Chapter VIII

PRINCIPLES OF SELECTION

Introduction:

Populations of livestock can be manipulated to approach more closely the ideals of the producer by two means:

1. To alter genotypic frequencies (the distribution of genes among individuals in the population) by manipulating systems of mating.

2. To alter gene frequencies – increasing alleles with favourable effects on the phenotype at the expense of less favourable alleles at the same loci – by selection and gene migration (and the latter can be thought of as a type of selection).

Selection and bases of selection:

Definition:

It is a process in which certain individuals in a population are preferred to others for the production of the next generation.

Selection is also can be defined as, differential reproduction among individuals with different genotypes.

Types of selection:

There are two types of selection:

1. Artificial and 2. Natural selection

1. Natural selection:

It is differential reproduction among individuals with different genotypes not resulting from manipulation of the population by breeder.

Natural selection acts on the phenotype, or the observable characteristics of an organism, such that individuals with favorable phenotypes are more likely to survive and reproduce than those with less favorable phenotypes.

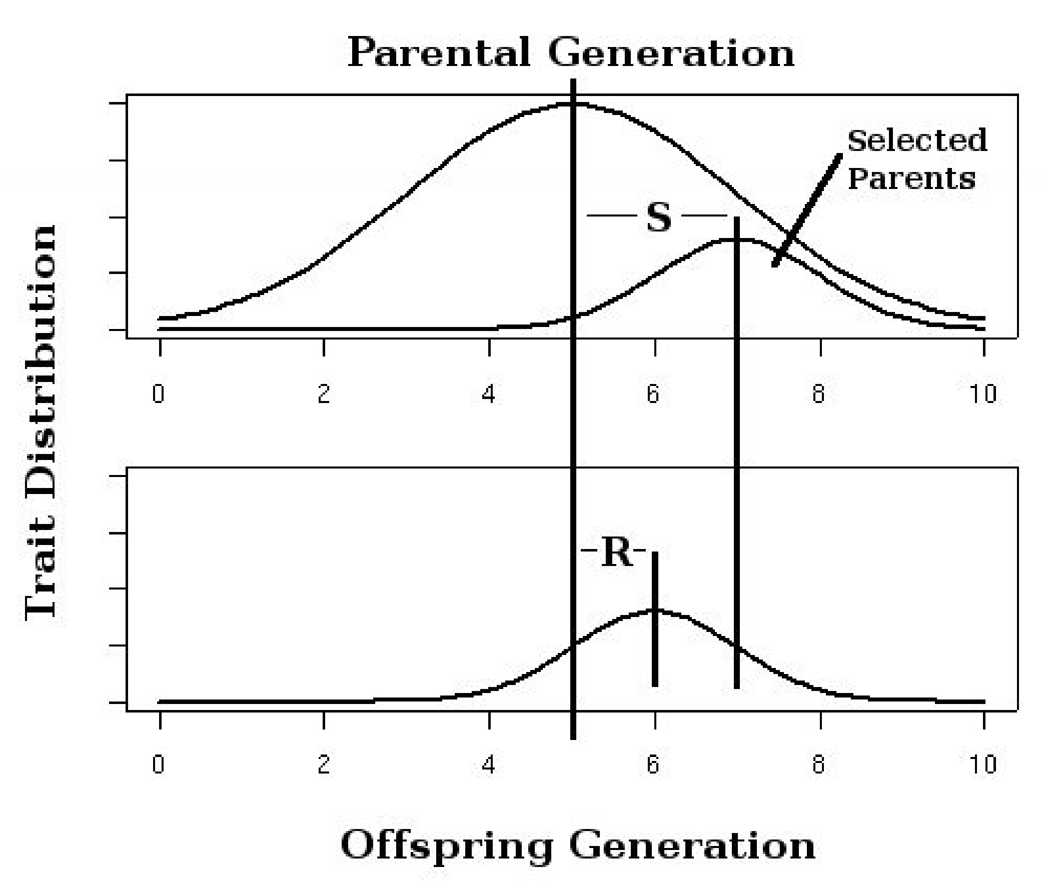
Also, natural selection arises from genetic differences among individuals in fitness (Darwinian fitness).

Fitness is number of offspring per individual which survive to breeding age.

Many traits contribute fitness such as disease resistance, age at sexual maturity, anatomy of the reproductive tract, libido, mating behaviour, maternal behaviour, milk production, and longevity.

2. Artificial selection:

In artificial selection the breeder chooses the parents of the next generation. The breeder determines which replacements will be retained and how long will be allowed to remain in the population.



The strategies of genetic progress through selection are:

1. Selection within breed/strain involves comparing animals of the same breed and mating the preferred animals to produce the next generation.

2. Selection between breeds or strains which can achieve dramatic and rapid genetic change when there are large genetic differences between the breeds chosen for the characteristics of economic importance.

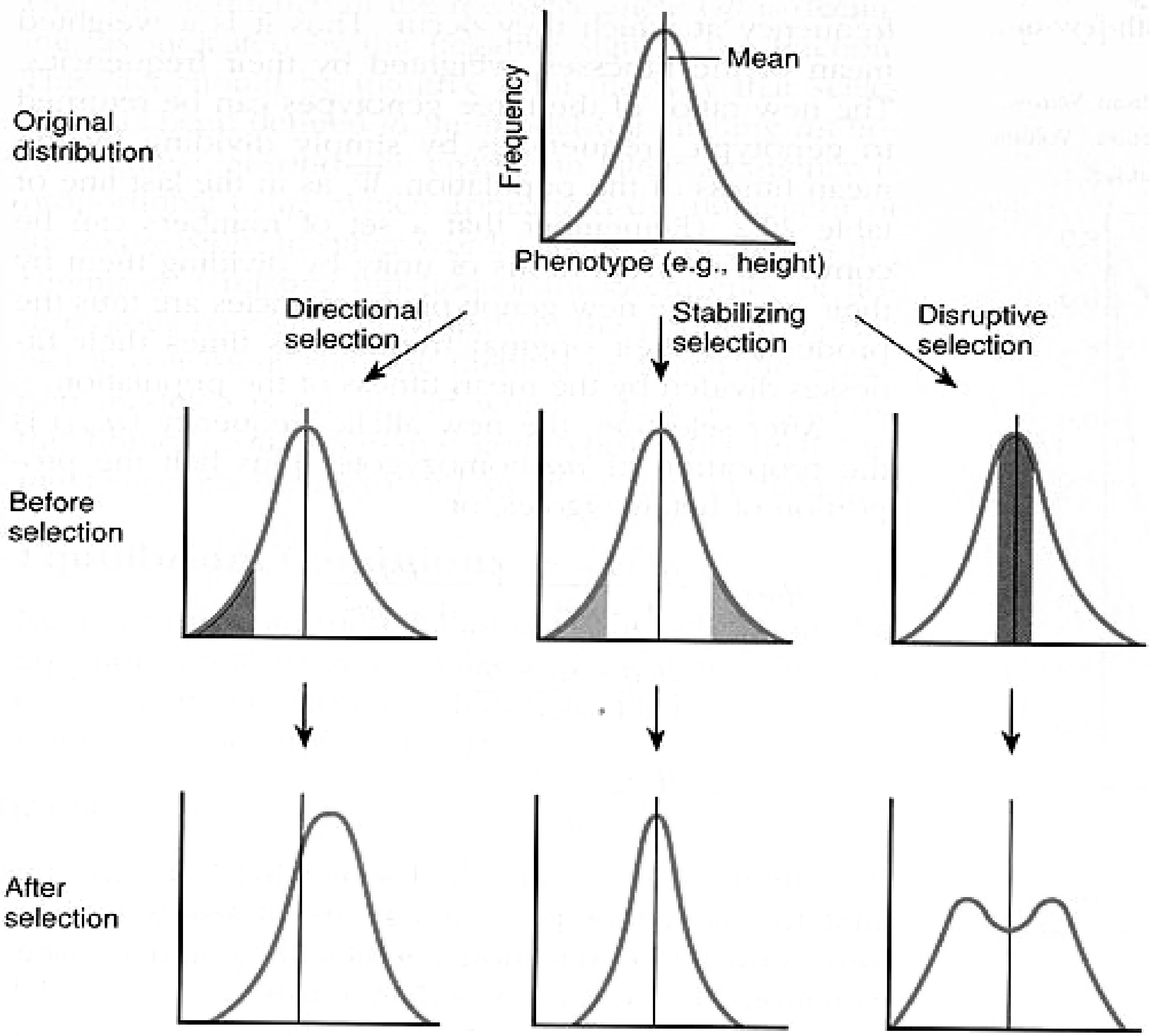
Bases and types of selection:

I. Selection for one trait.
II. Selection for multiple traits.

I. Selection for one trait:

There are three possible bases for differential reproduction among genotype:

1. Directional selection.
2. Stabilizing selection.
3. Disruptive selection.


Original distribution
Frequency
Mean
Phenotype (e.g., height)
Directional selection
Stabilizing selection
Disruptive selection
Before selection
After selection

1. Directional selection:

It is of the greatest concern to the animal produces.

It is selection of individuals to be parents of the next generation whose phenotypes more nearly approach a maximum (or minimum) for some trait, e.g. high body weight, high egg production, lower mortality.

Other individuals are not allowed to reproduce because they are poorer in phenotypic merit for the trait upon which selection is based.

The effect of directional selection for heritable trait is to change gene frequency in the next generation.

Alleles with favourable effects are increased in frequency at the expense of less favourable alleles at the same loci and assuming no change in the environment, the phenotypic average for the trait in the population is increased.

The name "directional selection" is descriptive of the increase in average phenotypic merit.

Methods of directional selection:

A. Individual selection:

Where selection of individuals based on their own phenotypic values (also called mass selection).

B. Between-family selection:

Where whole families are selected or rejected based according to the phenotypic mean of the family (we select the family with the largest mean).

This method is preferred when the heritability of the trait is low. But the efficacy of this method is reduced when the environmental variation common to the members of the same family is large.

Sib-selection and progeny testing are family-selection methods.

C. Within-family selection:

Where the best individuals within in each family are selected. The main case in which this method has an advantage is when there is a large common environmental variance.

EXAMPLE: The following table shows phenotypic values of 16 individuals in four families of full-sibs.

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

- **Individual selection:** we select A1, B1, A2, and D1 or B2
- **Family selection:** we choose all 4 individuals in family A
- **Within-family selection:** we select A1, B1, C1 or C2, and D1

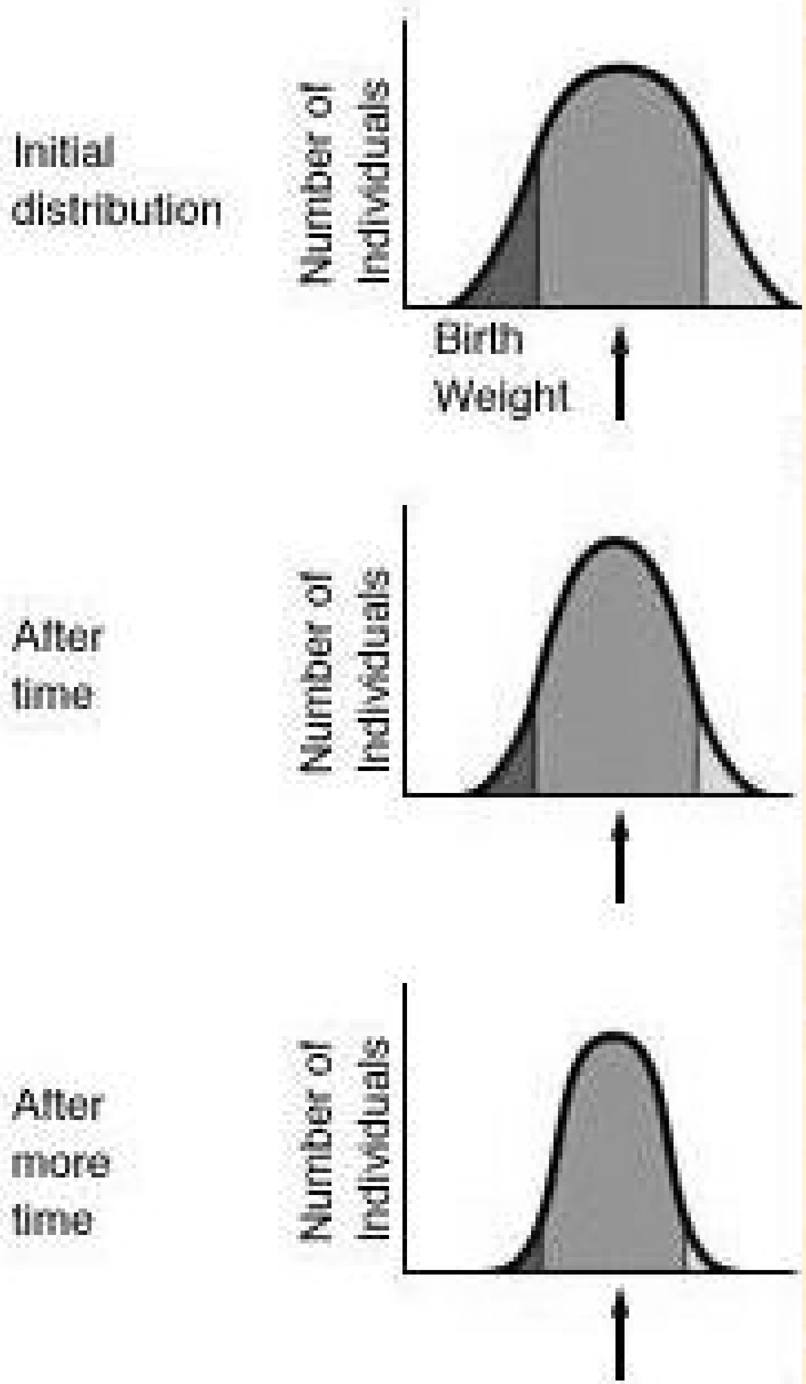
2. Stabilizing selection:

It can be done by two methods:

1. Phenotypes from around the population mean are selected e.g. practiced mainly in the breeding of pets and show animals weights.

2. In another less common form of stabilizing selection, the extremes of both directions are selected and paired with each other so that the mean of the population remain unchanged but variability is increased.

The effect of stabilizing selection causes no changes in gene frequency or in phenotypes.


Initial distribution
Number of Individuals
Birth Weight
After time
Number of Individuals
After more time
Number of Individuals

3. Disruptive (diversifying) selection:

It is that type of selection favouring both phenotypic extremes and the aim is to increase the magnitude of the extremes; and it is of limited importance in livestock breeding (in research for formation of inbred lines and divergent selection as sires are chosen for "maleness" and dams for "feminine" expression).

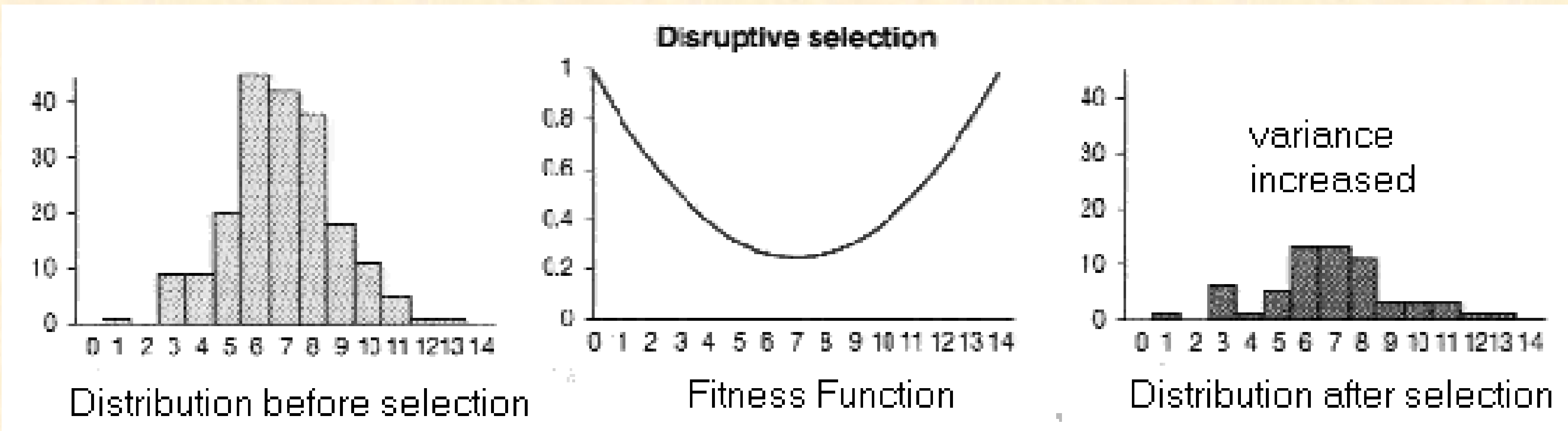
It is that type of selection characterized by:

1. **Favoring both phenotypic extremes,**
2. **With lower reproduction from individuals near the average.**

The effect of disruptive selection as with stabilizing selection could result in little change in average phenotype, breeding value or gene frequencies in the offspring generation.

If the selected parents were mated based on phenotypic similarity (assortative mating), offspring variance would be much increased and eventually separate and distinct sub-populations could be resulted

If the selected parents were mated based on disassortatively, offspring variance would be much reduced.


Disruptive selection
variance
increased
Distribution before selection
Fitness Function
Distribution after selection

Genetic effect of selection:
Selection does not create new genes.

Selection is practiced to increase the frequency of desirable genes in a population and to decrease the frequency of undesirable genes.

This may be illustrated by the following example, where A is the desirable gene and a the undesirable gene.

P	**AA**	**X**	**aa**
F1		**all Aa**	
		(Freq of A is 0.50)	
F2	**Aa**	**X**	**Aa**

Progeny	**1 AA freq. of gene A**
	2 Aa F2 is still 0.50
	1 aa

Let us assume that we cull all aa individuals in the (F2). If this were done, the remaining genes would be four A and two a.

Thus, the frequency of the A gene would be increased to 0.67 and that of the a gene would be decreased to 0.33.

The increased frequency of the A gene when the aa individuals were culled would also increase the proportion of AA individuals in the population.

If the frequency of A gene were 0.50, the proportion of AA individuals would be 0.50 multiplied by 0.50 or 0.25.

However, if the frequency of the A gene were increased to 0.67, the proportion of AA individuals would be 0.67 multiplied by 0.67 or 0.449.

If the frequency of desirable gene is increased, the proportion of individuals homozygous for the desirable gene also is increased.

If the selection is effective, the genetic effects of selection are to increase the frequency of gene selected for and – to decrease the frequency of gene selected against.

N.B.: Culling is another word for selection and it is used to describe the removal of inferior animals rather than the more positive selection of good ones. Thus selection and culling go together.

Genetic gain from selection:

Response to selection (R):

Definition:

It is the difference of mean phenotypic value between the progeny of selected parents and the whole of the parental generation before selection was made (population mean).

R = Average of the progeny of selected parents - Average of the population from which the parents are selected. $R = \bar{x}_P - \bar{x}_B$

The response to selection is dependent upon selection differential.

Selection differential:

It is the difference of mean phenotypic value between the individuals selected as parents and the whole individuals in the parental generation before selection was made (population mean).

S = Average of selected parents - Average of the *population* from which the parents are selected.

$$S = \bar{X}\text{ Selected} - \bar{X}\text{ Base}$$

NB: Response to selection is also dependent upon the selection differential, S.

The selection differential can be predicted in advance provided that two conditions hold:

I. The phenotypic values of the character being selected are normally distributed, and

II. Selection is by truncation (i.e. the individuals are chosen strictly in order of merit as judged by their phenotypic values) no individual being selected that is less good than any of those rejected.

It is important to note that a selection differential (S) can be calculated for both parents (the future sires and the future dams).

To calculate selection differential for males:

	Gain /day
Mean of selected males	2.00 kg /day
Overall herd mean	0.25 kg/day
Selection differential	(2.00–0.25) = 1.75 kg/day

To calculate selection differential for females:

	Gain / day
Mean of selected females	0.75 kg /day
Overall herd mean	0.25 kg/day
Selection differential	(0.75 – 0.25) = 0.50 kg/day

There two selection differentials are then averaged to give:

$$\frac{1.75 \text{ (for males)} + 0.50 \text{ (for females)}}{2} = 2.25/2 = 1.13 \text{ kg/day.}$$

Note what happens when there is no selection of females i.e. where the selection differential equals 0. The calculation then is:

$$\frac{1.75 \text{ (for males)} + 0.0 \text{ (for females)}}{2} = 1.75/2 = 0.88 \text{ kg /day.}$$

Clearly the potential genetic gain has been severely reduced from 1.13 kg/day to 0.88 kg/day.

The key to success in obtaining a high selection differential is to have plenty of variation to start with and many more animals than those needed to maintain the flock or herd size so that only the very best can be chosen as parents for the next generation.

Methods of estimation of selection differentials:

There are three ways of selection differential estimation:

1. Actual selection differential ($\bar{X}$ selected – $\bar{X}$ population).

2. Adjusted (effective) selection differential: actual selection differential weight for the number of progeny produced by each sire and dam.

Effective selection differential = $\dfrac{\sum X_i n_i}{\sum n_i} - \mu$

3. Standardized selection differential: is number of phenotypic standard deviations by which selected parents exceed the average of the population from which they were selected.

Also standardized selection differential (i) = actual selection differential expressed in standard measures for traits which are normally distributed that is:

$$i = S/\sigma P$$

So, $$S = i \,.\, \sigma P$$

To calculate the intensity of selection using this formula:

$$\text{Intensity (i)} = \frac{\text{Selection differential (SD)}}{\text{Phenotypic standard deviation }(\sigma P)}$$

From this equation we can see that selection differentials are dependent upon:

a. The proportion of the selection group (proportion saved P %) (where P% α 1/i)

b. The phenotypic standard deviation of the character (σP).

It is possible to calculate the intensity of selection using this formula:

$$\text{Intensity (i)} = \frac{\text{Selection differential (SD)}}{\text{Phenotypic standard deviation } (\sigma P)}$$

Factors affecting selection response:

The predicted response of a population to one generation of selection was show previously to equal:

$$R \text{ per generation} = h^2 \times S$$

Where:

R : is response of selection.

h^2: is heritability in the narrow sense.

S : is the selection differential.

$$R \text{ per year of selection} = \frac{h^2 \times S}{t}$$

Where t = the number of years constituting each generation.

Factors affecting response to selection: h2, S, t.

1. Heritability:

Heritability is the ratio of additive genetic variance to the sum of total genetic + environmental variance for a trait.

When h^2 is high i.e. much of the observed difference among individuals is caused by the average effects of their genes, and a large proportion of the superiority of selected parents will be transmitted to their progeny.

As h^2 increases, so does response to selection.

2. Selection differential and intensity of selection:

The response to selection may be generalized if the selection differential is expressed in terms of the phenotypic standard deviation σ P.

This standardized selection differential S/σP is called: the intensity of selection (i)

3. Generation interval (t):

It may be defined as, it is the time interval between the same stage in the life cycle of two successive generations.

It also defined as, the average age of the parents when their offspring which will produce the next generation are born.

For farm mammals, male and female generation intervals are not usually equal.

In meat animals, t for females is usually larger than for t for males. Since females, on the average, have longer reproductive lifes. Also, sires frequently are sold after a few seasons for use, to prevent them from mating their daughters and producing inbred progeny.

In dairy cattle, the male generation interval is often greater than the female t, because: dairy bulls are used extensively only after their daughters have been tested for milk production. By the time a progeny test is completed, a bull will be at least five years of age.

In poultry breeding operations, entire population are replaced with selected progeny at the same time. Under those conditions, male and female generation intervals are equal.

Generation intervals of domestic animals:

Species	Generation intervals
Human	25 years
Horse	9-13 years
Milk cows	4.5-5 years
Beef cattle	4-5 years
Sheep	3-4 years
Poultry	1-1.5 years
In Egyptian cow	6.1 years
In Buffalo	6.04 years

The relationship between the length of generation and the selection differential was investigated. When the generation intervals increases, the number of progeny increases and selection can be more intense.

For maximum progress i/t should be maximized.

Methods of selection

Selection can be classified on the basis of phenotypic selection or of genotypic (genetic) selection as the following:

I. Phenotypic selection:

- **A.** Individual or mass selection.
- **B.** Family selection.
- **C.** Within family selection.
- **D.** Combined selection.

II. Genotypic (genetic) selection:

- **A.** Pedigree selection.
- **B.** Family selection.
- **C.** Progeny testing selection.

Breeding value and the aids to selection:

Selection is the business of making decisions about the animal in the light of information.

Breeders have to start and consider the "Beeding value" (BV) of an animal.

Breeding value is the really it’s genetic worth and is what animal breeding is all about.

To help make decisions, there is a number of well recognized sources from which the required information can be obtained.

These are referred to "aids to selection" and are as follows:

A. Individual or mass selection.
B. Lifetime performance records.
C. Pedigree information.
D. Progeny performance.
E. Performance of other relatives (family selection).

Breeders have to start and consider the "Breeding value" (BV) of an animal.

Breeding value is the really it's genetic worth and is what animal breeding is all about.
The phenotype of an individual can then be shown as follows:

$$P = G + E = BV + E$$

An individual receives one half of its genetic makeup from each parent so that we expect the breeding value of an individual to be equal to the average of the breeding values of its parents:

Expected BV = ½ (BV of sire) + ½ (BV of dam).

This is only an expectation. A parent does not pass on the same genes to all its offspring. Random segregation occurs during meiosis such that a random member of each gene pair ends up in each gamete. This process is referred to as Mendelian Sampling. Therefore the actual breeding value of an individual is as follows:

BV = ½ BVS + ½ BVD ± sampling of genes.

Estimation of breeding value:

A. Individual's own performance or mass selection (Performance testing):

BV = heritability of the trait x (individual average – average of contemporaries).

<u>Or</u> BV = h2 x (individual deviation).

$$EBV = h^2\left(P - \overline{P}\right) \qquad Acc = \sqrt{h^2 x 1} = h$$

B. Multiple records on an individual (Lifetime performance records):

$$B.V = \frac{n\,h2}{1 + r\,(n-1)}$$ (Average deviation of the dam's records from her contemporaries).

$$\frac{n\,h2}{1 + r\,(n-1)}$$ (Accurcy) (Confidence factor).

C. Performance of other relatives (sib information or selection):

The formula for b which should be used in the formula for estimated breeding value is as follows:

$$b = \frac{gh^2 n}{1 + (n - 1)t}$$

Where

g = ½ for full sibs or ¼ for half sibs

h2 = heritability

n = the number of sibs.

t = the correlation among the sibs.

D. Pedigree information:

The breeding value concept can be used with pedigrees where the principle is to predict a BV for the subject animal in the pedigree:

$$\underset{\text{(Son)}}{\text{B.V}} = \frac{1/2\ n\ h2}{1 + r\ (n-1)}$$

(Average deviation of the dam's records from her contemporaries).

$$\frac{1/2\ n\ h2}{1+ r\ (\ n-1)}$$

Confidence factor (reg. coefficients).

E. Progeny performance (Progeny testing):

Being decisions on the performance of animal's progeny is called progeny testing.

It is a technique generally used for males because they are responsible for more progeny in their lifetime than any one female.

Progeny testing is usually in these situations:

a. For weakly inherited traits.

b. For traits expressed in one sex (e.g. milk production).

c. For traits expressed after slaughter (e.g. carcass composition).

The genetic principle behind progeny testing is simple.

As each offspring represents a sample of the genes parent (drawn at random), then the more samples that are examined, the more accurate is assessment of the parents.

Calculation of how many offspring are needed to show a real difference between sires is important fore both genetic and economic reasons.

The main points concerned with getting the best results from progeny testing are these:

a. Test as many sires as possible (5 or 10 would be minimal).

b. Make sure the dams are all randomized to each sire, within age groups if possible.

c. Produce as many progeny per sire as is possible (at least 10-15 of either sex for growth traits but up to 300-400 offspring for traits like calving difficulty and fertility).

d. No progeny should be culled until the end of the test.

Disadvantage of progeny testing:

1. Takes time.
2. The keeping of progeny groups for long periods can be an expensive operation.

Selection for several Or multiple traits:

Selection for multiple traits can be accomplished basically in three different types:

A. The tandom method of selection.
B. The method of independent culling levels.
C. Selection index method.

A.The Tandom method of selection:

The tandom method of selection means selection first for one trait and then for a second one and so on.

Advantage:

The breeder may resort to this method because they have not had proper training in method of genetic improvement.

Disadvantage

This method is likely to be wasteful, inefficient, and result in little genetic progress.

B. Independent culling levels

In this method of Independent culling levels several traits are considered simultaneously and a minimum acceptable phenotypic level is set for each trait.

When an individual fails below minimum phenotypic value in any trait it is culled regardless of it's phenotypic merit in other traits

In a flock of poultry:

Phenotypic level of egg yield = 220 eggs.

Phenotypic level of hatchability = 90%.

Phenotypic level of fertility = 95%.

A hen yield 250 eggs with hatchability 95% but fertility percent 90% will culled.

Advantages:

1. Take short time where selection for several traits in the same time.
2. In this method breeder can select or cull some individuals in early age

Disadvantages:

1. Cull some excellent individual in all traits except one.
2. Less efficient than selection index method

C. Selection index method:

Definition:

In selection index, the animals chosen for breeding are those with the highest scores based on all the traits for which they are being selected. Those with lowest total scores are culled.

The aim in computing a selection index is to derive an estimate in which the various traits are appropriately weighted to give the best prediction of the animal's breeding i.e. what it will produce when it breeds.

Advantages:

1. Selection index method is the most efficient method for making genetic improvement in dairy cattle than either the tandom method or Independent culling levels.

2. It is accounts for several important traits simultaneously.

3. It is accounts for heritability of each trait.

4. It includes the known genetic and phenotypic relationships among the traits.

5. Decisions are based in part on the relative economic importance of each trait.

Disadvantages:

1. Using several traits in constructing selection index reduces the intensity of selection for one trait in selection index.
2. Using several traits leads to difficulty in selection and in making selection index.

The information needed to construct a selection index is:

1. The variation seen in each trait – the phenotypic standard deviation.
2. The heritability of the traits.
3. The phenotypic correlations among the traits.
4. The genetic correlations between the traits.
5. The relative economic value (REV) of the traits.

Thank You For Your Attention