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Influencing uniformity in livestock genetically, through canalisation and plasticity

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Thanks to Hervé GARREAU, Catherine LARZUL, Christèle ROBERT-GRANIE, Mathilde DUPONT-NIVET

Canalising selection is a way to reduce environmental sensitivity

Outline

- Concepts of plasticity and stability
- Models
- Selection experiments
- Molecular evidence of genes affecting environmental sensitivity

Plasticity vs stability

$$P = G + E + G \times E$$

1 genotype n environments

n phenotypes

Plasticity:
the phenotype responds to the variations of the environment

Macro variations

Good in terms of evolution: adaptation

Example: [CO2] varied

⇒ changes in stomatal frequencies (oak)

⇒ Maintenance of leaf growth under optimal and stable conditions *(Kürschner et al 1998)*

In human, the body temperature may be kept almost constant, physiological mechanisms respond to the environmental changes (sweating, shivering)

Stability: the phenotype is constant whatever the environment

Micro variations

Good for breeders: homogeneous production

How to obtain stable phenotypes

$$P = G + E + G \times E$$

control

or control by way of selection

Is there any genetic control on the sensitivity of variations of the environment?

Models

Overdominance model

Heterozygotes are more stable (and robust) than homozygotes

Greater choice of metabolic pathways in response to the environmental signals

Not a general rule

Gillepsie and Turelli 1989
but Gebhart and Stearns 1992 ; Wu 2000 (tripoids vs diploids)

Epistatis model

Genes controlling mean of trait

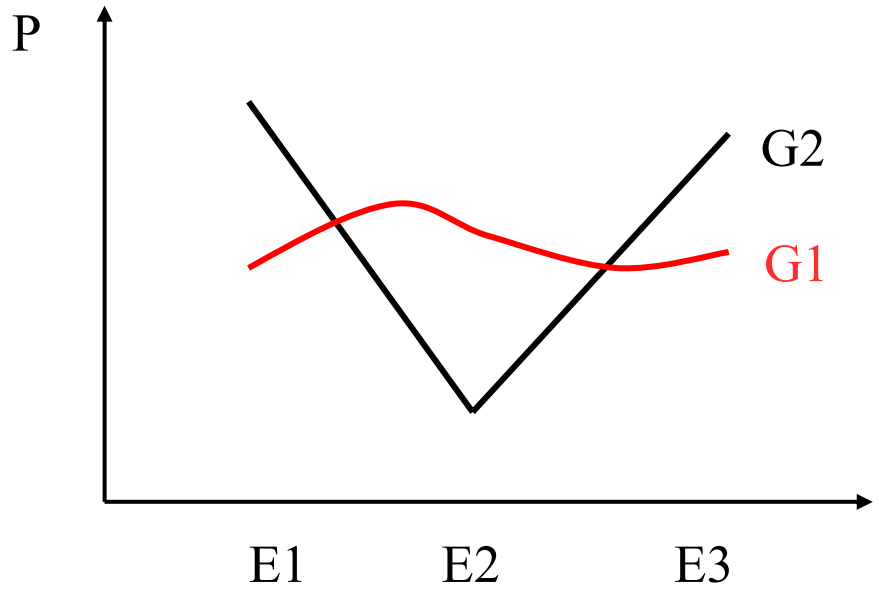
and

Genes controlling environmental sensitivity

Cardin & Minvielle 1986, Scheiner & Lyman 1991, Noach et al 1997, etc..

Reaction norms

1 phenotype = 1 curve



Reaction norms

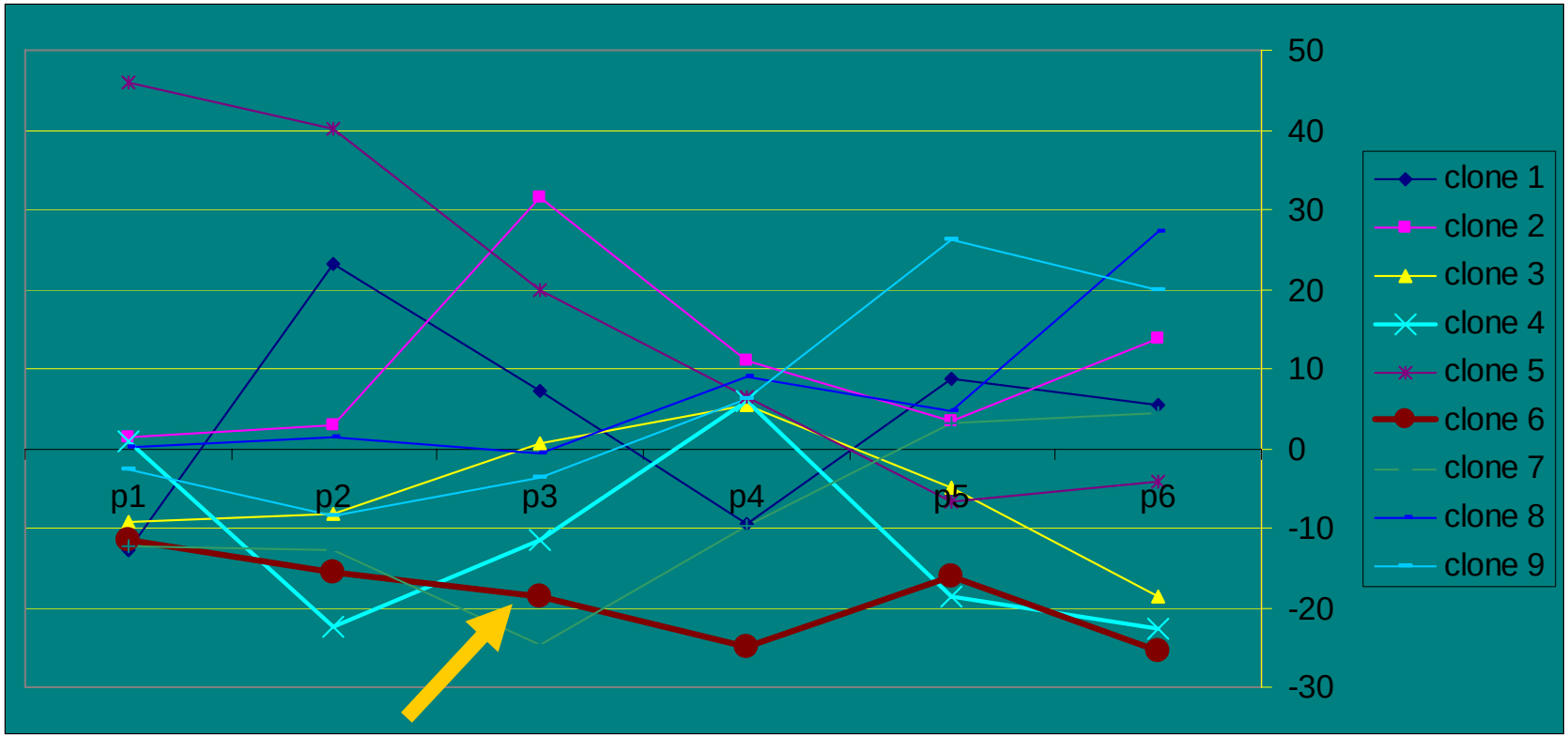
- Continuous or ordered environments
- 1 factor (temperature, food)
- Quantitative genetics theory developed

De Jong 1990; van Tiederen & Koelewijn 1990; de Jong 1995;

Kirkpatrick & Bataillon 1990

Clones

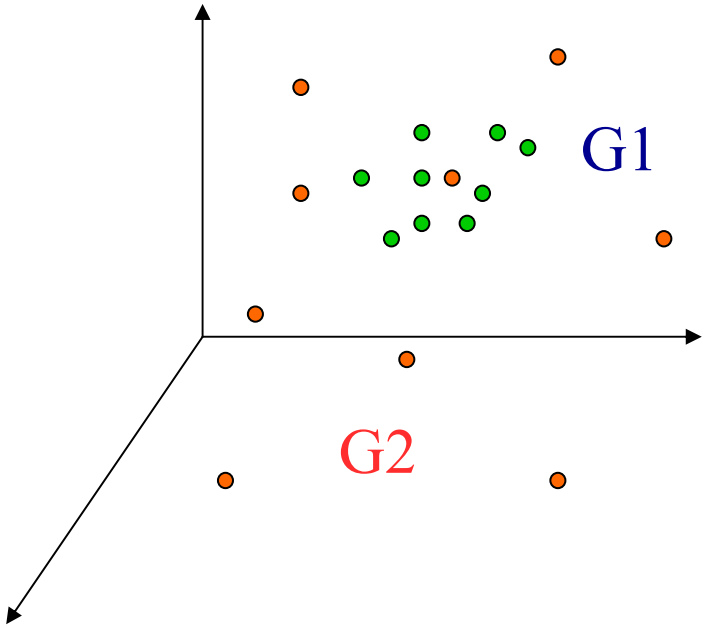
$$V_P = V_G + V_E + 2Cov_{(G,E)}$$



Dupont-Nivet et al (2006) *Genetics in Aquaculture IX, Montpellier*

The environmental variance as characteristic

Several and unknown factors



Parallel modelling of mean and (log) variance

Overall mean

Overall (log) variance

$$y_{ij} \sim N(\mu + u_i, (\exp)(\nu + v_i))$$

Additive genetic value on the mean

$$u \sim N(0, \sigma_u^2 A)$$

Additive genetic value on the (log) variance

$$v \sim N(0, \sigma_v^2 A)$$

Corr ρ_{uv}

SanCristobal-Gaudy et al (1998) GSE,
Hill & Zhang (2004) Genet Res ; Mulder et al (2007) Genetics

Estimation of genetic parameters

- AD hoc procedures
  - Garreau et al (2004) 8th World Rabbit Congress, Mexico
- REML/MAP
  - SanCristobal-Gaudy et al (1998)
- MCMC algorithm
  - Sorensen & Waagepetersen (2003) Genet. Res. Camb.
  - Ibanez (2006) PhD thesis

Evidence of non null genetic variances of variability in livestock

SanCristobal et al (2001) GSE	Sheep	Litter size
Ros et al (2004) Genetics	Snail	Adult weight
Sorensen & W. (2003) GenRes	Pigs	Litter size
Rowe et al (2006) GSE	Poultry	Body weight

among others …

Index for canalising selection

$$\hat{\nu}$$

Objective: small v for small variance

Predictions of response to canalising selection: good approximations available

- Genotypic level: SanCristobal et al (1998), Ibanez (2005)

$$E(v_{offspring} \,/\, \text{parent selected}) - E(v_{parent})$$

- Phenotypic level: SanCristobal et al (1998), Mulder et al (2007)

$$E(\sigma^2_{Y\,offspring} \,/\, \text{parent selected}) - E(\sigma^2_{Y\,parent})$$

Function of

$$h^2_u, \sigma^2_v, \rho_{uv}$$

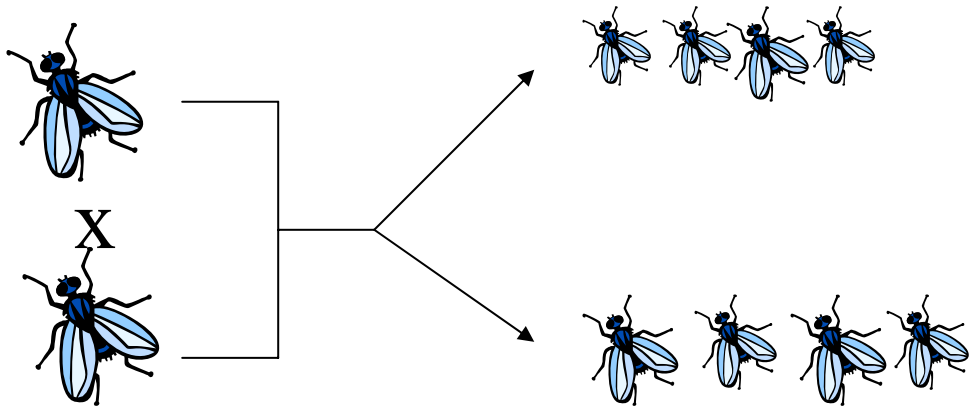
Size and type of experiment? Power?

- Beginning of answer in
  - Ibanez's thesis
  - Mulder's thesis

Selection experiments in laboratory animals and in livestock: various results

Evidence of genetic control if selection works

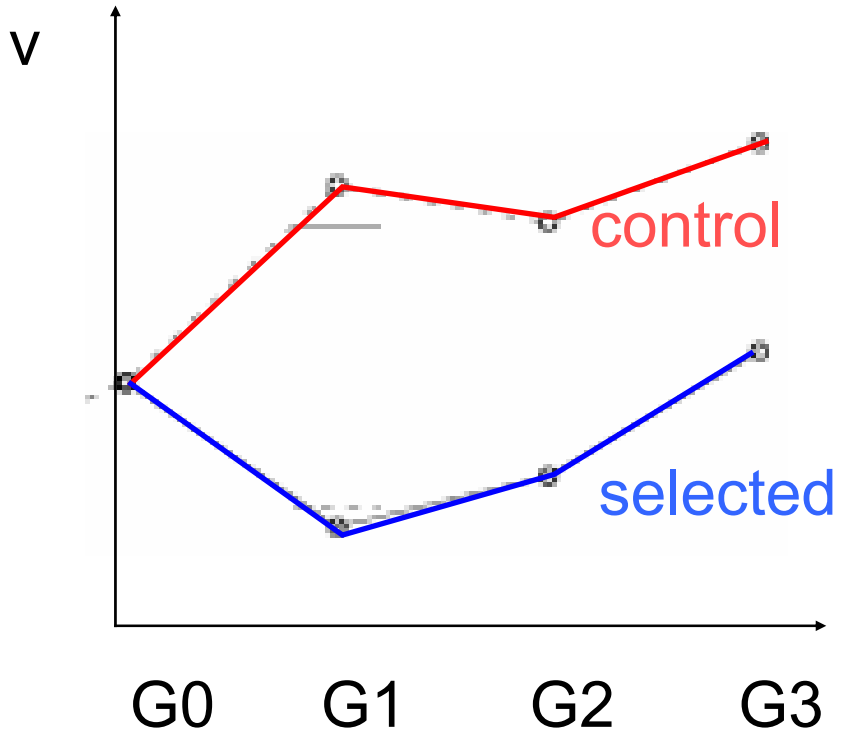
- *Scheiner and Lyman (1991):* null phenotypic plasticity after 20 generations of selection



m_1-m_2

Semeonoff 1977; Cardin & Minvielle 1986; Hillesheim & Stearns 1991; etc …

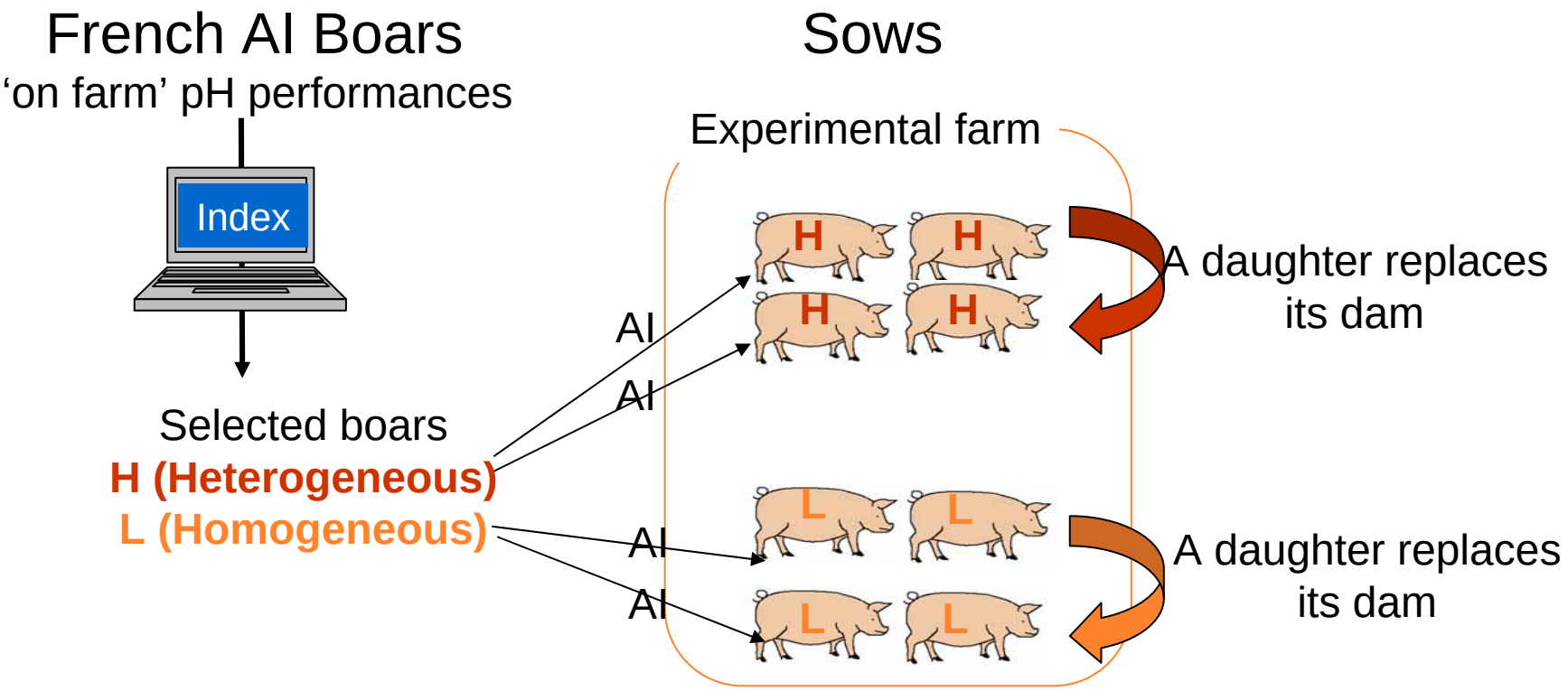
Snail experiment: selection for homogenisation of adult weight



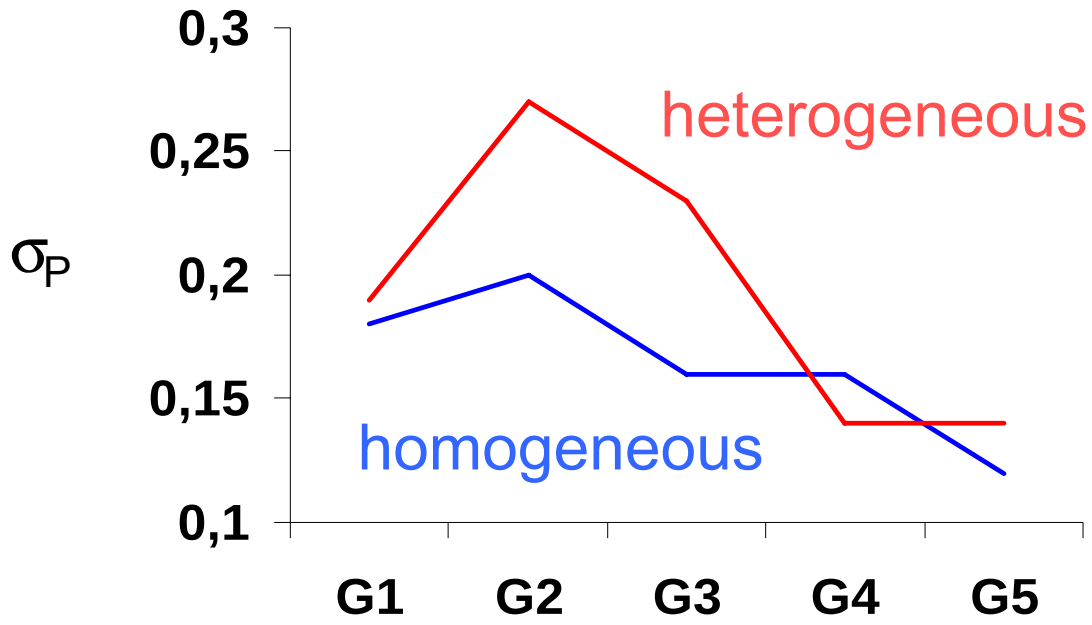
Significant genetic response in v, but no phenotypic difference

Pig experiment

2 open lines divergent for Semimembranous ultimate pH, with a constraint on the mean



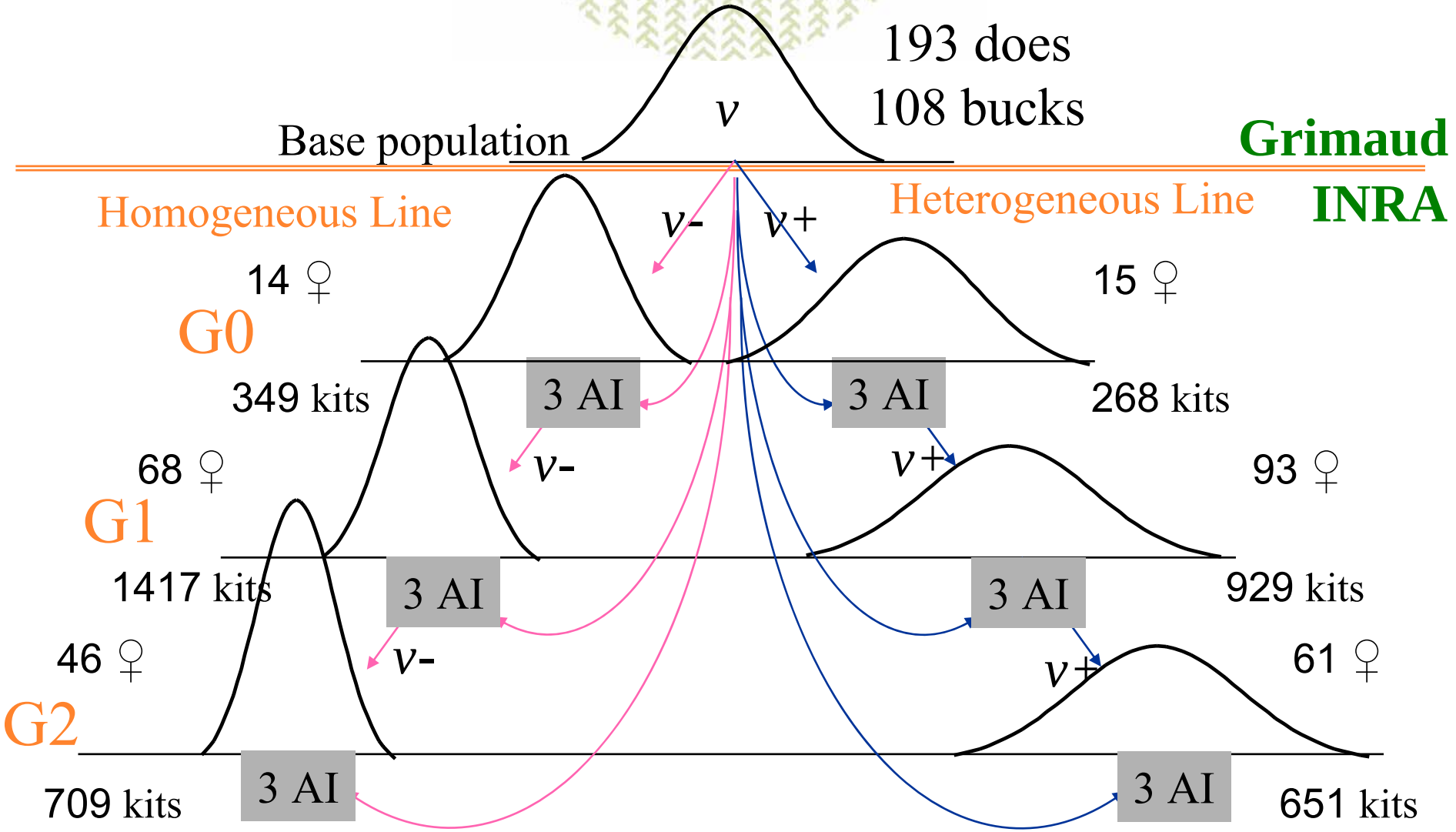
- Significant divergence in phenotypic standard deviation after G3 (p=0.03) , not any more after G4



- Can be explained by a too low accuracy in selection indices

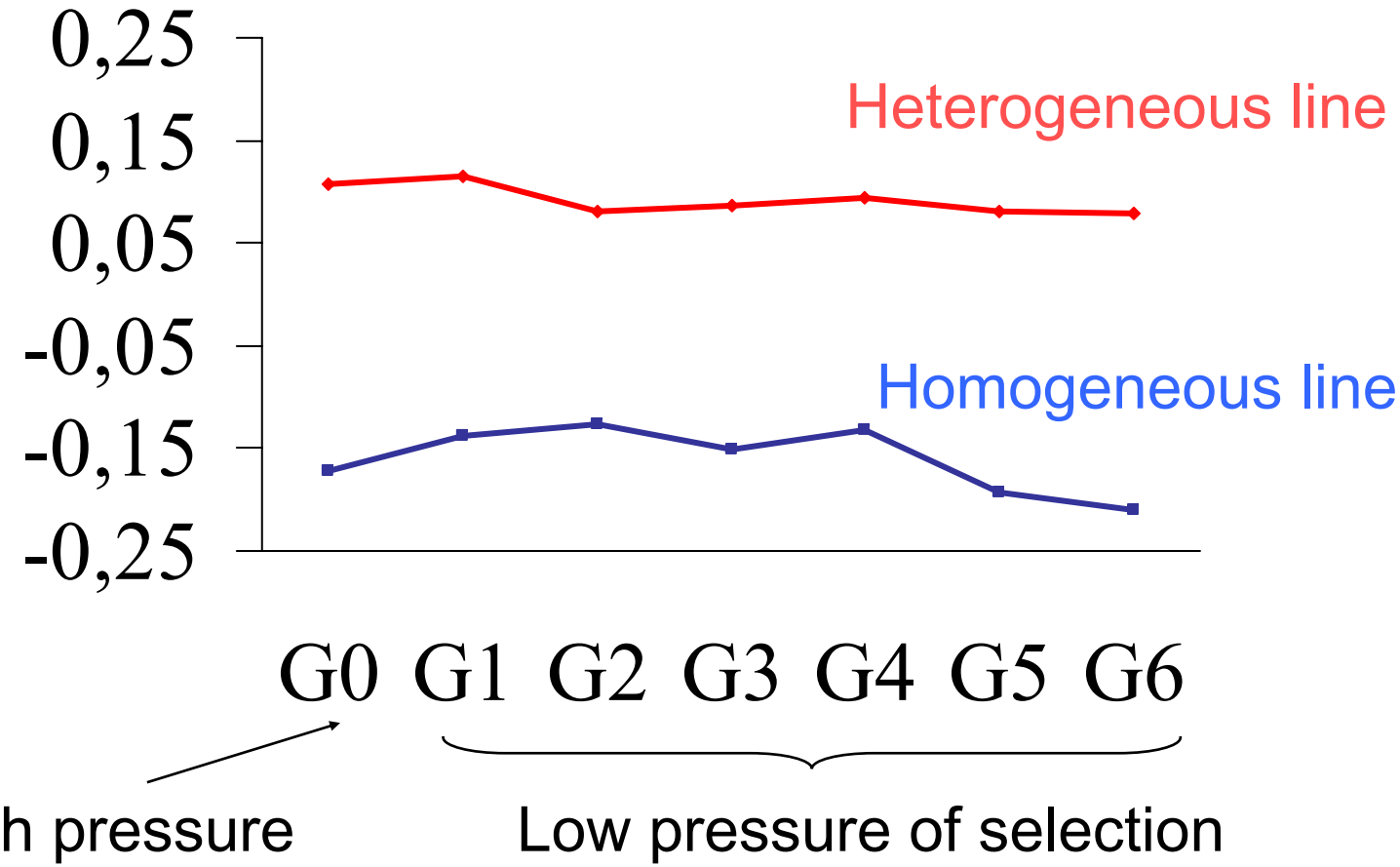
Larzul et al (2006) 8th WCGALP

Rabbit selection scheme (birth weight)



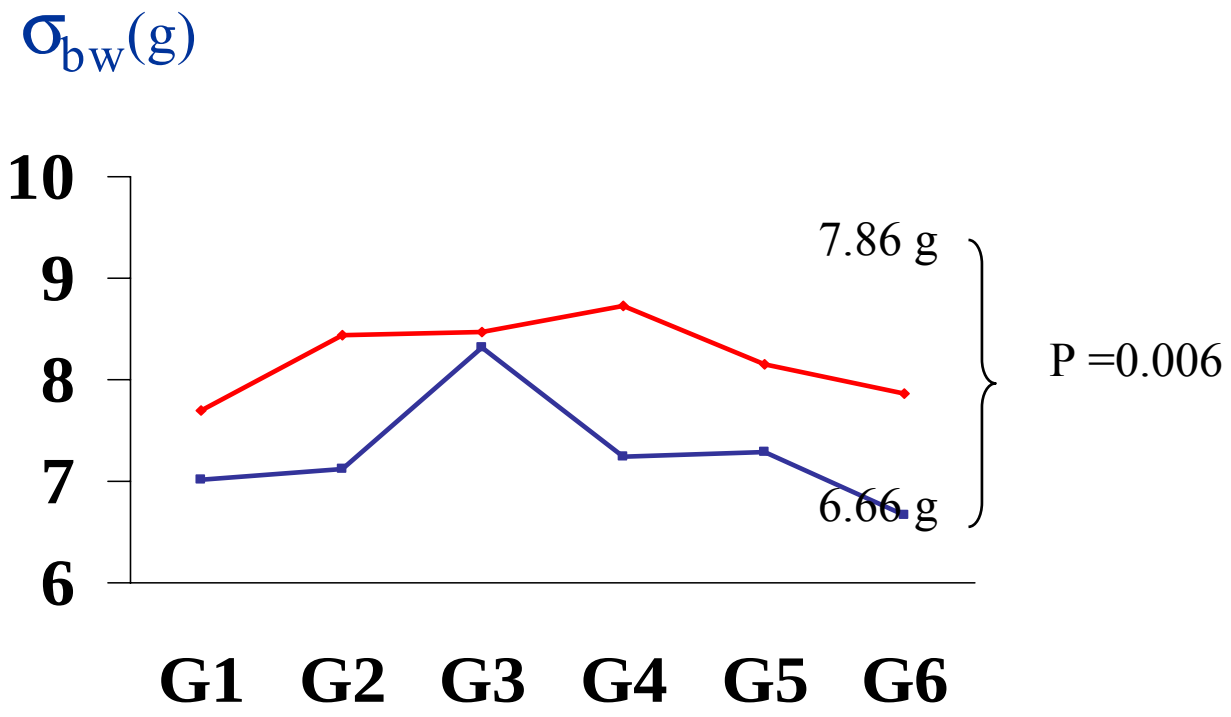
The genetic progress is maintained

V: direct cumulated response to selection



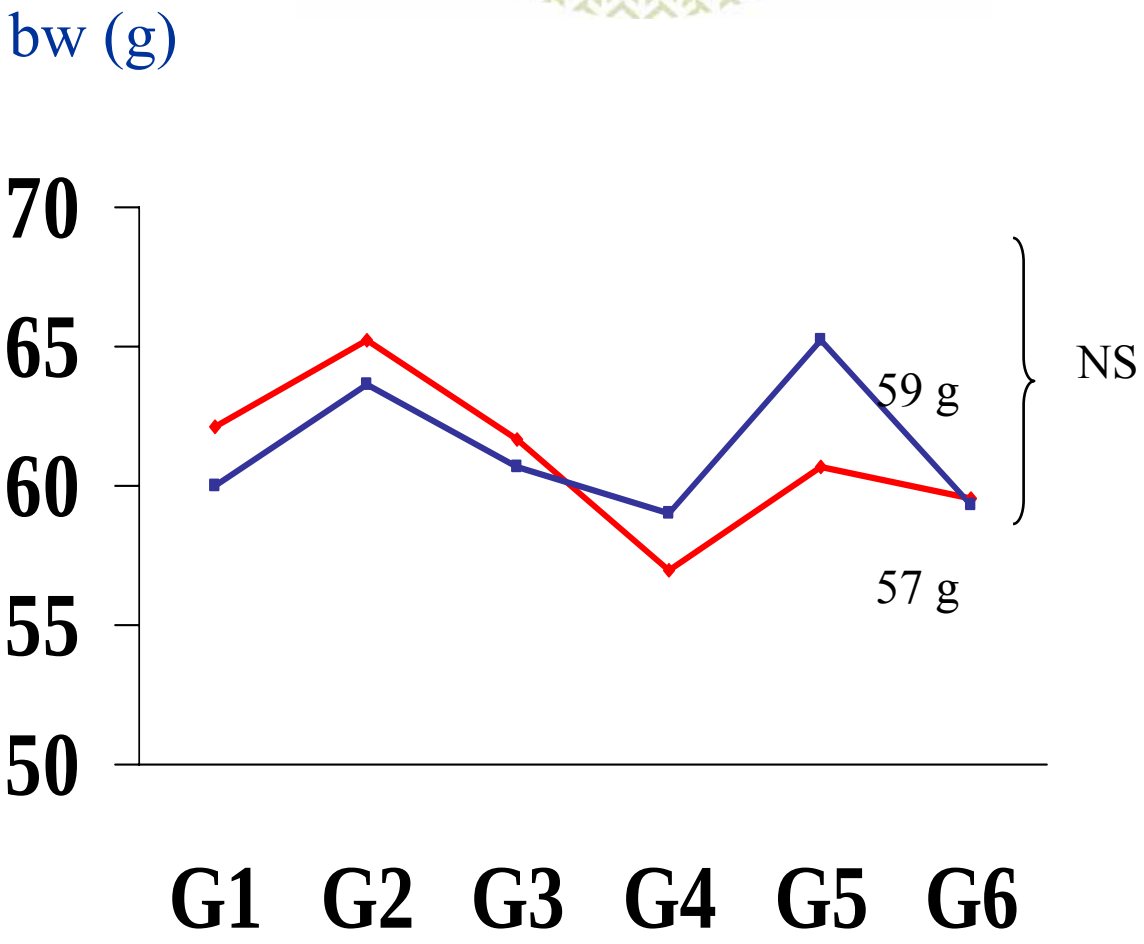
Garreau et al, submitted

Canalising selection acts on the phenotypic variance



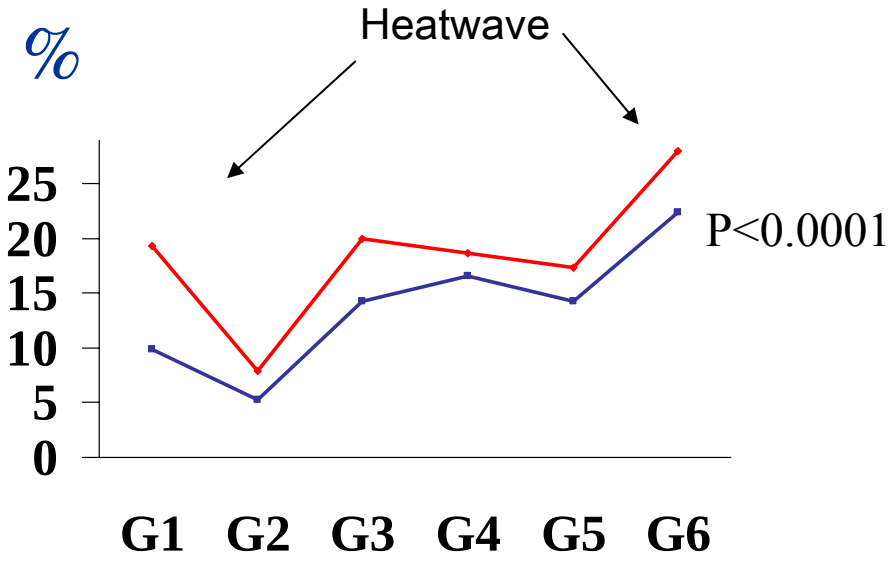
Birth weight: standard deviation

Canalising selection does not change the average weights

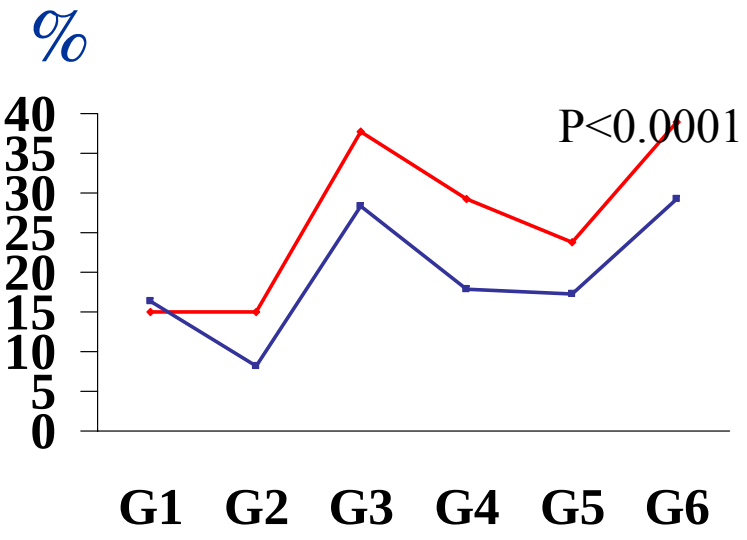


Birth weight : average

Selection for homogeneity of birth weight reduces mortality

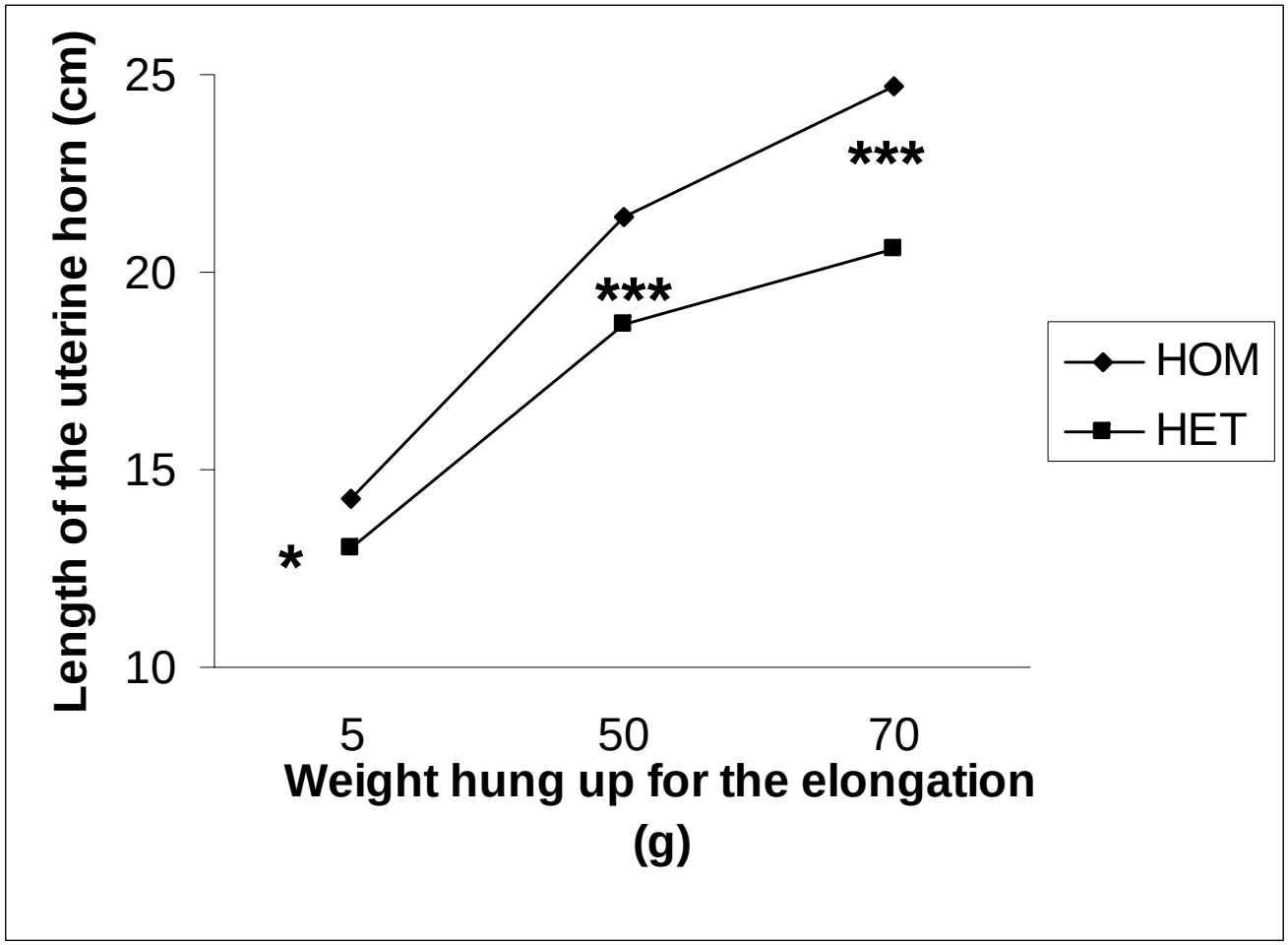


Mortality at birth



Birth to weaning

The variability is linked to the elasticity of the uterine horn



Bolet et al (2007) Livestock Science

Molecular evidence of genes affecting plasticity

Allele dependent phenotypic plasticity

Ubx	Drosophila	*Gibson & Hogness 1986*
ApoE	Human	*Reilly et al 1991*
Pgi	B. hordeacus	*Lönn et al 1998*
Tb1	Maize	*Lukens and Doebley 1999*
Abp	Drosophila	*Gibert et al 1999*
Hsp90	Drosophila	*Rutherford & Lindquist 1998*
	Arabidopsis	*Queitsch et al 2002*

Buffering, regulatory genes

- *Mackay & Lyman (2005)*

3 SNP in Ddc (Dopa decarboxylase): effects of 0.4 σ_G on CV_E on abdominal bristle number

Conclusion (1):

- Evidence of genetic control of plasticity

→Selection for homogeneous production may be possible for some traits

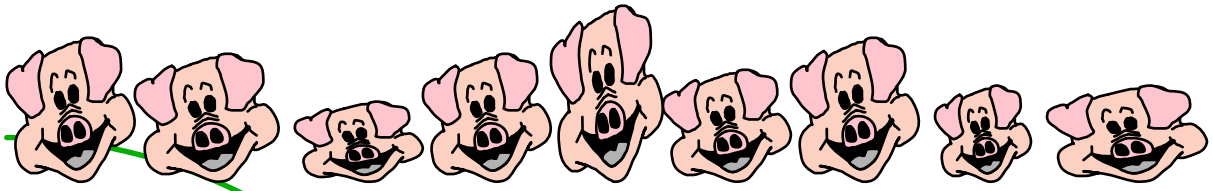
Conclusion (2)

- Tools for this selection:
  - Models

    reaction norms – environmental variance
  - Quantitative genetics theory

    approximate expression for response to selection in simplistic situations
  - Need to predict power in realistic situations to determine the size and type of any planned experiment
  - Need for a routine and general program for index calculation, available for the whole community

Time for exploration has begun



Let ’s try canalising selection in livestock !