Optimizing Breeding Program Design

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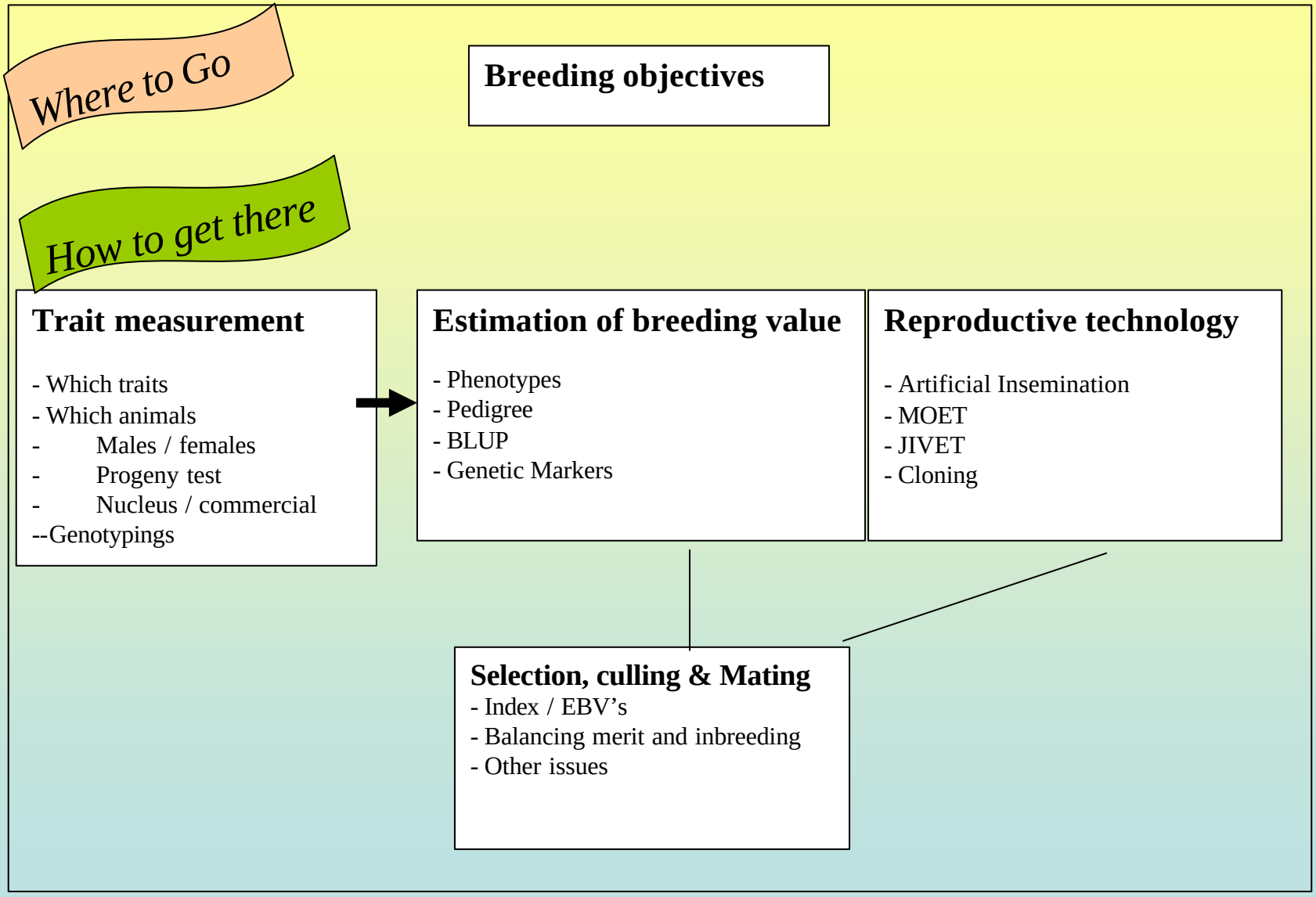
Outline / Introduction

- What is a *Good* Breeding Program
- What are design issues?
- What kind of decisions are involved?

Outline

- What is a *Good* Breeding Program
- What are design issues?
- What kind of decisions are involved? measurement / selection
- New Technologies
  - Genetic Markers
  - Reproductive technologies
- Their *joint* effect on breeding programs

Animal Breeding in a Nutshell



The framework of genetic improvement

Response $= \dfrac{i_m r_m + i_f r_f}{L_m + L_f} \sigma_G$

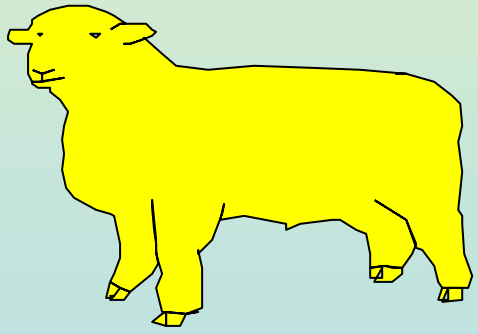
Genetic Variation in profit

\+ restrict inbreeding

Selection intensity

Selection accuracy

Generation Interval



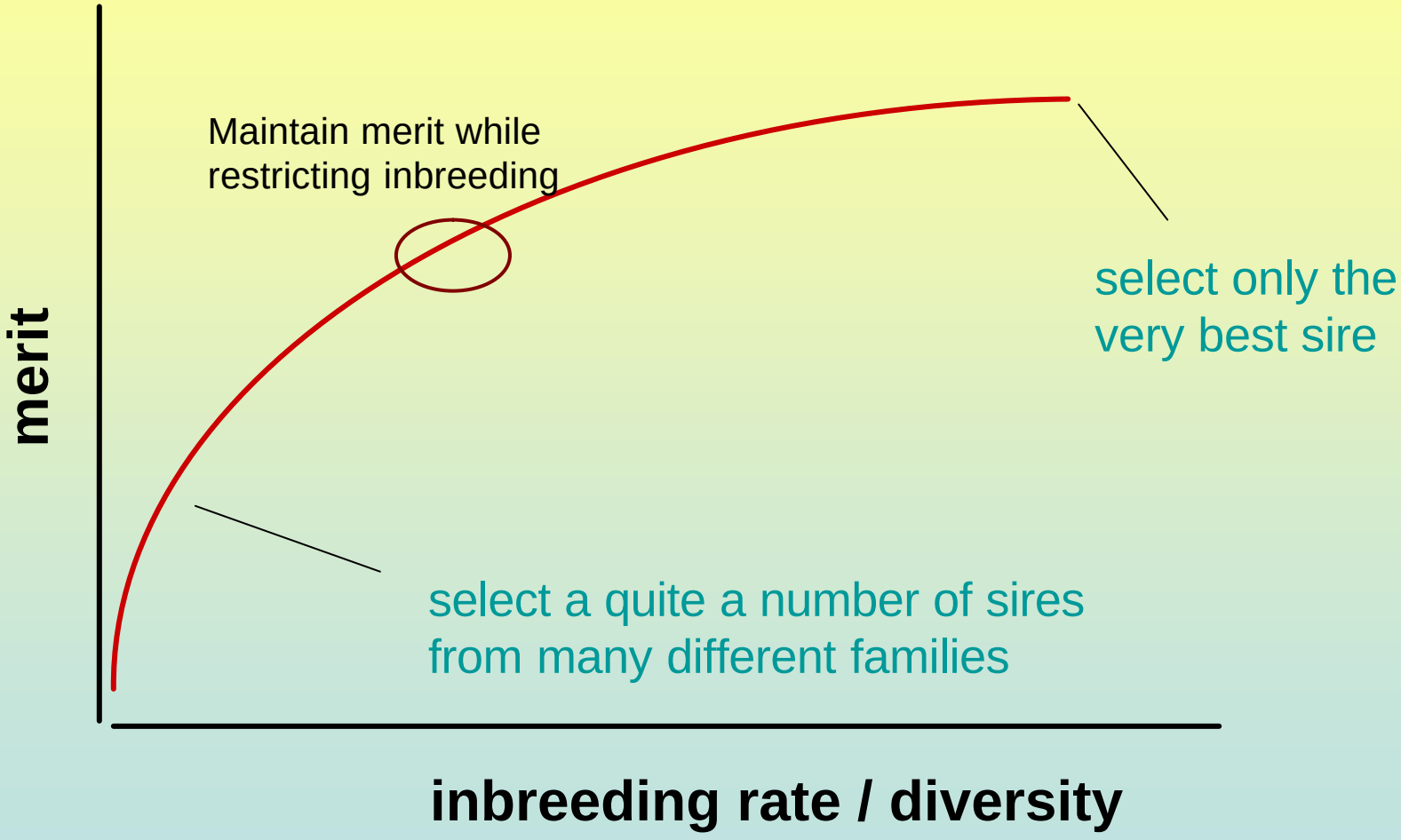
The *balancing act* of genetic improvement

Selection intensity vs risk/ inbreeding / diversity

Selection accuracy vs generation interval

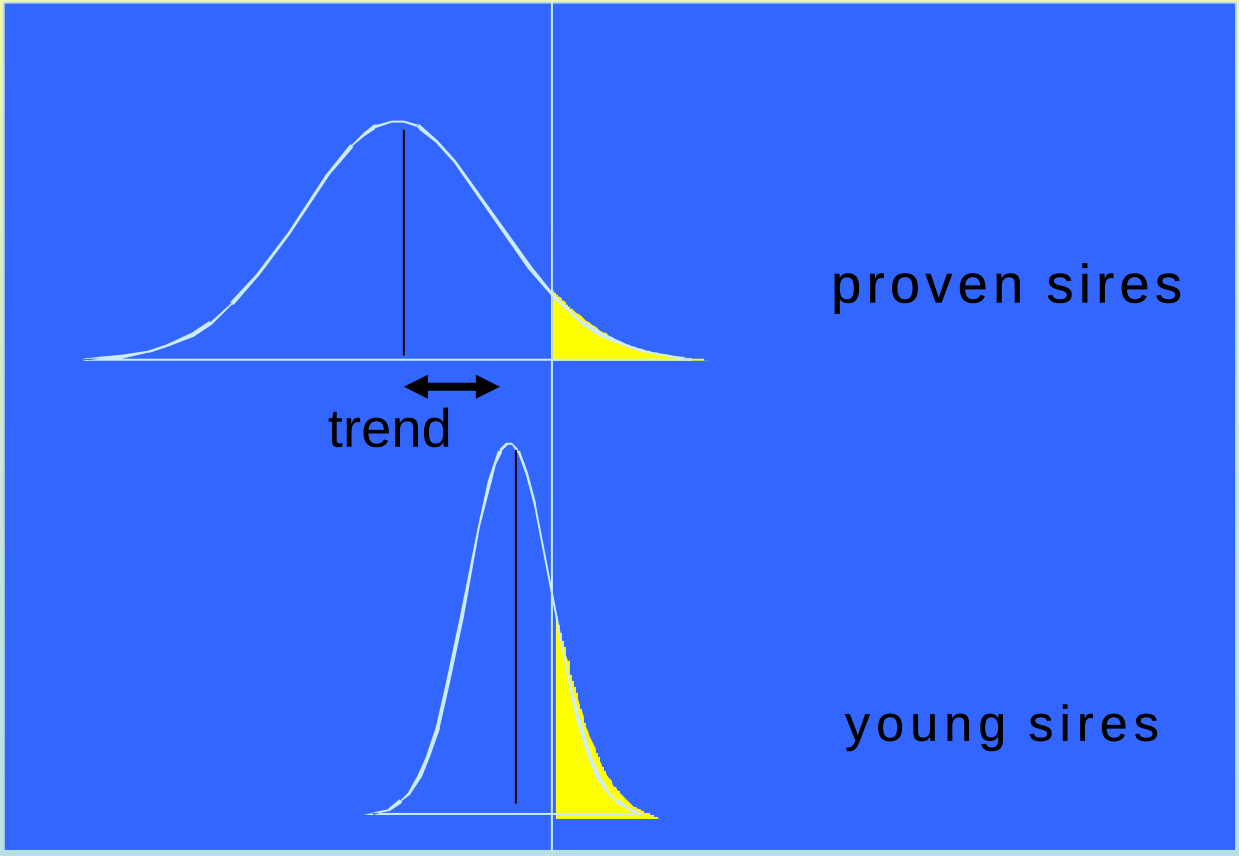
One trait versus another

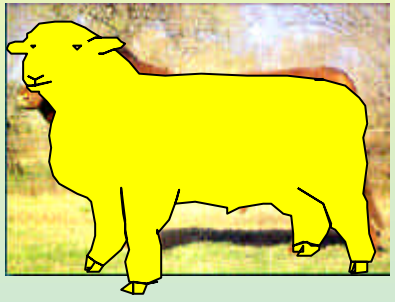
Balancing inbreeding and merit

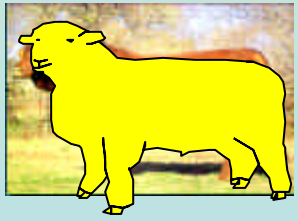


Optimizing Generation Interval

- Dilemma between young and old sires



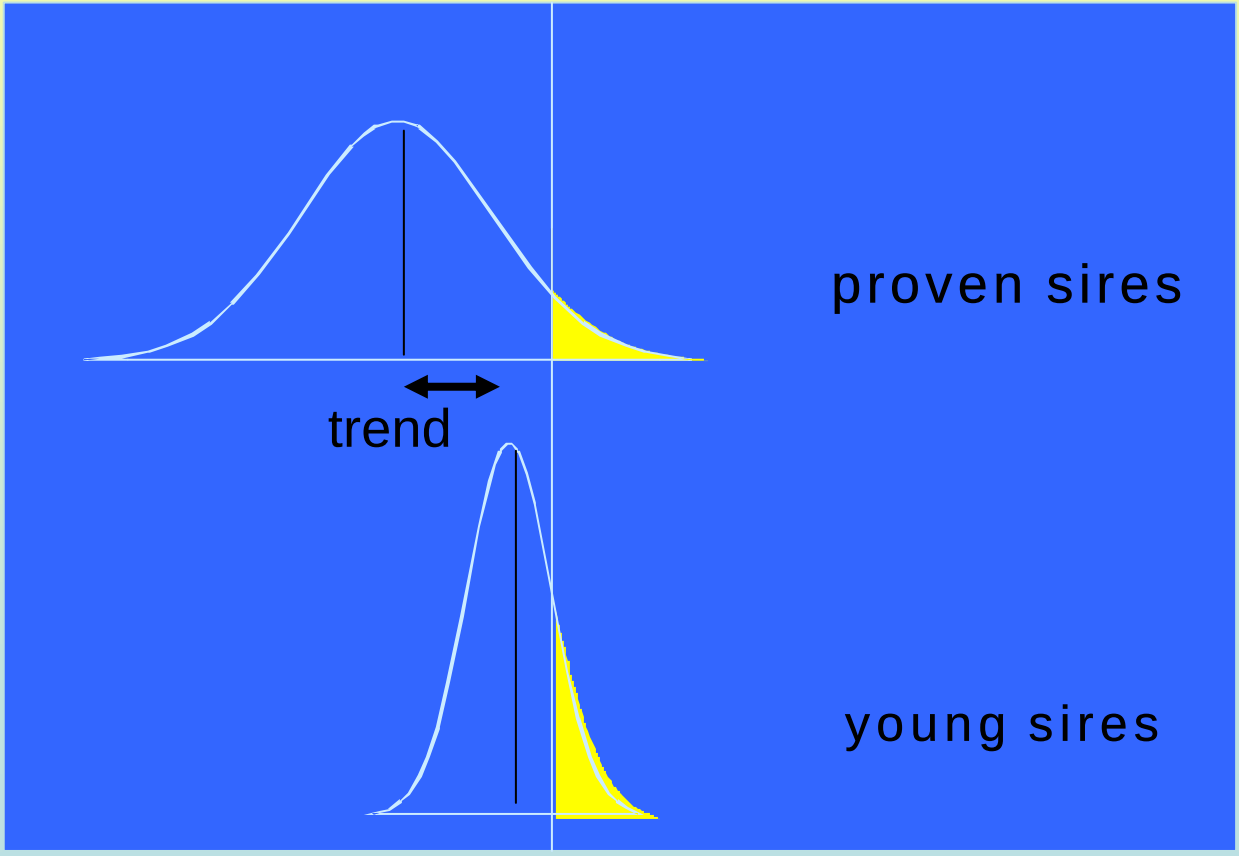


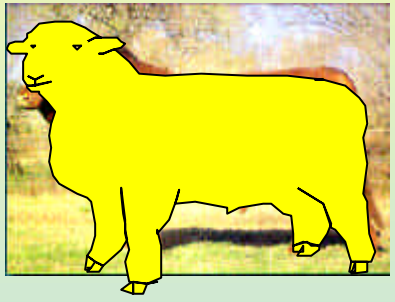


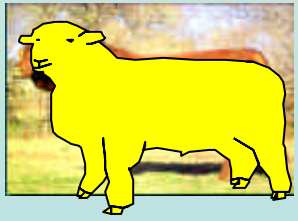
Genetic Evaluation helps

BLUP EBV Optimizes generation interval

- Dilemma between young and old sires

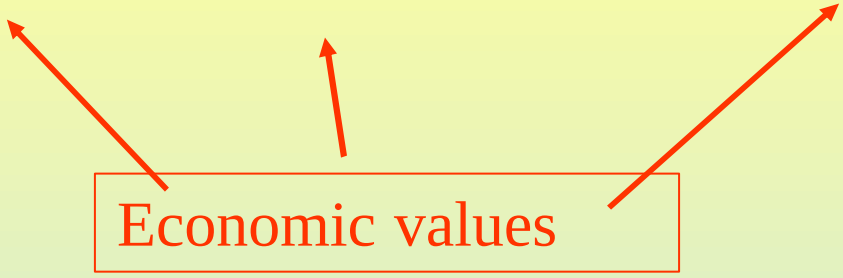






Breeding Objectives

$$\text{Index} = a_1 EBV_{MFD} + a_2 EBV_{FW} + \ldots + a_m EBV_{NLW}$$



Some useful terms

- Tactical vs strategic optimization
  - (e.g. BLUP vs Selection Index)

Modeling:

Stochastic	vs	Deterministic
Easier		More complex
More accurate		Need to approximate
More CPU		Less CPU
Not so suitable for optimization		Can optimize
Variation in outcome		One outcome

(Stochastic) Modeling of BP

- Draw a base population $A_i = [\ 0\ ;\ V_A\ ]$

- Give the phenotypes $P_i = A_i + E_i$
- Select = *f(BLUP*-EBV, EBV + QTL, Inbreeding)
- Mate (random/ assortative)
- Define offspring $A_i = .5A_s + .5A_d + MS$

N generations

$$\tfrac{1}{2}(1-\tfrac{1}{2}(F_s+F_d)V_A$$

Deterministic Models

- Predict within and between family variance
- Predict selection intensity
- Predict inbreeding
- Predict selection accuracy based on BLUP
  “pseudo BLUP”

Components of dG

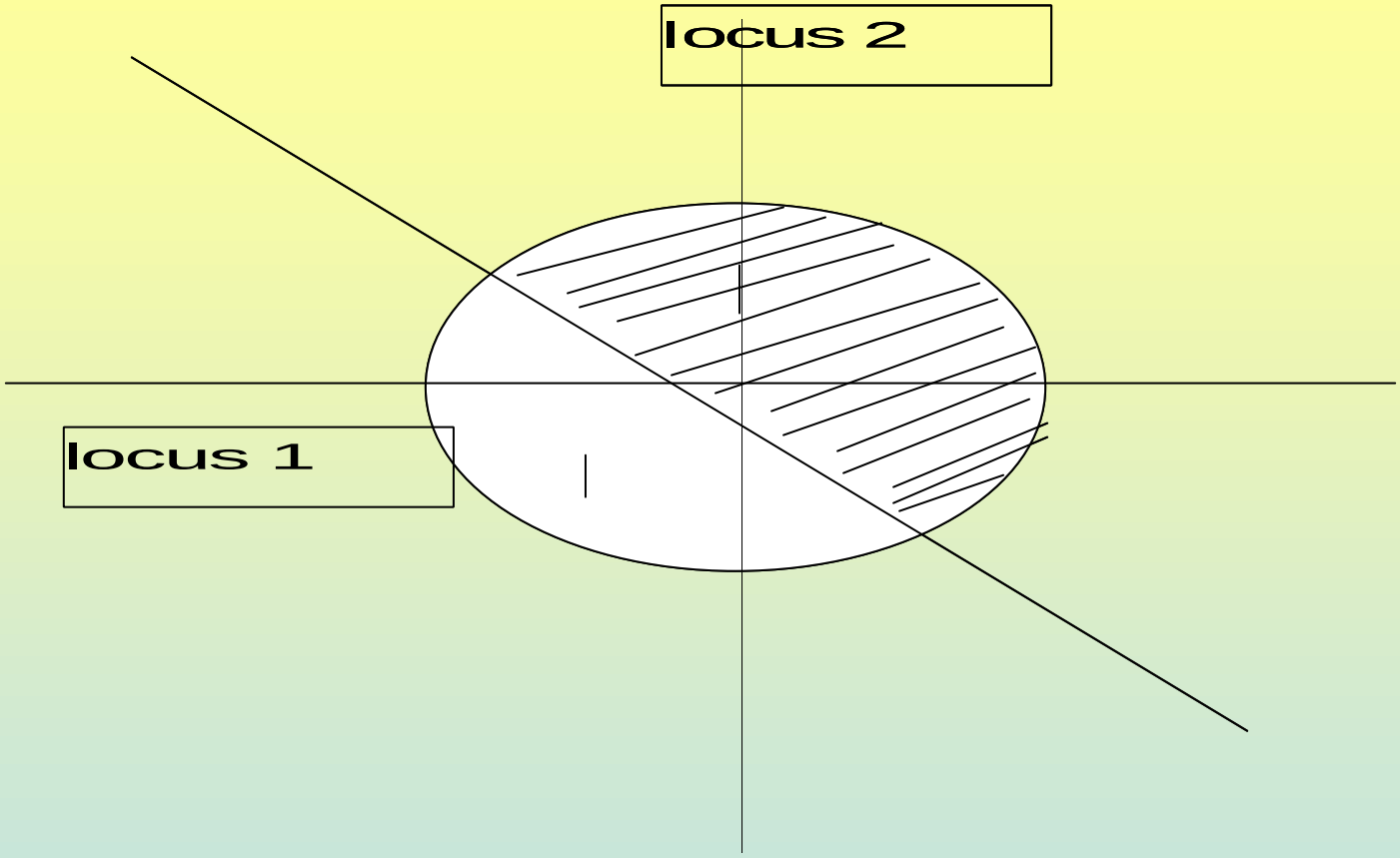
- Genetic Variance
- Selection Intensity
- Selection Accuracy
- Generation Interval

Genetic Variance:
Loss of variance due to selection

- Variance among selected individuals is lower
- Selected parents have a reduced variance
  - $V_{Ps} = (1-k) V_p \quad k = i\,(i-x)$
- "Bulmer Effect": Also their genetic variance is lower

V_A in selected group is reduced to$(1- r^2 k)$.

r = selection accuracy



Note:

Negative Covariance after selection

Effect of selection on V_A

$$s^2_{A_{t\_sel}} = (1 - r^2 k)\, s^2_{A\,t}$$

Effect of selection in next generation

full residual variance ….but genetic variance is still reduced

Only part coming from parents is reduced

New variance is generated due to *Mendelian Sampling*
This is NOT affected by selection“Bulmer Effect”:

$$\sigma^2_{A\,t+1} = \tfrac{1}{4}\sigma^2_{As\ t} + \tfrac{1}{4}\sigma^2_{Ad\ t} + \tfrac{1}{2}\sigma^2_{A\,0}$$

Variance over time

$$\sigma^2_{A\,t+1} = \tfrac{1}{4}\sigma^2_{As\,t} + \tfrac{1}{4}\sigma^2_{Ad\,t} + \tfrac{1}{2}\sigma^2_{A\,0}$$

(P-males=10%, P-females = 50%)

Gen	VA	V(sire)	V(dam)	Herit	Mean	R
1	1.00	0.58	0.68	0.50	0.00	0.90
2	0.82	0.51	0.58	0.45	0.90	0.77
3	0.77	0.49	0.56	0.44	1.68	0.74
4	0.76	0.49	0.55	0.43	2.42	0.73
5	0.76	0.49	0.55	0.43	3.15	0.73
6	0.76	0.49	0.55	0.43	3.88	0.73
7	0.76	0.49	0.55	0.43	4.61	0.73
8	0.76	0.49	0.55	0.43	5.34	0.73
9	0.76	0.49	0.55	0.43	6.08	0.73
10	0.76	0.49	0.55	0.43	6.81	0.73

Note

Only need to worry about this in deterministic simulation

Selection intensity (i)

- i is lower in finite populations
  - Order statistics effect
    - Not a large effect
- i is lower when EBVs are correlated
  - More important, esp. when correlation are high
    - And note that they can be high!!!

Order statistics effects

- mainly in very small groups/ populations -

Population size	Selected fraction		
	P=2%	P = 10%	P= 50%
2	-	-	0.564
4	-	-	0.663
10	-	1.539	0.739
20	-	1.638	0.767
50	2.249	1.705	0.785
100	2.328	1.73	0.791
400	2.396	1.75	0.796
infinite	2.421	1.755	0.798

For a good approximation,

use Burrow's formula

$$i_{\infty} - \frac{1-p}{2 * i_{\infty} * p * (N+1)}$$

Effect of correlated EBVs
- family structure -

How much do correlations reduce the selection intensity

$$i_r(t) = \sqrt{(1-t)}.i(0)$$

Rawlings (1976)

For f families each with n_f individuals

$$i_r(t) = \sqrt{1 - \frac{t(n_f - 1)}{n_f f - 1}} i(0)$$

or

$$i_r(t) = \sqrt{(1 - t_{av})} i(0)$$

t_{av} is the average correlation between EBV's in the population

Overestimates si when t_{av} is high!

Meuwissen 1991

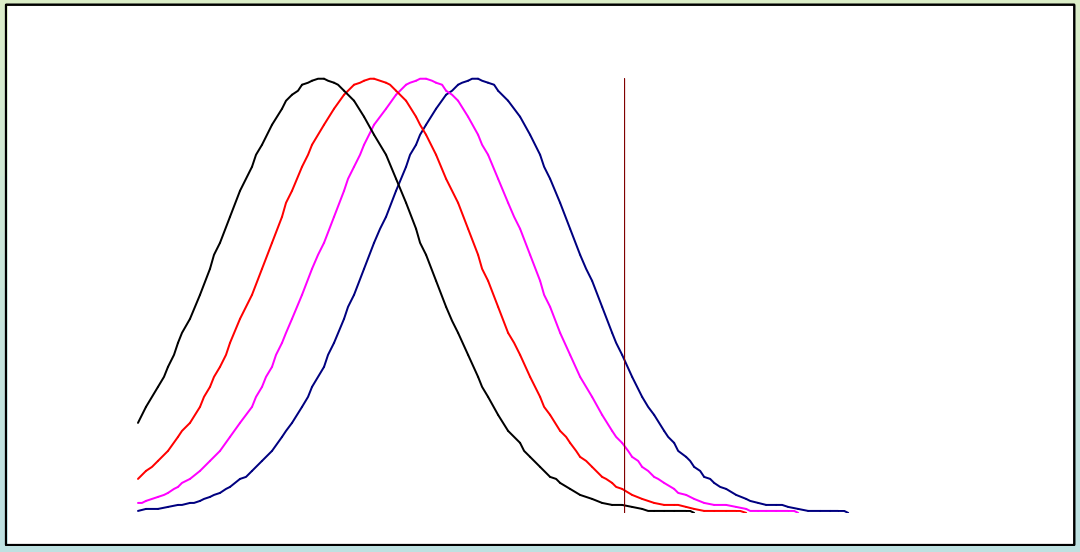
Selection Accuracy

- Pseudo BLUP
  - Selection Index
  - Iterated to accommodate EBV parents

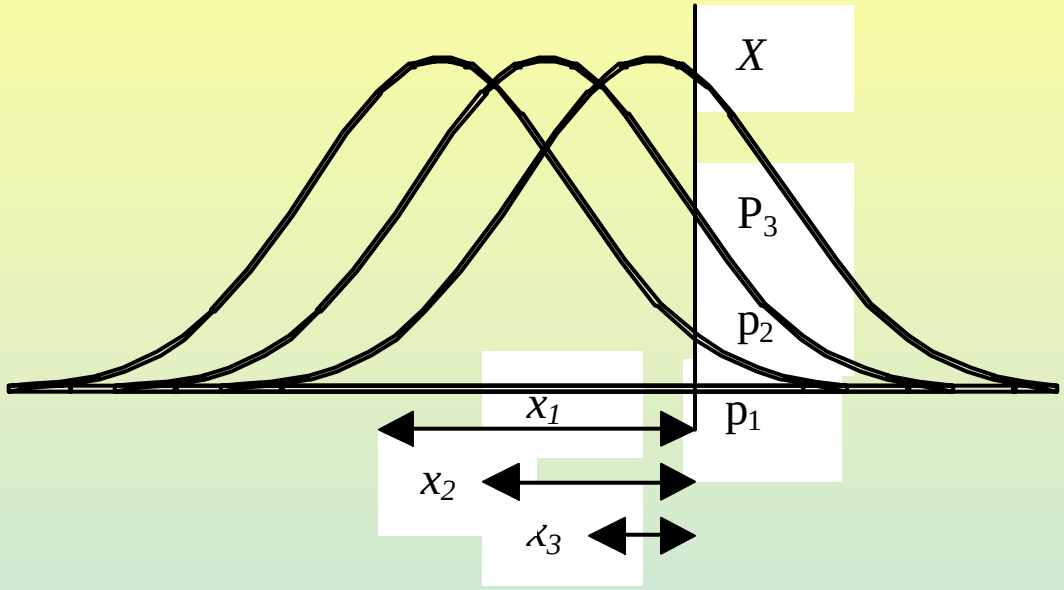
- Note that different age classes have different r

Overlapping Generations

- Selection across age classes
  - Different means (how much?)
  - Different SD?



An algorithm for finding common truncation point



ageclass	N in group	mean	SD	Proportion Selected	Nr Selected	Mean of selected	
1	50	10	1	0.28	14.17	11.18	
2	35	9.5	1	0.14	4.96	11.03	
3	15	9	1	0.06	0.87	10.74	
					20.0	11.12	mean of selected

Summary

- Need a deterministic model that predicts and optimizes genetic gain
  - Selection intensity
  - Selection accuracy
  - Generation intervals
  - Genetic Variation after selection
  - Inbreeding