

# The Genomic Revolution: *Global Perspectives on Dairy Cattle Breeding*

Filippo Miglior<sup>1,2</sup>, Gabriella Dodd<sup>2</sup>, Christine Baes<sup>2</sup>

<sup>1</sup>Lactanet Canada, Guelph, Canada

<sup>2</sup>University of Guelph, Guelph, Canada



**AdaptMitigate**  
Dairy Genome Project



**Net-Zero Dairy**  
GENOME PROJECT

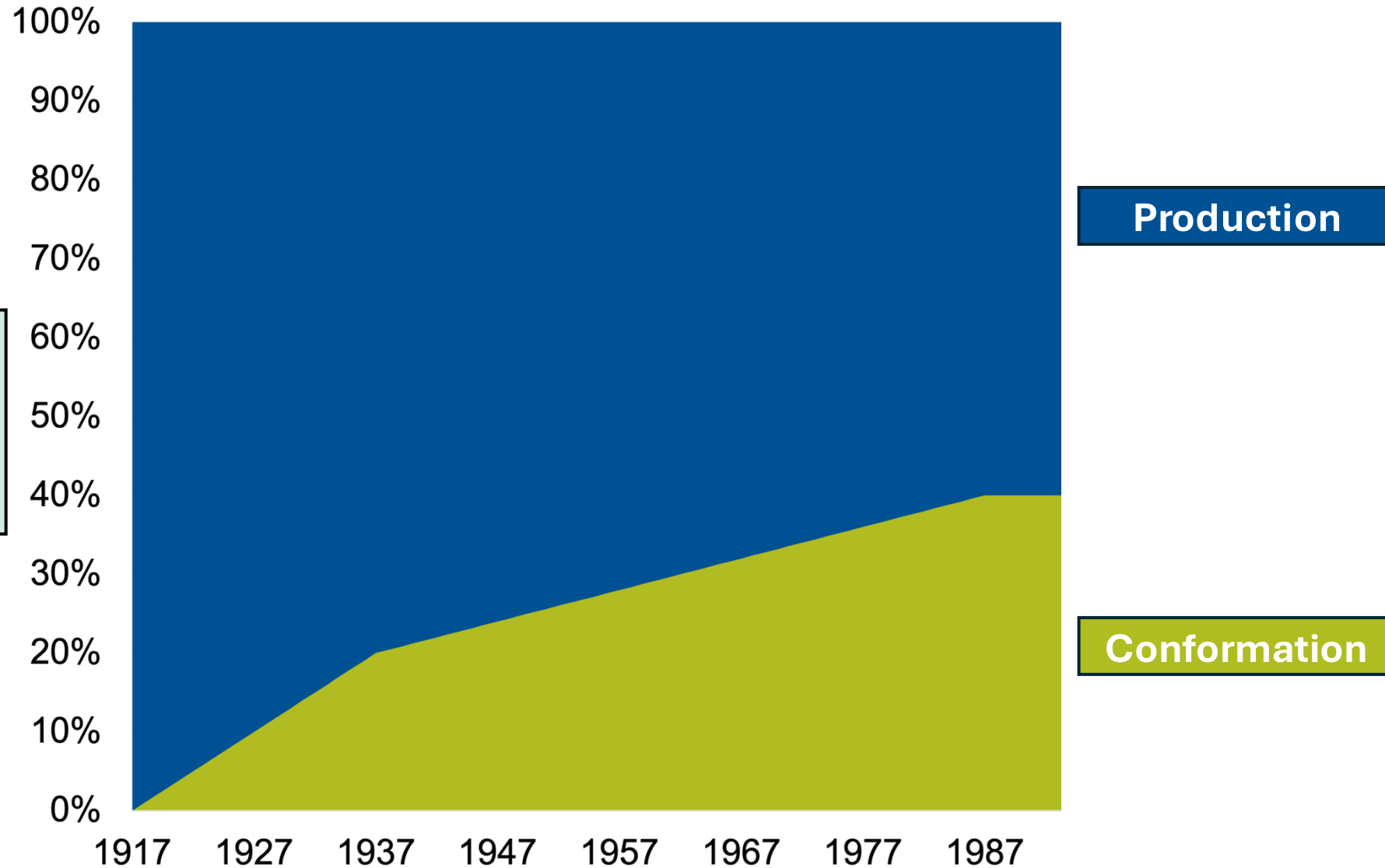
# Outline

How genomics has changed selection decisions

- What it means for profitability, health and environmental efficiency
- Past
- Genomic shift
- Novel traits & climate

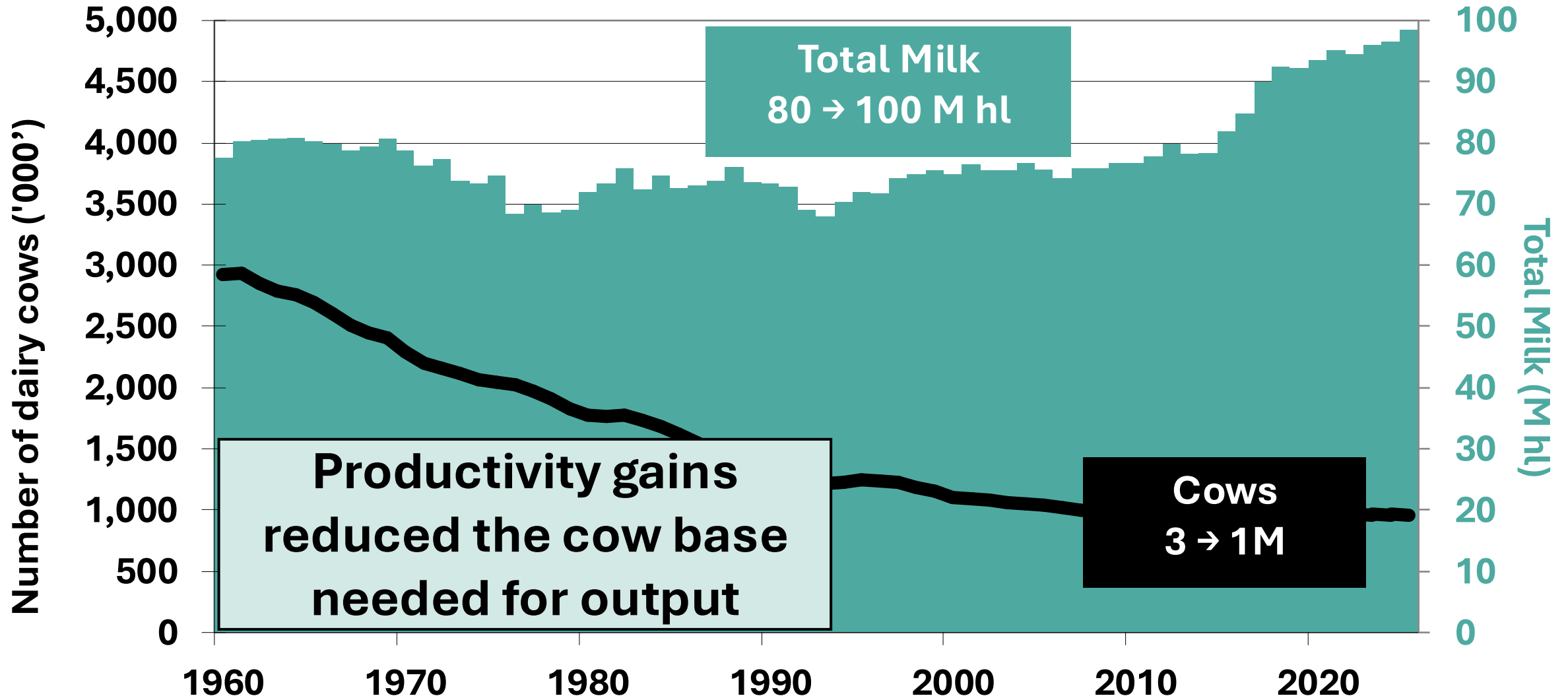
# Historical Breeding Goals

**Limited selection goals for decades**

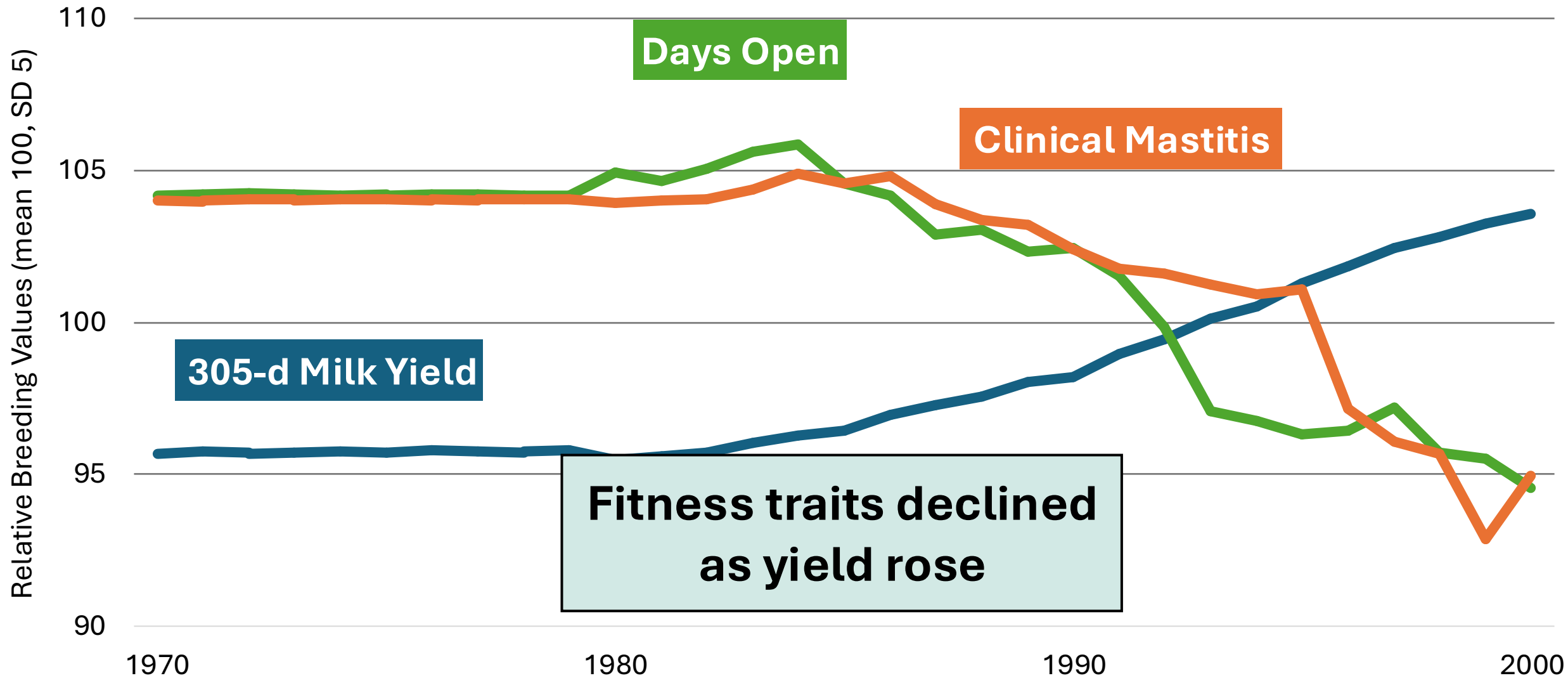


Miglior et al., 2017

# The Good News! ... 3× fewer cows



# The Problem ...



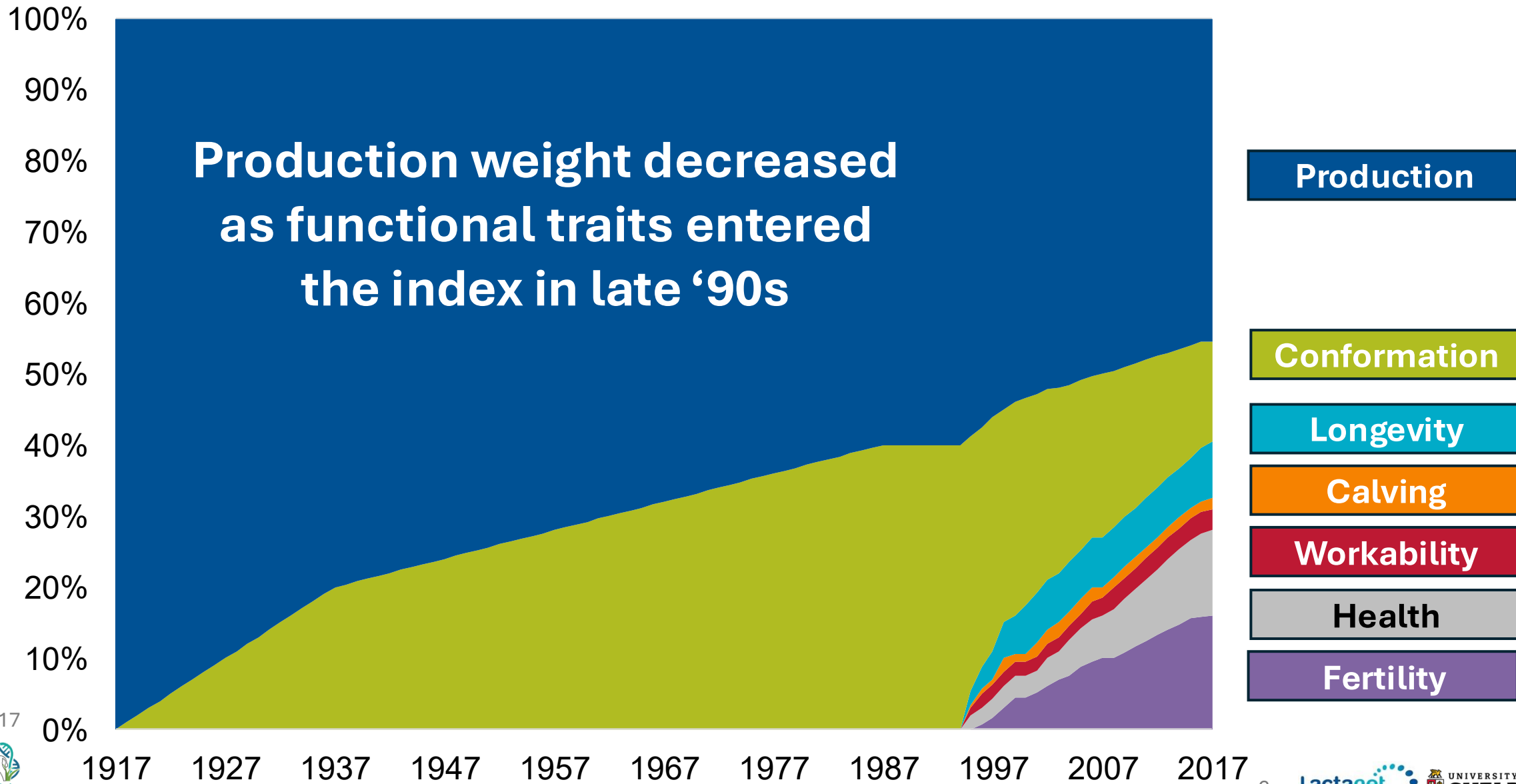
305-d Milk Yield

Days Open

Clinical Mastitis

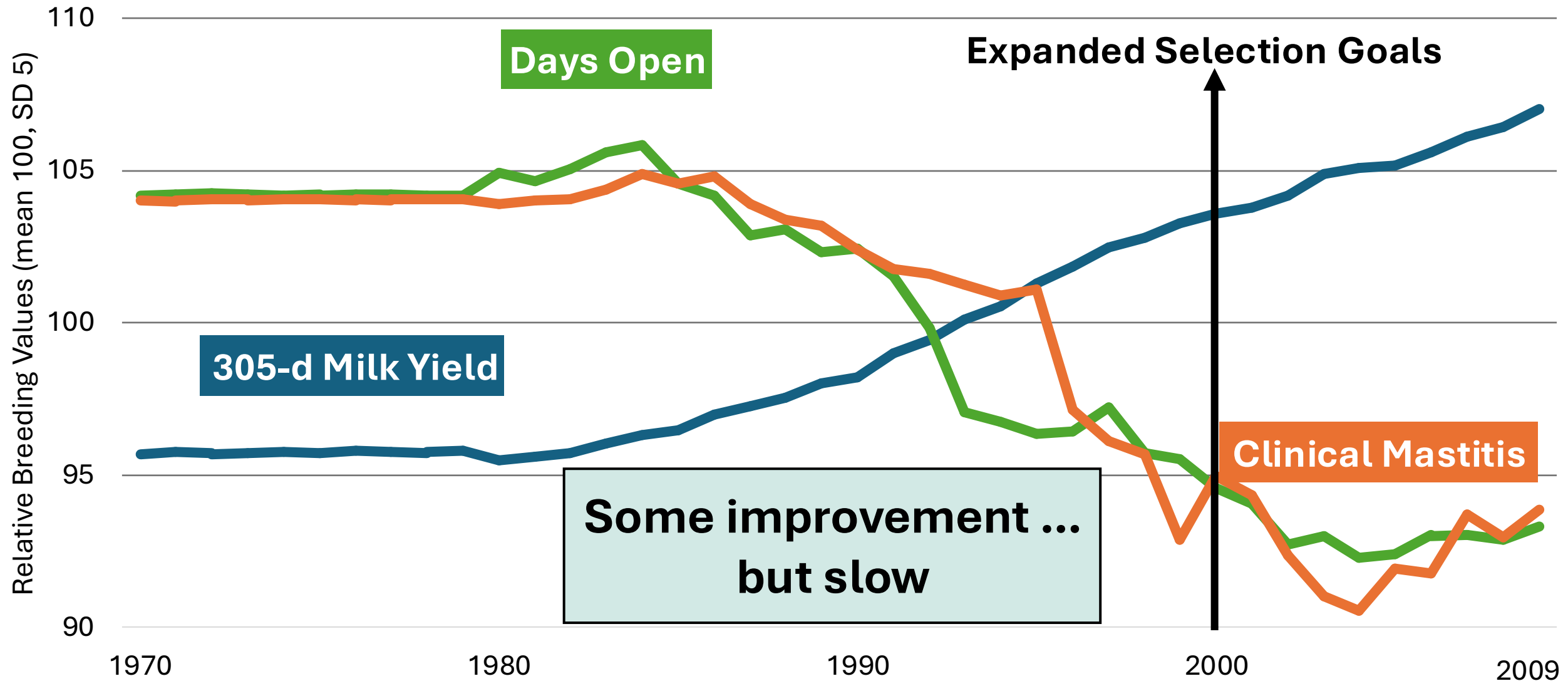
Fitness traits declined  
as yield rose

# Adjusting Breeding Goals



Miglior et al., 2017

# Slow Progress



Days Open

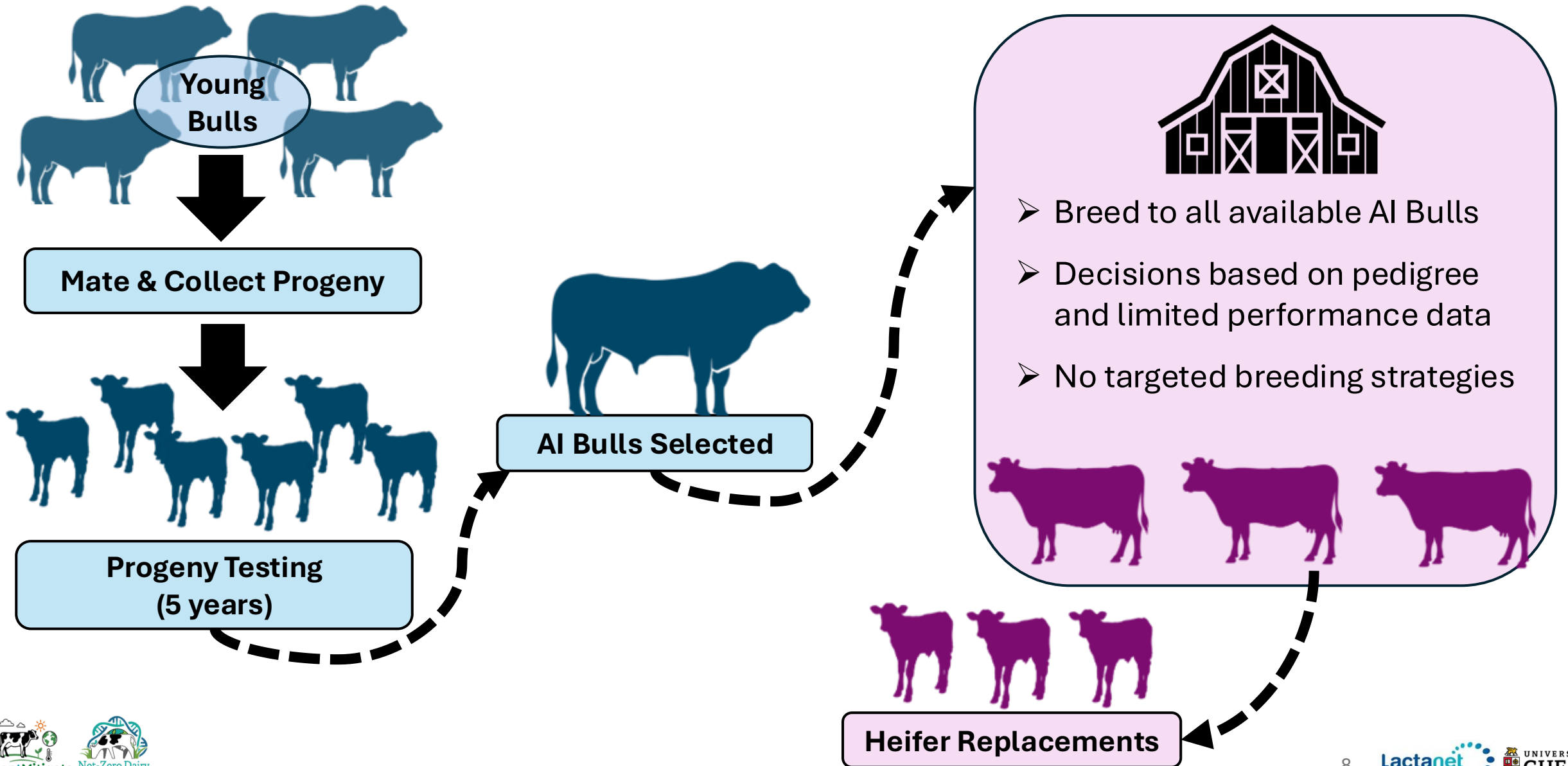
Expanded Selection Goals

305-d Milk Yield

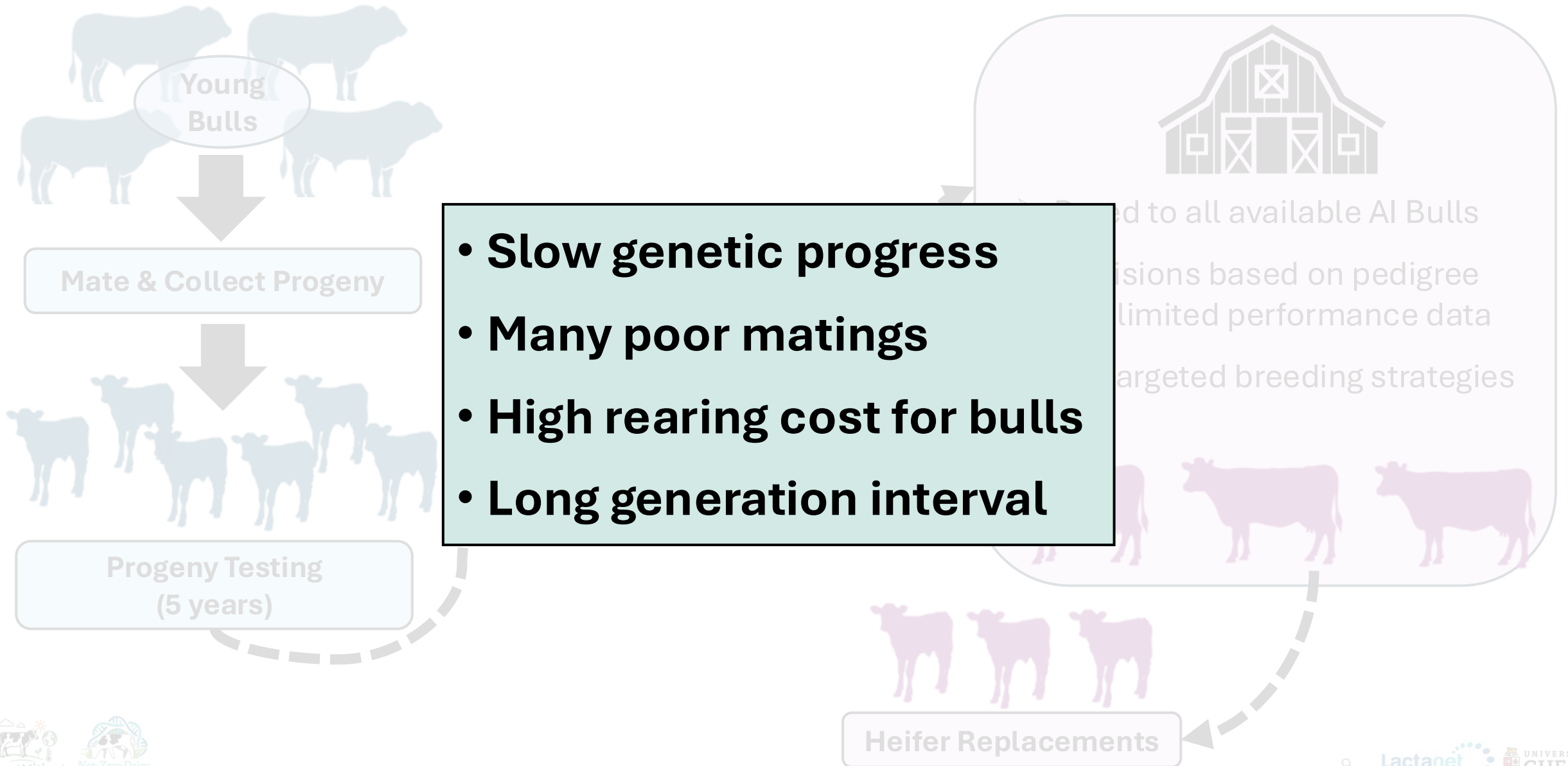
Clinical Mastitis

Some improvement ...  
but slow

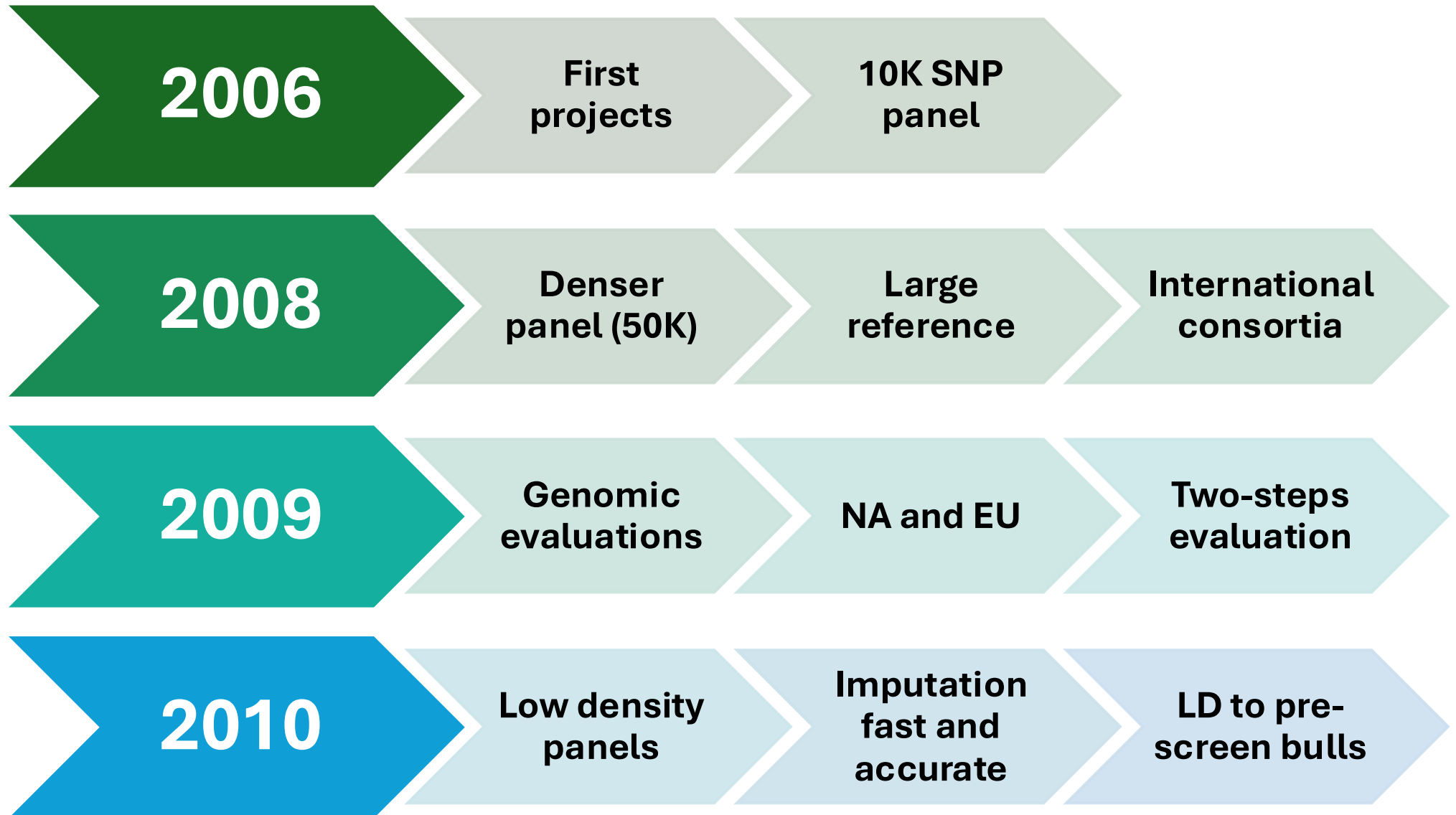
# Traditional Selection



# Traditional Selection

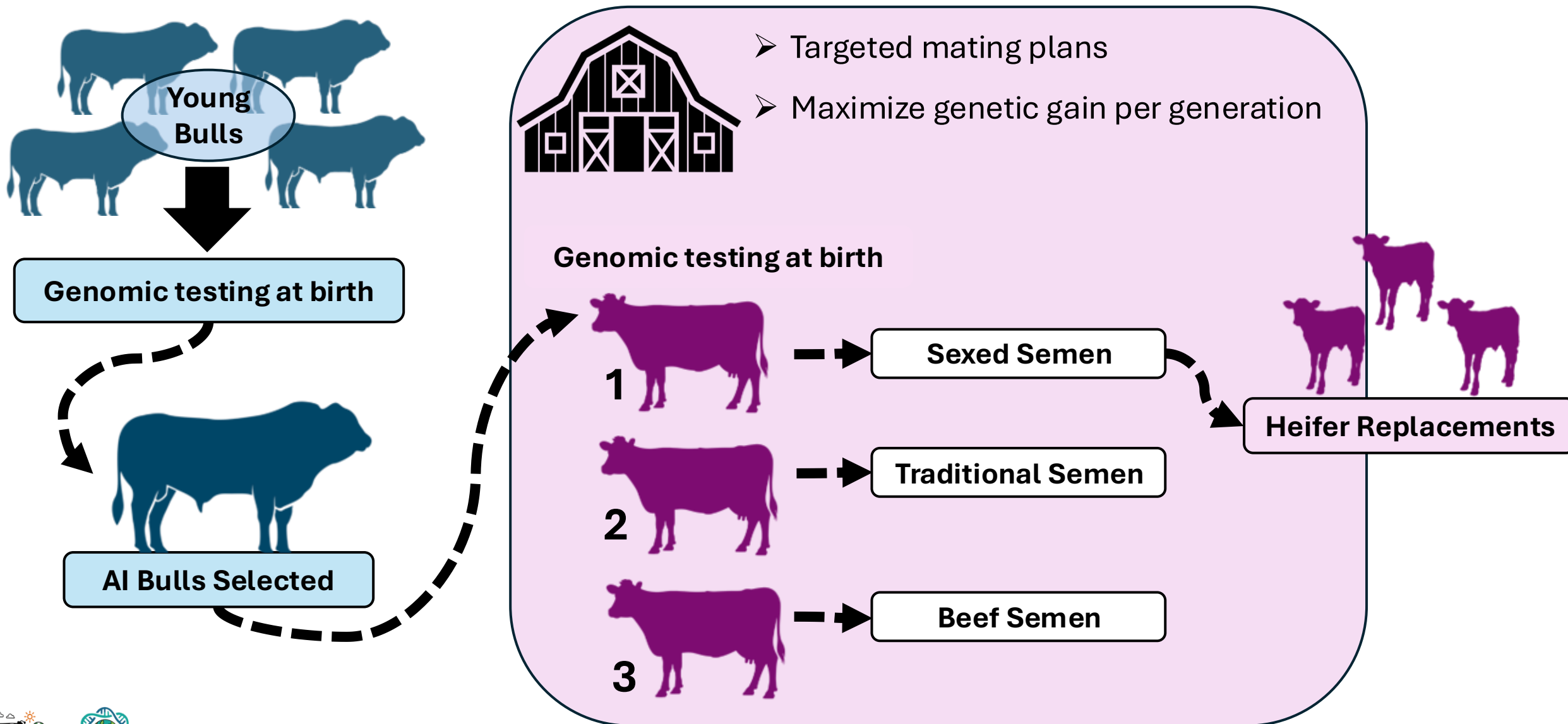


# The Genomic Rush

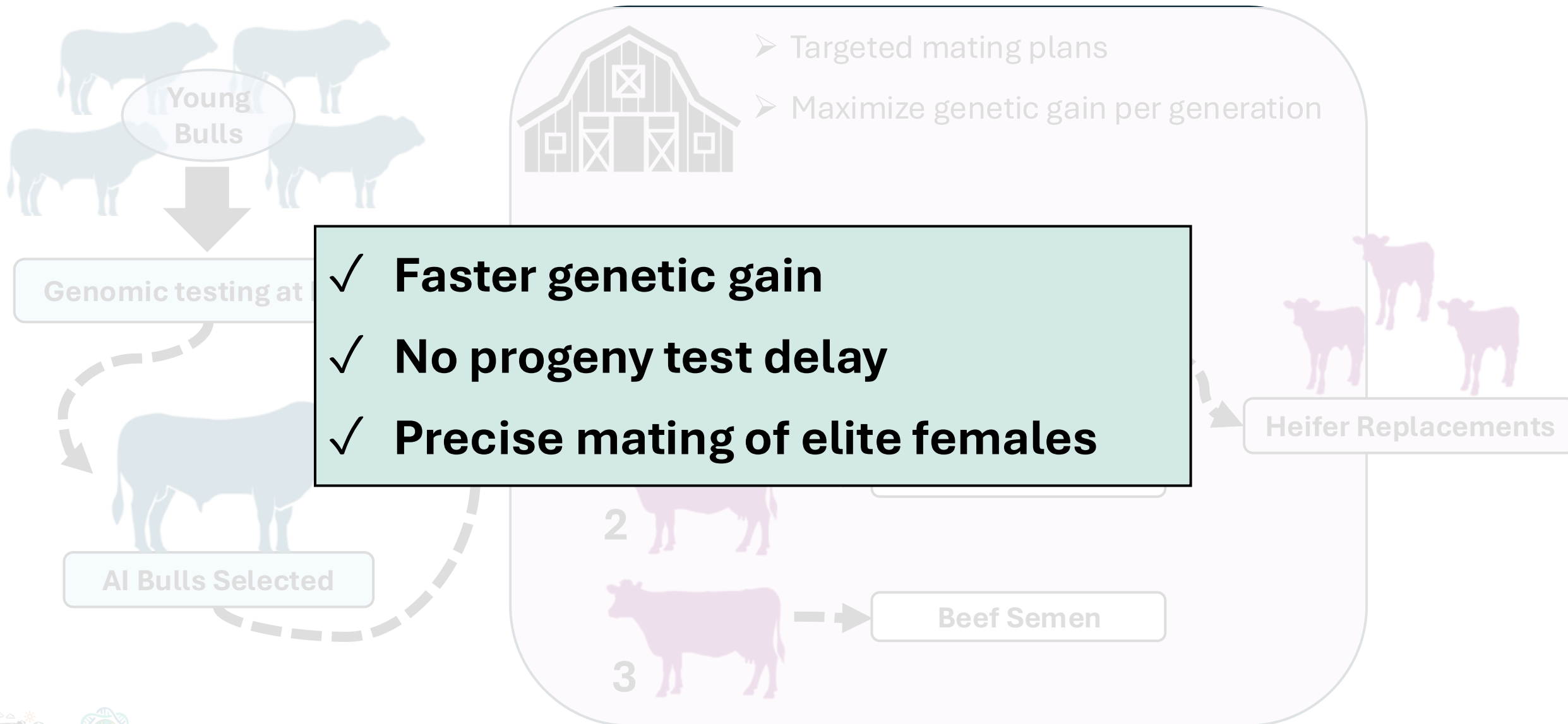


Gianola et al., 2009; Misztal et al., 2009

# Genomic Selection



# Genomic Selection



# Benefits of Genomic Selection

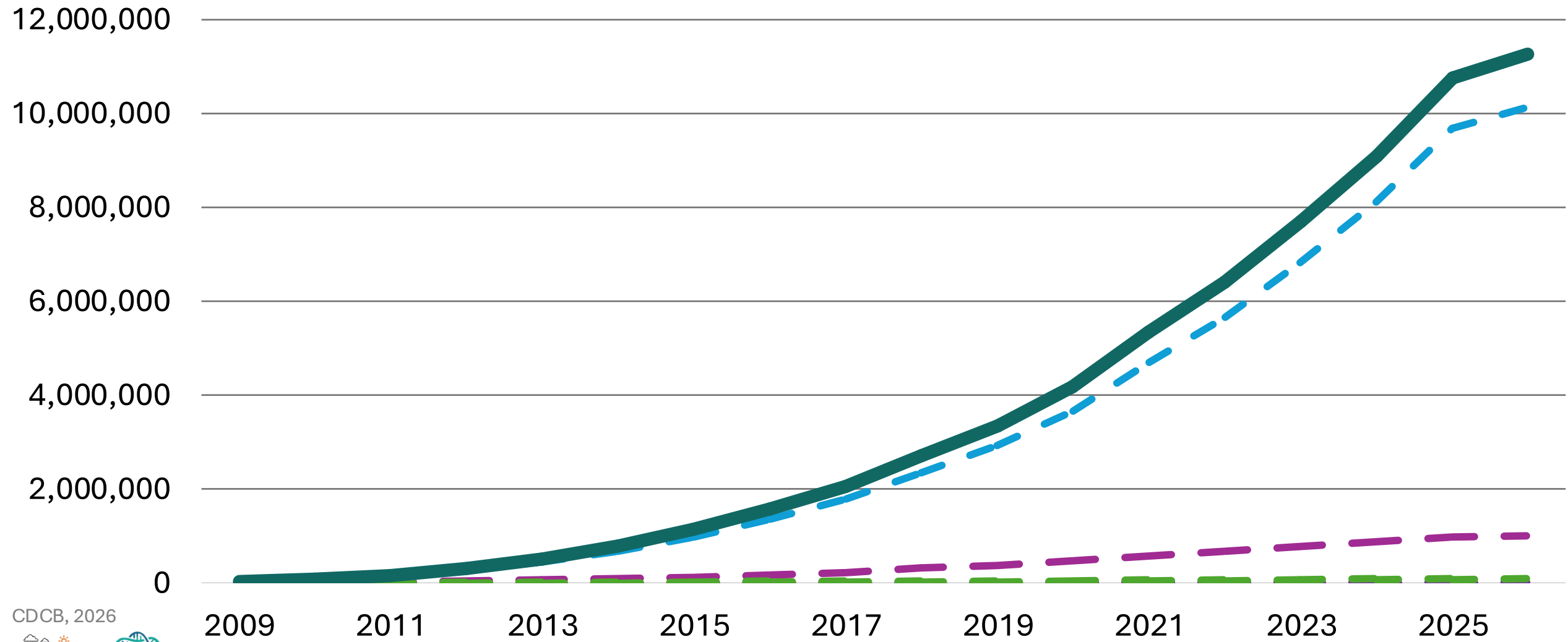
$$\text{Genetic change over time} = \frac{\uparrow \text{Accuracy} \times \uparrow \text{Selection intensity} \times \sqrt{\text{Genetic variation}}}{\downarrow \text{Generation interval}}$$

With genomic selection:

- **Genetic variation** is not altered
- **Selection intensity** is significantly increased
- **Accuracy of selection** is significantly improved
- **Generation interval** is significantly reduced

# Number of Genotypes

— Holstein — Jersey — Ayrshire — Guernsey — BrownSwiss — Total

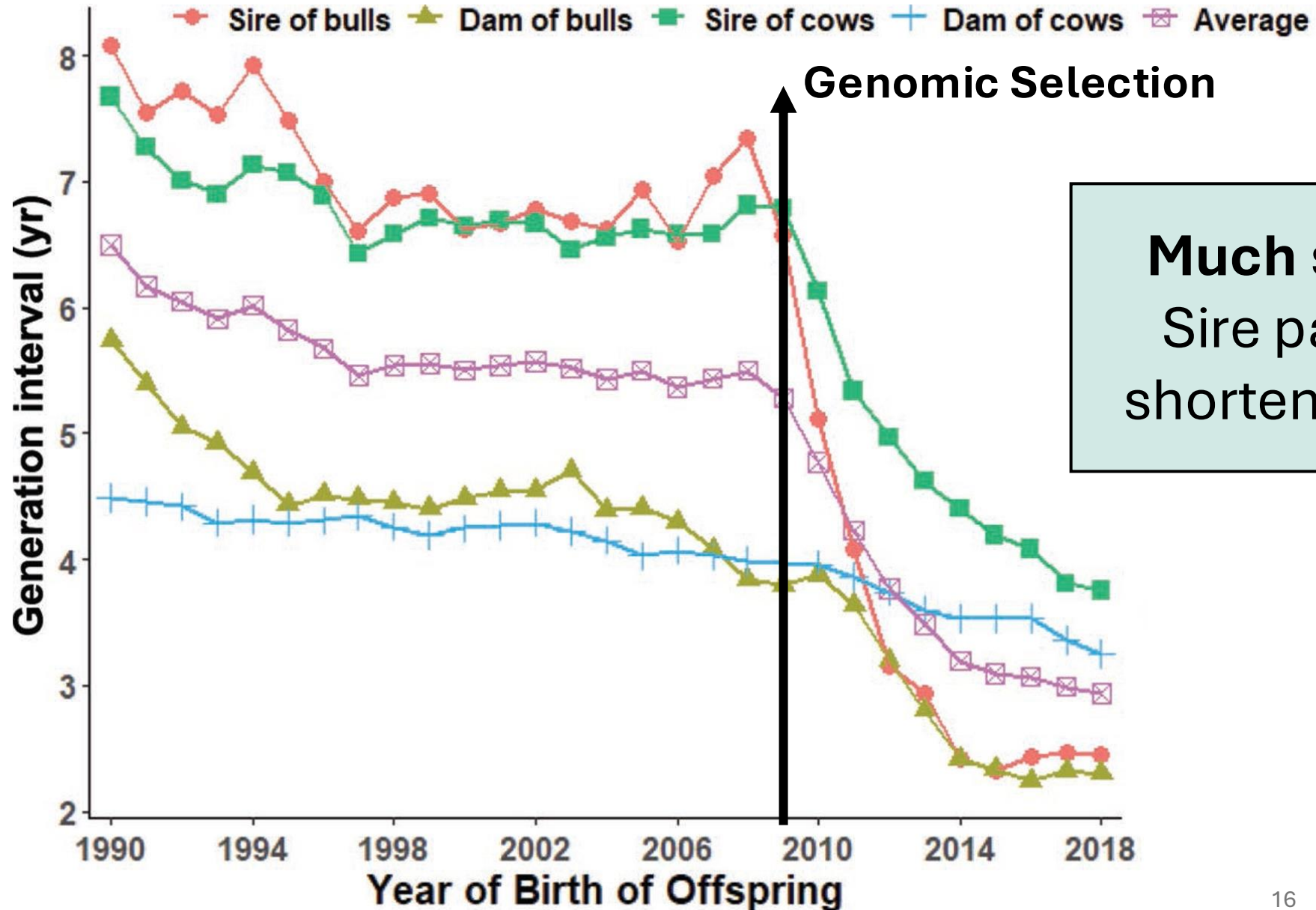




# Evidence of Gains *(1/4)*

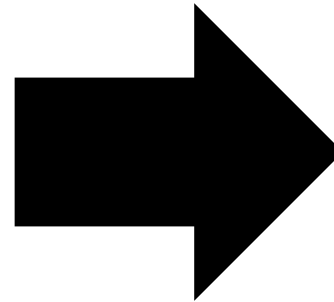
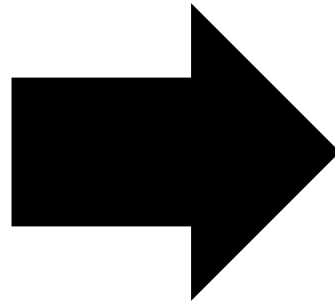
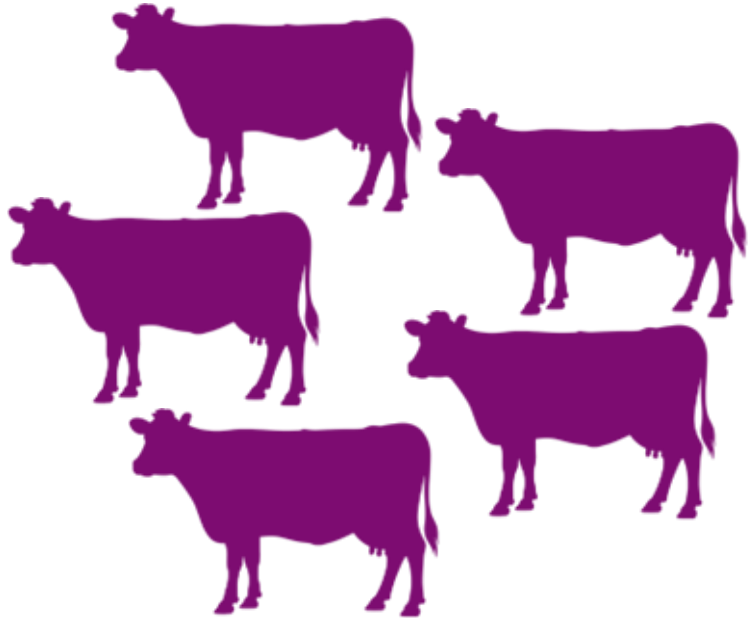
**Generation Interval  
Targeted Breeding**

# Generation Interval



Makanjoula et al., 2019

# Targeted Breeding



**Best!**

1



2



3



4



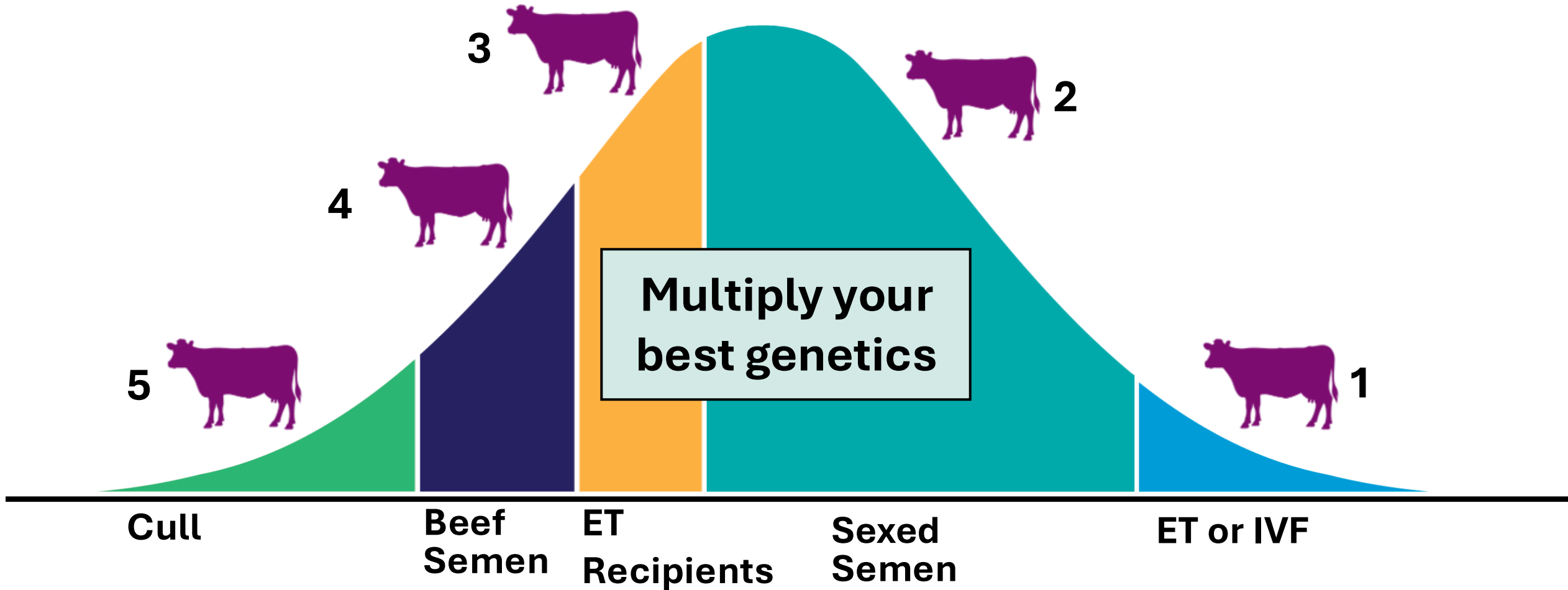
5



**Worst!**

**Early life ranking to  
target use of breeding  
technologies**

# Targeted Breeding



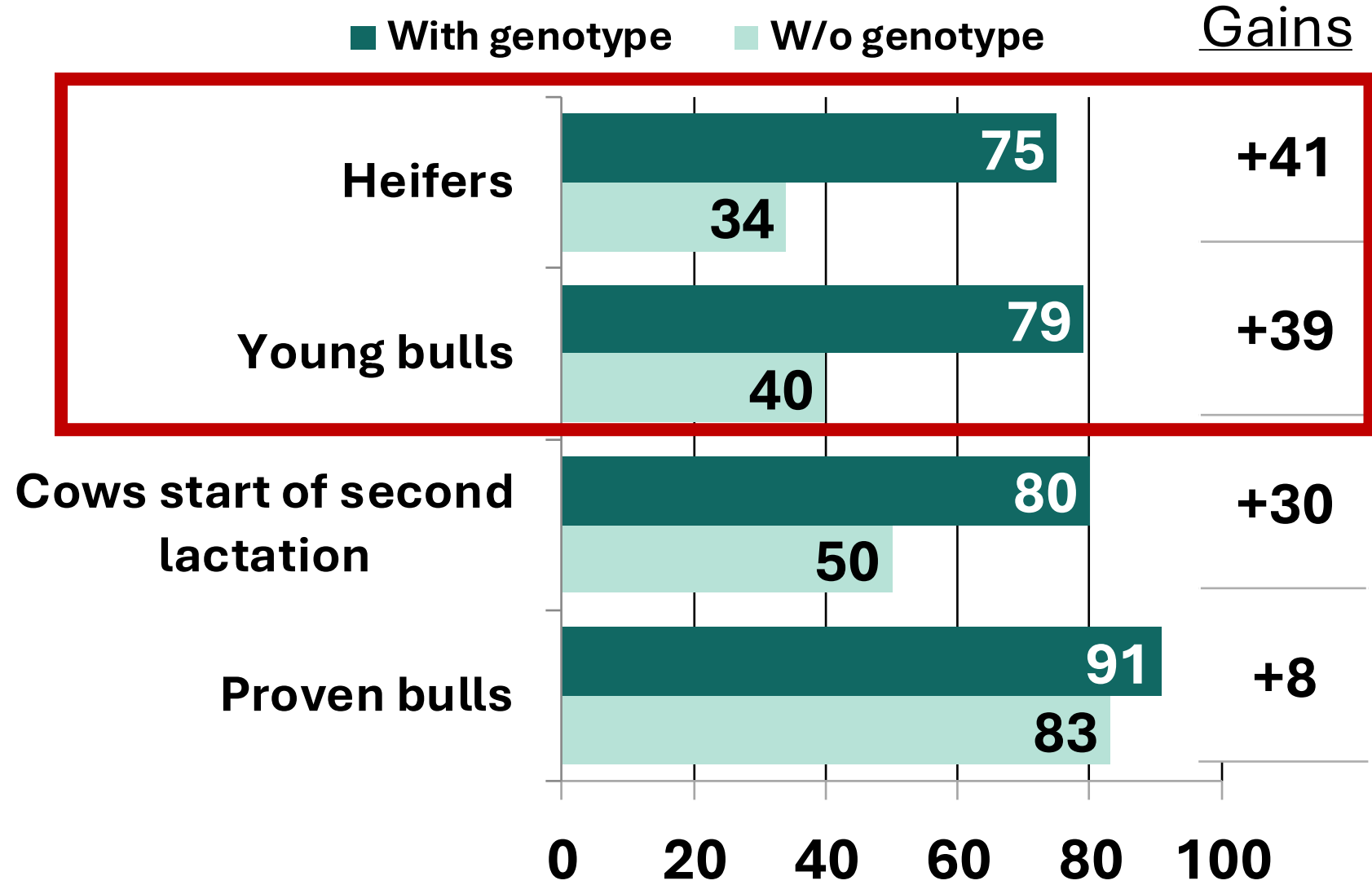


# **Evidence of Gains *(2/4)***

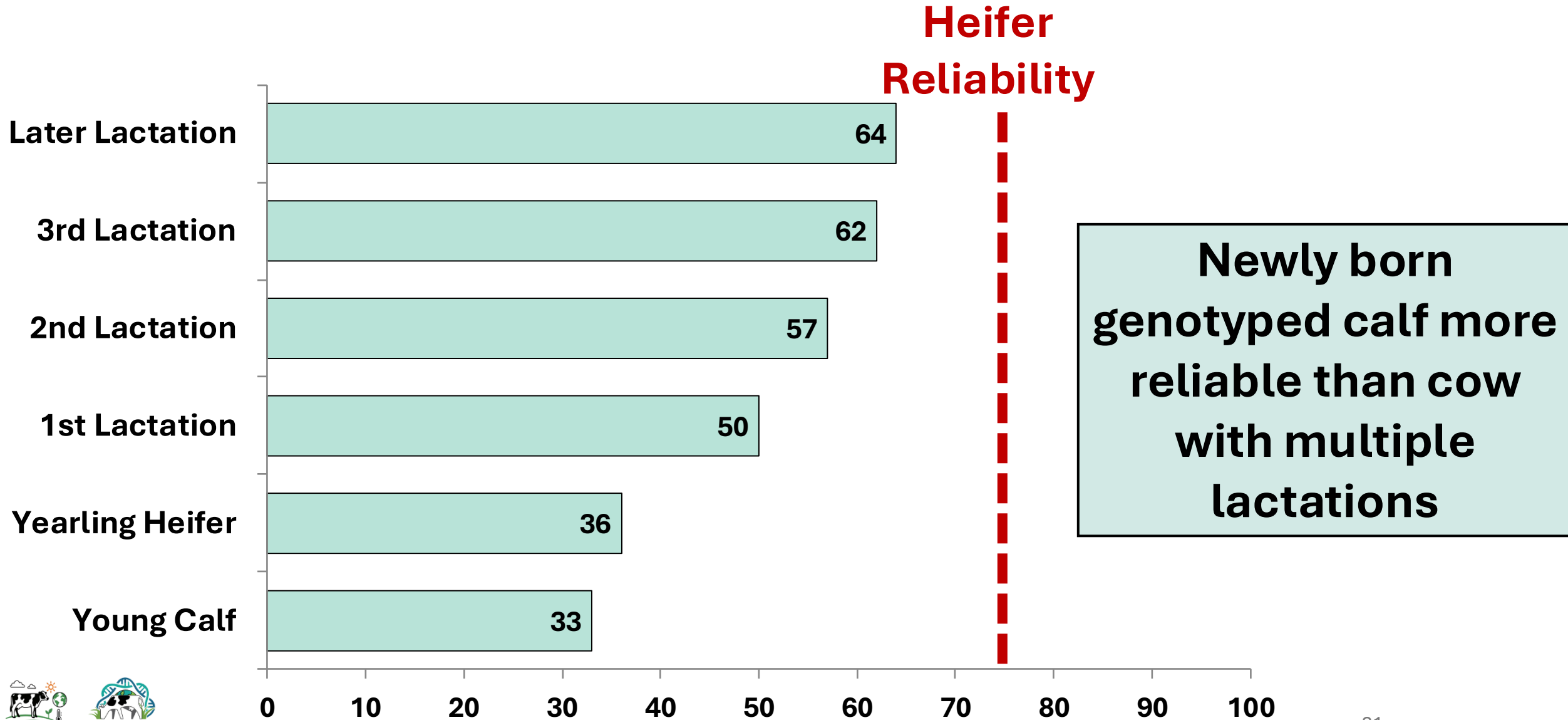
**Reliability**

# Gains in Reliability (LPI)

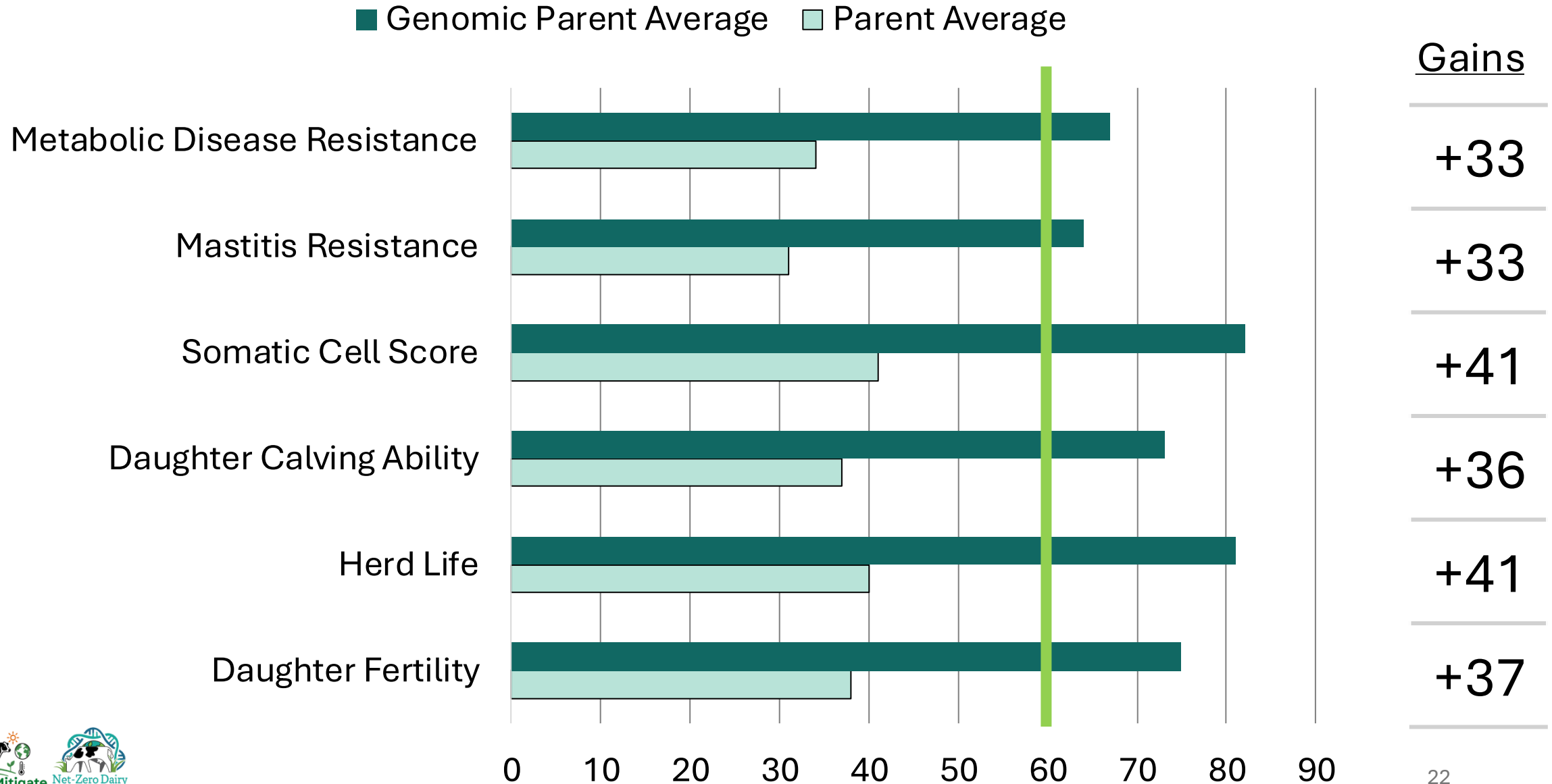
**Major gains in reliability for young animals**



# High Reliability Early in Life



# Reliability Gains also for Low Heritability Traits

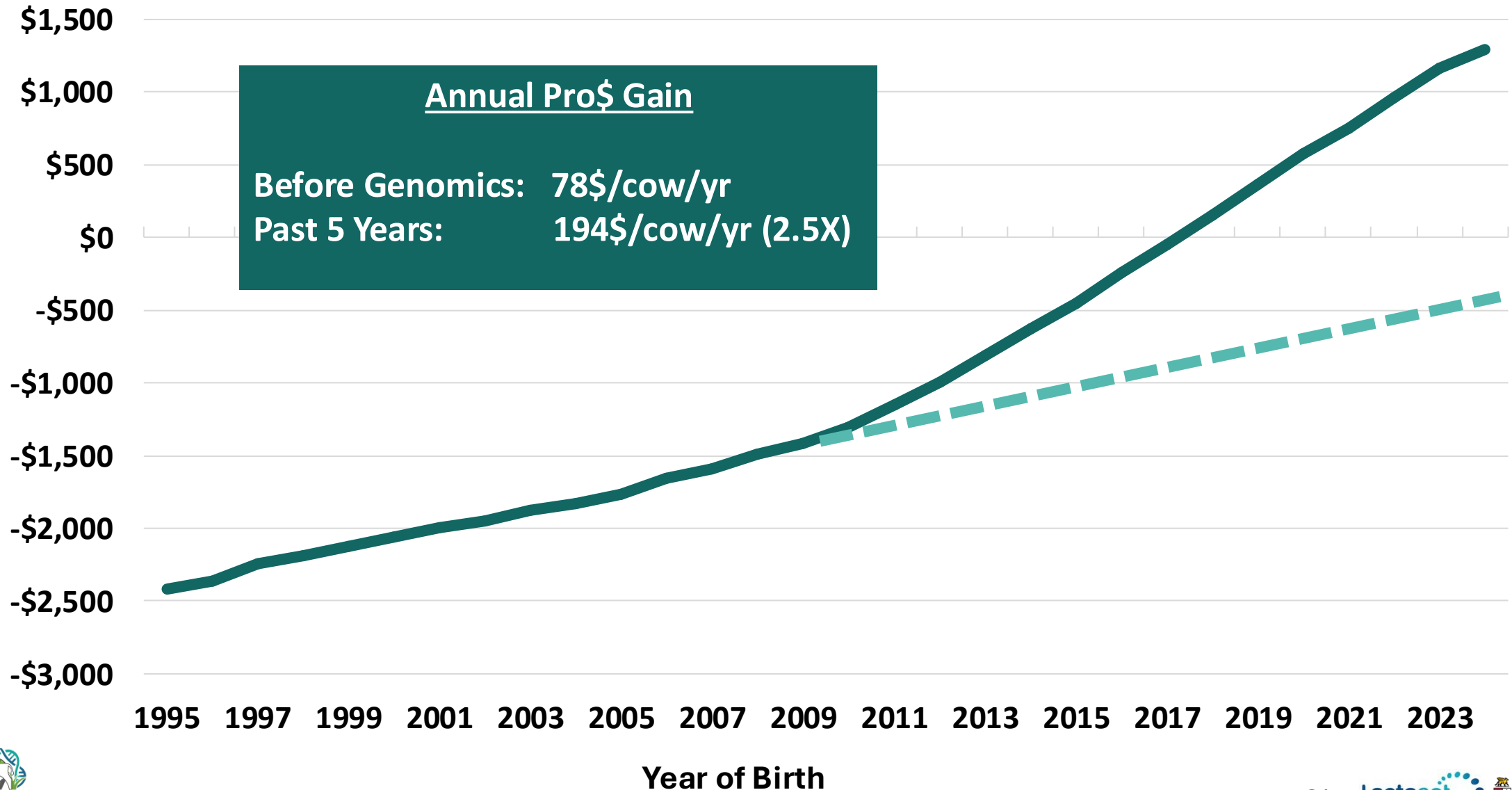




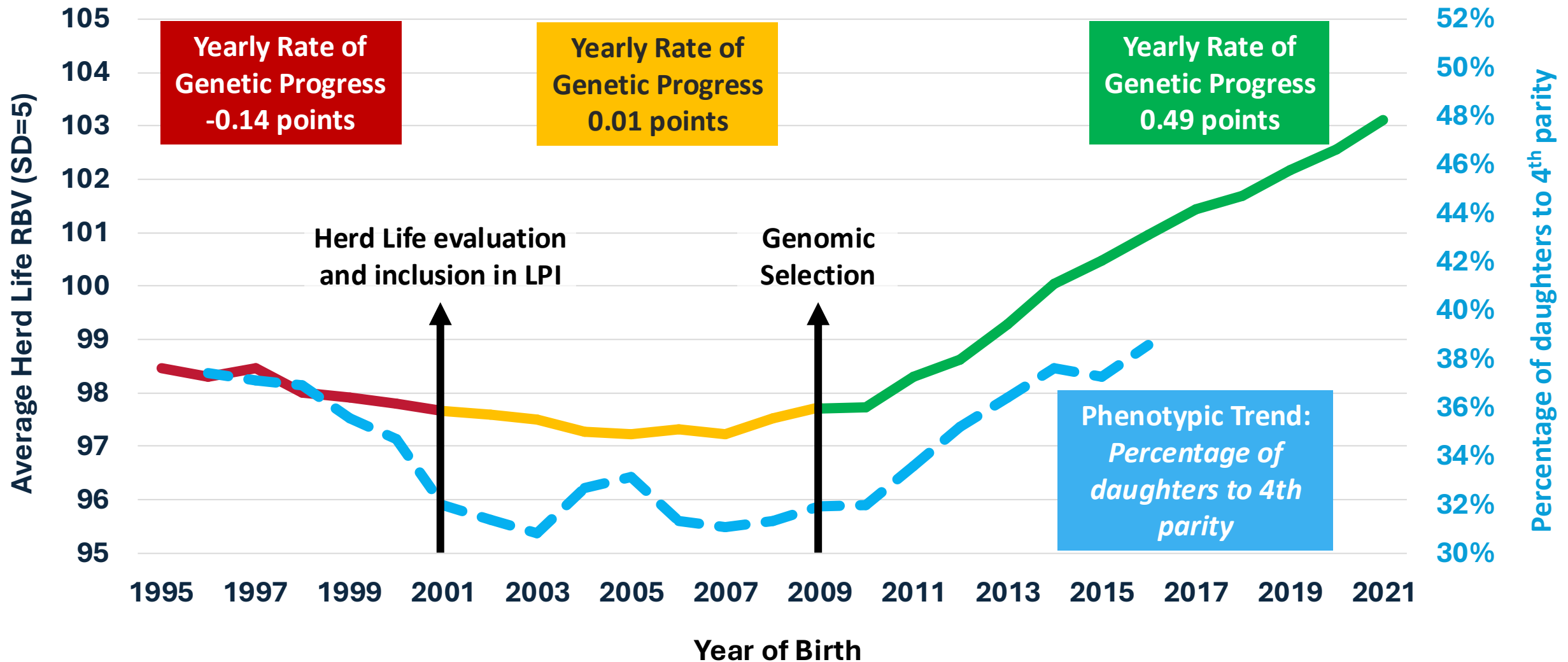
# **Evidence of Gains *(3/4)***

**Genetic Progress**

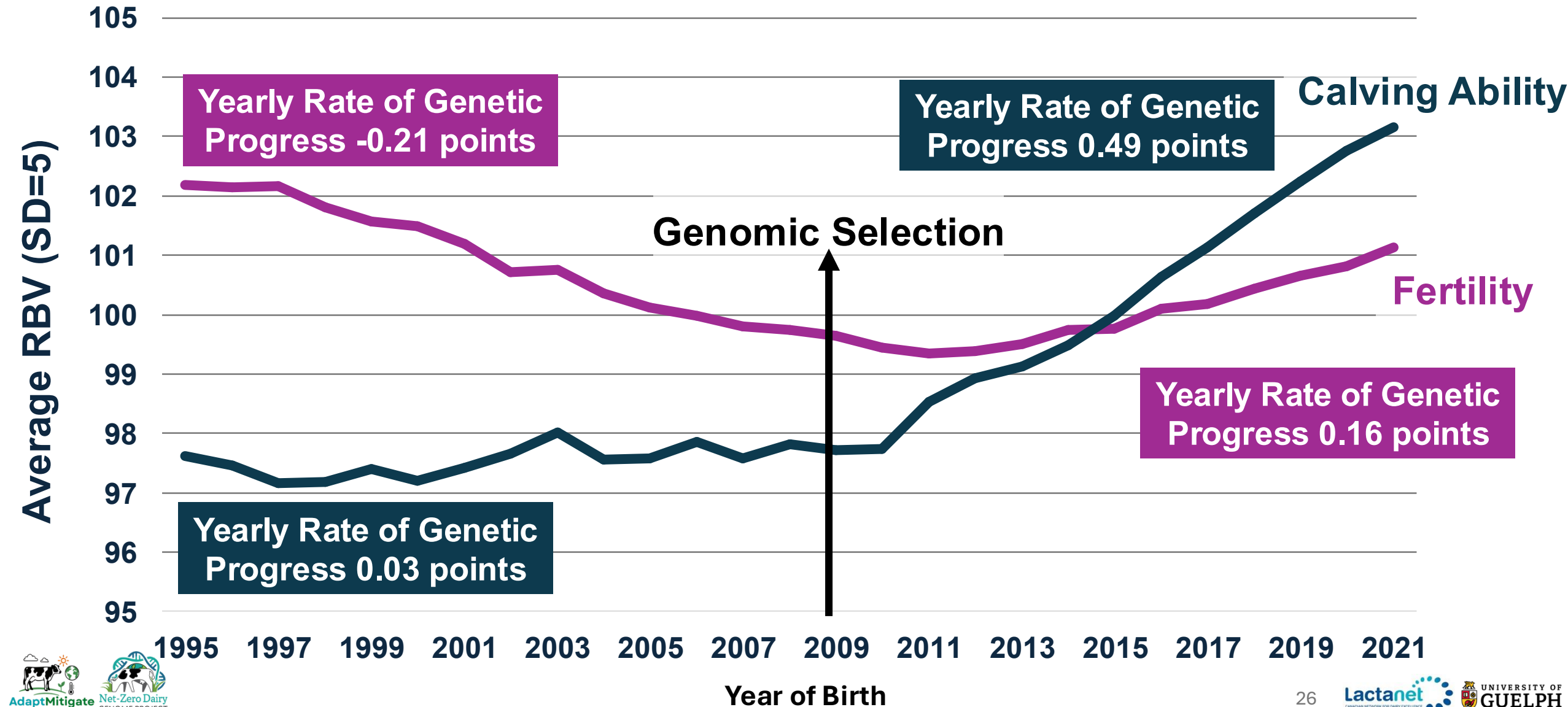
# 2.5 Times Faster Genetic Gain



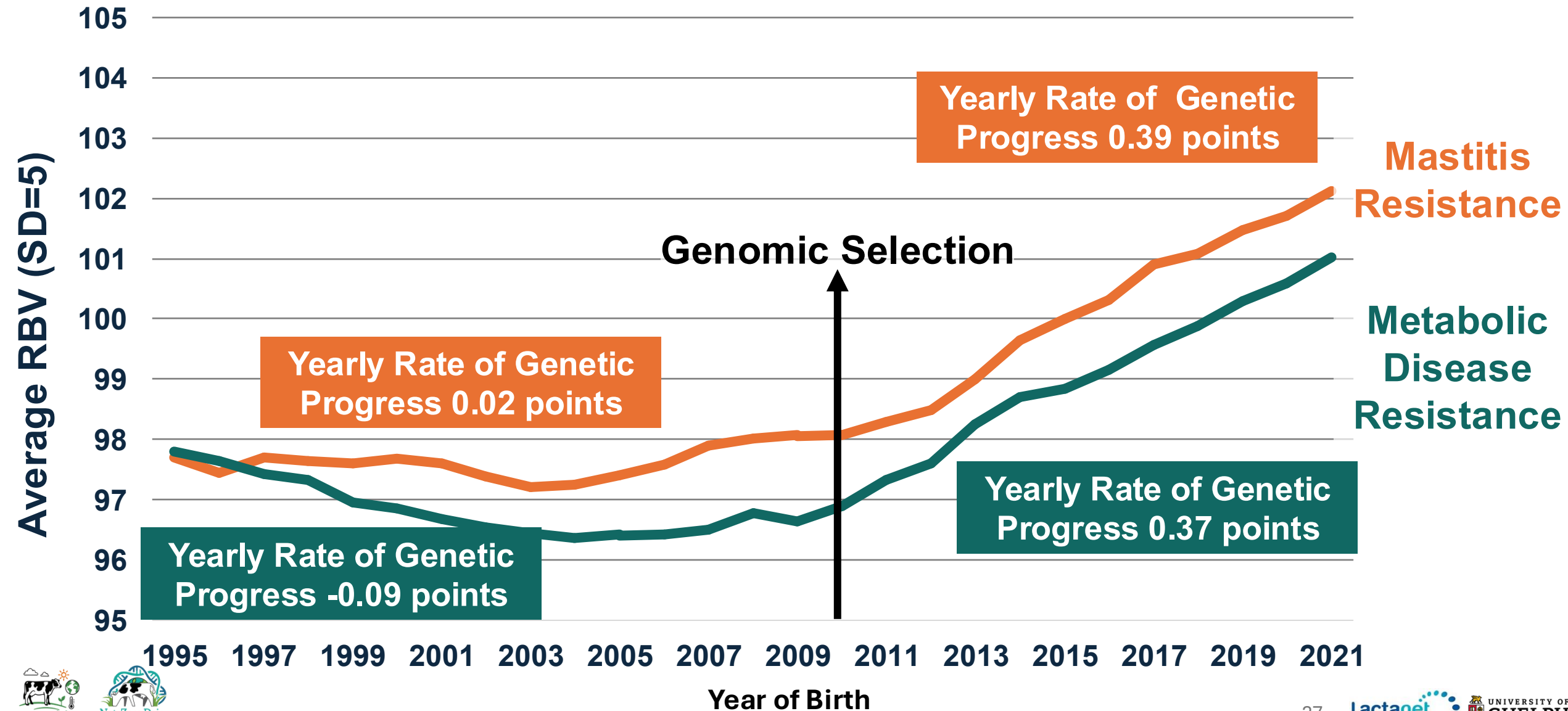
# Herd Life Trends in Holsteins



# Turning the Corner for Fertility



# Accelerating Gains also for Health





# Evidence of Gains *(4/4)*

**Novel Traits**

# Novel Opportunities

- Health Traits
  - Hoof Health\*
  - Calf Health\*
  - Fertility Disorders\*
  - Mastitis Resistance
  - Metabolic Disease Resistance
- Environmental Traits
  - Methane Efficiency\*
  - Body Maintenance Requirements\*
  - Feed Efficiency\*

**Genomics makes selection possible when phenotypes are expensive or low frequency**

*\*Single-Step Evaluation*

# Research



# Development



# Service



**Mastitis Resistance**  
Clinical Mastitis, SCS

2014

**Hoof Health Resistance\***  
8 most prevalent hoof lesions

2018

**Feed Efficiency\***

2021

**Calf Health\***  
Diarrhea & Respiratory Disease

2025

2016

**Metabolic Disease Resistance**  
Displaced abomasum, clinical & sub-clinical ketosis

2020

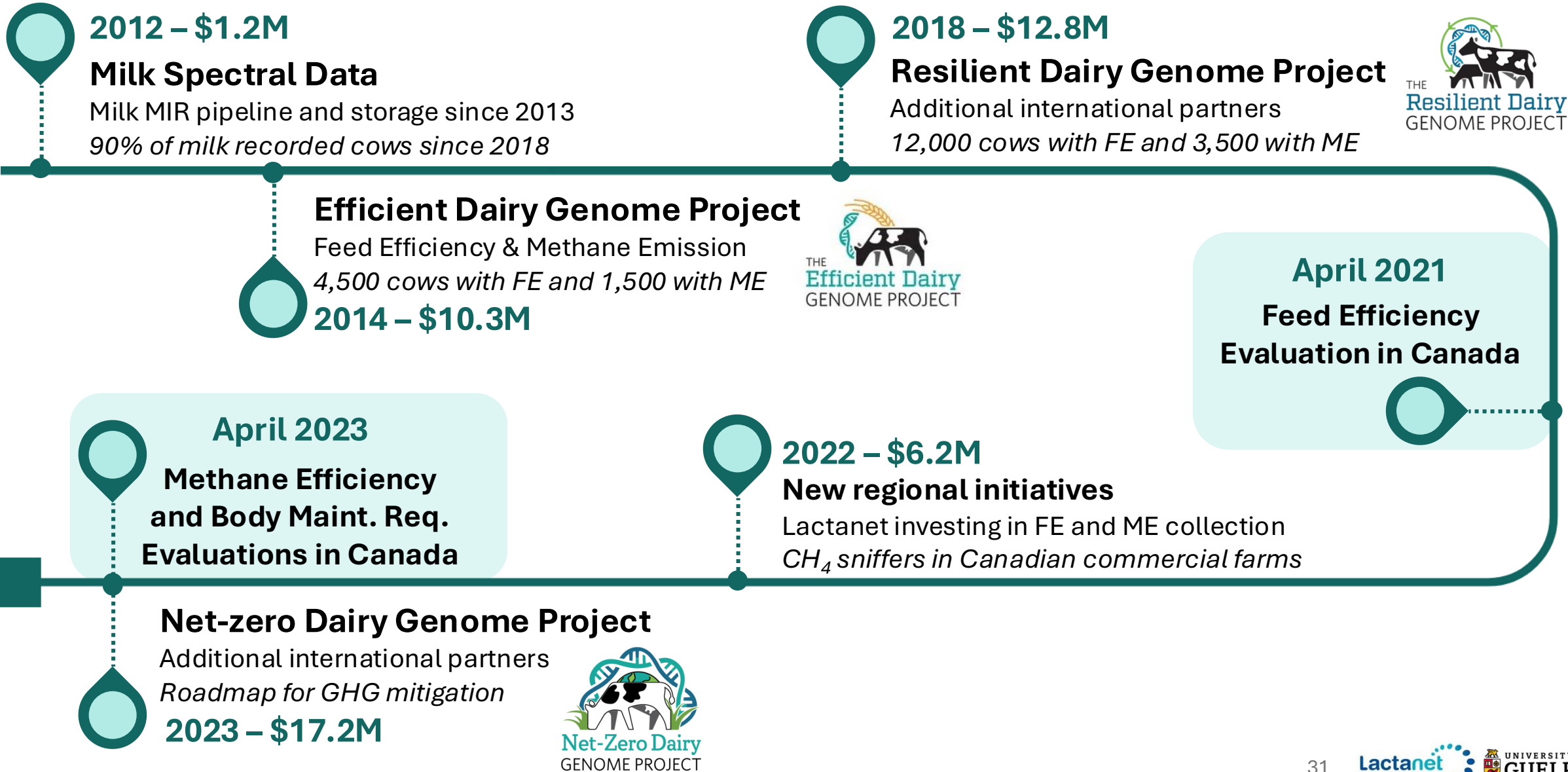
**Fertility Disorders\***  
Metritis, Retained Placenta, Cystic Ovaries

2023

**Methane Efficiency\* & Body Maintenance Requirements\***

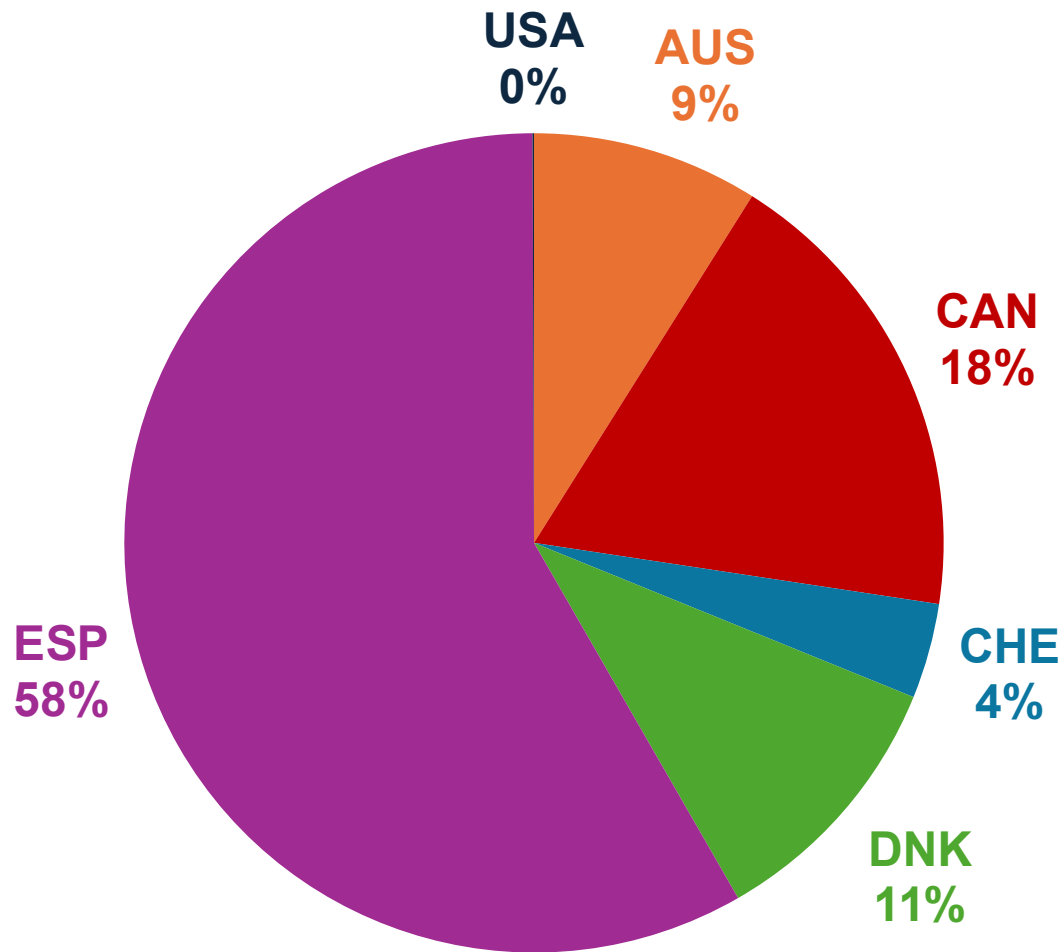
\*Single-Step Evaluations

# Building a Reference Population

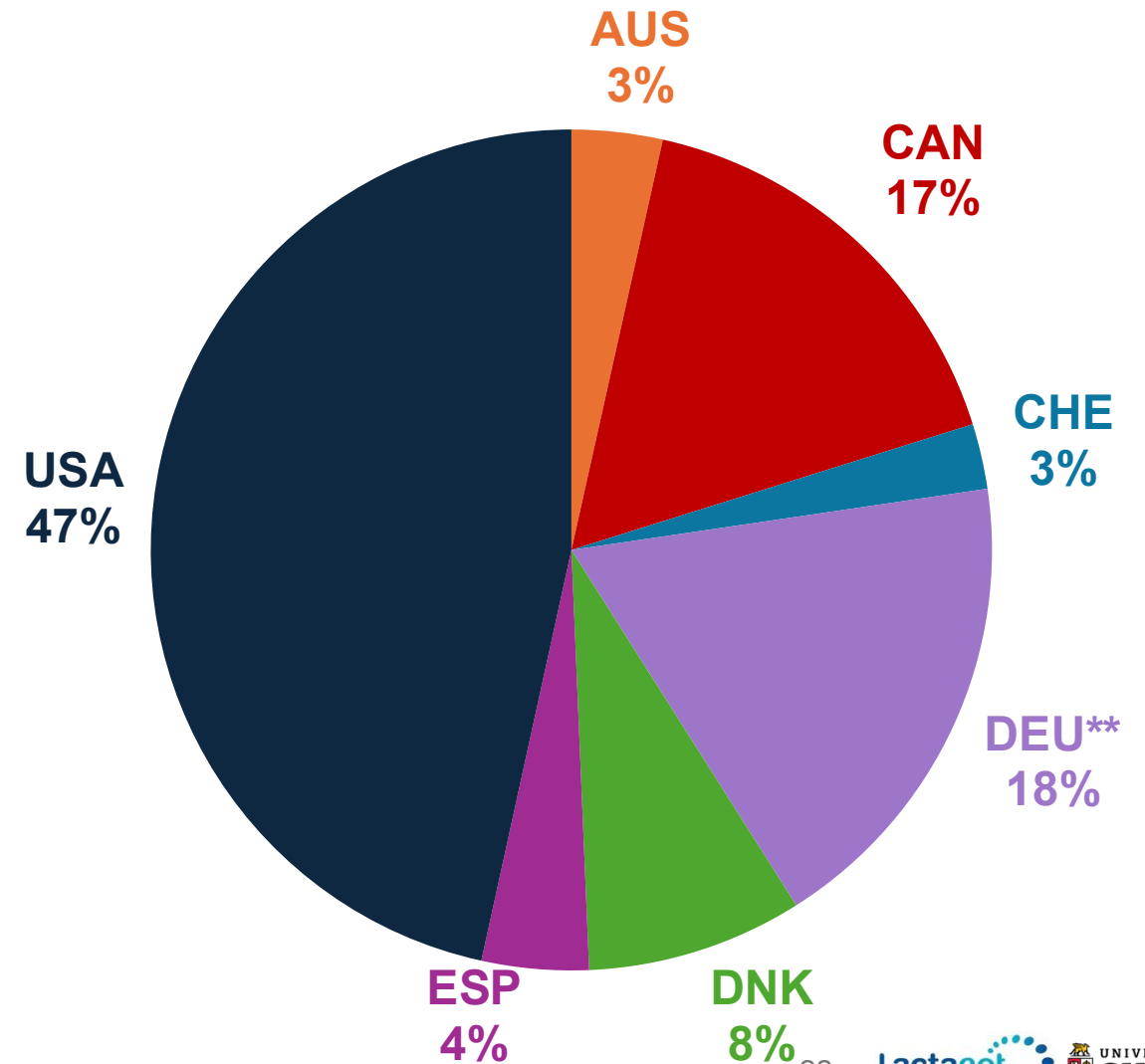


# Combined Reference Population (Oct 2025)

## Methane Emissions (N = 5,554)



## Feed Efficiency (N = 19,847)



# Methane Evaluations Worldwide

## Canada – Methane Efficiency (Apr 2023)

Lactanet & University of Guelph

- Single-step genomic evaluation
  - Methane predicted from mid-infrared (MIR) data
  - Independent of milk production traits
- Reliability:
  - 77% (young genotyped bulls, no daughters)
  - 56% (non-genotyped cows)
  - 87% (genotyped cows)
- Joint evaluation with Switzerland (Lactanet/Qualitas)

## Spain – Methane Concentration (Jun 2023)

CONAFE & INIA-CSIC

- Genomic evaluation
  - Direct methane measurement (ppm)
  - Data collected using sniffers

## Netherlands & Flanders – Methane Saved (Apr 2025)

CRV

- Genomic evaluation based on:
  - 10,000 cows using sniffers (ppm)
  - 900 cows using GreenFeed systems (g/day)
  - Expressed in g/day
- Reliability:
  - 46.5% (daughter-proven bulls)
  - 32.2% (genomic bulls)

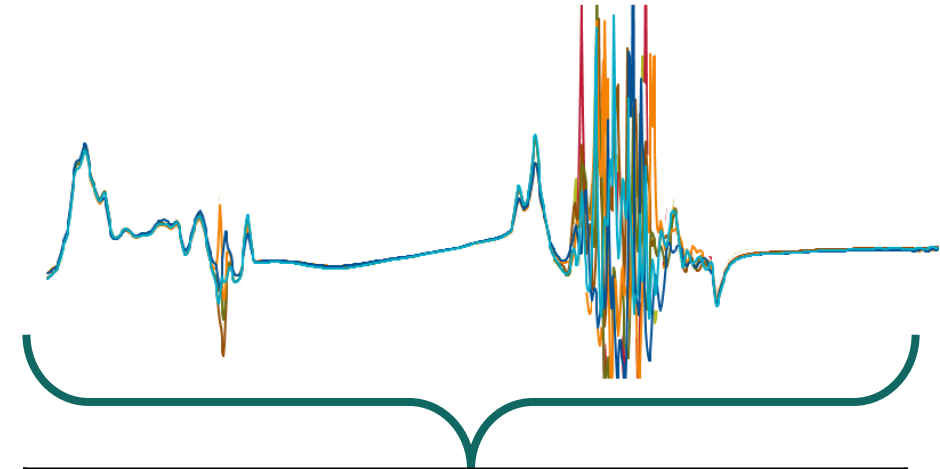
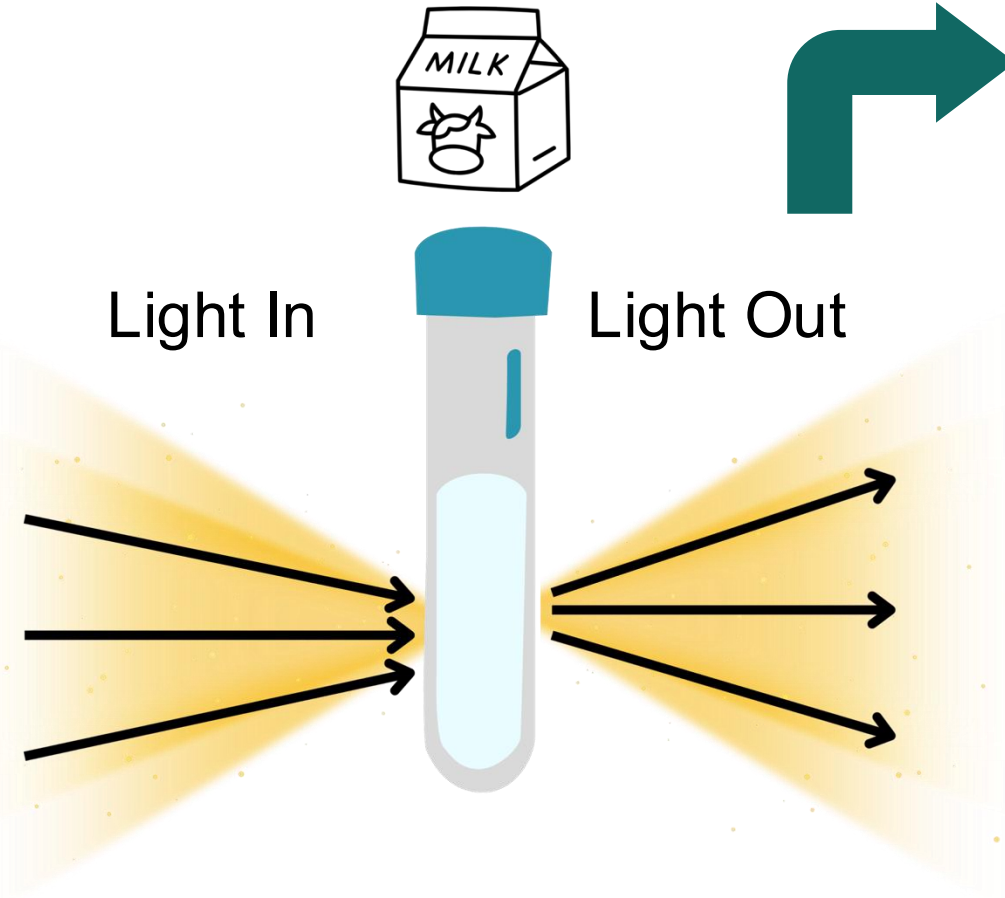
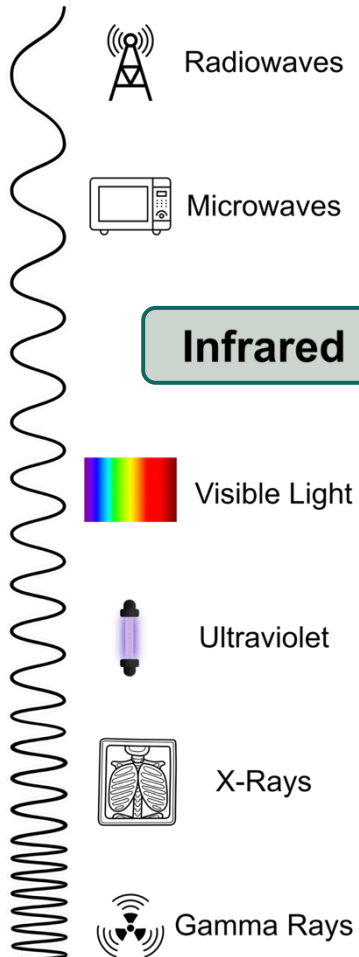
## Nordic Countries – Methane Index (May 2025)

Viking Genetics, SEGES Innovation, Aarhus University, and Nordic Cattle Genetic Evaluation

- Genomic evaluation
  - Methane concentration (ppm)
  - Measured using sniffers

# Milk Mid-Infrared (MIR)

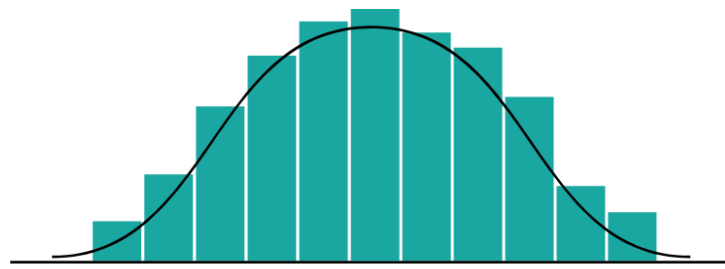
## Electromagnetic Spectrum



✓	<b>Fat</b>
✓	<b>Protein</b>
✓	<b>Lactose</b>
✓	<b>Milk Urea Nitrogen</b>
✓	<b>BHB</b>
✓	<b>Fatty Acids</b>
<b>New!</b>	<b>Methane Production</b>

# Methane Efficiency Evaluation

1. Methane production predicted from MIR spectral data
  - ↳ Machine Learning Model
  - ↳ Four-trait single step genomic evaluation ( $\text{CH}_4$ , Milk, Fat, Protein kgs)
2. Methane Efficiency (**ME**) = Select for higher efficiency to reduce  $\text{CH}_4$  emissions without affecting production



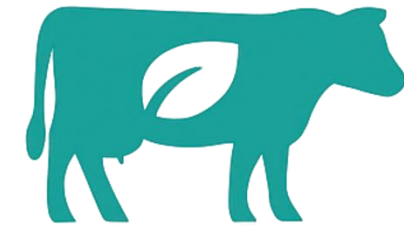
**+1 SD Sire RBV  
for ME**

Daughters produce ~3kg  
less  $\text{CH}_4$  per year



**-1.5%  $\text{CH}_4$ /cow/year**

Annual reduction through  
genetic gain



**20-30% herd  
 $\text{CH}_4$  cut by 2050**

Long-term herd impact  
with selection



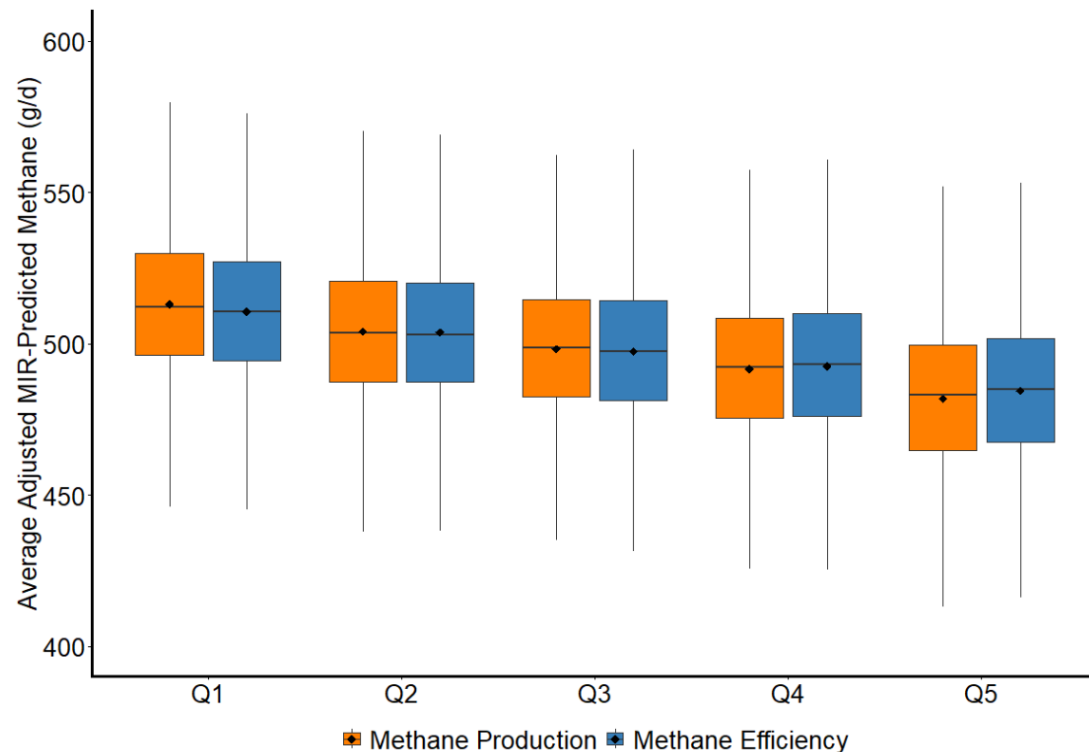
# Validation of Methane Efficiency

# Objectives of Validation Studies

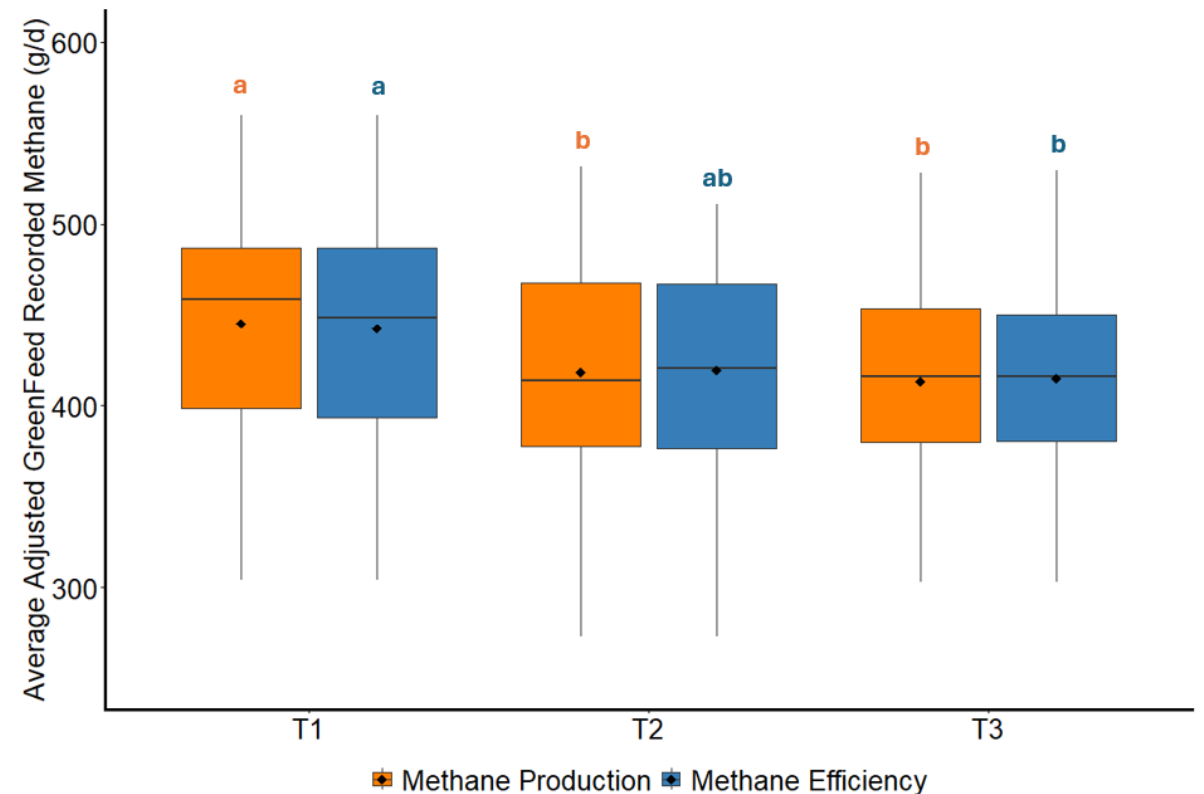
- Validate whether genomic evaluations for Methane Efficiency accurately identify low vs high emitting cows
  - In Canada and abroad
- Demonstrate that genetic selection for low-methane leads to permanent and cumulative reduction in phenotypic methane emissions (Interbull 2026)
  - Within-herd
  - Transgenerational
- Develop methods to integrate breeding values for methane into carbon calculators (ICAR 2026)
  - Farmers need recognition and rewards for breeding low-methane animals, which requires inclusion in carbon accounting systems
  - Target audience is inventory and carbon calculator methodologists that usually do not have a background in genetics

# Within-Country Validation

## 2023 genomic results to predict 2024-25 MIR predicted methane cows



## 2023 genomic results to predict 2024-25 GreenFeed methane cows



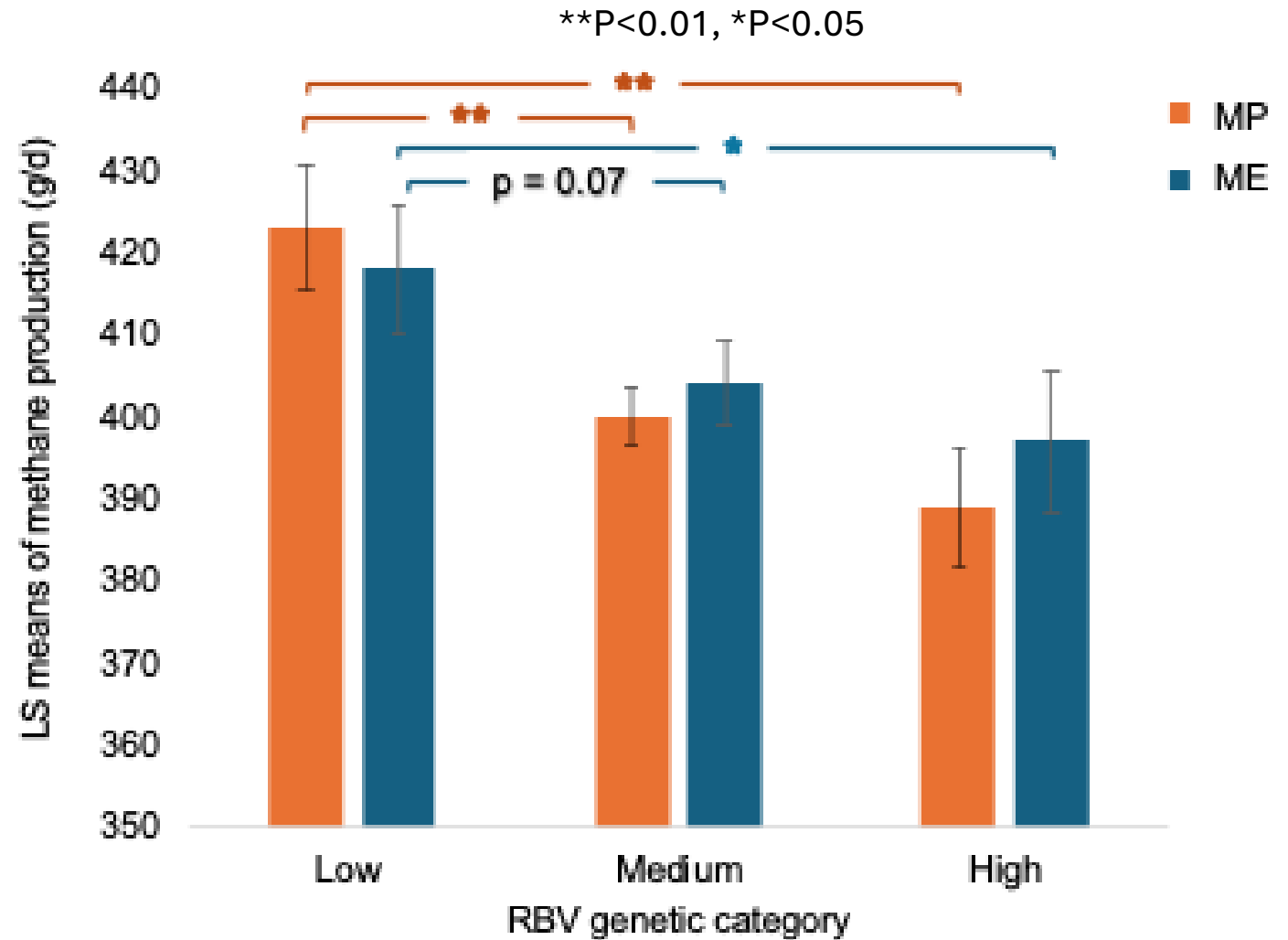
Pairwise comparisons among quintiles significant for both traits ( $P < 0.05$ )

Different letters indicate significant differences ( $P < 0.10$ )

# External Validation

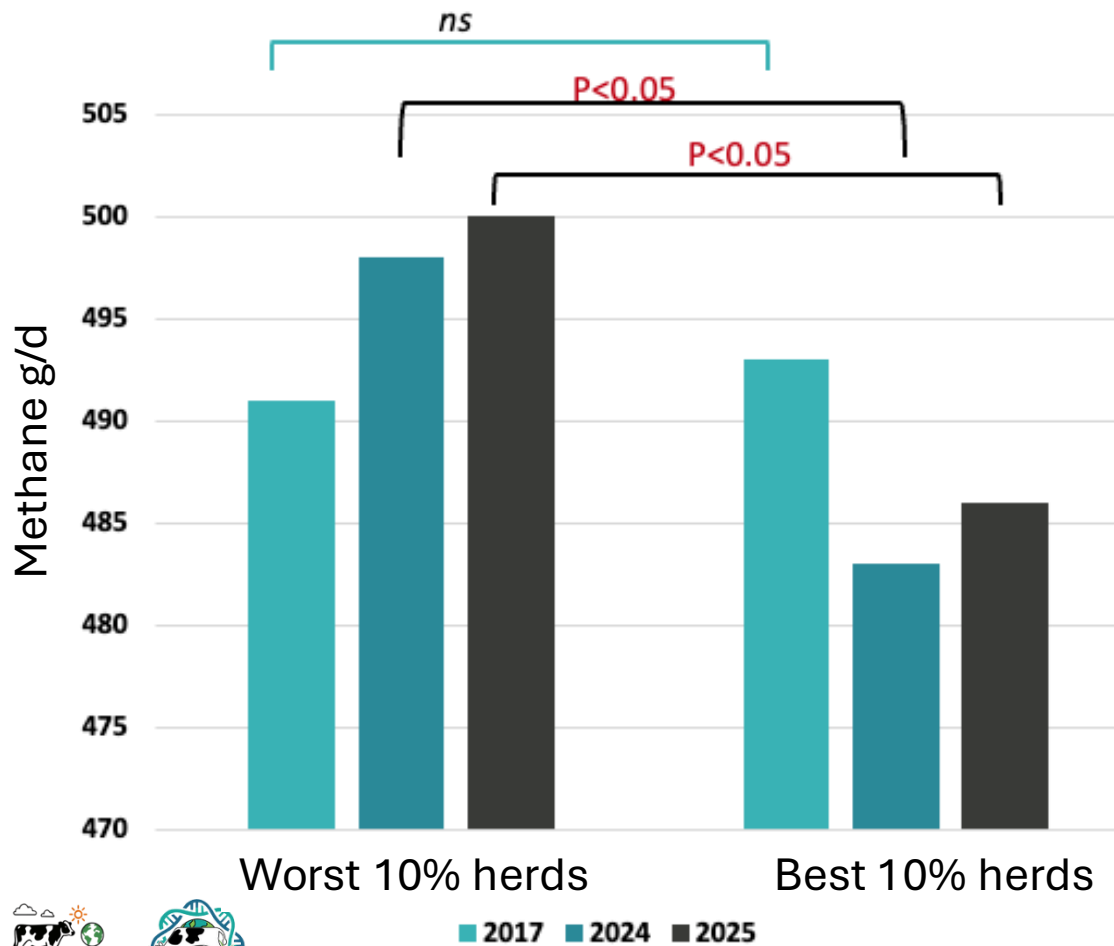
## 469 phenotyped and anonymized foreign cows

Least squares means and SE of methane production (g/d) by relative breeding value (RBV) genetic category for milk MIR predicted methane (MP) and methane efficiency (ME) traits in a pooled Holstein cattle population (Italy: n = 199; UK: n = 156; France: n = 114)

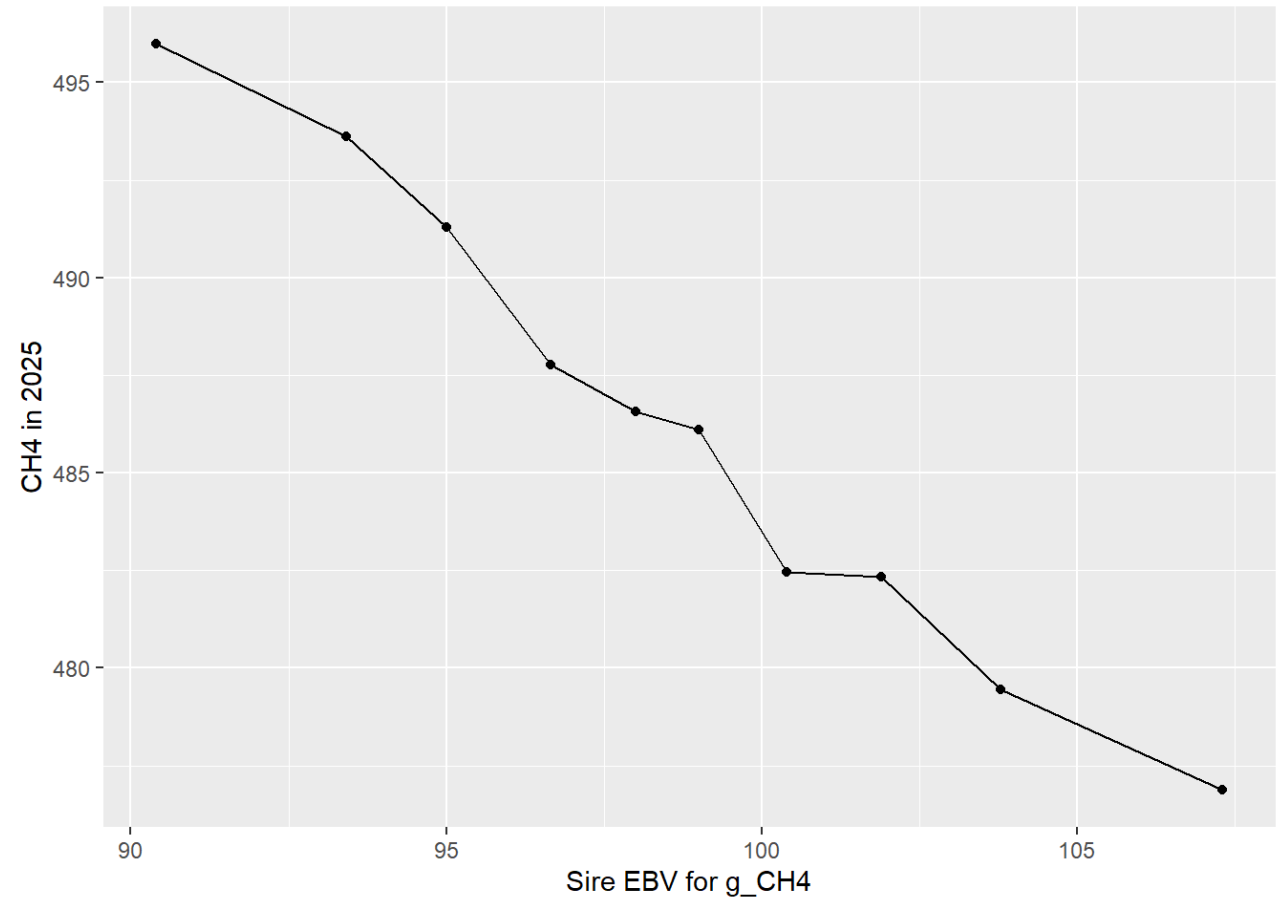


# Longitudinal Validation Within-herd & Transgenerational

393,000 primiparous cows from 1,757 herds



94,000 primiparous cows from 3,392 sires and 6,011 MGS



# Longitudinal Validation Within-herd & Transgenerational

393,000 primiparous cows from 1,757 herds

94,000 primiparous cows from 3,392 sires and 6,011 MGS

ns

**Herds with desirable genetic trend for methane have lower methane emissions**

**The net contrast between best and worst herds:  
5.3 kg CH<sub>4</sub>/cow/year**

Worst 10% herds

Best 10% herds

■ 2017 ■ 2024 ■ 2025

CH<sub>4</sub> in 2025

**Sires with desirable breeding values for methane get offspring with lower methane emissions**

**Compared to bottom sires, daughters of top sires:  
7.1-8.0 kg less CH<sub>4</sub>/cow/year**

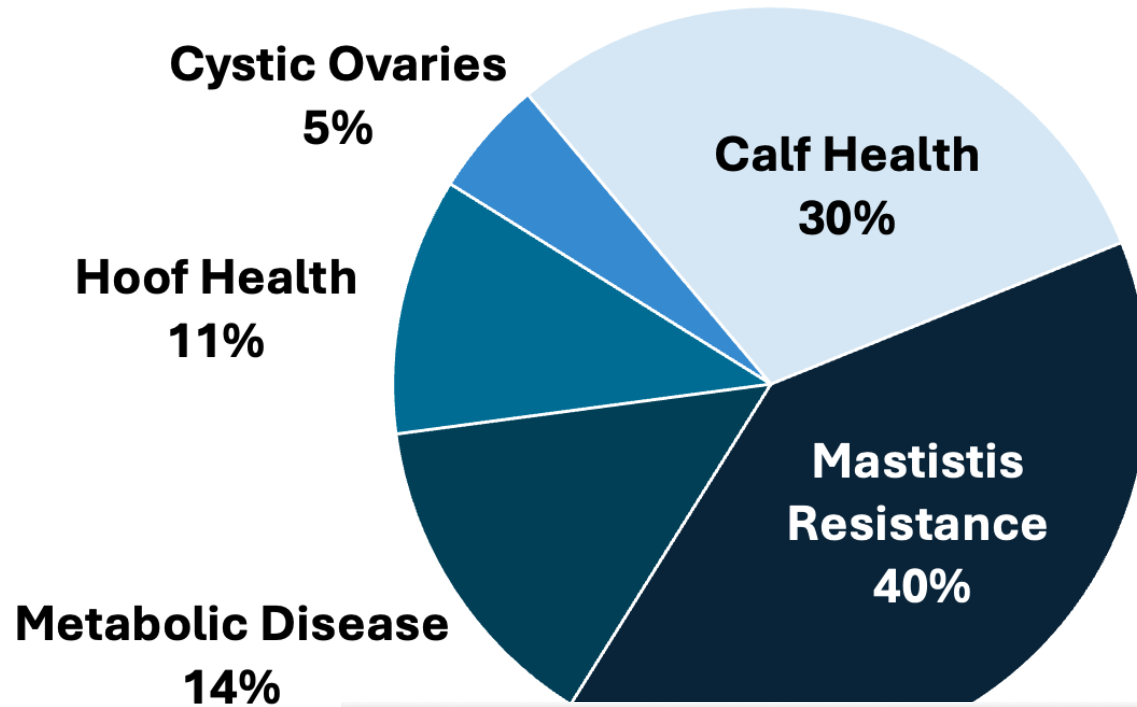
Sire EBV for g\_CH<sub>4</sub>



# Novel Traits in Aggregate Index

# Sub-indexes

## Health Index



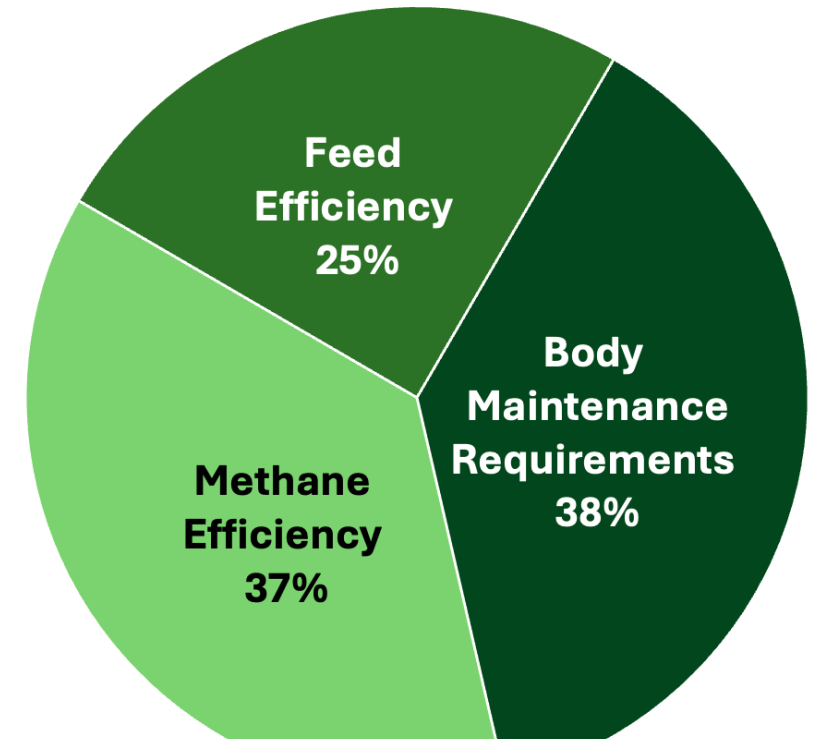
**JDS Communications®**  
2026; 7:210-215

<https://doi.org/10.3168/jdsc.2025-0875>  
Short Communication  
Genetics

### Development of a health subindex for genetic selection of bulls and cows in Canadian dairy operations

Douglas W. Bjelland,<sup>1\*</sup> John J. Crowley,<sup>1</sup> Caeli M. Richardson,<sup>1</sup> Natalie Howes,<sup>1</sup> Peter R. Amer,<sup>1</sup> Allison Fleming,<sup>2</sup> Cindy Jatton,<sup>2</sup> Christine F. Baes,<sup>3</sup> and Filippo Miglior<sup>2,3</sup>

## Environmental Impact Index



Animal 19 (2025) 101491



Contents lists available at ScienceDirect

Animal

The international journal of animal biosciences



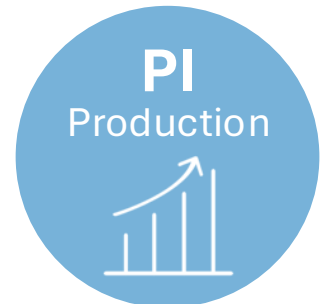
Breeding for sustainability: Development of an index to reduce greenhouse gas in dairy cattle<sup>☆</sup>

C. Richardson<sup>a,\*</sup>, P. Amer<sup>c</sup>, M. Post<sup>a</sup>, T. Oliveria<sup>a</sup>, K. Grant<sup>a</sup>, J. Crowley<sup>b</sup>, C. Quinton<sup>c</sup>, F. Miglior<sup>d,e</sup>, A. Fleming<sup>f</sup>, C.F. Baes<sup>g,h</sup>, F. Malchiodi<sup>g,h</sup>

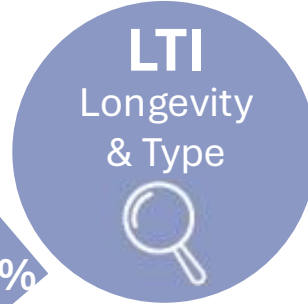


# Modernized LPI - April 2025 & 2026

**38% Body Maintenance Requirements**  
**37% Methane Efficiency**  
**25% Feed Efficiency**



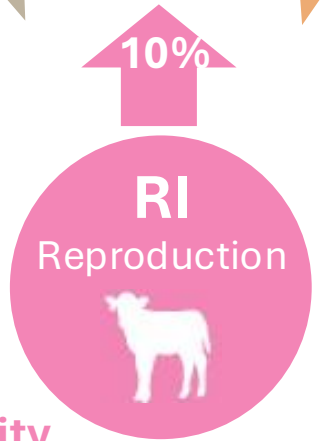
**60% Protein Yield**  
**40% Fat Yield**



**37% Mammary System**  
**33% Feet & Legs**  
**20% Herd Life**  
**5% Dairy Strength**  
**5% Rump**



**36% Teat Length**  
**25% Milking Speed**  
**18% Temperament**  
**15% Udder Depth**  
**-6% Udder Floor**



**90% Daughter Fertility**  
**10% Daughter Calving Ability**



**40% Mastitis Resistance**  
**30% Calf Health**  
**14% Metabolic Disease**  
**11% Hoof Health**  
**5% Cystic Ovaries**

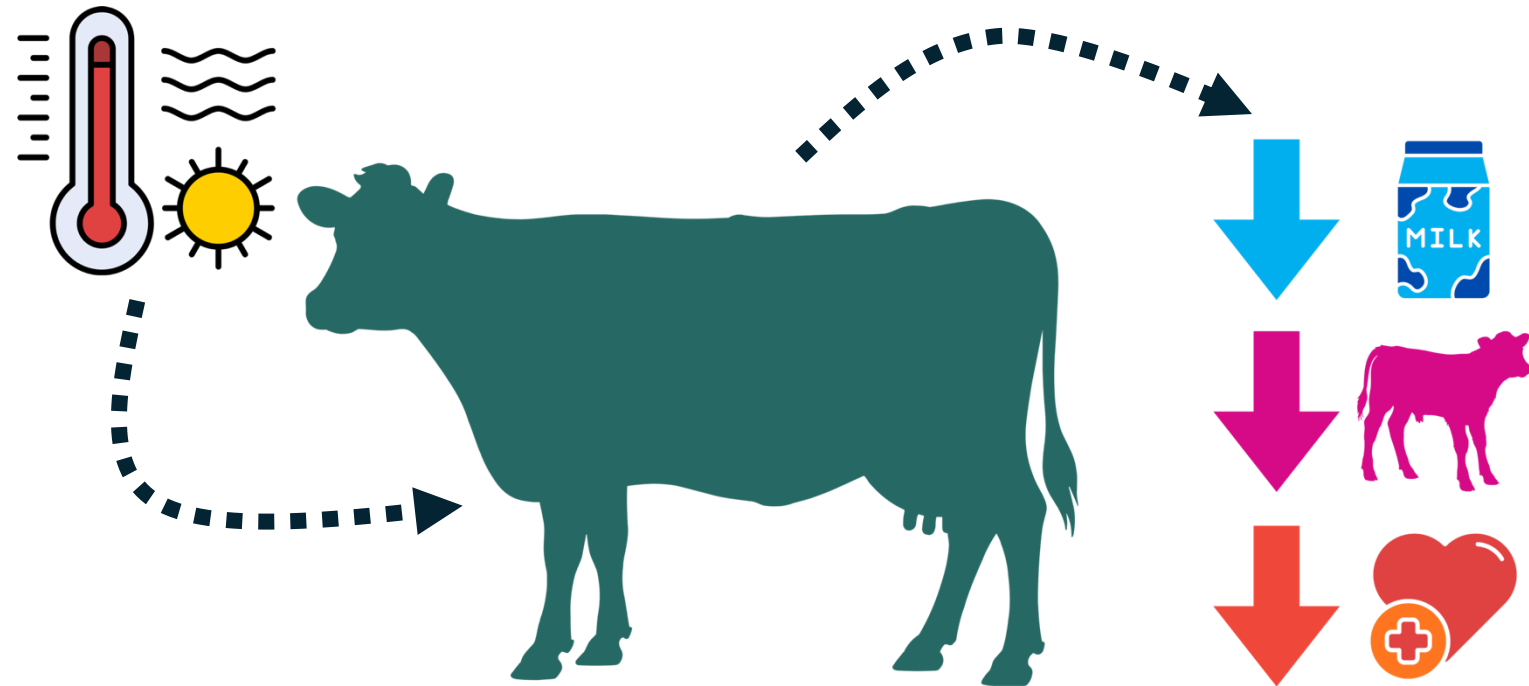


# Future Directions

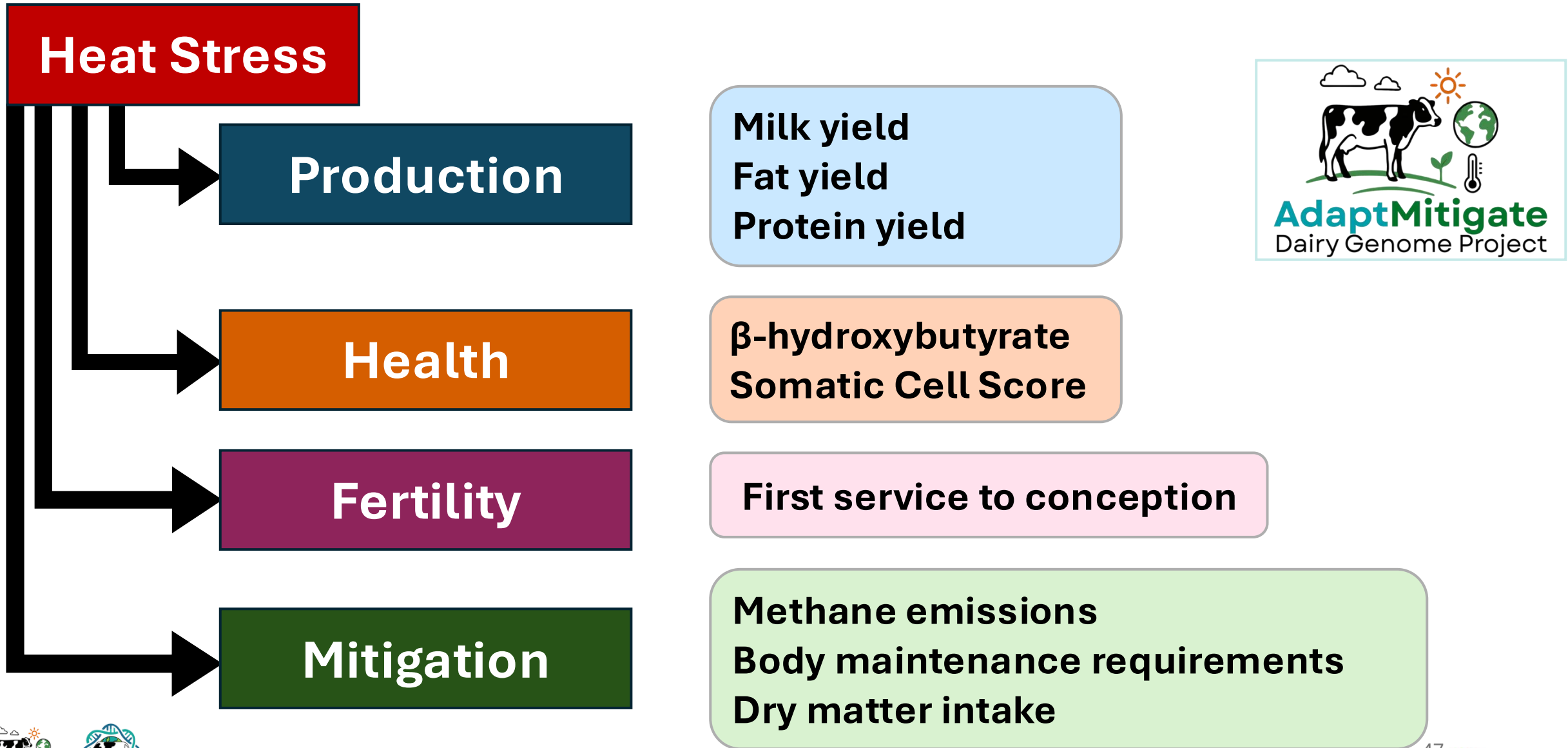
# Temperatures increasing more rapidly in Canada

## Heat tolerance

- High heat load has severe consequences on performance
- Able to select for more heat tolerant cows
- Genomics makes selection possible even with lower incidence of heat stress



# Direct Effects of Heat Stress



**Heat Stress**

**Production**

**Milk yield  
Fat yield  
Protein yield**

**Health**

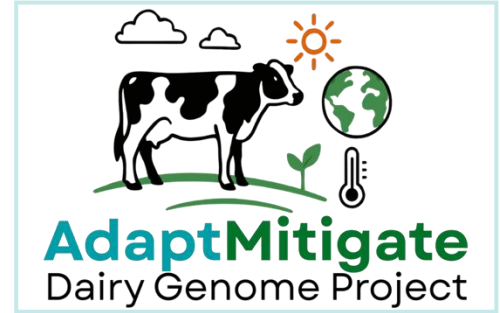
**$\beta$ -hydroxybutyrate  
Somatic Cell Score**

**Fertility**

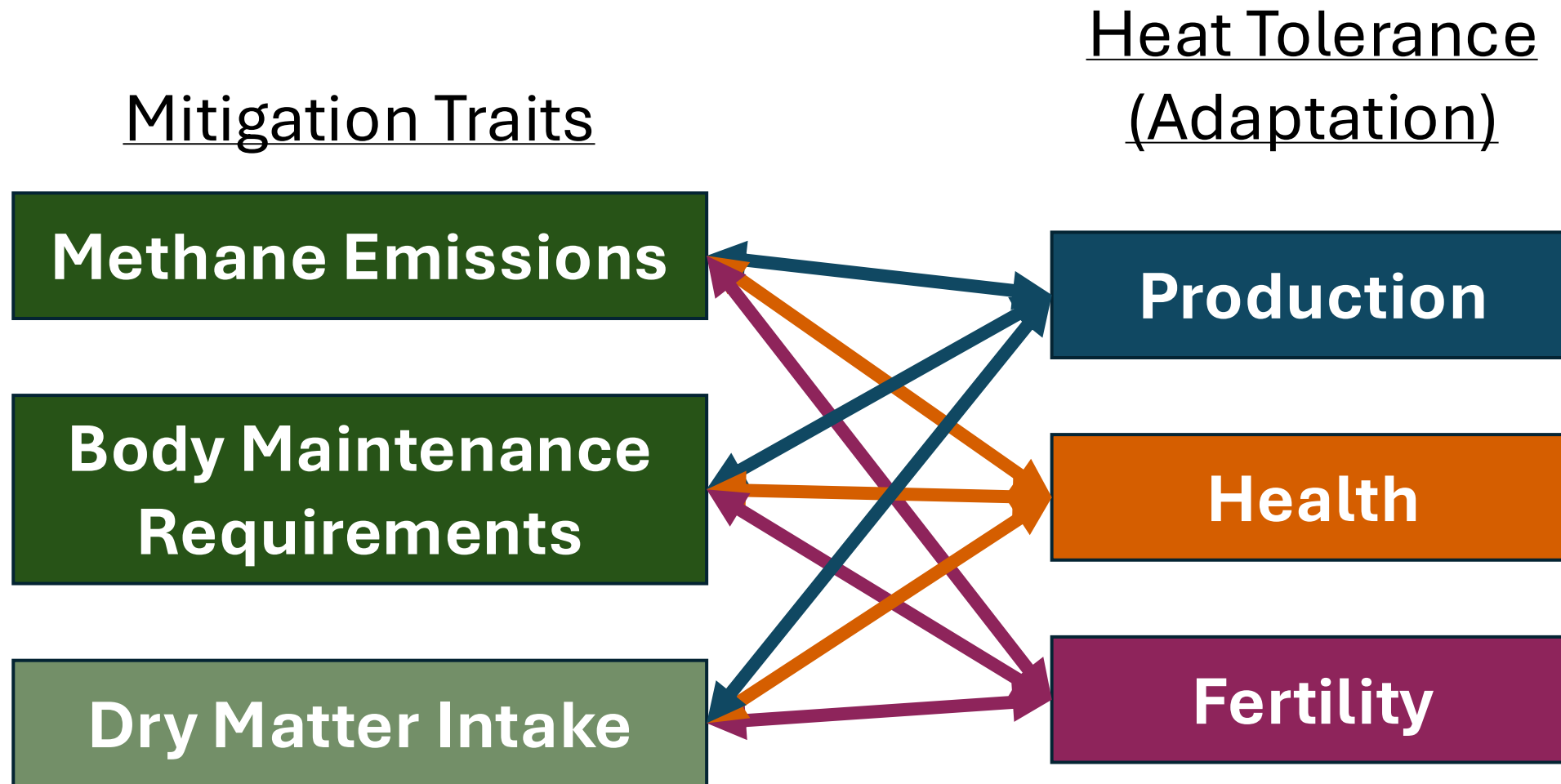
**First service to conception**

**Mitigation**

**Methane emissions  
Body maintenance requirements  
Dry matter intake**



# Interaction of Adaptation and Mitigation



# Current Status

## Early Insights

Heat Tolerance Trait	Correlation to CH <sub>4</sub>	Pattern Observed
Milk Yield	-0.10 to 0.26	No relationship
Fat Yield	-0.05 to -0.16	Favorable
Protein Yield	-0.03 to 0.09	No relationship

**Path to reducing methane emissions while sustaining productivity under heat stress is feasible**

# Economic Impact from Genomic Selection

Period	Progress / cow / year (Pro\$)	Net annual value to the industry
Before genomics (< 2008)	\$78	\$219 M / year
Introduction of Genomics (2009-2014)	\$158	\$443 M / year
Full Genomic adoption (2015-2024)	\$194	\$544 M / year

# Economic Impact from Genomic Selection

Period	Progress / cow / year (Pro\$)	Net annual value to the industry
Before (< 2009)		ear
Introduction (2009-2015)		ear
Full Genomic adoption (2015-2024)	\$194	\$544 M / year

**Net change since genomics: +\$325M/year**

**Genomics enables balanced progress, now extending to methane and climate resilience**

# Acknowledgements

## Deep thanks

- Beat and Henning
- Urs, Adrien and Qualitas team
- Joel, Maria and Agroscope team
- Joana, Cord and U Bern team



Agriculture and Agri-Food Canada



Environment and Climate Change Canada



THE UNIVERSITY OF BRITISH COLUMBIA



Qualitas



Agroscope



### Faculty



Dr. Filippo Miglor



Dr. Christine Baes



Dr. Flavio Schenkel

### PM & Postdocs



Dr. Ella Dodd



Dr. Coralie Machefert



Dr. Ricarda Jahnel



Dr. Samla Cunha

### PhD Students



Gabby Condello



Baran Amini



Tori Storing



Manu Silva



Julia Lisboa

### Industry Partners



Dr. Francesca Malchiodi



Dr. Caeli Richardson



Dr. Allison Fleming



Dr. Kristin Lee



Dr. Colin Lynch



Dr. Hannah Sweett

Filippo Miglor - fmiglor@uoguelph.ca