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Genetic improvement of pig : fertility, litter size and piglet viability

---

Luis Varona

ITM 17

MAY 2025 - ZARAGOZA

Pig Breeding

Piramidal Scheme

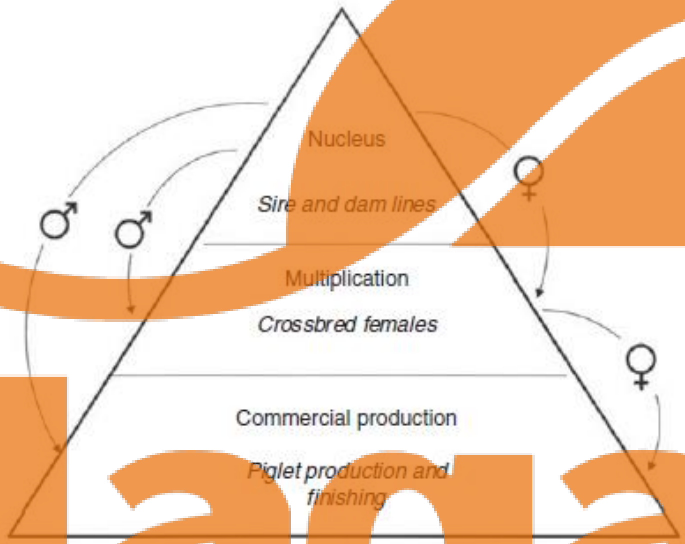
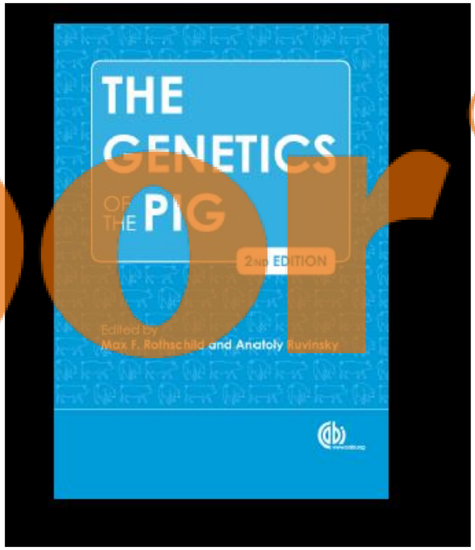


Fig. 16.2. Pig breeding pyramid.



THE GENETICS OF THE PIG

2ND EDITION

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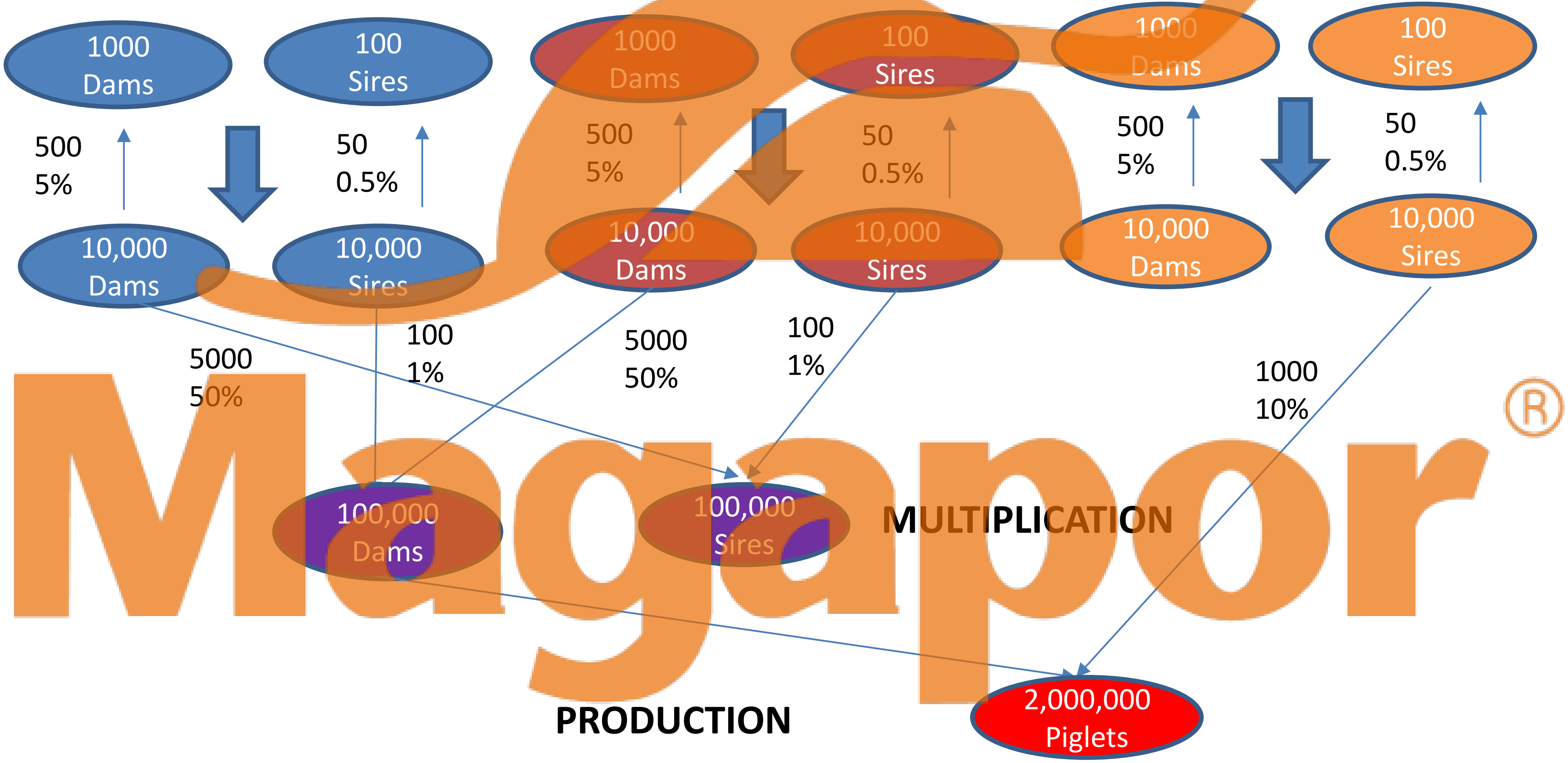
Pig Breeding Pyramid



1000 Dams

100 Sires

500 5%

50 0.5%

10,000 Dams

10,000 Sires

1000 Dams

100 Sires

500 5%

50 0.5%

10,000 Dams

10,000 Sires

1000 Dams

100 Sires

500 5%

50 0.5%

10,000 Dams

10,000 Sires

5000 50%

100 1%

5000 50%

100 1%

1000 10%

100,000 Dams

100,000 Sires

MULTIPLICATION

PRODUCTION

2,000,000 Piglets

Selection of pure lines

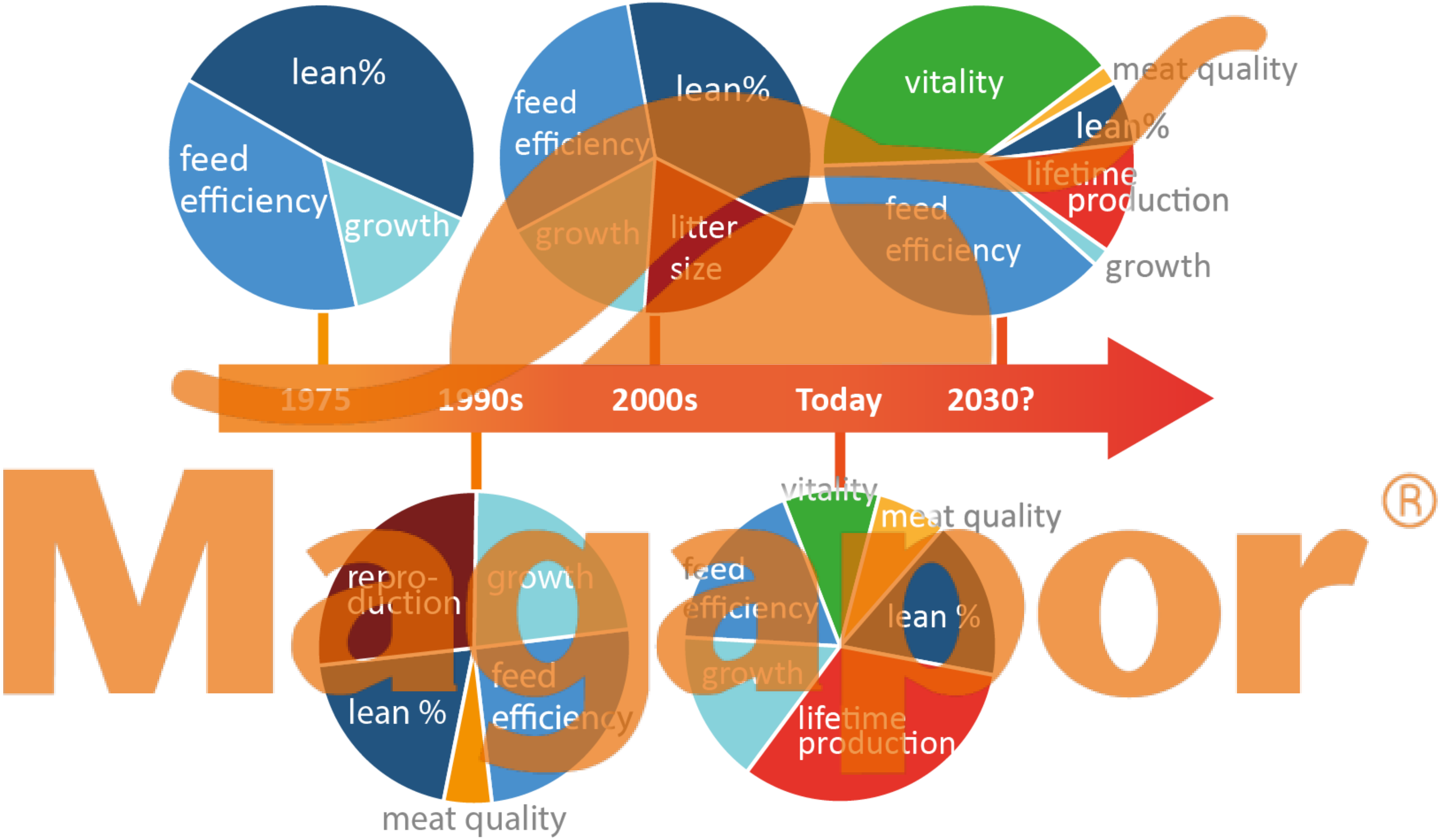
Paternal Lines (Terminal Sire)

- Growth
- Feed Conversion Ratio
- % Lean
- Killing out percentage
- Meat Quality

Selection of pure lines

Maternal Lines

- Growth
- Feed Conversion Ratio
- % Lean
- Killing out percentage
- Meat Quality
- Maternal Traits (litter Size, piglet survival, longevity…)



https://gb.pic.com/resources/never-stop-improving-genetic-improvement-in-the-pig-industry/

Response to Selection (R)

$$R = \frac{i \times r(u,\hat{u}) \times \sigma_u}{L}$$

i : Intensity of Selection

$r(u,\hat{u})$: Accuracy

σ_u: Genetic Standard Deviation

L: Generation Interval

Response to Selection (R)

$$R = \frac{i \times r(u,\hat{u}) \times \sigma_u}{L}$$

i : Intensity of Selection Very high

$r(u,\hat{u})$: Accuracy

σ_u: Genetic Standard Deviation

L: Generation Interval

Response to Selection (R)

$$R = \frac{i \times r(u,\hat{u}) \times \sigma_u}{L}$$

i : Intensity of Selection

$r(u,\hat{u})$: Accuracy

σ_u: Genetic Standard Deviation Population Specific

L: Generation Interval

Response to Selection (R)

$$R = \frac{i \times r(u,\hat{u}) \times \sigma_u}{L}$$

i : Intensity of Selection

$r(u,\hat{u})$: Accuracy

σ_u: Genetic Standard Deviation

L: Generation Interval

Low

Response to Selection (R)

$$R = \frac{i \times r(u,\hat{u}) \times \sigma_u}{L}$$

i : Intensity of Selection

$r(u,\hat{u})$: Accuracy
- Heritability
- Phenotypic information (own and from relatives)
- Genomic information

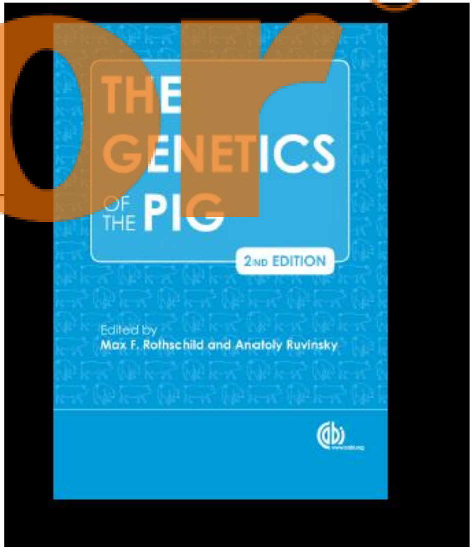
σ_u: Genetic Standard Deviation

L: Generation Interval

Heritability

Table 10.3. Heritability (h^2) estimates for female and male reproductive traits in the pig. Adapted from Rothschild and Bidanel (1998).

	Trait	No. of estimates	Mean h^2	Range
Female traits	Age at puberty	16	0.37	0–0.73
	Oestrus symptoms	3	0.21	0.09–0.29
	Ovulation rate	18	0.32	0.10–0.59
	Conception rate	3	0.10	0–0.29
	Prenatal survival rate	12	0.15	0–0.23
	Total number born	103	0.11	0–0.76
	Number born alive	118	0.10	0–0.66
	Number weaned	54	0.08	0–1.0
	Farrowing survival rate	12	0.07	0.03–0.14
	Birth to weaning survival rate	12	0.05	0–0.13
	Farrowing length	2	0.07	0.05–0.10
	Litter homogeneity at birth	6	0.08	0.03–0.1
	Litter weight at birth	18	0.24	0–0.54
	Birth assistance	2	0.05	0.05
	Litter weight at 21 days	22	0.14	0.07–0.38
	Weaning to oestrus interval	5	0.22	0.11–0.36
	Rebreeding interval	3	0.23	0.03–0.36
Male traits	Testis width	8	0.37	0.02–0.61
	Testis weight	5	0.44	0.24–0.73
	Semen volume	6	0.19	0.14–0.25
	Sperm concentration	6	0.19	0.13–0.26
	Sperm motility	6	0.11	0.06–0.18
	% Abnormal sperm	4	0.10	0.06–0.17
	Libido	13	0.15	0.03–0.47



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Response to Selection (R)

$$R = \frac{i \times r(u,\hat{u}) \times \sigma_u}{L}$$

i : Intensity of Selection

$r(u,\hat{u})$: Accuracy

- **Heritability (Generally Low)**
- Phenotypic information (own and from relatives)
- Genomic information

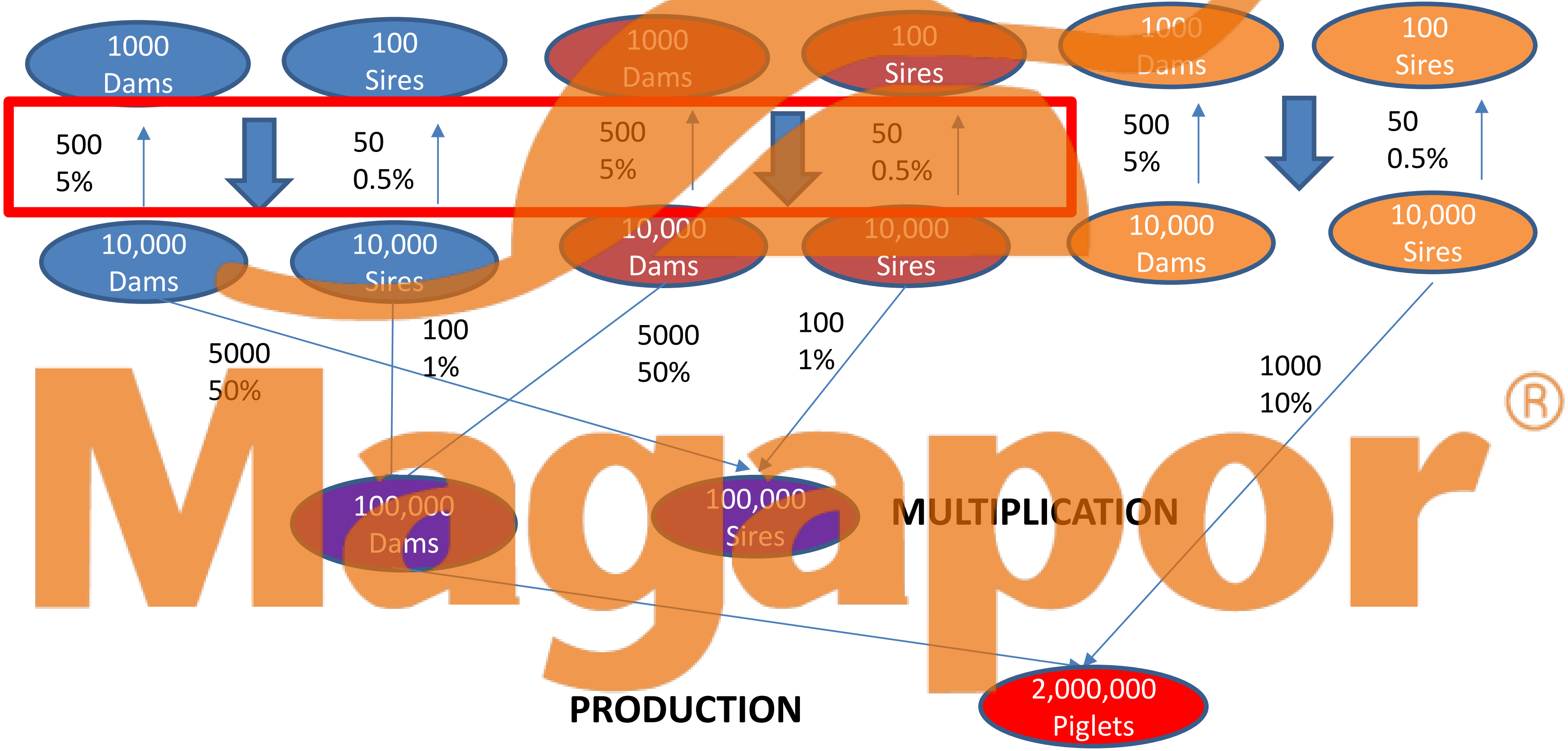
σ_u: Genetic Standard Deviation

L: Generation Interval

Phenotypic Information

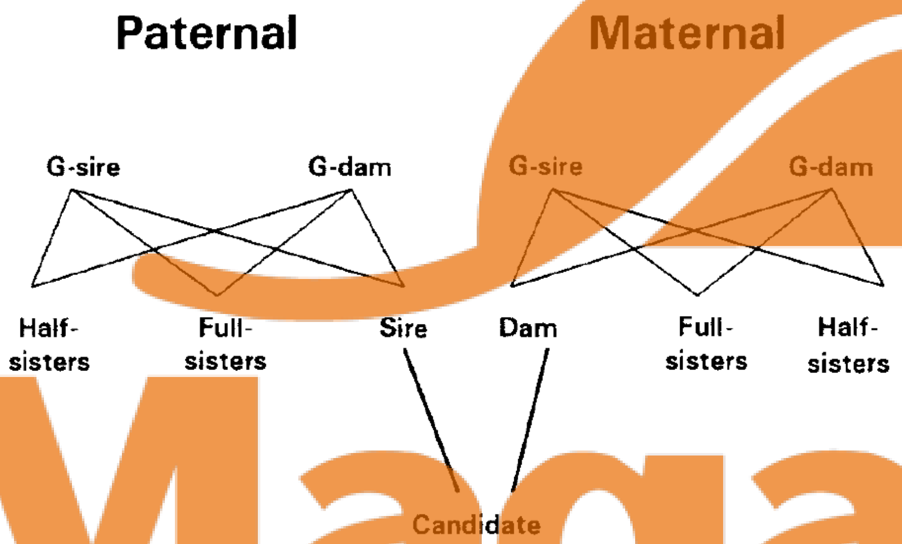
Magapor®

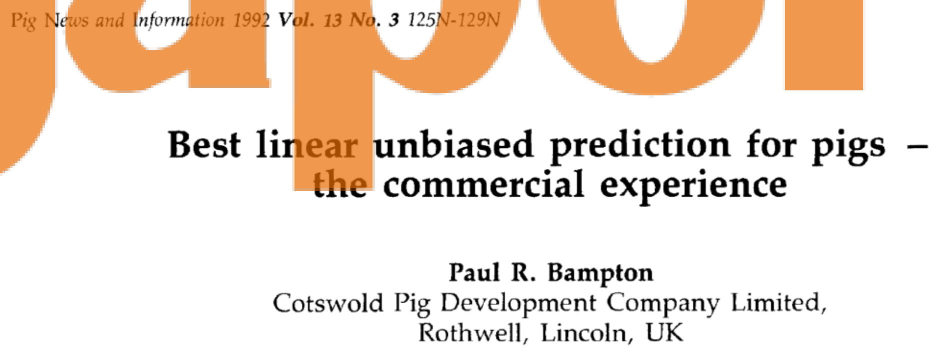
3 way- Piramidal Scheme



Phenotypic Information

Relatives Phenotypic Information

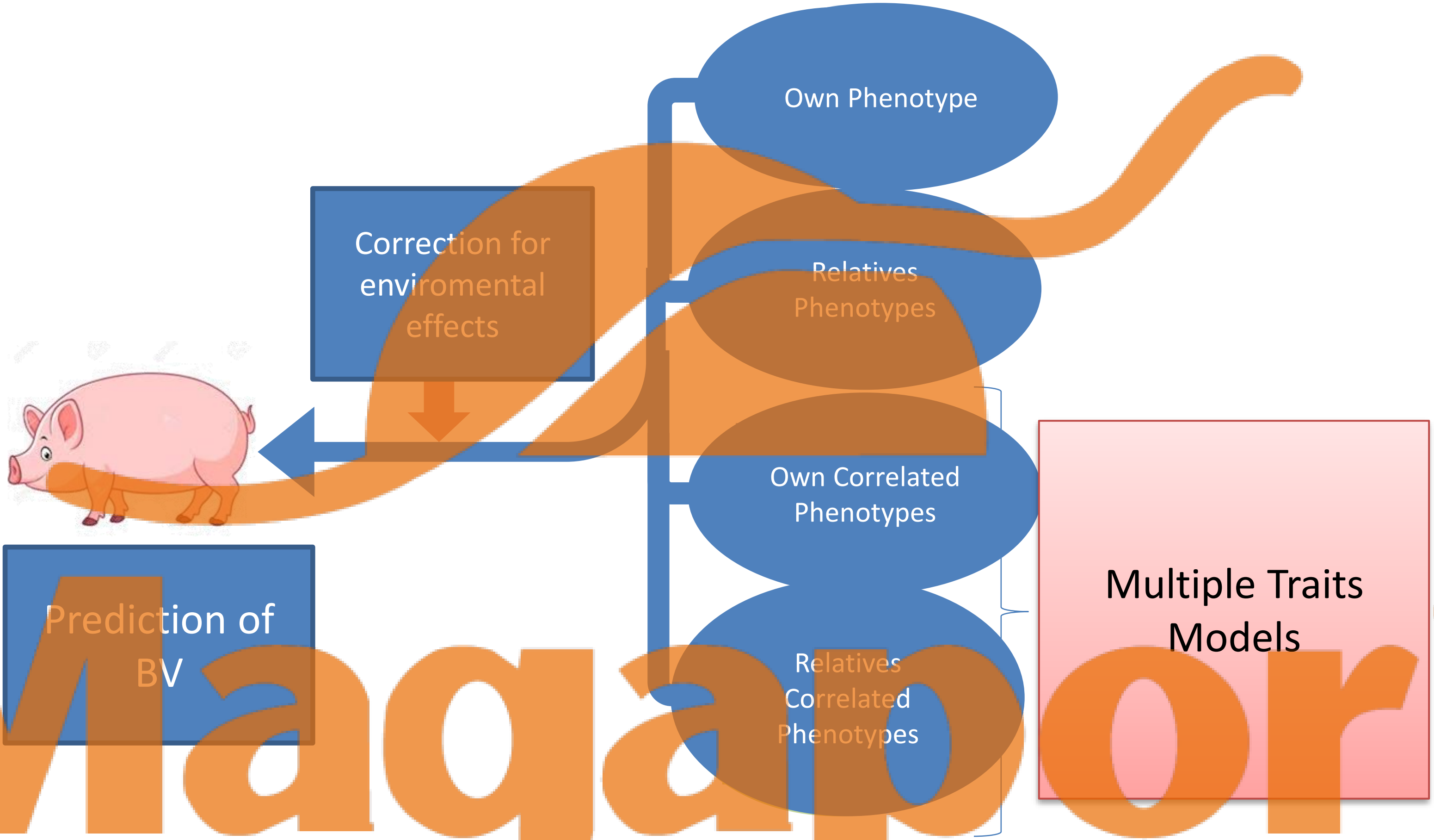



Pig News and Information 1992 Vol. 13 No. 3 125N-129N

Best linear unbiased prediction for pigs – the commercial experience

Paul R. Bampton
Cotswold Pig Development Company Limited,
Rothwell, Lincoln, UK

Phenotypic Information



Own Phenotype

Relatives Phenotypes

Own Correlated Phenotypes

Relatives Correlated Phenotypes

Correction for enviromental effects

Prediction of BV

Multiple Traits Models

$$\mathbf{y} = \mathbf{X}\mathbf{b} + \mathbf{Z}\mathbf{u} + \mathbf{e}$$

$$\begin{bmatrix} \hat{\mathbf{b}} \\ \hat{\mathbf{u}} \end{bmatrix} = \begin{bmatrix} \mathbf{X}'\mathbf{X} & \mathbf{X}'\mathbf{Z} \\ \mathbf{Z}'\mathbf{X} & \mathbf{Z}'\mathbf{Z} + \mathbf{A}^{-1}\dfrac{\sigma_e^2}{\sigma_u^2} \end{bmatrix}^{-1} \begin{bmatrix} \mathbf{X}'\mathbf{y} \\ \mathbf{Z}'\mathbf{y} \end{bmatrix}$$

Response to Selection (R)

$$R = \frac{i \times r(u,\hat{u}) \times \sigma_u}{L}$$

i : Intensity of Selection

$r(u,\hat{u})$: **Accuracy**

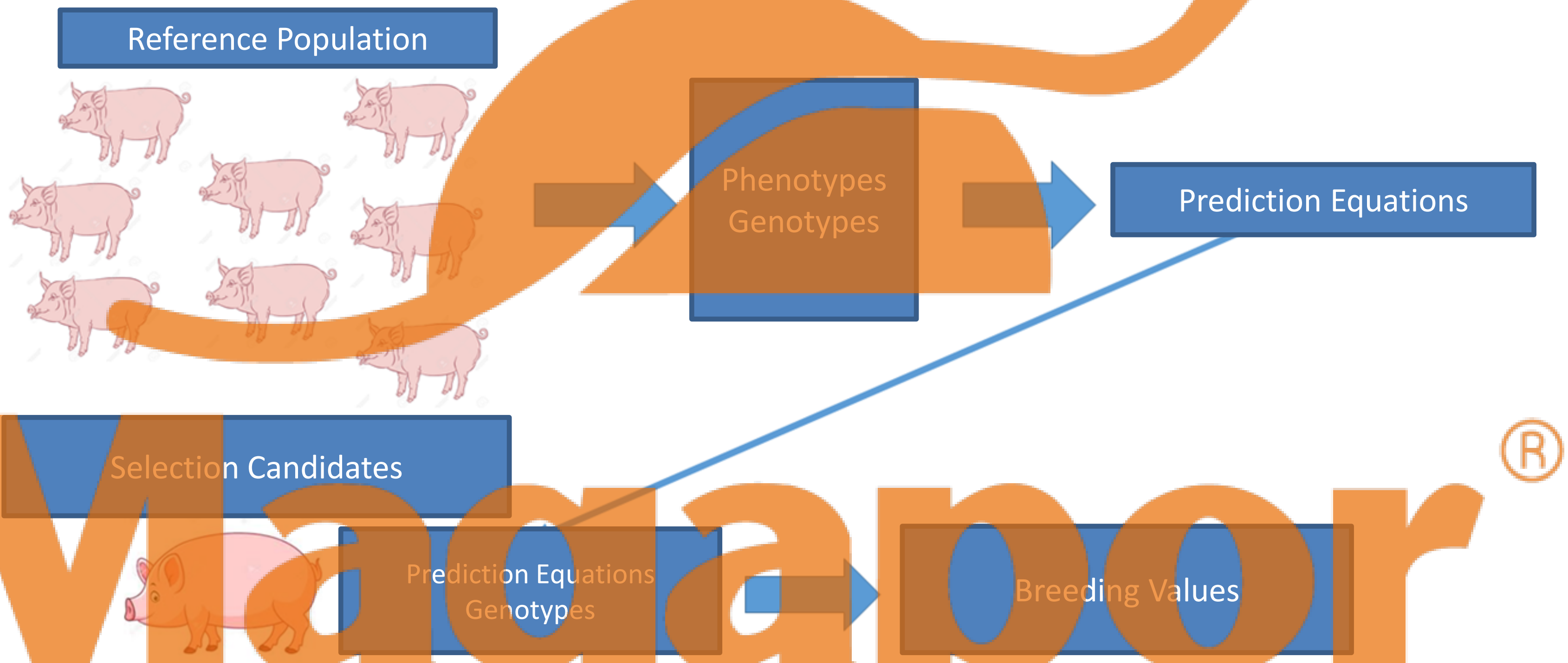
- **Heritability (Generally Low)**
- **Phenotypic information (ancestors, colaterals)**
- Genomic information

σ_u: Genetic Standard Deviation

L: Generation Interval

Genomic Selection

Genomic Selection



Reference Population

Phenotypes
Genotypes

Prediction Equations

Selection Candidates

Prediction Equations
Genotypes

Breeding Values

Genomic BLUP

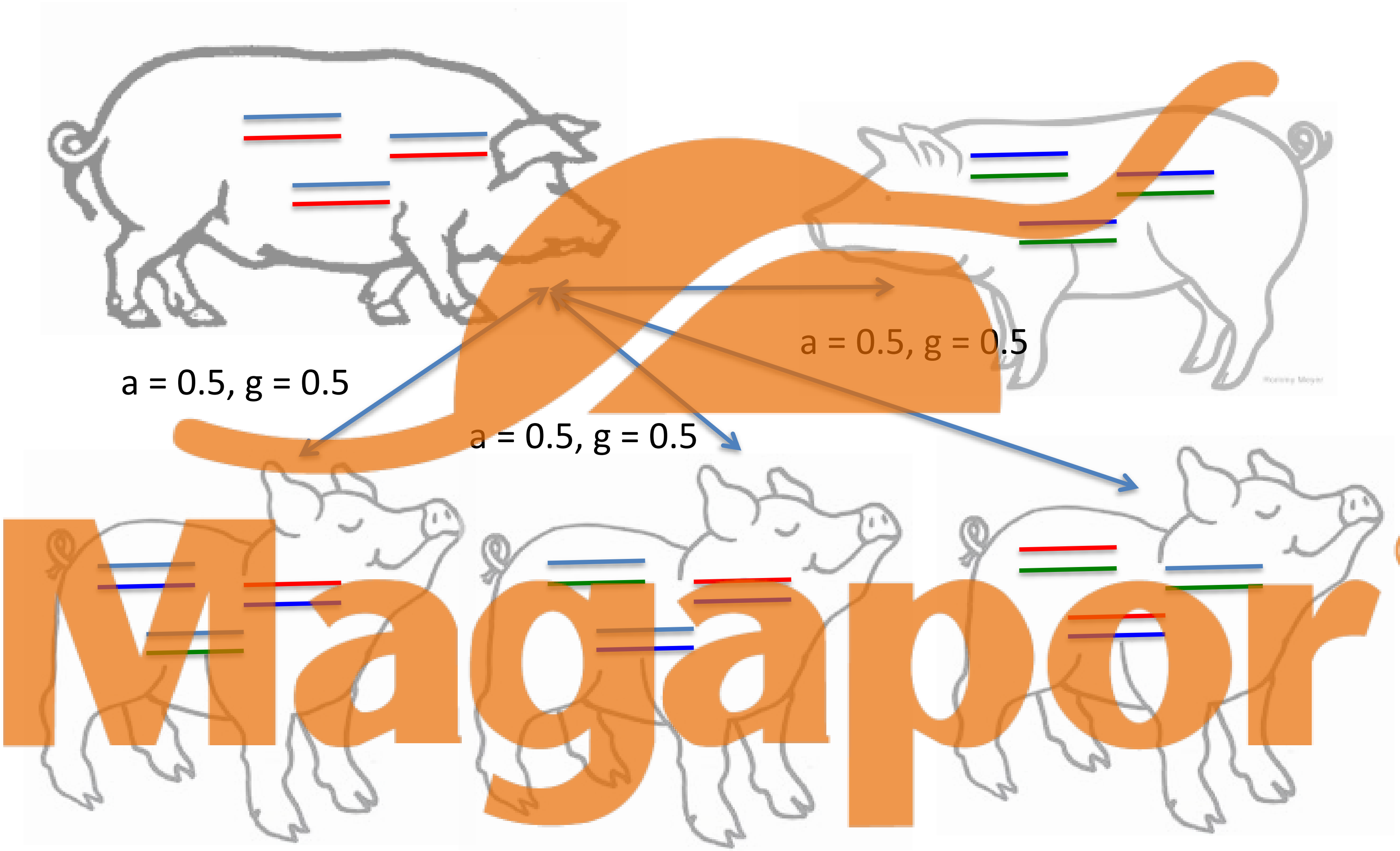
$$\mathbf{y} = \mathbf{Xb} + \mathbf{Zu} + \mathbf{e}$$

$$\begin{bmatrix} \hat{\mathbf{b}} \\ \hat{\mathbf{u}} \end{bmatrix} = \begin{bmatrix} \mathbf{X'X} & \mathbf{X'Z} \\ \mathbf{Z'X} & \mathbf{Z'Z} + \mathbf{A}^{-1}\dfrac{\sigma_e^2}{\sigma_u^2} \end{bmatrix}^{-1} \begin{bmatrix} \mathbf{X'y} \\ \mathbf{Z'y} \end{bmatrix}$$

$$\begin{bmatrix} \hat{\mathbf{b}} \\ \hat{\mathbf{u}} \end{bmatrix} = \begin{bmatrix} \mathbf{X'X} & \mathbf{X'Z} \\ \mathbf{Z'X} & \mathbf{Z'Z} + \mathbf{G}^{-1}\dfrac{\sigma_e^2}{\sigma_u^2} \end{bmatrix}^{-1} \begin{bmatrix} \mathbf{X'y} \\ \mathbf{Z'y} \end{bmatrix}$$

- G: Realized Relationship
- A: Expected Relationship

G vs A

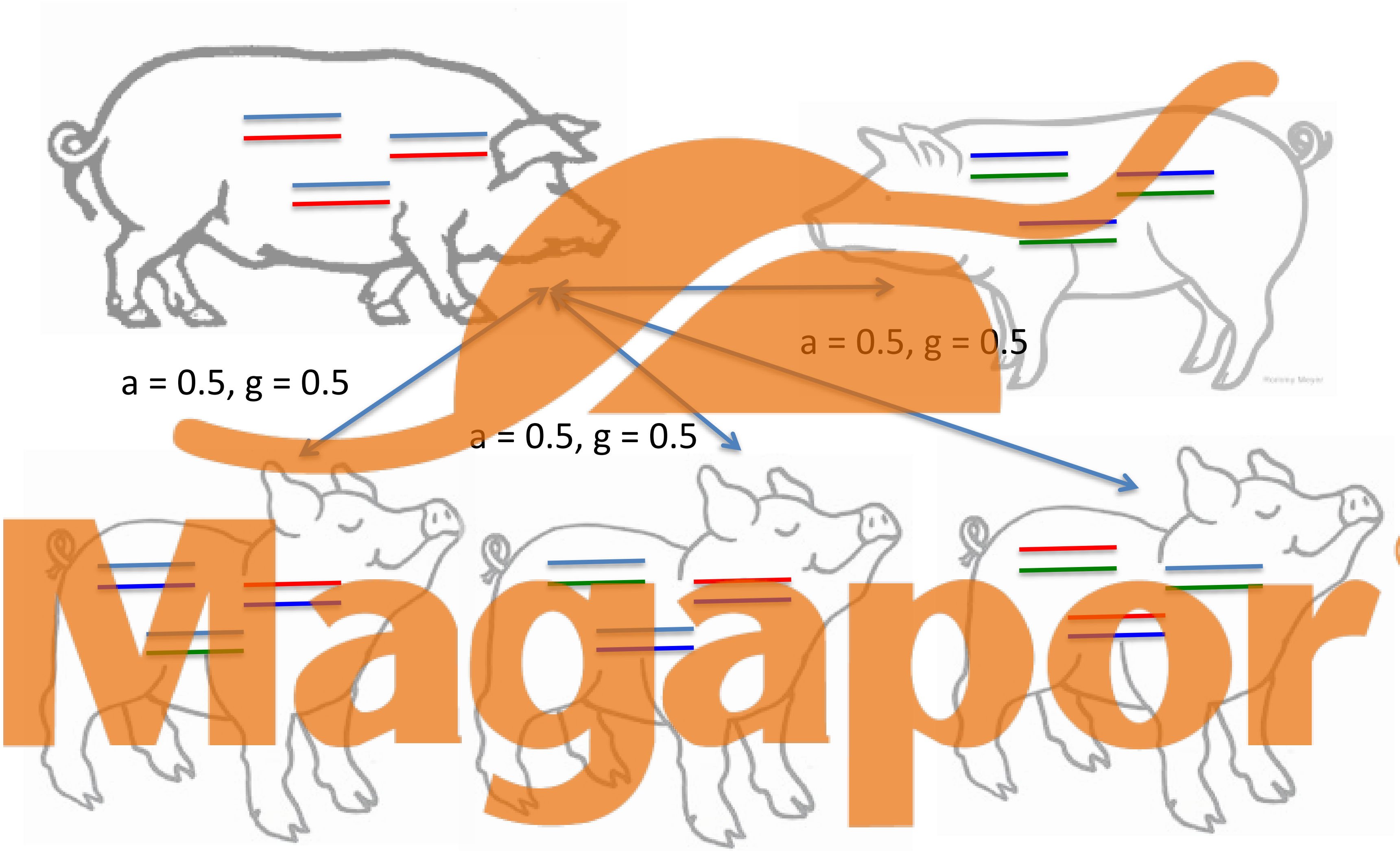


a = 0.5, g = 0.5

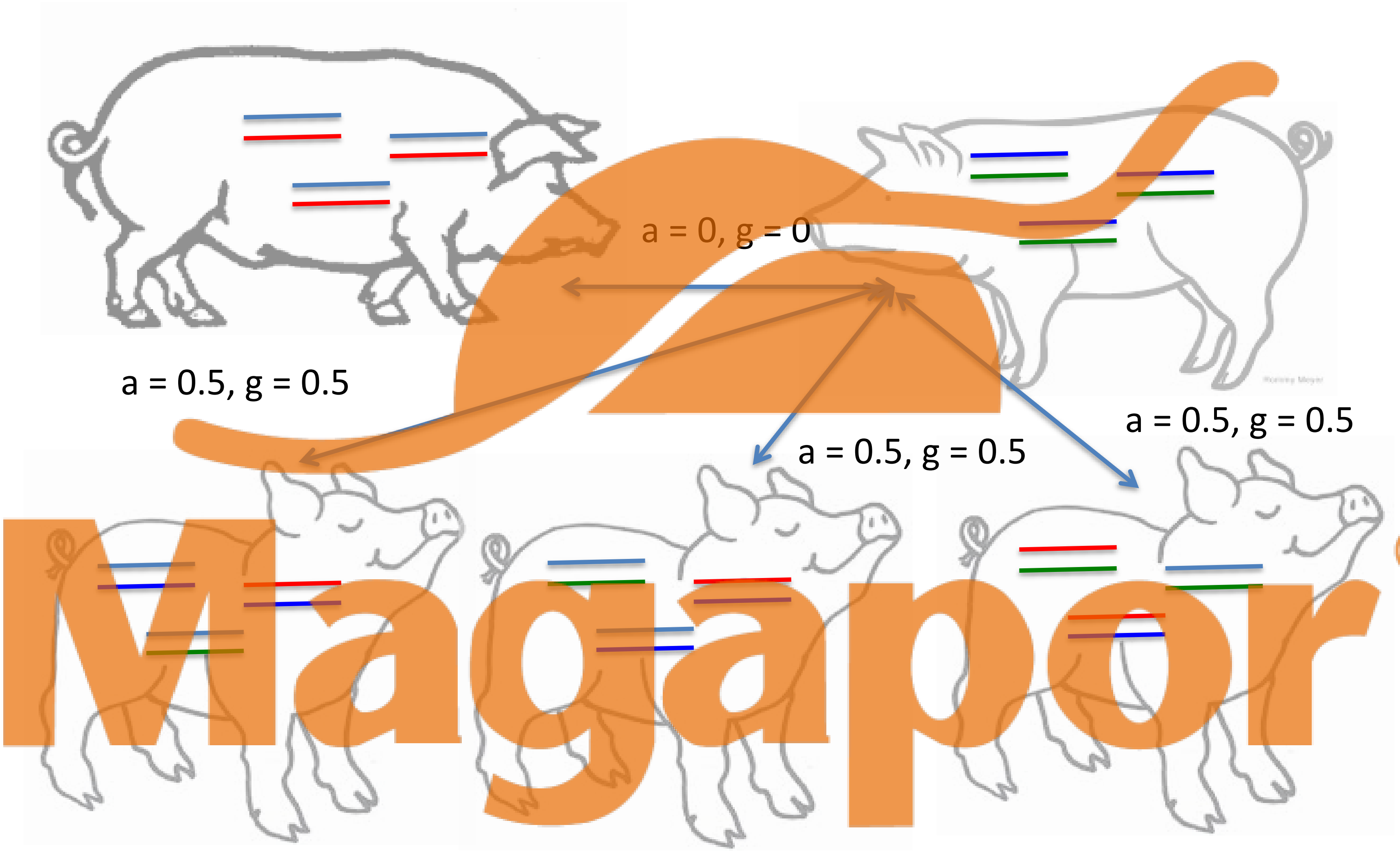
a = 0.5, g = 0.5

a = 0.5, g = 0.5

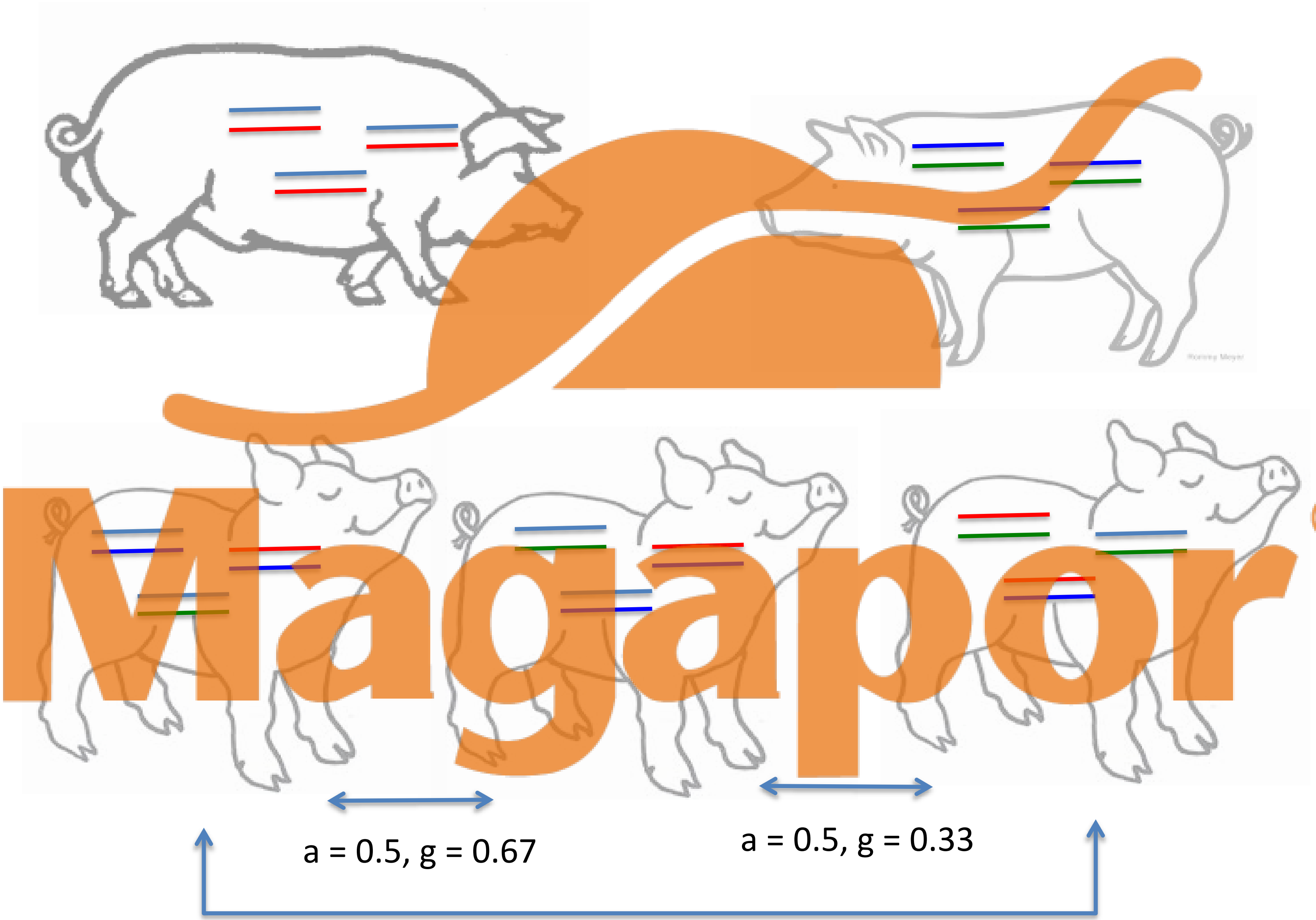
G vs A



G vs A



G vs A

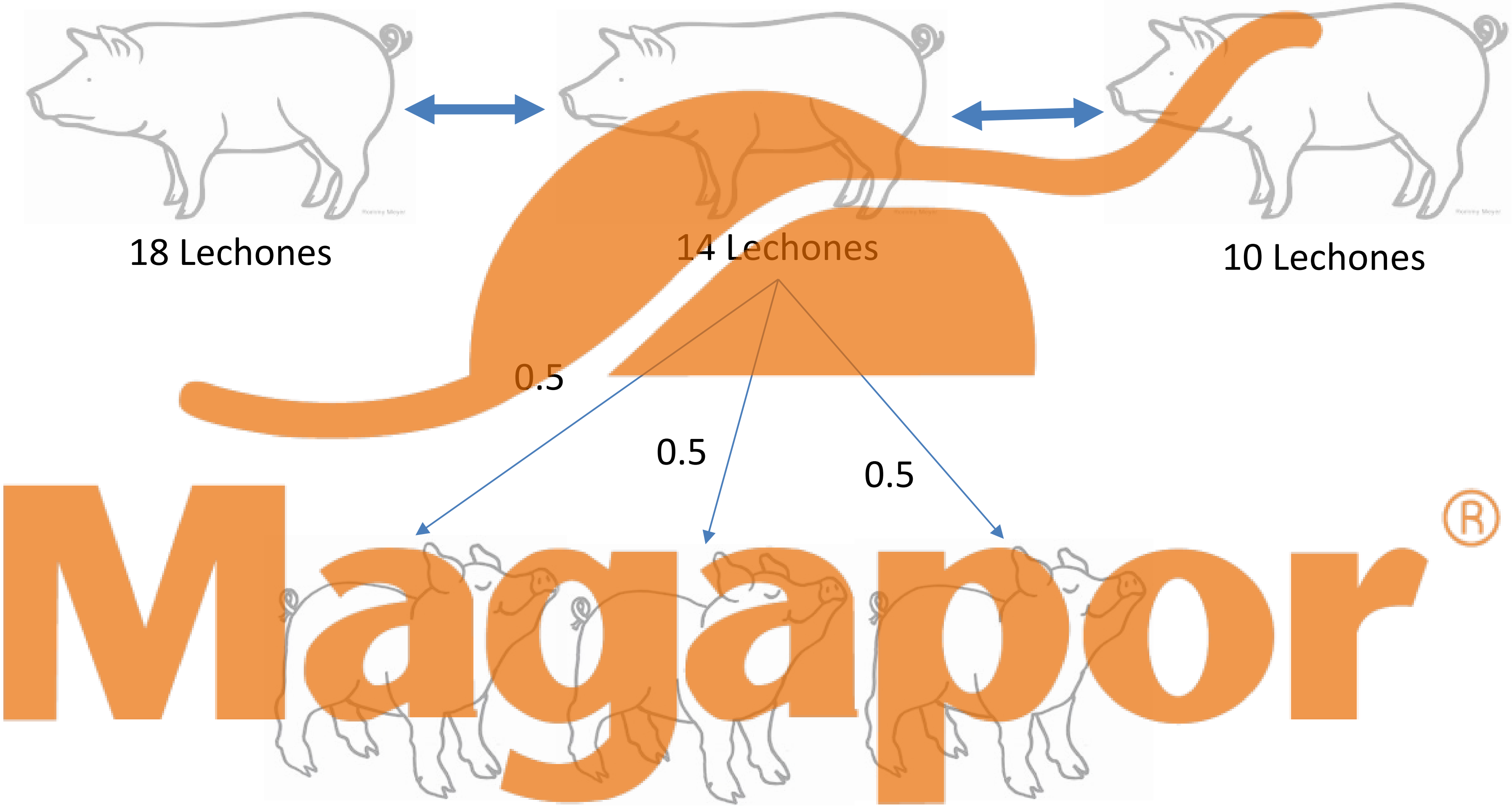


a = 0.5, g = 0.67

a = 0.5, g = 0.33

a = 0.5, g = 0.00

G vs A



18 Lechones

14 Lechones

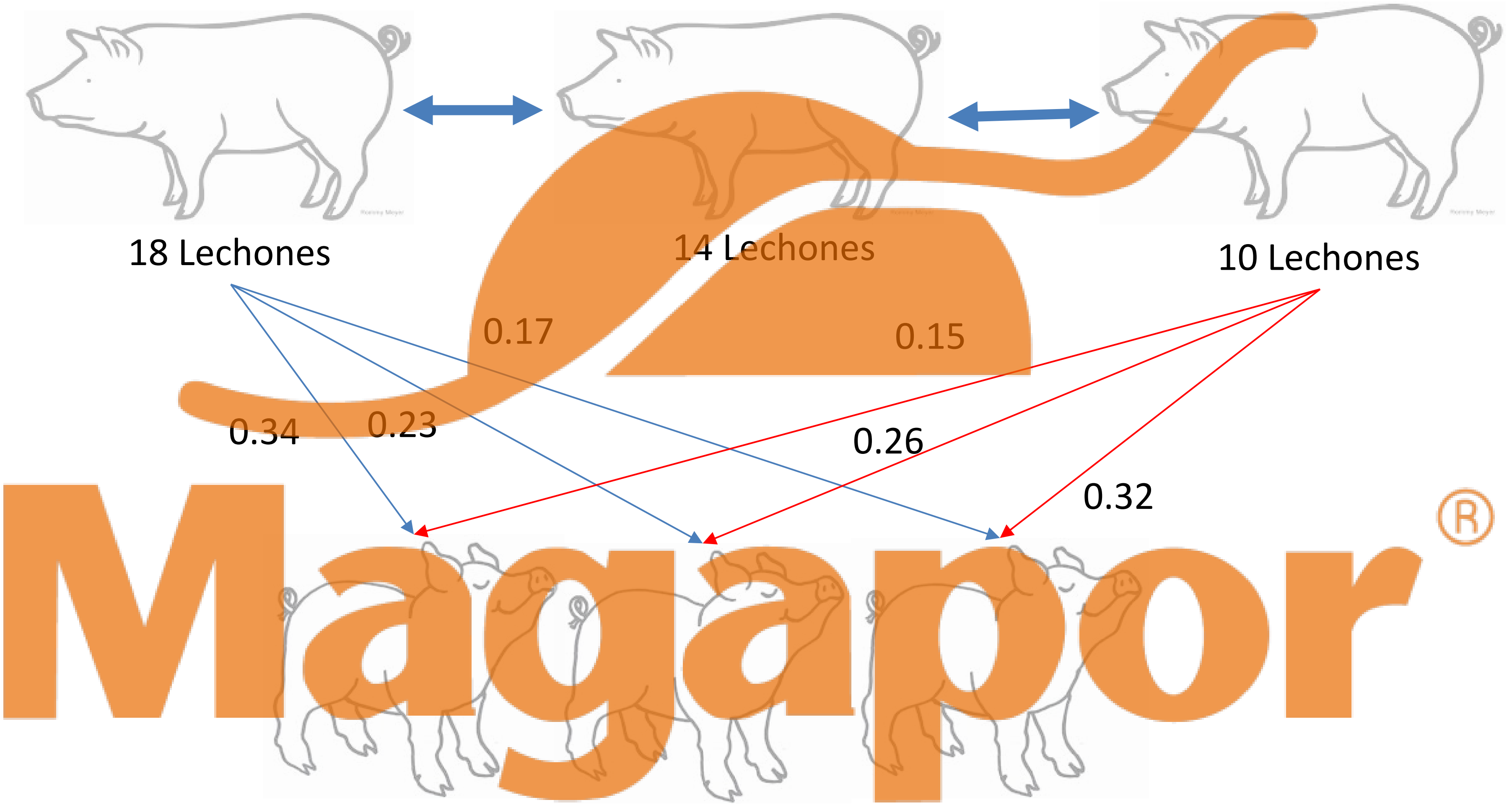
10 Lechones

0.5

0.5

0.5

G vs A



18 Lechones

14 Lechones

10 Lechones

0.17

0.15

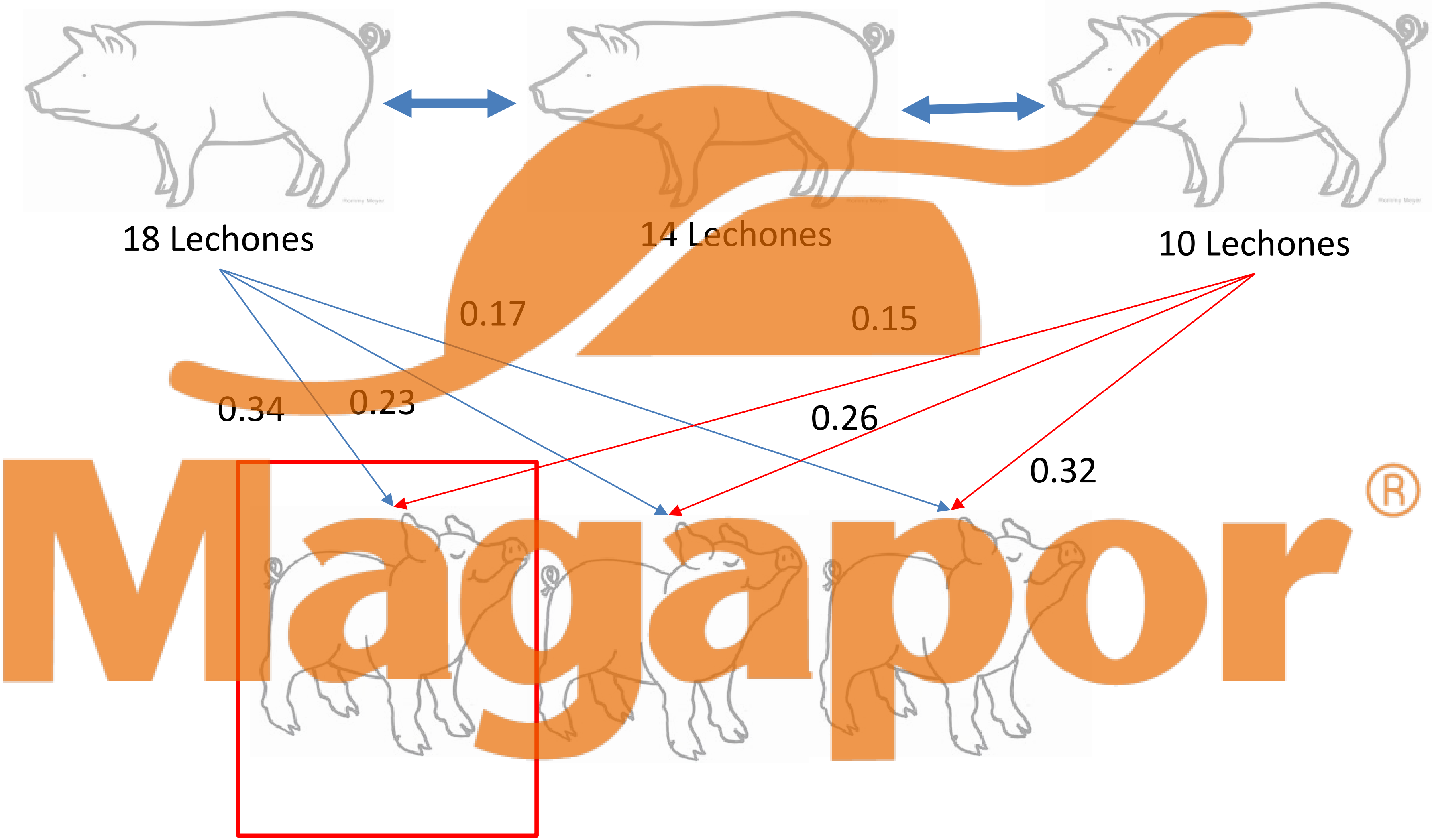
0.34

0.23

0.26

0.32

G vs A



Response to Selection (R)

$$R = \frac{i \times r(u,\hat{u}) \times \sigma_u}{L}$$

i : Intensity of Selection

$r(u,\hat{u})$: **Accuracy**

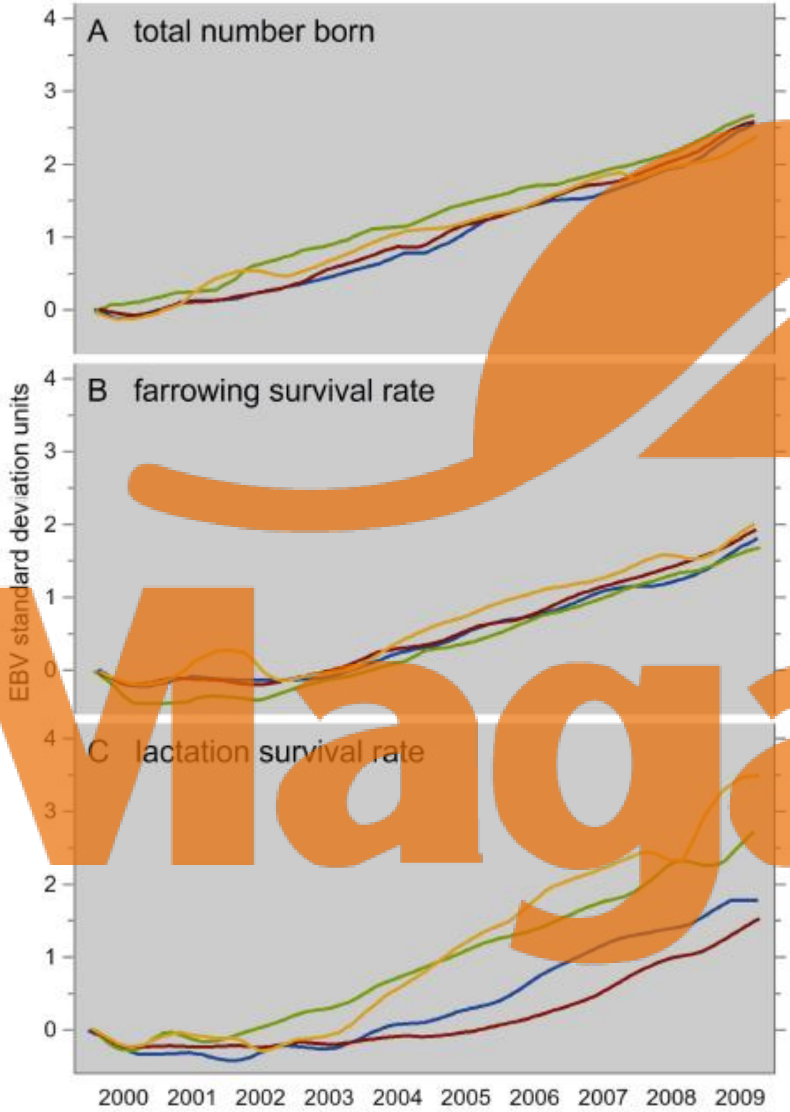
- **Heritability (Generally Low)**
- **Phenotypic information (ancestors, colaterals)**
- **Genomic information**
  - **Increase accuracy**
  - **Discriminate between full sibs**

σ_u: Genetic Standard Deviation

L: Generation Interval

Some Results

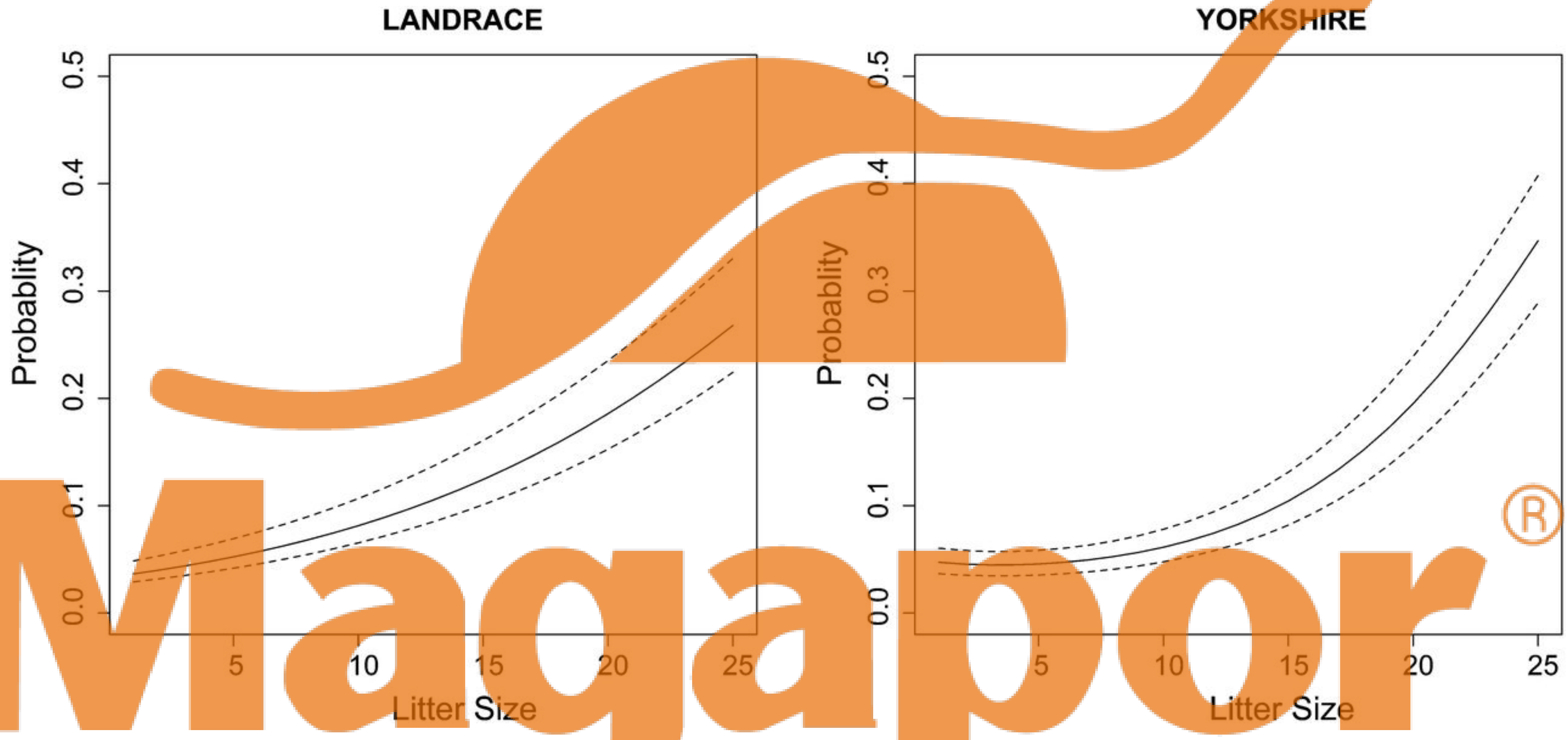
Genetic Trends



Knap et al. 2023. Genetic and phenotypic time trends of litter size, piglet mortality, and birth weight in pigs. Front. Anim. Sci. https://doi.org/10.3389/fanim.2023.1218175

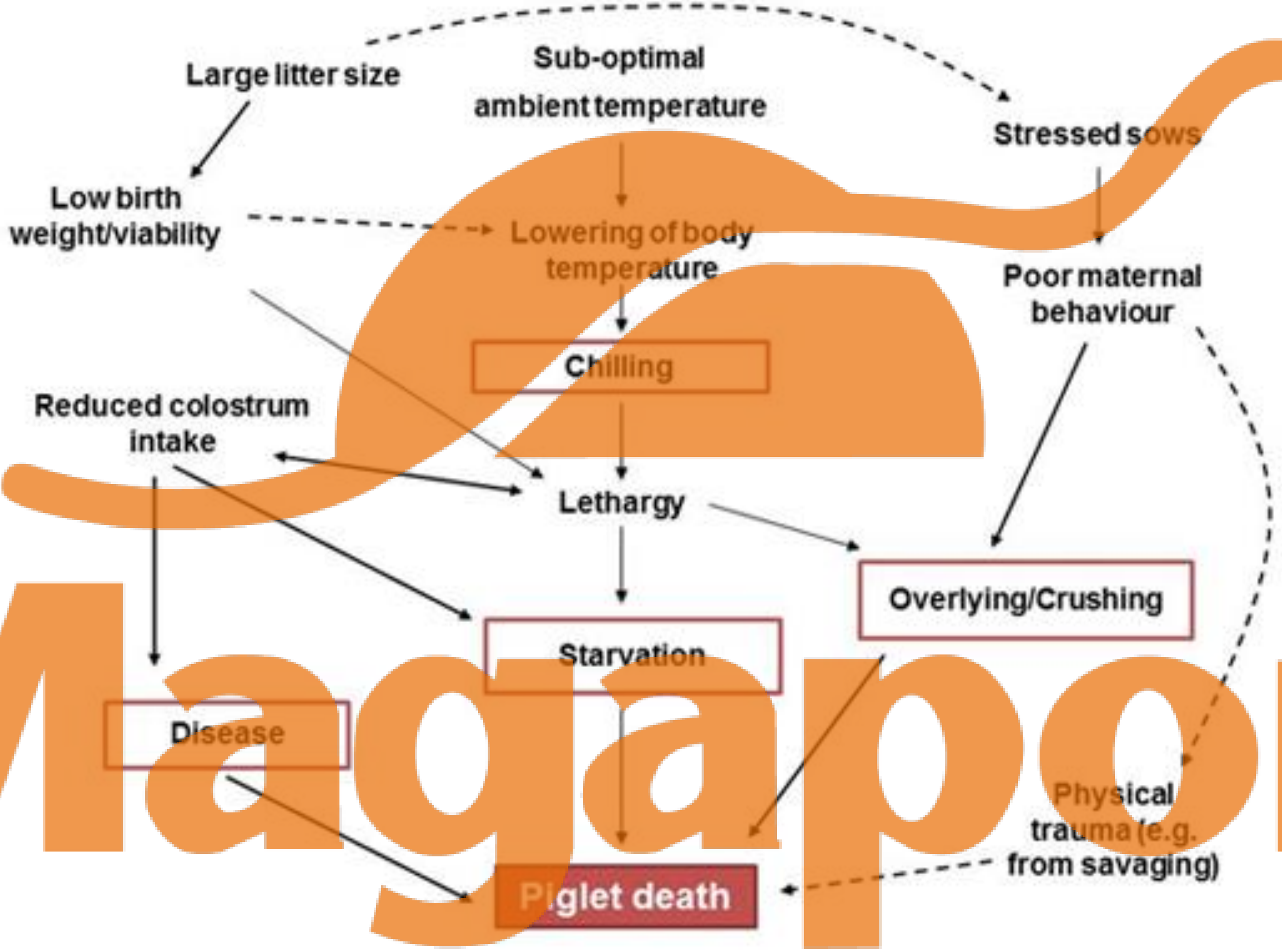
Undesirable Results

Piglet Mortality



Varona, L y Sorensen, D. A. 2014. Joint Analysis of Binomial and Continuous Traits with a Recursive Model: A Case Study Using Mortality and Litter Size of Pigs. Genetics 196:643-651.

Piglet Survival



Large litter size

Sub-optimal ambient temperature

Stressed sows

Low birth weight/viability

Lowering of body temperature

Poor maternal behaviour

Chilling

Reduced colostrum intake

Lethargy

Overlying/Crushing

Starvation

Disease

Physical trauma (e.g. from savaging)

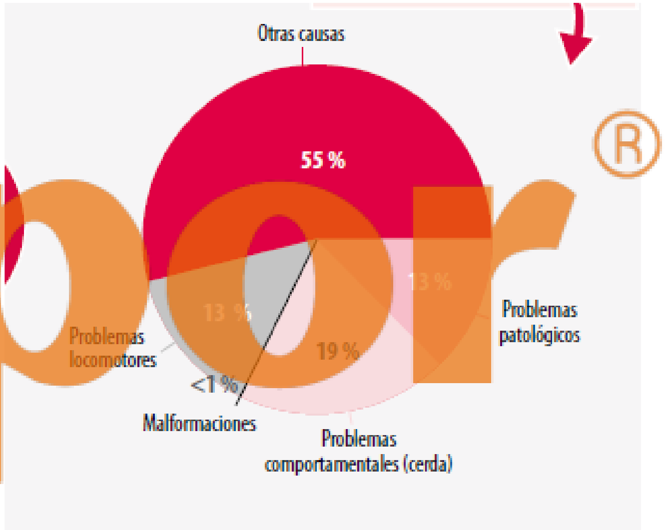
Piglet death

Fig 2. Predisposing risk factors of live-born piglet mortality

Piglet Survival

¿POR QUÉ Y CUÁNDO SE PRODUCEN LAS BAJAS DE LOS LECHONES EN LACTACIÓN?

Aitor Arrazola, Llibertat Tusell, Joaquim Tarrés, Núria Alòs y Raquel Quintanilla
BDporc. Genética y Mejora Animal. IRTA.



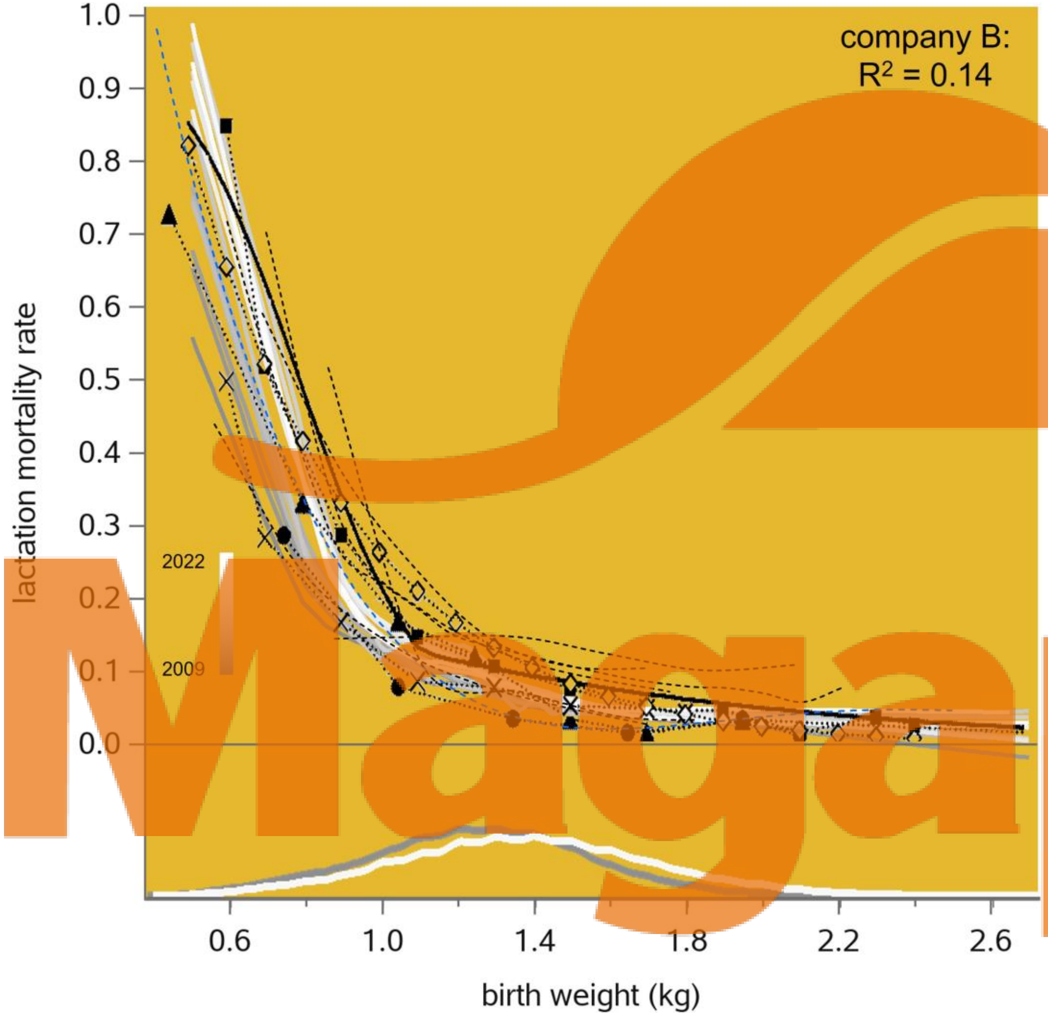
***Gráfica 1.** Motivos de baja de lechones durante la lactación.*

Piglet Survival (New Traits)

New Traits

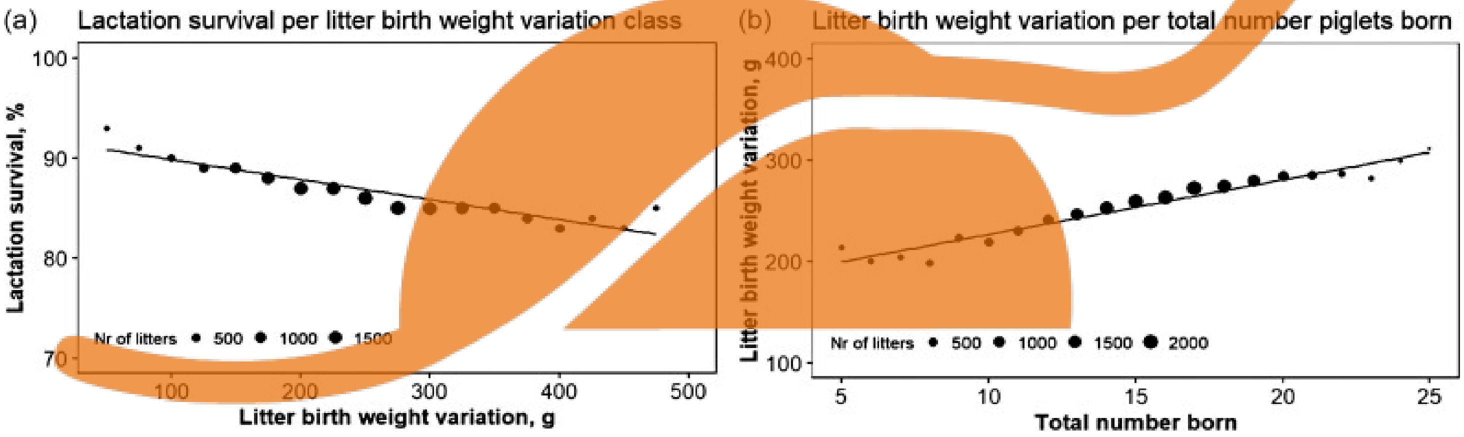
- Piglet Weight
- Uniformity
- Gestation Length
- Farrowing Duration
- Martenal Behaviour
- Congenital Defects

Piglet Weight



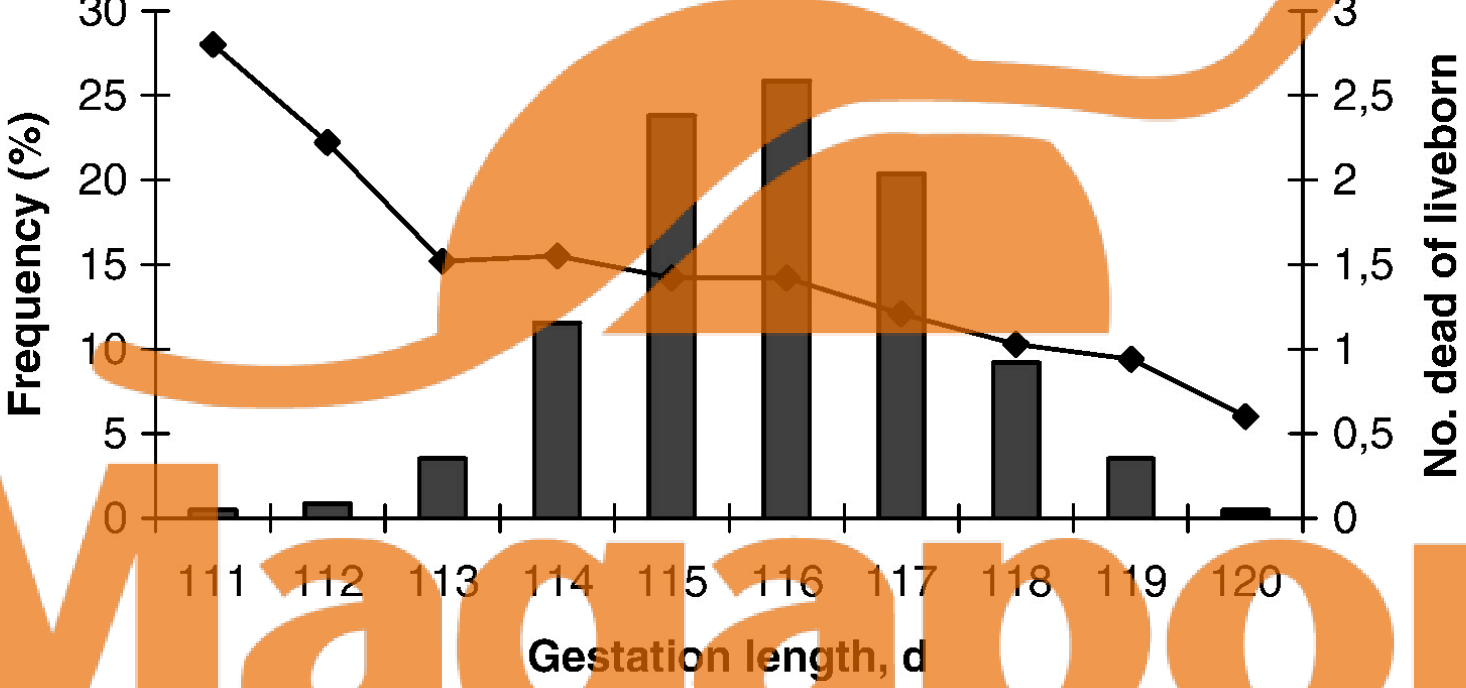
Knap et al. 2023. Genetic and phenotypic time trends of litter size, piglet mortality, and birth weight in pigs. Front. Anim. Sci. https://doi.org/10.3389/fanim.2023.1218175

Uniformity



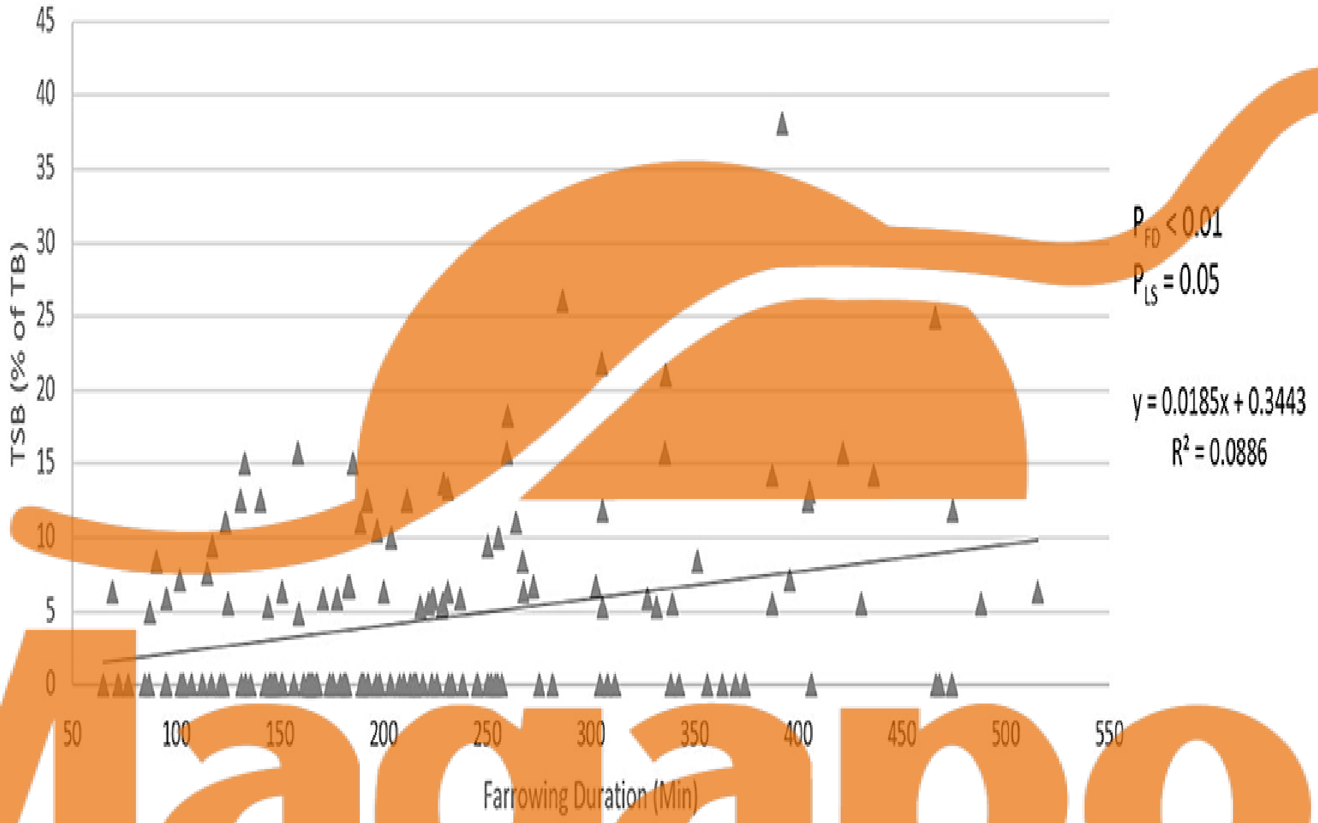
Knol et al., 2022. Genetic aspects of piglet survival and related traits: a review. J. Anim. Sci. 100:skac190

Gestation Length



Rydhmer et al., 2008. Genetic correlations between gestation length, piglet survival and early growth. Lives. Sci. 115:287-293.

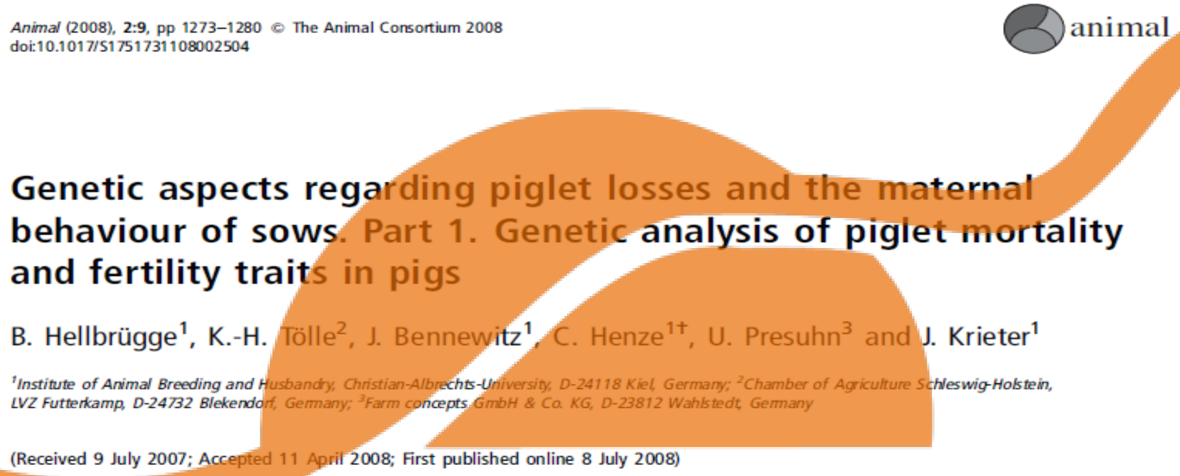
Farrowing Duration



Van den Bosch et al. 2022. Disentangling Litter Size and Farrowing Duration Effects on Piglet Stillbirth, Acid–Base Blood Parameters and Pre-Weaning Mortality. Front. Vet. Sci. https://doi.org/10.3389/fvets.2022.836202

Low Heritability (0.08-0.10) (Canario et al., 2006; Merour et al. 2010).

Maternal Behaviour



Animal (2008), **2:9**, pp 1273–1280 © The Animal Consortium 2008
doi:10.1017/S1751731108002504

animal

Genetic aspects regarding piglet losses and the maternal behaviour of sows. Part 1. Genetic analysis of piglet mortality and fertility traits in pigs

B. Hellbrügge[1], K.-H. Tölle[2], J. Bennewitz[1], C. Henze[1†], U. Presuhn[3] and J. Krieter[1]

[1]Institute of Animal Breeding and Husbandry, Christian-Albrechts-University, D-24118 Kiel, Germany; [2]Chamber of Agriculture Schleswig-Holstein, LVZ Futterkamp, D-24732 Blekendorf, Germany; [3]Farm concepts GmbH & Co. KG, D-23812 Wahlstedt, Germany

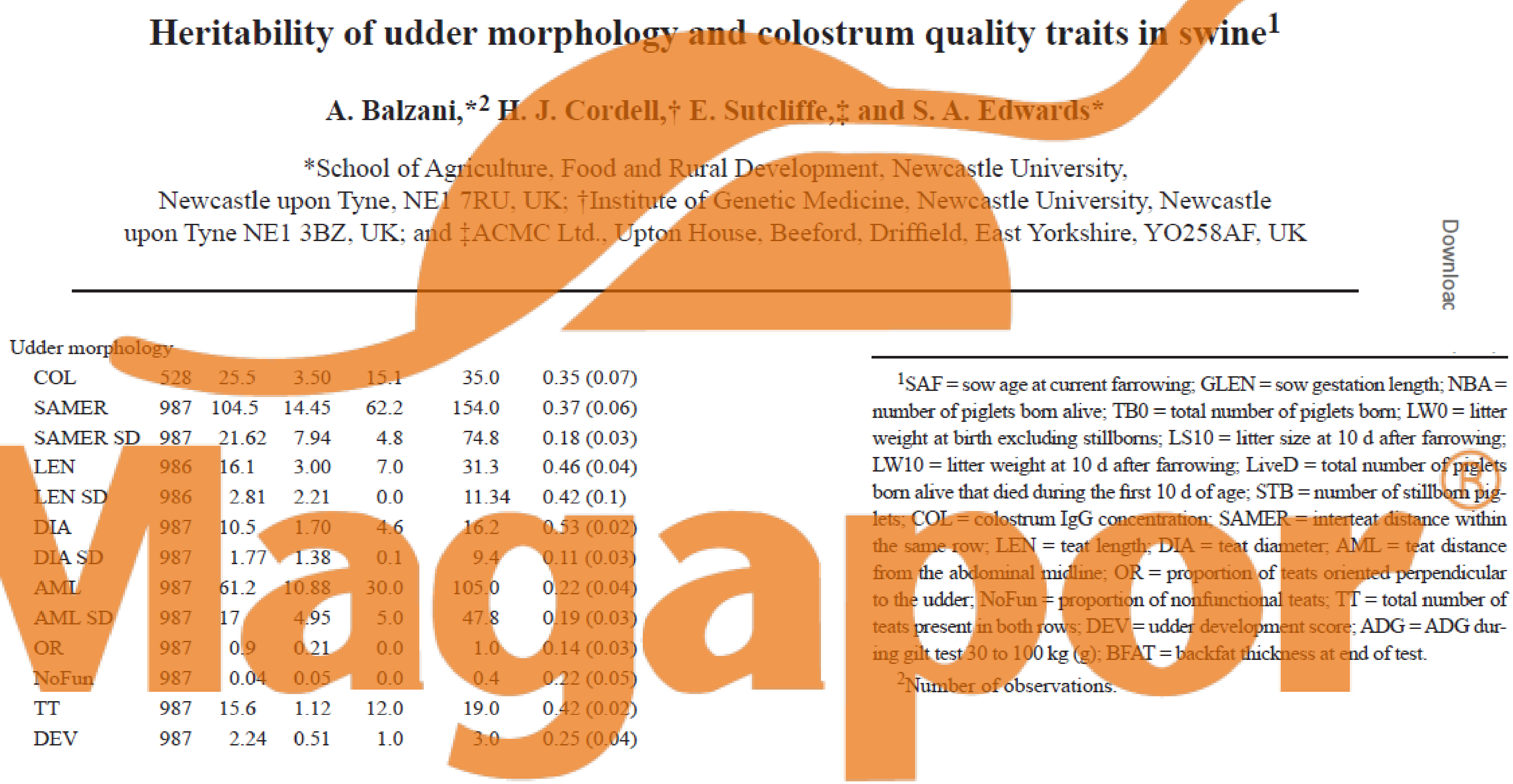
(Received 9 July 2007; Accepted 11 April 2008; First published online 8 July 2008)

Table 4 *Heritabilities (±s.e.), additive genetic variance (σ^2_a), random permanent sow effect (σ^2_{sow}), random common litter effect (σ^2_{ll}) and repeatability (t) for the different causes of piglet losses (LOSS)*

LOSS	$h^2 \pm$ s.e.	σ^2_a	σ^2_{sow}	σ^2_{ll}	t (%)
Survival rate (SR)	0.03 ± 0.01	0.03	0.02	0.09	12
Crushing (CRUSH)	0.03 ± 0.01	0.03	0.01	0.07	10
Crushing – early (CRUSH_E)	0.04 ± 0.02	0.05	0.02	0.10	15
Crushing – late (CRUSH_L)	0.01 ± 0.01	0.02	0.02	0.05	7
Crushing heavier piglets (CRUSH_H)	0.03 ± 0.01	0.03	0.03	0.05	10
Underweight (UW)	0.03 ± 0.02	0.04	0.07	0.12	18
Runt (RU)	0.05 ± 0.03	0.06	0.07	0.09	18

σ^2_e was set equal to 1.

Teats and Udder Morphology



Heritability of udder morphology and colostrum quality traits in swine[1]

A. Balzani,*[2] H. J. Cordell,† E. Sutcliffe,‡ and S. A. Edwards*

*School of Agriculture, Food and Rural Development, Newcastle University,
Newcastle upon Tyne, NE1 7RU, UK; †Institute of Genetic Medicine, Newcastle University, Newcastle
upon Tyne NE1 3BZ, UK; and ‡ACMC Ltd., Upton House, Beeford, Driffield, East Yorkshire, YO258AF, UK

Udder morphology						
COL	528	25.5	3.50	15.1	35.0	0.35 (0.07)
SAMER	987	104.5	14.45	62.2	154.0	0.37 (0.06)
SAMER SD	987	21.62	7.94	4.8	74.8	0.18 (0.03)
LEN	986	16.1	3.00	7.0	31.3	0.46 (0.04)
LEN SD	986	2.81	2.21	0.0	11.34	0.42 (0.1)
DIA	987	10.5	1.70	4.6	16.2	0.53 (0.02)
DIA SD	987	1.77	1.38	0.1	9.4	0.11 (0.03)
AML	987	61.2	10.88	30.0	105.0	0.22 (0.04)
AML SD	987	17	4.95	5.0	47.8	0.19 (0.03)
OR	987	0.9	0.21	0.0	1.0	0.14 (0.03)
NoFun	987	0.04	0.05	0.0	0.4	0.22 (0.05)
TT	987	15.6	1.12	12.0	19.0	0.42 (0.02)
DEV	987	2.24	0.51	1.0	3.0	0.25 (0.04)

---

[1] SAF = sow age at current farrowing; GLEN = sow gestation length; NBA = number of piglets born alive; TB0 = total number of piglets born; LW0 = litter weight at birth excluding stillborns; LS10 = litter size at 10 d after farrowing; LW10 = litter weight at 10 d after farrowing; LiveD = total number of piglets born alive that died during the first 10 d of age; STB = number of stillborn piglets; COL = colostrum IgG concentration; SAMER = interteat distance within the same row; LEN = teat length; DIA = teat diameter; AML = teat distance from the abdominal midline; OR = proportion of teats oriented perpendicular to the udder; NoFun = proportion of nonfunctional teats; TT = total number of teats present in both rows; DEV = udder development score; ADG = ADG during gilt test 30 to 100 kg (g); BFAT = backfat thickness at end of test.

[2] Number of observations.

Precision Livestock Farming

Smart Agricultural Technology 5 (2023) 100246

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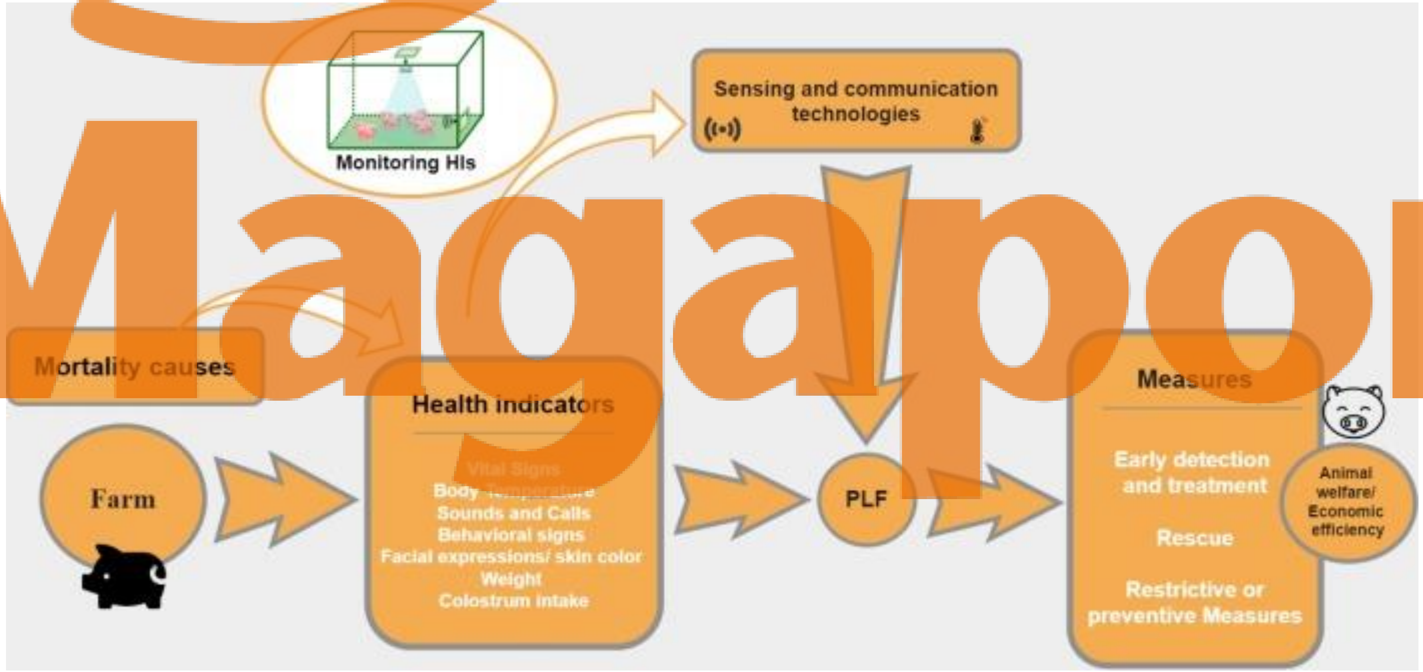
Improving piglets health and well-being: A review of piglets health indicators and related sensing technologies

Ehsan Sadeghi *, Claudie Kappers, Alessandro Chiumento, Marjolein Derks, Paul Havinga



Monitoring HIs

Sensing and communication technologies

Mortality causes

Farm

Health indicators

Vital Signs
Body Temperature
Sounds and Calls
Behavioral signs
Facial expressions/ skin color
Weight
Colostrum intake

PLF

Measures

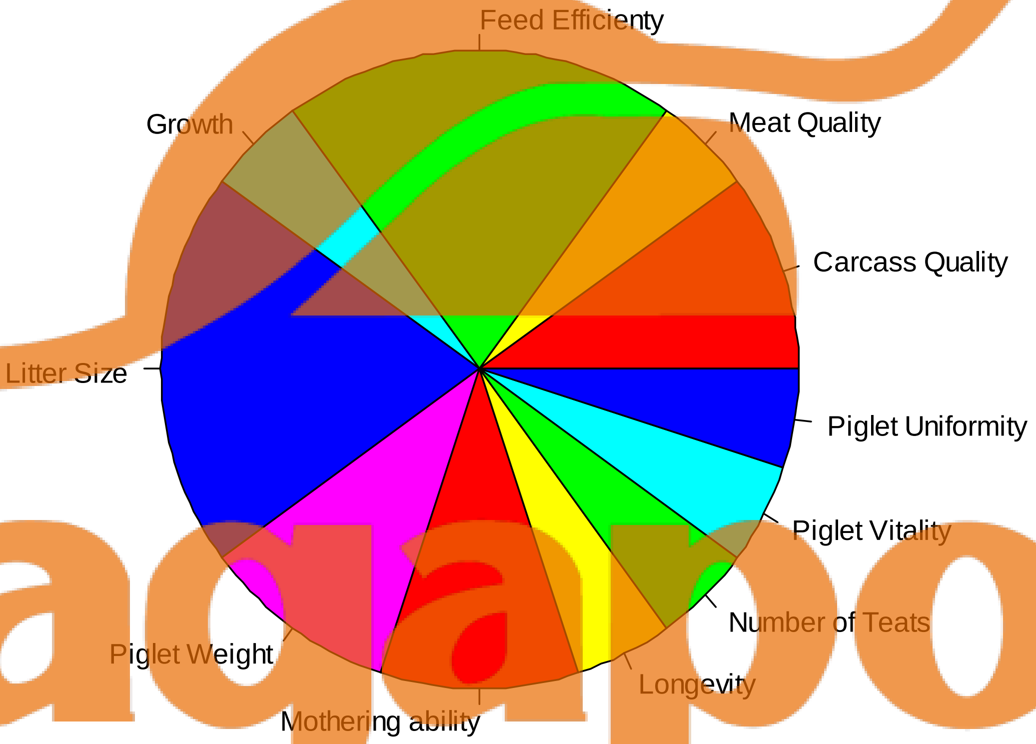
Early detection and treatment

Rescue

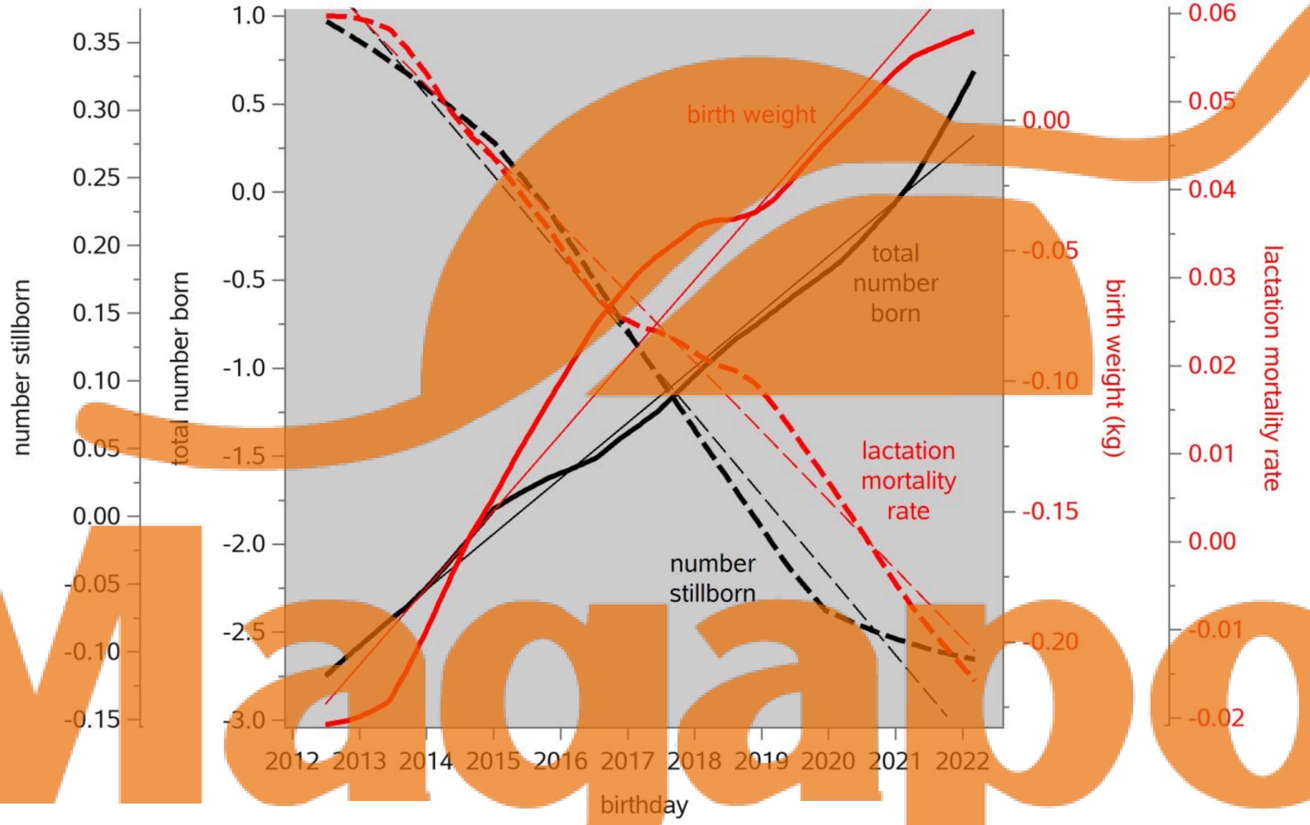
Restrictive or preventive Measures

Animal welfare/ Economic efficiency

Selection Indexes

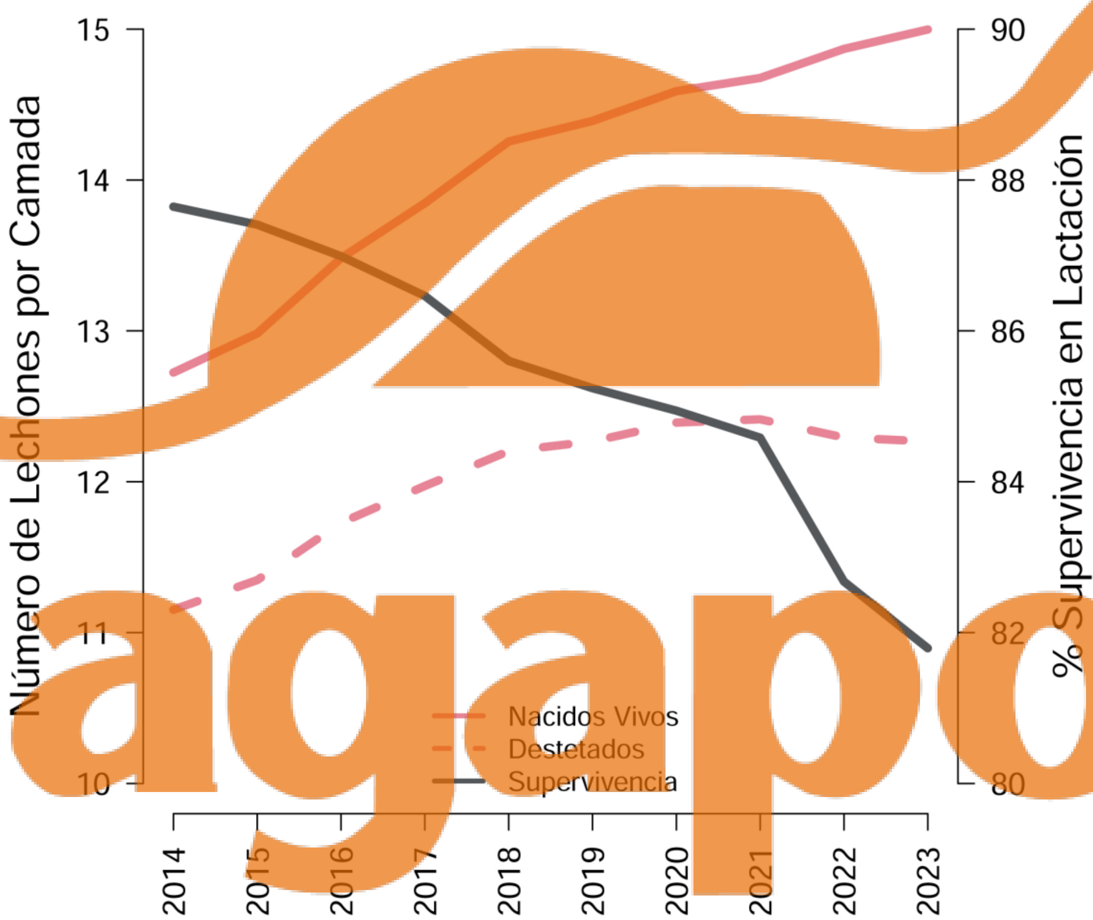


Results



Knap et al. 2023. Genetic and phenotypic time trends of litter size, piglet mortality, and birth weight in pigs. Front. Anim. Sci. https://doi.org/10.3389/fanim.2023.1218175

However?



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Crossbreeding Genomic Selection

Purebred Crossbred Genetic Correlation

BOARD INVITED REVIEW: The purebred-crossbred correlation in pigs: A review of theory, estimates, and implications[1]

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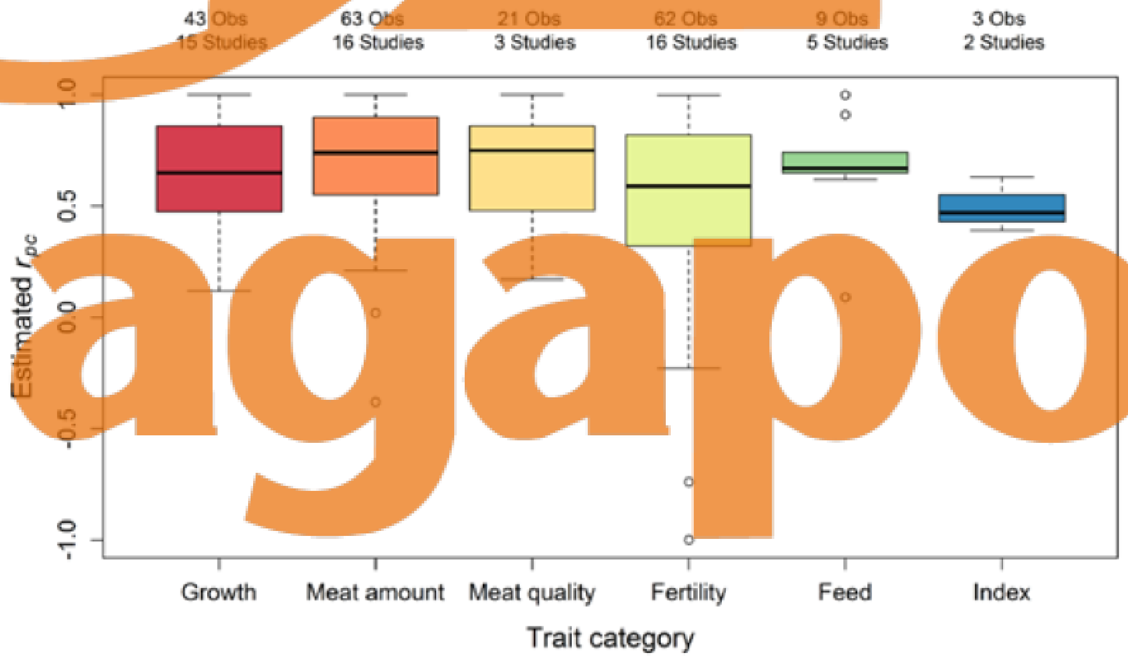

Figure 3. Estimated r_{pc} values for the 6 different trait categories.

Genotype Enviroment Correlation

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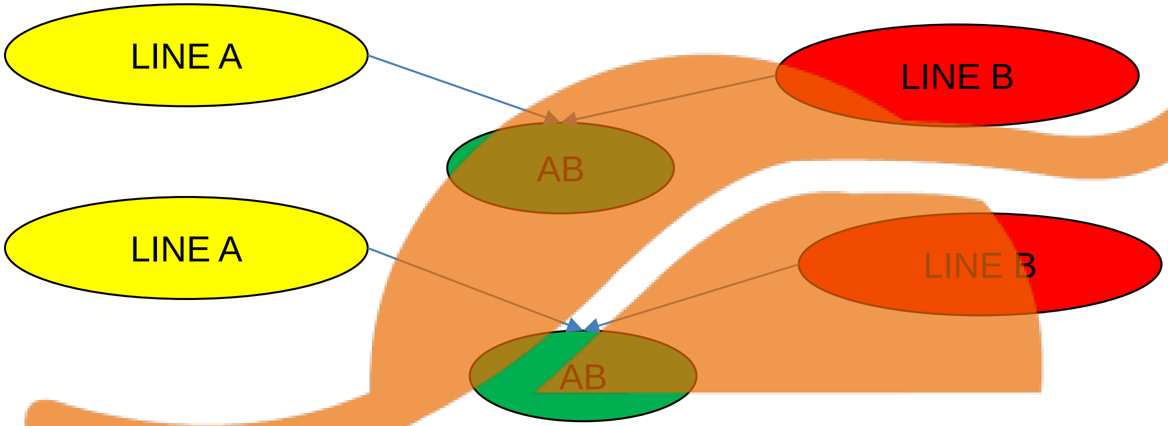
- Genes involved in piglet survival may differ between enviroments.

- Individuals with the best genotype in one enviroment can not be the best in other enviroment.

Reciprocal Recurrent Selection



- **Selection is based on crossbred individuals performance**
- **It maximized long term response in the crossbred population**
- **It is slow, because it requires the phenotypes of crossbred individuals**
- **It is specific for a particular cross and enviroment**

Genomic Reciprocal Recurrent Selection

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ANIMAL GENETICS AND GENOMICS

Review: optimizing genomic selection for crossbred performance by model improvement and data collection

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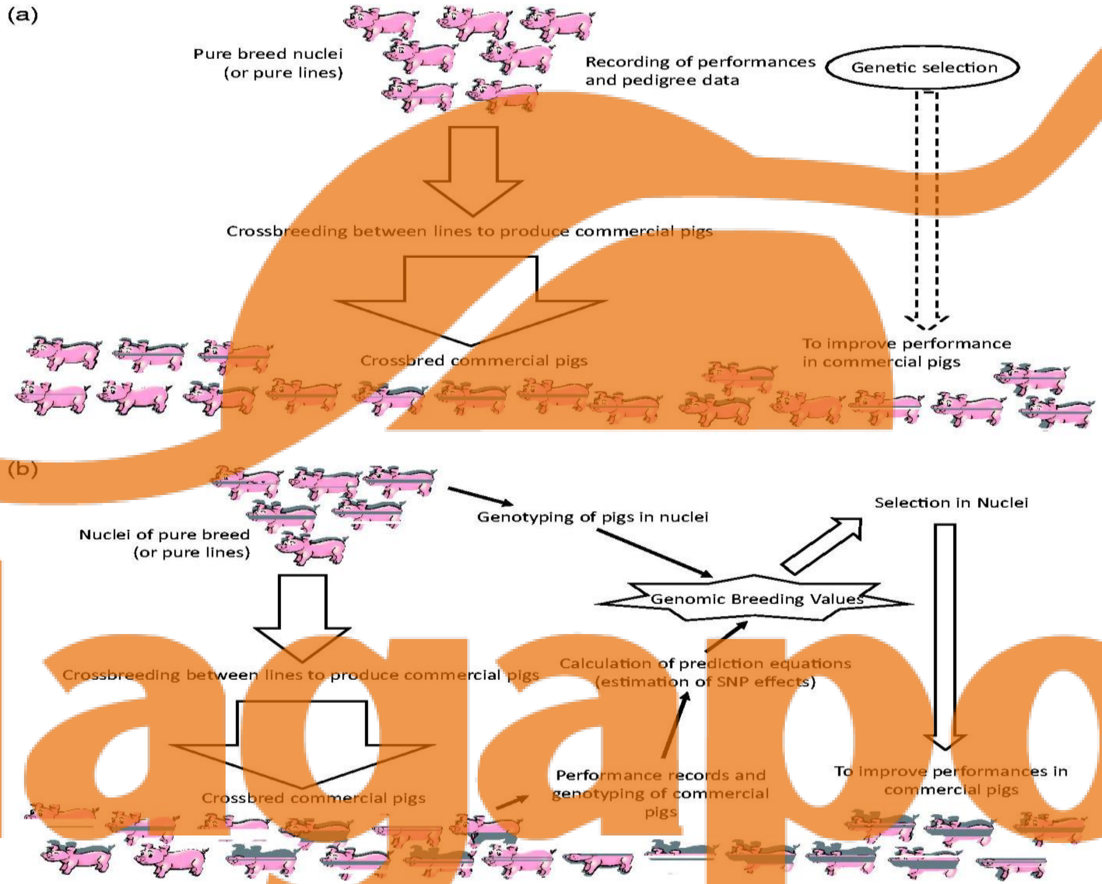
- **If the correlation between purebreds and crossbreds is less than 0.8, the cause is genotype-by-environment interaction.**

- **The benefit of phenotyping crossbred individuals increases as the correlation decreases and with larger populations.**

- **The benefit of phenotyping crossbred individuals requires knowledge of their pedigree and/or genomic information.**

Genomic Reciprocal Recurrent Selection



Samorè, A. B., & Fontanesi, L. (2016). Genomic selection in pigs: state of the art and perspectives. Italian Journal of Animal Science, 15(2), 211–232. https://doi.org/10.1080/1828051X.2016.1172034

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