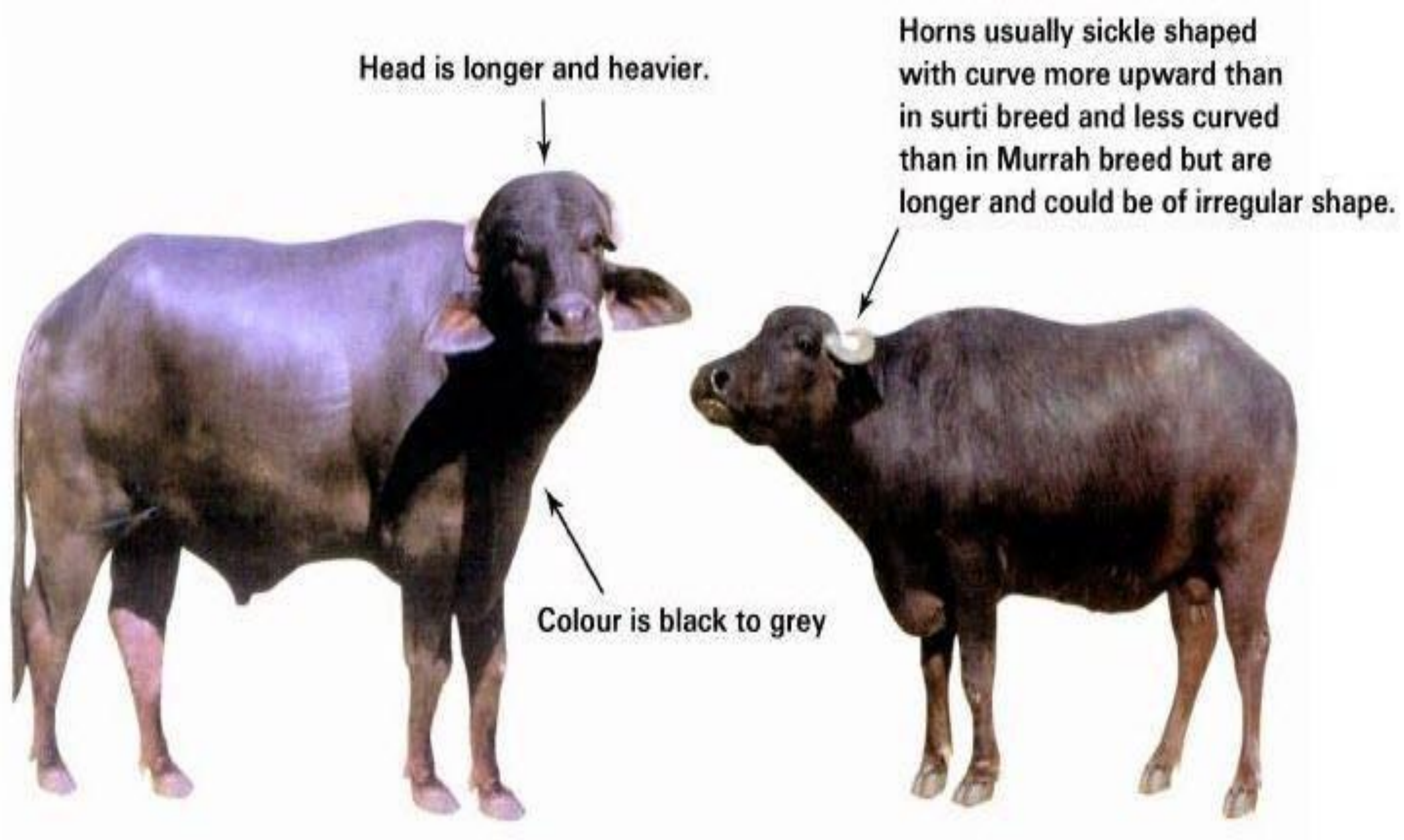
# Breed Characteristics

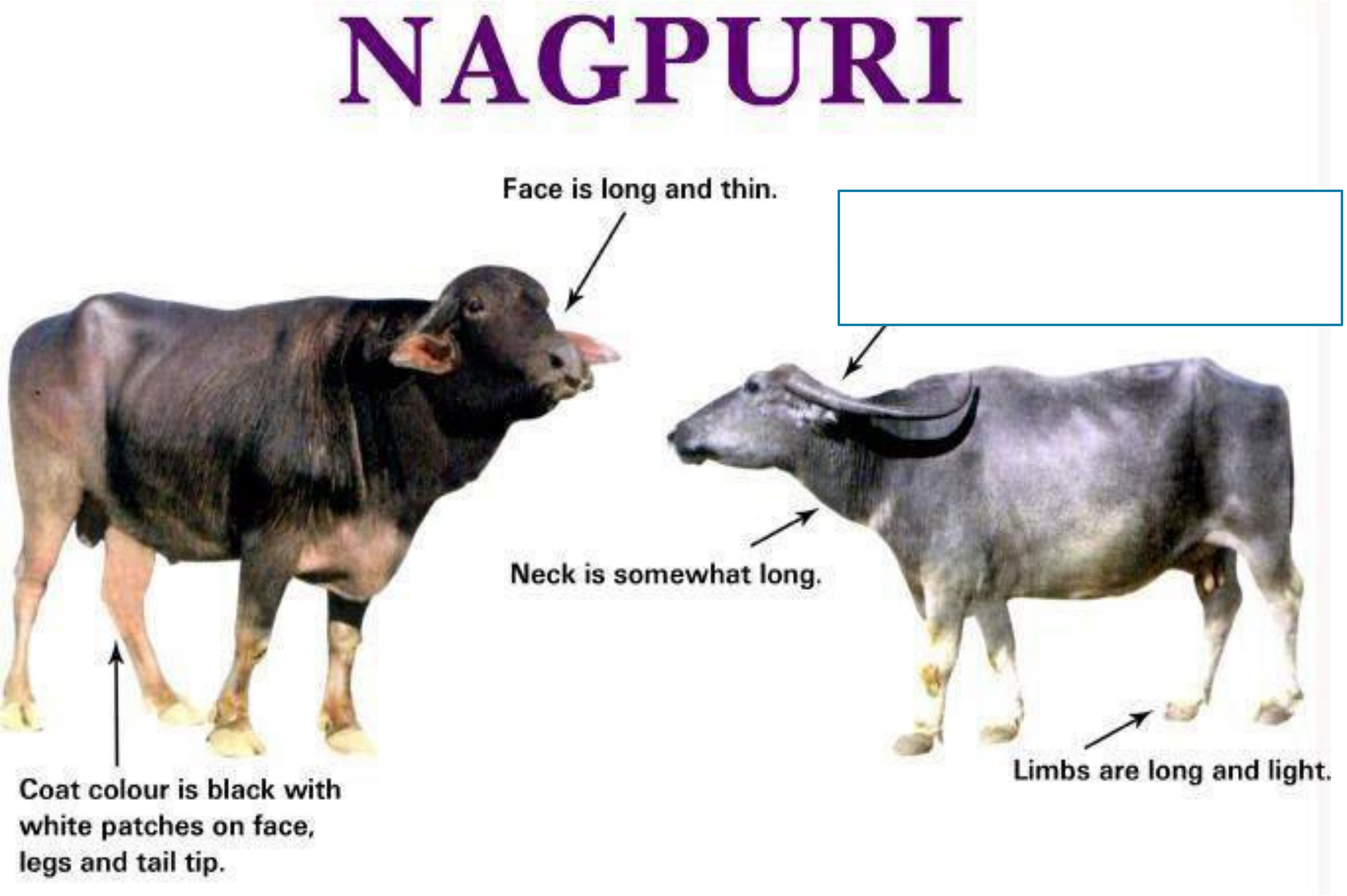
| Breed | Origin | Characteristics | Specifics/Peculiarities | Remarks |
|---|---|---|---|---|
| Surti | Baroda, Gujarat | Colour: rusty brown to silver grey,<br>Two white collars (jaw & brisket) | Sickle shaped horns | 900-1300 kg MY<br>8-12% far (high fat percent) |
| Mehsana (Surti X Murrah) | Mehsana, Gujarat | Black/brown colour | Longest Lactation | MY: 1200-1500 kg<br>Good lactation persistency<br>'Amul Milk' |
| Nagpuri | Maharashtra | Black with white patches (face, legs, tail)<br>Long thin face, long neck | Sword shaped horns | MY: 700-1200 kg |
| Pandharpuri | Maharashtra | | Sword Shaped horns | Longer letting down period |

# SURTI


Horns are sickle shaped,
moderately long and flat.
Coat colour is rusty brown
to silver-grey.
skin is black or brown
Tail is moderately long

# MEHSANA


Head is longer and heavier.
Horns usually sickle shaped with curve more upward than in surti breed and less curved than in Murrah breed but are longer and could be of irregular shape.
Colour is black to grey

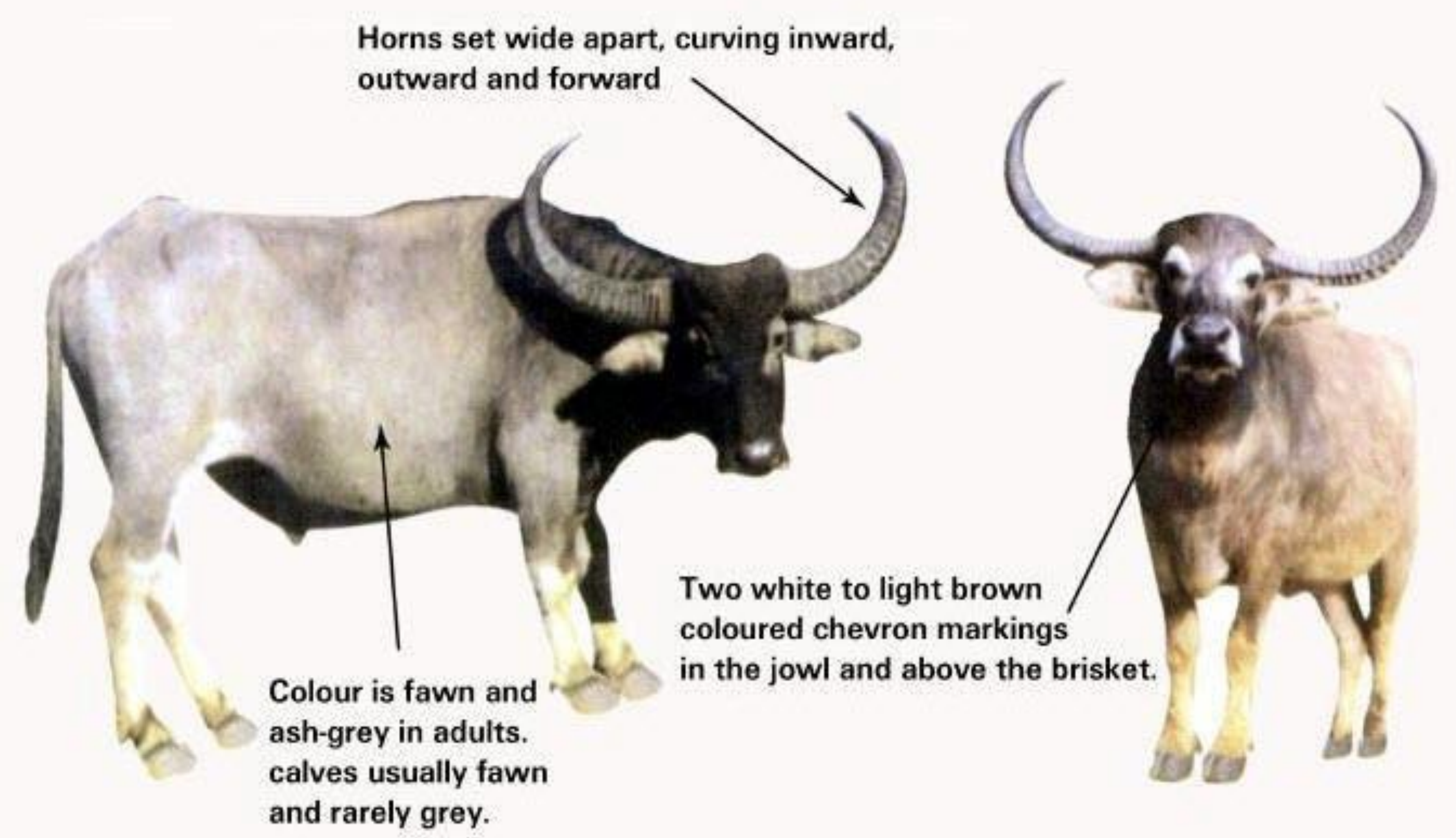

NAGPURI
Face is long and thin.
Neck is somewhat long.
Limbs are long and light.
Coat colour is black with white patches on face, legs and tail tip.


Sword shape horn

# Breed Characteristics

| Breed | Origin | Characteristics | Specifics/Peculiarities | Remarks |
|---|---|---|---|---|
| Toda | Nilgiri, Tamil Nadu | Fawn, ash grey colour,<br>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 |

# TODA


Horns set wide apart, curving inward, outward and forward
Colour is fawn and ash-grey in adults. calves usually fawn and rarely grey.
Two white to light brown coloured chevron markings in the jowl and above the brisket.

# Banni Buf

# Buffalo Special

| 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 |

# Pig Breeds

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

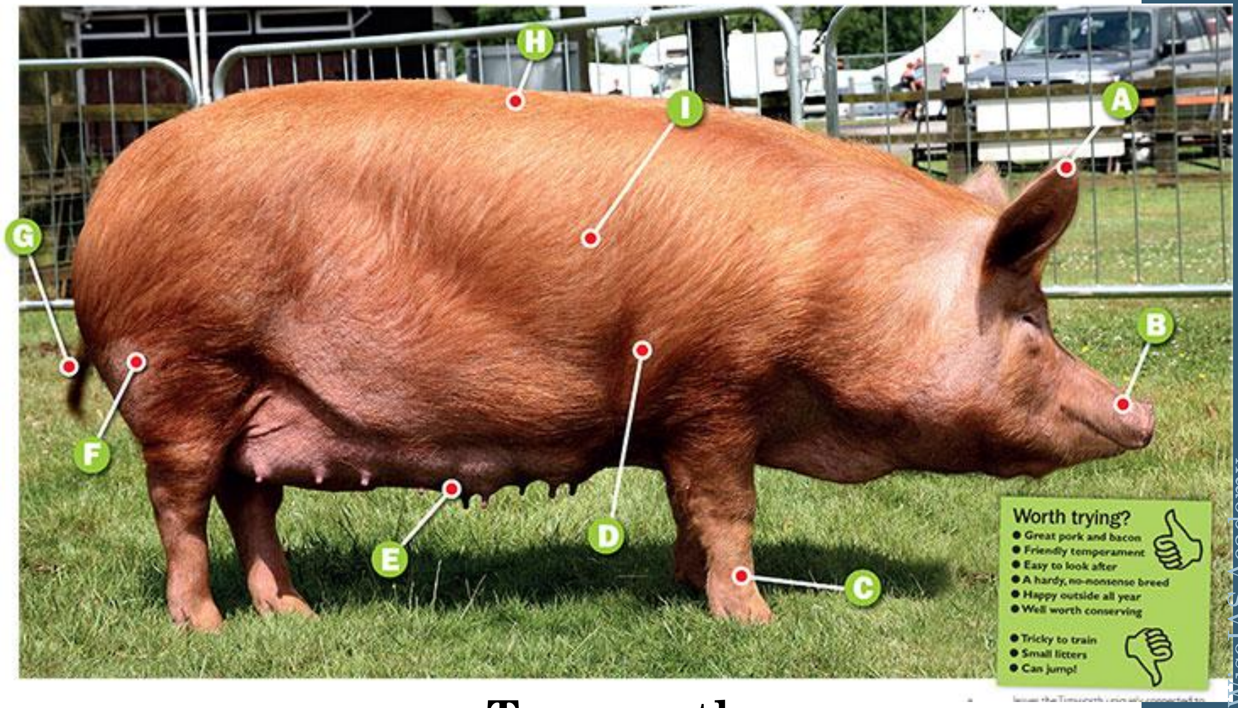

Large white
Yorkshire


Middle white Yorkshire


Hampshire Pig


Berkshire

**Duroc**




**Tamworth**

# Indigenous Pig Breeds

| Breed | Origin | Characteristics |
|---|---|---|
| Ghungroo | North Bengal, Assam | Black colour, pendulous ear,<br>Highly prolific – 6-10 piglets |
| Niang Megha | Meghalaya | Black, star shaped white patches on forehead<br>50-60 kg adult body weight |
| Andamani | Andaman & Nicobar | Adult body weight 68-70 kg, Black/rusty gray |
| Banda | Jharkhand | Pork, manure type;<br>Adult body weight 27-28 kg,<br>Litter size 4-7 piglets |
| Manipuri | Manipur | Adult body weight 96 kg (males), Litter size – 6-11 piglets<br>Meat taste preferred by local people |
| Wak Chambil | Garo hills, Meghalaya | Round & pendulous belly<br>Pork – unique flavour & taste<br>Used for religious & ceremonial occasions |

# Indigenous Pig Breeds

| Breed | Origin | Characteristics |
|---|---|---|
| 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 | |

# Pigs - Specifics

| 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 |

# MCQs - Breeds

- Which of the following is a dual breed of cattle
  JKPSC 2019

(A) Red sindhi

(B) Haryana

(C) Sahiwal

(D) Amritmahal

# MCQs - Breeds

- 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) 34 |
| (b) Buffalo | (2) 43 |
| (c) Goat | (3) 19 |
| (d) Chicken | (4) 16 |

Select the correct answer using the code below:

(A) a-1, b-2, c-3, d-4

(B) a-2, b-3, c-4, d-1

(C) a-2, b-4, c-1, d-3

(D) a-1, b-2, c-4, d-3

# MCQs - Breeds

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-1; b-3; c-1; d-4
- (B) a-2; b-4; c-3; d-1
- (C) a-1; b-4; c-2; d-3
- (D) a- 1; b-3; c-2; d-4

# MCQs - Breeds

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

(A) Kankrej

(B) Haryana

(C) Gir

(D) Amrit Mahal

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

(A) Haryana

(B) Red Sindhi

(C) Sahiwal

(D) Tharparkar

# MCQs - Breeds

- The heaviest Indian cattle breed is: JKPSC (2012)

(A) Rathi

(B) Ongole

(C) Sahiwal

(D) Kankrej

- Buffalo species having 48 chromosomes is known as: JKPSC (2012)

(A) River buffalo

(B) Water buffalo

(C) African buffalo

(D) Swamp buffalo

# MCQs - Breeds

- Match the livestock and poultry breed as per the recognition by the National Bureau of Animal Genetic resources (Jan, 2020)

| Species | No.of recognized breeds |
|---|---|
| i) Cattle | 1) 7 |
| ii) Sheep | 2) 3 |
| 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

# MCQs - Breeds

- Konkan Kapila cattle breed is native of ___________________
  a) Maharashtra and Goa
  b) Karnataka and Andhra Pradesh
  c) Kerala and Karnataka
  d) Maharashtra and Karnataka

- The swamp buffaloes distributed mostly in upper Brahmaputra valley of Assam is _________
  a) Luit
  b) Ghurrah
  c) Toda
  d) Chattisgarh

# MCQs - Breeds

- All Tamil Nadu cattle breeds are__________

  a) a. Milch breeds

  b) b. Draught breeds

  c) c. Dual purpose

  d) d. None of the above

- The wall-eyed buffalo breed

a. Bhadawari

b. Nili-Ravi

c. Murrah

d. Toda

# MCQs - Breeds

- Cross of Tharparkar and Holstein Friesian
  a) Karan Swiss
  b) Karan Fries
  c) Avikalin
  d) Avivastra

- Which of the following is not a Mysore type of cattle
  a) Amrihmahal
  b) Hallikar
  c) Bargur
  d) Krishna Valley

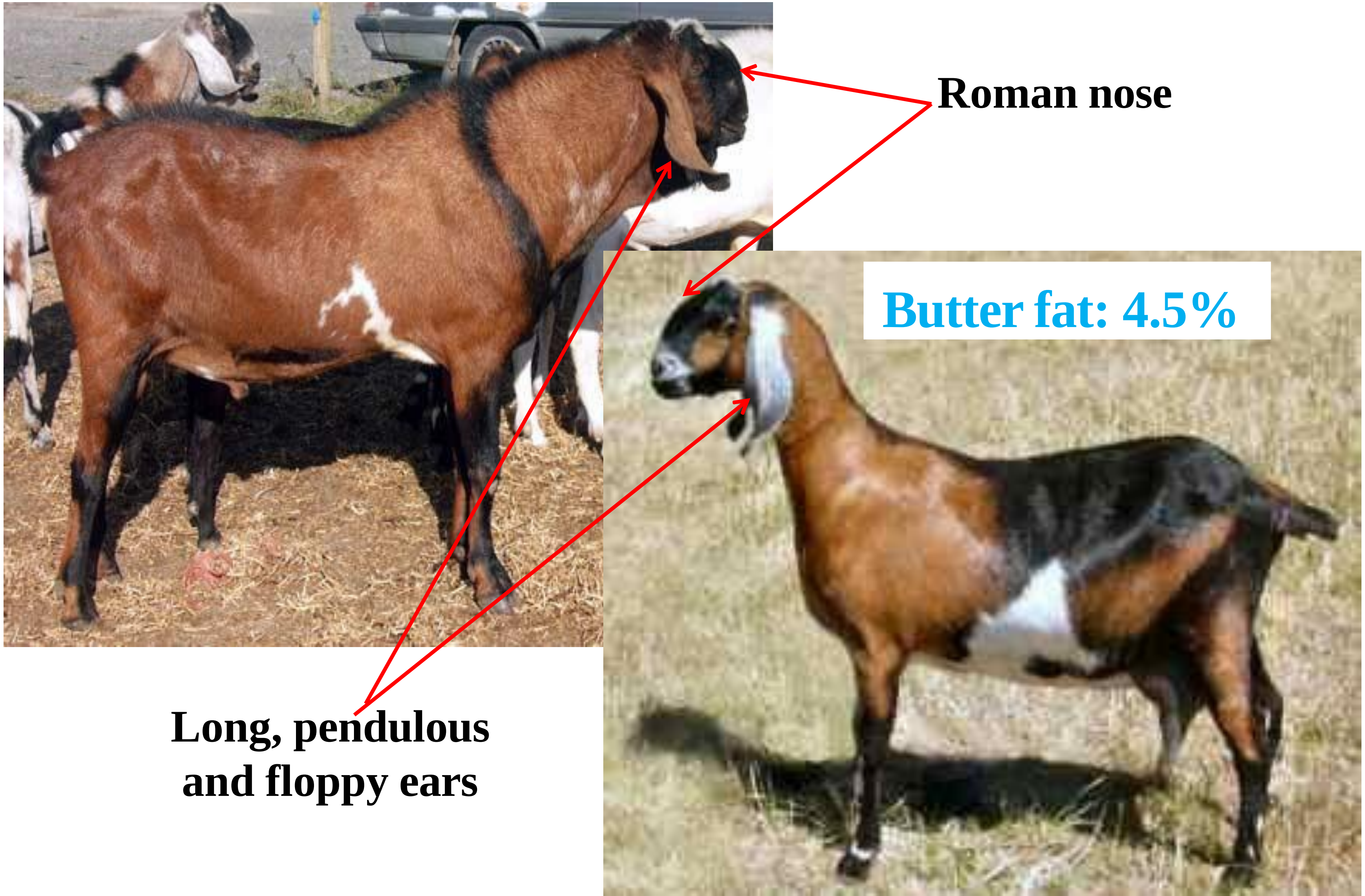
# Goat Breeds

# Exotic Goat Breeds

| Goat Breed | Origin | Characteristics | Specials |
|---|---|---|---|
| Saanen | Switzerland | Sabre shaped horns<br>Sensitive to sunlight<br>4-4.5 L milk/day<br>3-4% fat | "Milk Queen" of goat world |
| Toggenberg | Switzerland | Chocolate coloured body<br>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 |

# “Milk Queen” - Saanen

# ANGLO-NUBIAN GOAT : Jersey of goat( Dual Purpose)

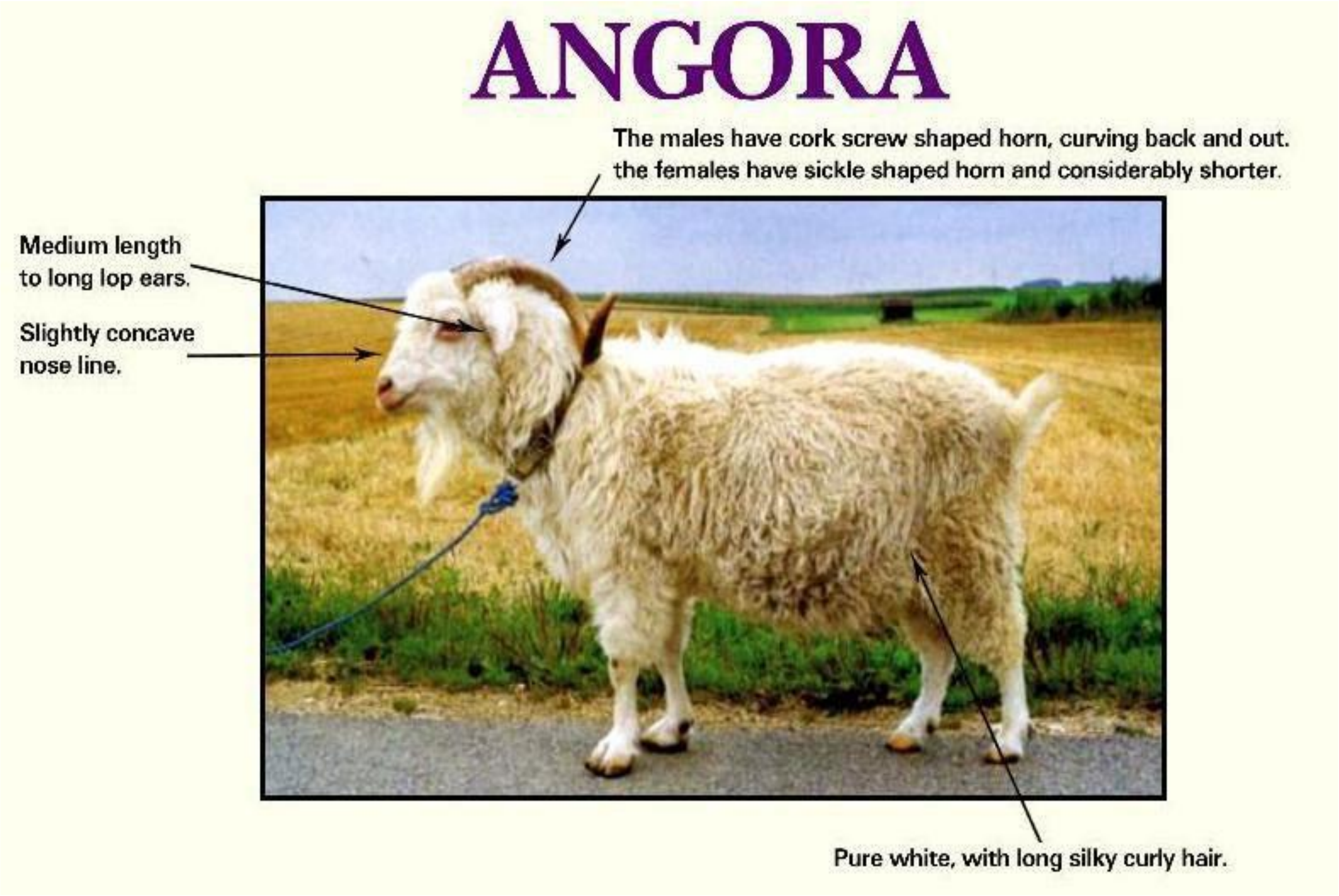


# ALPINE GOAT

Erect ears described as "alertly graceful“;

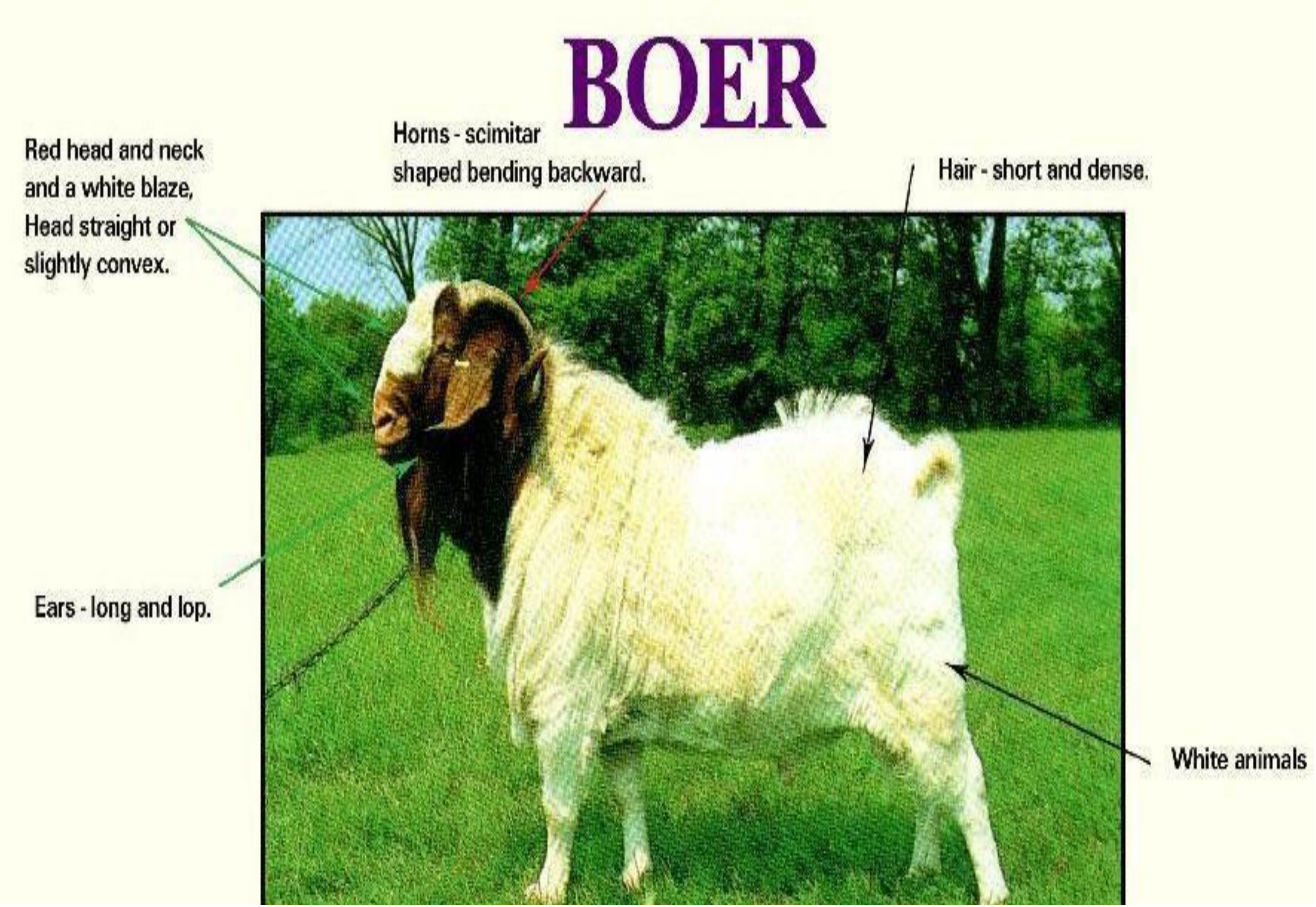
No distinct color

Alpine × Beetal crossbred developed at NDRI for milk purpose




**Angora goat : Mohair production;**
**Goat having sheep like texture;**

# ANGORA GOAT




Boer goat : high prolificacy and famous for meat production (broiler goat)

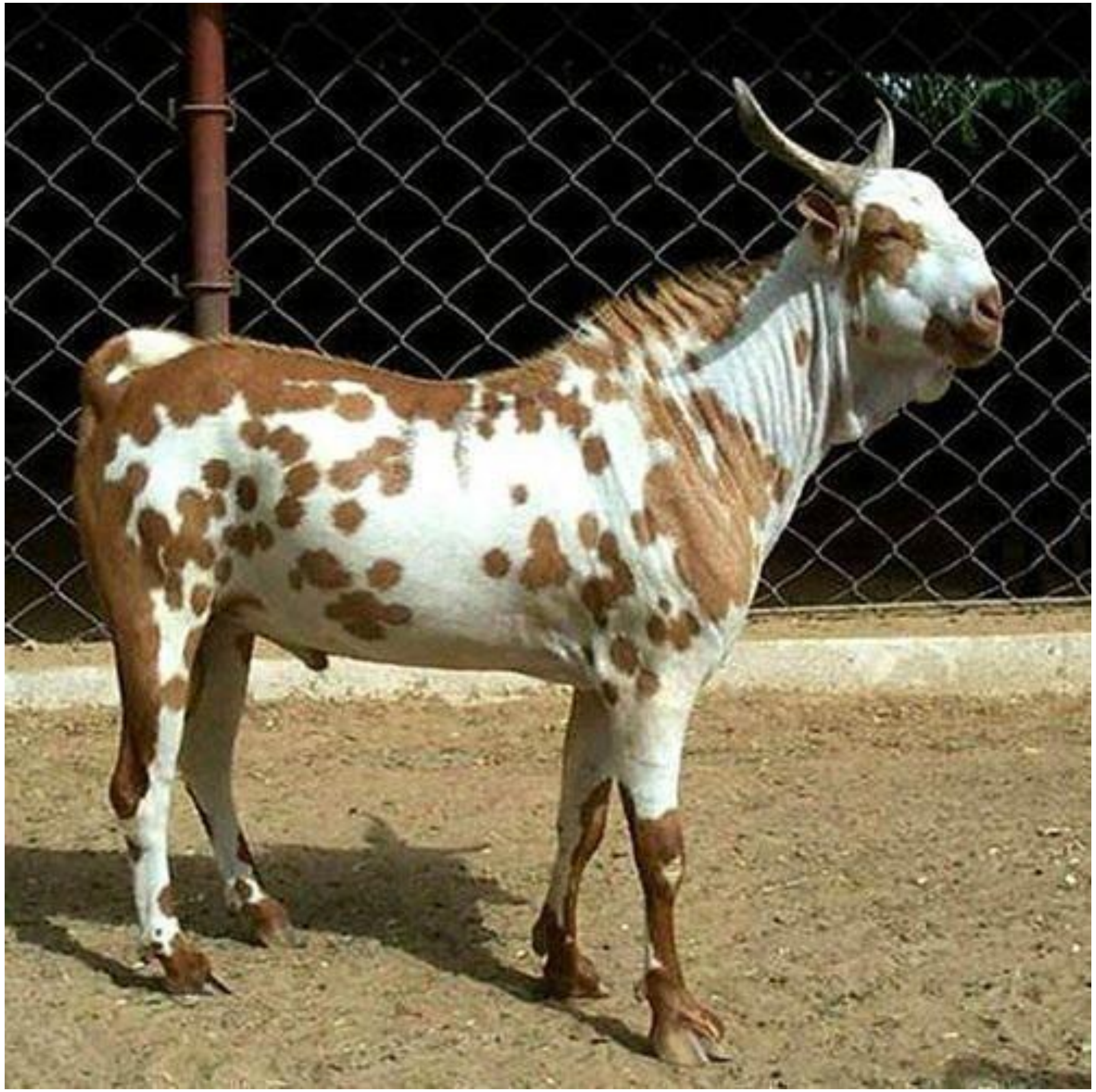
# Indigenous Goat Breeds

- 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

# Indigenous Goat Breeds

| Breed | Purpose | State | Characteristics | Specific |
|---|---|---|---|---|
| Beetal | Milch | Punjab | Males possess beard<br>Convex face, black lips<br>Long pendulous ears | Males possess beard |
| Jamnapari | Dual (Milk/Meat) | Uttar Pradesh | White colour<br>Both sexes horned<br>Thick hair on buttocks (feathers) | "Most majestic breed"<br>Parrot mouth<br>Milk – 3.89 kg/day avg<br>Butterfat (4.84%) - high |
| Barbari | Dual (Milk/meat) | Uttar Pradesh/ Rajasthan | Suitable for stall feeding<br>Wedge shaped body<br>City breed | Maximum milk fat (5%) |
| Jharkhana | Milk | Rajasthan | White spots on ear & muzzle<br>Twisted horns in both sexes | Skin popular for "tanning" purpose |
| Sirohi | Dual purpose | Rajasthan | Coarse, short hair<br>Brown/white/patched | |

# Barbari



# Indigenous Goat Breeds

| Breed | Purpose | State | Characteristics | Specific |
|---|---|---|---|---|
| Kutchi | Milk, Meat, Hair | Gujarat | | "Corkscrew horns" pointed upwards |
| Black Bengal | Meat, Hide | West Bengal | Black coloured<br>Both sexes – small-med horns<br>Beard in both sexes<br>Hair coat- short & lustrous | "Best chevon breed" of India<br>Skin – shoe making<br>Highly prolific |
| Changthangi | Wool, Meat | J&K (Ladakh) | White + Brown<br>Twisted horns in both sexes<br>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<br>Long hair, fine downy undercoat<br>White + greyish red mix | Pashmina producing breed |

# Kutchi

# Black Bengal

# Changthangi

# Chegu

# What you should 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 |

# What you should remember…

| Aspect | Breed |
| --- | --- |
| 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 |


Scimitar

# Sheep Breeds

# Exotic Sheep Breeds

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

# Exotic Sheep Breeds

Merino

Rambouillet

# Exotic Sheep Breeds

Dorset

Southdown

# Exotic Sheep Breeds

| 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 |

# Lincoln

# Karakul

# 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 |

## Nali – Yellow wool sheep

## Nellore

# Indigenous Sheep Breeds

| Trait | Breed |
| --- | --- |
| 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 |

# Synthetic Breeds of Sheep

| Breed | Exotic Inheritance | Crosses | Character | Place of development |
|---|---|---|---|---|
| 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???*

| Wool Fibre Type | Who Produces It? |
|---|---|
| Angora | Angora Rabbit |
| Mohair | Angora Goat |
| Pashmina (finest grade Cashmere) | Changthangi goat |
| Cashmere | Cashmere goats (group) – double coat (fine, soft undercoat)<br>Chinese, Iranian, Mongolian, Australian, American |
| Qiviut | Muskox (not domesticated) |

# Poultry breeds

# Exotic Breeds of Poultry – Classes

| American | Asiatic | English | Mediterranean |
|---|---|---|---|
| • Clean shanks<br>• Single/pea combs<br>• Dual | • Feathered shanks<br>• Pea combs<br>• Excellent meat<br>• Ornamental<br>• Moderate eggs no. | • Clean shank<br>• Various types of combs<br>• Good meat<br>• Variable egg<br>• (Dual) | • Clean shank<br>• Yellow shank<br>• Single combs<br>• Egg type |

# Exotic Breeds of Poultry

| PNRJW | BCL | English C-DOSA | Medical LAMA |
|---|---|---|---|
| **American** | **Asiatic** | **English** | **Mediterranean** |
| • Plymouth rock<br>• New Hampshire<br>• Rhode Island Red<br>• Jersey Black Giant<br>• Wyandotte | • Bramha<br>• Cochin/Shanghai<br>• Langshan | • Australorp<br>• Cornish<br>• Orpington<br>• Sussex<br>• Dorking | • Minorca<br>• Leghorn<br>• Ancona<br>• Andalusian |

# Indigenous Poultry Breeds

| Breed | Origin | Characteristics |
|---|---|---|
| Kadaknath/Kalamasi | Madhya Pradesh | Black pigmentation – external and internal surface<br>Light brown eggs<br>Purple comb, wattles and tongue |
| Aseel | Chattisgarh, Odisha, Andhra Pradesh | Fighting abilities – Game bird<br>Majestic gait, high stamina<br>Broody bird<br>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

**Desi/Backyard**
- CARI Nirbheek (Aseel cross)
- CARI Shyama (Kadaknath cross)
- Hitcari (Naked Neck cross)
- Upcari (Frizzle cross)

**Layers**
- CARI Priya
- CARI sonali – White leghorn X RIR
- CARI-Debendra – Synthetic broiler X RIR
- CARI Gold – Selective breeding in RIR

**Broilers**
- CARI Vishal (Caribro-91)
- CARI-rainbro (B-77)
- CARIbro – Dhanraja
- 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 |

# Other Strains

| Strain | Place |
|---|---|
| Giriraja, Swanadhara | Bangalore (KVAFSU) |
| Kalinga brown | CPDO, Bhubaneshwar, Odisha |
| Nandanam chicken (I and II) | TANUVAS |
| Lohmann | Suguna Poultry Farm Ltd., TN |
| Gramalakshmi | KAU, Kerala |
| Krishna J | JNKVV, Jabalpur |

# Other Poultry Birds from CARI

| Quails |
| --- |
| CARI Uttam |
| CARI Pearl |
| CARI Ujjwal, CARI Sweta |
| CARI Brown, CARI sunheri |

| Guinea Fowl |
| --- |
| Guncari – Egg |
| Kadambari – Meat |
| Chitambari – Egg |
| Swetambari - Meat |

| Duck |
| --- |
| Moti – Egg |
| Moti – Meat |

| Turkey |
| --- |
| CARI Virat |

# Ducks

Three registered breeds with NBAGR:

1. Pati Duck – Assam
2. Maithili – Bihar
3. Andamani – Andaman & Nicobar

*Khaki Campbell = Indian Runner + Mallard + Rouen

**Egg type**

- Khaki Campbell* (300 eggs/year)
- Indian Runner (200-300 eggs/year)

**Meat type**

- Muscovy – Quiet breed
- Aylesbury – White skin
- White Pekin, Rouen

# Turkeys

| | |
|---|---|
| Broad breasted bronze | • Black plumage |
| Broad breasted white | • Broad breasted bronze X White Holland |
| Beltsville small white | |

CARI Virat from CARI

# *All things Chicken*

| 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 |

# *All things Chicken*

| Trait | Breed |
|---|---|
| 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 |

# AGB
# Lecture 9

*Livestock Breeding Policy of India*

*Livestock Breeding Policy of States*

*Conservation of Livestock Breeds*

# National Breeding Policy

(DAHD, 2013)

# Breeding Policy for Cattle and Buffaloes

**Cattle**

- Selective Breeding of indigenous high yielding cattle in their home tracts
- Upgradation of ND cattle:
  - Exotic cattle – Jersey and Holstein Friesian
  - Indigenous cattle – Sahiwal, Red Sindhi, Gir and Tharparkar (Resource deficient areas)

**Buffalo**

- Selective breeding of major buffalo breeds
- Graing up of ND breeds – Murrah and Surti

**General**

- Production of high genetic potential males
- Formation of breed associations for indigenous breeds
- Produce high genetic merit bulls (disease resistant) for natural mating
- Use of semen of PT bulls for crossbreeding

# Breeding Policy for Sheep and Goats

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 BREEDS:**

- Upgrading – Chokla, Nali, Patanwadi, Malpura
- Crossbreeding - Suffolk, Dorset, Rambouillet, Soviet Merino

**GOAT BREEDS:**

- Upgrading – Beetal, Jamnapari

# Breeding Policy for Pigs

| | |
|---|---|
| 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 |
| Upgrading: | • Ghungroo, Dome (indigenous), Large white Yorkshire, Landrace (exotic) |
| Crossbreeding: | • Large white Yorkshire, Landrace, Hampshire, Duroc |

# Key Points

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

- **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
- **Maintain high-yielding varieties:** Focus on parent and grandparent stock
- **Advanced breeding technologies:** Use QTLs, CRISPR, transgenesis, RNAi → Identify and propagate robust, high-producing stocks

# Poultry Breeding

**Immune competence:**
- Develop strains adaptable to changing farm conditions

**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

# Gujarat – Breeding Policy

## Cattle and Buffaloes

- Conservation/Selective Breeding of identified breeds in core areas
- Pedigree selection to be taken up until AI infrastructure can be built to start progeny testing for breeds
- Exotic inheritance – 50%
- Permitted 75% in resource rich areas
- ND – upgradation using core breed/other breeds
  - Cattle: HF
  - Buffaloes: Mehsana, Surti, Murrah

## Sheep

- Sheep: Patanwadi (wool), Marwari (dual purpose), Deccani (meat)
- Goats: Surti (dairy), Mehsana (meat/dairy), Zalawadi (meat), Gohilwadi (meat)

- Genetic Upgradation
- Breed Conservation
- Reducing Mortality

- Approved Breeding Strategies: Selective Breeding, AI, Community involvement

# Gujarat – Core Areas Identified for Breeds

| S. No. | Breed | Core districts |
|---|---|---|
| 1. | Kankrej | Banaskantha, Patan, Mehsana, Gandhinagar, Kacchh, Surendranagar, Ahmedabad |
| 2. | Gir | Junagadh, Amreli, Bhavnagar, Surendranagar, Jamnagar, Rajkot, Porbandar, Botad, Dwarka, Gir, Somnath, Morbi |
| 3. | Dangi | Tapi, Dang, Narmada, Surat, Valsad |
| 4. | Banni | Kacchh |
| 5. | Jaffarabadi | Junagadh, Amreli, Bhavnagar, Rajkot, Jamnagar, Porbandar, Surendranagar, Botad, Dwarka, Gir, Somnath, Morbi |
| 6. | Mehsana | Banaskantha, Patan, Mehsana, Gandhinagar, Ahmedabad |
| 7. | Surti | Anand, Kheda, Vadodara, Surat, Tapi, Bharuch, Chhotaudepur, Panchmahal, Dahod |
| 8. | Graded buffaloes (Mehsana/Surti/Murrah) | Sabarkantha, Arvalli, Panchmahal, Kheda, Anand, Dahod, Vadodara, Bharuch, Chhotaudepur, Surat, Tapi, Navsari, Dang |
| 9. | Crossbred and ND cows and buffaloes | All districts |

# Maharashtra – Breeding Policy

## Cattle

- Resource based breeding
- Crossbreeding using exotic germplasm (HF/Jersey) – wherever possible
- Home/breeding tracts of identified indigenous breeds:
  upgradation with indigenous breeds – Dangi, Deoni, Red Kandhari, Gaolao, Khillar
- Purebred indigenous cattle – selective breeding and improvement in home tract
- Pedigreed germplasm of indigenous cattle *viz.* Gir, Tharparkar, Kankrej, Sahiwal, etc., to be utilised suitably

## Buffaloes

- **Descript Breeds (Murrah, Jaffarabadi, Pandharpuri, Nagpuri, Marathwadi, Surti):** Breed only within the same breed using purebred semen.
- **Upgrading Non-Descript (ND) Buffaloes:**
  - Use semen from **any identified descript breed** (Murrah, Jaffarabadi, Pandharpuri, Marathwadi, Nagpuri, Surti).
- **Conservation & Use:**
  - Conserve **Pandharpuri, Marathwadi, Nagpuri** in their native/similar areas.
  - Use these breeds for **crossbreeding/upgrading** ND buffaloes in suitable zones.

# Maharashtra – Breeding Policy

## Sheep & Goat

- **Sheep Breed Conservation:** Focus on breeds like **Deccani**, **Sangamneri**, **Lonand**, and **Madgyal**.
  - **Goat Breed Conservation:** Focus on breeds like **Osmanabadi**, **Sangamneri**, and **Konkan Kanyal**.
  - Selective Breeding for wool (sheep)/meat/milk (goat)/disease resistance

## Buffaloes

- **Descript Breeds (Murrah, Jaffarabadi, Pandharpuri, Nagpuri, Marathwadi, Surti):** Breed only within the same breed using purebred semen.
- **Upgrading Non-Descript (ND) Buffaloes:**
  - Use semen from **any identified descript breed** (Murrah, Jaffarabadi, Pandharpuri, Marathwadi, Nagpuri, Surti).
- **Conservation & Use:**
  - Conserve **Pandharpuri, Marathwadi, Nagpuri** in their native/similar areas.
  - Use these breeds for **crossbreeding/upgrading** ND buffaloes in suitable zones.

# Madhya Pradesh – Breeding Policy

| Cattle and Buffaloes | Sheep |
| --- | --- |
| • Malvi, Nimari, Kenkatha and Gaolao – Selective breeding in home tract<br>• Crossbreeding – Jersey/HF – 50% inheritance fixed<br>• Crossbreeding for development of ND cattle<br>• Upgrading with Sahiwal, Gir or Red Sindhi in areas unsuitable for crossbreeding<br>• Encourage breeders' societies for breed improvements | • Indigenous breeds –<br>  • **Bharat Merino** – selective breeding for meat and wool<br>  • **Shahabadi** – selective breeding for mutton production<br>• Crossbreeding –<br>  • Exotic inheritance (**75%)** – Corriedale or Rambouillet breeds<br>• **Grading up of ND with Shahabadi breed** |

# Madhya Pradesh – Breeding Policy

## 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 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.
- Marwari and Sirohi bucks for upgrading (Buck to doe ratio 1:15 to 1:20)
- ONBS for cluster areas to promote development

# Rajasthan – Breeding Policy

## 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)

# Rajasthan – Breeding Policy

## 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

## Buffaloes

- Breed of choice: Nili Ravi – Selective breeding
- Murrah

## AI Coverage to be increased from 20% to 50% in 5 years

## Embryo transfer technology to be used for faster genetic improvement

# Punjab – Breeding Policy

**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

# Punjab – Breeding Policy

## Pigs

- Breeds: Large White Yorkshire, Landrace, and their crosses
- Crossbreeding with Large White Yorkshire and Landrace
- Maintain 50% inheritance of each breed in crossbreds
- Focus on increasing litter size and growth rate

# Uttar Pradesh – Breeding Policy

## Cattle Breeding Policy:

- Indigenous Breeds – Improvement of indigenous cattle breeds like Sahiwal, 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

# Uttar Pradesh – Breeding Policy

## 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 –
- Crossbreeding – Large White Yorkshire, Landrace (75% exotic inheritance limit)

# Jammu and Kashmir Livestock Breeding Policy

(2019)

# Bovines - Cattle

- Jersey and Holstein Friesian for upgrading/crossbreeding
- Plain, irrigated, peri-urban areas –Jersey/HF
- Semi-hilly and hilly areas – only Jersey
- Selective breeding for resource-restricted areas
- Exotic inheritance limit: 75%  (temperate) | 50% (plains)
- ONBS to maintain inheritance limit and bull quality

# Bovines - Cattle

## Indigenous composition

- Sahiwal – plains and Shivalik hills (Jammu)
- Red Sindhi – ND tracts

## Ladakhi X Jersey cross – popularisation

## Selective breeding of Ladakhi cattle in other areas

## Use of sexed semen for better management

# Bovines - Buffaloes

Local population upgradation

- Murrah buffalo (frozen semen)

Local buffalo of R.S. Pura, Kathua, Samba region

- Nili Ravi (Elite germplasm)

Sexed semen for better management

# Ovines

- Exotic inheritance limit – 75%
- Propagate –
  - Dual purpose breeds – Corriedale, Suffolk
  - Meat type breeds – Dorper, Texel

# Ovines

**Kashmir division**

- Inheritance – 75% Merino
- Document and register Kashmir Merino
- Dual purpose breeding – Corriedale
- Conservation (*in situ & ex situ*) – Gurez, Karnai

**Jammu division**

- Inheritance – 75% Rambouillet
- Selective breeding for mutton production
- Gains in fine wool (24 micron diameter)
- Conservation (*In situ & ex situ*) – Baderwali/Gaddi and Punchi

# Ovines

**Leh district**

- Breed improvement – Changluk and Mulluk sheep for dual purpose
  - (selective breeding)
- Crossbreeding using Merino

**Kargil Division**

- Selective breeding of local sheep (Purki)
- Breeding of Merino for fine wool
- Crossing of Karakul breed for enhanced mutton production

# Caprine

| | |
|---|---|
| Kashmir division | • Bakerwali breed used for improvement of ND flocks – chevon production |
| Jammu Division | • Selective breeding of Bakarwali breed (private flocks)<br>• Increasing chevon production<br>• *In situ* conservation of Gaddi goat |
| Leh District | • Selective breeding of Pashmina goats<br>• Angora goats replaced by Changra |
| Kargil division | • Introduction of exotic (Swiss Alpine)/Indigenous germplasm in local goats<br>• Selective breeding of local goats |

## Poultry

- Selective breeding of Kashmir Favrolla
- Develop sustainable breeds
- Selective breeding of ducks and geese

## Equines

- Purebreeding of Zanskari horses (conservation)
- Improvement breeds (nucleus) – Kathiawari/Marwari – upgrading local horses

# Yak

- Selective breeding of Ladakhi yak – pastoral management
- Introduction of exotic germplasm
  - Datong breed

# Double humped camel

- *In situ* conservation (small population)
- Registration mandatory
- Structured breeding programme to avoid inbreeding

# Conservation of breeds

# Conservation

Preservation + Improvement to better use in future

*World level – FAO – Nodal Agency for conservation of livestock genetic resources*

**Reasons to conserve**

- Maintain genetic variation (within and between breeds)
- Exploiting heterosis
- Linked to history
- Aesthetic reasons
- Research
- Meeting future needs

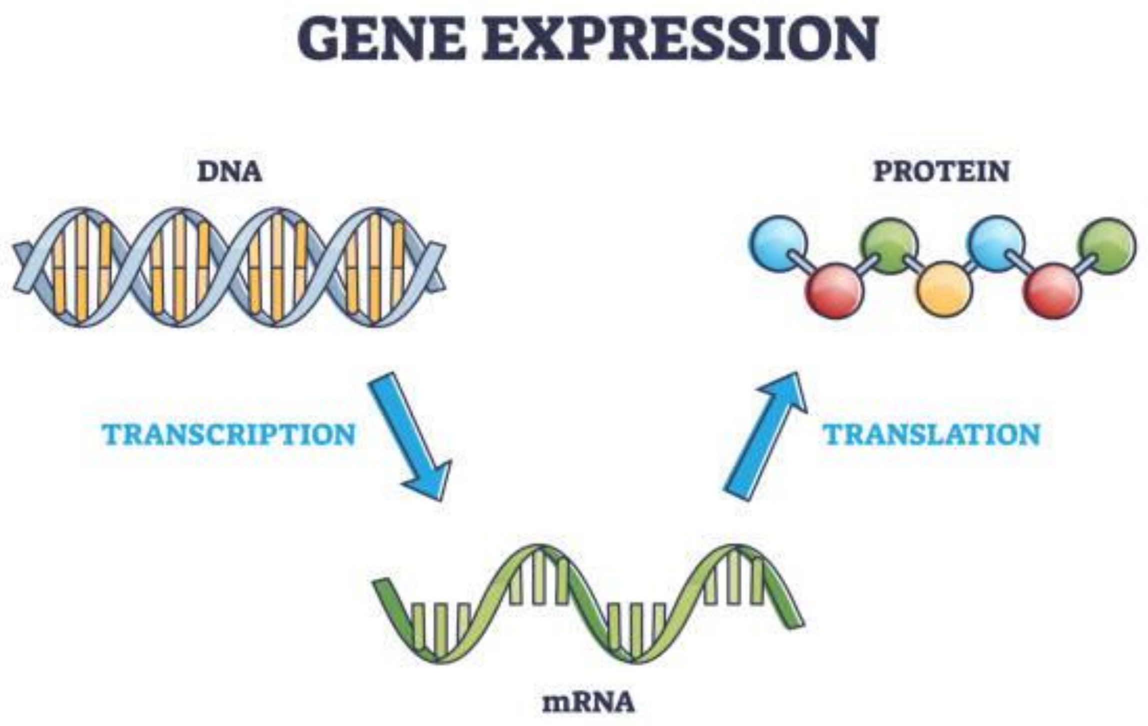
# Methods of Conservation

- In situ
  - Active - conservation + improvement through breeding programmes
    - Best method
  - Passive
  - Limitation:
    - Large number of animals – expensive
    - Not feasible for breeds that are not economically viable
    - Large number of animals maintained – avoid _______ and _________

- Ex situ
  - Good for economically unviable breeds
  - *In vivo* or *In vitro*
  - *In vivo* - conservation away from breeding tract (live animals)
  - *In vitro* - storage of live cells

*Lecture 10*

# Gene Expression




# Gene Expression

- The process by which information from a gene is used to synthesize functional gene products

# Regulation of Gene Expression

- Multiple Levels – DNA, RNA, Protein
- Control over – timing, location, amount of product
- Vital for – differentiation, morphogenesis, adaptability
- Based on this, types of genes:

| Constitutive | Facultative | Housekeeping | Inducible |
| --- | --- | --- | --- |
| rRNA genes | Human $\beta$-globin gene | GAPDH | HSP genes |

# DNA Replication

*(Semi-Conservative Replication)*

*Initiation*
*Elongation*
*Termination*

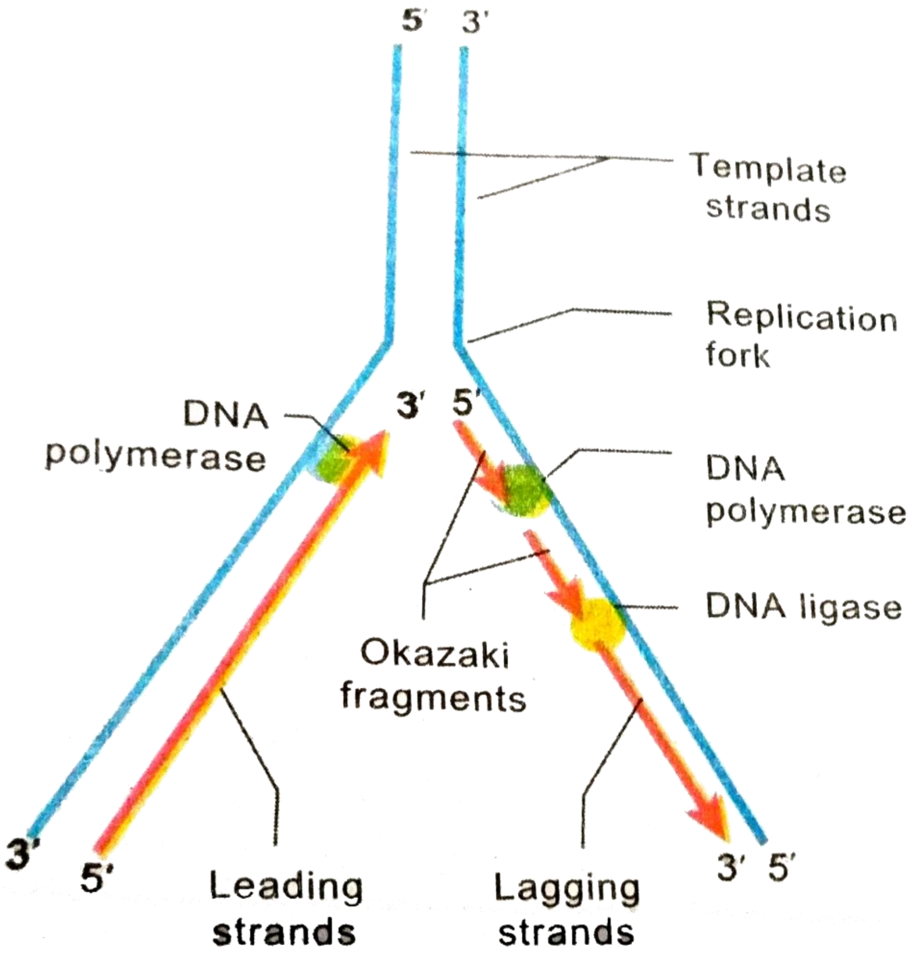
# DNA Replication – Enzymes Involved

- Helicase
- Primase
- DNA Polymerase III
- DNA Polymerase I
- Ligase
- Topoisomerase
- SSBP

# DNA Replication - Steps

1. Initiation

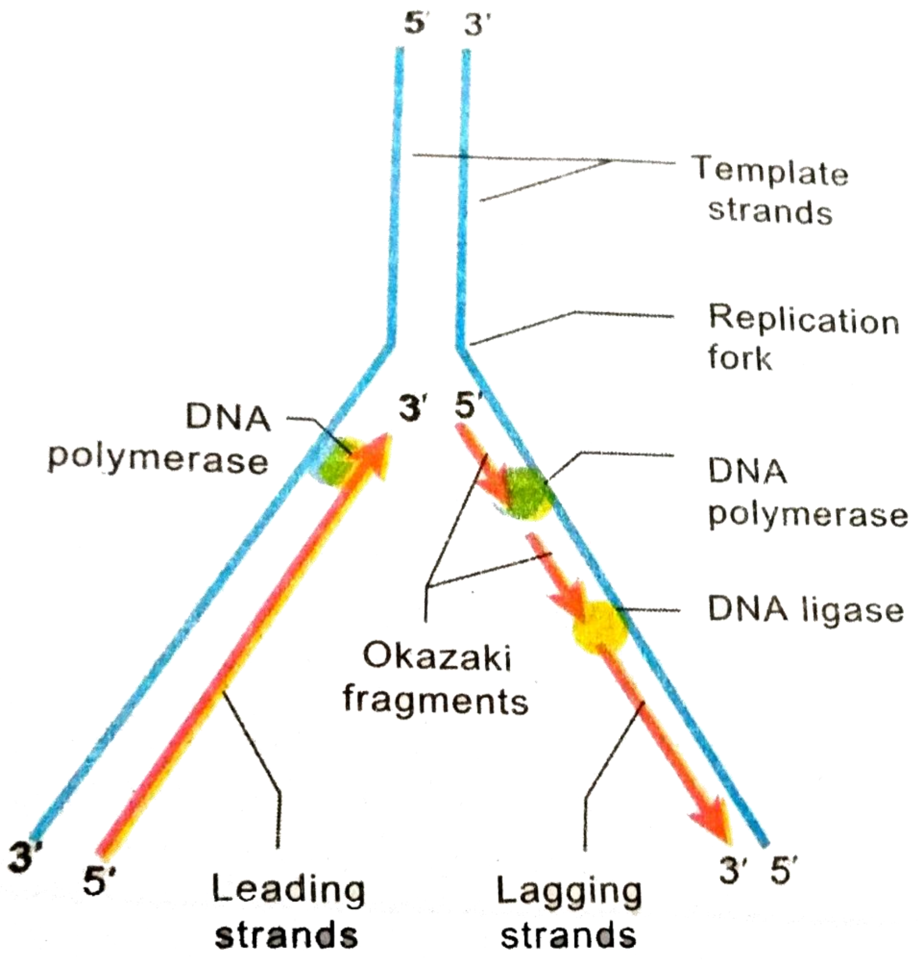
- Begins at specific location – origin of replication
- Initiator proteins – separate 2 strands
- Helicase for unwinding
- SSBP for stabilisation – prevent reannealing



# DNA Replication - Steps

2. Elongation

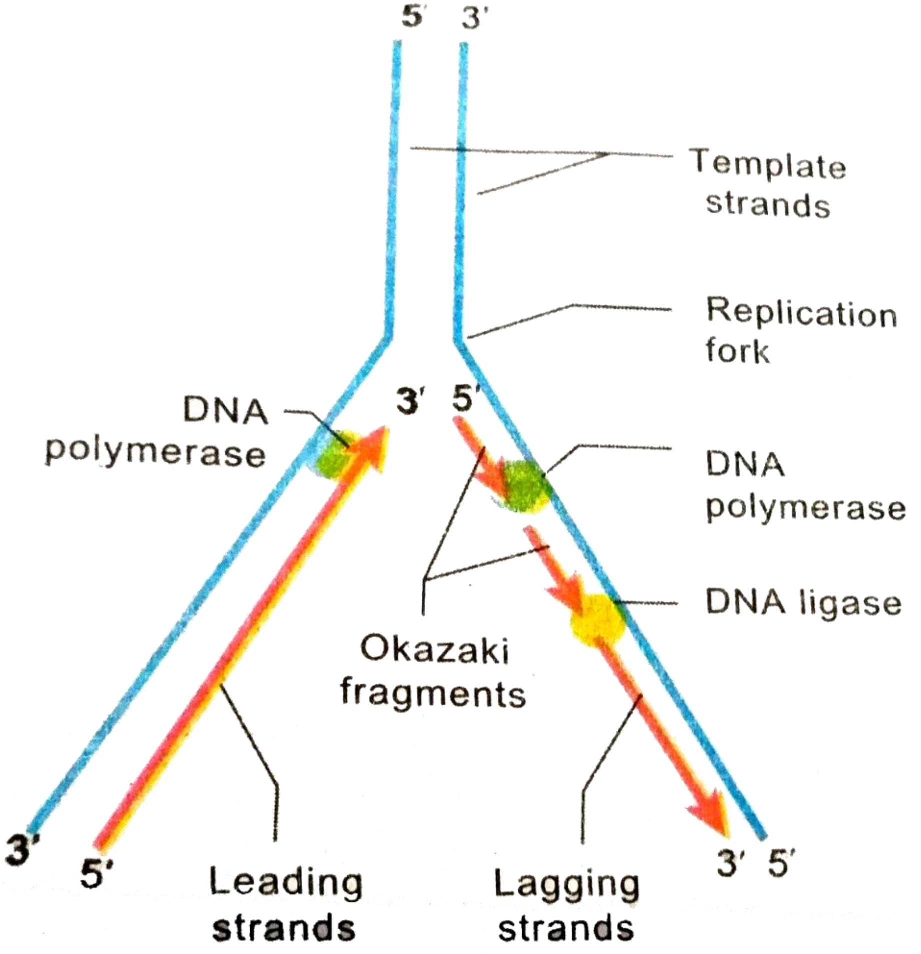
- Two strands – Leading and Lagging
- Leading strand – continuous replication
- Lagging strand – Okazaki fragments
- DNA Pol III – Adds nucleotides
- DNA Pol I – Replaces RNA primer with DNA
- DNA Ligase – Joins Okazaki fragments



# DNA Replication - Steps

3. Termination

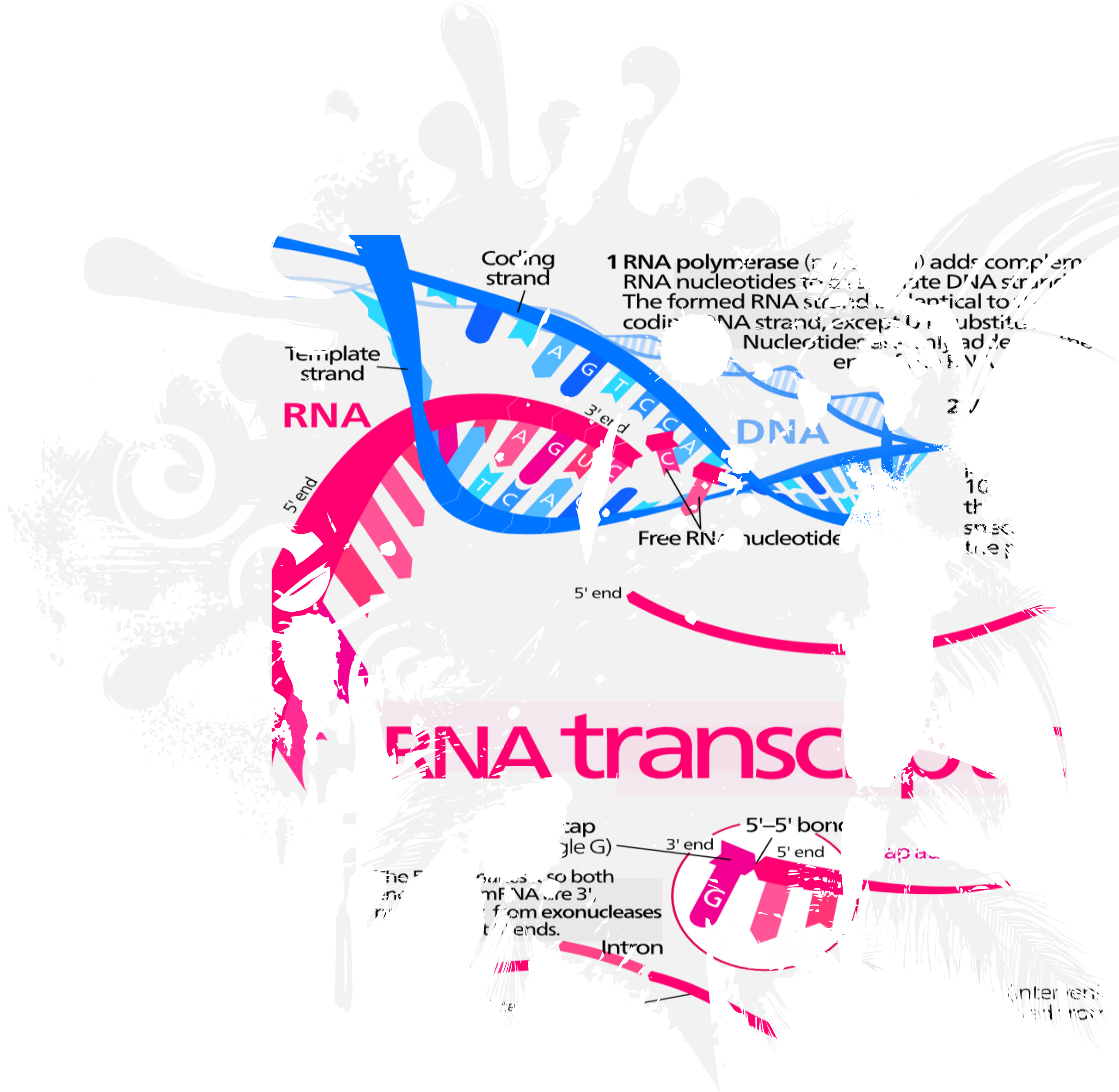
- Continues until full molecule is replicated
- Linear DNA –
  - Enzyme telomerase replicates the telomeres
  - Adds TTAGGG to ends of replicated DNA



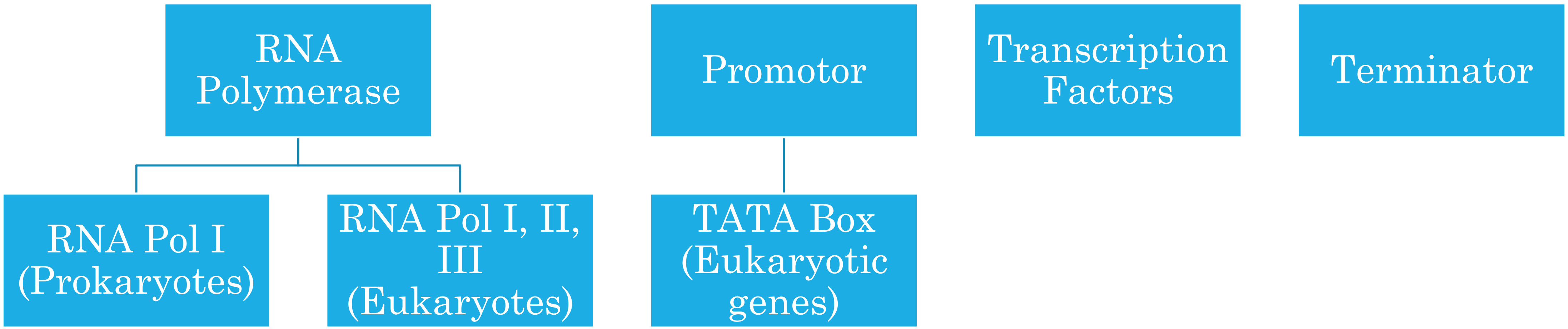
# Transcription

# *DNA → RNA*

*Information in DNA copied to a complementary RNA Strand*



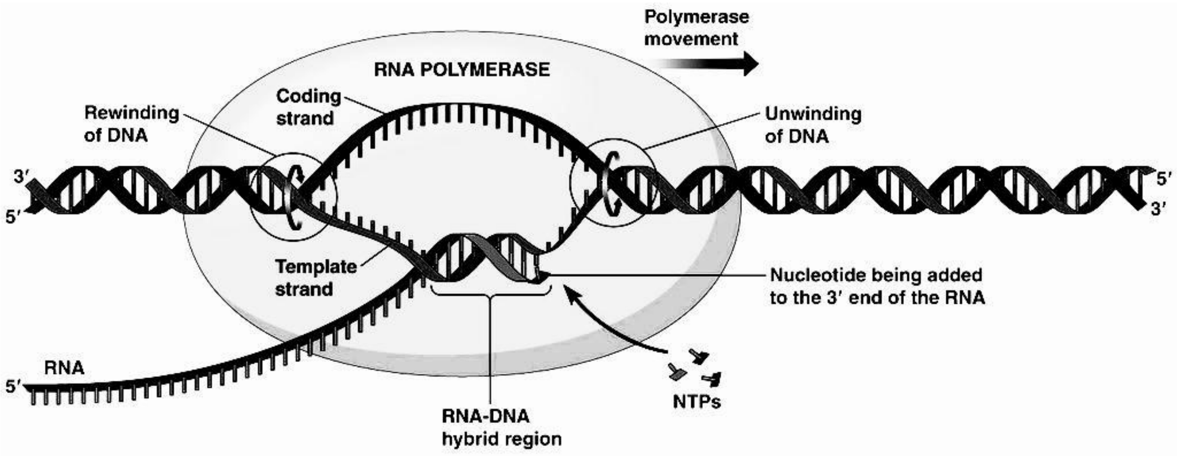
# Transcription – Key Enzymes & Components



# Steps in Transcription

1. **Initiation**

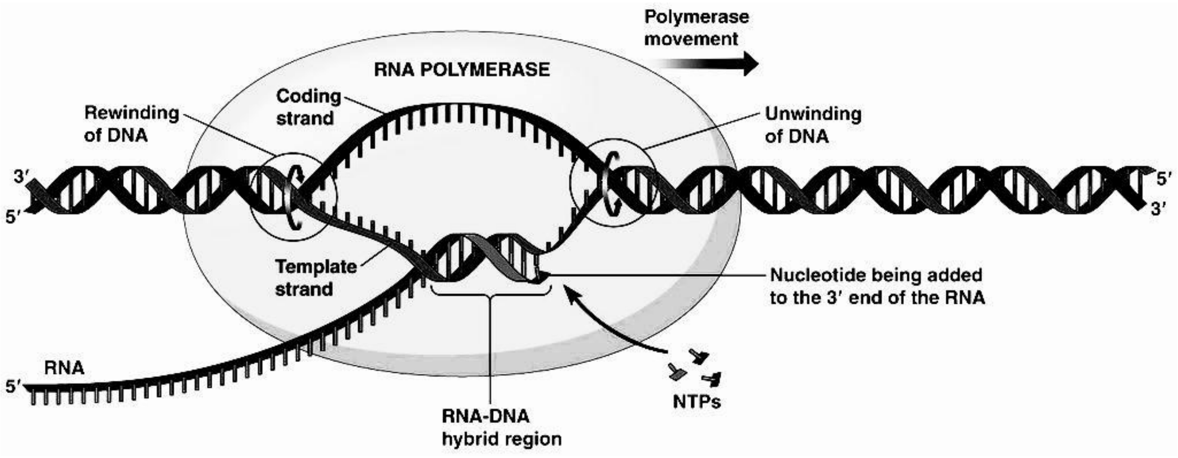
- RNA Pol binds to promotor
- TATA Box (Eukaryotes) – 25-30 bp upstream of transcription start site
- DNA double helix – separated
- Two strands:
  - Coding strand/Sense Strand
  - Template strand/Anti-sense strand



# Steps in Transcription

2. **Elongation**

- RNA Pol moves along template strand
- Strand read in 3’-5’ dir
- RNA molecule produced in 5’-3’ direction




3. **Termination**

- At the terminator sequence
- New RNA & RNA Pol released from DNA
- DNA double helix is reformed

# Processing of Eukaryotic Nascent mRNA

- Capping – 5’ cap addition (7-methyl guanine residues)
  - Protection from exonucleases
  - Facilitates translation
  - RNA export
- Tailing – Poly-A residues at 3’ end
- Splicing – removal of introns

# Transcription – Prokaryotes vs Eukaryotes

**Prokaryotic Transcription**

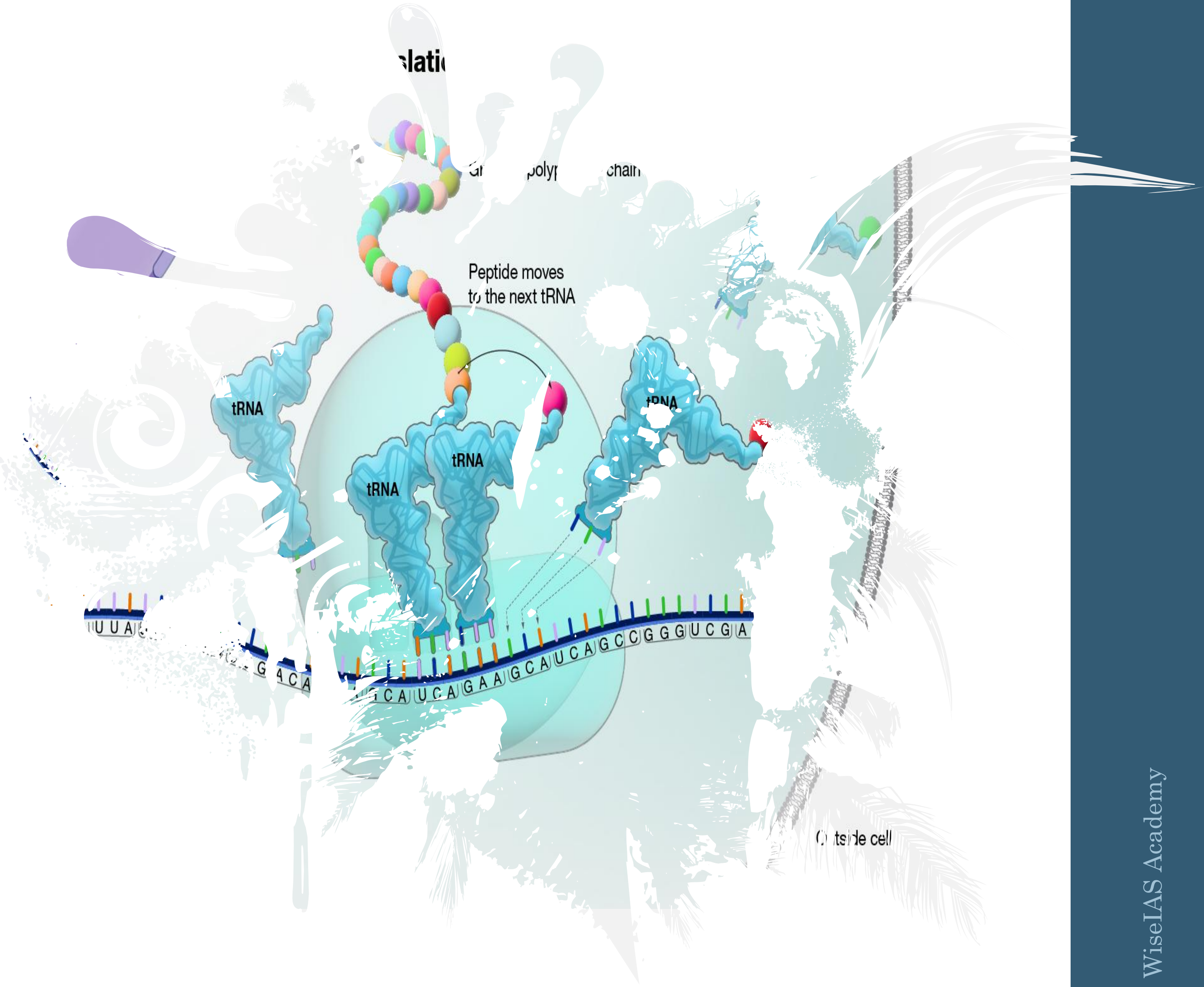
- Occurs in cytoplasm
- No post-transcriptional modifications of RNA
- Translation begins immediately

**Eukaryotic Transcription**

- Occurs in nucleus
- Post-transcriptional modifications are seen in nascent RNA
- Mature mRNA transported to cytoplasm for transcription

# Translation
## *mRNA⟶Protein*

Occurs in cytoplasm

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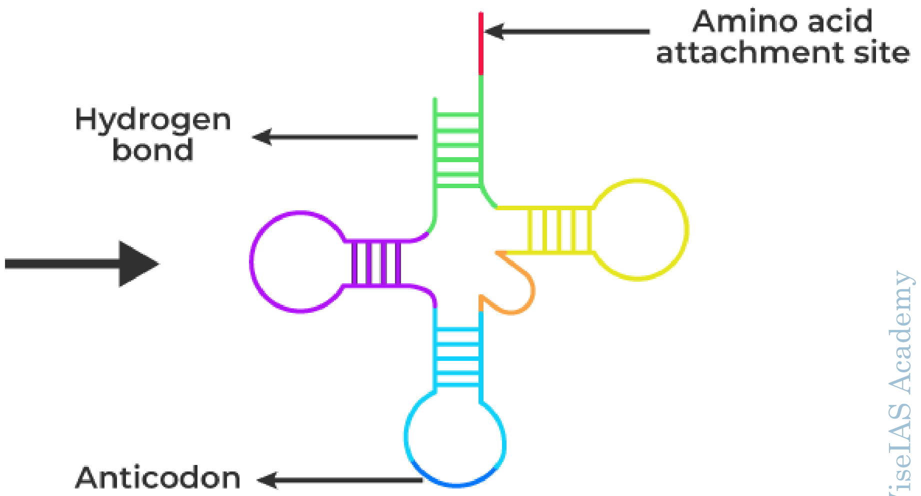
# Translation – Key Components

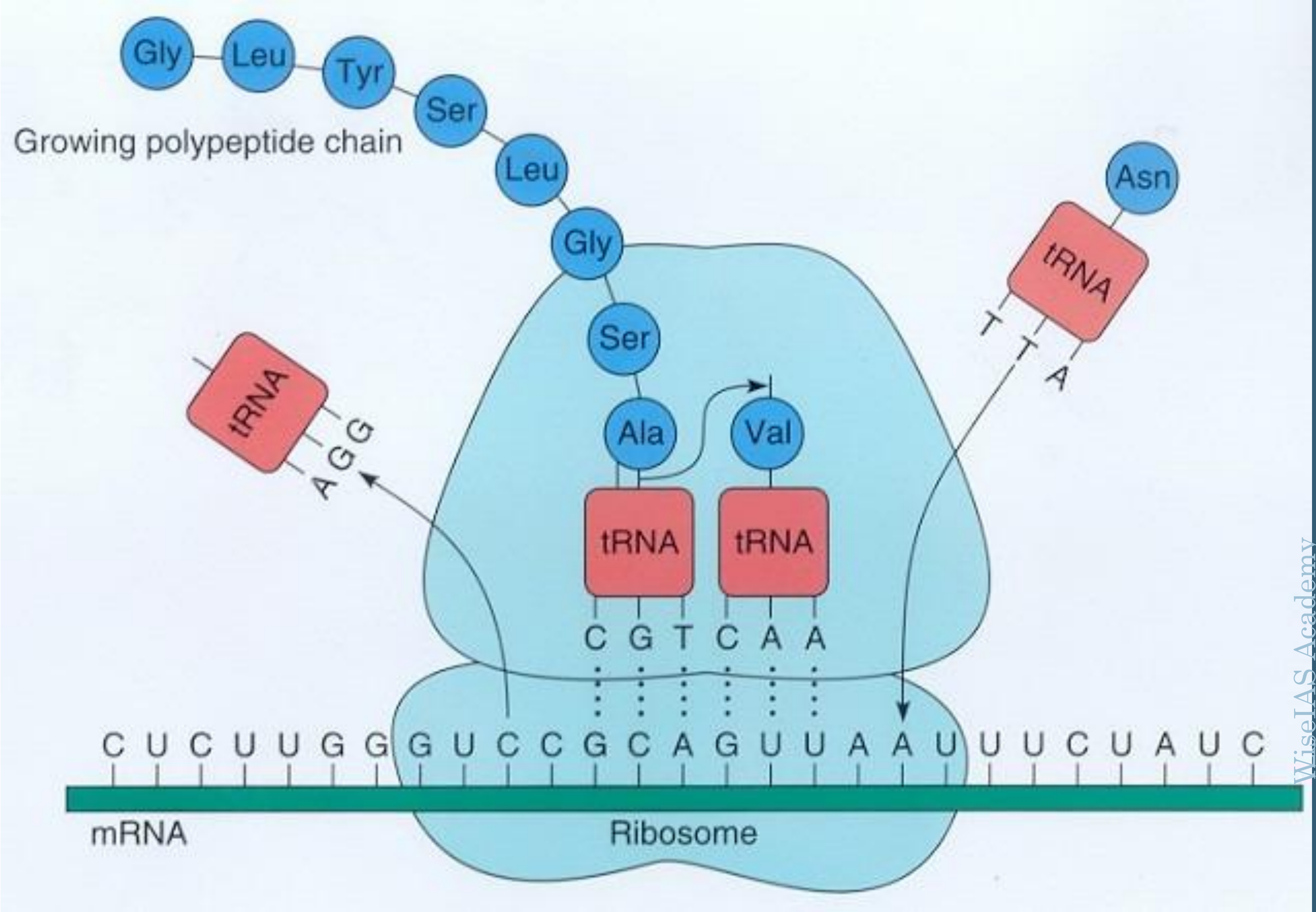
- mRNA
- Ribosomes
  - Two subunits – large and small
  - Prokaryotes – 70S (30S + 50S)
  - Eukaryotes – 80S (40S + 60S)
- tRNA
  - Adapter molecules
  - Clover leaf shaped
  - Site for mRNA at one arm, site for amino acid on the other
- Amino Acids



# Translation - Steps

1. **Initiation**

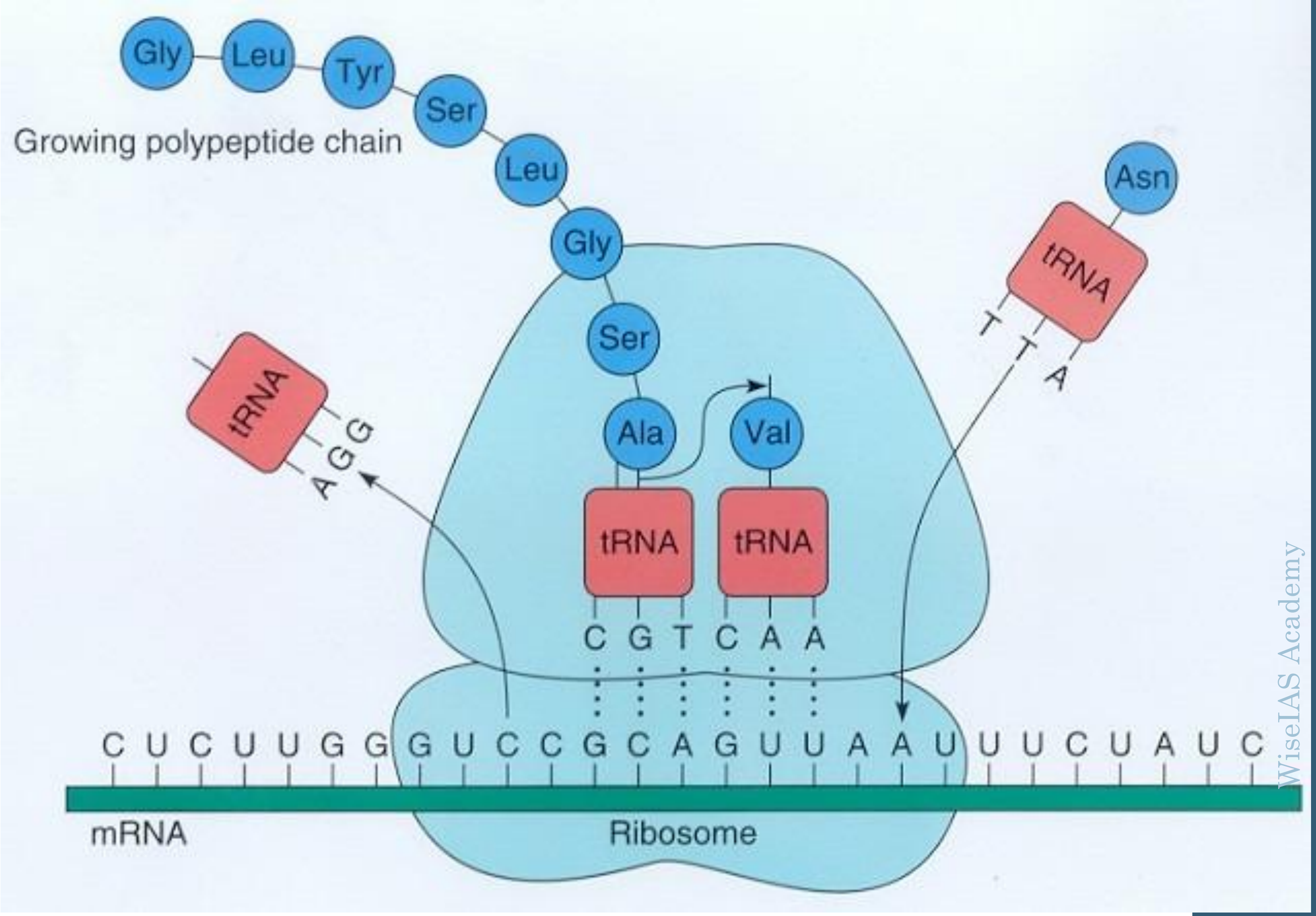
- Assembly of all required molecules
- Prokartoyes – initiation sequence
  - Shine Dalgarno sequence
- Eukaryotes –
  - Multiple initiation factors
  - 5' cap
- Begins with the codon – AUG (Met)



# Translation - Steps

2. **Elongation**

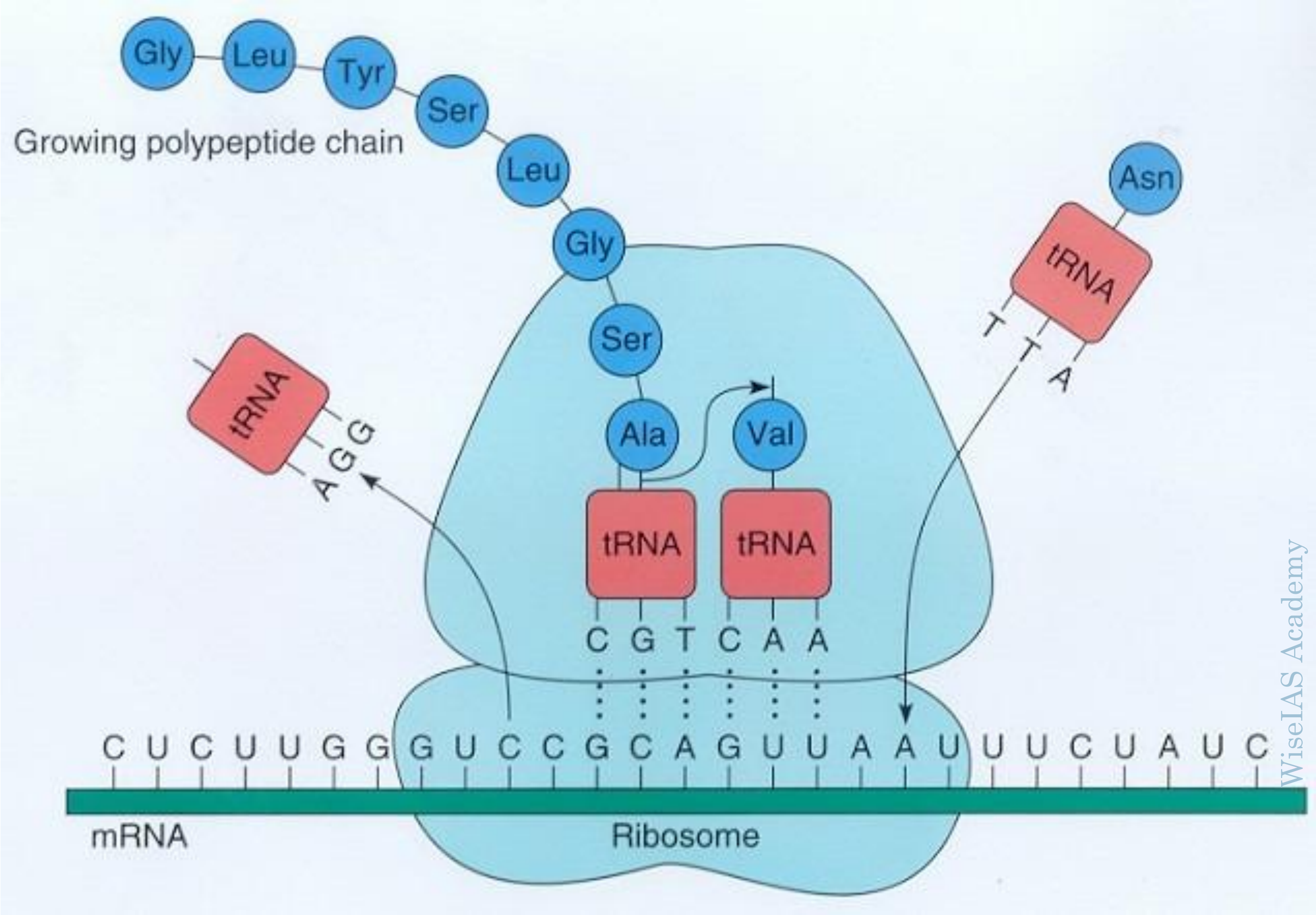
- Ribosome moves along mRNA
- Reads codons, adds amino acids
- Elongation factors –
  - EF-Tu (Prokaryotes)
  - eEF1 (Eukaryotes)
- Translocation –
  - Movement of ribosome to next codon
  - Aided by EF-G (prokaryotes) & eEF-2 (Eukaryotes)



# Translation - Steps

3. **Termination**

- mRNA reaches stop codons
  - UAA – ochre
  - UAG – amber
  - UGA – opal
- Triggers peptide release
- Ribosome dissociates from mRNA



# Translation – Prokaryotes vs Eukaryotes

## Prokaryotes

- Transcription & Translation are coupled

## Eukaryotes

- Transcription in nucleus & Translation in cytoplasm

# MCQs – Gene Expression

- Which enzyme catalyzes the synthesis of RNA from a DNA template during transcription?
  a) DNA polymerase
  b) Helicase
  c) RNA polymerase
  d) Ligase

- In eukaryotes, which type of RNA polymerase transcribes mRNA?
  a) RNA polymerase I
  b) RNA polymerase II
  c) RNA polymerase III
  d) All of the above

- Which enzyme unwinds the double helix during DNA replication?
  a) DNA polymerase
  b) Helicase
  c) Primase
  d) Topoisomerase

- In prokaryotes, translation occurs in the:
  a) Nucleus
  b) Endoplasmic reticulum
  c) Cytoplasm
  d) Mitochondria

# MCQs – Gene Expression

- Which enzyme catalyzes the formation of peptide bonds during translation?
  a) Aminoacyl-tRNA synthetase
  b) Peptidyl transferase
  c) Elongation factor
  d) Release factor

- Which of the following is a stop codon?
  a) AUG
  b) GGG
  c) UAG
  d) CCC

- Which enzyme unwinds the double helix during DNA replication?
  a) DNA polymerase
  b) Helicase
  c) Primase
  d) Topoisomerase

- In prokaryotes, translation occurs in the:
  a) Nucleus
  b) Endoplasmic reticulum
  c) Cytoplasm
  d) Mitochondria

# MCQs – Gene Expression

- Which enzyme joins Okazaki fragments together during DNA replication?
  a) DNA polymerase I
  b) DNA polymerase III
  c) DNA ligase
  d) Primase

- Which of the following is NOT a global regulator of translation?
  a) Initiation factors
  b) Ribosome availability
  c) Elongation factors
  d) Phosphorylation of initiation factors

Thank-you