Master
ANIMAL BREEDING AND
REPRODUCTION BIOTECHNOLOGY

Genetic improvement of pigs

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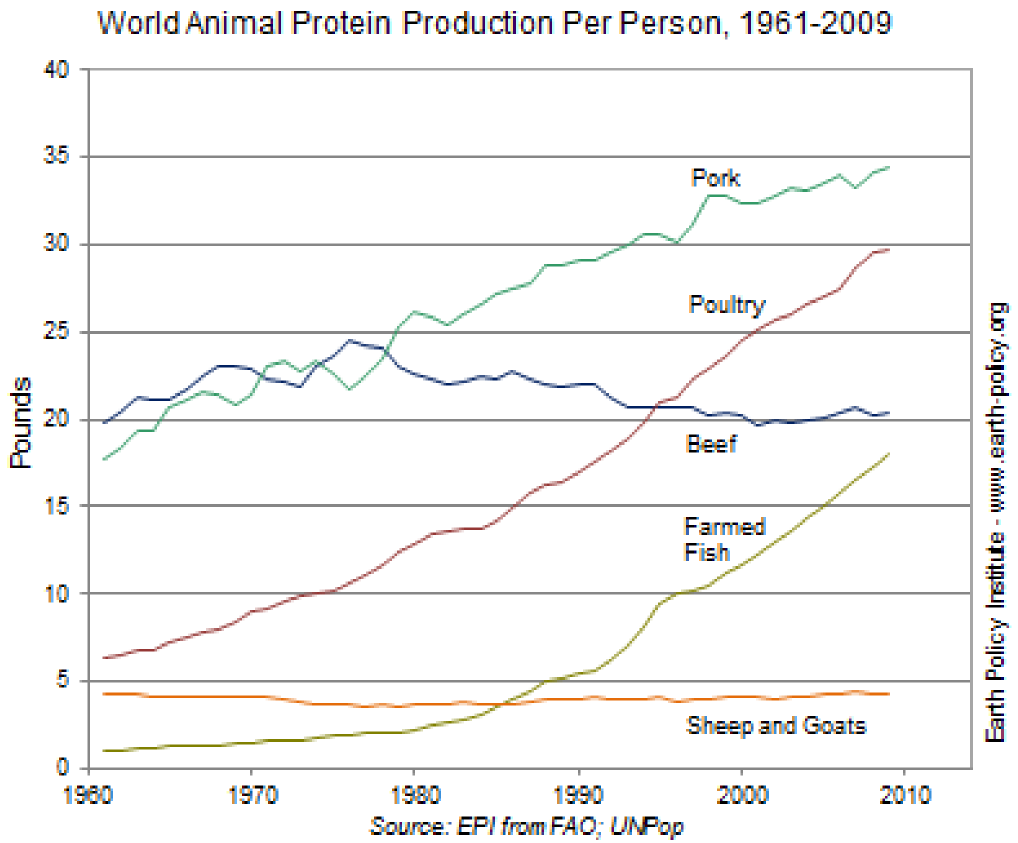
Outline

- Some elements on pig production
- Genetic improvement of pigs
  - General principles
  - Definition of the breeding goal
  - Genetic variability of economically important traits
  - Breeding schemes : development and optimisation
  - Use of crossbreeding
  - Controlling the efficiency of pig breeding schemes
  - What does genomics bring to pig breeding schemes

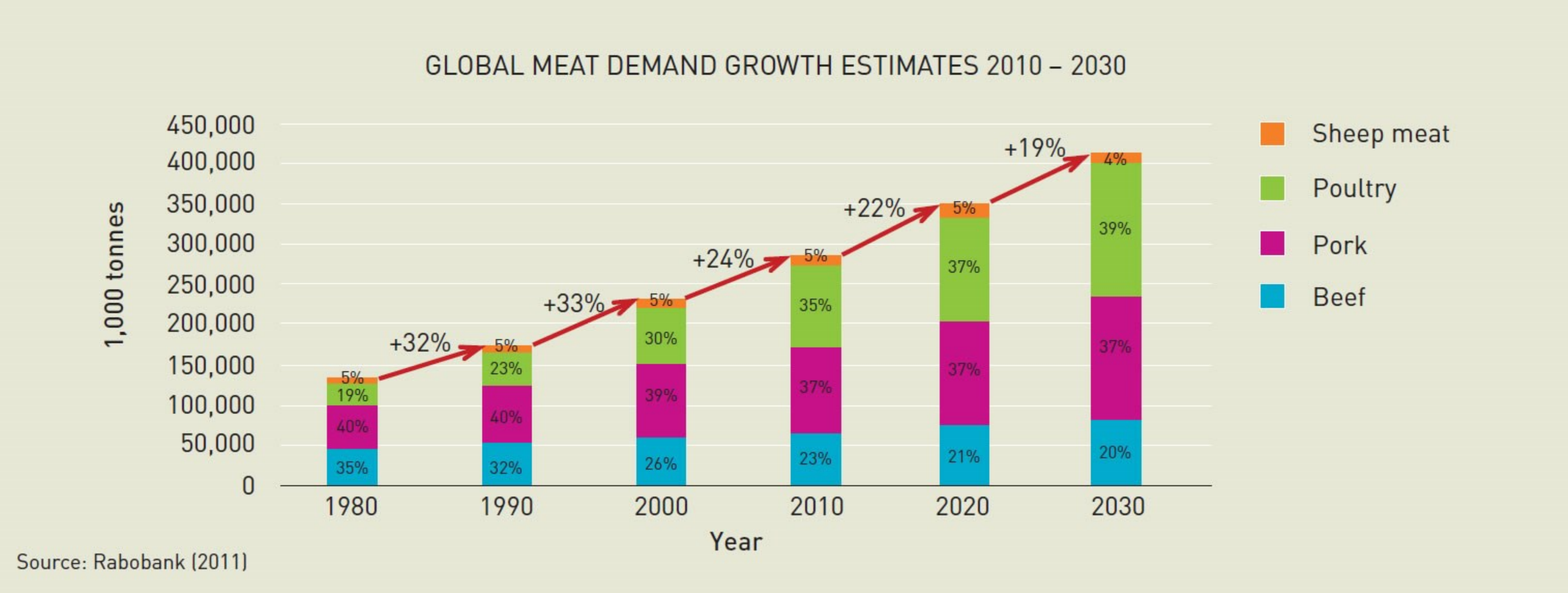
_01

Some elements on pig production

World pig production / consumption

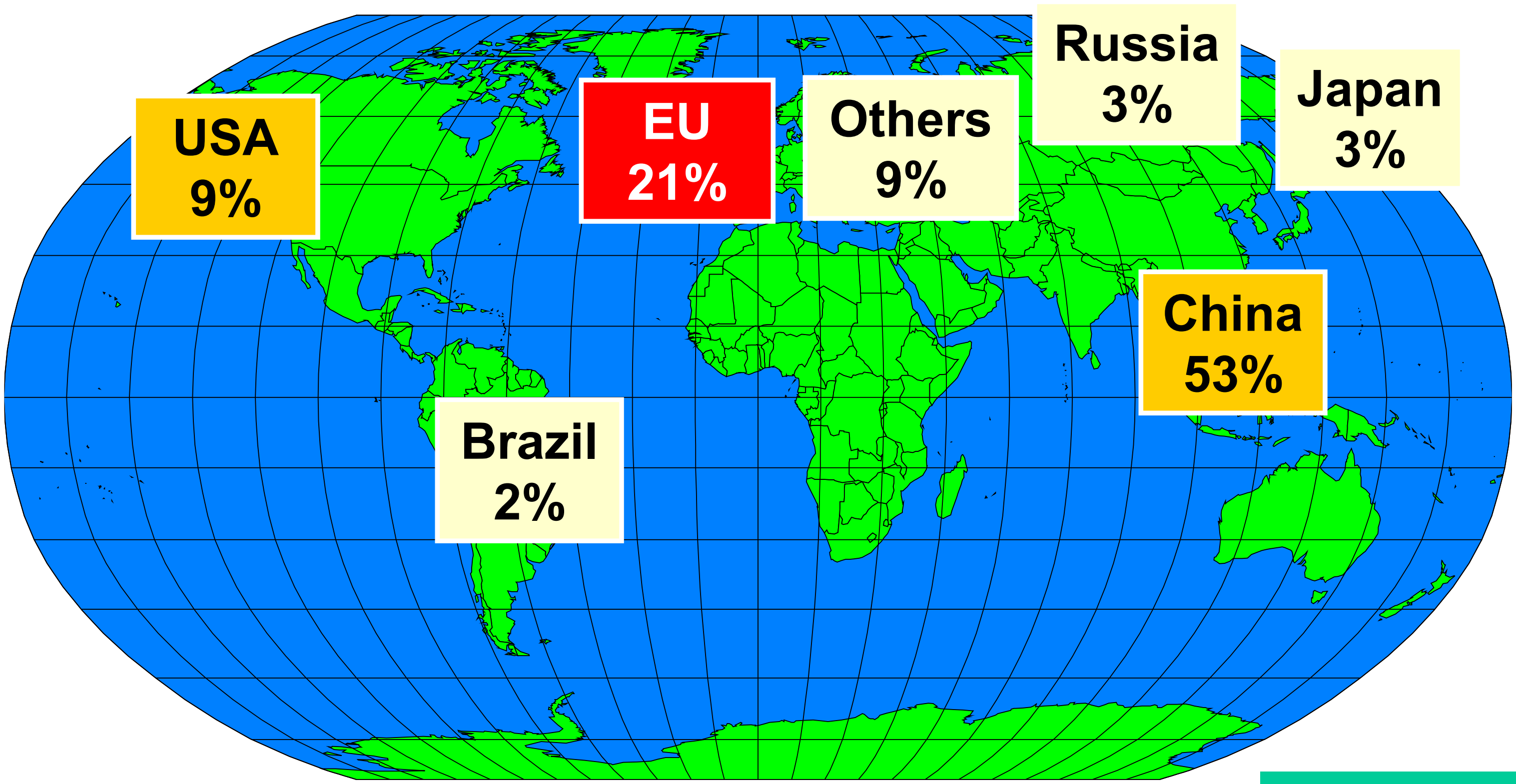


World pig production / consumption



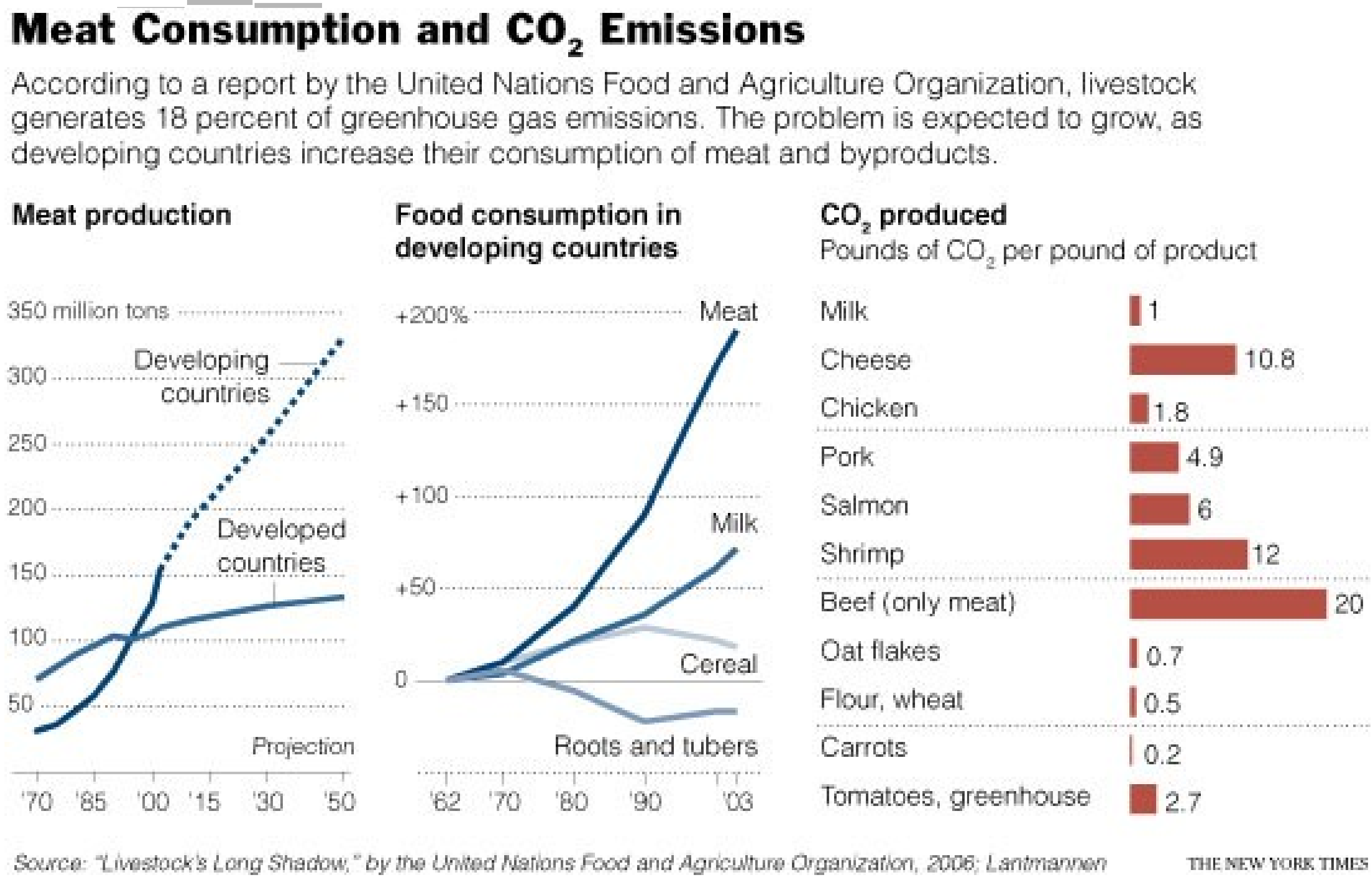
=> Further improvements in efficiency are required

Main pig meat consumers (% total)



Source : FAO

Increasing environmental concerns



Increasing welfare concerns

_02

Genetic improvement of pigs – General principles – Elements on pig production

Main characteristics of pig production

Homogeneity of production conditions

- **A dominant production system**
- Objective : production of (reasonable) quality meat at the lowest price
  - ✓ Standardised housing, feed & management conditions
- **Some exceptions**
  - ✓ Example : Local breeds (e.g. Iberian pigs), organic production

Homogeneity of the pig produced

- **Slaughtered at a given target weight**
  - ✓ (90 – 115 kg on average - differences between regions/countries
  - ✓ Some "heavy pig" chains (ex : Italy for Parme ham production)

Main characteristics of pig production

Conversely, pig meat is consumed in many different ways

- ☞ **Fresh meat**
- ☞ **Many processed products**
  - ✓ « cooked » or « dry » ham & sausages, “ready to use” dishes,…

Economic efficiency of pig production

Production costs

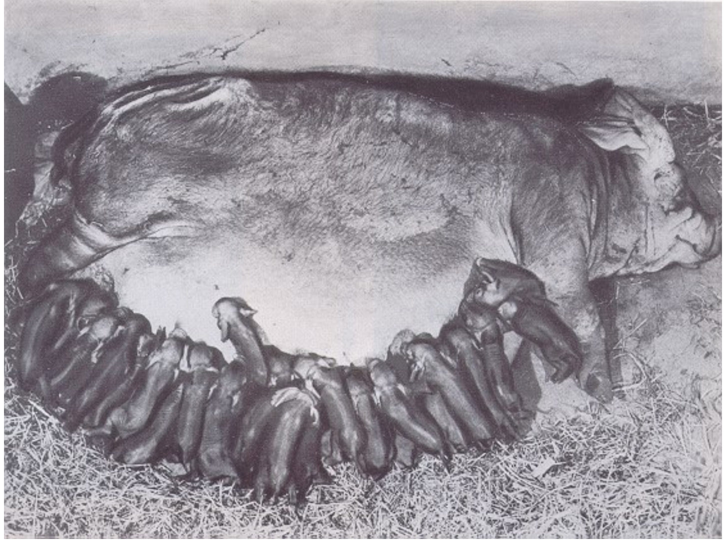
1. Production cost of piglets (up to 25 kg)
   - Is mainly a function of herd numerical productivity
2. Cost of the growth period :
   - Growth rate (cost of housing)
   - Feed conversion ratio (amount of feed consumed)
   - Mortality

Usage value of the slaughter pig

1. Quantitative aspect = dressing percentage
2. Qualitative aspects
   - Carcass composition (lean meat content)
   - Meat and fat quality (not paid to farmers except boar taint)

Numerical productivity

= Number of piglets produced per sow per unit of time



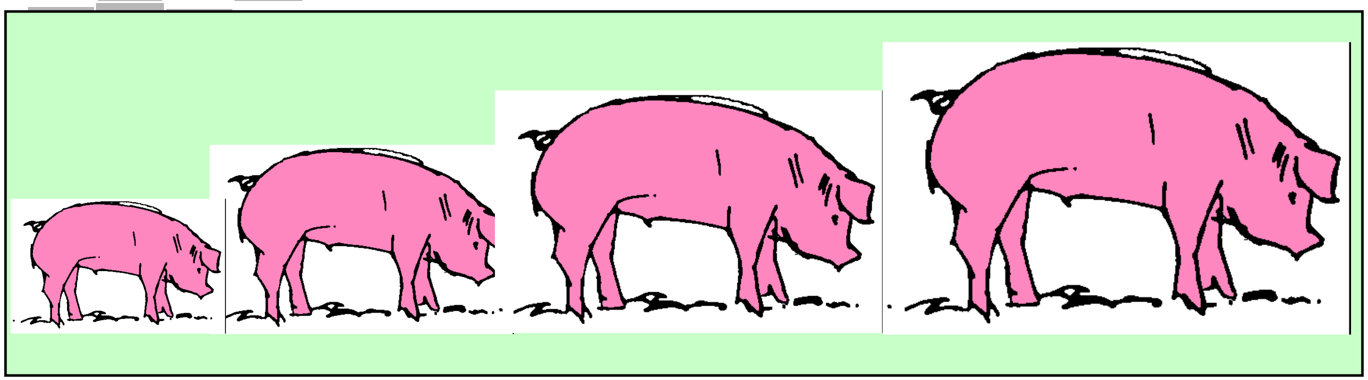
prolificacy

Maternal abilities

$$Pn' = \frac{\text{Nb litters} * \text{NVIV/litter} * (1 - \text{\%Mort BW}) * 365}{I_{\text{100kg-1st Farr.}} + (\text{Nb litters}-1) * \text{FI} + I_{\text{last farr. - culling}}}$$

unproductive periods

Traits of economic interest
GROWTH RATE



Related to the duration of the period from 25 kg to slaughter (D)

Low D reduced housing cost

Some characteristics of pig growth :

- Birth weight x 2 within 8 days
- x 5 within 3 weeks
- x 20 within 8 weeks
    - x 80 within 6 months !!

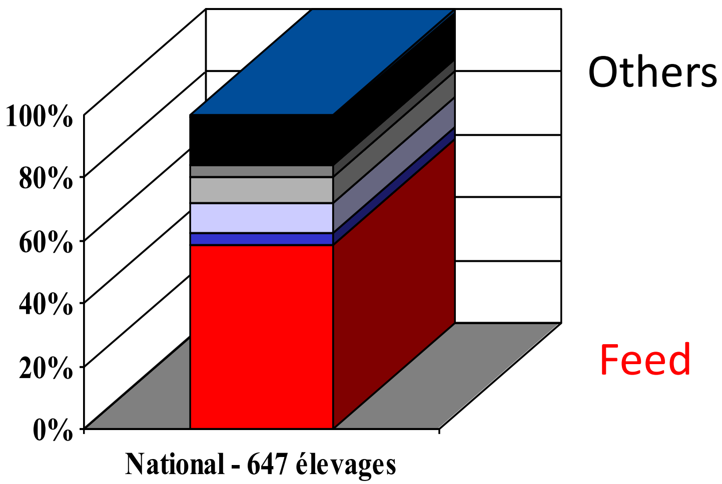
Growth curve = sigmoid, with an inflexion point around puberty

Traits of economic interest
FEED EFFICIENCY

Food conversion ratio = amount of feed (kg) necessary for 1 kg live weight gain

Considerable economic impact

Production costs
In weaning – fattening herds



Individual measurement :
Automatic feeders

Traits of economic interest
CARCASS TRAITS

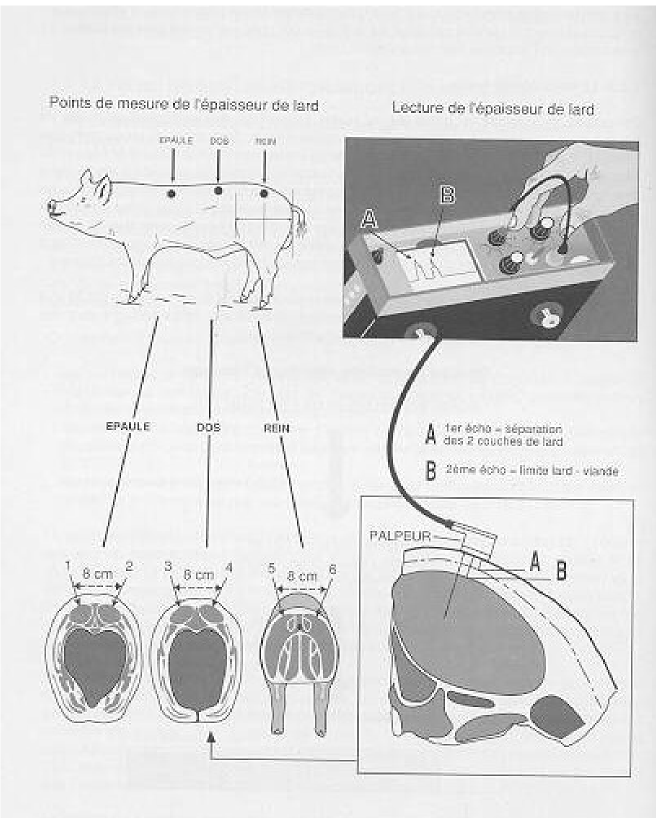
Definition of a carcass
EU regulation n°3220/84, modified by regulation n°3513/93)

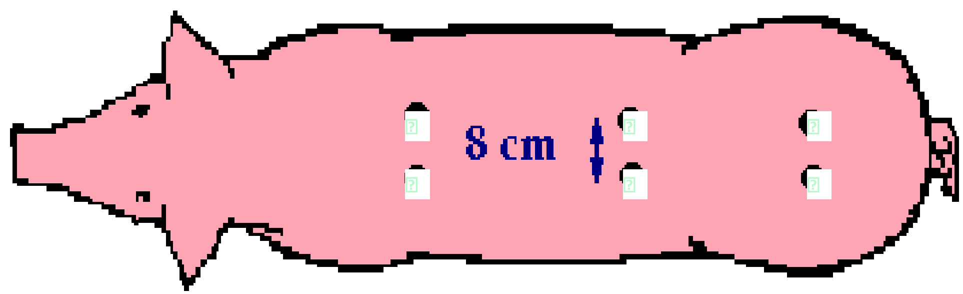
Dressing percentage

100 * Ratio of carcass to liveweight

Traits of economic interest
CARCASS TRAITS

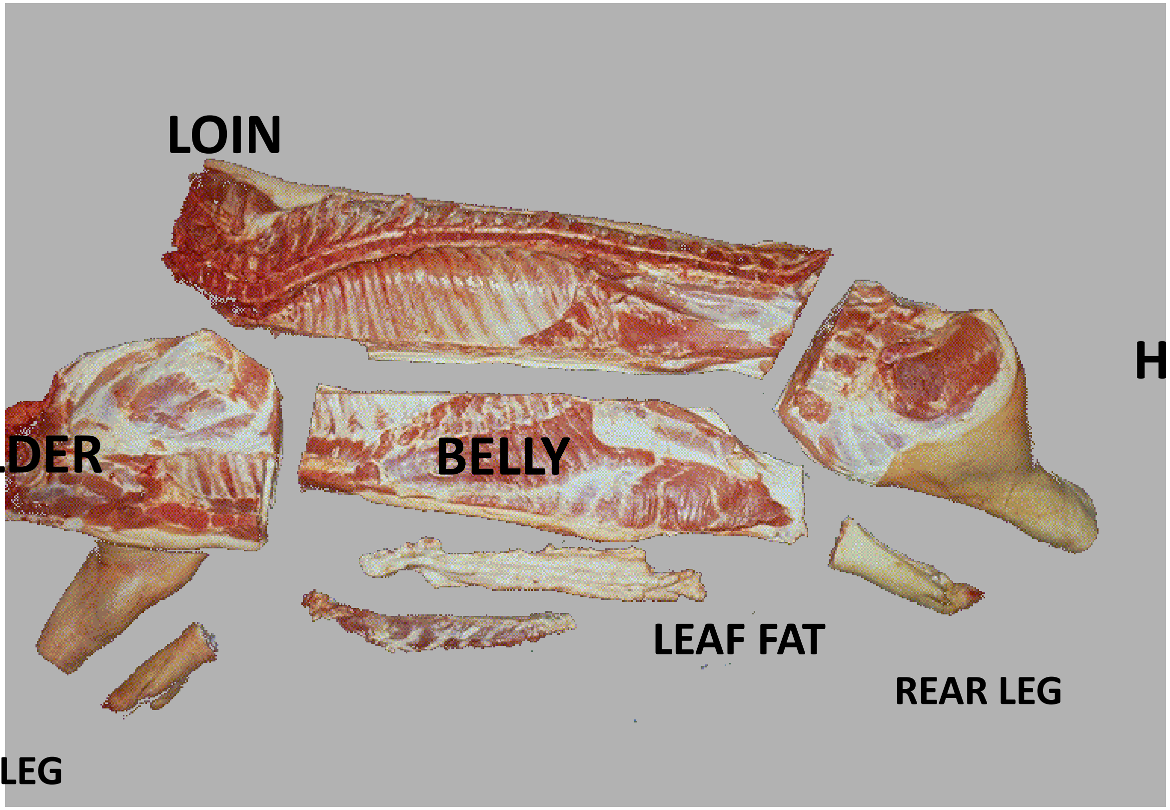
Estimation of carcass composition
Through ultrasonic backfat depth





Traits of economic interest
CARCASS TRAITS

Carcass cuts



Traits of economic interest
CARCASS TRAITS

X-ray tomography

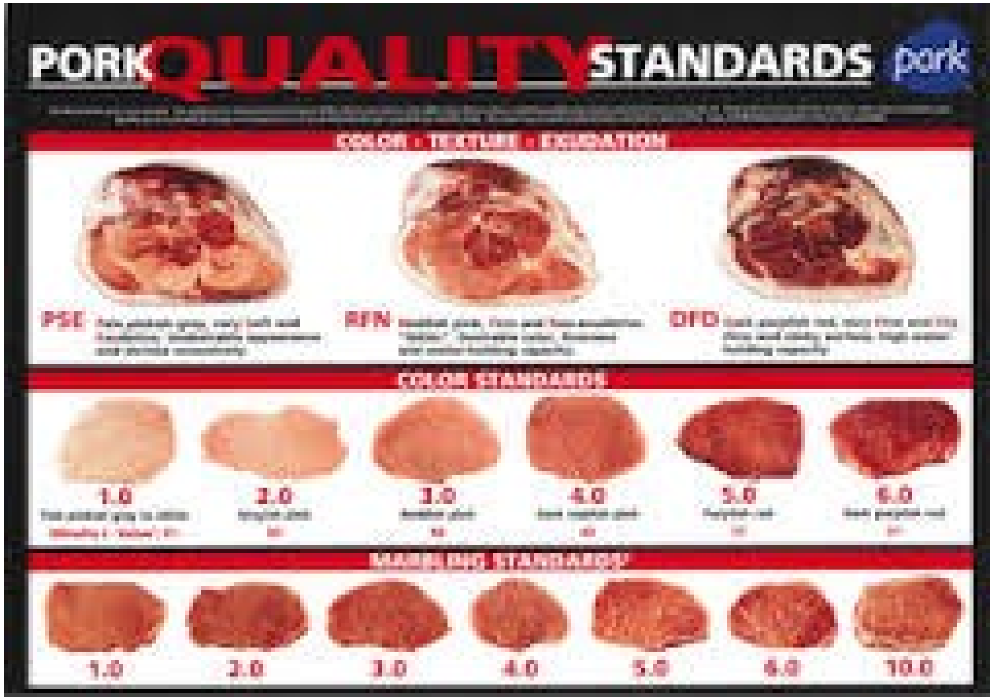
The different aspects of meat quality

Dietetic qualities
Consumers nutritional requirements

Hygienic qualities
Consumer health

Organoleptic qualities
Consumers satisfaction

Technological qualities
Meat processing



Economic consequences of product quality

For farmers :
no payment for meat quality
Some meat defaults can be forbidden

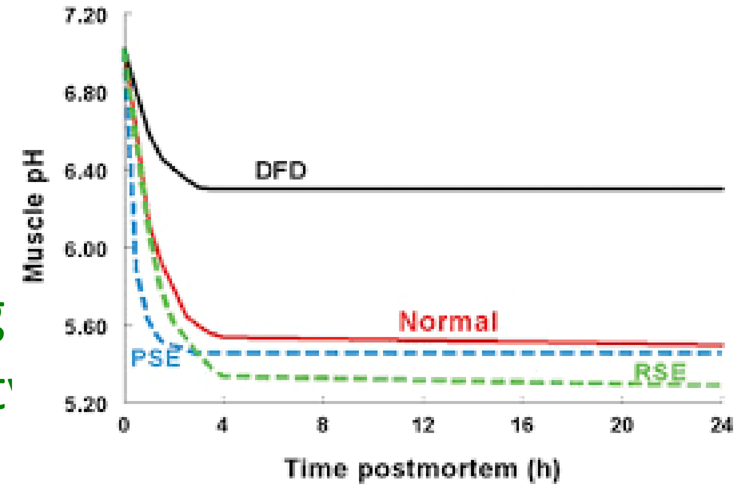
For slaughterhouses :
Weight losses through exudation (1 - 3%)

For distributors :
Weight losses through exudation (1 - 3%)
Selling difficulties

For processing units
Weight losses at cooking (1 - 10%)
Losses when making slides (0 – 50%)
Losses when conservation is poor

For consumers:
Weight losses at cooking (1 - 10%)

Meat technological quality criteria



Post mortem evolution of pH

Imbibition time
Exudation losses
Cooking losses

} Water Holding Capacit

Glycolytic potential (GP)
% water
% proteins

} Chemical composition

… measured on different muscles

Technological yields (Napole, cooking or drying %)
Fibre characteristics (?)

Fat quality criteria

Firmness
Rancid character
% water, % lipids
Fatty acid composition (polyinsaturated/saturated)

… + organoleptic and dietetic quality

Boar taint (androstenone, skatole)

Meat organoleptic quality criteria

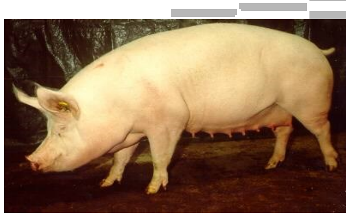
Intramuscular fat content (% IMF)
Shear force

… usually measured on the loin

Tenderness Juiciness Flavour	Consumer panel tests

_03 From pig production to pig breeding

Characterisation – use of genetic variability within … and between breeds


Large White


Landrace


provided by National Swine Registry
Duroc


Piétrain

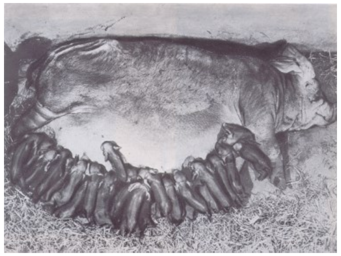

provided by National Swine Registry
Hampshire

Provided by Gregorio Hernandez Silva
Iberian pig


Bayeux


provided by Tran Thi Dan
Mongcai

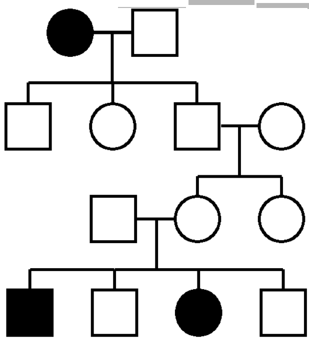

Meishan

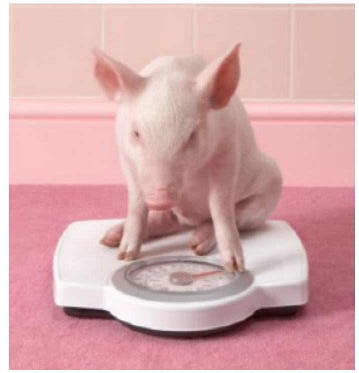

Fengjing


JinHua

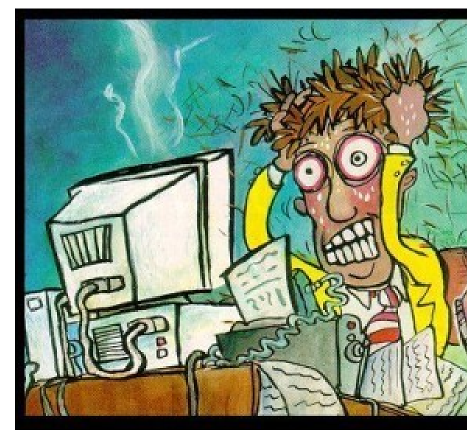

Wutsusan

Using pedigree, phenotypic
… and, more recently, molecular information





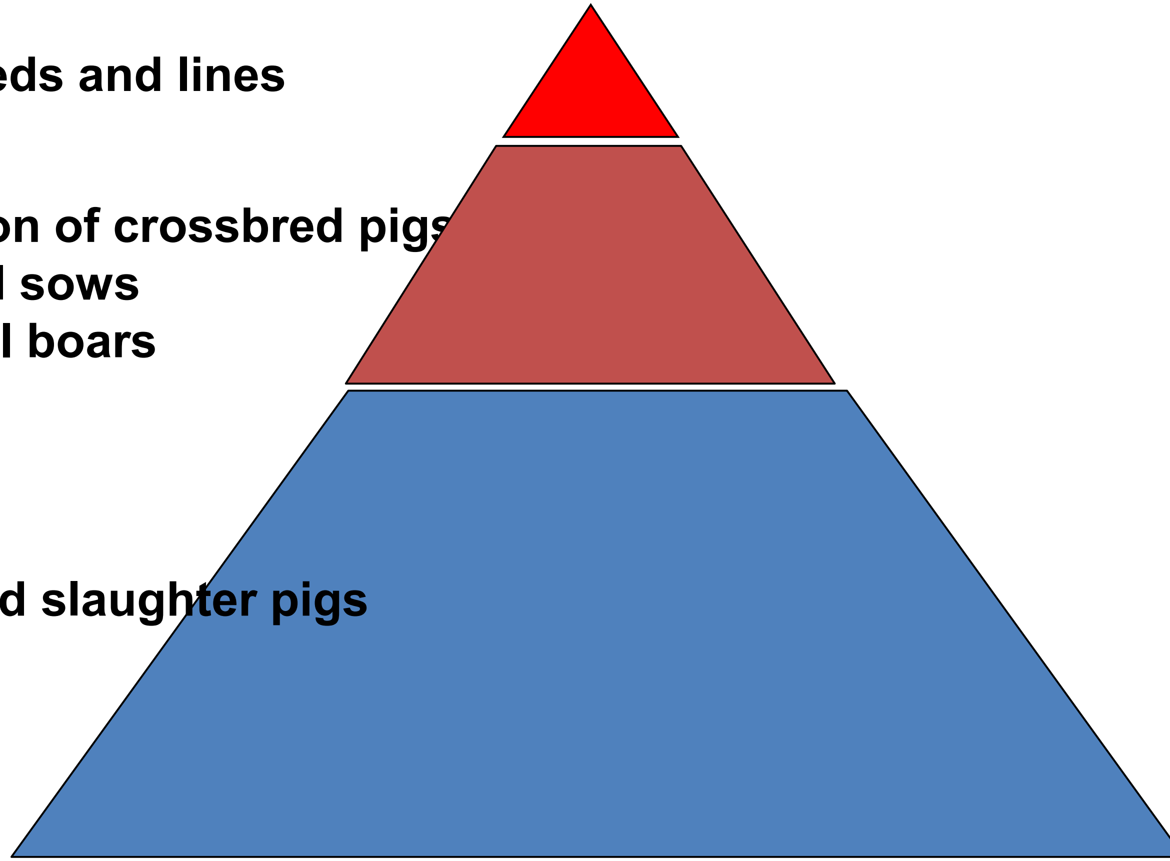
From IRTA



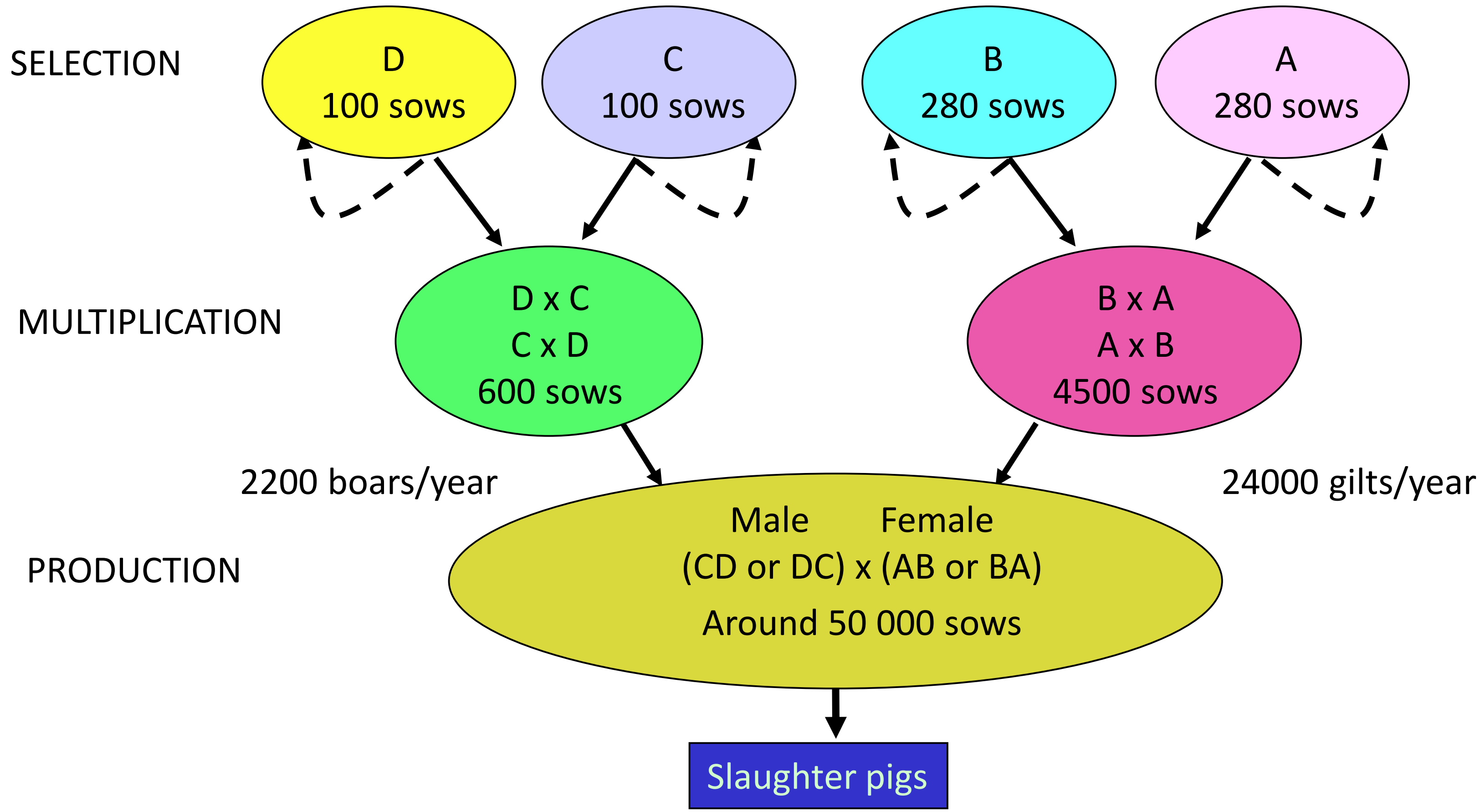
Pig breeding schemes

Pyramidal Organisation

Selection	**Pure breeds and lines**
Multiplication	**Production of crossbred pigs** **- Parental sows** **- Terminal boars**
Commercial level	**Crossbred slaughter pigs**



Pig breeding schemes – general principles



Definition of a breeding goal

Preliminary considerations

A breeding goal (BG) is characterised by :

- ☞ The set of traits we want improve or to control
- ☞ The relative weights of these traits
- ☞ **global genetic value $H = a_1 T_1 + a_2 T_2 + \ldots + a_i T_i$**

A correct definition of the BG is of major importance

- ☞ **determines the future of the population**
- ☞ **the breeding structures and tools**
  - ✓ example: including meat quality in the BG
    - ➢ move from individual selection to selection on sibs

Definition of a breeding goal

Determining trait weights – economic approach

✓ **Use of an economic function**

$$FE = f(x_1, x_2, \ldots, x_n, z_1, \ldots, z_p)$$

- **$x_1,\ldots,x_p$ = traits related to animal characteristics**
- **$z_1,\ldots,z_p$ = other traits**

✓ **Weight computation**

$$a = \left(\frac{\partial FE}{\partial x_i}\right)\Delta x_i$$

- **using analytic, graphical or finite difference methods**

Pig breeding goal – a typical example

Simple économic fonction : profit/slaughtered pig

Hypotheses : 1) Pig production efficiency ~ Pig producer annual profit PA

2) $PA = \sum_{i=1}^{n} P_i$ The herd profit is the sum of profit/pig P_i

P_i = Carcass Value $_i$ – Fattening Cost $_i$ – Piglet Cost $_i$

CV $_i$ = D% * live weight * Price/kg(= f(%lean))

FC $_i$ = FCR $_i$ * Feed Price/kg $_i$ + daily housing costs * AGE $_i$

PC $_i$ = Sow annual cost / N $_{piglets/sow/year}$

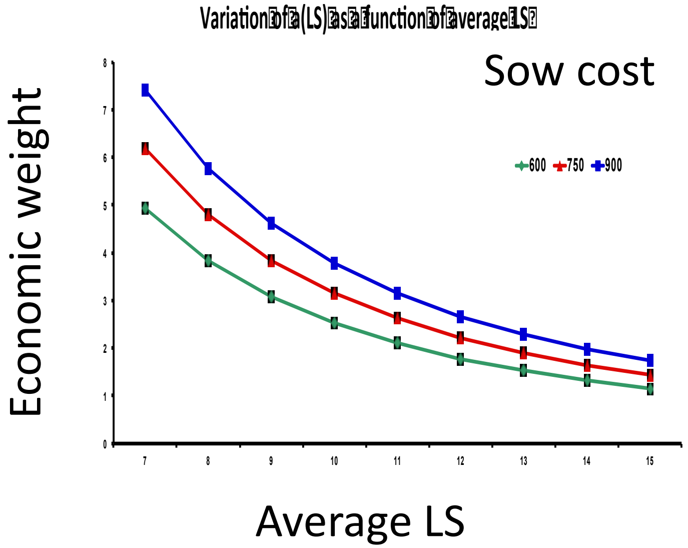
$$\frac{365 \cdot N \cdot NT \cdot T_s}{i_1 + (N-1)(G + L + I_{sf}) + i_2}$$

Definition of a breeding goal

Economic weight of litter size

- **Use of « finite difference » metod**

$$a_{LS} = PC_{\mu+\Delta} - PC_{\mu}$$



Strong variations with average LS

➔ Needs to be periodically recomputed

Definition of breeding goals

Trait choice

Specialised lines / populations

- ✓ (Grand)sire line BG = Production
- ✓ (Grand)dam lines BG = Production + reproduction

Economic approach

- ✓ Trait choice based on a . h^2 a = economic weight h^2 : trait heritability

Biological approach

- ✓ Improve the efficiency of biological functions
  - Ex: lean growth efficiency

Desired gains

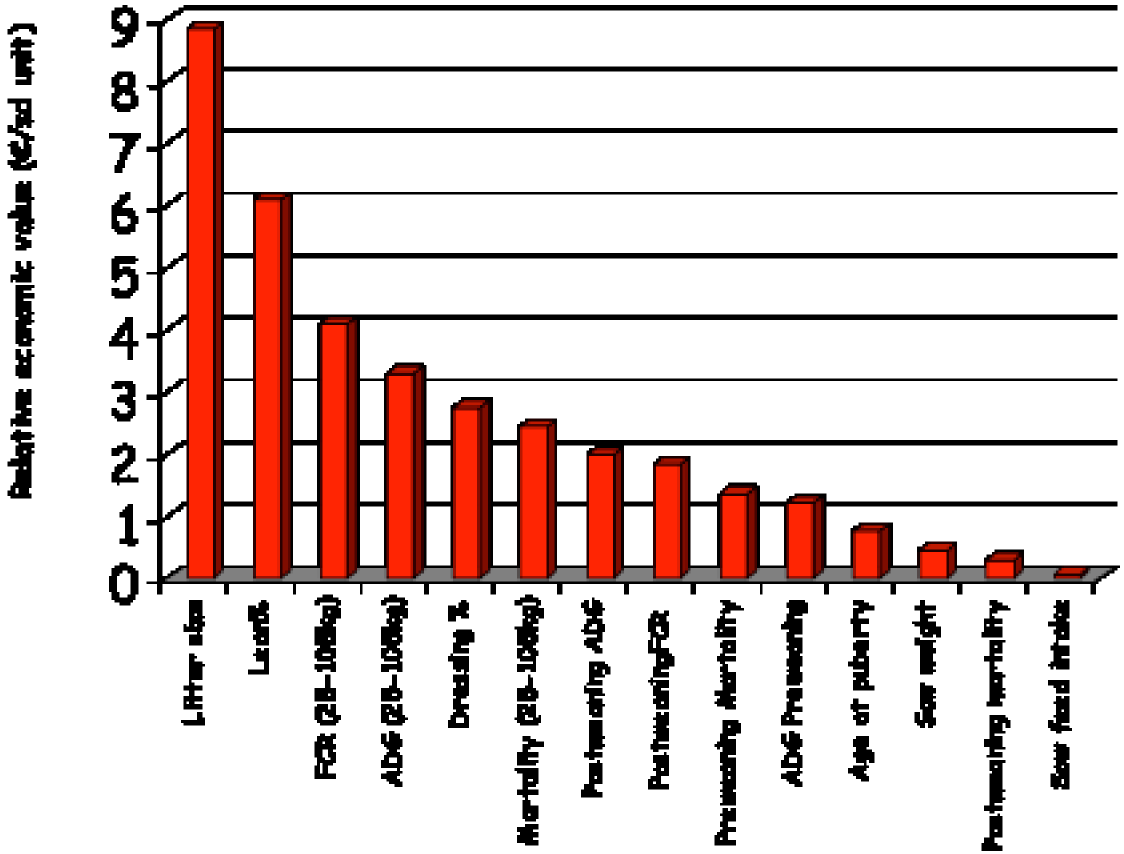
- ✓ Maintaining meat quality or food consumption at a desired level

Selection for an optimum

Selection against environmental variability (canalisation)

Definition of breeding goals

Main traits of economic interest



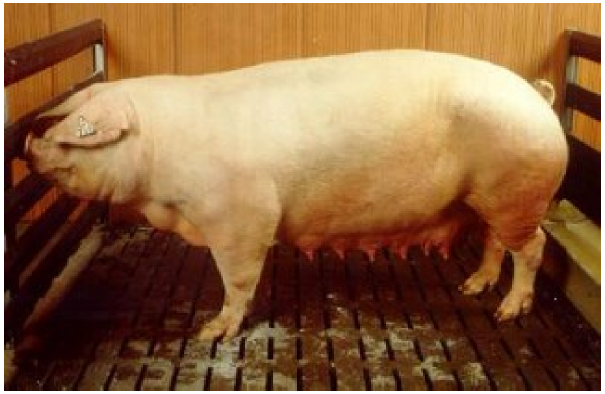
_04

Genetic variability of economically important traits

Variation between breeds
Major pig breeds

Large White

Landrace



Piétrain

Duroc

Variation between breeds
Major pig breeds

Exemple of comparative performance

Table 10.1. Examples of comparative reproductive performance of some pig breeds.[a]

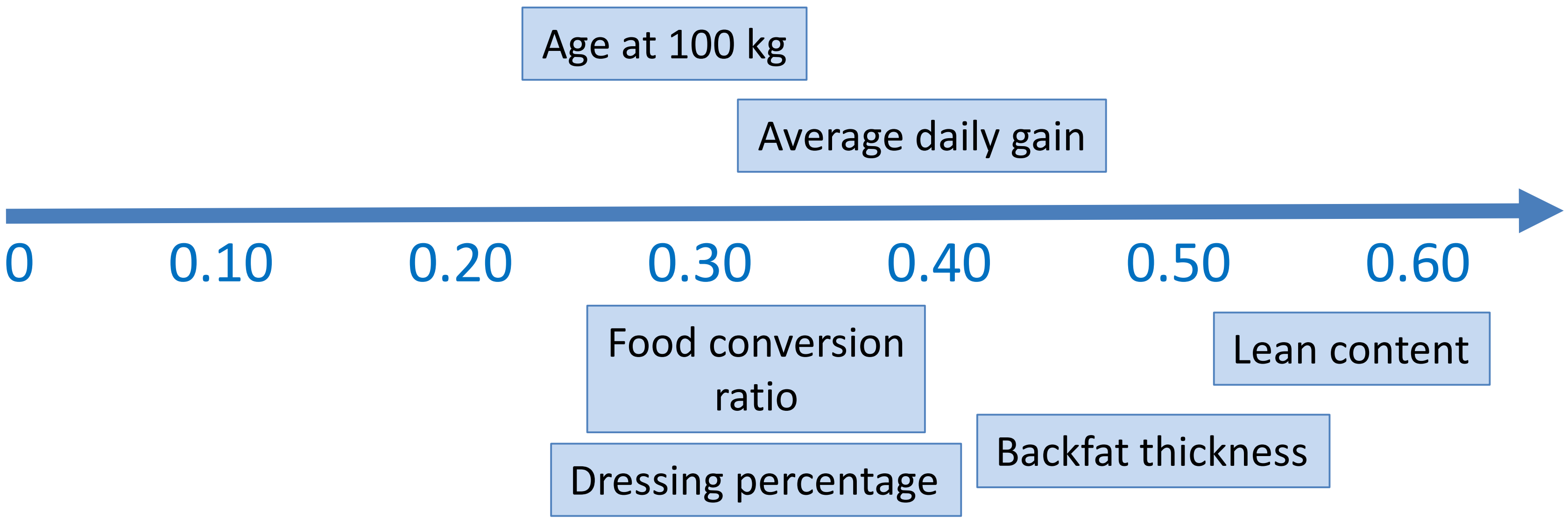
Trait	Breed: Large White – Dam line	Large White – Sire line	Landrace	Duroc	Piétrain	Reference
Total number born	14.2	–	14.6	9.9	–	DSP, 2008
Total number born	14.8	12.0	13.7	–	10.0	
Number born alive	13.6	11.0	12.5	–	9.3	IFIP, 2009
Number weaned	11.4	9.4	10.8	–	7.8	

[a]Standard errors of breed means range from 0.03 to 0.1.

Such comparisons are necessary, but should be interpreted with caution (vary according to the environment, time, sampling,…)

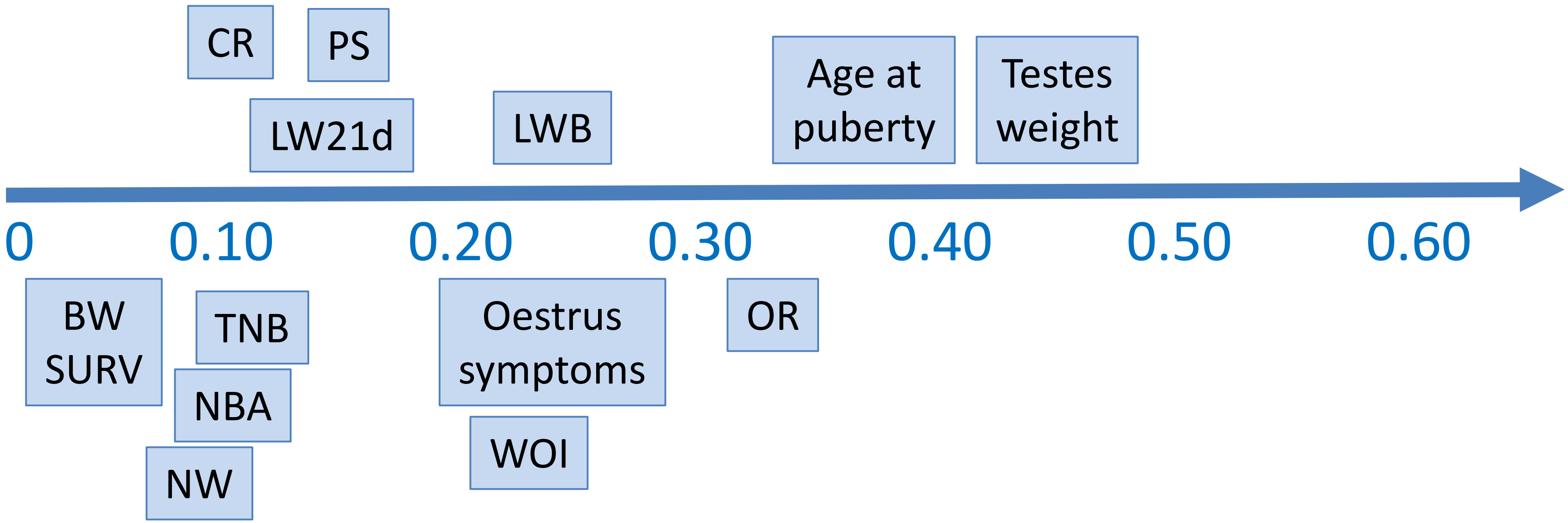
Within breed variation

Heritability values for production traits



Within breed variation

Heritability values for reproduction traits

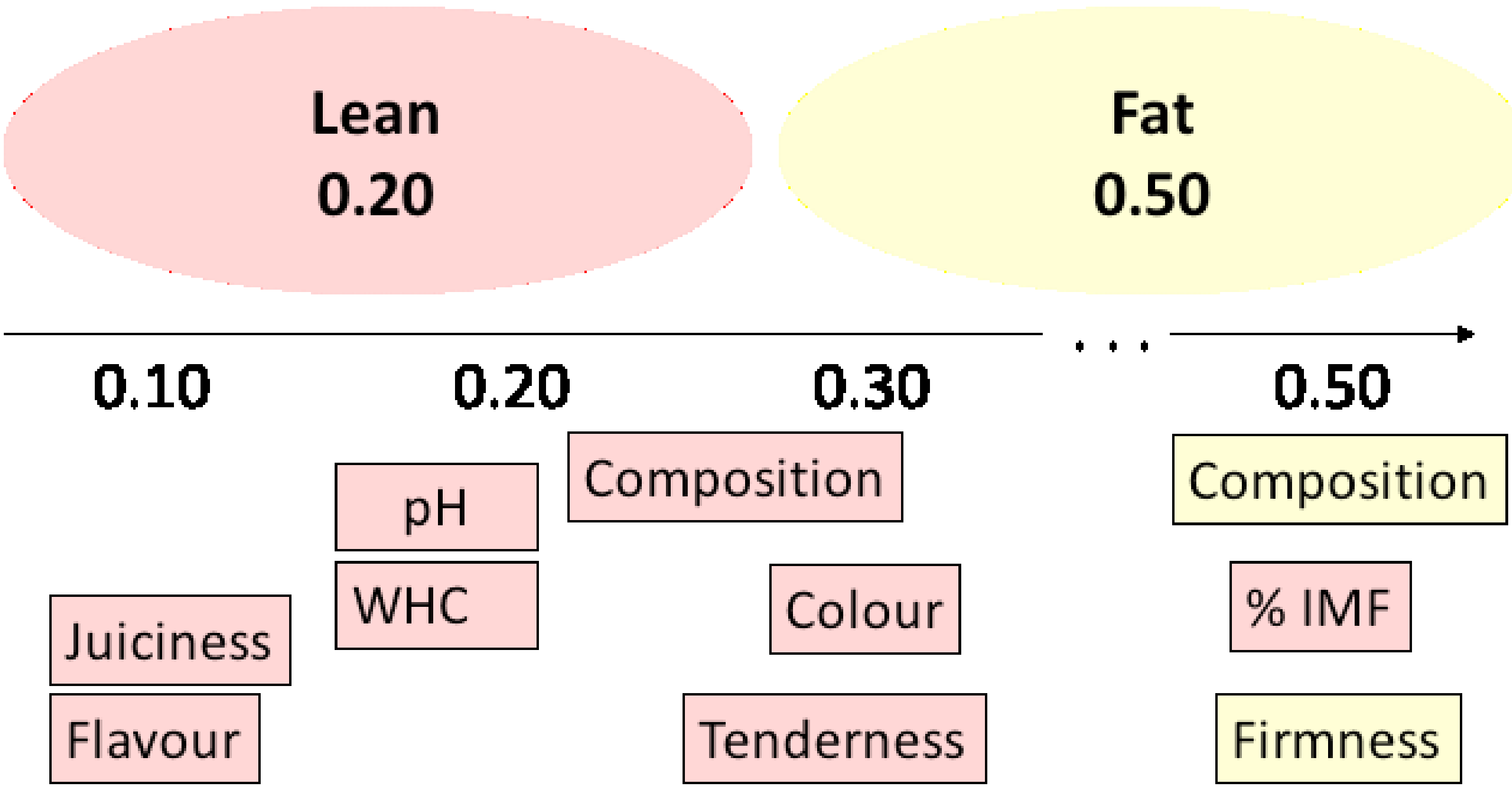


CR : conception rate; PS : prenatal survival; LWB, LW21d = litter weight at birth and 21 d of age, respectively; BWSURV : birth to weaning survival; TNB : total number born; NBA : number born alive; NW : number weaned; WOI ; weaning to oestrus interval; OR: ovulation rate

Within breed variation

Genetic parameters of production traits

Heritability values for meat quality traits



Within breed variation

Genetic parameters

Genetic correlations between production traits

	FCR	Dressing %	Lean%
ADG	-0,4 à -0,5	-0,3 à -0,2	-0,3 à +0,1
FCR		-0,2 à +0,1	-0,2 à -0,8
Dressing %			0,0 à +0,3

Within breed variation

Genetic correlations between sow reproductive traits

Table 10.4. Means of literature estimates of genetic and phenotypic correlations[a] among reproductive traits.

	AP	OR	PSR	TNB	FSR	NBA	BWSR	NW	LBW	L21W	ABW
AP		–0.06	–0.08	–0.04	–	0.07	–	0.09	–0.10	–0.15	–
OR	0.05		–0.36	0.32	–0.27	0.24	–0.38	0.01	0.24	0.03	–0.23
PSR	–0.01	0.14		0.50	0.3	0.55	–0.25	0.42	0.30	0.10	–0.41
TNB	–0.03	0.13	0.60		–0.25	0.92	–0.15	0.73	0.62	0.40	–0.41
FSR	–	0.06	–0.15	–0.08		0.01	0.17	–0.01	–0.10	0.05	0.22
NBA	–0.03	0.12	0.40	0.91	0.15		–0.14	0.81	0.64	0.55	–0.34
BWSR	–	–0.11	–0.14	–0.12	0.08	–0.22		0.15	–0.07	0.65	0.15
NW	–0.01	0.03	0.36	0.71	0.47	0.79	0.55		0.67	0.81	–0.23
LBW	–0.03	0.07	0.55	0.79	0.43	0.82	0.09	0.71		0.65	0.43
L21W	–0.04	0.02	0.08	0.42	0.36	0.46	0.65	0.80	0.61		0.60
ABW	–	–0.17	–0.32	–0.40		–0.44		–0.17	0.10	0.07	

[a]Genetic correlations above the diagonal, phenotypic correlations below.
AP, age at puberty; OR, ovulation rate; PSR, prenatal survival rate; TNB, total number born; FSR, farrowing survival rate; NBA, number born alive; BWSR, birth to weaning survival rate; NW, number weaned; LBW, litter weight at birth; L21W, 21-day litter weight; ABW, average birth weight.

Bidanel, 2011

Within breed variation

Genetic correlations between sow reproductive traits

Main results of table 10.4

- Age at puberty has low genetic correlations with sow productivity traits
- Ovulation rate, litter size and litter weight have positive genetic correlations
- Litter size and weight have negative, i.e. unfavourable correlations with the numbers and proportions of dead embryos / piglets as well as with average birth weight

Within breed variation

Genetic correlations between production and female reproduction traits

	Growth rate	Lean %	Meat quality
Age at puberty	favourable (-0,2)	-0.2 to 0.2	<0 with GP
Litter size	-0,4 à +0,2	0 à -0,3	= 0 with GP
fertility	Low & uncertain ?		?
Teat number	Independent ?		?
longevity	Independent ?		?

Within breed variation

Genetic correlations between meat quality traits

	Drip loss	Cooking loss	Tenderness
pH 1h post mortem	-0.27	-0.14	0.27
pH 24h post mortem	-0.71	-0.68	0.49
Reflectance	0.49	0.26	-0.16
Water holding capacity	-0.94	-0.25	-0.46
% intramuscular fat	-0.08	0.07	0.15

Within breed variation

Genetic correlations between meat quality and production traits

	Average daily gain	Lean%	Fat%
pH 1h post mortem	0	0.10	0.26
pH 24h post mortem	0	-0.13	0.15
Reflectance	0	0.16	-0.21
Water holding capacity	0	-0.19	0.02
% intramuscular fat	0.40	-0.34	0.30

Within breed variation

Genetic correlations of production traits with nitrogen (N) and phosphorus (P) excretions

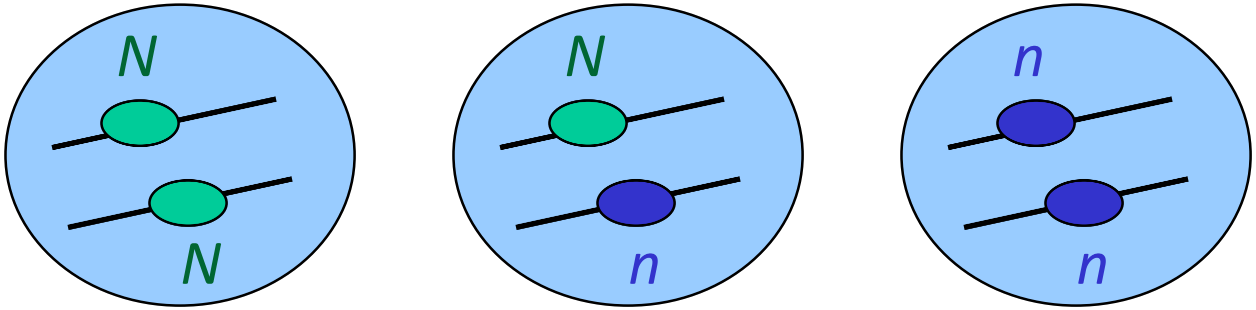
	Daily feed intake	Daily gain	Lean meat content
N excretion	0.55	-0.46	-0.72
P excretion	0.54	-0.50	-0.66

Saintilan et al (2013), J Anim Sci 91, 2542-2554

The Halothane sensitivity gene

Normal allele *N*
Mutant allele *n*

3 genotypes :



HAL is the Ryanodine Receptor 1 (RYR1) locus (chromosome 6)

Effects of the Halothane sensitivity gene

Normal allele ***N***
Mutant allele ***n***

Sensitivity to stress
NN* = *Nn* >> *nn

Meat quality
NN* > *Nn* >> *nn

Carcass quality
NN* < *Nn* < *nn

Economic interest of heterozygous pigs

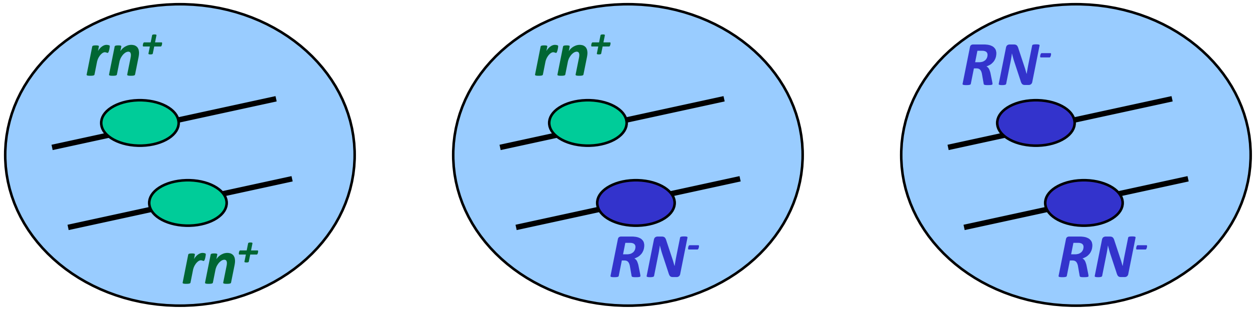
The RN gene

RN = acid meat gene

Normal allele rn^+

Mutant allele RN^-

3 genotypes :



RN is the PRKAG3 (Protein kinase AMP-activated gamma 3-subunit) locus (chromosome 15)

Effects of RN gene

Normal allele rn^+

Mutant allele RN^-

Meat quality*

$rn^+rn^+ >> RN^-rn^+ = RN^-RN^-$

Carcass quality

$rn^+rn^+ < RN^-rn^+ < RN^-RN^-$

*except flavour

Other major genes identified or suspected

- -IGF2
- -*ESR*
- -*A-FABP, H-FABP*
- -*MC4R*

Quantitative trait loci

> 16000 QTL detected

PigQTLdb http://www.animalgenome.org/

2015

Traits	Number of QTL
Drip loss	945
Average backfat thickness	158
Loin muscle area	132
Backfat at last rib	125
Carcass length	122
Average daily gain	82
Cervical vertebra length	80
Backfat at tenth rib	79
Teat number	74
Lean meat percentage	65
Ham weight	64
Intramuscular fat content	63
PH 24 hr post-mortem (loin)	59
PH for Longissmus Dorsi	54
Adipocyte diameter	52
....	....

Top 15 QTL/associations **2017**

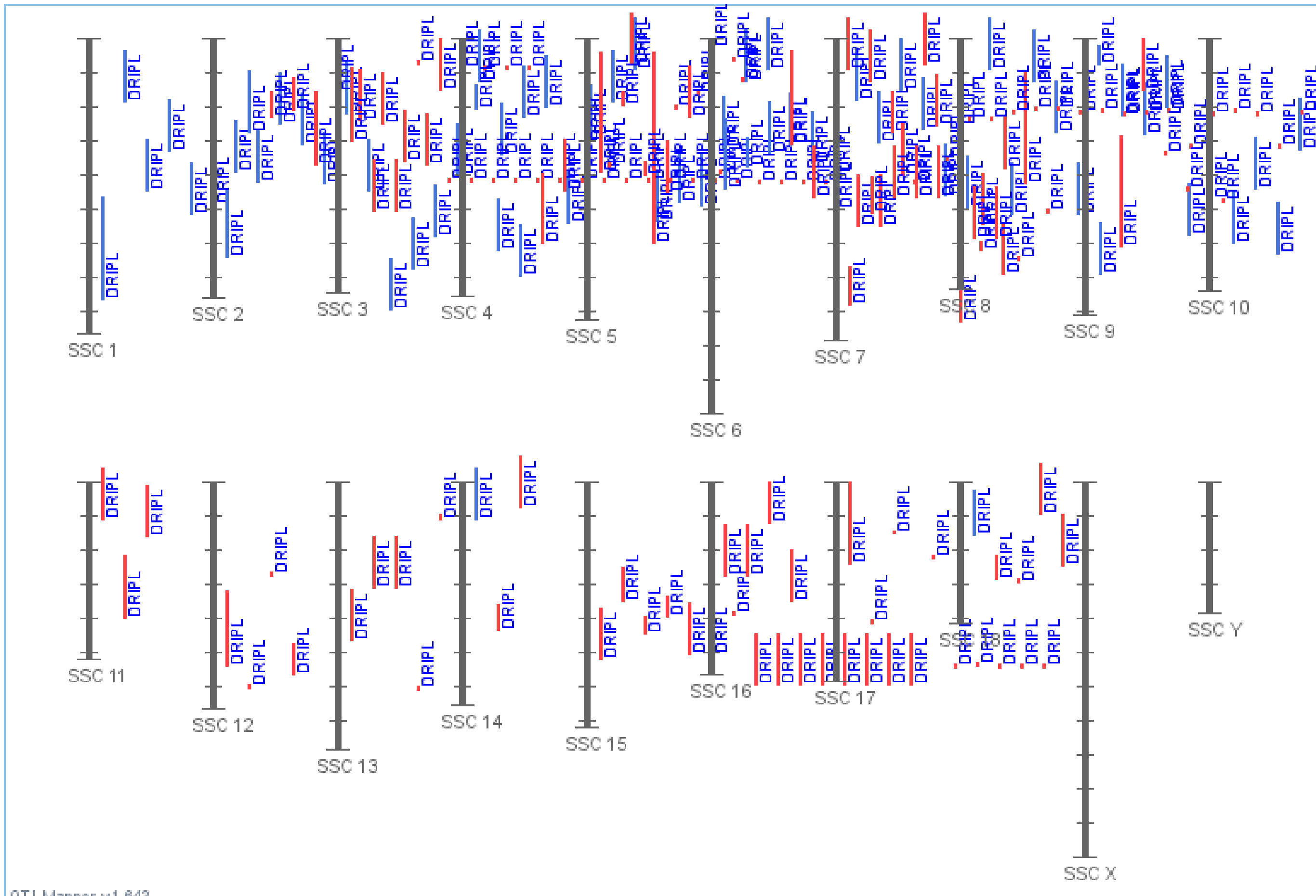
Traits	Number of QTL
Drip loss	1,071
Average daily gain	568
Mean corpuscular volume	344
Average backfat thickness	332
Loin muscle area	322
Intramuscular fat content	244
Red blood cell count	244
Hematocrit	244
Teat number	241
Backfat at last rib	240
Age at puberty	237
Mean corpuscular hemoglobin content	236
Enterotoxigenic E. coli susceptibility	218
Shear force	192
Backfat at tenth rib	190
....	....

Quantitative trait loci

1071 QTL detected for drip loss

PigQTLdb

Drip loss QTL

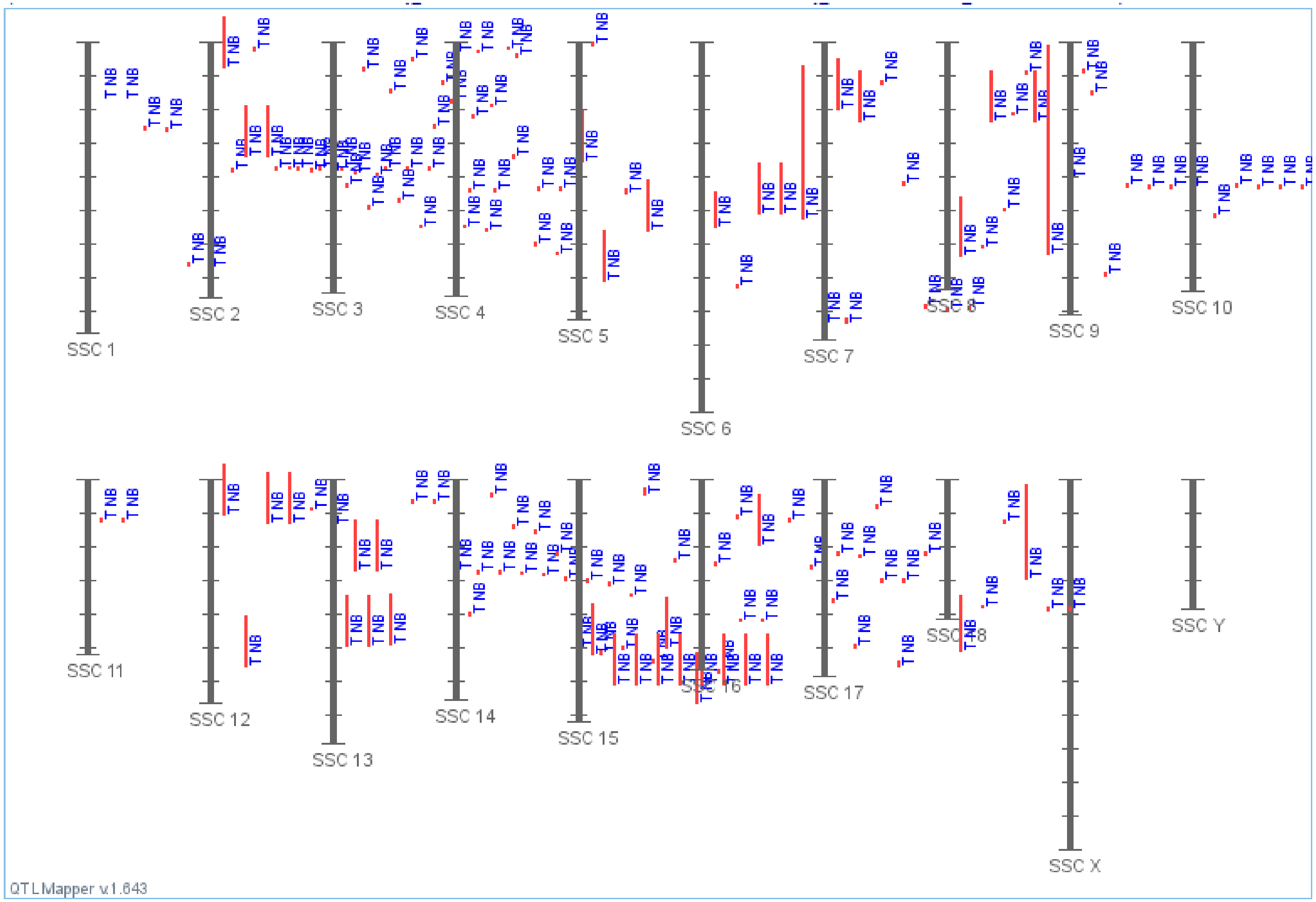


Quantitative trait loci

139 QTL detected for litter size

PigQTLdb

Total Number born



Distribution of QTL effects

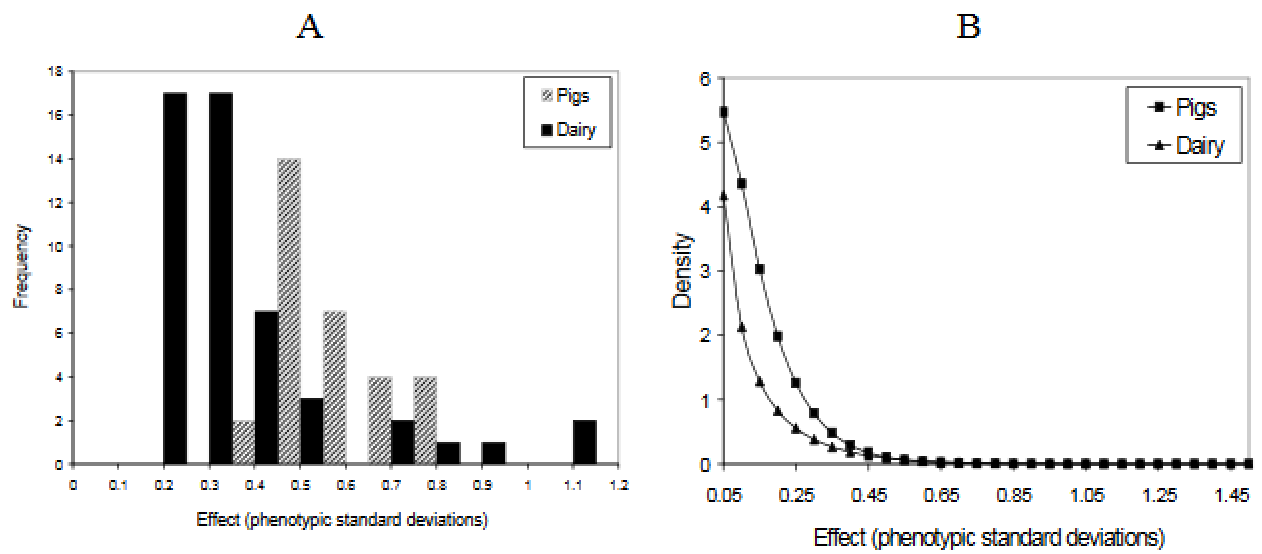


Figure 1.1 A. Distribution of additive (QTL) effects from pig experiments, scaled by the standard deviation of the relevant trait, and distribution of gene substitution (QTL) effects from dairy experiments scaled by the standard deviation of the relevant trait. B. Gamma Distribution of QTL effect from pig and dairy experiments, fitted with maximum likelihood.

Hayes & Goddard, 2001

Master
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REPRODUCTION BIOTECHNOLOGY

Genetic improvement of pigs – Part 2

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  - Definition of the breeding goal
  - Genetic variability of economically important traits
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  - Use of crossbreeding
  - Example of the French breeding scheme
  - Controlling the efficiency of pig breeding schemes
  - What does genomics bring to pig breeding schemes

Impact of pig biological characteristics on pig improvement schemes

- Favourable aspects

– High reproductive efficiency

- **Large number of offspring / female**

Cattle	**Pigs**
4.8 offspring /cow	**4.6 litters/sow**
4.8 * 0.5 * 0.8	**4.6 * 0.5 * 10**
≈ 1.9 daughters /dam	**≈ 23 daughters /dam**

– Generalised use of crossbreeding

– Development of AI

- **Essentially fresh semen**
- **Frozen semen : recent improvements**

Impact of pig biological characteristics on pig improvement schemes

- Favourable aspects

– Short generation interval

– Traits (growth - carcass) that are :

  - **heritable**
  - **Measured early in life**
  - **Measure on all candidates from both sexes**

– Homogeneity of breeding /management conditions

  - **(conventional breeding)**

– Homogeneity of slaughter pigs

  - **(90- 115 kg live weight)**

Impact of pig biological characteristics on pig improvement schemes

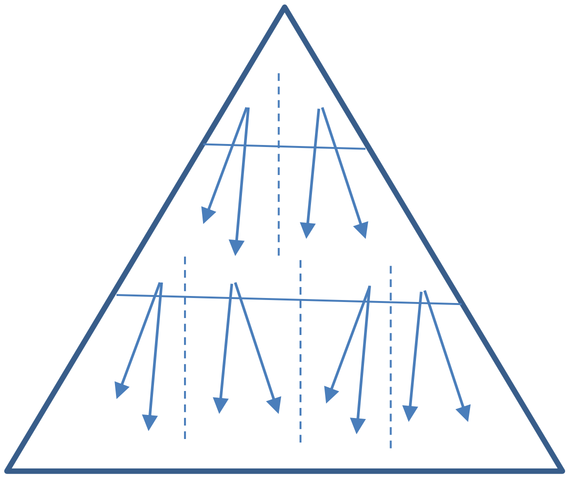
- Constraints

– Sanitary constraints

- « Vertical » diffusion of breeding pigs : one single provider
- No breeding pig in testing station

– Diversity of final products

- Fresh meat
- Processed products
  - Dry / cooked ham
  - Sausages
  - Processed dishes



Impact of pig biological characteristics on pig improvement schemes

- Constraints (2/2)

– **Fast and decentralised breeding decisions**
  - **Fast information flow required**

– **Some traits are more difficult to select**
  - **Reproduction traits : late and sex-limited expression**
  - **Meat quality : measured after slaughter**

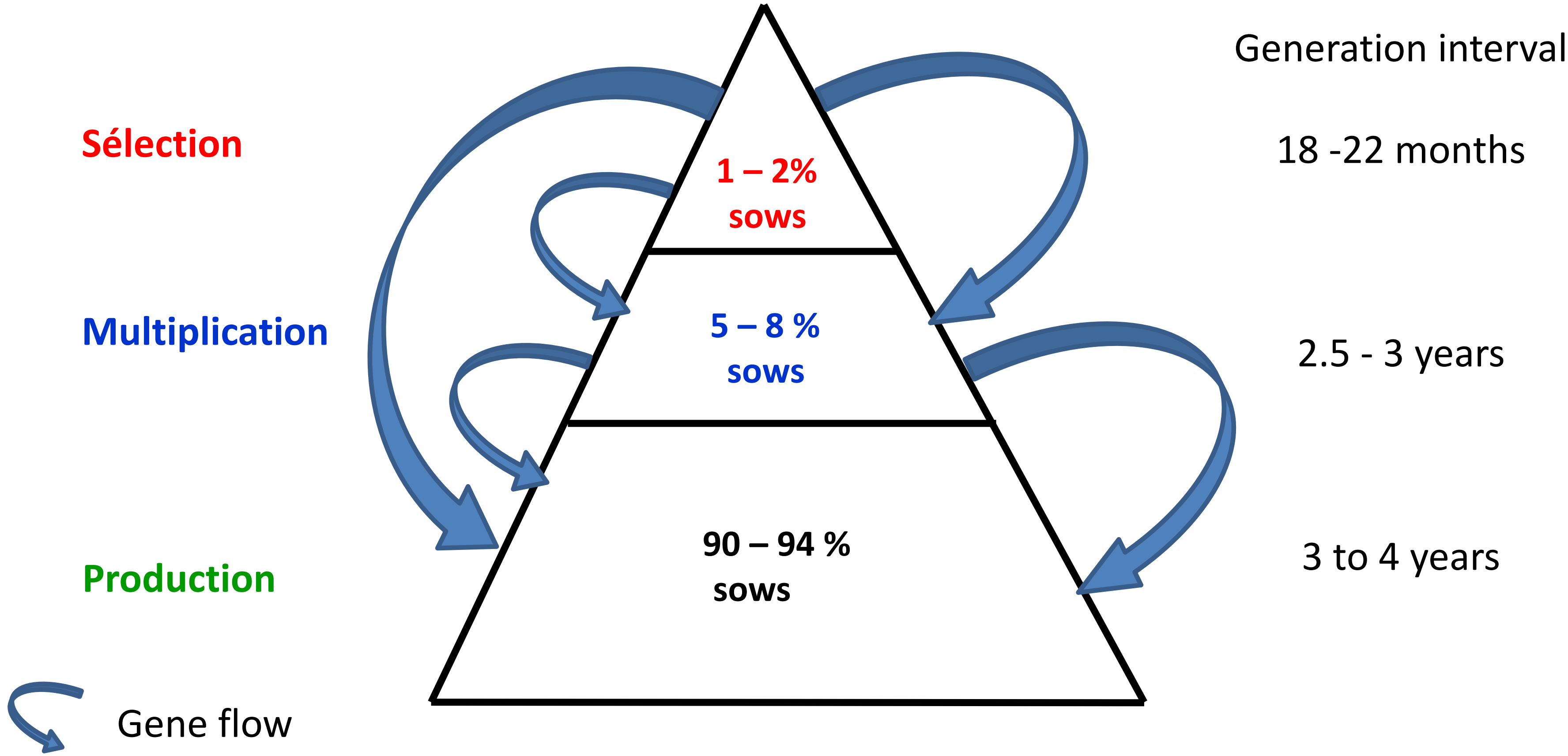
– **Development of AI, BLUP (and GS ?)**
  - **Adverse effects on genetic variability**

_05

Optimisation of breeding schemes

pig improvement schemes
main characteristics

- Pyramidal structure



Optimising a breeding scheme
- Factors to consider -

1) Genetic factors

- maximise

$$\Delta G_a = \frac{i\rho\sigma_a}{t}$$

2) Economic factors

- Selection costs
- Max(**D**G) for a given testing capacity

3) Technical factors

- Phenotype measurement
- Information processing

Interest of Nucleus herds in pigs

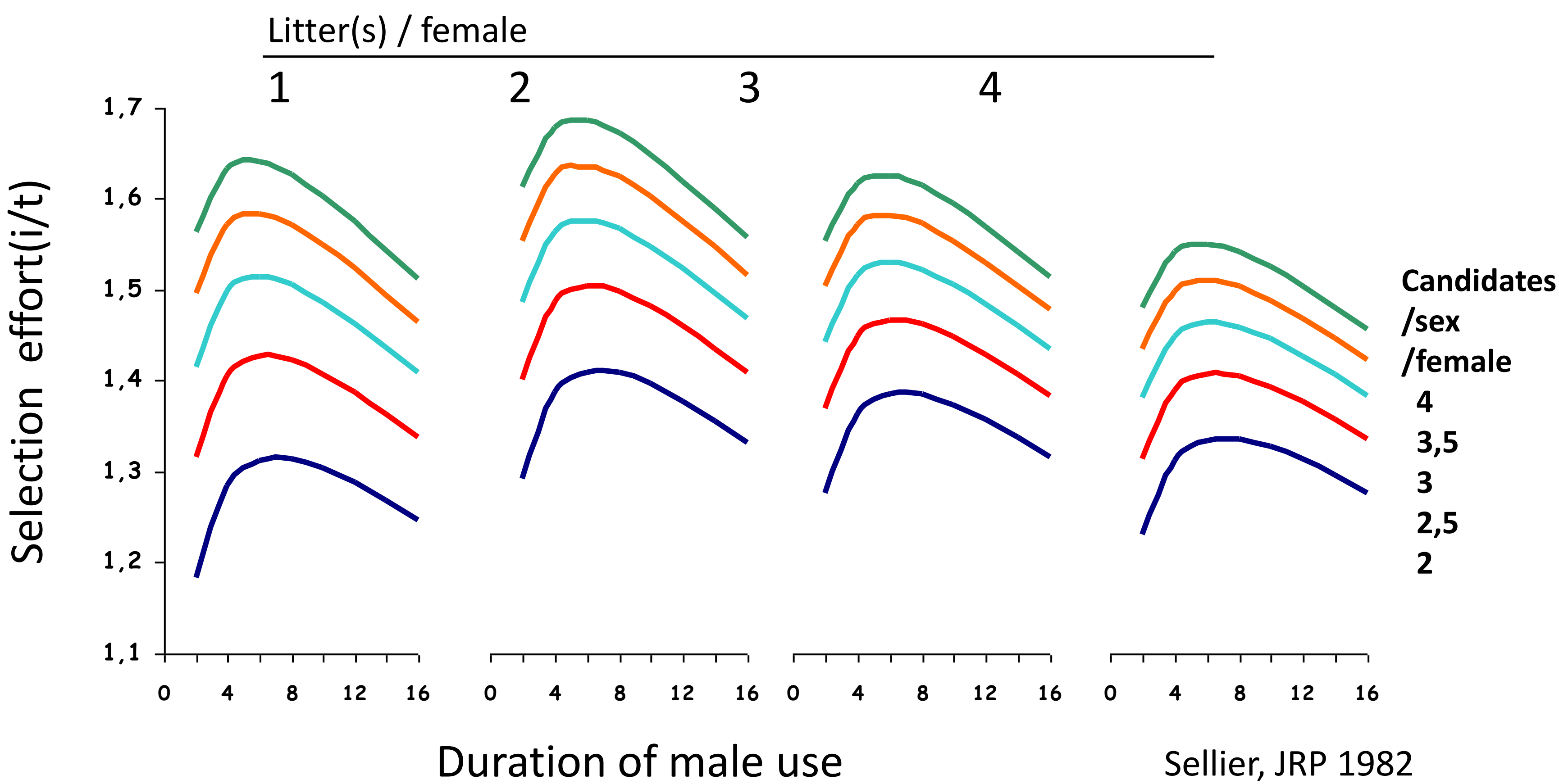
(Smith, 1959, Anim Prod, 1, 113-121)

Hypothesis: N=5000 tested candidates, T = 1000 breeding pigs necessary

	Open system	Nucleus	
Selected pigs	1000	20 (50 offspring each)	
N/T	5	250	
DG	1,36 $h^2 s_P$	2,70 $h^2 s_P$	
Generation 0	0	0	
1	0,68 $h^2 \sigma_P$	0	Nucleus creation
2	1,36 $h^2 \sigma_P$	0	Selection
3	2,04 $h^2 \sigma_P$	1,35 $h^2 \sigma_P$	Multiplication
4	2,72 $h^2 \sigma_P$	2,70 $h^2 \sigma_P$	
5	3,40 $h^2 \sigma_P$	4,05 $h^2 \sigma_P$	

Optimisation of a breeding scheme
- Genetic factors -

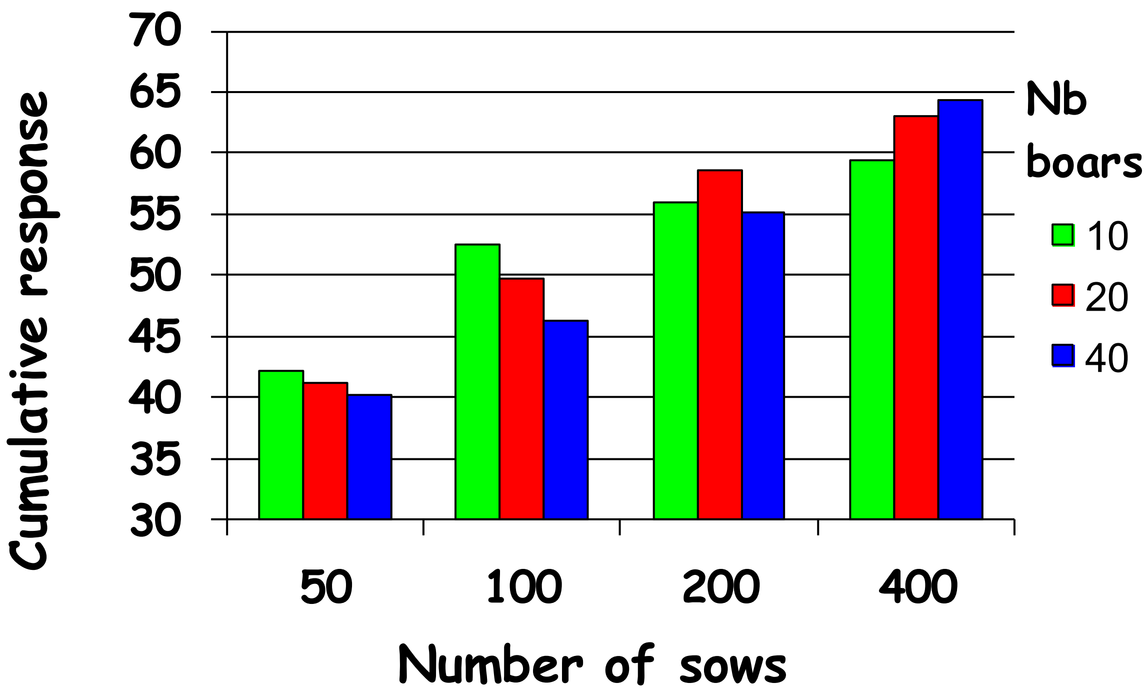
Variation of i/t ration as a function of the duration of male and female use



Sellier, JRP 1982

Optimisation of a breeding scheme
- Genetic factors -

Effect of population size on the efficiency of selection : the case of a maternal line (de Vries et al, 1989)



Optimisation of a breeding scheme
- Genetic factors -

Selection with BLUP - AM

Allows non contemporary animals to be compared

Theoretically, rules for age at culling are not necessary, as candidates can be directly compared to older animals

⇒ **Sows can be selected sequentially, which to an extra genetic gain of 3 - 4 %)**

⇒ **Sequential selection of boars also possible, but may lead to an over-use the best boars**

=> Optimum values established with standard selection theory remain close to optimum

Optimisation of a breeding scheme
- Technical factors -

Integration of meat quality in the breeding goal

Goal : avoid any deterioration of MQ

- Pb : MQ cannot be measured on the live animal

  - **Can this goal be reached by acting on the weights of production traits (PT) included in the selection objective**

  - **No, as MQ is unfavourably related to PT, a deterioration of MQ is obtained whatever the weights of PT**

  => MQ has to be included as a selection criterion

  - **MQ cannot be measured on living pigs**

  => Moving from individual testing to combined testing

_06

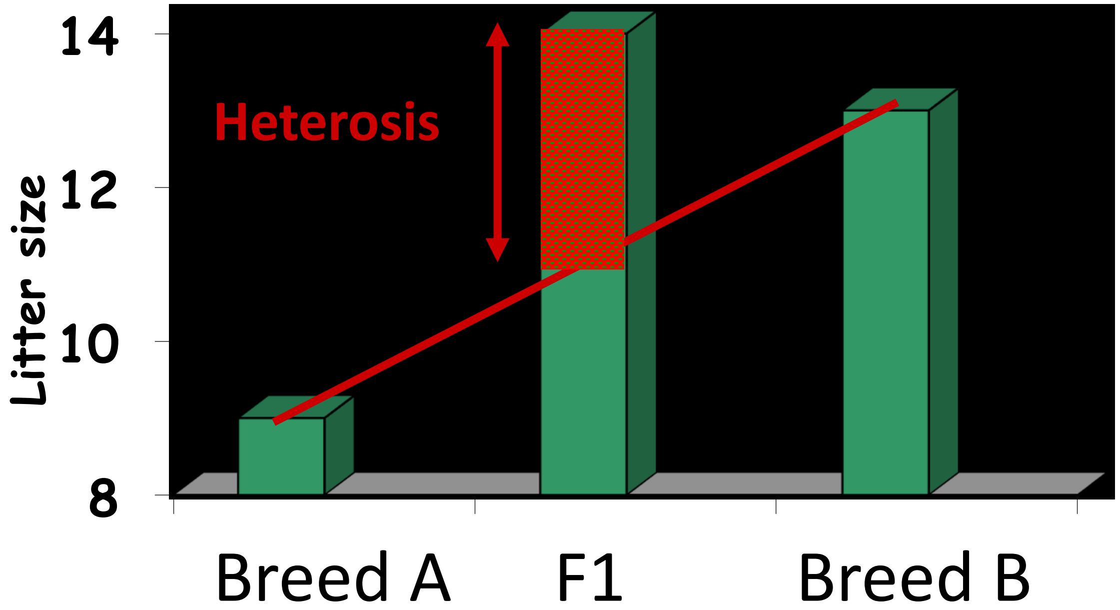
Use of crossbreeding

Objectives of crossbreeding

- **1 - Exploiting heterosis effects**
- **2 - Taking profit of complementarity effect**
- **3 - Using breed additive differences**
- **4 - Increasing genetic variability**
- **5 - Using major genes**

Heterosis

- Definition
  – For a given trait, mean deviation between F1 performance and the average of parental breeds



Direct and maternal heterosis

Direct heterosis

A → AB(BA) ← B

AB(BA)

Deviation between F1 mean performance (AB+BA)/2 and Purebred mean performance (A+B)/2

Maternal heterosis

C → C(AB) - C(BA) ← AB (BA)

C(AB) - C(BA)

Deviation between the mean performance of pigs from F1 sows [C(AB)+C(BA)]/2 and that of pigs from purebred sows (CA+CB)/2

Mean heterosis values for some traits of economic interest in pigs

Trait	Heterosis	
	Direct	Maternal
Age at 1st oestrus (d)	-12 (6%)	0
Total piglets born/litter	+0,25 (2%)	+0,66 (6%)
Weaned/litter	+0,49 (4%)	+0,84 (8%)
Piglet weaning weight (kg)	+0,5 (5%)	0,23 (2%)
Average daily gain (g/d)	+37 (6%)	0
Feed conversion ratio	-0,11 (4%)	0
Body composition	0	0
Meat quality	0	0

The complementarity effect

- Definition
  - Complementary aptitudes that are present either in one breed or in the other, but can hardly be present in a single breed
- Example

Sire breed with a high muscular Growth potential	x	Dam breed with good Reproduction and maternal abilities

Use of the complementarity effect in pigs

- Related to the expression of profit : $P= FM- SC/P_N$

	Breed A	Breed B
Sow annual cost (€)	**700**	**700**
« Production » margin	**77**	**70**
Numerical productivity	**20**	**25**
Profit/pig	**77-(700/20) = 42**	**70-(700/25) = 42**

- A x B cross : P = 73,5 - (700/25) = 45,5
- Gain due to the use of specialised lines = 3,5 €
  - = COMPLEMENTARITY

Using additive differences between breeds

- Absorption cross
  - Replacement of one population by another one with higher performances
  - Example: quasi-absorption of French Piétrain population by the German one
- Improvement cross
  - Limited introgression of genes from a higher performing breed
  - Example : introduction of English Large White (LW) in French LW during the 70’s

Use of major genes : the example of the halothane gene

Genotype	NN	Ns	ss
Viability	++	++	--
Muscle content	0	+	++
Meat quality	++	+(+)	--
Prolificacy	0	0	0
Feed conversion ratio	0	0	0

- Heterozygote pigs are the most interesting ones

Use of major genes : the example of the halothane gene

Paternal genotype with a high frequency of s allele

x

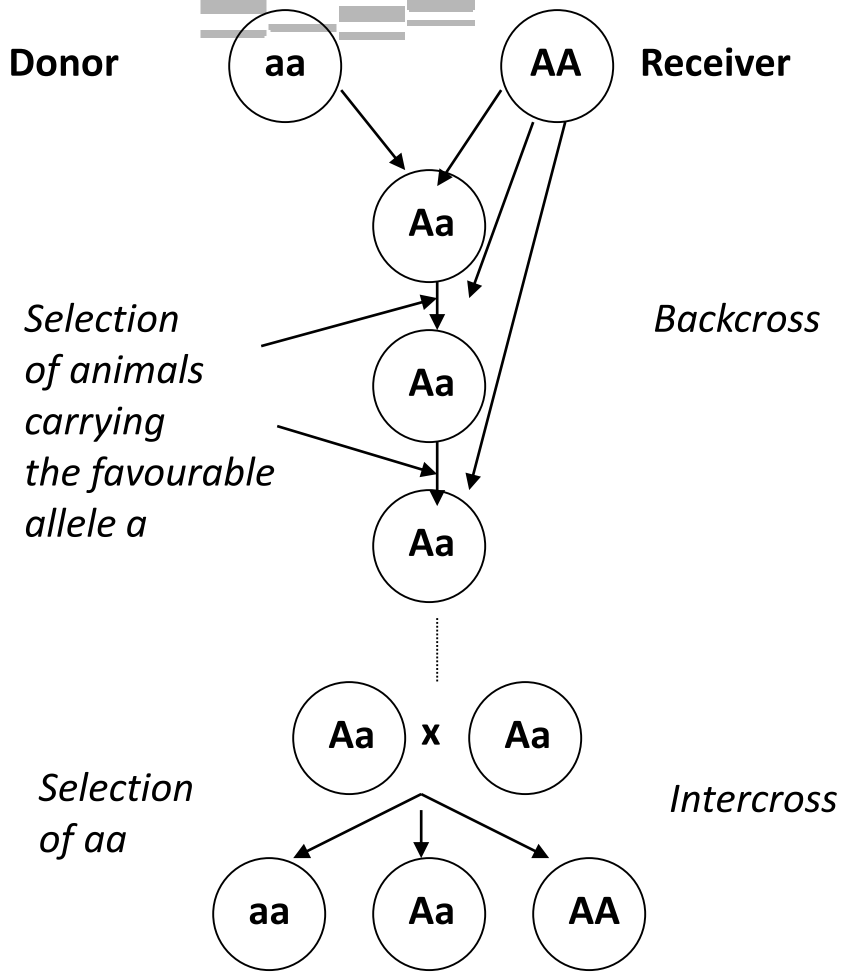
Maternel genotype free of the s allele

Classical selection for production traits

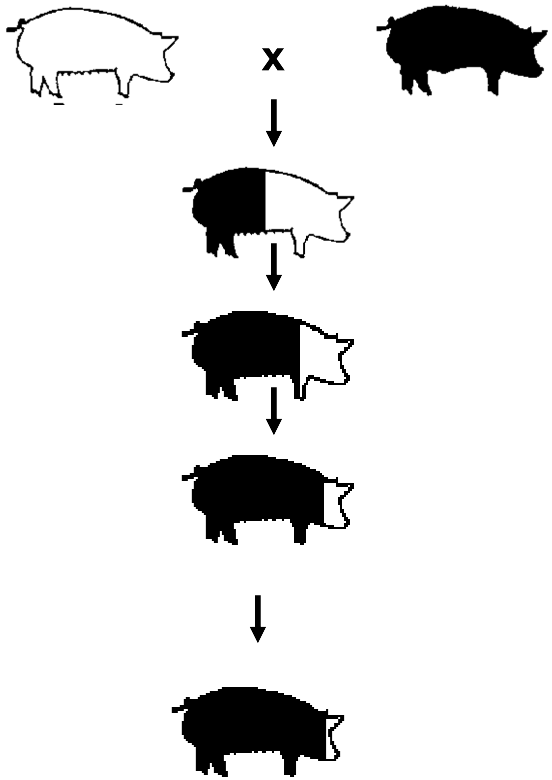
Selection for production and reproduction
Elimination of the s allele

Gene introgression through crossbreeding

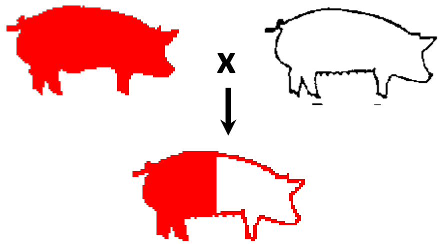
At the introgressed locus



Rest of the genome



Comparative interest of crossbreeding plans
Simple cross



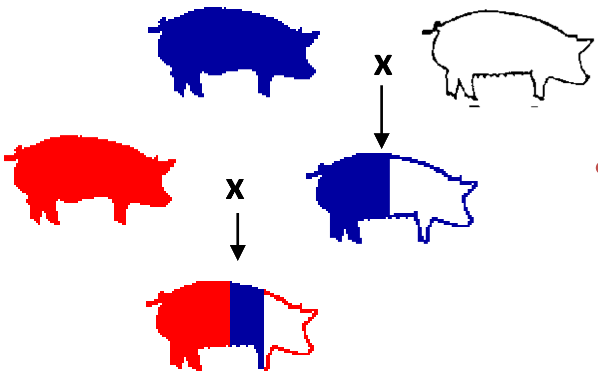
Allows to take profit of direct heterosis on :

Growth rate	+37g	+0,80 €
Feed conversion ratio	-0,11	+1,40 €
Litter size at weaning	+0,5	+1,25 €
Total		+3,45 €

+ Use of Hal gene
+ Use of complementarity effect

- Maternal heterosis effects cannot be exploited

Comparative interest of crossbreeding plans
3-way cross



- Use of direct heterosis effects :

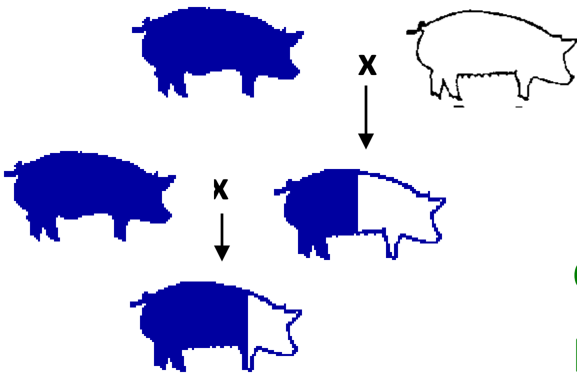
Growth rate	+37g	+0,80 €
FCR	-0,11	+1,40 €
LS at weaning	+0,5	+1,25 €

- Use of maternal heterosis effects

LS at weaning	+0,84	+2,10 €
Sexual maturity	-12	+ 0,10 €
TOTAL		+5,65 €

- + Use of Hal gene
- + Use of complementarity +3,50 €

Comparative interest of crossbreeding plans
Back cross



- **Use of 1/2 direct heterosis effects:**

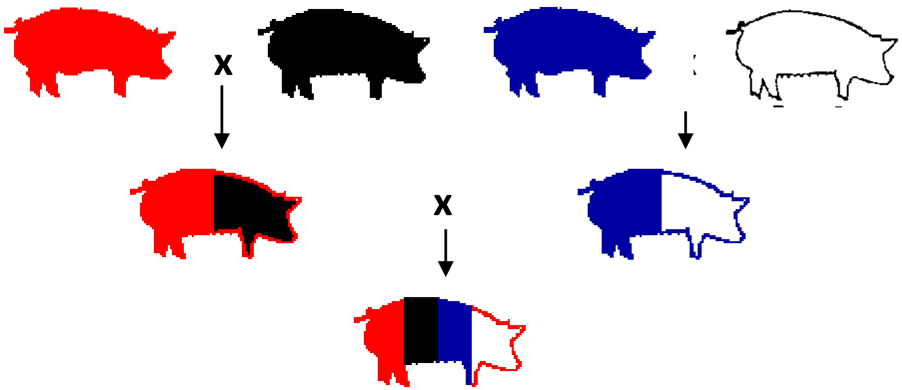
Growth rate	+18g	+0,40 €
FCR	-0,05	+0,70 €
LS at weaning	+0,25	+0,68 €

- **Use of maternal heterosis effects**

LS at weaning	+0,84	+2,10 €
Sexual maturity	-12	+ 0,10 €
TOTAL		+3,98 €

- **No use of Hal gene**
- **No use of complementarity**

Comparative interest of crossbreeding plans
4-way cross



- Use of direct heterosis effects :

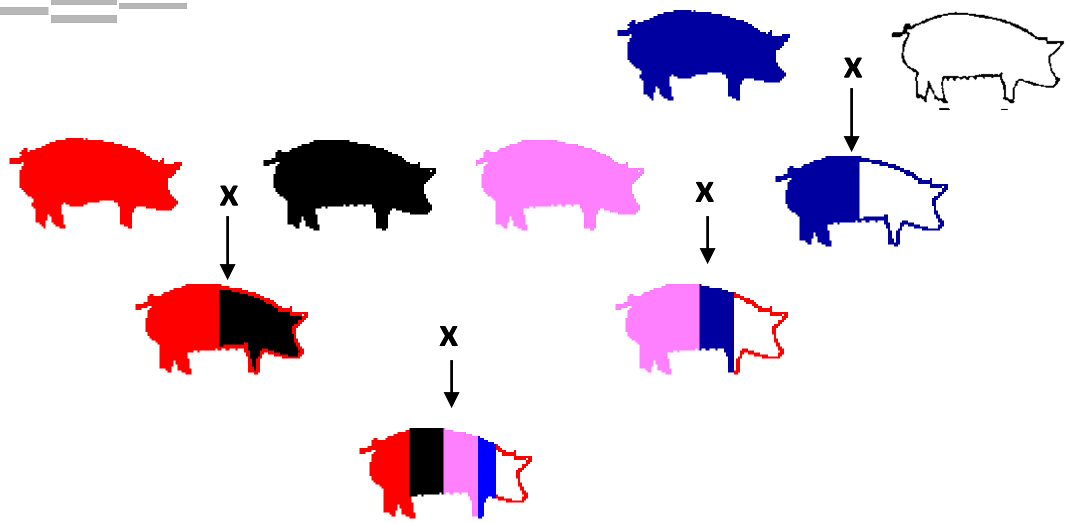
Growth rate	+37g	+0,80 €
FCR	-0,11	+1,40 €
LS at weaning	+0,5	+1,25 €

- Use of maternal heterosis effects

LS at weaning	+0,84	+2,10 €
Sexual maturity	-12	+ 0,10 €
TOTAL		+5,65 €

- + (Partial) use of Hal gene
- + Use of complementarity +3,50 €
- + Heterosis on (young) boar characteristics

Comparative interest of crossbreeding plans
3-level crosses



Same advantages as a 4-way cross (but a longer time is necessary for improved genes to reach the commercial level

Main advantage : it is easier to keep the property of purebred animals

Selection and crossbreeding

1 - effects of selection on between-breed variability

- Is crossbred performance the same as purebred performance ?
- Effects of selection on heterosis

2 - Specialisation of selection goals

3 - Selection for crossbred performance

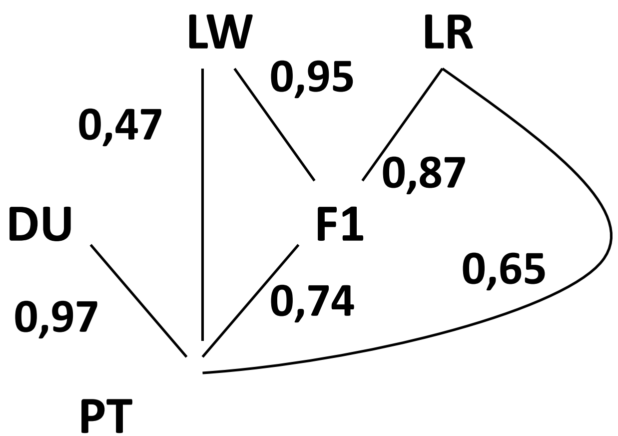
- Recurrent selection
- Combined purebred – crossbred performance (CCPS)
- Interest of genetic markers

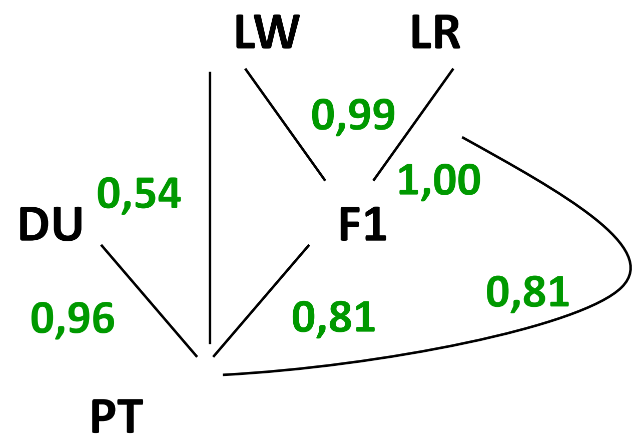
Selection and crossbreeding
Purebred and crossbred performance

h2 estimates at different stages of a crossbreeding scheme

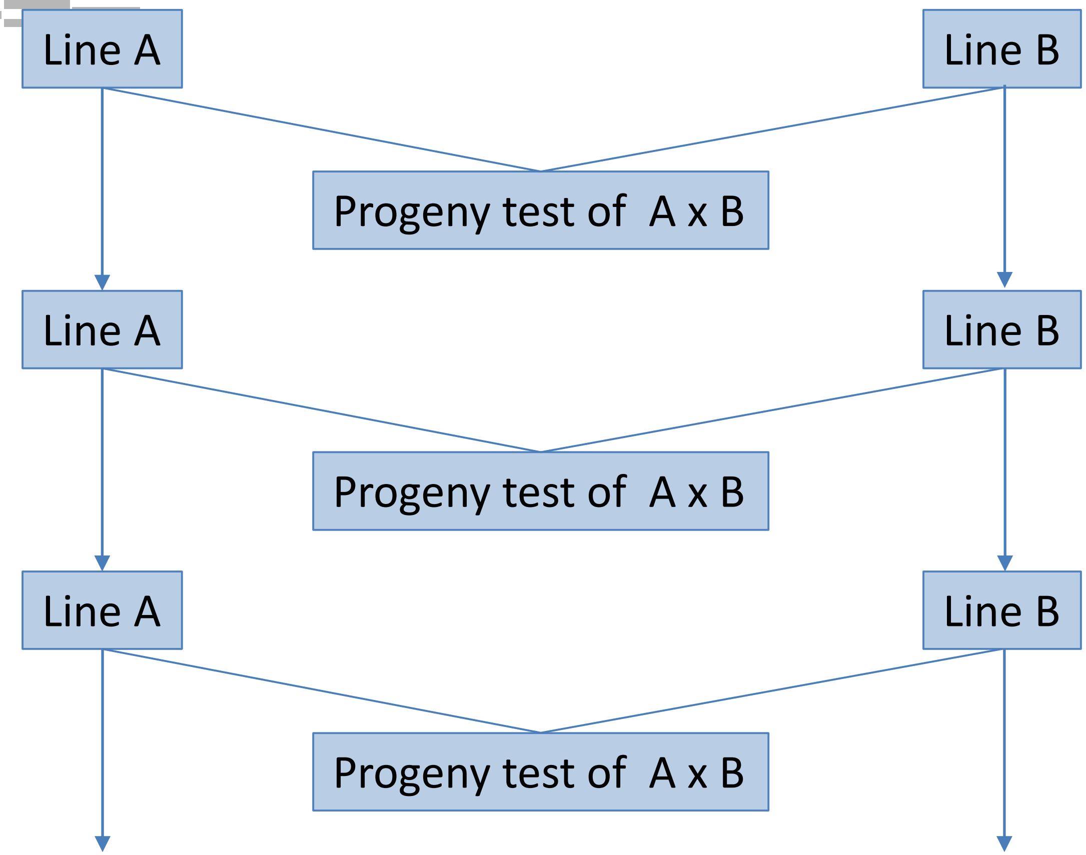
h2	LR	LW	DU	F1	PT
ADG	0,21	0,23	0,20	0,31	0,33
BFT	0,52	0,46	0,36	0,26	0,39

- **Genetic correlations between ADG and BFT at different stages**





Reciprocal recurrent selection



Combine Crossbred and purebred selection

EBV computed from both Purebred and crossbred information

Requires good pedigree information at the commercial level

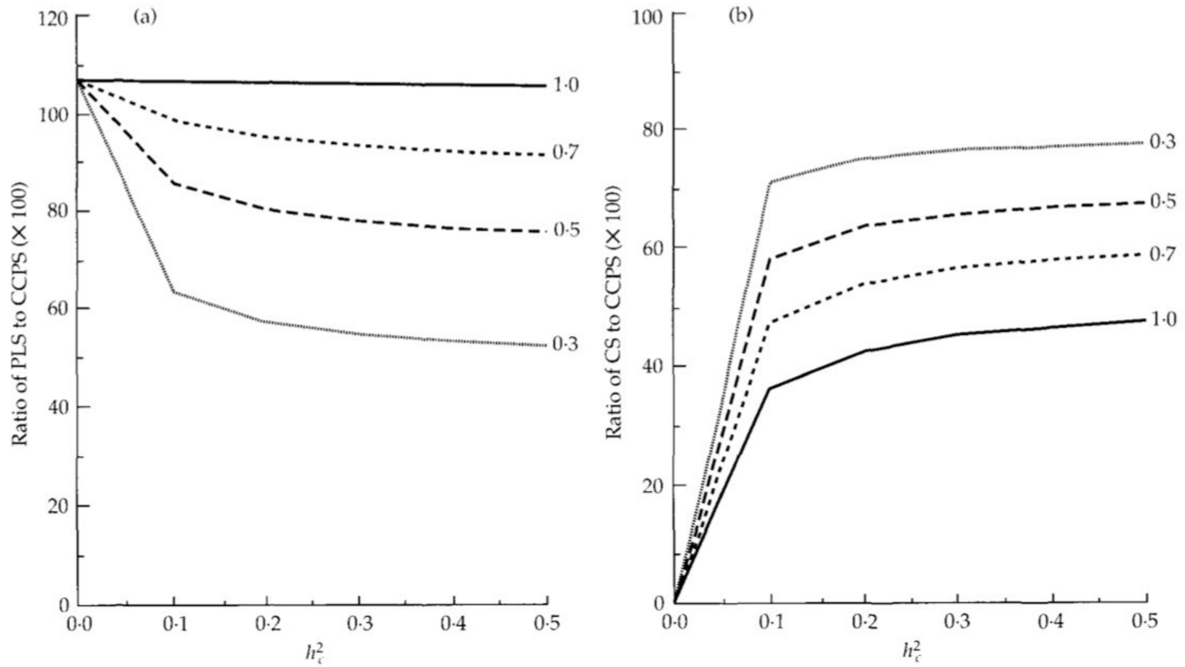
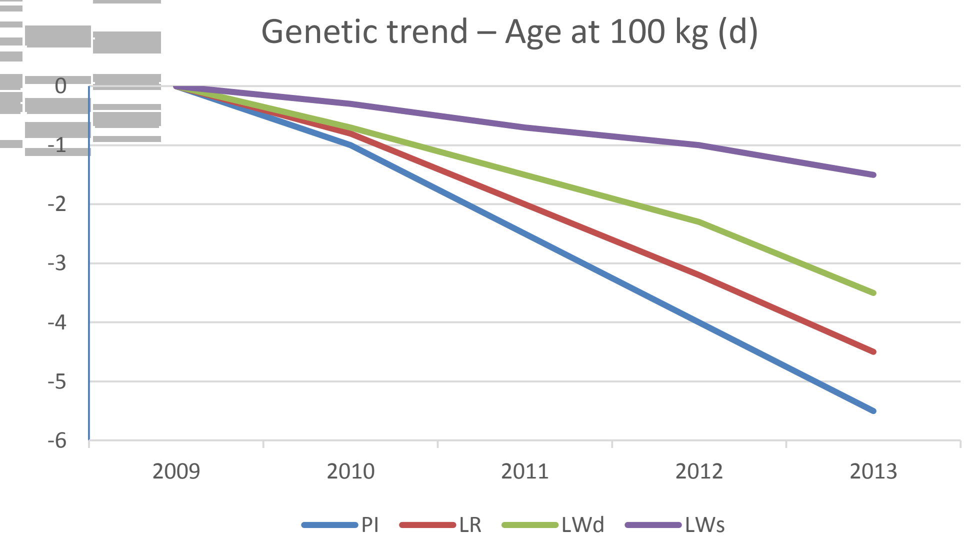


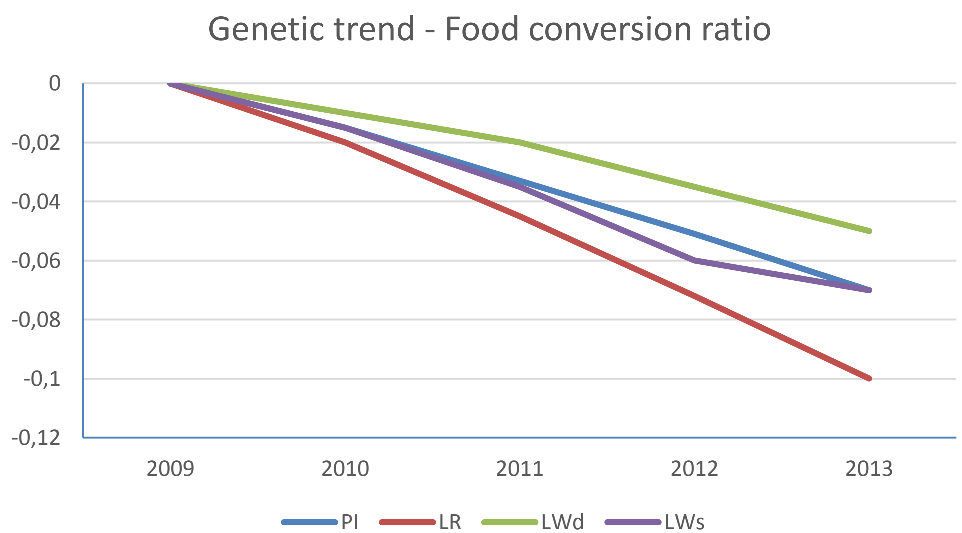
Figure 2 Relative merits of three different methods of selection assuming fixed total progeny for all methods. Crossbred responses from (a) PLS and (b) CS are given as a percentage of response from CCPS. Results are plotted as a function of h_c^2 for r_{pc} values of 1·0, 0·7, 0·5 and 0·3.

_08

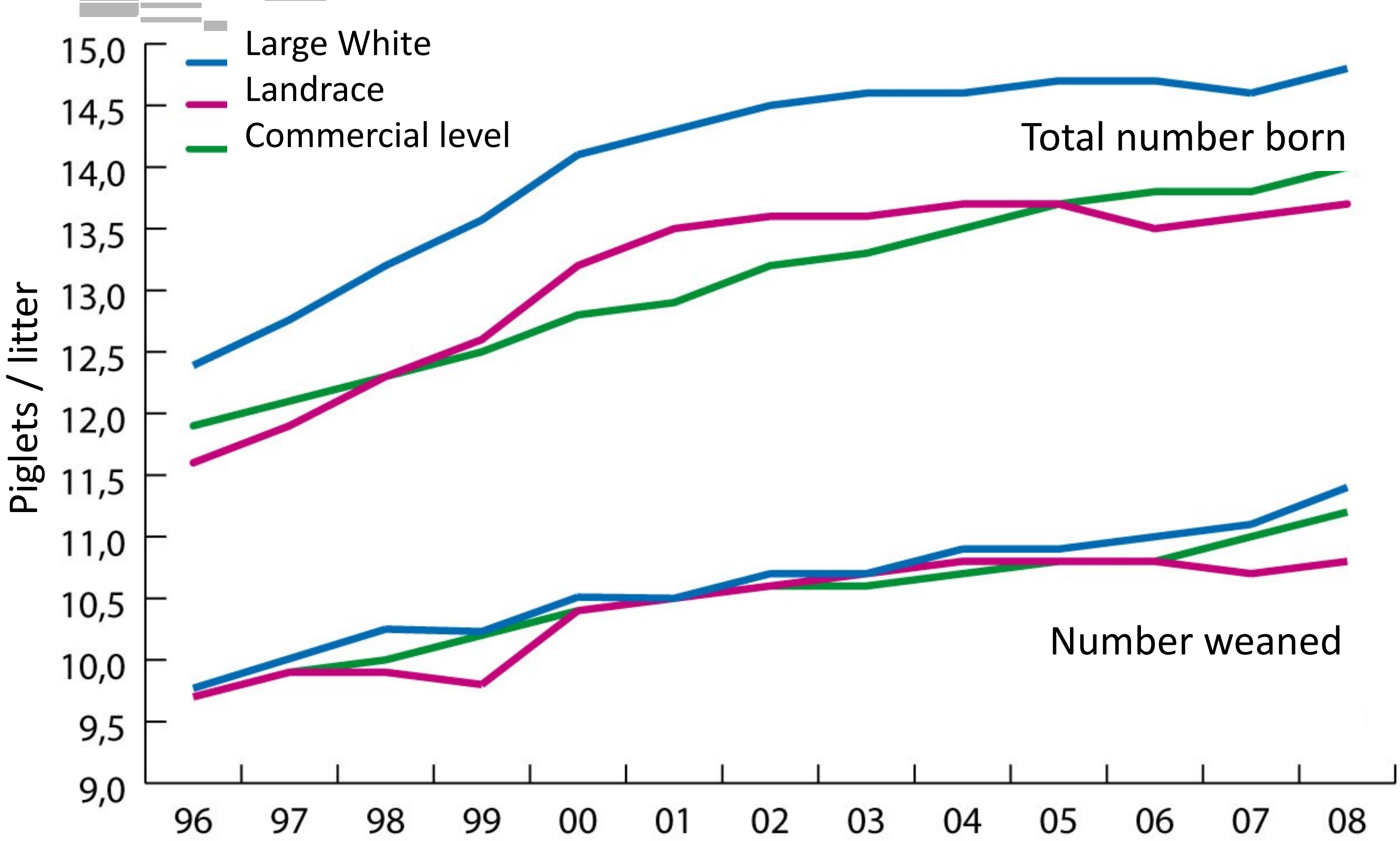
Controlling the efficiency of pig breeding schemes

BLUP estimates of genetic trends





Phenotypic (or genetic) trends at the commercial level



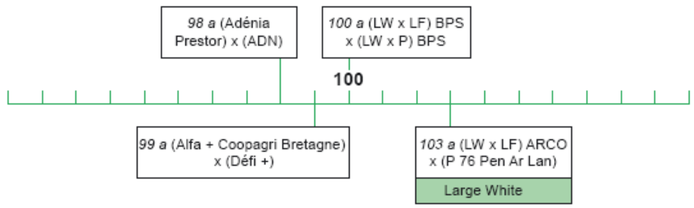
Checking the efficiency of breeding schemes
Control of « terminal products »

- Sample of slaughter pigs from different breeding organisations compared in an official test station

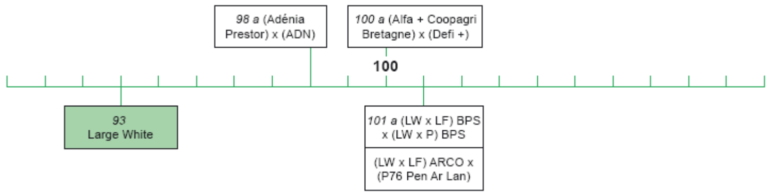
- Results officially published by the ministry of Agriculture

Ex : 24rd TP test

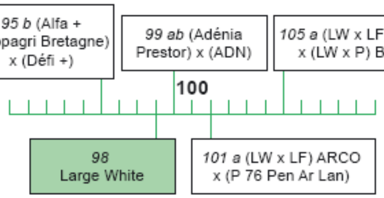
Growth index; 10 points = 2.30 euros



Carcass index; 10 points = 3.08 euros

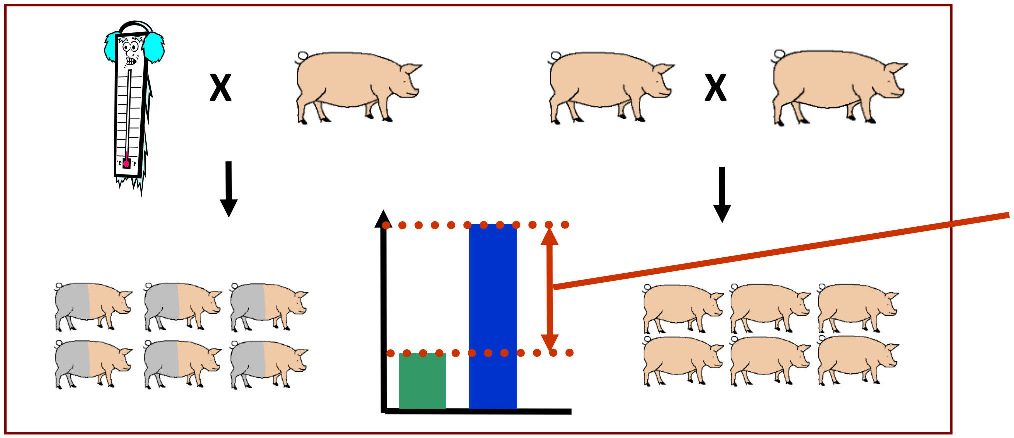


Meat quality index; 10 points = 1.16 euros



Checking the efficiency of breeding schemes
Use of frozen semen

SMITH, 1976 : use of frozen semen



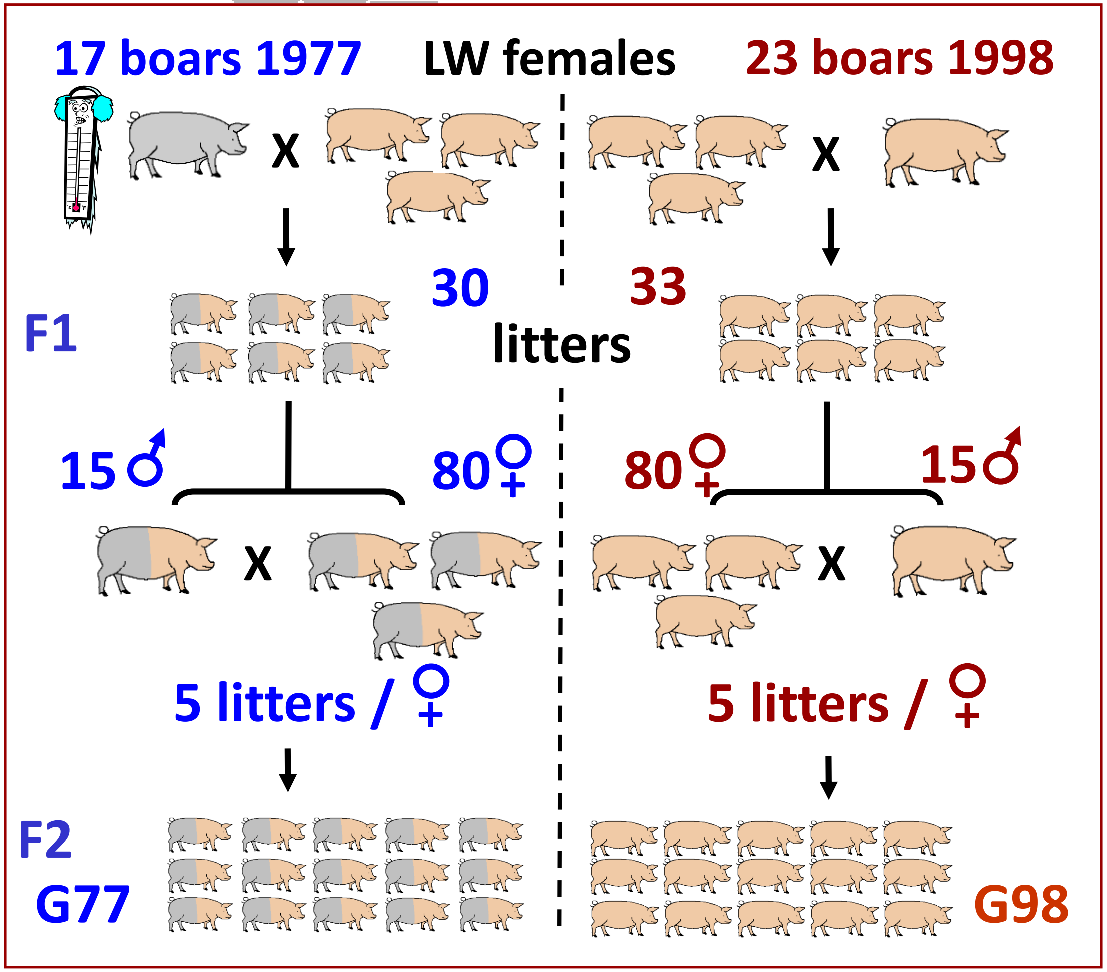
$$= \frac{\textbf{genetic trend}}{\textbf{2}}$$

1978 : stock of frozen semen of 1977 LW boars

1999 : INRA, ITP & French Ministry of Agriculture

reproduction, production, quality

Checking the efficiency of breeding schemes
Use of frozen semen



Experimental design

Reproduction traits

- **production traits**
- **meat and fat quality**

Estimation of genetic trends using frozen semen results

Carcass leanness

	Mean perf.	σ_{ph}	ΔG	P-value for H0 $\Delta G=0$
ham weight (kg)	9.7	0.50	+0.56	0.0053
loin weight (kg)	10.5	0.68	+0.85	0.0043
loin eye thickness (mm)	52.1	5.4	+5.97	0.0054
carcass lean content (kg/100kg)	55.7	3.5	+8.60	<0.0001

_09

Use of genomic information

Use of genomic information in pig breeding schemes

- **First utilisations**
  - **Parentage control**
  - **Control / production of given genotypes for major genes**
  - **Genotype / marker assisted introgression**
  - **Genotype / marker assisted selection (MAS)**
  - **Characterisation / management of genetic variability**
  - **individual / breed Traceability**

- **Genomic selection (GS)**

Marker Assisted Selection (MAS) in pigs

Apart from major genes (Hal, RN, IGF2,…), limited use… and limited efficiency of first generation MAS (with microsatellites) in pigs.

Why ?

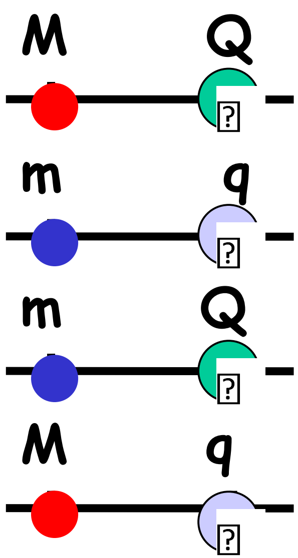
1. Most QTL mapped in experimental populations between divergent populations (LW x MS, LW x wild boar, …) : => QTL explain breed differences; they are not necessarily segregating within commercial populations
2. Most QTL were mapped with a low accuracy
3. First generation MAS used within-family LD => uneasy to use, limited gains in pigs
4. Few QTL were common between studies => validation required

Genomic selection : potential use in pigs

Genomic selection : General Principle

With low density marker panels (100-200/genome)

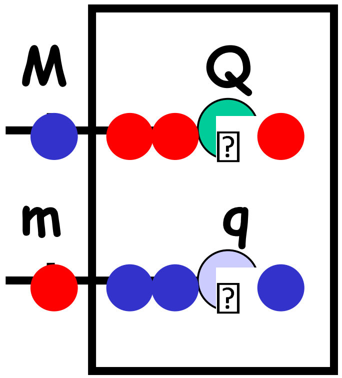
Linkage equilibrium



The QTL genotype can be inferred from Marker information only within-family

With high density marker panels (at least 10^3 or 10^4 markers)

Full disequilibrium



The QTL genotye can be inferred from marker information at the population level

Genomic selection : potential use in pigs

Genomic selection : General Principle

Step 1 :

Phenotype and genotype individuals for several thousand SNP

= reference population => estimate the effect of each chromosomal fragment

Step 2 : genotype candidates and compute a genomic EBV from genomic information and segment effects

Or

Single step : genomic information is used to modify the relationhip matrix

Genomic selection : potential use in pigs

Benefits from genomic selection ?

- A higher genetic trend ?

$$\Delta G = \frac{i \, \rho \, \sigma_a}{T}$$

- increase selection intensity ?
- **increase accuracy of EBV ?**
- reduce generation interval ?

- Decreasing selection costs ? NO

Genomic selection : potential use in pigs

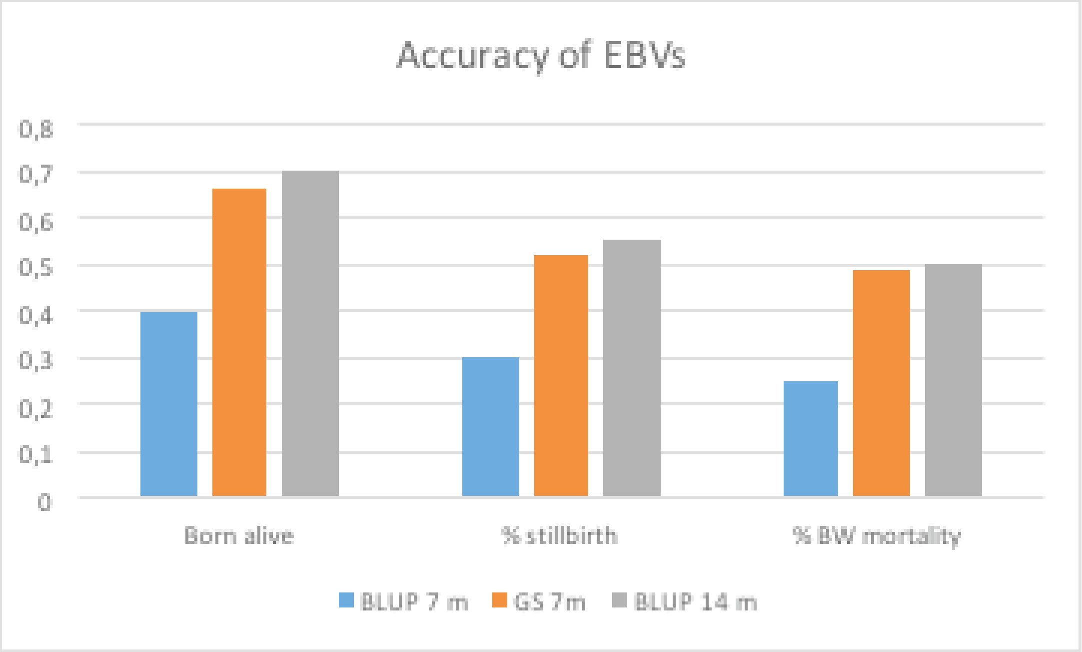
- increase accuracy of EBV ?

Average CD (correlation(EBV,BV)²) with BLUP-AM evaluation

	Age100	*BF100*	ADG	FCR	DFI	KO%	LEAN%	MQI	Teats	NBA
Active AI boar	*0.68*	*0.73*	0.34	0.37	0.28	0.24	0.51	0.23	0.65	0.26
Active on-farm boar	*0.63*	*0.69*	0.29	0.32	0.22	0.18	0.46	0.17	0.59	0.25
Active sow	*0.58*	*0.66*	0.28	0.32	0.22	0.18	0.44	0.18	0.54	0.36
Piglet at birth	*0.31*	*0.34*	0.15	0.17	0.12	0.10	0.23	0.10	0.29	0.16
Young candidates (end of test)	*0.52*	*0.60*	0.23	0.27	0.17	0.13	0.39	0.13	0.48	0.16

Genomic selection : potential use in pigs

Gain in accuracy of young animals' EBV



From Hendrix Genetics

Genomic selection in pigs

Genomic selection in a sire line : a simulation study

Sire pig population :

- ~1000 sows (5 herds). 50 boars
- 7 reproduction batches; overlapping generations
- Sire line selected for a combination of 2 production traits :

VGEglob = 1*VGEcar1 + 1*VGEcar2

Reference scenario : AM - BLUP

- **car 1 : measured on ♂ & ♀ candidates** ***(many records)***
- **car 2 : measured on a limited number of sibs** ***(few records)***

Alternative scenarios: Genomic evaluations

- **Genotyped ♂ & ♀ candidates**
  → estimated genomic value

2 scenarios for reference populations

Tribout et al (2012; 2013)

Genomic selection in pigs

Genomic selection in a sire line : a simulation study

Genome :

- **10 pairs of chromosomes of 1M length (genome = 10 M)**

- **each chromosome carries 1500 SNP (MAF > 0.05)**

  mean distance between 2 SNP = 67 Kb

  minimum distance between 2 SNP = 28 Kb

- **each chromosome carries**

  - 10, 30 or 60 QTL for trait 1

  - 10, 30 or 60 QTL for trait 2

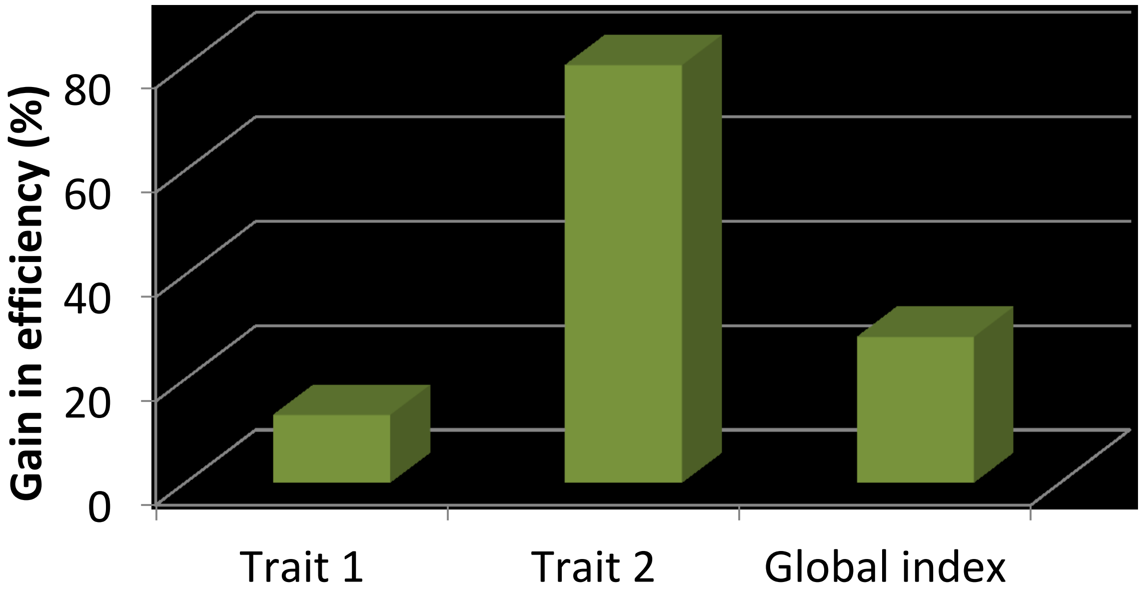
the 2 traits are genetically independent at the beginning

Tribout et al (2012; 2013)

Genomic selection in pigs

Genomic selection in a sire line : a simulation study

Response to selection

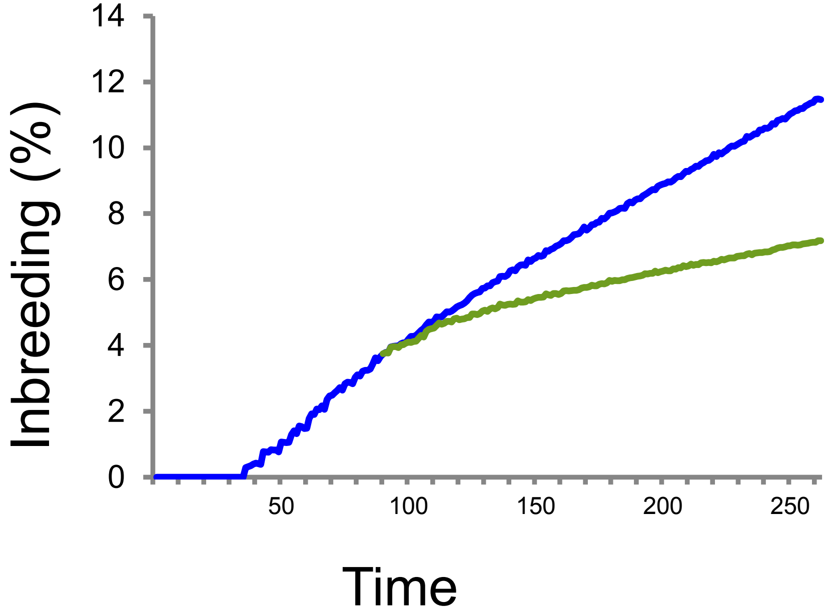


Tribout et al (2012; 2013)

Genomic selection in pigs

Genomic selection in a sire line : a simulation study

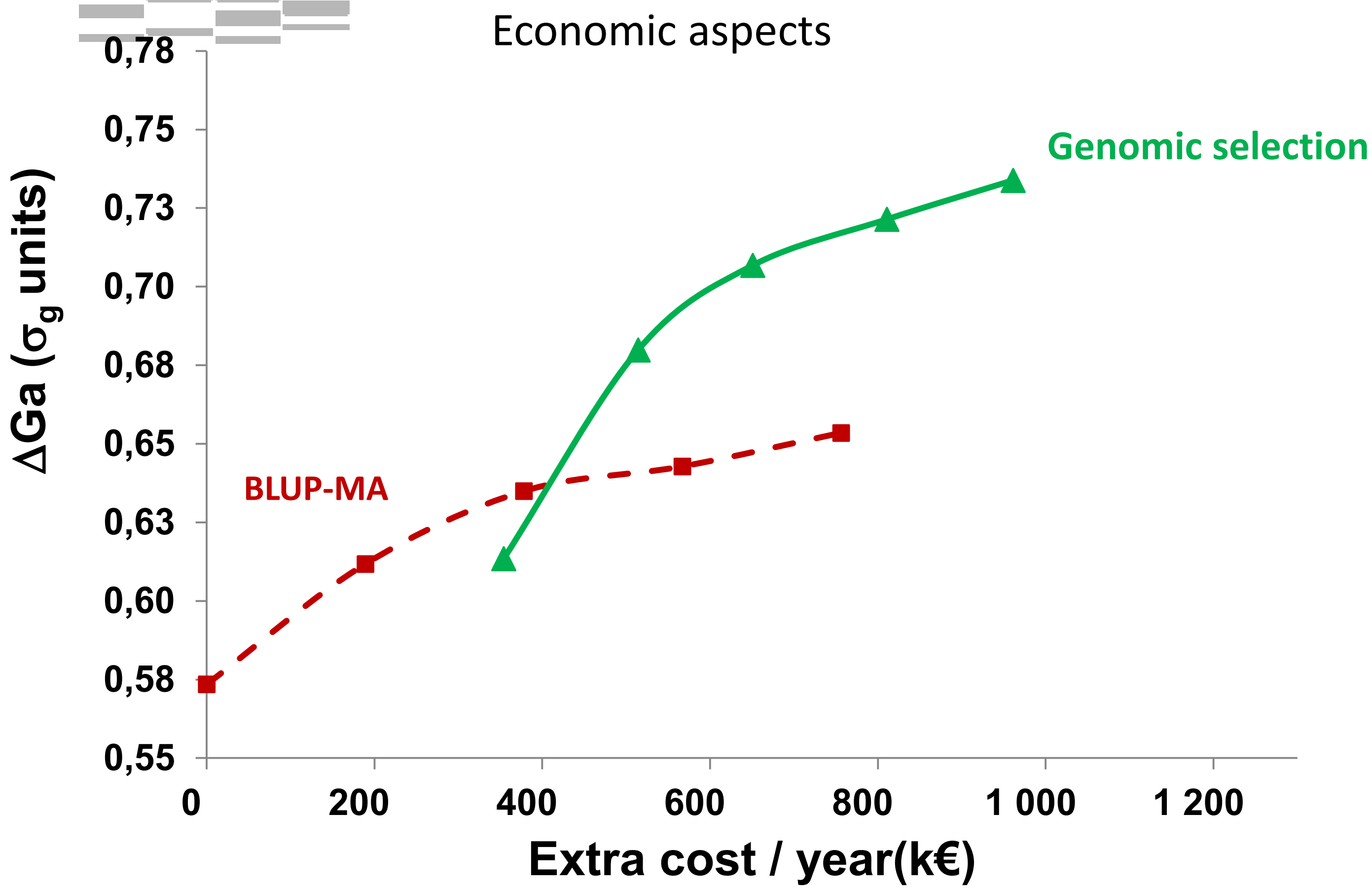
Inbreeding



Tribout et al (2012; 2013)

Genomic selection in pigs

Genomic selection in a sire line : a simulation study



Tribout et al (2012; 2013)

Genomic selection : potential use in pigs

- New goals / criteria that are difficult to measure
  - Feed intake, manure production
  - Behaviour
  - Health
  - ,…

➔ Major interest for the selection of such traits

➔ But their economic interest and their genetic architecture has to be known before integrating them in selection schemes

Genomic selection : potential use in pigs

Other potential interest of genomic selection :

Select populations for crossbreeding

Current principle : « Improving purebred performances also increases performances in crossbreeding »

BUT : Performance at the selection level ≠ performance at the commercial level (rg [0,4 à 0,9])

Genetic trend commercial level ≤ Genetic trend selection level

Genomic selection : potential use in pigs

Hypothesis :

1. Reference population of crossbred pigs »
   - phenotyping and genotyping with SNP microarray
   - estimation of chromosomal fragment effects on phenotypes

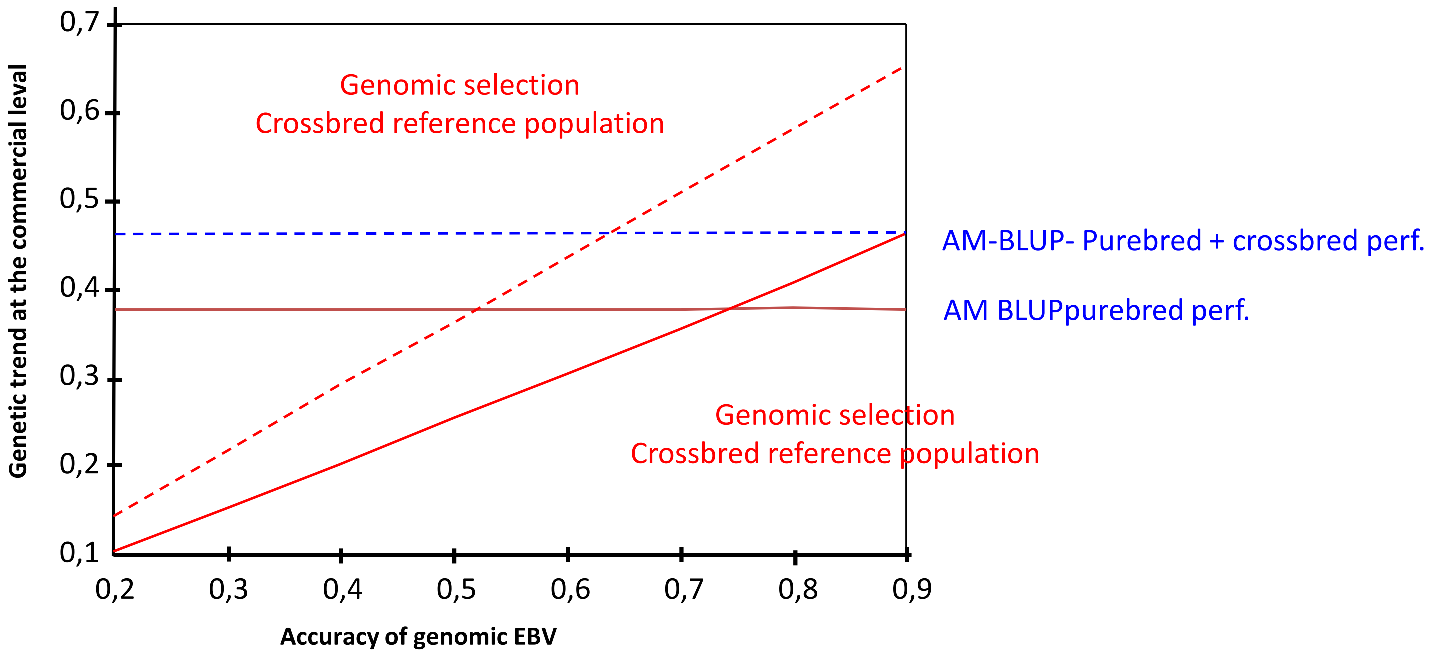
2. Genotyping purebred candidates
   - Computing EBV from the crossbred reference population
   - NO NEED TO COLLECT PEDIGREE INFORMATION

➤ Higher genetic trend at the commercial level

Genomic selection : potential use in pigs

h² purebred performance (PP) = h² crossbred performance (CP) = 0,4

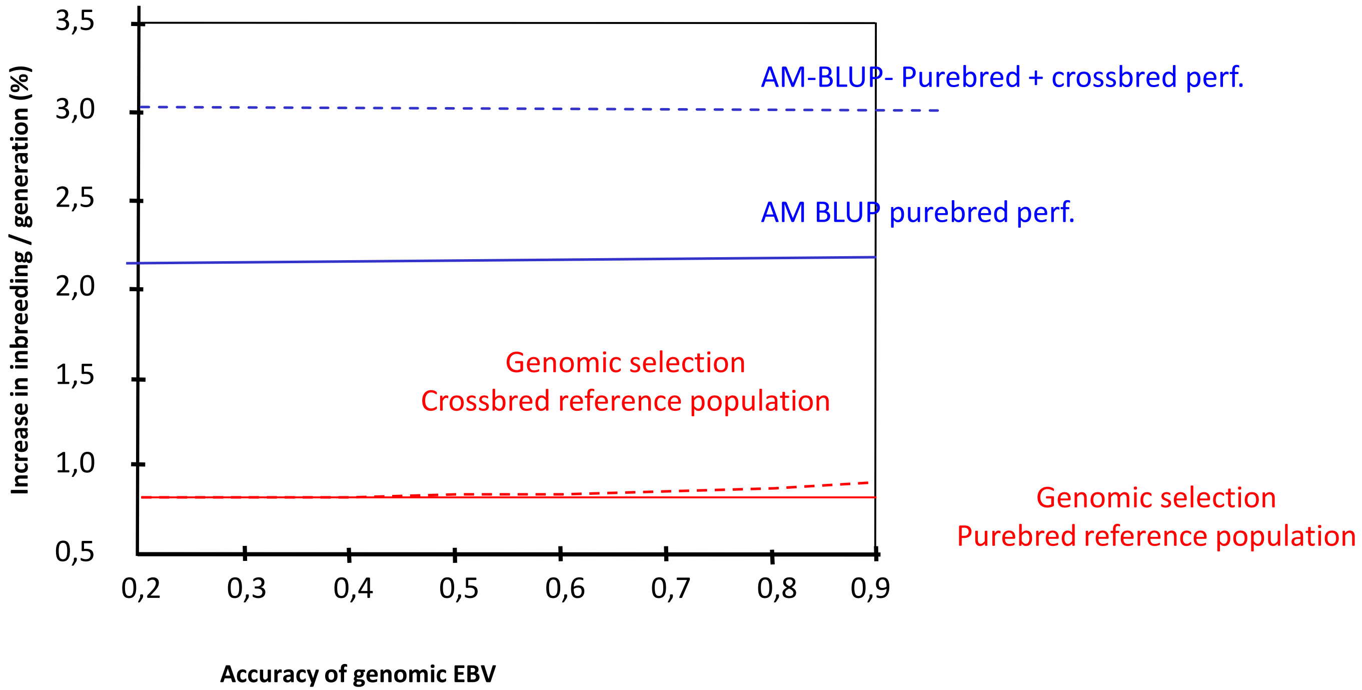
Genetic correlation (PP, CP) = 0,7



From Dekkers, 2007

Genomic selection : potential use in pigs

Genomic selection : impact on inbreeding



AM-BLUP : High weight of family information ≠ Genomic selection : Selection on individual genotype

From Dekkers, 2007

Single step genomic BLUP

$$y = Xb + Wu + e$$

$$Var(u) = H \otimes G_0 \qquad Var(e) = I \otimes R_0$$

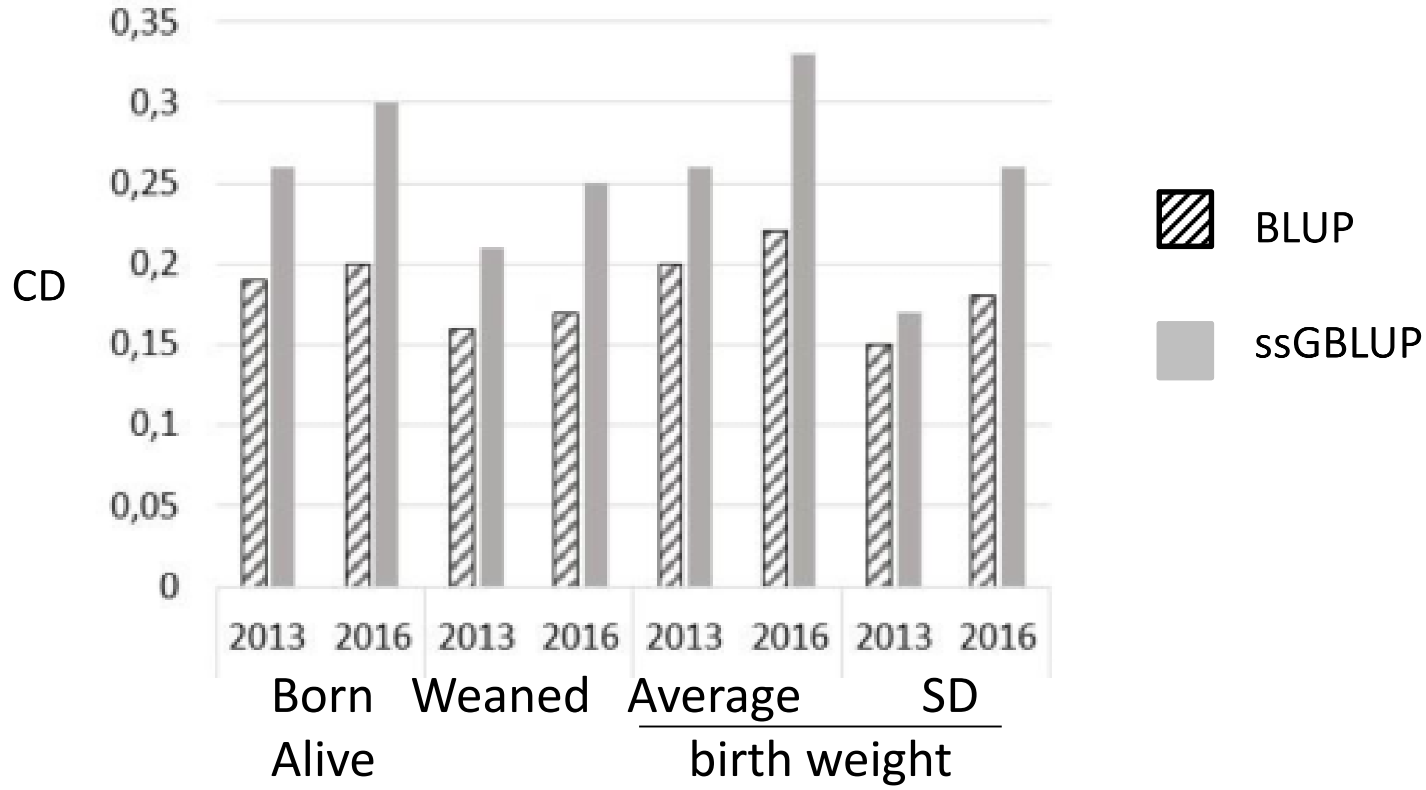
H

$$\begin{bmatrix} X'R^{-1}X & X'R^{-1}W \\ W'R^{-1}X & W'R^{-1}W + H^{-1} \otimes G_0 \end{bmatrix} \begin{bmatrix} \hat{b} \\ \hat{u} \end{bmatrix} = \begin{bmatrix} X'R^{-1}y \\ W'R^{-1}y \end{bmatrix}$$

H genomic relationship matrix

See e.g. Legarra et al., 2014, Livest. Sci. 166:54-65

Use of Single step genomic BLUP In French Landrace breed



Bouquet et al., 2017, J. Rech. Porc 49: 31-36

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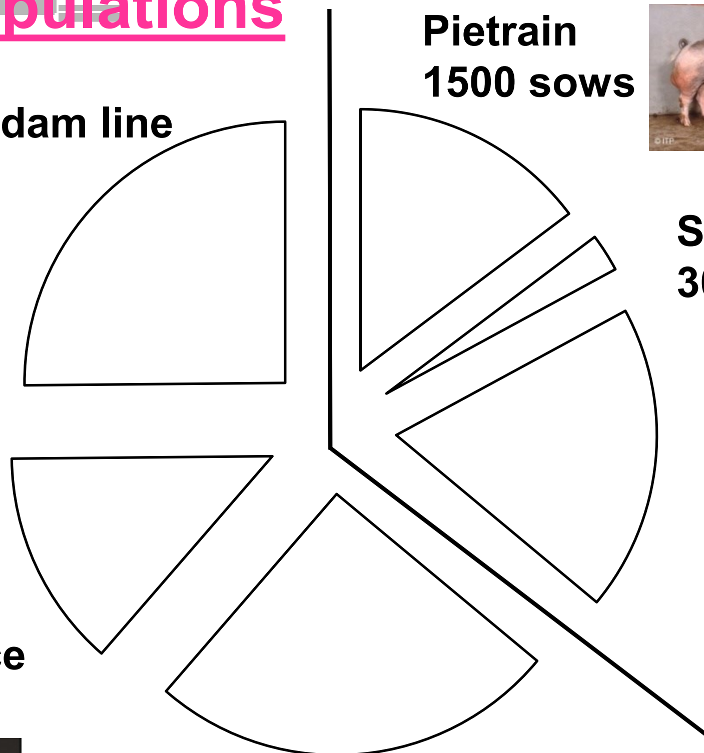
Example of the French breeding scheme

Selection : pure breeds and lines

Dam type populations

Sire type pop.



(Source : IFIP – Le porc par les chiffres

Commercial level : crossbred slaughter pigs

Most frequent crossbreeding system in France

Piétrain

Landrace

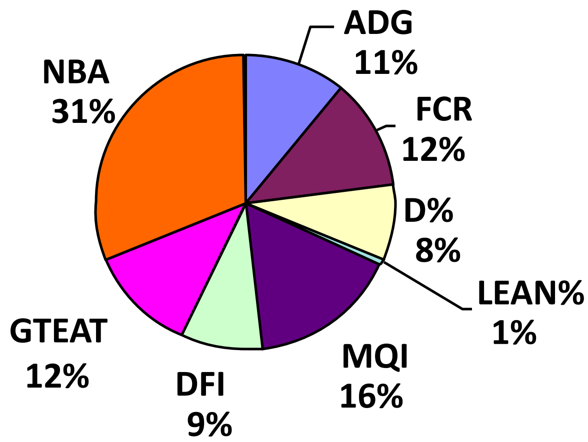
Large White

LW x LF sow

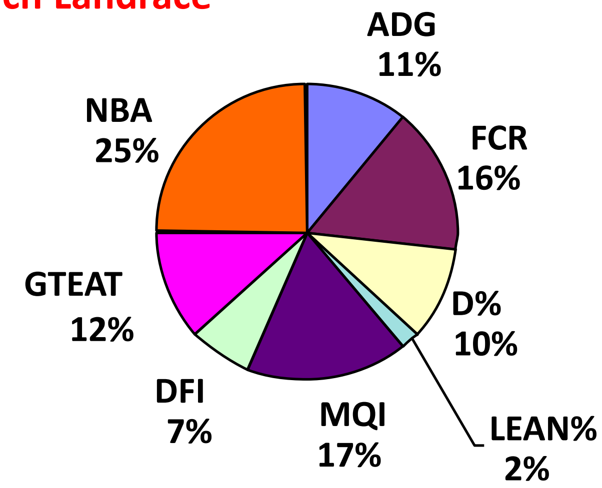
Slaughter pig

The French national pig breeding scheme
Breeding goal (2010 – 2014)

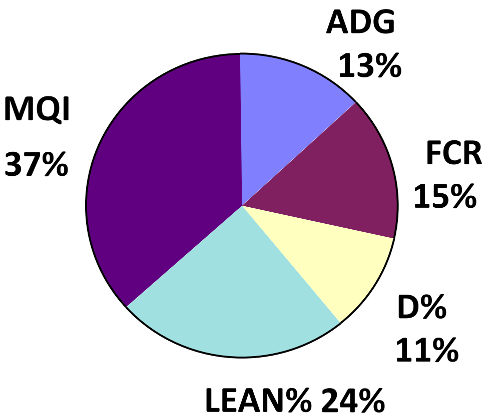
Large White – dam line



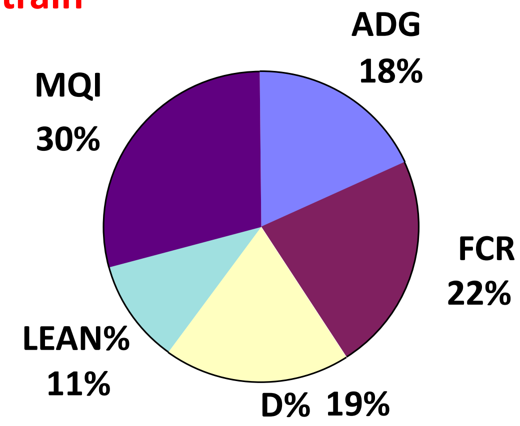
French Landrace



Large White – sire line



Piétrain

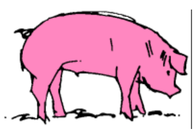


The French national pig breeding scheme

on-farm performance test

production traits

Young male and female candidates



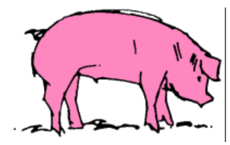
- age at 100 Kg
- backfat thickness at 100 Kg
- Loin depth (male lines)
- (Meat quality)

« reproduction » traits

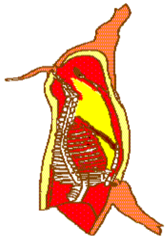
- numbers of live born piglets
- number of functional teats

station performance test

slaughtered sibs from young candidate males



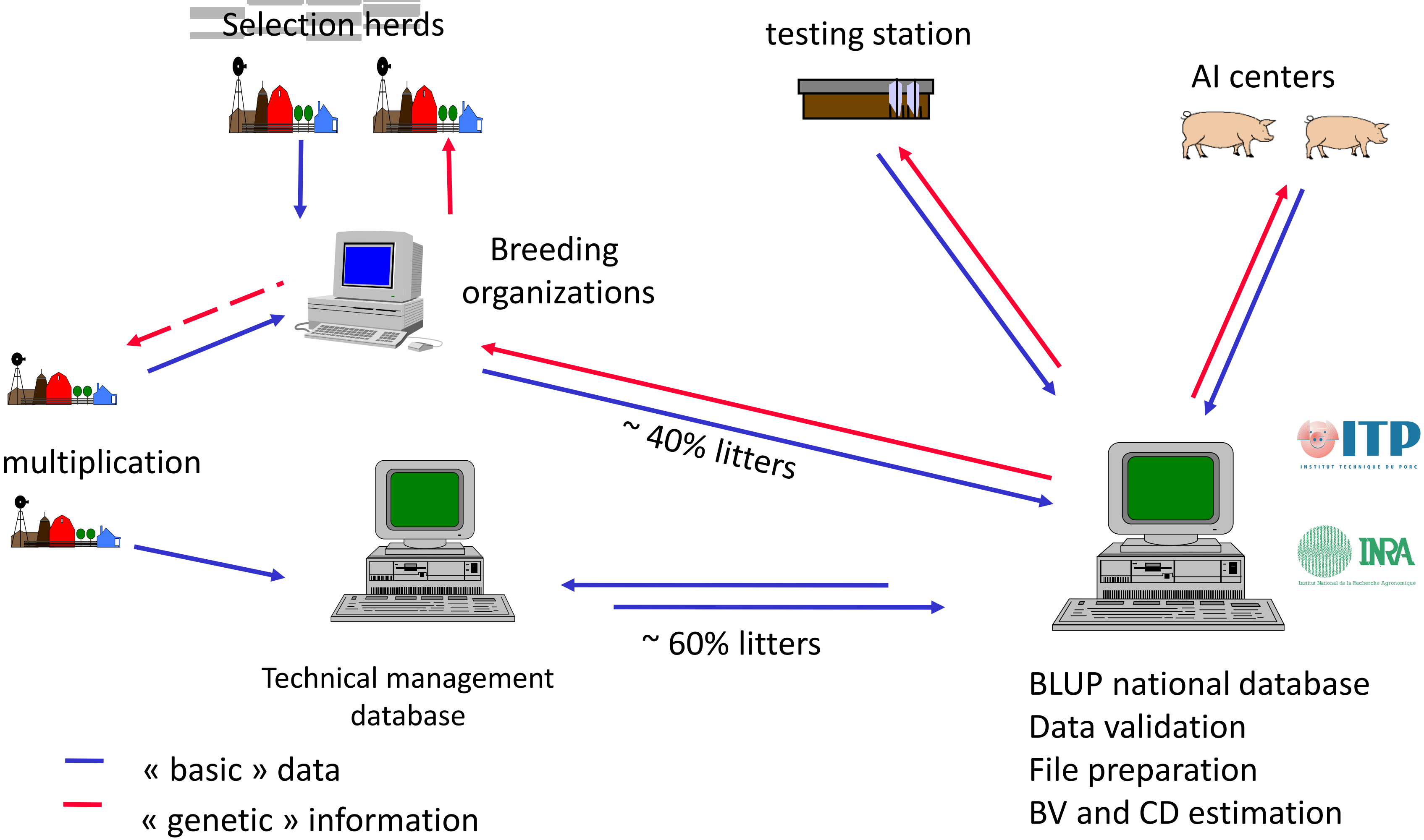
- average daily gain
- daily feed intake
- feed conversion ratio



- dressing percentage
- carcass lean content
- meat quality index

The French national pig breeding scheme

Information flow



The French national pig breeding scheme

Genetic evaluation

- Based on animal model – BLUP (until 2016) – Single step genomic selection since 2016

- Evaluation performed independently in each population

- Joint evaluation for production and reproduction traits

- Evaluation performed every week

- Performed by IFIP (French Pig Institute)

National genetic evaluation of pigs
Combined EBVs

EBVs for each trait are combined as follows :

EBV (ADG)
EBV (FCR) → "growth"

EBV (D%)
EBV (MU%) → "carcass"

EBV (MQI)

"growth" + "carcass" + EBV (MQI) → global EBV (male lines)

global EBV (male lines) + EBV (NBA), EBV (GTEAT), EBV (DFI) → global EBV (female lines)

National genetic evaluation of pigs
Results sent to breeders

- after each evaluation :

    Growth, carcass and reproduction EBVs + accuracies

    - of all boars and sows of the herd
    - of all AI boars
    - of young males and females tested on farm

- every six months :

    Estimated genetic trends (per breed, herd, sex)

    Estimated breeding values of pigs sent to multiplication herds

    Elements on Connectedness, management of genetic variability