Tamil Nadu Veterinary and Animal Sciences University

AGB - Unit III

# Principles of Animal Breeding (3+1)

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**UNIT-3**

# PRINCIPLES OF ANIMAL BREEDING

## THEORY

**Livestock and Poultry Breeding:** History of Animal Breeding. Classification of breeds. Economic characters of livestock and poultry and their importance. Selection, types of selection, response to selection and factors affecting it. Bases of selection: individual, pedigree, family, sib, progeny and combined, indirect selection. Method of selection, Single and Multi trait. Classification of mating systems. Inbreeding coefficient and coefficient of relationship. Genetic and phenotypic consequences of inbreeding, inbreeding depression, application of inbreeding. Out breeding and its different forms. Genetic and phenotypic consequences of outbreeding, application of outbreeding, heterosis. Systems of utilization of heterosis; Selection for combining ability (RS and RRS). Breeding strategies for the improvement of dairy cattle and buffalo. Breeding strategies for the improvement of sheep, goat, swine and poultry. Sire evaluation. Open nucleus breeding system (ONBS). Development of new breeds or strains. Current livestock and poultry breeding policies and programmes in the state and country. Methods of conservation- livestock and poultry conservation programmes in the state and country. Application of reproductive and biotechnological tools for genetic improvement of livestock and poultry. Breeding for disease resistance.

**Breeding of Pet, Zoo and Wild animals:** Classification of dog and cat breeds. Pedigree sheet, selection of breeds and major breed traits. Breeding management of dogs and cats. Common pet birds seen in India and their breeding management. Population dynamics and effective population size of wild animals in captivity or zoo or natural habitats. Planned breeding of wild animals. Controlled breeding and assisted reproduction. Breeding for conservation of wild animals.

## PRACTICAL

Computation of selection differential and intensity of selection, Generation interval, expected genetic gain, correlated response, EPA and Most probable producing ability (MPPA). Estimation of inbreeding and relationship coefficient. Estimation of heterosis. Computation of sire indices. Computation of selection index.

## Text and Reference Books

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# INTRODUCTION AND BRIEF HISTORY OF ANIMAL BREEDING

## INTRODUCTION

Animal breeding is defined as the application of principles of quantitative genetics for the improvement of farm animals. (The term animal breeding refers not so much to the mating, reproduction and rearing of animals) Relative to other technologies, the gains obtained through genetic improvement are permanent and relatively cheap, although it is slow.

There are two important tools available with the animal breeder viz. **Selection** and **mating system or breeding system** for changing the genetic properties of the population. Selection decides the choice of individual to bred as parents to produce offspring for the next generation and mating systems decides which males would be mated with which females or the control of the way in which the parents are mated. A combination of both selection and mating system is known as breeding plans. Animal breeding was started from the domestication of wild animals and was practiced even when principles of genetics were not known.

### Domestication of Animals:

The domestication of most animal species now in use took place in prehistoric times (7000 to 8000 years ago). It is rather difficult to be precise about the exact place of domestication of different animals in the world. Domestication might have been place simultaneously and independently in several regions. Available evidences, however, indicate that most of the animals had been domesticated in Central and Western Asia, though there is some evidence for it in Egypt and Europe. Dog was the first animal domesticated. Sheep and goats were the first domesticated ruminants. Chicken and elephants were first domesticated in India. Some of the species and the region in which they were domesticated are given below.

| Species | | Region |
|---|---|---|
| Cattle | - | Europe and Asia (2100 BC) |
| Sheep | - | Europe |
| Swine | - | China (3000 B.C) |
| Horse | - | Eastern Europe and Western Assia |
| Ass | - | Egypt / Africa |
| Camel-Single humped | - | Arabia / North-East Africa |
| - Two humped | - | Asia |
| Rabbit | - | Spanish peninsula / Southern France |
| Turkey | - | America (Mexico and Peru) |

## BRIEF HISTORY OF ANIMAL BREEDING

Animal breeding practices like selection, mating of superior animals, inbreeding and outbreeding were followed in earlier days without knowing the basic principles of genetics. There was a new impetus to livestock industry around 1760 when the industrial revolution began and the demand for agriculture and livestock products increased.

During 18th century **Robert Bakewell** (1725-1795), an English farmer born in 1725 at Dishley, England carried out new methods of breeding in horse, cattle and sheep and succeeded well. He developed **Shire horses**, **Longhorn cattle** and **Leicester sheep**. Both Longhorn cattle and Leicester sheep are typical meat breeds. He is generally acknowledged as the first great pioneer in animal breeding (Father or Founder of animal breeding).

Bakewell's great contribution to animal breeding was that he tried out new methods of breeding. He purchased animals from different places for his breeding work to create a wide base. He selected only those individuals, which he considered more suitable for his work. He inbred intensively for several generations in order to consolidate the type. He rejected all the animals with undesirable characters. Robert Bakewell was the first to conduct systematic progeny testing of rams and bulls. He achieved this by hiring out selected animals to other breeders for a given fee. He retained the right to inspect all the progenies. Later he used only those males, which gave the best progeny, in his own herds.

**Principles of Bakewell:**

1. Breed the best to the best
2. Like produces like or some likeness to ancestor
3. Inbreeding produces refinement and prepotency

**Tompkins** and **Galliers** were the other contemporary breeders who laid the foundation of **Hereford cattle**. **WilliamHumphrey** developed **Hampshire Down breed of sheep**. Bakewell's work was continued by Colling brothers (**Charles Colling** and **Robert Colling**). Colling brothers developed **Shorthorn breed of cattle** by following intensive inbreeding, which became the most famous cattle of 19th century.Towards the end of 18th century, Breed Associations and Official Herd Books for various breeds appeared. Performance recording was the notable event in animal breeding after the time of Bakewell.

In 1890's rapid method of fat determination and in a few years (1895) the first association for milk recording on farm was started at Denmark. Subsequently the growth rate, feed consumption and carcass quality in pigs were also recorded. Production performance recording were also introduced into breeding flocks of sheep and poultry. In 1879, trap nesting of laying hens was first introduced in Austria. The first cow testing association was established in 1892 at Vejen in Denmark.

After the rediscovery of Mendel's principles in1900, it was not known then how Mendelian genetics could be applied to quantitative characters having continuous variations. Conflict between Mendelianists and Biometricians developed as each saw the other's theory as being incompatible with their own. By 1909 a reconciliation became available following *Johannsen's* discovery that in beans a quantitative trait, seed weight was influenced by both genes and environment and *Nilsson Ehle's*(1908) demonstration that several genes could act additively to control grain colour in wheat.

Hardy-Weinberg law, the basis of population genetics, was formulated in 1908, and since that time many scientists have contributed to our understanding of animal breeding in one form or another. Early biometricians working in the field were *FrancisGalton* and *Karl Pearson* while Sir *Ronald Fisher* and *Sewall Wright* advanced their ideas to lay the foundations of modern biometric techniques. Professor *J.L Lush* at Iowa, *Henderson* at Cornell, *Robertson* at Edinburgh and *Van Vleck* at Cornell / Minnesota have advanced our understanding of the quantitative and statistical nature of animal breeding. The pioneer in the application of population genetics to animal breeding was **Prof. J.L.Lush**. He is regarded as the Father of modern animal breeding. In the 1950's and 1960's research work on long-term selection experiments involving various livestock and poultry were initiated. During the period from 1960 to 1980, the literature is full of research regarding selection studies, heritability and correlation analyses.

Animal breeding is no longer an art but an applied science. Therefore, animal breeding is the planned genetic alteration of the population so that the animals can better fulfill the demands dictated by production requirements.

**HERD BOOK / CENTRAL HERD BOOK**

It is an official record book used to record various breeds of cattle. It is a record of purebreds or pedigree animals of a breed conforming to the breed standards. The herd book supposes to have a) Register of births b) Final register of males and c) Final register of females. The registers were to maintain detailed information on production performance of each animal, its characteristics, conformation, reproductive performance and prizes won in competitions, etc. The real purpose of herd book is to furnish the data which gives an insight into the inherited make up of the breeding animals. The other aim of the establishment of herd book was authoritative definition of breed characteristics with rules for such definition and the formulation of rules and regulations for the operation of herd book. Directions were also given for the maintenance and submission of returns.

***Closed Herd Book:*** It means that no individual can be recorded in the herd, flock or studbook that does not have the duly recorded registered ancestry.

***Open Herd Book:***It is one that admits animals when they meet in certain specific requirements and only one or neither of the parents is registered.

Towards the end of eighteenth century, breed associations and official herd books for various breeds appeared. The first stud book was started for the English Thoroughbred horses in 1791. **George Coates** published the first herd book of cattle for the Shorthorn cattle in 1822. In 1876, the first herd book for swine was started for Berkshire breed in America. The first herd book for Indian cattle, Red Sindhi and Sahiwal was opened in 1941.

**HERD BOOKS IN INDIA**

The Indian Council of Agricultural Research (ICAR) started herd book for Red Sindhi and Sahiwal breeds in 1941. In 1942, this was expanded to cover Hariana and Murrah. In 1945, this covered Gir and Kankrej breeds. In 1947, Tharparkar, Kangayam and Ongole breeds were also included. The criteria for minimum milk production for each breed in 300 days lactation is as follows.

| | | | |
|---|---|---|---|
| Sahiwal | – 1700 kg | Tharparkar | – 1400 kg |
| Red Sindhi | – 1400 kg | Gir | – 1100 kg |
| Hariyana | – 1100 kg | Kankrej | – 700 kg |
| Ongole | – 700 kg | Kangayam | - 500 kg |
| Murrah | – 1400 kg | | |

For entering in Central Herd Register animals must have unique identification number, must be over 6 months of age and confirm to the breed characteristics and dam's or daughters besides themselves satisfy the milk yield qualifications. Any breeder or farm owner interested can apply to the herd book section under the Ministry of Agriculture, Department of Livestock Development in the prescribed form for registration. Each state has a standing committee. This committee visits the farmer and after the inspection of records and verification of the animal, recommends for the admission of the animal for registration in the herd book. The owner must be willing to faithfully and accurately maintain all records of performance and pedigree and to send monthly statements of birth, death and transfer. The record must be open for inspection.

**FLOCK BOOK:** Designates the Official records for purebred sheep.

**STUD BOOK:** Official records for horses, ponies and jack.

**REGISTRATION CERTIFICATE**

It is a written record of the ancestry of an animal issued by Registry Association. This may contain considerable pertained information covering the animal's date of birth, name of the breeder, sire and dam and the respected registration number etc.Sometimes Registration Certificate is synonymously used with the name Pedigree. Pedigree, however means the written records of ancestry of animals and may not be used to refer to a registration certificate when referred to by a breeder.Pedigree is usually written in the bracket or in tabular form.

**<u>Livestock and poultry population</u>(in Millions)**

| | **World#** | **India*** | **Tamil Nadu*** |
|---|---|---|---|
| Cattle | 1525.9 | 192.49 | 9.519 |
| Buffaloes | 203.5 | 109.85 | 0.518 |
| Sheep | 1195.6 | 74.26 | 4.5 |
| Goats | 1128.11 | 148.88 | 9.89 |
| Pigs | 952.63 | 9.06 | 0.0667 |
| Camels | 38.67 | 0.25 | - |
| Horses & Ponies | 59.998 | 0.34 | - |
| Total Poultry | 33097 | 851.81 | 1120.8 |
| Backyard poultry | | 317.07 | |
| Commercial poultry | | 534.74 | |

* Source: 20th All India Livestock Census **2017**,DAHD&F,GoI
# FAO Statistic (World Statistics) **2020**

First Livestock Census throughout British India was conducted during 1919 – 1920

## Taxonomical classification of livestock (Farm animals)

Taxonomy is a branch of biology that deals with the identification, nomenclature and classification of living organisms.

The living organism is classified broadly into two kingdoms

**Animal kingdom**: includes all animals

**Plant kingdom**: includes all living plants

Under animal kingdom there are 5 phylas.

| | | |
|---|---|---|
| **Chordata** | : | A phylum comprising all animals that have a notochord during some stage of their development. It includes the cephalochordate, neochordata and vertebrata. |
| **Invertebrata** | : | Division of animal kingdom comprising all forms that have no spinal cord. |
| **Vertebrata** | : | A sub phylum of chordata comprising all animals that have a vertebral column. It includes mammals, birds, reptiles, amphibians and fishes. |
| **Mammalia** | : | A class of warm blooded vertebrate animals including all that possesses mammary gland, sweat glands, hair and suckles their young ones. |
| **Aves** | : | It is a class including birds characterized by feathers, warm blooded, vertebrates with four chambered heart. |
| **Primates** | : | The order of mammals to which man belongs characterized by increasing digital mobility, replacement of claws by flat nails, development of stereoscopic vision and progressive development of cerebral cortex. |
| **Ungulata** | : | Hoofed animals |
| **Carnivore** | : | A large order of placental mammal including dogs and cats adapted for predation as evidenced by dentition and jaw articulation. |
| **Artiodactyala** | : | An order of mammalia characterized by having an even number of toes and by having the main limb axis passes between the third and fourth toes. |
| **Perisodactyla** | : | An order of exclusive herbivorous mammals distinguished by an odd number of toes and mesoxomic feet *i.e.* with axis going through third toe. |
| **Felidae** | : | The cats and sabre toothed cats, a family of mammals in the super family felocidae |
| **Canidae** | : | Family of carnivore mammals in the super family canidae including dogs and their allies |
| **Suidae** | : | A family of paleodont artiodactyls in the super family suidae including wild and domestic pigs. |
| **Equidae** | : | A family of perisodactyle mammals in the super family equidae including horses, zebras and donkeys |

**IMPORTANT ECONOMIC TRAITS IN FARM ANIMALS ARE AS FOLLOWS:**

| | **Dairy Cattle** | **Pig** | **Sheep** | **Poultry** |
|---|---|---|---|---|
| ***Reproductive Traits*** | AFC<br>Services per conception, service period, calving interval, twinning. | Litter size<br>Litter per year, Survival ability | Age at first mating,<br>litters per year. | Age<br>Fertility |
| ***Production traits*** | Milk yield per lactation | Weaning weight, Slaughter weight, Age at slaughter | Fleece diameter, fleece weight, | Egg size, Number<br>Laying period |
| ***Quality traits*** | Milk fat composition<br>Milk protein composition<br>Somatic cell counts | Lean carcass<br>Dressing percentage<br>Fat depth | Medullation, killing out per cent | Growth<br>Flavour and taste<br>Shell colour |
| ***Aesthetic traits*** | Polled<br>Soft skin | Skin colour<br>Teat numbers | Polled | Feather colour<br>Fighting<br>Body conformation |
| ***Behavioural traits*** | Temperament | Temperament | Temperament | Broodiness |

**DESCRIPTION OF ECONOMIC TRAITS IN CATTLE AND BUFFALOES**

**Definitions / Formulae**

| | | | |
|---|---|---|---|
| **1.** | **Age at first calving (AFC)** | **:** | Age of a cow or buffalo in days at the time of first calving. |
| **2.** | **Life time daily yield (LDY)** | **:** | Milk yield per day from birth to culling, which can be used as an overall indicator of technical performance at the farm, as it averages out total milk production over every day a cow has been alive |
| **3.** | **Milk yield per day of lactation** | **:** | Average milk production per day upto 305 days lactation |
| **4.** | **Lactation length (LL)** | **:** | Number of days in milk yield from the date of calving to the date of drying or cessation of milk production (the order of lactation should be indicated as I, II, III *etc*). |
| **5.** | **Lactation milk yield (LMY)** | **:** | Milk yield from the date of calving to the date of drying or cessation of milk production (the order of lactation should be indicated as I, II, III *etc.*). |
| **6.** | **305-days milk yield** | **:** | Milk yield from the date of calving to 305$^{th}$ day of lactation. If the lactation length is less than 305 days, the milk yield for the lactation period is considered as 305-day milk yield. When the lactation length is more than 305 days, milk yield for the lactation is converted to 305 days using correction factor. |
| **7.** | **Peak yield** | **:** | Highest day milk yield during the lactation period |
| **8.** | **Average daily milk yield** | **:** | Average daily milk yield in kg is calculated by dividing the lactation milk yield by the lactation length. |
| **9.** | **Fat percentage** | **:** | The fat content of milk is the proportion of milk, by weight, made up by butterfat |
| **10.** | **Average fat percentage** | **:** | Average of fat done with milk samples drawn during lactation at fortnightly intervals. |
| **11.** | **SNF (solids not fat)** | **:** | The substances in milk other than butterfat and water; which include casein, lactose, vitamins and minerals which contribute significantly to the nutritive value of milk. |
| **12.** | **Age at Puberty** | **:** | Defined as the age at which the female or male gonads become capable of releasing the gametes (Oocytes or |

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|---|---|---|---|
| | | | Spermatozoa). Puberty in females is defined as the age at the first expressed estrus with ovulation. |
| **13.** | **Age at sexual maturity (ASM)** | **:** | The age at which the female become capable for insemination and pregnancy. |
| **14.** | **Age at first service (AFS)** | **:** | Age of a cow or buffalo in days at the time of first service |
| **15.** | **Dry period ( DP)** | **:** | Number of days from the date of dry to the date of next calving (the order of dry period should be indicated as I, II, III *etc.*). |
| **16.** | **Service period ( SP)** | **:** | Number of days from the date of calving to subsequent service resulting in conception. |
| **17.** | **Calving interval or inter-calving period (CI)** | **:** | Number of days from the date of one calving to the date of next calving (the order of calving interval should be indicated as I, II, III *etc.*). |
| **18.** | **Total days in milk** | **:** | This is the sum of lactation length for all the lactations. |
| **19.** | **Days open (%):** | **:** | It is the percentage of total service period (days) in all lactations to the herd life. |
| **20.** | **Days dry (%):** | **:** | It is the percentage of total days dry in all lactations to the herd life. |
| **21.** | **Conception rate** | **:** | Number of services required per conception. It should be calculated for I calving, II calving *etc.* |
| **22.** | **Fertility index (Bulls):** | **:** | $= \frac{\text{No. of Conceptions}}{\text{No. of inseminations}} \times 100$<br><br>This is called the fertility index for the $i^{th}$ bull but if estimated for the entire herd, it is then called as conception rate or pregnancy rate or fertility rate. |
| **23.** | **Structural soundness** | **:** | The structural soundness of bulls influence the ability of a bull to deliver his genetics to the point of fertilisation (in the cow) for as long as the cattle breeder chooses to use the bull in the herd. It embraces a range of traits of the more rigid skeletal structure as well as the softer tissues critical to bull function namely Feet and legs, Head and eyes, Sheath and penis. |
| **24.** | **Body conformation** | **:** | It is one of the utmost important qualities that a cattle producer must know about and understand |

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|---|---|---|---|
| | | | when raising a good, solid breeding herd of cattle. It is the desirable and undesirable skeletal and muscular structures of an animal |
| **25.** | **Disposition or Temperament** | **:** | It is a moderately heritable trait, so producers can make improvements through genetic selection as good animal-handling practices throughout the production system also can improve the disposition of cattle and reduce the negative effects of stress during shipping and processing |
| **26.** | **Breeding efficiency** | **:** | Overall reproductive efficiency of the animal is expressed as percentage. It is estimated for the lifetime of a cow/buffalo based on the number of calvings in lifetime as under: |

The breeding efficiency is a complex phenomenon controlled by both genetic and non-genetic factors, the non- genetic factors being climate, nutrition, and level of management. The breeding efficiency varies not only between species and breeds but also among the animals within the same breed. Even the best feeding and management cannot coax performance beyond the genetic limit of an inferior animal. The initial formula for working out the breeding efficiency of dairy cows was given by Wilcox et al. (1957) and was based on a calving interval of 365 days. Since the buffaloes have a gestation period of 310 days the calving interval is increased to 400 days. Thus the formula for working out the reproductive efficiency has been modified by many workers (Tomar, 1965).

**1) Tomar's Formula (1965):**

$$\text{Breeding efficiency (\%) in Zebu cows} = \frac{(\text{No. of calving intervals X } 365) + 1020}{\text{Age at first calving + Sum of calving intervals}} \text{ X } 100$$

$$\text{Breeding efficiency (\%) in Buffaloes} = \frac{(\text{No. of calving intervals X } 365) + 1040}{\text{Age at first calving + Sum of calving intervals}} \text{ X } 100$$

**2) Wilcox formula (1957):**

$$\text{B.E.} = \frac{365\ (N-1)}{D} \text{ X } 100$$

Where, N = Total Number of calvings

D = No of days from 1$^{st}$ to last calving.

**18.** The life time production and production efficiency of the animals can be evaluated by the following parameters.

- Life time milk production = Sum of all lactation yields
- Average lactation milk yield = Sum of lactation yields / No. of lactations
- Average daily milk yield = Sum of all lactation yields / No. of days in lactations

Milk yield per day of first calving interval = Lactation yield / No. of days in calving interval.

**DESCRIPTION AND MEASUREMENT OF ECONOMIC TRAITS IN SHEEP AND GOATS**

**Definitions / Formulae:**

| | | | |
|---|---|---|---|
| 1. | **Age at sexual maturity** | | The age at which the female become capable for pregnancy |
| 2. | **Age at first Lambing** | : | Age of a ewe in days at the time of first lambing. |
| 3. | **Tupping percentage** | : | Number of ewes mated to the number of ewes put to ram. |
| 4. | **Ewe productivity efficiency ( EPE)** | : | It is the total weight of lambs produced per kg of ewe body weight per year |
| 5. | **Age at first tupping (AFT)** | : | Age of a ewe/doe in days at the time of first service |
| 6. | **Litter size at birth** | : | The number of offspring given by the ewe in a single lambing |
| 7. | **Litter size at weaning** | : | The number of offspring given by the ewe in a single lambing which have survived till weaning which is generally 3 months. |
| 8. | **Lambing percentage** | : | Number of ewes lambed to the number of ewes put to ram. |
| 9. | **Weaning percentage** | : | Number of lambs weaned to the number of ewes born. |
| 10. | **Birth percentage** | : | Number or twin births to the total number of births. (Total number of ewes lambed.) |
| 11. | **Lambing interval** | : | It is the time interval between successive lambings. Number of days from the date of one lambing to the date of next lambing. |
| 12. | **Type of lambing** | : | singles, twins triplets and quadruplets |
| 13. | **Birth weight** | : | Weight of lamb in kg at Birth( weighed within 24 hrs) |
| 14. | **Weaning Weight** | : | Weight of lamb in kg at 90 days. |
| 15. | **Six months weight (6 BW)** | : | Weight of lamb in kg at 180 days. |
| 16. | **Nine months weight (9 BW)** | : | Weight of lamb in kg at 270 days. |
| 17. | **Twelve months weight (12 BW)** | : | Weight of lamb in kg at 360 days. |
| 18. | **Adult weight Male / female (18 BW)** | : | Weight of the animal in kg at 540 days. |

| | | | |
|---|---|---|---|
| **19.** | **Weight at first lambing / kidding** | **:** | Weight of the ewe/doe after first lambing. |
| **20.** | **Weight at Market age** | **:** | Weight of lamb in kg at the market age of 180, 270 or 365 days. Usually for Indian sheep 9th month weight is called market age |
| **21.** | **Pre- weaning growth rate** | **:** | Daily weight gain in grams from the date of birth to the date of weaning. |
| | Pre - weaning growth rate $= \dfrac{\text{Weaning weight (90}^{th}\text{ day) – Birth weight}}{90}$ | | |
| **a)** | **Post- weaning growth rate** | **:** | Daily weight gain in grams from the date of weaning to the date of marketing. |
| | Post- weaning growth rate $= \dfrac{\text{Weight at market age (180, 270 or 365 day) – Weaning weight}}{\text{Weight at market age (180, 270 or 365 day)}}$ | | |
| | **Metabolic Weight:**<br>The metabolic weight is generally used to calculate the weight of active tissue. Metabolic weight is calculated as the live weight raised to the power of 0.75. | | |
| | **Kleiber Ratio :**<br>The Kleiber ratio is calculated by dividing the Average Daily Gain (ADG) with the animal's metabolic weight. It gives a good indication of how economically an animal grows; therefore a positive value is desirable. | | |
| | **Pre weaning mortality**: Number of lambs died from birth to 90thday (weaning) to the number of lambs born alive | | |
| | **Post weaning mortality**: Number of lambs died from weaning to 365 days to the number of lambs weaned. | | |
| | **Adult mortality**: Number of adult sheep died during the year to the number at beginning of the year. | | |
| | **Hot carcass weight**<br>Weight of the carcass after slaughter after the removal of the head, hide, intestinal tract, and internal organs**.** | | |

| | |
|---|---|
| | **Pre slaughter weight**<br><br>The weight of the animal which is fasted for 8-10 hours prior to slaughter**.** |
| | **Empty live weight**<br><br>It is the difference between slaughter weight and weight of digestive content. |
| | **Dressing percentage (DP)**<br><br>The percentage of the live animal weight that becomes the carcass weight at slaughter. It is determined by dividing the carcass weight by the live weight, then multiplying by 100**.** |
| | **Primal cuts**<br><br>Lamb is divided into large sections called primal cuts *i.e.*, shoulder, rack, breast, loin and leg.These large cuts are then broken down further into individual retail cuts that are sold at supermarket or butcher's shop. |
| | **Fleece weight.**<br><br>a) Grease fleece weight: Weight of raw fleece in kg shorn in a year. (Usually first shearing at six months and then annually.)<br>b) Clean fleece weight: Weight of clean fleece derived from raw fleece. |
| | **Fibre thickness or fineness of wool**:<br>Average diameter of a wool fiber in microns. |
| | **Fiber density**:<br>Average number of wool fibers per square centimeter area. |
| | **Staple length**:<br>Length of a wool fibre in centimetre obtained by measuring the natural staple without stretching the crimp |
| | **Medullation percentage**:<br>Number of medullated fibres to the total number of fibres examined. |

**GOATS:**

| | | |
|---|---|---|
| **1. Age at first kidding** | : | Age of the doe in days at the time of first kidding. |
| **2. Lactation length** | : | Number of days in milk from the date of kidding to the date of cessation of milk production. |
| **3. Lactation milk yield** | : | Milk yield in kg from the date of kidding to the date of cessation of milk production. |

| | | |
|---|---|---|
| **4. 150 day lactation milk yield** | **:** | Milk yield in kg from the date of kidding to 150th day of lactation. If the lactation length is less than 150 days, it is taken as 150days milk yield. |
| **5. Kidding interval** | **:** | Number of days from the date of one kidding to the date of next kidding. The time period between successive kiddings. |
| **6. Twinning ability** | | Can be determined as number of twin kidding over number of total kidding per year |
| **7. Incidence of multiple births** | **:** | Number of multiple births to the total number of births. |
| **8. Birth weight** | **:** | Weight of a kid in kg at birth. |
| **9. Weaning weight** | | Weight in kg at weaning. |
| **10. Weight at market age** | **:** | Weight in kg at market age of 180, 270 or 365 days. Usually for Indian goats, 9th month weight is called as market weight. |
| **12.Growth rate** | | |
| **a) Pre-weaning growth rate** | **:** | Daily weight gain in grams from the date of birth to the date of weaning. |

$$\text{Pre- weaning growth rate} = \frac{\text{Weaning weight } (90^{th} \text{ day}) - \text{Birth weight}}{90}$$

**b) Post- weaning growth rate** **:** Daily weight gain in grams from the date of weaning to the date of marketing.

Post- weaning growth rate =

$$\frac{\text{Weight at market age (180, 270 or 365 day)} - \text{Weaning weight}}{\text{Weight at market age (180, 270 or 365 day)}}$$

**13.Mortality percentage:**

a. Pre weaning mortality: Number of kids died from birth to 90thday (weaning age) to the number of kids born alive.
b. Post weaning mortality: Number of kids died from weaning to 365 days to the number of kids weaned.
c. Adult mortality: Number of adult goats died during the year to the number at beginning of the year.

**DESCRIPTION AND MEASUREMENT OF ECONOMIC TRAITS IN SWINE AND POULTRY**

| **Economic traits in pigs :** | | | |
|---|---|---|---|
| 1. | **Litter size at birth** | : | Number of piglets born in a litter**.** |
| 2. | **Litter size born alive** | : | Number of piglets born alive in a litter |
| 3. | **Litter size at weaning** | : | Number of piglets weaned per litter on 56th day. |
| 4. | **Birth weight** | : | Weight of a piglet in kg at birth**.** |
| 5. | **Litter weight at birth** | : | Weight of all piglets at birth in a litter. |
| 6. | **Weaning weight** | : | Weight of a piglet in kg at 56th day of age(weaning) |
| 7. | **Litter weight at weaning** | : | Weight of all piglets in a litter in kg at weaning. |
| 8. | **Weight at market age** | : | Weight of a piglet in kg at the market age of 154 or 210 days. |
| 9. | **Structural soundness** | : | Structural soundness is hence an integral part of this fertility. The boar's ability to remain fertile is dependent on his structural soundness. Elements of a boar's conformation are heritable. |
| 10. | **Body conformation** | : | Body conformation measurements in the pig. Body conformation measurements in the pig including abdominal circumference at the navel (A), the length of the body from rump to the front of the shoulder blade (B), shoulder height (C), and thorax height (D). |
| 11. | **Loin eye area** | : | It is recorded on the cut surface of the *Longissimus dorsi* muscle at the interface of 12th and 13th ribs on both the sides of the carcass after tracing on tracing paper. The traced area is measured using compensating Planimeter with optical tracer and reported in $cm^2$. |
| 12. | **Back fat thickness** . | : | It is measured at the P2 position which is 65mm down the left side from the midline, at the level of the head of the last rib. The procedure is performed with the pig standing. Pigs are usually restrained in a stall, weigh crate or walkway; however, no restraint is needed if the pig stands quietly |
| **13. Feed efficiency:** | | : | Weight of feed consumed in kg for producing one kg of live weight. |
| **14. Mortality percentage:** | | | |
| a) | Pre weaning mortality | : | Number of piglets died from birth to 56th day (weaning) to the number of piglets born alive. |
| b) | Post weaning mortality | : | Number of piglets died from weaning to 365 days to the number of piglets weaned. |
| c) | Adult mortality | : | Number of adult pigs died during the year to the number at beginning of the year. |
| **15.** | **Age at puberty (days)** | | Age of the sow in days when it shows signs of first heat |
| **16.** | **Age at 1st Farrowing (days)** | | Age of the sow in days when it first gave birth |

| | | | |
|---|---|---|---|
| 17. | **Lactation length** | | Number of days the sow gives milk to the piglets |
| 18. | **Milk yield** | | Total amount of milk in liters given by the sow after each farrowing |
| 19 | **No of teats** | | Number of teats pertaining to each sow |
| 20. | **Carcass Cutting Yield** | | (Pounds of meat/ Carcass weight) x 100 |
| 21. | **Lean meat yield** | | the amount of muscle relative to the weight of the carcass |
| 22. | **Dressing percentage (DP)** | | (Carcass Weight / Live Weight) x 100 |

**23. Growth rate:**

**a) Pre- weaning growth rate:** Daily weight gain in grams from the date of birth to date of weaning.

.

$$\text{Pre- weaning growth rate} = \frac{\text{Weaning weight } (56^{th} \text{ day}) - \text{Birth weight}}{56}$$

**b) Post- weaning growth rate:** Daily weight gain in grams from the date of weaning to the date of marketing.

$$\text{Post- weaning growth rate} = \frac{\text{Weight at market age (154 or 210 days)} - \text{Weaning weight}}{\text{Weight at market age (154 or 210 days)}}$$

| **ECONOMIC TRAITS OF CHICKEN / BROILERS** | | |
|---|---|---|
| 1 | **Growth rate** | Weight of chick in gms per day at 2, 4, 6 and 8 weeks |
| 2 | **Body weight at 4 weeks** | Weight of a chick in grams at $4^{th}$ week |
| 3 | **Dressing percentage** | It is calculated by dividing the warm carcass weight by the shrunk live weight of the animal and expressing the result as a percentage |
| 4 | **Hatch weight** | Weight of a chick in grams at hatching. |
| 5 | **Fortnightly weight up to 8 weeks:** of age. | Weight of a chick in grams at 2, 4, 6 and 8 weeks |
| 6 | **Feed efficiency:** | Feed consumed in kg to produce 1 kg live weight at 6 or 8 weeks of age. |
| 7 | **Livability (0-8 weeks):** | Number of chicks alive at $8^{th}$ week to the number of chicks at the start (0 day), expressed as percentage.<br>$$\frac{\text{Number of chicks alive at } 8^{th} \text{ week}}{\text{Number of chicks housed at 0 day}} \times 100$$ |
| **ECONOMIC TRAITS OF CHICKEN / LAYERS** | | |
| 1 | **Body weight at maturity** | Body weight of the bird in gms when it attains maturity |
| 2 | **Age at first egg** | Age of the bird in days when it lays the first egg |

| | | | |
|---|---|---|---|
| 3 | **Fertility** | | Percentage of fertile eggs to the total eggs set for hatching |
| 4 | **Egg weight** | | Weight of the egg in gms |
| 5 | **Hatchability** | | Percentage of chicks hatched to the total number of fertile eggs set for hatching (or) percentage of chicks hatched to the total number of eggs set for hatching |
| 6 | **Egg shape index** | | defined as the ratio of width to length of the egg |
| 7 | **Shell texture** | | The structure and the texture of the egg shell |
| 8 | **Rate of lay for individual bird** | | No. of eggs laid up to a fixed date or age<br>---------------------------------------------------- X 100<br>No. of days in lay |
| 9 | **Yolk index** | | It is the ratio between height and diameter of yolk under defined conditions |
| 10 | **Albumin index** | | It is the height : width ratio of the albumin when the egg is broken onto a flat surface |
| 11 | **Haugh index or The Haugh unit** | | It is a measure of egg protein quality based on the height of its egg white (albumen)<br>$HU = 100 * \log_{10} (h - 1.7w^{0.37} + 7.6)$<br>Where<br>• HU = **Haugh unit**<br>• h = observed height of the albumen in millimeters<br>• w = weight of egg in grams<br>The **Haugh unit** value ranges from 0 - 130 and it can be ranked as below:<br>• AA : 72 or more<br>• A : 71 - 60<br>• B : 59 – 31<br>• C : 30 or less |
| **12.** | **Hatch weight** | **:** | weight of a chick in grams at hatching |
| **13.** | **Weight at 20 weeks** | **:** | Weight of a chick in grams at 20 weeks of age |
| **14.** | **Age at maturity** | **:** | Age in days from the day of hatch to the date of first egg |
| **15.** | **Weight at maturity** | **:** | Weight of a bird in grams on the day of first egg. |
| **16.** | **Age in maturity in flocks without trap nesting** | **:** | Age in days of a flock when |
| | a) the first egg in the flock was laid | | |
| | b) 30% production ( on hen-day basis) is reached or | | |
| | c) 50% production ( on hen-day basis) is reached | | |
| | | | |
| **17.** | **Egg production at 40 weeks** | **:** | Number of eggs laid by a pullet from the date of first egg to the completion of 40 weeks of age. |

**18) Hen day production at 40 weeks of age:**

$$\frac{\text{Total number of eggs laid by a flock up to 40 weeks}}{\text{Number of hen-days}} \times 100$$

**19) Hen housed production at 40 weeks of age:**

$$\frac{\text{Total number of eggs laid by a flock up to 40 weeks}}{\text{Number of hens housed at 20 weeks X Number of days}} \times 100$$

**20) Hen day production at 72 weeks of age:**

$$\frac{\text{Total number of eggs laid by a flock up to 72 weeks}}{\text{Number of hen-days}} \times 100$$

**21) Hen housed production at 72 weeks of age:**

$$\frac{\text{Total number of eggs laid by a flock up to 72 weeks}}{\text{Number of hens housed at 20 weeks X Number of days}} \times 100$$

**22) Livability (0-20 week):** Number of hens alive at 20th week to the number of chicks housed at the start (0 day) expressed as percentage.

$$\frac{\text{Number of hens alive at 20}^{th}\text{ week}}{\text{Number of chicks housed at the start (0 day).}} \times 100$$

**23) Livability (20 to 72 week):** Number of hens alive at 72nd week to the number of chicks housed at the start (20th week), expressed as percentage.

$$\frac{\text{Number of hens alive at 72nd week}}{\text{Number of chicks housed at the 20}^{th}\text{ week.}} \times 100$$

**24) Feed efficiency (feed conversion ratio):** Feed consumed in kg to produce one kg egg mass / a dozen eggs.

**25) Egg weight or Egg size:** Average weight of three consecutive eggs in grams laid during 40weeks of age.

**Galton's Law of filial regression:**

**Francis Galton** (1822-1911) stated: Offspring of outstanding parents often have a tendency to regress towards the average of the breed / population from the mid parent value. This is referred to as the Galton's law of filial regression. In studying human stature, Galton found that progeny of tall parents were not usually as tall as parents and the progeny of short parents were not as short as parents. In each case, progeny were nearer the population mean and Galton expressed this as the regression towards the population average.

The superiority of outstanding parents may be due to a) suitable combination of genes and type of gene action b) a satisfactory environment. The reasons for regression are: when the parent reproduces, due to segregation and independent assortment of genes, the suitable combination is broken up and the average results. The regression may also be due to the environment in which the offspring are brought up which is much different from that of the parent. It should be remembered that the law of regression can be applied with confidence only to the average of large number of observations.

**Galton's Law of Ancestral Heredity:**

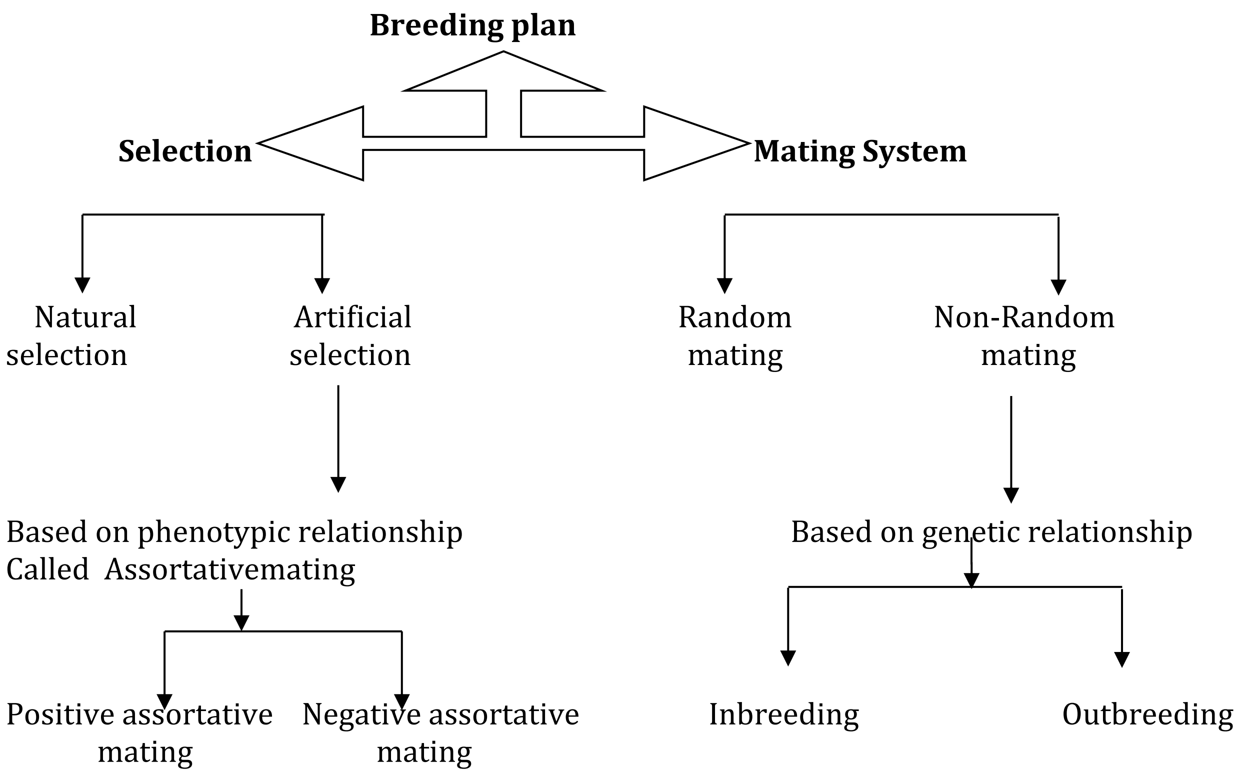
According to this law, correlation between an individual and its ancestor is $(½)^n$, where 'n' is the number of generations intervening. i.e. this correlation is half $(½)^1$ for an individual and a parent, $(½)^2$ for an individual and a grand-parent, $(½)^3$ for an individual and a great grand-parent and so on.

## SELECTION

Breeders can change the genetic properties of the population by two ways:

1. **Selection** (choice of individuals to be bred as parents)
2. **Mating system** (control of the way in which parents are mated).

The combination of both selection and mating systems constitutes a **breeding plan**.




Selection is choosing parents of the next generation. Selection is the process in which certain individuals in a population are given an opportunity to produce offspring while others are denied this opportunity. Selection in animal breeding concerns itself with differential rate of reproduction within a population, whereby animals with some characters tend to have more offspring than animals without those characters.

### Genetic effects of selection

Selection does not create new genes but only sorts the existing genes. By selection we allow those animals possessing favorable genes to reproduce and those individuals with undesirable genes are discarded. Therefore selection increases the frequency of desirable genes and decreases the frequency of undesirable genes in a population. If the frequency of desirable gene is increased, the proportion of individuals homozygous for that desirable gene is also increased.

***Selection is of two kinds: 1. Natural selection 2. Artificial selection***

**1. Natural Selection:** Natural selection is influenced by nature and not by man. The main force responsible for natural selection is "**Survival of the fittest**" in a particular environment. e.g. wild animals. In long run, natural selection leads to an improved genetic acclimatization of the population to the prevailing environmental condition mainly with regard to fertility among the parents and viability among their progeny. Natural selection is a very complicated process and many factors determine the proportion of individuals that will reproduce. They are

1. Differences in degree of fertility of individuals in that population.
2. Differences in mortality in the population especially in early life.
3. Differences in the duration and degree of sexual activity.
4. Differences in the lifetime of different individuals.

**2. Artificial Selection**

Artificial selection is the selection practiced by man. Artificial selection can be defined as the efforts of man to increase the frequency of desirable genes in his herd / flock by locating or saving those individuals with superior performance. It may differ from natural selection both in intensity and direction. This merely sorts genes and permits the better ones to be saved and the poorer ones to be discarded. Artificial selection has two aspects: **Replacement selection and Culling**. In replacement selection we decide which individuals will become parents for the first time. The new animals selected to replace the existing parents that have been culled are called replacements.

**Culling** is the process of removal of poor / inferior animals from the breeding population. Culling decides which parents will no longer remain parents. While doing culling, decision should be firm that culling has been made for genetic or environmental reasons. It is easy to cull poor looking stock but genetically this achieves little if they are poor because of environmental reasons. e.g. In dairy cows high yielders will be thin and poor looking and dry cows will be fatty. Selection and culling go together and they are really just different sides of the same coin. They involve different sets of animals, but their purpose is the same. Artificial selection is aptly called as the "Keystone of the arch" of the animal breeding.

**COMPLICATIONS OF SELECTION:**

Selection is carried out on for a variety of traits in different species. Speed in racehorses, milk yield in dairy cattle, litter size in swine, wool yield in sheep, market weight in goats and egg production in poultry. In farm animals' selection should always be directed to greater utility. However, selection is not so simple a task to produce immediate results. Selection is also not always successful. If selection were always be effective, the animal breeder's problems would be largely resolved. But the failures of selection serve to dampen the enthusiasm of many people engaged in animal breeding. The complications can be classified as two basic types.

**1. Genetic complications of selection**

i. Heredity and environment
ii. Genotype and phenotype
iii. Heritability
iv. Type of gene action
v. Correlation of traits
vi. Effects of inbreeding
vii. Regression to the mean (Galton's law of filial regression)

**2. Operational complications of selection**

i. Objectives in selection
ii. Number of traits
iii. Foundation stock
iv. Level of performance
v. Systems of selection
vi. Length of time
vii. Number of animals

**1. Genetic complications:**

**i) Heredity and environment:**

Most traits of economic importance are controlled by many genes and are greatly influenced by environment also. The environment therefore may so alter the traits as to mask the real genetic worth of the individuals. For example, an animal with a faster growth rate raised on faulty environment (deficient diet) and an animal with poor genetic constitution for rate of growth but raised in a good environment can be responsible for mistakes in selection.

This effect of environment can be responsible for mistakes in selection. However, this effect could be overcome by keeping the stock under selection in a standard and suitable environment where in the better genotype will be able to express itself fully themselves. Under such conditions, the breeder will have a chance to recognise the differences that are hereditary and thus increase the accuracy of selection.

**ii) Genotype and phenotype:**

Genotype is animal's genetic constitution. The genotype remains constant for an animal through out its life. But phenotype is the result of interaction between the genotype and environment in which the animal is developing. The phenotype unlike the genotype changes with time. Hence it affects selection.

Selection is done for the genotype but seldom could it be assessed correctly. So the genotype is assessed based on phenotype of the individual though it is not accurate. If we know the transmitting abilities of our animals the progress from selection will surely be there. But it will not be possible even after extensive progeny tests.

The performance also varies with the age of the individual. So for the selection to be effective, it should be done at the market age when the economic traits show up in meat animals like sheep swine and poultry. Cows should be selected at the end of first lactation.

**iii) Heritability:**

Most selection processes are based on phenotypic differences. Though we are selecting on phenotypic basis, our aim is to effect genotypic basis. If the phenotype accurately reflects the genotype the selection will be quite accurate. But phenotype is not the true indicators of genotype. Heritability of a trait may be defined as that portion of the phenotypic variation that is due to additive gene action. If most of the phenotypic variation is due to environment progress from selection will be slow. On the other hand, if the additive genetic variation is larger than the heritability estimate will more accurately predict the genotype.

The heritability values are not constant and vary from herd to herd and in the same herd from time to time. Inbreeding for instance increases homozygosity of genes and reduces the hereditary variation. Heritability therefore will decrease with inbreeding and increase with outcrossing.In other words phenotype or individual selection will be more effective in herds and for traits where the heritability is high. Hence, knowledge of heritability of economic traits in livestock is therefore essential for a breeder. Heritability estimates are ratios expressed in percentage and usually designated as $h^2$.

**iv) Regression to mean:**

The offspring of outstanding parents often have a tendency to regress towards the average of the breed from which they were selected. This is referred to as **Galton's law of filial regression**. This may be

a. **Due to combination of genes**

   When they reproduce due to segregation and independent assortment of genes, the suitable combination is broken up and the average results.

b. **Due to environment**

   The regression may also be due to the environment where in the offspring are brought which is much different from that of parent.

**How to avoid this regression?**

1) If the superiority of the parents is due to lucky combination of genes little could be done to interfere with the laws of segregation and independent assortment.
2) If the superiority of the parents is due to high percentage of homozygosity of favorable genes, by adopting inbreeding the gene pool could be maintained in the offspring.
3) If the superiority of the parents is due to heterosis i.e. Aa (heterozygous) better than AA or aa (homozygous) it is not possible to control the segregation of genes. So heterozygous individuals that are superior could be used for market but not for breeding.

The environmental part of regression can be leveled out a great deal by keeping the same environment as far as possible from year to year. This is another reason why animals should be tested and selection should be made under conditions similar to one in which their offspring are to perform.

**v) Type of gene action:**

Genes act differently in different combinations. This makes accurate selection more difficult. For instance, when A is dominant to a, AA and Aa individuals who have the same phenotype will be selected with equal preference. But AA will breed true whereas Aa will segregate. But in case of over dominance, Aa will produce larger effect than AA / aa.

So in heterozygous condition selection will not produce desired results. Only crossing of appropriate inbred lines will produce the desired effect. Hence the job of the breeder is to increase the frequency of favorable alleles and to discard the less favorable ones.

**vi) Correlation of traits:**

Some characteristics are positively correlated for example, rate of gain in weight and efficiency of gain in swine. Whereas, some others are negatively correlated for example, milk yield and butter fat percentage in dairy cattle. If the desirable traits are positively correlated selection becomes somewhat easier. If you select for one trait the other automatically improves. Whereas, for the traits with negative correlation: selection for one trait will affect the other trait. Hence, knowledge of correlation of different traits will be of great help in avoiding mistakes in selection.

**vii) Effect of inbreeding:**

It is generally known that a decline in all attributes of vigor usually accompanies inbreeding. Breeders therefore hesitate to practice inbreeding. However, it is necessary to practice inbreeding in order to induce gene segregation and to fix desirable gene combinations. Inbreeding increases prepotency. Regularity of transmission is increased with increased homozygosity that is obtained only through inbreeding and selection.

**To avoid depressing effects of inbreeding**

i. Choose foundation stock that is superior in production.
ii. Rigid selection from beginning to offset the possible bad effects of inbreeding on performance.
iii. Flexible system of mating that permits besides close breeding, mating of best individuals that is controlled breeding.

**2. Operational complications:**

**i) Objectives of selection:**

Many failures in selection of livestock may be attributed to a lack of definite objective as a result of which selection has changed its direction frequently. Selection will be more effective when the breeder has definite objective for which to strive. The objective should be defined by measurements. Judgment should be used along with measurements, but should never replace measurements.

**ii) Number of traits:**

When a single trait is subjected to selection it is very simple to rank the individuals in order of their merit for the trait. This becomes increasingly difficult as the number of trait is increased. An animal may be good in one trait and deficient in another. Only a few individuals will be good in all the characters that are under selection. To simplify this problem, the number of traits must be kept as small as possible and must be those with greatest value from the stand of utility.

**iii) Foundation stock:**

Selection will be ineffective if the foundation animals are genetically poor and also where there is no genetic variability. Selection merely sorts genes and permits the better ones to be saved and poorer ones to be discarded. Therefore it is important to start with good foundation stock.

**iv) Level of performance:**

In available stock, selection will be effective for the first few generations and then it becomes ineffective for further progress. When the level of performance rises after a few years, due to increased homozygosity and frequency of desirable genes, further progress is slow, unless it is accompanied by a system of mating that will bring about new gene combinations.

For example, by artificial insemination is used as a tool, for increase in milk production. The improvement will be achieved in few generations and afterwards the progress is less and less. Then it does not mean that the sire used is not inferior, but the level of performance of the herd has become higher.

**v) System of selection:**

Too much rigidity in the systems of selection may be a handicap to progress in animal breeding programme. For example, a breeder may specify that no cows should be selected with the lactation yield less than 2000 kg. But only few cows will be available and after few years very few animals will reach the standard. A selection index giving relative importance to each trait is good. But the importance of the trait at that particular time should be taken into consideration for selecting the trait.

**vi) Number of animals:**

Where there are few animals in the herd, selection is very much restricted. Selection pressure will be applied effectively since it will cull most of the animals leaving few that will not be able to replace the stock. Also there will be little opportunity for genetic segregation.

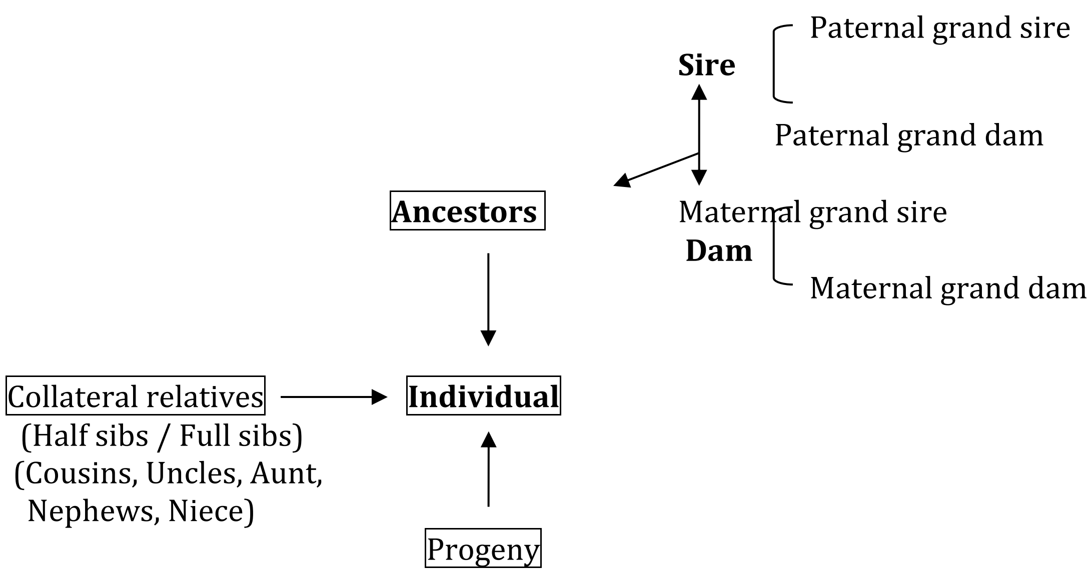
**vii) Length of time:**

The turnover in livestock is slow in number of animals and in number of generations because small herds or flocks offer so little opportunity for genetic segregation. So the breeder must be prepared to continue his project for a relatively longer period of time. Progress in a single generation is apt to be masked by environmental effect and it takes many years to turn over several generations in large animals. Although progress per year is small real improvement can be effected over a long period of time.

# Aids to Selection (Selection criteria / Basis of selection)

***Individuality tells us what an animal seems to be, his pedigree tells us what he ought to be but the performance of his progeny tells us what he is.***

Any progress in animal breeding through the application of selection and mating methods will depend upon the ability to recognize those animals, which possess superior inheritance. Those superior animals must be mated together for the production of better offspring. The superior breeding stock can be identified based on the performance of its own and or that of its relatives. The kinds of relatives an individual possesses are shown below.




In selection the breeding value of an individual is judged / estimated from several aids viz. its own phenotype/performance, performance of its ancestors, its progenies, its collateral relatives (sibs). These aids are also called as tools to selection. The selections based on these aids are respectively known as

1. Individual selection or Mass selection
2. Pedigree selection
3. Family and sib selection
4. Progeny testing

**Individual selection**

Selection on the basis of individuality means that selecting an individual on the basis of its individual phenotypic value (appearance / type and production performance). This is otherwise known as Performance test. Selection based on individuality is strictly phenotypic and phenotype is taken as the sole estimate of the individual's genotype. The individual performance/ phenotypic value can be expressed in terms of breeding value (B.V). The B.V of an animal is estimated from its phenotypic value as a deviation from the population mean multiplied by the heritability of the trait and it is known as **Probable Breeding Value (PBV)**. The PBV of an individual is the estimated genetic superiority of the individual over the average of the group from which it was selected.

It is determined as $\mathbf{PBV = P + h^2 (P_i - P)}$

Where, $h^2$ is the heritability of the character

$P$ = is the population mean

$P_i$ = is the phenotypic values of the individual

**Mass selection**: Mass selection is a term often used for individual selection especially when the selected individuals are put together *en masse* for mating. e.g. Drosophila in a bottle. The term individual selection is used more specifically when the mating is controlled or recorded as in the case of large animals.

Individual selection is effective only when the characters being selected are expressed in both sexes and traits with high heritability such as growth rate, body type etc. Though individual selection is easy to practice it has the following **limitations**:

i) It is difficult to practice if the trait is sex limited. e.g. milk production, litter size.
ii) Individual selection is not effective if the heritability of trait is low.
iii) It cannot be practiced for carcass traits.

Individual selection may be for i) type (appearance) and ii) Performance (Production) or both

**Individual Selection for Type:** It is the outward confirmation of individuals, i.e. the morphological characters and physical measurements like body colour, size, shape of horn, ears and body length, height and girth etc. Breed type refers to the complex external characteristics, which are typical of the breed. Usually there are official standards set for each of the breeds by the respective Breed Associations. In show ring besides the physical confirmation an aesthetic value is always attached to beauty and behavior of animals. How much attention should be given to type in selection depends upon the relative value it fetches in the market over production traits and how closely type is correlated with production.

**Individual Selection for Production / Quantitative traits:** In case of individual selection for production traits it is necessary to maintain accurate records and all available records should be used. Before utilizing the data it should be standardized to remove the effect of non-genetic (environmental) factors to a uniform comparable basis. Average of many records will reduce the environmental variations in production. Incomplete records should not be considered.

The phenotypic merit of the individual for quantitative traits is determined by comparing the individual's own phenotype with that of the average of all the individuals within a group from which it is selected and is called **trait ratio.**

$$\textbf{Trait ratio} = \frac{\textbf{Individual's record for a trait}}{\textbf{Group average for the same trait}} \times 100$$

The individual selection for production can be based on

i) Single measurements / single record and

ii) Based on multiple measurements (repeated measurements).

***Based on single record****:* Select the individual based on single record, even though multiple or repeated records are available.

***Based on multiple records***: For traits like milk yield, fleece weight, litter size repeated observations can be made and multiple records are available. The advantage of multiple records is that it increases the accuracy of selection, since it takes the average of multiple records. The disadvantage is that it increases generation interval.

For traits with higher heritability, annual genetic gain is higher if selection is based on first (single) available record. But for the traits with very low heritability and repeatability, selection using multiple records is advantageous.

## 2. Pedigree Selection

Pedigree is a record of an individual's ancestors related to it through its parents or Pedigree of an animal is a record of its ancestor, which includes sire, dam, grand sire, grand dam, and earlier ancestors. From a practical standpoint knowledge on the productivity of the ancestors is necessary if pedigree is to be useful; such pedigrees are known as **performance pedigree**. The B.V of an animal is estimated on the basis of the performance of their ancestors.

***Circumstances in which pedigree selection is performed/ useful:***

1. Pedigree selection is practiced when the breeder wants to select the individuals before they reach productive age or when the production performance of the individual is not available.
2. It can be practiced for traits, which are expressed later in life. e.g. carcass traits.
3. It is useful when the selection is for sex-limited traits e.g. milk production
4. Pedigree can be used as a guide for preliminary selection of sires for progeny testing,
5. Pedigree information is cheap to use.

In pedigree selection the following principle is involved. Each parent passes a sample half of its genes to its offspring, the other half being received from the other parent. The percentage of ancestral genes is halved in each generation. This decides the genetic relationship between an individual and his ancestor(s). This relationship is reduced to half in each generation.

| Type of relationship | Degree of relationship |
|---|---|
| Sire –Progeny | 0.50 or 50 % |
| Dam -Progeny | 0.50 or 50 % |
| Grand parent – Grand progeny | 0.25 or 25 % |
| Great grand parent – Great grand-progeny | 0.125 or 12.5 % |

Therefore, ancestors more closely related to the individual (recent ancestor) should receive most emphasis in pedigree appraisal than distant ancestors (great grand parents). The inclusion of more remote ancestors results only in marginal gain in accuracy of selection due to the halving process and sampling nature of inheritance.

When individual record is not available, pedigree selection is preferred. But it must be remembered that if the individual is having records, it should be given more importance than its ancestors. The current trend is that the pedigree information is combined with the information from collateral relatives and information from the individual's own record for efficient selection. However, over emphasis should not be given for pedigree in selection programme.

***Limitations:***

i) One is not entirely sure of the genetic makeup of the parents since phenotype is not necessarily indicative of the genotype due to complications by dominance, epistasis and environment.

ii) Due to sampling nature of inheritance for genes that are heterozygous makes it impossible for us to be exactly sure of what the individual (offspring) has received from its parents (whether it is better half or the poor half)

**3. Family Selection and Sib Selection**

Family selection is based on performance of collateral relatives. The procedure to estimate the B.V of an individual on the basis of family mean is called the **family selection or sib selection** depending upon the inclusion or exclusion of individual's own record in estimating the family mean. Family in animal breeding consist of full sib and half sib families. In random mating population, half sibs have a relationship of 25 % and full sibs have a relationship of 50% such family members are collaterally related and not directly related. Here the individual does not receive any gene from collateral relatives. Because of their common ancestor, the individual and collateral relatives will have certain genes in common.

**Family selection:** Here the selection is based on mean phenotypic value of the family. If the records of the individual are included in arriving in the family average and used as a criterion for selection, then it is known as family selection. Here the whole families are selected or rejected as units according to the mean phenotypic value of the family. The efficiency of family selection rests on the fact that environmental deviations of the individuals tend to cancel each other out in the mean value of the family.

**Sib-selection:** Some characters cannot be measured on the individual that are to be used as parents i.e. the individual's records are not included in arriving the family average and selection can only be based on the value of relatives and this method of selection is called Sib-selection. This is also a family selection but the selected individual has not contributed to the estimate of their family mean.

***Indications:***Family selection / sib selection is recommended

1. When the character has low heritability
2. When the character is sex limited.
3. When the characters are carcass trait and threshold traits like twinning in cattle, disease resistance, survival or death etc.

Generally family selection and sib selection are practiced largely in swine and poultry where the numbers of progeny produced by female are high (large families).For the family / sib selection is to be successful, two conditions have to be full filled

1. The number of progenies in each family should be large, so that average value is more accurate.
2. There should not be common environmental effect (c-effects) among the family members i.e. little variation due to common environment as the c-effects decrease the accuracy of family average.

**Common environment (c-effects):** The environmental effects, which are different for different families but same for all members of one and the same family, are known as common environmental effects denoted as c-effects. The family members share common environment during pre and postnatal stage. The c-effects thus create resemblance within family members over and above the resemblance due to having common genes and this contributes to the variation between families. The c-effects are more for full-sibs than for half-sibs.

**Advantages of family/sib selection**:

1.It does not increase generation interval.

2. It may be more advantageous than individual selection for threshold traits.

**Disadvantages:**

1. There is possibility of increase in inbreeding since the entire sib group or members of family are selected.
2. It increases the cost and space requirements, since it requires larger families.

**Within family selection:** It is the selection criteria when individuals are selected on the basis of their performance expressed as deviation from their family mean. The individuals that exceed their family mean by the greatest amount are selected instead of selecting the whole family. Thus it is opposite to family selection because family mean is given no weight. This selection criterion is preferred when a large component of environmental variance (c-effects) common to all members of a family exist. The best e.g. is the pre weaning growth in pigs wherein a large part of the variation in weaning weight is influenced by milk production of the sow and its mothering ability and hence the environmental variance is common to all members of a family. The selection within family eliminates the environmental differences among families. In this method each family contributes equally to the parents of next generation.

***Advantages*****:** i) When compared to family selection, it is economic in terms of number of animals to be maintained and space requirement. ii) Rate of inbreeding is reduced.

**4. Progeny Testing**

Progeny testing is a method of estimating the individual's transmitting ability/ breeding value for any specific trait based on the average performance of its progeny. The principles of the progeny test comes from the sampling nature of inheritance i.e. ***each offspring of a sire carries a sample half of his genes and if enough samples (progenies) are studied, the average is close to the sire's true genetic merit***. It estimates the breeding value/transmitting ability of the sire more accurately since it is based on the average performance of many of its offspring. The B.V of the sire is twice the mean deviation of the progenies from the population mean. Progeny testing gives the best and most reliable information about the genetic merit of the sire when compared to other aids to selection. Progeny test is generally carried out for males, but in pluriparous species it can be carried out in females also. Sire has a greater impact on the herd in terms of number of progeny he can leave behind as compared to the female. Therefore it is called that the **"Bull is half the herd"**.

***Requirements / Precautions to be taken for progeny testing:***

1. Females mated to each sire should be a random sample and there should not be any selection among progeny to be studied to estimate the breeding value of the sire.
2. Large number of progenies should be studied to reduce sampling error. When the heritability of the trait is high, less number of progenies is required; but when the heritability is low large numbers of progenies are required.
3. Progenies should not be culled until the end of the test.
4. Progeny of any sire should not be subjected to special environmental influences. Every effort should be taken to control the non-genetic variations.
5. The data recorded should be adjusted / corrected for environmental effects such as herd, year, season, age at first calving, lactation length etc.

***Indications:*** Progeny testing is recommended,

1. When the character has low heritability
2. When the character is sex limited.
3. For carcass traits, which require sacrifice of the animal and for selecting traits expressed late in life.
4. For testing animals for the presence of any recessive genes i.e. to identify the carrier individuals for harmful genes.

**Advantages:**

1. It is the most accurate aid to selection if conducted properly.
2. It is a better method for selecting the sire for sex-limited traits, traits with low heritability and carcass traits.

**Limitations / Drawbacks / Disadvantages:**

1. It takes long time and increases the generation interval and therefore reduces the annual genetic gain.
2. It is expensive – because of the necessity of maintaining a large number of breeding bulls for longer period awaiting the test results and for milk recording on large number of progenies.
3. Sires can be selected only when the progeny come for production by the time the sire become old.
4. Effective only when adequate number of progenies is tested.

## METHODS OF SELECTION (MULTI TRAIT SELECTION)

**Methods of selection for more than one trait:**

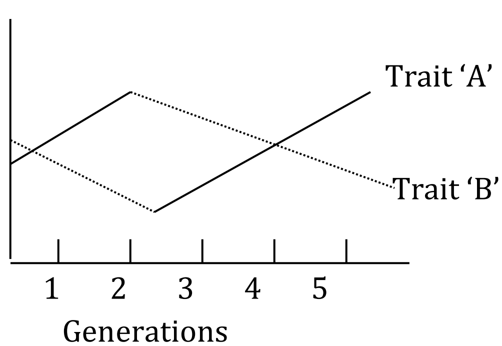
From the practical standpoint, the net value of an animal depends upon several traits that may not be of equal economic value. e.g. a dairy cow will be more economical to maintain if she produces more milk with higher fat % for a longer lactation period and remained dry for a shorter time between successive calving. On the other hand if a cow produces more milk daily with low fat % with shorter lactation length will not be economical to maintain. The traits may be independent of each other. Therefore, it is essential to estimate the total breeding worth of an animal based on several characters, which is known as **multi trait selection**.

There are three methods, for selecting more than one character in a breeding programme. They are:

1. Tandem method
2. Independent culling levels
3. Total score or Selection index

**1. Tandem Method:**

In this method selection is practiced for only one trait at a time until improvement has been made in the trait. Selection efforts for this trait are then relaxed and efforts are directed towards the improvement of a second, then a third and so on. The time spent for each trait depends upon its importance. The efficiency of this method depends on the genetic correlation between traits. If there is positive correlation between traits selected than the result will be desirable and if there is negative correlation the effects will be undesirable. If the traits are negatively correlated then when trait 'A' improves, the trait 'B' becomes worse (**See-saw effect**).




***See-saw effect*** – If trait 'A' and 'B' are negatively correlated

**Merits:**

1. It is simple to practice.
2. The intensity of selection is more.
3. If there is a desirable genetic correlation with other traits, it produces progress in the related traits.

**Demerits:**

1. Only one character is considered at a time.
2. Efficiency of this method is low.
3. It takes very long period of time to achieve desirable efficiency. In the mean time the breeder may change his goal.
4. If there is undesirable correlation between traits that will also hinder the progress. i.e. genetic improvement obtained in previous generations will be lost.

**2. Independent Culling Method or Independent Culling Levels:**

In this method selection may be practiced for two or more traits at a time or at different times in the lifetime of an individual. In this method, for each trait a minimum standard is set so that each animal must meet those standards in order to be selected. The failure to meet the minimum standard for any one trait makes the animal to be rejected. The effectiveness of this method depends on the level kept for each of the traits. In case of keeping low levels, very few animals are culled and it affects the genetic progress. On the other hand, if the standards kept are high, the number of animals selected will be very small. e.g. In dairy cattle selection for two traits: Milk Yield and Fat per cent is as follows

| | **Milk yield** | **Fat percentage** | |
|---|---|---|---|
| **Minimum standard** | **3000 kg** | **4.0%** | |
| Cow-A | 3000 kg | 4.5 % | Selected |
| Cow-B | 2500 kg | 5.0 % | Rejected |
| Cow-C | 4000 kg | 3.0 % | Rejected |
| Cow-D | 3200 kg | 3.5 % | Rejected |

**Merits:**

1) This method is superior to Tandem method because simultaneous selection is made for more than one trait.
2) Independent culling levels are easy to perform.
3) It allows culling animals earlier, which are inferior in early expressed traits.

**Demerits:**

1) In this method there is possibility of culling genetically superior animals for some traits if they are less than the culling levels for any one of the traits whereas, mediocre animals those just meeting the minimum standards are likely to be selected.

2) The proportion selected for each trait will depend on the total animals to be saved for breeding. Therefore this method **reduces the selection intensity** with increase in number of traits to be selected.

3) If genetic correlations among traits are in the undesirable direction, it will further reduce the efficiency.

Generally this method has been used in selection of animals for show purposes where the animals are selected for type, colour and body conformation traits ignoring its performance for economic traits.

**3) Selection Index or Total Score Method:**

In this method the animal is scored for its merit in each of the traits included in selection. In total score or selection index method culling levels are flexible. An index is a single numerical value, which is the total of scores given for each trait considered in the selection. Each trait is weighted by a score and the individual scores are summed to a **total score / index value** for each animal which is the selection criterion. By this method, superiority in some traits can be made up by mediocrity in others. Thus selection index is a total score that includes all the advantages and disadvantages of an animal. The animals with highest score / index are selected for breeding.

The amount of weight given to each trait depends on the relative economic value,$h^2$ of characters and genetic correlation among characters. Selection index method is the most efficient of the three because it results in more genetic improvement. The index is the best estimate of candidate's breeding value.

The principle of selection index theory for animals was developed by Hazel (1943). If there are 'n' traits under selection the selection index is constructed by multiple regression analysis as:

$$\text{Selection Index (I)} = b_1X_1 + b_2X_2 + \cdots + b_nX_n$$

Where, I = selection index

$X_1, X_2$ - - - $X_n$ are the phenotypic value of the 1,2 - - - - n traits of the individual

$b_1, b_2$ - - - $b_n$ are the corresponding weighing factors of the trait (multiple regression coefficient) by which the each measurements / phenotypic value to be weighed.

The **b's**are estimated by solving set of normal simultaneous equations whose number is equal to the number of traits under selection.

The equation in matrix form can be written as: **[P] [b] = [G] [a]**

where [P] = is the phenotypic variance – covariance matrix

[b] = is the vector of weighting factors

[G] = is the genotypic variance – covariance matrix

[a] = is the vector of relative economic values

The **b** values are obtained by solving the simultaneous equations and $\therefore [b] = [P]^{-1}[G]\ [a]$ If more than two traits are involved in a selection index the b's are obtained by following the Matrix algebra procedure.

e.g. Selection index for wool production in sheep where $b_i$ values for clean wool weight, fibre diameter and staple length were $b_1 = 1.34$ ; $b_2 = -0.90$ and $b_3 = 0.20$ respectively

**I = [1.34 x clean wool weight in gram]+ [-0.90 x fibre diameter in micron] + [0.20 x staple length in cm]**

The animals are then arranged in the order of merit of index values and those with the highest values are selected for the breeding programme. If 'n' equally important traits are included in the index selection, the genetic improvement in the individual traits is only about $1/\sqrt{n}$ time as efficient as selection for a single trait alone.

***Merits:***

1. Most efficient method of selection among the three methods.
2. It allows the individuals, which are superior in some traits to be selected regardless of their deficiency in other traits.
3. All the characters are given proper weightage for optimum selection.
4. The advantage of index method increases with the number of traits. Thus it requires less time to bring about an overall improvement.

***Demerits:***

1. Selection index is difficult to construct because of complex computations involved.
2. The relative economic value, genetic parameters are likely to change from time to time and from population to population. Therefore, an index selected for a particular generation and for particular population cannot be valid subsequently.
3. The efficiency of the index is reduced unless the genetic parameters are estimated with good precision from large data.

**Construction of Selection Index:**

Information required for the construction of selection index or calculations of weighing factors are as follows:

1. Phenotypic variance ($V_P$) and additive genetic variance ($V_A$) of all the traits
2. Phenotypic covariance ($COV_P$) and additive genetic covariance ($COV_A$) among the traits
3. Relative / net economic value ($a_i$) of all the traits.

The construction of selection index for ‘n’ traits ($X_1, X_2 \ldots\ldots X_n$) are as follows:

**Step: 1**

Using the above information, ‘n’ normal simultaneous equations are formed as

$$\mathbf{V_{P\,(X1)}\, b_1 + COV_{P\,(X1X2)}\, b_2 + \ldots + COV_{P\,(X1Xn)}\, b_n = V_{A\,(X1)}\, a_1 + COV_{A\,(X1X2)}\, a_2 + \ldots + COV_{A\,(X1Xn)}\, a_n}$$

$$\mathbf{COV_{P\,(X2X1)}\, b_1 + V_{P\,(X2)}\, b_2 + \ldots + COV_{P\,(X2Xn)}\, b_n = COV_{A\,(X2X1)}\, a_1 + V_{A\,(X2)}\, a_2 + \ldots + COV_{A\,(X2Xn)}\, a_n}$$

$$\Downarrow$$

$$\mathbf{COV_{P\,(XnX1)}\, b_1 + COV_{P\,(XnX2)}\, b_2 + \ldots + V_{P\,(Xn)}\, b_n = COV_{A\,(XnX1)}\, a_1 + COV_{A\,(XnX2)}\, a_2 + \ldots + V_{A\,(Xn)}\, a_n}$$

Where:

$a_i$= relative/ net economic value assigned to traits - $X_i$ ( i = 1,2,…,n)

$b_i$= partial regression coefficient (weighing factor) for traits -$X_i$ (i = 1,2,…,n)

**Step: 2**

The estimated values of genetic and phenotypic variances of the traits, covariance’s among the traits and net economic values of each trait are substituted and then the values of the weighing factors i.e. $b_i$ values are obtained by solving the normal simultaneous equations formed in the step-1

**Step: 3**

The Selection Index (I) = $b_1X_1 + b_2X_2 + \text{-- - - -} + b_nX_n$

The $b_i$ and $X_i$ values are substituted in the index to obtain the selection index value for each animal.

**Conclusion:**

Independent culling method is more efficient than tandem method but inferior to selection index method. i.e. Index method is the most superior and tandem selection is least whereas the efficiency of independent culling level method is intermediate.

**Multi trait – multi source selection index:**

In the construction of selection index different traits may not have equal heritability estimates but some may have low heritability. Thus it may not be possible to make improvement in the lowly heritable traits. The accuracy of selection for such traits can be increased by using the information from other sources (individual's relative's records) for such traits. Such a selection index using information from different sources is known as multi trait – multi source selection index which is constructed on the principles of selection index theory.

**Restricted selection index:**

It is obvious that due to selection there will be change / response in each of the trait included in the index and even in other traits not included in the index. If a breeder wants no change or partial change an in particular character, restricted selection index is constructed by solving the equations dealt by Kempthorne and Nordskog (1959). Generally it is followed for traits, which have negative genetic correlations. e.g. In poultry the situation arises when one wants to increase the egg production without affecting the egg size, which is negatively correlated. Egg size is kept constant while using an index to maximize progress in genetic economic value based on egg weight, body weight and production.

**Multi Stage Selection:**

Selection involves the identification of the individuals which are superior and sometimes it is a complex process to be completed in different stages / ages of the animal and the process of selection conducted in different stages of the animal is known as **multi stage selection.** This type of selection is followed when information obtained sequentially at different ages of the animal and sometimes the required economic weights are difficult to define properly and also to reduce the cost of selection programme. Broadly speaking there are two stages of selection. The selection of the first stage is based on physical attributes of phenotypic performance and the selection at the second stage is based on the breeding value of the animals, which is the final selection.

## SIRE EVALUATION

The results of progeny testing are expressed in the form of an index, which is the index of the genetic worth of the sire, and such an index is known as **sire index.**

In other words, an attempt to express what a sire would have produced, if he had been a cow is the sire index of the bull. It is the operational part of progeny testing called as 'sire proof'. Based on sire index a numerical value is obtained which indicates the production ability of the sire. The sire index helps in ranking the bulls in order of their merit to choose the best.

### Methods of indexing sires / Sire Index:

The different indices developed are for two purposes viz. indices, which simply rank the sires, and the indices, which provides the estimates of breeding value of sires. The B.V is estimated for indexing in a single herd as well as for indexing in many herds.

**1. Simple Daughter's Average Index** (Edwards,1932)

$$I = \bar{\mathbf{D}}$$

Where, $\bar{\mathbf{D}}$ is the average of all daughters of a sire under test.

This is the simplest way to evaluate the breeding worth of the bull from their daughter's production performance. If the number of daughters per sire is large and if all the daughters are included without selection, this provides the sound basis of selection. The defect in this method is that it does not consider the production level of the dams allotted to the sire.

**2. Equi-parent Index or Intermediate Index / Yapp's Index / Mount Hope Index**

Hanson (1913) proposed this index and it is also called as Yapp's index (1925)or Mount Hope index because it was first used at Mount Hope Farm in 1928.

$$I = 2\bar{\mathbf{D}} - \bar{\mathbf{M}}$$

Where,

$\bar{\mathbf{D}}$ = average for daughter of the sire; $\bar{\mathbf{M}}$ = average for dams of the daughters

This index is based on the principle that the two parents contribute equally to the genetic make up of the progeny. This index places the daughter exactly half way between production level of the dam and genetic worth of the sire. This index aims at adjusting the daughter average for the varying production level of the dams but suffers from the defect that it overcorrects for the differential production levels of dam mated to different sires i.e. if the set of cows mated to a sire is inferior to the average, the index over estimates the sire's breeding worth and vice versa. To minimize this defect, dam-daughter pair should be selected randomly. In addition, this index assumes that the heritability of the trait under consideration is one.

**3. Regression Index / Rice Index** (Rice 1944)

Regression defines the relationship between parent and offspring when used as a measure in inheritance. Rice proposed this index based on the fact that the overall regression of daughter's record on those of their dams was approximately 0.5.

$$\mathbf{I = 0.5\,(Intermediate\ index) + 0.5\,(Breed/herd\ average)or}$$
$$\mathbf{I = (Intermediate\ index + Breed\ average)\ /\ 2}$$

Regression index is less variable than intermediate index and have the same accuracy. It has advantage of including the breed average as a reference point.

**4. Tomar Index (1965)**

This index depends on dam-daughter comparison and on simultaneous use of the merits of the dams and the daughters over their contemporary herd averages.

$$\mathbf{I = \bar{D} + (De + Me)}$$

Where,

$\mathbf{\bar{D}}$= daughters average

**De** = Daughter's expected average = √ D x Daughter'scontemporary herd average

**Me** = Dam's expected average = √ M x Dam's contemporary herd average

**M** = Dams average

**5. Corrected Daughter Average Index / Krishan's Index (Krishnan,1956)**

$$\mathbf{I} = \bar{\mathbf{D}} - \mathbf{b}\,(\bar{\mathbf{M}} - \bar{\mathbf{A}})$$

Where,

$\bar{\mathbf{D}}$= Average of the daughters of the sire; $\bar{\mathbf{M}}$= Average of the dams of the daughters

$\bar{\mathbf{A}}$= Herd / breed average; **b** = Regression of daughters record on dam record = 0.5 h2

This index eliminates the disadvantages of simple daughter's average index and equi-parent index. It corrects the daughters average for the influence of differential production level of dams. The term b (M –A) in the index is the correction for the genetic superiority or inferiority of the set of dams allotted to a sire over the herd average. It is four times as efficient as intermediate index. However, it suffers from the defect that it does not take into the consideration of performance of contemporaries living at the same time.

**6. Contemporary daughter average index**

The sire index was proposed by Sundaresan*et al*. (1965). In this index the records of the daughters of a sire are compared with the daughters of all other sires in the same herd born in the same season. This herd mate or contemporary comparison reduces the environment variations due to herd, year and season.

$$\mathbf{I} = \mathbf{H} + \frac{\mathbf{n}}{\mathbf{n}+\mathbf{k}}\,(\bar{\mathbf{D}} - \bar{\mathbf{C}}_{\mathbf{D}})$$

Where, H = Herd average; n = No. of daughters per sire

$\bar{D}$= Daughters average; $\bar{C}_D$= Contemporary daughters average

k = Constant based on sire error variance.

**7. Dairy Search Index or Sundaresan index or Corrected Contemporary Daughter Average Index**

The index was proposed by Sundaresan *et al.* (1965) and it was developed at NDRI, Karnal and it is also known as Dairy Search Index. The index is an extension of the contemporary daughter average index. This index uses the performance of contemporaries and the variation in the number of daughters in the progeny group in estimating the breeding worth of the sire. It also corrects for the non-genetic effects like year and season and for the differences in production level of dams allotted to different sires. In this index only first lactation 305-day milk yield of the daughters are taken into consideration. (Contemporaries are those individuals that are in same year, same season along with the daughters of the bull under test).

There aretwo indices

i) Formula for sire evaluation at farm level

ii) Formula for sire evaluation for Key Village Schemes.

i) **Formula for sire evaluation at farm level**:

$$\mathbf{I = H + \frac{n}{n+12}(\bar{D} - \overline{C_D}) - b(\bar{M} - \overline{C_M})}$$

Where,

H = Herd average; n = No. of daughters per sire

$\bar{D}$ = Daughters average; $\overline{C_D}$ = Contemporary daughters average;

$\bar{M}$ = Dams average; $\overline{C_M}$= Contemporary dams average;

b = Intrasire regression of daughters on dams = 0.5 $h^2$

ii) **Formula for sire evaluation for Key Village Schemes.**

$$\mathbf{I = H + \frac{n}{n+12}(\bar{D} - \overline{C_D})}$$

**8. Herd mate / Stable mate comparison**

Herd mates are all daughters of other sires that complete records in the same month. Herd mate comparison eliminates the environmental differences like herd, year, season, and feeding and managemental effects.

$$I = \bar{\mathbf{D}} - \mathbf{0.9}\ (\bar{\mathbf{H}}_{\mathbf{m}} - \bar{\mathbf{A}}) - \bar{\mathbf{A}}$$

Where,$\bar{\mathbf{D}}$= daughters average; $\bar{\mathbf{A}}$= herd average; $\bar{\mathbf{H}}_{\mathbf{m}}$= herd mate average

When sires daughters are distributed in many herds, additional adjustments can be added to increase the accuracy of comparing the different sires. The daughters average increases as the production level of herds in which the bull is used increases. The factor 0.9

is used because about 90 % of the difference of the herd mates from the breed average is reflected in the production level of the daughters of a sire.

### 9. Contemporary comparison

This method is similar to herdmate comparison with additional requirement that a herdmate be of the **same age**. It was developed by Robertson and his coworkers (1952) for estimating the breeding worth of the sire having daughters in more than one herd. In this method only the first lactation 305 day milk yield is taken for proving the sire.

$$\mathbf{I = 2b\,(CC) + H_f}$$

where CC = Contemporary comparison herd

$$\mathbf{CC = \frac{\sum w_i(\bar{D}_i - \bar{C}_i)}{\sum w_i}}$$

where CC = Contemporary comparison herd

$D_i$ = average of daughters in $i^{th}$ herd

$C_i$ = average of contemporaries in $i^{th}$ herd

$\Sigma w_i w_i$= weightage for $i^{th}$ herd

b is the regression of future daughter on performance of present daughters

$$\mathbf{b = \frac{0.25 \sum w_{i.} h^2}{1 + (\sum w_i - 1)\, 0.25 \sum w_{i.} h^2}}$$

where $h^2$ = heritability of the trait

$H_f$ = average of the first calvers in the herds

### 10. Best linear unbiased prediction (BLUP)

This was developed by C.R Henderson (1973), which is the most efficient and powerful method of sire evaluation than the other conventional methods. It estimates expected breeding value (EBV) of sire by adjusting the data for all known non-genetic sources such as for herd, year and season effects, age of the dam, parity etc.

It uses all available information (i.e. the information provided by the daughters, information from other relatives) more efficiently and more flexibly in estimating the breeding values.

Animals across contemporary groups can be also compared. It provides estimates of breeding values of many sires born in different years and different locations simultaneously and also provides the estimates of response to selection.

BLUP also eliminate errors due to complications such as non-random mating, environmental trend over time, bias due to culling and selection.

The model that describes the effect of sire and herd-year-season is as follows:

$$\mathbf{Y_{ijk} = \mu + H_i + s_j + e_{ijk}}$$

Where $Y_{ijk}$= performance of $k^{th}$ progeny of $j^{th}$ sire in $i^{th}$ herd-year-season

$\mu$ = overall mean

$H_i$ = effect of $i^{th}$ herd-year-season (fixed effect)

$s_j$ = effect of $j^{th}$ sire (random effect)

$e_{ijk}$ = residual error

**Other methods:**

In addition to the above the following methods are also developed for sire evaluation. i) Least-squares technique ii) Maximum likelihood method iii) Restricted maximum likelihood method (REML).

## COMBINED SELECTION

Selection of individual on the basis of information from two or more sources i.e. information of the individual phenotype as well as information from various relatives / family average is called **Combined Selection.** This done by the technique of multiple regression analysis. The gain expressed from combined selection is always higher than those obtained from either individual selection or family selection alone particularly for low heritable traits.

Based on the various sources of information available different combined selection indices have been constructed.

**1. Osborne index**:

Osborne (1957) developed selection index based on combining information of records of the individual and its family members by giving proper weightage attached to sire-family and dam-family averages and individual records in poultry for improving egg production. This is known as Osborne Index.

Because of simplicity, this index has been used worldwide for improvement of egg production traits. The indices were developed for two sexes separately i.e. for selection of pullets ($I_F$) and cockerels ($I_M$).

Index for pullets : $$\boldsymbol{I_F = (P - \overline{P}) + w_2(F_D - \overline{P}) + w_3(F_S - \overline{P})}$$

Index for cockerels: $$\boldsymbol{I_M = w_2(F_D - \overline{P}) + w_3(F_S - \overline{P})}$$

where P = individual's own performance; $\bar{P}$= flock average

$F_D$= dam family average; $F_S$= sire family average

$w_2$= weighing factor for dam family

$$\boldsymbol{w_2 = \frac{2n\ (1 - h^2)}{4 + (n - 2)\ h^2}}$$

$w_3$= weighing factor for sire family

$$\boldsymbol{w_3 = \frac{4\bar{n}\ d(1 - h^2)(2 - h^2)}{[4 + (\bar{n} - 2)\ h^2][4 + \{\bar{n}(1 + d) - 2\}\ h^2]}}$$

where n = number of pullets per dam

$\bar{n}$= average number of pullets per dam

d = number of dams mated to a sire

$h^2$= heritability of the trait under selection

In practice the index is worked out for all those pullets whose sire and dam family averages are more than the flock average and are arranged in descending order. Required number of pullets is selected which are having highest index value. Index values for cockerels are worked out for those, which belong to the best 4 – 5 sire families as well as best dam families, of these best sires are selected.

**2. Abplanalp Index**

Abplanalp (1974) proposed the following combined selection index for the selection of pullets and cockerels

Index for pullets: $\boldsymbol{I_F = b_1(P - P_{DF}) + b_2(P_{DF} - P_{SF}) + b_3(P_{SF} - \bar{P})}$

Index for cockerels: $\boldsymbol{I_M = b_4(P_{DF} - P_{SF}) + b_5(P_{SF} - \bar{P})}$

Where, P = individual performance; $\bar{P}$ = flock average

$P_{DF}$=dam family average; $P_{SF}$ =sire family average

$b_i$ = weightage to be given to the $i_{th}$ source of information.

**3. Matrix Method (Construction of index for combined selection)**

There are situation when information from several sources viz. the individual, its parents, FS, HS etc. are available. The general methodology for predicting the breeding value of an individual for a trait is the construction of selection index, the criterion of selection by which any number of information for a trait can be combined.

e.g. When there are 'n' sources of information (X1, X2 ...Xn) available for a trait, where X's are the phenotypic values of an individual or a group of relatives from which the B.V of the individual is predicted for the trait. This involves matrix and takes the form of a multiple regression of B.V on all sources of information.

The index of an individual is represented as:

$$\boldsymbol{I = b_1X_1 + b_2X_2 + b_3X_3 + \cdots + b_nX_n}$$

Where, $X_1$, $X_2$, $X_3$…$X_n$= phenotypic value of individual ($X_1$) and its relatives ($X_2$, $X_3$…$X_n$) and $b_1$, $b_2$, $b_3$… $b_n$ = are the weighing factors of the information.

The weighting factors are estimated in such a way that the correlation ($r_{1A}$) between the index and the B.V of the individual is maximum. The b's values so obtained are the partial regression coefficient of the individual's B.V on each source of information. The maximization leads to a set of simultaneous equations equal to the number of sources of information.

**Construction of index for combined selection**

**e.g.** There are three sources of information viz. the individual ($X_1$), the parents - dam ($X_2$)and its parental half sib ($X_3$ ) then three simultaneous equations will be constructed as :

$$\mathbf{V_{P\,(X1)}\,b_1 + COV_{P\,(X1X2)}\,b_2 + COV_{P\,(X1X3)}\,b_3 = V_{A(X1)}}$$

$$\mathbf{COV_{P\,(X2X1)}\,b_1 + V_{P(X2)}\,b_2 + COV_{P\,(X2X3)}\,b_3 = COV_{A(X2X1)}}$$

$$\mathbf{COV_{P(X3X1)}\,b_1 + COV_{P(X3X2)}\,b_2 + V_{P(X3)}\,b_3 = COV_{A(X3X1)}}$$

After substituting the values of the phenotypic ($V_P$) and additive-genetic ($V_A$) variances of each measurement, and additive-genetic covariances ($COV_A$) and phenotypic covariances ($COV_P$) between the measurements in the equations, the values of weighing factors ($b_1$, $b_2$, $b_3$) are estimated by solving the equations.

The genetic gain expected from this combined selection is always higher than those obtained from either individual selection or any other selection aids alone.

**Most Probable Producing Ability (MPPA) or Breeding Value of Cow or**

**Estimated Producing Ability (EPA):**

MPPA is a method of selection for traits, which are, repeated several times in the life of an animal e.g. milk production in cows, litter size in pigs etc. It is used to predict the future performance of animals and helps to rank the animals especially dams in a herd for selection.

As most of the economic traits are influenced by environment, the error due to environmental variation can be eliminated if selection based on several records of the same individual. The repeatability is an indicator of the extent to which an animal's superiority in one measurement will be seen in subsequent measurements of the same animal. Therefore the repeatability value is used in estimating MPPA.

$$\boldsymbol{MPPA = H + \frac{nr}{1 + (n - 1)r}\ (C - H)}$$

Where,

H = Herd average, C = Individual cow average,

n = number of records and r = repeatability of the trait

## RESPONSE TO SELECTION / GENETIC GAIN

The basic effect of selection is to change the gene frequencies in the population. The changes of gene frequency are almost hidden from us because we cannot deal with the individual loci concerned with the metric characters. The effects of selection that can be observed are therefore restricted mainly to changes of the *population mean* and *variance*. The change in performance of progeny generation due to artificial selection is known as response to selectionor genetic change or genetic gain and is symbolized as 'R'. Response to selection (per generation) is defined as a difference of mean phenotypic value between the offspring of selected parents and the whole of parental generation before selection.

Response to selection per generation $\boldsymbol{R = \bar{O} - \bar{P}}$

Where,

$\bar{O}$ = mean phenotypic value of the offspring of the selected parents

$\bar{P}$= mean phenotypic value of the population from which parents are selected

**SELECTION DIFFERENTIAL**

The selection divides the parental population in to two parts viz. selected and culled animals. The culled animals are inferior whereas the selected are superior for a trait under selection. Thus the two groups differ in their mean phenotypic value. The superiority of the selected parents over the population mean before selection is the phenotypic superiority and is called as the **selection differential** denoted by **'S'**.

The selection differential (S) is defined as the difference between mean phenotypic values of the individuals selected as parents and the mean of the population before selection. The selection differential is sometimes referred as ***Reach***.

$$\boldsymbol{S = \bar{P}_S - \bar{P}}$$

Where, $\bar{P}_S$= is the mean phenotypic value of the selected parents.

$\bar{P}$ = is the population mean before selection was made.

In livestock normally fewer males than females are required for breeding. The value of selection differential differs for males and females. Therefore the S for pooled over sexes is estimated as S = Sm + Sf / 2. In cattle to maintain constant population size about 2/3 of the female calves are retained for breeding while only 5 % of bull calves are needed for natural service and only 1% is needed for artificial insemination purpose. The percentage of progeny needed as replacement stock to maintain constant population sizes in different species are given below:

| Species | Female % | Male % |
|---|---|---|
| Dairy cattle | 50 to 65 | 4 to 6 |
| Beef cattle | 40 to 50 | 3 to 5 |
| Sheep and goat | 45 to 55 | 2 to 4 |
| Swine | 10 to 15 | 1 to 2 |
| Chicken | 10 to 15 | 1 to 2 |
| Horse | 35 to 45 | 2 to 4 |

The selection differential also depends on the proportion of the population selected. The smaller the proportion the larger the S. Even for the same proportion selected the S will vary if the populations differ in their phenotypic standard deviation. The 'S' will be greater in the population with larger standard deviation.

**PREDICTION OF RESPONSE TO SELECTION**

The response to selection / genetic gain per generation can be predicted by the following formula.

$$\mathbf{R}\ \textit{(expected)} = \mathbf{h^2\ S}$$

where $h^2$ = heritability of the trait and S = selection differential

The whole amount of selection differential is not transmitted to the progeny but its portion equal to $h^2$ is transmitted.

**Proof:** Where $h^2$ is the proportion of phenotypic superiority of parents that is seen in their offspring or we know that the $h^2$ is equivalent to the regression of an individual's breeding value on its phenotypic value. The deviation of the progeny from the population mean is by definition the breeding value of the parents and so the R is equivalent to the breeding value of the parents. The heritability ($h^2$) is thus an important concept in relation to response to selection (R).

If $h^2 = 1$ then $R = S$

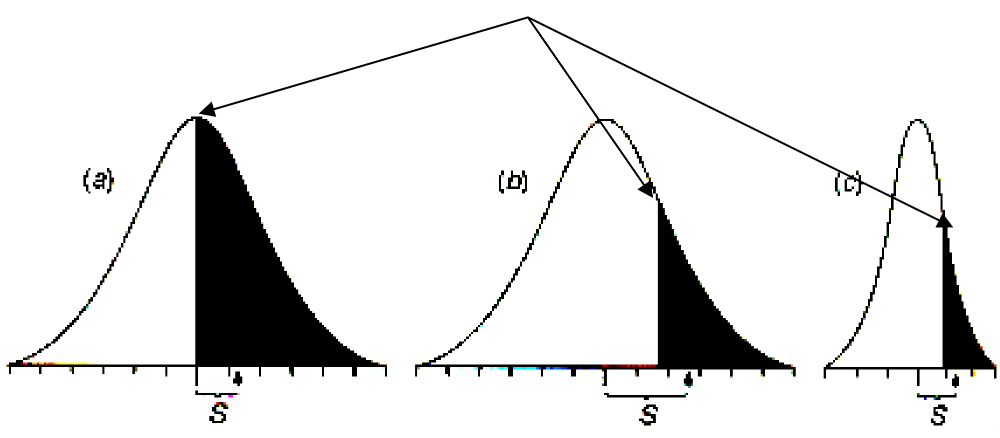
If $h^2 = 0$ then $R = 0$

and the general prediction equation of **R** for any value of $h^2$ will be $R = h^2S$. Response is generally less than or equal to selection differential as heritability ranges from 0 to 1.

## SELECTION DIFFERENTIAL AND INTENSITY OF SELECTION

The selection differential cannot be estimated without practicing the selection among parent generation. However, the selection differential can be predicted in advance provided that two conditions hold: the phenotypic values of the character being selected are normally distributed and selection is by ***truncation****.* Truncation selection means that individuals are chosen strictly in order of merit as judged by their phenotypic values and that no individual being selected below the point of truncation. Under these conditions the selection differential depends only on the **proportion of the population selected**, and the **phenotypic standard deviation** of the character.

Point of truncation




Diagrams to show how the selection differential, 'S' depends on the proportion of the population selected, and on the variability of a normally distributed character. All the individuals in the stippled areas, beyond the point of truncation, are selected.

*(a) 50 per cent selected; standard deviation 2 units; S = 1.6 units*

*(b) 20 per cent selected; standard deviation 2 units; S = 2.8 units*

*(c) 20 per cent selected; standard deviation 1 units; S = 1.4 units*

The dependence of the **S** on these two factors is illustrated diagrammatically. The graphs show the distribution of phenotypic values, which is assumed to be normal. The individuals with highest values are selected sharply by dividing at the point of truncation and all below are rejected. The arrow in each figure marks the mean value of the selected group, and S is the selection differential. In graph (a) half the population is selected, and the selection differential is rather small; in graph (b) only 20 per cent of the population is selected, and the selection differential is much larger. In graph (c) 20 per cent is again selected, but the character represented is less variable and selection differential is consequently smaller.

The response to selection may be generalized if the selection differential is expressed in terms of phenotypic standard deviation unit, $\boldsymbol{\sigma_P}$. This standardized selection differential **S/** $\boldsymbol{\sigma_P}$ is called **intensity of selection** symbolized by **i**.The standardized selection differential is used to compare the different methods of selection.

Then the selection differential (S) is taken in another form as:

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

Where,

i = intensity of selection ( standardized selection differential)

$\sigma_P$ = phenotypic standard deviation of the trait

Therefore the expected response in earlier equation ($R = h^2 S$) becomes

$$\boldsymbol{R = i\sigma_P h^2}$$

This reoriented equation of R can also be taken in terms of accuracy of selection as:

$R = i\,\sigma_P\,h^2 = i\sigma_P h \times h$

$= i\,\sigma_P(\sigma_A / \sigma_P)\,h$ since $h = \sigma_A / \sigma_P$

$$\boldsymbol{R = i\sigma_A h}$$

where, $\boldsymbol{\sigma_A}$ is the square root of the additive genetic variance

**i** expresses the S in standard deviation units

This equation is some times used in comparisons of different methods of selection.

The intensity of selection **i** can also be determined from tables of the properties of the normal distribution. If **'p'** is the proportion selected, i.e. the proportion of the population falling beyond the point of truncation, and **'z'** is the height of the ordinate at the point of truncation, then it follows from the mathematical properties of the normal distribution that

$$\boldsymbol{\frac{S}{\sigma_p} = i = \frac{z}{p}}$$

The value of **i** for any value of **p** are worked out and available for reference. Generally decrease in proportion selected the intensity of selection '**i**' increases.

## GENERATION INTERVAL

Generation interval is defined as the average age of parents at the time of the birth of their offspring, which became parents in next generation and it is symbolized by **'L'**. If parents produce more than one offspring in their life then the rate of response to selection depends on the average age of parents when their offspring are born.

Generation interval in different species of livestock:

| | | |
|---|---|---|
| Dairy Cattle | : | 4 - 4½ years |
| Beef Cattle | : | 4½ - 5 years |
| Swine | : | 1 ½ - 2½ years |
| Sheep and Goat | : | 2 - 2½ years |
| Chicken | : | 1 - 1½ year |
| Horses | : | 9 -13 years |

### Factors affecting generation interval:

i) Species ii) Selection schemes iii) Sex iv) Breeding age

Thus, the generation interval is specific to species, sex within the species, and also influenced by the number of offspring raised in any generation, and by the age at which the reproduction starts. Multiple ovulation and embryo transfer technique would reduce generation interval.

### Annual genetic gain (Progress per unit of time)

Annual genetic gain is the ratio between responses per generation to generation interval (L) in years.

$$\text{Response per unit of time (year) or Annual genetic gain} = \frac{\text{Response per generation}}{\text{Generation interval (in years)}}$$

$$= \frac{\mathbf{h^2S}}{\mathbf{L}}$$

The progress per unit of time is more important in practice than progress per generation. It is essential to compare the progress for the same trait in different species like milk yield in zebu / exotic with buffalo etc. So interval between generations is an important factor in calculating response to selection per unit of time i.e. Response per year or annual genetic gain.

**Realized heritability:**

The response to selection can also be used as a means of estimating heritability in the base population by rearranging the equation, $R = h^2S$, as $\mathbf{h^2 = R / S}$ and this is called realized heritability. i.e. Realized heritability is a ratio of response to selection to the selection differential. Realized heritability does not provide a valid estimate of the heritability for the following reasons.

1. Responses of characters with high heritability are expected to be reduced after the first generation of selection so that realized heritability after first generation will underestimate heritability in base population.
2. The systematic changes due to inbreeding depression, random drift and environmental trends will be included in the response, unless they are removed by comparison with the control line the realized heritability is not a valid estimate of heritability.

## FACTORS AFFECTING RESPONSE TO SELECTION

The change in performance due to artificial selection is known as response to selection and it depends on the following factors:

1. Additive genetic variability in the trait ($V_A$)
2. Intensity of selection (i)
3. Accuracy of selection ($r_{AP}$)
4. Population size
5. Generation interval

**1.Additive genetic variability in the trait ($V_A$):** The selection acts on additive genetic variability. The variation in breeding values (BV) of the individuals within the population is the raw material to act for artificial selection. The selection will not be effective to bring change if there are no genetic differences among animals. Therefore if $V_A = 0$, the $R = 0$. The magnitude of R increases with the increase indifferences in B.V between animals.

**2. Intensity of selection (i):**The intensity of selection depends on the proportion (p) of the population selected and amount of variation in the character concerned. When 'p' is small, the selection is said to be more intense or rigorous. But when p is large (increase in proportion selected) then there is decrease in intensity of selection. The 'R' will be more when 'p' will be small. If all animals are selected, the 'S' will be zero and no change in progeny mean will occur. The change occurs if some of the best animals are selected.

**3. Accuracy of selection ($r_{AP}$):** The selection is effective only when the animals with highest B.V. are selected. The accuracy of selection is taken as the correlation between the true B.V. of an animal and the source of information (selection criteria) which is denoted as $r_{AP}$ where A is the true B.V. and P is the selection criteria. The selection criteria may be a single record or average of repeated records of the animals itself or on any relative viz. dam or average performance of a group of relatives like full sibs, half sibs or progeny groups. The $r_{AP}$ is equal to square root of heritability ($r_{AP}$=h). Thus if heritability estimate is higher, the $r_{AP}$ will also be higher.

**4. Population size:** The effect of population size on response to selection can be viewed in terms of inbreeding and genetic drift. Both will arise in small population.

i) **Inbreeding**: Inbreeding is unavoidable in a population of small size. Generally the inbreeding will reduce the amount of genetic variability ($V_A$) and reduction in performance (inbreeding depression). This causes a decrease in R to selection.

(ii) **Genetic drift**: As a result of sampling of small number of genes in small population, the genetic drift arises which means that there is random change in gene frequency. This may cause the loss of favorable alleles from the population. This will thus reduce the response to selection.

**5. Generation interval:** The generation interval is different in different species. Therefore, in order to get the response per year, the response to selection is divided by the generation interval. The genetic gain per year is higher in the herd that breeds with younger animals (at younger age) than the herd with animals comparatively at later age.

**SELECTION LIMIT (or) SELECTIONPLATEAU (or) SELECTION CEILING**

Due to continuous selection there will be no genetic variance and hence there will be no response to further selection. The response to selection cannot be expected to continue indefinitely unless new variation is created. The gene segregating in the base population will be brought to fixation or equilibrium by selection in sooner or later generations. Therefore the response will slowly diminish; gradually approaches zero and finally cease or stop in long term. When there is no response to selection the population is said to be at a **plateau or selection limit or selection ceiling**.

**Factors affecting selection limits:**

1) Exhaustion of genetic variance: Many loci control the quantitative traits. As a result of continuous selection for long time, it is expected that the genes will get fixed and there will remain no genetic variance. This will lead zero $h^2$ estimates and thus no change in population mean for the selected trait.

Reasons of failure to respond in the presence of genetic variance

i) Over dominance gene action
ii) Low frequency of recessive genes
iii) Negative genetic correlation
iv) Genotype-environmental interaction
v) Natural selection
vi) Linkage.

## CORRELATED RESPONSE TO SELECTION

A change in response in an unselected character (Y) resulting from the selection of another character (X), which is genetically correlated, with the character (Y) is called as ***correlated response.***

The magnitude and direction of correlated response depends generally on the amount and sign of genetic correlation between these two traits. The genetic correlation between two characters brings about change in both the characters when selection is done for either of the character. If the genetic correlation is positive then the selection for one character will automatically lead to the improvement of the second character without doing selection for it. This associated change in the second character, as a result of change due to selection in first character is called as the correlated response to selection.

Expected response of a character 'Y' when selection is applied for another character 'X' may be deduced in the following way.

The response of character X, directly selected is: $\mathbf{R_X = i\, h_X \sigma_{A(X)}}$

The response by definition is the mean breeding value of the selected animals. Therefore the correlated response is the product of the regression of the breeding value of the correlated character Y on the breeding value of X and the direct response of character X. Therefore the correlated response (CR) in trait Y is given as:

$$\boldsymbol{CR_Y = b_{(A)XY} R_X} \qquad \text{Whereas } b_{(A)\,XY} = \frac{CovA}{\sigma 2AX} = r_A \frac{\sigma_{AY}}{\sigma_{AX}}$$

$$= i h_X \sigma_{AX} r_A \frac{\sigma_{AY}}{\sigma_{AX}}$$

$$= i h_X r_A \sigma_{AY}$$

or, by putting $\sigma_{AY} = h_Y \sigma_{PY}$, the correlated response becomes

$$\boldsymbol{CR_Y = i h_X h_Y r_A \sigma_{PY}}$$

Where i = intensity of selection

$h_X$ = square- root of the $h^2$ of the trait X; $h_Y$ = square- root of the $h^2$ of the trait Y

$\sigma_{AX}$ = square-root of the additive genetic variance of the trait X

$\sigma_{AY}$ = square-root of the additive genetic variance of the trait Y

$r_A$ = genetic correlation between traits X and Y

The term $h_X r_A h_Y$ is called as ***co-heritability*** ($h_{XY}$) because it is equivalent to heritability in the response to direct selection. Similar to $h^2$, the co-heritability is the ratio of additive genetic covariance to the phenotypic covariance between X and Y traits.

Thus the correlated response can be predicted if the genetic correlation between the traits and the heritability of the traits are known. Conversely, if correlated response is measured by experiment and heritability of the traits is known, the genetic correlation can be estimated (realized genetic correlation).

**INDIRECT SELECTION**

The practice of improving one character by selecting on another related character is called **indirect selection**. In other words, if we want to improve character Y (desired character), we might select for another character X (secondary character) and achieve progress through correlated response of the character Y. The basis of indirect selection is the high genetic correlation between the traits.

The conditions under which indirect selection would be advantageous are:

1. If the desired character (Y) is difficult to measure with precision, than character (X) or when the information on character X becomes available early in life or when the desired character may be costly to measure, as for example the efficiency of feed conversion. Then it may be economically better to select for an easily measured correlated character, such as growth rate.

2. If the desired character is measurable only in one sex and the secondary character is measurable in both, then higher intensity of selection will be possible by indirect selection.

3. It is applicable when the two characters have high genetic correlation and the heritability of character under selection $h^2_X$ is higher than $h^2_Y$, then correlated response ($CR_Y$) will be higher than direct response ($R_Y$)

The merit of indirect selection over the direct selection as a rate of expected response is described as the ratio of $CR_Y$ to $R_Y$. Assuming equal intensity of selection for desired and secondary traits ($i_x = i_y$), the merit of indirect selection is

$$\frac{CR_Y}{R_Y} = \frac{i_X h_X r_A \sigma_{AY}}{i_Y h_Y \sigma_{AY}} = \frac{i_X h_X r_A}{i_Y h_Y}$$

It can be seen from the expression that indirect selection will be better than direct selection, if $r_A h_X$ is greater than $h_Y$. The $r_A h_X$ is the correlation between the breeding value of the desired character (Y) and phenotypic values of selected character (X). Thus indirect selection cannot be expected to be better than direct selection unless the secondary character (X) has a substantially higher heritability and the genetic correlation between the traits is high.

## RECURRENT SELECTION and RECIPROCAL RECURRENT SELECTION

**Inbreeding:** Inbreeding is defined as the mating between animals, which are more closely related to each other than the average relationship between all individuals of the population.

**Heterosis (or) Hybrid Vigour:** Heterosis is a phenomenon in which the progenies of crosses between two pure bred populations /inbred lines exceed the average of two parental breeds / lines. Heterosis is due to dominance, over dominance and epistasis (non-additive gene action).

**Diallele Crossing:** Crossing of two or more inbred lines derived from the base population in all possible combinations in order to evaluate their genotype with respect to some quantitative characters is called as diallele crossing. It is a method of progeny testing and could be utilized for selecting breeds / strains / lines for crossing to exploit heterosis to maximum level. It provides information on general combining ability (GCA) and specific combining ability (SCA).

**Strain:** A group of related animals produced by intensive selection and random breeding in a closed flock for five generations for a particular trait (s) and a name is given for the strain.

**Inbred Line:** A group of related animals with in a breed / strain produced by close inbreeding (Parent-offspring / Full sib mating) for successive years so that the progeny has inbreeding coefficient of more than 37.5 per cent.

**General Combining Ability (GCA):**

In diallel cross a set of lines are crossed at random, each line being crossed simultaneously with other line. The average performance of a single line in cross combination with other line measures the GCA. The GCA is caused by additive effects and epistatic effects based on additive gene combination (additive x additive)

**Specific combining ability (SCA) / Special combining ability**

The performance of particular cross may deviate from the average GCA of the two lines involved and this deviation is known as SCA of that cross. The SCA is caused by dominance effects and epistatic effects based on dominate gene combinations (additive x dominance and dominance x dominance).

**SELECTION FOR COMBINING ABILITY:**

Since the production of inbred lines, selection and crossing is costly and time consuming a number of short cut selection methods have been developed which aims at improving the SCA of particular combination and would also helps in building considerable genetic variation in the lines used for breeding. They are

1. Recurrent selection (RS) or Recurrent to inbred tester
2. Reciprocal recurrent selection (RRS)

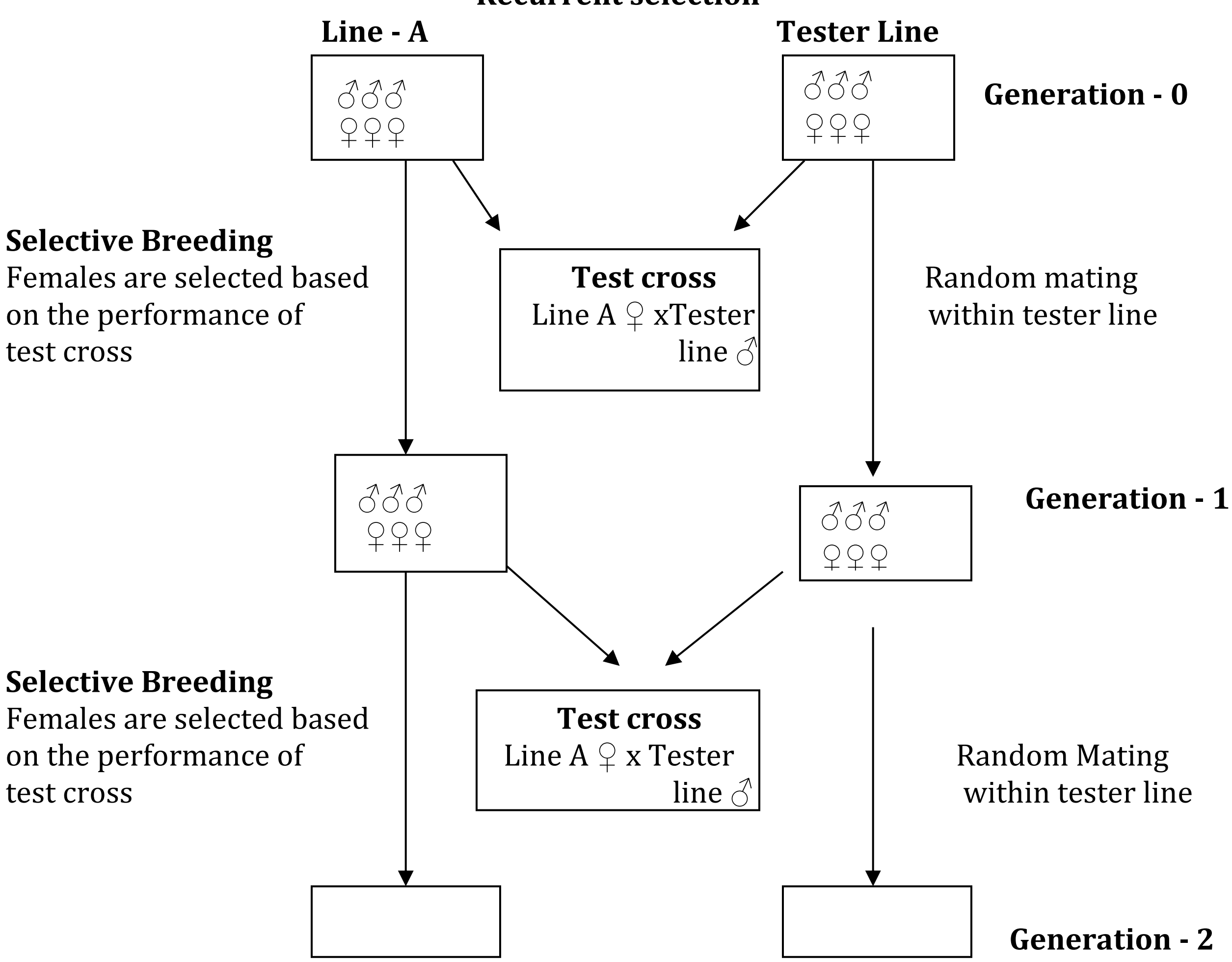
From the causes of heterosis explained it is clear that we require a pair of lines that differ widely in the gene frequencies at all loci that affect the character and that show dominance. Again these lines have to be test crossed for GCA and SCA.

The RS and RSS are the selection methods for combining ability which results in improved crossbred / hybrid progeny performance by crossing the selected lines for exploiting the non-additive gene action (over dominance and epistasis). The procedure includes inbreeding and cross breeding combined with selection.

## 1. Recurrent selection (RS)

It is a method of selection for improvement of SCA. This selection procedure was proposed by Hull (1945) to produce stock, which combines well with a constant tester line. The tester line, a highly inbred line presumably homozygous at most loci and known to have a good GCA, is employed to test the value of new line (A). Large number of females from line A to be tested is crossed with the tester line males and their progenies are evaluated (Females of line A are usually crossed to inbred males, minizing the deleterious effects of inbreeding on fertility). The tested females are selected on the performance of their testcross progenies. The selected females of line A are then mated with males of their own line to produce next generation parents of line A. This cycle is repeated until the individuals of the population combine well with tester line.

**Recurrent selection**



In this method at heterotic loci the frequencies of those alleles that are complementary to the alleles of the tester line are increased. For example if the tester line is AA recurrent selection will increase the frequency of 'a' allele in the segregating population which eventually will become 'aa' there by the segregating population will become homozygous in a way complementary to the inbred tester line. By this method the GCA of tester line and SCA of the cross are improved. The crossbred progenies are used for commercial production and not for further breeding. This method has practical difficulty of producing and maintaining the highly inbred tester line.

**Reciprocal recurrent selection (RRS)**

It was proposed by Comstock and co-workers (1949). RRS is a system of selection for improving both GCA and SCA and nicking ability of two specific populations /inbred lines. The RRS implies progeny testing of each of the two lines by crossing with each other.

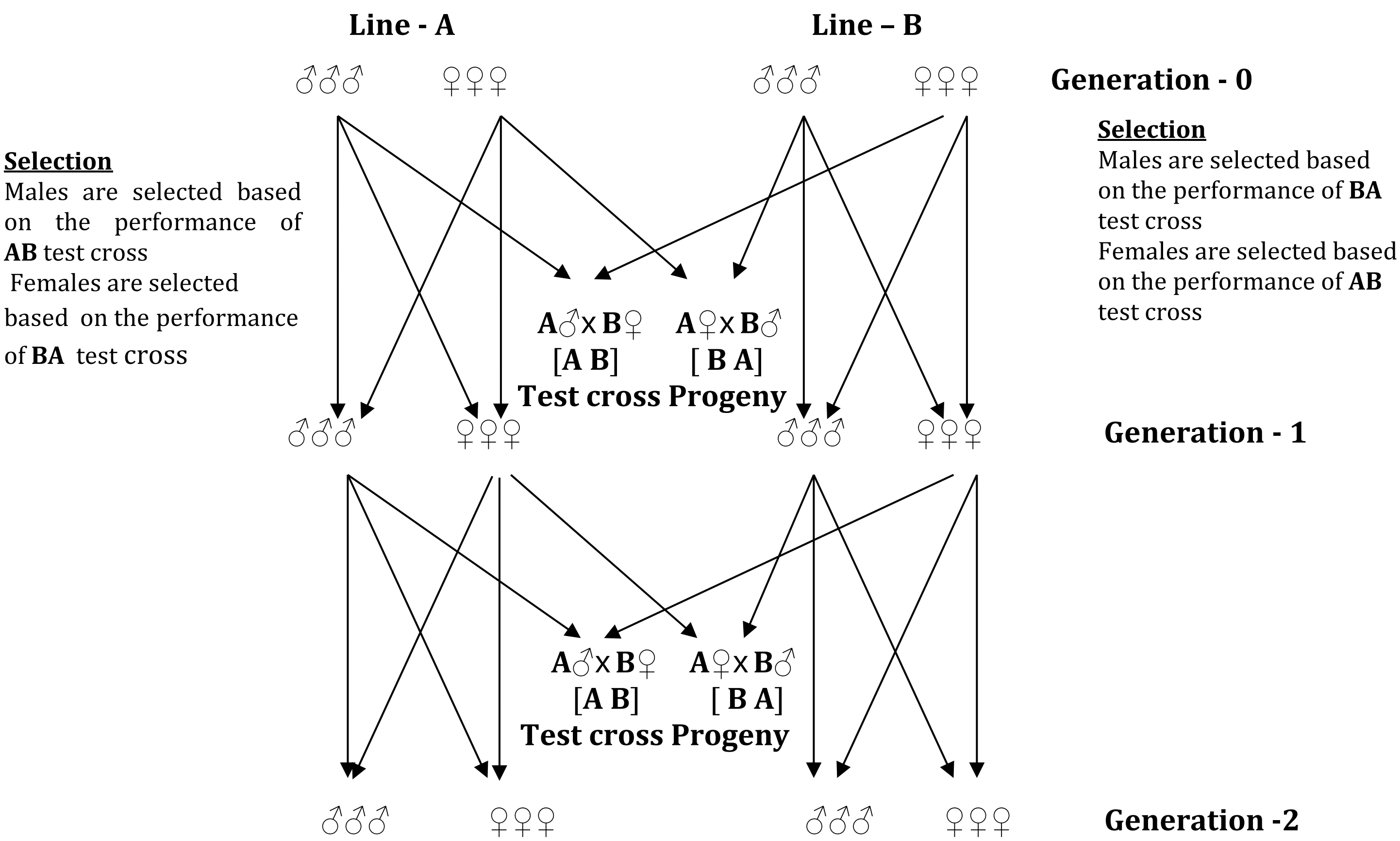
The operation procedures involve two segregating populations / lines (A and B), each serving as the source material for selection and also serving as tester for the other population. The number of males of **A** line are crossed with females of **B** line and vice versa. i.e. reciprocal crosses are made between these two lines. The males and females of each of the two populations are selected based on the performance of test cross progeny (AB or BA). The rest of the parents are discarded along with the entire test cross progenies, which are used only to check or test combining ability of the parents. Selected parents of the A and B lines are remated to members of their own line (i.e.A with A and B with B) to produce the next generation of parents to be tested. The whole cycle is repeated each generation until best possible results are obtained by crossing. The ultimate goal is the production of commercial hybrids by crossing between the two lines.

The principle involved in RRS assumes that individuals in the two segregating populations are not completely homozygous but at a high frequency of homozygosity in opposite ways for all pairs of genes. Crossing them and selecting the individuals to reproduce each population on the basis of the performance of their progeny in test cross theoretically directs the two populations more homozygous in opposite directions. i.e., complementary adjustments of genotypes in two populations that will exhibit better heterosis by crossing.

RS and RRS are effective only if there is a genetic difference between two segregating populations. RS and RRS would be expected to be more useful only if over-dominance or non-additive gene actions (intra allelic and inter allelic) are important.

RS and RRS are commonly used in poultry and swine breeding. This method is difficult to be adopted in case of large animals primarily because of the difficulty and costly in producing truly inbred lines of high inbreeding coefficient. Since RS and RRS involve progeny testing, it increases generation interval and hence slower the genetic progress.

**Reciprocal recurrent selection**



# BREEDING / MATING SYSTEM

These are two ways by which the action of breeder can change the genetic properties of the population. First by the choice of individuals to be bred as parents which is otherwise known as selection. The second is by the control of the way in which the parents are mated which is mating system (or) breeding system. A combination of both selection and mating system is known as breeding plan.

So far the discussion has concerned how the breeder selects parents for the next generation. His next task is to decide how to breed them i.e. how to mate them together. This is the area of breeding system.

Systems of breeding do not crate any new genes. They sort out the existing in to new pattern. Success therefore depends upon the proportion of favourable genes present in the foundation stock or selected individuals. Genes that are not present in foundation animals can sometimes be found in other strains or population can be introduced through crossing. Mating is a process that determines which males (selected) are bred to which females (selected).

Primarily mating system can be classified as

a) Random mating

b) Non-random mating

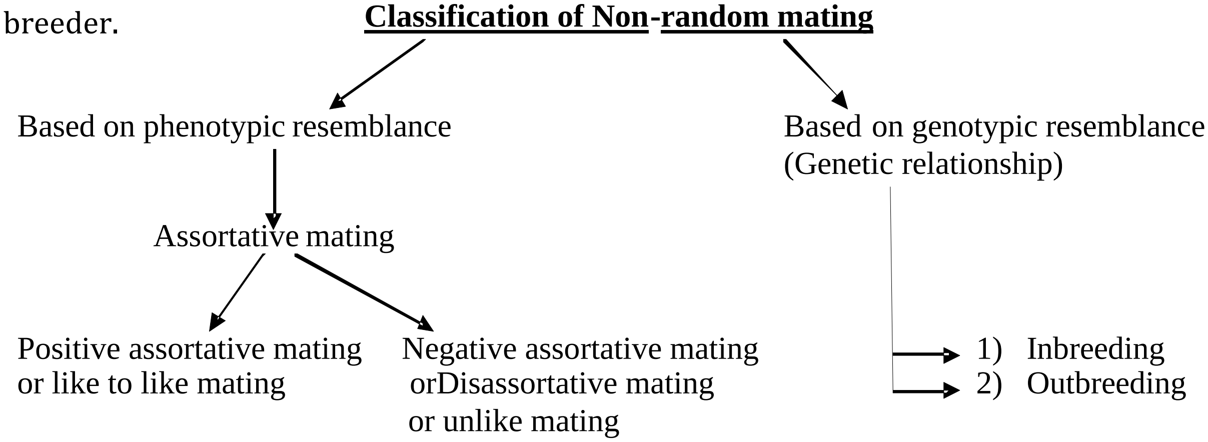
**Random Mating: (Panmixia or Panmixis)**

It is defined as the type of mating in which any individual of one sex has an equal chance of mating with any other individual of the opposite sex in the population. It is a type of mating in which any female in a population has an equal chance to be mated with any male in a population. Therefore the frequency of mating is dictated by chance.

**Non-random mating**:

Artificial mating in which the mating is decided or planned or controlled by the breeder.

**Classification of Non-random mating**



**I. Based on phenotypic resemblance:**

**Assortative Mating**: Here mating is based on phenotypic resemblance.

If the mated pairs are phenotypically similar it is called as positive assortative mating. If it is phenotypically different it is called as negative assortative mating.

a**) Positive assortative mating or Like to like mating**

If mated pairs are of the same phenotype more often than would occur by chance it is called as assortative mating. Positive assortative mating tends to create more genetic and phenotypic variation in the offspring generation than would be found in a comparable randomly mated population.

The consequence of assortative mating with a single locus in terms of genotypic frequencies among the progeny is to increase the frequencies of homozygotes and reduce that of heterozygotes. It results in subdividing the population into groups and mating takes place more frequently within than between the groups.

e.g.

Large animal x Large animal

Medium animal x Medium animal

Small animal x Small animal

**b) Negative assortative mating or Disassortative mating or Unlike mating**

If mated pairs are of the same phenotype less often than would occur by chance is called as disassortative mating. It is mating of individuals of unlike phenotype. Negative assortative mating tends to decrease variation and increase phenotypic uniformity in the population. This is also called as "Corrective mating". It leads to increase the heterozygotes and reduce homozygotes in the population.

e.g.

Large animal x Small animal

Large animal x Medium animal

Small animal x Medium animal

**II. Based on genetic resemblance:**

a) **Inbreeding:** Mating of related animals. If choice of the mates is based on genetic relationship between them, then the mating system is said to be consanguineous or inbreeding.

b) **Outbreeding:** Mating of unrelated animals. When the relationship between individuals which are mated together is less close than the average relationship within the population, the mating system is referred as outbreeding.

| Inbreeding | Random mating | Out breeding |
|---|---|---|
| ↓ | ↓ | ↓ |
| ↑ Homozygotes<br>↓ Heterozygotes | No change of<br>Gene frequency &<br>Genotype frequency | ↑ Heterozygotes<br>↓ Homozygotes |

The effect of positive assortative mating is similar to those of inbreeding but to a lesser extent.

## INBREEDING

Inbreeding is defined as mating between animals which are more closely related to each other than the average relationship between all individuals of the population. Inbreeding is mating between animals related by ancestry. Two animals are said to be genetically related when they have one or more ancestors in common in the first 4 to 6 generations of their pedigree.

Inbreeding may either be occasional or consistently carried out for several generations. If it is consistently carried out for several generations (recurrent inbreeding), it can be classified as

1) Close inbreeding
2) Line breeding
3) Strain (breeding) formation

**1. Close inbreeding:**

Example: Mating between sibs or between parents and progeny / offspring i.e. sire x daughter or son x dam.

Close inbreeding is a severe or strict form of inbreeding. The matings are made between sibs or between parents and progeny. This type of mating is carried out to produce inbred lines with relatively high degree of homozygosity.

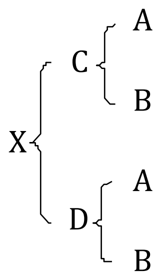
The most often used method is 'full sib' mating. Same effect can also be achieved by consistently back crossing the progeny to the younger parent. Half-sib mating is very much slower in reaching homozygosity but it is less risky.

Close inbreeding is done

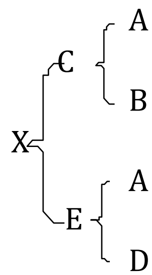
a) To develop inbred lines

b) To discover undesirable recessive genes with the help of parent X offspring mating

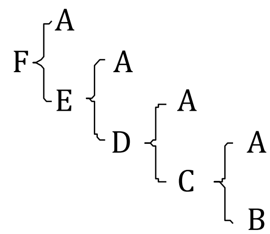
c) To get more phenotypically uniform progeny



Full-sib mating



Half-sib mating



Repeated back crossing

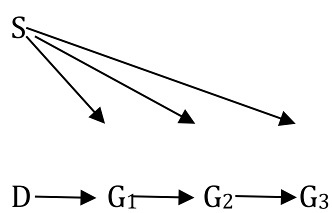
**2. Line breeding:**

Line breeding is a form of inbreeding in which the relationship of an individual or individuals is kept as close as possible to an admired or outstanding ancestor. The ancestor is usually a male because a male can produce more number of progenies during its life time than a female.

The line breeding is taken in two ways,

1) Half-sib mating or cousins mating. Here the rate of inbreeding is less than close inbreeding.

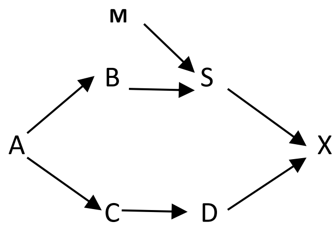
2) The second ways is the mating of animals in such a way that their descendants are mated to outstanding animal (sire) up to 3 to 4 generations. e.g.

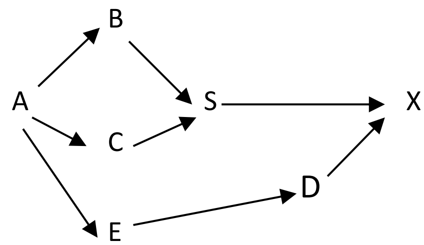


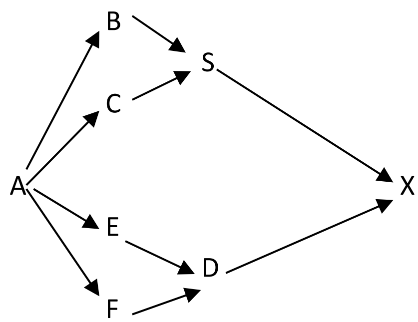

Here rate of inbreeding is high

In view of the various forms of line breeding it is difficult to classify some matings either close inbreeding or line breeding e.g. sire x daughter mating is taken as close inbreeding but it effectively concentrate the inheritance of the sire and hence logically should be called as line breeding. Half-sib mating is also considered as line breeding.

**Example pedigree to illustrate line breeding**

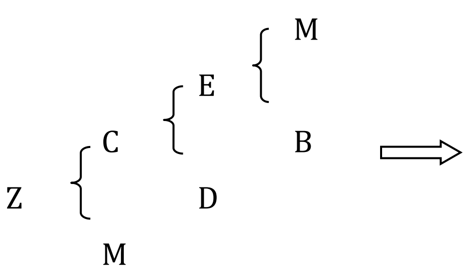


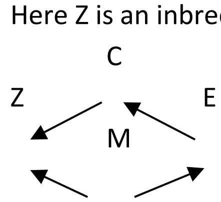




In general, line breeding is milder form inbreeding and the relationship (R) is not so close as it is found in close breeding. In this method an attempt is made to concentrate the inheritance of one ancestor or line of ancestor in the line bred offspring. The primary purpose is not to increase the homozygosity but to retain/ concentrate on a good proportion of genes/ traits of a particular outstanding ancestor (Sire/Dam) among its descendants.

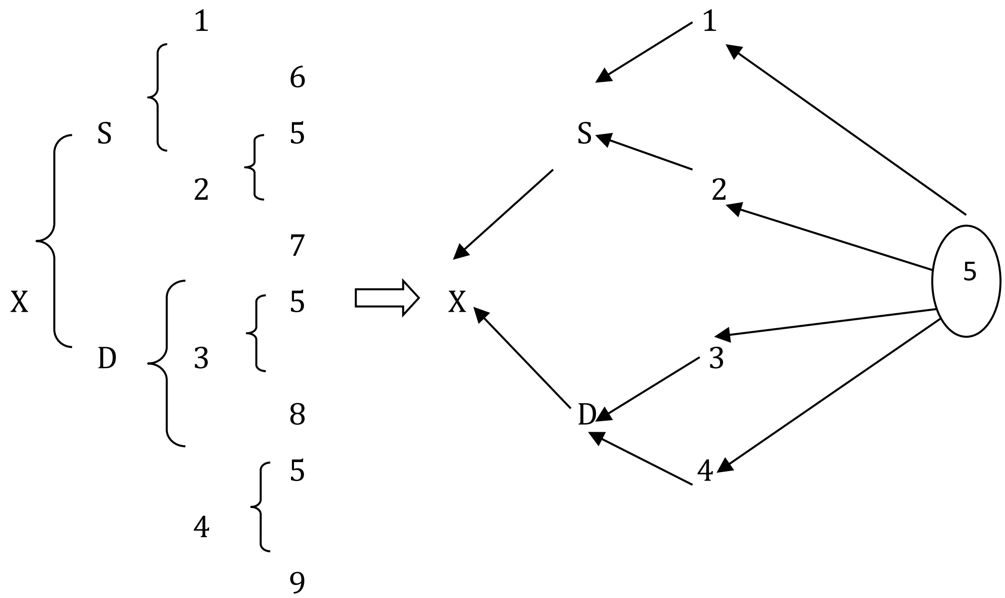
Generally a sire is not mated to his own daughter and matings are made between half-sibs or grand sire and granddaughter. e.g.




Here Z is an inbred individual line bred to M




$F_Z = (½)^{0+2+1} = (1/2)^3 = 0.125$




Here X is an line bred individual line bred to ‘5’. $F_5$ = 0.0625

The mating of animals which are more distinctly related like mating between cousins is also called as line breeding.

The following points should be remembered while practising line breeding: /Merits of line breeding/ when line breeding should be practised?

(i) Line breeding should be practised in pure bred population of a high degree of excellence after identifying outstanding individuals.

(ii) Line breeding is probably most useful when the outstanding sire is dead or not available for breeding purposes.

(iii) Line breeding also builds up homozygosity and prepotency like other kinds of inbreeding.

(iv) When progress by inbreeding comes to standstill line breeding makes additional progress possible.

(v) It can be practised to distinguish a breed into families or lines.

(vi) Line breeding is useful where there is much epistasis i.e. by producing different line and crossing these lines for combining ability or nicking ability.

**Danger of line breeding:**

The selected ancestor (sire) for line breeding should not posses any genes for undesirable characters. Since the line breeding tends to make genes good or bad homozygous.

Line breeding was used extensively in the past in the development of British breeds of cattle such as Angus, Hereford and Shorthorn.

**3. Strain Formation:**

This is the mildest form of inbreeding. When a population of individuals are allowed to breed without entry of new animals for at least three to five generations then it is termed as strain breeding.

Since the population is closed from the entry of new animals, homozygosity increases due to small population size. A breed can be subdivided into different strains based on specific characteristics/ traits by the strain breeding.

**[How to develop inbred lines:** To develop inbred line select outstanding animals from purebred with good performance population and no obvious genetic defects in the population and the selected animals relatives also should be superior in these respects.

Initially, inbred as rapidly as possible for the early exposure of any detrimental or lethal recessive genes that may be present in the original stock. For that follow either parent x offspring matings i.e. sire to his own daughter or a dam to her own son. If the selected parent posses recessive lethal genes they are paired with its offspring and their progeny exposes the defect. Similarly if the parent posses superior genes, they will be paired with its offspring mating and expressed in their offspring.

If recessive defects are found to be present in the inbred line it may be advisable to discard the line and select the superior line. If an inbreeding coefficient of at least 0.375 (corresponding to two generations of full sib mating) is reached, then such a line is called inbred line. Once two or more superior lines of animals are formed by inbreeding and inbreeding has reached 40 to 50 %, it is often desirable to propagate the line by half-bother x half-sister matings. This will help to slow the rate of increase of inbreeding and also more individuals can be breed.

**How to improve inbred lines:**

Once inbred lines are formed, matings must continue to be made within the inbred line to keep it pure. Follow Reciprocal Recurrent Selection (RRS) and Recurrent Selection (RS) methods for further improvement of the lines].

**Genetic effects of inbreeding:**

1) It makes more pairs of genes in the population homozygous regardless of the kind of gene action involved (i.e. desirable/ undesirable or favourable / unfavourable). All phenotypic effects of inbreeding result from this effect of increasing homozygosity.
2) Inbreeding did not change the frequency of the genes in the population.
3) Inbreeding brings many recessives to light as it increases the frequency of both dominant and recessive homozygotes.

**Consequences of inbreeding:**

1) Inbreeding does not increase the number of recessive alleles in a population but merely brings them to light through increasing the frequency of homozygotes.
2) Inbreeding fixes character in an inbred population through increased homozygosity whether or not the effects are favourable or unfavourable.
3) Since inbred parents posses more pairs of genes homozygous particularly for dominant genes and they transmit the same genes to their offspring, they are more likely to be prepotent than non-inbred (individual) parents.
4) Inbreeding accompanied by selection may increase the phenotypic uniformity among the animals with in the population.

**Phenotypic effects of inbreeding**:

1. Lethal / harmful deleterious recessive genes causing hereditary abnormalities remain hidden in outbred herds (as heterozygotes). Usually these genes being covered by their dominant alleles in heterozygous form. When inbreeding occurs, the genes appears as homozygous form and exhibit / express their effects phenotypically.

**2. Inbreeding depression:**

Inbreeding depression is the reduction in the mean phenotypic value shown by characters connected with reproductive capacity, vigour (viability), physiological efficiency, e.g. fertility, number of services per conception, embryonic death, litter size in pigs, reduction in milk yield and growth rate.

Generally inbreeding tends to reduce fitness. The decrease in performance resulting from inbreeding is called inbreeding depression. Inbreeding depression is generally greatest for traits associated with natural fitness such as viability and reproductive ability because there is more dominance at the loci affecting these traits than at loci affecting other traits and heritability of these traits will be generally low. In general, performance in reproductive traits and viability traits decreases at the rate of around 1% of the mean, for every 1% increase in the inbreeding coefficient.

Different species vary in the effect of inbreeding but it is likely that pigs will show problems at lower levels of inbreeding than would cattle. One would expect few problems up to about 10% F and increasing difficulties in excess of 20 % (A level of 10 % achieved within 2-4 yrs may be more series than 10% in 10 yrs).

Results of some inbreeding experiments

**Cattle**

| $F_x$ | Average no. of AI/conception/co |
|---|---|
| 0 | = 2.0 |
| 0 - 24.9 | = 2.46 |
| 25 - 29/9 | = 2.25 |
| 30 - 39.9 | = 3.11 |
| 40 – 49.9 | = 3.17 |
| 50 & above | = 3.58 |

| Male fertility | AI / Conception |
|---|---|
| With inbred bulls | =3.0 |
| With outbred bulls | =1.92 |

**On birth weight of calves**

| Fx | |
|---|---|
| 0 | = 81.3 lbs |
| 40 % | = 74.0 lbs |
| 45% | = 72.0 lbs |
| >50% | = 65.9 lbs |

**Poultry:** Reduction in egg production of 0.43% for each 1% increase of inbreeding coefficient. Inbreeding increase chick mortality.

**Pigs:** Inbreeding decrease litter size at birth, viability between birth and weaning, post weaning growth rate.

**Change of population mean on inbreeding:**

Inbreeding does not change gene frequencies in the population but it increases the frequencies of homozygous genotypes and decreases the heterozygous genotype frequencies. Therefore, a change of population mean on inbreeding must be connected with a difference of genotypic value between homozygotes and heterozygotes.

Consider a population that is subdivided into a number of lines with a coefficient of inbreeding F. Consider a locus 'A' with two alleles A1 and A2 and p and q being the gene frequencies for these alleles in the whole population. The genotypic values assigned to the genotypes A 1A 1, A 1 A2 and A2 A2 are +a, d and –a respectively. Then the population mean derived as :

| Genotypes | Frequency | Value | Frequency x value |
|---|---|---|---|
| A 1A 1 | p2+ pqF | + a | p2a + pqaF |
| A 1 A2 | 2pq – 2pqF | d | 2pqd – 2pqdF |
| A2 A2 | q2 + pqF | – a | - q2a- pqaF |

Sum : p2a + pqaF + 2pqd – 2pqdF – q2a – pqaF

MF = p2a – q2a + 2pqd – 2pqdF

= a(p2-q2) + 2pqd -2pqdF

= a [(p+q)(p-q)] + 2pqd – 2pqdF

= a (p-q) + 2pqd – 2pqdF

= Mo – 2pqdF

Where Mo is the population mean before inbreeding and -2pqdF is the change of mean on inbreeding.

Therefore, inbreeding depression for a single locus can be algebraically expressed as:

MF = Mo – 2dpqF

For all loci concerned is

MF = Mo – 2F∑dpq

Where,

Mo = is the mean value of the population for a particular character before inbreeding.

MF = is the mean values of the population for a particular character after inbreeding.

F = is the inbreeding coefficient of the individual

d = dominance i.e. heterozygote does not have a value average to that homozygote.

p = frequency of one allele

q = frequency of another allele

Therefore, the inbreeding depression is $-2F\sum pqd$ which depends on (i) dominance, ii) inbreeding coefficient and iii) relative frequencies of alleles. Genes at intermediate frequency (0.5) at the beginning of inbreeding show highest depression.

Another conclusion that can be drawn from the equation is that when loci combine additively, the change of mean should be directly proportional to the coefficient of inbreeding.

Economic traits connected with reproduction, viability, milk yield and growth rate show inbreeding depression, characters like fat %, back fat thickness in pigs do not show inbreeding depression. Swine is the commonly affected farm animal due to inbreeding.

**3. Reduction in physiological efficiency (Physiological basis of inbreeding effects):**

Adverse effects of inbreeding in animals are known to be due to the action of several pairs of recessive genes. As a general rule the action of recessive genes is unfavourable to the well-being of the individual.

a) The action of such genes is through the failure to produce required enzymes or through the production of proteins and other components.

b) Inbred animals are usually less able to cope with their environment when compared to non-inbred animals. This is shown by reduction in fertility, viability, growth rate etc. This may be due to some physiological insufficiency and perhaps to a deficiency or lack of balance of hormone from the endocrine system.

## EFFECT OF INBREEDING ON DIFFERENT KINDS OF GENE ACTION

Inbreeding increases the homozygosity and its effect on the phenotype depending upon the kind of gene action involved.

**(i) Dominance and recessiveness :**

The decline in vigour that accompanied by inbreeding is due to the uncovering of detrimental recessive genes through increased homozygosity and the reduction in population mean is due to reduction in average values of recessive genotypes. The reduction in phenotypic value depends on the values and number of the dominant genes involved.

(However, if complete homozygosity were attained and this is not very likely and there would be no further decrease in values because there would be no further uncovering of recessive genes).

**(ii) Over dominance:**

If a trait exhibit over dominant type of gene action i.e. heterozygous genotypes are superior to either of the homozygotes than due to inbreeding there is a decrease in the number of heterozygous and increase in the number of homozygous individuals in the population which result in a deterioration of the trait.

e.g. value of { dd – 140
DD – 140 } where as the Dd value is 180

**(iii) Epistasis:**

It is interallelic interaction of genes i.e. interaction between pairs of genes that are not alleles. Epistatic gene action may also be responsible for the deterioration of a trait when inbreeding is practiced. Under actual conditions we have no way of knowing what kinds of epistatic gene action affect the various traits.

(From the theoretical standpoint, developing inbred lines, crossing them and then developing a new synthetic population from the cross should be helpful in fixing a larger number of favourable combinations of genes with epistatic effects).

**(iv) Additive gene action**:

In additive gene action, there are no dominant or recessive genes, nor are there interactions between the various alleles or pairs of genes. Inbreeding would cause both plus and neutral genes to become more homozygous. When this (additive) was the only kind of gene action involved for a trait then the merit of the population will improve until genetic variation was exhausted. When this point was reached no further improvement would result.

However, all most all economic traits are affected by both additive and non-additive types of gene action. (VD + VI).(Therefore it is necessary to develop superior inbred lines by fixing superior genes in inbred lines and then cross them to get combinations of genes that will give hybrid vigour or heterosis).

**Prepotency:**

Prepotency is the ability of an individual to breed stock like itself or stamp its characteristics on its offspring to such an extent that they resemble their parents more closely than is usual. It will increase with inbreeding and increase of homozygosity.

A high degree of homozygosity and the possession of a high percentage of dominant genes are the requirements that will enable an animal to stamp its own characteristic on majority of its offspring.

Prepotency refers to property of the characteristics and not the individual breed or sex.

Prepotency is not transmissible from parents to offspring.

Prepotency is measured by the estimate of inbreeding coefficient (F).

**Genetic homeostasis:**

Continued inbreeding may reduce heterozygosity only to a certain level beyond which further reduction does not occur. The phenomenon of maintenance of genetic variability in a population in the face of all the forces acting to reduce it is termed as genetic homeostasis.

Homeostasis is a term devised by W.B. Cannon to denote the tendency of a physiological system to react to an external disturbance in such a way that the system is not displaced from its normal values.

**Strain:** Close the selected flock for outside breeding Intensive selection and random breeding is followed for 5 generation for a particular trait or traits and a name is given for the strain.

**Line:** From a strain-select animals / birds at random – make full sib / half-sib mating for successive year so that the progeny has inbreeding coefficient of >50 %.

**Autozygous:** Refers to genes that are identical by descent i.e. two genes at a locus are derived from a single gene from a common ancestor or originated from the replication of one single gene in a previous generation.

**Allozygous:** Refers to genes that are identical in state i.e. similar in structure and function but not copies of the same gene from a common ancestor.

## MEASUREMENT OF INBREEDING AND RELATIONSHIP COEFFICIENT

There are two types,

**I. Computation of coefficient of inbreeding from pedigreed population**

It is a direct method of estimating the 'F' of an individual. In this method particulars of the pedigree of the population is required.

**II. Computation of coefficient of inbreeding from the population size**

It is a indirect method. In this method we could estimate only the average 'F' of all individuals of a generation i.e. the rate of inbreeding in a population and the individual 'F' cannot be estimated in this method. It is only a approximation and the approximation is not close enough if population size is very small.

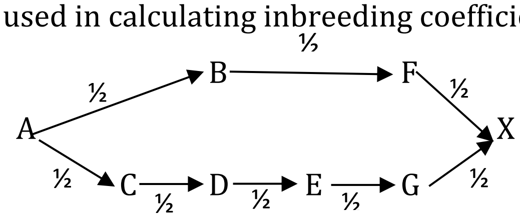
**I. Computation of inbreeding coefficient of an individual from pedigreed populations:**

There are four methods available to estimate the inbreeding coefficient of an individual from pedigreed populations

**1) Path coefficient method:**

The method was developed by Wright (1921). It is a simple and flexible method of calculating 'F' for a wide variety of inbreeding problems. This coefficient is the probability that the pair of alleles carried by the gametes that produced it were identical by descent. Computation of the 'F' therefore requires no more than the tracing of the pedigree back to common ancestors of the parents and computing the probabilities at each segregation.

Principle used in calculating inbreeding coefficient




Suppose there is an individual X, whose parents F and G have a common ancestor A, and that a number of generations exists between A and parents F and G.

What is the probability that the individual X inherits (receives) two alleles which are identical by descent?

Assume any locus in the ancestor 'A'. The probability that B and C inherit the same allele from A is ½ and they inherit different alleles is ½. The probability that the latter genes is identical with the former on account of earlier inbreeding is however ½ $F_A$ = A' inbreeding coefficient. The total probability that B and C inherit genes which are identical by descent is therefore ½ + ½ $F_A$ =½ $(1+F_A)$. i.e. the total probability that B and C inherit genes which are identical by descent is thus ½ $(1+F_A)$.

The probability that B further transmit the gene which it obtained from A to F is ½ and that F further transmits the gene to X is similarly ½.

The same reasoning can be applied for the gene which 'C' passes to D and so on. The probability that X recessives two alleles which are identical by descent is thus ½ $(1+F_A)$ $(½)^{2+4}$

The individual 'X' can however have other common ancestors than A and the general formula is sum of all the coefficients of inbreeding and formula becomes

$$F_X = \sum (½)^{n1 + n2 + 1} (1+F_A)$$

Where,

n1 is the no. of generations from the CA to one parent / sire

n2 is the no. of generations from the CA to other parent / Dam

FA is the inbreeding coefficient of CA

∑ is summation i.e. add all pathways & for all CA's

Coefficient of relationship: represented by RXY,

$$R_{XY} = \frac{\Sigma (½)^{n_1 + n_2} (1+F_A)}{\sqrt{(1+F_X)(1+F_Y)}}$$

Where,

n1 is the no. of generations from 'X' to CA

n2 is the no. of generations from 'Y" to CA

FA is the inbreeding coefficient of CA

FX and FY are the inbreeding coefficient of individual X and Y

**2) Probability Method:**

This method was introduced by Malecot (1948). (Used by Narain 1966 to study the effect of linkage in selfed population).This method does not differ in principle from the Wright's inbreeding coefficient (F) estimation formula, but instead of working from the present back to the common ancestors we work forward keeping a running tally generation by generation and compute the inbreeding that will result from the matings now beings made. This method use the probabilities of genes being identical by descent for examining inbreeding systems. This method is based on the fundamental measure of consanguinity in respect of an individual as well as of two individuals. The chief uses of this method are for planning mating to give the least inbreeding and for calculating the 'F' generation by generation in a fully pedigreed population.

**3) Coancestry method:**

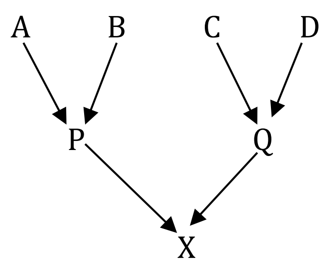
This method also referred as the coefficient of Kinship or consanguinity since it is based on degree of relationship by descent between the two parents. It will be symbolised by 'f'. The degree of relationship has assumed several names in the literature such as

Coefficient of relationship – by Wright

Coefficient of de parente- byMalecot

Coefficient of kinship<br>
Coefficient of consanguinity } by Falconer<br>
Coefficient of coancestry

The F of an individual depends on the amount of common ancestry in its two parents. Therefore, instead of thinking about the inbreeding of the progeny we can think of the degree of relationship by descent between the two parents.




i) Here the F of the individual is equal to the coefficient of parentage between its parents. i.e. $F_X = r_{PQ}$.

ii) coefficient of parentage between two individuals is the average of four coancestries between their parents.

$$r_{PQ} = \frac{1}{4} (r_{AC}+r_{AD}+ r_{BC} + r_{BD})$$

iii) coefficient of parentage of an individual with itself

$$r_{XX} = \frac{1}{2} (1+ F_X)$$

iv) coefficient of parentage of two individual is equalent to the mean coancestry of one individual with two parents of other individual is $r_{PC}$

$$r_{PC}= \frac{1}{2} (r_{AC} + r_{BC})$$

This rule is applicable when the individuals under question belong to different generations e.g. A & Q

This rule also gives $r_{PQ} = ½ (r_{PC} + r_{PD})$.

**4) Generation matrix method:**

Introduced by Bartlett and Haldane (1934) and later elaborated by Fisher (1949). This method makes use of the elementary properties of matrices in which the expected frequencies of different mating types after a specified numbers of generations of inbreeding can be obtained besides the measurement of inbreeding coefficient of individual.

**II. Estimation of effective number and rate of inbreeding in an un pedigreed / random bred population**

In an idealized population the rate of inbreeding ΔF is related to the population size 'N' and ΔF = 1/2N where N is the number of individual in an idealised population. Generally any deviation from the idealised breeding structure is expressed in terms of the effective number of breeding individuals or the effective population size 'Ne'.

Ne is the number of individuals that would give rise to the same rate of inbreeding to the conditions under consideration, if they are bred in the manner of idealized population. The effective number can be calculated from the observed number i.e. number of sires and dams used in generation and we can easily determine the rate of inbreeding i.e. ΔF = 1/2Ne

In domestic animals the sexes are generally unequal or in other words the no. of males is much less than the no. of females but they contribute equally to the next generation under such situation the effective number (Ne) and rate of inbreeding (ΔF) is calculated as

1/Ne = since the sampling variance is proportional to the reciprocal of the number and the effective number is twice the harmonic mean of the numbers of the two sexes.

$$1/Ne = 1/4Nm + 1/4Nf$$

$$Ne = \frac{4NmNf}{Nm+Nf}$$

$$\Delta F = 1/2Ne = 1/8Nm + 1/8Nf$$

Where,

Nm is the no. of males

Nf is the no. of males

**Example:** In a random mating flock of poultry, 50 cocks are mated to 250 hens. Find out the effective number and rate of inbreeding

$$Ne = \frac{4 \times 50 \times 250}{50 + 250} = 166.7$$

$\Delta F = 1/2x166.7$ or $1/8x50 + 1/8x250 = 0.003$

**Uses of inbreeding**

Inspite of some obvious disadvantages of inbreeding there are certain instances where it may be useful in livestock production/improvement.

1. The most practical use of inbreeding is to develop different inbred lines that can be used for crossing purpose to exploit Heterosis.
2. Inbreeding may be used to determine the actual genetic worth of an individual. This is done by mating a sire to its 25 to 35 daughter before it is used extensively in Artificial Insemination programme.
3. Inbreeding could be used as a practical way to select against a recessive gene that is of economic importance. Since inbreeding brings out the hidden undesirable / deleterious recessive genes; both recessive homozygotes and heterozygotes parents can be identified and culled.
4. Inbreeding is also done to produce genetically uniform animals to be used in experiments and to promote genetic purity e.g. laboratory - rats, mice and rabbits.
5. Inbreeding may be used to form distinct families within a breed and for regrouping the genetic material.
6. Inbreeding is used in increasing the prepotency of sire when the sire is homozygous for the genes controlling the trait.
7. It is necessary if relationship to a desirable ancestor is to be kept high.

**Panmictic index (P)**

It is the probability that two genes at a locus in an individual are independent by descent.

$P = 1- F$

Where F is the inbreeding coefficient of an individual.

If all genes present in the population are independent and are not identical by descent and this point is the base population and by its definition has an inbreeding coefficient of zero and the panmictic index is one.

**Danger of intense breeding:**

1. It will make undesirable genes homozygous at so rapid rate. (It will be impossible to discard all homozygous individuals. The lowered sale value of the defectives uncovered by the inbreeding will cause some loss).
2. Some of the undesirable genes will become 'fixed' in the whole herd.

## HETEROSIS or HYBRID VIGOUR

Heterosis is a phenomenon in which progeny of crosses between purebred populations or inbred lines exceed the average of the two parental populations.

Heterosis is the superiority of the outbred animals (F1) over the average of their parents in individual merit (Lush).

In 1912 one of the American pioneers in maize genetics G.H.Shull coined the term heterosis to describe the hybrid vigour obtained from crossing.

Complementary to the phenomenon of inbreeding depression is its opposite, hybrid vigour or heterosis. When inbred lines are crossed, the progeny show an increase in performance of those characters that previously suffered a reduction from inbreeding or in general terms, the fitness lost on inbreeding tends to be restored on crossing. The amount of heterosis is the difference between the crossbred (F1 /F2) and inbred means. Heterosis is simply inbreeding depression in reverse.

1. Heterosis in F1 = Mean of F1 offspring – Mean of parent breed / line

$$H_{F1} = M_{F1} - M_{\bar{p}}$$

2. % Heterosis = $\frac{\text{Mean of } F_1 - \text{Mean of parent breed /line}}{\text{Mean of parent breed /line}} \times 100$

$$\% H_{F1} = \frac{M_{F1} - M_{\bar{p}}}{M_{\bar{p}}} \times 100$$

**Causes of heterosis:**

1) **Dominance**: Possessing more number of dominant genes in an individual.

e.g. Line I X Line II

Genotype: AAbb X aaBB

↓

$F_1$: AaBb

The average daily gain for Line I = 1.80 lbs; The average daily gain for Line II = 1.80 lbs The average daily gain for $F_1$ = 2.20 lbs.

If several pairs of genes control one trait

Breed I X Breed II

Parents :AABBCCdd X aaBBCCDD

$F_1$ : AaBBCCDd

Here $F_1$ would be superior to both parents for that particular trait.

2**) Overdominance:** where heterozygous conditions is much more superior to any of the homozygous conditions. Example:

| Parents | Genotype | Avg. daily gain | Mean ADG |
|---|---|---|---|
| $P_1$ | $A_1A_1\ B_1B_1$ | 1.60lbs | 1.60 lbs |
| $P_2$ | $A_2A_2\ B_2B_2$ | 1.60lbs | |
| $F_1$ | $A_1\ A_2\ B_1\ B_2$ | 2.20 lbs | 2.20 lbs |

However, in $F_2$ ($F_1$ X $F_1$) due to segregation and recombination of genes, the means would regress and only 4 out of 16 individuals would retain the induced heterozygosity and heterosis.

| No. of Parents | Genotype | Avg. daily gain |
|---|---|---|
| 1 | $A_1A_1\ B_1B_1$ | 1.60lb |
| 2 | $A_1A_1\ B_1\ B_2$ | 1.90lb |
| 1 | $A_1A_1\ B_2B_2$ | 1.60lb |
| 2 | $A_1\ A_2\ B_1B_1$ | 1.90lb |
| **4** | $\mathbf{A_1\ A_2\ B_1\ B_2}$ | **2.20lb** |
| 2 | $A_1\ A_2\ B_2B_2$ | 1.90lb |
| 1 | $A_2A_2\ B_1B_1$ | 1.60lb |
| 2 | $A_2A_2\ B_1\ B_2$ | 1.90lb |
| 1 | $A_2A_2\ B_2\ B_{12}$ | 1.60lb |

Total = 16 Only 4/16 of the individuals have mean ADG of 2.20 lbs

**3) Epistasis:** is the interallelic interaction of genes i.e. interaction between pairs of genes that are not alleles. There are many different kinds of epistatic gene action, but their effects on the quantitative traits are difficult to measure accurately because of their complexity.

**4) Difference in gene frequency between two populations:**

In a single locus with two alleles, the frequencies are p and q in one population and p' and q' in the other population. The difference of gene frequency between the two population be **'y'** i.e. $y = p - p' = q' - q$

| Example | Population I | Population II |
|---|---|---|
| Gene frequency: | $p + q = 1$ | $p' + q' = 1$ |
| | $0.6 + 0.4 = 1$ | $0.3 + 0.7 = 1$ |

$y = p - p' = q' - q$

$= 0.6 - 0.3 = 0.7 - 0.4 = 0.3$

In general $H_{F1} = M_{F1} - M\bar{p}$

$= dy^2$

where d = dominance

y = difference in gene frequency between the two populations.

Let us consider two populations referred to as the "parent populations". The parent populations are crossed to produce $F_1$ or first crossbred generation and $F_1$ individuals are mated to produce $F_2$. The amount of heterosis shown by the $F_1$ and the $F_2$ will be measured as the deviation from the mid – parent value ($M\bar{p}$)

First consider the effects of a single locus with two alleles where frequencies are p and q in one population and p' and q' in the other. Let the difference of gene frequency between the two populations be 'y' so that y = p – p' = q'– q.

Therefore p' = p – y and q' = q + y

The algebra is then simplified by writing the gene frequencies of p' and q' in the second population as (p - y) and (q + y).

Let the genotypic values be a, d, -a for the three genotypes $A_1A_1$ , $A_1$ $A_2$ , $A_2A_2$ respectively. They are assumed to be the same in the two populations, epistatic interaction being disregarded. Now we have to find the mean of each parent population and the mid parent value ($M\bar{p}$),then the mean of the $F_1$. The parental population means $Mp_1$ and $Mp_2$ are found as

$Mp_1 = a(p–q) + 2pqd$

$Mp_2 = a(p–y–q–y) + 2d\,(p–y)(q+y)$

$= a(p–q–2y) + 2d[pq + py – qy– y^2]$

$= a(p–q–2y) + 2d[pq + y(p-q) – y^2]$

Therefore,the **Mid-parent value ($M\bar{p}$) is :**

$M\bar{p} = (Mp_1 + Mp_2) / 2$

**$= a(p – q – y) + d[2pq + y(p - q) – y^2]$** ---------------------------------------- (1)

**Mean of $F_1$:**

When the two populations are crossed to produce $F_1$. Individuals taken at random from one population are mated to individuals taken at random from the other population. This is equivalent to taking genes at random from the two populations and the frequencies of zygotes in the $F_1$ will given as :

Frequencies of zygotes in the $F_1$

| | | Gametes from $P_1$ | |
|---|---|---|---|
| | Allele Frequency | $A_1$<br>p | $A_2$<br>q |
| Gametes from $P_2$ | $A_1 : p' = p - y$ | $p(p-y)$ | $q(p-y)$ |
| | $A_2 : q' = q + y$ | $p(q+y)$ | $p(q+y)$ |

$A_1A_1 = p(p\text{-}y)$

$A_2A_2 = q(q+y)$

$A_1 A_2 = q(p-y) + p(q+y)$

$= pq - qy + pq + py$

$= 2pq + y(p - q)$

Then the population mean in the $F_1$ can be calculated as

| <u>Genotype</u> | <u>Frequency</u> | <u>Value</u> | <u>Frequency x Value</u> |
|---|---|---|---|
| $A_1A_1$ | $p(p\text{-}y)$ | 'a' | $ap(p - y)$ |
| $A_1 A_2$ | $2pq + y(p - q)$ | 'd' | $2pqd + d\, y(p - q)$ |
| $A_2A_2$ | $q(q+y)$ | '-a' | $-aq(q+y)$ |
| | | | Sum |

Therefore the mean genotypic value of the $F_1$ is

**$M_{F1} = a\,(p - q - y) + d[2pq + y\,(p - q)]$ ----------------------------------- (2)**

The amount of heterosis expressed as the difference between the $M_{F1}$ and $M\bar{p}$

$H_{F1} = MF_1 - M\bar{p}$ i.e. (2) – (1)

$= dy^2$ for single locus

For several loci $H_{F1} = \sum dy^2$

Where, $H_{F1}$ = Heterosis in $F_1$

d = dominance

$y^2$ = square of the difference in gene frequencies for a particular locus

$H_{F2} = M_{F2} - M\bar{p}$

$= ½\, dy^2$

$= ½\, H_{F1}$

Thus heterosis is due to :

1. Dominance (d): complete dominance, partial dominance or over dominance. Loci without dominance (i.e. loci for which d =0) cause neither heterosis nor inbreeding depression
2. Difference in gene frequency between two loci or populations ($y^2$ )
3. Epistasis is also a cause for heterosis.

**Types of heterosis:**

1) **Parental heterosis**: Referring to the performance of animals as parents. It is of two types: a) **Paternal heterosis** b) **Maternal heterosis**

2) **Individual heterosis**: Referring to non – parental performance.

Heterosis is greatest for traits most closely associated with reproduction and viability. Traits that are highly heritable seem to be affected very little by heterosis, where as those that are lowly heritable are affected to a greater degree.

# OUTBREEDING SYSTEMS

The mating of unrelated individuals is called as outbreeding or genetic disassortative mating which is opposite or complementary to the inbreeding. Outbreeding is the mating of animals which are distinctly less closely related to each other than the average of the population i.e. the individuals that have no common ancestors in the proceeding 4 to 6 generations of their pedigree. The general effects of outbreeding are the opposite of those of inbreeding. Outbreeding increases the heterozygosity and variability of the population. The reasons for outbreeding are:

i) To utilize the advantages of hybrid vigour or heterosis.
ii) To introduce new genes in a closed population.
iii) To evolve a new breed
iv) To produce market/ commercial animals.

Outbreeding systems are broadly classified as:

1. Crossbreeding
2. Outcrossing
3. Topcrossing
4. Linecrossing → Incrossing : Mating between inbred lines within a breed
   ↘ Incrossbreeding : Mating between inbred lines of different breeds.
5. Strain crossing
6. Grading up
7. Species hybridization or species crossing

# Crossbreeding

The mating of animals from different established breeds is called crossbreeding. The progeny produced is called crossbred.

**Crossbreeding is done for the following purposes:**

1) To exploit hybrid vigour or heterosis and for commercial production of market animals. (Every time parental breeds have to be crossed for producing market animal).

2) **Complementarity** is the second reason for crossbreeding i.e. to combine good qualities of two or more breeds. This refers to the additional profitability obtained from crossing two populations resulting not from heterosis but from the manner in which two or more characters complement each other.

The distinct breeds have different good qualities. One breed may be superior for one or more traits than the other breeds(s), while other breed(s) may be superior for some other desired traits. For example, exotic breeds of cattle from European origin are better for high milk production but have low disease resistance whereas the zebu breeds of cattle are poor for milk production but have better disease resistance. The crossbreeding may combine these good qualities of the two breeds in a single population / new breed. This is known as the complementarity in crossbreeding.

Certain crosses show more complementarity than others, depending on the extent to which the populations differ in reproductive performance and in production traits. Generally to get greater complementarity from the most prolific population, dams are used as a source rather than of sires.

3) Crossbreeding has been used in recent years to establish a broad genetic base in the development of **new breeds or synthetics.** A single population that is a mixture of various populations is called **Synthetic** or **Composite**. Generally synthetics are formed by one or two crossings between two or more populations. This single population containing genes from each of the population involved. New breeds are formed from the synthetic population by selection.

**Types of crossbreeding:**

The crossing of different breeds can be practised in different ways depending upon the number of breeds used and the manner of their crossing. The major forms are the 1. **Regular crossing or Systematic crossing** and **2. Composite crossing.**

**1. Regular or Systematic crossing:**

This is mating of the same cross on regular basis to take advantages of the heterosis and complementarity. The crossing exploits non-genetic effects through heterosis and the additive effects through complementarity when two or more characters complement each other. The heterosis may be parental (maternal or parental) and the individual heterosis. There are two basic methods of regular crossing known as

A. **Specific crossing** and B. **Rotational crossing**

**A) Specific crossing**: this can be further grouped in to the following forms.

(i) Two breed crosses or single cross or two-way cross

(ii) Three breeds crosses or triple crossing or three- way cross

(iii) Four breed crosses or double two breed crosses or four-way cross

**(i) Two breed crossesor single cross or two-way cross:**

Two pure breeds are crossed together. This may be restricted with crossing of only the purebreds or may be extended to crossing the crossbreeds (*Interse* mating) or with males of pure breed (backcrossing or criss-crossing).

**a) Two pure breed crosses:**

**A x B**
↓
AB

Two different populations (inbred lines,strains or breeds) are crossed with each other to produce $F_1$ which is used only for production purpose and not for breeding. Themain aimis toexploitheterosis and to some extentcomplementarity.

**Demerits:**

1. Large number of the parental type (line/ strain/purebred) has to be maintained in order to continue the crossing.

2. In this type of crossing 100% individual heterosis can be obtained but no opportunity to benefit from maternal or paternal heterosis (because the parents are never themselves crossbred. They are straight bred /line).

**b. *Inter se* mating:**

This is the crossing of crossbred progeny having the same level of inheritance of two breeds like crossing of $F_1$ with $F_1$. This is done to create a number of genetic groups.

**c. Back crossing:**

**A x B**

↓

**AB ♀ x A♂ or B♂**

↓

**(AB)A**

or

**(AB)B**

Back crossing is the mating of crossbred $F_1$ animals (usually female) back to males of the parental populations / breeds. Here maternal heterosis (100%) from AB♀are exploited. But backcross progeny on an average 50% less heterozygous than 1st cross AB progeny. Therefore, the back cross progeny show on an average only 50% of individual heterosis. Both males and females of back cross progeny are sent to market.

Back crossing is also called as **Test Cross**. This method is commonly used in genetic studies. It is done to find out the $F_1$ is homozygous or heterozygous. The $F_1$ is mated again with homozygous recessive parent. If the $F_1$ is heterozygous the phenotypic ratio will be 1:1. If the $F_1$ is dominant homozygote the phenotypic ratio will be 1: 0.

**d. Criss-crossin**g:

It is similar to back crossing except that both the parental breeds (P1 and P2) are used alternately in each generation as shown below:

**A x B**

↓

**AB x A**

↓

**[(AB)A] x B**

↓

**[((AB)A)B] x A**

**(ii) Three breeds crosses or triple crossing or three- way cross:**

Three-way cross or triple cross

**A x B**

↓

**AB x C**

↓

**(AB)C**

In this system of cross breeding three breeds are used (A, B, C). First generation crossbred female (AB) are crossed with males of third breed/line. Thus utilizing the hybrid vigour of the dam; i.e. maternal heterosis (100%) in addition to individual heterosis (100%).

Here the $F_1$ females are generally retained for further breeding with 3rd breed in order to improve female reproductive ability (i.e. to utilize maternal heterosis). At the end of three breed cross both males and females are sold as commercial market animals.

**(iii) Four breed crosses or Double two breed crosses or Four-way cross:**

Four breeds are used. In this four-way cross, the crossbred progeny from two separate two-way crosses are mated to produce commercial progeny called 'double hybrids' (AB.CD).

| | | | |
|---|---|---|---|
| Grand Parents : (Lines) | **A x B** ↓ | | **C x D** ↓ |
| Parents : | **(AB)** | **x** ↓ | **(CD)** |
| Commercials: | | **(AB.CD)** (each line 25%) | |

In four-way cross both parental and maternal heterosis as well as individual heterosis are exploited. This method is used extensively in poultry breeding using different inbred lines.

**B) Rotational crossing:**

The males of two or three breeds are used in regular sequence (rotation) in successive generations on crossbred females of the previous generations. Thus it is called as rotational crossing which may involve two or three breeds. In pig breeding, this method have been used widely with different breeds for the production of market animals / hybrids.

**Types of rotational crossing:**

i. **Rotational criss-crossing:**

Breed A and B are crossed to produce an F1 generation, then AB females are backcrossed to males from breed A. The resulting female are back crossed to B male and so on to breeds A and B alternatively.

| Breed | Proportion of genes from | | |
|---|---|---|---|
| **A x B** | **A** | **B** | **Average Heterozygosity** |
| ↓ | | | |
| **AB x A** | **½** | **½** | **1** |
| ↓ | | | |
| **[(AB)A] x B** | **¾** | **¼** | **½** |
| ↓ | | | |
| **[((AB)A)B] x A** | 3/8(37.5) | 5/8(62.5) | **¾** |

If rotational criss-crossing has been applied for a number of generations, a situation of equilibrium is reached with respect to the proportion of the different breeds in the genetic constitution of the crossbreeds. At equilibrium 2/3$^{rd}$ of inheritance is from immediate sire and 1/3 is from other sire breed.

**Advantage:**

(i) The crossbred female can be retained for breeding and only purebred sire have to be purchased when compare to two-way cross (For males – Frozen semen can be used).

(ii) Both maternal and individual heterosis are exploited.

**Disadvantage:**

It does not allow any exploitation of complementarity (because the population involved in the crossing cannot be restricted in use to a single purpose)

**ii. Three-way rotational crossing:**

Three breeds are used in this system. Females of crosses are used on sire of pure breeds in rotation. Here the crossbred females are retained for breeding in order to utilize the maternal heterosis and crossbred males are sold. Advantage and disadvantages are similar to criss-crossing.

e.g.

**Three breed** **<u>Proportion of genes from</u>** **Average**

| | A | B | C | Heterozygosity |
|---|---|---|---|---|
| **A x B** | | | | |
| ↓ | | | | |
| **AB x C** | ½ | ½ | 0 | 1 |
| ↓ | | | | |
| **[(AB)C] x A** | ¼ | ¼ | ½ | 1 |
| ↓ | | | | |
| **[((AB)C)A] x B** | 5/8 | 1/8 | 2/8 | ¾ |
| | (62.5) | (12.5%) | (25%) | |

At equilibrium 57% of the genes (4/7) comes from the breed of the last used male, 29% (2/7) from the previous sire breed and 14% (1/7) from the 3rd sire breed which will be used for the next back crossing. Here heterosis is continuously maintained at 6/7 level. (85.7%).

**iii. Four-way rotational crossing:**

Four-way rotation can also be practised by using fourth breed D on females of the [(AB)C] crossbred. Thereafter from breeds A, B, C and D are used in succession for each new generation. In this system frozen semen of the sires (A,B,C, & D) can be used without maintaining purebred populations.

**Fraction of heterosis as indicated by average heterozygosity, expected in the most common types of regular crossing**

| Type of crossing | Fraction of heterosis | | |
|---|---|---|---|
| | **Individual** | **Maternal** | **Paternal** |
| **Straight bred** | 0 | 0 | 0 |
| Two breed cross | 1 | 0 | 0 |
| Back cross | | | |
| Cross breed female x pure male | ½ | 1 | 0 |
| Pure bred female x crossbred male | ½ | 0 | 1 |
| ***Three breed crosses*** | | | |
| Cross breed female x pure male | 1 | 1 | 0 |
| Pure bred female x crossbred male | 1 | 0 | 1 |
| **Type of crossing** | **Fraction of heterosis** | | |
| | **Individual** | **Maternal** | **Paternal** |
| Four breed cross | 1 | 1 | 1 |
| Rotational crossing | | | |
| Two sire breeds | 2/3 | 2/3 | 0 |
| Three sire breeds | 6/7 | 6/7 | 0 |

## 2. Composite crossing to produce synthetic/ Composite / New breed

This is alternate to regular crossing. It is done by producing one or few crosses between two or more populations to produce a single population having genes from each of the population. This single population of a mixture of various crossbred populations is called a synthetic or composite. This synthetic population is improved by selection within it. In the past, this crossing system with selection has resulted in the development of new breeds .e.g. Santa Gertrudis,.Jamaica Hope, Australian Milking Zebu (AMZ) which were developed by selection within a synthetic.

**Crossing for production of new breed**: The need for development of new breed arises only when we are not satisfied with the existing breeds as regards their production level. The great majority of our present day breeds of farm animals have been founded by crossing different breed types with each other in an attempt to combine their desirable traits in the new breeds e.g. Amrithmahal cattle was originally developed by crossing three distinct varieties viz. Hallikar, x Hagalvadi x Chitaldurga. The breed was developed to combine phenotypic characters like external appearance, body built, compactness and behavioural attributes.

Similarly synthetic populations of cattle to evolve new breeds have been produced by crossing of *Bostaurus* and *Bosindicus* with the objectives to combine the high production (milk) of*Bostaurus* breeds with heat tolerance and disease resistance of *Bosindicus* breeds. e.g. Sunandini, Karan Swiss, Karan Fries, Jersind, Jerthar and Frieswal.

**Procedure:** First choose the improver breed (1 or 2) and the native breed to be improved. One or few crosses are made between two or more selected populations / breeds in order to produce a single population of animals containing a mixture of genes from each breed and it is called **synthetic or composite**. After the formation of synthetic with desired exotic blood level follow selection and *inter se* mating within it for several generations to produce a new breed with expected characteristics.

Generally the superior performance found in $F_1$ over the average of parents is reduced in $F_2$ (50% reduction). To counteract the decline/ reduction and to stabilize the performance selection procedure is followed.

**Guidelines to be followed in crossing:**

(i) Ensure that the animals used in the original crossing have been intensively selected in terms of relevant characters. It is of no use stating a synthetic with inferior animals.

(ii) To maximise the variance in breeding values amongst the foundation animals (in the synthetic), use as many unrelated animals as possible from each of the contributing populations.

**Major obstacles in the development of new breeds**

1) Time and expense involved is high
2) Large number of animals should be raised to give a broad base of genetic variability for selection.
3) Difficulty in selling the new breed to farmers / producers even if ithad real merit.

## SYNTHETIC BREEDS OF DAIRY CATTLE

| India | Other Countries |
|---|---|
| 1. Taylor cattle of Patna | 1. Australian Milking Zebu |
| 2. Sunandhini | 2. Australian Friesian Sahiwal |
| 3. Karan Swiss | 3. Jamaica Hope |
| 4. Karan Fries | |
| 5. Frieswal | |
| 6. Jersind | |
| 7. Jerthar | |

**1. Taylor cattle of Patna:** It is a composite of Shorthorn and Jersey or Guernsey bulls (introduced in 1856 by Commissioner of Patna – Mr.Taylor) and local zebu cows of Patna. The breed is localized with an average milk yield of 5-6 liters / day. These animals are humpless and black, grey or red in colour.

**2. Sunandhini:** This synthetic breed was evolved by Indo-Swiss project located at Mattu Patti in Kerala. This breed is evolved by crossing Jersey and Brown Swiss (5/8) with non-descript local cattle. The stabilized crossbreds were recognized as a breed in 1977.

Age at first calving -30-38 months, Milk yield - 2000 Kg in 305 days.

**3. Karan Swiss:** This breed was developed at National Dairy Research Institute, Karnal in Haryana. This breed was evolved by crossing Brown Swiss with Sahiwal. Brown Swissinheritance varied between 50–75% and the rest from Sahiwal. The breed was established in 1977. Age at first calving : 30-32 months, Milk yield: 2500-3800 kg per lactation, Calving interval: 400 days.

**4. Karan Fries :**Developed at NDRI, Karnal. This new breed was evolved by crossing primarily HF bulls and Tharparkar cows. HF inheritance varied from 50 to 62.5% and the rest is Tharparkar. Age at first calving : 32-35 months, Milk yield :3500-4000 kg per lactation

**5. Frieswal:** Evolved at Project Directorate on Cattle, Meerut from HF and Sahiwal crosses produced in military dairy farms. It has 5/8 HF and 3/8 Sahiwal inheritance with milk yield around 3500Kg / Lactation.

**6. Jersind:** This breed was evolved by crossing Jersey x Red Sindhi at Allahabad.

**7. Jerthar :**This breed was evolved by crossing Jersey bulls x Tharparkar cows at Bangalore.

**8. Australian Milking Zebu:** Evolved by crossing Sahiwal (1/3) and Jersey (2/3) at New South Wales, Australia.

**9.Australian Friesian Sahiwal:** This breed was evolved by crossing Sahiwal (bulls) and

Friesian (cows) at Queensland, Australia.

**10.Jamaica Hope:** Native of the West Indies with 80 % of Jersey, 5 % of Friesian and 15 % of Sahiwal inheritance. The breed was developed in Hope Agricultural Station at Jamaica to improve milk production under their conditions. In conformation, the breed is similar to Jersey though they are large with no specific colour pattern. It varies from fawn, brown and grey to black.Average lactation milk yield: 2000 – 3200 kg with 4.8% fat. Age at first calving: 34 months; Calving interval: 440 days.

## NEW BREEDS OF SHEEP

1. Hissardale
2. Avivastra (Avi - sheep in Sanskrit)
3. Avikalin (Kalin - carpet in Persian)
4. Bharath Merino
5. Sandyno (Nilagiri synthetic)
6. Kashmir Merino
7. Avimans
8. Indian Karakul
9. Pattanwadi synthetic

**Hissardale** is a fine wool breed originated during early part of 20$^{th}$ century at Govt. Livestock Farm, Hissar through crossing Australian Merino rams with Bikaneri (Magra) ewes. The exotic inheritance is stabilized at 75%.

**Avivastra** is a synthetic Apparel wool strain evolved at Central Sheep and Wool Research Institute (CSWRI), Avikanagar in Rajasthan from a crossbred population of 5/8 to 3/4$^{th}$Rambouillet and 3/8 Chokla and ¼ Malpura.

**Avikalin** is a synthetic carpet wool strain evolved at Central Sheep and Wool Research Institute, Avikanagar in Rajasthan from a foundation population of Rambouillet (1/2 to 5/8) and Malpura (1/2 to 3/8) with exotic inheritance at 50% level.

**Bharath Merino** was evolved at CSWRI, Rajasthan from a crossbred foundation of Rambouillet or Soviet Merino and Chokla, Malpura or Nali with exotic inheritance 75%.

**Sandyno –** a fine wool breed was evolved in Sheep Breeding Research Station, Sandynallah, Ooty, Tamil Nadu from *interse* mated population of 5/8 Merino and 3/8 Nilagiri.

**Kashmir Merino –** This breed was evolved in Jammu and Kashmir state by crossing ¾ Tasmanian Merino and ¼ indigenous (Gaddi, Bhakarwal and Poonchi). It is a fine wool breed.

**Avimans –** mutton synthetic, developed at CSWRI, Rajasthan by crossing Malpura and Sonadi with Dorset and Suffolk with exotic inheritance at 50% level.

**Indian Karakul –** evolved by crossing Marwari, Malpura and Sonadi with Karakul at CSWRI, Rajasthan with exotic inheritance - 75%.

**Patanwadi synthetic –** evolved by crossing Patanwadi with Ramboulliet and Merino at GAU, Dantiwada with exotic inheritance – 50%

### Advantages of crossbreeding

1. Both maternal and individual heterosis are exploited
2. It helps to introduce desirable characters in to a breed in which they have not existed formerly.
3. It helps to evolve a new breed.
4. Crossbred animals usually exhibit an accelerated growth, vigour and fertility.
5. It can be used to produce commercial stock to meet market demand.
6. Once the first crossbred females are produced no need to maintain females of the pure breeds. Males of the different pure breeds can be purchased for breeding or frozen semen can be used.

**Disadvantage:**

1. The breeding merit of crossbred animals may be reduced because their genetic composition is heterozygous in nature.
2. Crossbreeding requires maintenance of two or more purebreds in order to produce crossbreds.
3. The crossbreds lacks in the performance of qualitative characters.

## Outcrossing

It is the mating of unrelated animals within a breed. It usually applies only to matings within a purebred but show no relationship for at least 4 to 6 of its previous generations. If two herds or flocks within the same breed are separated for 4 to 6 generations and the sire from one herd/ flock is used in another herd / flock that amounts to outcrossing. Outcrossing within a herd by use of selected sires is also called as **selective breeding**. This system of selection and outcrossing is very effective for characters governed by additive effect of genes having high heritability. The outcrossing is practised to exploit intra herd variability.

**Uses of outcrossing:**

1. It can be practised in a purebred herd/flock when there is lack of selection response due to decrease in genetic variability.
2. To reduce inbreeding in a closed population.
3. To introduce new genes with reference to colour, horn type etc.
4. Highly effective for characters (milk production) that are largely under the control of genes with additive effects.
5. It is the effective system for genetic improvement, if carefully combined with selection.

## Line crossing

Usually refers to crossing of inbred lines within a specific breed. The mating of sires of one line or in combination to dams of another line or line combination. Line crossing takes advantage of both increased homozygosity within a line and increased heterozygosity as the difference between lines. Line crossing is mating done to exploit heterosis.

**Incrossing :** is the mating between inbred lines within a breed.

**Incrossbreeding :** is the mating between inbred lines of different breeds.

e.g. Incrossing in Poultry: The commercial layer chickens are called hybrids e.g. Babcock, Bovans, Hyline developed from White Leghorn breed.

| | | | | |
|---|---|---|---|---|
| **Pure lines** (RRS/RS are followed for maintaining and to make further improvement in pure lines) | A x A → A | B x B → B | C x C → C | D x D → D |
| GP **Crossing Grand/Great grand Parents** (pureline) [Based on Diallele crossing and Combining abilities (GCA & SCA) different lines are selected for crossing] | A x B ↓ | | C x D ↓ | |
| **Hatchery Level** | AB | x | CD | |
| | | ↓ | | |
| **Commercial chicks** | | Hybrid ABCD | | |

## Strain crossing

It is the mating between strains within the same breed. This method mainly aims at producing commercial animals by crosses between strains. e.g. Crossing of different White Leghorn Strains.

WLH strains A (England) x WLH strain B (Australia)

↓

WLH strain crossbred AB

Diallele crossing is also done using different strains to evaluate their genotype for better utilization of heterosis.

## Top crossing

Top crossing is a term used for mating of a inbred males of a certain family to females of another family or non-inbred population of the same breed. Top cross usually refers to the best sire in a pedigree. A top cross is made when a breeder goes back to the original genetic source of the breed or strain for some new genetic material for further genetic improvement of the breed / strain.

e.g.1. Angus breeders from America return to Perth (Scottland) to buy a stud sire to top cross their Angus breed.

2. Indian Jersey is top crossed with newly imported Jersey.

## Grading or Grading-up

(Breed substitution or breed replacement)

Grading is the continuous use of sires of one pure breed starting with foundation females which are of non-descript animals or another breed or no particular breed at all (called Mongrel or Scrup animals). Mongrel is a crossbred that is unacceptable or unplanned.

Grading-up is backcrossing to the same breed takes place generation after generation. The object is to change the genetic makeup of a mixed population to a 'pure bred' with each new generation, the proportion of genes from the original mixed population decreases to half the proportion present in the previous generation, so that after 4 generations, it has decreased to 6.25 and after 5$^{th}$ generations to 3.125 per cent.

Example: Grading-up

| Generation | Female | x | Registered Sire (Pure Breed) | Average proportion / % of genes | |
|---|---|---|---|---|---|
| | | | | Local | Pure Breed |
| $F_1$ | ND Female | x | Male (not the same animal) | 50 (½) | 50 (½) |
| $F_2$ | $F_1$ Female | x | ” | 25 (¼) | 75 (¾) |
| $F_3$ | $F_2$ Female | x | ” | 12.5 (1/8) | 87.5 (7/8) |
| $F_4$ | $F_3$ Female | x | ” | 6.25 (1/16) | 93.75 (15/16) |
| $F_5$ | $F_4$ Female | x | ” | 3.125 (1/32) | 96.875 (31/32) |
| $F_6$ | $F_5$ Female | x | ” | 1.563 (1/64) | 98.437 (61/64) |

Grading is done to raise quickly the performance level of mongrel or non-descript to the level of the purebred.

Five generations are sufficient to raise the level of pure bred as 96.9% in the mongrel.

After five generation of repeated back crossing to a particular breed the animals with 96.9 per cent pure and become eligible to be registered as purebred. In India, grading is normally done in buffaloes to change non-descript animals to Murrah breed.

**Breed substitution:**

It is also a type of grading up programme i.e. establishing a ‘pure bred-herds’ of a migrant breed as quickly as possible by means of a grading–up procedure.

e.g. grading-up of local cattle with migrant breed namely Jersey cattle.

| Generation in local animals | Mating programme | Proportion of migrant blood |
|---|---|---|
| 0 | Local x Jersey | -- |
| 1 | (LJ) x J | 50% J |
| 2 | [(LJ)J] x J | 75% J |
| 3 | [((LJ)J)J] x J | 87.5 % J |
| 4 | [(((LJ)J)J)J] x J | 93.75 % J |
| 5 | [((((LJ)J)J)J)J] x J | 96.875 % J |

After 5 generation of the repeated back crossing the migrant breed Jersey blood level in our local cattle will be 96.9% i.e. the local animal is almost replaced by Jersey breed in that area. In the programme frozen semen straws of Jersey breed can be used and need not maintain Jersey bulls.

**Advantages of Grading-up:**

1. It is followed to increase the number of purebred population, if they are relatively scare or new to that area.
2. To introduce a new gene or desirable quantitative traits in a population e.g. to create a polled strain of a horned breed. If we have only one mutant animal that is heterozygous for the dominant polled gene P~

P = polled gene dominant.

PP }<br>Pp } polled animals<br>pp horned animal

Mating programme to create polled strain with animals of horned breed by grading –up programme

Polled x horned<br>Pp ↓ pp<br>Select polled offspring (Pp) x Horned (pp)<br>↓<br>Select polled offspring (PP) x Horned (pp)

To ensure that polled strain has as much genetic variation, 3-4 crosses are carried out. Finally the polled animals are test crossed to find out homozygous (PP) individuals. The breeding programme to be followed in introducing the polled gene to a horned breed is called **'Introgression'**.

3. Grading-up can be practised in all species for genetic improvement.
4. For grading-up programme minimum number of bulls / sire is sufficient or even frozen semen straws are enough.
5. It is not so expensive. It is the most economical way of lifting the commercial stock rapidly towards the level of the purebreds.

**Disadvantages:**

1. This process requires 4-5 generations/ several years i.e. In cattle 5x4= 20 years are required to achieve the goal.

2. The first cross usually shows marked improvement in productivity over the original female stock. But the magnitude of further improvement becomes progressively less as the process of grading up advances.
3. Due to increase in the level of exotic inheritance, the progeny will be less resistant to diseases and poor in adaptation to local environment etc. and sometimes genotype x environment interaction puts a limit to use this system.

Therefore, grading can be practised after fixing the target for level of exotic inheritance based on the level of performance. In dairy cattle the level of Jersey / H.F. inheritance should not exceeds 50 – 62.5%. Continuous backcrossing in the grading-up programme is both unnecessary and undesirable.

## Species Hybridisation

Defined as the mating of individuals which belong to two different species. It is the widest possible kind of outbreeding.

e.g. **1) Mule/ Hinny:**

Horse (*Equuscaballus*) Ass (*Equusasinus*)

a. Mare (64) x Jack ass (62)

↓

**Mule**

b. Stallion (64) x She ass (Jennet)

↓

**Hinny**

The mule combines some of the superior qualities of both species. It has size, strength and sprit of the horse, along with the sure footedness, lack of excitability, endurance and ability to thrive on poor feed which are characteristics of the ass.

Usually chromosome number differ with species. In crosses between species the sperm may fertilize the egg but generally embryo survival is low. If it survives to sexual maturity then it is usually sterile.

Horse has 32 pairs and ass has 31 pairs of chromosomes and the mule comes to posses 63 single chromosome. Male mules are always sterile but female mules (mare mule) are occasionally fertile.

Female Mule (Mare Mule) (63ch) 32+31

32 (Horse Type) | 31 If egg is polar body

(The mare mule (63 nos.) has given birth to mule foals and horse foals when bred to Jack ass and Stallion respectively. The possibility is that the female mule with 63 chromosomes occasionally produce an egg containing nothing but hoses type i.e. 32 single chromosome egg and all ass chromosomes were extruded in the polar body. Therefore, the mare mule function as mare as far as the egg is concerned. Similarly if all horse chromosomes were extruded in the polar body, the mare mule function as ass egg (31 chromosomes). True breeding of mules are theoretically impossible).

**Haldane's rule:**

In the $F_1$offsprings of a cross between two species, one sex is absent, rare or sterile and the sex is always the heterogametic sex (males). Therefore, the male mule/ hinny is always sterile. Generally hinny is inferior to mule as a work animal.

**2) Cattalo:**

European cattle x American bison
(*Bostaurus*) cow (60) bull (60) (also reciprocal cross)

↓

$F_1$ Males are sterile
Females are fertile x European cattle Bull

↓ (Back cross)

$F_2$ $F_2$ Female x American bison

↓ (Back cross)

**Cattalo**

Cattalo is the term applied to various combinations of domestic cattle (*Bostaurus*) and American bison.

Crosses between European cattle (cow) and the American bison have been made. It is referred as a generic cross. The males are sterile but many females are fertile. By backcrossing these $F_1$ females to cattle and to bison (males) attempts to form a new breed the 'cattalo' have been made but commercial success was not achieved.

Cattalo is useful in production of meat, and is well adapted to cold / tropical conditions.

**3. Pienniu**: is produced by crossing cattle and yak in Tibet.

| | | |
|---|---|---|
| Cattle (male) | x | Yak (female) |
| 60(*Bostaurus/indicus*) | ↓ | (60) (*Bosgranniens*) |
| | Pienniu | |

$F_1$ and 1st back cross males are sterile and female hybrids are fertile.

**4.Zebroid:**

| | | |
|---|---|---|
| Zebra (32) Male | x | Horse (64) |
| (*Equus zebra*) | ↓ | (*Equuscaballus*) |
| | Zebroid | |

Zebroid i.e. Zebra x Horse hybrid is fairly popular in the tropics because of its docility and its resistance to diseases and the effect of heat. Zebroid males are sterile and females are occasionally fertile.

**5. Other species hybrids:**

Cattle x buffalo → Beefalo

Goat x Sheep → Geep

Lion x Tiger → Liger

Ass x Zebra → Asbra

Mithun x Cow → Jatsa ($F_1$ male)

→ Jatsamin ($F_1$ female)

Mithun x Siri cow → Jechha ($F_1$ male)

→ Jessam ($F_1$ female)

Crosses between sheep and goats may to develop but the embryos die and are resorbed or aborted long before the normal gestation period is completed.

# NUCLEUS BREEDING SYSTEMS (NBS)

The genetic improvement in productivity per animal in the shortest possible time with nominal cost is the main aim of the animal breeder. The conventional breeding programmes viz., selection and mating systems have made significant contribution in the genetic improvement of livestock in the developed countries by large scale field progeny testing schemes but the rate of genetic improvement had been low in developing countries like India.

The main reasons are

(i) Non availability of sires with high genetic merit in required numbers

(ii) Poor spread of AI due to lack of infrastructure

(iii) Small size of farmers' herd, high cost of data recording in the field condition

(iv) Small population size and less intensity of selection for female in organised herds.

In India typical breed structure consist of

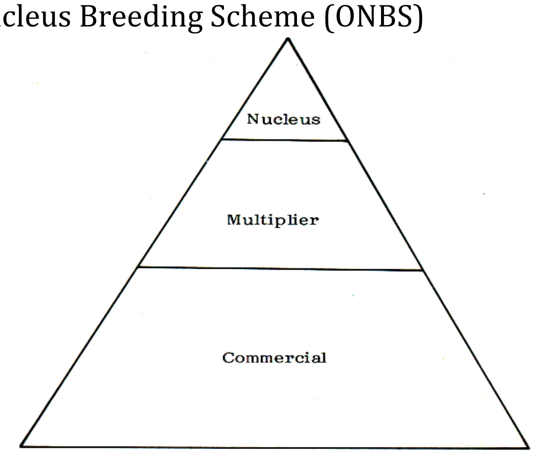
(i) Organized herds – i.e. animals kept at organized/ institutional farms.

(ii) Commercial herds/flocks – i.e. animals reared by farmers also called as village herds/flocks which are very small to the extend of 1-2 animals per farmer but collectively village herds constitute more population.

To increase the overall genetic merit of the breed and to overcome the above constraints a new concept named as Nucleus Breeding System / Scheme (NBS) was introduced. Depending upon the direction of gene flow the NBS are of two types

(i) Closed Nucleus Breeding Scheme (CNBS)

(ii) Open Nucleus Breeding Scheme (ONBS)




A typical breed structure consisting of three tires in the shape of a pyramid. The area of the pyramid devoted to each tier reflects the relative numbers of animals in each tier.

Under the NBS, the breed structure consists of three tiers in the shape of pyramid. They are nucleus, multiplier and commercial. Some time there are only two tiers – nucleus and commercial. The area of the tires reflects the relative number of animals in the breed. The nucleus tier consists of elite males and females. The nucleus herd, breeds on its own male and female for replacement stocks and occasionally introduce a sire or dam from another nucleus herd. The main objective of nucleus herd is to maximize the genetic gain and to produce and supply superior males to the multiplier/commercial farmers for breeding. The multiplier takes the males and sometimes the females from the nucleus herd to produce sufficient breeding stock to meet the demand of commercial/farmers herds. Thus the genetic gain achieved in nucleus herd is passed on from nucleus herd to multiplier and then to commercial herds.

**(i) Closed Nucleus Breeding Scheme (CNBS)**

In CNBS there is one way gene flow with direction from top to down herds i.e. from Nucleus → Multiplier → Commercial / farmers herds. Because no genes flow into the nucleus tier from other two tiers the scheme is called CNBS.

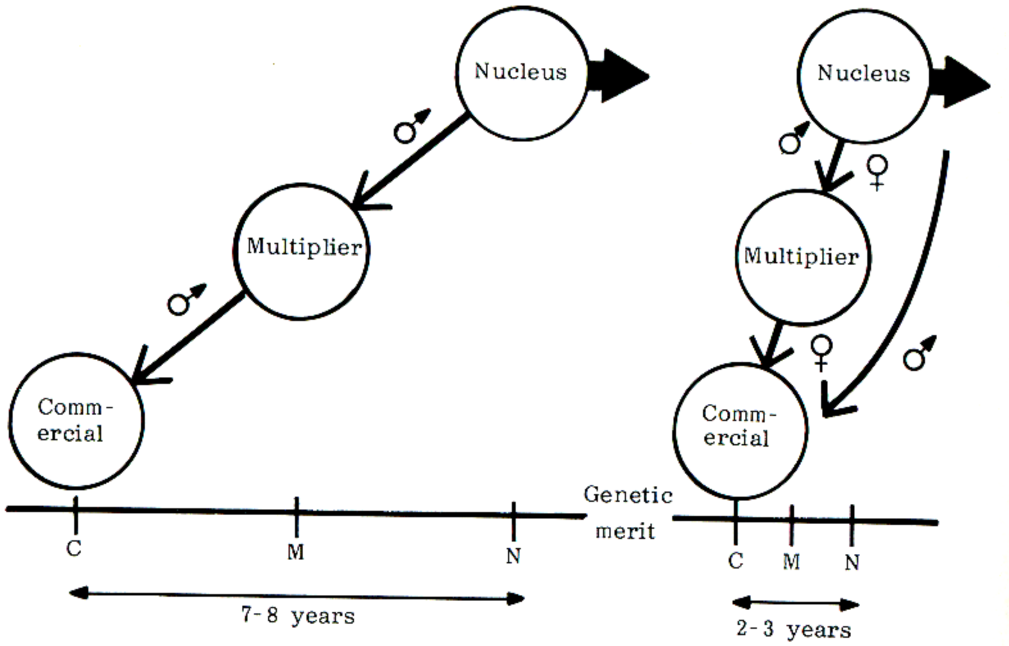
In the scheme the genetic improvement made only in nucleus herd and passed on to Multiplier and then to the Commercial. Generally CNBS takes time for transfer of genetic progress from one tier to the next. The resultant difference in performance between any two adjacent tires is called **improvement lag** which is usually expressed in terms of the number of years of genetic improvement which represent the difference in performance between adjacent tiers.

The improvement lag can be reduced by

(i) Transferring of males and females of nucleus tiers directly to the commercial tier.

(ii) Keeping males and females in the lower tiers for shorter periods of time. (Breeding stock to be replaced at short intervals).

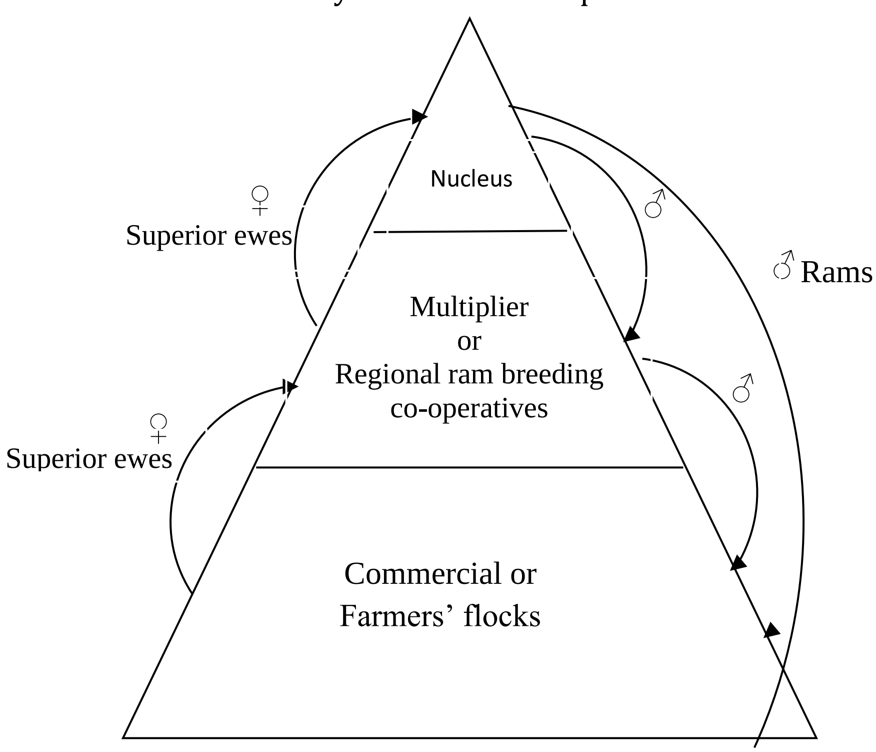
The CNBS is mainly practised in modern pig and poultry breeding programme to avoid the risk of introducing diseases in the nucleus herd/flock.




**(ii) Open Nucleus Breeding Scheme (ONBS)**

This is often called group breeding scheme or cooperative breeding schemes. In this scheme the gene flow is both ways i.e. downward from Nucleus to other lower tiers/flocks and upward from multiplier/commercial to nucleus tier / flocks.

The rams born in the nucleus flock are evaluated and the best are chosen and supplied to the village flocks for breeding. Similarly, superior females from commercial flock are selected and introduced into nucleus flock. This reduces the rate of inbreeding in the nucleus flock and increases the genetic progress because the superior animals are also available with farmers. This scheme is mostly followed in sheep and also in cattle.



**How to run ONBS:**

The ONBS can be operated as an organized flock which preferably an Institutional (Govt) farm or by establishing breed societies or by a group of breeders. It should carry out proper recording and breeding practices in the nucleus flock. The supporting base population (commercial) is from the village flocks of cooperating breeders / farmers. Here, cooperation from the farmers is highly essential in running of ONBS for getting superior breeding rams from the nucleus flock. In ONBS, every year lowest yielding 10% of the ewes in the nucleus are replaced by purchase of the best ewes from village flock. In turn farmers will be supplied with superior rams. Hence, the scheme is called as **cooperative breeding scheme.**

The NBS can also run with using MOET (Multiple Ovulation and Embryo Transfer Technology) in cattle. If MOET is used in NBS it is called MOET Nucleus Scheme. [In MOET more than one progeny (average of 8 progeny) from superior donor cows/ year can be obtained. i.e. 4 embryos/ flush and 4 flush /year and with 50% ET success rate]

**Advantages of ONBS over CNBS:**

1) ONBS is two- way flow of genes and hence genetic improvement is faster.
2) Improvement lag is substantially reduced.
3) Annual response to selection is increased by 10 to 15%.
4) Rate of inbreeding in the nucleus tier is substantially reduced when compared to ONBS.

**Disadvantages (practical difficulties in ONBS)**

1) Continuous cooperation is required between the cooperating breeders to run the ONBS.
2) Opening the nucleus population to regular importation from other herds/ flocks belongs to cooperating breeders result in high risk of introducing diseases to the nucleus herd/flock.

## CURRENT BREEDING PROGRAMME IN THE STATE AND THE COUNTRY

India possesses vast and varied forms of Animal Genetic Resources and are widely spread in diverse agro-ecological regions of our country. The mega biodiversity of farm animal breeds of our country comprises of 43 well-defined breeds of cattle, 16 well-defined breeds of buffaloes, 43 well-defined breeds of sheep, 34 well-defined breeds of goats, 09 breeds of camels, 07 breeds of horse, 19 breeds of poultry, 08 breeds of pigs, 02 breeds of donkeys, 01 breed of ducks and 01 breeds of Geese.

Among different breeds of cattle only few of these are of dairy type (Red Sindhi, Sahiwal, Gir and Rathi). A large majority of the breeds are of the draught type (Kangayam, Umblachery, Bargur, Alambadi, Pulikulam, Amritmahal, Hallikar, Khillari, Malvi, Nagori, Bachaur, Dangi, Kenkatha, Kherigarh, Nimari) and few breeds are in-between called dual-purpose (Hariana, Kankrej, Ongole, Tharparkar, Deoni, Gaolao, Krishna Valley, Mewati). In addition, non-descript and crossbred cattle and buffaloes are also found which far exceeds the well defined breeds population.

On the basis of experimental results and constrains of earlier polices and by considering the demand for milk, requirement of draught power, farming systems, production environments, availability of inputs as well as marketing channels following National Cattle Breeding Policy was evolved.

### Cattle and Buffalo Breeding Policy – India

The current breeding policy recommended by National Commission on Agriculture and adopted by Central and State Governments are:

**1. Selective breeding**: In case of well-defined indigenous breeds of dairy, draught and dual cattle in their respective breeding tract for improvement of milk, draught capacity and both through associated herd progeny testing programme. By selective breeding it is expected that genetic improvement will be 1 to 1.5 % per annum in organised herds and 10 to 20 % per annum in farmers' herds.

**2. Grading-up for improvement of low producing non-descript cattle:**

The low producing local non-descript cows at drought prone areas, where feed and fodder resources are not available in sufficient quantity can be genetically improved by grading-up with bulls belongs to superior indigenous breeds like Sahiwal, Tharparkar, Red

Sindhi, Gir, Deoni, Hariana, Kankrej etc. available in that breeding tract. The bulls to be used for this purpose should be from superior dam which have more than 2000kg as lactation milk yield.

**3. Crossbreeding for improvement of low producing non-descript cattle:**

In milk shed areas around cities and industrial town where good market for milk is available and good resources of feed and fodder and water supply are exist crossbreeding of low producing non-descript zebu cows with exotic breeds like Holstein Friesian and Jersey can be undertaken.

The choice of the exotic breed as

| | |
|---|---|
| Holstein Friesian | : for the irrigated plains and hilly terrain |
| Jersey | : for coastal and other areas |

The optimum level of exotic inheritance should be 50%.

**4. For breeding crossbred cattle:**

*Inter-se* mating with crossbred pedigreed / proven bulls (exotic inheritance 50 %) is recommended.

5. **For improving buffaloes:**

India possesses most important breeds of buffaloes and has about 58 per cent of the total world buffalo population. The breeding policy recommended for buffaloes are:

**Selectivebreeding** for recognised breeds in their respective breeding tract. For improving non-descript buffaloes **grading-up** with recognised breeds viz., Murrah, Surti is recommended.

In Addition to breeding policy the committee also recommended the following for breed improvement and preservation.

1. Conservation of indigenous breeds and their germplasm.
2. Crossbreeding with exotic breeds should be totally banned in the home tract of the important cattle breeds.
3. Import of germplasm should be allowed only in very specific cases and after taking all the precautions to prevent the ingress of diseases into the country.

## Breeding policy -Tamil Nadu

The native cattle breeds of Tamil Nadu are Kangayam, Umblacherry, Burgur, Puliklam and Alambadi/ Hallikar and all are draught breeds. In addition, non-descript draught cattle are also found in sizable number which exceeds the total population of well-recognised breeds. In case of buffaloes, **Toda** is the only recognised breed confined to the Nilgiris.

The government of Tamil Nadu has clearly stated the breeding policy as early as 1982 (G.O. MS.No.713, Agriculture dt 20.3.1982) and the salient points are:

1. Selective breeding of Kangayam, Umblacherry and Hallikar in their respective breeding tract.
2. Crossbreeding / Grading-up of non-descript cattle with exotic dairy cattle breeds. Choice of the exotic sire breeds are Jersey or Holstein Friesian.
3. Use of Holstein Friesian(HF) in the Nilgiris, Kodaikanal and Kanyakumari district and in the rest of the state Jersey is recommended. (Introduction of HF in the plains has to be discouraged as the crosses have problems of adaptation, low fat and SNF content and needs for more green fodder and concentrate feed).
4. The level of exotic inheritance is restricted to 50% in order to maintain the disease resistance capacity in crossbreds (if the level of exotic inheritance is 75% or more there are higher calf mortatility, susceptible to many diseases, increasing of age at first calving and calving interval etc.)
5. In respect of breeding of crossbred cows crossing with 50% crossbred (Jersey or Holstein Friesian cross) pedigreed/ proven bulls is recommended to stabilize the exotic inheritance around 50%.

**Buffaloes:** In Tamil Nadu non-descript buffaloes constitute the majority of buffalo population. Therefore, in respect of buffaloes, **upgrading** of local buffaloes with Murrah or Surti have been recommended as improver breed and continuation of **selective breeding** in case of pure Murrah is recommended.

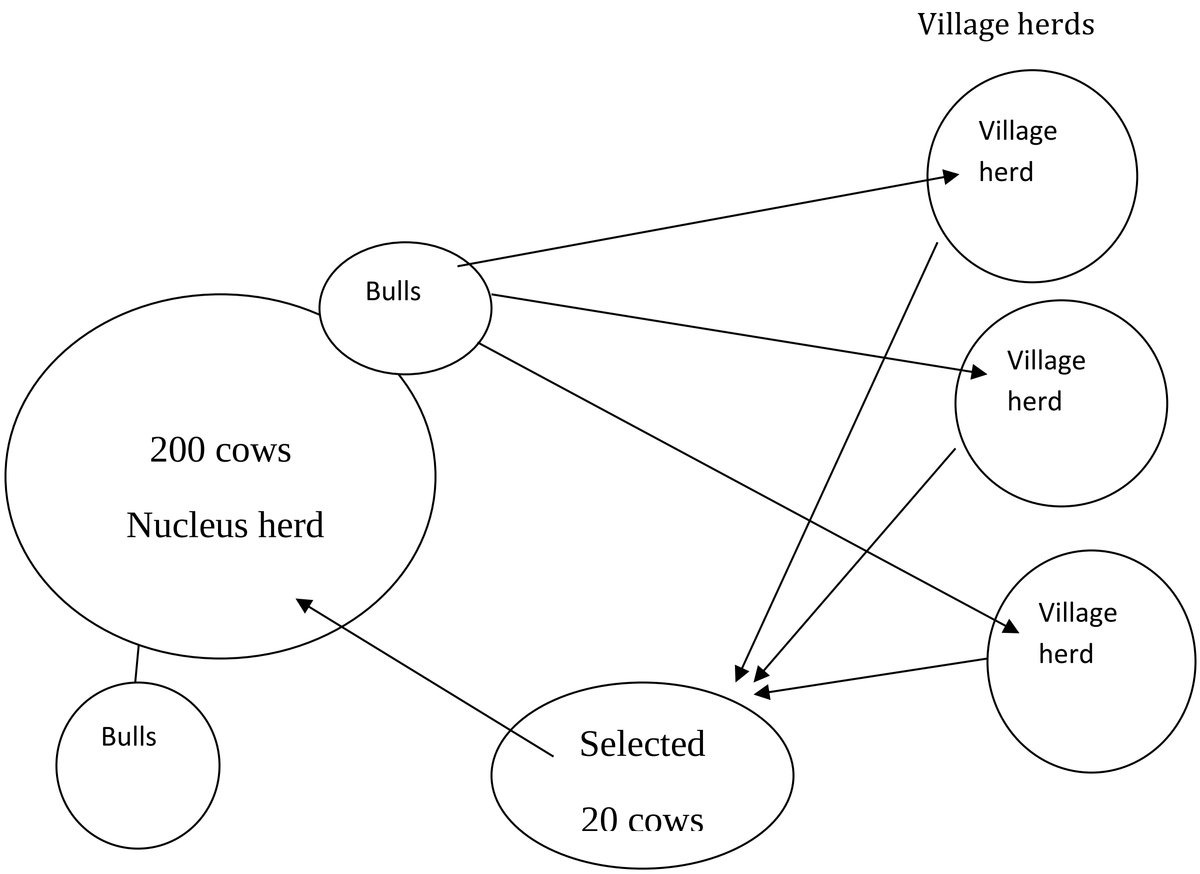
In addition to the above the following have been recommended for further genetic improvement of cattle,

1. Production and use of genetically superior crossbred bulls for Artificial Insemination to improve milk production in the crossbred cows.

2. Initiation and strengthening of milk recording and progeny testing programme in the crossbred population under field condition.

3. In case of draught breeds of cattle – formation of Breeders' Societies, selective breeding and conservation measures to be taken

## ONBS for cattle



## Crossing for the production of new breed/ synthetic or composite breed

The need for development of new breed arise only when we are not satisfied with the existing breeds as regards their production level. The grant majority of our present day breeders of farm animals have been founded by crossing different breed types with each other in an attempt to combine their desirable traits in the new breeds e.g.

Amrithmahal = Hallikar + Hagalvadi + Chitaldurga

To produce new breeds of cattle generally *Bostaurus* breeds are crossed with *Bosindicus* breeds are crossed with *Bosindicus.* The aim is to combine the improved production capacity (milk) of *B.taurus* breeds with heat tolerance and diseases resistance capacity of *Bosindicus* breeds.

Procedure: first choose the improver breed (1 or 2) and the native breed to be improved. One or few crosses are made between two or more selected populations/breeds in order to produce a single population of animals containing a mixture of genes from each breed and it is called Synthetic or composite. After the formation of synthetic with desired exotic blood level follow selection and inter se mating with in it, for several generation to produce a New breed with expected characteristics.

Generally the superior performance found in $F_1$ over the average of parents is reduced in $F_2$ (50% reduction). To counteract the decline/ reduction and to stabilize the performance selection procedure is followed.

**Guidelines to be followed in crossing:**

(iii) Ensure that the animals used in the original crossing have been intensively selected in terms of relevant characters. It is of no use stating a synthetic with inferior animals.

(iv) To maximise the variance in breeding values amongst the foundation animals (in the synthetic), use as many unrelated animals as possible from each of the contributing populations.

**Major obstacles in the development of new breeds**

4) Time and expense involved is high
5) Large number of animals should be raised to give a broad base of genetic variability for selection.
6) Difficulty in selecting the new breed to producers even if ithad real merit.

## CLASSIFICATION OF DOMESTIC ANIMALS

All living things are arranged in a hierarchy of categories such as Kingdom, Phylum, Class, Order, Family, Genus and Species. The kingdom is the highest taxonomic category. Kingdoms are divided in to phyla (singular: phylum). Phyla are divided into classes, and they, in turn into orders, families, genera (singular: genus), and species. The species is the lowest basic unit in taxonomy. The scientific / zoological name of an organism consists of two words viz. generic name (first word) and the species name (second word) e.g. *Bos indicus.* This is the binomial system of nomenclature proposed by **Carolus Linnaeus** (1707–1778) a Swedish Botanist who is referred to as the **father of taxonomy**.

The animal kingdom is detailed into 10 phyla. The domestic animals are coming under the phylum *chordata* and in its sub phylum *vertebrata*. The sub phylum vertebrate has two super classes: *Agnata* and *Gnathostomata* (animals with jaws and lateral appendages). The super class *Gnathostomata* has 6 classes and all farm animals are kept under the class *mammalia* and poultry are kept under the class *Aves.*

The morphological and physiological characters formed the basis of dividing the animal kingdom into species and breeds within a species. Each species of farm animals contains a number of breeds.

**Species:** Species is a basic unit in taxonomy. It is a group of animals, which are similar in morphological characteristics, reproductively isolated and genetically distinct from other group of individuals.

**Breed:** A breed is a collection of individual within a species, which have a common origin and share a certain number of morphological and physiological characters as long as they breed among themselves. According to L. Kaufman an animal breed is a relatively large group of individuals within a species, which have a common origin and can be distinguished by a narrow variation scale of specific characteristics, which are passed on to offspring within the limit of the same fluctuations. A breed is a genetic entity developed over a long period of time as a result of planned mating and selection. The mating of animals within a breed maintains the purity of breed.

**Varieties:** If a particular breed is distributed over a large area and selection proceeds in different direction in individual regions, considerable differentiation can occur within the breed. Such a group of animal, which has certain common characteristics that differentiate it from other groups within the same breed, is called a **variety or regional type**.

## Zoological classification of Farm Animals

**Kingdom: Animalia** **Phylum: Chordata** **Class: Mammalia**

| **Order** | *Artiodactyla* (Even-toed hoofed mammals) | | | | | | | | *Perissodactyla* (Odd-toed hoofed mammals) |
|---|---|---|---|---|---|---|---|---|---|
| **Family** | *Bovidae* (Hollow horned) | | | | | | *Suidae* (Non-ruminants) | *Camelidae* (Ruminants) | *Equidae* |
| **Genus** | *Bos* | *Bubalus* | *Ovis* | *Capra* | *Bibos* | *Bison* | *Sus* | *Camelus* | *Equus* |
| **Species** | *B.indicus* (Zebu cattle) *B.taurus* (European Cattle) | *B.bubalis* (Buffalo) | *O.aries* (Sheep) | *C.hircus* (Goat) | *B.frontalis* (Mithun) | *B.granniens* (Yak) *B.bison* (American bison) | *S.domesticus* *S.scrofa* (Pig) | *C.bactrianus* (Asian two humped) *C.dromedarius* (Arabian one humped camel) | *E.caballus* (Horse) *E.asinus* (Ass) |
| **chromosome No. (2n)** | 60 | 50 | 54 | 60 | 58 | 60 | 38 | 74 | Horse: 64 Ass: 62 |

## Zoological classification of the class Aves (Birds)

**Kingdom: Animalia** **Phylum: Chordata** **Class: Aves**

| **Order** | *Galliformes* (Chicken like birds with strong beaks and heavy feet) | | | | | | *Anseriformes* (Broad bills with filtering ridge or teeth) | | | *Columbiformes* |
|---|---|---|---|---|---|---|---|---|---|---|
| **Family** | *Phasianidae* | | | | *Meleagrididae* | *Numididae* | *Anatidae* | | | *Columbidae* |
| **Genus** | *Gallus* | *Coturnix* | *Phasianus* | *Pavo* | *Meleagris* | *Numida* | *Anser* | *Cairina* | *Anas* | *Columba* |
| **Species** | *G.gallus* (Chicken) | *C.coturnix* (Japanese quail) | *P.colchicus* (Ring-necked Pheasant) | *P.cristatus* (Pea fowl) | *M.gallopavo* (Turkey) | *N.meleagris* (Guinea fowl) | *A.anser* (Goose) | *C.moschata* (Muscovy duck) | *A.platyr-hynchos* (Duck) | *C.livia* (Pigeon) |
| **Chromo-some (2n)** | 78 | 78 | 82 | 80 | 82 | 78 | 80 | 80 | 80 | 80 |

# CLASSIFICATION OF CATTLE BREEDS

India has 30 indigenous breeds of cattle in addition to the vast cattle population, which comes under the non-descript category. Many of these breeds have been named after their place of origin. Some of the breeds are completely different from each other in respect of morphological characteristics, whereas the others have some common characteristics. Many researchers tried to classify the breeds into different groups according to their place of origin, type and physical characteristics especially horn shape and size, and coat colour and based on utility. The major types identified are humpless (*Bos taurus*), humped (*Bos indicus*) and crossbreds between these two.

### Classification Based on Physical Characteristics

According to FAO Manual "Zebu cattle of India and Pakistan" prepared by Joshi and Phillips (1953) the cattle breeds are grouped into six categories.

| Group | Name of the Breeds |
|---|---|
| I*. Lyre-horned grey* with wide forehead, prominent orbital arches, and thin, flat or dished face | Kankrej, Tharparkar, Malvi, Kenkatha, Kherigarh |
| II. Short-horned, white or grey with coffin- shaped skull | Hariana, Ongole, Rathi, Nagori, Bachaur, Mewati, Krishna Valley, Gaolao |
| III. Lateral-horned, red, red and white or black and white with heavy built body | Sahiwal, Red Sindhi, Gir, Nimari, Deoni, Dangi |
| IV. '**Mysore**' breeds; grey, long backward pointing horns | Kangayam, Bargur, Alambadi, Amritmahal, Hallikar, Khillari, |
| V. Small hill cattle (Dwarf breeds) | Lohani, Ponwar, Siri, Terai |
| VI. Cattle of Sri Lanka | Sinhala, Tamakaduwa |

### Classification Based on Utility

Based on utility the cattle breeds are broadly classified into three categories

i. **Dairy breeds**: Cows of these breeds are high milk producers, but bullocks are of poor draught quality.

ii. **Draught breeds:** The majority of the indigenous breeds belong to this group. Cows produce little amount of milk but are reared only to produce bullocks. Bullocks are powerful and good draught animals.

iii. **Dual-purpose breeds:** Cows of this group are fairly good milkers and bullocks provide good draught power.

| Dairy breeds | Draught breeds | Dual-purpose breeds |
|---|---|---|
| Sahiwal,<br>Red Sindhi,<br>Gir,<br>Rathi | Kangayam, Umblachery, Bargur,<br>Alambadi, Pulikulam, Amritmahal,<br>Hallikar, Khillari, Malvi, Nagori,<br>Bachaur, Dangi, Kenkatha, Kherigarh,<br>Nimari,<br>Red Kandhari, Ponwar, Siri<br>**Dwarf breeds:** Punganur, Vechur | Hariana, Kankrej, Ongole,<br>Tharparkar, Deoni, Gaolao,<br>Krishna Valley, Mewati |

**New breeds/ Crossbred strains developed are:** Sunandini, Frieswal, Karan Fries, Karan Swiss.

**General Characteristics of Zebu Cattle:**

* Zebu cattle belongs to *Bos indicus* group.

* Presence of hump - situated over the withers (Thoracic humped).

* Have narrow body, longer legs, and well-developed dewlap than the *Bos taurus* which have deep body, short legs and a small dewlap.

* Skin is generally much looser than that of *Bos taurus*

* Adapted to harsh agro-climatic conditions, utilize poor quality feed.

* Has resistance to tropical diseases

* Bullocks provide excellent draught power for agricultural operations

* Chromosome morphology: The Y –chromosome is acrocentric *Bos indicus* and it is sub-metacentric in *Bos taurus*

**Description for the most important /well known breeds:**

**i. Dairy Breeds**

**SAHIWAL (LOLA, MONTGOMERY, TELI, MULTANI, LAMBI BAR)**

**Habitat:** Montgomery district in Pakistan. Ferozepur and Amritsar districts in Punjab.

**Physical and functional characteristics:**

1. Various shades of reddish dun, fawn and roan with or without white markings.
2. Heavy breed with symmetrical body.
3. Known as "Lola" owing to the loose skin.
4. Horns are short and stumpy. Muzzle – light coloured.
5. Tail is long with black switch almost touching the ground.
6. Male: Massive hump, dewlap is voluminous sheath pendulous.
7. Best Indian dairy breed Average 305 milk yield - 2270 kg with fat percent - 4.9.
8. Age at first calving – 40 months.

**RED SINDHI (SINDHI, RED KARACHI)**

***Habitat:*** Sind Province in Pakistan especially Karachi and Hyderabad.

**Physical and functional characteristics:**

1. Medium size and in shape they are compact and symmetrical.
2. Colour: Distinct red, varying from dim yellow to dark red. Muzzle dark coloured.
3. Horns are thick at the base, emerge laterally and curve upward.
4. Dewlap is abundant both in males and females but thin and hangs well in nice folds.
5. Hump is well developed in bull, sloping gradually forward but with abrupt fall in the back.
6. Most economical milk producers amongst Indian cattle. Average milk yield - 2150 kg with fat per cent - 4.5. Age at first calving - 44 months.

**GIR (GUJARATI, BHODALI, KATHIAWARI, SORTHI, SURATI)**

***Habitat:*** Gir hills and forests in the south of the Kathiawar in Gujarat on the West coast in India.

**Physical and functional characteristics:**

1. Medium size with well proportionate and robust constitution.
2. Colour varies from entire red with light patches to a mottled white and red or chocolate-brown
3. A broad convex massive forehead.

4. Ears are very large and pendulous, folded like a curled up leaf with a notch at the tip almost meeting at the end of the muzzle when stretched.

5. Renowned breed known for tolerance under stress conditions.

6. Cows are good milkers. Average lactation milk yield - 2100 kg with fat per cent - 4.4.

7. Age at first calving : 45 –54 months.

**RATHI**

**Habitat:** Bikaner, Ganganagar and Jaisalmer district of Rajasthan.

**Physical and functional characteristics:**

1. Medium size with symmetrical body.
2. Colour of the animal is brown with white patches all over the body
3. Forehead is medium size and lean
4. Ears are medium in length, while dewlap is voluminous.
5. Lactation milk yield ranged from 1100 to 2800 kg with fat percent: 3.7 - 4.0.
6. Age at first calving – 47 months.

**ii) DUAL PURPOSE BREEDS**

**THARPARKAR (WHITE SINDHI, GREY SINDHI, THARI)**

***Habitat:*** Arid, semi-desert tracts of south-east Sind in Pakistan, Kutch in Gujarat, Jaisalmer and Jodhpur Rajasthan.

**Physical and functional characteristics:**

1. Deep, stockily built animal of medium size.
2. White or grey with darker extremities.
3. Legs comparatively short and straight.
4. Cows – fairly good milkers. Average lactation milk yield - 1750 kg with fat percent - 4.9.
5. Age at first calving – 41 months.
6. Bullocks good for ploughing and carting.

**KANKREJ (WADAD, WAGED, VAGADIA, TALABDA, NAGAR, BONNAI)**

**Habitat:** South-east of the Rann of Kutch in Gujarat.

**Physical and functional characteristics:**

1. One of the heaviest Indian cattle breeds.
2. Colour is silver grey, iron grey or steel black. In males, hump and hindquarters are always darker than the barrel.
3. Horns curved upward and outward in a lyre-shaped fashion.

4. Ears large, pendulous and open.

5. Peculiar gait of the breed with hardly any movement of the body.

6. Naval flap is prominent in females, while males have medium and pendulous sheath.

7. Bullocks – excellent draught animals.

8. Cows - fairly good milkers. Average lactation milk yield -1750 kg.

9. Age at first calving – 48 months.

**HARIANA**

**Habitat:** Districts of Rohtak, Hissar, Jind, Gurgaon and part of Karnal in Haryana and Delhi.

**Physical and functional characteristics:**

1. Compact and well proportionate body.

2. Colour is white and light grey.

3. Long and narrow face with flat forehead and a well marked bony prominent at the centre of the poll.

4. Horns are short and horizontal.

5. Sheath is short and tight and naval flap is absent in bulls.

6. Bullocks – for ploughing and carting.

7. Cows – fairly good milkers. Average lactation milk yield - 1000 kg.

8. Age at first calving – 52 months.

**ONGOLE (NELLORE)**

**Habitat:** Ongole taluk in Guntur districts in Andhra Pradesh.

**Physical and functional characteristics:**

1. Large and heavy animals.

2. Popular coat colour is (glossy) white.

3. Prominent forehead, horns are short and stumpy.

4. Hump is well developed and erect.

5. Dewlap is large, fleshy and hanging in folds extending to the naval flap.

6. Bullocks – powerful and good for heavy ploughing and carting.

7. Cows – fairly good milkers. Average lactation milk yield - 700kg with fat percent – 5.

**DEONI (Dongerpati, Dongari)**

**Habitat:** Bidar district of Karnataka and Latur district of Maharashtra

**Physical and functional characteristics:**

1. Medium sized well-built animal with prominent forehead.
2. Colour – white with black face or irregular black spots.
3. Horns – medium, emerge from the side of the poll with outward and backward curve.
4. Lactation milk yield – 800 – 1000 kg. Age at first calving - 53 months.
5. Bullocks are powerful, well suited for all agricultural works.

**<u>iii). DRAUGHT BREEDS</u>**

**KANGAYAM (KANGANAD, KONGU)**

**Habitat:** Erode, parts of Coimbatore, Dindigul and Karur districts in Tamil Nadu.

**Physical and functional characteristics:**

1. Medium sized animals.

2. Kangayam cattle are usually grey or white and grey with black markings in fetlocks.

3. Horns are longer, curving outwards and backwards then inwards and almost complete a circle at the point where they approach the tips.

4. Forehead is broad with a shallow groove at the center.

5. Dewlap is thin and short. Sheath is well tucked up to the body.

6. Medium, stout legs with well-developed wide thighs and hard, strong hooves.

7. Draught capacity – a pair of bullocks can be able to pull 3 – 4 tonnes over a distance of 10 - 20 km without rest.

8.Total partial milk yield - 540 kg per lactation and age at first calving - 40 months.

**UMBLACHERY (JATHI MADU, MOTTAI MADU, MOLAI MADU, THERKATHI MADU)**

**Habitat:** Thiruvarur and Nagapattinam districts in Tamil Nadu.

**Physical and functional characteristics:**

1. Small, very compact and well built.

2. Coat colour is grey varying from admixture of black to full grey with white markings on face and legs. All legs below hocks have white markings either socks or stockings.

3. Head is small and straight. Well pronounced white star in the forehead is specific to this breed.

4. Horns - short, curving outwards and inwards, sometimes spreading laterally.

5. Hump - medium sized and not fleshy.

6. Sheath - well tucked up to the abdomen.

7. Legs - short, straight and squarely set under the body.

8.Total partial milk yield - 400- 500 kg per lactation and age at first calving - 52 months.

**BARGUR**

**Habitat:** Bargur hills at Bhavani taluk of Erode district in Tamil Nadu.

**Physical and functional characteristics:**

1. Medium size, more compact
2. Colour - Red with white spots/patches of variable extent in the body. Horns, eyes, muzzle and hooves are brown in colour.
3. Thin and leafy ears.
4. Horns – closer at the roots inclining backwards, outwards and upwards with a sharp forward curve at the tip.
5. Tucked up sheath.
6. Short and strong legs. Very good for mhote plough and carting work with large power of endurance.

**PULIKULAM**

**Habitat:** Maintained as migrating herds in Madurai, Sivaganga and Virudhunagar districts in TN.

**Physical and functional characteristics:**

1. Smaller in size, strong and active with compact body and short legs, by appearance resembles Kangayam but small sized.
2. Colour – grey with reddish brown or fawn marking on one or two points of the bod
3. Horns – generally take backward and outward sweep

**AMRITHMAHAL**

**Habitat:** Hissan, Chikmagalur and Chitradurga districts in Karnataka.

**Physical and functional characteristics:**

1. Medium sized animal with compact tucked in body.
2. Colour – grey, varies from white to nearly black
3. Head is long and tapering towards muzzle
4. Horns - Long, emerge from top of the poll, fairly close together in backward and upward direction.
5. Legs are strong, long with hard hooves

**HALLIKAR**

**Habitat:** Mysore, Mandya, Bangalore, Kolar, Tumkur, Hassan and Chitradurga districts in Karnataka.

**Physical and functional characteristics:**

1. Medium size, muscular and compact.
2. Grey to dark grey colour with deep shading on the fore and hindquarters. Frequently light grey marks on the face, dewlap and under the body.
3. Prominent forehead and furrowed in the middle.
4. Long face and tapers towards the muzzle.
5. Horns emerge near each other from the top of the poll and carried backward, each in a straight-line for nearly half their length and with a gentle and graceful sweep, bend forward and slightly inward toward the tips. Horns touch the neck almost in front of hump.
6. Ears are tapering to a point.
7. Dewlap is thin and moderately developed.

**KHILLARI (Mandeshi and Shikari)**

**Habitat:** Kolhapur, Solapur, Sangli and Satara districts in Maharashtra and Belgaum, Bijapur and Dharwad districts of Karnataka.

**Physical and functional characteristics:**

1. Originated from Hallikar or Amrithmahal
2. Medium sized, cylindrical, compact long body with stout strongly set lips
3. Forehead is long narrow with a gradual convex bulge backward to the horn
4. Colour – greyish white
5. Horns – long and pointed and follow the backward curve of the forehead
6. Bullocks are well known for their quick draught capacity

**PUNGANUR**

**Habitat:** Chittoor district in Andhra Pradesh.

**Physical and functional characteristics:**

1. Dwarf variety, similar to Vechur
2. Colour – white, grey or light brown to dark brown
3. Horns are black, small and crescent shaped
4. Legs are short with hard compact hooves
5. Reared for milk. Lactation milk yield 550 kg with 5 percent fat.
6. Body height – 107 cm

**VECHUR**

**Habitat:** Kottayam districts in Kerala.

**Physical and functional characteristics:**

1. Dwarf cattle, compact body. Height below 100 cm with average body weight 130– 70 kg.
2. Colour – solid colour, light red black or fawn and white.
3. Head – long with narrow face
4. Horn – small, thin curving forward and downward
5. Hump – prominent in male
6. Tail – long, almost touching the ground
7. Skin is smooth and glossy
8. Adaptable to hot humid environment
9. Milk yield – 500kg per lactation with 6.2 percent fat. Milk is considered to have high medicinal value.

**IMPORTANT EXOTIC DAIRY BREEDS OF CATTLE**

**JERSEY**

**Habitat:** Jersey island in the English Channel.

**Physical and functional characteristics:**

1. Small and compact body.
2. Fawn colour with or without white markings.
3. Protruding eyeballs.
4. Double dished forehead and head.
5. Early sexual maturity.

6. High butter fat levels.
7. Average milk production: 4500 kg /lactation with 4.5 percent fat.
8. Age at first calving: 26 – 30 months
9. Breed of choice for upgrading non-descript cows in plains

**HOLSTEIN FRIESIAN**

**Habitat:** Originated in two provinces of Netherlands (North Holland and West Friesland).

**Physical and functional characteristics:**

1. Large size.
2. Coat colour is predominantly black and white.
3. Head: long and narrow and straight with slightly rounded shoulders.
4. Dairy breed. Average milk production: 6000 – 7000 kg with low fat percent:3 – 3.5.
5. Age at first calving: 28 - 32 months and calving interval
6. Least heat tolerant, require quality feed and fodder and better management practices.

Preferred for upgrading non-descript cattle in hill areas/high land areas.

**BROWN SWISS**

**Habitat:** Has their origin in the Alpine regions of several European countries (Switzerland).

**Physical and functional characteristics:**

1. Large size.
2. Distinctly brown, light brown to grey colour
3. Large heads which are usually dished.
4. Thick loose skin.
5. Dual purpose (milk and meat).
6. Average milk production - 5000 kg / lactation with 4.0 per cent fat.
7. Age at first calving: 28 - 30 months.

## Breeds of Buffaloes

The buffaloes are normally classified into River and Swamp types though both are called *Bubalus bubalis.* Most of the animals in India are River type though Swamp type is also found in certain parts of the country especially in eastern parts of India. Swamp buffalo is more or less a permanent denizen of marshy lands, where it wallows in mud and feeds on coarse marsh grass. The river buffaloes are found throughout India where clean water of rivers, irrigation canals and ponds are available to wallow. India is considered as the home tract for some of the best dairy buffalo breeds. There are 10 recognised breeds of riverine buffaloes (2n = 50). There also exist a number of buffalo populations, which has not been defined or recently defined as breeds.

The well recognised breeds of buffaloes are classified into the following five groups:

1. Murrah group: Murrah, Nili – Ravi
2. Gujarat group: Jaffarabadi, Surti, Mehsana
3. Uttar Pradesh breeds: Bhadawari, Tarai,
4. Central India group: Nagpuri, Pandharpuri, Kalahandi, Manda, Jerangi, Sambalpur
5. South India group: Toda and South Kanara

**Description for the most important /well known breeds:**

**MURRAH (DELHI, KUNDI, KALI)**

**Habitat:** Rhotak, Hissar Jind and Gurgaon in Haryana and Delhi.

**Physical and functional characteristics:**

1. Large and heavy, massive body.
2. Coat colour: jet-black with white markings on tail.
3. Horns: short and tightly curved in a spiral form.
4. Hips broad, fore and hindquarters are drooping.
5. Tail is long reaching up to the fetlocks with white switch.
6. Average milk production: 1700 – 2300kg/lactation (1675 kg-305-day milk yield); Fat percent: 7.3.Age at first calving - 45 – 50 months.

**NILI-RAVI (NILI)**

**Habitat:** Ferozepur and Amritsar districts in Punjab and Sahiwal district in Pakistan.

**Physical and functional characteristics:**

1. Medium sized.
2. Colour is black-brown (fawn not uncommon) with white markings on forehead, face, muzzle, legs and tail.
3. Head is elongated, bulging at top and depressed between eyes.
4. Peculiarity of the breed is the walleyes.
5. Horns: small, tightly curved and circular in cross section.
6. Average milk production: 1820kg (305-day milk yield); Fat percent: 6.8.
7. Age at first calving : 45 – 50 months

**JAFARABADI (BHAVANAGRI, GIR, JAFFARI)**

**Habitat:** Junagarh, Bhavnagar and Amreli districts in Gujarat.

**Physical and functional characteristics:**

1. Large sized. Heaviest among Indian buffaloes.
2. Colour is usually black.
3. Horns are heavy, emerge out by compressing the head, inclined to droop at each side of the neck and then turning up at points (ring-like).
4. Forehead is very prominent, broad and convex.
5. Average milk production: 1000 - 1200 kg; Fat percent: 7.7.
6. Age at first calving – 45 months
7. Bullocks are heavy and are used for ploughing and carting

**MEHSANA (MAHESANI, MEHSANI, BANNI)**

**Habitat:** Banaskandha, Sabarkandha, Gandhinagar and Ahmedabad districts in Gujarat.

**Physical and functional characteristics:**

1. Medium sized with lowest deep body.
2. Colour is usually black.
3. Head is longer and heavier.
4. 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.
5. Average milk production: 1890 kg (305-day milk yield); Fat percent: 7.0
6. Age at first calving - 42 months

**SURTI (CHAROTAR, DECCANI, GUJARATI, NADIADI, SURATI, TALABDA)**

**Habitat:** Kaira, Baroda, Bharuch and Surat districts in Gujarat.

**Physical and functional characteristics:**

1. Medium sized.
2. Coat colour is rusty brown to silver-grey. Skin is black or brown
3. Peculiarity of the breed is that there are two white collars, one around the jaw and the other at the brisket.
4. Horns are sickle shaped, moderately long and flat.
5. Head is long and eyes are prominent. Back is straight.
6. Average milk production: 1770 kg in 350 days. (305-day milk yield -1065 kg) ; High fat percentage : 7.5-8.3. Age at first calving: 45 months.

**BHADAWARI**

**Habitat:** Agra district of Uttar Pradesh and Gwalior district of Madhya Pradesh.

**Physical and functional characteristics:**

1. Medium sized with wedge shaped body
2. Body is light or copper coloured
3. Head is small, legs - short and stout.
4. Tail is thin, long with black or white markings
5. Average milk production 800 – 1000kg / lactation.
6. Bullocks are reputed good draught animals.

**NAGPURI (ELLICHPURI, BERARI,GAULANI,GAULI, VARADI)**

**Habitat:** Nagpur, Wardha, Akola and Amravati districts in Maharashtra.

**Physical and functional characteristics:**

1. Horns: long, flat, curved and carried backwards on each side of the neck nearly to shoulders.
2. Coat colour is black with white patches on face, legs and tail tip.
3. Face is long and thin.
4. Neck is somewhat long with cylindrical barrel.
5. Limbs are long and light.
6. Average milk production: 1055 kg (305-day milk yield) ; Fat percent: 7.0-8.5.
7. Age at first calving: 56 months

**TODA**

**Habitat:** Udhagamandalam (Udhagamandalam and Gudalur taluks) district in Tamil Nadu.

**Physical and functional characteristics:**

1. Medium sized animal.
2. Colour is fawn and ash-grey in adults. Calves usually fawn and rarely grey.
3. Horns: typical, set wide apart, curving outward, slightly downward and upward with the points being recurved inward, forming a crescent shape.
4. Two white to light brown coloured chevron markings in the jowl and above the brisket.
5. High fat content (8.2 per cent) in milk, apparent resistance to mastitis and capable of surviving in high altitude are some of the specific characters of the breed.
6. Average milk production: 500 kg (200-day milk yield). Age at first calving: 48 months

# <u>Breeds of Sheep and Goats</u>

India's vast genetic resources in Sheep and Goat are reflected by the availability of 40 breeds of sheep and 20 breeds of goats. Most of the breeds of sheep and goats are evolved naturally through adaptation to agro-ecological conditions. These breeds are named after their place of origin or on the basis of prominent characteristics. Most of the breeds of sheep and goats are very well adapted to the harsh climate, long migration, and lack of vegetation and drinking water. A large proportion of sheep and goats are of the nondescript or mixed breeds.

## Sheep

On the basis of the agro climatic conditions sheep breeds are classified into four regions.

i - North-western, Central Arid and semi-arid region ii - Southern Peninsular Region

iii -Eastern Region iv Northern Temperate Region

On the basis of wool characteristics they are classified as

i. Apparel wool breeds ii. Superior carpet wool breeds

iii. Coarse carpet wool breeds and iv. Hairy meat breeds

**Exotic breeds used in India**

i. Fine wool breeds – Merino, Rambouillet

ii. Mutton type breeds – Suffolk, Dorset

iii. Dual Purpose breeds – Corriedale iv. Pelt breeds – Karakul

## Goats

Goats are also classified on the basis of their location into four regions similar to sheep.

On the basis of their utility they are classified as meat, milk, dual and for fibre (Pashmina) production.

**Exotic breeds used in India**

i. Dairy breeds – Saanen, Alpine, Toggenburg, Anglo-Nubian

ii. Meat breeds – Boer iii. Mohair – Angora

**REGION AND UTILITY WISE CLASSIFICATION OF SHEEP AND GOATS**

## I - North-western, Central Arid and semi-arid region

***(Punjab, Haryana, Rajasthan, Gujarat, Uttar Pradesh and Madhya Pradesh)***

| SN | Sheep | Goat |
|---|---|---|
| 1. | Nali[2] | Beetal -meat |
| 2. | Chokla[2] | Barbari-dual |
| 3. | Malpura[3] | Jamnapari-dual |
| 4. | Marwari[2] | Jhakrana- milk |
| 5. | Magra[2] | Marwari- dual |
| 6. | Jaisalmeri[2] | Kutch-meat |
| 7. | Pugal[2] | Mehsana-milk |
| 8. | Sonadi[3] | Sirohi-dual |
| 9. | Patanwadi[2] | Zalawadi-dual |
| 10. | Muzzafarnagri[3] | Gohilawadi-dual |
| 11. | Jalauni[3] | Surti-milk |
| 12. | Hissardale[1] | |

## II - Southern Peninsular Region (Maharashtra, Andhra Pradesh,

***Karnataka, Tamil Nadu and Kerala)***

| SN | Sheep | Goats |
|---|---|---|
| 1. | Deccani[3] | Sangamneri-dual |
| 2. | Bellary[3] | Malabari-milk |
| 3. | Nellore[4] | Osmanabadi-dual |
| 4. | Mandya[4] | Kanniadu-meat |
| 5. | Hassan[4] | Kodiadu-meat |
| 6. | Mecheri[4] | Salem Black-meat |
| 7. | Kilakarsal[4] | |
| 8. | Vembur[4] | |
| 9. | Coimbatore[3] | |
| 10. | Nilagiri[1] | |
| 11. | Ramnad White[4] | |
| 12. | Madras Red[4] | |
| 13. | Trichy Black[3] | |
| 14. | Kenguri[4] | |

**III -Eastern Region**

**(Bihar, West Bengal, Orissa, Assam, etc.)**

| Sl. No | Sheep | Goat |
|---|---|---|
| 1. | Chottanagpuri[3] | Ganjan-meat |
| 2. | Shahabadi[3] | Bengal-meat |
| 3. | Balangir[3] | |
| 4. | Ganjam[3] | |
| 5. | Tibetan[2] | |
| 6. | Bonpala[3] | |

**IV Northern Temperate Region**

**(Jammu and Kashmir, Himachal Pradesh, hilly regions of Uttar Pradesh)**

| Sl. No | Sheep | Goats |
|---|---|---|
| 1. | Gaddi[2] | Gaddi-hair |
| 2. | Rampur Bushair[2] | Changthangi-Pashmina |
| 3. | Bhakarwal[3] | Chigu- Pashmina |
| 4. | Poonchi[2] | |
| 5. | Karnah[2] | |
| 6. | Gurez[2] | |
| 7. | Kashmir Merino[1] | |
| 8. | Changthangi[2] | |

[1] - Apparel wool breeds

[2] - Superior carpet wool breeds

[3] - Coarse carpet wool breeds

[4] - Hairy meat breeds

## BREEDS OF SHEEP

**Sheep breeds of Tamil Nadu:**

**Mecheri**:

**Home tract and distribution**: Mecheri, Kolathur, Nangavalli, Omalur and Tarmangalam Panchayat union areas of Salem district and Bhavani taluk of Erode district.

**Colour and Conformation:** Medium sized, light brown sometimes with white spots on head and body. Ears medium sized and tail is short and thin. **Both sexes are polled**.

Weaning weight – 10.9 kg; 6 months weight – 15.6 kg; 12 months weight – 21.1 kg.

Mature rams – 34.6 kg. Mature ewes – 28.6 kg.

Dressing percentage: 53.4

Better skin quality and higher dressing percentage are distinguishing features of this breed.

**Kilakarsal:**

**Home tract and distribution**: Ramnad district.

**Colour and Conformation:** Medium-sized, coat is dark tan with black spots on head, belly and legs. Tail is small and thin. Males have twisted horns and females are hornless.

Weaning weight – 8.5 kg; 6 months weight – 14.1 kg

Adult body weight: Rams – 29.6 kg. Ewes – 21.3 kg.

**Vembur :**

**Home tract and distribution** : Tuticorin and parts of Virudhunagar districts.

**Colour and Conformation:** Tall animals. White with irregular red or fawn and black spots and patches all over the body. Ears are medium-sized and drooping. Tail – thin and short. Males are horned and ewes are hornless. Attractive colour pattern and height are the special features of this breed.

Weaning weight – 11.9 kg; 6 months weight – 16.0 kg; 12 months weight – 22.4 kg

Adult body weight: Rams – 43.0 kg. Ewes – 29.9 kg.

**Coimbatore:**

**Home tract:** Coimbatore district, chiefly reared on migration, migratory tract – Erode and Coimbatore Districts in Tamil Nadu and Palakkad and Thrissur districts in Kerala.

**Colour and Conformation:** Medium-sized, white with varying extent of black or tan in head neck extending up to shoulder/ chest and back. Ears – medium sized. Tail is small and thin. 35 % of the males are horned and females are hornless. Fleece – white, coarse and hairy.

Weaning weight –12.4 kg; 6 months weight – 15.9 kg; 12 months weight – 21.5 kg

**Adult body weight: Rams – 35.5 kg. Ewes – 24.5 kg**

Average anuual greasy fleece weight – 0.4 kg

**<u>Nilagiri</u> :**

**Home tract**: Nilgiri hills.

**Colour and Conformation**: Medium sized. Body colour is white, exceptionally with brown patches on face and body. Face line – convex, giving a typical Roman nose. Males have horn buds and scurs. Females are hornless. Fleece is fine and dense. Tail is medium in length and thin.

Weaning weight –11.8 kg; 6 months weight – 15.0 kg; 12 months weight – 19.7 kg

Adult body weight: Rams – 30.6 kg. Ewes – 25.0 kg.

6 months greasy fleece weight – 0.62 kg

**<u>Ramnad White</u> :**

**Home tract and distribution :** Ramnad and Tirunelveli districts.

**Colour and Conformation**: Medium sized, predominantly white with black markings over the body. Ears are medium sized. Males have twisted horns. Females are hornless.

Weaning weight –7.3 kg; 6 months weight – 8.4 kg; 12 months weight – 16.3 kg

Adult body weight: Rams – 31.2 kg. Ewes – 22.5 kg.

**<u>Madras Red</u> :**

**Home tract and distribution :** Kancheepuram, Chingleput, Vellore and Thiruvannamalai districts.

**Colour and Conformation**: Medium-sized, body colour – brown. Rams have strong corrugated and twisted horns. Ewes are hornless.

Weaning weight –13.5 kg; 6 months weight – 15.7kg; 12 months weight – 21.9 kg

Adult body weight: Rams – 35.5 kg. Ewes – 23.2 kg.

Dressing percentage – 41.2%.

**<u>Tiruchy Black</u> :**

**Habitat :** Perambalur, parts of Villupuram, Salem, Dharmapuri, Vellore and Thiruvannamalai districts.

**Colour and Conformation**: Small animals. Body is completely black. Males have twisted horns. Ewes are hornless. Fleece is extremely coarse and hairy.

Weaning weight – 9.4 kg; 6 months weight – 10.7 kg; 12 months weight – 16.8 kg Adult body weight: Rams – 25.8 kg. Ewes – 18.5 kg.

Average fleece weight – 0.4 kg

## Other south Indian breeds of sheep

**Karnataka**

**Deccani:**

**Distribution:** Parts of Karnataka, Andhra Pradesh and Maharashtra

**Colour and Conformation:** Medium – sized animal. Predominantly black or black with white markings. Ears are medium-long and drooping. Tail is short and thin. Fleece is extremely coarse and hairy. Males are horned and ewes are polled.

| | | | |
|---|---|---|---|
| Weight at weaning | 13.6 kg | Weight at six months | 20.9 kg |
| Adult males | 38.5 kg | Adult females | 28.6 kg |

Litter size –Single; Annual greasy fleece yield 0.74 kg

**Bellary:**

**Home tract and Distribution** :Bellary district of Karnataka

**Colour and Conformation**: Medium-sized animals with body colour varies from white to black.

Weight at weaning 11.1 kg; Weight at six months 16.3 kg; Weight at 12 months 18.7 kg

Six month greasy fleece weight 0.30 kg

**Mandya:**

**Home tract and Distribution** :Mandya and bordering Mysore districts of Karnataka

**Colour and Conformation**: Small animals. Colour is white; sometimes face is light brown in colour. Compact body with typical reversed U shape conformation from the rear. Ears are long and drooping. Tail is short and thin. Fleece is extremely coarse and hairy. Both sexes are polled.

Weight at weaning 9.7 kg; Weight at six months 12.8 kg; Weight at 12 months 21.0 kg

Annual greasy fleece yield 0.37 kg

<u>**Andhra Pradesh**</u>

<u>**Nellore:**</u>

**Home tract and Distribution**: Nellore and parts of Prakasham and Ongole districts of Andhra Pradesh

**Colour and Conformation**: **Tall animals**. White in colour with light brown spots on the head, neck, back and legs; completely brown colour is also seen. Rams are horned and ewes are polled. Ears are long and drooping. Tail is short and thin.

Weight at weaning 12.0 kg; Weight at six months 16.6 kg; Weight at 12 months-22.7 kg

Some of the sheep breeds are known for their unique characteristics like Magra for lustrous wool; Changthangi for wool; Garole for high fecundity; Chokla and Pattanwadi for best carpet quality wool; Mecheri and Mandya for mutton and Deccani, Marwari, Hassan, Jaisalmeri, Chokla and Coimbatore for their hardiness and capability to travel long distances.

**Exotic sheep breeds**

<u>**Dorset**</u> **:**

**Origin –** England.

Medium sized mutton breed. There are two types: horned and polled strains. Ears, legs and face are white free from wool; skin and lips are pink in colour.

Legs are short and straight.

Weight at 4 months – 18 – 22 kg; Weight at 9 months – 30 – 35 kg

Adult body weight: Rams - 80 – 110 kg. Ewes – 50 – 80 kg.

<u>**Suffolk**</u> :

**Origin –** England.

Mutton breed. Face, ears and legs are black in colour. Males and females are hornless. Legs are short and straight.

Head and ears are free from wool.

Adult Rams – 100 to 135kg. Adult Ewes 70 – 100 kg.

<u>**Merino**</u> :

**Origin –** Spain. Merino is a thin tailed, fine wool breed.

Colour and conformation: Animals are white and skin is pink. Head and legs are covered by wool. Rams have spiral horns. Ewes are polled. Types - Australian, Soviet and Spanish.

**Weaning weight – 15.1 kg ; 6 months weight – 20.1 kg.**

**Mature rams – 75 kg. Ewes – 65 kg.**

Fleece weight: Rams – 4 to 5 kg. Ewes – 3 to 4 kg. Staple length – 5 – 10cm.

**Rambouillet : Strain originated from Spanish Merino**.

**Origin** – France.

**Colour and Conformation:** It is white and the skin is pink. Rams are horned and ewes are polled. Large head with white hair around nose and ears. It is used for wool and meat.

Mature rams: 100 – 120 kg. Ewes: 60 – 90 kg

**Corriedale:**

**Origin** – New Zealand

It has 50% Merino inheritance and rest Lincoln and Leicester

It is a hardy dual purpose breed. Both sexes are polled and face, ears and legs are covered with white hairs.

Mature rams: 80-110kg. Ewes: 55-85 kg.

Annual greasy fleece weight 4.5 –5.5 kg

**Karakul :**

**Origin:** Bokhara (Central Asia).

It is a pelt (fur) breed reared mainly for their lamb pelts which are used for manufacturing garments. Pelts are produced through slaughtering of lambs within 24 – 48 hours of birth. The quality of pelts determined by its type of curls, size, tightness of curls, lustre and weight. Medium sized breed.

Poor mutton quality. First imported to India in 1975.

Mature rams weigh: 80 kg and ewes: 60 kg.

# BREEDS OF GOATS

**Goat Breeds of Tamil Nadu**

**Kanni Adu :**

**Home tract and Distribution** : Parts of Tirunelveli, Virudhunagar and Tuticorin districts

**Colour and Conformation:** Tall animals, predominantly black in colour with two colour varieties *viz*. Pal – Kanni (Black with white colour on either side of the face, under belly and inner side of the legs) and Cheng- Kanni ( Black with reddish brown colour on either side of the face, under belly and inner side of the legs). Ears – medium. Males and females are horned. Udder small and round with small teats placed laterally.

3 months weight – 10.9 kg; 6 months weight –12.7 kg; 9 months weight – 15.2 kg

12 months weight –20.6 kg. Adult body weight: Buck – 38.3 kg. Doe – 30.4 kg.

Age at first kidding – 14.6 months. Kidding percentage: 159.50.

Litter size: singles – 32.0%. Twins – 46.5%.

**Kodi Adu :**

**Distribution:** Parts of Tuticorin and adjoining areas of Ramanathapuram, Tanjore and Pudukottai districts.

**Colour and Conformation:** They are tall, long animals with slender body. White in colour with splashes of black or red colour. Based on the colour they are classified as Karum Porai (Blackish) and Chem Porai (Reddish brown). Both sexes are horned. Tail is medium and thin. Suitable for coastal areas. Used as a leader in sheep flock while grazing.

Adult body weight: Buck – 39.5 kg. Doe – 32.2 kg.

Age at first kidding – 15-18 months. Kidding interval: 8-10months.

Litter size: singles – 49.7.0%. Twins – 44.8% and triplets – 5.5%

## Other Indian goat breeds

**Jamnapari :**

**Home tract :** Agra, Mathura and Etawa district in Uttar Pradesh.

**Colour and conformation: Large animals**. There is great variation in coat colour but the typical coat is white with small tan patches on head and neck. The typical character of the breed is a highly convex nose line – Roman nose, with a tuft of hair, yielding a parrot mouth appearance. The ears are very long (27cm), flat and drooping. Both sexes are horned. A thick growth of hair on the buttocks is known as feathers. The udder is well developed. It has been extensively utilised to upgrade indigenous meat and milk breeds.

Reproduction: Age at first kidding – 24 months. Kidding percentage: 124.25%.

Kidding interval - 7-8 months. Twinning – 43%

Average lactation yield - 202 kg. Lactation length -190 days

Adult body weight: Buck – 44.7 kg. Doe – 38.0 kg. Dressing percentage - 44.6.

**Bengal (Black Bengal) :** Individuals of this breed are sometimes distinguished by colour as Black, Brown, Grey and White.

**Home tract and distribution:** Distributed throughout all eastern and north-eastern India mainly in West Bengal, Bihar and Assam.

**Colour and Conformation:** Small animals. Predominant coat colour is black; brown, grey and white are also found. The hair coat is short and lustrous. The nose line is slightly depressed. Both sexes have small to medium horns. Beard is observed in both sexes.

**Litter size: Singles - 45% Twins - 51%**

Adult body weight: Buck – 32.4 kg. Doe – 20.4 kg.

Dressing percentage: 46. Skins are of excellent quality and highly prized.

**Tellicherry (Malabari)**: Distribution :Calicut, Kannur and Tellicherry districts of Kerala.

**Colour and Conformation:** Medium-sized animals. Coat colour varies from completely white to completely black, but majority of the animals are white in colour. Both sexes have slightly twisted horns directed outward and upward. Males have beard. Ears are medium-sized. Udder is large and round with medium-sized teats.

Adult body weight : Buck – 38.9 kg. Doe –31.1 kg.

Average lactation yield : 43.8 kg. Lactation length – 143 days.

**Barbari :**

**Distribution :**Agra, Aligarh districts of Uttar Pradesh and Bharatpur district of Rajasthan.

**Colour and Conformation:** Small animals. Coat colour – white with small brown patches. Ears are short tubular, with slit opening in front, erect, directed upward and outward. Both sexes have twisted horns. Bucks have large, thick beard.

Adult body weight : Buck – 37.8 kg. Doe –22.5 kg.

Average lactation yield : 107 kg. Lactation length – 150 days

Twinning – 64%. Triplets –13%. This breed is suitable for stall feeding management practices.

**Beetal:**

**Distribution :** Punjab, Haryana.

**Colour and Conformation:** Large animals. Coat colour – predominantly black or brown with white spots of different sizes. The face line is convex with typical Roman nose appearance. Ears are long, flat, curled and drooping. Both sexes have thick medium sized horns.

Adult body weight: Buck – 59.0 kg. Doe – 35.0 kg.

Average lactation yield : 177 kg. Lactation length – 187 days

Age at first kidding – 18 months.

Singles – 41% Twinning – 52%

**Sirohi:**

**Distribution :** Rajasthan and Gujarat

**Colour and Conformation:** Medium - sized animals. Coat colour – predominantly brown with light or dark brown patches. Ears are flat, leaf like, drooping .

Adult body weight : Buck – 50.0 kg. Doe –23.0 kg.

Average lactation yield : 71 kg. Lactation length – 175 days

Singles 91.5% Twinning – 1.5%.

Dressing percentage – 47%

**Surti:**

**Distribution** : Gujarat.

**Colour and Conformation:** Medium sized animals. Coat colour – white with well developed udder and large conical teats.

Adult body weight : Buck – 32.0 kg. Doe – 29.5 kg. Milk yield : 2.5 kg/day.

## Exotic Goat breeds

**Saanen :**

**Origin** – Saanen valley in Switzerland.

**Colour and Conformation**: White coat or light cream with short hair. Face straight, ears short and erect. Wattles are common.

Buck – 95 kg. Does – 65 kg. Milk yield – 2 to 5 kg/day.

Average milk yield 2-5kg/day. Lactation length – 8 to 10 months.

**Alpine :** Origin : Alps

**Conformation :** Large animals, long legged and hardy, small ears and Roman nose

Mature Bucks : 90 kg. Does : 85 kg

Average lactation milk yield – 2300kg in 10 months.

**Anglo Nubian :**

**Origin:** Cross between Nubian of Egypt and Jamnapari from India with English parentage. No fixed colour. One of the largest and heaviest European breeds with Roman Nose and pendulous ears. Known as "**Jersey Cow**" of the goat world.

Mature Bucks : 80 kg. Does : 60 kg. Milk yield – 3 kg per day.

**Toggenburg :**

**Origin:** Toggenburg valley of Switzerland

**Colour and Conformation**: very hardy and high milk producing breed, light brown to dark chocolate body colour. Small white ears and white stripes on both sides of the face.

Mature Bucks: 80 kg. Does: 65 kg. Average milk yield – 5.5 kg per day.

**Boer :**

**Origin** – South Africa.

**Colour and Conformation:** Large size. White animals with red head and neck and a white blaze. Head straight or slightly convex. Ears are long. Horns – Scimitar shaped bending backward.

Body weight at 8 months – 42 kg.

Age at first kidding – 15 months. Adult body weight: Buck: 75 – 90 kg. Doe: 50 – 60 kg.

**Angora Goat:**

**Origin:** Angora in Turkey

Angora is small in size with short legs and horns twisted. Tail – short and erect. Most important goat breed for production of fibre called Mohair. Average yield of Mohair is 3 kg annually. Mature Bucks: 60 kg. Does: 40 kg

# BREEDS OF SWINE

There are three type of indigenous pigs: Desi, Ghori and Ankamali. Some locally known populations are Nicobari and Andaman wild pigs, Doom (Assam) and Ghungroo (West Bengal). Desi pigs are mostly black in colour, smaller in size, slow growers when compared to their western counterparts.

**1. <u>Large White Yorkshire</u> :**

**Origin** - England

**Physical and Functional Characteristics***:* Colour of the breed is white, pink skin, occasionally black skin covered with fine white hairs. Large size with moderately long and slightly dished forehead and well proportioned anatomy with firm flesh. Thin medium sized erect ears slightly inclined forward and fringed with white hairs. Long fine neck and full to the shoulders, straight and well set legs, level with the body. Good milking and mothering ability. Growth rate feed conversion ability, and carcass qualities are good. Most famous breed of swine thrives well under different climatic conditions and many countries import this breed to improve their local stock and establish different varieties.

Weaning weight: 10 kg Weight at 154 days: 50 – 60 kg

Weight at 210 days: 70 – 90 kg Average litter size - 10-12

Average adult body weight: Boar - 300 – 450 kg, Sow - 250-350 kg 2.

2. **Middle White Yorkshire:**

**Origin:** England. It is a cross of Large white Yorkshire with smaller Yorkshire breeds of England.

**Physical and Functional Characteristics:** Colour: white, wrinkle-free skin (smooth), medium size with moderately short head and upturned dished face, nearly erect ear, slightly inclined forward, fairly short and straight legs, well set apart, mature early with high percentage of lean meat to bone. The breed is hardy, grows rapidly, gives good dressing percentage but is not so prolific as Large White Yorkshire.

Body weight: Boar -250-340 kg, Sow -180-270 kg

**3.Berkshire:**

**Origin:** England

**Physical and Functional Characteristics:** Colour: Black with white markings are on the tip of the snout and tail and lower portion of the legs. Medium-sized, short head, very dished face and medium-sized erect ears. Long body, straight, long and well set legs. Known for their growth, early maturity and quick fattening.

Body weight: Boar: 275-375 kg, Sow: 200-290 kg

**4.Landrace:**

**Origin:** Denmark

**Physical and Functional Characteristics:** Colour: White with rather common black spots. Long body with large drooping ears, long snout and legs. Superior carcass quality and less back fat thickness. More prolific breeders with a litter size of 9 to12 and have good mothering ability.

Body weight: Boar- 300-350 kg, Sow- 200-320 kg

**5.Hampshire:**

**Origin -** England

**Physical and Functional Characteristics***:* Colour: Black with white belt, encircling the body and including the forelegs and feet. Small sized with erect ears and well developed short legs. Moderately prolific with highly developed maternal instinct. High feed conversion ratio and has been successfully used in crossing with other meat breeds.

Average litter size: 7-8, Litter weight: 60 kg at 21 days.

**6.Tamworth:**

**Origin**: England

**Physical and Functional Characteristics***:* Colour: Golden red colour varies from light to dark. Medium sized with long and narrow head, medium-sized ears and is somewhat erect, long neck and strong back. These are less prolific than white breeds. Valued for its hardiness and vigor and widely used in the improvement of tropical pigs in South East Asia.

Body weight: Boar: 200-360 kg, Sow: 180-320 kg.

**7. Essex Saddleback:**

**Origin**: England

**Physical and Functional Characteristics:** Colour: Black with white ‘saddle’ covering the shoulders and fore legs. Head is long with straight snout and the ears have a forward pitch without being floppy. It is known for its prolificacy.

**8. Duroc:**

**Origin**: USA

**Physical and Functional Characteristics***:* Colour - Moderately red with shades varying from golden red to cherry red. Large sized with excellent growth rate and feed efficiency. Highly prolific sows and are good mothers. This breed is popular in South East Asia for its colour, hardiness and fast growth.

Body weight : Boar: 400 kg, Sow: 350 kg

**9. Poland –china :**

**Origin –** Ohio, USA

**Physical and Functional Characteristics***:* Colour: Black with white patches or black body with white markings on the face, limbs and tail. Long sized, deep body and is wide over the back. Ears are distinctly drooping. This breed is noted for the ease with which thrives on and for its tolerance to strong sunlight and high temperature. The sows are very prolific with litter size reaching up to 16 but mothering ability is poor.

Body weight : Boar: 400-430 Kg, Sow: 320-340 Kg.

**10. Chester White:**

**Origin**: Chester county, Pennsylvania, USA

**Physical and Functional Characteristics***:* Colour: Characteristic white with occasional bluish spots on the skin. Face is of medium length and is straight with very moderate dish. Sows are prolific and milk well which make them excellent mothers.

# POULTRY BREEDS

The term poultry includes a number of avian species such as chicken, ducks, turkeys, quails, geese, ostrich and guinea fowls. Of these chicken alone account for 90 % of the total poultry population.

**BREEDS OF CHICKEN**

They are classified according to the place of origin or on the basis of utility

| Based of origin | Based on utility |
|---|---|
| 1. American class<br>2. Mediterranean class<br>3. English class<br>4. Asiatic class | 1.Meat type<br>2. Egg type<br>3. Dual purpose<br>4. Game<br>5. Ornamental |

In general birds differ in

1. Plumage colour 2. Skin colour 3.Comb Pattern 4.Egg shell colour
5. Ear lobe colour 6. Shank feathering

The common comb types are single. Rose and pea comb

The common plumage colours are white, buff (light yellow), black, brown, blue, red and barred.

**1. AMERICAN CLASS**

The important breeds are

1. Plymouth Rock 2.Rhode Island Red 3.New Hampshire and 4.Wyandotte

The common characters of the chicken breeds belonging to this class is

1. Medium sized birds 2. Dual purpose breeds 3. Skin colour is yellow
4. Red ear lobes 5. Clean shanks 6. Lay brown shelled eggs

**1. Plymouth Rock:**

**Origin:** Developed in America in the middle of the 19$^{th}$ century using crosses of Dominique, Java, Cochin and perhaps Malay and Dorking

Plumage colour – Barred, white, buff, silver penciled, partridge and blue; but the famous varieties are barred and white.

Comb pattern – single; Skin colour – yellow; Egg shell colour - brown

They have long body with prominent breast. In this breed the gene for barring is located in the sex chromosome and is used for auto sexing.

Weight : Cock- 4.3 kg; Hen-3.4 kg Utility – dual purpose

**2. Rhode Island Red (RIR):**

**Origin:** Developed in the New England states of Massachusetts and Rhode Island with inheritance from the Malay breed.

Plumage colour : Red buff, white and brown but the common one is red buff

Comb pattern : single or rose; Skin colour – yellow; Egg shell colour - brown

Weight : cock- 3.86 kg; Hen-2.95 kg; Utility – dual purpose; Egg yield 140 –170/year

**3. New Hampshire:**

**Origin:** New breed developed from RIR by intensive selection for rapid growth, fast feathering, early maturity and vigorwhich took place in New Hampshire.

Plumage colour: yellowish brown (Chest nut red)

Comb pattern - single; Skin colour – yellow; Egg shell colour - brown

This breed was developed for 1. Early maturity 2. Rapid feathering 3. Large size eggs 4. Good quality meat 5. To eliminate broodiness

Weight : Cock- 3.8 kg; Hen - 2.9 kg Utility – dual purpose

**II. ENGLISH CLASS**

The important breeds are

1. Cornish 2. Australorp 3.Sussex 4.Dorking 5.Red cap 6.Orpington

The common characters are

1. Medium sized 2. Meat type breeds 3.White skin except Cornish (yellow skin) 4. Red ear lobes 5. Lay brown shelled eggs except Dorking and Red cap

6. Clean shank 7. Hens are broody

**1. Cornish**

**Origin:** Developed in the shire (county) of Cornwall, England where they were known as “Indian Games”. They show the obvious influence of Malay and other oriental blood.

Plumage : White, Dark, white laced red and buff

Comb pattern - pea; Skin colour – yellow; Egg shell colour - brown

This breed has very deep and broad breast and the fowls have heavy flesh with distinct shape. Best contemporary table fowls

Weight : Cock- 4.5 kg; Hen : 3.6 kg Utility – meat type

**2. Australorp**

**Origin:** Developed in Australia from Black Orpington stock.

Plumage colour – black

Comb pattern - single; Skin colour – white; Egg shell colour - brown

Weight : Cock : 3.8 kg Hen : 2.9 kg Utility – dual-purpose

**3. Sussex**

**Origin:** It is one of the oldest breeds of fowl originated in the county of Sussex, England where they were prized as table fowl more than 100 years ago.

Plumage colour – speckled, red and light

Comb pattern - single; Skin colour – white; Egg shell colour - brown

Weight : Cock : 4.0 kg Hen : 3.2 kg Utility – dual-purpose

**4. Dorking**

**Origin:** this breed is believed to have originated in Italy, having been introduced in Great Britain at an early date by the Romans.

Plumage colour – white, silver gray and coloured.

Comb pattern - single; Skin colour – white; Egg shell colour - white

Weight : Cock : 3.4 kg Hen : 2.72 kg Utility – dual-purpose

**5. Red cap**

A rare member of the English class, these are characterized by having a large rose comb. They are one of the few breeds with red ear lobes that lay white-shelled eggs.

**6. Orpington**

**Origin:** this breed was developed in England at the town of Orpington in County Kent during the 1880s.

Plumage colour – white, buff, black and blue.

Comb pattern - single; Skin colour – white; Egg shell colour - brown

Weight : Cock : 4.5 kg Hen : 3.6 kg Utility – dual-purpose

**III. MEDITERRANEAN CLASS**

It is mainly of Italian origin. The important breeds are

1. Leghorn 2.Minorca 3.Andalusian 4.Ancona

The common characters are

1. Small size birds with light body 2. Egg type breeds 3.White ear lobes

4. Lay white shelled eggs 5. Clean shank

**1. Leghorn:**

**Origin** – city of Leghorn, Italy

Variety- white, brown, black, buff, red, silver, columbian

Comb pattern – single and rose; Skin colour – yellow; Egg shell colour - white

Compact and light body, small head, long back and shanks, attain early maturity.

Weight : Cock : 2.7 kg; Hen : 2.0 kg; Utility – egg-type; Egg yield : 150 to 200/year

**2. Minorca**:

**Origin:** developed in the Mediterranean area from an island off the coast of Spain..

Plumage colour: White, buff and black

Comb pattern – single or rose; Skin colour – white; Egg shell colour - white

Largest and heaviest Mediterranean breeds and famous for production of large chalk-white shelled eggs Beak, shank and toes are black in colour. Comb, wattles and ear lobes are larger in size.

Weight : Cock : 4.0 kg; Hen : 3.5 kg; Utility – ornamental type

**3. Andalusian**

**Origin:** Developed initially in Spain, the breed has undergone considerable development in England and United States.

Plumage colour: black, white and blue

Comb pattern - single; Skin colour – white; Egg shell colour – white

The whites and blacks when mated together will produce only blue offspring. When two blues are mated the offspring will be in the ratio of one black, two blues and one white; Weight: Cock – 3.1kg; Hen – 2.5 kg; Utility – ornamental type

**IV. ASIATIC CLASS**

The important breeds are

1. Brahma 2.Cochin 3.Langshan

They contributed for the development of American breeds. The common characters are 1. Large body 2. Red ear lobes 3.Yellow skin (except Black Langshan -pinkish white in colour)4. Lay brown-shelled eggs 5. Broody and poor layers 6. Feathered shanks

**1.Brahma**

Name derived from river Brahmaputra in India

**Origin:** China

Plumage : Light, dark and buff

Comb pattern - pea; Skin colour – yellow; Egg shell colour - brown

Massive bird, well feathered with proportionate body. Feathered shanks. Good mothers with relatively slow rate of growth and delayed maturity.

Weight Cock : 5.4 kg and hen : 4.3 kg;

Utility – very heavy fowl used for the production of roosters and capons

**2.Cochin (Shanghai fowl)**

**Origin** – Shanghai region of China

Plumage colour: Black, white, buff and partridge

Comb pattern - single; Skin colour – yellow; Egg shell colour - brown

Large & deep body, massive appearance, thickly feathered shanks & cushion like structure at the base of the tail.

Weight : Cock - 4.9 kg and hen – 3.8 kg

Utility – Ornamental birds, frequently used as foster mothers for game birds.

**3.Langshan.**

**Origin** – Langshan region of china

Plumage colour: Black and white

Comb pattern : Single

Shorter than Brahma and Cochin. This bird has large tail feathers. They appear to be very tall, with long legs and tail carried at a high angle.

Weight: Cock – 5.0 kg; Hen – 4.1 kg; Utility – dual-purpose.

## INDIAN BREEDS

Indian breeds are mostly rare and have very low value. The most popular breeds are

1. Asil 2. Chittagong 3.Busra 4.Kadaknath 5. Miri 6. Nicobari

**1. Asil**

Found in Andhra Pradesh, Uttar Pradesh and Rajasthan,

Known for its pugnacity, high stamina, majestic gait & dogged fighting qualities.

Plumage colour : Red, white, black and brown

Comb pattern – pea Earlobes and wattles – red

Hen are good setters & efficient mothers with round and short body, broad breast and straight back

Weight : Cocks – 4 to 5 kg and hen – 3 to 4 kg; Utility - Game

**2. Kadaknath**

Present in western Madhya Pradesh

Plumage : Bluish black

Skin, beak, shanks, toes and feet are slate like in colour. Most of the internal organs and muscles are black in colour.

Weight : Cock - 1.5 kg and hen – 1.0 kg

**BREEDS OF DUCKS**

Duck breeds are either classified as meat-type or egg-type

1. Meat-type breds – Aylesbury, Muscovy, Pekin, Rouen, Cayuga and Call ducks.
2. Egg-type breeds – Indian Runner and Campbell.

**Note:**

1. Muscovy ducks are otherwise called as Musk duck or Brazilian ducks.
2. Indian Runner ducks characteristically stand erect and their carriage is almost perpendicular.
3. Khaki Campbell ducks are prolific egg layers and can lay around 365 eggs in a laying year.

# ANIMAL GENETIC RESOURCES OF INDIA

## State of Genetic Diversity

Traditionally, India has been a mega biodiversity center and rearing of domesticated animals viz. cattle, buffalo, sheep, goat, pig, camel, horse, donkey, yak and mithun has been practiced since time immemorial. In poultry, apart from chicken, domesticated strains of avis such as ducks, geese, quails, turkey, pheasants and partridges also exist. Other species viz. elephant, dog, rabbit and pigeon are also important in some of the regions.

Assessment of Genetic Diversity

Cattle

India has 50 indigenous breeds of cattle in addition to the vast cattle population which comes under the non-descript category. There are 3 major types of cattle breeds as per their utility (i) Milch breeds – Sahiwal, Gir, Rathi and Red Sindhi (few animals only at organized farms); (ii) Draft breeds – Anritmahal, Bachaur, Bargur, Dangi, Hallikar, Kangayam, Kenkatha, Kherigarin, Khillari, Malvi, Nagori, Nimari, Ponwar, Umblachery, Red Kandhari and Siri, and (iii) Dual-purpose breeds – Deoni, Gaolao, Hankrej, Krishna Valley, Mewati, Ongole and Tharparkar, Vechur and Punganur are the dwarf breeds. The population of some breeds like Nagori, Hariana, Ponwar, Kherigarh, Mewati, Hallikar, etc. is declining mainly due to mechanization of agriculture. In addition to these, there exist some stable populations in different regions that significantly contribute to the food and agriculture production of that region. These are Alambadi, Binjharpuri, Ghumsuri, Pullikulam, Kumauni, Ladakhi, Malnad Gidda, Mampati, Manapari, Motu, Red Pumea, Shahabadi, Gangatiri, ThoTho, and Tarai. There are no wild relatives of cattle in India. Some of the crossbred strains developed are Sunandini, Frieswal, and Karan-Fries, Except Sunandini, the population of other strains is small.

## Buffalo

India possesses the richest source of germplasm of buffalo and the best dairy breeds are domesticated in north-western region of the country. There are 19 recognised breeds of riverine buffaloes (2N = 50) in India. These include large sized breeds – Murrah, Nili-Ravi and Jaffarabadi; and medium sized – Mehsana, Marathwada, Nagpuri, Pandharpuri, Bhadawari, Surti and Toda. Murrah is the best dairy breed and is most sought after. There also exist a number of buffalo populations, which have not been defined as breeds.

**Goat**

Diversity in goats, represented by 34 breeds. Goats of temperate Himalayan region (Changthangi and Chegu) possess the finest quality under-coat called cashmere or pashmina. The goat breeds found in north and north-western region viz. Jamunapari, Marwari, Zalawadi, Beetal, Kutchi, Sirohi, Barbari, Mehsana, Surti, Jhakrana and Gohilwadi are large in size and primarily used for meat and milk purpose. In the southern and peninsular part of India, goats with dual production of meat and milk viz. Sangamneri, Osmanabadi, Kanai Adi and Malabari are found. The highly prolific meat breeds (Ganjam and Black Bengal) are found in the eastern region. Some other populations are also found in different parts of India like Andaman Feral goat, Barren goat, Teressa (A & N Islands); Bidari (Karnataka); Assamese hill goat (Assam) and Attapady Black (Kerala), Wild relatives of domesticated goat include Markhor, Himalayan lbex, Himalayan Tahr and Nilgiri Tahr.

**Sheep**

There are 44 breeds of sheep in India. A sizeable population of sheep is non-descript due to inter-mixing of breeds. These breeds can be classified on the basis of major product i.e. apparel wool (3 breeds), carpet wool (11 breeds), meat and carpet wool (15 breeds), and meat (15 breeds). Some of the sheep breeds are known for their unique characteristics like Magra for lustrous wool; Changthangi for fine wool; Garole for high fecundity; Chokla and Pasttanwadi for best carpet quality wool; Mandya for mutton; and Marwari, Decanni, Hassan, Jaisalmeri and Chokla for their hardiness and capability to travel long distances. Some other population groups like Kheri and Munjal in Rajasthan, Biangi in Himachal Pradesh and Dumba in Gujarat are also available.

Bharat Merino, Avikalin, Avivastra, Avimanns, Nilgiri Synthetic, Patanwadi synthetic, Kashmir Merino and Indian Karakul are synthetic breeds developed in India.

**Camel**

The camel in India are single humped (camelus dromedaries) although a very small number (about 100) of double-humped camel (Camelus bactrinus) are also present. Camel are used for transportation and agricultural operations. There are a total of 9 breeds (Bikaneri, Jaisalmeri, Kachchhi, Marwari, Mewari, Sindhi, Shekhawati, Mewati and Malvi).

**Horse**

There are 7 important breeds of Indian horses namely Kathiawari, Marwari, Bhutia, Manipuri, Spiti and Zanskari. Kathiawari is well known for its pace and speed, and possesses good endurance power. Manipuri breed is used for polo –racing and military transport.

**Donkey**

Three distinct types of donkeys; Indian donkeys, Indian wild and Kiang are available in India. Grey colour predominates but black, white and even piebaid colours are also seen. Indian wild donkeys are available in Rann of Kutch. Kiang is available in Sikkim, Himachal Pradesh and Ladakh, and is dark red brown with white underparts. Various types of donkeys have not been avaluated and characterized.

**Pig**

There are 10 types of indigenous pigs – Desi, Ghori and Anikamali. Some locally known populations are: Nocobari pigs and Andaman wild pigs (A & N Islands), Doom (Assam), and Ghungroo (West Bengal).

**Rabbit**

India does not have indigenous rabbits (Oryctolagus cuniculus), and the Hispid hare (Caprolagus hispidus) is the nearest related species. There are three major types of Indian hare. The black napped hare (Lepus nigricollis nigricollis) is found in most parts of the country, major concentration being in Southern India. The other variety of Indian hare is rufous-tailed hare (Lepus nigricollis ruficaudatus). Their distribution ranges from Himalayas to river Godavari. The desert hare (Lepus nigricollis dayanus) is found in Western desert zone of India.

Rabbits have been imported from other countries and reared under various agro-climatic regions. The various rabbit breeds available in India are New Zealand White, Soviet Chinchilla, Grey Giant, and White Giant for meat and fur, and Russian, British and German Angora for hair.

**Yak**

One breed have been identified in Indian yaks. Indian yaks can be classified into distinct types viz. Ladakhi, Himachal, Sikkim and Aunachal types. Wild yak (Bos mutus) is found in Changthang valley of Ladakh.

**Mithun**

There are three distinct types of mithuns viz. Nagami, Zosial and Arunachali. Nagami mithuns are mostly found in the Zunheboto district of Nagaland and the Ukhrul district of Manipur; Zosial are found in Mizoram and Arunachali in Arunachal Pradesh. Mithun is used primarily as a sacrificial animal and regarded as social status symbol. Wild Gaur (Bos Gaurus) is present in wild life sanctuaries.

**Poultry**

**Fowl:** India and the neighbouring countries in the east are considered to be the original home of the well-known Red Jungle Fowl (Gallus gallus) from which the present day domestic birds have descended. The fowl population of India can be classified into two types – desi/indigenous and improved/exotic. The birds are raised mostly by the rural folks as a backyard enterprise. About 19 breeds of fowl have been documented. The status of most of these breeds except Aseel, Kadaknath, Kashmir Faverolla, Miri and Nicobari is not known.

Most of the present day populations are commercial hybrids involving White Leghorn, Cornish, Barred Plymouth Rock, Rhode Island Red and Black Australorp. Some crossbred strains of fowl have been developed to use them for rural poultry production. Some of these are Giriraja, Vanaraja, Krishna-J. Yamuna, Kalinga Brown, Dhanraja, Mrityunjay, Cari Gold, Debendra, Nandanam-1, Girirani, Athula, Gramalakshmi, Gramapriya, Vanaraja.

**Duck:** Two breeds of Ducks have been documented, Pati and Maithili are mainly reared for egg production and are concentrated in Assam and Bihar state of India. Other Indian breeds of ducks are Indian Runner, Nageshwari, Sythetemete, Kuttanadu Chara and Chemballi, Khaki Campbel – a synthetic breeds is being used as an improver breed**.**

**Quail:** Japanese quail (Cotumix coturnix japonica) is the domesticated varsion of common wild quail (Coturnix coturmox). Indian subspecies of quail, viz. Rain, Grey and Button quail collectively known as 'Bater' has distinct popularity as game bird. Quails are seen in diversified colour varieties. Commonly seen plumage is a mixture of different shades of brown with some black patterns.

Besides the cultural and religious considerations for animals keeping, all the breeds of different domestic livestock and poultry species are contributing significantly to food and agriculture in terms of milk meat, wool, fibre, egg, manure, fuel and draft power. Variations in regional demand for animal products have influenced the use of different AnGR.

**The AnGR capable of surviving the following specific conditions are** :

| Conditions | AnGR |
|---|---|
| High altitude | Mithun, Yak, Changthangi, Gaddi, Gurez, Karnah, Poonchi, Rampur Bushaair, Bhakarwal and Nilgiri sheep; Changthangi, Chegu, Gaddi goat; Siri cattle; Double Humped Camel |
| Saline condition | Chilka Buffalo, Goat breed in Andamans |
| Desert | Nali, Chokla, Jaisalmeri, Magra, Kheri, Pungal, Marwari sheep; Rathi, Tharparkar cattle; Jhakrana, Sirohi, Marwari goats; camel. |
| Hot humid climate | Bachaur, Vechur, Umblacherry, Kangayam cattle; Balangir, Bonpala, Chotanagpuri, Ganjam, Garole, Tibetan and Madras Red sheep; Bengal and Ganjam goat |

## CONSERVATION OF GERMPLASM

Conservation is defined as the management of human use of the biosphere for the greatest sustainable benefit to present generation while maintaining its potential to meet the needs and aspirations of future generations. Thus, conservation is positive embracing preservation, maintenance, sustainable utilization, restoration and enhancement of the natural environment.

**Preservation:**

Preservation is the part of conservation by which a sample of animal genetic resource population is designated to an isolated process of maintenance, by providing an environment free of human forces which might bring about genetic changes.

**Reasons for Conservation:**

There are a number of reasons for the conservation of domestic breeds:

a) Genetic variation both within and between breeds is the raw material with which the animal breeder works to bring about genetic improvement through selection. Therefore, loss of genetic variation will limit our capacity to respond to changes in animal production in future.

b) Breeds with specific qualities like disease resistance, heat tolerance, prolificacy etc. may be required under special or low input conditions.

c) Magnitude of heterosis depends upon the breeds crossed. For exploiting heterosis it is necessary to maintain breeds that differ widely and combine well.

d) Indigenous breeds are linked intimately with the history and culture of a certain region or ethnic group. As such they are worthy of being preserved.

e) Future requirements of type and quality of animal produce (meat, milk, skin, draught power).

f) Breeds with unique physiological traits are of great values as they provide missing links in the genetic history eg. Study of blood group - biochemical polymorphism.

g) To evaluate magnitude of genetic change due to selection, maintenance of sample as controlled population is very much essential.

h) Variety of population are an assets for research workers in biological evaluation, behavioural studies, etc

i) Preservation with diverse sizes, colors and other morphological features, for aesthetic reason.

**CATEGORIES OF DOMESTIC POPULATION:**

**EXTINCT**: No possibility of restoring the population, no pure bred males or females can be found.

**CRITICAL**: Close to extinction, genetic variability reduced below that of ancestral population.

**ENDANGERED**: In danger of extinction, because of the number is too small to prevent genetic loss through inbreeding. Preservation must be enacted.

**VULNERABLE**: Some disadvantages effects endanger the existence of the population.

**INSECURE**: Population no. is decreasing rapidly

**NORMAL**: Population not in danger of extinction.

**Vulnerability of uniparous populations:**

| STATUS | NO. OF BREEDING FEMALES |
|---|---|
| Normal | more than 10000 |
| Insecure | 5000 to 10000 |
| Vulnerable | 1000 to 5000 |
| Endangered | 100 to 1000 |
| Critical | less than 100 |

**<u>Identification of breeds</u>**

However, a few important steps are to be initiated before embarking on the process of conservation. Though theoretically all breeds need conservation, it is not practically feasible. The breeds selected for conservation should have some unique features. The most important consideration is the number of breeding females that reaches a critical level below which the breed will be at risk. It is necessary to select some of the breeds for conservation based on the biological and economic values, genetic status, and their historical, ecological and social importance. However, when the number of breeding females in a breed is less than 750 in cattle, 1500 in sheep, 500 in goats, 150 in pigs, the breed is considered as endangered. Based on the number of breeding females the status of the breed may be classified as normal, insecure, vulnerable, endangered or critical.

**<u>Characterization</u>**

Characterization of a breed includes the study of the origin of the breed, geographical distribution, similarity with other breeds etc., Morphological features and utility of the breed are also to be documented. Purity of the breed should not be taken as homogeneity, since variability exists even within purebred populations. Purity essentially implies that the population is free from the influence of other populations. Of late the uniqueness of the breed is genetically determined by using microsatellite markers.

**Breed characterization includes**

1. General information
2. Demographic details
3. Morphological features
4. Economic traits
5. Economic uses
6. Managemental systems.

**Breeds need to be conserved: (Acharya, 1990)**

Cattle -Bachur, Dangi, Kenkatha, Siri, Kherigarh.

Buffalo - Toda

Sheep -Nilgiri, Hissardale, Mandya, Bhakarwal, Poonchi,Karnah, Gurez.

Goats - Jamunapari, Barbari, Surti.

Camel - Double humped camel

Poultry - All indigenous breeds of poultry will require urgent consideration.

**METHODS OF CONSERVATION:**

Once it has been decided to conserve a breed, basically there are two methods of conservation i.e. in situ and ex situ.

**In Situ Conservation :**

In situ conservation can be done either in the habitat or outside the habitat such as biological farms. The major advantages are that the animals are always available for immediate use and from aesthetic point of view; live animals are a pleasure to look at and create awareness among people. The limitation is that large numbers have to be maintained to avoid genetic drift and inbreeding. Maintenance of live animals in large number exclusively for conservation can be very expensive.

**Advantage:**

1. Live animals can be evaluated and improved over years.
2. Genetic defects, if any, could be eliminated
3. Live animals are always available for immediate use.
4. The expenditure of live animal maintenance is compensated from its produce.

**Disadvantage:**

1. More number of animals have to be maintained
2. If small population to be maintained considering cost of maintenance, inbreeding may result.

**Ex situ conservation**

Ex situ conservation consists of preservation in the form of frozen semen, frozen oocyte, frozen embryos, embryonic stem cells and DNA. Semen of at least 25 unrelated males must be preserved to avoid inbreeding in future generations. Embryos can be frozen and stored for longer periods without any genetic change. To maintain variability, embryos from 35 different matings may be obtained. The cost of maintenance of frozen embryos will be relatively cheaper compared to the maintenance of live animals.

1. **Haploid forms:** a.frozen semen
   b.frozen eggs / oocyte

2. **Diploid forms:** a. frozen embryos
   b. live animal -
   gene pools (with random mating)
   breeds or lines(with random mating)
   breeds or lines ( with divergent mating)

**Advantages:**

1. Easily done without any change in the genetic structure - population as a whole need not be maintained
2. Resource requirement for in situ preservation in quite large as compared to cryogenic methods.

**Limitations:**

1. *Ex situ* preservation using frozen semen delays the restoration of a breed.

2. An important danger faced by a breed restored from cryogenic is from the important changes in the environment like germs, climate, etc. that have taken place over the years.

The ideal situation will be a combination of *in situ* and *ex situ* methods. For conservation of any livestock breed the understanding and concern of the administrators and academicians are essential. Above all, the participation of the stake holders is vital for the success of the programme. At the global level, the Food and Agriculture Organization of the United Nations, Rome is the nodal agency for documentation and providing impetus for conservation. In India, National Bureau of Animal Genetic Resources, Karnal (Haryana) is the coordinating centre for the conservation of livestock genetic resources.

## APPLICATION OF REPRODUCTIVE AND BIOTECHNOLOGICAL TOOLS FOR GENETIC IMPROVEMENT OF LIVESTOCK AND POULTRY

The convention on Biological Diversity defines biotechnology as any biotechnological application that uses biological living systems, biological living organisms or derivatives thereof, to make or modify products or process for specific use.

The genetic variation in a population and the methods to exploit the genetic ability decides the magnitude of genetic improvement of livestock species. The traditional breeding programmes based on performance recording and crossbreeding have made genetic improvement in animal production. During the last two decades, newer technological breakthrough in the field of reproduction, genetics and related aspects have opened the new area of animal improvement.

### I. Reproductive biotechnologies :

The biotechniques in reproduction have made significant contribution in increasing the reproductive efficiency, global transport and multiplication of genetic material and conservation of unique genetic material for use in future. These techniques are A.I., E.T., embryo production and preservation, semen and embryo sexing, embryo splitting and cloning.

#### i. Artificial insemination (AI)

The AI has played a valuable role to bring genetic change in animal populations. 2 specific advantages of A.I. are:

a) Dissemination of superior germplasm by widespread use of outstanding males.
b) Introduction of new genetic material by importing semen instead of live animals,
c) Progeny testing under different environments so as to increase the rate and efficiency of selection
d) Use of frozen semen in future even after the death of sire.
e) Reduction in spreading the sexually transmitted diseases.

(ii) Frozen semen technology

It is also a valuable technique whereby the semen is stored for longer time without loss of viability for use in A.I. This may promote conservation of endangered genotype, though it requires cryopreservation facilities.

**(iii) Embryo transfer technology (ETT)**

It is a composite technology involving superovulation, estrus synchronization, A.I., embryo recovery, embryo transfer and sometime cryopreservation and micro manipulation of embryos. This augments the fertility of females and brings faster genetic change.

Super ovulation and AI: The donors selected are those which are genetically superior whereas the recipients are those having low production. The donors are super ovulated by injecting gonadotrophins mainly FSH and ECG between days and 12 of oestrus cycle. FSH is injected for 4-5 days daily twice whereas ECG | injected only once. The donors are inseminated during super oestrus with semen from fertile and high genetic merit bulls, Embryo recovery: The uterine horns of the super ovulated donors are flushed using phosphate buffer saline solution containing antibiotics and serum using & 2- way Rusch catheter. The outflow is passed through an embryo filter.

Embryo transfer: The embryos are transferred to the recipients. The successful pregnancy (implantation) rate is about 50%.

The ETT has certain advantages:

a. Rapid multiplication of rare genotype
b. Low cost in transporting embryos instead of living animals which also require quarantine.
c. Rapid improvement of livestock to produce elite herd Twinning rate can be increased
d. Prenatal sex determination
e. Control on sexually transmitted diseases

f. Animal conservation programme

**(iv) In vitro produced (IVP) Embryos**

The embryos can also be produced in vitro which involves the in vitro maturation (IVM) of oocytes, followed by fertilization (IVF) with the use of in vitro capacitated spermatozoa. The newly formed zygotes are cultured in suitable media to develop upto the transferable stage. Therefore, the in vitro production (IVP) of embryos technology requires the following steps:

a. Collection of immature oocytes- Following a local anesthesia, an ultra sound probe is inserted into the vagina to puncture the follicle> 2 mm diameter using a transvaginal curvilinear transducer, This is known as ovum pick-up (OPU)
b. Maturation of oocytes (IVM)-in culture medium preferabley TCM 199
c. Sperm capacitation-by use of Heparin
d. in vitro Fertilization (IVF)- in fertilization medium
e. Culture of embryos — In culture media
f. Embryo sexing, freezing and transfer to the uterus

The IVP embryos technology thus allows the repeated collection of oocytes for bulk production of high quality embryos from livestock of high economic value or unique genotype or endangered genotype so as to propagate such genotype at a much faster rate.

**(v) Embryo cryopreservation**

Like freezing of semen, the freezing of embryos is possible and is a practice. It is useful as a conservation programme for endangered or unique genotype so as to propagate such genotype at a faster rate.

**(vi) Embryo splitting**

The embryo splitting is a beneficial technique in which the embryo is divided into halves to have two embryos or into one quarter to get 4 embryos or sometimes to get 16 embryos from single embryo. The aim of embryo splitting is to obtain greater number of offspring from a given donor. The halving or quartering of embryos increases the intensities of selection for females nearly to that of males. The identical twins can be thus produced which will facilitate sire testing, reduction in Insemination cost, testing of maternal traits, to study the interactions and to have info by sacrificing one twin. However, the survival rate of split embryos is less.

**II. Genetic biotechniques**

More recent biotechniques in the field of genetics have demonstrated the potential for genome analysis and manipulation of genome.

**(i) Genome analysis**

This includes the study of chromosomal karyotyping, chromosomal aberrations and genetic characterization of population to know the variation in blood groups biochemical polymorphism and DNA markers.

The methods of examining DNA polymorphism may be divided into two categories as under:

(a) **Site directed polymorphism**: This involves the techniques to search known sequences or genes for polymorphism. These include restriction enzyme polymorphism (RFLP), sequence polymorphism, sequence — specific oligonucleotides and conformational polymorphism.

i. **Sequence polymorphism:** All methods of describing differences between the DNA of animals depend upon detecting differences in the neucleotide sequence. This method is more efficient to determine the sequence of a specific gene.

ii. **Restricted fragment length polymorphism (RFLP):** These are the fragments of DNA produced by cutting with restriction enzymes. There exists a large battery of restriction enzymes which cut DNA at specific sequences; these recognition sites may be 4-8 bases long. If an enzyme cuts the DNA of some but not all animals at a particular site then a polymorphism is inferred in atleast one of the bases in the recognition site.

iii. **Sequence specific oligonucleotides**: These are sets of PCR (Polymerase Chain Reaction) primers which function in an allele specific manner.

iv. **Conformational polymorphism**: They are used to detect polymorphism in specific locations which relies upon detecting sequence-specific mobility of PCR products under electrophoresis

(b) **Anonymous polymorphis**: Which covers the methods which reveal arbitrary polymorphism i.e. polymorphism which are developed on a purely random basis. These include minisatellite, microsatellite, RAPD (Random Amplified Polymorphic DNA) markers.

a. **Minisatellite and Microsatellites**: They are the regions of repeatitive DNA and are highly polymorphic spots on non-coding regions characterized by repeating DNA blocks each of which contains upto several hundred of base pair in size. The minisatellites are tandom repeats of short sequences (15-60 bp long), interspread in the most chromosomes.

b. **Random Amplified polymorphic DNA (RAPD)**: This is another form of variation useful in DNA polymorphism analysis with high level of detectable polymorphism. It is the polymorphic DNA which is amplified randomly by PCR analysis. Randomly designed single primer is used to amplify a set of anonymons polymorphic DNA fragments. When the primer is short, the priming may take place at several sites in the genome that are located within amplifiable distance, The polymorphism detected by this method is called RAPD.

**ii. Manipulation of genome**

**(a) Transgenesis**

The genetic composition of an individual can be altered now. The technique uses the genetic engineering technology to put single functional gene or gene clusters into the chromosomal DNA. The foreign DNA is introduced into th animal such that all the cells of an animal including germ cells are genetically changed. The animal whose genetic composition is altered by introducing foreign (exogenous) DNA is said to be transgenic. This whole process is called the transgenesis.

**(b)Cloning**

The cloning has been successfully achieved in animals using early embryonic source material (sheep, cattle, pig), nuclear transplantation, embryonic cultured cell line and somatic cells of adult animals (Dolly sheep and cattle). Clones have been produced using embryonic, foetal and adult cells. The cloning involves the fusion of a donor cell (embryonic or somatic) to an oocyte or zygote (of the recipient) following its enucleation. Thus the genetic material of the donor cell is transferred to the enucleated recipient cell. The recipient cell is usually a secondary oocyte which can be obtained following ovulation in vivo or by in vitro maturation of oocytes. The enucleation (removal of genetic material) accomplished either by splitting the oocyte or by removing the chromosomes by aspiration. The cloning technology has certain promises viz.

(i) Cloning of a proven valuable animal

(ii) Creation of thousands of precise duplicates of genetically engineered animals in a single generation

(iii) It is much simpler and effective means of conservation of breeds, biopsies, hair follicles and blood samples might be suitable sources of to grow in the laboratory and frozen for long term storage

(iv) It may be used to increase population size

(v) It may use the embryos cloned from cells of high performing F1 individuals to retain heterosis

## Breeding for Disease Resistance in Animals

Disease resistance is often defined as reduction of pathogen growth on or in the animals. It denotes less disease development in a genotype than that in the susceptible variety and is a relative attribute. Generally, the rate of reproduction is considerably reduced which limits the spread of disease. Animals are almost always resistant to certain pathogens but susceptible to other pathogens; resistance is usually pathogen species-specific or pathogen strain-specific.

### Types of Disease Resistance

#### 1. Vertical Resistance

It is qualitative resistance or race specific resistance governed by major genes and is characterized by phenotype specificity it is easily overcome by new races of the pathogen.

#### 2. Horizontal Resistance

It is Quantitative or durable resistance, controlled by polygene's and is host nonspecific. These genes provide the animals with defensive structures or toxic substances that slow down or stop the advance of the pathogen into the host tissues and reduce the damage caused by the pathogen. The defenses in quantitative resistance develop slower and perhaps reach a lower level than those in the race specific resistance. It is durable resistance and never breaks down to new strains of disease, as doe's vertical resistance.

The type of resistance term was coined by Vanderplank.

### Steps in breeding for Disease Resistance

1. **Identification of Resistant Breeding Sources**: Animals that may be less desirable in other ways, but which carry a useful disease resistance trait. Ancient known animals and wild relatives are very important to preserve because they are the most common sources of enhanced disease resistance. Others include mutations, somaclonal variation and unrelated species.

2. **Breeding Methods:** Crossing of a desirable but disease-susceptible animal variety to another variety that is a source of resistance, to generate livestock populations that mix and segregate for the traits of the parents. The methods of crossing include selection, introduction, marker assisted selection, genetic engineering; hybridization includes backcross, pedigree methods. Among these methods marker assisted selection & backcross methods are important.
3. **Screening**: This may require artificial epidemics created by inoculation of pathogen on to the animal population.
4. **Selection of Disease-Resistant Individuals**: Breeders are trying to sustain or improve numerous other animal traits related to yield and quality, including other disease resistance traits, while they are breeding for improved resistance to any particular pathogen. Each of the above steps can be difficult to successfully accomplish, and many highly refined methods in animal breeding and are used to increase the effectiveness and reduce the cost of resistance breeding.

**Advantages of Breeding for Disease Resistance**

a) Resistant varieties offer the cheapest means of disease control.
b) Resistant varieties obviate the use of medicines ,thus reduce environmental pollution
c) Effectiveness of resistant varieties is not affected by environmental conditions.
d) It safeguards against the inadvertent release of such varieties that are most susceptible than earlier varieties.

**Problems in Breeding for Disease Resistance**

a) Resistance breakdown
b) Horizontal resistance being durable but difficulty relates to an accurate & reliable assessment of the level of resistance.
c) Sometimes there is negative correlation between yield & disease resistance
d) For introgression of multiple resistances in varieties against several diseases requires meticulous planning and far greater effort than that required for single resistance.

# Pet Animal Breeding

## Dog breeding

A pet or companion animal is a domestic animal kept for a person's company, amusement and enjoyment as opposed to livestock, laboratory animals, working animals and sport animals which are kept for economic reasons. They are kept for their attractive appearance and their loyal or playful characteristics or for their songs.

Pets also generally seem to provide their owners with non-trival health benefits, helps to relieve stress. There us now a medically – approved class of "therapy animals" mostly dogs that are brought to visit confined humans. Walking a dog can provide both the owner and the dog with exercise, fresh air and social interaction.

The most popular pets are Dogs, Cats and Birds (Parrot, Myna, love birds) and few fancy species of rodents like guinea pigs, hamsters and fancy (white) rats . Even peacocks, fishes are also kept in many household as pets.

Animal welfare and over population are the problems (concerns in keeping pet animals.

## Kennel club or Kennel council or canine council

is an organization for canine affairs that concerns itself with the breeding, showing and promotion of more than one breed of dog.

A club that handles only one breed is known as a breed club. Kennel clubs handles only purebred dogs, not hybrid or cross breds.

The kennel club of India was established in 1978

## Role of Kennel club:

1. Undertake registration of purebreds and maintain the recognized registry.
2. Maintain breed standards
3. It issue pedigrees for purebreds and litters
4. It issue the rules for conformation dog shows and trails and accreditation of judges.

5. It host annual shows across the country and awards championships to various breeds of dogs.

Kennel club of the United Kingdom is the oldest recognized Kennel club in the world. As of 2011the KC recognized 211 breeds of dog. But FCI (World Canine Organization) recognizes 343 breeds. The important kennel clubs are (FCI), American Kennel Club, Australian National Kennel Council, Canadian Kennel Club, The Kennel Club, New Zealand Kennel Club and United Kennel Club

**Pedigree sheet**

Pedigree is a record of an individual's ancestors related to it through its parents or pedigree of an animal is a record of its ancestor, which includes sire, dam, grand sire grand dam and earlier ancestors.

- Pedigree is normally maintained up to 4 generations.
- Both parents should be registered with the kennel club of the place.
- The pup should be eligible for registration in a kennel club or dog breeders' association, otherwise the market value of the dog and its progeny may be less than of the registered dogs.

## Classification of Breeds of Dogs

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Carnivora

Family: Canidae

Genus: Canis

Species: C. lupus

Subspecies: **C. l. familiaris**

**Dog:** The Diploid number of Chromosomes (2n) = 78

The domestic **dog** (*Canis lupus familiaris*) is a subspecies of the gray wolf (*Canis lupus*), a member of the Canidae family of the mammalian order Carnivora. The dog was the first domesticated animal and has been the most widely kept working, hunting, and pet animal in human history.

Dogs have been selectively bred for thousands of years, sometimes by inbreeding dogs from the same ancestral lines, sometimes by mixing dogs from very different lines. The process continues today, resulting in a wide variety of breeds, hybrids, and types of dog. Centuries of selective breeding by humans have resulted in dogs being considerable more genetically diverse then most other mammals, and as such dogs are the only animal with such a wide variation in appearance without speciation, "from the **Chihuahua** to the **Great Dane".**

# Classification of Breeds of Dogs

The **American Kennel Club** (AKC) divides dogs into seven groups. The breed of choice depends on the utility and preference

The British Kennel Club **The Kennel Club** classified the domestic dogs into seven main groups on the basis of body size, morphology, behavior, place of breeding (origin) and utility

| American Kennel Club | British Kennel Club |
|---|---|
| **1. Sporting Group(Gun dogs)** | **1. Gundogs** |
| **2.Non-sporting Group (Utility)** | **2. Utility Breeds (Non-sporting Breeds)** |
| **3.Working Group** | **3. Working** |
| **4.Herding Group** | **4. Pastoral** |
| **5.Hound Group** | **5. Hound Breeds** |
| **6.Terrier Group** | **6. Terrier Breeds** |
| **7.Toy Group** | **7.Toy Breeds** |

## Classification of Dog breeds based on other traits

**Based on Size :** Small dog breeds, Medium dog breeds, Large dog breeds and Giant dog breeds

**Based on Characteristics**

Smartest dog breeds

Best family dog breeds

Hypoallergenic dog breeds

Best guard dog breeds

Kid friendly dog breeds

Fluffy dog breeds

Best watch dog breeds

Easy to train dog breeds

Low shedding dog breeds

**Based on Color Type:** White dog breeds, Black dog breeds, Blue dog breeds, Brown dog breeds, Red dog breeds Grey dog breeds, Golden dog breeds

**Top 30 Dog Breeds**

| | | |
|---|---|---|
| 1.Labrador Retriever | 11.Shih Tzu | 21.Cavalier King Charles Spaniel |
| 2.German Shepherd Dog | 12.Miniature Schnauzer | 22.Boston Terrier |
| 3.Beagle | 13.Doberman Pinscher | 23.Maltese Dog |
| 4.Golden Retriever | 14.Chihuahua | 24.Australian Shepherd |
| 5.Yorkshire Terrier | 15.German Shorthaired Pointer | 25.Pembroke Welsh Corgi |
| 6.Bulldog | 16.Siberian Husky | 26.Pug |
| 7.Boxer | 17.Pomeranian | 27.Cocker Spaniel |
| 8.Poodle | 18.French Bulldog | 28.English Mastiff |
| 9.Dachshund | 19.Great Dane | 29.English Springer Spaniel |
| 10.Rottweiler | 20.Shetland Sheepdog | 30.French Brittany |

**Commonly seen breeds of dog in India**

| | | |
|---|---|---|
| 1.Alsatian /German Shepherd | 8. Dobermann Pinscher | 15. Pug |
| 2.Beagle | 9. Great Dane | 16. Labrador |
| 3.Boxer | 10. Greyhound | 17. Golden Retriever |
| 4.Bull Dog | 11. Lhasa Apso | 18. Saint Bernard |
| 5.Collie | 12. Pointer | 19. Cocker spaniel |
| 6.Dachshund | 13. Pomeranian | 20. Rottweiler |
| 7. Dalmatian | 14. Poodle | |

**SPORTING GROUP (Gun dogs)**

Dogs that were originally trained to find live game and/or to retrieve game that had been shot and wounded. This group is divided into four categories - Retriever, Spaniels, Hunt/Point/Retrieve and Setters although many of the breeds are capable of doing the same work as the other sub-groups. They make good companions, their temperament making them ideal all-round family dogs. It is said that they are perhaps the most intelligent of the breeds, resulting in their wide variety of uses and their ease of training. They are active dogs requiring plenty of exercise and attention.

- Cocker Spaniels will not abide rough handling or teasing.
- The stars of the sporting group are the Golden Retriever and Labrador Retriever. They enjoy the attention of well-behaved children and will usually put up with some bratty

behavior. They are relatively easy to train, easy to care for, and often seem to be perpetually young.

- The setters are very high energy dogs that are fine for active families, and the pointers are working dogs that tolerate children but are not particularly easy to train as house pets.
- **Breeds commonly seen in India: Cocker spaniel, Golden Retriever, Labrador, Pointer**

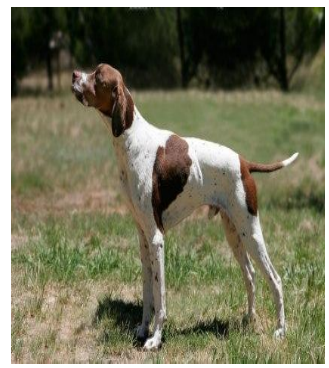
**Sporting group breeds should be kept confined in a secured fence, they enjoy the attention of well behaved children, easy to train and care.**

**Labrador**

**Golden Retriever**

**Cocker Spaniel**

**Pointer**



**LABRADOR**

The Labrador Retriever is a strongly built, medium-sized, short, a dog with a sound, athletic, well-balanced conformation that enables it to operate as a hunting dog for long hours in difficult conditions, and the temperament to be a family companion. The Labrador Retriever is the most intelligent and easiest to train of all dog breeds.

- **Origin –** United Kingdom, Canada.
- They have webbed paws for swimming, useful when they retrieve their prey, hence the name retriever
- Active dog of strong body
- Coat short, dense, smooth and glossy
- Colour black, chocolate or yellow and free from markings
- Ears large and hanging close to head
- Height 50-60 cm and body weight 25-35 kg; tail thick at the root and tapering toward the tip
- **Temperament :** Gentle, Intelligent, good-tempered, kind, outgoing, Agile.

- **Best :** Good with kids, dog friendly, trainability, adaptability, intelligence (ranking 7), popularity (ranking 1).

**GOLDEN RETRIEVER**

Golden Retriever, an active and powerful animal.He's highly intelligent and trainable. He loves to play games and have fun. Coat flat or wavy and dense with water-resistant undercoat. Ears moderate in size,Tail long, straight and feathered.

- **Origin** - Scotland
- Active and powerful animal
- Coat flat or wavy and dense with water-resistant undercoat
- Colour any shade of gold and cream but not red or tan
- Ears moderate in size
- Height 50-60 cm and body weight 30-35 kg
- Tail long, straight and feathered.
- **Temperame**nt: intelligent, kind, friendly, confident, reliable, trust worthy.
- **Best:** Good with kids, trainability, dog friendly, intelligence (ranking 4), popularity (ranking 4) and adaptability.

**COCKER SPANIEL**

American Cocker Spaniel originated in the United States, its ancestor is Spain's bird dog.

They love people and crave attention and affection from their masters

- **Origin** - England
- Small sporting dog of compact body
- Head round with deep and broad muzzle
- Ears long, drooping and covered with fine hair;
- Coat flat, close, silky, soft and wavy of black, black and tan, liver-red and roan colour
- Height 35-40 cm and body weight 11-13 kg
- The tail docked in early life and remains in line with the back.
- **Temperament:** outgoing, sociable, even tempered, trusting, joyfull, and Merry.
- **Best:** Good with kids, dog friendly and adaptability.

**POINTER**

Pointer is a medium sized dog, well balanced with distinctive face"square", floppy ears, and a tail that is carried Hanging when the dog is standing and the level of the back or slightly above when the dog is moving.

- **Origin** - Spain
- Active dog
- Compact and muscular body with broad chest; coat short, fine, smooth and uniformly distributed
- Colour lemon, orange, lemon and white, liver and white, black and white and sometimes whole black
- Ears set fairly high, medium sized and lying close to the head
- Height 60-65 cm and body weight 25-30 kg
- Tail fairly long, smooth, tapering and carried straight in line with back.
- Temperament: Lively, affectionate, submissive and calm.

## NON-SPORTING DOGS (Utility group)

The name "Utility" basically means fitness for a purpose and this group consists of an extremely mixed and varied bunch, most breeds having been selectively bred to perform a specific function not included in the sporting and working categories. This is a diverse group of dogs ranging in size from the small Bichon Frise to the 60-pound Dalmatian and including the Finnish Spitz and two of the three Poodle varieties. These dogs have come to be known as companions even though they started out with a variety of jobs in their native lands.

- English Bulldog was designed to grab a bull by the snout and hang on for dear life until the animal could be killed.
- The Standard Poodle was a German hunting dog, Of the non-sporting dogs, the Dalmatian and Chow Chow are probably the most misunderstood. The Dalmatian is an active, independent, athletic dog that needs a firm hand
- The personalities of these dogs range from the calm of the Bulldog to the high energy of the Dalmatian and cover about everything in between. Families looking for a Dalmatian should choose their source very carefully to avoid getting a hyperactive, fearful, aggressive, or deaf puppy.

- The remaining non-sporting breeds are Boston Terrier, Bulldog, French Bulldog, Lhasa Apso, Schipperke, Tibetan Spaniel, Tibetan Terrier.

***Known for companionship, available in various size.***

**Breeds commonly seen in India: Bull Dog, Dalmatian, Lhasa Apso and Poodle**

| Bull Dog | Dalmation | Lhasa Apso | Poodle |
|---|---|---|---|
|  |  |  |  |

**BULL DOG**

The perfect Bulldog must be of medium size and smooth coat; with heavy, thick-set, low-swung body, massive short-faced head, wide shoulders and sturdy limbs. The general appearance and attitude should suggest great stability, vigor and strength.

- England
- A low statured animal, broad and compact body
- Head characteristically heavy and face wrinkled; nose short, wide and black; jaws broad and square
- Body coat short, fine and smooth; whole coat colour acceptable and it may be various degree of red, brindle, fawn, fallow and white, and their piebald combinations
- Short tail thick at the root and tapering at the tip
- Males heavier than females; average height 35-40 cm and body weight 20-25 kg
- Temperament: friendly, docile, gregarious, willful.
- Best: good with kids, cat friendly, dog friendly, watchdog, popularity (ranking 6), adaptability.
- It is a Hypoallergenic dog.

**DALMATIAN**

Dalmatian the origin of Yugoslavia. Calm and alert, contour symmetry, strong, muscular, and lively, not shy expression, be clever and sensible, obedient easy training, perceptive, vigilance is strong, easy to get along with children. The Dalmatian dog has great powers of endurance, and run very fast.

- Origin from Dalmatia (Austria)
- Strong dog having muscular Body
- Body coat smooth and white colour with black spots or liver spots which may vary in size but never form patches
- Ears set high and gradually tapering to a round point and covered with spotted hair
- Height -50-60 cm and body weight 22-25 kg; tail short, fine and straight.
- **Temperament** : Active, playful, intelligent, outgoing, friendly, energetic and sensitive.
- **Best :** Good with kids, dog friendly, trainability, intelligence and, adaptability.

**LHASA APSO**

Lhasa dog body looks like a lion, hair long and rich, especially the head, ears, tail hair is the most abundant, can be dragged to the ground. It is the ideal family dog. Lhasa is also known as the "holy dogs of exorcism".

- **Origin** - Tibet
- Small active house dog
- Body completely covered with long, straight, dense coat with golden, smoke, slaty, black, white, brown or parti-colour
- Ears drooping and eyes dark
- Average height 20-25 cm and body weight 6-7 kg.
- **Temperament:** Energetic, layful, fearless, friendly, assertive, intelligent, lively, spirited and alert.
- **Best :** Good with Kids, friendly with cat and dog,

**POODLE**

Poodle called " poodle ", is a very intelligent and loves hunting dog.

- **Origin -** Germany
- A small animal of majestic look
- Various strains are standard Poodle, miniature Poodle, blue Poodle and toy Poodle
- Coat thick, curly and fluffy of different colours like whole white, black, brown, apricot, blue and silver
- Ears long, wide and drooping
- Height 25-40 cm and body weight 3-25 kg, depending upon the strain
- Toys are smallest followed by miniature and standard strains
- Tail docked and held high.
- **Temperament :** Active, intelligent, alert, faithful, trainable, instinctual.
- **Best :** Trainability, watchdog, intelligence, popularity, adaptability.

**HERDING DOGS** (Pastoral dogs)

Herding dogs that are associated with working cattle, sheep, reindeer and other cloven footed animals. Usually this type of canine has a weatherproof double coat to protect it from the elements when working in severe conditions. Many are favorites for obedience competition for their strong working bond with their owners. They are mostly medium-to-large in size, Several of these breeds have gone on to excel in police work, search and rescue, tracking, service to handicapped owners, and as sentries and couriers during wartime.

The German Shepherd, a versatile working dog, is part of this group, as is the Border Collie.

The Border Collie is not a breed for everyone. It is very smart and must be kept very busy. Border Collie rescue always has several dogs whose owners did not realize these things before they bought the dog.

The other herding breeds are calmer. The German Shepherd is prone to temperament problems because of over breeding, so it is imperative to seek out a responsible breeder who deals only in dogs of good temperament. The German Shepherds from European working lines tend to have higher drives than the US dogs; these dogs also must have work to do or they can become destructive.

**Breeds commonly seen in India: Collie and German Shepherd**

| German Shepherd | Border Collie |
|---|---|
|  |  |

The rough-coated Collie is a true family companion. If grooming is not in your repertoire, try smooth-coated version of the breed. The Old English Sheepdog must be groomed often to prevent mats and is somewhat hard-headed.

***Herding dogs are more active, intelligent, courageous and determined*. They need meaningful exercise**

**ALSATIAN / GERMAN SHEPHERD**

German Shepherd is a strong, agile, well muscled, alert and energetic. Very smooth, very harmonious front and rear hindquarters.

- Place of origin Germany
- As part of the herdig group, the German Shepherd is a working dog developed originally for herding sheep. Because of their strength, intelligence and abilities in obedience training they are employed as police dogs and war dogs, around the world. The German Shepherd Dog is the world's leading police, guard and military dog
- A double-coated animal
- Hair smooth and glossy
- Under-coat woolly and protects from cold

- Usually grey, dark tan and various shades of black and white
- Average height of male 60-70cm and of female 55-60 cm
- Body weight 25-35 k
- Ears are erect and smooth
- well-muscled, strong and long neck
- Long hairy tail slightly curved at the end, may extend up to the hock.
- **Temperament:** Gentle, intelligent, good tempered, kind, outgoing and agile.
- **Best:** Good with kids, trainability, watchdog, intelligence, popularity and adaptability.

**COLLIE** ( Rough Collie , Smooth Collie, Border Collie)

He was an excellent shepherd, he is willing to learn and be content. . IQ is equivalent to a 6-8 year old child, smart is one of his characteristics. Suitable for living outside, need a large number of sports, is a very good guard home dogs.

- A collie is a distinctive type of herding dog.
- Ultimately originating in Britain, especially in the upland areas of the north and west.
- It is a medium-sized, fairly lightly-built dog with a pointed snout, and many types have a distinctive white pattern over the shoulders.
- Collies are very active and agile, and most types have a very strong herding instinct.
- Common use of the name "collie" in some areas is limited largely to certain breeds – such as to the Rough Collie in parts of the United States, or to the Border Collie in many rural parts of Great Britain.
- The fur may be short, flat, or long, and the tail may be smooth, feathered, or bushy
- vary in colouration, with the usual base colours being black, black-and-tan, red, red-and-tan, or sable.
- Many types have white along with the main color, usually under the belly and chest, over the shoulders, and on parts of the face and legs.
- **Temperament :** Intelligent, alert, energetic , tenacious and responsive.
- **Best:** Good with kids, trainability, watchdog, intelligence, popularity and adaptability.

**WORKING BREEDS**

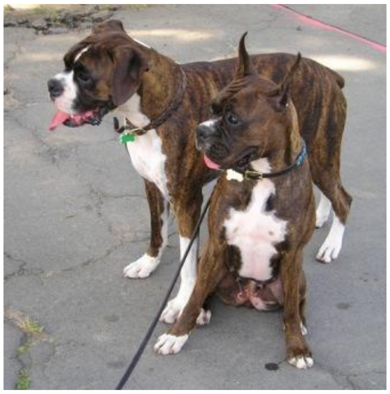
Over the centuries these dogs were selectively bred to become guards and search and rescue dogs. Arguably, the working group consists of some of the most heroic canines in the world, aiding humans in many walks of like, including the Boxer, Great Dane and St. Bernard. This group consists of the real specialists in their field who excel in their line of work.

- The working dogs are medium-to-giant size and are often independent and difficult to manage. Some were developed to guard palaces, homes, and livestock, occupations that require true grit. Others were draft animals, hauling carts of fish or cheese or carrying the worldly goods of nomadic tribes.
- Several of these breeds are jacks of many trades; Rottweiler as a cattle drover and farmer's protector; and Akitas as palace guards and big game hunters.
- Many of these breeds are aloof and independent with strangers. Working dogs should be accustomed to children at an early age, for a child's staring, quick and unpredictable movements, and high-pitched voice can trigger prey drive in unsocialized or poorly socialized adults of these breeds.
- With few exceptions, working breeds are not suitable for first time dog owners without a commitment to formal obedience training and willingness to establish and maintain control from the moment the puppy walks in the door.
- Many of the working breeds have thick, downy undercoats and moderately long topcoats that shed once or twice each year. The undercoats are fine and drift everywhere; the topcoats are somewhat coarse and can pierce human skin. During shedding, these dogs should be combed daily.
- Many working dogs are susceptible to degenerative joint disease, particularly hip dysplasia, and should only be purchased from breeders who clear their breeding stock of this genetic abnormality.

Often independent and difficult to manage. Not suitable for first time dog owners, hairs tends to shed regularly and need combing, many are susceptible to degenerative joint diseases.

**Breeds commonly seen in India: Boxer, Great Dane, St. Bernard, Rottweiler, Dobermann Pinscher and Mastif**

**Boxer**



**Dobermann Pinscher**

**Great Dane**

**St. Bernard**

**Rottweiler**

**BOXER**

The shape and appearance pretty strong. Head and body is quite big, black nose. Ear growth position is higher, ordinary workers cut the tip of ear. The body is square, a short tail, always hold high. Best guard dogs, can also be used for guide dogs for the blind. Because of its compliance is good, is a good companion dogs.

- **Origin** - Germany
- A medium-sized sturdy dog with broad head, short nose and strong jaws
- Muscular body covered with smooth coat of red, fawn or brindle
- Tail placed high and docked leaving behind 4-5cm stump .
- **Temperament:** Playful, intelligent, friendly, devoted, loyal, energetic, calm, fearless, brave. Best watchdog.

**GREAT DANE**

Great Dane made in Germany, from Denmark. Great Dane dog clever, brave, loyal to their masters. Tall in stature, body height more than 70cm, weight 45kg above. It is the dog fighter, quick-tempered, vindictive, easy training, can raise cultivate ability and obedience command guard dog.

- **Origin** - Germany
- Large-sized, muscular and strong animal of active disposition
- Coat short, dense, soft and glossy
- Colour whole black, fawn, pure white with black or blue patches
- Ears small and erect with falling tip
- Face long and narrow
- Average height usually more than 75 cm and body weight more than 55 kg
- Tail thick at the root and tapering to the termination below the hock joint.
- **Temperament :** Gentle, friendly, devoted, reserved, confident, loving.
- Best watchdog.

**DOBERMAN PINSCHER**

The Doberman Pinscher is military and police dog. Medium in size, body is square. Compactly built, muscular and powerful, for great endurance and speed. Looks elegant attitude, self-confidence, showing their noble temperament. It is lively, alert, firm, smart, brave loyal and obedient.

- Origin from Germany
- An alert dog has smooth, compact and muscular body
- Body coat smooth, short, thick, and glossy , Colour black, brown or blue
- Extremities light in colour; ears small and erect, but slightly droped forward
- Tail docked in early life leaving behind 2-3 cm long stump
- Height of adult male 65-70 cm and of adult female 60-65 cm; body weight 25-35 kg.
- **Temperament :** Intelligent, alert, obedient, loyal, energetic, fearless.
- **Best :** trainability, watchdog, intelligence, adaptability.

**SAINT BERNARD**

The saint bernard dog mostly hybrids. It is a kind of be worthy of the name of the giant working dogs, weight can reach 100 kg, height up to 1 meters.Saint Bernard dog kind, friendship, love and children together. It is loyal to his master. In Denmark, whenever a storm, they display one's skill to the full, save countless distress in the snowfield in.

- **Origin** - Switzerland
- One of the heaviest dogs with a massive and broad forehead, straight back, deep chest and heavy legs
- Coat either short-haired or long-haired
- Thighs and tail well feathered in long-haired dogs
- Height 65-75 cm and body weight 75-90 kg
- Occasionally 90 to 100 kg in some specimens
- Tail set high, long and slightly curved, and always carried low.
- **Temperament :** Friendly, lively, calm, watchful, gentle.
- **Best :** Good with kids, friendly with cat and dog and watchdog.

**THE ROTTWEILER**

The Rottweiler physically strong, moves rapidly, momentum is powerful, is one of the most has the courage and strength of the dog in the world. The dogs have been used for guarding the cows are wise and strong, easy to breed. The Rottweiler is good dog, to attack the intruder. In order to let the dog did obey orders, breeders should strict training, dogs born with the talent, in the middle ages, rich businessmen in order to avoid the money stolen, the purse hanging in the Rottweiler neck.

- The Rottweiler, or Rottweil *Metzgerhund* ("Butchers Dog"), is a "medium to large size, stalwart dog"
- Breed originating in Germany as a herding dog.
- It is a hardy and very intelligent breed.
- Rottweilers also worked as draught dogs, pulling carts to carry livestock to slaughter, meat and other products to market.
- Some records indicate that earlier Rottweilers may have also been used for hunting although the modern Rottweiler has a relatively low hunting instinct.
- The skull is of medium length, broad between the ears. The forehead line is moderately arched as seen from the side.

- The coat consists of a top coat and an undercoat. The top coat is of medium length, coarse, dense and flat. The undercoat must not show through the top coat. The hair is a little longer on the hind-legs.
- **Temperament:** Alert, good-natured, steady, devoted, obedient, self assured, courageous and calm
- Best watchdog, and intelligence and popularity.

**HOUND GROUP**

Two basic types are scent and sight hounds. Scent hounds are lethargic, almost frenzied to get about the business, difficult to train for obedience. They require a significant amount of exercise and can be described as dignified, aloof but trustworthy companions. The hounds come in many sizes. The scent hounds, who follow their noses anywhere, and sight hounds, whose gaze lingers on the horizon in the search for game..

- The scent hounds are friendly critters accustomed to working with their handlers in the field. Sigh hounds, bred to work independently of the hunter, tend to be aloof and rather tough to obedience train.
- The scent hounds are Basset; Beagle; Black and Tan Coon hound; Bloodhound; Dachsunds (three coats types - wire, smooth, and long and two sizes - standard and miniature);
- The sight hounds are pictures of grace and elegance with their long legs, slender bodies, and long noses. They are Afghan Hound; Greyhound; Ibizan Hound; Irish Wolfhound; Saluki; Scottish Deerhound; and Whippet. Rhodesian Ridgebacks are also used as guard dogs, and Greyhounds still race at tracks in several states.

## Breeds commonly seen in India: Beagle, Dachshund and Greyhound

**Beagle**

**Dachshund**

**Greyhound**

**BEAGLE**

Beagle, also known as "Beagles", is a hunting dog. Frequently ranked in the top ten of the most popular dogs in the United States, Japan. Standard shape: the head was a large dome shape, large hazel-colored eyes, muscular body and tail more coarse.

- The Beagle is a breed of small to medium-sized dog.
- A member of the Hound Group, it is similar in appearance to the Foxhound
- But smaller, with shorter legs and longer, softer ears.
- Beagles are scent hounds, developed primarily for tracking hare, rabbit, and other game.
- They have a keen sense of smell and tracking instinct that sees them employed as detection dogs for prohibited agricultural imports and foodstuffs in quarantine around the world.
- Beagles are intelligent, and are popular as pets because of their size, even temper, and lack of inherited health problems.
- These characteristics also make them the dog of choice for animal testing.
- **Temperament :** Gentle, intelligent, even tempered, determined, amiable andexcitable.
- **Best :** Good with kids, dog friendly and popularity.

**DACHSHUND**

Dachshund is a short, long, canine. The name derives from German, meaning " badger dogs ". This breed was developed for the tracking, and hunting badgers and other burrowing animal. Interestingly, although the word "Dachshund" is a German word, but it is not commonly used in Germany, the Germans often call it Dackel or Teckel.

- Germany
- Low set, short limbed animal with compact long body
- There are 2 recognized strains of Dachshund, via. Dachshund and Miniature Dachshand; each strain has 3 varieties, viz.
    - smooth haired,
    - long haired and
    - wire haired.
- Ears long and thick, large and drooping with rounded tip; height 20-25 cm and body weight 3-5 kg.
- **Temperament :** Clever, courageous, devoted, lively, playful and stubborn.
- **Best :** Watchdog, popularity and adaptability.

**GREYHOUND**

The Greyhound is an athlete, strong, balanced and elegant, with a long head and neck, clean shoulders, deep chest, back arched and sound legs and feet.The breed has remarkable speed, agility and endurance.

- **Origin** - Egypt
- Large-limbed, slender, thin animal; broad chest and narrow waist
- Face long and narrow with blunt pointer nose
- Coat fine short and smooth, common colour red and fawn, specimen of black, brindle, white and other colours are also acceptable
- Height of adult male 70-75 cm and of female 65-70 cm; body weight 25-35 kg; tail is low set, long, tapering and strong.
- **Temperament :** Affectionate, athletic, even tempered, gentle, intelligent and quiet.
- **Best :** Good with kids ,dog friendly, adaptability.

## TERRIERS

The terriers are also hunting dogs, but their game is generally vermin, not birds and animals for the dinner table. With few exceptions, terriers developed in the British Isles to control rats, mice, foxes, and other predatory animals that raided farmer's grains and chickens, shopkeepers storage bins, and housewives' kitchen larders. The terriers come in wire, smooth, and soft coats and in short- and long-legged body types.

- Terrier temperament is fiery. The smallest terriers are scrappy, ready to take on even giant sized adversaries. They can also be quite independent and difficult to train for the weak-of-will.
- The wire-haired terriers have special grooming needs. Dead hairs must be pulled out of their coats to maintain good coat color and texture. The hard-coated terriers are Airedale, Australian, Border, Cairn, Irish, Lake land, Miniature Schnauzer, Norfolk, Norwich, Scottish, Sealyham, Skye, Welsh, West Highland White, and Wire haired Fox.
- Terriers are not generally good for rowdy children, for they will give back as good (or better) than is dished out. Three terriers, the Border, Irish, and the Soft-coated Wheaten, are considered to be generally good with children. The others are recommended only for families with older, well-behaved youngsters.
- Hard-coated terriers are often preferred by families with allergies because they do not drop their dead hairs throughout the house. Instead, the dead hairs must be pulled out in order to keep the skin healthy and maintain the coats' rich colors and bright whites. Many terrier owners prefer to have a groomer do the job.
- Most terriers are tough to train, for they have their own idea of how the world works and that idea frequently differs from the owners'. Few will back down from a confrontation with another dog.

  ***Quite independent and difficult to train, some breed needs special grooming, not good for rowdy children***

## TOY BREEDS

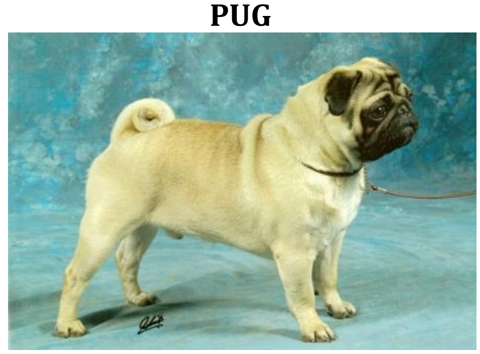
Small companion or lap dogs. Many of the Toy breeds were bred for this capacity although some have been placed into this category due to their size. They should have friendly personalities and love attention. They do not need a large amount of exercise and some can be finicky eaters. They are intelligent companions but owners must be discretionary with their attention as spoiled dogs can become protective of their owners. Ideally these dogs are extroverted companions and not untouchable ornaments.

- Diminutive size does not mean a mildness of temperament; many little dogs are as tough as their larger cousins.
- As a rule (Pug excepted), they do not like small children, and their movements can be too quick for elderly family members. Many will not sell to a family with young children or very active children.
- Toy dogs are generally easy care pets. Some (Shih-Tzu, Pomeranian, Yorkshire Terrier, Maltese, and Pekingese) require heavy grooming; some (Japanese Chin, Toy Poodle, and English Toy Spaniel) require moderate grooming; and other require little or no grooming.
- The important thing is to keep the long, fine hairs free of tangles and mats to avoid pain and skin problems for the dog and a big grooming or vet bill for you. Some need relatively more exercise than larger breeds.
- Most are less than 12 inches tall and weigh less than 12 pounds.
  ***Good companion to ladies, are tougher than their large cousins, except pug other breed don't like children, required grooming. Chihuahua is the smallest breed of dog native of Chihuahua state in Mexico.***

**Breeds commonly seen in India: Pomeranian** and **Pug**

**Pomeranian**

**PUG**



**POMERANIAN**

The Pomeranian is a compact, short back, active toy dogs, originating in Germany. He has a soft, dense undercoat and a thick coat. Tail is set high, having densely feathered tail flat on his back. He is alert in character, intelligent expression, lively manner and curious nature.

- **Origin** - Poland
- The Pomeranian (often known as a Pom) is a breed of dog of the Spitz type, named for the Pomerania region in Central Europe (today part of eastern Germany and northern Poland) and classed as a toy dog breed because of its small size
- Toy breed, very active
- Outer coat long, straight, course and thicker around the neck; undercoat soft and woolly
- Only whole colour free from any admixture is accepted
- Pomeranian comes in the widest variety of colors, including white, black, brown, red, orange, cream, blue, sable, black and tan, brown and tan, spotted, brindle, plus combinations of those colors. The most common colors are orange, black or cream/white.
- Height 15-28 cm and body weight 1.5-3.9 kg
- Ears are small and erect
- Tail hairy and carried on the back.
- **Temperament :** Active, playful, intelligent, sociable, friendly and extroverted.
- **Best :** Cat friendly, popularity and adaptability.

**PUG**

Pug is small pet dogs, a family companion, intelligent, stable personality, gentle, lively and full of fun, most likes playing with children.

- **Origin** - China
- Small breed
- Short back and rounded ribs
- Coat short, soft, fine, smooth and glossy of black, silver on apricot fawn
- Ears are rose or button shaped
- Height 25-30cm and body weight 6-8 kg
- Tail tightly curled and often double curled.

- **Temperament** :playful,stubborn,attentive,sociable,clever,charming,docile,quiet.
- **Best :**watchdog.

**INDIAN BREED OF DOGS**

- A large variety of domesticated, semi-domesticated and feral dogs are found in different parts of India.
- Dogs are kept as pets in urban and rural areas but only sporadic attempts have been made for the identification, maintenance, breeding and utility of local dogs.
- Indeed in many parts of India one can see dogs having similar characteristics.
- A few well-bred ,family –bred and locality-confined dogs of India are the Rampur hound, Gaddi, Bhutia, Banjara / Sanehta and hunting Rajapalayam dog of Tamil Nadu.

**RAJAPALAYAM**

- This breed is a native of Rajapalayam in Tamil Nadu, India which was developed in a hunting dog in Tamil Nadu and Karnataka.
- It is a hound, and therefore should be kept in optimum working condition
- Dogs tail, long and slender with broad chest and narrow waist.
- Body coat short and dense.

- The most prized colour is milk white, with a pink nose and golden eyes. However, other colours including spotted or solid, black, and brown, are known to occur.
- As with many fully white dogs, there is a high incidence of deafness in this breed.Puppies born with whitish or blue eyes are deaf.

- An extremely handsome and graceful dog, the Rajapalayam has a gait similar to the trotting of a thoroughbred horse.
- The height at shoulder usually 40-50 cm. Males always heavier than females.

**GADDI**

- Heavy and muscular strong animal of active habits; considered to be developed from the wild dog of Yamuna riverine of Meerut region
- The Gaddi is thought to have been developed by the Asur King Mahidant of Meerut by crossing the wild dingo like hounds
- Body coat short, close and rough with long hair on thighs and terminal part of tail; body coat may grow longer in winter
- Coat colour usually dull white with lighter colour on the belly
- Height 50-70 cm and body weight 25-50 kg; males heavier than females; tail hairy, extends up to hock; ears small and curved.
- Gaddi Kutta is a mastiff-type mountain dog found in northern India, especially states in the western Himalayas region (Himachal Pradesh, Uttarakhand, and Kashmir). They are also called the Indian Panther Hound, as well as Mahidant Mastiff, the former pointing to the breed's skills and the latter to its origins. Though initially bred for hunting purposes, the multi-talented Gaddi Kutta is widely used by local shepherds, mostly Gaddis (from the tribe of the same name) and are reputed to be strong enough to repulse attacks by snow leopards, and to have the intelligence to herd stray sheep and goats back to their pens.

**MUDHOL HOUND**

- The Mudhol Hound is an Indian breed of dog of the sight hound type.
- The breed is also known as Caravan Hound and the feathered variety is commonly referred to as a Pashmi. In the villages he is known as the Karwani.
- It is a common companion among village folk in India's Deccan Plateau, who use the dog for hunting and guarding.
- The head is long and narrow, broad between the ears with a tapering muzzle
- The nose is large, and may be black, liver, or flesh coloured

- The males are 68–72 cm in height at the withers and the females are 64–68 cm tall.
- The chest is strong and deep with well sprung ribs.
- The abdomen is tucked in. The hind quarters appear wide and well-muscled.
- The tail is strong at the base, not too long, set low and carried in a natural curve
- There are two coat varieties—one with an entirely smooth coat and the other with silky featherings on the ears, legs, and tail.
- All colours and combinations of colours are acceptable

**RAMPUR HOUND**

- The Rampur Greyhound is native to the Rampur region of Northern India, which lies between Delhi and Bareilly

- Thin, slender dog of bony appearance
- Coat short, close and rough of fawn to brown colour

- Ears small and half curved
- Chest broad and waist narrow with raised croup
- Height 40-60 cm and body weight 25-40 kg males being heavier than females
- Tail long, straight and tapering.

**HIMALAYAN SHEEPDOG**

- The Himalayan Sheepdog is an Nepali breed of dog that has become a very rare breed.
- Often called the Bhote kukur. They are similar in appearance to the Newfoundland (dog) and the Tibetan Mastiff.
- They have a large body and have been known to have a loud bark.
- It is a large breed. Its height typically lies between 26 to 32 inch (66 to 82 cm) range.

- Its a lighter breed in comparison with The Tibetan Mastiff and its weight range is from 28 to 38 kg (62 to 84 lbs).
- Its double coat is long, and found in a wide variety of colors from solid black to light brown with the rarest being white.
- This breed normally has different shades throughout its body. The usual resemblance in almost all dogs of this breed is a white color fur patch on the chest.
- It sheds its double coat once a year. All dogs of this breed have long, round and hairy tail.

**COMBAI**

- The Combai is a bear hound found in the south of India
- This breed of dog is slightly shorter than the Rajapalayam , but appears heavier because of its powerful build.
- The Combai is usually red or brown, with a black mask, and with a dark line along the back.
- The chief differences between the Rajapalayam and the Combai breeds are that the Combai has more powerful jaws, often with a black mouth, much more pendent ears, rich red colour and a savage temper.

- It has, like Rhodesian Ridgeback, a ridge of fur along its back.
- Their coats are easily maintainable, and are less prone to skin disorders, fungal and yeast infections, and parasite infestation.
- The breed, having evolved naturally many centuries ago, is more immune to most diseases compared to the man-designed breeds.

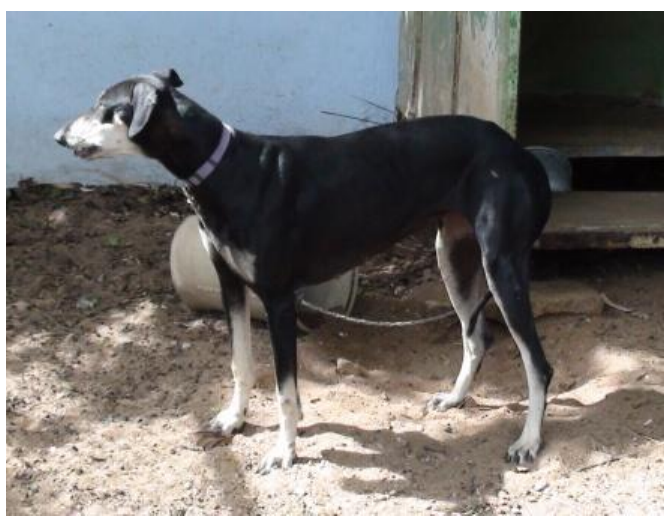
**CHIPPIPARAI**

- The Chippiparai is a sight hound breed of dog from the south of India. Thought to be a descendant of the Saluki, today it is found in the area around Periyar Lake.
- It is used primarily for hunting wild boar, deer and hare. It is said to be an excellent hunter, and is also used for guarding the home.

- The typical color is a silver-grey, with very limited or no white markings. Other colors, particularly variations of grey and fawn, also occur.
- This is a handsome dog, tall (27-32 inches at the withers) and powerful.
- It has a short coat that is very close; on the whole the coat if kept groomed has a shine on it.
- A shining, shell-like appearance is greatly desired.
- This kind of coat makes it ideal for hot climates.
- This hound is also less prone to ticks and fleas, with their short coat providing easy detection.

**KANNI DOG**

- Dog for the sheep farming in the grazing land.



- The Kanni is found in and around Tirunelveli, Kovilpatti, Kazhugumalai, Kileral, Kodangipatti, Sivakasi, and Madurai.

- It is said that the name Kanni comes from the fact that the dog used to be given as a gift to the bridegroom just before the marriage.
- They are usually of four colours, brown, cream, black & tan and brindle.
- The Kanni is kept by families who do not sell them but may gift them if a promise is made to look after them well.
- They are not allowed to roam on the streets and brought up as pet animals.
- They are given a diet of milk in the morning, corn porridge in the afternoon and a "Ragi" porridge in the evening.
- Meat is given once a week or once a month only. The breed is now extremely rare, and on the verge of extinction.
- Efforts to revive the breed have not been taken up, as specimens are few, and there exists little information about them.
- Found among the flock of Vembur sheep and Kanni goat. It is a good watch dog.

## CHOOSING A DOG

- There is an infinite variety of size, shape, coat texture and inherited ability in the pedigree breeds which have been developed by knowledgeable dog breeders over the years.
- In the past, the breeds were developed to encourage an ability for certain types of work such as herding, tracking game, retrieving, guarding or as warning watch dogs. The characteristics which made the dogs suitable for these jobs are still present today, although the majority of the dogs are kept in idleness and boredom.
- The domestic pets are strongly influenced by the work for which it was developed. For instance, the hound may be difficult to halt or recall when it is following scent, gundog may dig and to work underground will exercise in the flowerbeds. Hence selection of right dog and breed is very important to keep them as a pet.
- The important matter to considered are size, coat type, dog or bitch, adult or puppy, pedigree or mongrel.

  **Size, shape, coat texture and inherited ability are the important factors in choosing a dog.**

## SIZE

### Giant breeds

- Magnificent animals, often gently in temperament and very quiet and restful in the house, making themselves quite small in their own corner.
- However, they do need a lot of room in a car or every thing, from collar to veterinary treatment, costs more.
- They need more food, more medication and boarding kennel cost are higher. Giant breeds tend to be short lived.

### Large breeds

- May be boisterous in play, and aggressive with other dogs if not properly controlled.
- Large breeds which have full swishing tails can do a lot of damage within the home.

**Long haired breeds**

- They may need an hour's grooming every day. Professional trimming for Poodles, Bichons and Terriers is a regular expense.

**Medium size dogs**

- Suit many families, their home and their cars. There is plenty of choice within this group.

**Small dogs**

- This category tend to be noise.
- Small terrier bred to the vermin exterminators have quick snapping jaws which may make them unsuitable as pets for small children.

**Very small toy dogs**

- Dog under 4.5 kg in weight are not really suitable for the rough tumble of family life.
- Toy dogs tend to become devoted to one or two adults who handle them carefully.

**COAT TYPE**

- There is variety of coat type in dogs, from absolutely hairless, naked skinned Chinese Crested, through to smooth-coated dogs like Bull Terriers, thick double weatherproof coats like Labradors; Spaniel type silky coats; harsh, bristly Terrier coats, curly, non-shedding poodles; rough, wiry Wolfhounds; to the dog with very deep corded coat like Puli.
- All dog hair tangles and matts more quickly than human hair. Smooth-coated dogs require minimal grooming and mud dries on them quickly if they have been swimming or wallowing.
- All coat types will require some attention. Dog such as the Old English Sheep dog and the Afghan will need to be brushed and combed daily in order to keep the skin healthy and the coat clean. Long-haired dogs tend to smell when they are wet or damp.
- Poodles and Bedlingtons will require clipping and bathing every 6-8 weeks. Terriers will need hand tripping twice a year.

## DOG OR BITCH

- This is one of the major decision when the pet owner should consider while acquiring a dog.
- In the larger, guarding breeds males tend to be significantly larger in size, more dominate in temperament and require firm handling.
- Bitches in general are more biddable, more sympathetic and kindly with children and often intuitively quicker to define their owner’s wish.
- On the other hand bitches can experience mood swings and variable temperament during the estrous cycle.
- If you want a dog as a permanent companion to be available for anything the family wants to do, then the male is perhaps more suitable, unless there are definite plan to control estrus in the bitches.

## SELECTION OF PUPS

- The pup should have the breed characters.
- Decide the type of the dog that you may require - large, medium or small.
- Breed of dog should be decided after considering space availability, temperament of the neighbour, compound wall, etc.
- Pup should be purchased from a member of kennel club
- Most of the pups at 4-6 weeks of age look very fine and lovable. A healthy pup should be fat, with bright eyes, but should not be pot bellied.
- If possible, the litter can be watched for the individual pup behaviour. A boldest and loveliest pup should be selected and not the one that lags behind or hides.
- They should have loose, pliable skin and glossy coat, Give maximum consideration to the breed conformation.
- Bright and clear eyes would denote good condition. Avoid pups with discharge from the eyes or nostrils.
- Pups below average in bodyweight (According to the breed) should not be selected. When the litter size is large, some of the pups might be under weight, but they pick up soon.
- Overshot or undershot jaws, and such other congenital deformities should be avoided especially if the animals, are to be presented for shows.

- The gums should be pink in colour. Paleness of the gum indicates poor condition.
- The eyes including the iris should be of the same colour, shape and size.
- The ears should not have any discharge or foul smell.
- Tail should not be broken or crooked. It should be in conformity to the requirements of the breed. If docking has been done check up whether the wound have properly healed up without an objectionable scar.
- Examine all the four limbs, count the digits (should be equal in number) Accessory digits, if present, should be removed.
- Presence of beads at the region where the ribs join the sternum is Suggestive of rickets and such pups will require special attention, or else the bones may be deformed later.

  ***Breed character, Kennel club registration, select a bold pup, bright eye, pink gum are signs of health***

# Cat Breeds and Breeding

Cats have been associated with humans for at least 9,500 years, and are currently the most popular pet in the world. Cats are second most popular pets in India after dogs.

## Advantage of cat as pet

- Cats are independent and self-sufficient and make excellent companions for old people and it require less care and maintenance than dog.
- Cats fit well into apartment living and the less active lifestyle of the elderly person.
- Cats are clean, generally requiring very little or no house-training. They do not require much from the owner; they only have to be fed regularly.
- They also need shelter. Cats can be **toilet-trained** very easily. A simple tray and a few training sessions can dispense with the problem of dealing with their dirt, especially for indoor cats.
- Depending on the circumstances, cats can be used to control mice and other rodents can be as companions, aid disabled people and alert people with hearing disability
- The initial purchase price and the cost of feeding and keeping a cat is usually less than that for a dog.

Because of all these advantages and with the rise of nuclear families and apartment culture, popularity of cats as pet is increasing day by day.

## Taxonomy of Domestic cat

Cats, are believed to be first domesticated by the ancient Egyptians around 2600 BC. It was only in the 19th century that the first pedigree (with a family lineage) breeds were developed. In fact, more than 300 breeds and varieties are recognized now, the main distinguishing characteristics being head shape and the length of hair.

- The cat (*Felis catus*), also known as the domestic cat or house cat is distinguished from the other felines by its small size and is valued by humans for its companionship.
- The Domestic cat is one of the 38 species of the cat family or Felidae.
- They are the descendants of may be three or four of the wild Felidae species, foremost of which is the Felis silvestris lybica or the African Wild cat.

- Mostly mixed breeds. Besides the Pedigree and non pedigree domestic pet cats, there are the Working cats kept for their rodent catching asbility and the Feral cats, the descendants of cats which at one time have been domesticated at least to some extent.

| **Taxonomy of the domestic cat** | | |
|---|---|---|
| Kingdom | | Animalia |
| Phylum | | Chordata |
| Class | | Mammalia |
| Order | | Carnivore |
| Family | | Felidae |
| Genus | | *Felis* |
| Species | | *Catus* |
| **Domestic cat and some of its wild relatives** | | |
| Domestic cat | *Felis catus* | Worldwide |
| African wild cat | *Felis silvestris lybica* | Africa |
| Indian desert cat | *Felis silvestris ornate* | South west Asia; northern India |
| Jungle cat | *Felis chaus* | Egypt to India |
| Sand cat | *Felis margarita* | Sahara to Turkestan |
| European wildcat | *Felis silvestris silvestris* | Scotland to south east Russia |

- A group of cats is referred to as a "**clowder"** or a "**glaring**", a male cat is called a "**tom**" or "**tomcat**"[ (or a "gib" if neutered), a female is called a "**molly**"] or (especially among breeders) a "**queen**",and a pre-pubescent juvenile is referred to as a "kitten".
- A pedigreed cat is one whose ancestry is recorded by a cat fancier organization.Cats of unrecorded, mixed ancestry are referred to as domestic short-haired or domestic long-haired cats, by coat type, or commonly as random-bred, moggies (chiefly British), or (using terms borrowed from dog breeding) mongrels or mutt-cats.
- The domesticated cat and its closest wild ancestor are both diploid organisms that possess 38 chromosomes.

| | | |
|---|---|---|
|  |  |  |
| Indian desert cat | Domestic cat | Jungle cat |
|  |  |  |
| African wild cat | Sand cat | European wild cat |

**Classification of Cats**

**Two classifications** : 1.Natural system 2. Cat show system

**1. Natural standard classification**

i. **Breed** (morphology, form structure)
ii. **Variety** (breed subdivisions)
iii. **Hair length and color:** Long-haired, short-haired, hairless
iv. **Body size and type :** Medium, long-limbed, short-limbed

**2. Show standard classification**

1. **Longhaired Cats:**
   - Balinese,
   - Somali, American
   - Curl,
   - Maine Coon,
   - Scottish Fold,
   - Persian/Himalayan,
   - Birman

2. **Shorthaired Cats:**
    - Siamese,
    - Burmese,
    - Abyssinian,
    - Color Point,
    - Havanah Brown Exotic Shorthair,
    - American Shorthair,
    - Bengal (Hybrid)
3. **Rex:**
    - Cornish Rex,
    - Devon Rex,
    - Sphynx (Hairless)

**Cat breeds**

**1. Abyssinian Cats**

- Abys, as they are lovingly called, are the fourth most popular cat breed a according to statistics from the Cat Fanciers' Association (CFA). Elegant and regal-looking, Abyssinians are easy to care for and make ideal pets for cat lovers. Country: Egypt.
- Abyssinian Appearance: Abyssinians are lively and expressive, with slightly wedge-shaped heads, half-cupped ears, medium length bodies and well-developed muscles. Their legs are long and slender, They have short thick hair that's very soft. and close-

lying to their bodies. There are four different color variations of Abyssinians which are Ruddy, Blue, Fawn and Red.

- Abyssinians are not lap cats, but are affectionate, loyal and normally mix well with children and other pets. Known for their curiosity, playfulness and need to explore their surroundings.  Since they are very active cats, they do need a good amount of exercise daily

**2. Sphynx Cats**

- Native of Canada originated by mutation. The Sphynx, a hairless, wrinkled wonder with big ears and eyes and pronounced cheekbones is one of the newer cat breeds. The breed's unique look has caught the eye of many cat lovers. Though rare, it has recently become one of the most in-demand cats in the U.S.They are energetic, silly and playful, and love to be the center of attention. The Sphynx also gets along well with other cats and dogs.The Sphynx is not an outdoor cat. Because their skin is exposed,

**3. Oriental Cats**

- One of the most loyal cats. The oriental cat's history is unique. Created by U.S. breeders who wanted to expand the look of the Siamese cat by introducing a range of colors, the breed was divided into two groups: shorthairs and longhairs. It is known to have more than 300 different color and pattern combinations. The oriental cat tends to be an entertainer and loves to interact with people. These cats are also very vocal, so expect a lot of pleasant conversation in your household. The oriental cat is good with adults as well as older children,

**4. American Shorthair Cats**

- The American shorthair cat has a reputation as "America's breed They were valued for their ability as great hunters and killing disease-carrying rats that threatened passengers. The breed is known to have a very even temperament with a good disposition and keen intelligence. Another testament to its mellow nature is the shorthair's ability to get along with other pets and its gentle nature around children. A shorthair is considered an ideal pet for a working family with children.

**5. Birman Cats**

- Believed to have originated in Burma, the friendly, blue-eyed Birman cats are considered sacred cats of the Kittah priests. Birmans are friendly, intelligent and affectionate cats, and make great companions for those seeking a cat that takes an interest in the events occurring around them. Active, yet gentle, Birmans are generally calm and mild-mannered, and normally get along with other household pets and children.

- **6. Ragdoll Cats**


- Native of United States. It is a large and heavy long coated cat crossbred origin. It has oval blue eyes and a semi-long silky coat, which comes in the four traditional pointed colors: seal, chocolate, blue and lilac; and three divisions: solid or colorpoint, particolor mitted, and particolor bicolor..
- Ragdolls are extremely mild-mannered and friendly, and often seek out human companionship, This breed is particularly good with children and other pets and is easily trained to learn the same tricks as dogs, such as playing fetch, rolling over or begging. Because they are gentle and sometimes lack the ability to defend themselves, ragdolls should not be left unattended outdoors. Easily trainable, this cat will lie limp like a rag doll, hence its name.

- **7. Siamese Cats**

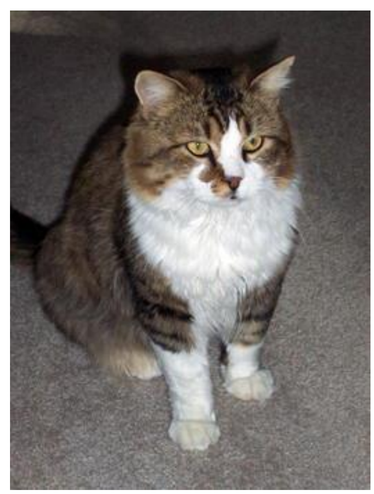
- Siamese cats are one of the oldest recognized and established breeds of cat. This shorthaired breed is one of the most sociable of all feline breeds and one of the most popular, widely recognizable by their blue, almond-shaped eyes, short coat, elongated body and chiseled, wedge-shaped faces. The ears are almond shaped and always blue. The tail is long and tapering and free of kinks.
- Siamese cats are believed to have hailed from Asia; specifically Thailand Siamese cats have loud, low-pitced meows and are quite vocal, often times demanding attention. Normally active and playful cats, this breed seeks out companionship from their human counterparts, whether that entails sitting laps or being in bed with their owners. Siamese cats are often compared to dogs since they tend to follow their owners around, and have been known to willingly walk on leashes.

**8. Exotic Shorthair Cats**

- The Exotic shorthair cat is a cross between Persians and American Shorthairs. Exotic cats are bred to meet the Persian standard in almost every way with one exception: their coats. Exotics, unlike their Persian counterparts, have short, thick, dense coats, making them popular among people who enjoy the Persian personality but don't want the hassle or the time required for daily grooming. The Exotic does not require daily combing. The appearance is cobby with short, stout legs holding up a round, muscular physique.
- Exotics are acceptable in any color and in any coat pattern, including color point (like Siamese), white, striped, and calico. Finally, the shorter nostrils make the Exotic more sensitive to heat. High temperatures may lead to breathing problems. Exotic cats are known to show more affection and loyalty than other feline breeds, and commonly follow their owners throughout the home.

**9. Maine Coon Cats**



- One of the oldest natural breeds in North America, Maine Coon cats are known for their intelligence and playfulness, as well as their size (12 to 18 pounds). One of the largest breeds of domestic cats, they are lovingly referred to as "gentle giants". The Maine Coon is a long-haired breed. The Maine Coon's distinguishing feature is its smooth, shaggy, and water-repellent coat, which can come in a variety of colors, though brown is currently the favorite. Its hair is long and silky and is shorter on the shoulders and longer on the stomach.

- Maine Coons are people-oriented, energetic and highly-intelligent, making them an easy breed to train. They have a very small voice for their large size; their voice is more of a chirp than it is a meow.

**10. Persian Cats**

-   

- The Persian is a large to medium-sized cat, with a well-balanced body and a sweet expression on its face. Originated in Persia (now Iran). Persian cats are very beautiful and they come in many different colors. Their fur is almost 8 inches in length and thick. Persians should be groomed at least once a day to prevent knots and matting of the fur. The life expectancy of a Persian cat is around 15 to 16 yrs. Persians are more of a lazy breed so measuring their food is very important. Persian cats make great companions for those who are looking for a low-energy breed.

- It has a huge and round head, small ears and a comparatively short tail. While solid silver is the most popular color for the Persian currently, there are more than 80 colors available today, including black, blue, cream, and smoke. These Persians are susceptible to a number of health problems.

**11. Himalayan cats**

- The Himalayan, also called colour point Persian, is a breed of cat with extremely long, fluffy fur, and the blue eyes and the points of a Siamese. With their name it appears that they are of Indian origin, but, in reality, are the result of crossing from Siamese (for the markings) and Persians (for coat-length and temperament), and share the characteristics of both breeds. The body of a Himalayan is white, but the points come in many different colours: blue, brown, lilac, chocolate, flame, red and cream. The points can also be tabby or tortoiseshell-patterned.
- Himalayan cats requires a good amount of grooming.  The Himalayan cat breed is generally calm and mellow. These cats are prone to quite a few health problems like eye ulcers, teeth loss, joint problems and feline hypertrophic cardiomyopathy which is a heart disease that can be fatal.

**12. Rusty-spotted Cat**

- These are the most commonly kept cats of India. Being indigenous, they are well suited to Indian climate. They have grey fur with rusty spots all over the back and flanks, while the underbelly is white with large dark spots. The tail, thick and about half the length of the body, is darker in colour than the body and the spots are less distinct.

**13. Bombay Cat**

- Bombay cat originate from black cats of Asian origin. They are found in two varieties i.e.The British and American Bombay.

- The Bombay is a muscular yet agile cat with a black coat. The heads of Bombay cats are rounded and wide with a short tapered muzzle. The eyes, which are of golden or copper colour, are rounded and wide set, and their ears are broad, slightly rounded and medium sized and, like the eyes, set wide. The Bombay has a coat that is short, satiny and tight to the body. Bombay cats get along well with children and prefer to be around humans. This intelligent cat also enjoys playing and exploring.

**14. Russian Blue**

- The Russian Blue is a robust breed, with firm muscles and an overall dose of good looks. It is of a medium size, and muscular. The Russian Blue appears bigger than it actually is because of its double coat, which is the most eye-catching feature of this breed. The coat is bright blue, preferably lavender at the base (root), darkening along the shaft up to the tips of the guard hairs (protective hairs in the topcoat), which are tipped in silver.

- The eyes are yellow while the Russian Blue is a kitten, and by four months there is a bright green ring around the pupil. As the cat matures, the eye color graduates into a bright, vivid green. One of the more curious and amusing features of the Russian Blue is its “smile.” It has a slightly upturned mouth, which is frequently compared to the enigmatic Mona Lisa smile.

**15. Bengal Cat**

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- The Bengal stands out among cats for its lush, dense, and remarkably soft coat. The preferred colors are black or brown spotted, and black or brown marbled, but breeders have also engineered Bengals that are snow spotted (white), and snow marbled. The spots should be in sharp contrast to the background color.
- Bengals often possess a trait called glittering, which makes the coat appear to have been dusted with gold or pearl. This is a long, muscular, medium- to large-sized cat, with a broad head and muzzle, high cheekbones, and pronounced whisker pads. The eyes are round and wide, with dark markings around the eyes (mascara) and the ears small and rounded at the tips. The Bengal's muscular, athletic build is one of its most defining features; it is never delicate.

**13. Burmese**

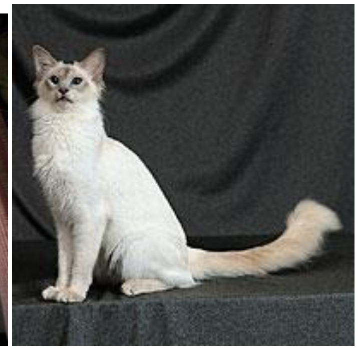
- Burmese are extremely people-oriented cats. They are almost dog-like in their tendency to follow their owners to give and receive affection. The breed can be broadly divided into two types: European Burmese and contemporary Burmese. The European Burmese possesses longer, narrower muzzles with a less pronounced nose break, and a slightly narrower head; the contemporary Burmese has shorter, broader muzzles, a pronounced nose break, and broader, rounder head shapes. Additionally, the contemporary Burmese bears the brown coat proudly, while the European Burmese sports brighter colors like red.

**17. Manx**

- 

- Best-known for its lack of tail, the Manx is native to the Isle of Man, located between England and Ireland. This round, cuddly breed is also fun-loving and friendly. The most striking feature of the cat is its small "stub" of a tail, which is classified into four varieties: rumpy, rumpy-riser, stumpy, and longy.
- There are also two types of Manx coats: shorthair and longhair. The shorthair's double coat is glossy and padded, while the longhair has a silky and plush double coat. There are many different types of accepted color and varieties, including white, black, brown spotted, silver tabby, and black tipped. Curiously, the Manx has a rabbit-like gait, appearing to hop around rather than walk.

**18.Balinese**

-  

- The breed standard for the Balinese is identical to the standard for the Siamese in most respects, including overall body type and color, with the obvious differences being in overall coat length, and in the full plume tail. The coat is single coated, with only minimal shedding. In fact, the Balinese is noted for its lack of shedding amongst long coated cats.
- It is both dainty and muscular. The head is wedge shaped, the eyes slanted and vivid blue, the ears are remarkably large, open and pointed, and the profile is linear. Colors are standard with the Siamese as well: seal point, blue point, lilac point, and chocolate point. The general life span for the Balinese is 18-22 years

**BIOLOGICAL DATA**

| | | |
|---|---|---|
| Age at sexual maturity | : | 8-9 months |
| Mating weight | : | 2500 g |
| Oestrous cycle | : | 14 - 21 days |
| Duration of oestrus | : | 3 - 6 days |
| Gestation | : | 63 days |
| Litter size | : | 3 - 6 |
| Weaning age | : | 5 - 6 weeks |

## REPRODUCTIVE DETAILS

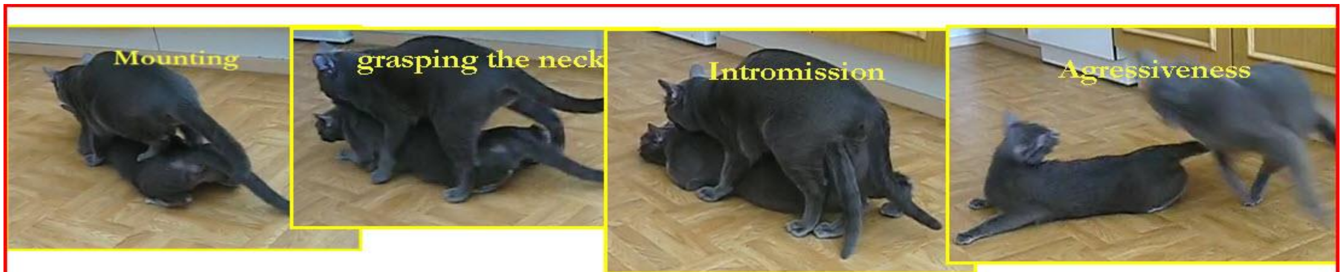
- Female cats are seasonally polyestrous, and the season begins in January and end in October
- Cats normally reach sexual maturity at 5–10 months (females) and to 5–7 months (males), although this can vary depending on breed.
- Oestrus cycle is 14-21 days and during this period more number of males are attracted. Males will fight each other and succeeded male will mate.

## SIGNS OF ESTRUS

- The female in estrus can be identified by the 'calling', although this can be more like shrieking or wailing in some breeds such as Siamese. Some Persians content themselves with dainty little mews and miaows.
- The female displays some brazen behaviour, rolling and dragging herself around the floor, flicking her tail and raising her rump to expose the reddened vulva.
- She may also lose interest in her food. Picking her up by her neck folds (as an interested tom would do) and stroke along her back may show positive response with pleasure, pads her feet and raises her tail.



**BREEDING OF CAT**

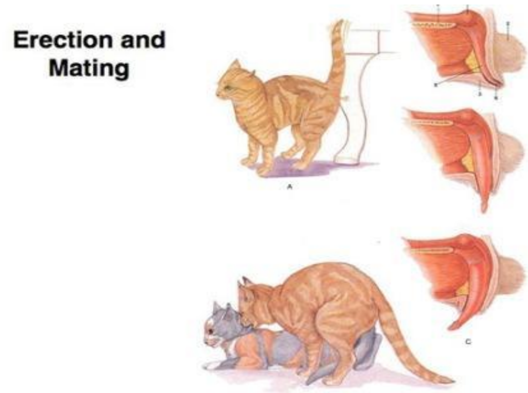


Different stages of mating

- If a decision has been made to breed, the health of the cat must be thoroughly evaluated.
- For female, information like previous estrus period, breeding date and the outcome, health record, vaccination detail, disease history should be noted.
- The timing of breeding is best determined by the queen/s behaviour.
- As the queen enters estrus, she begins to show a coital crouch when in the presence of a male cat or in response to genital stimulation.
- A receptive female will solicit attention from the male cat and allow mounting and intromission.
- Mating in cats occurs rapidly, lasting between 30 seconds and 5 minutes.
- The tom cat mount and clasps the flanks of the female with his forelegs, her with his hind limbs, and grasps the dorsal aspect of her neck with his teeth.
- This grip is inhibited, and so only in very rate case penetrates the female's skin.
- Almost immediately, the male treads rapidly with his hind limbs and shows pelvic thrusts, resulting in intromission.

- In domestic cats, intromission is almost immediate followed by ejaculation.

- The male immediately begins to dismount this cause the female to elicit a very shrill postcopulatory cry, after which she usually turns aggressively to wards the male.
- The aggressiveness is less to wards known mates.
- After mating female will vigorously roll on the floor, it shows other reactions like rubbing and licking that lasts between 30 seconds and several minutes.
- If the male is present she usually adopts a receptive position shortly after and breeding begins again.
- Cats resume mating with in 30 minutes and experienced pair will mate ten times in an hour.
- For LH surge and ovulation minimum of four mating is essential with in a period of 24 hours.
- The estrus period will normally end abruptly by 24 to 36 hours after initiation of mating.
- The female cat will not come to estrus until the kittens are weaned or until next breeding season.
- If the female does not conceived, she will either enter pseudopregnancy or return to estrus cycle.




| | |
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|  |  |
| **coital crouch** | **grasping the dorsal aspect of neck with teeth** |

**GESTATION, KITTENING AND WEANING**

- The gestation period for cats is between 63–67 days, with an average length of 66 days.
- The size of a litter averages three to five kittens, with the first litter usually smaller than subsequent litters.
- Kittens are weaned at between six and seven weeks, and
- Females can have two to three litters per year
- Cats are ready to go to new homes at about 12 weeks old, or when they are ready to leave their mother.

# COMMON BIRDS IN INDIA

**Pet Bird:**

A tame animal kept in a household for companionship, amusement, etc.

**Advantages**

- Birds serve as a tame and talking companion.
- The cost of keeping a feathered pet is much less than that for dogs and cats.
- Birds appeal to all types of people and are ideal for the house bound and those without gardens.
- They have long life span compared to many other pets.
- Many birds are kept for their talking, singing ability, sports purpose etc.
- Birds are actually not talking, they are only mimicking the sound by repetition.

**Common pet birds seen in India are**

- Parakeets
- Mynah
- Mannikins
- Pigeons and Doves
- Koels.

Keeping this birds is not permitted as per Indian wild life act.

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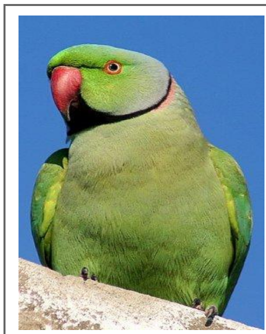
|  |  |  |  |  |

**PARAKEETS**

- The term parakeets generally applies to long tailed slender bird belonging to the family Psittacidae.
- In India there is no parrot but only parakeets (parrot like birds). The common parakeets are:

| | |
|---|---|
| Budgerigars | *Melopsittacus undulatus* |
| Rose ringed parakeet | *Psittacula krameri* |
| Blossom headed parakeet or plum head parakeet | *Psittacula cyanocephala* |
| Blue winged parakeet Or Bamboo parakeet or Malabar parakeet | *Psittacula columbodis.* |

- Parakeets, if acquired young can learn to talk quite well and they will develop elaborate vocabulary.
- In training a young bird to talk, it is best to keep it out of hearing distance of other birds of its kind and to patiently repeat over and over the word that is being taught.
- It is best to speak more slowly than normal because the birds have a tendency to speed up the words when they repeat them.
- There is no sex difference in the ability of birds to mimic words.
- The genus *Psittacula* is made up of the larger parakeets; the males all have red beaks.

**THE INDIAN RING NECK PARAKEET**

- The Indian ring neck parakeet, *P.krameri manillensis*, is one of the most beautiful of the larger parakeets.

- The Rose-ringed Parakeet (*Psittacula krameri*), also known as the Ringnecked Parakeet, is a gregarious tropical parakeet species that is popular as a pet.
- This non-migrating species is one of few parrot species that have successfully adapted to living in 'disturbed habitats', and in that way withstood the onslaught of urbanization and deforestation. In the wild, this is a noisy species with an unmistakable squawking call.

- As is the case with all *Psittacula* (Afro-Asian Ringnecked Parakeet) species, the Rose-ringed Parakeet is sexually dimorphic.
- The adult male sports a black neck-ring and pink nape-band while the hen and immature birds of both sexes either show no neck rings, or display shadow-like pale to dark grey neck-rings and light (lighter coloured than surroundings) nape-bands.
- The birds are about 17 inches long with a long, tapering tail that makes up about half the body length.
- The primary colour is pastel green.
- Males have a narrow, black band above the nostrils that connects the eyes; below the beak is a black band that goes down the throat and then spreads out and back, making a black band below the cheek.
- There is a light blue band above the black, and a light rose band below the blue.
- The tail and flight feathers show some yellow; some blue tinting may appear on the nape of the neck and down the back.
- The beak is red; an orange ring surrounds the eye.
- Females are a duller green and lack the black, blue, and rose-coloured rings.
- Young ring necks are dull in colour, and it may take two or three years before the males develop their beautiful colour markings.
- Indian ring neck parakeets make excellent pets and are good talkers; ring necks are being bred in blue and yellow forms.
- An African subspecies, the African ring neck, P.K.Krameri, is smaller and lighter in colour.



**THE MALABAR PARAKEET**

The Malabar (or blue-winged ) parakeet, P columboides is another beautiful bird.

- The male is primarily gray. A black band completely circles the neck; a blue band is below the black band and changes to a light green.
- The wings and tail feathers are dark blue with a yellow tinge to the tips; yellow also appears on the vent and underside of the tail.
- Males have a red beak, and there is a tinge of green around the eyes. Females have a black head and do not have the collar.
- The Malabar Parakeet also known as the Blue-winged Parakeet, (*Psittacula columboides*) is endemic to the Western Ghats of southern India.
- The species is evolutionarily close to Layard's parakeet (*Psittacula calthropae*) endemic to Sri Lanka.
- They breed in the dry season after the northeast Monsoon and the chicks fledge before the southwest Monsoon in June.
- They nest in holes in trees, especially old woodpecker and barbet nests.
- The birds begin breeding in December and eggs are laid in December and January.
- The usual clutch was 4 eggs which hatch after about 23 days.
- The female initially broods with the male bringing food and later the male takes over. The chicks

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|  |  |
| Male | Female |

**BLOSSOM HEADED PARAKEET OR PLUM HEAD PARA**

- The Blossom-headed Parakeet (*Psittacula roseata*) is a parrot which is a resident bree India eastwards into Southeast Asia.
- It undergoes local movements, driven mainly by the availability of the fruit and blosso up its diet.
- Blossom-headed Parakeet is a bird of forest and open woodland. It nests in holes in white eggs.
- This is a green parrot, 30 cm long with a tail up to 18 cm. The male's head is pink bec on the back of the crown, nape and cheeks.
- There is a narrow black neck collar and a black chin stripe.
- There is a red shoulder patch and the rump and tail are bluish-green, the latter tippe
- The upper mandible is yellow and the lower mandible is dark.
- The female has a pale grey head and lacks the black neck collar and chin stripe patcl
- The lower mandible is pale. Immature birds have a green head and a grey chin.
- Both mandibles are yellowish and there is no red shoulder patch.
- The different head colour and the yellow tip to the tail distinguish this species from t headed Parakeet (*Psittacula cyanocephala*).
- Blossom-headed Parakeet is a gregarious and noisy species with range of raucous ca

**THE PLUM HEADED PARAKEET**

The Plum-headed Parakeet (*Psittacula cyanocephala*) is a parrot which is a resident breeder in Pakistan, India, Sri Lanka and Bangladesh. It is endemic to the Indian subcontinent.

- The Plum-headed Parakeet is a mainly green parrot, 33 cm long with a tail up to 22 cm. The male's head is red, becoming purple-blue on the back of the crown, nape and cheeks. There is a narrow black neck collar and a black chin stripe. There is a red shoulder patch and the rump and tail are bluish-green, the latter tipped white. The upper mandible is orangish-yellow and the lower mandible is dark.
- The female has a grey head, corn-yellow upper-mandible and lacks the black neck collar, chin stripe and red shoulder patch. Immature birds have a green head and both mandibles are yellowish.
- The different head colour and the white tip to the tail distinguish this species from the similar Blossom-headed Parakeet

**MYNAH**

  - *Gracula religiosa* (Hill Mynah)
  - *Acridotherus tristes* (common Mynah)

- 

**Hill Mynah** *Gracula religiosa*. The Mynah bird is native to Asia and India. It is primarily black.

- There is a white patch on its wings; the bill is orange.
- A bare, yellow skin patch extends from below the eye back toward the nape of the neck; its legs are yellow. It feeds primarily on fruits.
- The Mynah bird is noted for its ability to mimic the human voice and other sounds.
- Hill Mynah is well known for its talking and mimicking skills.
- The voice of Mynah comes close to duplicating human tonal qualities.
- A myna's sex is immaterial with regard to its power of mimicking and indeed it is often difficult to decide their sex.
- Keeping Mynah birds can be more time consuming than keeping other species of birds because of their diet.
- They consume fruits, and because of this, their cage needs to be cleaned at least once a day.

**The common Myna** The Common Myna or Indian Myna (Acridotheres tristis) also sometimes spelled Mynah, is a member of family Sturnidae, (starlings and mynas) native to Asia.

- An omnivorous open woodland bird with a strong territorial instinct, the Myna has adapted extremely well to urban environments.
- The myna has been introduced in many other parts of the world and its distribution range is on the increase.

- It is a serious threat to the ecosystems of Australia.
- The Common Myna is an important motif in Indian culture and appears both in Sanskrit and Prakrit literature
- The Common Myna is readily identified by the brown body, black hooded head and the bare yellow patch behind the eye.
- The bill and legs are bright yellow. There is a white patch on the outer primaries and the wing lining on the underside is white.
- The sexes are similar and birds are usually seen in pairs

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| **Common Mynah** | **Hill Mynah** |

**MANIKINS (NUNS/MUNIAS)**

- There are different species like black headed munia - *Lonchura malacca*, white backed munia -*Lonchura striata*, spotted munia - *Lonchura punctulata.*
- Munias are very popular as cage birds. During the breeding season the cock sings weakly for his mate. Munias are very sociable birds.
- *Lonchura* is a genus of the estrildid finch family, and includes munias (or minias), mannikins, and silverbills.
- They are resident breeding birds in Africa and in South Asia from India and Sri Lanka east to Indonesia and the Philippines.
- The name mannikin is from Middle Dutch *mannekijn* 'little man' (also the source of the different bird name*manakin.*

- Some of the *Lonchura* species were formerly placed in *Spermestes*. Others have been placed in a genus of their own
- They are small gregarious birds which feed mainly on seeds, usually in relatively open habitats, preferring to feed on the ground or on reeds and grasses.
- Several species have been noted to feed on algae such as *Spirogyra*.
- The nest is a large domed grass structure into which 4–10 white eggs are laid. Some species also build communal roosting nests for overnight rest.
- The species in this genus are similar in size and structure, with stubby bills, stocky bodies and long tails. Most are 10–12 cm in length.
- Plumage is usually a combination of browns, black and white, with the sexes similar, but duller and less contrasted for immature birds.
- The similarities within this group and the existence of subspecies with differing vocalisations and plumage mean that some races may be elevated to species status.
- African and Indian Silverbill are now usually considered distinct species, and the two races of Black-throated Munia are often also split.
- The munias are popular in the bird trade and many freed or escaped birds have formed feral colonies in different pockets across the world.
- The Red Munia *Estrilda amandava* and Green Munia *Estrilda formosa* also take the name munia, but are in the *Estrilda* genus.

- the *Estrilda* genus.

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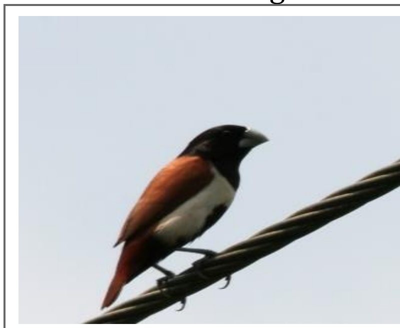
|  |  |  |
| **Black head munia** | **Silver bill munia** | **Scaly breasted munia** |

**PIGEONS AND DOVES**

- This group of birds is classified in the family Columbidae.
- The pigeons and dove have fairly uniform appearance.
- The term 'dove' tends to be reserved for smaller birds, but this does not apply in every instance.
- Most species eat seed, but a few genera subsists largely on fruit.
- Blue rock pigeon-*Columba livea*
- Spotted Dove - *Streptopelia chinensis*
- Fancy pigeons

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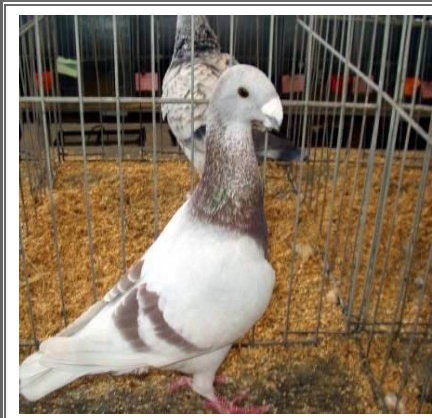
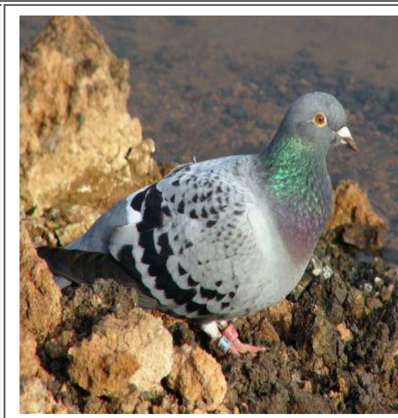
|---|---|---|
| **Rock pigeon** | **Spotted dove** | **Fantail - fancy pigeon** |

|  |  |
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| **Homer pigeon** | **Homing pigeon** |

**KOELS - EUDYNAMYS SCOLOPACEA**

- The true koels, *Eudynamys*, are a genus of cuckoos from Asia, Australia and the Pacific.
- They are large sexually dimorphic cuckoos which eat fruits and insects and have loud distinctive calls.
- They are brood parasites, laying their eggs in the nests of other species.
- In New Zealand the Long-tailed Koel is known as the Long-tailed Cuckoo
- Two other species, the White-crowned Koel and the Dwarf Koel, are also known as koels but are in their own monotypic genera.
- The male is all black, about the same size but slimmer than the crow. The female is brown, profusely spotted and barred with white.
- Male's loud sound is monotonus calls - kuo kuo kuo and the female has metallic clicking call which carries a long way.

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| **Asian male Koel** | **Asian female Koel** |

**LOVEBIRDS**

- The genus group *Agapornis* are referred to as lovebirds and are native to Africa.
- There are nine species, three species are fairly common.
- Lovebirds are very hardy and long-lived.

- They make excellent pets and tame readily if obtained at a young age; older birds may become aggressive.
- Determining the sex of lovebirds is difficult.

**THE BANGALESE (OR SOCIETY) FINCH**

- The Bengalese (or society) finches, *Lonchura striata domestica*, are probably derived from the white-backed munia, Lonchura striata. These small birds are about 4 inches long.
- The white-backed munia is found in India and Ceylon.
- It is primarily brown with very dark, almost black, head and breast; the rump and underside are white.
- There are about eight different varieties of the domesticated Bangalese or society finch.
- The categories are self chocolate, pied chocolate, dilute chocolate and white, white with brown eyes, self fawn, pied fawn, dilute fawn and white, and white with ruby eyes.

## POPULATION DYNAMICS

A **<u>population</u>** is a group interbreeding individuals / organisms that occupy a certain area at a certain time. The area a population occupies is not always the same, the total number of individuals changes frequently, and the age and sex composition is constantly shifting. It is dynamic. Therefore, **<u>wildlife population dynamics</u>** are the study of factors and their interactions that control or influence the growth and decline of wildlife.

Elements of population dynamics:

1. Population size or density per unit area
2. Age and sex structure
3. Productivity

These three things are controlled by (i) reproduction, (ii) movement and (iii) mortality.

Every habitat sets limits on the total population it can support, by virtue of its capability to provide food, shelter, nesting places, drinking water or other essentials for that animal species. For some species, the limiting factor is space between one individual and another. So, we may think of a given habitat as a box of definite dimensions (which probably change seasonally). Within this box, the population lives. Through reproduction, it tends to become more crowded; but since the box always has definite capacity, every addition over that capacity means that there is a corresponding death or departure from the box (mortality or movement).

In spring, where seasons are regular, the box becomes large with the start of the growing season. The young are brought forth in this expanded box. Then, as the box shrinks with the coming of winter, the losses occur. Movement outside the box is often the same as mortality, since, if the young individuals are lucky, they will find suitable habitat not already occupied.

To manage this situation, we can remove the individuals from the box and reduce the amount of natural mortality or movement. This is called **hunting harvest**.

**Carrying capacity concept:**

**Carrying capacity** is briefly stated as the number of individuals which can be supported (i.e. carried) on a given area for a significant period of time. Where there are seasons of marked environmental adversity, such as cold snowy winters or hot dry summers, then the carrying capacity will drop accordingly during the unfavourable season. Then as the favourable season is reached again, the carrying capacity rises. Ordinarily, wild animals are quite attuned to this annual fluctuation of carrying capacity, bringing forth their young close to the beginning of the season of high carrying capacity. As the habitat-box grows, the population expands through reproduction and growth to keep it full.

Carrying capacity may fluctuate around some general level, rising above it in some years and dropping below it in others. This is the usual case where the habitat elements stay much the same from year to year while the seasonal climate varies. But, where key habitat elements change from year to year, carrying capacity reflects their trend.

(i) Short-term changes in important elements can be caused by such periodic events as flooding, drought and fire.

(ii) Long-term changes in important habitat elements and through them carrying capacity are frequently caused by plant succession and by changes in land-use.

Therefore, the wildlife manager must make his managerial decisions on the basis of partial information concerning population levels, structure and dynamics.

**Patterns of population structure and dynamics:**

The structure and dynamics of a given population are strongly influenced by the

(i) sex ratio
(ii) age distribution among the sexually mature females
(iii) nutritional state
(iv) effects of crowding or harassment
(v) stresses of weather and disease, etc.

The loss is the sum of mortality and movement, which are local events.

**Relation of population dynamics to harvest:**

Two extreme situations which could influence the variations in the patterns of population dynamics are:

(i) No cropping by humans (hunting or trapping)

(ii) Heavy cropping

When there is no cropping by man (say in a park or sanctuary), the population quickly fills its box and the competition between individuals, either for space or for some other habitat necessity will arise. In such a competitive situation, the strong (i.e. the healthy prime adults) will have the advantage over the weak (i.e. young, the sick and the aged). This is reflected in the pattern of mortality, since the heavy losses are among the very young and very old. This situation will have an influence on the sex ratio, where severe competition exists on young males; which will result in a small annual survival of young with the large part of the population in the prime years and heavy mortality among old.

When heavy annual cropping of both sexes is done, the population structure differs. The annual removal of a substantial proportion of the population reduces competition among individuals. This improves the chances of survival among the weaker / young members of the population.

Natality is the production of new individuals in a population through birth; while mortality deals with the level of death within a population. Natality is influenced by breeding age, mating habits and population density. The factors of mortality include predation, disease and parasites, weather, starvation, pollution, hunting and accidents. Wildlife population dynamics are affected by factors such as births, deaths, immigration and emigration. The balance of births and immigrations with deaths and emigrations will result in zero population growth.

## EFFECTIVE POPULATION SIZE

The effective population size ($N_e$) is a measure of how well the population maintains genetic diversity from one generation to the next. Genetic diversity is lost at the rate of ½ $N_e$ per generation. Populations with small effective population sizes lose genetic diversity at a faster rate than those with large effective population sizes.

The concept of $N_e$ is based on the genetic characteristics of a theoretical or ideal population that experiences no selection, mutations or migration and in which all individuals are asexual and have an equal probability of contributing offspring to the next generation. However, real population differs greatly from ideal population. Estimating how rapidly a real population loses genetic diversity requires comparison of the genetic characteristics of the real population with those of the ideal population. A real population that loses genetic diversity at the same rate as an ideal population of size 50 (1 % per generation) has an effective population size of 50, regardless of its actual size.

Strictly defined, **effective population size** is the size of a theoretically ideal population that loses genetic diversity at the same rate as the population of interest. Or effective population size (Ne) (or) effective number is defined as the size of a standard population, equally divided between males and females which would have the same rate of inbreeding as the one in question.

In general, the effective size of a population is based on three characteristics:

1. The number of breeders - Large number of breeders pass on a larger proportion of genetic diversity to the next generation.
2. Their sex ratio - A heavily biased sex ratio in the breeders will result in loss of genetic diversity as the underrepresented sex will contribute unequally large proportion of offspring's genetic diversity.
3. The relative numbers of offspring they produce during their lifetime – Differences in the family size also result in loss of diversity since some individuals contribute few or no offspring to the gene pool.

In the idealized population, the rate of inbreeding (△F) is related to population size.

$$\triangle F = \frac{1}{2N}$$

The effective population size is related to △F in the same way.

$$\triangle F = \frac{1}{2Ne}$$

$$Ne = \frac{1}{2\triangle F} \quad [Ne \cong N+1/2] \; [\triangle F \cong 1/2N+1]$$

In wild animals, the sexes are often unequally represented among breeding individuals and, in general, fewer males than females are used. The two sexes however, contribute equally to the genes in the next generation. Therefore, the sampling variance attributable to the sexes must be calculated separately.

In idealised population $N = N_m + N_f$, i.e. equal number of males and females. When unequal number of males and females are there then the effective number is twice the harmonic mean of the number of two sexes. It is twice the harmonic mean because the population size is $N = N_m + N_f$

The harmonic mean is $\frac{1}{[1/2\,(1/N_m + 1/N_f)]}$

So $\frac{1}{Ne} = \frac{1}{4\,N_m} + \frac{1}{4\,N_f} = \frac{Nm + Nf}{4\,Nm\,Nf}$

$$Ne = \frac{1}{\frac{N_m + N_f}{4\,N_m\,N_f}} = \frac{4\,N_m\;N_f}{N_m + N_f}$$ --------- **Equation - 1**

The rate of inbreeding is then,

$$\triangle F = \frac{1}{8N_m} + \frac{1}{8N_f}$$

This method assumes that the population is not growing, has no overlapping generations, and that the family sizes have a poisson (random) distribution – this is the theoretically expected distribution, if each individual in the population has an equal opportunity to breed.

Unfortunately, in captive populations, family size distributions are rarely determined by random mating and are not poisson in form. In unmanaged populations, many more adults than expected may fail to produce offspring; while in intensively managed population, fewer adults than expected may fail to produce. So, a more accurate method of estimating Ne would incorporate information of family size. The family size of an individual is the total number of offspring it produces during its lifetime and that survive to adulthood. In this case, both mean family size (k) and the variance in family size ($V_k$) need to be calculated across all the individuals; individuals who fail to breed must be included, contributing family size of zero. Now, it is possible to calculate $N_e$ separately for each sex.

The effective size of males is

$$N_{e(m)} = \frac{N_m + \bar{k}_m - 1}{\bar{k}_m + \frac{V_{Km}}{\bar{k}_m} - 1}$$

Where, $\bar{k}_m$ is the average number of young surviving to adulthood across all males; $N_m$ is the number of adult males in the population during a generation; and $V_{k(m)}$ the variance in number of young surviving to adulthood, which is defined as

$$V_{k(m)} = \frac{\sum (k_m - \bar{k}_m)}{N_m}$$

Where, sum is over the number of adult males in the population; and $k_m$ is the number of offspring surviving to adulthood for each male.

The effective size for female ($N_{e(f)}$) is calculated as that of males using family size data for females. Then the effective size for the overall population is determined using equation – 1, by replacing $N_m$ with $N_{e(m)}$ and $N_f$ with $N_{e(f)}$:

$$Ne = \frac{4\, N_{e(m)} * N_{e(f)}}{N_{e(m)} + N_{e(f)}}$$

**Inbreeding effective size** (Nef) refers to the size of an ideal population that would allow the same accumulation of pedigree inbreeding as the population of interest. Nef is a measure of effective population size that emphasizes the effect that small population size has on the chances of relatives mating with each other. Such mating leads to loss of heterozygosity. Effective population size (Nef) can be estimated by calculating the harmonic mean of the population size over time from the founding generation to the penultimate generation.

$$N_{ef} = \frac{t}{\frac{1}{N(0)} + \frac{1}{N(1)} + \frac{1}{N(2)} + \cdots + \frac{1}{N(t-1)}}$$

Where,

t= number of generations for which we have population size data

N(0) is the size of the founding population,

N(1) is the size of the population after one generation etc. and

N(t − 1) is the size of the population one generation ago.

Variance effective size, Nev, refers to the size of an ideal population that would accumulate the same amount of variance in allele frequencies as the population of interest.

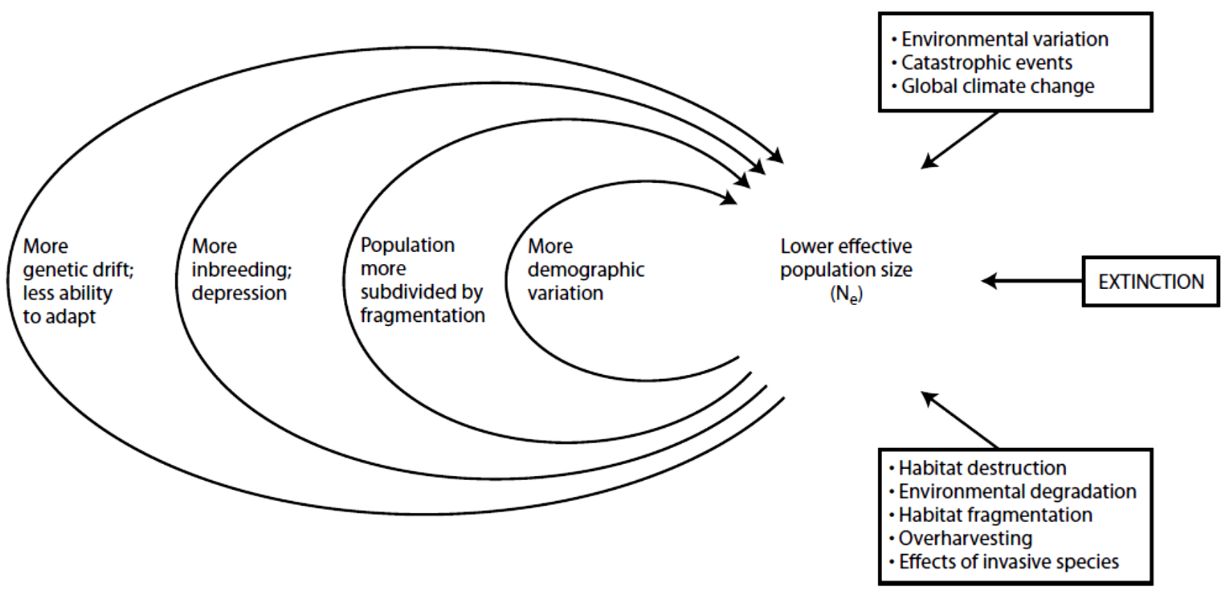
$$N_{ev} = \frac{t}{\frac{1}{N(1)} + \frac{1}{N(2)} + \cdots + \frac{1}{N(t)}}$$

when the sexes are not contributing equally to the allele pool,

$$N_e = \frac{4NmNf}{N_m + N_f}$$

The inbreeding effective size is more sensitive to the number of original founders N(0)] and the variance effective size is more sensitive to the number of offspring in the current generation N(t).

Nef gives an indication of loss of heterozygosity and Nev gives an indication of the increase in variance of allele frequencies between subpopulations. Increasing populations generally have a larger Nev than Nef, while declining populations will generally have larger Nef than Nev. Where as eigenvalue effective size, Neλ, focuses on the rate at which unique alleles are lost from a population.



**EXTINCTION VORTEX**

Eg. Eastern fence lizards, Sceloporus undulatus, at Tyson Research Center in eastern Missouri, USA.

Sceloporus population at Tyson from 1996 to 2000.

| Year | Population Count |
|---|---|
| 1996 | 140 |
| 1997 | 250 |
| 1998 | 110 |
| 1999 | 26 |
| 2000 | 180 |

$$N_{ef} = \frac{t}{\frac{1}{N(0)} + \frac{1}{N(1)} + \frac{1}{N(2)} + \cdots + \frac{1}{N(t-1)}} = \frac{4}{\frac{1}{140} + \frac{1}{250} + \frac{1}{110} + \frac{1}{26}} = \frac{4}{0.058} = 68.9 = 69$$

This estimated effective population size (69) means that, in terms of genetic inbreeding, this population (with a mean census size of 148 lizards over 5 years) will accumulate the effects of inbreeding at the same rate as a population that had a constant size of only 69 individuals.

$$N_{ev} = \frac{t}{\frac{1}{N(1)} + \frac{1}{N(2)} + \cdots + \frac{1}{N(t)}} = \frac{4}{\frac{1}{250} + \frac{1}{110} + \frac{1}{26}} = \frac{4}{0.05655}$$

= 70.73 = 71

Nev 71 means that, in terms of genetic drift, this population (with a mean size of 148 over 5 years) will accumulate the effects of drift at the same rate as a population that had a constant size of 71 individuals.

**Minimum Viable Population (MVP)** is the smallest isolated population (of a given species in a given habitat) having a 99% chance of remaining in existence for 1,000 years, despite the foreseeable effects of demographic stochasticity, genetic drift, environmental stochasticity (random changes in the environment), and natural catastrophes.

**50/500 rule**

The "50" part of the 50/500 rule states that populations with an inbreeding effective population size (Nef) under 50 are at immediate risk of extinction. This is because, in such small populations, inbreeding and demographic stochasticity can quickly push the population into an extinction vortex. The "500" part of the rule means that populations with a variance effective size (Nev) of less than 500 are at long-term risk of extinction. In these populations, genetic drift may be a strong force, leading to eventual loss of genetic variation.

Example: European adder (Vipera berus) - venomous snake

Adult male and female adders in each year

| Year | Number of adults | No. of males | No. of females | Corrected population size |
|---|---|---|---|---|
| 1984 | 138 | 98 | 40 | |
| 1985 | 40 | 29 | 11 | |
| 1986 | 34 | 24 | 10 | |
| 1987 | 42 | 32 | 10 | |
| 1988 | 37 | 27 | 10 | |
| 1999 | 41 | 29 | 12 | |
| 2000 | 34 | 27 | 7 | |

This resulting loss of genetic variation can influence the dynamic and persistence of population through is inbreeding depression loss of phenotypic variation and plasticity and loss of evolutionary potential. This leads to accelerated decline towards extinction in a process terrmed extinction vortex.

The expected loss of genetic variation (as heterozygosity) per generation is H= -1/2 N. where, N is size of adult population. An ideal population of 10 adults would be expected to lose ½ x10 or 5 % of its heterozygosity in one generation. A population of 500 adults annually loses more than 10 % of original heterozygosity in 200 years and about 100 adults may lose 5 times that much in same period.

## PLANNED BREEDING OF WILD ANIMALS

This is an important feature to be taken care of during the mating of wild animals. To have a planned breeding of wild animals, one should understand the reproductive biology of the concerned wild animal species.

| **Animal** | **Age of puberty** | **Estrus related feature** | **Gestation period** |
|---|---|---|---|
| Elephant | 10 – 12 years | 16 weeks estrus cycle | 22 months |
| Tiger | 3.5 – 5 years | Polyestrus | 98 – 114 days |
| Leopard | 2 – 3 years | Polyestrus | 98 – 105 days |
| Lion | 3-6 years | Polyestrus | 98 – 114 days |
| Cheetah | 14-16 months | Seasonally Polyestrus | 90 – 95 days |
| Jungle cat | 9 10 months | Probably Polyestrus | 66 days |
| Spotted deer | 16-18 months | -- | 210 – 225 days |
| Sambar deer | 16 months | -- | 240 days |

**Captive breeding** is the process of breeding animals in human controlled environments with restricted settings, such as wildlife reserves, zoos and other conservation facilities; sometimes the process is construed to include release of individual organisms to the wild, when there is sufficient natural habitat to support new individuals or when the threat to the species in the wild is lessened. Captive breeding programs facilitate biodiversity and may save species from extinction. However, such programs may also reduce genetic diversity and species fitness.

For captive breeding, genetic diversity is essential to know the number of animals that are necessary to start the breeding. The population must be sufficiently large, so that the chances of complete extinction due to untimely death may be kept at the minimum. It should also be large as enough to maintain the maximum possible genetic diversity. Genetic diversity cannot be achieved by increasing the numbers alone, because many species vary in terms of sex ratio, breeding pattern, population fluctuations etc. These characteristics affect the gene pool of a population.

Captive breeding will not be successful if habitat conservation measures for the species are not in place. There is no point in breeding an endangered species in zoos for introduction or reintroduction if the habitat is not available for the species. **Habitat degradation** and **fragmentation** are also issues that need to be addressed.

Successful captive breeding programs need to be matched with successful introduction and/or reintroduction strategies. Wildlife biologists must understand how an endangered species uses its habitat and how they interact with each other in the wild. The reintroduction of these captive populations into natural habitats is not always successful. Due the small founder (initial) populations, many individuals in these populations become inbred and therefore their level of fitness is reduced. This means that they are less likely to survive in the wild.

**Goals of Captive Breeding**

The main goal of most captive breeding programs for endangered species is to *establish captive populations that are large enough to be **demographically stable** and **genetically healthy**.*

Captive breeding is generally undertaken when a species has reached critical population levels where risk of extinction is likely. These programs are usually undertaken with the following goals:

- Maintain a healthy age structure (demographics) within the population
- Ensure that reproduction is successful
- Protect the population against disease
- Preserve the gene pool to avoid problems of inbreeding
- Provide animals to re-establish or restock wild populations when needed

One of the problems with breeding threatened species in such a captive environment is that they may undergo evolutionary changes in ways that compromise their fitness in the wild. Captive populations may encounter different genetic problems in captivity influenced by their conditions. These can include:

- Higher level of inbreeding due to small founder population
- The favouring of harmful mutations through genetic drift
- Loss of genetic diversity
- Genetic adaptations to captive conditions rather than natural conditions

**Issues / limitations of Captive Breeding**

1. Need of establishing a self-sufficient captive populations - This means that the genetic diversity of captive populations is likely to be low.
2. Poor success in reintroductions - The species must be able to survive once it is released into its natural habitat. The longer it is in captivity, the less likely it is to survive in the wild.
3. High costs
4. Domestication - Some species are very difficult to breed in captivity due to their natural behaviours. For example, migratory birds and fish that are highly mobile and are extremely difficult to breed in captivity.
5. Preemption of the recovery techniques
6. Disease outbreaks
7. Captive breeding programs tend to have species bias. Although many animal species are endangered worldwide, mammal species tend to be favoured for captive breeding programs.

The maintenance of viable captive population of most, if not all, threatened species should therefore be an important component of the strategy to preserve the worlds biodiversity. *Ex-situ / In-situ* conservation is just one of many options open to zoo managers / wildlife managers, but often represents the only hope for species nearing extinction in the wild. However, zoos and aquaria undoubtedly have considerable capacity to preserve threatened species. Zoo hold *ex situ* population assigned to highest risk categories like the endangered and the vulnerable categories.

**CONTROLLED BREEDING AND ASSISTED REPRODUCTION**

This is gaining more significance now-a-days and is being considered as one of the significant factors linked to effective conservation of different wild animal species belonging to various taxonomical classes.

**1. Artificial Insemination**

This technique is used in multiple species of the animals ranging from the honey bee to elephant. The semen or spermatozoa are collected from donor males, processed and frozen for long-term storage and for world-wide distribution to inseminate females of the same species to propagate new generations. This significant reproductive technology is useful in captive breeding of wild animal species like the highly valued and endangered wild animals. Eg. Tigers, Lions, Elephants, Chimpanzees, etc. Frozen semen banks are highly required with history of the concerned wild animal species used for further advancement of breeding. Electro-ejaculators are being used to collect semen from male genital organs, involving the application of varied and measured electric current over the selected sites of the body. Female genitalia based diseases like pyometra , metritis , etc. may be fully avoided by using this assisted reproductive technology.

Problems associated with AI in wild animals:

(i) Use of anesthesia for both semen collection from male and insemination of the female.

(ii) The fertility of semen obtained by artificial techniques is often less than that produced by natural ejaculation and the sperm usually begin to deteriorate soon after collection

(iii) The timing of AI to co-inside with the ovulation requires a detailed knowledge of female reproductive cycle

However, use of hormones to bring the female into estrus can allow the insemination to be planned ahead. In spite of problems encountered, AI using fresh and frozen semen has been successfully performed in many cases. The first AI in wild animal species with frozen semen occurred in 1973 in a wolf.

**2. Embryo transfer**

- Many genetically superior wild animals germplasm may be used for breeding purpose and the associated factors with embryo-transfer are:-
  - Timely recovery of embryos
  - Timely deposition of embryos
  - Superior germplasm of the bulls used for production of embryos.
- Embryo-transfer techniques in wild animal species may help in minimizing the risk of disease- transmission associated with the long-distance movement of breeding wild animals.
- Embryo-tansfers were frequently carried out in deer and camelid species, in general. Studies have to be undertaken with regard to super-ovulatory responses in multiple-species of wild animals reared under captive conditions.

First successful nonhuman primate surgical ET in a baboon was done in 1975.

**3. Conservation and genome banking:**

Genome banking includes cryogenic storage of semen, ova, embryos and tissues for further production of animals which can be accomplished after thawing of the cryopreserved materials and transfer to the recipients. By micromanipulation, one can produce twins and hemi-embryos, out of which one copy can be grown and the other copy can be preserved in gene bank. The programme of genome banking needs characterization, selection, collection, processing, culture and cryopreservation of sperm cells, embryos and embryonic cells of different species of animals, mapping of genomes, etc. Besides, there is a need to develop the germplasm policies, central repository to fulfill both short-term and long-term objectives for providing storage space for semen, embryos, oocytes, cell lines and DNA from a wide range of animal species and to develop animal germplasm data base.

**4. Cloning technology**

A clone is a group of individuals which are identical in all respects.

- Though much progress has not been made in wild animal species with regard to cloning technology, it is to be understood that the cloning of a targeted wild animal species from an adult somatic cell may be considered as one of the technological advances with regard to assisted reproduction in wild animals.

- It is significant that in many animals the great majority of cloned embryos may perish before reaching full term. If the cloned embryos have more epigenetic errors, then there is likelihood of death among such cloned embryos. It is a known fact that cloned embryos contain fewer cells than the case with normal embryos.

Since cloned individuals are identical, the genetic diversity is reduced. This apprehension can be negated if individuals of diverse genetic attributes are cloned in a planned manner.

***5. In-vitro* embryo production**

The embryos may be preserved even after the death of the concerned wild animal. However availability of experiment-based information are scarce in nature.

**6. Cryopreservation of wild animal species:**

The need of conservation will have to be recognized by the scientists and conservationists so that the *ex situ* conservation programmes will become the nuclei of genetic material for dwindling populations of wild animals. The extinction may be softened by the "**frozen zoo concept**".

**7. Application of DNA technology:**

Effective breeding management requires data on population size, sex ratio, age structure and genetic variation. As it is very difficult to assess the animals in the dense vegetation, DNA analysis techniques such as Restriction Fragment Length Polymorphism (RFLP), DNA fingerprinting, Random Amplified Polymorphic DNA (RAPD), microsatellite sequences, etc. can be used to find out the level of polymorphisms.

**CONSERVATION OF WILD ANIMALS**

**Conservation** means the maintenance of a reasonable number of members of every species from the largest mammals to the smallest invertebrates in their own habitat without destroying that habitat – according to Noel Simon.

According to Indian Forest record (1965), **conservation** means planned management and wide use of natural resources, so as to prevent over-exploitation, destruction or neglect i.e. wildlife conservation. Preservation means saving and maintaining the wild animals against injury or destruction as well as keeping them safe and undisturbed from private or public use.

**Causes of extinction / depletion of resources:**

(i) Hunting

(ii) Destruction of habitats

- Establishment of new human settlements, croplands, grazing grounds, quarry in mining sites, etc.
- Deforestation caused by jhuming, felling of trees for timber / firewood, fire and over-grazing, etc.
- Damages of the forest / grassland by acid rain
- Pollution of water bodies, killing aquatic plants and animals.
- Building of roads and rails through ecologically fragile areas
- Construction of dams and reservoirs destroying habitats of wildlife and block spawning and migration of certain fishes

(iii) Destruction of habitats – Vultures and kites feed on carcasses. Since the carcasses are buried or burnt now, the population of larges flying bird, California Condor (*Gymnogyps calfornianus*) has started declining.

(iv) Migratory routes – changes in settling areas and routes of migratory animals result in their going astray and perishing.

(v) Exotic species – Introduction of exotic species produce ecological imbalance due to removal of biological-control such as:
Eg. Goats and rabbits introduced in Pacific and Indian Ocean islands have destroyed habitats of reptiles, birds and plants.

(vi) Low fecundity

(vii) Industrial and environmental pollution

(viii) Economic considerations

**Categories of wild animals for the purpose of conservation**

**EXTINCT:** No possibility of restoring the population, no pure bred males or females can be found, even the last individual has died.

**CRITICAL:** Close to extinction, genetic variability reduced below that of ancestral population.

**ENDANGERED:** In danger of extinction, because of the number is too small to prevent genetic loss through inbreeding. Preservation must be enacted.

**VULNERABLE:** Some disadvantageous effects endanger the existence of the population.

RARE: Species with small populations in the world, not endangered and vulnerable, but are at risk.

**THREATENED:** Species in any one of the above three categories - endangered, vulnerable or rare.

**INSECURE:** Population no. is decreasing rapidly

**NORMAL:** Population not in danger of extinction.

**METHODS OF CONSERVATION:**

Once it has been decided to conserve a species, basically there are two methods of conservation i.e. *in situ* and *ex situ*.

1. Haploid forms: a. frozen semen
   b. frozen eggs / oocyte
2. Diploid forms: a. frozen embryos
   b. live animal

***In situ* preservation:**

*In situ* conservation can be done either in the habitat such as biological farms in zoological parks or sanctuaries. The major advantages are that the animals are always available for immediate use and from aesthetic point of view; live animals are a pleasure to look at and create awareness among people.

**Advantage:**

1. Live animals can be evaluated and improved over years.
2. Genetic defects, if any, could be eliminated
3. Live animals are always available for immediate use.

**Disadvantage:**

1. More number of animals have to be maintained
2. If small population to be maintained considering cost of maintenance, inbreeding may result.
3. Maintenance of live animals in large number exclusively for conservation can be very expensive.

***Ex situ* method:**

*Ex situ* conservation consists of preservation in the form of frozen semen, frozen oocyte, frozen embryos, embryonic stem cells and DNA. The cost of maintenance of frozen embryos will be relatively cheaper compared to the maintenance of live animals.

**Advantage:**

1. Easily done without any change in the genetic structure - population as a whole need not

be maintained

2. Resource requirement for *in situ* preservation in quite large as compared to cryogenic methods.

**Limitations:**

1. *Ex situ* preservation using frozen semen delays the restoration of a species.

2. An important danger faced by a species restored from cryogenic is from the important changes in the environment like germs, climate, etc. that have taken place over the years.

**PROJECTS RELATED TO BREEDING OF WILD ANIMALS**

Various **projects** were established towards better breeding aspects of the selected wild animal species.

**Crocodile Breeding Project**

- Due to the large scale hunting for their skin, 3 species of crocodiles – the Mugger or Fresh water or Swamp crocodile, the Gharial and the Salt water or Estuarine crocodile got reduced in their numbers.
- From 1st April, 1975, the actual project was started with the following objectivities:
    - To continue the task of locating best crocodile areas within the country.
    - To collect eggs as soon as possible after laying and transport them to central protection area for hatchery incubation and to rear the young one until it assumes size for release back into the wild.

**Elephant Project**

The project was started officially in 1991-92; but launched in 1993 by the central Government to afford protection to elephants and it had following objectives:-

- To identify the limiting factors of the habitat and to remove it by the management.
- To adapt systematic management plans.
- To eliminate human exploitation and disturbances.
- To build up the elephant habitat to reduce limiting factors.
- To develop the elephant by planning and propagating the favourite food plants of the elephant.

**Project Lion**

Lion is the top carnivore in the food chain of the ecosystem. In 1972, this project was initiated in India. Accordingly, to facilitate successful breeding of lions, following were implemented in this project:-

- Shifting of all maldharis from sanctuary and their resettlement outside it.
- Construction of barricades along the water resources to prevent entry of cattle.
- Fencing of periphery of the Gir sanctuary by dry rubble wall of 1 meter height as the protective measure.
- Minimizing of human interferences within the ecosystem.
- Securing of full co-operation of legislators, public and maldharis.
- Improving the habitat of lions in Gir region.

**Project Tiger**

- On recommendations from the task force set up by the Indian board for wildlife, Project Tiger was initiated as a Central Sector Scheme in 1973. The breeding of tigers was facilitated by improvement of tiger habitat by identifying and limiting of the limiting factors of the habitat for tiger population. Thorough emphasis was given on protection of tigers, fire-protection, disease control, shifting of villages inside the tiger reserve areas, grazing control, development of water resources, enhancement of research and population estimation etc. Many tiger reserves were started and tiger conservation was aimed in these.

Details of the projects can be read from Ranga, M.M. (2012) Wildlife management and Conservation. 2nd Ed. Agrobios (India), Jodhpur.

## List of endangered wild animals in India

| Sl. No. | Name of the Species | Name of the coordinating Zoo | Names of the participating Zoos | Number of animals of the species in captivity |
|---|---|---|---|---|
| 1. | Asiatic lion (*Panthera leo*) | Junagarh | Hyderabad, Bhopal, New Delhi, Rajkot | 80 |
| 2. | Bengal tiger (*Panthera tigris*) | Bhopal | New Delhi Hyderabad, Bhubaneswar, Chhatbir, Chennai | 255 |
| 3. | Snow leopard (*Panthera uncia*) | Darjeeling | Leh, Kufri, Nainital, Gangtok | 18 |
| 4. | Clouded leopard (*Panthera nebulosa*) | Sepahijala | Guwahati | 14 |
| 5. | Asiatic cheetah (Acinonyx jubatus venaticus) | Junagarh | -- | -- |
| 6. | Golden cat (*Catopuma temmincki*) | Guwahati | | 3 |
| 7. | Tibetan wolf (*Canis lupus*) | Darjeeling | Gangtok, Nainital, Kufri | 21 |
| 8. | Wild dog (*Cuon alpinus*) | Visakhapatnam | Chennai | 30 |
| 9. | Brown bear (*Ursus arctos*) | Kufri | Leh | 2 |
| 10. | Sun bear (*Helarctos malayanus*) | Aizawl | Guwahati | 2 |
| 11. | Red panda (*Ailurus fulgens*) | Darjeeling | Gangtok, Yachuli | 18 |
| 12. | Binturong (*Arctictis binturong*) | Sepahijala | Guwahati, Aizawl | 13 |
| 13. | Pangolin (*Lepus nigricollis*) | Bhubaneswar | -- | 8 |
| 14. | Lion tailed monkey (*Macaca silenus*) | Chennai | Mysore, Trivandrum | 60 |
| 15. | Pig-tailed monkey (*Macaca nemestrina*) | Sepahijala | Guwahati | 18 |
| 16. | Stump tailed monkey (*Macaca radiate*) | Aizawl | Guwahati | 51 |
| 17. | Phayre's leaf monkey (*Trachypithecus phayrei*) | Sepahijala | -- | 14 |
| 18. | Crab eating monkey (*Macaca fascicularis*) | Chidiyatapu (Port Blair) | -- | 12 |
| 19. | Nilgiri langur (*Semnopithecus johnii*) | Chennai | Mysore | 27 |
| 20. | Golden langur (*Trachypithecus geei*) | Guwahati | Island near Guwahati | 14 |
| 21. | Capped langur (Trachypithecus pileatus) | Rangapahar | -- | 6 |
| 22. | Hoolock gibbon (*Hoolock leuconedys*), | Itanagar | Aizawl, Guwahati, Sepahijala | 11 |
| 23. | Rhinoceros (*Rhinoceros unicornis*) | Guwahati | Patna, New Delhi, Kanpur | 36 |

| | | | | |
|---|---|---|---|---|
| 24. | Indian bison (*Bos gaurus*) | Mysore | Chennai, Bondla | 37 |
| 25. | Wild ass (*Equus hemionus khur*) | Junagarh | -- | 11 |
| 26. | Himalayan tahr (*Hemitragus jemlahicus*) | Gangtok | Darjeeling, Kufri, Chopta | 3 |
| 27. | Nilgiri tahr (*Nilgiritragus hylocrius*) | Ooty | -- | 1 |
| 28. | Markhor (*Capra falconeri*) | Pehalgaon | -- | - |
| 29. | Blue sheep (*Pseudois nayaur*) | Gangtok | Darjeeling | - |
| 30. | Serow (*Nemorhaedus sumatraensis*) | Guwahati | Manipur | 6 |
| 31. | Swamp deer (*Cervus duvauceli*) | Lucknow | Jaldapara WLS | 115 |
| 32. | Thamin deer (*Cervus eldii*) | Manipur | Guwahati, Kolkata, New Delhi | 177 |
| 33. | Mouse deer (*Tragulus meminna*) | Hyderabad | Bhubaneswar | 13 |
| 34. | Musk deer (*Moschus chrysogaster*) | Chopta | Gulmarg, Gangtok, Kufri | 11 |
| 35. | Hangul (*Cervus elaphus hanglu*) | Shikargah | -- | 1 |
| 36. | Chiru (*Pantholops hodgsonii*) | Leh | -- | 2 |
| 37. | Pygmy hog (*Sus salvanius*) | Basistha | Guwahati | 112 |
| 38. | Himalayan monal (*Lophophorus impejanus*) | Manali | Darjeeling, Gangtok | 23 |
| 39. | Blood pheasant (*Ithaginis cruentus*) | Gangtok | Darjeeling | -- |
| 40. | Cheer pheasant (*Catreus wallichi*) | Chail | Almora | 48 |
| 41. | Hume's pheasant (*Syrmaticus humiae humaie*) | Aizawl | -- | 4 |
| 42. | Grey Peacock pheasant (*Polyplectron bicalcaratum*) | Guwahati | Kolkata, Darjeeling | 60 |
| 43. | Sclater's (mishmi) monal (*Lophophorus sclateri sclateri*) | Yachuli | -- | -- |
| 44. | Tibetan eared pheasant (*Crossoptilon harmani*) | Yachuli | -- | -- |
| 45. | Temminck tragopan (*Tragopan temminckii*) | Yachuli | -- | -- |
| 46. | Blyth's tragopan (*Tragopan blythii*) | Kohima | -- | 12 |
| 47. | Western tragopan (*Tragopan melanocephalus*) | Sarahan | -- | 8 |
| 48. | Styr tragopan (*Tragopan satyra*) | Darjeeling | Gangtok | 2 |
| 49. | Grey jungle fowl (*Gallus sonnerati*) | Tirupati | -- | 33 |
| 50. | Red jungle fowl (*Gallus gallus gallus*) | Morni | Chail, New Delhi, Aizawl | 209 |
| 51. | Vultures (White backed Vulture, Himalayan Griffon Vulture, etc.) | Pinjore | Hyderabad, Bhopal, Junagarh, Bhubaneswar, Rajabhatkhawa, Guwahati | 93 |
| 52. | Falcons (Eagles, Hobbies, Kestral, Harrier, accipiter, etc. | Chhatbir | Jaipur | 3 |

| | | | | |
|---|---|---|---|---|
| 53. | Bustards (Great Indian bustard, Lesser florican, Bengal florican, Hubara bustard) | -- | -- | 1 |
| 54. | Nicobar pigeon (*Caloenas nicobarica*) | Chidiyatapu, Port Blair | Ahmedabad | 42 |
| 55. | King cobra (*Ophiophagus Hannah*) | Pilikula | Bangalore, Mammalapuram | 35 |
| 56. | Water monitor (*Varanus salvator*) | Chidiyatapu, Port Blair | Mammalapuram | 40 |
| 57. | Painted roof turtle (*Chrysemys picta picta*) | Kukrail | Mammalapuram | 2 |
| 58. | Himalayan salamander (*Tyletotriton verrucosus*) | Darjeeling | -- | |
| 59. | Malabar giant squirrel (*Ratufa indica*) | Pilikula | Chennai, Pune | |
| 60. | Malabar grey hornbill (*Ocyceros griseus*) | Kodanadu (Kerala) | Hyderabad | |
| 61. | Malabar pied hornbill (*Anthracoceros coronatus*) | Kodanadu (Kerala) | Hyderabad | |

## Bottleneck and founder effects:

Genetic drift can cause big losses of genetic variation for small populations.

Population bottlenecks occur when a population's size is reduced for at least one generation. Because genetic drift acts more quickly to reduce genetic variation in small populations, undergoing a bottleneck can reduce a population's genetic variation by a lot, even if the bottleneck doesn't last for very many generations.

A **founder effect** occurs when a new colony is started by a few members of the original population. This small population size means that the colony may have:

- reduced genetic variation from the original population.
- a non-random sample of the genes in the original population.