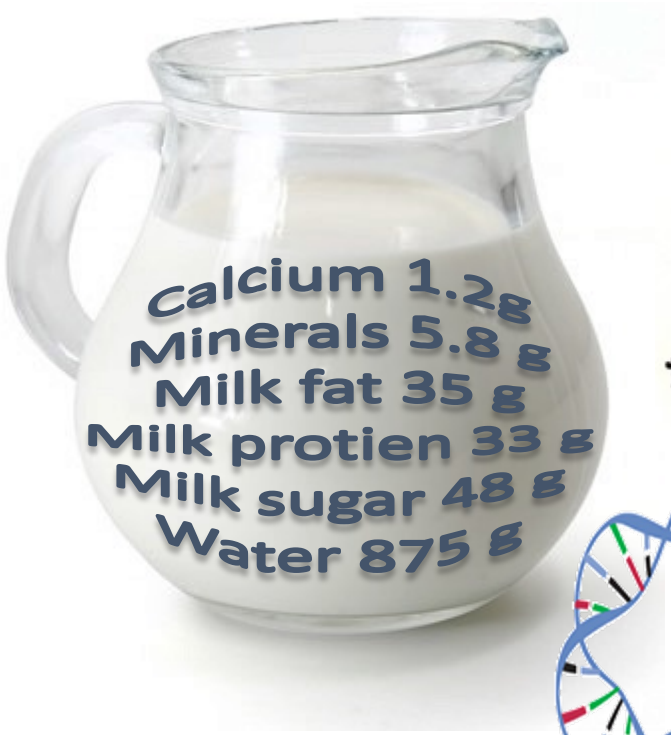
World Holstein Fresian Federation2023
Tuesday, November 21st, Puy Du Fou, France
@BaesC1

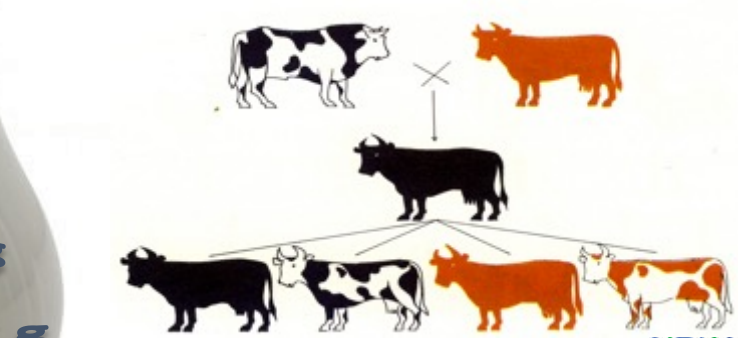
Phenotyping for Feed Efficiency: Using Genetics and Genomics to Improve Livestock Sustainability

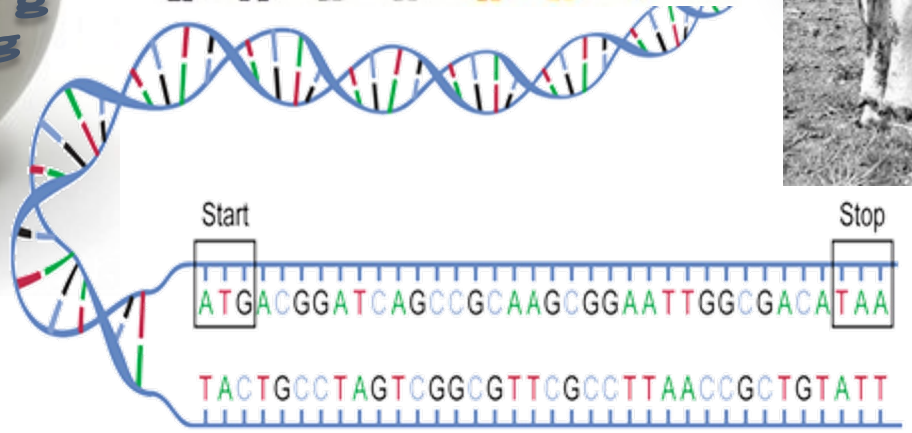
C. F. Baes, F. Schenkel, G. Kistemaker , K. Parker-Gaddis, R. Baldwin, A. Butty , J. Burchard, O. González-Recio, J. Lassen, M. VandeHaar, D. Segelke, J. Pryce, R. Tempelman, F. Peñagaricano, K. Weigel, J. Koltes, F. Miglior, RDGP Consortium Partners, FARR Consortium Partners

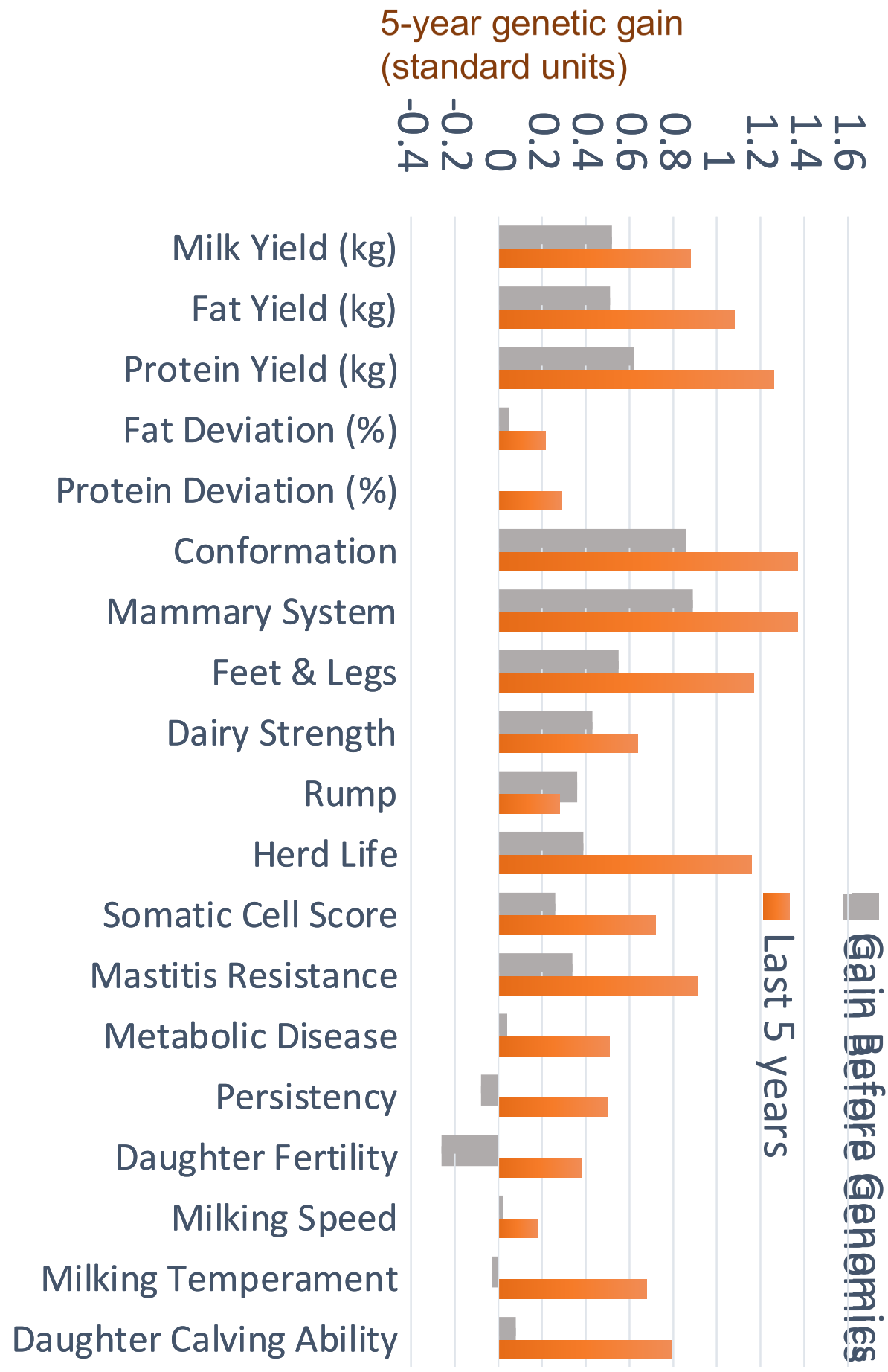
A Simple Equation… that can get very complicated!

Phenotype = Genotype + Environment









(Adopted from *Beavers and Van Doormaal, Lactanet*)

Sustainable Livestock Genetics: Decades in the making

"Efficiency is measured by a comparison of production with cost in energy, time, and money"

Harris, 1970

"Animal breeding determined only by short-term market forces leads to unwanted side effects"

Olesen et al., 2000

"One of the things that has become clearer as we've done genomes, is that we're probably much more genetic animals than we want to confess we are"

Venter, 2015

What is a sustainable cow?

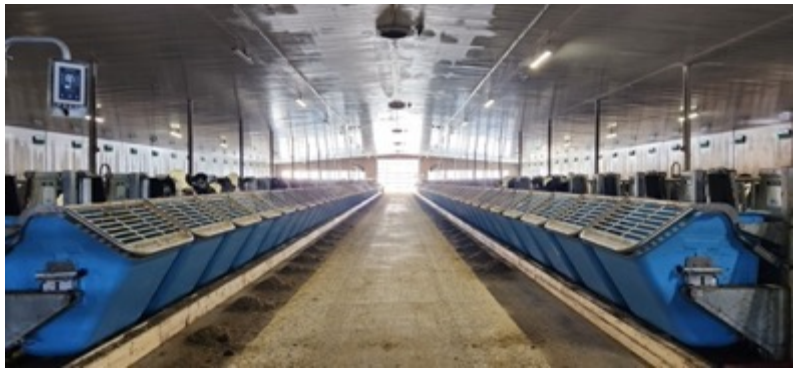
an animal able to adapt rapidly to changing conditions
without compromising its productivity, health or fertility
while becoming more resource-efficient
and reducing its environmental burden.

Past,Current and Future Projects

THE Efficient Dairy GENOME PROJECT

THE Resilient Dairy GENOME PROJECT

- International database for Feed Efficiency and Methane Emissions
- Genomic Evaluations for Feed Efficiency launched by Lactanet 2021
- Genomic Evaluations for Methane April 2023
- Resiliency Index (novel fertility, health, and efficiency traits) expected 2024



NEWLY FUNDED:

Alberta RDAR project ~$2M

Sunalta Feed Bins & Sniffer prototypes at Elora

AFC Alberta Milk project $892K

Alberta CH_4 Sniffers, KTT, weight scale at Sunalta

MAPAQ & Dairy Farmers of Quebec PLQ project ~$3.17M

- Quebec CH_4 Sniffers, Nutrition R&D & trainees

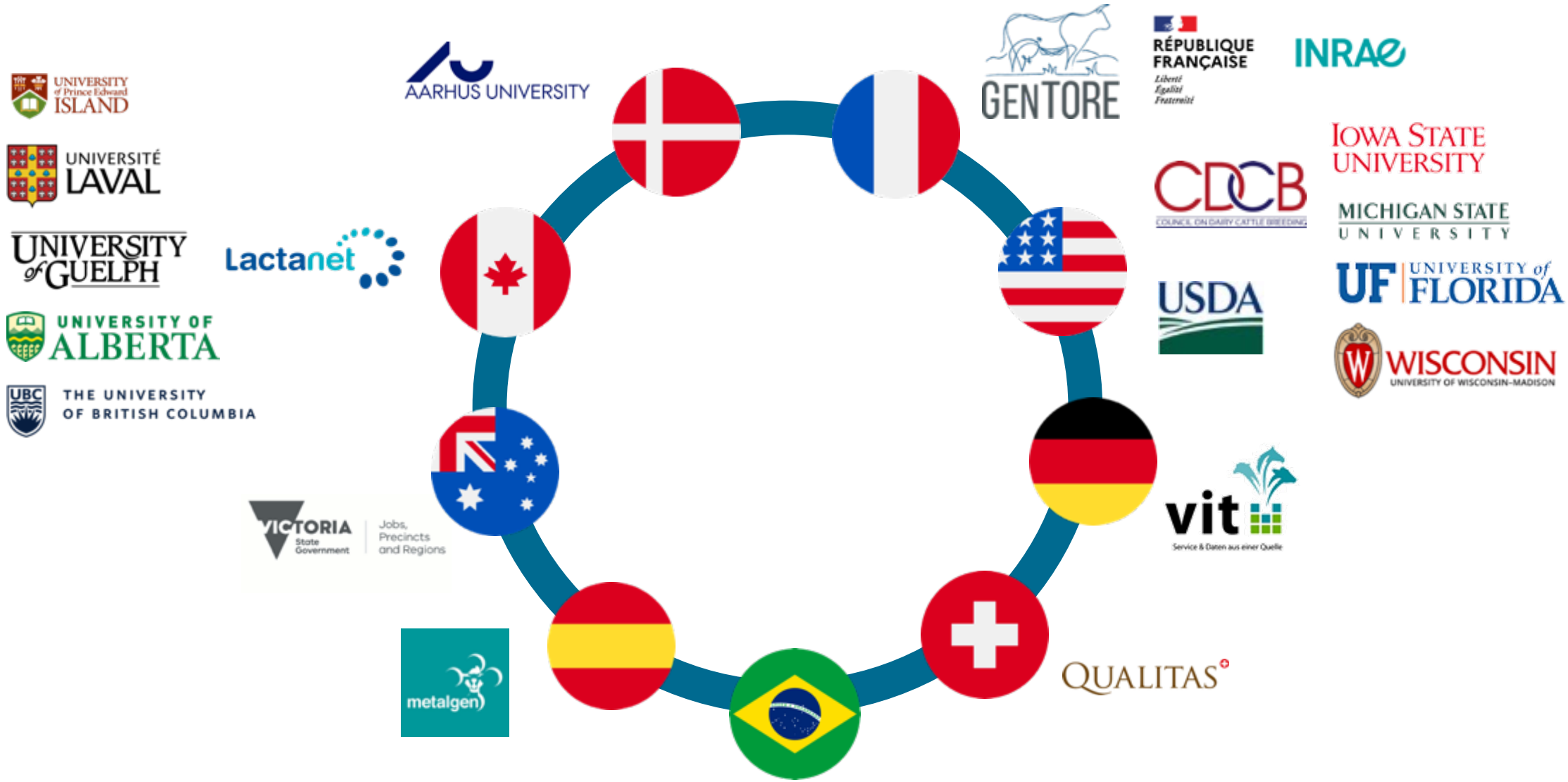
BC Dairy project $136K

Dairy Cluster project $980K

DFO Cash support $160K + $10K IK

Genome Canada ICT ~$16M

National and International Research Partnerships



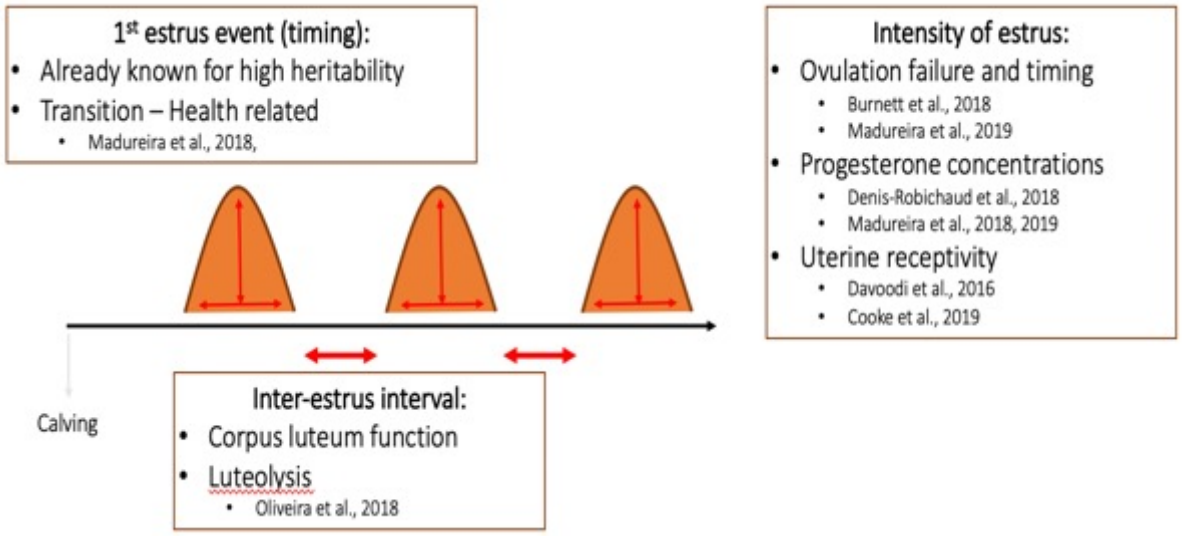
1. ‘Closer-to-biology’ fertility

Dr. Ronaldo Cerri

THE UNIVERSITY OF BRITISH COLUMBIA

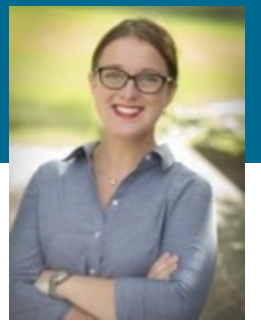
1. “Closer-to-Biology” Fertility

- Standardized phenotypes based on automated sensors
- Physiological factors affecting estrous expression and embryo survival
- Genomic markers of estrus expression and fertility
- Size and Position Score (SPS)
- Transmission Ratio Distortion



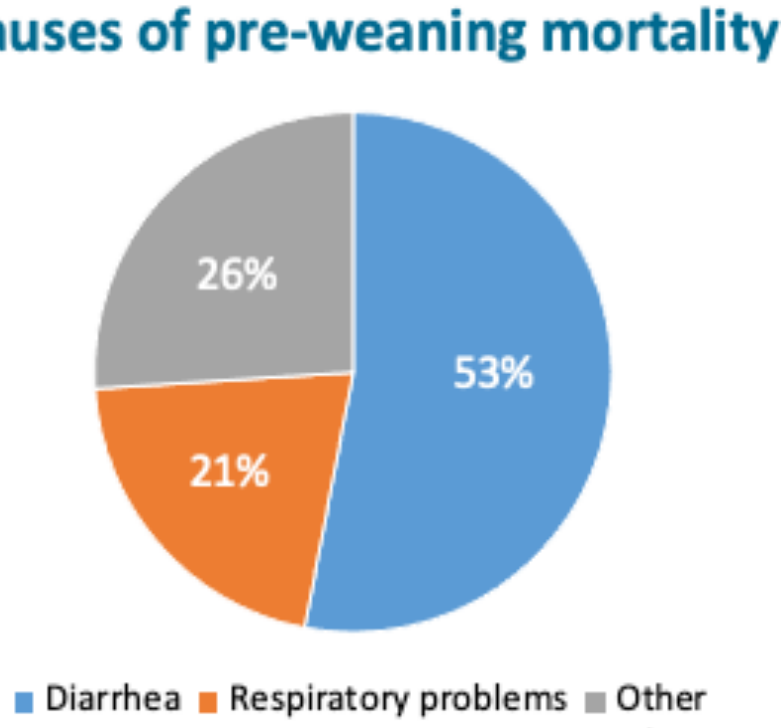
Madureira et al., 2022, 2021
Martin et al., 2021, 2022

2. Enhanced disease resistance



Dr. Christine Baes

- Fertility disorders in routine genomic analyses (Lactanet, 2020)
- Develop methods for routine phenotyping of
  - Calf health (Emma Hyland, Colin Lynch)
  - Leukosis (Renee Bongers)
  - Feed efficiency of calves (Kyle Hoeksema)
  - Johne's disease (Aisha Fong / Chrissy Rochus)
  - Effects of homozygosity (Makanjuola / Obari)

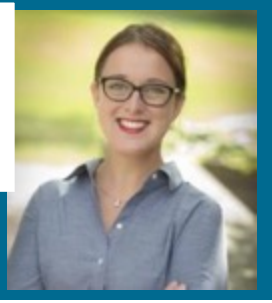


Lynch et al., 2021; 2022; 2023
Bongers et al., 2023
Fong et al., 2023

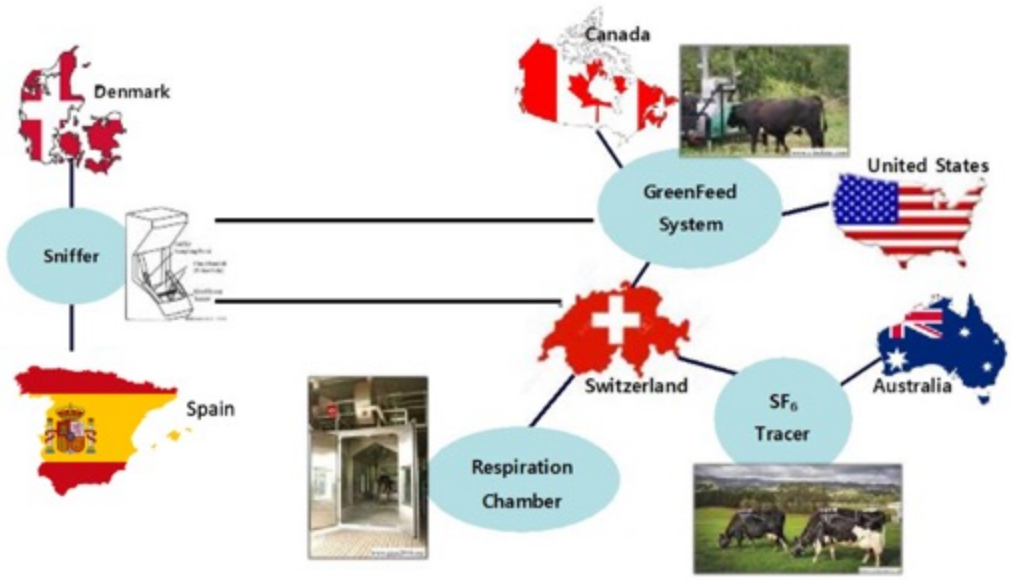
3. Feed efficiency and methane emissions

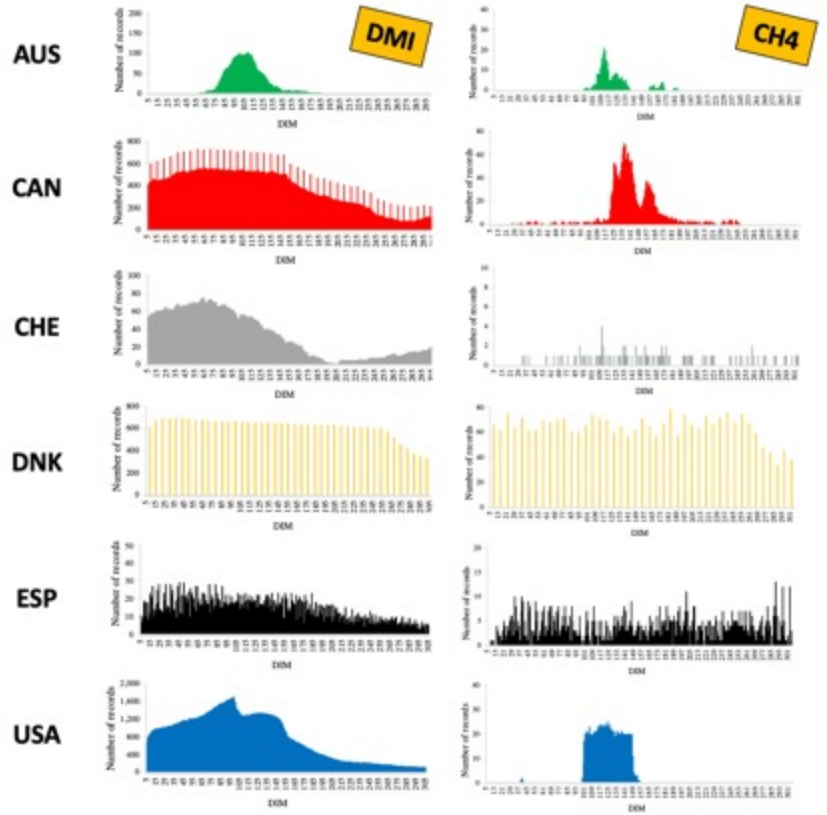
Lactanet

Dr. Gerrit Kistemaker



Dr. Christine Baes





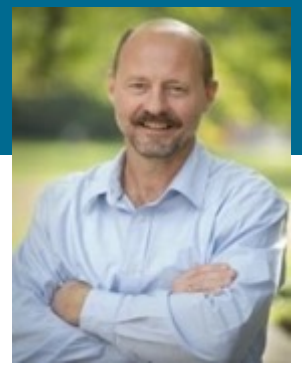
Enlarging the reference population for

- **Feed efficiency** (17,000 animals)
- **Methane emissions** (7,800 animals)

van Staaveren et al., 2023

4. Genomic and environmental relationships

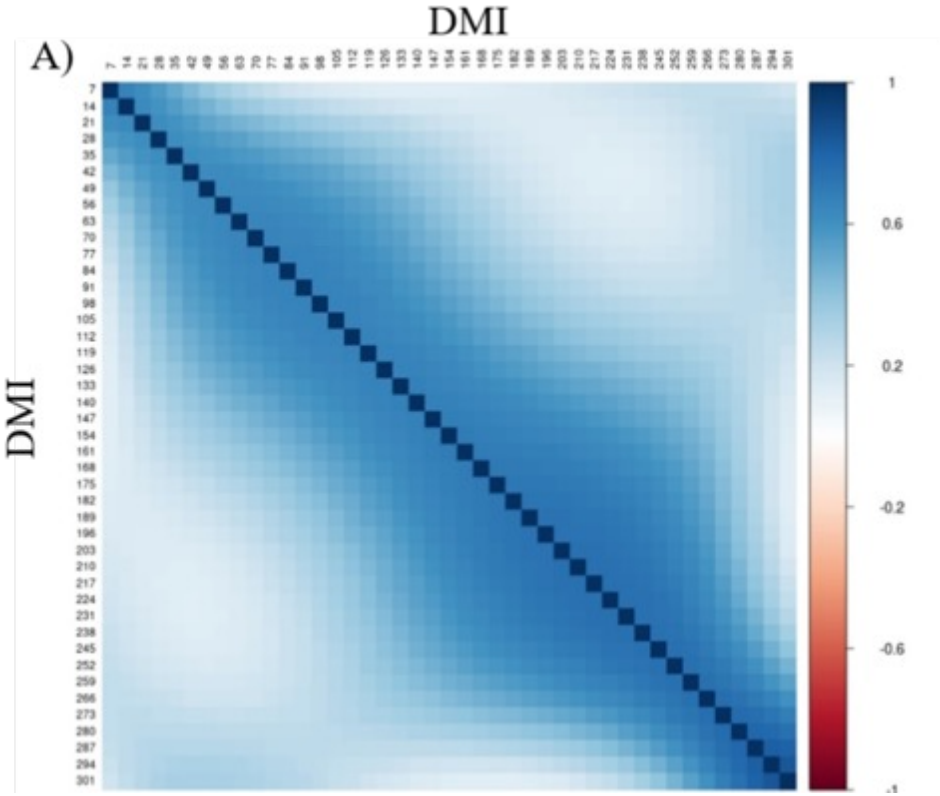
UNIVERSITY of GUELPH



Dr. Flavio Schenkel

Genetic parameters and prediction of EBVs of resilience traits

- Multi-trait analysis to identify genomic regions with pleiotropic effects on resilience traits
- Genomic predictions for resilience indicator traits using copy number variants
- Investigate the effects of heat stress on important traits



Houlahan et al., 2023

4. Genomic and environmental relationships

Fertility

- **Alcantara et al., 2022.** Machine learning classification of hormonal synchronization protocols for Canadian Holsteins cows. *JDS*
- **Martin et al. 2022.** Reproductive tract size and position score: Estimation of genetic parameters for a novel fertility trait in dairy cows. *JDS*
- **Oliveira at al. 2022**. Genome-Wide Association Analyses Reveals Copy Number Variant Regions Associated with Fertility and Disease Traits in Canadian Holstein Cattle, *PAG 2022*

Heat Stress

- **Campos et al. 2022**. Using publicly available weather station data to investigate the effects of heat stress on milk production traits in Canadian Holstein cattle, *CJAS*
- **Rockett et al. 2022**. Estimation of genetic parameters and prediction for heat tolerance in Holsteins using test-day production records and NASA POWER weather data. *JDS*
- **Rockett et al., 2023.** Phenotypic analysis of heat stress in Holsteins using test-day production records. *JDS*

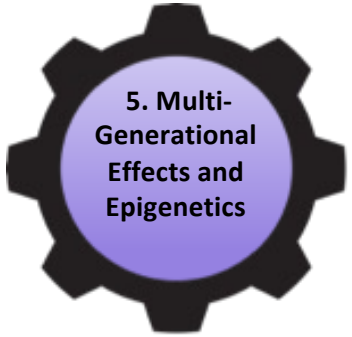
Calf Health

- **Bongers et al. 2022**. Incorporation of enhanced disease resistance into genetic evaluations. 2022 Interbull meeting.
- **Bongers et al. 2022**. Genetic analysis of leukosis milk ELISA test records in Holstein cows. 2022 ADSA meeting.
- **Lynch et al. 2022**. A Canadian genetic evaluation for calf health: preliminary analysis. 2022 WCGALP.
- **Van Staaveren et al. 2023**. Recording of calf health diseases for use in breeding programs. *CJAS*

Feed Efficiency / Methane

- **Shadpour et al., 2022.** Predicting dry matter intake in Canadian Holstein dairy cattle using milk MIR and other predictors via ANN. *JDS*
- **Shadpour et al., 2022.** Predicting methane emission in Canadian Holstein dairy cattle using milk MIR and other predictors via ANN. *JDS*
- **Lopes at al. 2022.** Estimates of genetic parameters for environmental efficiency traits for first lactation Holsteins. *2022 ICAR & WCGALP meetings*
- **Houlahan et al. 2022**. The dynamic behavior of genomic predictions for feed efficiency over lactation. *2022 ICAR & WCGALP meetings*
- **Kamalanathan et al., 2023**. Genetic Analysis of Methane Emissions in Holstein Dairy Cattle. *Animals*

5. Multi-generational effects and epigenetics



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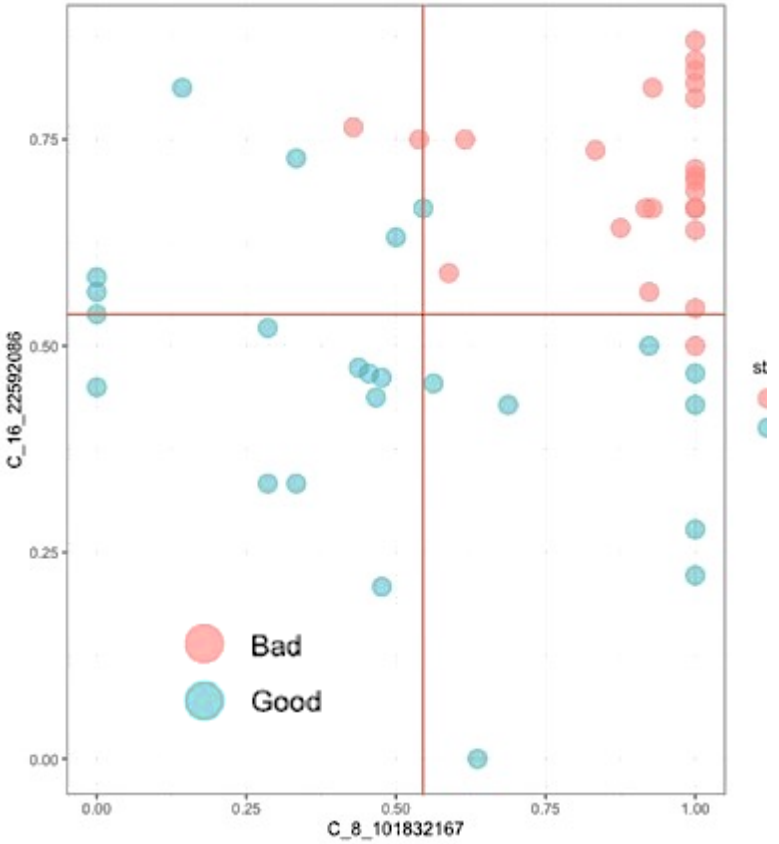
Dr. Marc-André Sirard

- Quantify effect of early environment (i.e., cow's production) on resilience of daughters
- Survey for epigenetic signature on precisely phenotyped animals
  - Whole Genome Bisulfite Sequence
    - 24 healthy (good)
    - 24 with mastitis, poor performance, infertility, lameness (bad)



Methylation level of C_16_22592086 (on the y-axis) and C_8_101832167 (on the x-axis)

6. Data management

Dr. Paul Stothard

Management of project database

- Whole-genome sequence data analysis for variants, genotypes, functional annotations
  - SnakeMake pipeline to call SNPs?
- Genome browser integration of GWAS findings, epigenetic signatures, & annotated sequence variation

SnakeMake pipeline developed for calling SNPs from methylation sequencing – Coverage now 50x

Sample	Average coverage	Bases with >10X coverage (Mbp)	Filtered SNPs
2258	25.73	2.49	3,813,056
2260	13.29	1.17	1,202,679
2261	29.19	2.52	4,109,577
2262	15	1.22	1,345,862
2267	5.88	0.37	274,853
2268	21.46	2.42	3,216,416
8761	14.5	1.72	1,634,613

Next steps: compare WGBS-called SNPs to SNPs from conventional WGS to gauge performance and utility of this approach.

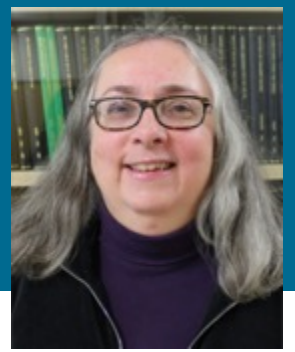
Herman et al., 2022

7. GE3Ls: sustainability and social acceptance

UNIVERSITY of GUELPH

Dr. Getu Hailu

UNIVERSITY OF ALBERTA



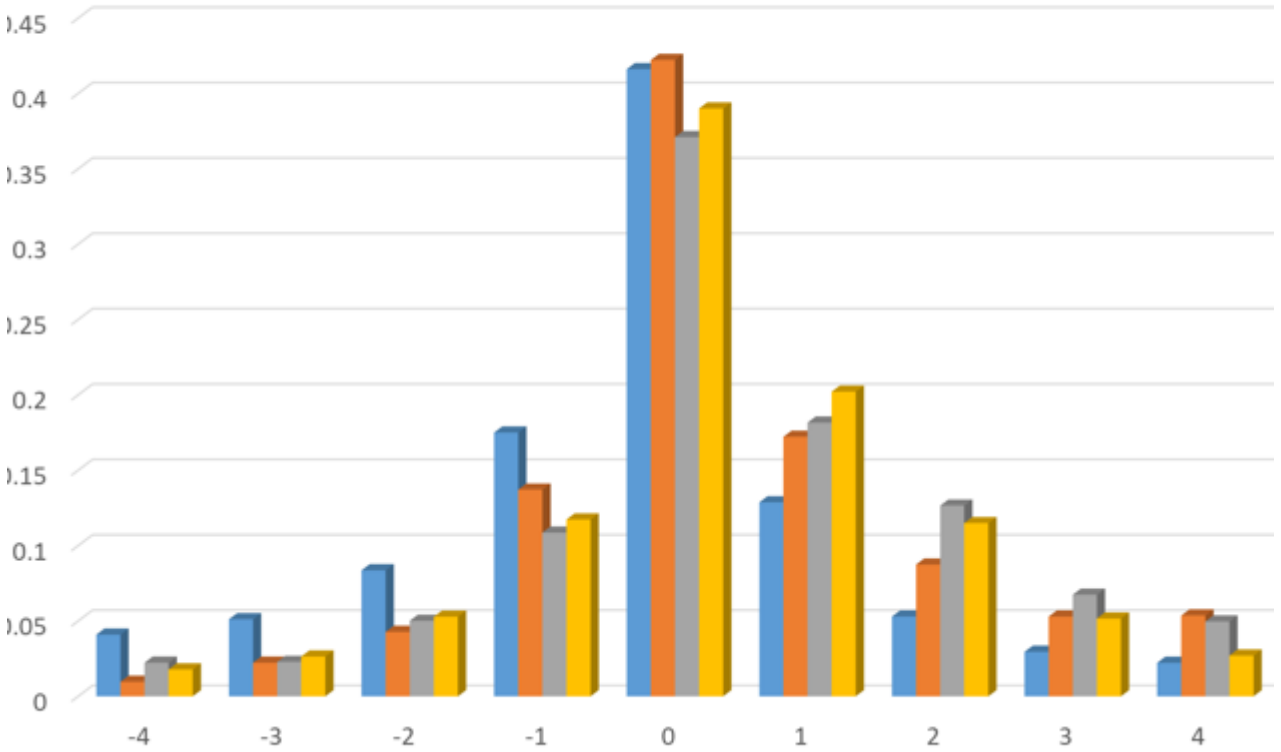
Dr. Ellen Goddard

7. GE^{3}LS: Optimizing traits to maximize sustainability and societal acceptance

- Farm level decisions about tradeoffs between traits
- Farm/Market level outcomes from selection of resilience traits
- Public acceptance of dairy under different breeding strategies

Goddard et al., 2022

Public Perceptions: Benefits of Genomic Selection minus Risks of Genomic Selection



8. Translation and Implementation

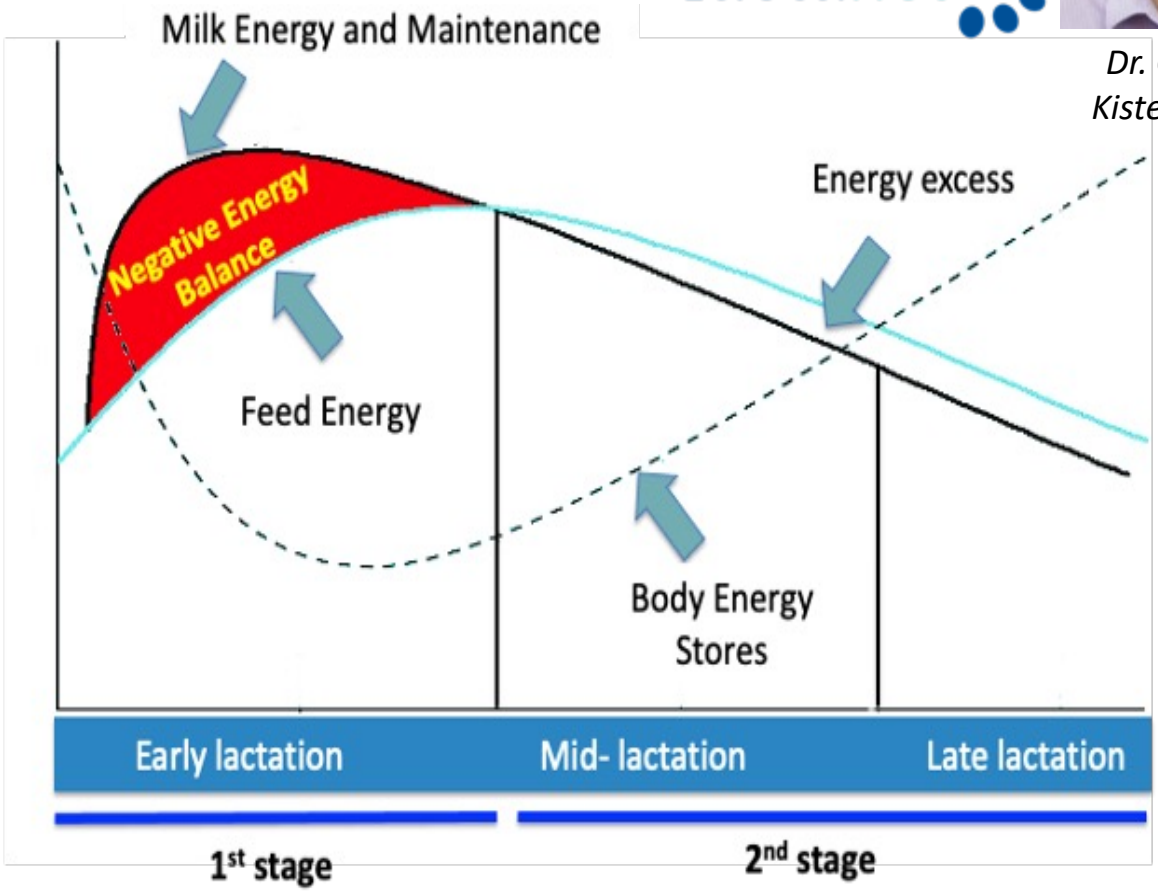
Dr. Gerrit Kistemaker

Implement fertility disorder evaluations (done 2020)

Feed efficiency evaluations (2022)

Methane evaluations (2023)

Develop resiliency index



Overall aim is to select for cows that use less feed at the same level of production and body size after peak of lactation

Overall: Environmental Efficiency

- RDGP data base is sizeable and growing
  - Canada, US, Denmark, Switzerland, Germany, Spain, Australia
  - About 3,200 cows for methane emissions
- CH4 sniffers installed soon in multiple commercial farms
- CH4 emissions predicted **accurately** (~0.85) using milk MIR
  - Evaluations for **CH4 emissions** ready to be launched in April 2022
- New Genome Canada project just funded
  - GHG mitigation roadmap using genetic and nutrition strategies
  - Reduce GHG emissions by 54% (6.72 Mt CO2-eq)

Leveraging Genomics to Achieve Dairy Net-Zero

Christine Baes, Filippo Miglior, Rachel Gervais, Paul Stothard

+ National and International Partners

Interdisciplinary Challenge Team Competition

Start: 2023?

Project Duration: 4 years

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Freie Universität Berlin

QUALITAS

AARHUS UNIVERSITY

CONAFE
Confederación de Asociaciones de Frisona Española

INIA
Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria

WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

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UNIVERSITY OF GUELPH

DAIRY FARMERS OF CANADA
LES PRODUCTEURS LAITIERS DU CANADA

SEMEX
Genetics for Life

UNIVERSITÉ LAVAL

UCDAVIS
UNIVERSITY OF CALIFORNIA

UNIVERSITY OF ALBERTA

Lactanet

abacusbio.
BRIDGING SCIENCE & BUSINESS

GenomeCanada

Christine Baes
Professor and Canada Research Chair, University of Guelph

Rachel Gervais
Professor, Université Laval

Fawn Jackson
Chief Sustainability Officer, Dairy Farmers of Canada

- Ermias Kebreab
- Professor and Associate Dean, University of California Davis

Filippo Miglior
Senior Advisor, Lactanet Canada

Michael von Massow
Professor, University of Guelph

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Director, Genetics & Analytics
Semex

Caeli Richardson
Plant and Animal Geneticist
AbacusBio

Debora Santschi
Director, Innovation, Lactanet Canada

Flavio Schenkel
Professor
University of Guelph

- Paul Stothard
- Professor, University of Alberta

The Long Road to Environmental Sustainability

2012

Milk Spectral Data

- Milk MIR pipeline and storage since 2013
  90% of milk recorded cows since 2018

2014

Efficient Dairy Genome Project

- Feed Efficiency & Methane Emission DB
  4,500 cows with FE and 1,500 with ME

2018

Resilient Dairy Genome Project

- Additional international partners
  12,000 cows with FE and 3,500 with ME

2022

New regional initiatives

- Lactanet investing in FE and ME collection
  CH_4 sniffers in Canadian commercial farms

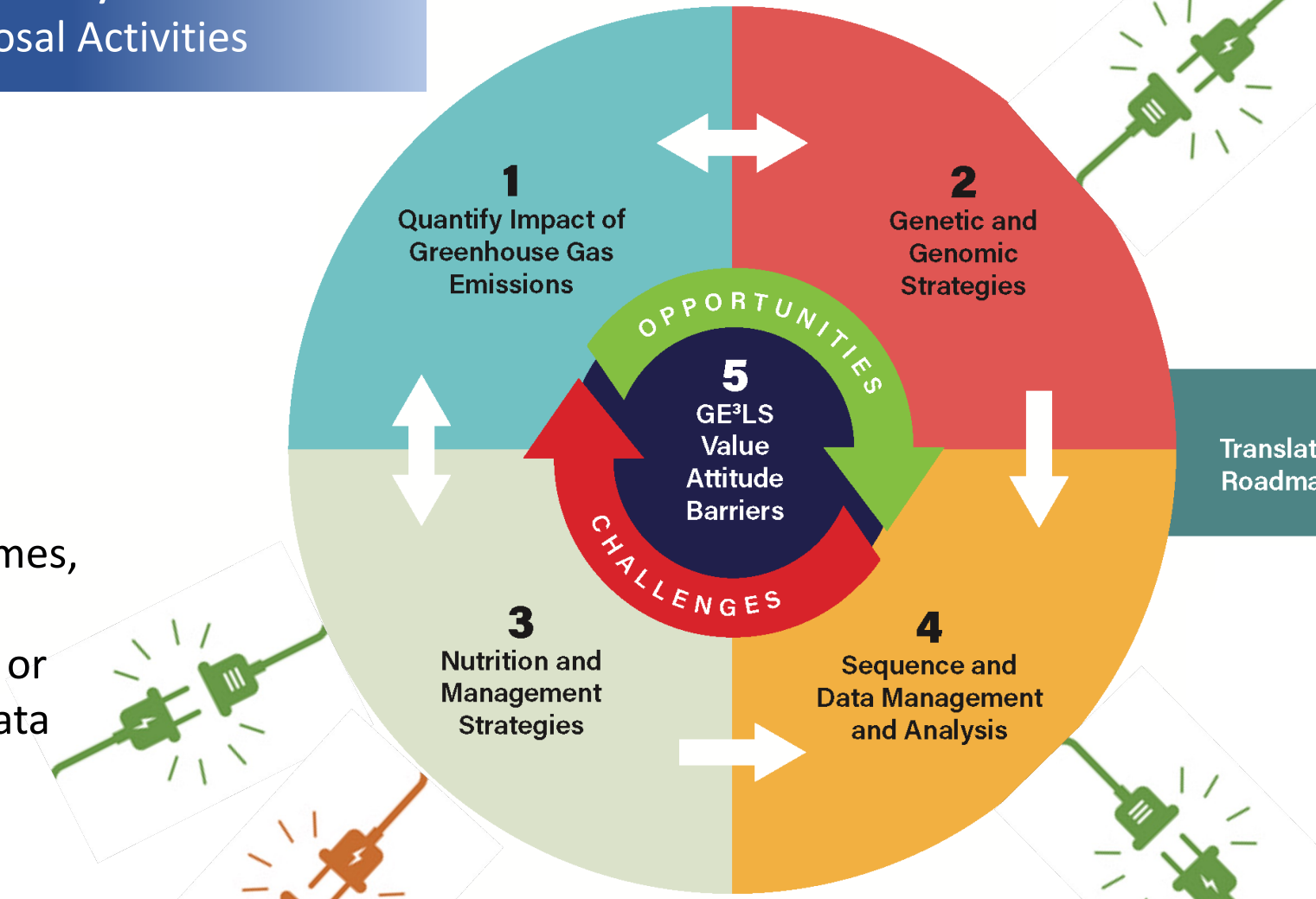
2023

Dairy$_{Zero}$ Genome Project

- New Genome Canada program
  Roadmap for GHG mitigation
  **Pending Formal Approval*

Since 2013, multiple projects to genotype cows with medium-high density chips -> over 45,000 cows

Leveraging Genomics to Achieve Dairy Net-Zero:
Proposal Activities



Results from other studies for augmenting genomic evaluations

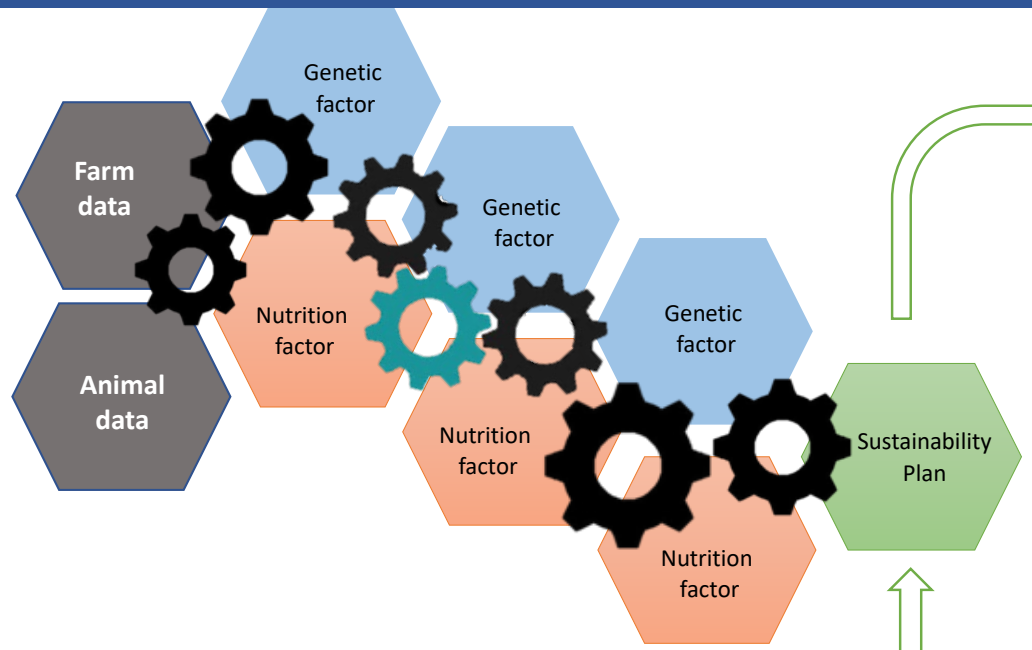
Forages, legumes, plant-soil interactions or feedstuffs data

Microbiome samples

Plants, soils, or ruminant data

Adaptation of ruminant agrifood systems

A Roadmap for Greenhouse Gas Reduction



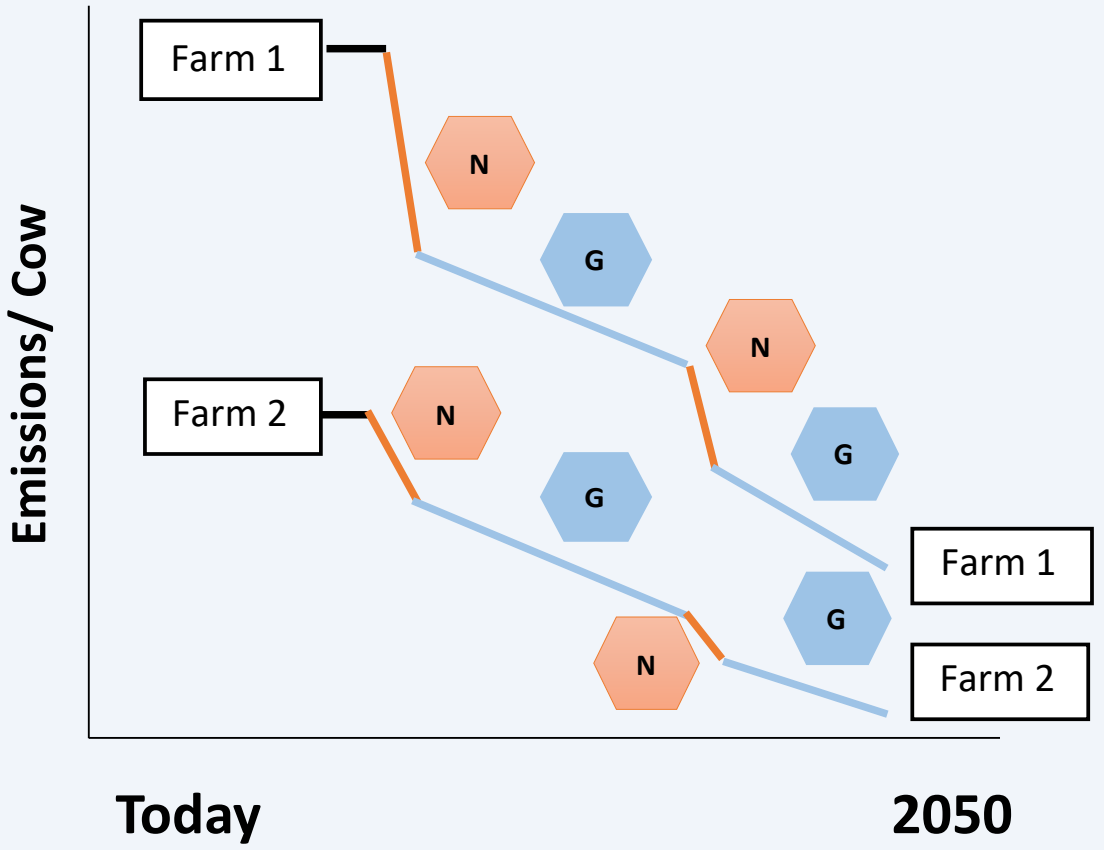
Industry Toolbox

Tailored genetic-specific mitigation strategies

Tailored nutrition-specific mitigation strategies

Combined genetic-nutrition strategy and messaging

On-farm Plan



Social and Economic Benefits

- 55% GHG reduction by 2050 (-6.7Mt CO_2 eq)
  - Conservative estimate of $50/tonne of carbon = $338M
- Cumulative benefits / year of selection = additional $102M/year due to improved production efficiency and animal welfare
- Positive impact on consumers, rural communities and environment
- Methane Efficiency allows selection for reduced methane emissions without impacting production levels

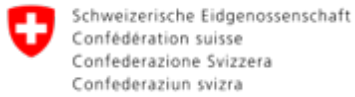
Leveraging Genomics to Achieve Dairy Net-Zero: Deliverables

- A roadmap (overall goal) and embedded toolbox for GHG reduction
- Quantify impact and uncertainty surrounding GHG mitigation strategies
- Understand biological architecture to deliver novel mitigation tools for methane emissions
- Report on public and wider stakeholder attitudes to such reductions
- Producer engagement to help ensure uptake of mitigation approaches
- Translate relevant results to beef production systems and vice-versa
- Accurate and robust method for estimating individual animal and herd-level GHG emissions **for use in national policy** and **GHG inventories**

Overall Summary

- The global population is changing, but the need for high-quality protein is increasing
- Livestock genetics and genomics are tools to improve sustainability of livestock:
  - Economic
  - Environmental
  - Society

Acknowledgements



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Thanks to a fantastic team!

www.resilientdairy.ca/

THE Resilient Dairy GENOME PROJECT