New technologies going (that may go) into genomic EPD

Daniela Lourenco | Andre Garcia

July 5, 2023

UNIVERSITY OF
GEORGIA
College of Agricultural & Environmental Sciences
Animal Breeding and Genetics Group

How much data goes into EPD calculations?

9.6M BW

10.1M WW

4.9M PWG

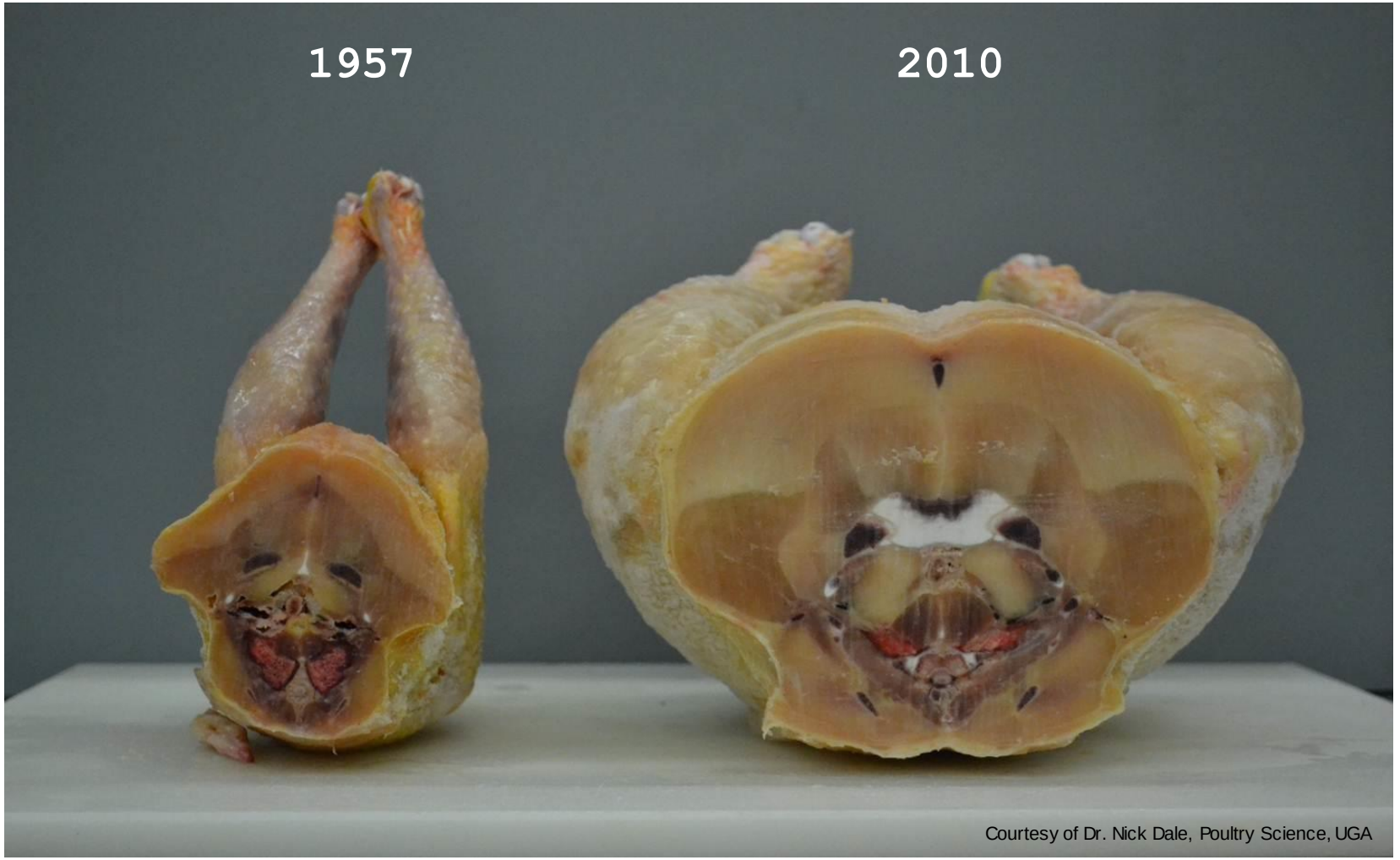
2.6M US

131k CR

34K FI

- Predicting things is very hard
  - Gather enough data
  - Use the right statistical tools

Pre-genomic EPD



Goal: Keep improving

Reducing environment impact

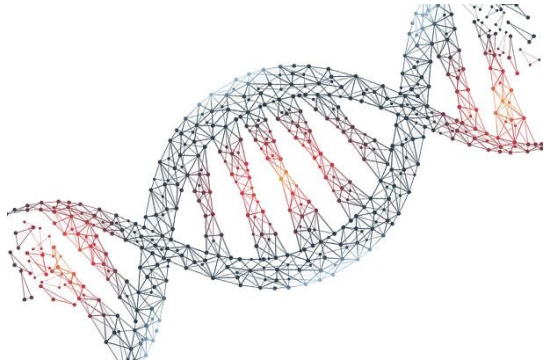
More efficient and healthier animals

Not competing for water resources

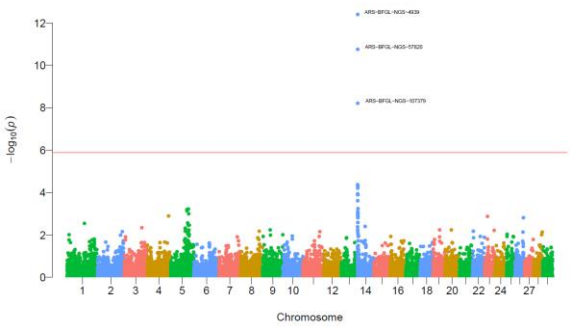
Not competing with human food

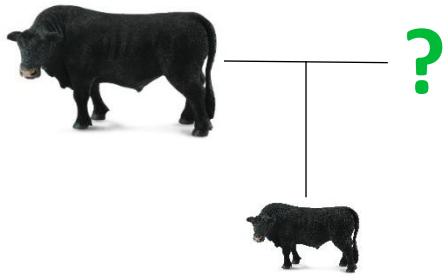
Increase animal protein production

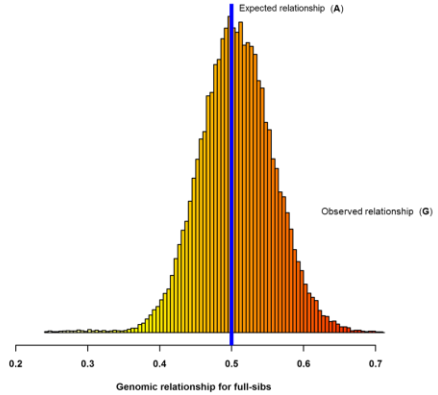
Prereq 4 → **Prereq 3** → **Prereq 2** → **Prereq 1** → **Ultimate Goal**



https://www.progressivedairy.com/topics/a-i-breeding/improved-genomic-selection-for-health-and-other-traits



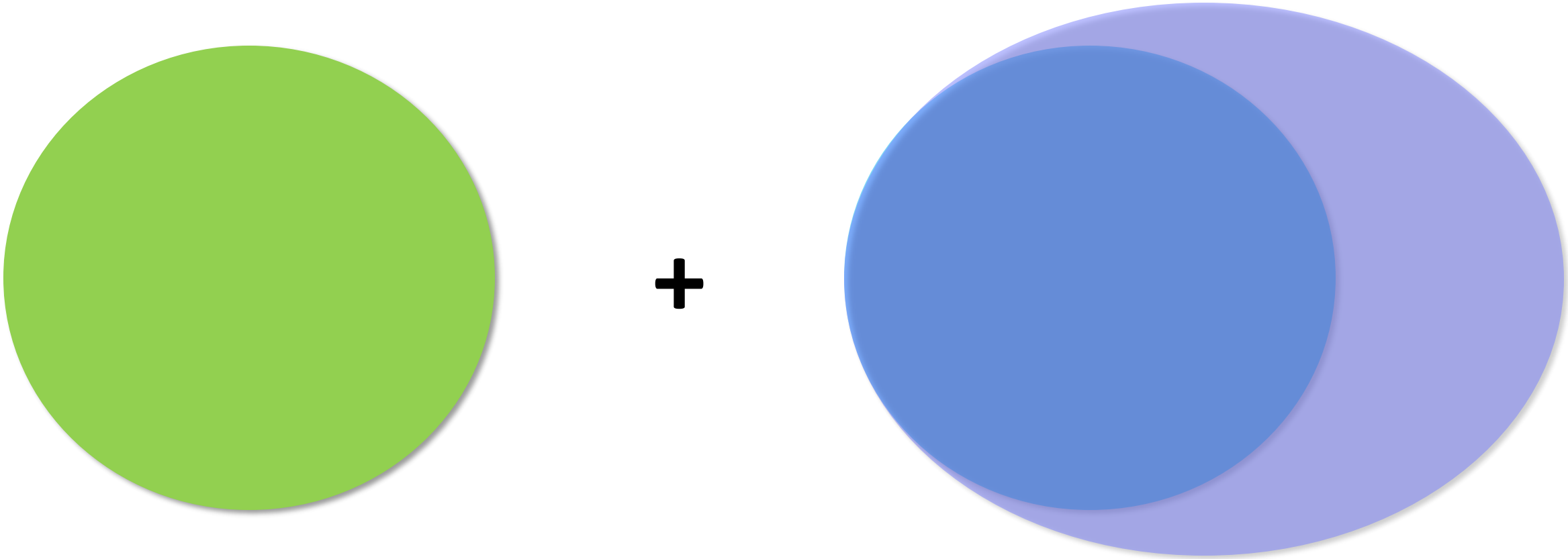




Why is genomic info helpful?

$$\Delta G = \frac{i\, r\, \sigma_a}{L}$$

Why does genomic info work?

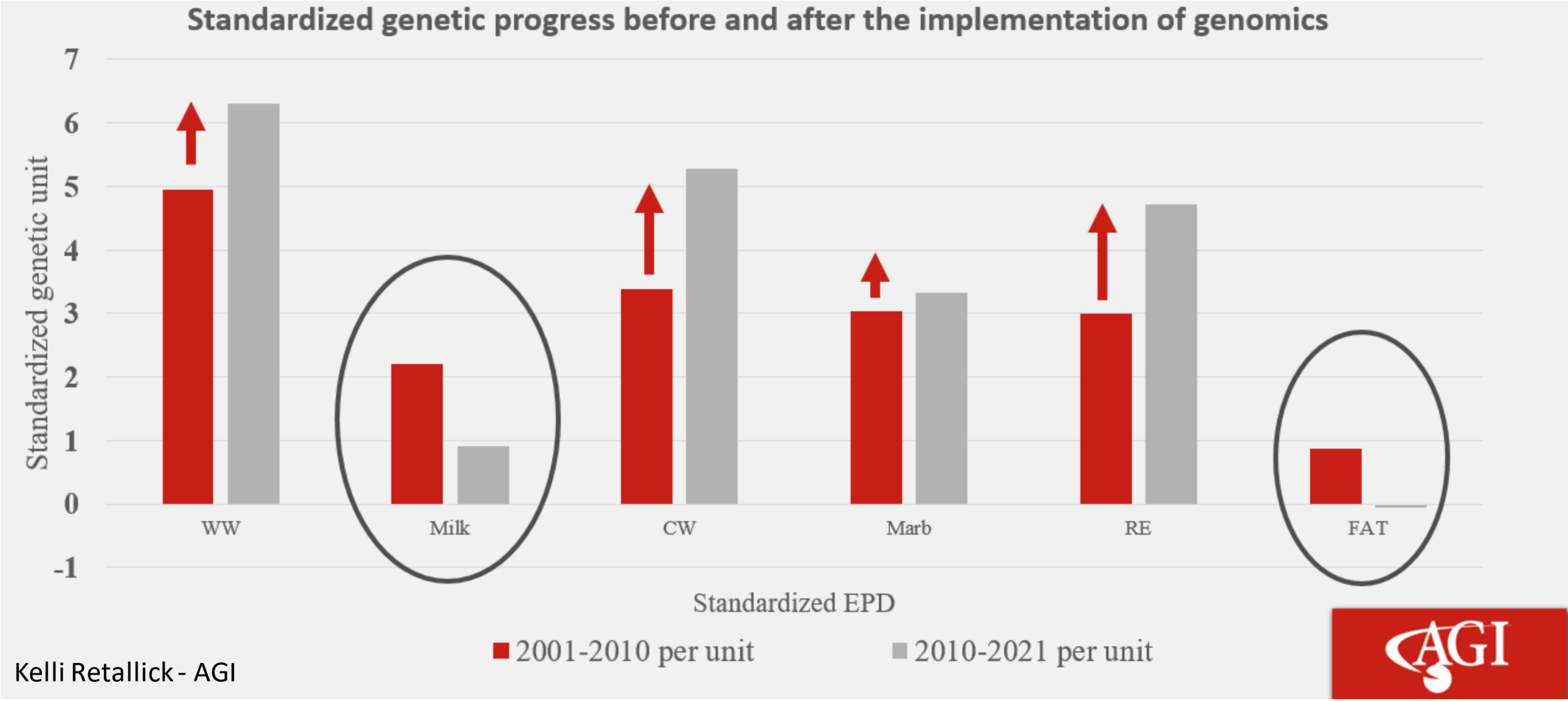


Phenotypes

Pedigree

Genotypes

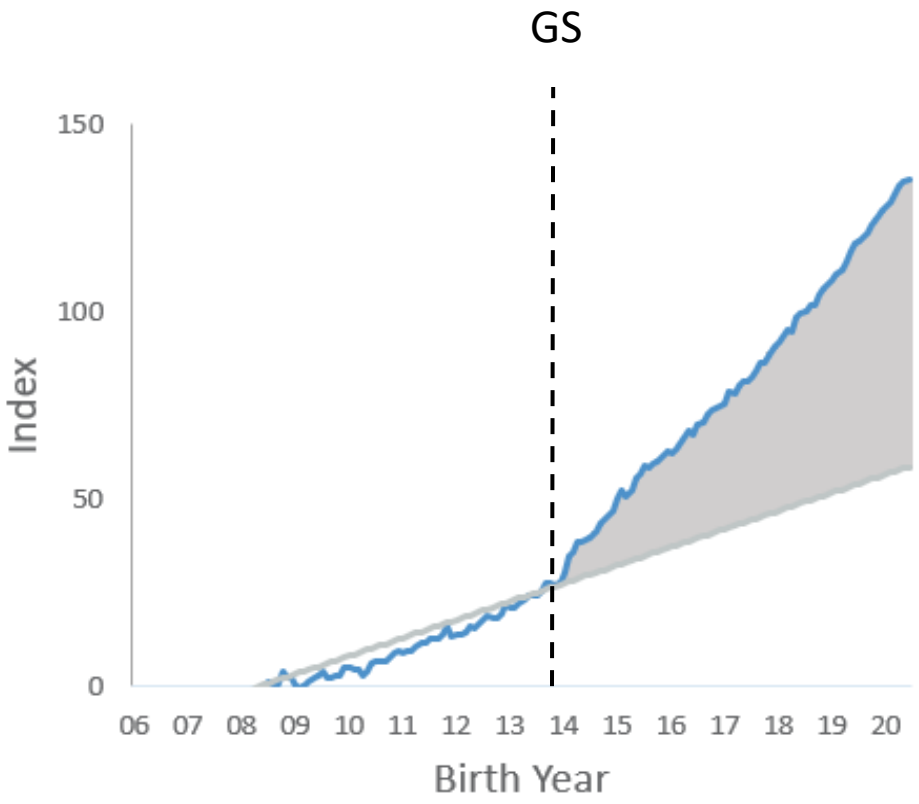
Changes after genomics - beef



Kelli Retallick - AGI

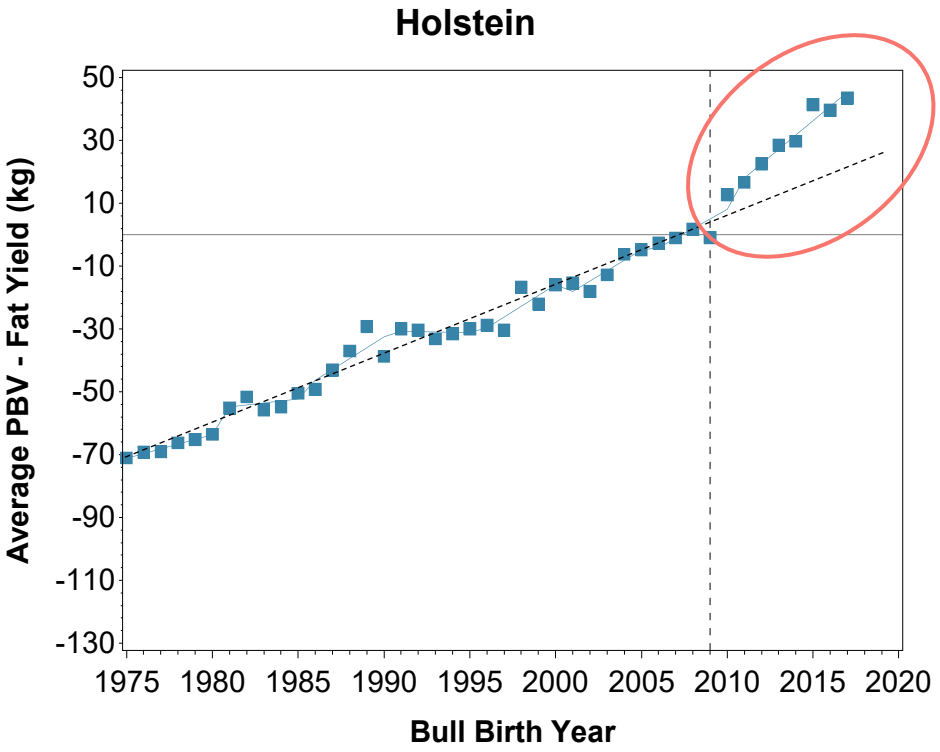
Changes after genomics - pigs

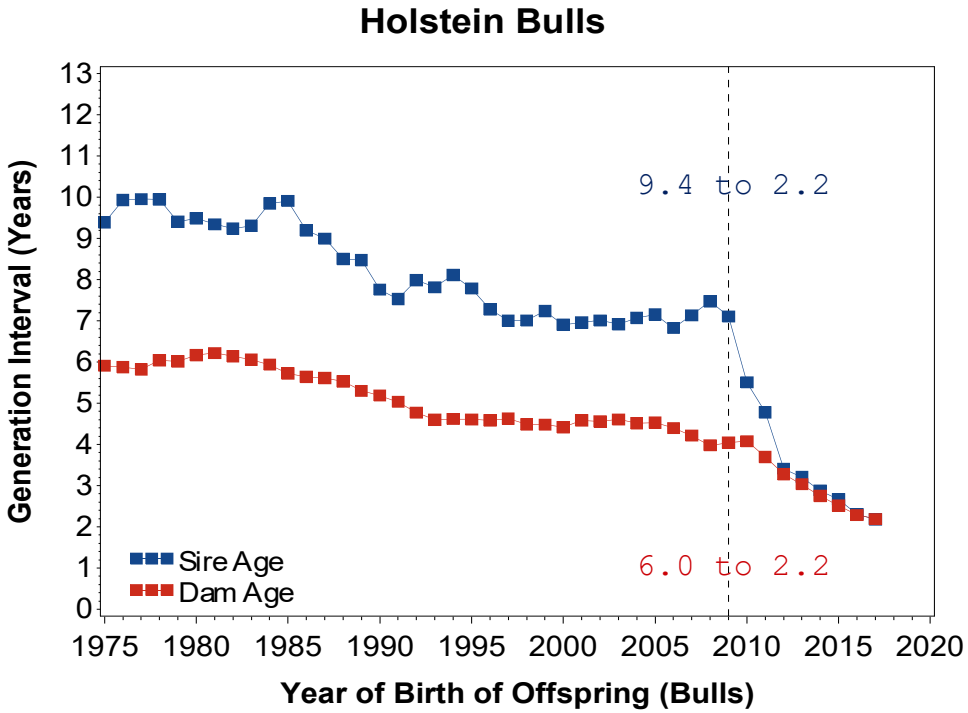
PIC



Changes after genomics - dairy

- > 2x after genomics for Holsteins

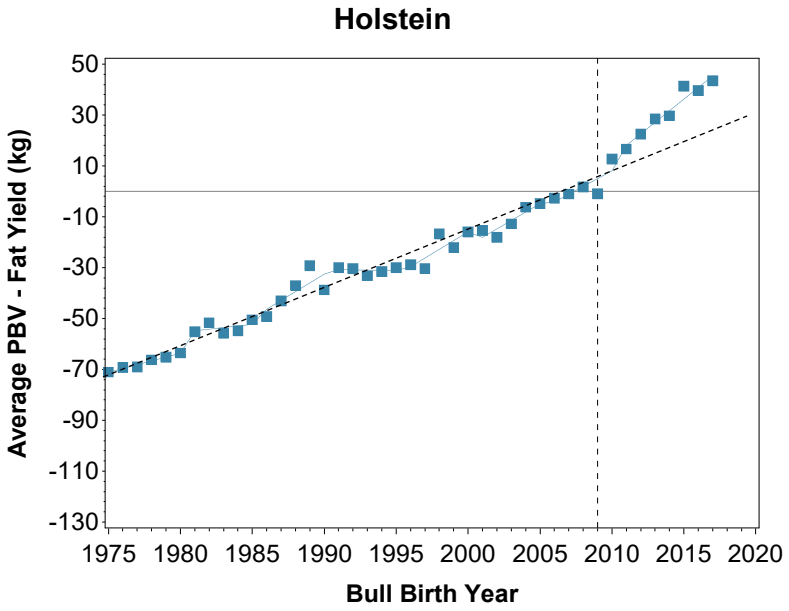


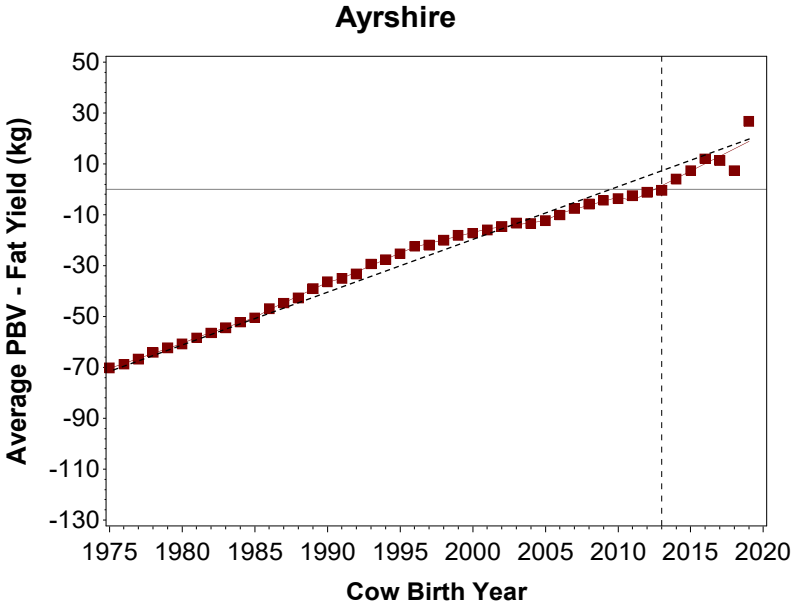


Guinan et al. (2023)

CDCB
COUNCIL ON DAIRY CATTLE BREEDING

Changes after genomics - dairy



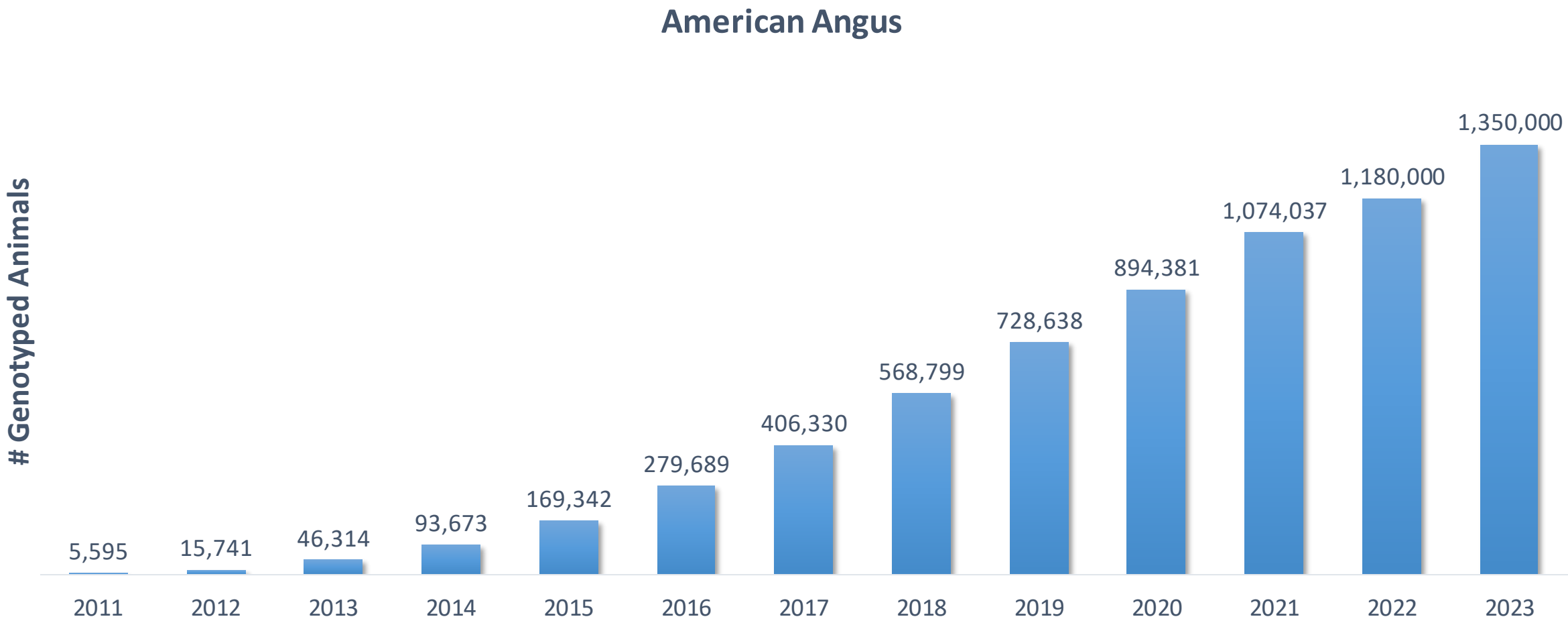


Guinan et al. (2023)

CDCB
COUNCIL ON DAIRY CATTLE BREEDING

- Adoption: 2013 vs 2009
- Genotypes: 16k vs. 5.5M
- Benefits depend on the level of adoption

Massive uptake of genomics in 15 years

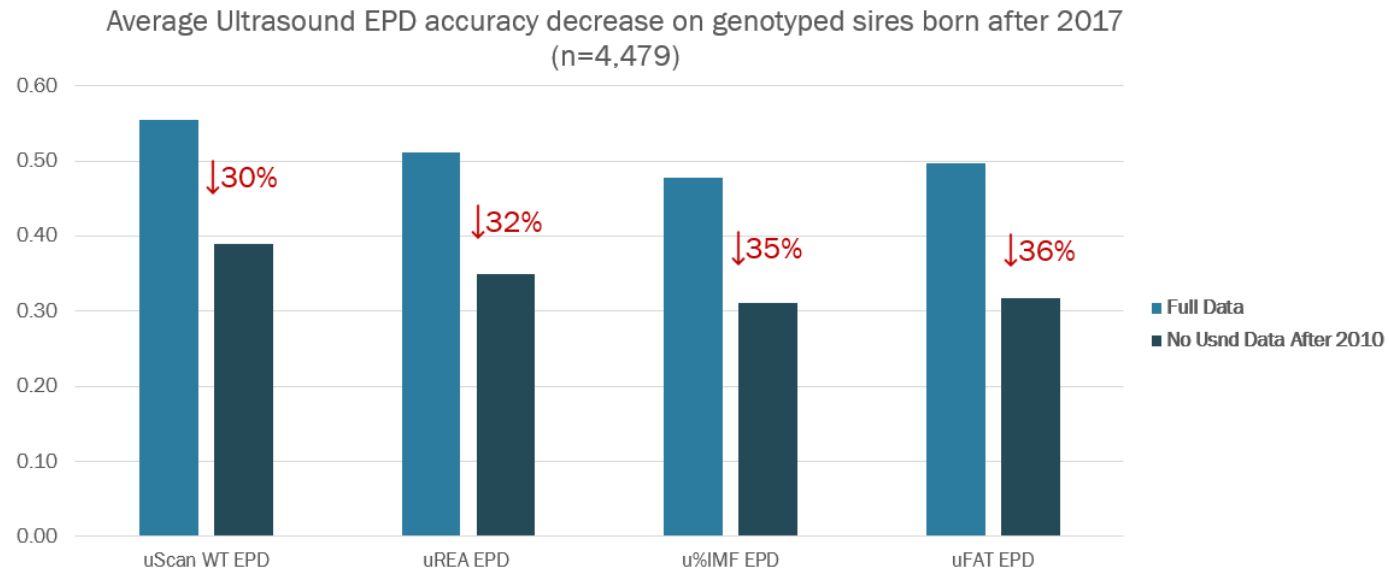


Genotypes work together with phenotypes

- Genotypes do not replace phenotypes…they work together

Impact of eliminating all US carcass records from 2010

Greater than 30% accuracy decrease in Ultrasound EPDs on young genotyped sires with record elimination



ANGUS THE BUSINESS BREED

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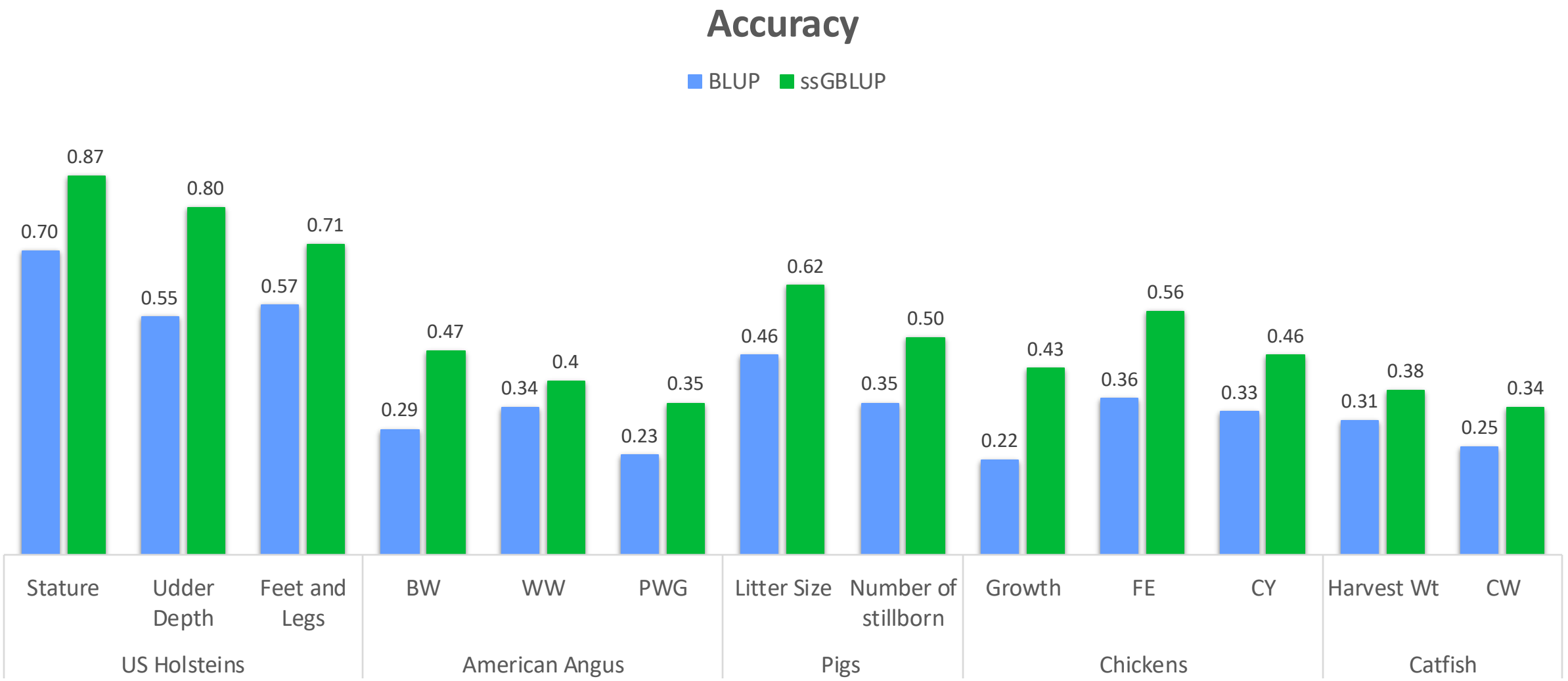
Genotypes work together with phenotypes

Genomics

Phenotypes

Gain in accuracy in GEPD vs. EPD



Tsuruta et al. (2021)

Lourenco et al. (2018)

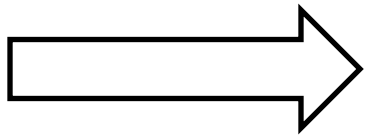
Lourenco et al. (2016)

Lourenco et al. (2015)

Garcia et al. (2018)

New technologies / sources of info

- Whole-genome sequence
- Phenomics
  - Self-tracking sensors and cameras
- Gut microbiome
- Blood work (metabolites)
- Enviromics (better characterization of the environment)



- More accurate EPD for many traits
- Improve farm animal populations

Selecting sequence variants to improve genomic predictions for dairy cattle

Paul M. VanRaden, Melvin E. Tooker, Jeffrey R. O'Connell, John B. Cole & Derek M. Bickhart

Genetics Selection Evolution **49**, Article number: 32 (2017) | Cite this article

Incorporation of causative quantitative trait nucleotides in single-step GBLUP

Breno O. Fragomeni, Daniela A. L. Lourenco, Yutaka Masuda, Andres Legarra & Ignacy Misztal

Genetics Selection Evolution **49**, Article number: 59 (2017) | Cite this article

Predicting Growth and Carcass Traits in Swine Using Microbiome Data and Machine Learning Algorithms

Christian Maltecca, Duc Lu, Constantino Schillebeeckx, Nathan P. McNulty, Clint Schwab, Caleb Shull & Francesco Tiezzi

Scientific Reports **9**, Article number: 6574 (2019) | Cite this article

Front. Anim. Sci., 11 February 2021 | https://doi.org/10.3389/fanim.2021.650324

Grand Challenge in Precision Livestock Farming

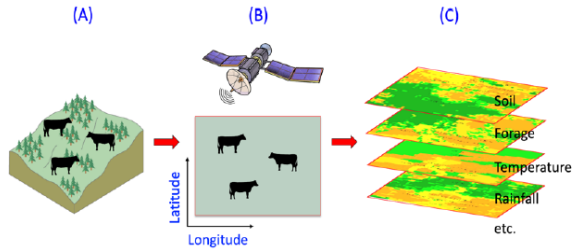
Guilherme J. M. Rosa*

Department of Animal and Dairy Sciences, Department of Biostatistics & Medical Informatics, University of Wisconsin-Madison, Madison, WI, United States

Genetic evaluation including intermediate omics features

Ole F Christensen, Vinzent Börner, Luis Varona, Andres Legarra

Genetics, Volume 219, Issue 2, October 2021, iyab130, https://doi.org/10.1093/genetics/iyab130



Enviromics-enabled precision breeding for adapted cattle:

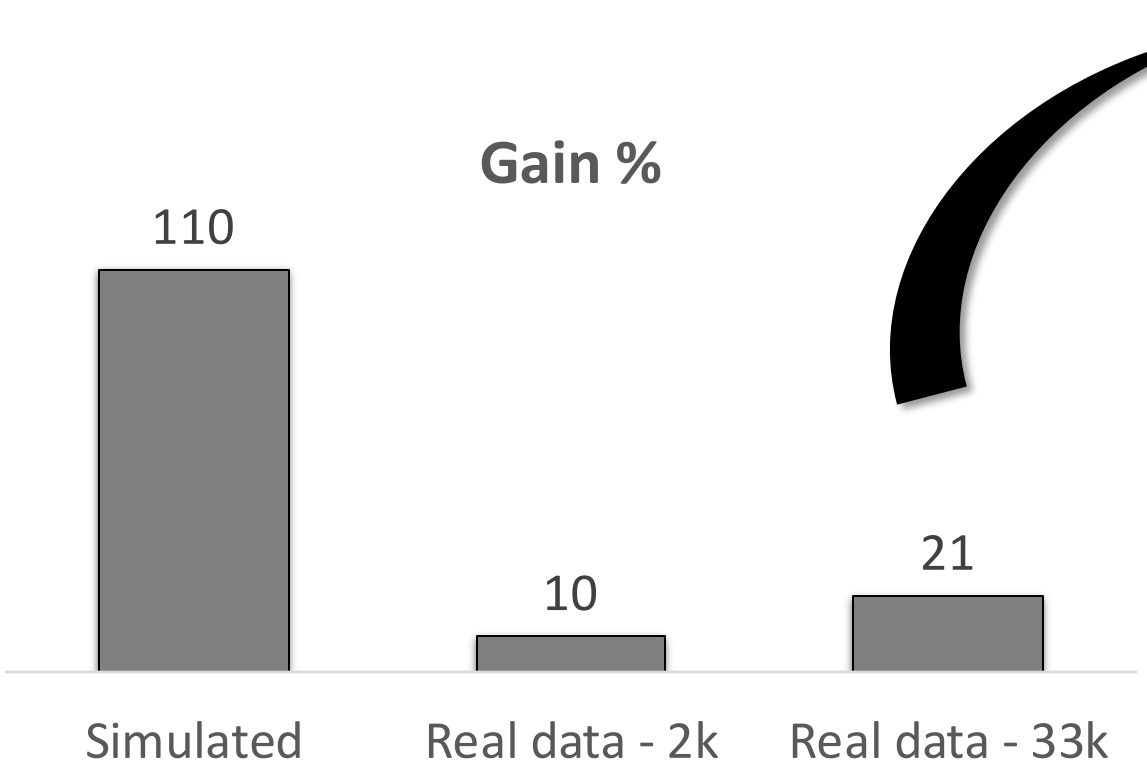
Rosa, Lourenco et al. (2022)

"Whenever new technologies generate different data, we need to make the most out of that"

New technologies that could go into GEPD

- Whole-genome sequence
- Phenomics
  - Self-tracking sensors and cameras
- Gut microbiome
- Blood work (metabolites)
- Enviromics

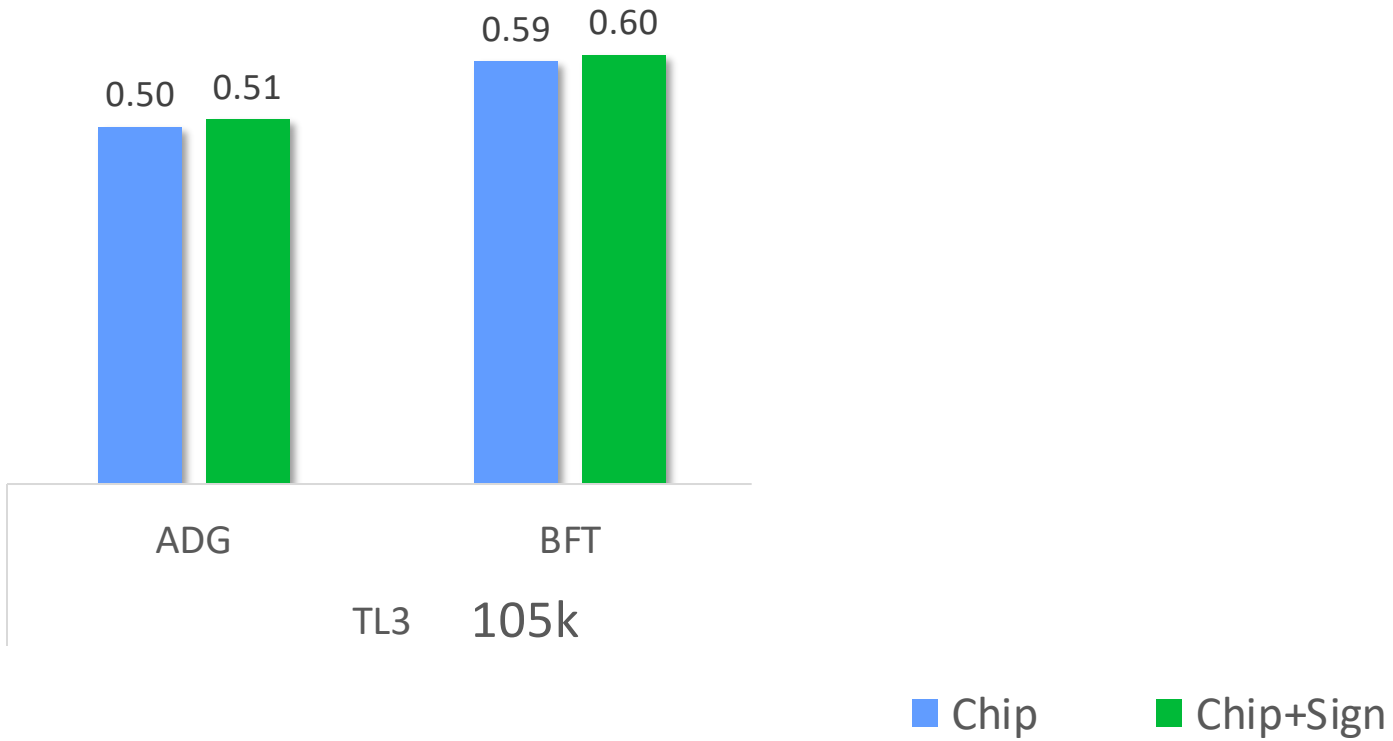
Whole-genome sequence



- 50k SNP may not be enough
- We should use sequence data

Whole-genome sequence for GEPD

- Prediction accuracy = cor(DEBV, GEBV)



Other uses for whole-genome sequence

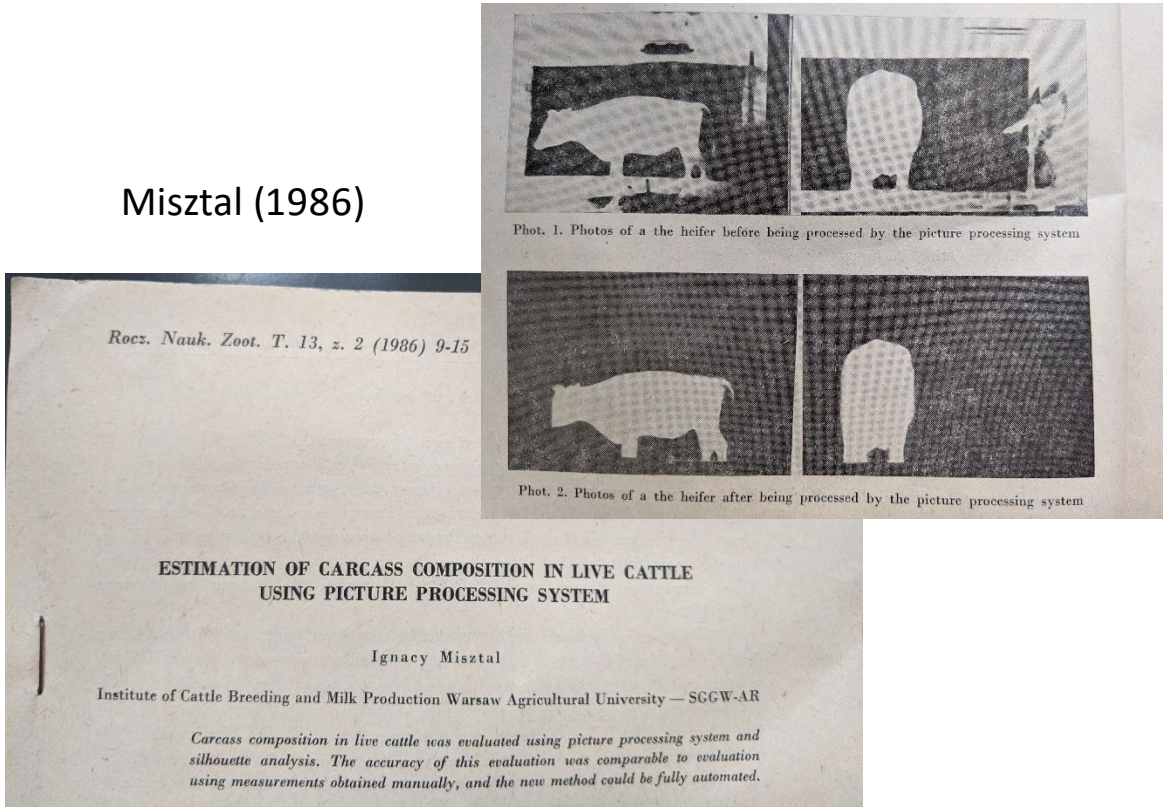
- Genomic predictions
  - Flexibility – change the SNP panel at any time
- Genetic architecture of traits
- New mutations
- Problematic haplotypes

- $100 - $200 per sample

Phenomics

- High-throughput phenotyping (phenomics) – computer vision systems (CVS)
  - Sensors and cameras
  - Collecting data 24/7
  - Feed intake, grazing behavior
  - Fertility, welfare, resilience
  - Temperature, gas emission
  - …

Misztal (1986)



Phot. 1. Photos of a the heifer before being processed by the picture processing system

Phot. 2. Photos of a the heifer after being processed by the picture processing system

Rocz. Nauk. Zoot. T. 13, z. 2 (1986) 9-15

ESTIMATION OF CARCASS COMPOSITION IN LIVE CATTLE USING PICTURE PROCESSING SYSTEM

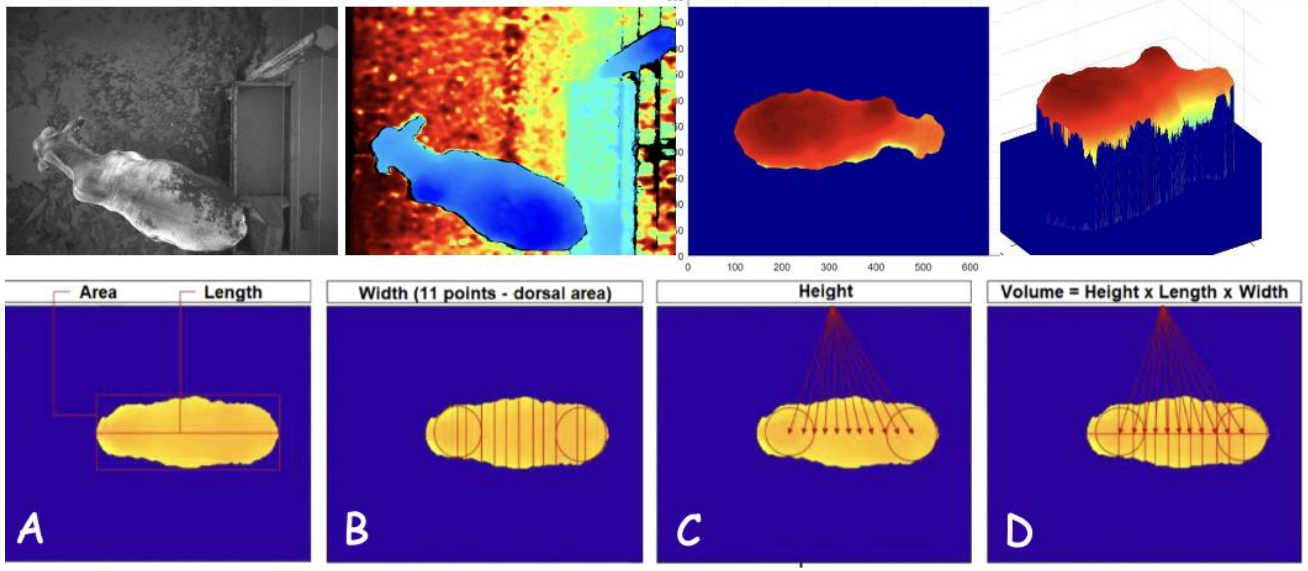
Ignacy Misztal

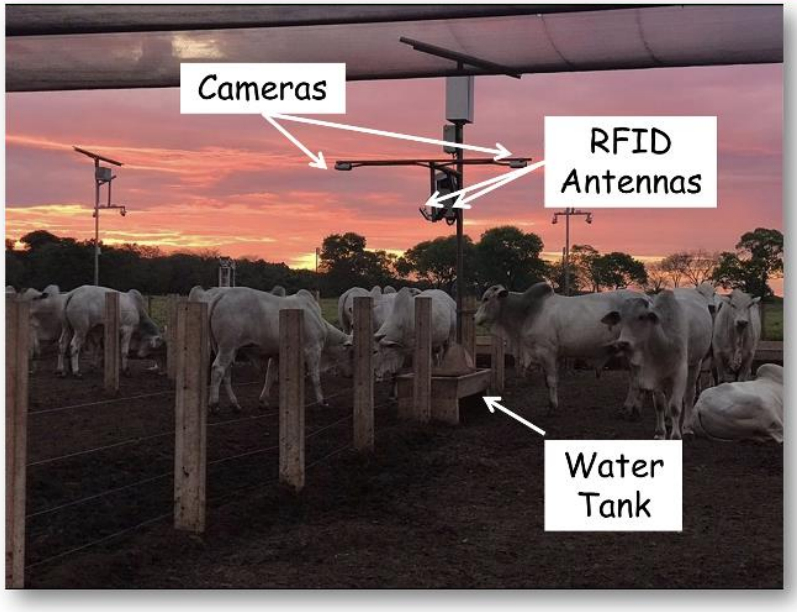
Institute of Cattle Breeding and Milk Production Warsaw Agricultural University — SGGW-AR

Carcass composition in live cattle was evaluated using picture processing system and silhouette analysis. The accuracy of this evaluation was comparable to evaluation using measurements obtained manually, and the new method could be fully automated.

Phenomics

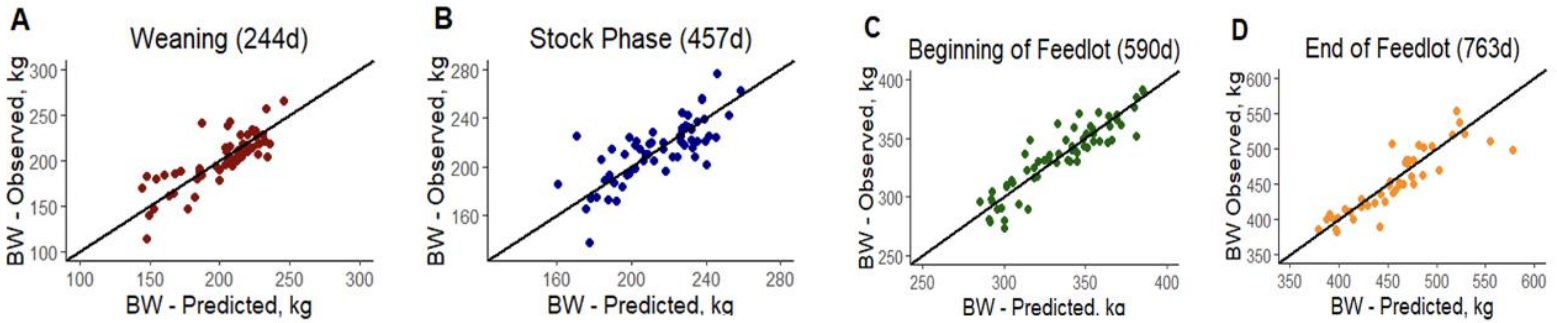
Monitoring Growth Development in Beef Cattle





Guilherme Rosa (UW)

João Dorea (UW)



Accuracy = 0.89 to 0.96

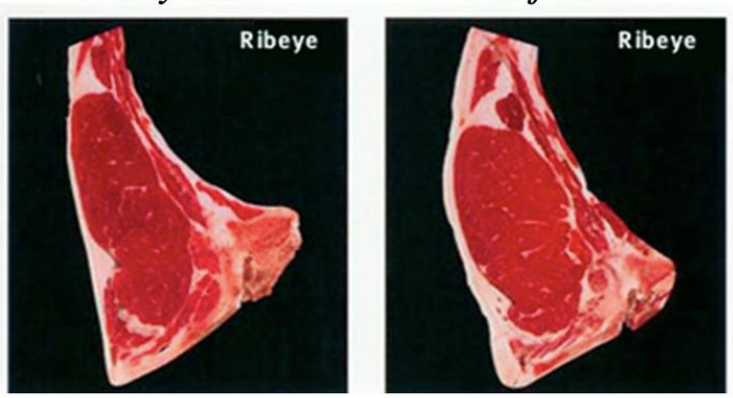
Cominote et al., 2020 – *Livestock Science* 232:103904

Phenomics

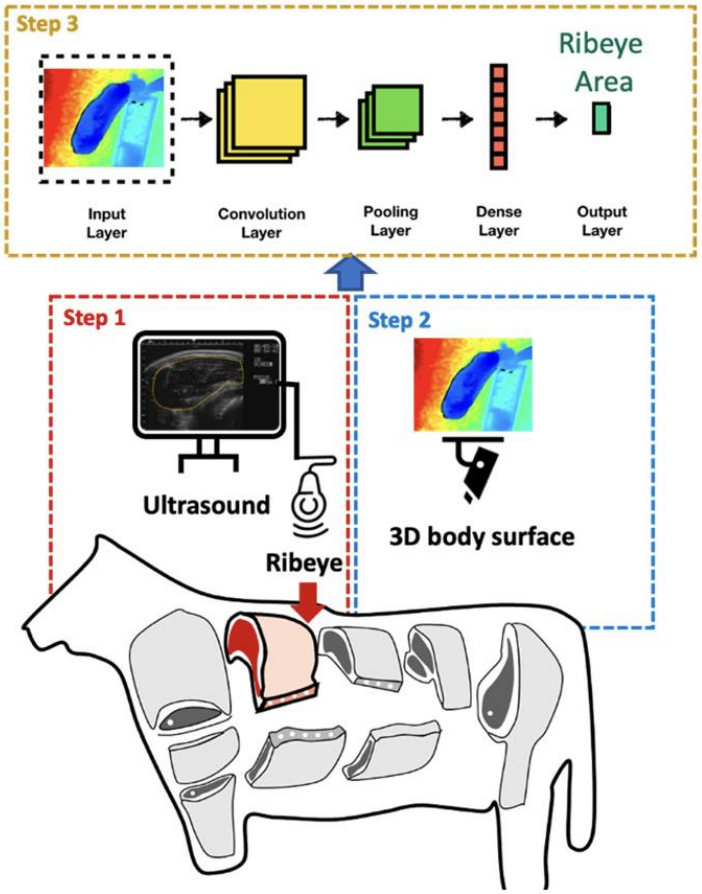
3D Body Shape: Predicting Ribeye Area and Shape of Live Calves

- Beef semen has been used in genetically inferior cows to produce crossbred (beef x dairy) animals
- Very important source of income for dairy farmers
- Frequently reported as lacking quality and shape uniformity

Dairy Steer *Beef Steer*



Source: Angus Beef Bulleting



Caffarini et al., 2022 – (under-review)

Guilherme Rosa (UW)

João Dorea (UW)

Is using phenomics a reality?

- Machine learning
  - Artificial intelligence
  - Algorithms to automatically learn from the data and make predictions

- Limitations
  - Requires new on-farm devices and large data storage
  - Expensive to teach a machine (computing resources and time)
  - Image recognition comes with an appetite for computing power (Thompson et al., 2020)

"Computing limitations have a short lifespan"

Is using phenomics a reality?

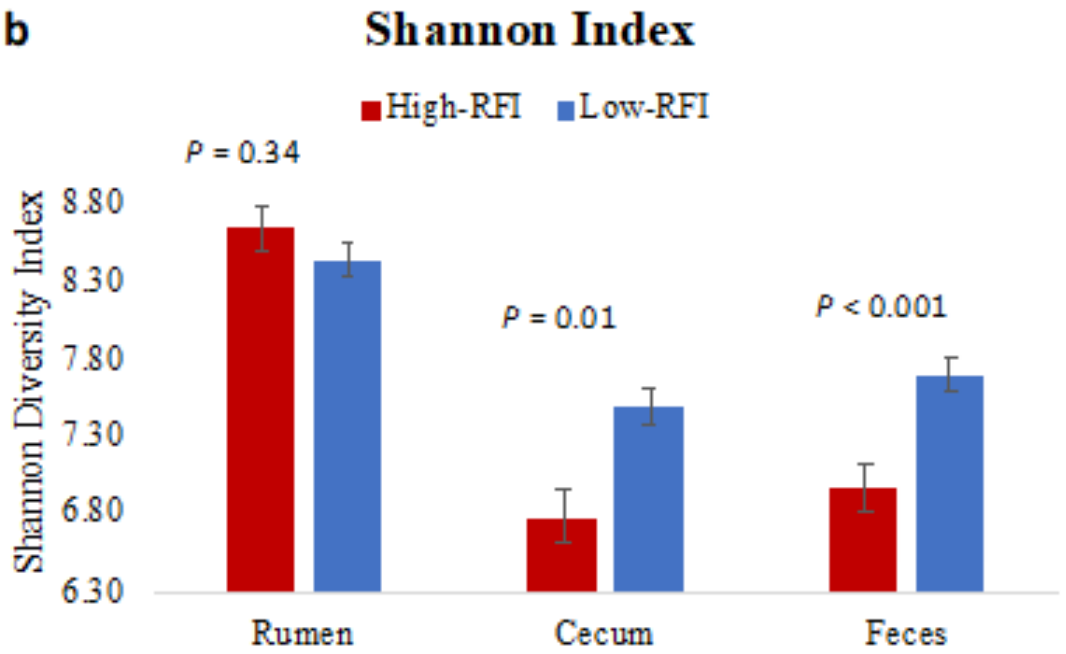
- Where are we at now?
  - Collecting data
  - Learning how to extract the most important features

- Implications
  - Trait definitions may change
  - New traits in the evaluation system
  - Reality within 5 years

Microbiome information

J. Lourenco's team at Leo McDonnell's Ranch

Microbiome information



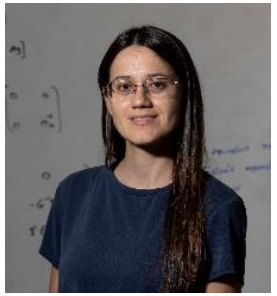
J. Lourenco (unpublished)

- Genomic testing from animals and microbial diversity index as a trait
  - Microbiome is used as a proxy trait -> should we collect microbiome info or RFI
- Host-microbiome interaction: Genomic testing for animals and microbes into evaluations

Microbiome – under investigation

- Connection between microbiome and several traits
- Can microbiome replace FI recording?
- How to include microbiome info into genomic evaluations?
  - Samples on 1500 animals
  - Beef cattle data



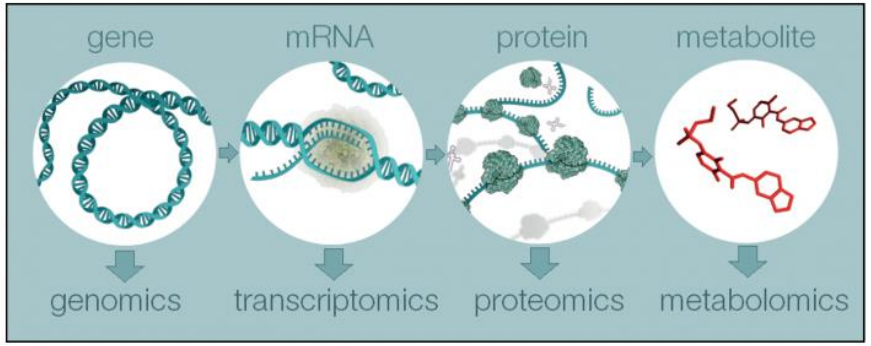



Is using microbiome a reality?

- Where are we at now?
  - Collecting data
  - Learning how to use this information
  - Still unclear how helpful it can be
  - $40 per sample + sampling costs by trained personnel
- Implications
  - New traits in the evaluation system
  - More complex models

Metabolites

- Metabolite profile
  - Intermediate omics data



OPEN

Integrative analyses of genomic and metabolomic data reveal genetic mechanisms associated with carcass merit traits in beef cattle

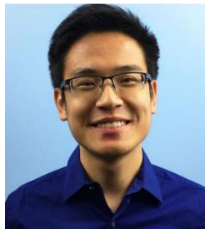
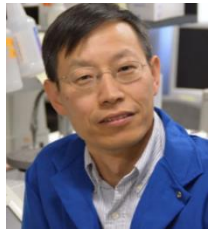
Jiyuan Li[1], Yining Wang[1,2], Robert Mukiibi[3], Brian Karisa[4], Graham S. Plastow[1✉] & Changxi Li[1,2✉]

- 100s of metabolites available for < $15
- How to include this information for genomic evaluations?
  - Index? Correlated trait? Similarity matrix?

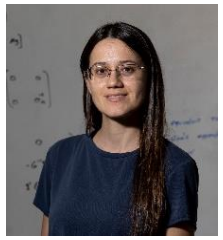
Metabolites – under investigation

- Statistical methods
  - Metabolites
  - Function annotation
  - Sequence data

- GP in commercial pig data





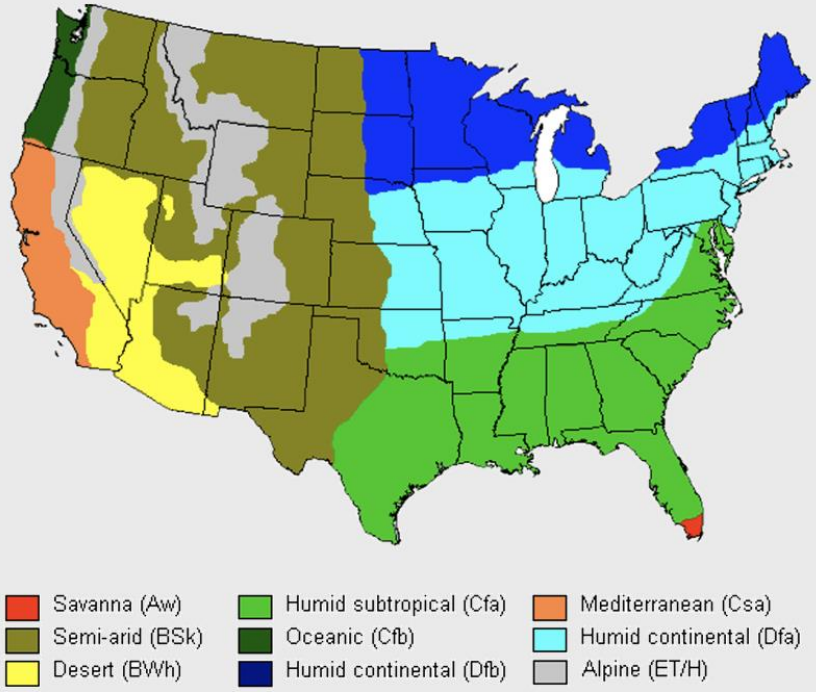
Is using metabolites a reality?

- Where are we at now?
  - Collecting data
  - Learning how to use this information
  - Still unclear how helpful it can be

- Implications
  - New traits in the evaluation system
  - More complex models

Enviromics

Integrating Enviromics, Genomics, and Machine Learning for Precision Breeding of Resilient Beef Cattle (USDA AFRI 2023-68014-39816)



PI: Guilherme Rosa (UW-Madison)

Enviromics

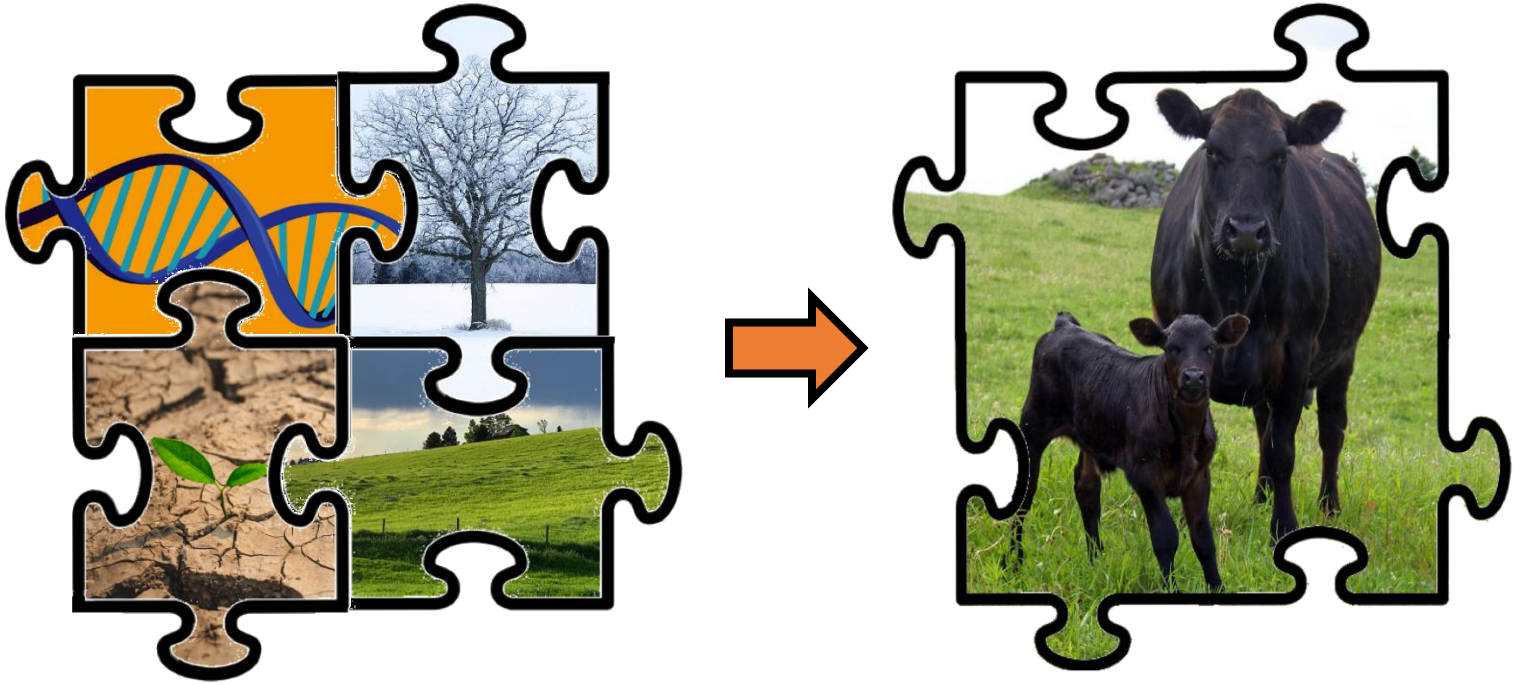
FOX 2 now

NATIONAL

At least 2,000 cattle die after extreme heat bakes Kansas

by: Hannah Adamson, Nexstar Media Wire
Posted: Jun 17, 2022 / 01:07 PM CDT
Updated: Jun 17, 2022 / 01:07 PM CDT

- Top priority of the USDA stakeholders



G x E

Courtesy of:
Guilherme Rosa

Enviromics

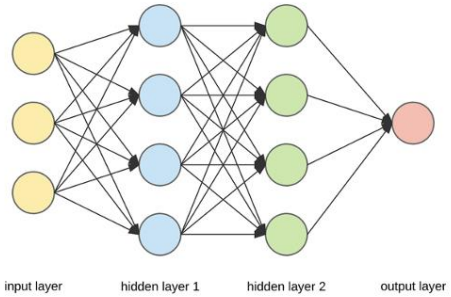
AGI

- 9K+ herds (1970-2020)
- 9.3M+ birth weights
- 9.8M+ weaning weights
- 4.8M+ post-weaning weight gain
- 126K+ heifer pregnancy
- full pedigree information
- 1M+ genotypic information

Farm management

Soil, climate, and weather information

Forage density and quality



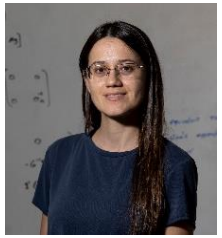
Data analytics

Extension and outreach







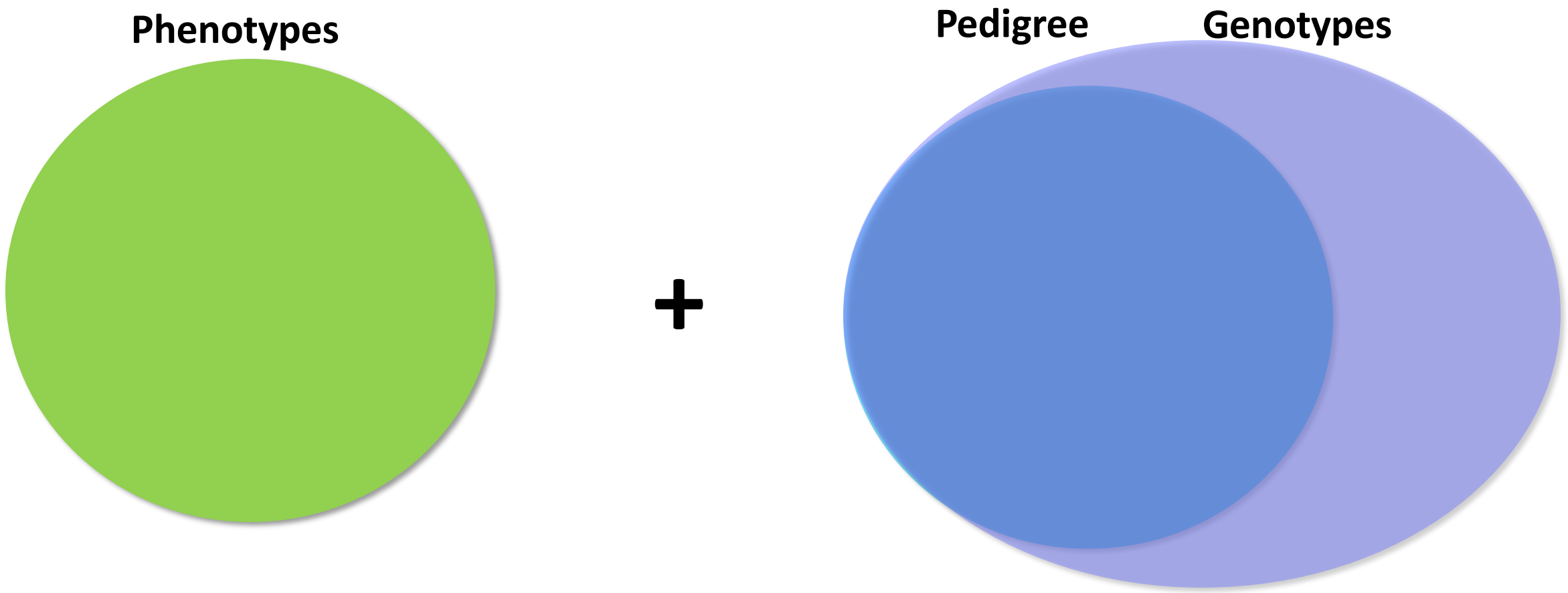
- Statistical methods for precision breeding
  - Best animals for each production system/environment

Is enviromics a reality?

- It's a reality in plant breeding, not in animal breeding
- Animal breeding – only temperature and humidity
  - Dairy cattle evaluations – Australia
  - Pig evaluations – one company in the USA

- Where are we at now?
  - Collecting data
  - Learning how to process and use this information
- Implications
  - More complex models

Final remarks



Final remarks

- Why are we investigating new sources of information?
  - Increase accuracy of GEPD
- How can new sources of data impact current genomic evaluations?
  - More data and computational challenges
  - Weekly evaluations may become outdated
- What will change for beef cattle producers?
  - Will collect more data
  - Price of new technologies always decrease with time
  - More accurate GEPD for better decisions and improved ΔG

Final remarks

$$\Delta G = \frac{i\, r\, \sigma_a}{L} \times \delta$$

How much you trust the geneticists

UNIVERSITY OF GEORGIA

UGA AB&G team

USDA
NIFA

ANGUS
THE BUSINESS BREED
AMERICAN ANGUS ASSOCIATION
3201 Frederick Avenue • St. Joseph, MO 64506 • (816) 383-5100 • Fax (816) 233-9703 • E-mail: angus@angus.org

AGI

PIC

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

CDCB
COUNCIL ON DAIRY CATTLE BREEDING

DNA GENETICS
Greater gains. Improved performance.

ABCZ

Rural Development Administration
National Institute of Animal Science

WAGYU
AMERICAN WAGYU ASSOCIATION

BAYER
Crop Science

U.S. Registered Holsteins
FOR MAXIMUM PROFIT
HOLSTEIN ASSOCIATION USA, INC.

THE MASCHHOFFS
Progressive Farming. Family Style.

ABS

SEMEX
Genetics for Life

PEAK

PFHBiPM

PLEMDAT

Topigs Norsvin

methodgenetics

ANCP