Background

From lectures 9 and 10

- Originally: $EBV_i = h^2P = b_1P$
  where P is an individual's own phenotype and b_1 is index weight (equal to h^2)

- But EBVs are more accurate if EBVs are calculated using additional information sources

Information from relatives

Different sources of family information are weighted into an index

$$EBV = b_1P + b_2P_f$$

weight

own performance

weight

family performance

Types of family information sources

- own performance
- mean performance of full sibs
- mean performance of half sibs
- performance of sire and / or dam
- performance of progeny

$$EBV = b_1P + b_2P_2 + b_3P_3 + \dots\dots\dots b_nP_n$$

Examples of accuracies

	h^2=0.1	h^2=0.3	
own information	0.32	0.55	*equal to sqrt h^2*
mean of 10 half sib	0.23	0.33	
mean of 1000 half-sibs	0.49	0.50	*max is sqrt 0.25 = 0.5*
mean of 1000 full-sibs	0.70	0.71	*max is sqrt 0.5 = 0.71*
mean of 100 progeny	0.85	0.94	*max approaches 1.0*

Information from correlated traits

Different sources of trait information are weighted into an index

$$EBV_x = b_1 P_x + b_2 P_y$$

weight

phenotype trait x

weight

phenotype trait y

Assumes a correlation between traits x and y

Information from correlated traits

Require EBVs for trait x, have information on both traits x and y, traits x and y are correlated

- select on trait x EBVs from trait x phenotypes→ response in trait x (and response in trait y)

- select on traits x EBVs from trait x and y phenotypes → <u>more</u> response in trait x (and <u>more</u> in trait y)

  '*trait y provides additional information on trait x*'

Multiple trait selection indexes: terminology

Breeding objective *'where to go'*

- traits you want to improve

Selection criteria *'how to get there'*

- traits that are an information source

Economic value (ev)

- are used to weight EBVs (describe relative importance of the different traits)
- equal the $ value of increasing trait by one unit, assuming all other traits remain constant
- calculated from knowledge of production system

Selection criteria:

all information sources (trait phenotypes, including correlated traits)

Determine optimal weights for each information source by multiple regression

Breeding objective:

Breeding values for all traits in objective, each weighted by its economic value

Multiple trait selection indexes:

$$\text{index}(\$) = b_1 EBV_1 + b_2 EBV_2 + b_3 EBV_3$$

index weights (b)

- are optimal weights for each information source
  - uses relationships between information sources
  - also uses the relationship between information sources and traits in objective
  - also takes into account <u>economic values</u> of objective traits

Example: Weight and feed intake

- r_A=0.5 r_P=0.3
- weight (W) h^2=0.5 σ_P=17Kg
- feed intake (FI) h^2=0.3 σ_P =25kg

BO	***SC***	b_W	b_{FI}	R_W	R_{FI}
Weight	**Weight**	**0.5**	**0**	**10.2**	**5.8**
Weight	**Weight & FI**	**0.45**	**0.11**	**10.3**	**6.5**
assumes ev weight =1 and ev FI = 0					
Weight & FI	**Weight & FI**	**0.25**	**-0.07**	**4.8**	**-3.2**
assumes ev weight =1 and ev FI = -1					
Weight & FI	**Weight & FI**	**0.25**	**-0.25**	**-1.9**	**-8.1**
assumes ev weight = 1 and ev FI = -2					

Response using a selection index

More information

More accuracy

More response

$$R = i \; r_{I,A} \, \sigma_A$$

Selection accuracy:

correlation between index (ebv) and true breeding value

Selection on own phenotypes

$$R = i \; h^2 \; \sigma_P$$

$$R = i \; h \; \sigma_A$$

Accuracy of mass (phenotypic) selection

Selection on a selection index

$$R = i \; r_{IA} \; \sigma_A$$

Accuracy of index selection

BLUP

Best Linear Unbiased Prediction:
a tool for genetic evaluation

Consider the features we want in an EBV / index

High accuracy, for high response

- highest correlation between true and estimated breeding value (‘best’)

Lack of any bias, for fair comparison

- true breeding values are distributed around predicted breeding values (‘unbiased’)

BLUP and accuracy

BLUP maximises accuracy by:

- calculating EBVs using <u>all</u> information sources

  (*information from relatives, and in multi-trait BLUP information from correlated traits)*

- using proper index weights

Note that this is what a selection index does

BLP = selection index

BLUP and lack of bias

BLUP ensures EBVs are unbiased:

- ‘unbiased EBVs are a matter of fair comparison’

Note this is the u in BLUP

BLP + unbiasednees = BLUP

Possible causes of bias ‘fixed effects’

Problem: Some animals reared as singles, other as twins

Solution: Correct phenotypes for effect of rearing type

Problem: Animals producing in different herds

Solution: Take phenotypic deviation from herd mean

Problem: Animals are measured at different ages

Solution: Correct phenotypic observations for the mean of the appropriate age

This could be achieved by selection index

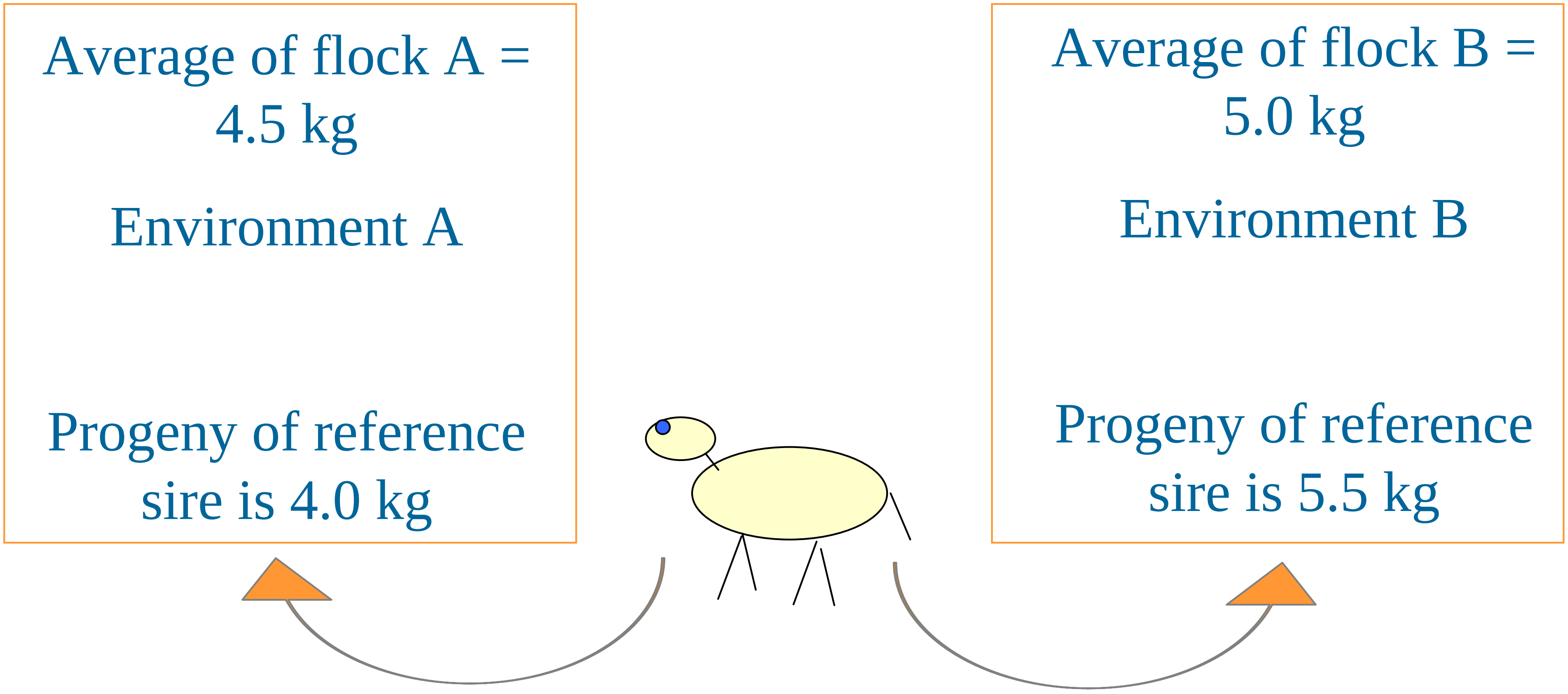
Possible causes of bias 'fixed effect confounded with genetic effect'

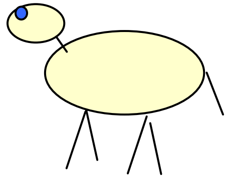
Problem: Animals producing in different herds, and the different herds have different genetic means

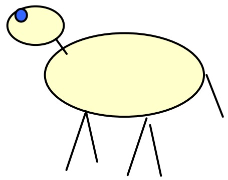
No longer can take phenotypic deviation from herd mean

Solution: Use reference sires as links between herds, and simultaneously evaluate herd and sire effects (see next two slides)

A feature of BLUP


Average of flock A = 4.5 kg
Environment A
Progeny of reference sire is 4.0 kg
Average of flock B = 5.0 kg
Environment B
Progeny of reference sire is 5.5 kg

In flock A  has an EBV of -1 kg

In flock B  has an EBV of +1 kg

Thus flock A is 2 kg genetically superior to flock B

	P_{av}	$=$	G_{av}	$+$	E_{av}
A:	4.5		4.5		0
B:	5.0		2.5		2.5

Possible causes of bias ‘unequal merit of mates’

Problem: Some sires have better mates

Solution: Account for mates by evaluating all animals jointly

A feature of BLUP

Sire 1: +300	Dam 1: +200	Progeny: +250
Sire 2: +300	Dam 2: +300	Progeny: +300

This would make sire 2 look better, unless we accounted for the fact that sire 2 had a better mate

Possible causes of bias ‘selection bias’

Problem: There is culling and selection

- worst sires have more progeny culled ‘culling bias’
- animals are from selected parents

Solution: Do joint evaluation *A feature of BLUP*

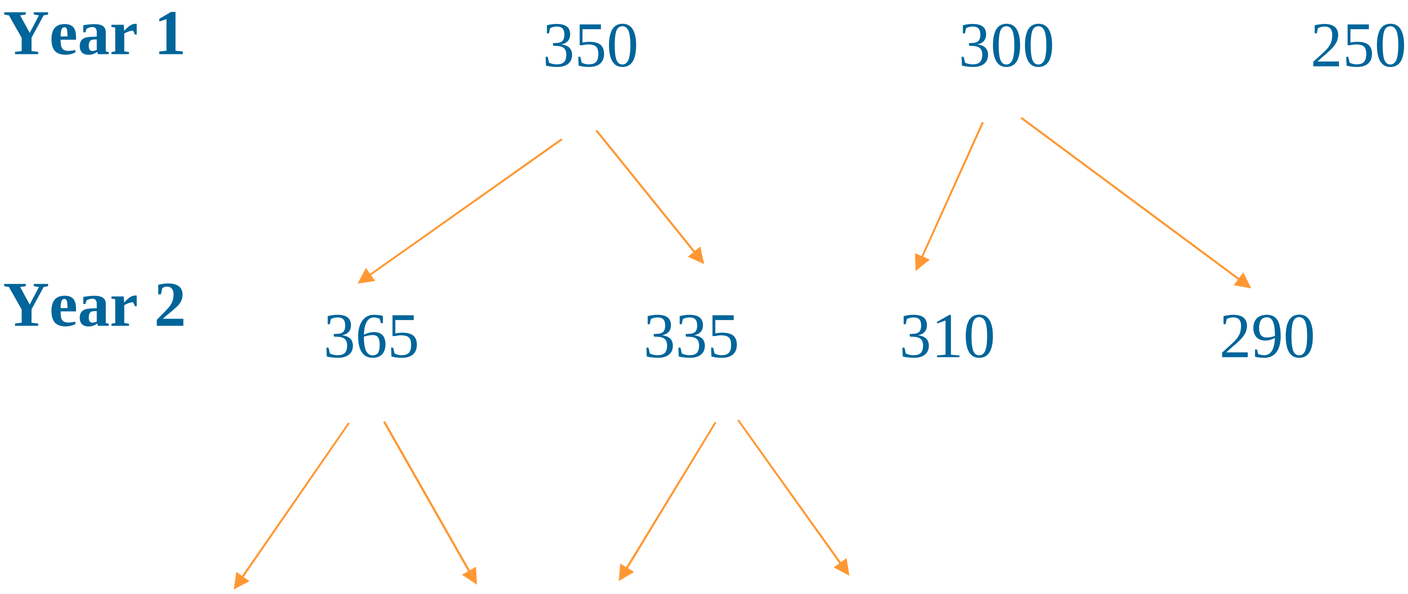
- account for culling bias by evaluating first and later traits jointly
- account for selection by joint evaluation over years

Culling bias

ID	*Sire*	*Weaning Weight*	*Progeny mean*	*Yearling Weight*	*Progeny mean*
101	1	160		300	
102	1	140	140	280	280
103	1	120		260	
104	2	140		280	
105	2	120	120	260	270
106	2	100		no record as culled	

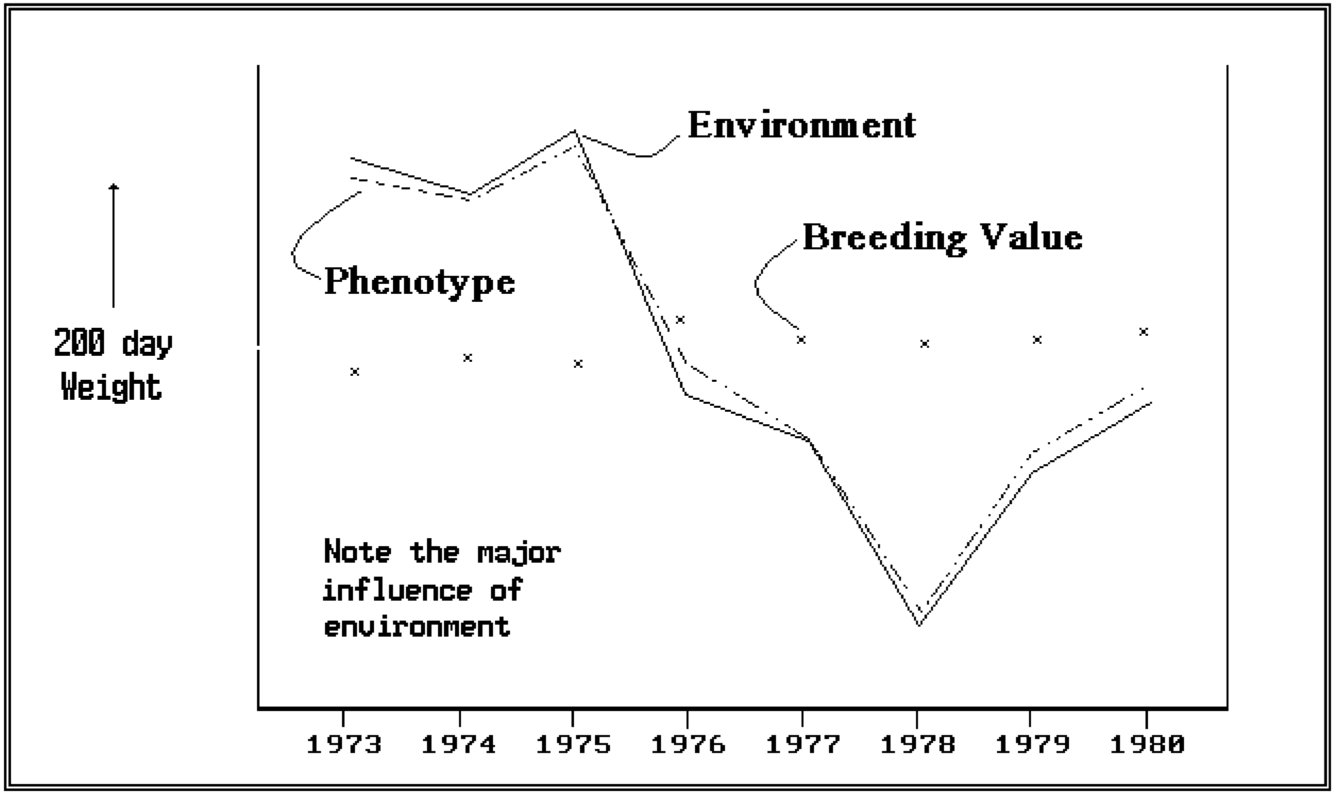
- Sire 2 gets an unfair 'lift' in progeny mean of yearling weight, due to culling at weaning. This is accounted for if traits are evaluated jointly

Animals are from selected parents



- Genetic mean changes as years go by. This is accounted for by joint evaluation over years (requires genetic links between years)

Genetic trends can be observed by plotting BLUP EBVs over years



From: Australian Simmental breeders association report, 1981

Possible causes of bias 'unbalanced designs'

Problem: Some animals have more information than others

- different number of sibs
- different number of progeny
- etc.

Solution: Construct a selection index for each animal

A feature of BLUP

How BLUP works

- A joint evaluation of all animals
  - uses all additive genetic relationship
  - uses data on all animals jointly
- Works as a linear model
  - corrects different effects for each other
  - jointly estimates animal effects and fixed effects
- Has selection index properties

Advantages of BLUP

Optimally weights different information sources

- many different sets of weights can exist as each animal has a different information sources. BLUP derives optimal weights automatically

Allows comparison of EBVs of animals in different herds

- but genetic links between herds must exist

Advantages of BLUP continued

Accounts for non-random mating, selection and culling

- but mates and non-selected animals must be included in the analysis

Provides an estimate of genetic trend

- but genetic links between years must exist

Requirements of BLUP

Pedigree information

– records of sire and dam

Phenotypic information

– accurate measurements
– accurate allocation to fixed effect classes

Genetic parameters

BLUP is used to calculate EBVs for industry (LAMBPLAN, BREEDPLAN)

Terminals - Top 150

Analysis Date Friday, 15 June 2001

LAMBPLAN

Sires

ID	Stud of breeding	Wwt	Pwwt	Ywt	Pfat	Pemd	Carcase +	Progeny	Inbreeding & Accuracies Coeff	Weight	Carcase	Sire	Sire of Dam
161972-1999-990196	HILLCROFT FARMS	5.46	14.95	14.94	-1.19	1.62	226.64	38	0.133	83	70	1619721998980093	1630001993930134
162368-1998-980211	KURRALEA	6.60	12.39	12.69	-0.89	2.50	215.20	1148		97	96	1623681994940260	8600401992920175
162204-1999-990453	BETHELREI	8.52	13.38	15.87	-1.18	1.11	211.75	224		93	89	8601221993930205	1619721995950289
161972-1998-980093	HILLCROFT FARMS	5.15	14.40	16.00	-1.08	0.25	207.51	12		80	74	1630001993930134	1603361992920349
161972-1998-980527	HILLCROFT FARMS	8.46	13.45	10.97	-1.66	-0.47	204.10	25		85	76	1619721996960091	1630001993930134
860122-1993-930205	OHIO	6.95	11.94	13.72	-1.60	0.49	203.76	1522		98	97	8601221992920200	8601221987870073
161143-1999-990204	DERRYNOCK	8.39	12.10	12.19	-0.49	2.19	203.60	38		82	76	1623681998980211	1640001993930411
160060-1996-960004	ANNA VILLA	8.56	14.90	16.18	-0.48	0.24	200.47	151		93	87	1632801992920016	1623541990900584
161143-1999-990201	DERRYNOCK	5.43	11.83	11.14	-1.19	0.83	199.83	39		83	77	1623681998980211	1613151995950042
230034-1997-970904	BURWOOD	4.98	11.01	8.82	-2.27	-0.55	198.82	380	0.003	96	92	2300091994940171	2300341994940314
163677-2000-000140	FELIX	6.69	13.56	13.36	-0.59	0.61	197.98	56		70	63	1619721995950289	1600341994940020
160060-1997-970115	ANNA VILLA	6.30	14.47	11.69	-0.42	0.24	196.90	118		90	83	1600601996960004	1600601992920057
162204-1999-990394	BETHELREI	7.42	12.97	14.27	-1.03	0.14	196.85	24		82	74	8601221993930205	1622041996960579
161143-1999-990064	DERRYNOCK	5.10	11.20	10.10	-0.72	1.60	196.01	18		80	74	1623681998980211	1640001994940317
161972-1996-960020	HILLCROFT FARMS	5.32	12.96	10.66	-0.80	0.36	195.20	83		88	75	1630001993930134	
160185-1996-960001	JOLMA	6.19	10.29	10.42	-1.56	0.63	194.57	101		90	83	1630001993930134	1613151991910870
161235-1997-970830	POLLAMBI	7.10	10.69	10.35	-0.88	1.50	194.54	34		87	79	1700991993930002	1612351991910691
163677-1999-990307	FELIX	7.09	12.52	11.59	-1.29	-0.47	192.45	54		83	74	8601221993930205	1636771994940008
162368-1999-990290	KURRALEA	5.53	10.84	10.58	-0.62	1.59	192.11	68		69	62	1623681998980211	1630001993930160
860074-1995-950044	ADELONG	7.17	14.47	13.22	-0.80	-0.94	191.15	448		96	94	8600741993930189	
163000-1998-980575	RENE	7.59	12.01	13.06	-0.50	0.99	190.92	12		71	60	1623681994940260	8600371992920165
162368-1997-970443	KURRALEA	6.58	12.13	7.96	-1.00	0.08	190.69	178		88	83	1640001993930411	8600401992920175
160034-1999-991208	MOSSLEY	5.52	13.45	10.27	-0.53	0.04	190.41	17	0.003	78	70	1621001998980130	1600341994940171
161437-1999-990006	WARBURN	5.41	10.97	10.93	-1.21	0.37	190.26	14		73	65	1604621994940012	1640001993930411
160001-1998-980575	NEWBOLD	7.60	11.69	11.57	-0.26	1.48	189.97	89		87	75	1600011997970211	1640001993930411
160085-1998-980007	ALLENDALE	5.71	12.83	13.40	-0.12	1.00	189.76	65		89	83	1604621994940012	1603361991910163
163000-1993-930134	RENE	5.25	9.55	13.73	-1.52	0.65	189.72	1359	0.062	98	97	1630001991910075	1630001987870053
860482-1998-980065	CLARONDEN	5.90	9.96	8.49	-1.70	0.10	189.57	153		87	78	8600371996960003	8600371989890172
161972-1995-950289	HILLCROFT FARMS	5.74	9.65	11.84	-0.92	1.55	189.35	344		96	93	1630001993930134	1619721990900299

Multi-trait BLUP

- In a multi-trait BLUP, EBVs are simply weighted by their economic values

$$\text{index}(\$) = ev_1 EBV_1 + ev_2 EBV_2 + ev_3 EBV_3$$