Building Blocks of (quantitative) Genetics

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Building Blocks

Variation, Heritability
Breeding Values
Selection response
Correlations, G x E
Genetic Similarity

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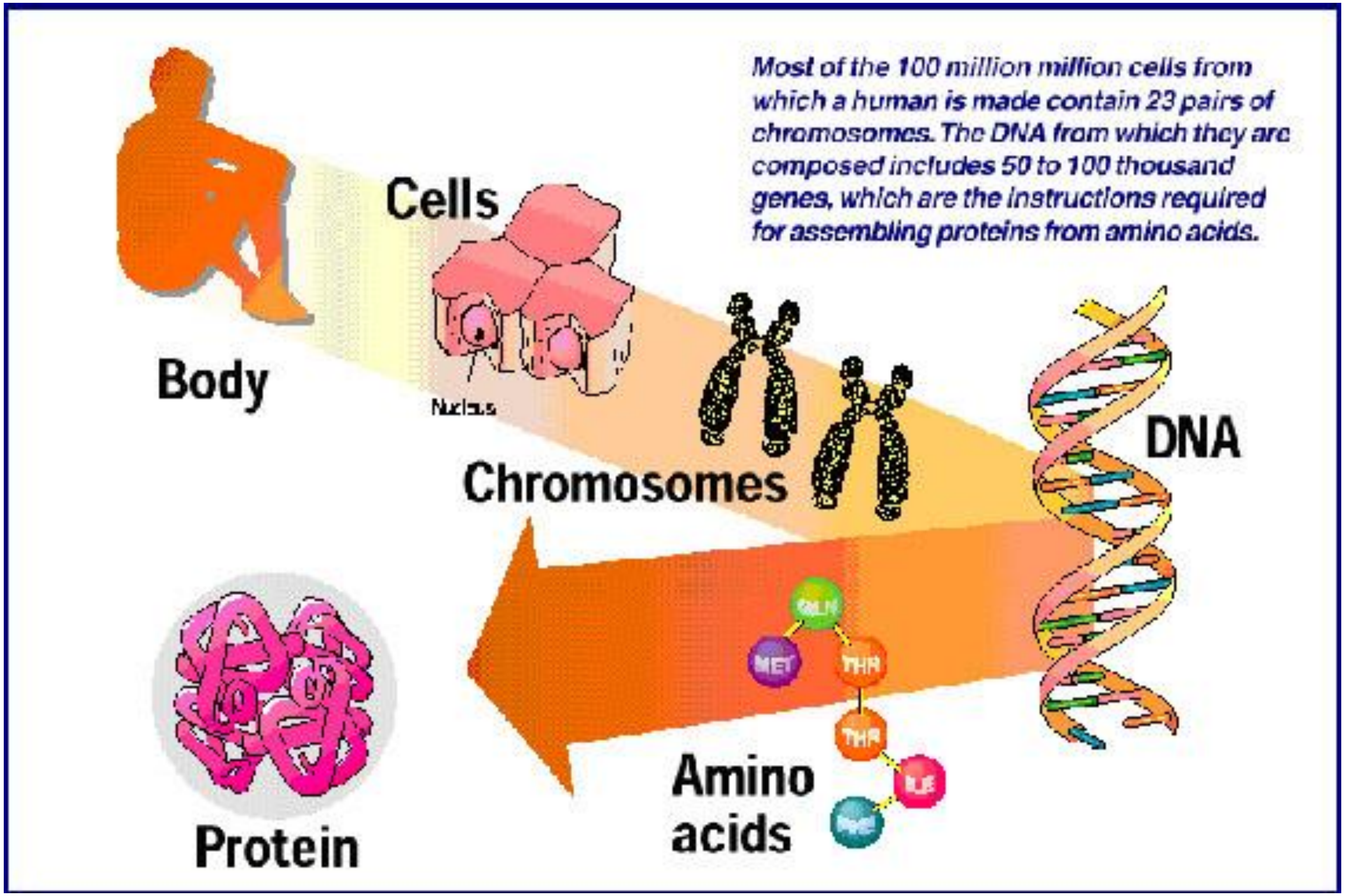
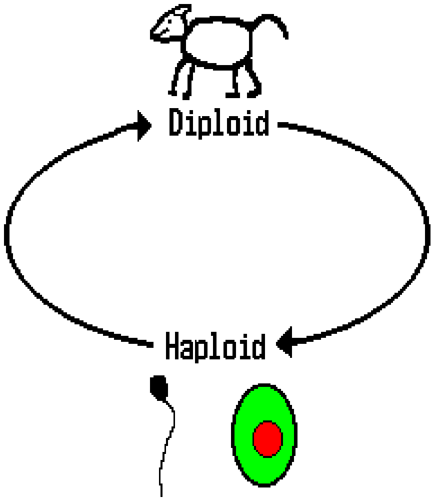
From DNA to Organism





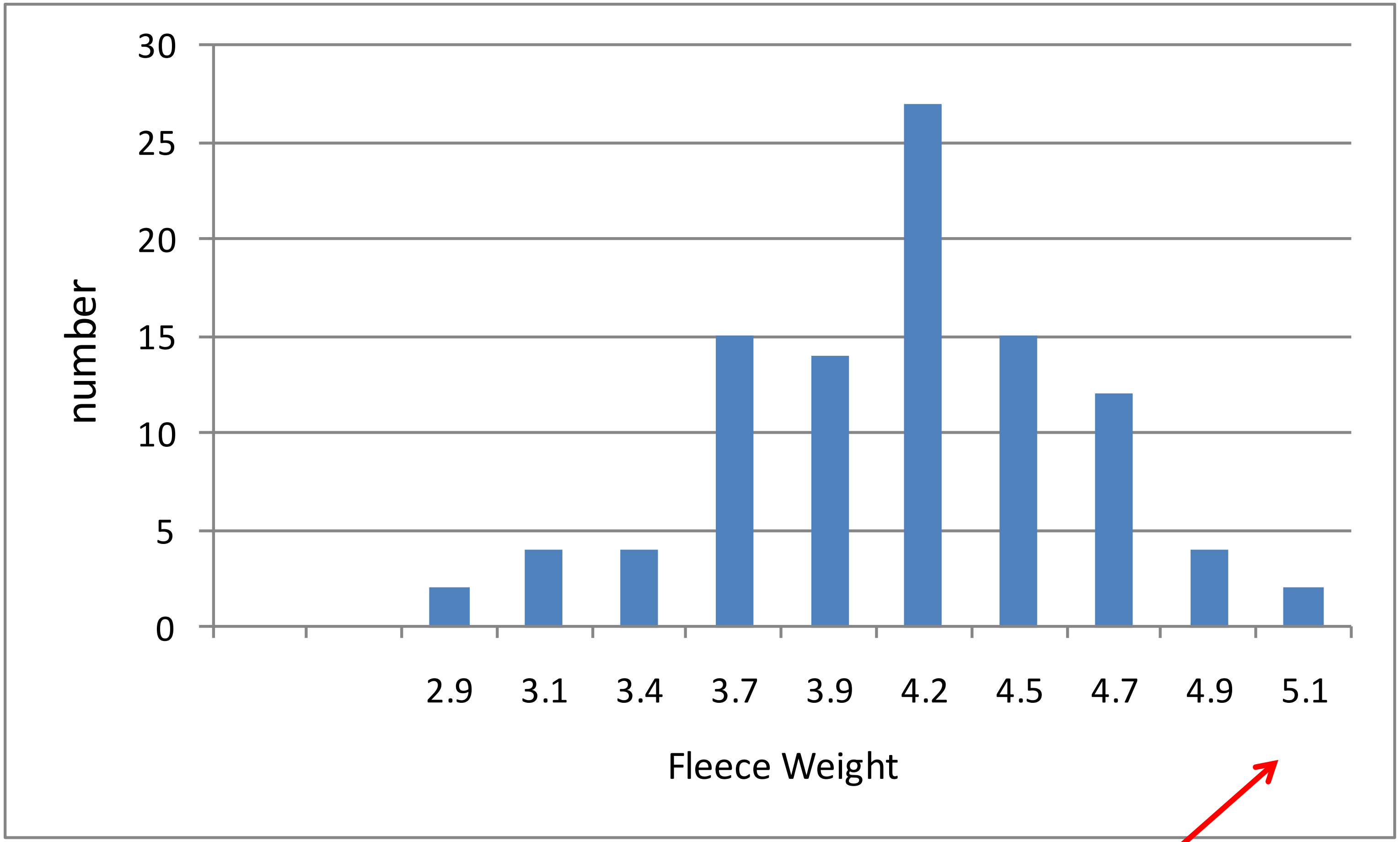
Parents pass on only 1 allele of a pair
Parents transmit 50% of their genes

Progeny receive 2 alleles (chromosomes -sets);
One of each parent

Quantitative Genetics: Variation is key

Courtesy: Peter Parnell

Variation is key



We want them all like these

Prediction of breeding values

Best ewe cuts 5.2 kg of wool

What can we expect from its progeny?

Prediction of breeding values

In real life we observe phenotype P

but want to estimate breeding value A

$$P = \text{genotype} + \text{environment} + G \times e$$

$$= A + \underbrace{NA + e + Gxe}_{E}$$

$$P = \mathbf{A} + E$$

$$\mathbf{A} \downarrow$$

Breeding Value = the bit that gets passed on

A breeding Value – genetically

frequency of A1		0.5					
		from mum					
		0.5	0.5	Progeny Genotype Frequency			Pog Mean
	dad	A1	A2	A1A1	A1A2	A2A2	
1	A1A1			0.5	0.5	0	0.5
0	A1A2			0.25	0.5	0.25	0
-1	A2A2			0	0.5	0.5	-0.5

A breeding Value – genetically

frequency of A1		0.5					
		from mum					
		0.5	0.5	Progeny Genotype Frequency			Pog Mean
	dad	A1	A2	A1A1	A1A2	A2A2	
1	A1A1			0.5	0.5	0	1
1	A1A2			0.25	0.5	0.25	0.5
-1	A2A2			0	0.5	0.5	0

Dominance,….. still BVs are additive

A breeding Value – genetically

frequency of A1		0.9					
		from mum					
		0.9	0.1	Progeny Genotype Frequency			Pog Mean
	dad	A1	A2	A1A1	A1A2	A2A2	
1	A1A1			0.9	0.1	0	0.9
0	A1A2			0.45	0.5	0.05	0.4
-1	A2A2			0	0.9	0.1	-0.1

Allele frequencies almost fixed….. still BVs are additive

Prediction of breeding values

Best ewe cuts 5.2 kg of wool

Ewe P = 1.2 Kg

Estimated breeding value ewe

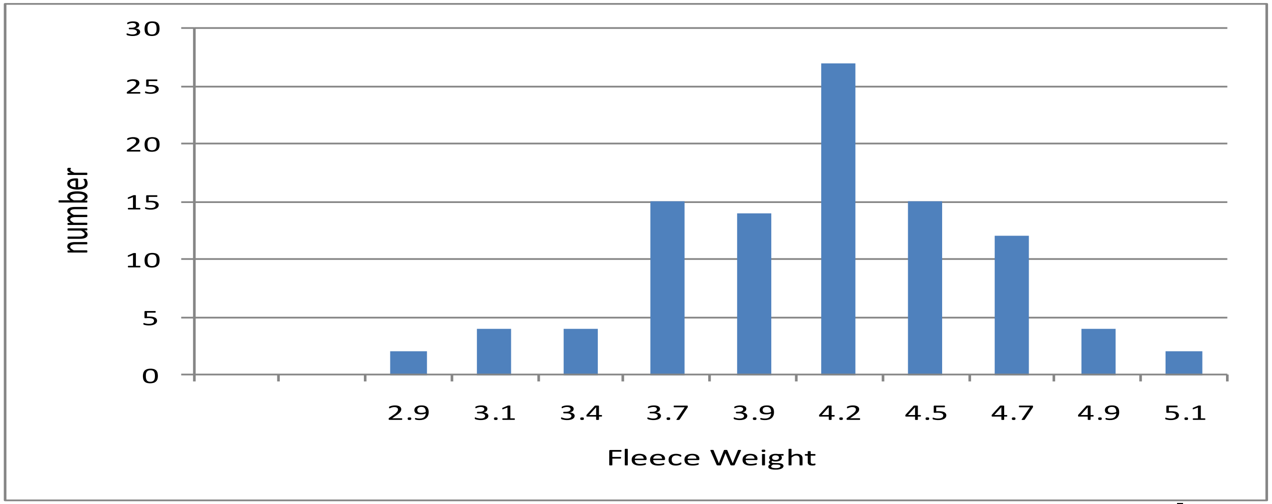
= heritability * 1.2 kg = 0.4 kg

Progeny gets ½ of breeding value of ewe

Expected prog performance = mean + ½ EBV_{ewe}

= 4.2 kg

Heritability
proportion of parent superiority passed on to progeny



Mean = 4 kg

Best Ewe = 5.2 kg

Mean of his progeny = 4.18 kg

→ heritability is 30% progeny get ½ EBV_{RAM}

une

Heritability

- Heritability is the proportion of phenotypic variance due to additive genetic effects (breeding value)

- The more heritable a trait

  – the more of the observed variation is due to breeding value rather than environmental effects

  – The more of parental superiority is passed on to progeny

Heritabilities for sheep traits

in merino

Adult mean fibre diameter	0.60
Yearling mean fibre diameter	0.55
Adult body weight	0.40
Carcass weight	0.40
Hogget clean fleece weight	0.39
Carcass fat depth (mm)	0.30
Yearling staple strength	0.30
Post weaning eye muscle depth (C)	0.30
Yearling greasy fleece weight	0.30
Post weaning weight	0.30
Yearling clean fleece weight	0.29
Weaning weight	0.25
Yearling worm egg count	0.20
Post weaning fat depth (C)	0.20
Birth weight	0.15
Weaning worm egg count	0.15
Number of lambs born	0.07
Number of lambs weaned	0.06

What do we use heritability for?

- To predict response to selection
  - how much of its superiority does a group of selected animals will be transmit to its progeny?

Flock Mean = 4 kg Mean of best ram**s** = 5.2 kg

Mean of their progeny = 4.2 kg

→ heritability is 30%

- To determine the breeding value of an individual
  - how much of an individuals superiority is due to additive genetic versus environmental effects

Flock Mean = 4 kg Mean of best ram = 5.2 kg

Mean of its progeny = 4.18 kg

→ heritability is 30%

Selection response

Genetic change due to selection:

Per generation: Parent Superiority * heritability

in example; *Parent Superiority=* *+1.2 kg fleece weight*
Heritability is *30% (different for each trait)*

Per year:

genetic change per generation/ generation interval

generation interval =

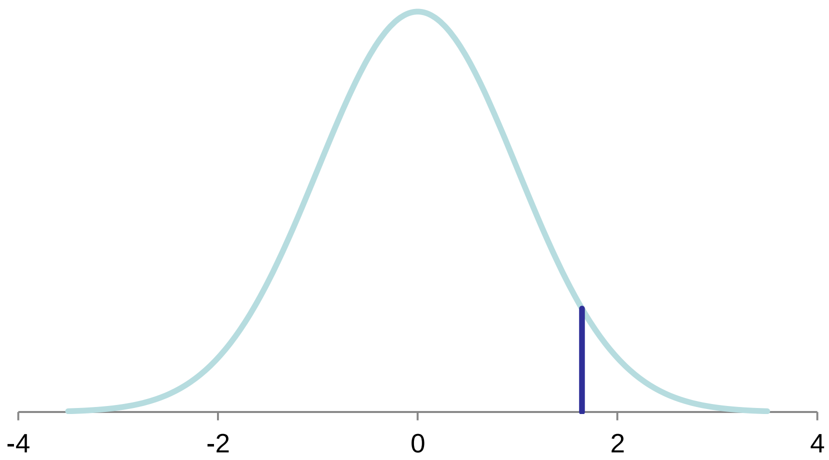
L = average age of the parents when progeny are born

Predicting response to selection

Parent Superiority

- Predicted from proportion selected > selection intensity

proportion selected (p)		5 %
selection intensity (i)		2.06
threshold (x)		1.65



<u>Example: Fleece Weight:</u>
Mean =4
Phenotypic SD = 0.6

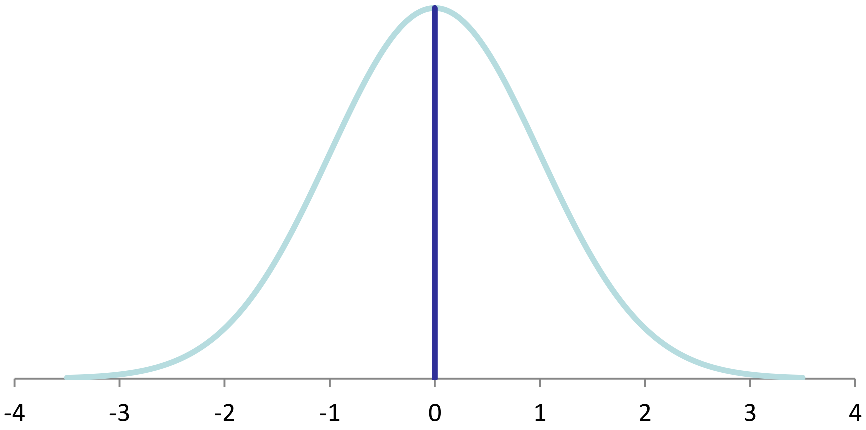
Mean of selected males = + 2.06 SD
= + 1.2 kg
= 5.2 kg

Predicting response to selection

Parent superiority

- Predicted from proportion selected > selection intensity

proportion selected (p)		50 %
selection intensity (i)		0.8
threshold (x)		0.0



<u>Example: Fleece Weight:</u>

Mean =4

Phenotypic SD = 0.6

Mean of selected males = + 0.8 SD

= + 0.48 kg

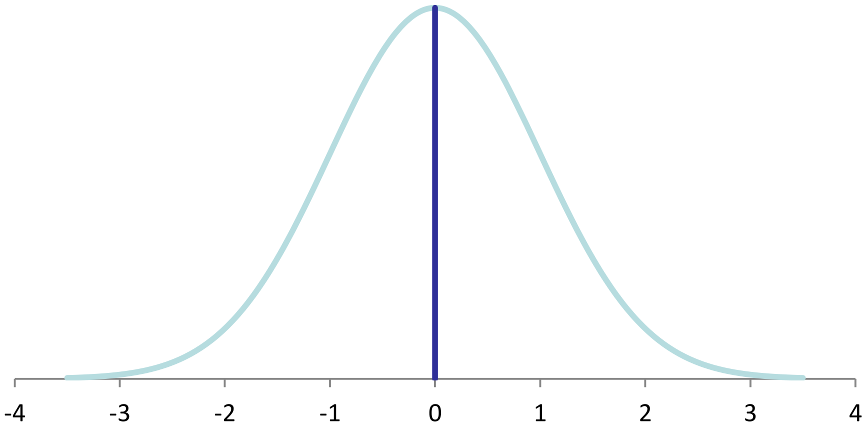
= 4.48 kg

Predicting response to selection

Parent superiority

- Predicted from proportion selected > selection intensity

proportion selected (p)		50 %
selection intensity (i)		0.8
threshold (x)		0.0



<u>Example: Fleece Weight:</u>

Mean =4

Phenotypic SD = 0.6

Mean of selected males = + 0.8 SD

= + 0.48 kg

= 4.48 kg

Response to selection - worked example

- 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
- 10% mortality/random culling in adults
- Trait heritability = 0.35, and Phenotypic SD =0.6kg

- What is Response per year?

Result

Optimizing age structure in breeding programs

flock size 180

first drop	2	rams
first drop	2	ewes
mortality	10	%
mating rate	30	ewes/ram
weaning rate	90	%

trait mean	4	Kg
Phenotypic SD	0.6	Kg
h2	0.35	

	males		females
optimize ages here: nr matings	2	years	4

Age class Table

L		2	3	4	5	6	7	8	9	TOTAL
2.47	Males	3	3	0	0	0	0	0	0	6
3.37	Females	52	47	42	38	0	0	0	0	180

	males	average	females
proportion retained for breeding	0.04		0.65
selection intensity	2.16	1.37	0.575
Response/gen		0.288	Kg
generation interval	2.47	2.92	3.37
Response per year		0.098	Kg

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

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Relationships between traits

- Animals with higher growth rate tend to be fatter
- Animals with higher weaning weight tend to have higher birth weight
- Animals with lower body weight tend to have smaller litter sizes
- Sheep with finer fleeces cut less wool

→ correlations

Types of correlations

- Phenotypic correlations
  - measure association between observed performance
  - Cows that produce more milk tend to have lower fertility

- Genetic correlations
  - measure association between breeding values
  - Bulls that give daughter that produce more milk tend to have daughters with lower fertility

  - Due to pleiotropy or linkage (may be +ve or –ve)

Use of correlations

- Predict change in one trait when selecting on another
  - (use genetic correlation)
- Construct selection indexes involving multiple traits
- Provide an additional information source in terms of predicting breeding values

Indirect selection

Selecting on one trait when interested in response in another trait

- If traits is difficult or expensive to measure
  - Feed intake
  - Carcase Traits

Select on another correlated trait that is easier to measure

- If traits can only be measured late in life

Select on a correlated trait that can be measured earlier

- If traits have very low heritability

Select on a (highly) correlated trait that is more heritable

Genotype x environment (G x E) interaction

- Occurs if
  - different breeds (genotypes/sires) rank differently in different environments
  - difference between breeds (genotypes/sires) is smaller or larger in different environment

i.e. the genetic correlation (r_A) between the same trait expressed in different environments is < 1

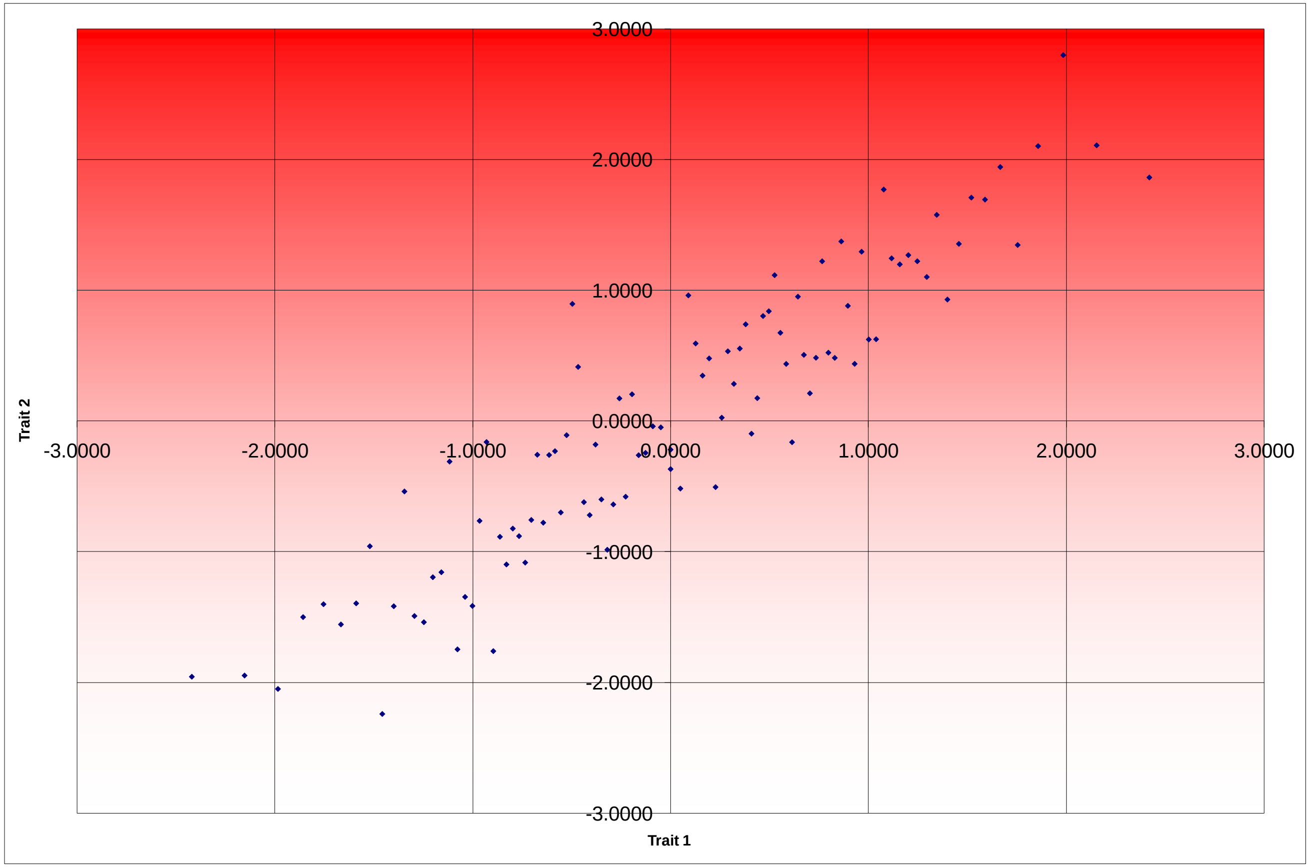
Example: yearling weight in beef cattle (hypothetical)

	Temperate	Tropical	Average
Bos. Taurus	340	230	285
Bos. Indicus	290	250	270
Average	315	240	277.5

Effect of breed depends on which environment the animals are performing

Re-ranking of animals in different environments

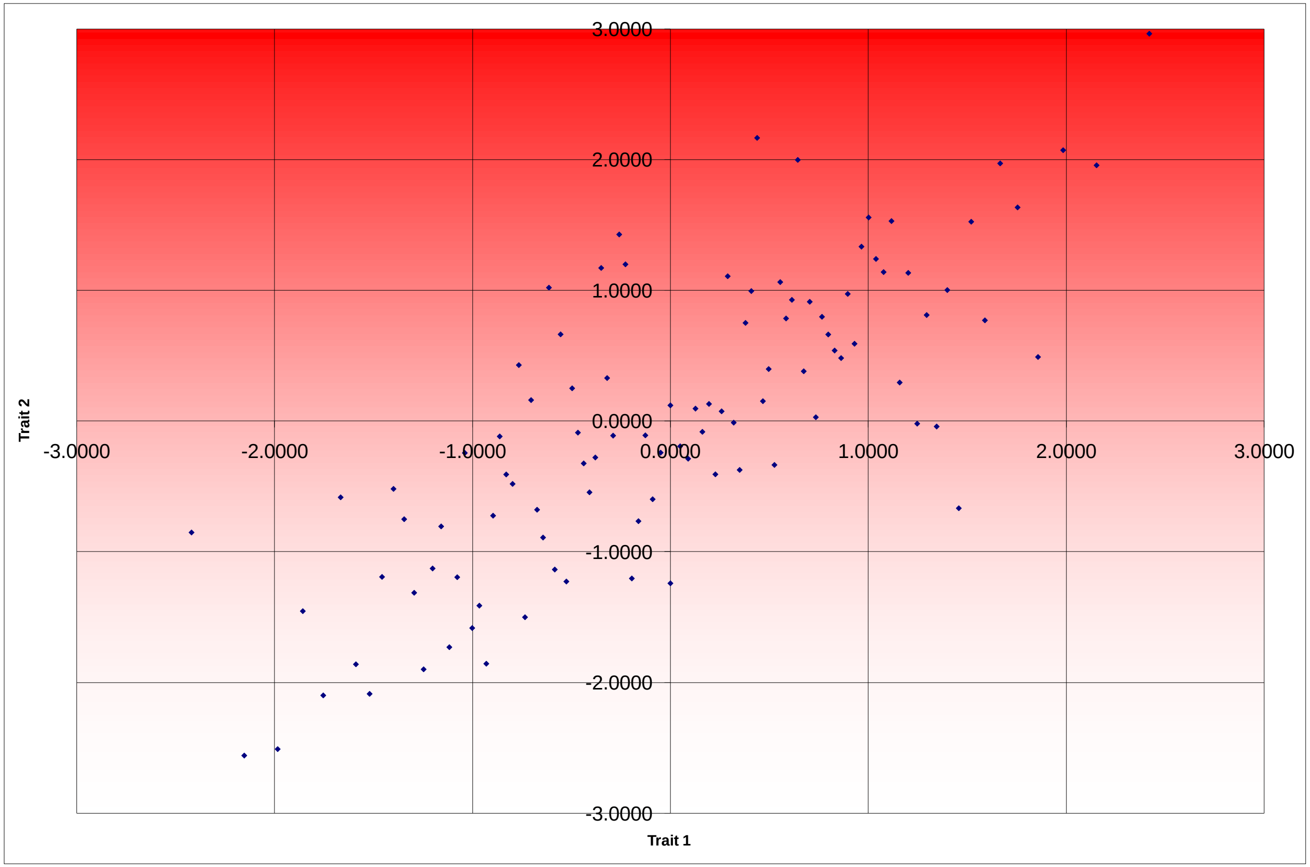
2.4209	1.8649
2.1543	2.1107
1.9854	2.8011
1.8583	2.1049
1.7550	1.3481
1.6670	1.9448
1.5898	1.6956
1.5207	1.7107
1.4578	1.3569
1.3998	0.9309
1.3459	1.5788
1.2953	1.1035
1.2476	1.2237
1.2022	1.2705
1.1590	1.2001
1.1175	1.2460
1.0777	1.7726
1.0392	0.6268
1.0020	0.6253
0.9659	1.2968
0.9307	0.4385
0.8964	0.8825
0.8629	1.3753
0.8301	0.4843
0.7979	0.5243
0.7662	1.2234
0.7351	0.4853
0.7043	0.2132
0.6740	0.5074
0.6439	0.9528
0.6141	-0.1609
0.5846	0.4381
0.5552	0.6762
0.5259	1.1173
0.4967	0.8413
0.4675	0.8047
0.4383	0.1763
0.4090	-0.0956
0.3796	0.7413
0.3500	0.5558
0.3200	0.2854
0.2897	0.5349
0.2588	0.0270
0.2273	-0.5045
0.1950	0.4802
0.1616	0.3486
0.1267	0.5946
0.0898	0.9625
0.0494	-0.5155
0.0000	-0.3666
0.0000	-0.2178
-0.0494	-0.0473
-0.0898	-0.0394
-0.1267	-0.2425
-0.1616	-0.2602
-0.1950	0.2059
-0.2273	-0.5778
-0.2588	0.1743
-0.2897	-0.6370
-0.3200	-0.9838
-0.3500	-0.5987
-0.3796	-0.1791
-0.4090	-0.7186
-0.4383	-0.6196
-0.4675	0.4153
-0.4967	0.8974
-0.5259	-0.1071
-0.5552	-0.6985
-0.5846	-0.2295
-0.6141	-0.2588
-0.6439	-0.7767
-0.6740	-0.2569
-0.7043	-0.7558
-0.7351	-1.0820



Correlation = 0.90

Re-ranking of animals in different environments

2.4209	2.9650
2.1543	1.9576
1.9854	2.0733
1.8583	0.4902
1.7550	1.6353
1.6670	1.9722
1.5898	0.7707
1.5207	1.5256
1.4578	-0.6676
1.3998	1.0026
1.3459	-0.0420
1.2953	0.8114
1.2476	-0.0201
1.2022	1.1341
1.1590	0.2948
1.1175	1.5307
1.0777	1.1402
1.0392	1.2407
1.0020	1.5582
0.9659	1.3351
0.9307	0.5916
0.8964	0.9731
0.8629	0.4819
0.8301	0.5397
0.7979	0.6626
0.7662	0.7979
0.7351	0.0290
0.7043	0.9129
0.6740	0.3809
0.6439	1.9989
0.6141	0.9275
0.5846	0.7852
0.5552	1.0636
0.5259	-0.3361
0.4967	0.3979
0.4675	0.1521
0.4383	2.1674
0.4090	0.9949
0.3796	0.7511
0.3500	-0.3743
0.3200	-0.0122
0.2897	1.1083
0.2588	0.0743
0.2273	-0.4080
0.1950	0.1308
0.1616	-0.0826
0.1267	0.0952
0.0898	-0.2885
0.0494	-0.1932
0.0000	0.1199
0.0000	-1.2422
-0.0494	-0.2420
-0.0898	-0.5986
-0.1267	-0.1096
-0.1616	-0.7665
-0.1950	-1.2051
-0.2273	1.1994
-0.2588	1.4282
-0.2897	-0.1117
-0.3200	0.3291
-0.3500	1.1718
-0.3796	-0.2790
-0.4090	-0.5457



Correlation = 0.70

Similarity amongst relatives

- Why do we expect relatives to look (perform) alike?

- How much do we expect two relatives to look (perform) alike?
  - Consider
    - Full sibs
    - Half sibs
    - Parents vs offspring
    - grandparent vs grandchild
    - uncle / aunt vs nephew / niece

University of New England

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Genetic similarity

- Depends on genetic relationship
- Depends on trait

The most important relationships

Relationship	Degree	a
Full Sib	1st	½
Half Sib	2nd	¼
Parent-offspring	1st	½
Grandparent-grandchild	2nd	¼

Degree of genetic similarity

- Depends on genetic relationship
- Depends on trait (-heritability)

Why do relatives look / perform alike?

Measurement of same trait on two relatives

- $P_x = A_x + E_x$
- $P_y = A_y + E_y$

A correlation between phenotypes for the same traits exists for pairs of relatives due to similar genes or similar environment

- Building Blocks

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