New challenges in animal breeding

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Roslin Internal Seminar, Roslin Institute, University of Edinburgh, March 28, 2024

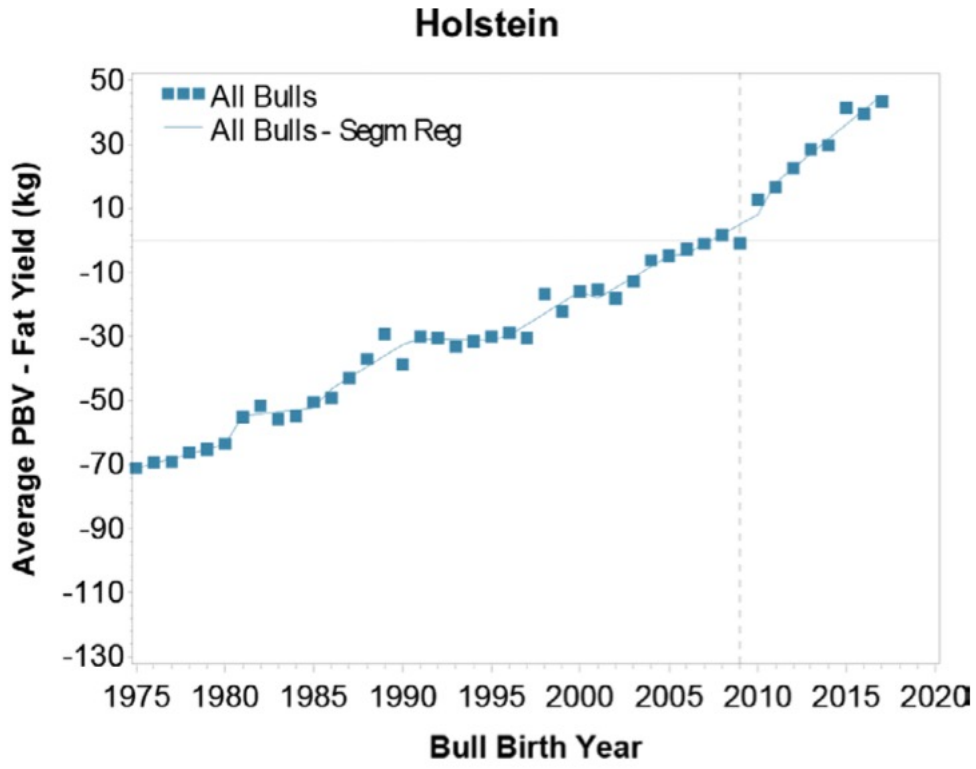
PORO TU

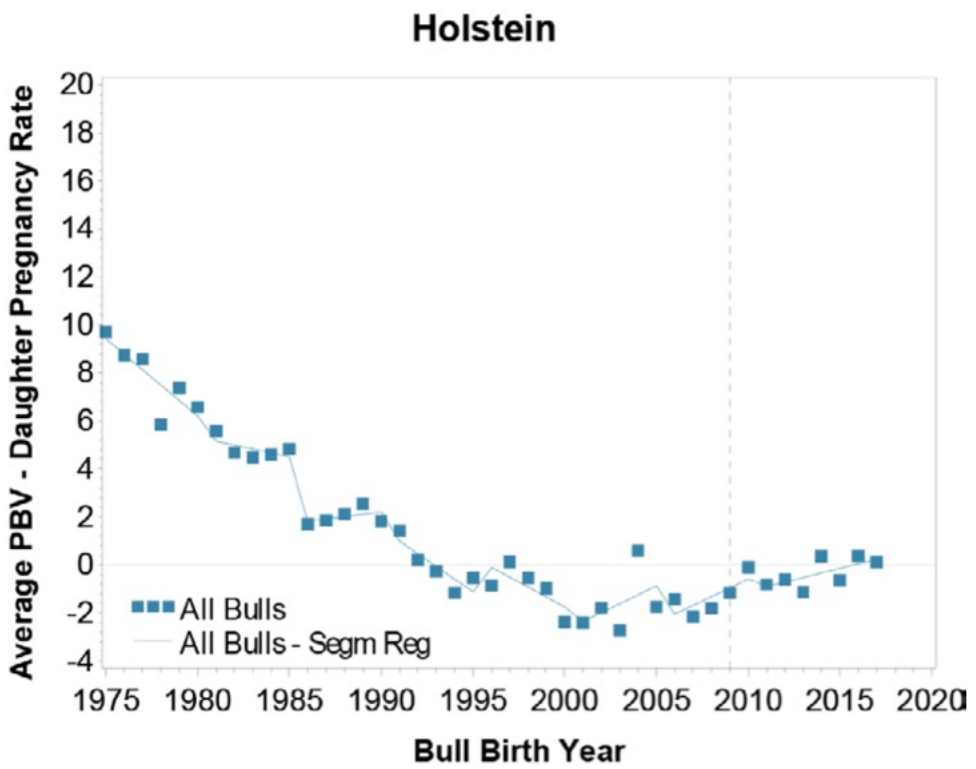
Genomic selection

- Expectations
  - High accuracy for all traits
  - Lower generation interval
  - Improvements for previously hard-to-improve traits
  - Lower costs – no progeny testing

- Reality
  - Acceleration of trends for selected traits
  - Acceleration of correlated responses
  - Changes in genetic parameters
  - Disruption in some industries

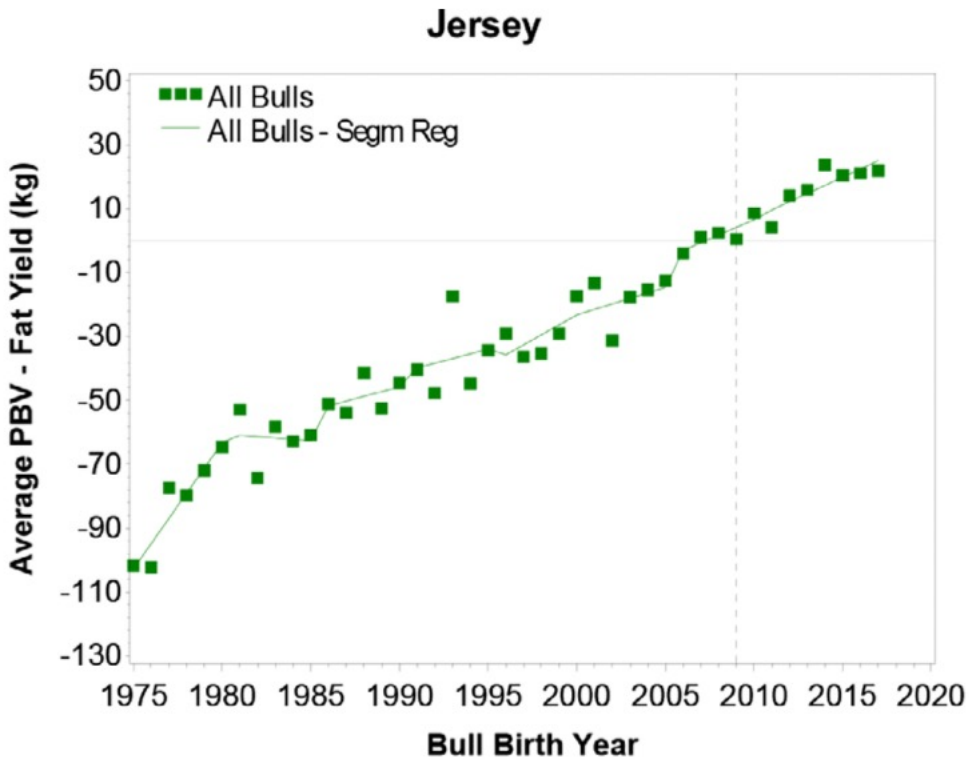
Trends for bulls for fat and fertility - Holsteins

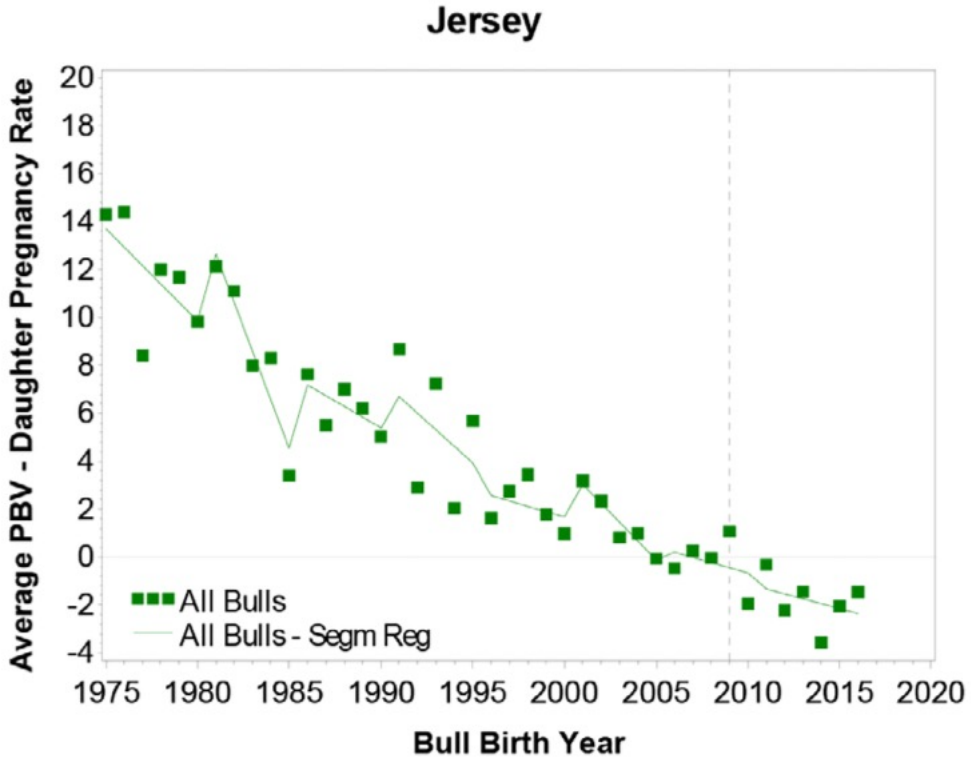




Guinan et al., 2023

Trends for bulls for fat and fertility - Jerseys





Guinan et al., 2023

Recent informal reports

- Deteriorating sow survival and pig mortality in pigs
- Deteriorating feet & legs in beef
- Short teats and increased calf mortality in dairy
- Increased sensitivity to heat stress in dairy
- Deteriorating disease resistance across species

Why problems?

- Unbalanced breeding?
- Fundamental limits?

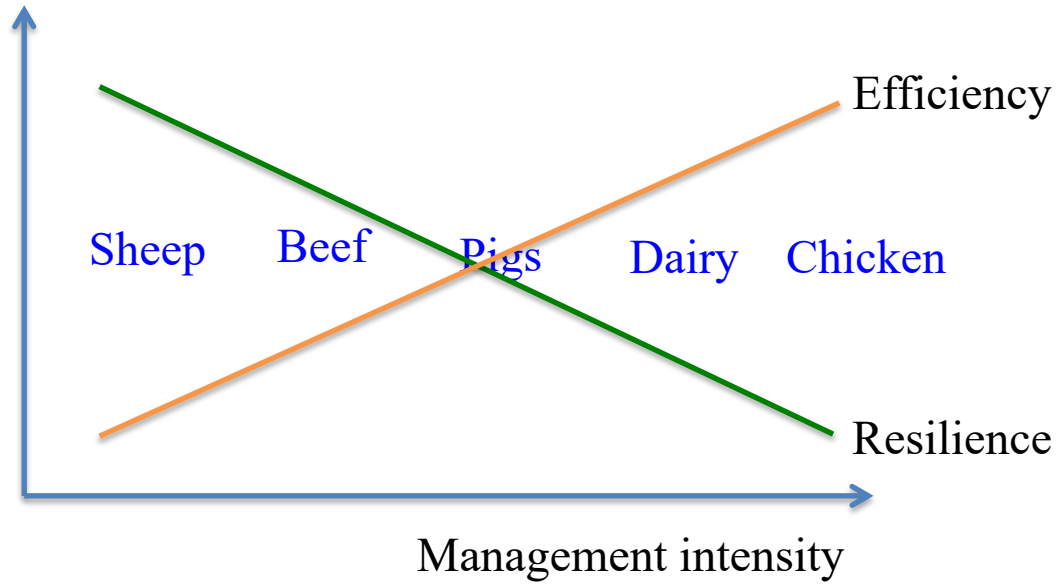
- If “DNA designer” exists, can we design perfect animals?

Genetic selection as optimization

- Selection for one trait or an index
- Gains on selected traits
- Losses on correlated antagonistic traits

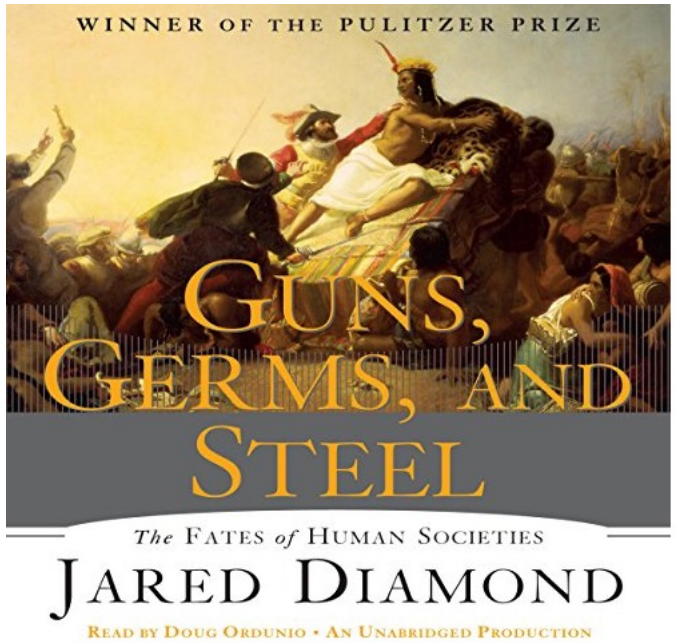
- Losses compensated by improved environment/management

Resilience/efficiency and management intensity



History of selection strategies

- Domestication
- Unformal
- Large-scale single-trait for production traits
- Multi-trait with fitness traits
- Genomic



Livestock Production Science
Volume 93, Issue 1, 1 April 2005, Pages 3-14

Go to Livestock Production Science on ScienceDirect

Genetics of adaptation and domestication in livestock ☆

Sandrine Mignon-Grasteau [a], Alain Boissy [b], Jacques Bouix [c], Jean-Michel Faure [a], Andrew D. Fisher [d], Geoffrey N. Hinch [e], Per Jensen [f], Pierre Le Neindre [b], Pierre Mormède [g], Patrick Prunet [h], Marc Vandeputte [i], Catherine Beaumont [a]

Domestication

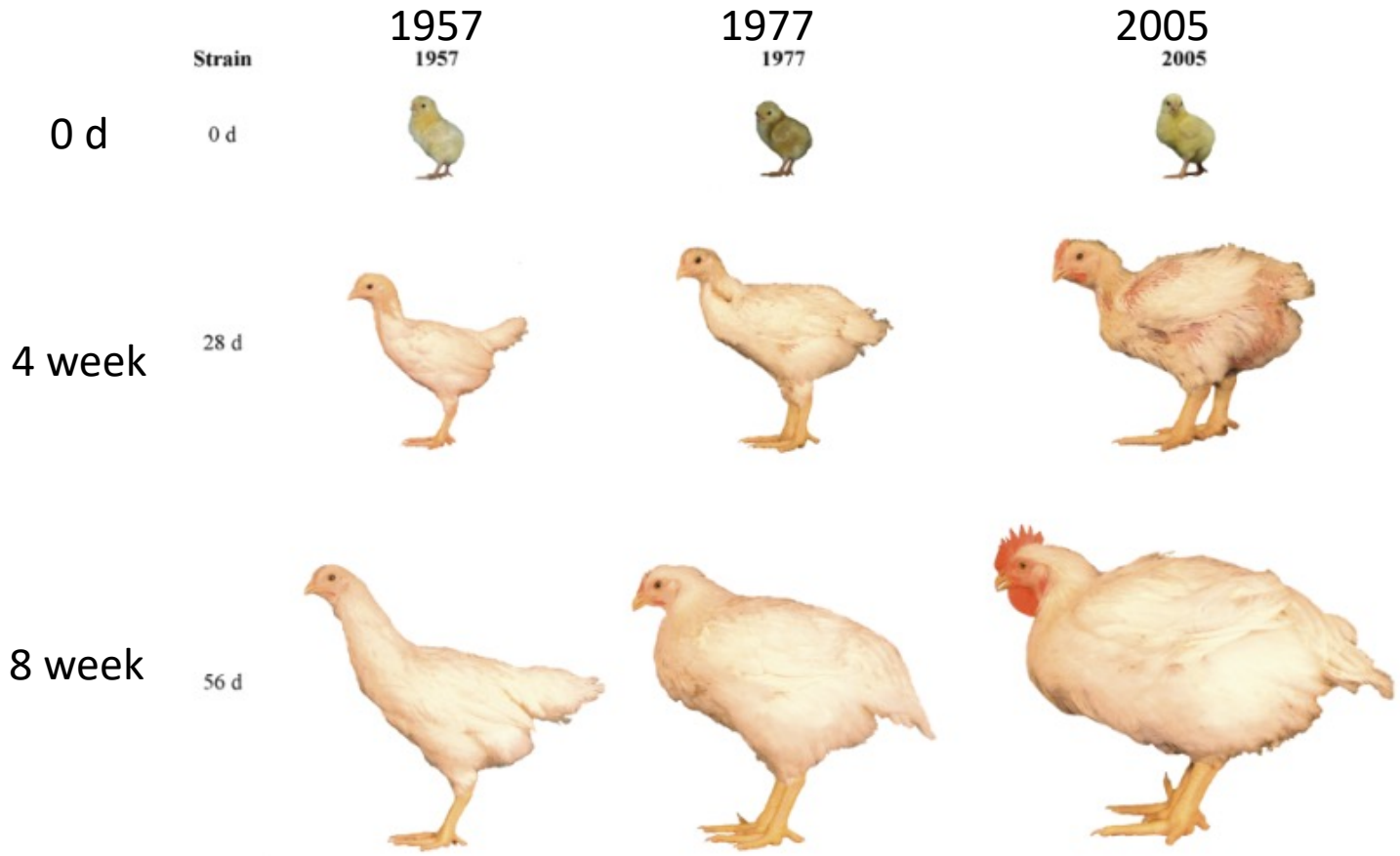
Winners

Growth
Milk
Mating procedures

Losers

Food finding
Seasonal reproduction
Predator avoidance
Brain size
...

Example of effects of mostly single-trait selection



Zuidhof et al. (2014) http://dx.doi.org/10.3382/ps.2014-04291

The Woman and her Hen

A Woman wanted two rather than one egg a day from her Hen. She overfed the Hen which caused the Hen to stop laying eggs entirely.

Aesop, 500BC

Side effects of intensive selection for growth in broiler chicken

- Unlimited appetite / obesity ➔ artificial lightning
- Poor survival of males ➔ male supplementation
- Increased susceptibility to diseases ➔ antibiotics
- Low hatchability ➔ alternate heating/cooling of incubators
- …

All companies – similar problems at same time

Initially problems kept confidential

Eitan and Soller, 2014

Undesirable side effects of selection for high production efficiency in farm animals: a review

W.M. Rauw[a,*], E. Kanis[b], E.N. Noordhuizen-Stassen[c], F.J. Grommers[c]

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[b]*Animal Breeding and Genetics Group, Wageningen Institute of Animal Science, Wageningen Agricultural University, P.O. Box 338, 6700 AH Wageningen, The Netherlands*

[c]*Department of Herd Health and Reproduction and Interdepartmental Section Veterinary Medicine and Society, University of Utrecht, P.O. Box 80151, 3508 TD Utrecht, The Netherlands*

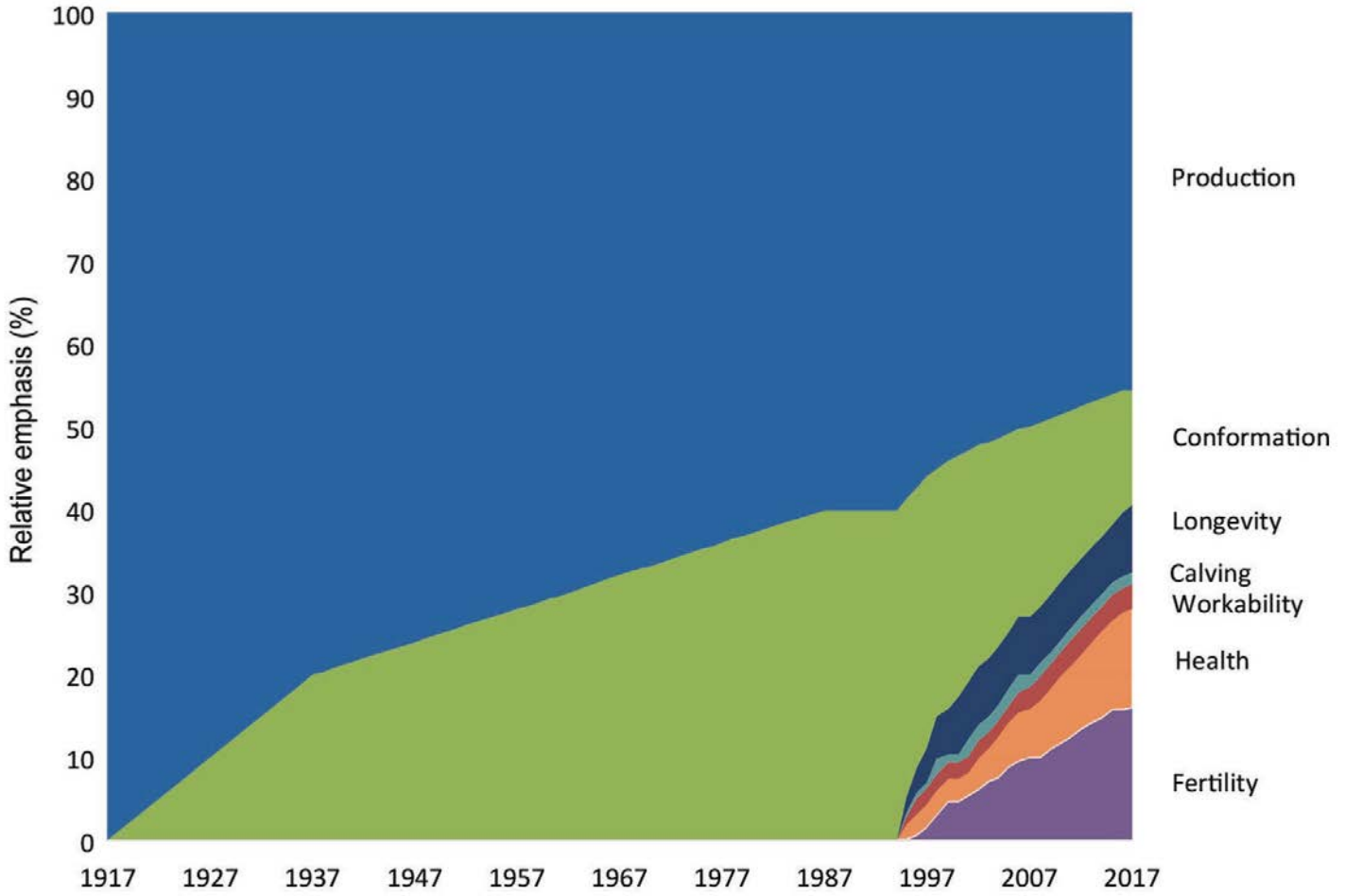
Received 4 July 1997; accepted 29 April 1998

…over 100 references on undesirable(cor)related effects of selection … in broilers, pigs and dairy cattle….

Future application … DNA-techniques .. ….more dramatic consequences….

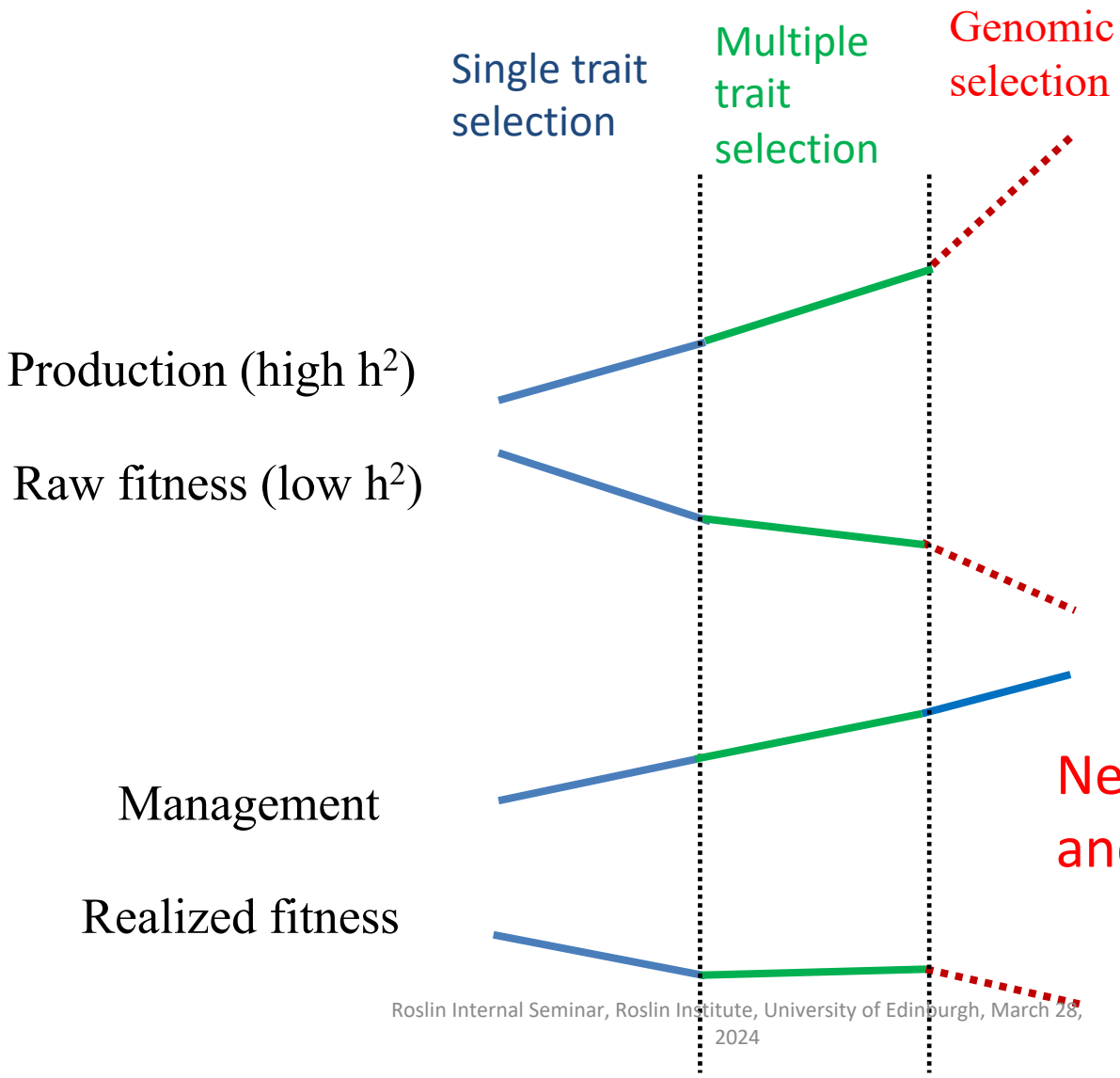
Selection for more than production traits alone may prevent such.

Changes in US dairy index



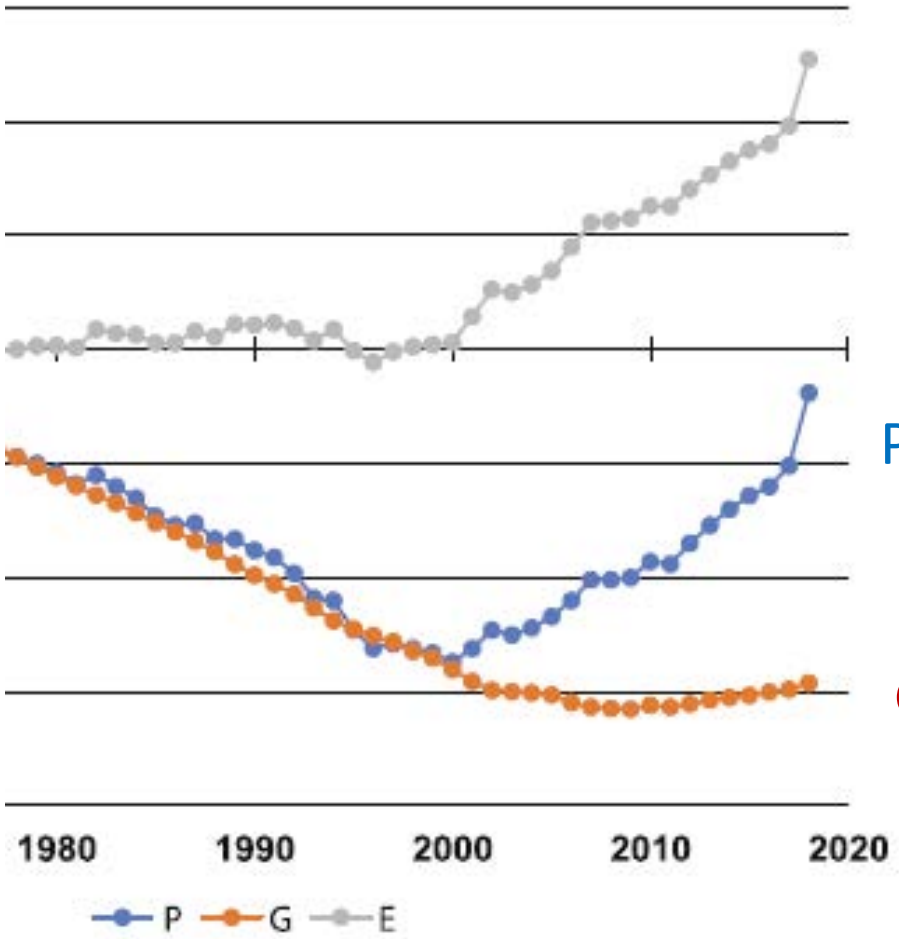
Miglior et al., 2017

Hypothetical trend changes in 3 stages of genetic selection



Negative changes accelerate and management cannot catch up!

Trends for daughter pregnancy rate



Environmental - management

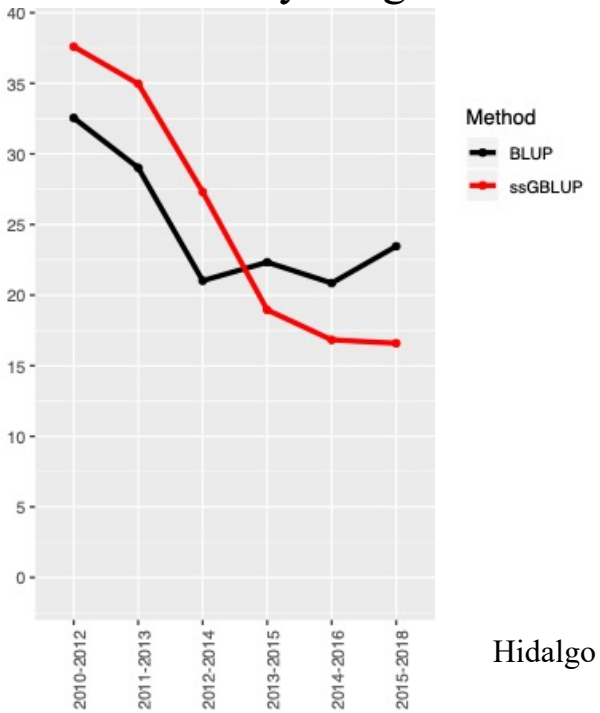
Phenotypic

Genetic

Brito et al., 2021

Changes in (co)variances in pigs due to genomic selection

Heritability for growth



Hidalgo et al. (2019)

Genetic correlation with reproduction

Hidalgo et al., 2023

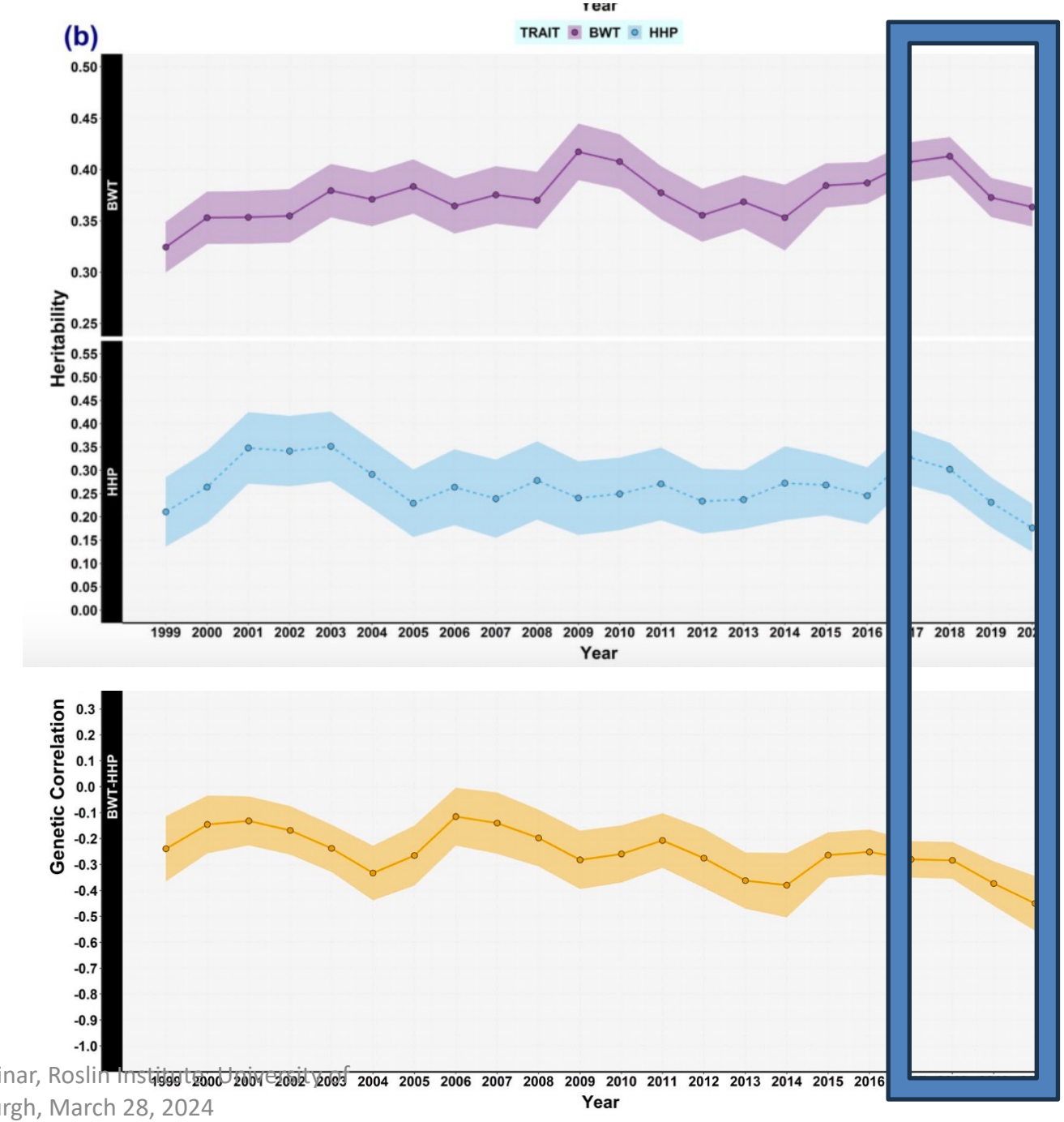
Heritability halved, antagonistic correlations -0.3 ➔ -0.5

Parameters for body weight and egg production (Sosa-Madrid, 2023)

2M body weights
45k eggs counts

3 year windows
No genomics

gibbsf90



Why changes in genetic parameters?

- Bulmer effect
- G x E
- Recessives
- Changes in gene frequencies

- Changing resource allocation
- Changes in trait definitions
- …

Cases of changing correlations - resource allocation

- Milk and dairy form
  - Old times: fat cows lose milk by getting fat
  - New time: Cows need fat as body reserves during negative energy balance

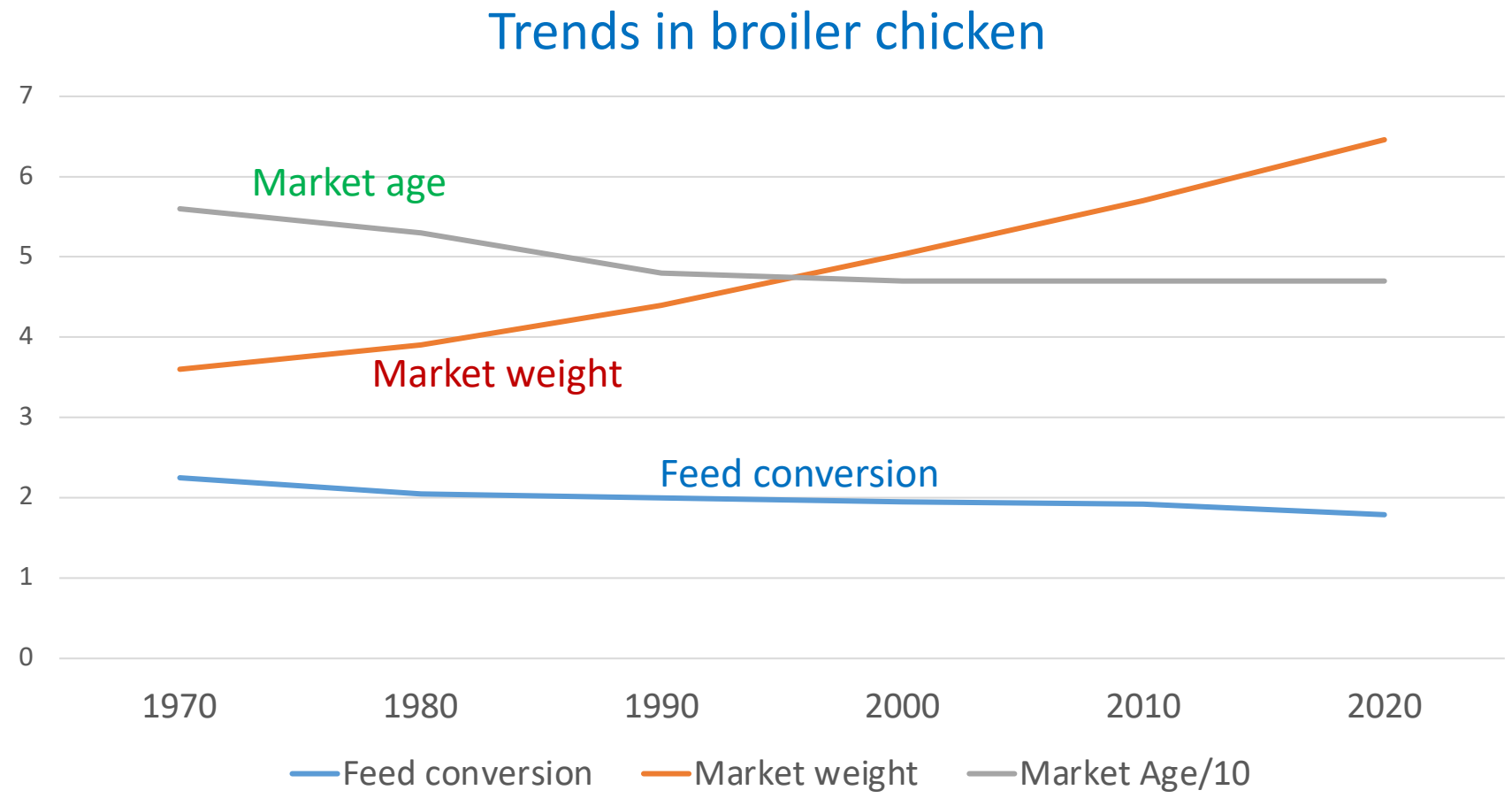
- Production and fertility
  - When production low, fertility OK
  - When production very high, energy redirected from fertility

fertility = innate_fertility - α production

How to circumvent negative effects?

- Start or expand recording for problematic traits
- Update selection index
  - Needs estimates for last generation
- Focus on traits where the parameters are changing rapidly
  - Needs estimates generation by generation
- *Make veterinarians and nutritionists work harder!*

Fundamental limits of selection



https://www.nationalchickencouncil.org/about-the-industry/statistics/u-s-broiler-performance/

Models for health traits in different parities

- Multiple health traits
- Censoring
- Correlations with production traits

- Example – uterus prolapse n pigs
  - Incidence increasing
  - Many reasons for disposal
  - Some animals alive

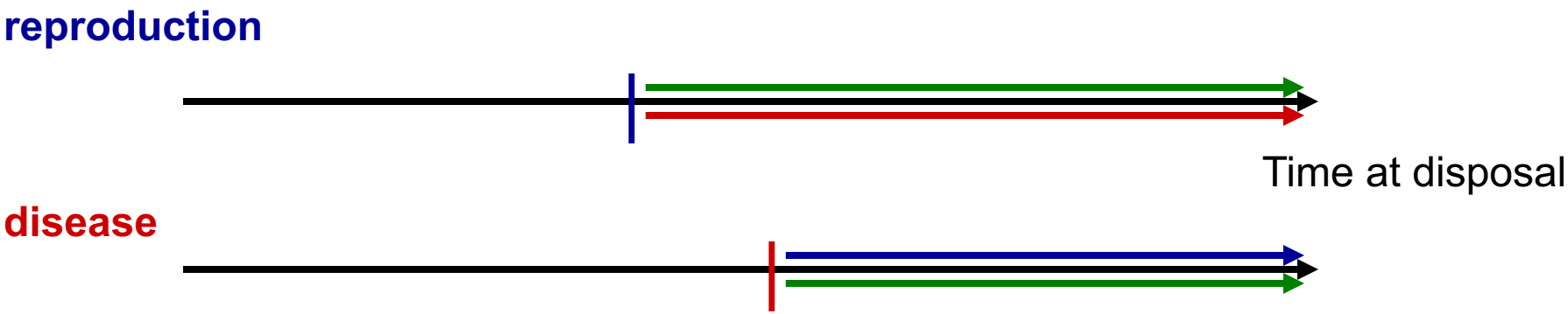
Survival for sows

- Many reasons for disposal
- Why sow disposed?
  - Genes (QTLs) for each reason separately?
  - General poor fitness?
- Few general categories for disposal
  - Reproduction, disease, other

Can all be analyzed jointly?

Censored data

Disposal for: **Reproduction**
Disease
Other reasons



Traits combinations

Parity at Disposal

Repro	Disease	Other
2	2+	2+
3+	**3**	3+
1+	1+	**1**

One trait observed, others censored

Results

Reasons correlated at > 0.8

Low survival due to lower fitness?

Variances different for each trait – multitrait analysis more accurate

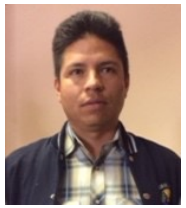
Survival model better if multitrait version available

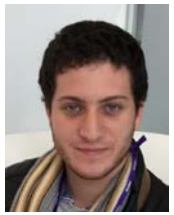
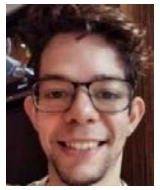
Arango et al., 2005

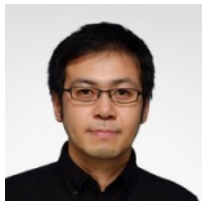
Conclusions

- Selection as optimization – winner and loser traits
- Decline in low heritability traits compensated by improved management
- With genomic selection
  - Faster progress for high h^2 traits
  - Trait antagonism intensifies
  - Management cannot catch up

UGA AB&G team





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AGI

USDA United States Department of Agriculture
Agricultural Research Service
Warmwater Aquaculture Research Unit

zoetis

Smithfield

USDA Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE
Cool and Cold Water Aquaculture Research

Cobb

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Genetics for Life

PEAK

PFHBiPM

PLEMDAT

Topigs Norsvin

methodgenetics

ANCP

Relationships among mortality, performance, and disorder traits in broiler chickens: a genetic and genomic approach

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