Session 77

Trade-offs between health, production and welfare in pigs and poultry

Which tools do we have, and which research is needed?

The future of pig and poultry breeding

Lisanne Verschuren & Pieter Knap

August 2023

Topigs Norsvin

PIC®

EAAP + WAAP + Interbull Congress 2023

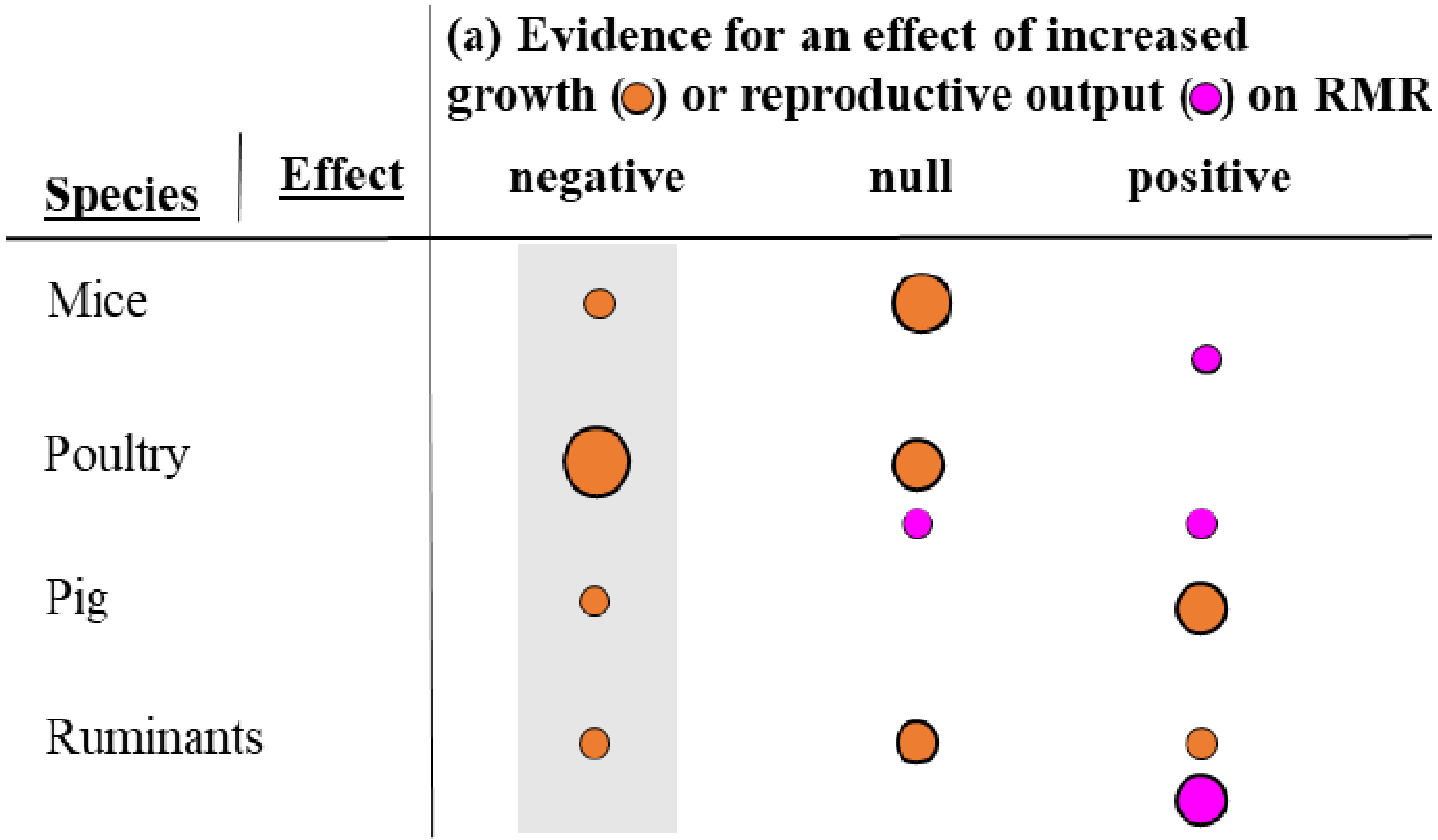
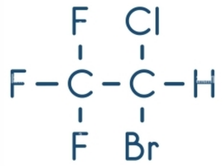


Figure 2. Evidence for association between resting metabolic rate (RMR) and selection for growth or reproductive output when feed intake is not restricted (a), and effects of a genetically reduced RMR on health or reproduction

Douhard *et al.* (2021) https://doi.org/10.3920/978-90-8686-940-4_54

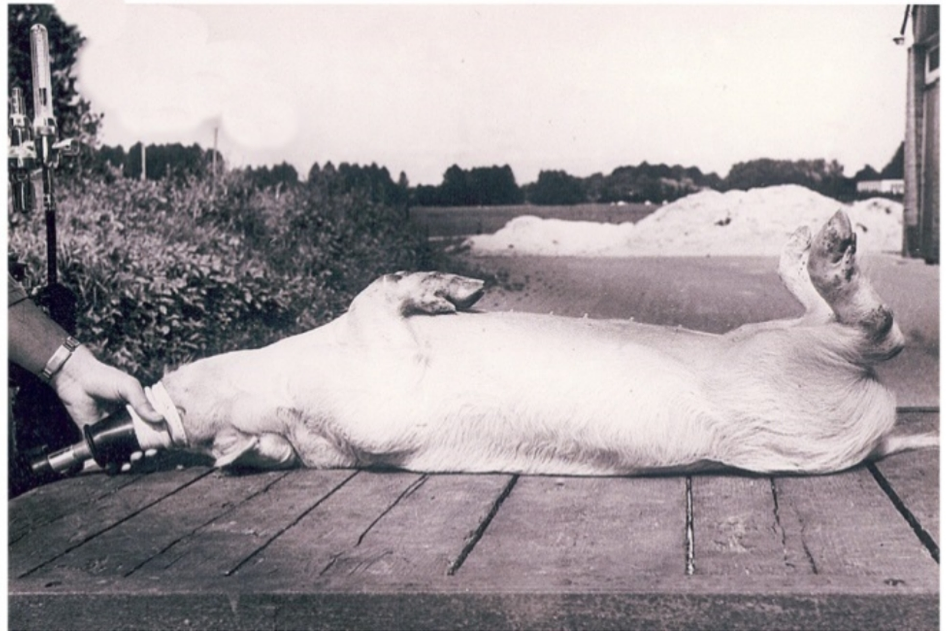
Trade-off systems in breeding: some history



- 1970s: lean content ↔ **P**orcine **S**tress **S**yndrome & **P**ale **S**oft **E**xudative meat

Figuur 2. Philippe Lampo (Faculteit Diergeneeskunde) voert de halothaantest uit (Uit: *Boerderijrevue*, april 1979).

halothane negative (NN) or carrier (NP)

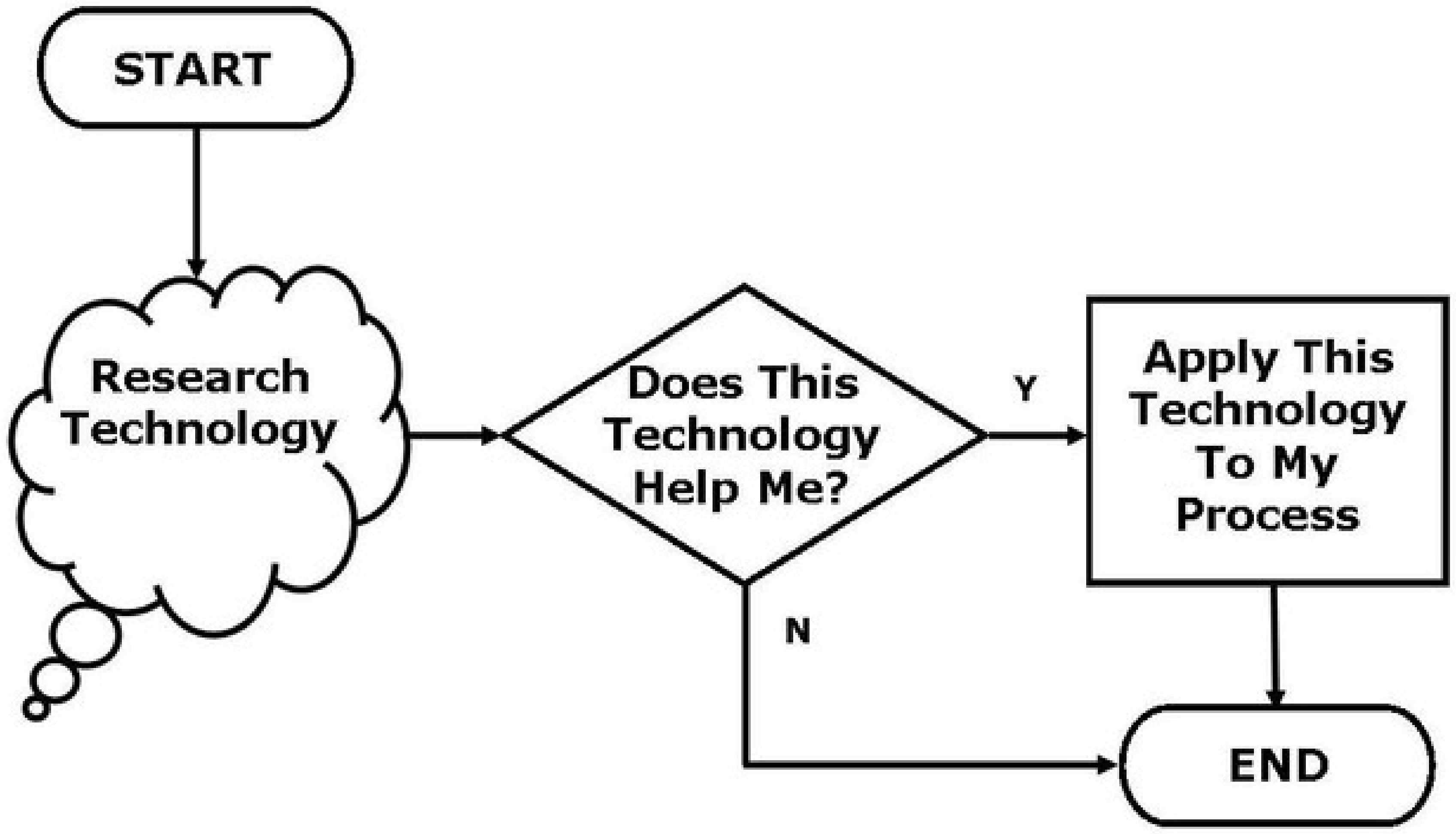


halothane positive (PP)

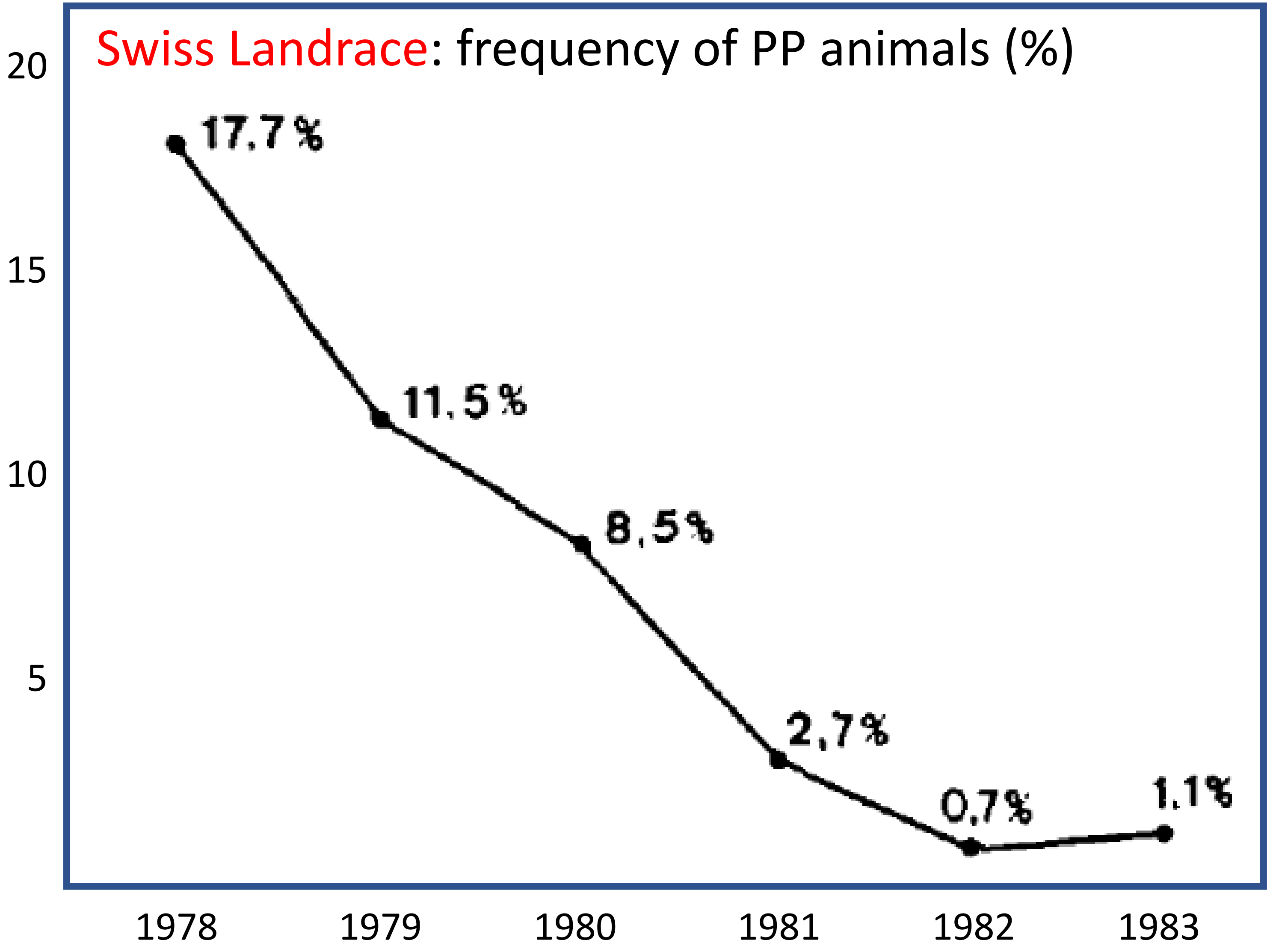
	Number of studies	Difference PP – NN Mean	Minimum	Maximum
Growth traits (approx. 25-90 kg)				
Growth rate (gm/day)	12	-2	-47	28
Daily food consumption (kg)	9	-0.07	-0.46	0.06
Food conversion ratio (food/liveweight gain)	11	-0.06	-0.30	0.02
Carcase traits (approx. 90 kg)				
Lean (% by weight)	8	2.6	0.9	4.6
Ham (% by weight)	7	0.7	0.3	1.0
Average backfat (mm)	14	-1.0	-4.0	1.0
Killing out%	6	1.0	0.2	2.6
Eye muscle area (cm^2)	7	1.1	-2.7	3.4
Carcase length (mm)	9	-11	-29	1
PSS traits				
Postweaning mortality (and transport losses)%	3	9.8	4.7	17.0
PSE (% of carcases)	4	46	22	80
Meat colour (% paler than NN)†	14	15	0	50
Meat quality (% worse than NN)†	7	31	16	78
pH 45 min post mortem	11	-0.31	-0.66	0.02
CK activity (log units/litre)	6	0.50	0.06	0.79

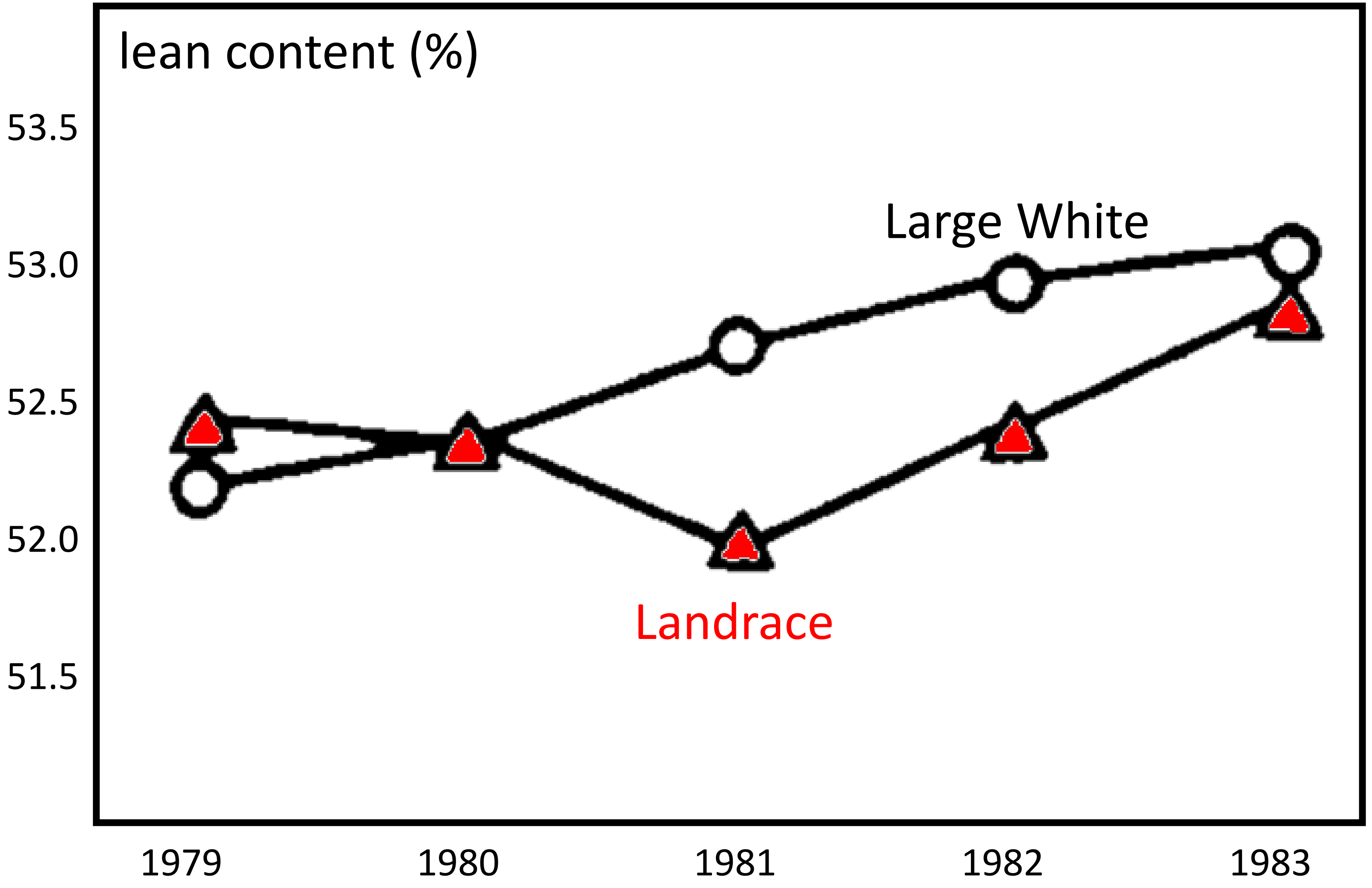
Webb, Carden, Smith & Imlah (1982) http://www.wcgalp.org/proceedings/1982/porcine-stress-syndrome-pig-breeding

Interesting. And what do we do with it?



www.linkedin.com/pulse/technology-sounds-great-what-do-we-dan-grove





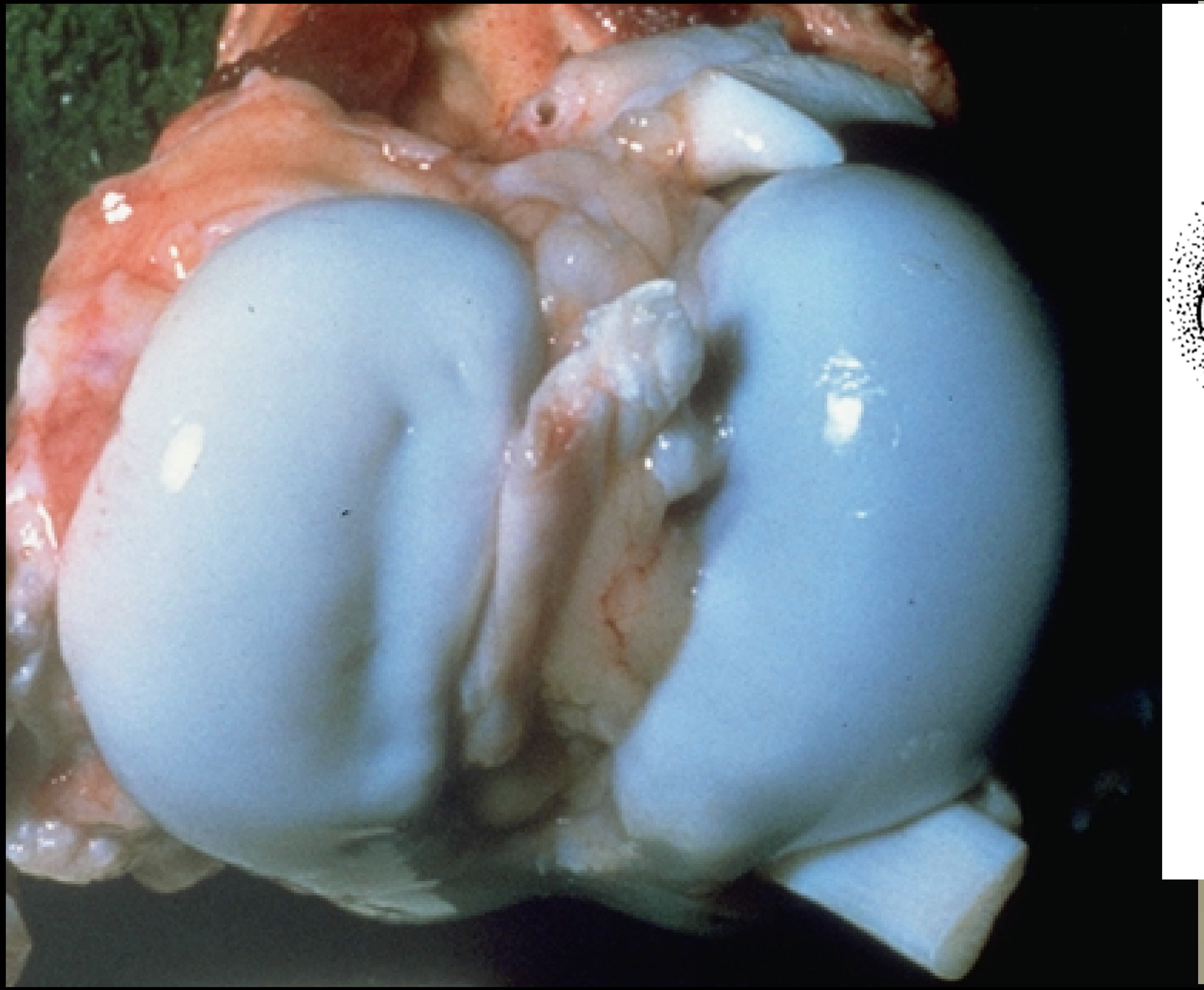
Vögeli, Schwörer, Kühne & Wysshaar (1985) Animal Blood Groups and Biochemical Genetics 16:285-296.

SUISAG

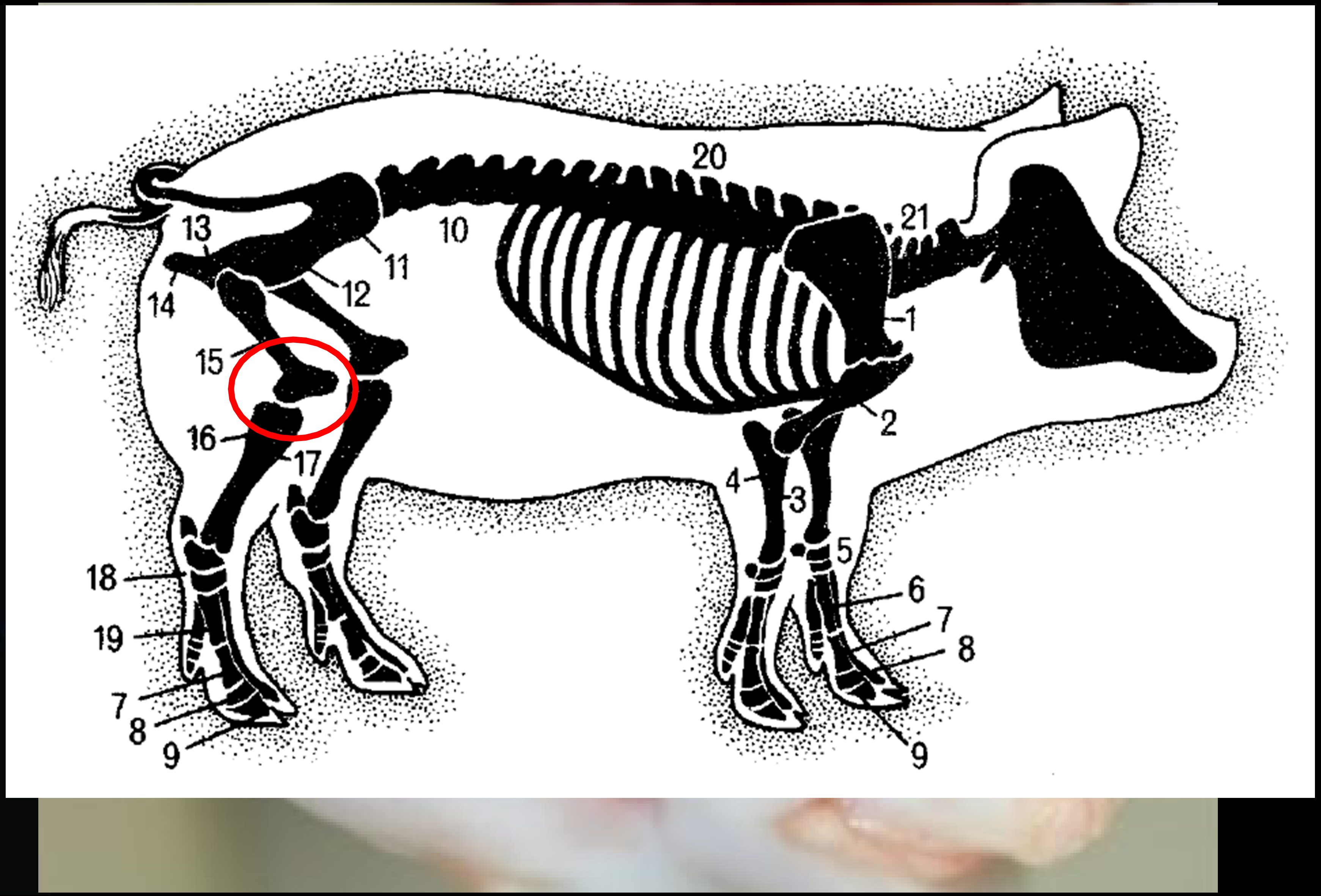
Trade-off systems in breeding: some history

- 1970s: lean content $\leftrightarrow$ PSS & PSE
- 1980s: growth rate $\leftrightarrow$ leg soundness

healthy femoral condyle



osteochondrosis



Morfologische onderzoekingen bij slachtvarkens laten zien dat er tegenwoordig nauwelijks nog dieren zijn waarbij er geen osteochondropatische veranderingen aantoonbaar zijn (Dämmrich, 1970, 1972; Hermann, 1972; Grøndalen, 1974)

Morphological investigations reveal that currently (= 1976 !) there are hardly any pigs that do <u>not</u> show any osteochondropathic changes.

wel aangenomen dat er een sterke samenhang is met het feit dat men de laatste 10 à 15 jaar vooral varkens heeft willen fokken van een duidelijk vleestype. Ook wordt door sommigen gesteld dat de beengebreken zich meer klinisch openbaren, omdat de huisvestingsomstandigheden veel harder geworden zijn. (Bollwahn, 1966; Bollwahn e.a., 1970; Christensen, 1953; Dämmrich, 1970, 1972; Flock, 1969; Grøndalen, 1974, Hermann, 1969, 1972; Kurzweg e.a., 1972; Sabec, 1961, 1974 en Schilling, 1963). Door de te snelle gewichtstoename zou de skeletrijping hier geen gelijke tred mee kunnen houden en ontstaat er een wanverhouding tussen lichaamsgewicht en de structuur d.w.z. de geschiktheid voor mechanische belasting van het skelet. Men ziet daarom de osteochondropatische veranderingen in het skelet juist vooral op die plaatsen optreden waar de functioneel-mechanische belasting het grootst is (lumbale wervels, mediale condyl van de femur, epiphysairschijven distale ulna etc.)

- An assumed strong connection to selection for a "meaty" type of the past 15 years
- At the same time, housing conditions became more intensive
- Skeletal maturation cannot keep up with fast body growth rate
- Imbalance: body weight ↔ mechanical load on the bones
- Most where this load is most severe:
  femoral condyles, ulnar epiphyses (i.e. the joints)

Studiecommissie "Beengebreken" (1976) https://edepot.wur.nl/380318

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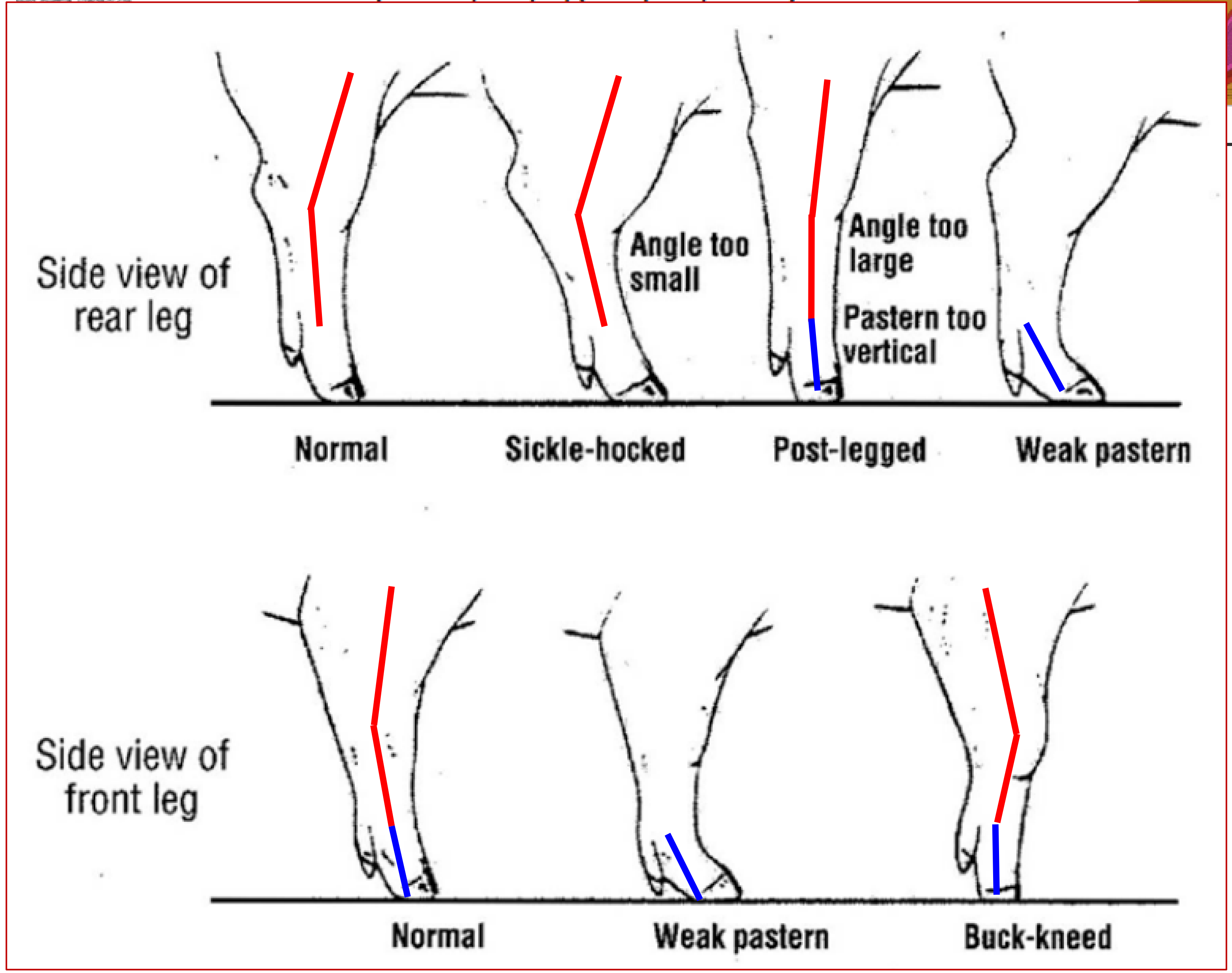
- Followed by 20 years of phenotypic selection
- Visual appraisal of the leg conditions
- Exterior. Effectively scored as *good* or *bad*
- Zero ΔG

Studiecommissie "Beengebreken" (1976) https://edepot.wur.nl/380318



Livestock Production Science

Volume 19, Issues 3–4, July 1988, Pages 473-485

Genetic control of front-leg weakness in Duroc swine. II. Correlated responses in growth rate, backfat and reproduction from five generations of divergent selection ☆

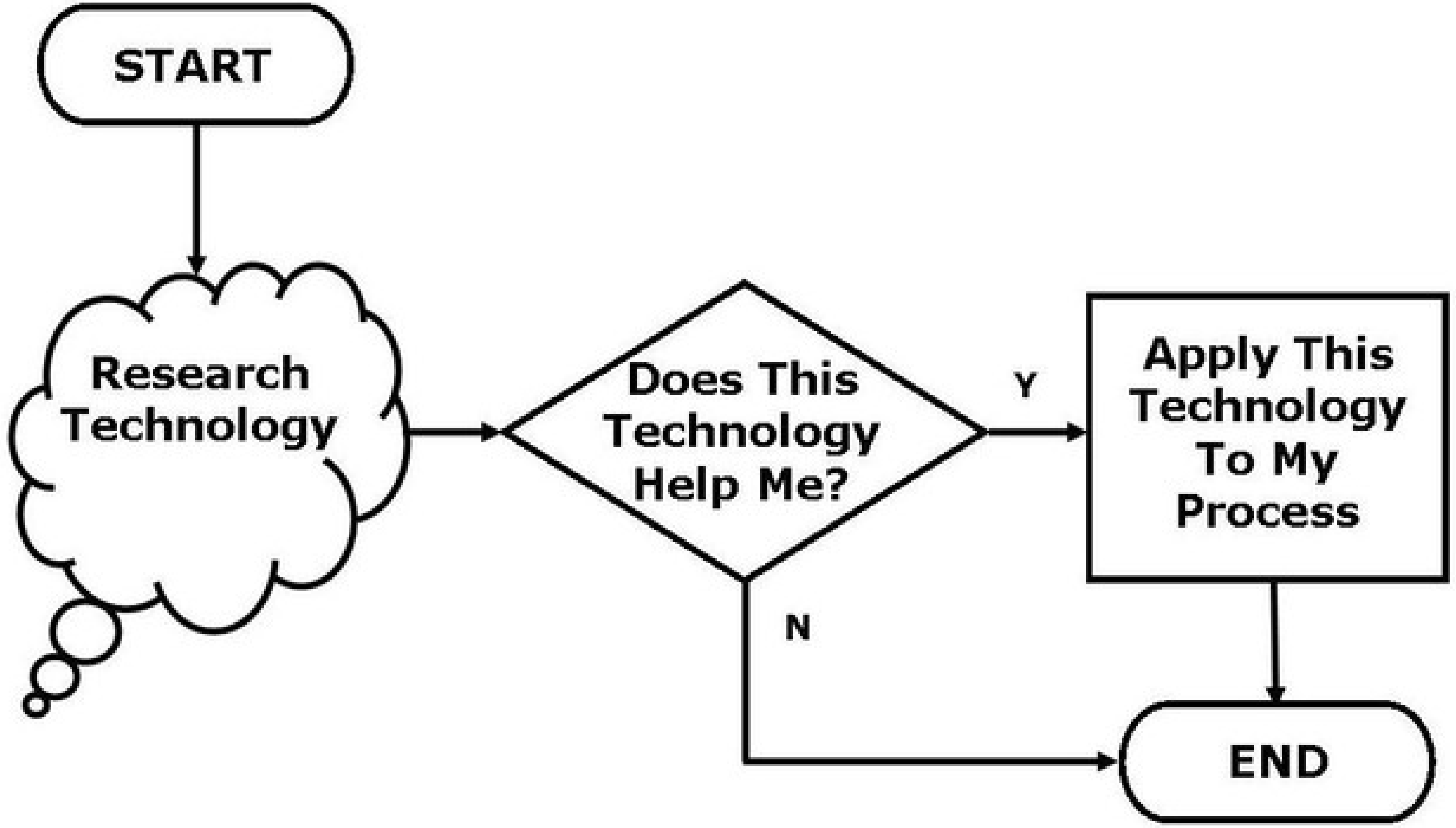
← Phenotyping:

not a narrative, but angles: **numbers**

Can be BLUPped – that works miracles

Moeller & Stalder (2006) https://porkgateway.org/wp-content/uploads/2015/07/genetic-aspects-of-female-longevity.pdf

Interesting. And what do we <u>do</u> with it?



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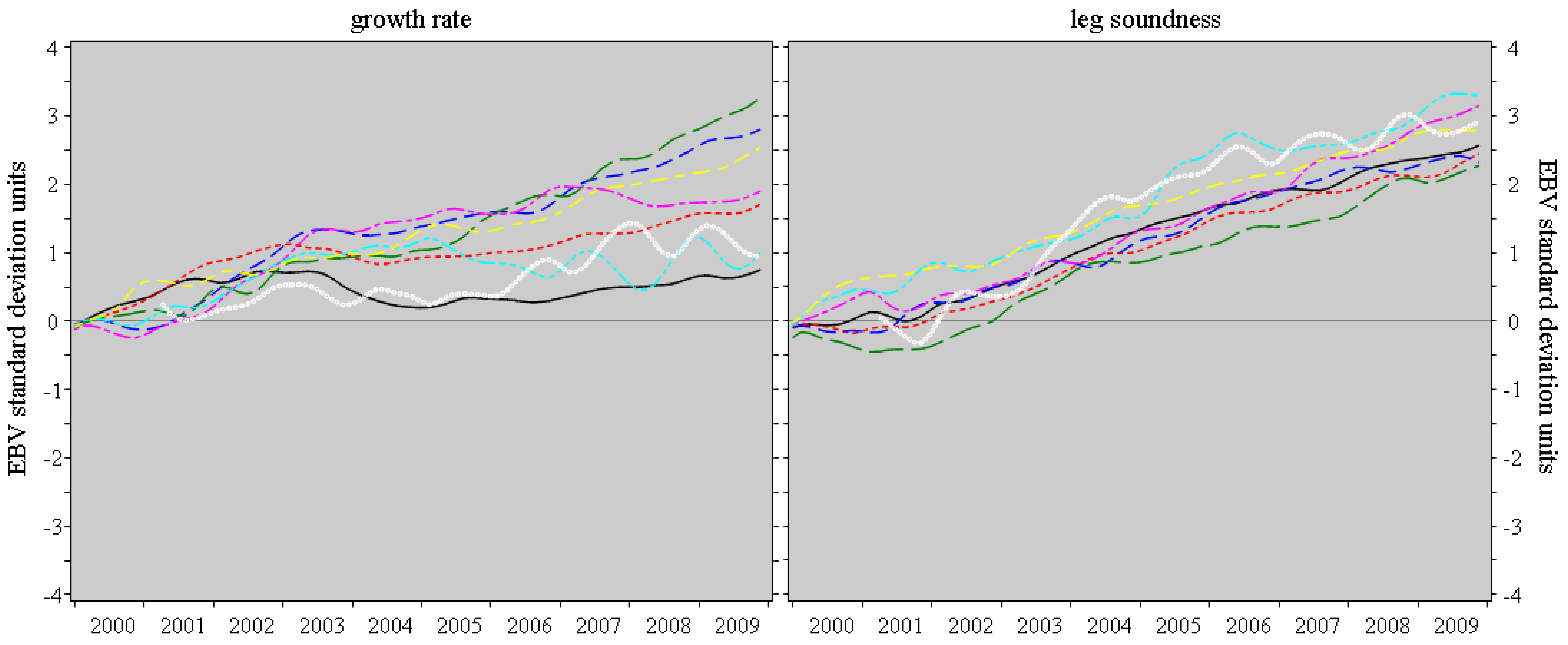
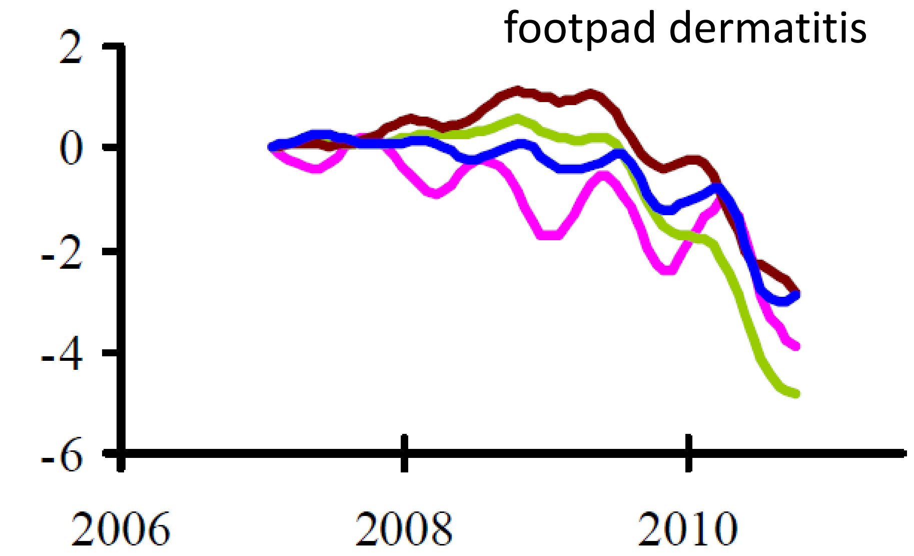
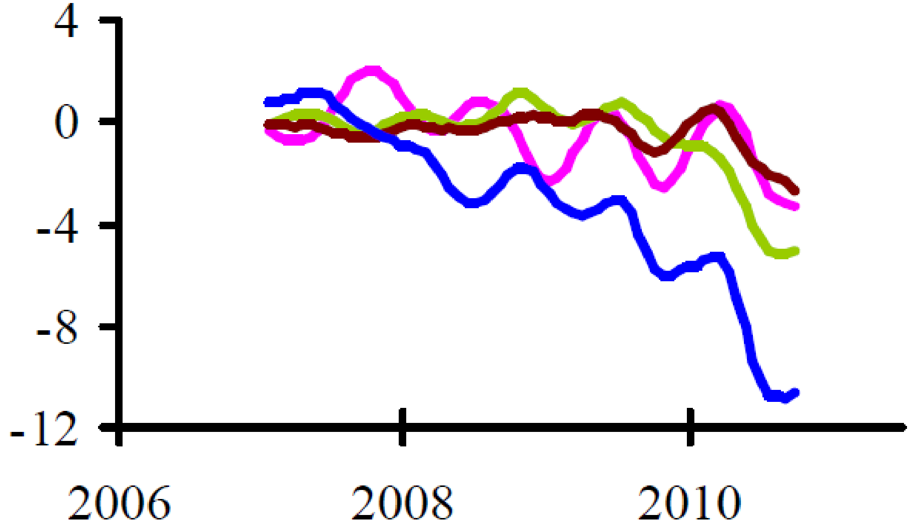
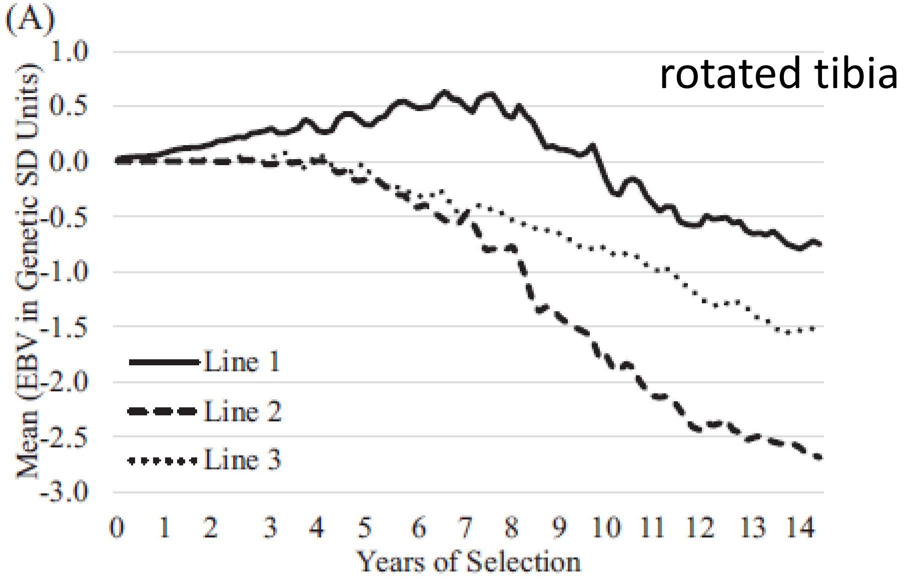
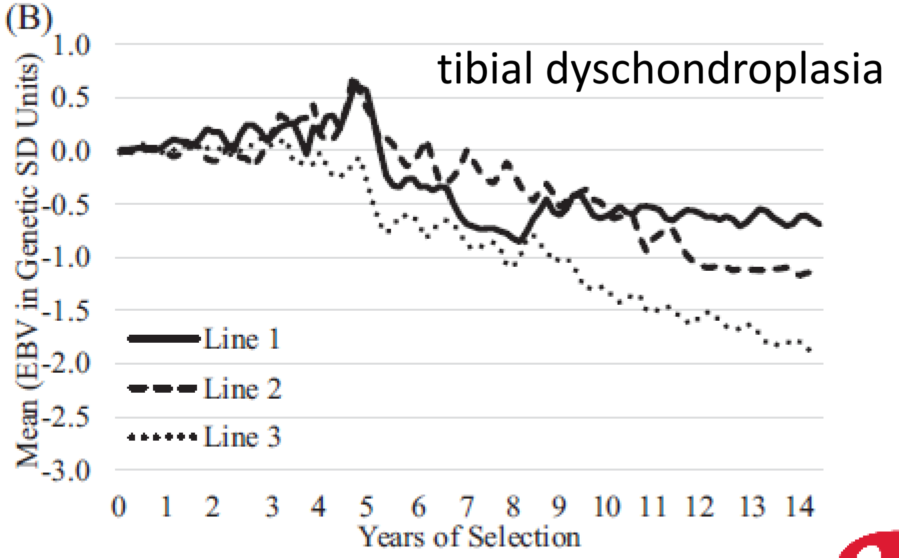


Knap (2012) Pig breeding for increased sustainability. In: Encyclopedia of sustainability science and technology (ed. R.A. Meyers), Springer, New York, USA. Volume 11, pp. 7972-8012.









extension.umn.edu/sites/extension.umn.edu/files/turkey-footpad-dermatitis-scores.png
Kapell (2013) lohmann-breeders.com/lohmanninfo/selection-for-improved-leg-health-in-purebred-broiler-lines

Quiroz-Bucheli et al (2020) doi.org/10.17151/bccm.2020.24.1.5
Siegel, Barger, Siewerdt (2019) doi.org/10.3382/japr/pfz052

Trade-off systems in breeding: some history

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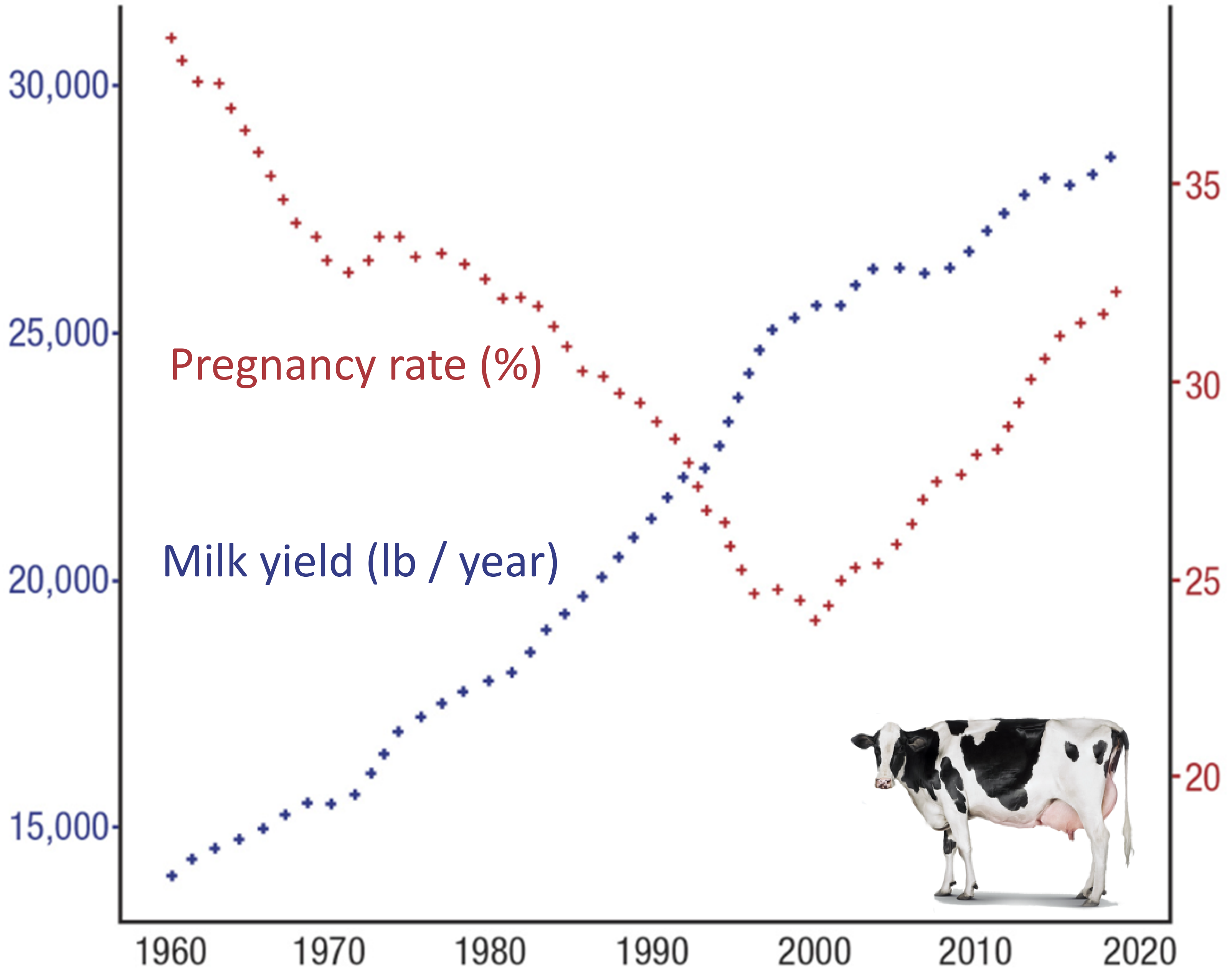
- 1980s: growth rate ↔ leg soundness
- 2000s: milk yield ↔ fertility



www.agproud.com/articles/print/57370-genetic-tools-have-reversed-cow-fertility-decline

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Conclusions

1. Increased production levels
    - good for increasing Δ€
    - good for reducing the carbon footprint

...have often led to trade-offs

- bad for animal welfare

...due to genetic antagonisms

2. Genetic antagonisms can be neutralized:
    - select for both traits at the same time
    - requires phenotyping & statistics & focus

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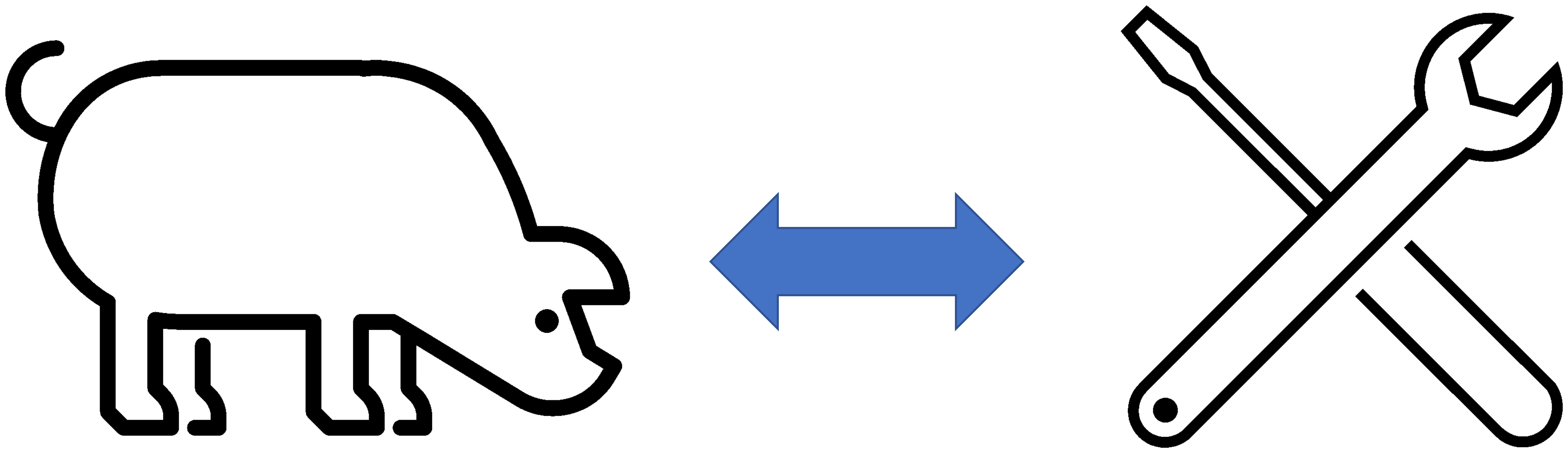
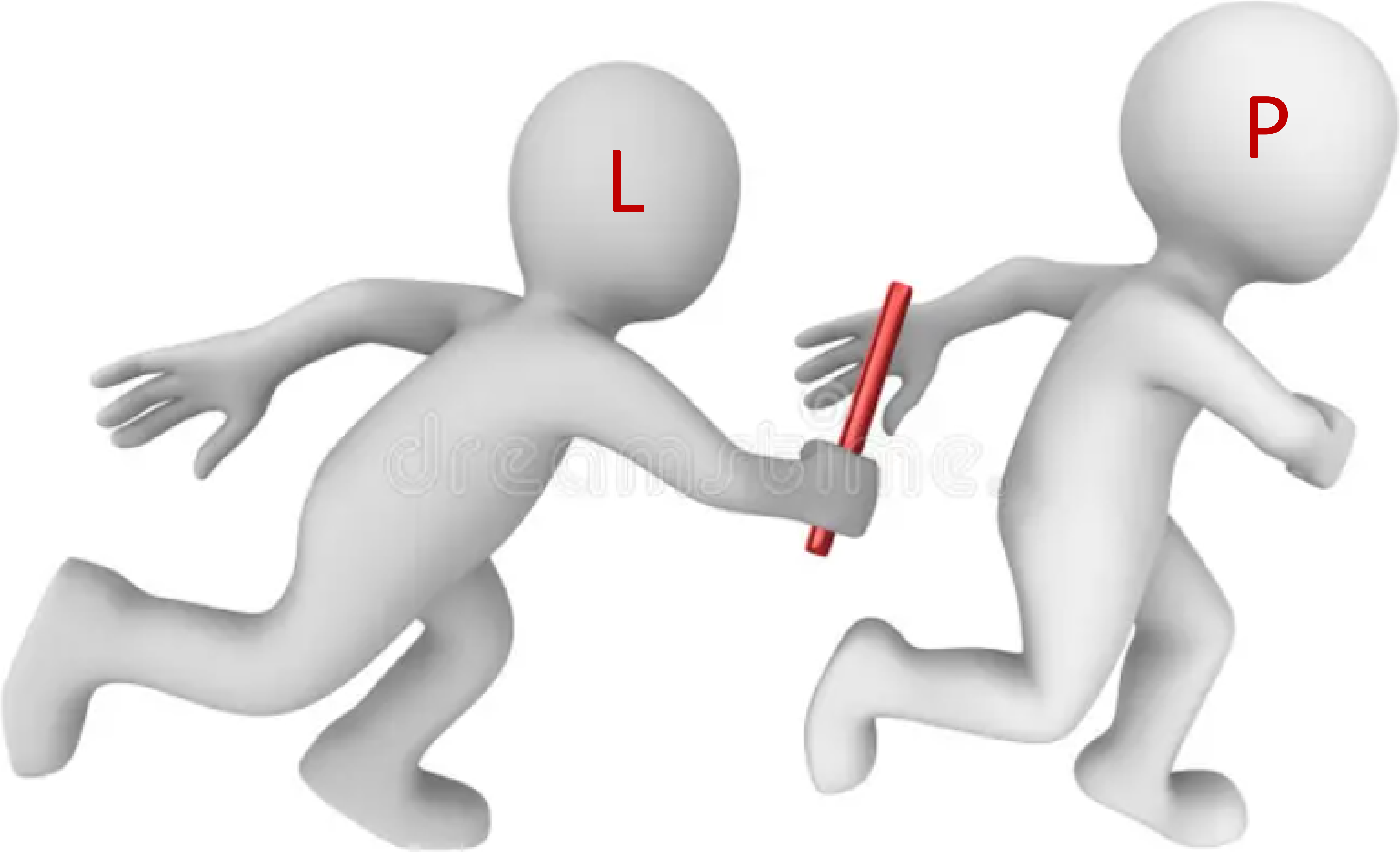


Trends

Simple → Complex

Static → Dynamic

Selection candidate → Group process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Digital phenotyping

www.zdnet.com/article/fitbit-sense-2-review/

Pérez-Enciso and Steibel *Genet Sel Evol* (2021) 53:22
https://doi.org/10.1186/s12711-021-00618-1

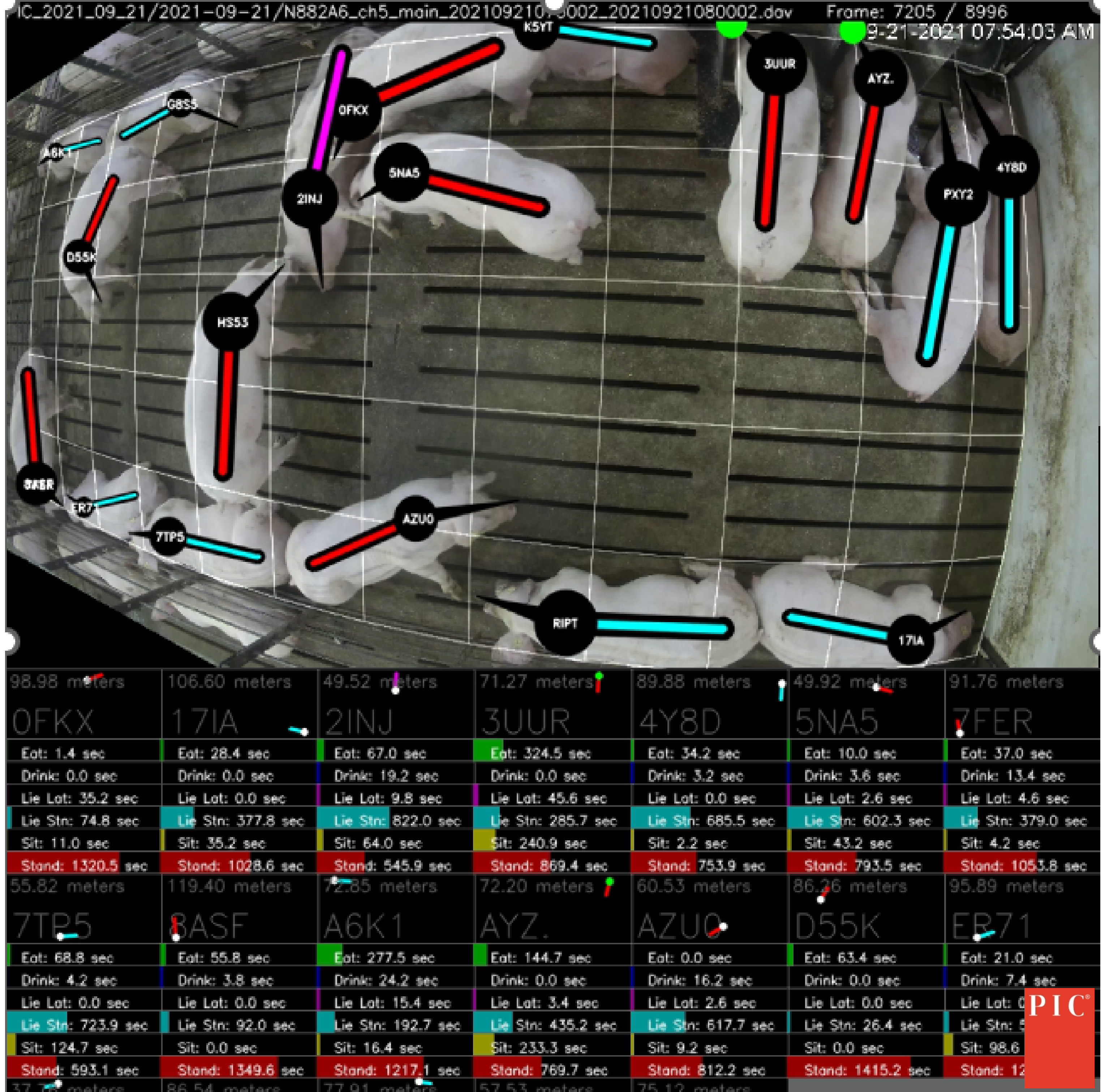
Genetics Selection Evolution

OPINION Open Access

Phenomes: the current frontier in animal breeding

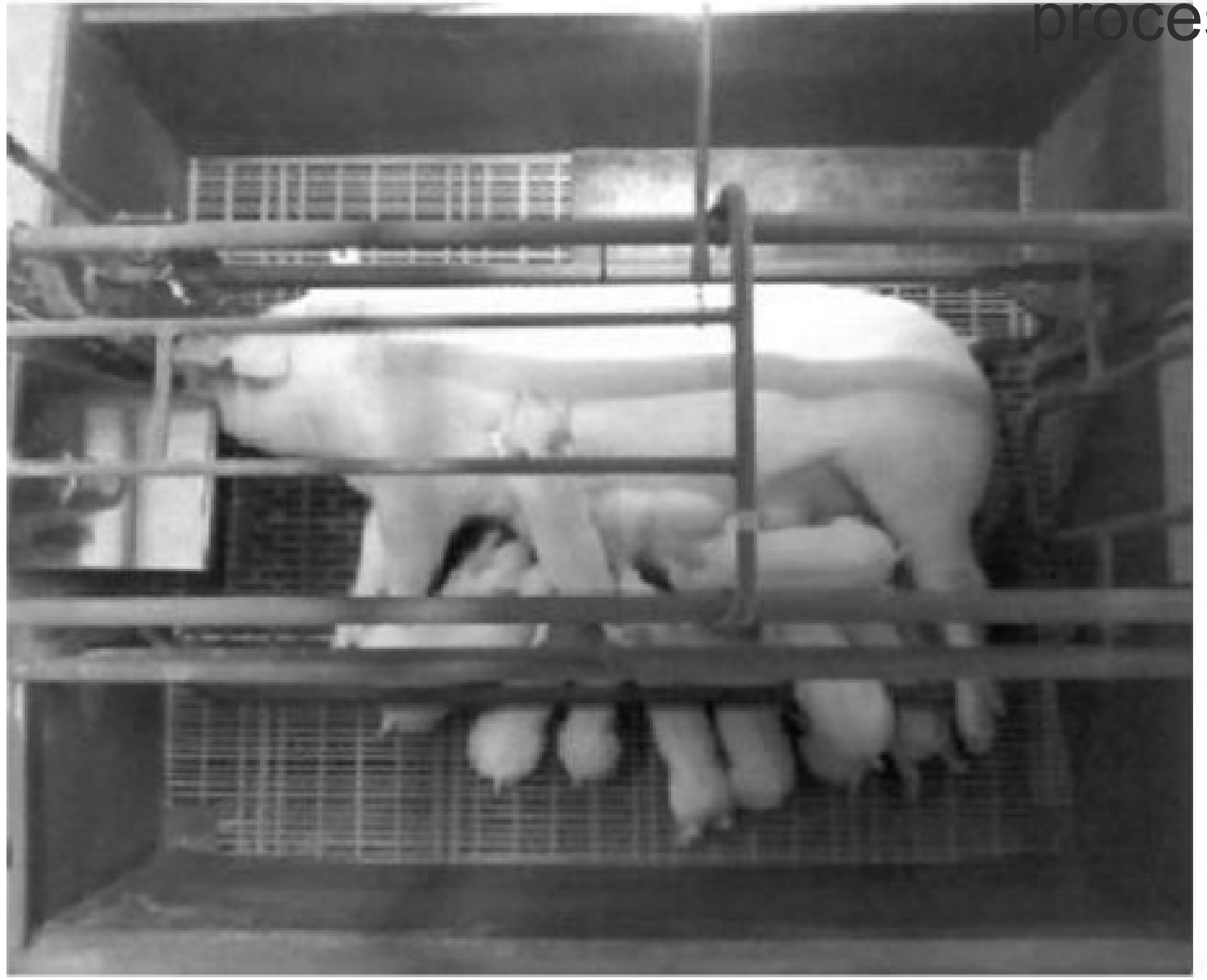
Miguel Pérez-Enciso[1,2*] and Juan P. Steibel[3,4]

- Phenomics: "the acquisition of high-dimensional phenotypic data on an organism-wide scale" (Houle et al, 2010)
- *Big data* challenges ← heterogeneity & rapid change over time of the data, not because of their size
- Two novelties:
    - New traits that could not be recorded before
        - behaviour

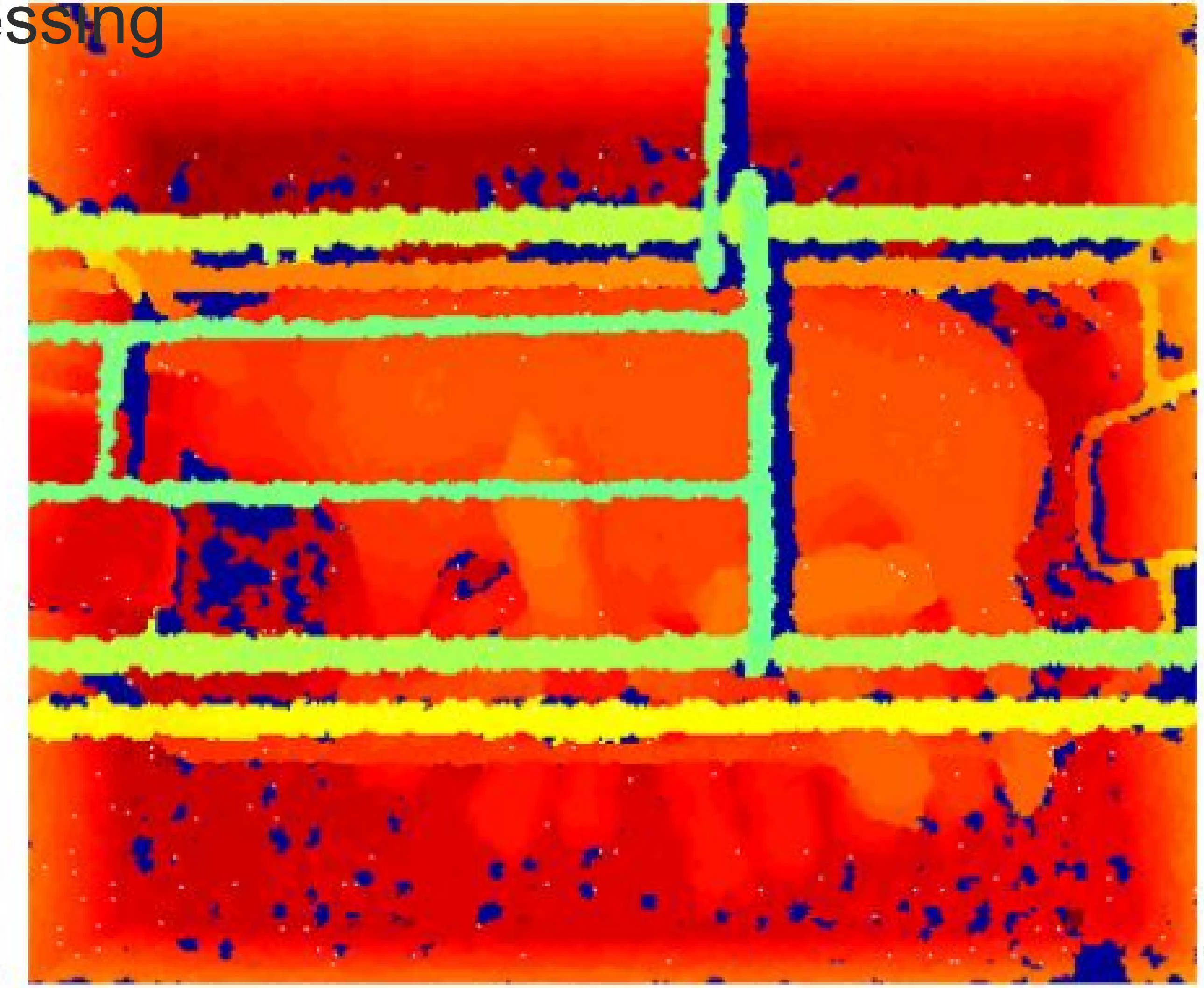


Perez-Enciso & Steibel (2022) doi.org/10.1186/s12711-021-

Automatic recognition of lactating sow behaviors through depth image processing



digital image

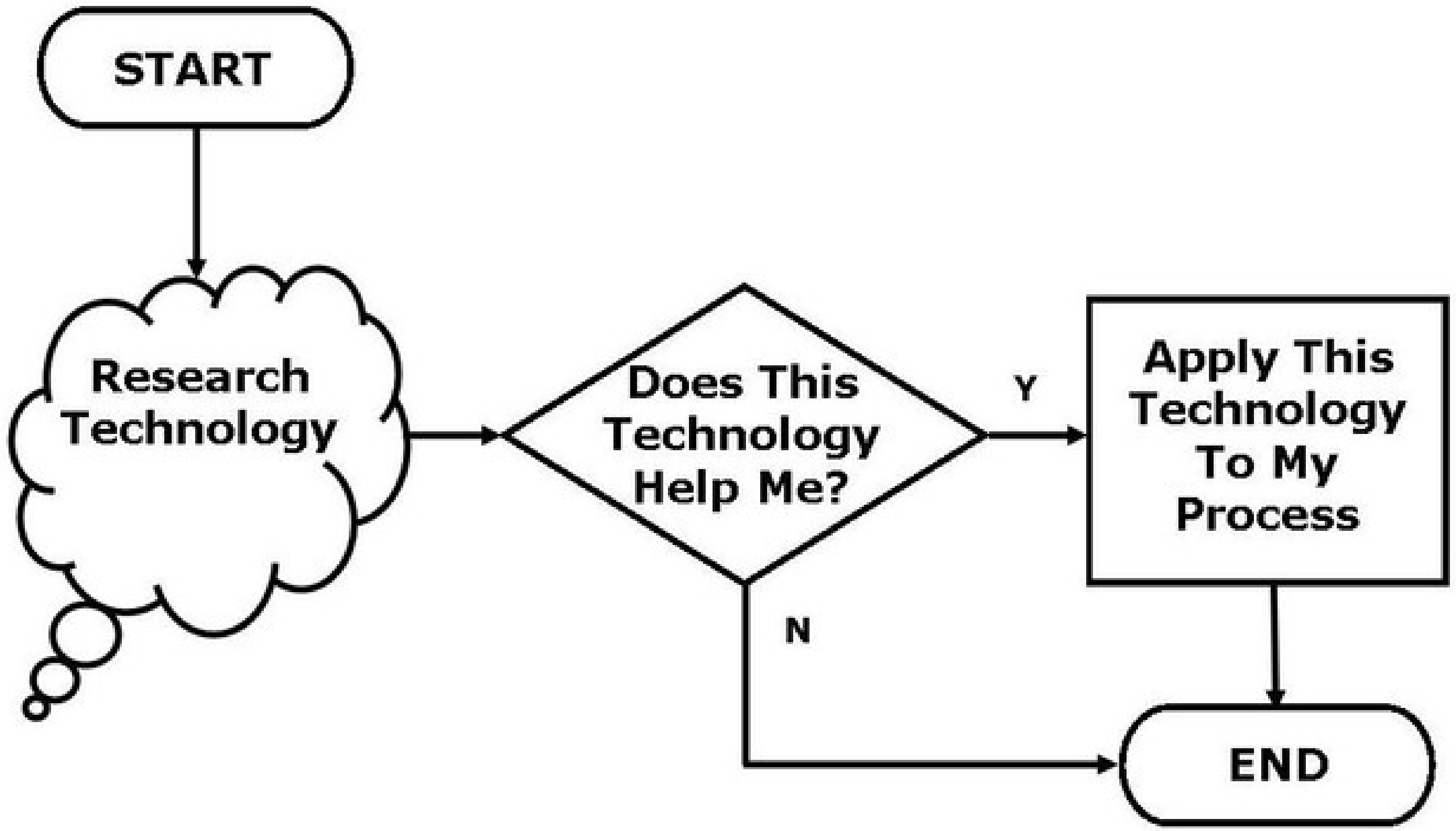


raw depth image

Maternal behaviour, farrowing, savaging, crushing

Lao et al. (2016) doi.org/10.1016/j.compag.2016.04.026.

Interesting. And what do we <u>do</u> with it?



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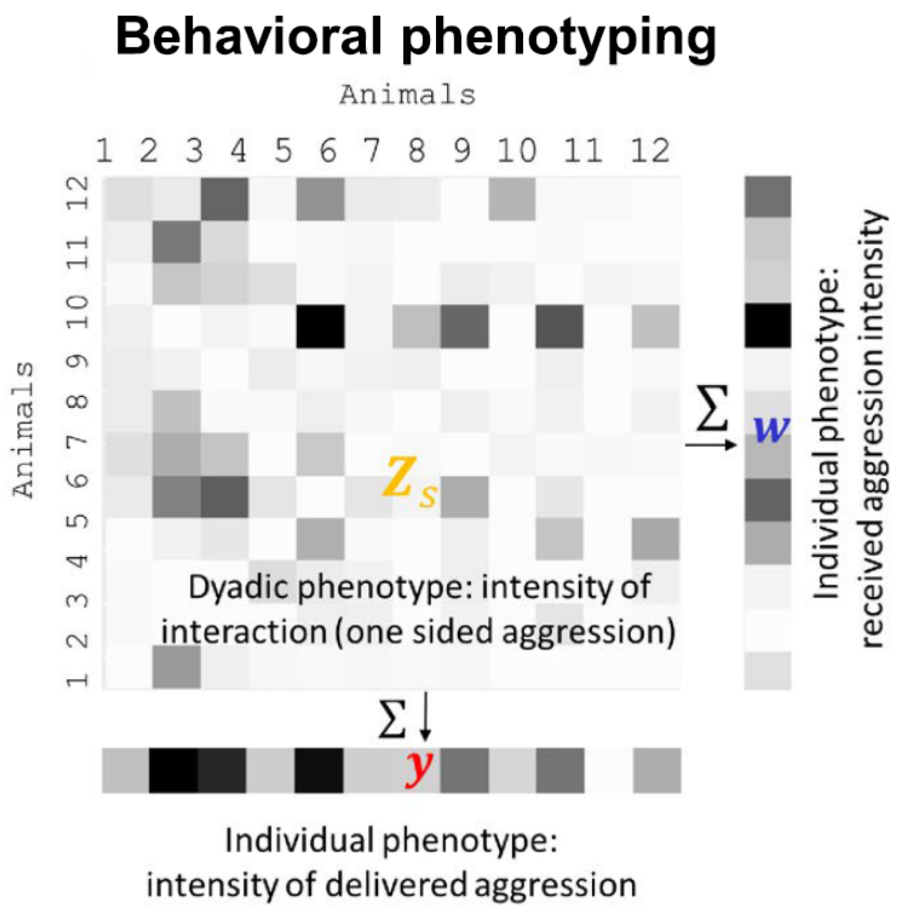

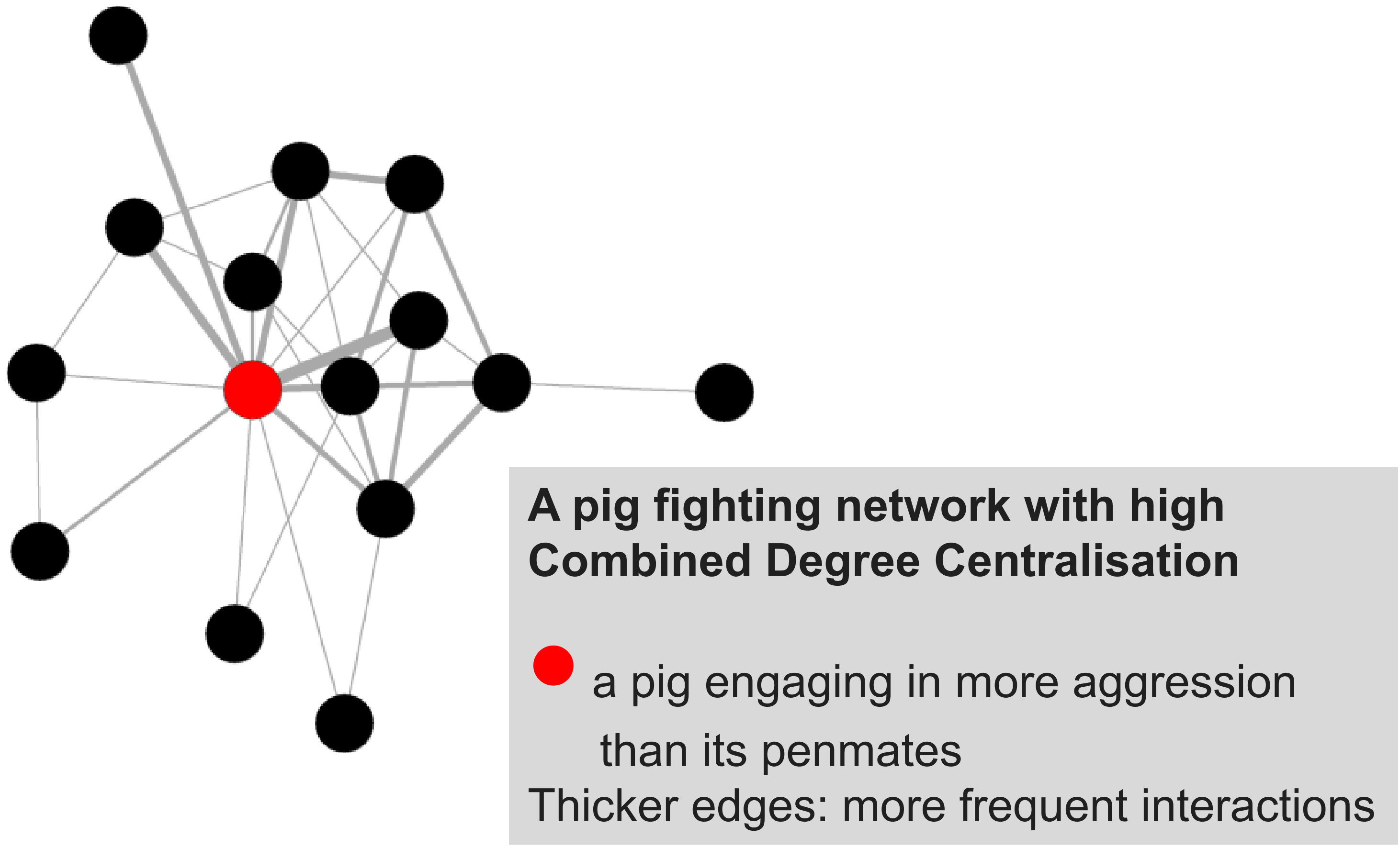

Perez-Enciso & Steibel (2022) doi.org/10.1186/s12711-021-

Foister, Doeschl-Wilson, Roehe, Arnott, Boyle, Turner (2018) doi.org/10.1371/journal.pone.0205122

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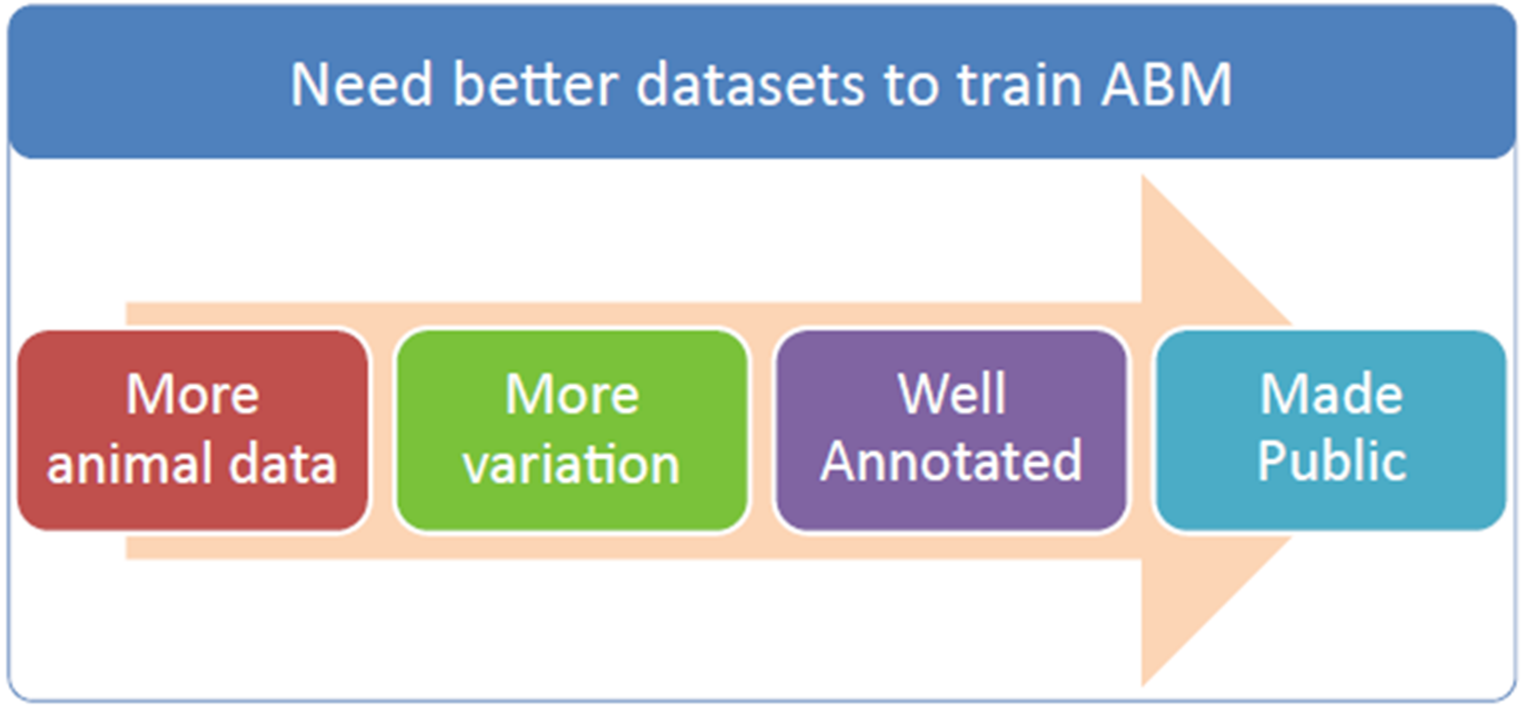
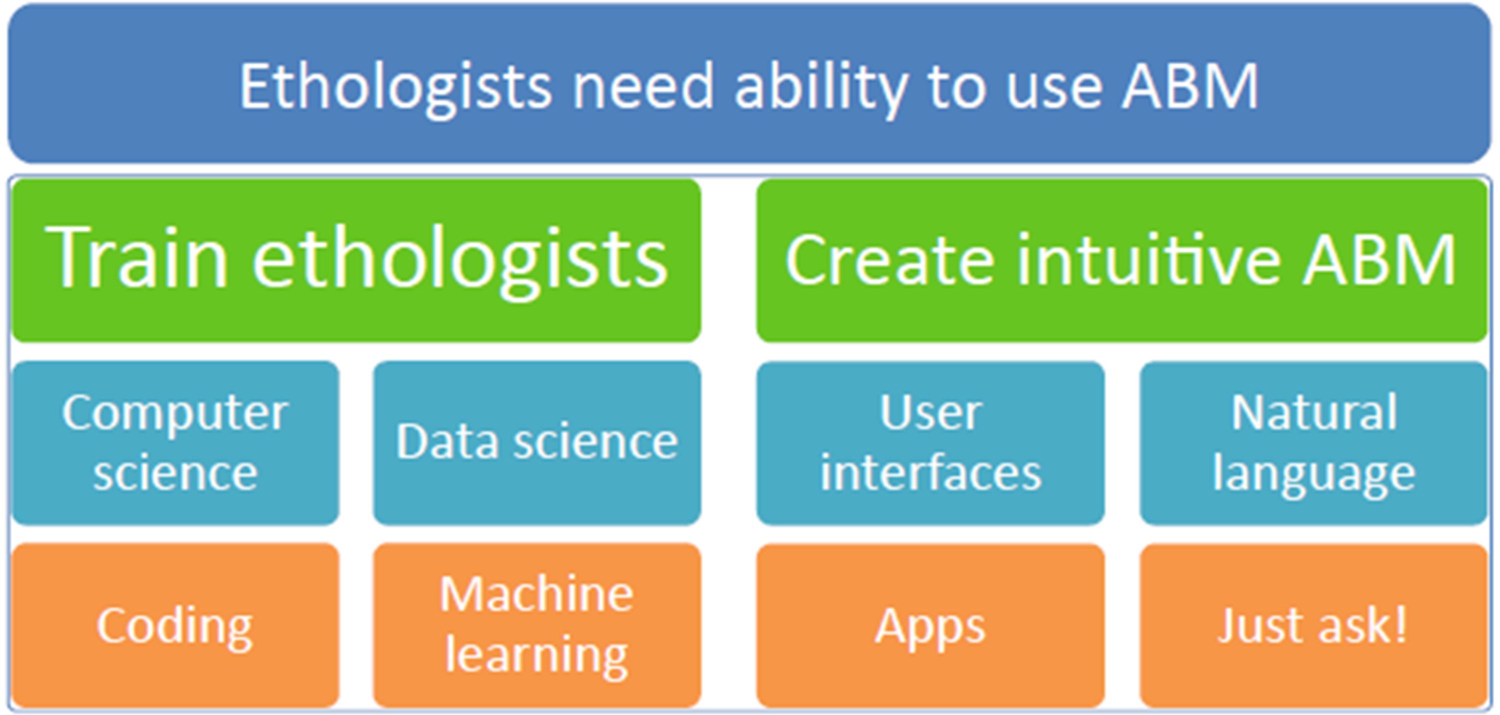
  Automated **B**ehaviour **M**onitoring





Perez-Enciso & Steibel (2022) doi.org/10.1186/s12711-021-

Siegford et al. (2023) doi.org/10.1016/j.applanim.2023.106000

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    - methane emission ← spectroscopy
  - Classical traits can be expanded:
    - more objective → more accurate

Perez-Enciso & Steibel (2022) doi.org/10.1186/s12711-021-

Neural Network vs visual: heritability goes up x 2.3 to x 5

	$\frac{h^2(NN)}{h^2(visual)}$	
line	front	rear
A	2.6	3.4
B	2.3	2.7
C	5.0	2.7
D	3.0	2.8
E	2.9	2.0

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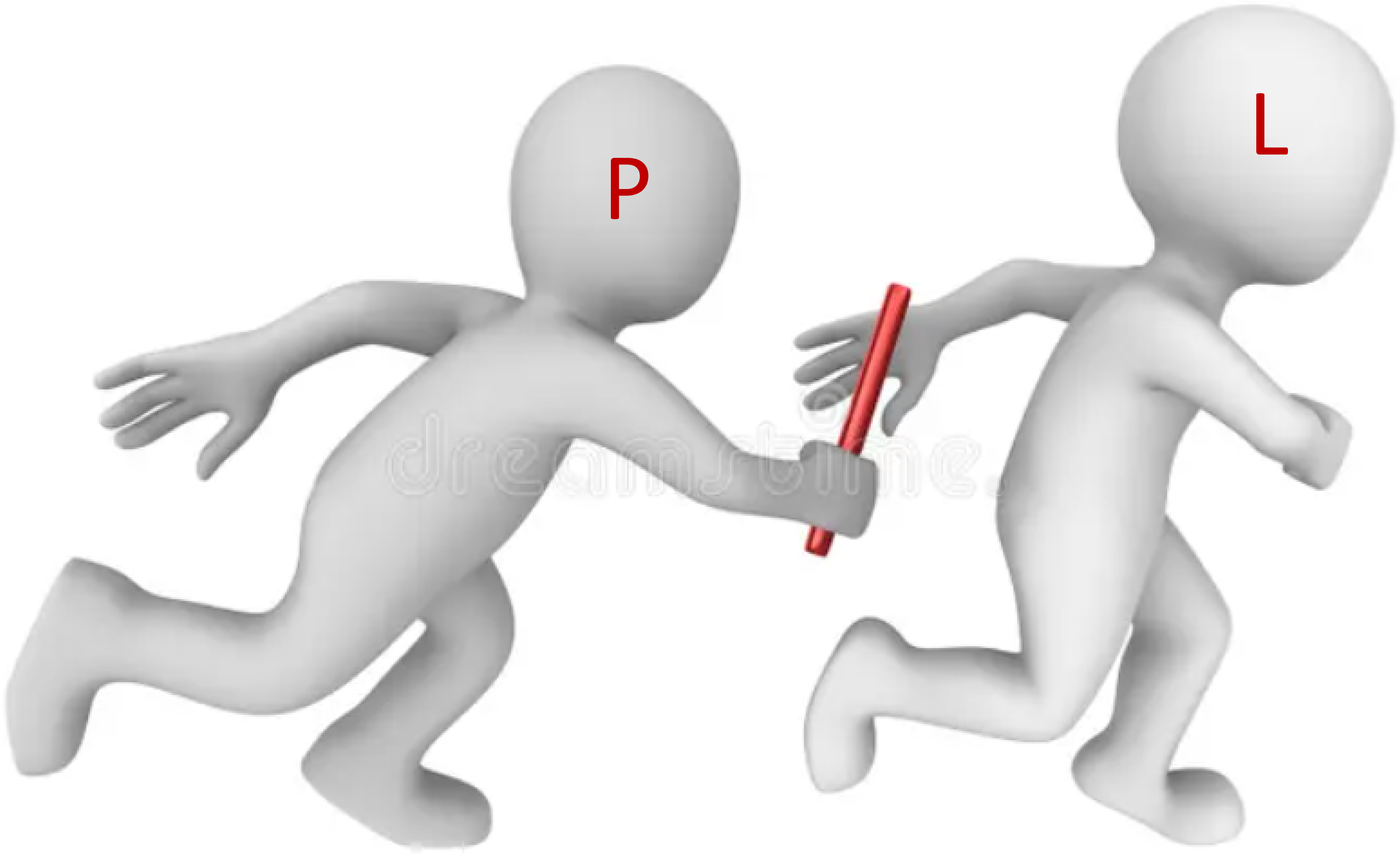
    - longitudinal
    - non-invasive
    - many animals
    - commercial conditions

Perez-Enciso & Steibel (2022) doi.org/10.1186/s12711-021-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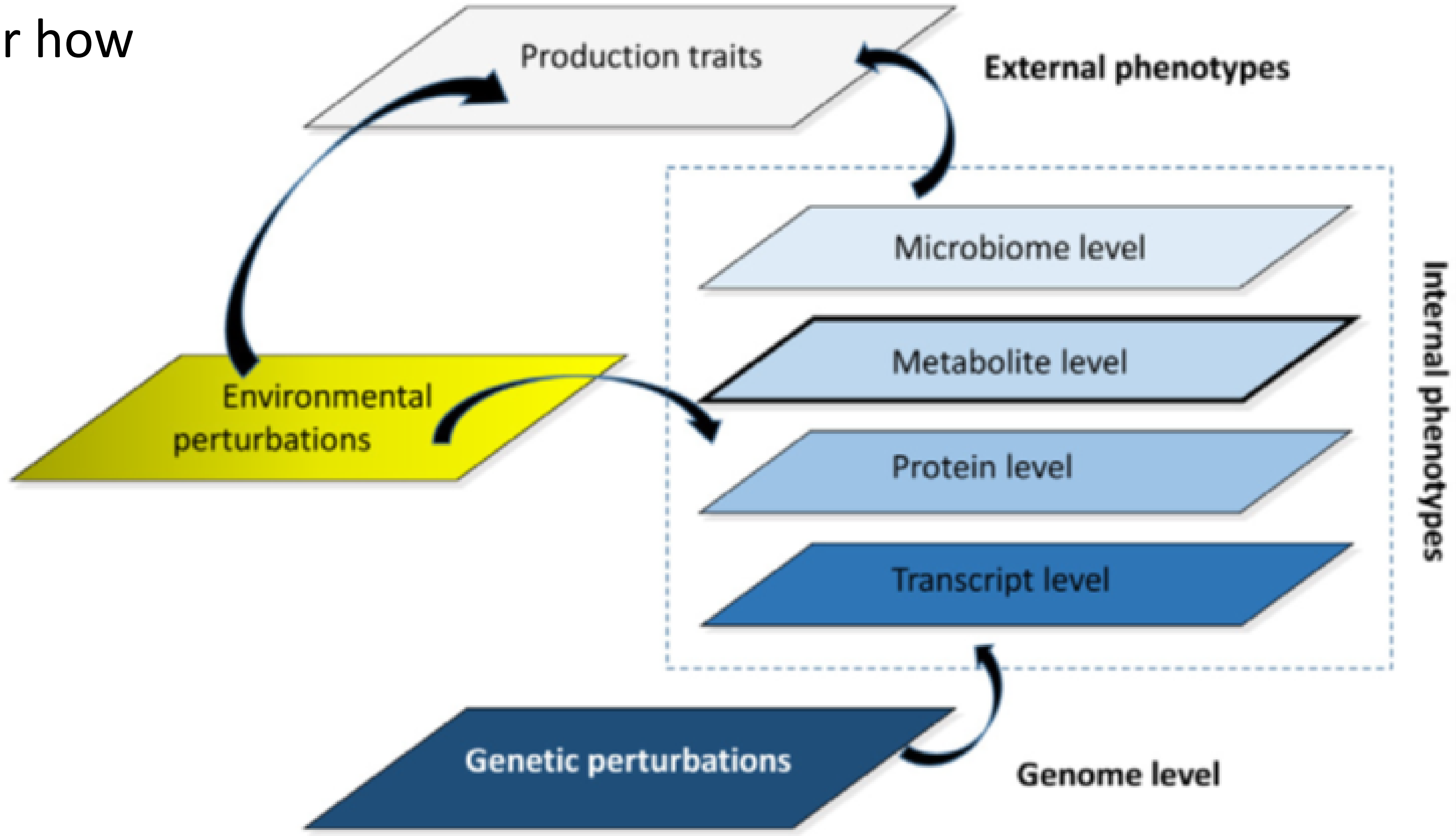
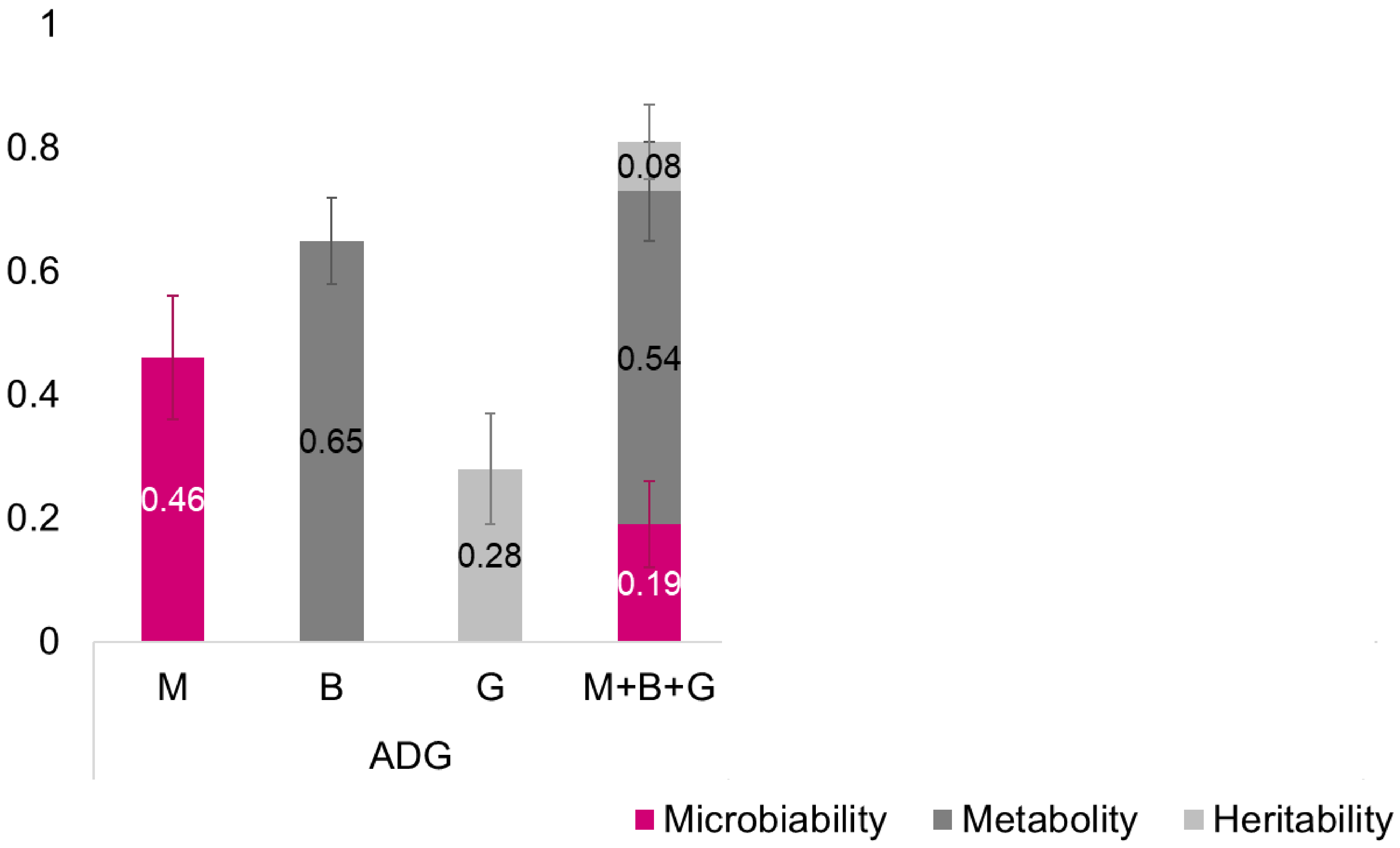


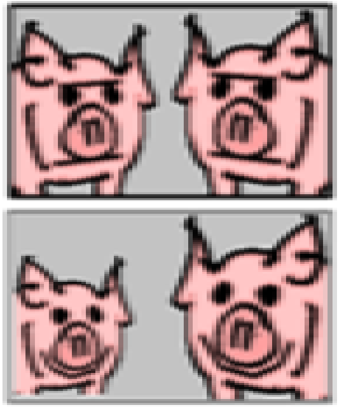
Fontanesi (2016) doi.org/10.2527/af.2016-0011
Perez-Enciso & Steibel (2022) doi.org/10.1186/s12711-021-

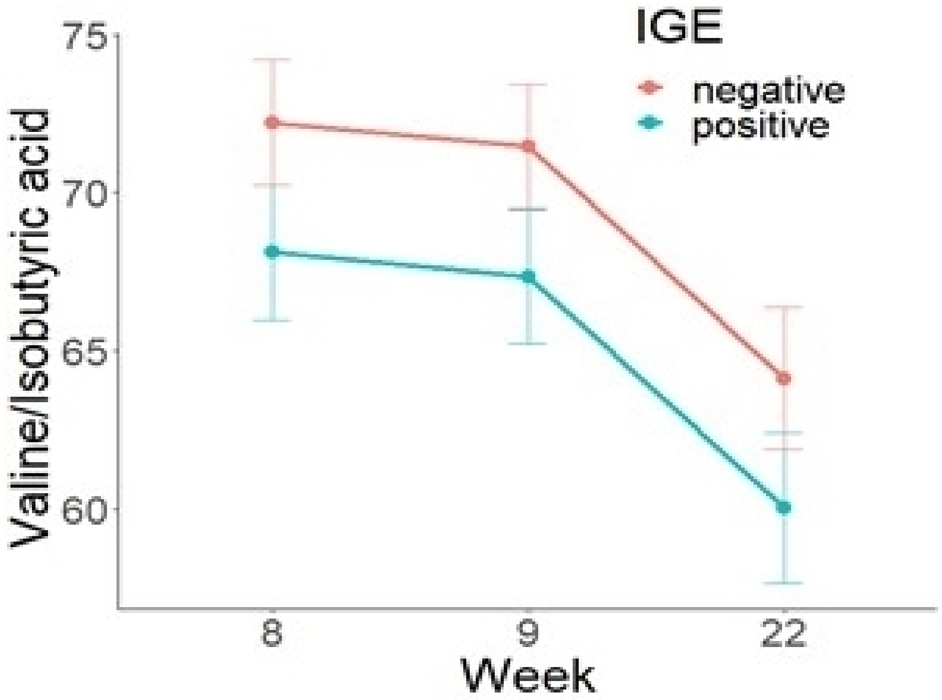
Phenotypic variance explained



Verschuren (2021) Doctoral dissertation, Wageningen University and Research

Metabolite levels & Indirect Genetic Effects





Pigs with **negative** or **positive** indirect genetic effects on growth of their penmates

Valine, leucine, isoleucine levels

Dervishi *et al.* (2021) doi.org/10.1038/s41598-021-02814-x

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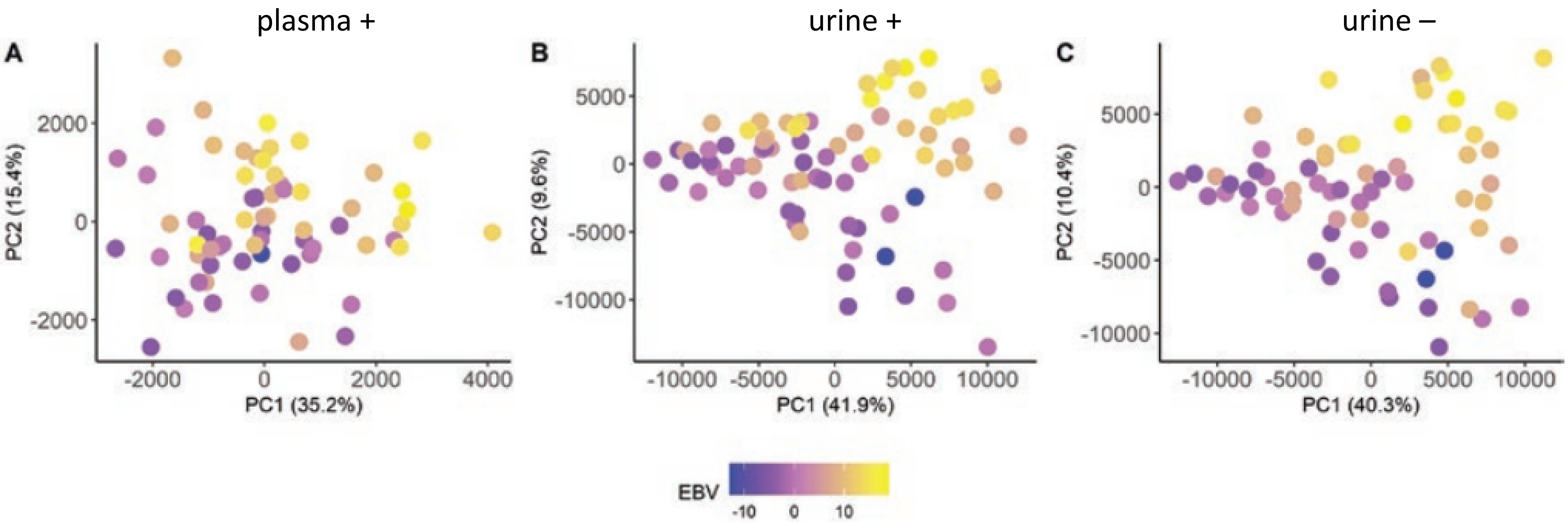
Metabolite levels & nitrogen efficiency



Metabolite ion intensities that discriminate between low and high EBV for nitrogen retention:

First and second Principal Components

Van der Peet-Schwering *et al.* (2021) doi.org/10.1093/jas/skab101

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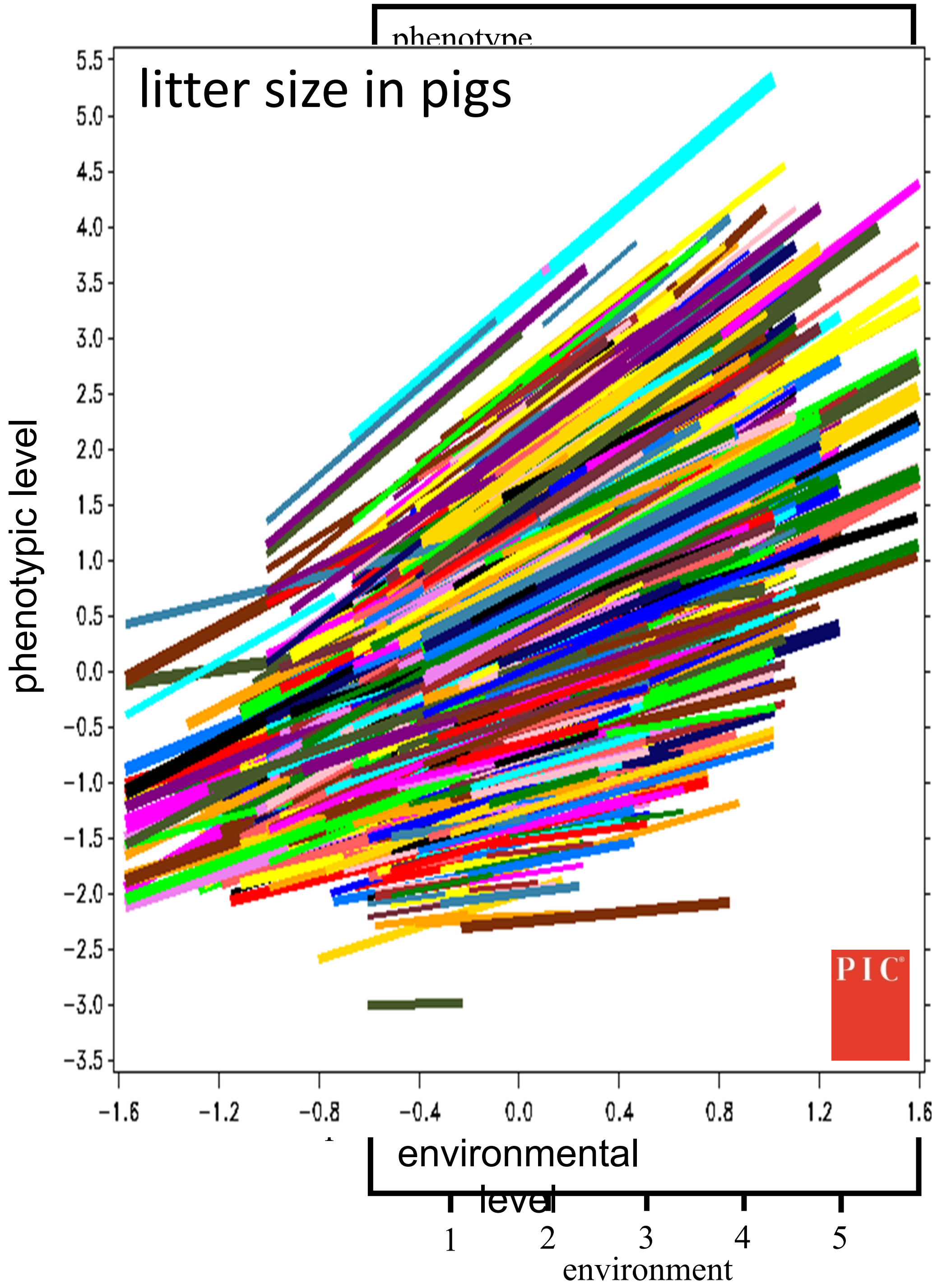
  - redesign breeding schemes
    - explicitly allow for high-dimension phenomics (~ reaction norms)



Genotype x Environment Interaction
Environmental Sensitivity

Knap & Su (2008) doi:10.1017/S1751731108003145
Perez-Enciso & Steibel (2022) doi.org/10.1186/s12711-021-

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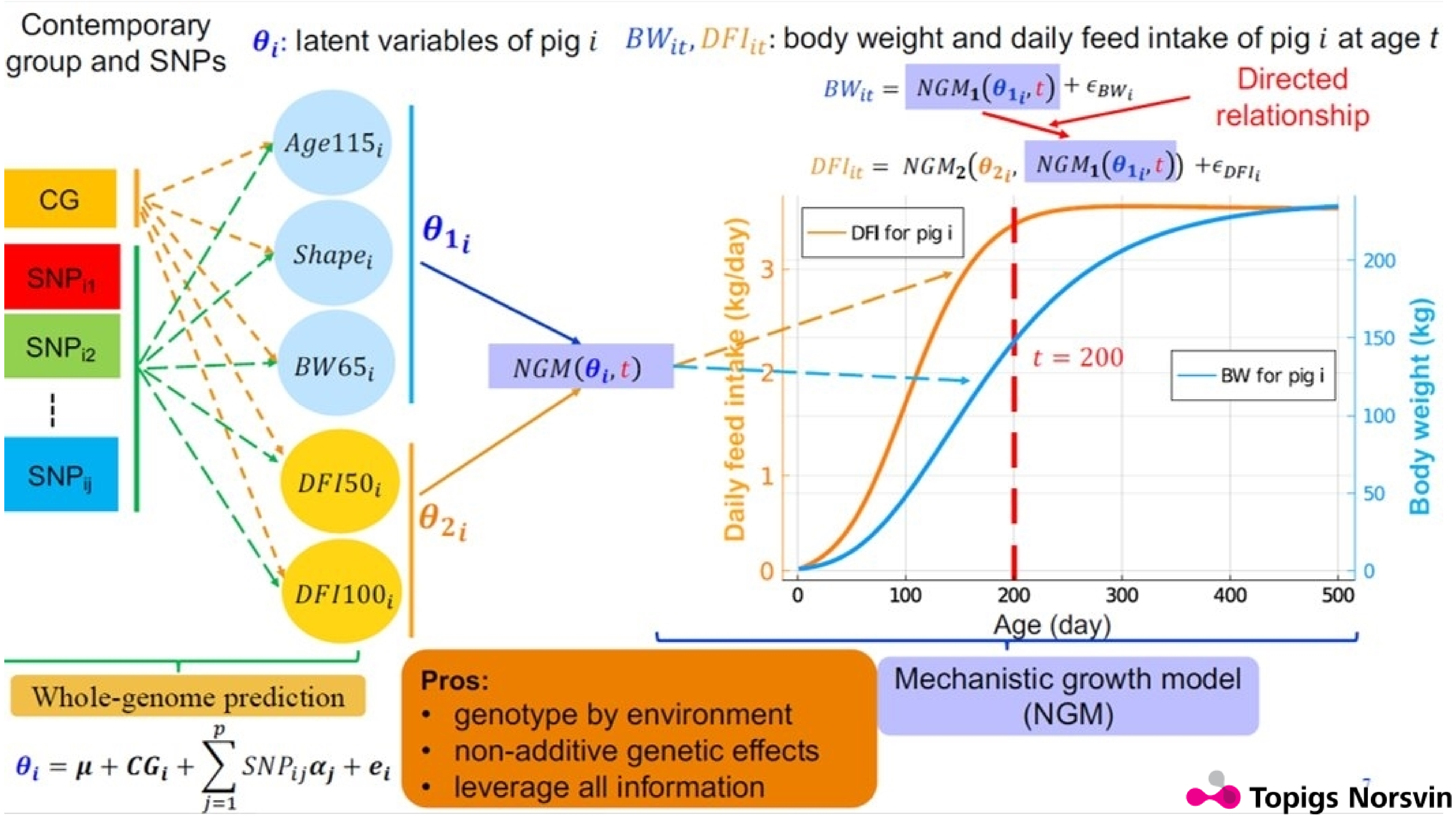
    - explicitly allow for high-dimension phenomics (~ reaction norms)
    - use phenomics data to integrate mechanistic biological models into genetic evaluation

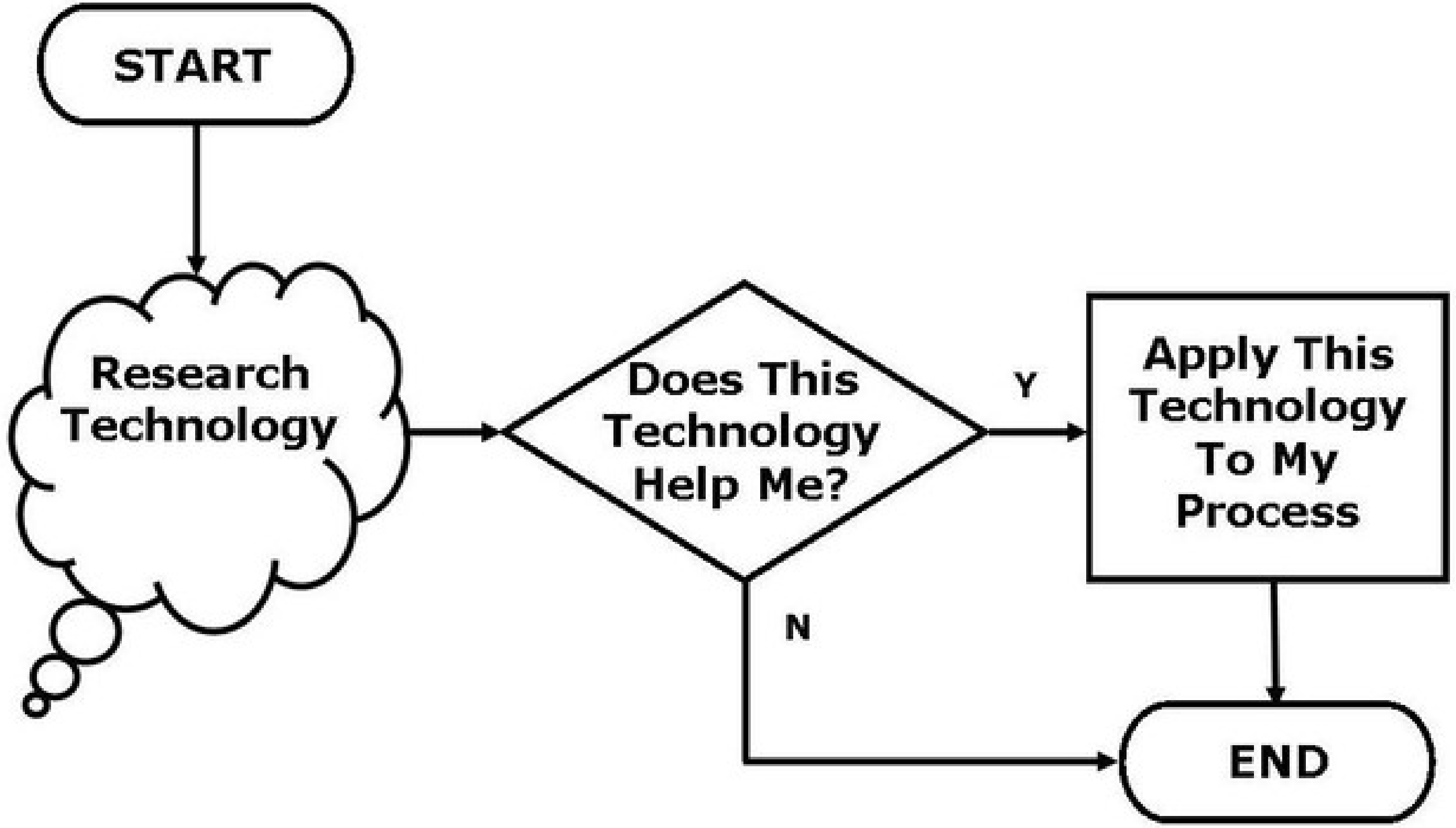
Perez-Enciso & Steibel (2022) doi.org/10.1186/s12711-021-

Mechanistic biological models



Yu et al. (2021) *Journal of Animal Science* 99.Supplement_3:18-19.

Interesting. And what do we <u>do</u> with it?



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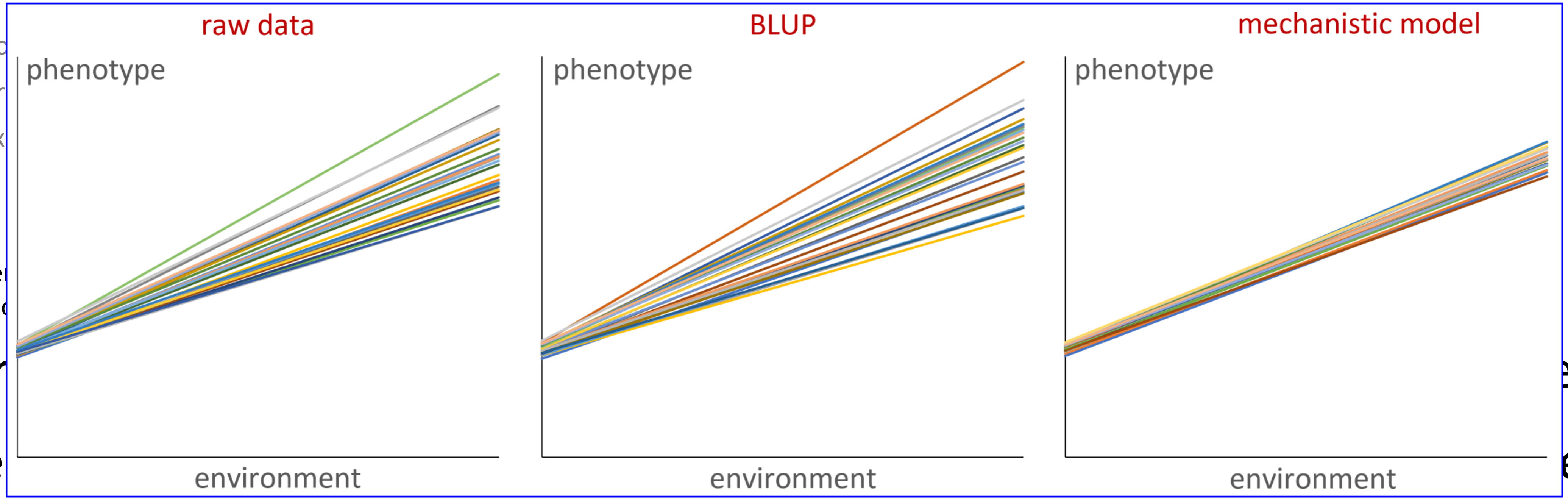
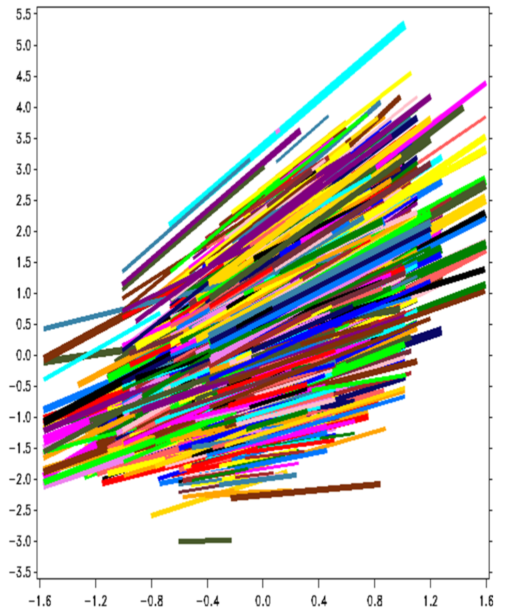
  - redesign br   eaction norms)

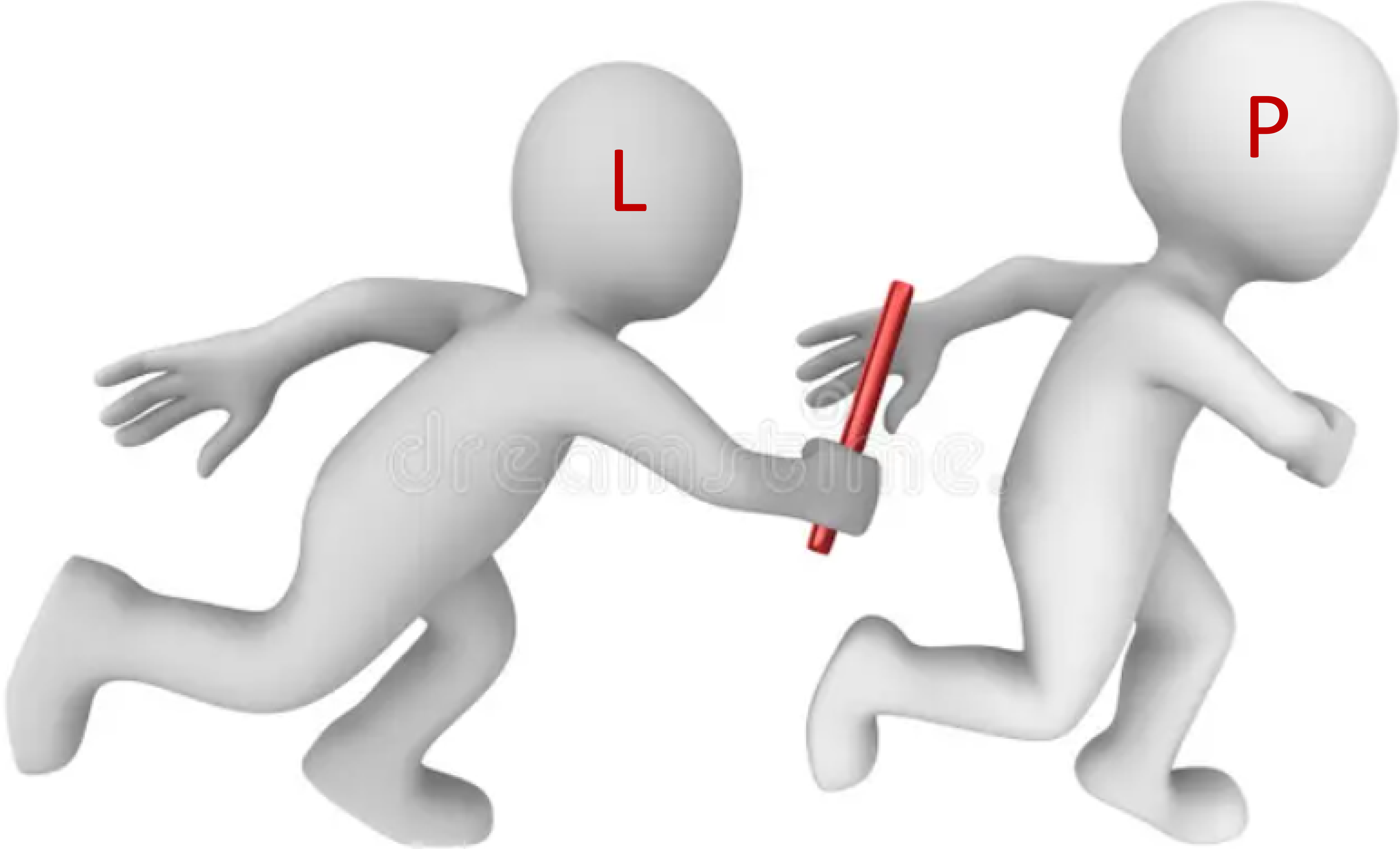


    - use phe   evaluation
    - example: wheat yield per hectare in France, 28 genotypes, 16 locations
    - raw data → BLUP → mechanistic model
      - better capture of non-linear effects
      - more uniform (and much more accurate) slopes → less evidence for GxE
      - a linear model of a non-linear system produces phantom interaction effects
      - non-linear model is much more appropriate



De los Campos, Pérez-Rodríguez, Bogard (2020) doi.org/10.1038/s41467-020-18480-y

Perez-Enciso & Steibel (2022) doi.org/10.1186/s12711-021-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- Phenomics: the acquisition of high-dimensional phenotypic data on an organism-wide scale (Houle et al, 2010)
- *Big data* challenges ← heterogeneity & rapid change over time of the data, not because of their size
- Two novelties: new traits, expanded classical traits
- Novel options to explore

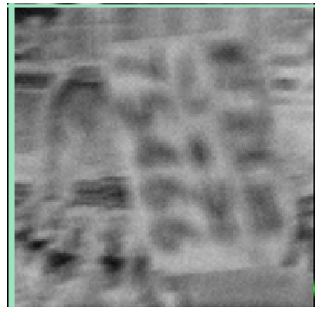
Key factor: animal identification

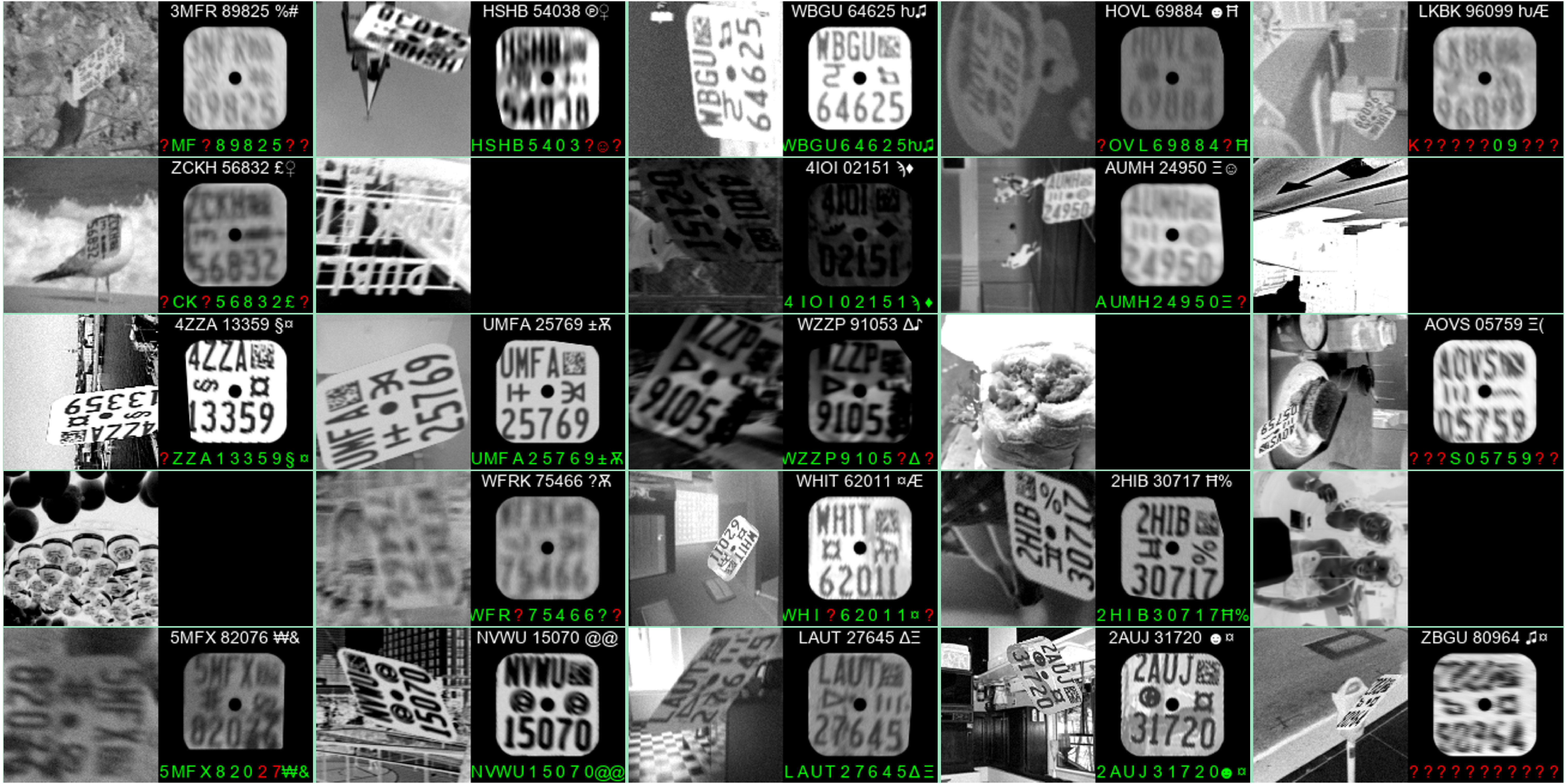
- Necessary, for breeding
- Difficult

LitterMax eartags

- 2 mio permutations for ID
- QR code
- error trapping codes
- the trick is to make the robot read them correctly

Perez-Enciso & Steibel (2022) doi.org/10.1186/s12711-021-





3MFR 89825 %#
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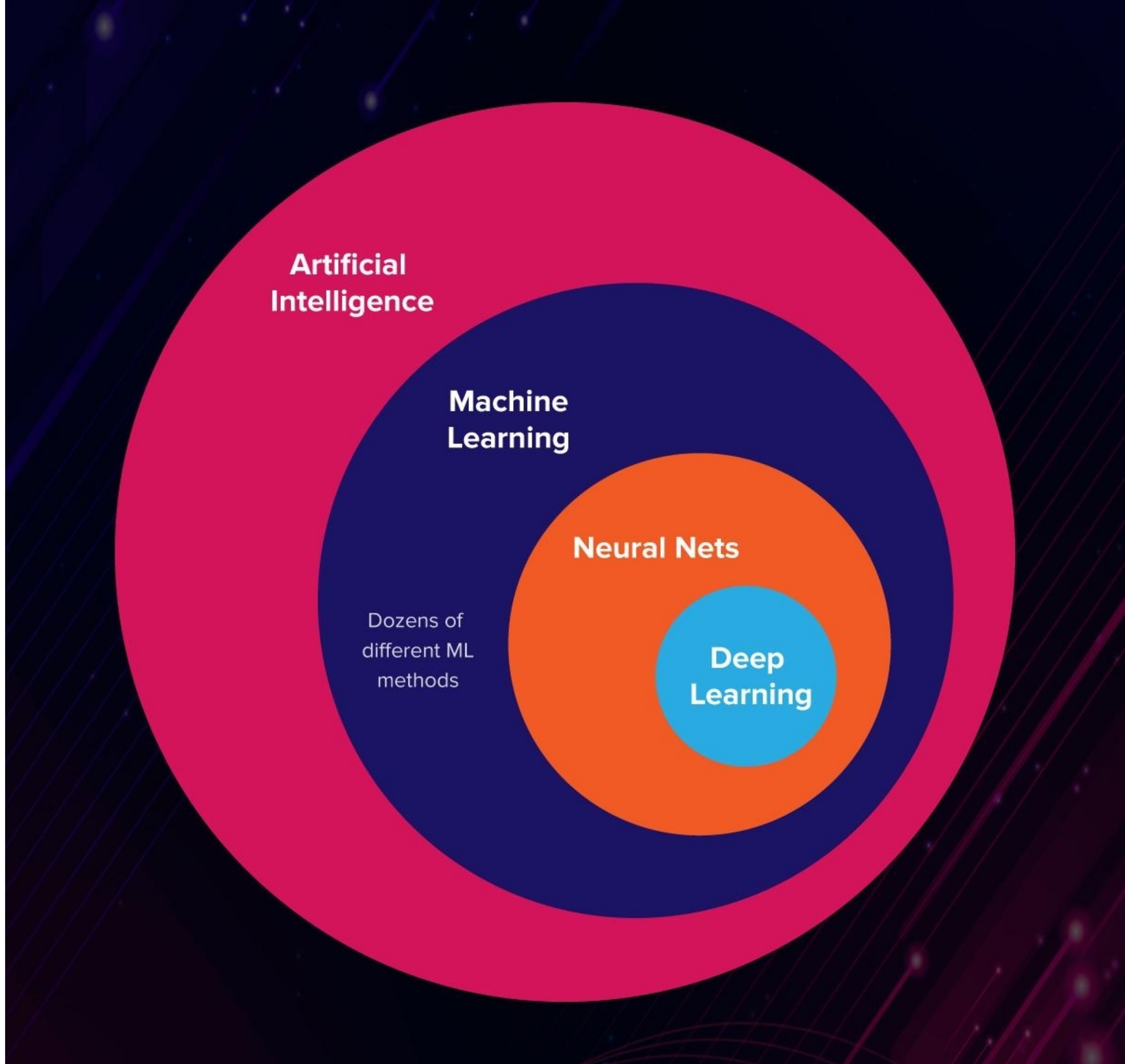
- Phenomics: the acquisition of high-dimensional phenotypic data on an organism-wide scale (Houle et al, 2010)
- *Big data* challenges ← heterogeneity & rapid change over time of the data, not because of their size
- Two novelties: new traits, expanded classical traits
- Key factor: animal identification
  - necessary
  - difficult
- Key factor: internet access
  - challenging in rural areas
- Key factor: heterogeneity of the data
  - non-random missing data
  - imputation: Variational Auto-Encoders, Generational Adversarial Networks
- *There is an enormous range of analytical tools to be developed*

Perez-Enciso & Steibel (2022) doi.org/10.1186/s12711-021-

Statistical methods

cloud2data.com/how-to-make-artificial-intelligence

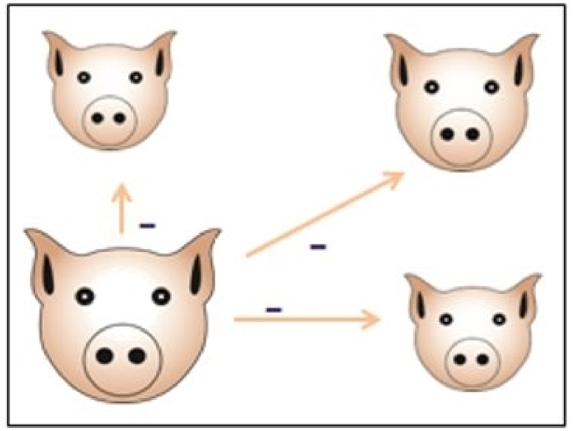


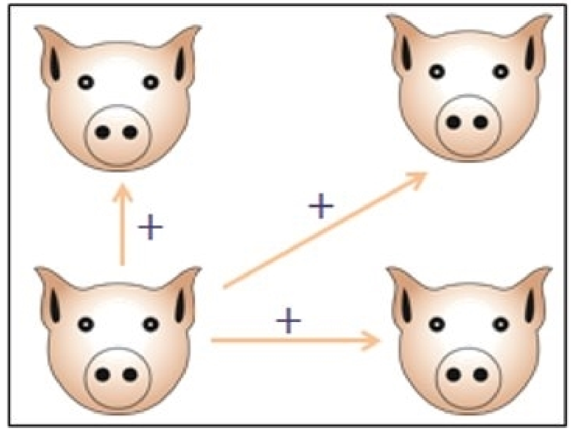
serokell.io/blog/ai-ml-dl-difference

Classic modeling

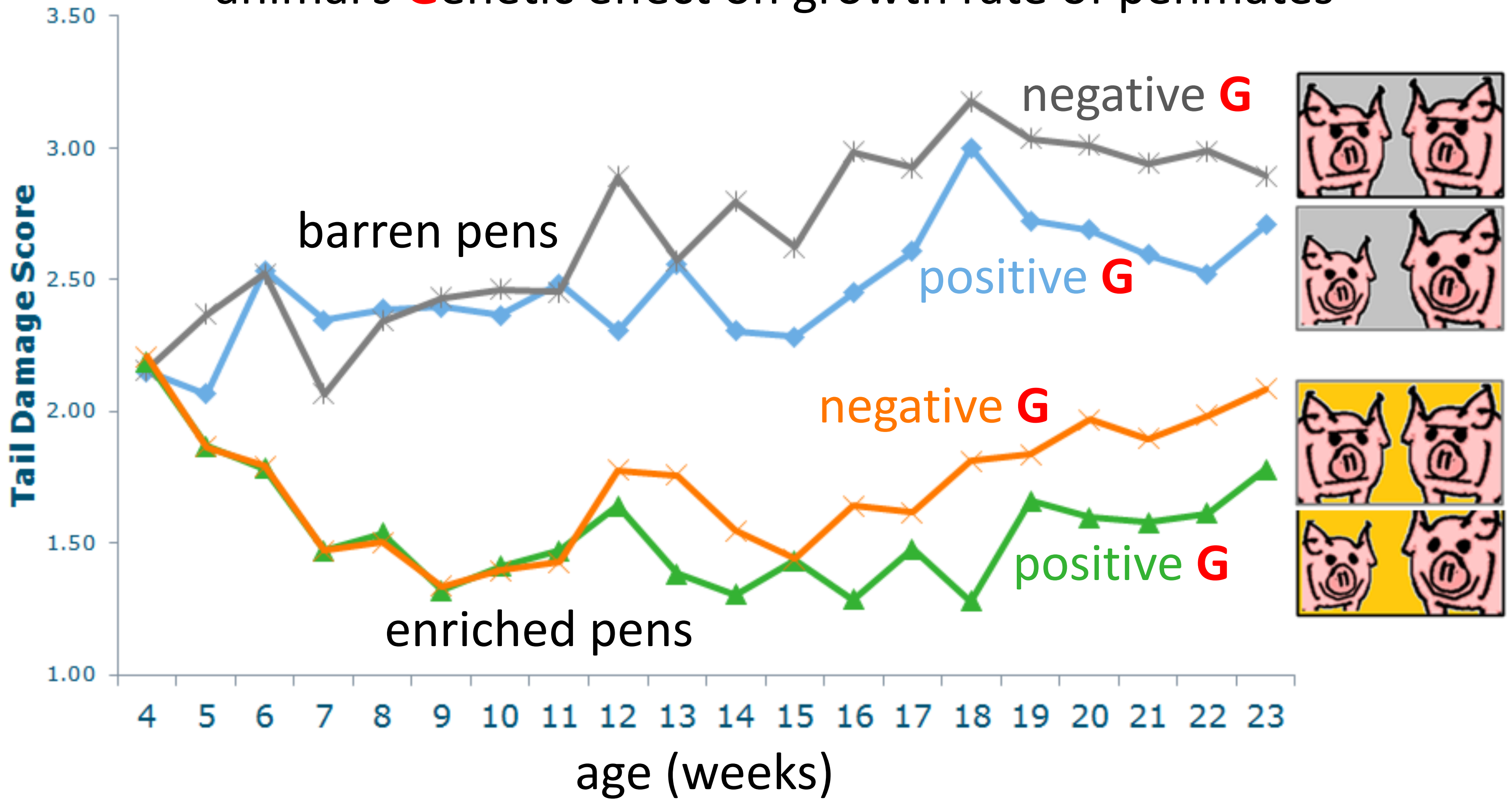
Multi-trait model with individual behavior and production trait

$$\begin{pmatrix} x \\ w \\ y \end{pmatrix} = f(M)$$



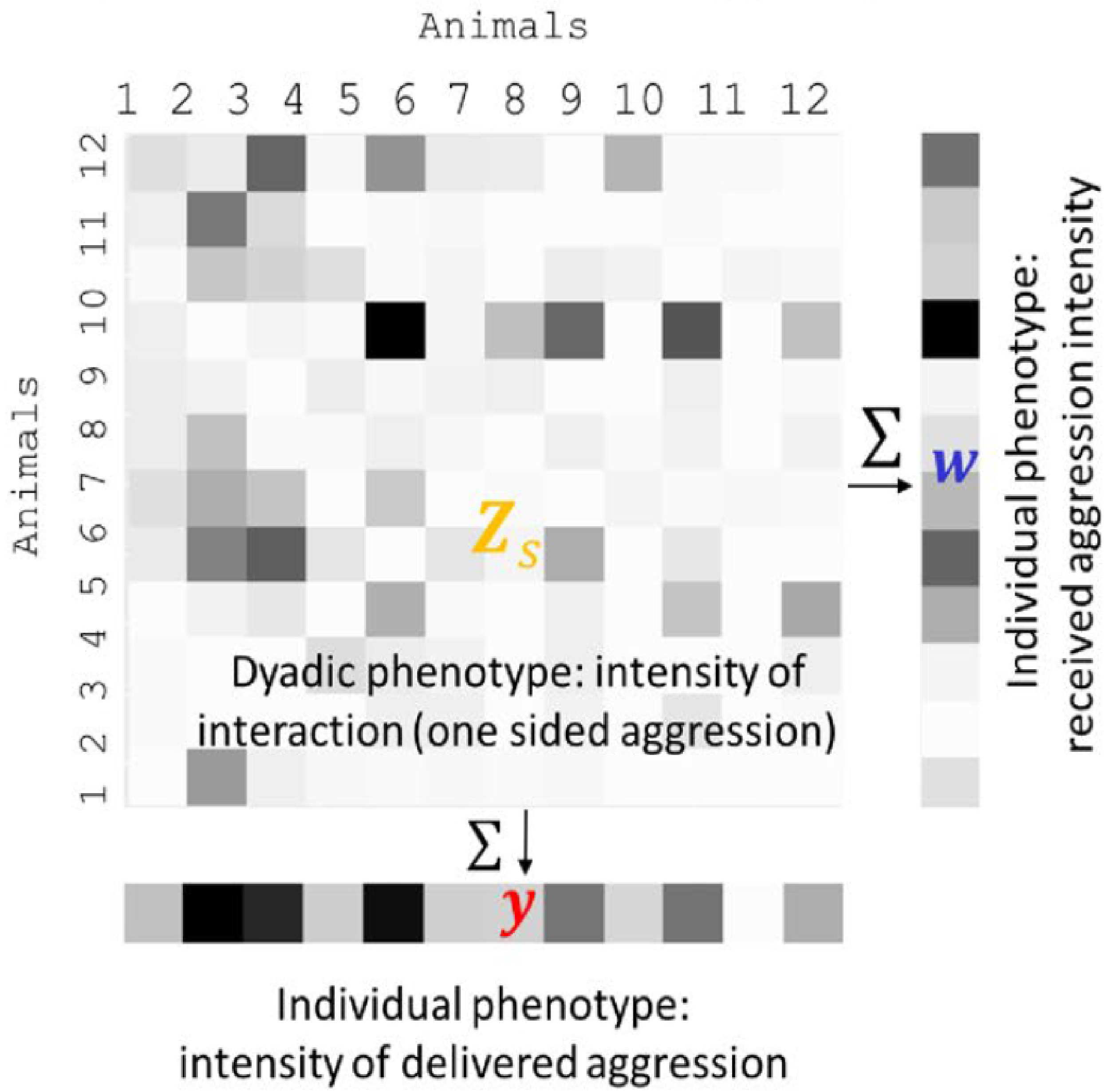


tailbiting:
animal's Genetic effect on growth rate of penmates



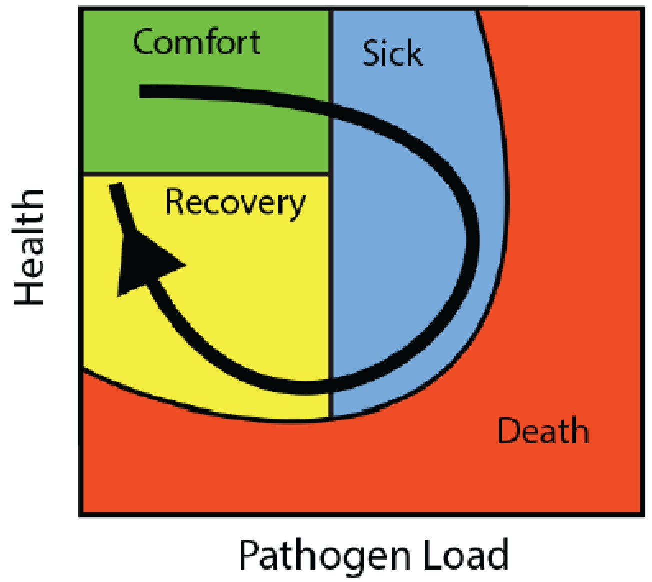
Camerlink et al. (2015) doi.org/10.1007/s10519-014-9671-9
Pérez-Enciso & Steibel (2022) doi.org/10.1186/s12711-021-00618-1

Behavioral phenotyping

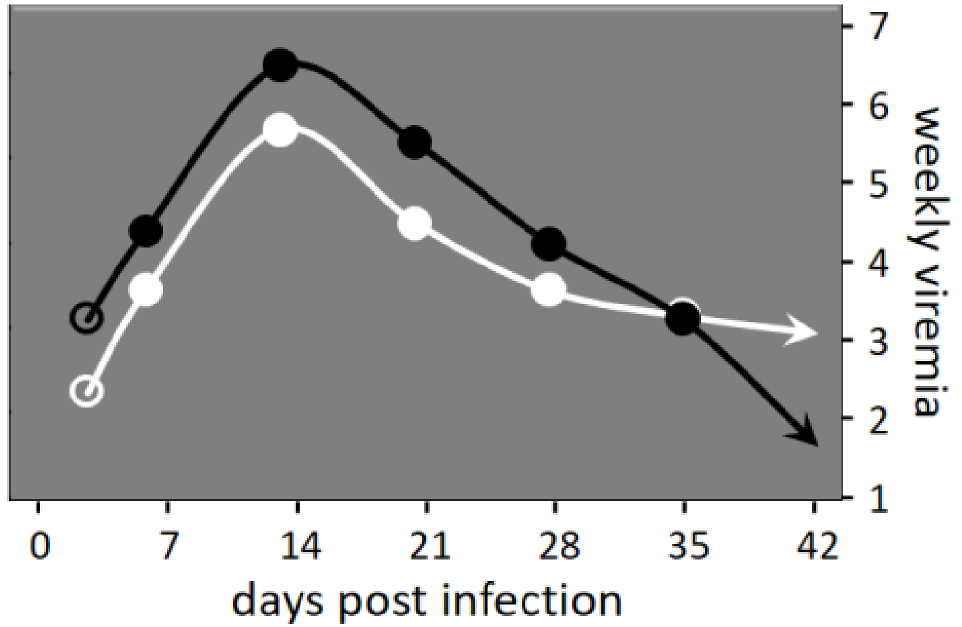


Novel models

Perez-Enciso & Steibel (2022) doi.org/10.1186/s12711-021-00618-1

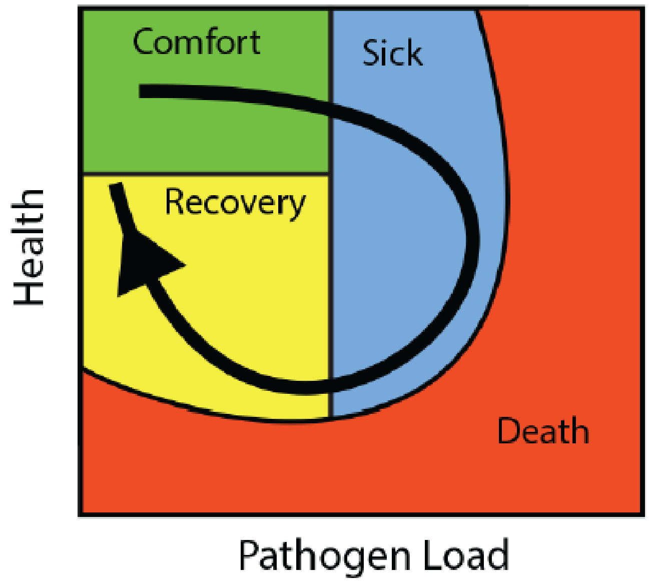


Example: two pigs infected with PRRS virus and followed for 6 weeks

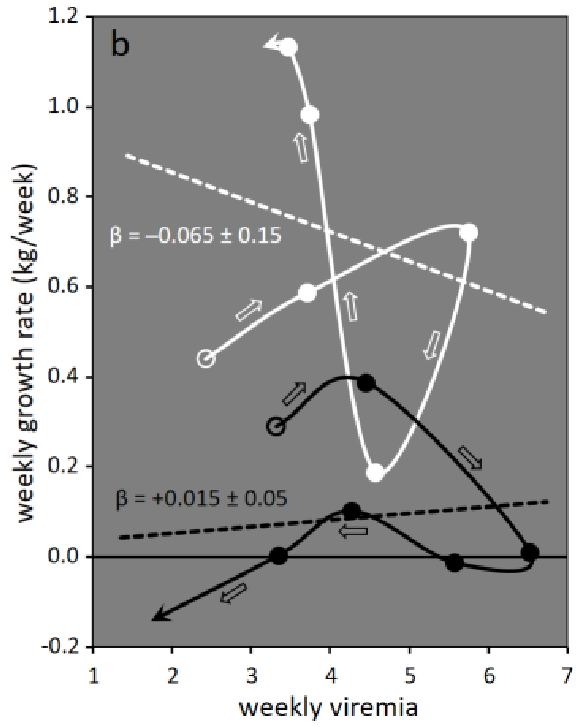


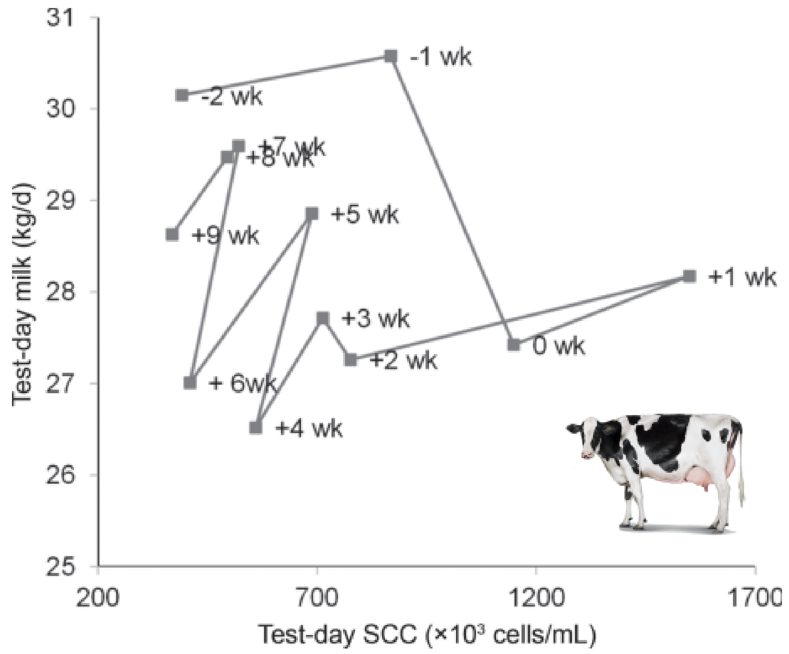
Torres, Oliveira, Tate, Rath, Cumnock & Schneider (2016) doi.org/10.1371/journal.pbio.1002436

Knap & Doeschl-Wilson (2020) doi.org/10.1186/s12711-020-00580-4



- Stages of infection associated with the strongest loss of health & performance
  - insight into underlying resilience mechanisms and target genes
  - design effective, timely & targeted treatment
- "These patterns cannot be described by mathematical functions"
- Requires novel indicators to
  - capture the trajectory characteristics
  - support routine genetic evaluation



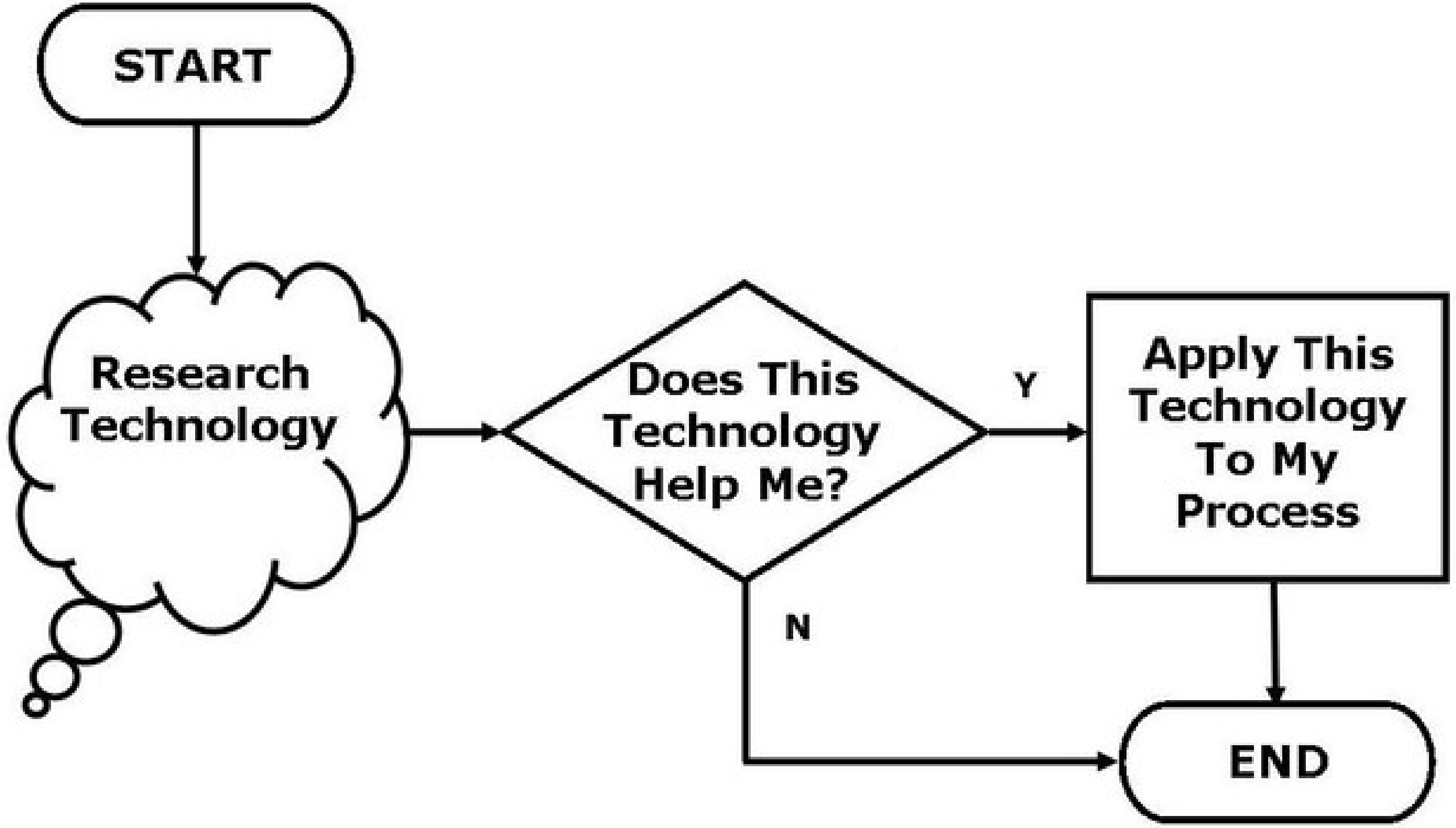


Torres, Oliveira, Tate, Rath, Cumnock & Schneider (2016) doi.org/10.1371/journal.pbio.1002436

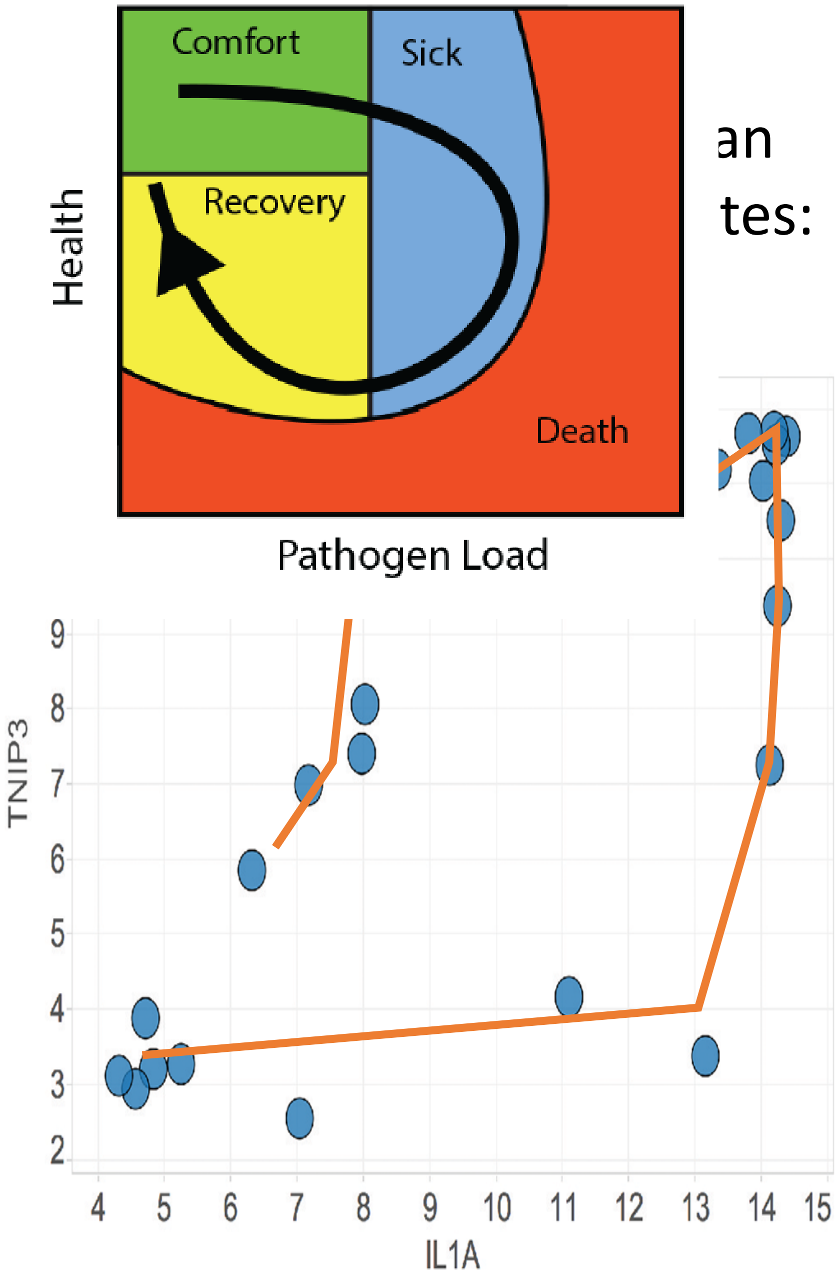
Detilleux (2018) doi.org/10.3168/jds.2017-13976

Knap & Doeschl-Wilson (2020) doi.org/10.1186/s12711-020-00580-4

Interesting. And what do we <u>do</u> with it?



www.linkedin.com/pulse/technology-sounds-great-what-do-we-dan-grove



an

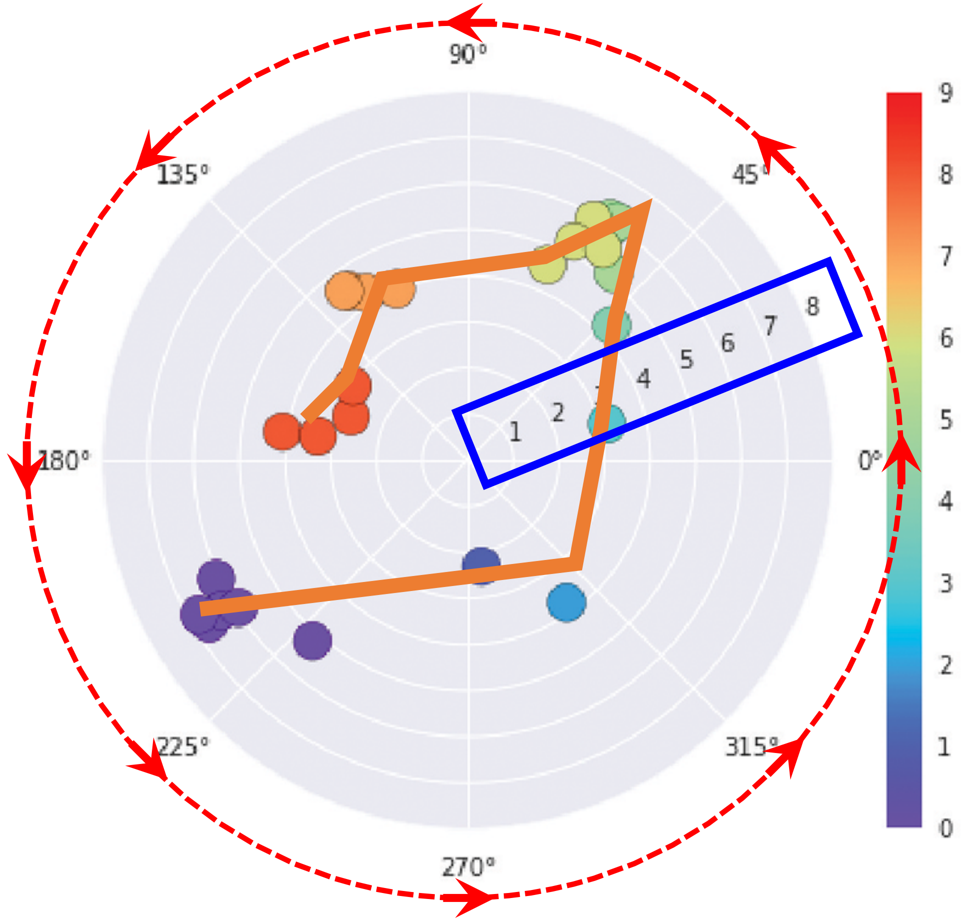
tes:

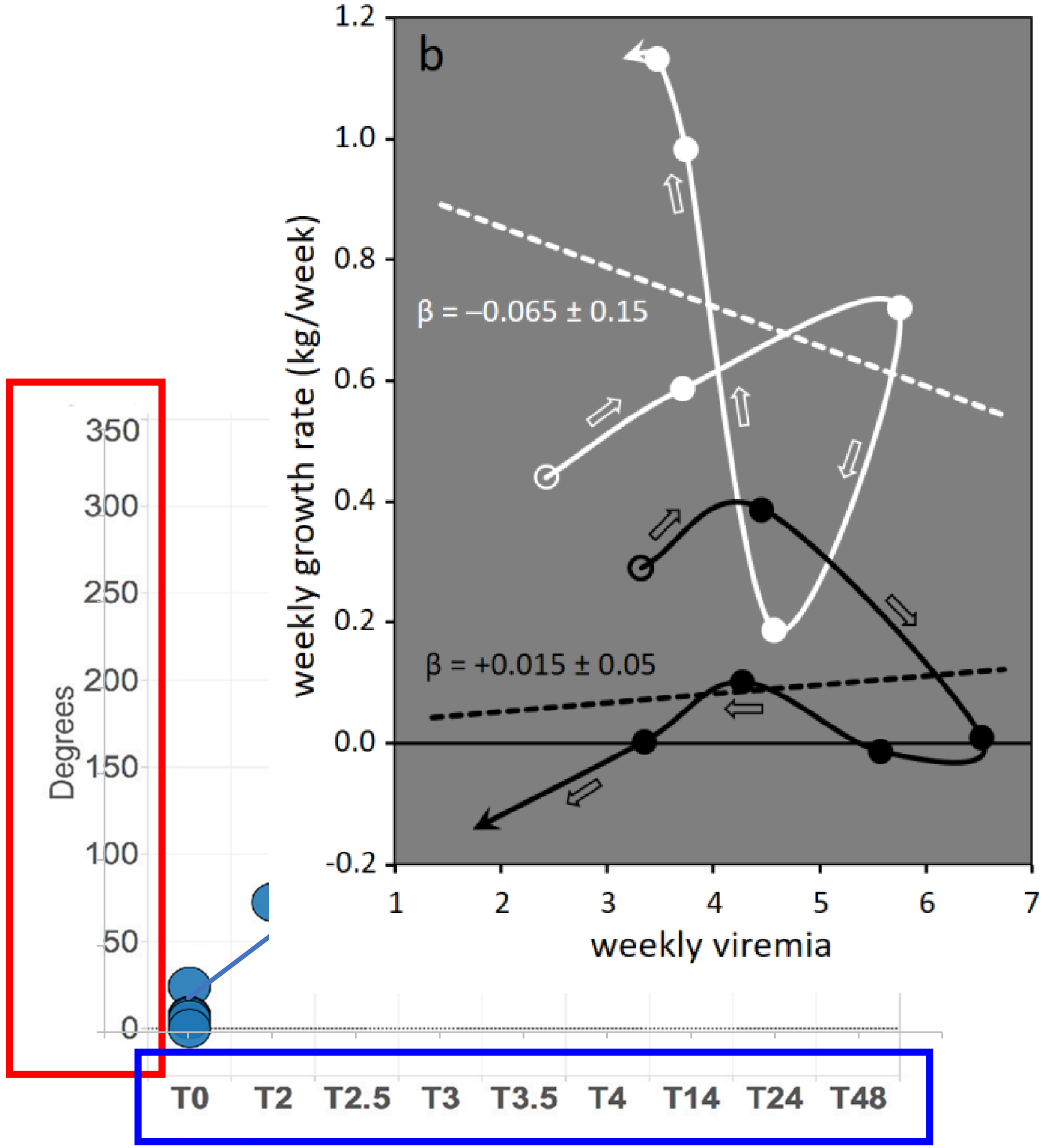
$$r = \sqrt{x^2 + y^2}$$

$$\varphi = \arccos\left(\frac{x}{r}\right)$$

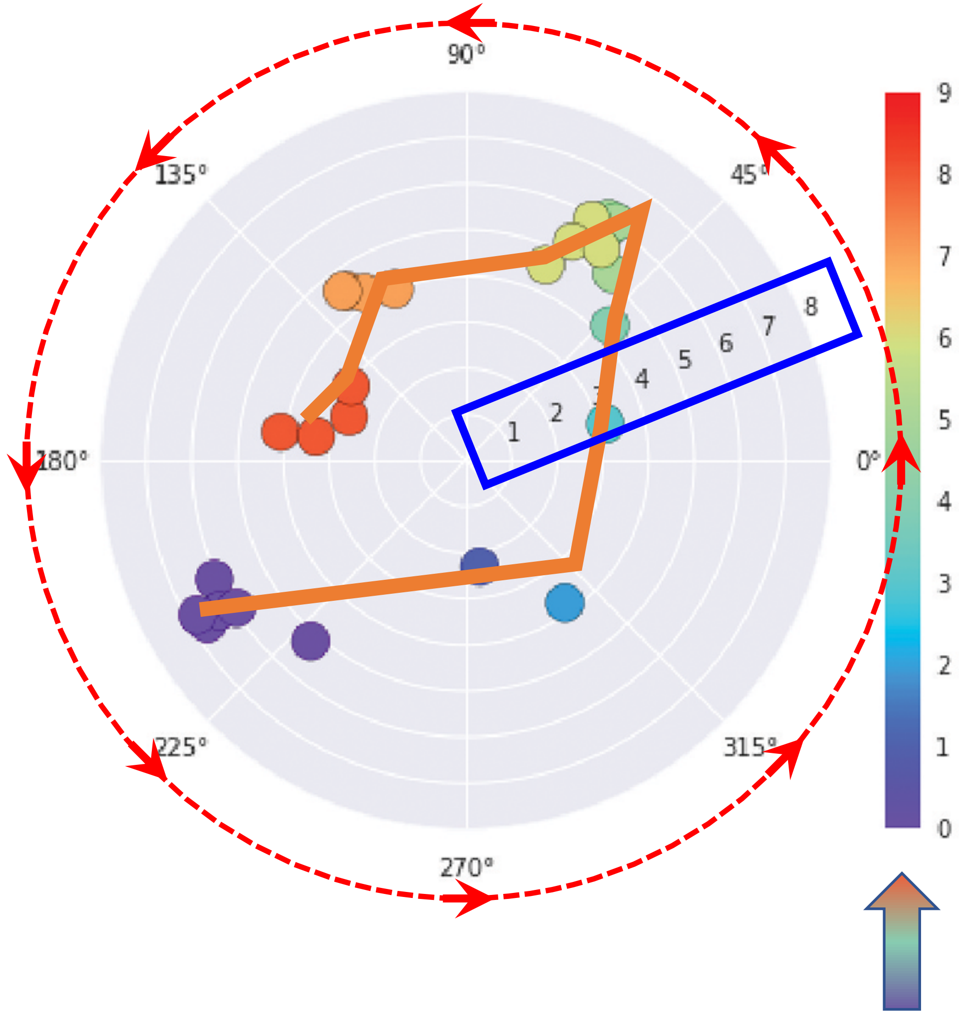
Polar coordinates:

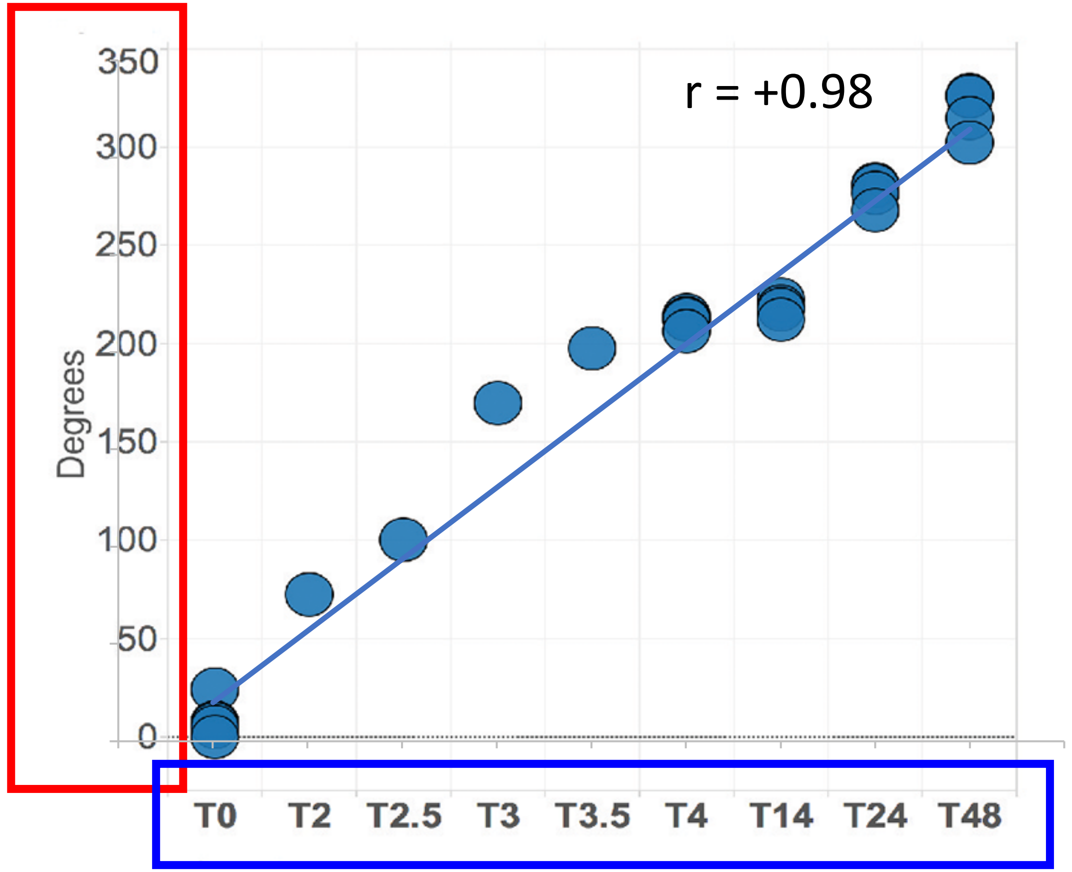
r , φ

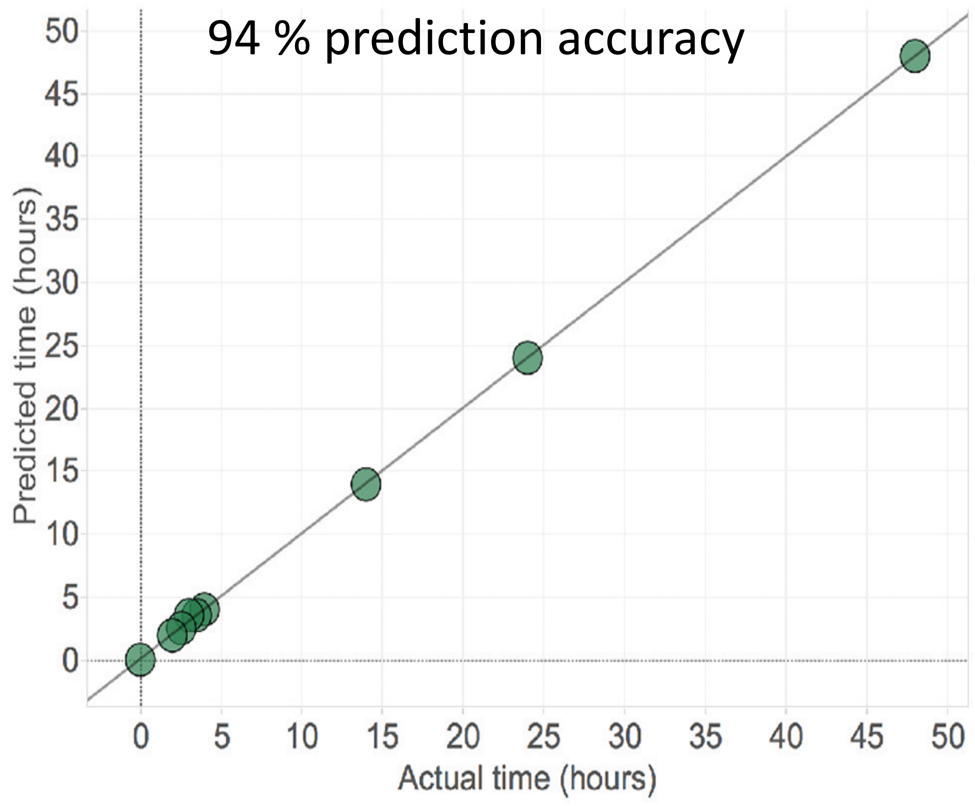




Rath, Allen & Schneider (2018) doi.org/10.1371/journal.pone.0200147



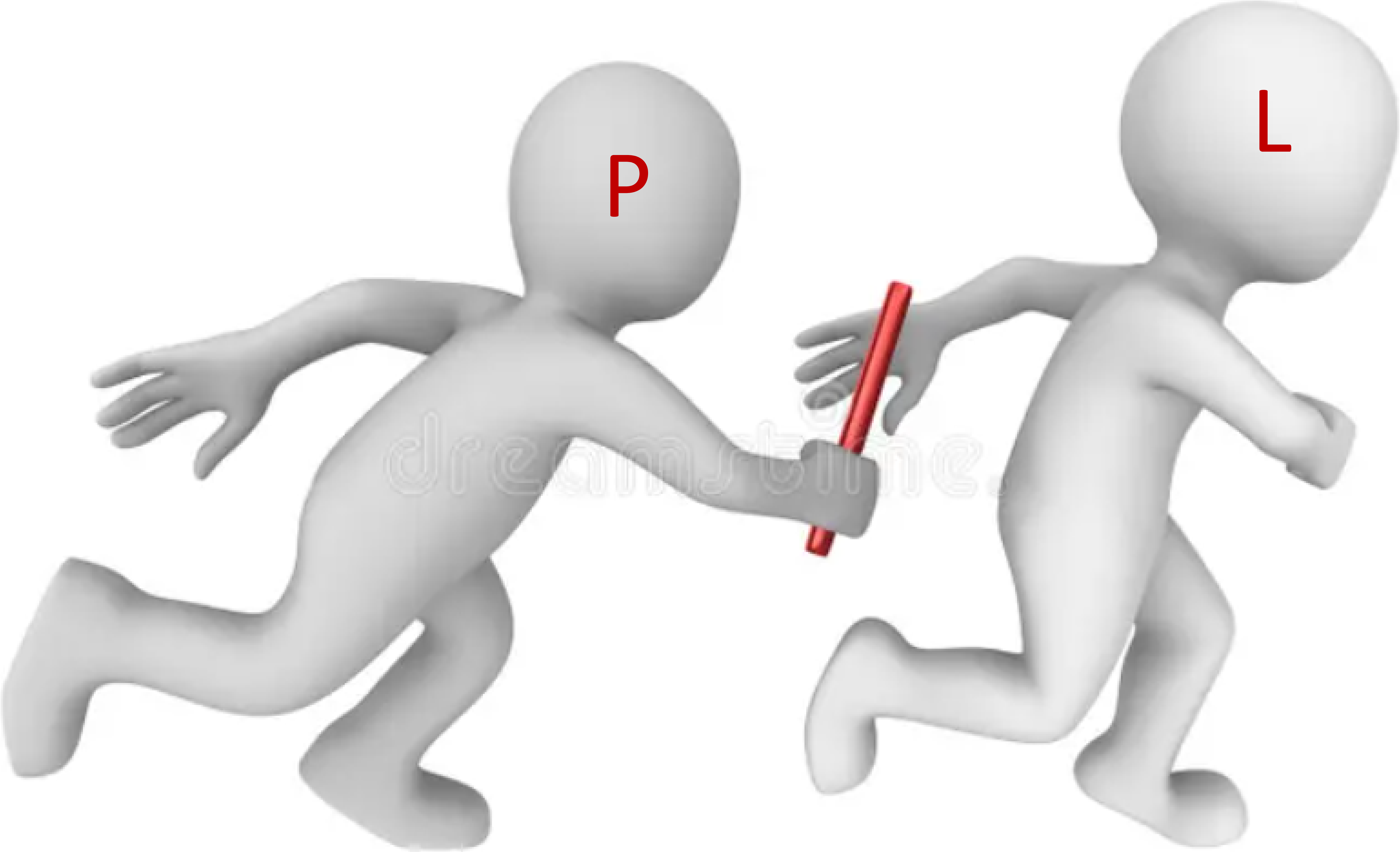




The effect is on the timing of an event (the colours of above)

- → a simple linear prediction equation
- crossvalidation:
- predicted effect in samples that were not in the training dataset

Rath, Allen & Schneider (2018) doi.org/10.1371/journal.pone.0200147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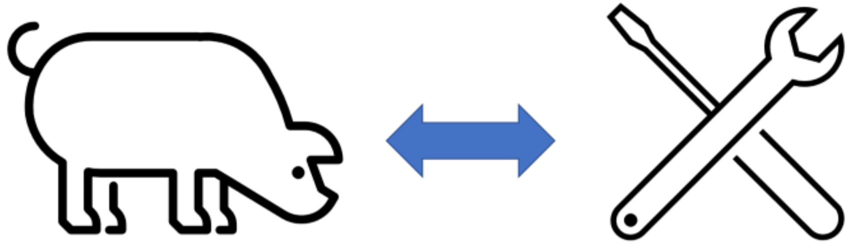


Conclusions

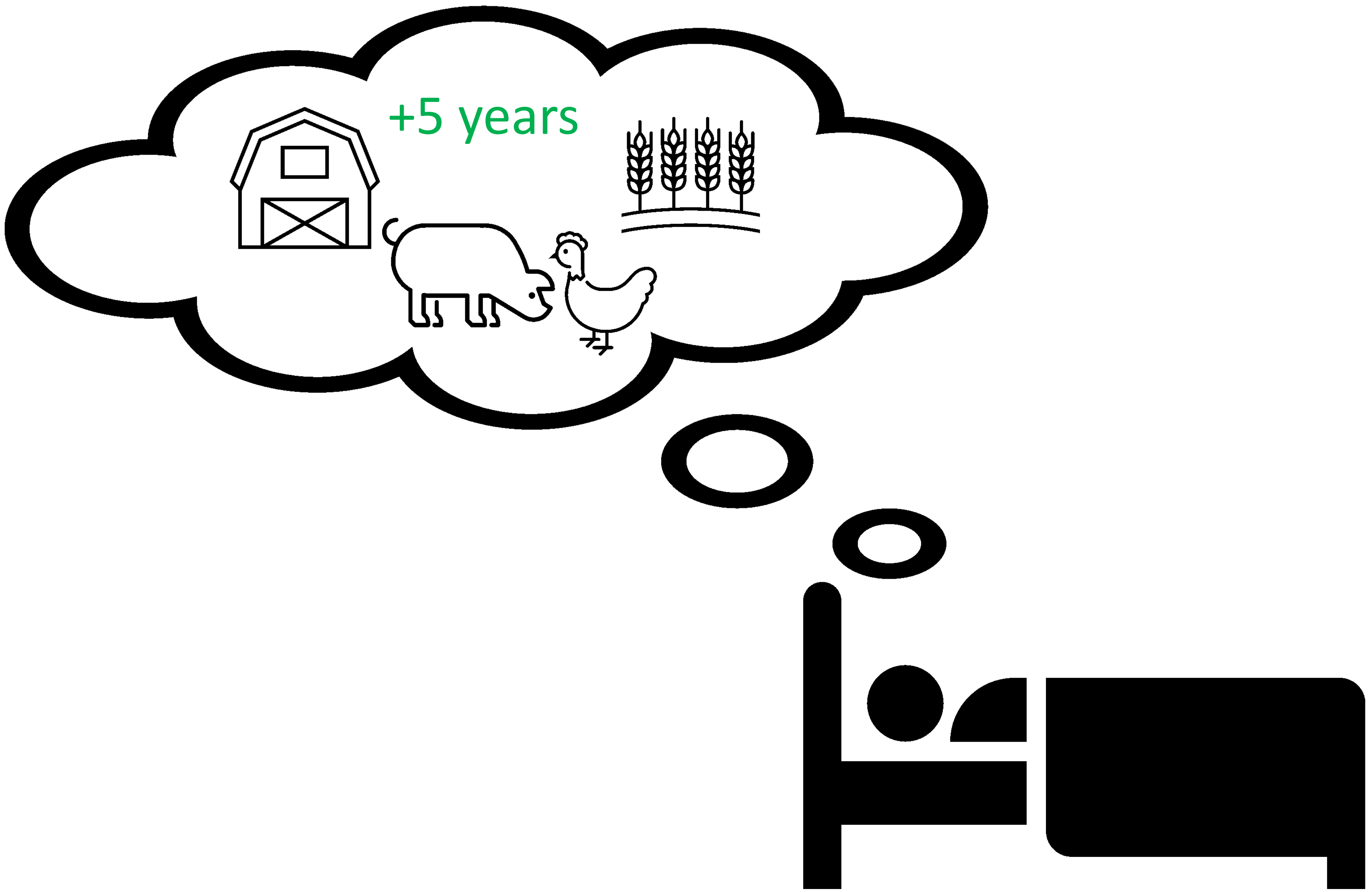
1. Increased production levels have often led to trade-offs due to genetic antagonisms
2. Genetic antagonisms can be neutralized: select for both traits at the same time
3. Rapid increase in availability of tools

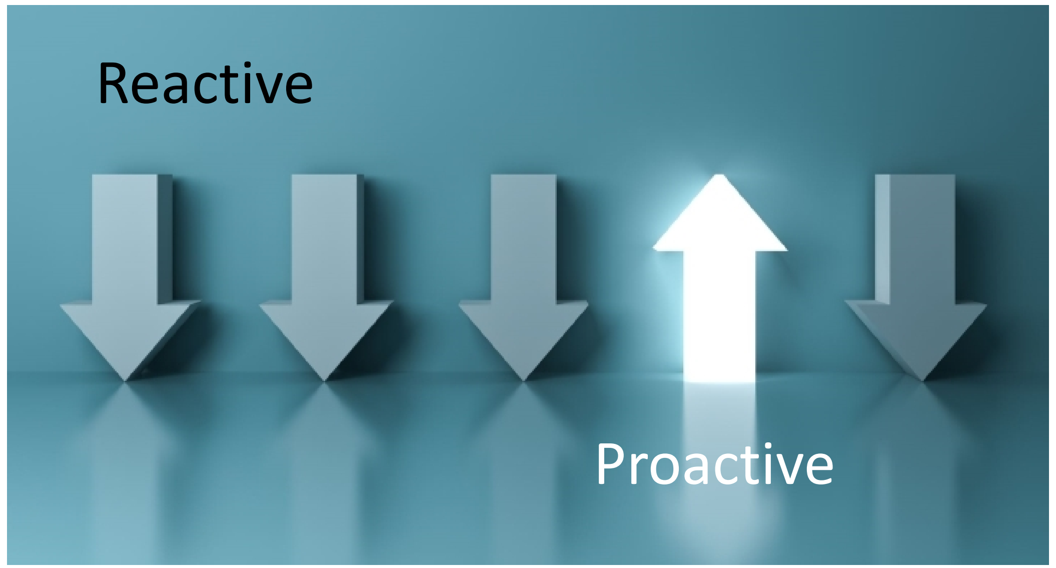
   Understand the existing phenotype

   Create new phenotypes

   to simultaneously select for antagonistic traits

We have a dream…





Session 77

Trade-offs between health, production and welfare in pigs and poultry

Which tools do we have, and which research is needed?

The future of pig and poultry breeding

Lisanne Verschuren & Pieter Knap

August 2023

Topigs Norsvin

PIC

EAAP + WAAP + Interbull Congress 2023