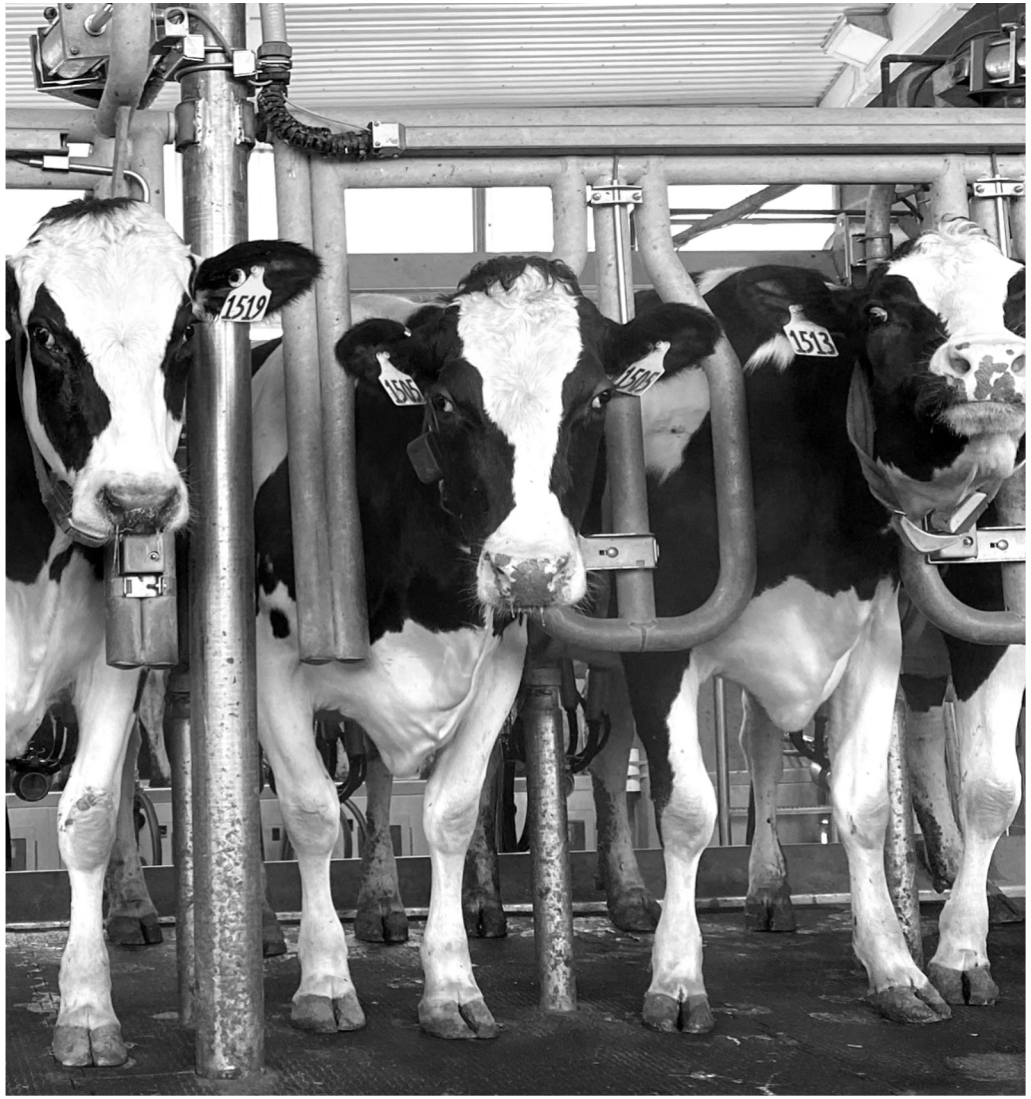
SUSTAINABLE DAIRY BREEDING:

Working within the US National Evaluation System



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ASAS-CSAS Annual Meeting | June 29, 2022 | Oklahoma City, OK

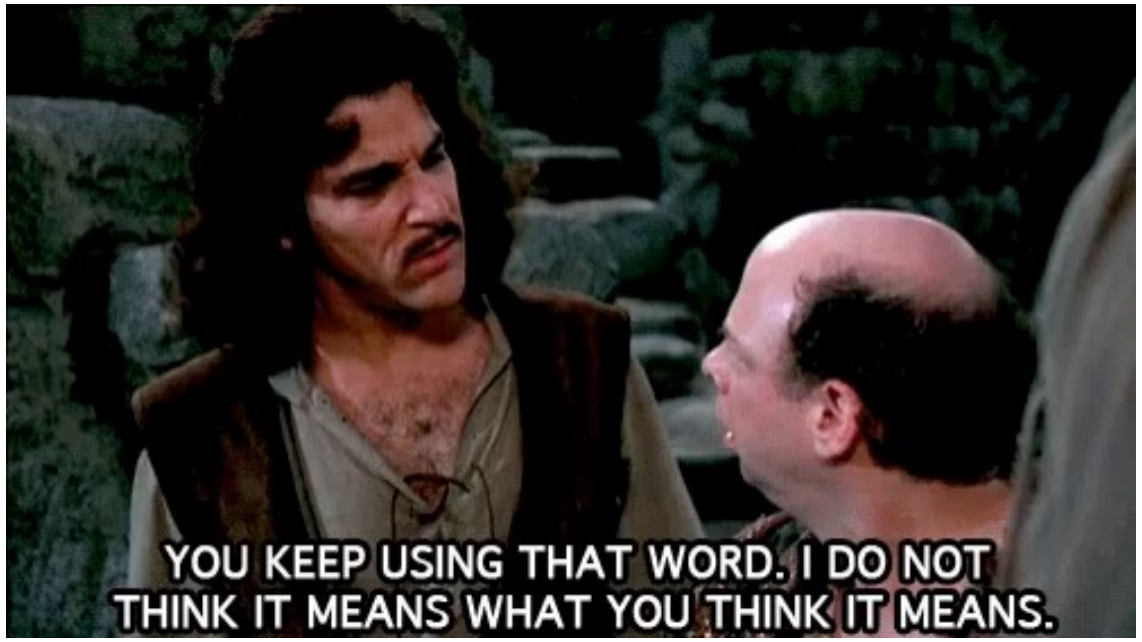
TOPICS FOR DISCUSSION

1. How have we been addressing sustainability in US dairy breeding?

2. What are the opportunities?
    1. Preserving genetic diversity
    2. New sustainability traits

WHAT IS SUSTAINABILITY

> the ability to be **maintained** at a certain rate or level
>
> *-Oxford Languages*



The Princess Bride (1987)

WHAT IS SUSTAINABILITY

"the **balance** between the **environment**, **equity**, and **economy**"
-UCLA Sustainability Committee

"conditions under which **humans** and **nature** can exist in productive harmony to support present and future generations"
-US Environmental Protection Agency

"development that meets the needs of the present **without compromising** the ability of future generations to meet their own needs"
-UN World Commission on Environment and Development

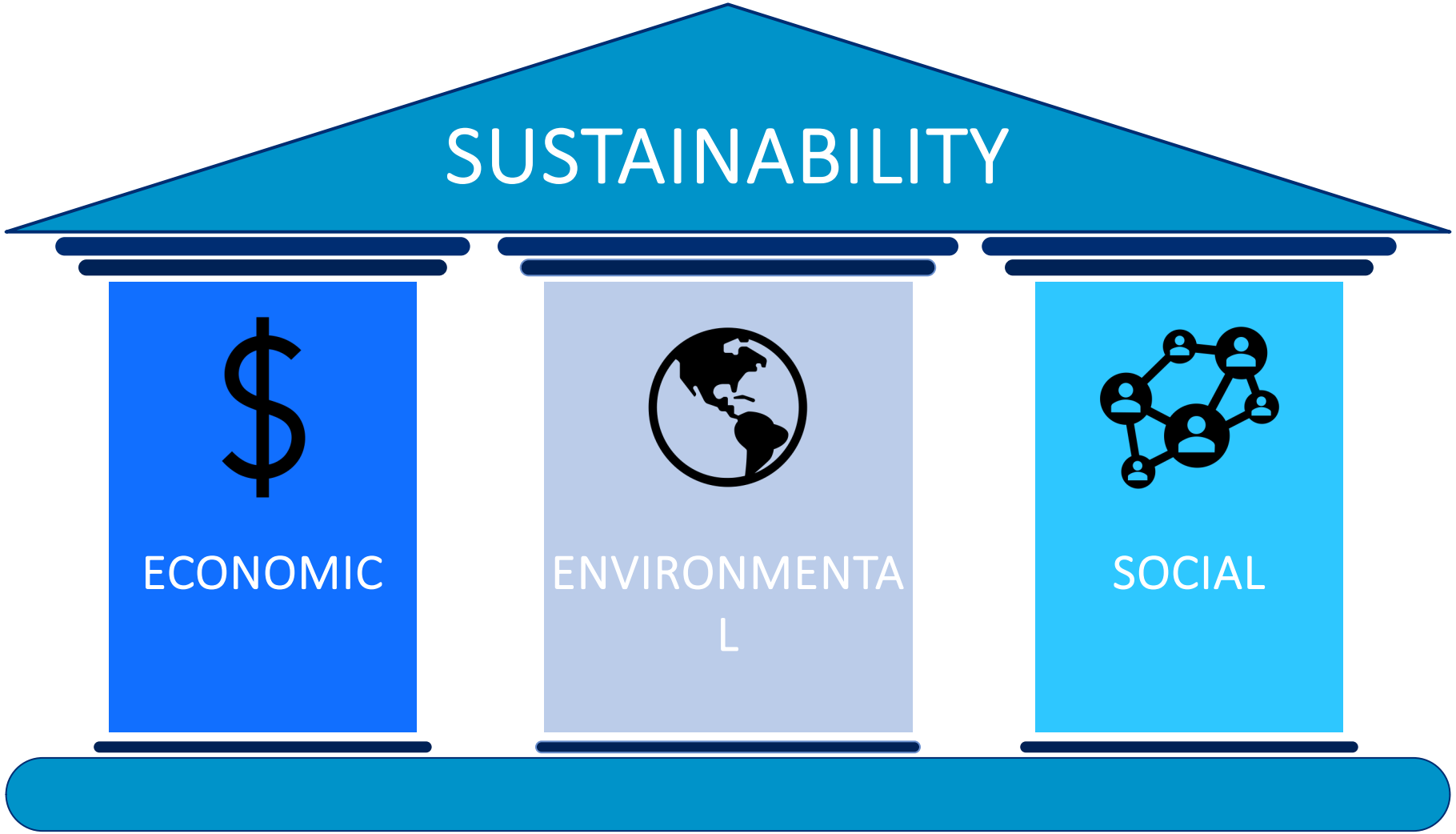
WHAT IS SUSTAINABILITY

Farm Bill
[Food, Agriculture, Conservation, and Trade Act of 1990 (FACTA), Public Law 101-624, Title XVI, Subtitle A, Section 1603 (Government Printing Office, Washington, DC, 1990) NAL Call # KF1692.A31 1990]

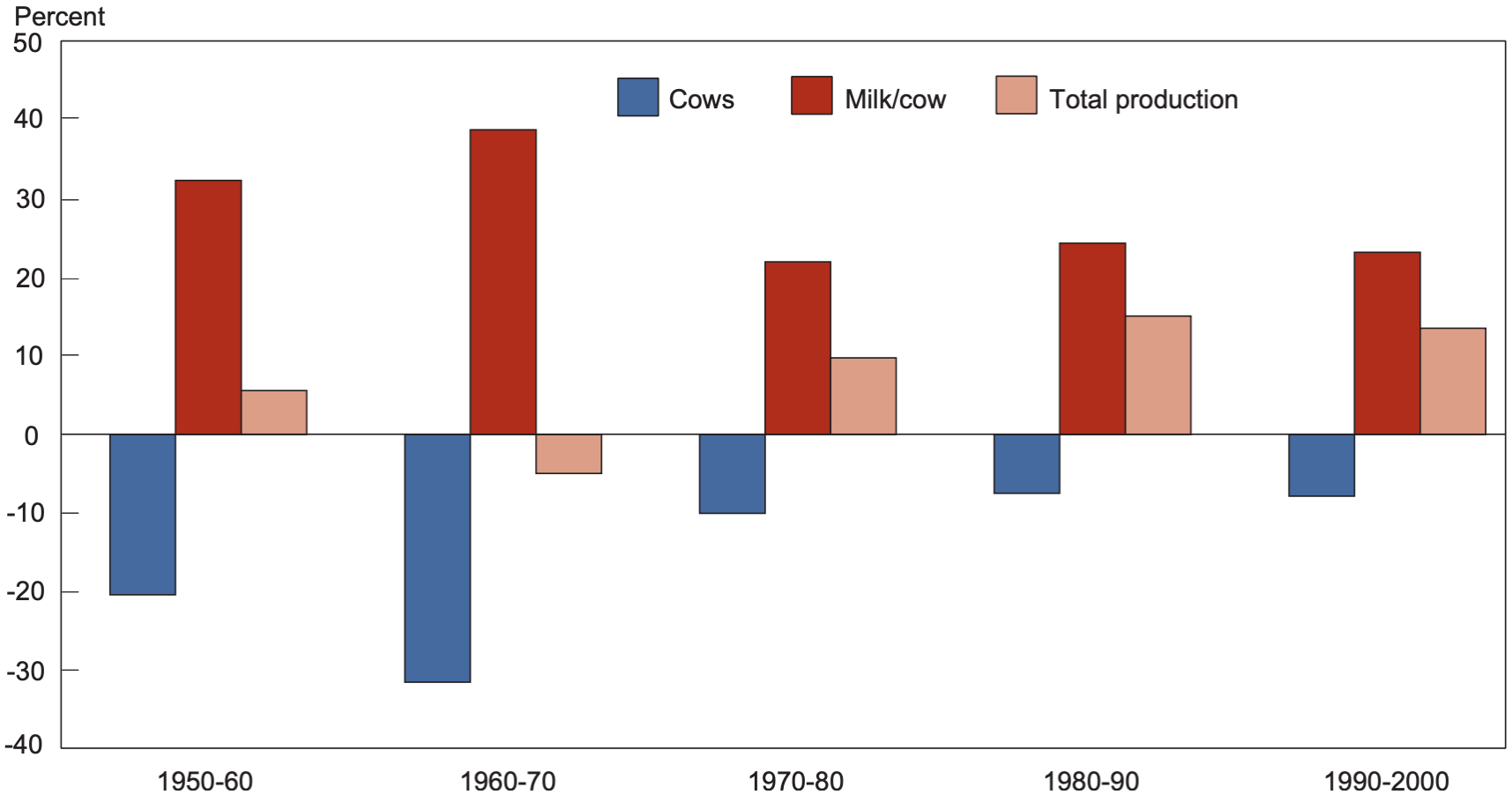
"**sustainable agriculture** [is] an integrated system of plant and animal production practices… that will, over the long term:

- Satisfy **human** food and fiber needs;
- Enhance **environmental quality** and the **natural resource** base upon which the agricultural **economy** depends;
- Make the most efficient use of **nonrenewable resources** and on-farm resources and integrate, where appropriate, **natural biological cycles** and controls;
- Sustain the **economic viability** of farm operations; and
- Enhance the quality of life for **farmers** and **society** as a whole"

WHAT IS SUSTAINABILITY

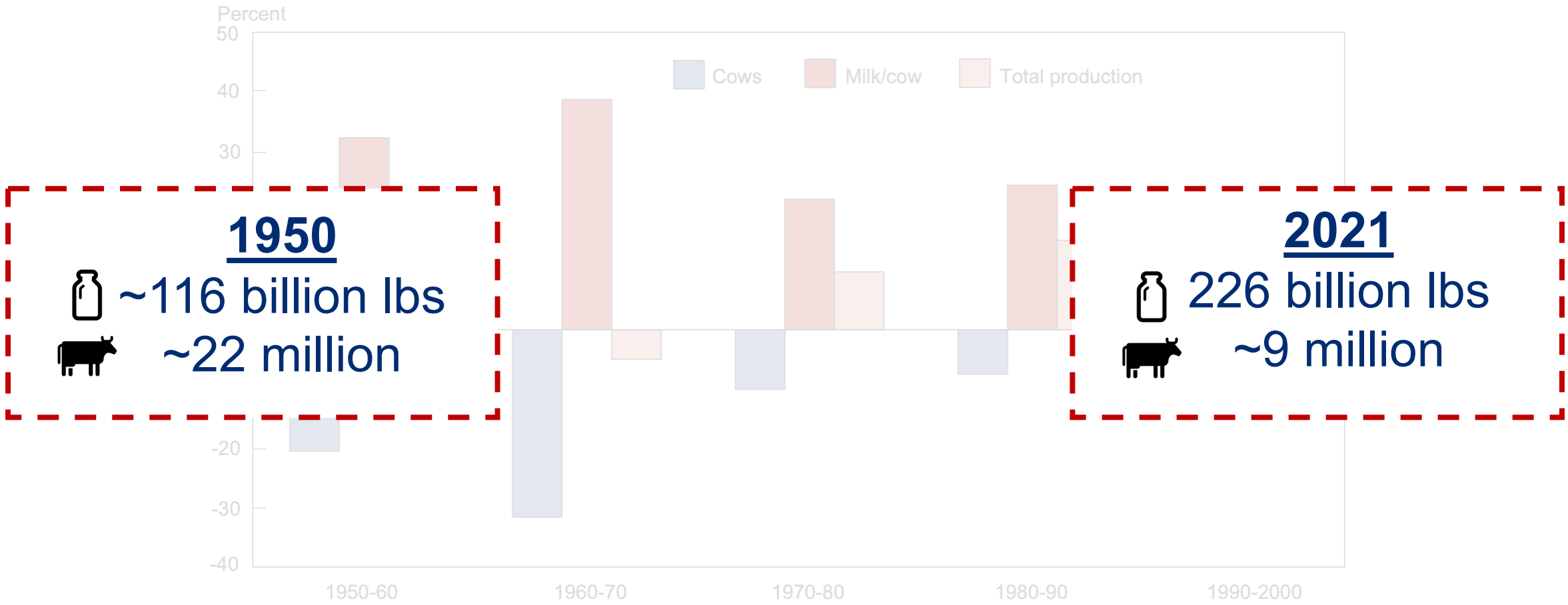


EFFICIENCY AS SUSTAINABILITY



Blayney (2002) USDA Statistical Bulletin 978
Hoard's Dairymen (2022) Monthly Milk Production

EFFICIENCY AS SUSTAINABILITY



1950
~116 billion lbs
~22 million

2021
226 billion lbs
~9 million

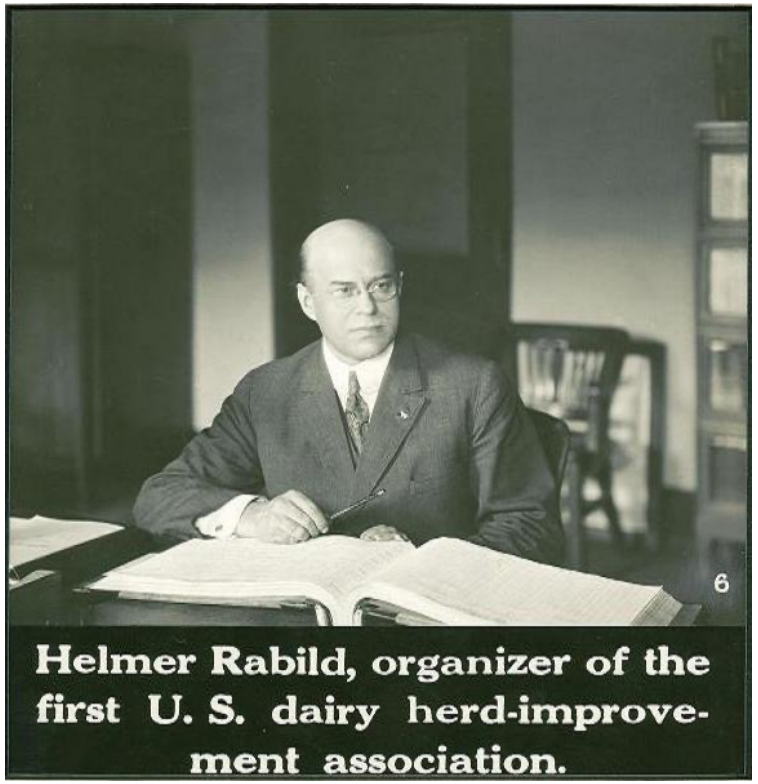
Blayney (2002) USDA Statistical Bulletin 978
Hoard's Dairymen (2022) Monthly Milk Production

FIRST, SOME HISTORY

1908 USDA Bureau of Animal Industry organized cow testing associations nationally

1915 Some bull associations calculated daughter-dam differences for their own bulls

1926 USDA calculated sire evaluations for 23 bulls and sent results directly to each bull's owner



https://aipl.arsusda.gov/aipl/history/hist_eval.htm

FIRST, SOME HISTORY

DAIRY HERD IMPROVEMENT RECORD

BUREAU OF DAIRY INDUSTRY, DEPT. OF AGRICULTURE

1935 Milk records available for ~2% of dairy cows

https://aipl.arsusda.gov/aipl/history/hist_eval.htm

FIRST, SOME HISTORY

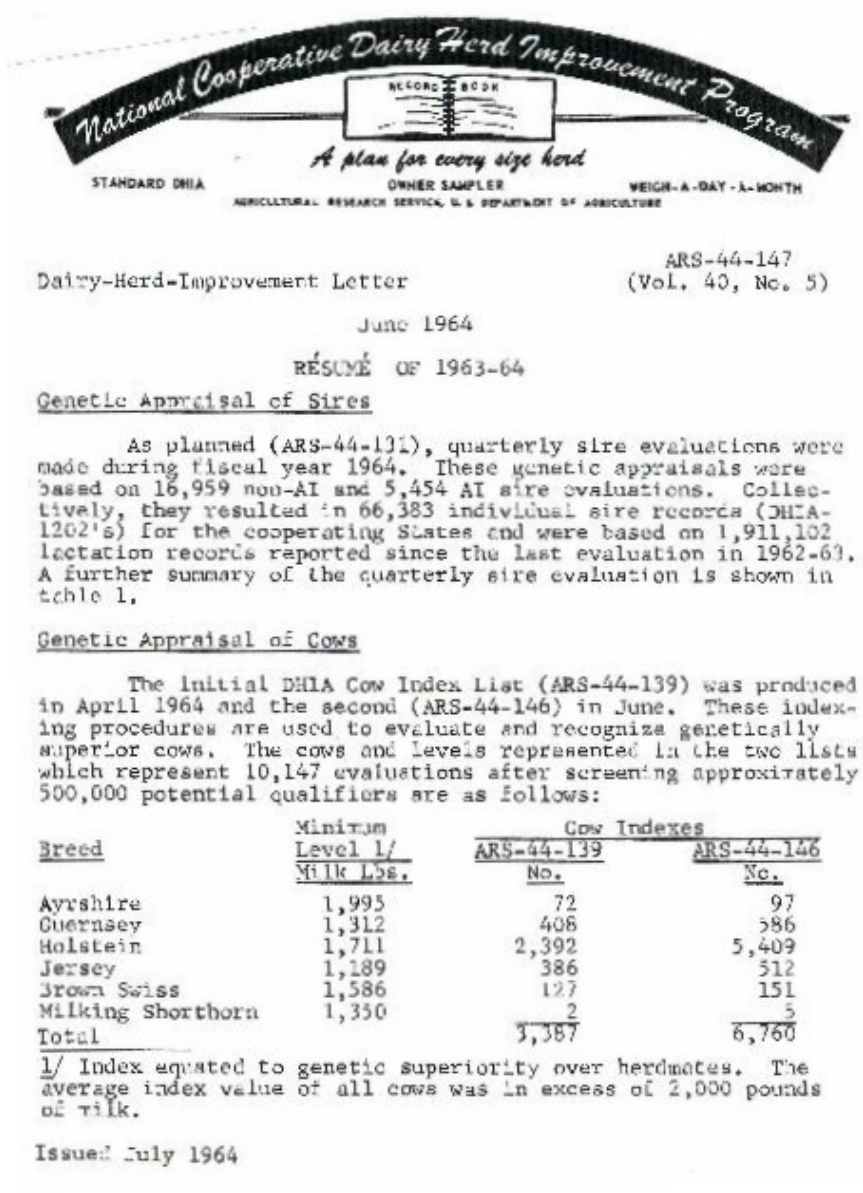
1962 Sire evaluations computed with herdmate comparison

1964 National evaluations replaced regional processing center evaluations

1989 Animal model implemented considering relationships among all cows and bulls

2009 First official genomic evaluations

2013 Calculation and distribution of evaluations transferred to Council on Dairy Cattle Breeding



National Cooperative Dairy Herd Improvement Program

A plan for every size herd

STANDARD DHIA OWNER SAMPLER WEIGH-A-DAY-A-MONTH

AGRICULTURAL RESEARCH SERVICE, U. S. DEPARTMENT OF AGRICULTURE

ARS-44-147
Dairy-Herd-Improvement Letter (Vol. 40, No. 5)

June 1964

RÉSUMÉ OF 1963-64

Genetic Appraisal of Sires

As planned (ARS-44-131), quarterly sire evaluations were made during fiscal year 1964. These genetic appraisals were based on 16,959 non-AI and 5,454 AI sire evaluations. Collectively, they resulted in 66,383 individual sire records (DHIA-1202's) for the cooperating States and were based on 1,911,102 lactation records reported since the last evaluation in 1962-63. A further summary of the quarterly sire evaluation is shown in table 1.

Genetic Appraisal of Cows

The initial DHIA Cow Index List (ARS-44-139) was produced in April 1964 and the second (ARS-44-146) in June. These indexing procedures are used to evaluate and recognize genetically superior cows. The cows and levels represented in the two lists which represent 10,147 evaluations after screening approximately 500,000 potential qualifiers are as follows:

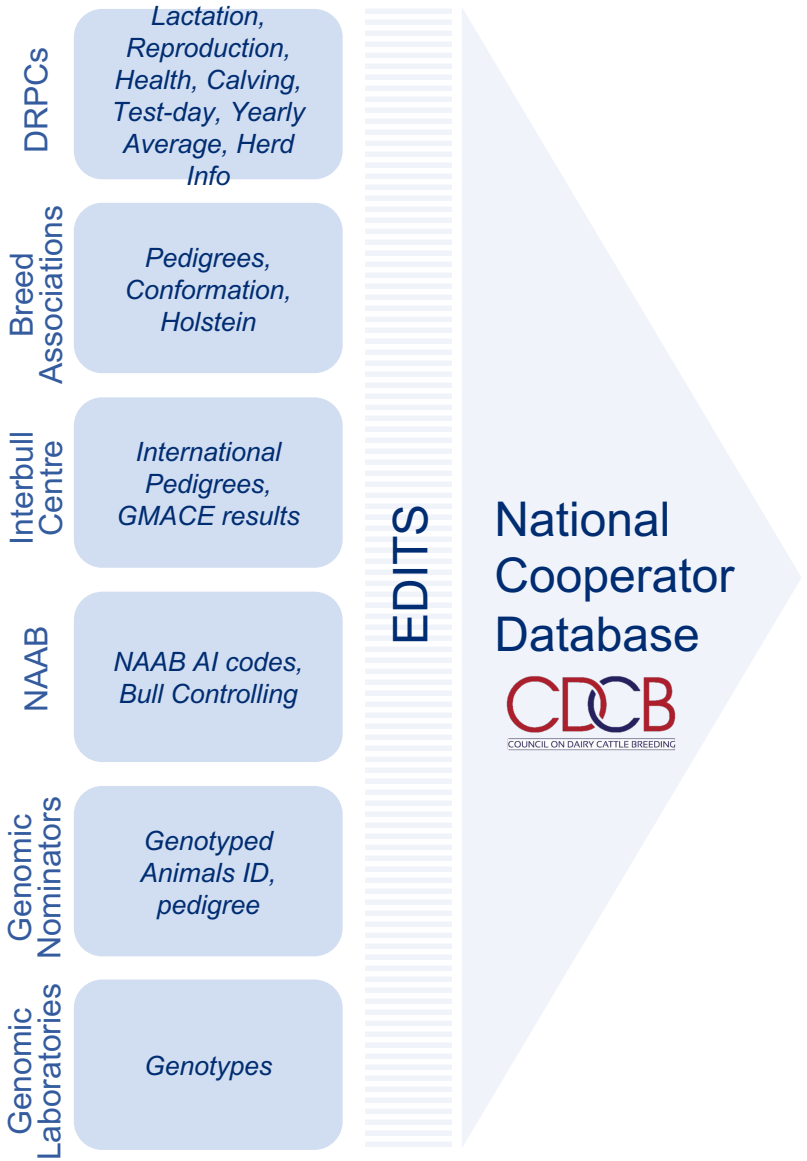
Breed	Minimum Level 1/ Milk Lbs.	Cow Indexes ARS-44-139 No.	Cow Indexes ARS-44-146 No.
Ayrshire	1,995	72	97
Guernsey	1,312	408	586
Holstein	1,711	2,392	5,409
Jersey	1,189	386	512
Brown Swiss	1,586	127	151
Milking Shorthorn	1,350	2	5
Total		3,387	6,760

1/ Index equated to genetic superiority over herdmates. The average index value of all cows was in excess of 2,000 pounds of milk.

Issued July 1964

2022 NATIONAL EVALUATION SYSTEM

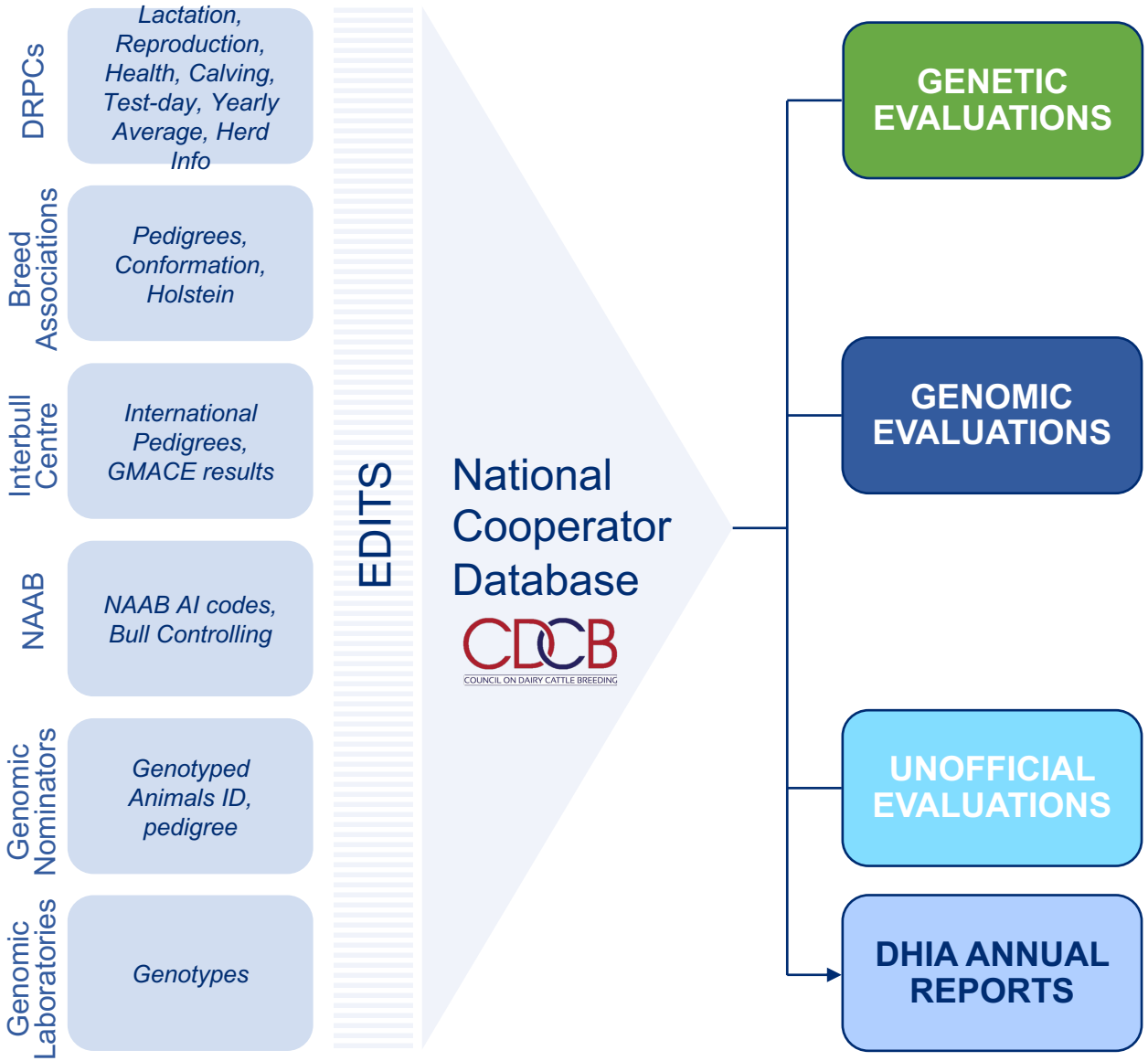
DRPCs	*Lactation, Reproduction, Health, Calving, Test-day, Yearly Average, Herd Info*
Breed Associations	*Pedigrees, Conformation, Holstein*
Interbull Centre	*International Pedigrees, GMACE results*
NAAB	*NAAB AI codes, Bull Controlling*
Genomic Nominators	*Genotyped Animals ID, Pedigree*
Genomic Laboratories	*Genotypes*



> 100 million LACTATIONS

> 90 million PEDIGREES

> 5 million GENOTYPES


DRPCs
Lactation, Reproduction, Health, Calving, Test-day, Yearly Average, Herd Info
Breed Associations
Pedigrees, Conformation, Holstein
Interbull Centre
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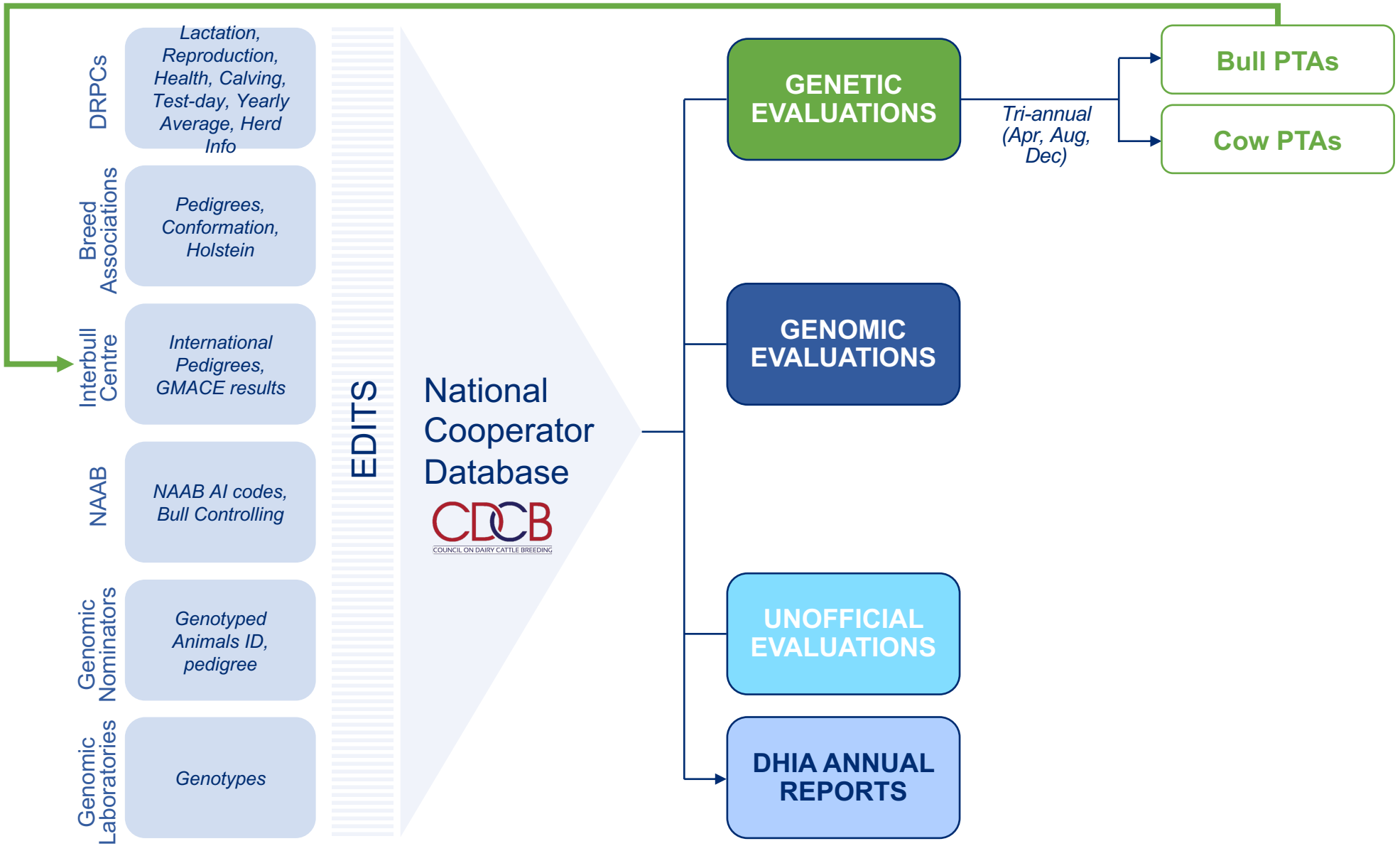
CDCB
COUNCIL ON DAIRY CATTLE BREEDING
GENETIC EVALUATIONS
GENOMIC EVALUATIONS
UNOFFICIAL EVALUATIONS
DHIA ANNUAL REPORTS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Tri-annual (Apr, Aug, Dec)
Bull PTAs
Cow PTAs
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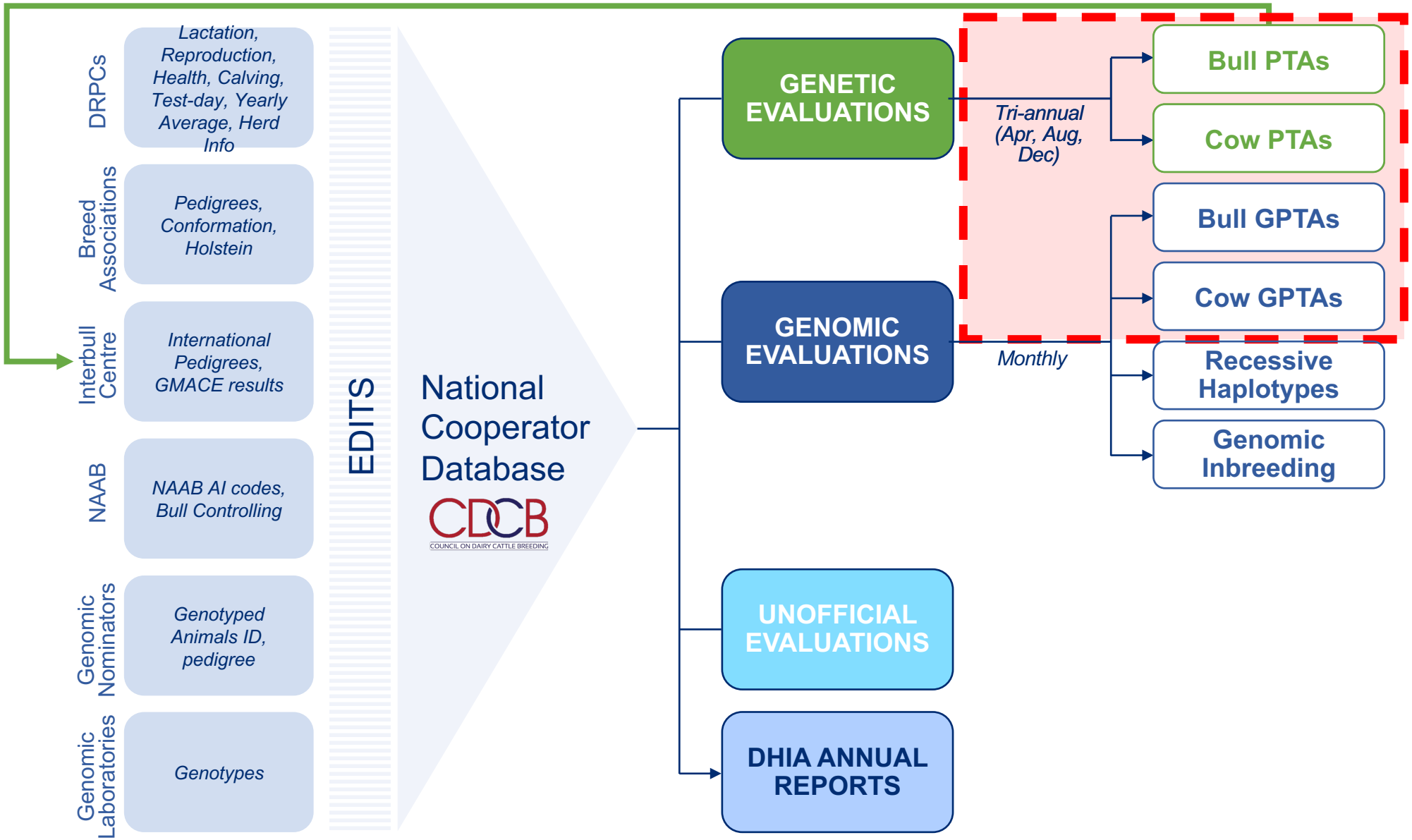
DHIA ANNUAL REPORTS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Monthly
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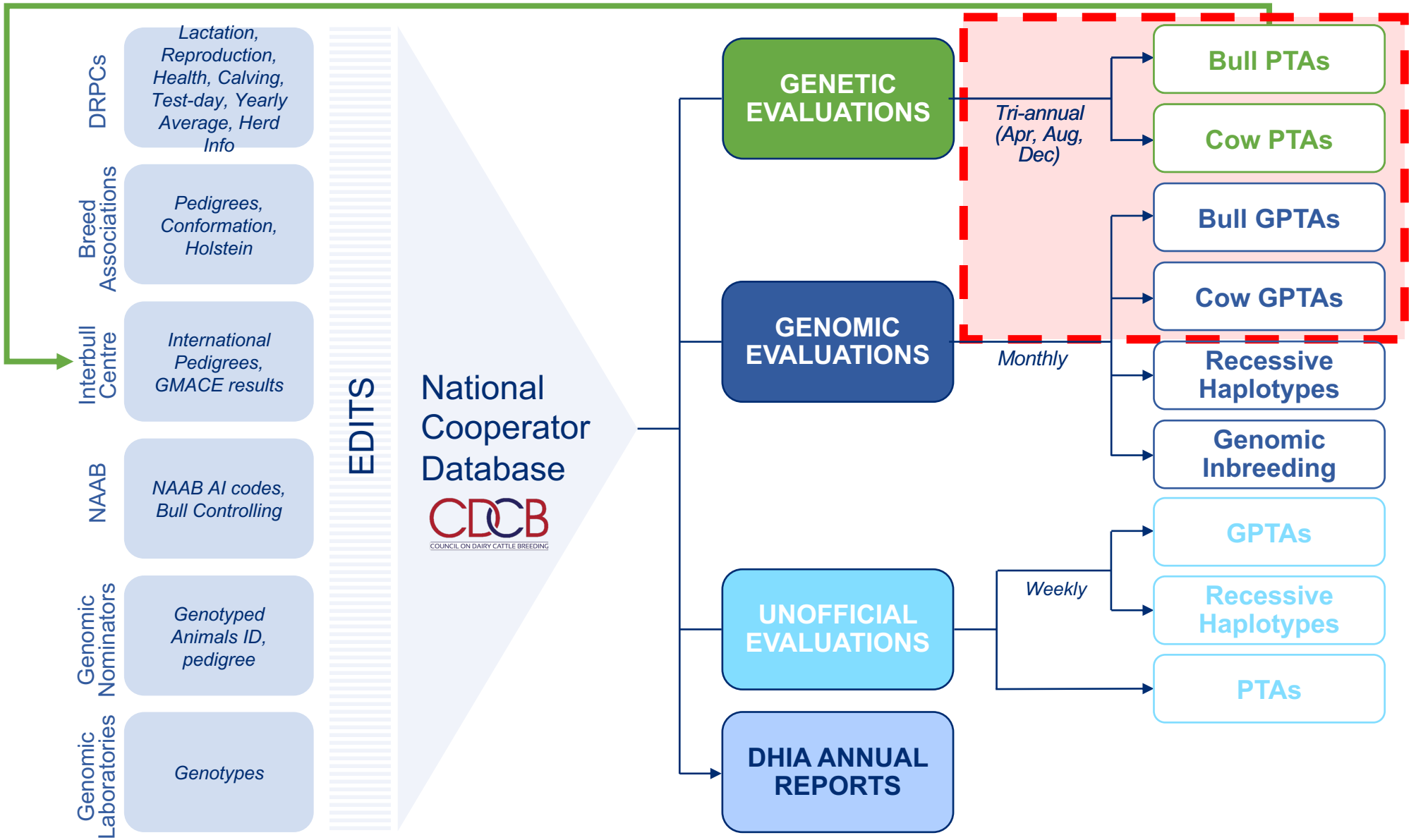
Cow PTAs
Bull GPTAs
Cow GPTAs
Recessive Haplotypes
Genomic Inbreeding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Weekly
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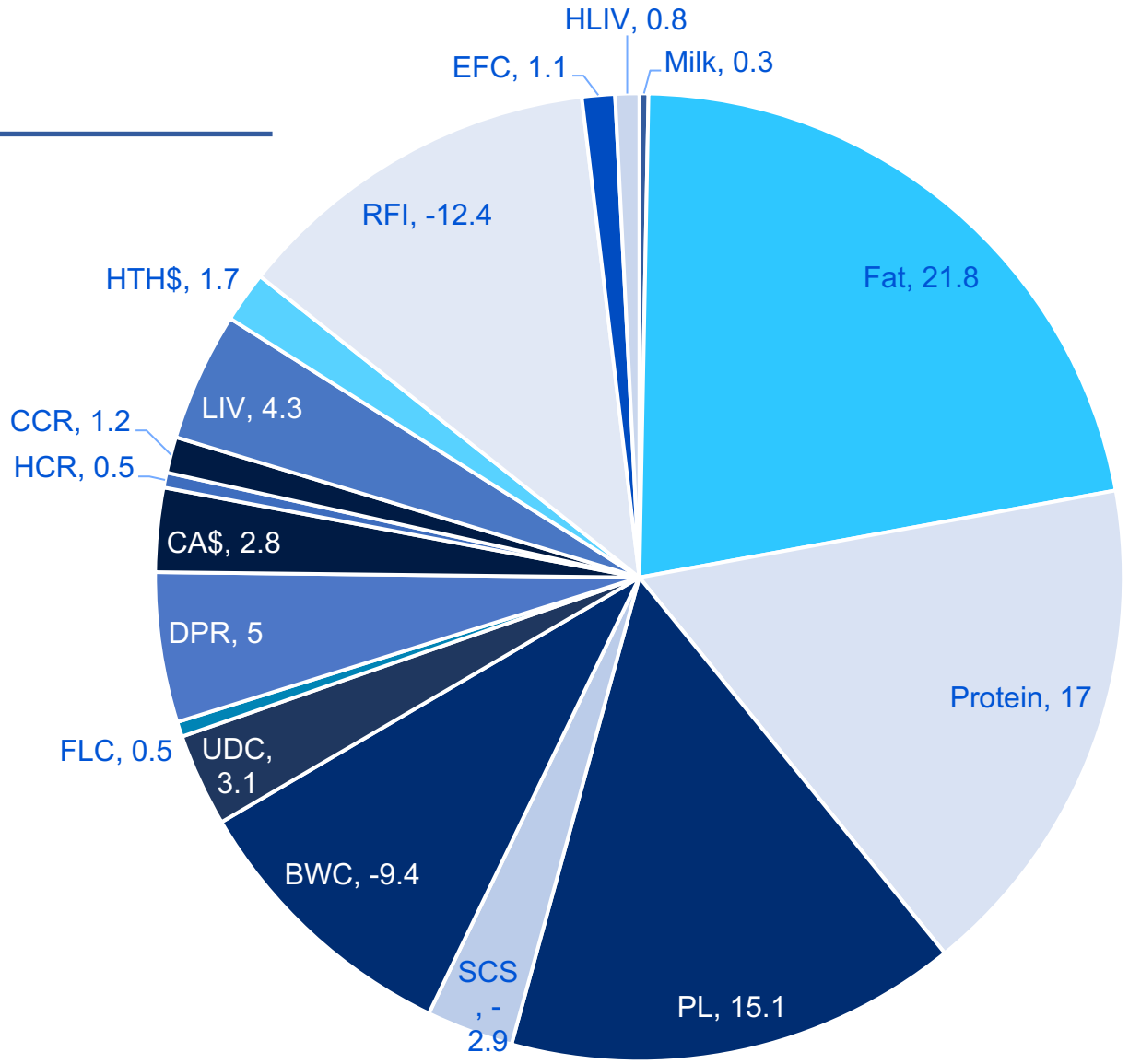
Cow PTAs
Bull GPTAs
Cow GPTAs
Recessive Haplotypes
Genomic Inbreeding
GPTAs
Recessive Haplotypes
PTAs

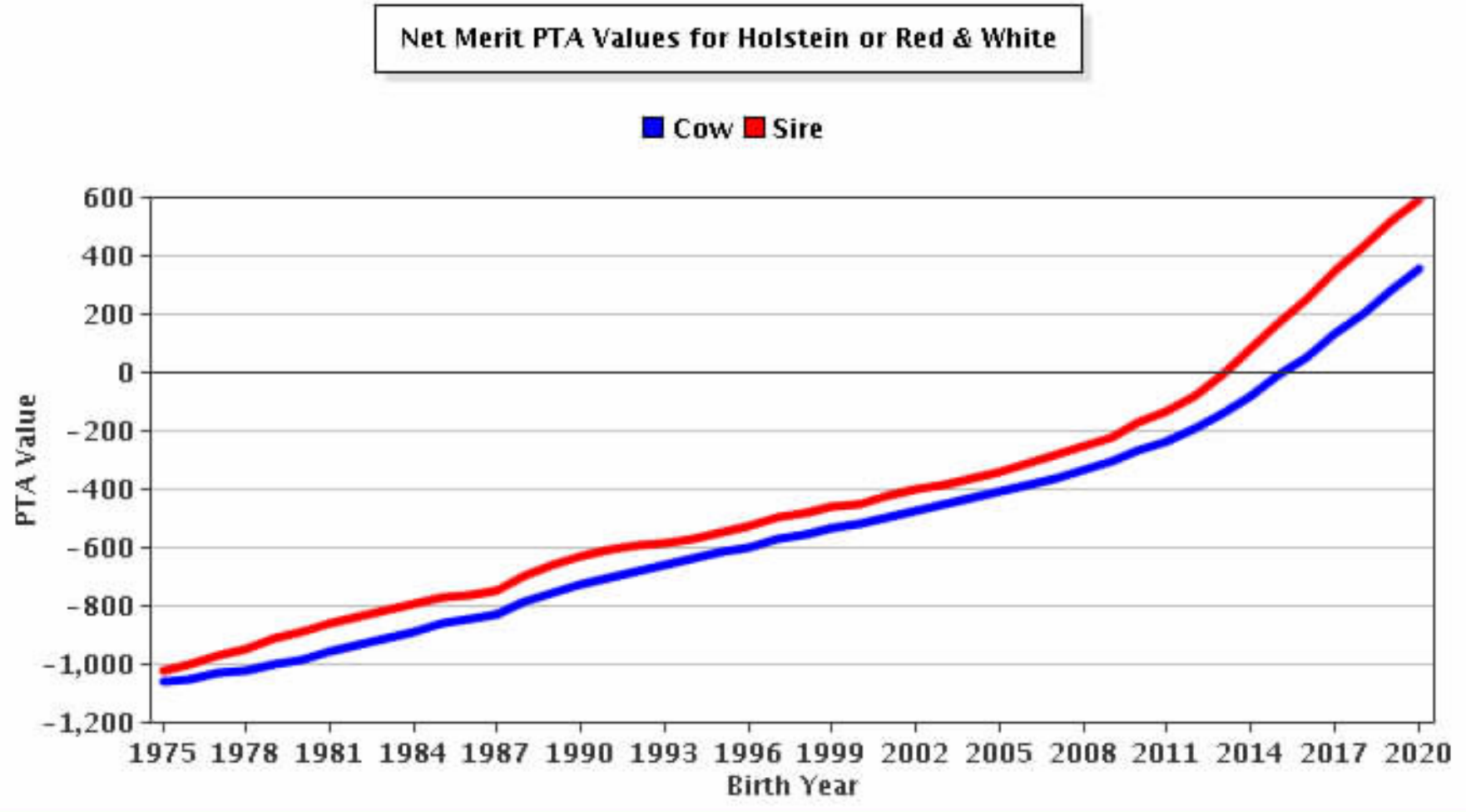
NET MERIT (NM$)

Relative values in 2021 NM$ for each:

Yield Traits
Productive Life
Somatic Cell Score
Body Weight Composite
Udder Composite
Feet/Legs Composite
Daughter Pregnancy Rate
Calving Ability
Heifer Conception Rate
Cow Conception Rate
Livability
Health Traits
Feed Saved
Early First Calving
Heifer Livability

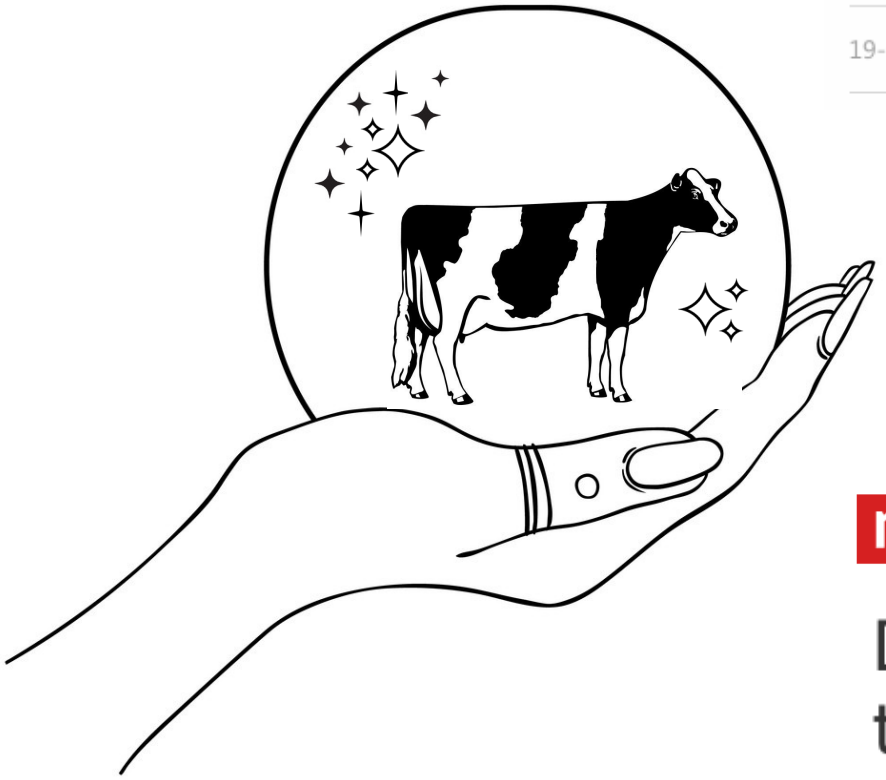


NET MERIT (NM$)



CDCB, Bovine Genetic Trends
https://queries.uscdcb.com/eval/summary/trend.cfm?R_Menu=HO.nm#StartBody

THE LONG GAME



DAIRY GLOBAL

Surviving high North American feed prices

19-08-2021 | Nutrition | Article

Rise of ethical milk: 'Mums ask when cows and their calves are separated'

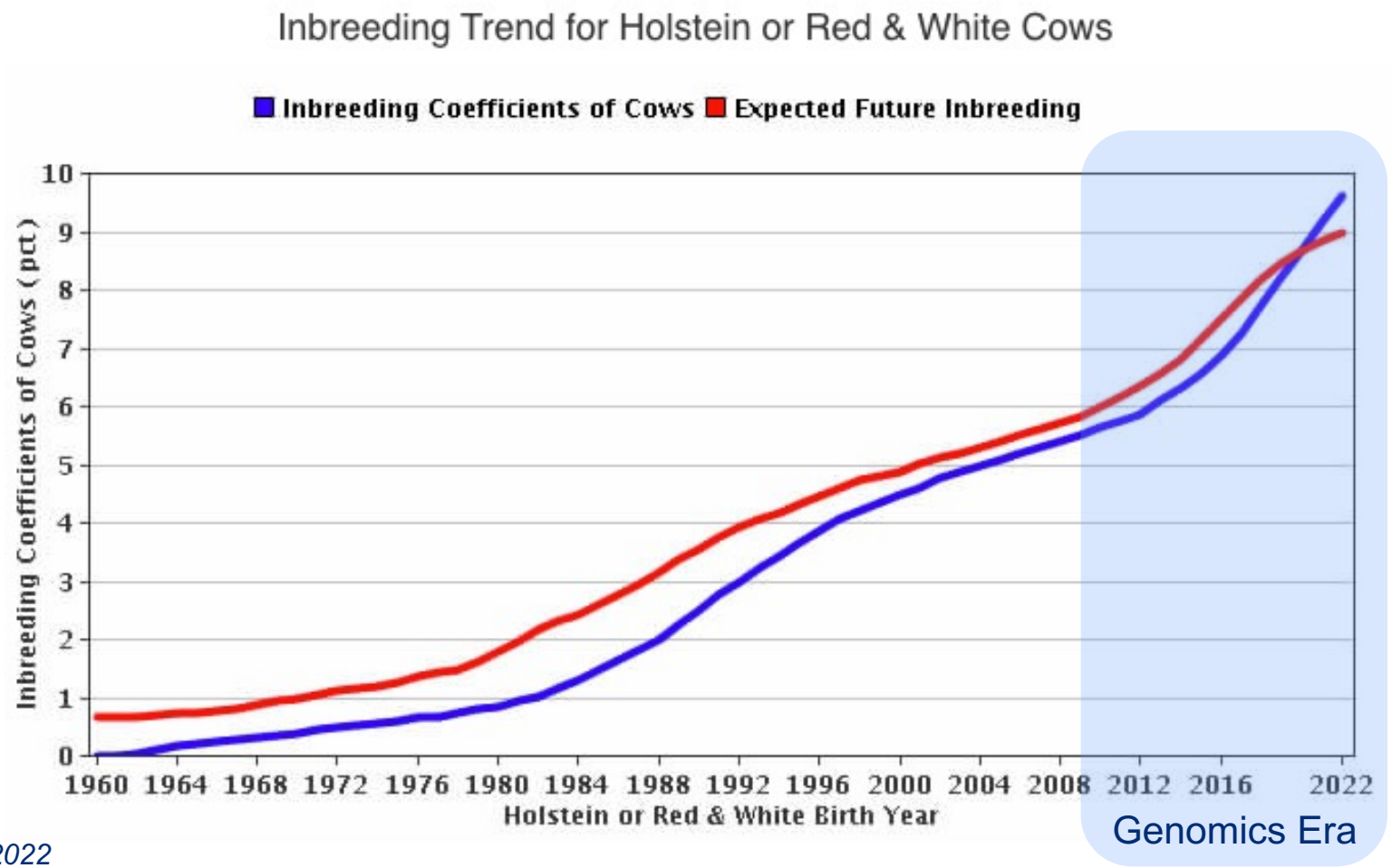
Search US edition
The Guardian
News website of the year

npr

Days of intense heat have killed thousands of cattle in Kansas

June 16, 2022 · 12:39 PM ET

PRESERVING GENETIC DIVERSITY



Council on Dairy Cattle Breeding, 2022
https://queries.uscdcb.com/eval/summary/inbrd.cfm

PRESERVING GENETIC DIVERSITY

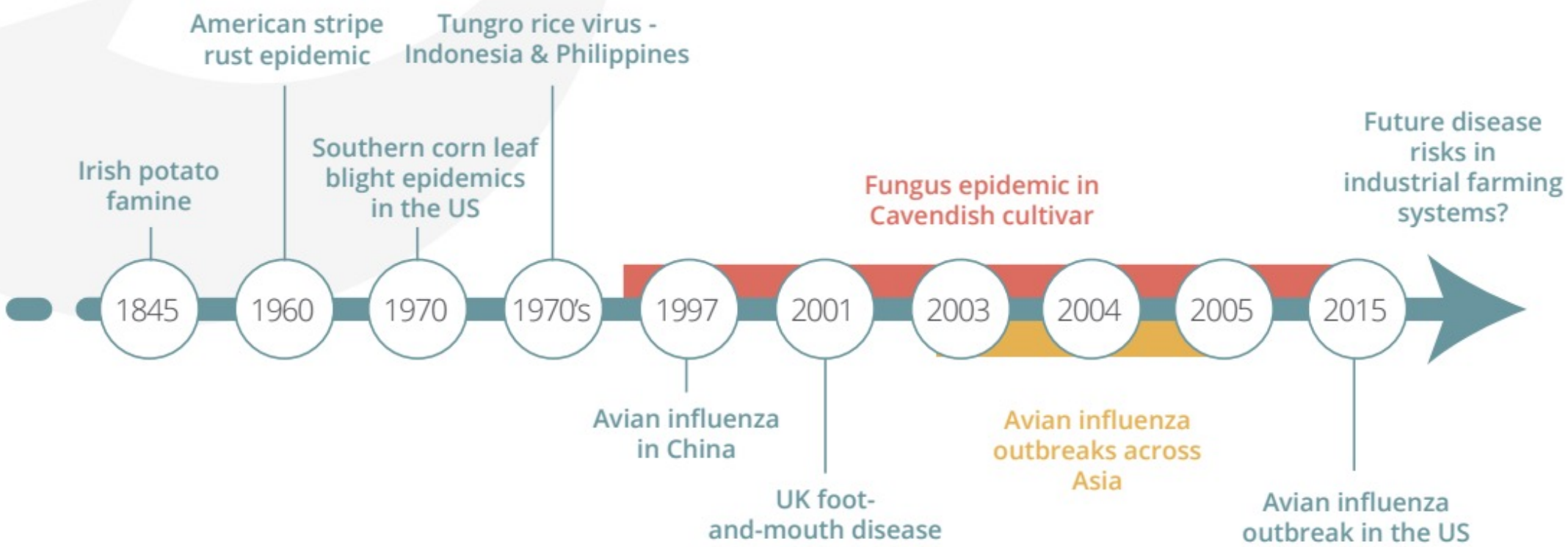
- **Inbreeding:** proportion of the genome that is identical due to shared ancestry
- **Inbreeding Depression:** decrease in fitness due to increased inbreeding
  - Harmful loci increase in frequency
  - Haplotypes like HH1

Breed	EFI
Ayrshire	7.0
Brown Swiss	7.2
Guernsey	7.9
Holstein	7.3
Jersey	7.9
Milking Shorthorn	4.5

Council on Dairy Cattle Breeding, 2022
https://webconnect.uscdcb.com/#/summary-stats/breed-means-bases-heterosis-inbreeding-regressions

PRESERVING GENETIC DIVERSITY

FIGURE 3 - A TIMELINE OF DISEASE OUTBREAKS IN HIGHLY-SPECIALIZED SYSTEMS



International Panel of Experts on Sustainable Food Systems
https://www.ipes-food.org/_img/upload/files/UniformityToDiversity_FULL.pdf

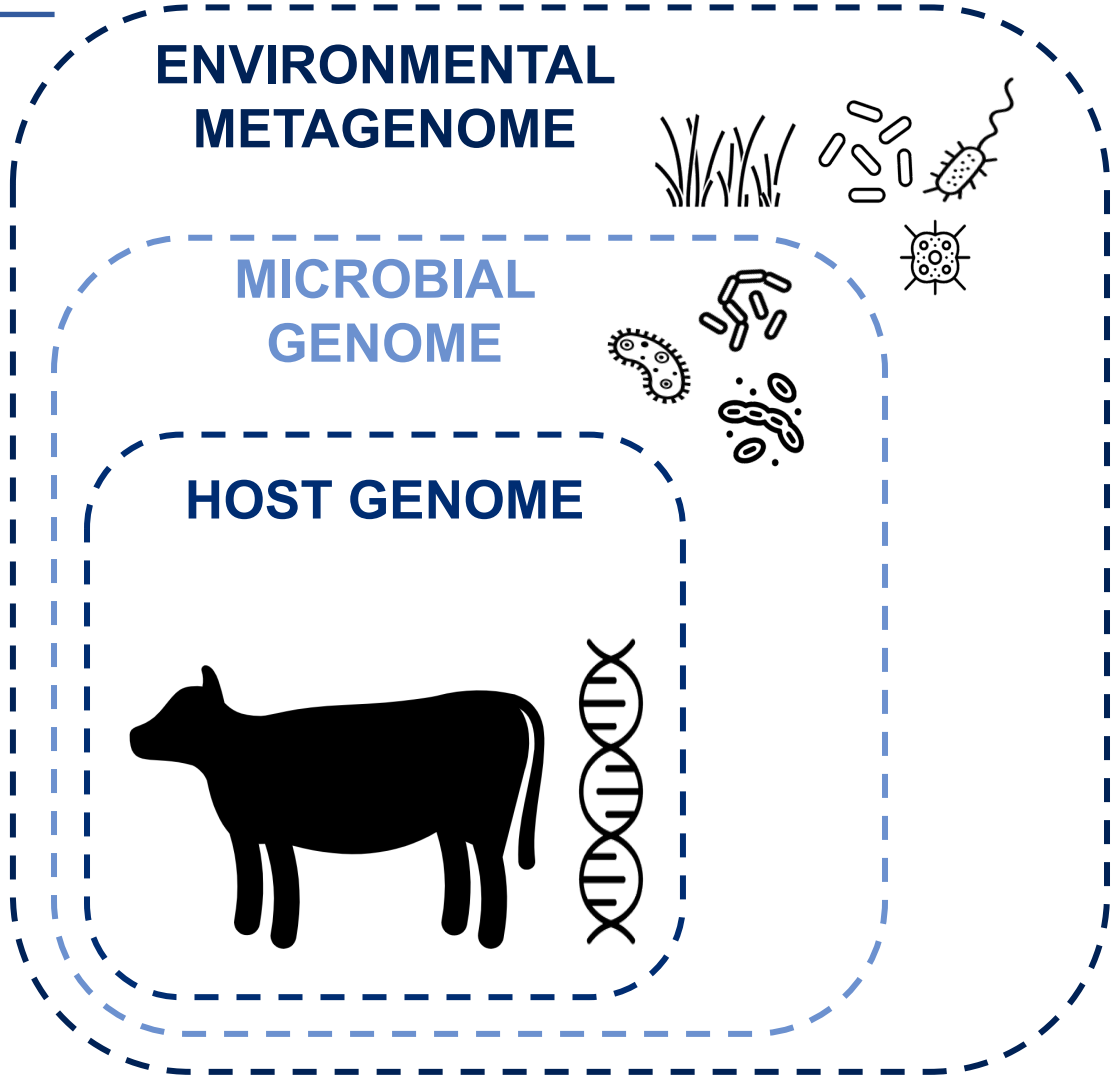
PRESERVING GENETIC DIVERSITY

- Inbreeding is unavoidable, but can be managed!
- Male genetic variation is very limited
- We must conserve female genetic diversity
    - Out-crossing
    - Cross-breeding

Pawnee Farm Arlinda Chief (above)

Round Oak Rag Apple Elevation (above)

LEVERAGING THE MICROBIOME



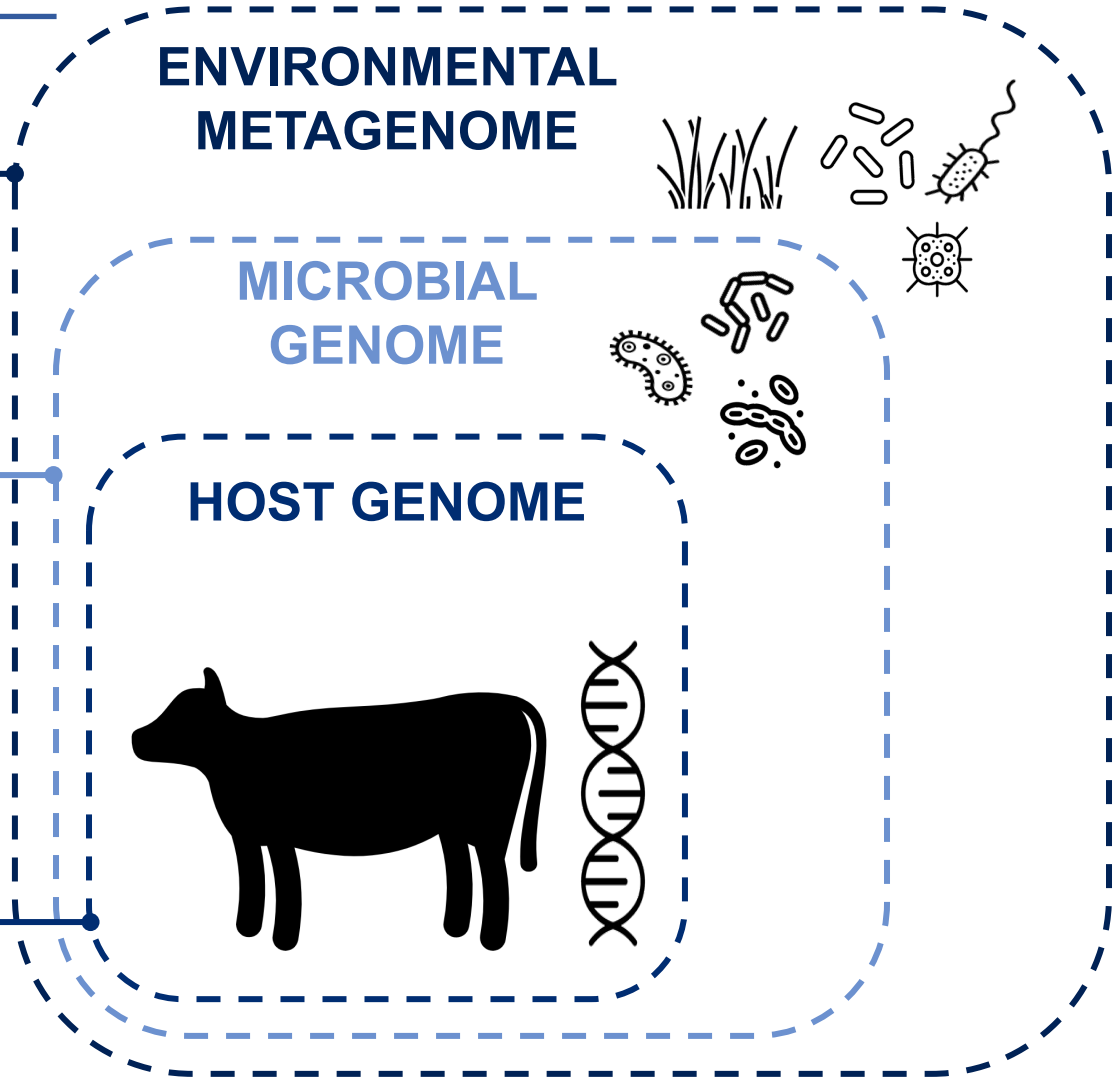
LEVERAGING THE MICROBIOME

Management
Nutrition

Thousands of genomes

- Diet variations
- Hormonal changes
- Circadian rhythms

One genome



LEVERAGING THE MICROBIOME

BUT….

- The goal of genomic selection is to maximize the amount of information that can be predicted at birth from the same, inexpensive DNA sample
  - Costs of mass-phenotyping microbiomes
  - Data standardization and flow

- Microbiome insights may be more practical for on-farm interventions than genomic selection

LEVERAGING THE MICROBIOME

- Taxonomic composition varies over lifetime and by physiological state
- Multiple bugs can produce the same effect

"It's the song, not the singer"
(Doolittle & Booth 2017)

Biochemical functions are more conserved

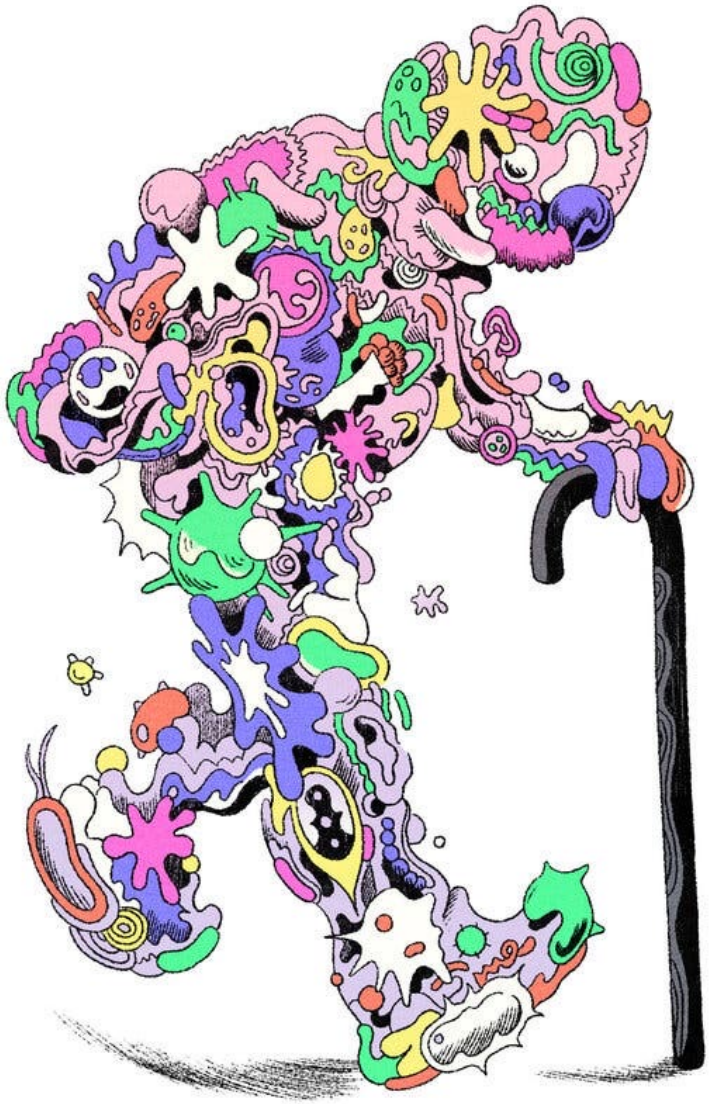
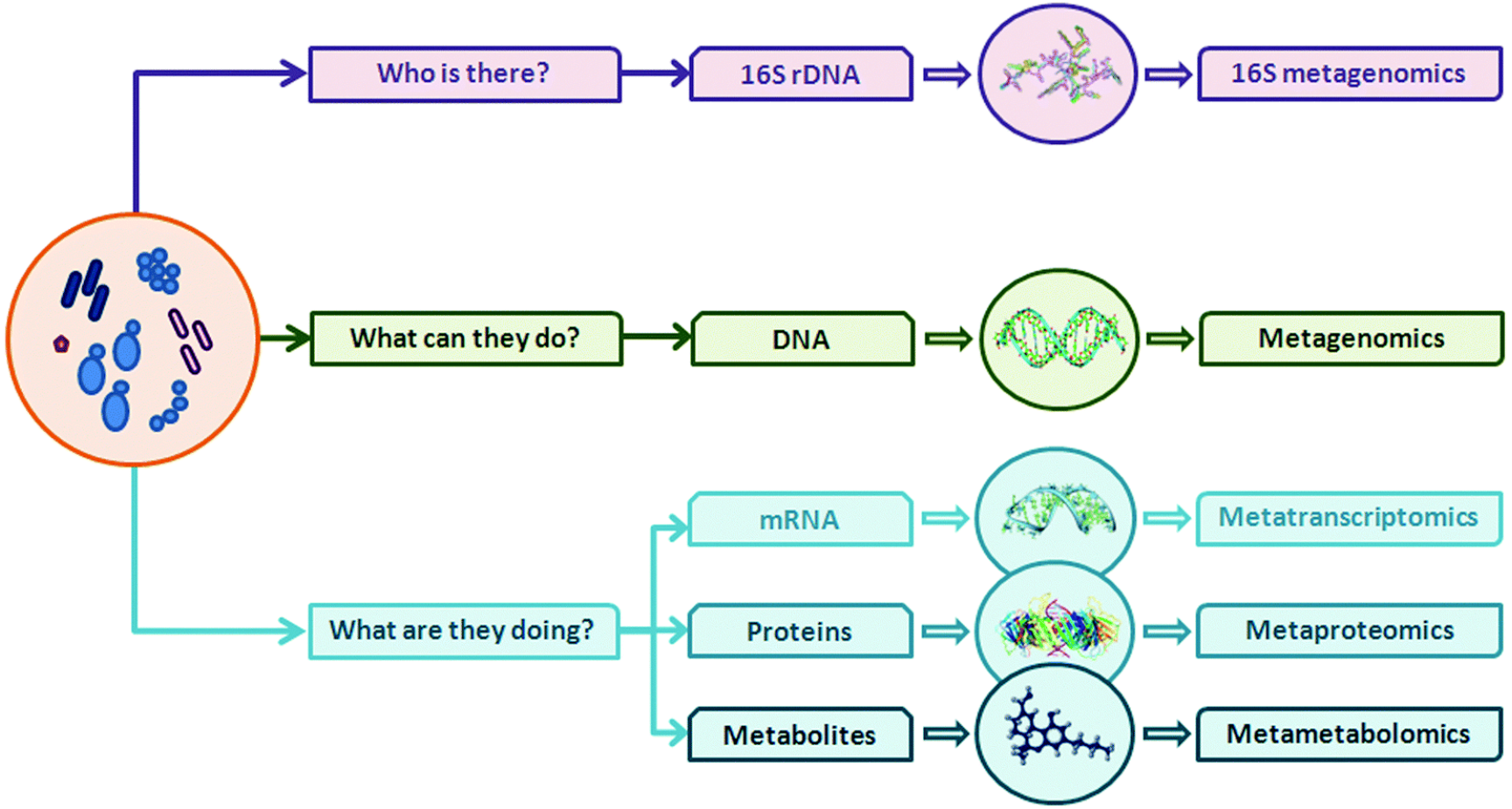


Image: NY Times (2021) "A Changing Gut Microbiome May Predict How Well You Age"

LEVERAGING THE MICROBIOME

We should select on molecular signatures for greater impact

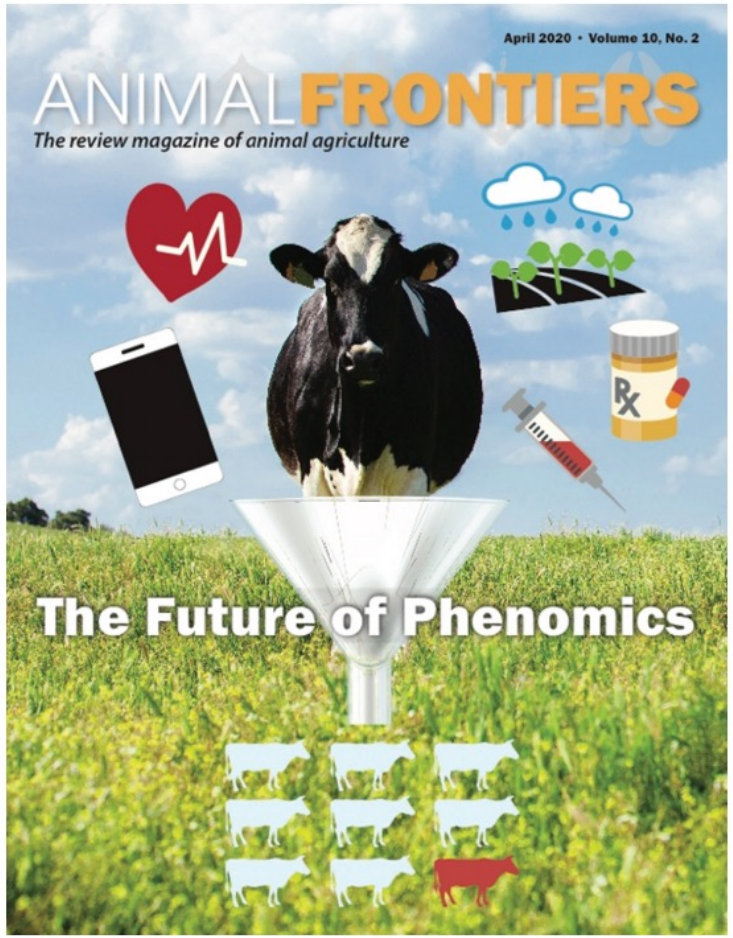


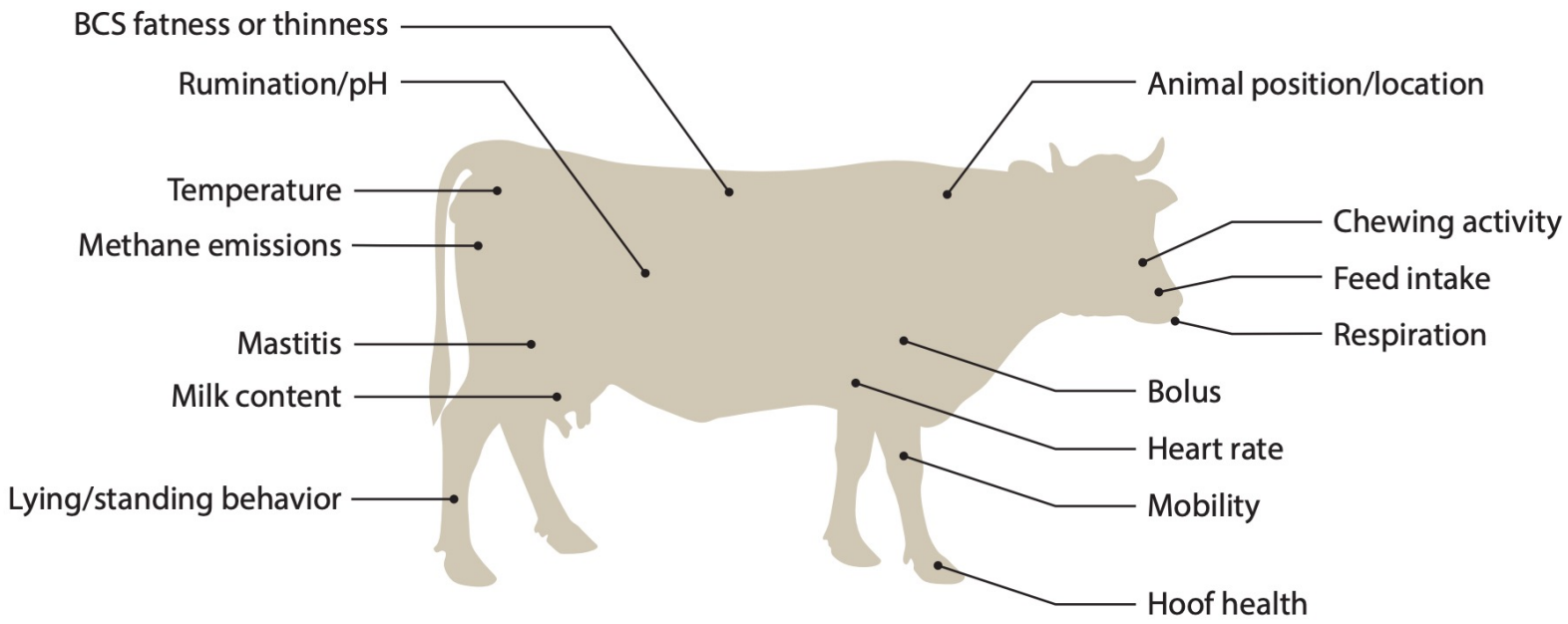
Addis et al., 2013

NEW SUSTAINABILITY TRAITS

- HEAT STRESS
- FEED EFFICIENCY
- METHANE EMISSIONS
- MICROBIOME
- ORGANIC SYSTEMS
- GRAZING SYSTEMS
- ROBOTIC SYSTEMS

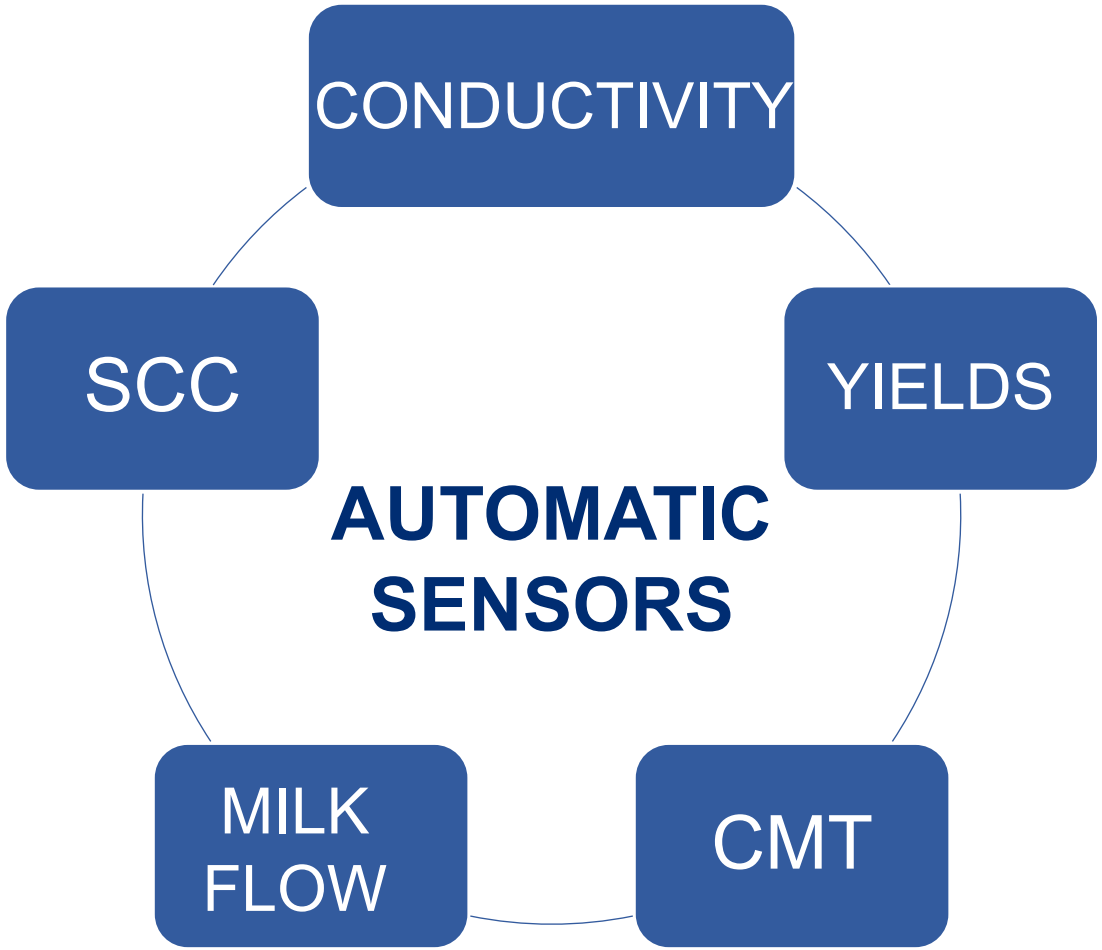
HIGH-THROUGHPUT PHENOTYPING





Halachmi et al 2019

HIGH-THROUGHPUT PHENOTYPING



These are very useful for management decisions:

- Monitoring subclinical mastitis
- Managing bulk tank SCC
- Culling
- Selective dry therapy

HIGH-THROUGHPUT PHENOTYPING

- No standard data definitions or SOPs
- No standard validation, maintenance, or calibration protocols
- System bias and individual sensor bias
- Animal ID: phenotype mismatches
- Non-representative sampling
- Data storage, flow, quality control & assurance

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- No standards exist for sharing sensor-generated data
- Frequent software and technology updates could limit use and disrupt data flow
- Some companies plan to own sensor-generated data
- Currently, CDCB offers data stewardship but sole ownership and rights pertaining thereto remain with producer

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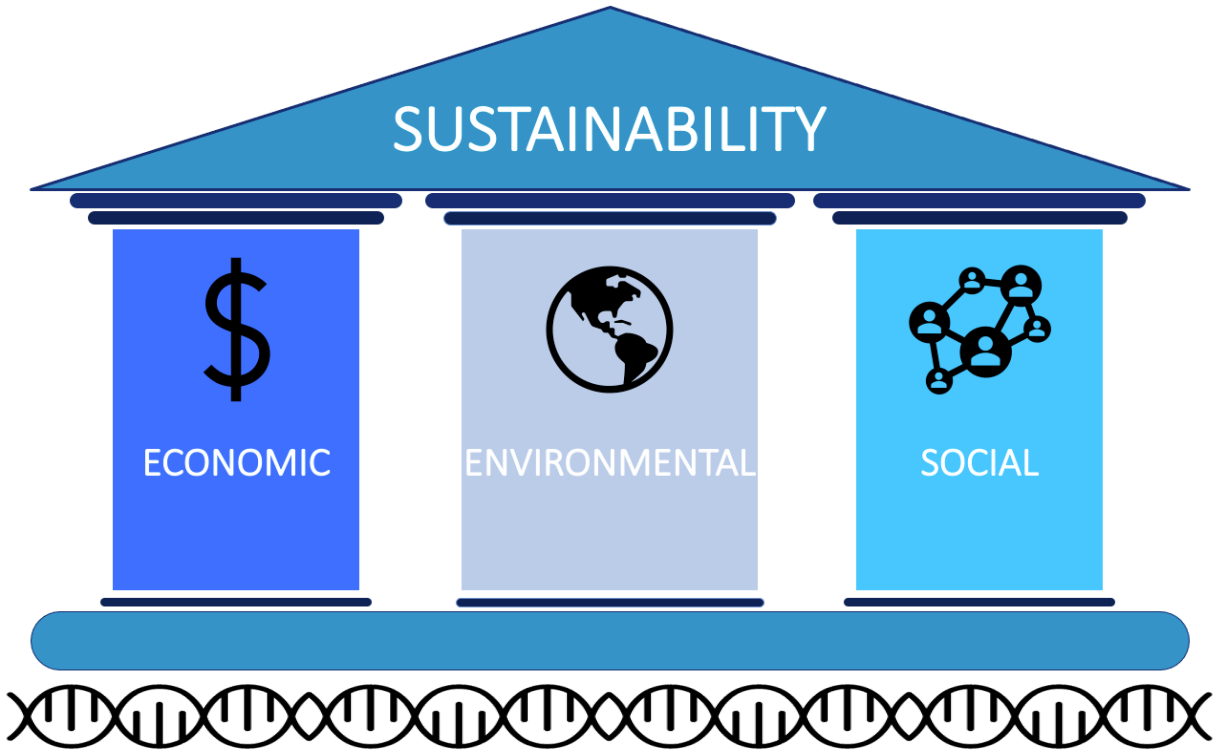
1. How can we standardize it?

2. Who can use it?



Key Messages

- Sustainability breeding goals should support the balance environmental, economic, and social needs
- Preserving genetic diversity must be a top priority
- High-throughput phenotyping represents a big opportunity to measure new traits impacting sustainability
- Big data standardization and sharing protocols need to be established

THANK YOU

Data were available to the authors from CDCB under USDA Agricultural Research Service Material Transfer Research Agreement #58-8042-8-007. While CDCB offers data stewardship, sole ownership and rights pertaining thereto remain with the producer and we thank U.S. dairy producers for sharing their data for research use. Special thanks to Duane Norman of CDCB for his review and feedback on this research.

This work was supported by USDA-ARS project 8042-31000-002-00-D, “Improving Dairy Animals by Increasing Accuracy of Genomic Prediction, Evaluating New Traits, and Redefining Selection Goals”

Contact: asha.miles@usda.gov