Positive and Negative Impacts of Genomic Selection

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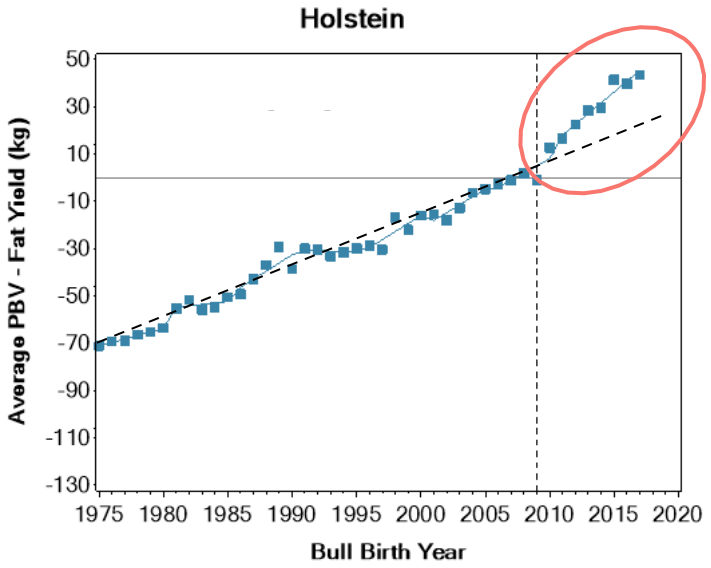
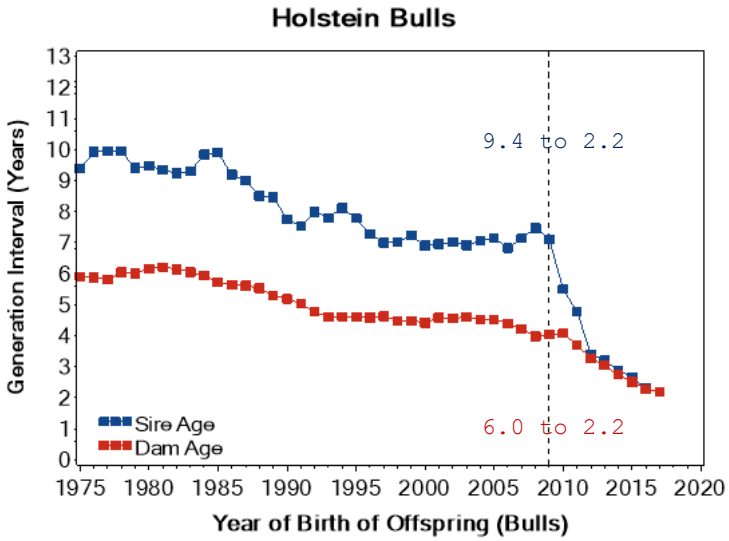
University of Georgia

Changes after genomics - dairy

- > 2x after genomics for Holsteins

Guinan et al. (2023)





Negative effects of genomic selection

- Informal industry reports:
  - Deteriorating sow survival 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

- Recessive genes or pleiotropy?

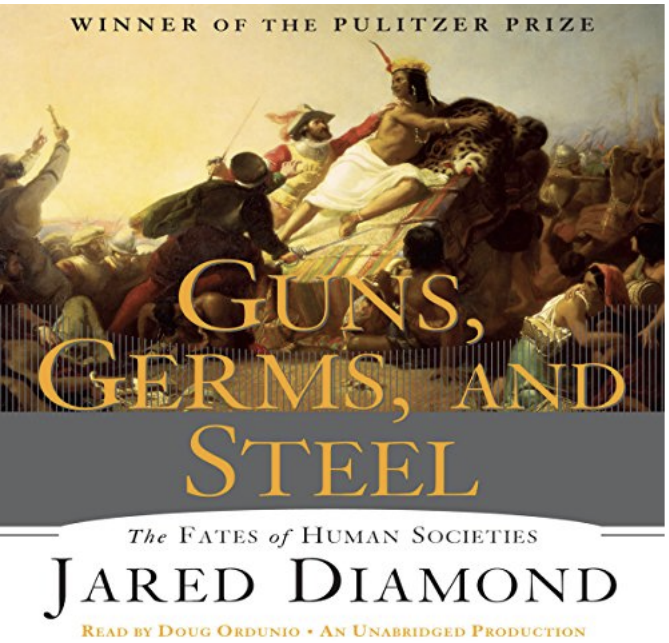
Genetic selection as optimization

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

- Losses compensated by improved environment/management

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

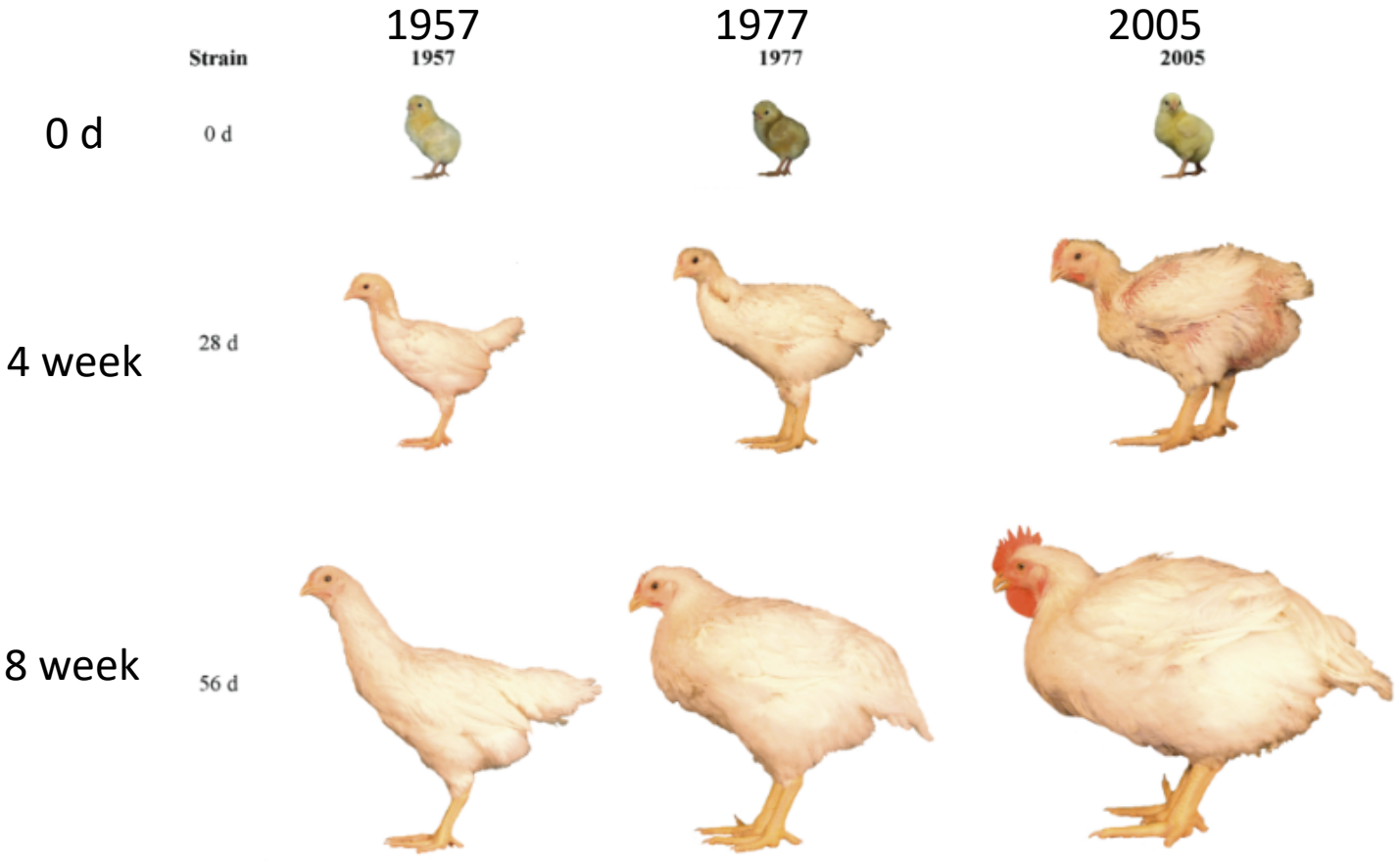
Winners

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

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

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 for high production efficiency, …with respect to metabolic, reproduction and health traits, in broilers, pigs and dairy cattle….

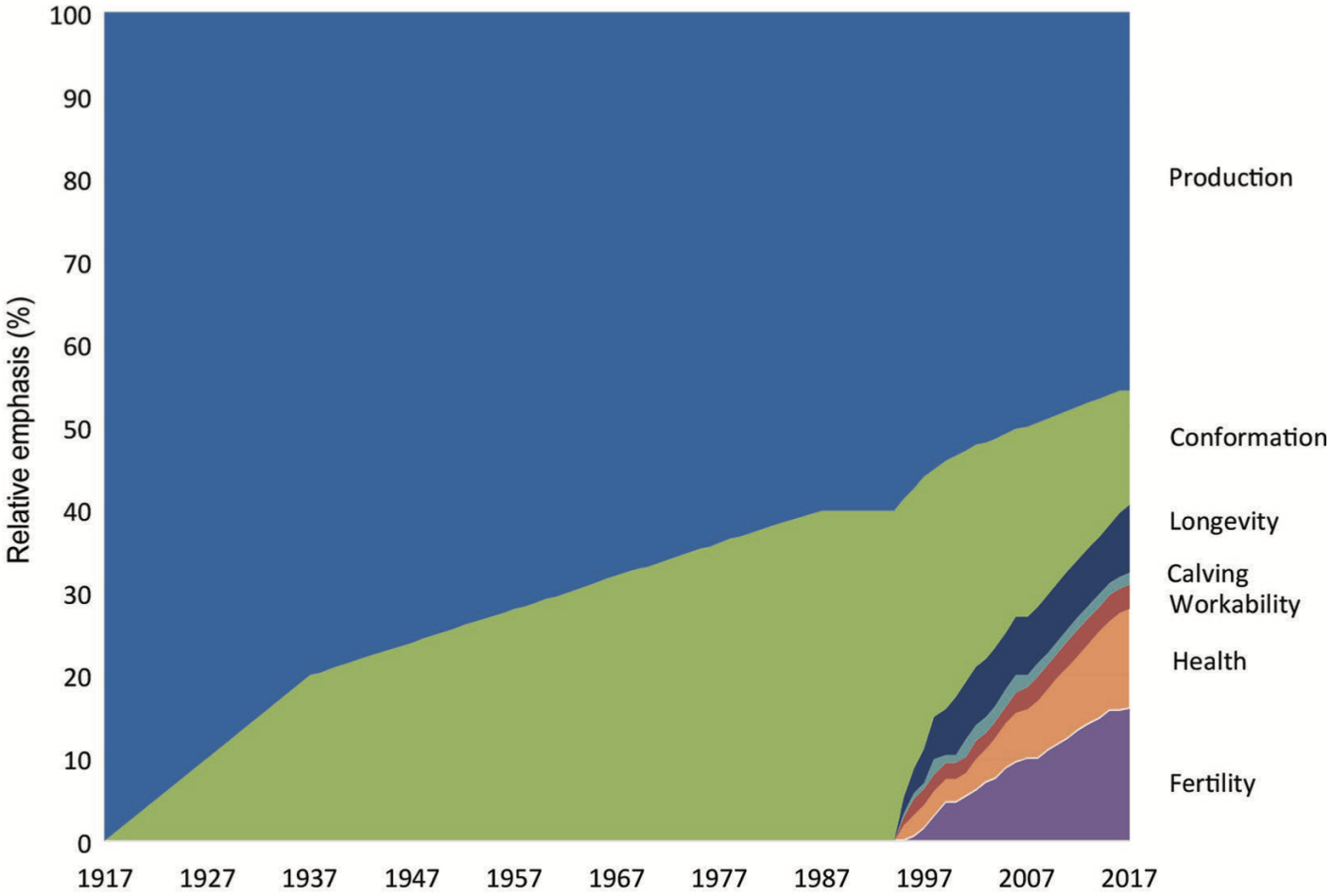
Future application … DNA-techniques .. may increase production levels even faster ….more dramatic consequences for behavioral, physiological and immunological traits

Selection for more than production traits alone may prevent such.

Multitrait selection

- Decline in some traits too hard to be compensated by management
- New trait recording
- Progress in computing – multitrait animal models
- Selection index

Changes in US dairy index



Miglior et al., 2017

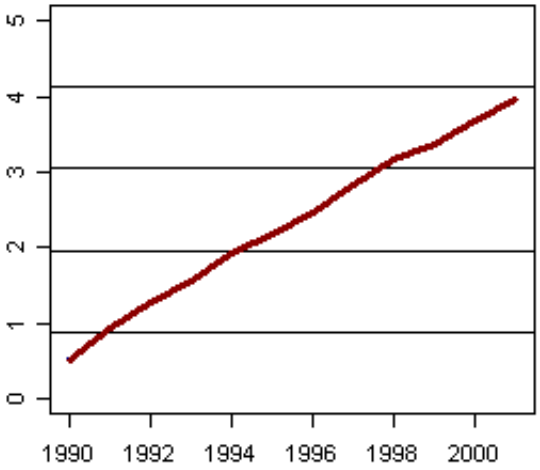
Do we need to select for heat tolerance – or use better management?

- Genetic selection for heat stress with data from weather stations (Ravagnolo et al., 2001)
  - Negative correlations ~ -0.4➔continuous deterioration

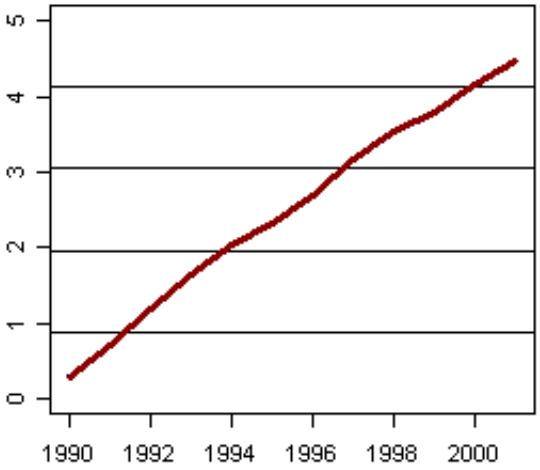
- National evaluation for heat stress in Holsteins (Aguilar et al., 2011)
  - 90 million test days
  - 9 million animals
  - 3-trait RRM

Genetic trends of daily milk yield for 3 parities – regular effect

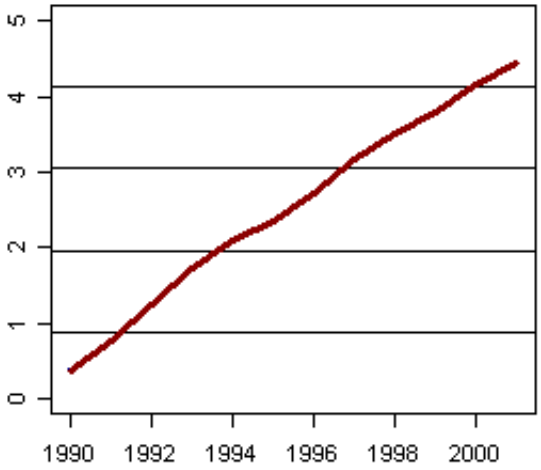
First



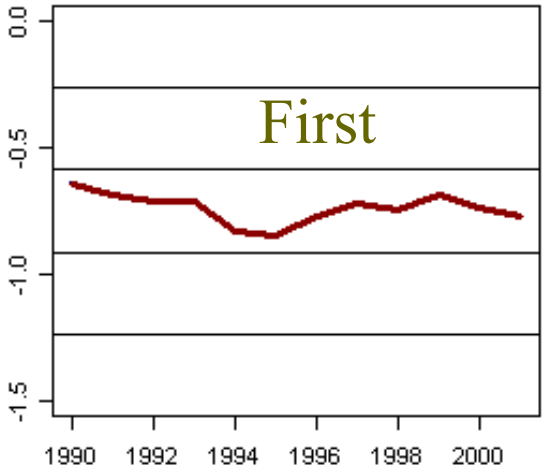
Second

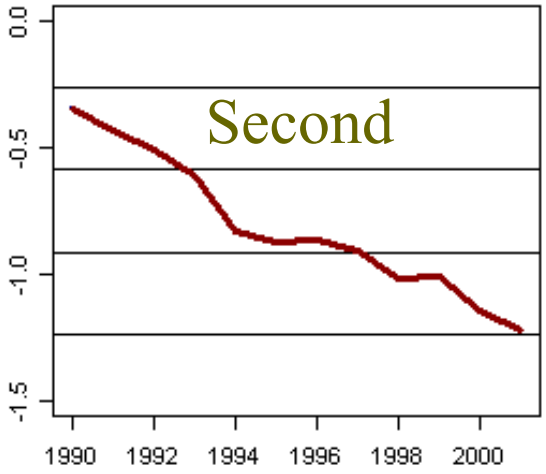


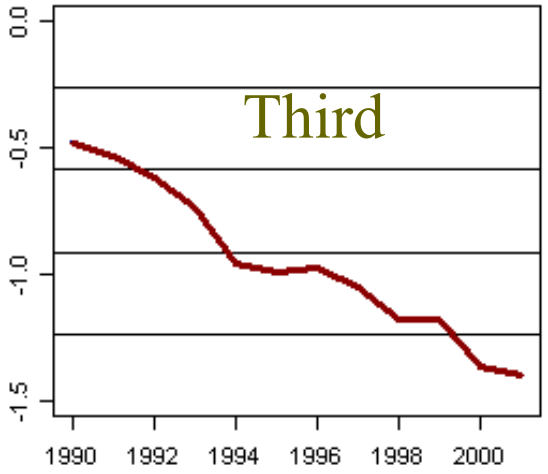
Third



Genetic trends for heat stress effect at 5.5° C over the threshold







Negative selection for heat stress partially compensated by correlated selection for fertility and survival

High accuracy EBV for old bulls only

Industry approach to heat stress in 2010s

- Poor milk and fertility ➔ better sprinklers and fans
- Still poor fertility and poor heat detection ➔ timed AI
- Low survival and not enough replacements ➔ sexed semen

Genomics

Prediction of Total Genetic Value Using Genome-Wide Dense Marker Maps

T. H. E. Meuwissen,* B. J. Hayes† and M. E. Goddard†,‡

Journal of
Animal Breeding and Genetics

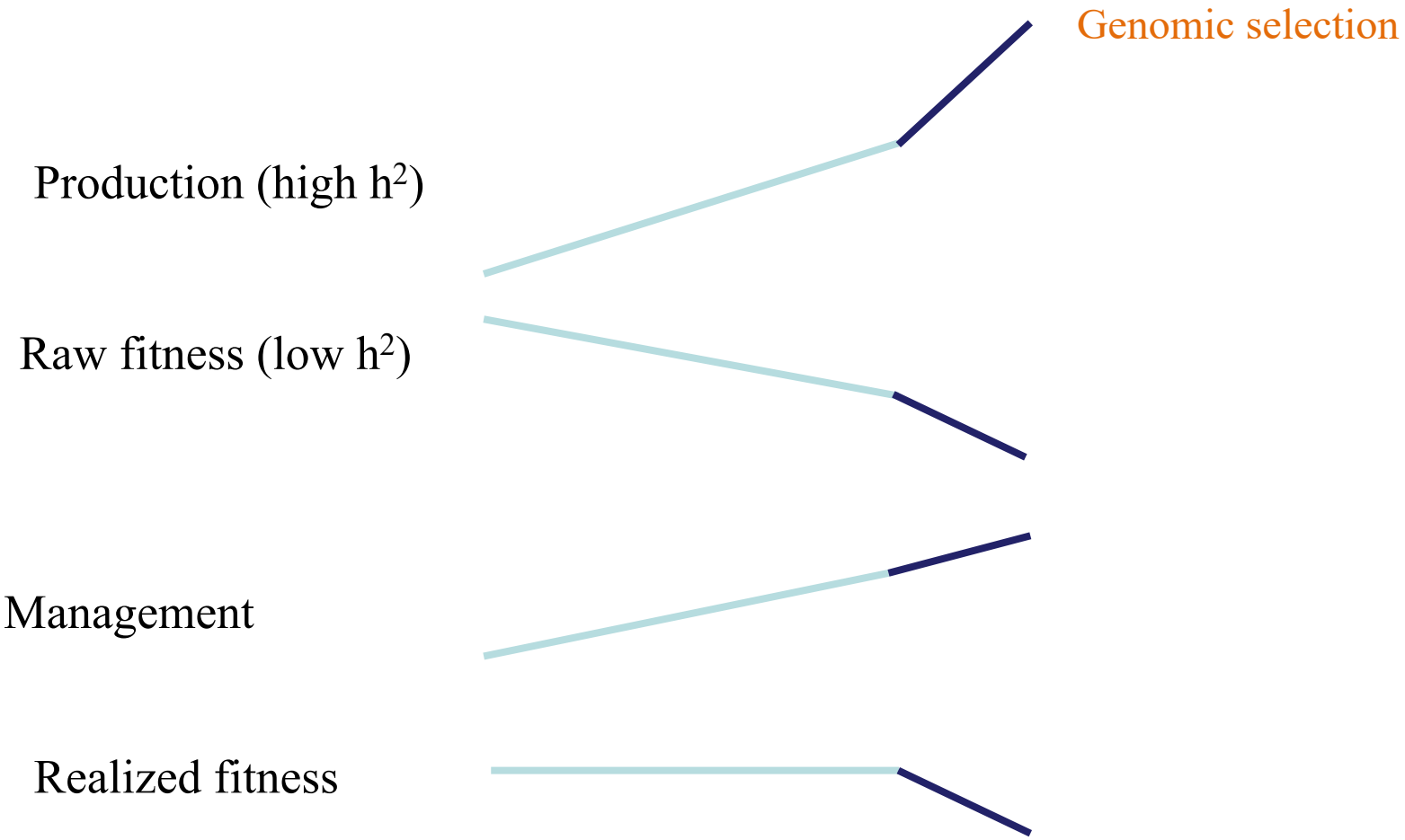
Strategy for applying genome-wide selection in dairy cattle

L.R. Schaeffer

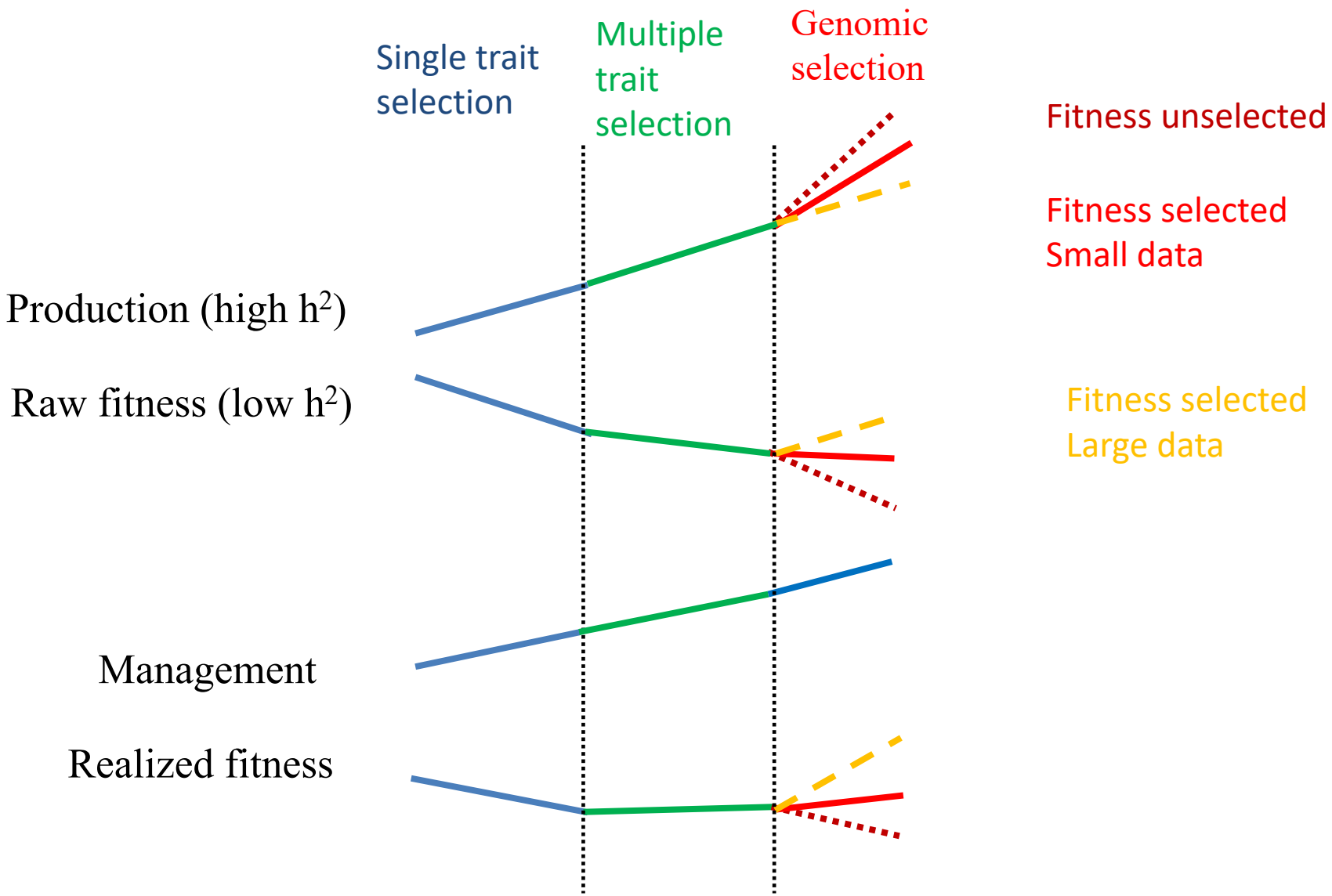
Effects of genomic selection

- High accuracy for well recorded traits
- Low accuracy for low h^2 traits with little information
- GEBV for young genotyped animals – lowered generation interval
- Acceleration of trends for selected traits
- Acceleration of correlated responses
- Changes in genetic parameters

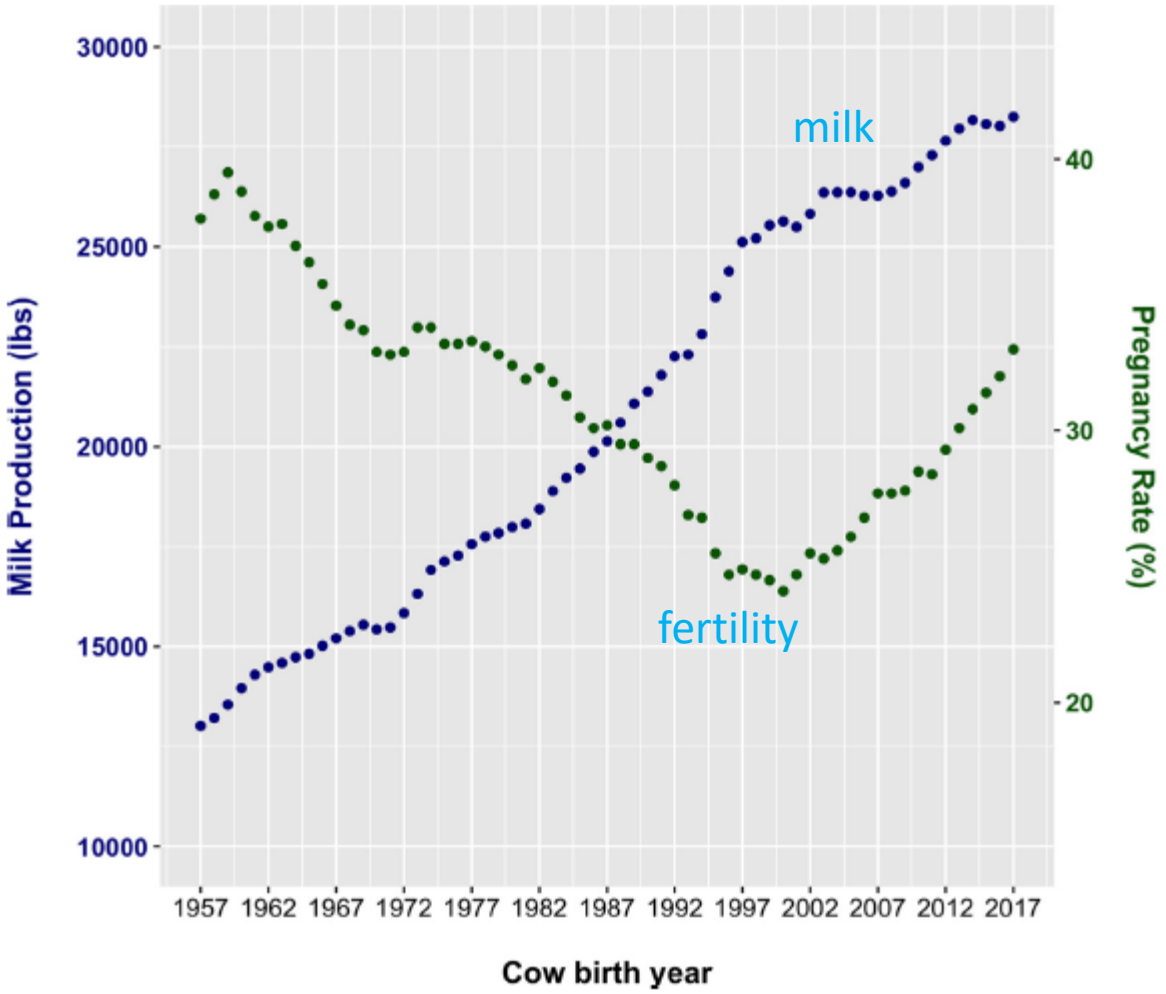
Hypothetical trend with genomics – fitness not in index



Hypothetical trend changes in 3 stages of genetic selection

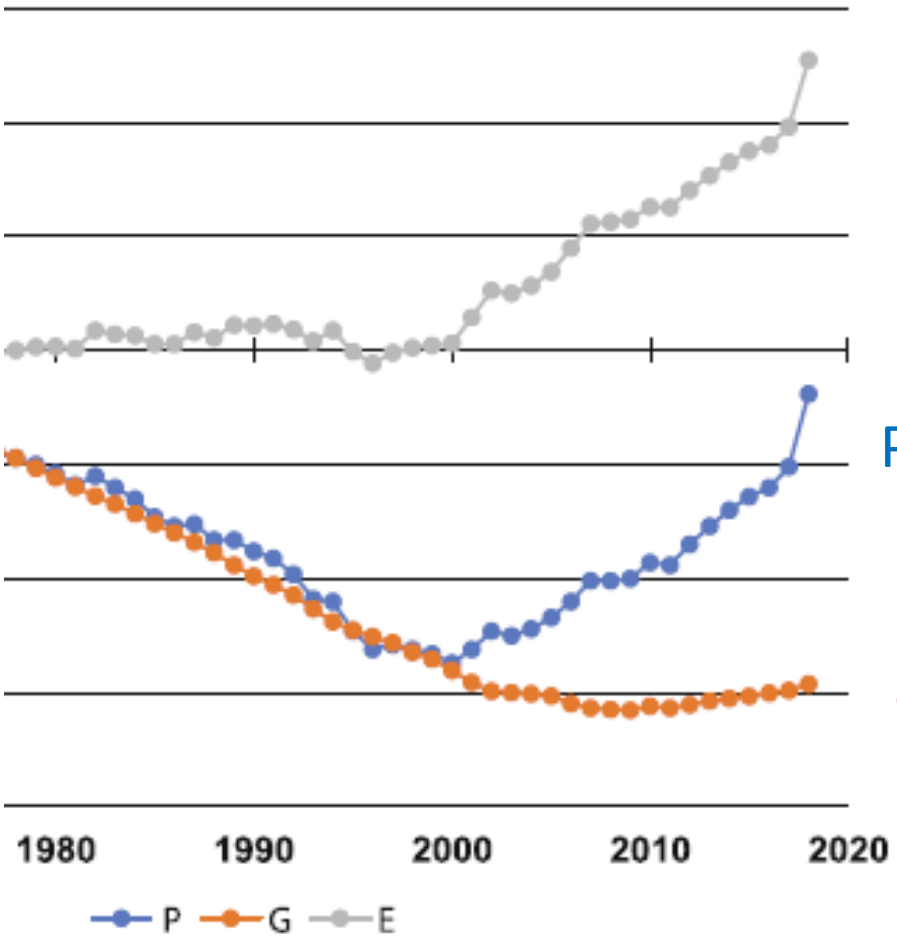


Phenotypic trends for milk and daughter pregnancy rate in Holsteins



Brito et al., 2021

Trends for daughter pregnancy rate



Environmental - management

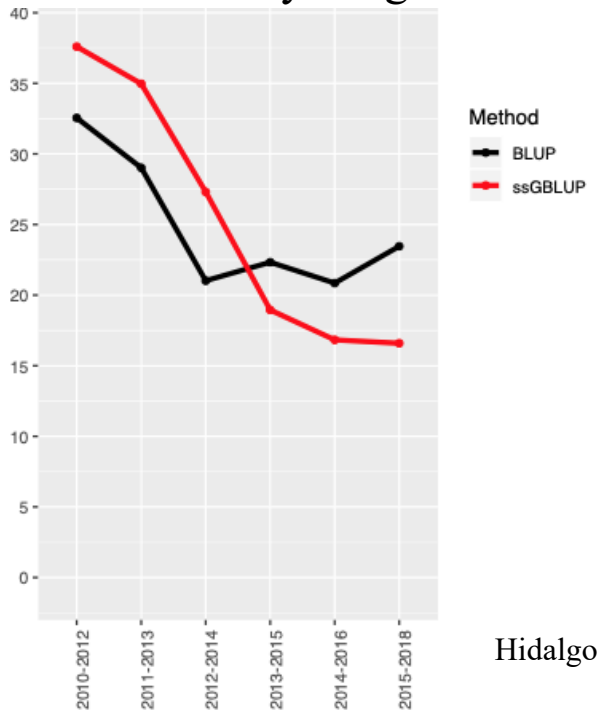
Phenotypic

Genetic

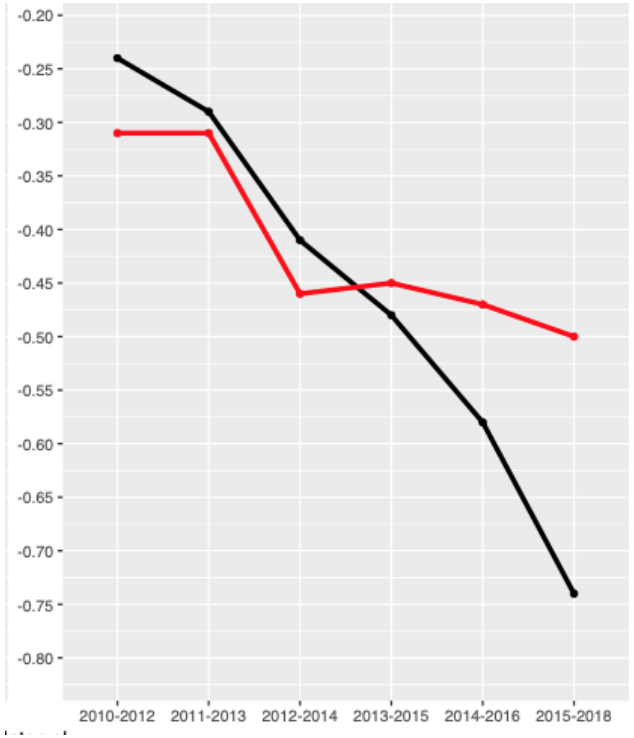
Brito et al., 2021

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

Heritability for growth



Genetic correlation with reproduction



Hidalgo et al. (2019)

Heritability decreases, antagonistic correlations intensify

Selection and resource allocation theory

- Van der Waaij, 2004; Rauw, 2012; Knapp, 2014

- More energy for production ➔ fitness more antagonistic
  - Genetic correlations ➔ -1
  - h^2 of selection index decline

- Fast selection ➔ unbalanced animals (Huber, 2015)

Problems and species

- Genomic selection efficient with large data
- Fraction of performance to fertility data in species
  - ~ 1 in cattle
  - 1/15 in pigs
  - 1/200 in layers
- More problems expected in pigs and chickens than in dairy
- Problems with early mortality/morbidity when affected animals not genotyped

Genomic gain for production and fitness traits – example in pigs

- 1000 sows per generation
- 15 piglets per sow
- 4 generations

- Gain per generation:
  - 0.65 phenotypic SD for growth
  - 0.02 phenotypic SD for number of born dead

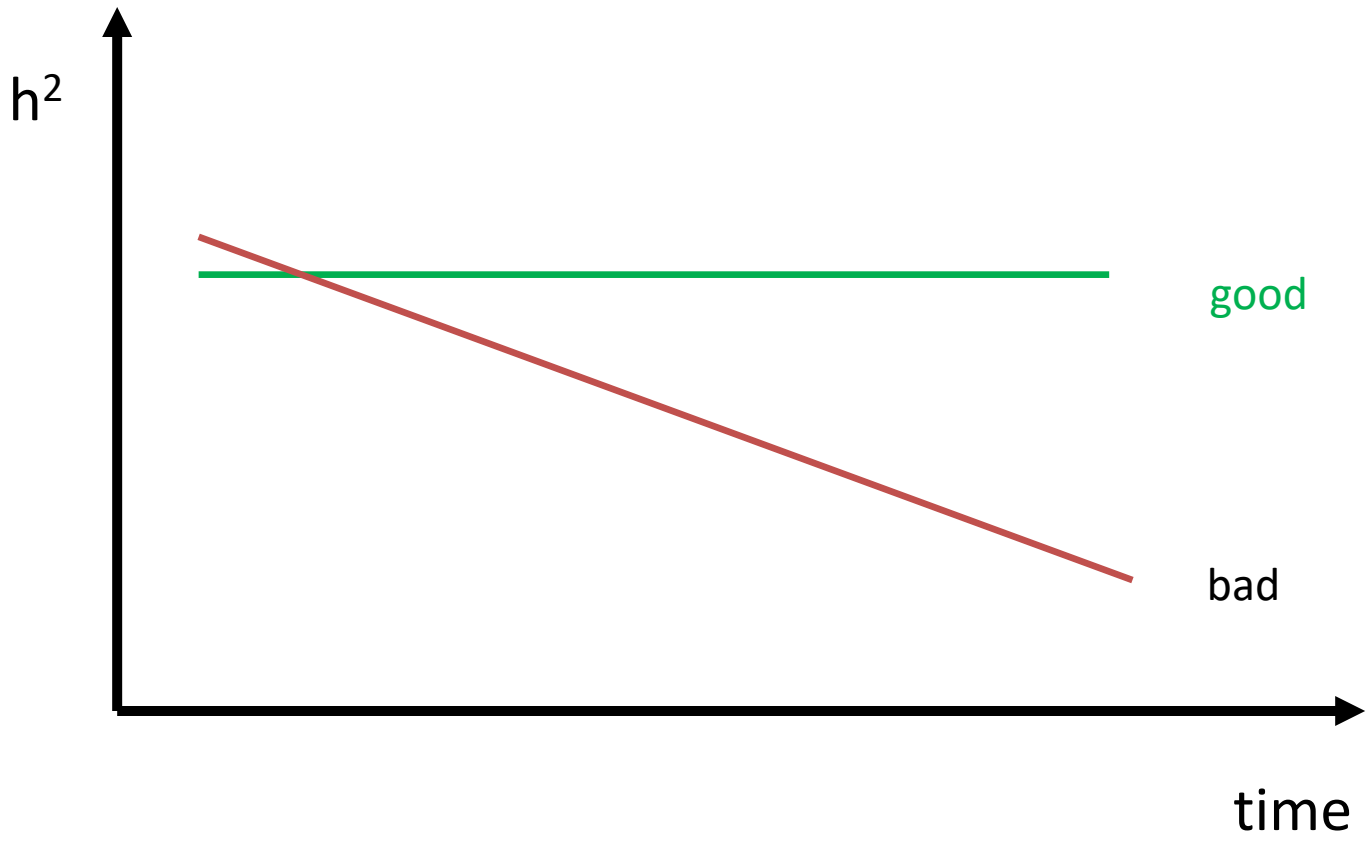
- Genomic favors bigger populations with better recording

How to mitigate negative effects of genomic selection?

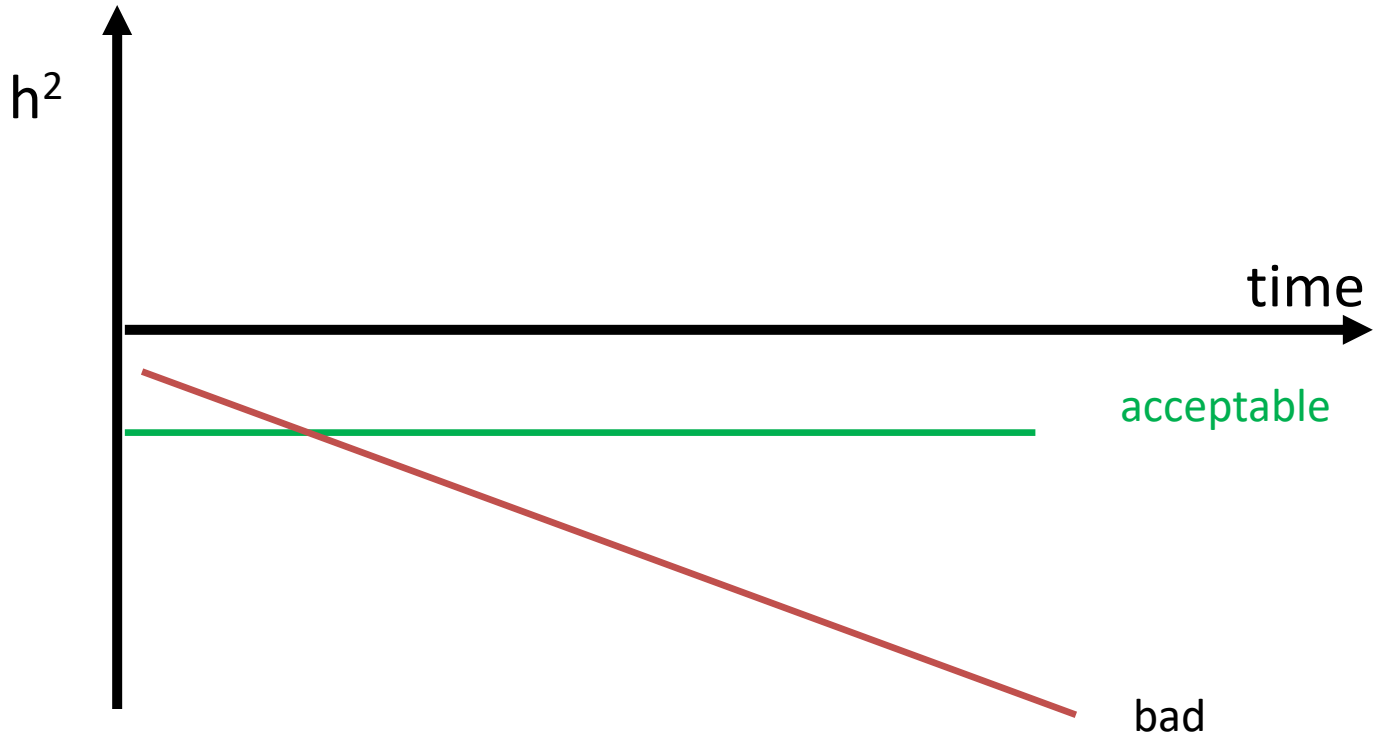
- Identify declining traits, record, evaluate and include in selection index
  - Need updated index with current genetic parameters
  - Need methods for parameter estimation with large-scale genomics
  - Lag from action to market

- If recording difficult, use general fitness traits: survival, productive life…

Possible changes in heritability



Possible changes in genetic correlations



How to estimate h^2 and r_g by generations

- REML or Bayesian
  - High computing cost
  - Base population parameters
- Need method that will work with national population and by recent time slices

$$acc_i = corr(y_i - Xb_i, \hat{u}_i)/h$$

Legarra et al. (2008)

$$corr(y_i - Xb_i, \hat{u}_j) = ? \quad acc_j \; corr_{ij} \; h_i$$

$$corr_{ij} = \frac{corr(y_i - Xb_i, \hat{u}_j)}{h_i \; acc_j} \pm \frac{1}{h_i \; acc_j \sqrt{N_{val}}}$$

Estimation of heritabilities

$$\widehat{h^2} = \frac{c^2 + \sqrt{c^4 + 4c^2 M_e / N}}{2}, c = corr(y - Xb, \hat{u})$$

N – # animals in reference population

N_{val} – number of animals in validation

Me – number of independent chromosome segments (about 15k in Holsteins)

US Holsteins -- milk -- 1 million genotyped

Initial h^2	Estimated h^2
0.35	0.33

Broiler chicken - growth – 150k genotyped

Initial h^2	Estimated h^2
0.30	0.14

Found correct by company

Conclusions

- Selection as optimization – winner and loser traits
- Decline in low h^2 traits compensated by improved management
- Low h^2 traits can be improved with selection, to a limit
- With genomic selection
  - Variances change
  - Faster progress for high h^2 traits
  - Faster decline for antagonistic unselected traits
  - Management improvements cannot catch up
- Higher risks for pigs and chickens, lower for dairy

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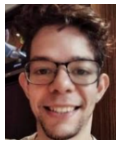

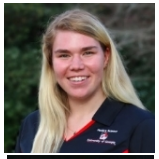

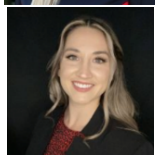

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