

# Selection and inbreeding

# Balancing Selection and Inbreeding

- Higher selection intensities make bigger gain
  - Fewer animals are selected, so also more inbreeding
  - This trend is more evident with higher rates of fecundity , e.g. with new reproductive technologies
  - Genetic evaluation (BLUP) favors selection of related animals
- rationalization of selection make inbreeding restriction methods a necessity

# Why restrict inbreeding

- Avoid loss of genetic variation/genetic diversity
- Inbreeding depression
- Increase of homozygotes with deleterious recessives
- Inbreeding is closely associated with risk (and genetic drift)

# How to restrict inbreeding?

- Mating policies mostly affect
  - progeny inbreeding (*short term*)
  - but not *long term* rate of inbreeding  $\Delta F$
  - The long term inbreeding rate depends on ....  
*effective population size ( $N_e$ )*
- Long term inbreeding is restricted by restricting the average co-ancestry among selected parents

# Effective Population Size: $N_e$

## Accounting for unequal sex ratio

- Effective pop'n size ( $N_e$ ) reduces towards sex with fewer breeding individuals

$$N_e = \frac{4 \cdot N_m \cdot N_f}{N_m + N_f}$$

Males / generation	2	2	2	5	20	1
Females / generation	2	20	200	200	200	99999
N	4	22	202	205	220	100,000
$N_e$	4	7.3	7.9	19.5	72.7	4

With selection, this formula underpredicts inbreeding (2x)  
But it shows that usually, it is controlled by using enough sires

# Inbreeding rate

- Inbreeding occurs due to the mating of relatives
- In a closed population inbreeding is inevitable
- Inbreeding rate ( $\Delta F$ ) describes the increase in  $F$  over time

# Example of BLUP selection

Terminals - Top 150

Analysis Date Friday, 15 June 2001

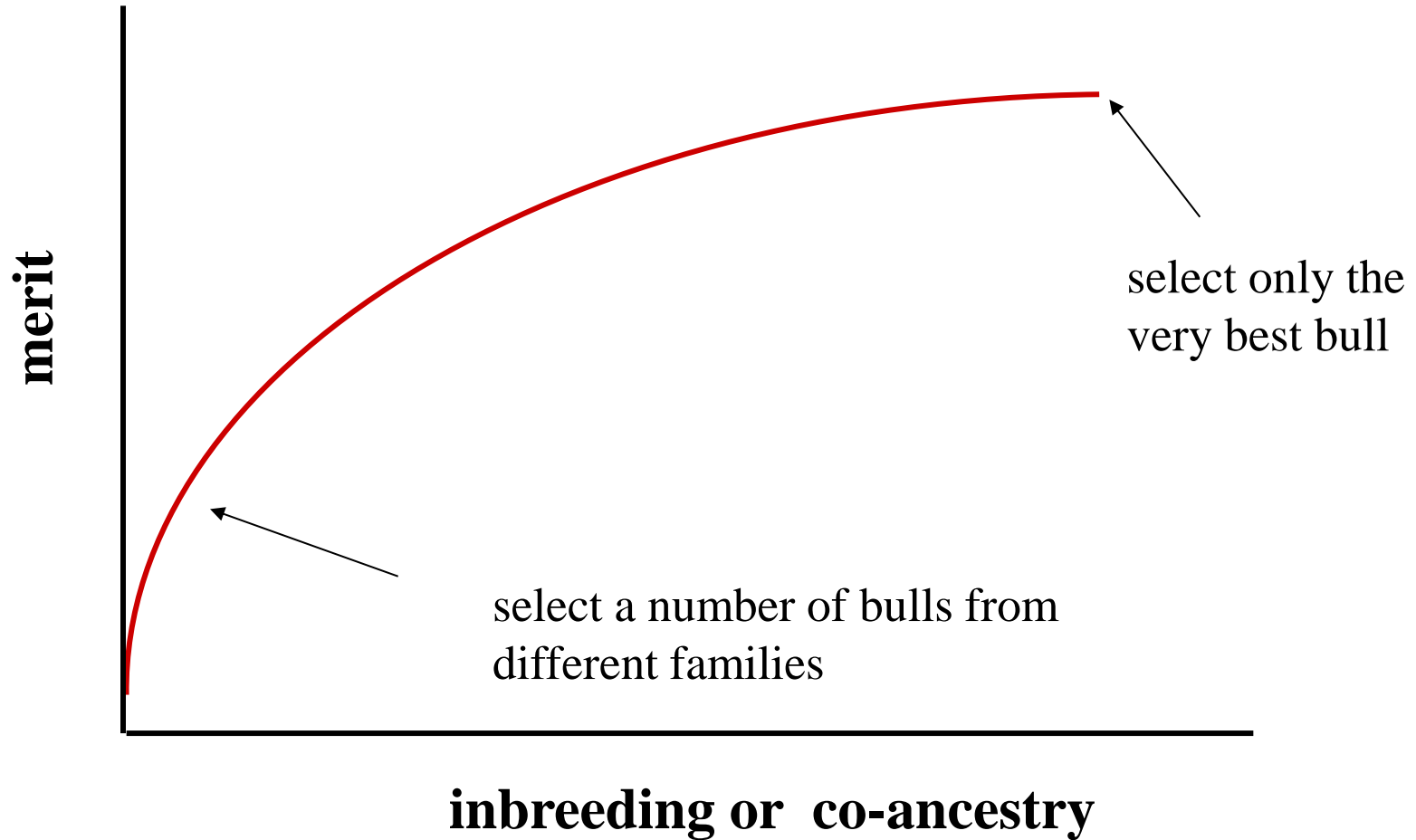


Sires

ID	Stud of breeding	Wwt	Powwt	Ywt	Pfat	Pernd	Carcase +	Progeny	Inbreeding & Accuracies			Sire	Sire of Dam
									Coeff	Weight	Carcase		
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	WARRURN	5.41	10.97	10.93	-1.21	0.37	190.26	14		73	65	1604621994940012	1640001993930411

These are sibs so might not select all of them as flock sire

# Balancing inbreeding and merit





# Jointly optimizing merit and inbreeding

*Wray and Goddard, 1994*

$$x'G + \lambda x'Ax$$

$\lambda$  = penalty on inbreeding

- merit:  $x'G$ 
  - $x$  = vector with each animal's contribution to progeny
  - $G$  = the vector with merit (EBV's) for each animal
- Co-ancestry:  $x'Ax$ 
  - $x$  = vector with each animal's contribution to progeny
  - $A$  = Numerator Relationships Matrix

Remember:  $\Delta F = x'Ax/2$

$$F_i = 0.5 a_{ij}$$

# Vector $x$ of animal contributions

Source of animals	Animal#	$x =$ Contribution	
Male candidates	1	0	} $\Sigma = 0.5$
	2	.1	
	3	.05	
	4	0	
	5	.01	
	6	0	
	7	0	
	8	0	
	...	...	
Female candidates	101	0	} $\Sigma = 0.5$
	102	.01	
	103	.01	
	104	.01	
	105	0	
	106	0	
	107	0	
	108	.08	

Note that this does not only determines number of selected sires and dams, but also allows for unequal contributions

# Balancing inbreeding and merit

- Restricting co-ancestry but this slows genetic (short term) progress
- How much inbreeding can we afford?
- Often inbreeding is restricted by limiting  $\Delta F$  to a certain preset value
- This optimal value may depend on your situation (how open is your nucleus?)

# Optimizing genetic contributions

- Maximize objective function

$$x'G - \underline{\lambda}x'Ax$$

How much  
inbreeding can we  
afford?

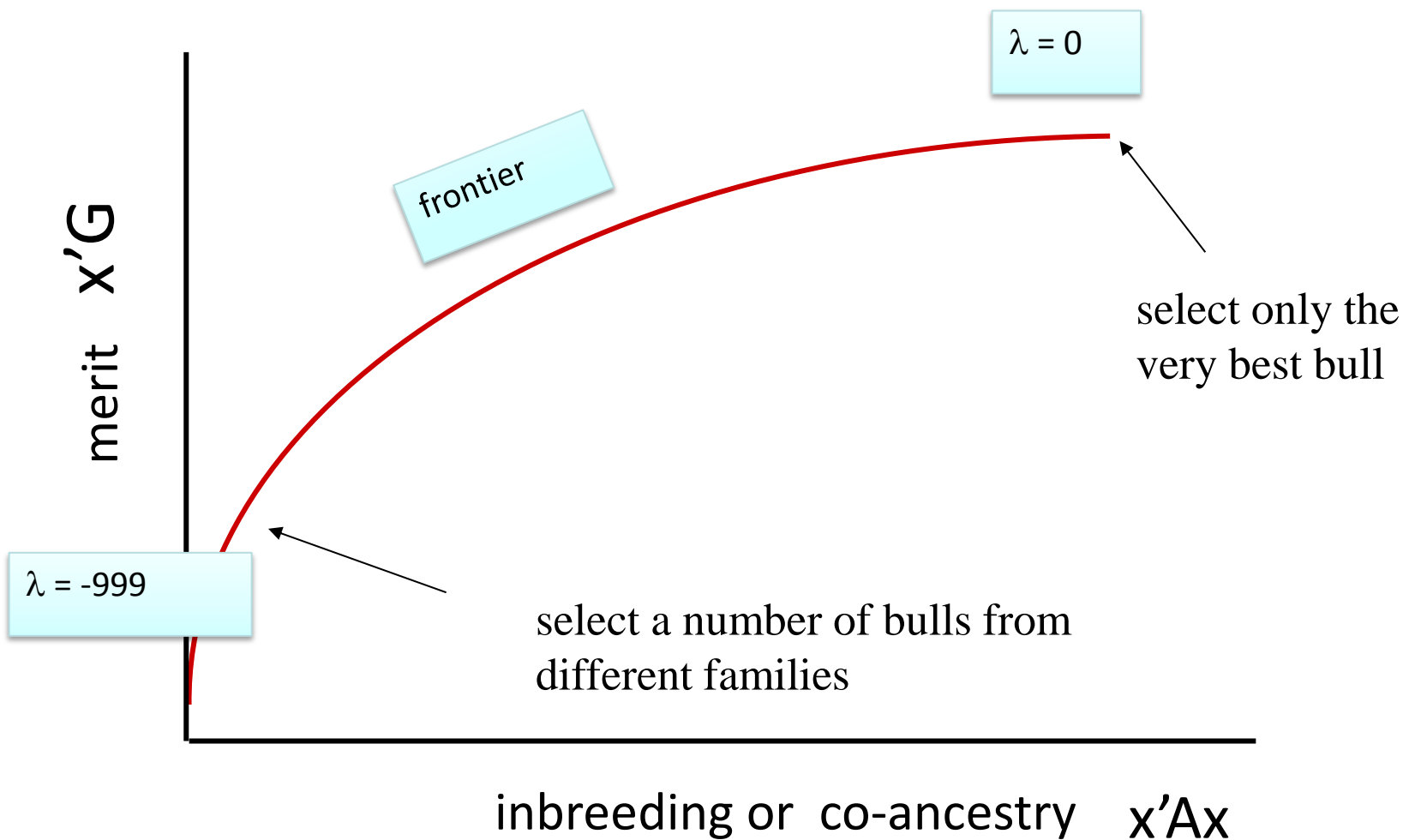
Question: what is best value for  $\lambda$  ?

Could preset rate of inbreeding (e.g. 1%)  
and determine  $\lambda$  accordingly (Meuwissen, 1997)

Alternative: look at graph (next slide)

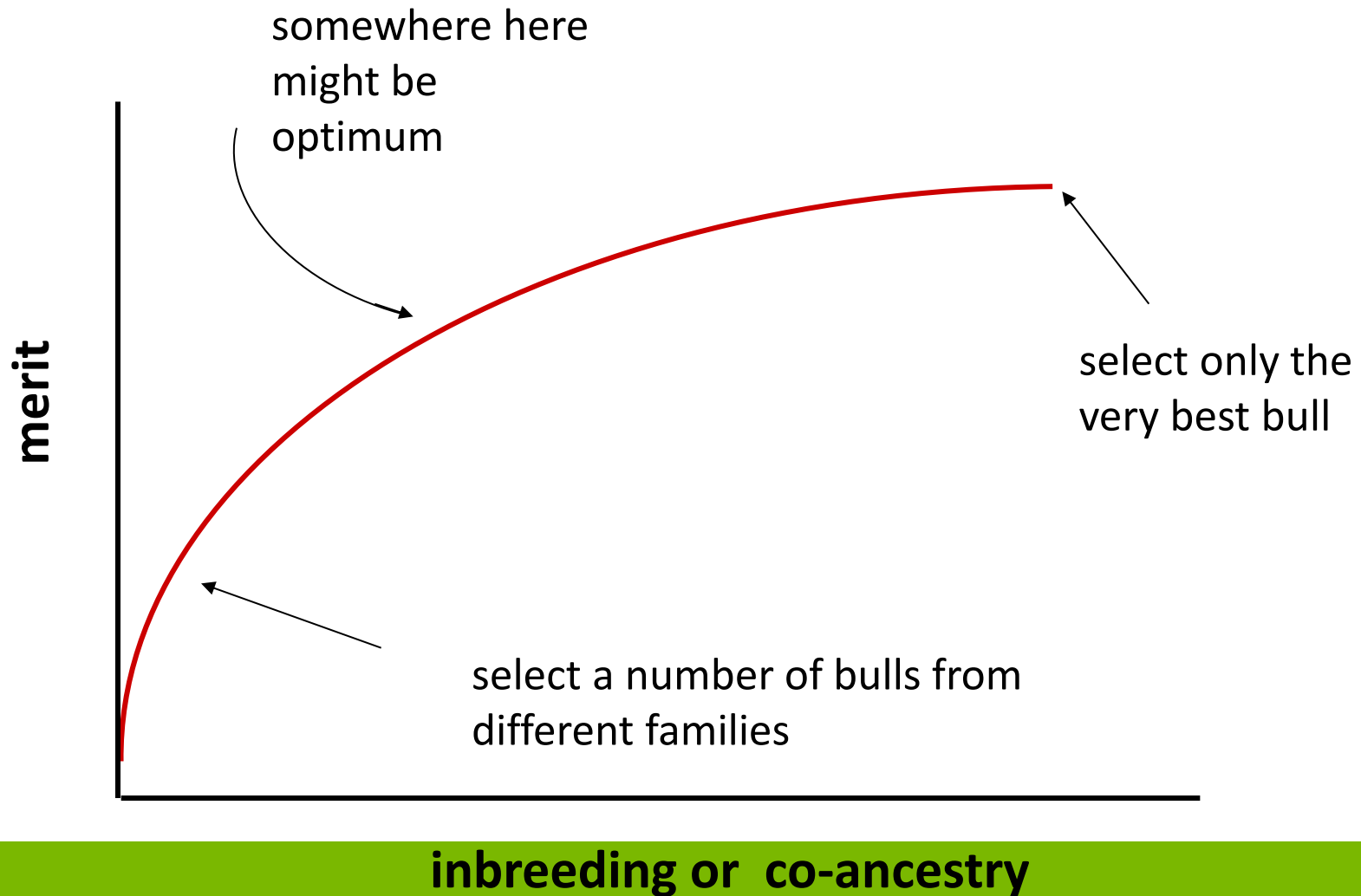
# Balancing inbreeding and merit

$$x'G - \underline{\lambda}x'Ax$$



# Balancing inbreeding and merit

This graph will look different for each population



# Example Optimal Contributions

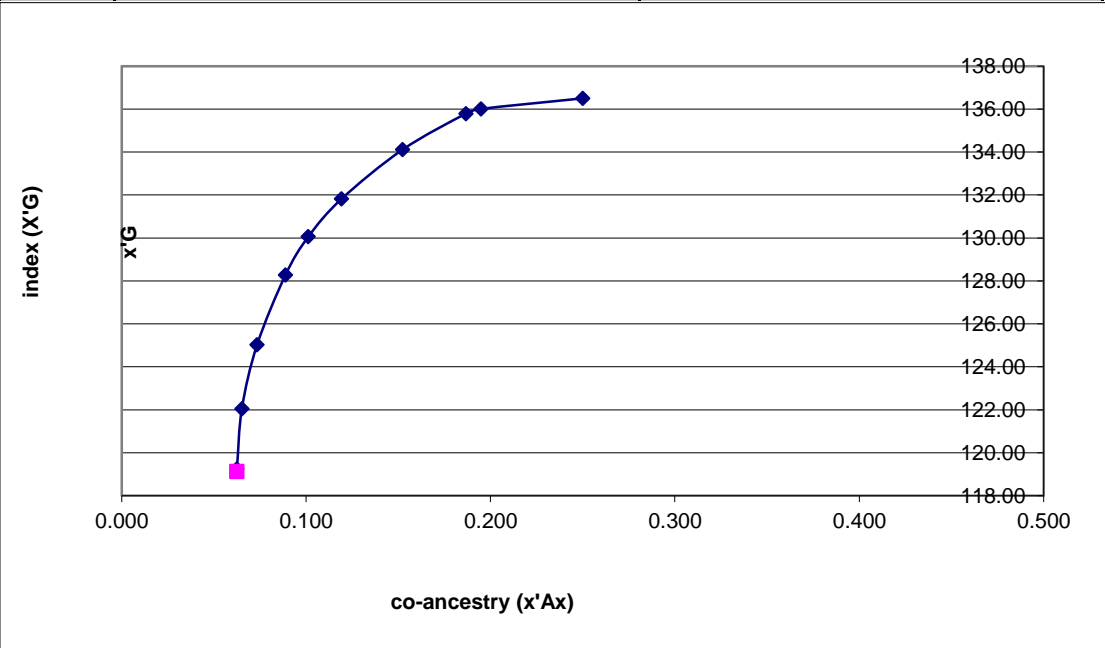
xGxAx.xls

	X	nmales	nfemales
Male 1	0.125	4	4
Male 2	0.125		
Male 3	0.125		
Male 4	0.125		
Female 1	0.125		
Female 2	0.125		
Female 3	0.125		
Female 4	0.125		

Find optimal contributions

G	Relationships Matrix							
127	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
122	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
150	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
109	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
120	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
123	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
89	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
113	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

average merit of progeny	x'G	119.12
Inbreeding weight	$\lambda$	-9999999.0
average co-ancestry of progeny	x'Ax	0.063

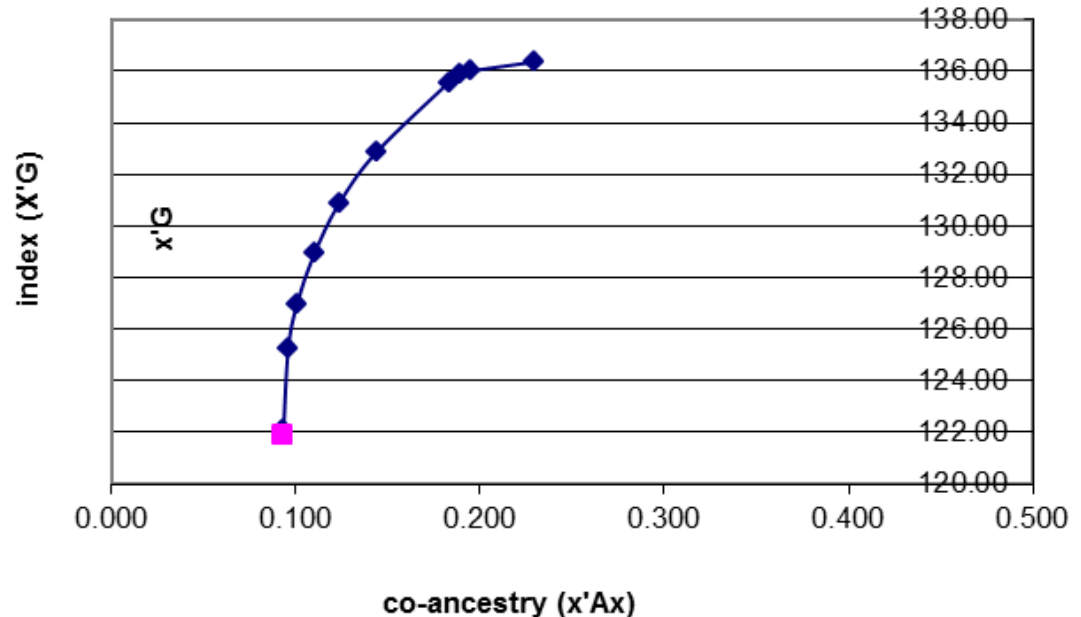


# Example Optimal Contributions

xGxAx.xls

	X	nmales	nfemales	G	Relationships Matrix							
Male 1	<b>0.127</b>	4	4	<b>127</b>	<b>1.00</b>	<b>0.00</b>	<b>0.25</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.50</b>	<b>0.00</b>
Male 2	0.108			<b>122</b>	0.00	<b>1.00</b>	<b>0.00</b>	<b>0.25</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.50</b>
Male 3	0.129			<b>150</b>	0.25	0.00	<b>1.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.25</b>	<b>0.00</b>
Male 4	0.136			<b>109</b>	0.00	0.25	0.00	<b>1.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.25</b>
Female 1	0.189			<b>120</b>	0.00	0.00	0.00	0.00	<b>1.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
Female 2	0.177			<b>123</b>	0.00	0.00	0.00	0.00	0.00	<b>1.00</b>	<b>0.25</b>	<b>0.00</b>
Female 3	0.049			<b>89</b>	0.50	0.00	0.25	0.00	0.00	0.25	<b>1.00</b>	<b>0.00</b>
Female 4	0.085			<b>113</b>	0.00	0.50	0.25	0.25	0.00	0.00	0.00	<b>1.00</b>
average merit of progeny	$x'G$											121.91
Inbreeding weight	$\lambda$											<b>-9999999.0</b>
average co-ancestry of progeny	$x'Ax$											0.093

Find optimal contributions



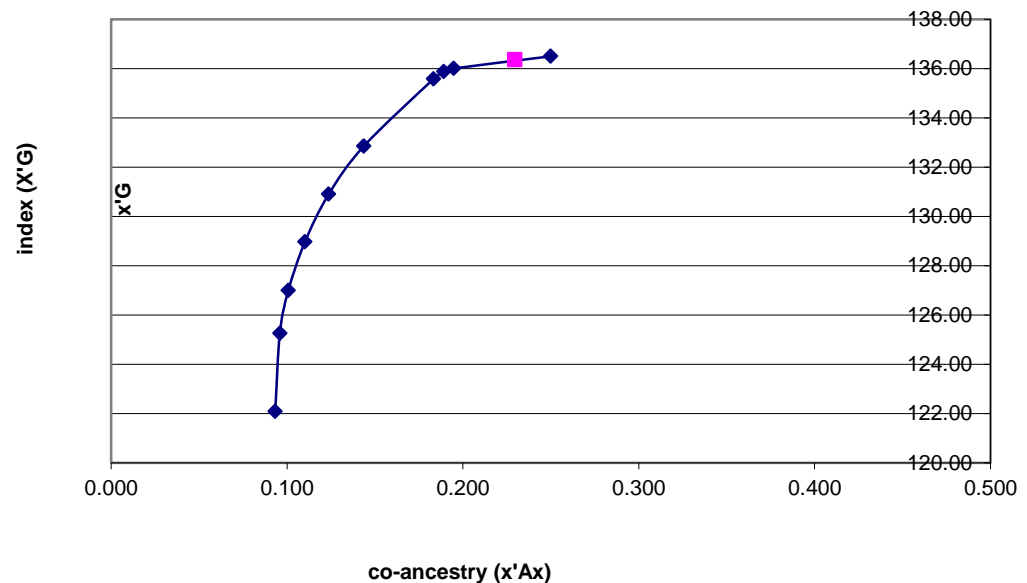


# Example Optimal Contributions

xGxAx.xls

	X	nmales	nfemales	G	Relationships Matrix							
Male 1	<b>0.000</b>	4	4	<b>127</b>	<b>1.00</b>	<b>0.00</b>	<b>0.25</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.50</b>	<b>0.00</b>
Male 2	0.000			<b>122</b>	0.00	<b>1.00</b>	<b>0.00</b>	<b>0.25</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.50</b>
Male 3	0.500			<b>150</b>	0.25	0.00	<b>1.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.25</b>	<b>0.00</b>
Male 4	0.000			<b>109</b>	0.00	0.25	0.00	<b>1.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.25</b>
Female 1	0.000			<b>120</b>	0.00	0.00	0.00	0.00	<b>1.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
Female 2	0.500			<b>123</b>	0.00	0.00	0.00	0.00	0.00	<b>1.00</b>	<b>0.25</b>	<b>0.00</b>
Female 3	0.000			<b>89</b>	0.50	0.00	0.25	0.00	0.00	0.25	<b>1.00</b>	<b>0.00</b>
Female 4	0.000			<b>113</b>	0.00	0.50	0.25	0.25	0.00	0.00	0.00	<b>1.00</b>
average merit of progeny	$x'G$											136.50
Inbreeding weight	$\lambda$											<b>0.0</b>
average co-ancestry of progeny	$x'Ax$											0.250

Find optimal contributions

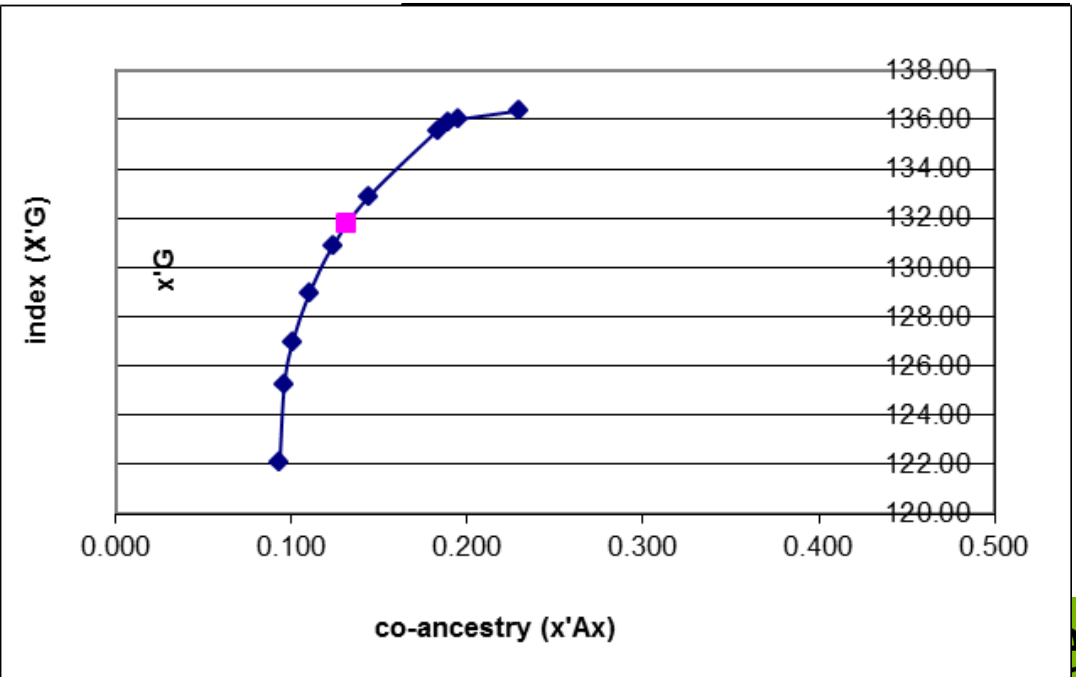


# Example Optimal Contributions

xGxAx.xls

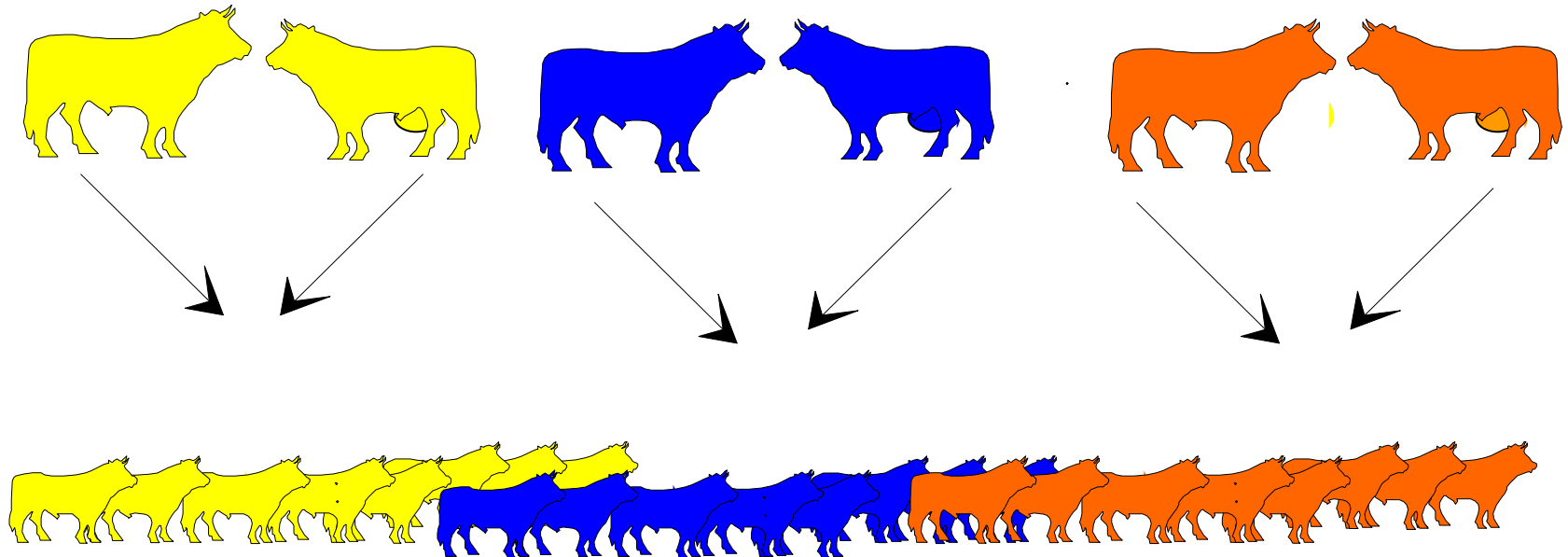
	X	nmales	nfemales	G	Relationships Matrix									
Male 1	<b>0.063</b>	4	4	127	1.00	0.00	0.25	0.00	0.00	0.00	0.50	0.00		
Male 2	0.076			122	0.00	1.00	0.00	0.25	0.00	0.00	0.00	0.50		
Male 3	0.361			150	0.25	0.00	1.00	0.00	0.00	0.00	0.25	0.00		
Male 4	0.000			109	0.00	0.25	0.00	1.00	0.00	0.00	0.00	0.25		
Female 1	0.208			120	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00		
Female 2	0.238			123	0.00	0.00	0.00	0.00	0.00	1.00	0.25	0.00		
Female 3	0.000			89	0.50	0.00	0.25	0.00	0.00	0.25	1.00	0.00		
Female 4	0.055			113	0.00	0.50	0.25	0.25	0.00	0.00	0.00	1.00		
average merit of progeny	$x'G$												131.75	
Inbreeding weight	$\lambda$													<b>-50.0</b>
average co-ancestry of progeny	$x'Ax$													0.132

Find optimal contributions



This is more than simply moving back from BLUP to mass selection (penalizing family info)

# Between versus within family selection



Own information (performance or *genotype*):

More variation within families

More within-family selection – ***less inbreeding***

Advantage of  
genomic selection

Ultimately, genetic gain is about utilizing Mendelian sampling Variance

# Conclusion      Optimal Contribution Selection

- OCS is the only sensible selection method
  - Optimality subject to some degree of subjectivity
  - Separates best prediction of merit from selection rule
  - Play with number of parents as well as progeny per selected parent → optimizes contributions
  - Different from simply giving more weight to family info
- Hard to deterministically predict response to OCS