For individual parents we can predict progeny merit by

- Estimating breeding values of each parent

$$EBV = h^2 P$$

- Averaging these to predict progeny merit

$$\hat{G}_o = \frac{EBV_{Sire} + EBV_{Dam}}{2}$$

For a given selection policy (breeding operation) progeny merit is predicted by

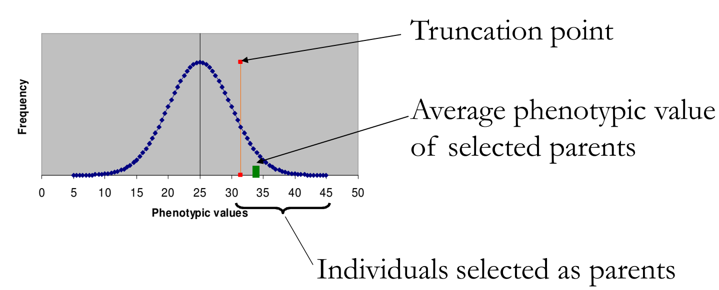
- Predicting the phenotypic superiority of selected parents
- Predicting superiority of progeny generation

Predicting progeny merit for a selection policy (i.e. response to selection) is useful as it allows us to compare different selection policies

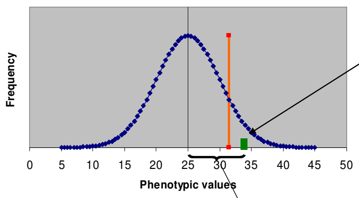
- For example, is there greater genetic gain if
  - Breeding females are kept for three years only, requiring more replacements each year but quicker turnover

  OR
  - Breeding females are kept for five years, requiring less replacements each year but slower turnover

Assume that individuals are selected as parents only if their phenotypic value is greater than a truncation point



The selection differential (S) is the phenotypic superiority of selected parents (i.e. mean of selected parents – population mean)



Average phenotypic value of selected parents

S *In this example S is ~9 units*

S is averaged if different proportions of males and females are selected

$$S = \frac{S_{Male} + S_{Female}}{2}$$

For example

- Mean of selected males is 32kg, mean of all male candidates is 27kg. S_{male} = 5 kg
- Mean of selected females is 25kg, mean of all female candidates is 22kg, S_{female} = 3 kg
- Average S is 4 kg

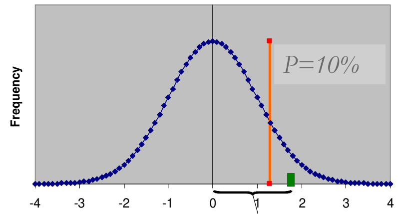
Rather than determine S directly (as in the previous slides) it is more useful to determine S from a knowledge of the selection policy

Determining S from knowledge of the selection policy

First determine selection intensity (*i*)

- Selection intensity (*i*) is the number of phenotypic standard deviation units that selected parents are superior to the mean
- *i* is obtained from selection intensity tables according to the proportion (P) of animals selected as parents

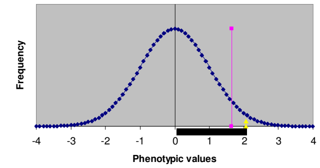
Continued



Standard deviation units

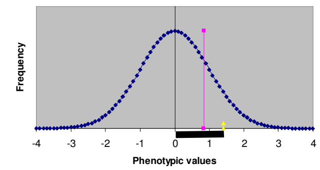
i *In this example i=1.75*
(from selection intensity tables for P=10%)

Selection intensities



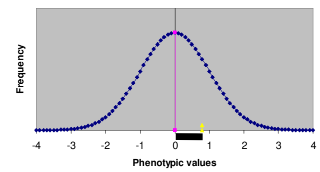
5 out of 100 animals selected

p = 5%, i = 2.06



20 out of 100 animals selected

p = 20%, i = 1.40



50 out of 100 animals selected

p = 50%, i = 0.80

Continued

Note the relationship between proportion selected (P) and selection intensity (*i*)

- Select few individuals → low P and high *i*
- Select many individuals → high P and low *i*

Continued

i is averaged for males and females

$$i = \frac{i_{Male} + i_{Female}}{2}$$

For example

- 2 out of 100 males selected:
  - P_{male} = 2% and i_{male}=2.421
- 80 out of 100 females selected:
  - P_{male}=80% and i_{female}=0.350
- Average *i* is 1.38

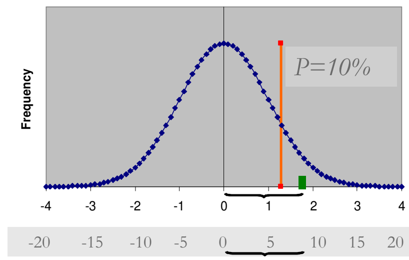
Continued

Then determine S by multiplying *i* by the phenotypic standard deviation

$$S = i\sigma_p$$

The selection differential is equal to the selection intensity multiplied by the phenotypic standard deviation.

Continued

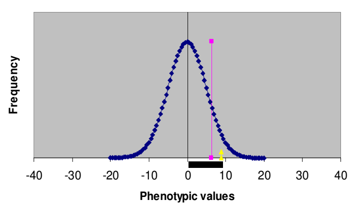


Standard deviation units

Phenotypic units for σp=5

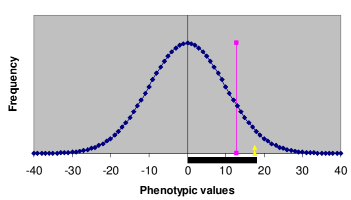
In this example i=1.75 and S=8.75 as $S = i\ \sigma_p = 1.75 \times 5$

Phenotypic standard deviation



σ_P=5, p=10%, *i*=1.76

$S = i\ \sigma_P = 1.76 \times 5 = 8.8$

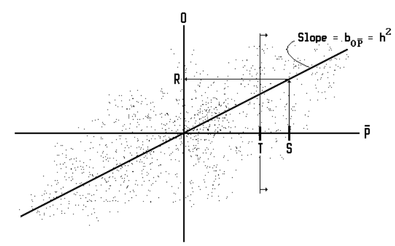


σ_P=10, p=10%, *i*=1.76

$S = i\ \sigma_P = 1.76 \times 10 = 17.6$

Predicting superiority of the progeny generation

Only the heritable portion of the phenotypic superiority of selected parents will be passed onto the offspring



Thus offspring mean superiority (over a no selection policy) equals the selection differential multiplied by the heritability

Continued

Thus

$$R_{gen} = Sh^2$$
$$R_{gen} = i\sigma_p h^2$$
$$R_{gen} = \frac{i_{male} + i_{female}}{2}\sigma_p h^2$$

where R_{gen} is response per generation.

From R_{gen} to R_{year}

It is also useful to determine response per year (R_{year})

This requires calculation of the generation interval (L)

Generation interval (L)

Generation interval (L) is the average age of parents when progeny are born

L is calculated seperately for males and females and then averaged

For example

- Equal numbers of 2 and 3 year old bulls selected as parents L_{male}= 2.5 years
- Equal numbers of 2, 3 and 4 year old cows selected as parents L_{female}= 3.0 years
- $L_{average}$= 2.75 years

Continued

Another example of calculating L

Age structure of animals selected for breeding					
Age (years)	2	3	4	5	Total
Male	7	5			12
Female	200	150	100	50	500

$$L_{male} = \frac{(7x2) + (5x3)}{7+5} = 2.4\,years$$
$$L_{female} = \frac{(200x2) + (150x3) + (100x4) + (50x5)}{200+150+100+50} = 3.0\,years$$
$$L_{average} = \frac{2.4+3.0}{2} = 2.7\,years$$

Continued

Given

$$R_{gen} = \frac{i_{male} + i_{female}}{2} \sigma_p h^2$$

and

$$L = \frac{L_{male} + L_{female}}{2}$$

$$R_{year} = \frac{i_{male} + i_{female}}{L_{male} + L_{female}} \sigma_p h^2$$

Alternatively

$$\frac{R}{year} = \frac{R}{gen} x \frac{gen}{year}$$

where

$$\frac{gen}{year} = \frac{1}{L}$$

Balancing i and L: consider age structures

Age	2	3	4	5	6
Males	5	5			
Females	100	100	100	100	100

Higher i : replacing 5 / 250 males and 100 / 250 females
Higher L : Lm=2.5 years, Lf=4.0 years, L=3.25 years

Age	2	3	4	5	6
Males	10				
Females	125	125	125	125	

Lower i : replacing 10 / 250 males and 125/ 250 females
Lower L : Lm=2.0 years, Lf=3.5 years, L=2.75 years

$$R_{year} = \frac{i_m + i_f}{L_m + L_f} \sigma_P h^2$$

Thus high i → high L & low i → low L

- this does not fit well with maximising i / L

The *best compromise* between i and L is required

Example of response calculation

- Sheep breeder has 180 ewe flock, selecting for FW
- Rams first selected at 2 years old, and mated for 2 years
- Ewes first selected at 2 years old, and mated for 4 years
- Each ram mated to 30 ewes, 90% lambing, 50:50 sex ratio
- No significant mortality in adults
- Trait heritability = 0.25, and σ_P=0.6kg
- What is R per year ?

Answer

Age structure of animals selected for breeding					
Age(yrs)	2	3	4	5	Total
Male	3	3			6
Female	45	45	45	45	180

- 180 ewes, 90% lambing → 162 lambs total (81 of each sex)
- Need to select 3 out of 81 males each year
  - P=3/81=3.7%, which corresponds to an *i* of 2.18
- Similarly need to select 45 out of 81 females each year
  - P=45/81=55%, which corresponds to an *i* of 0.72
- L_{male}=2.5years, L_{female}=3.5years

$$R_{year} = \frac{i_{male} + i_{female}}{L_{male} + L_{female}} \sigma_p h^2$$

$$R_{year} = \frac{2.18 + 0.72}{2.5 + 3.5} x0.6x0.25 = 0.07kg$$

FW is expected to increase by 0.07kg per year