Modern Research and Modern Tools to Match Cattle Genetics to the Environment

Jared Decker
Wurdack Chair of Animal Genomics
University of Missouri

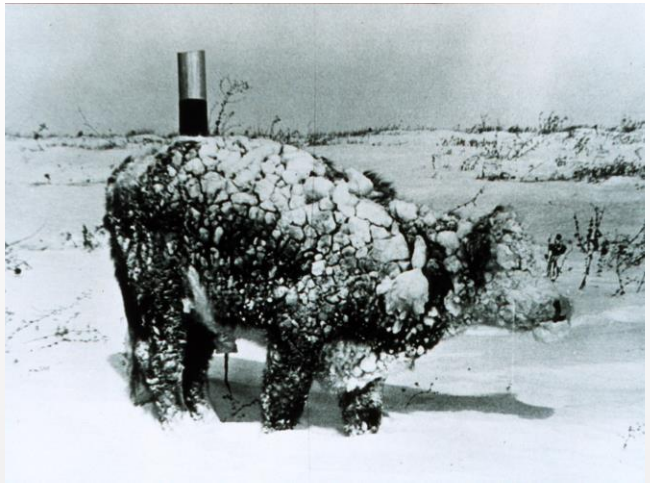
Matching Cattle Genetics to the Environment

Measure and predict the *correct* traits *directly* connected to the *biology* of environmental stress

Matching Cattle Genetics to the Environment

Is it a worthwhile goal???

Genetics and Environment



Environmental stressors cost the beef industry ~$1 Billion per year

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Research from 1960s

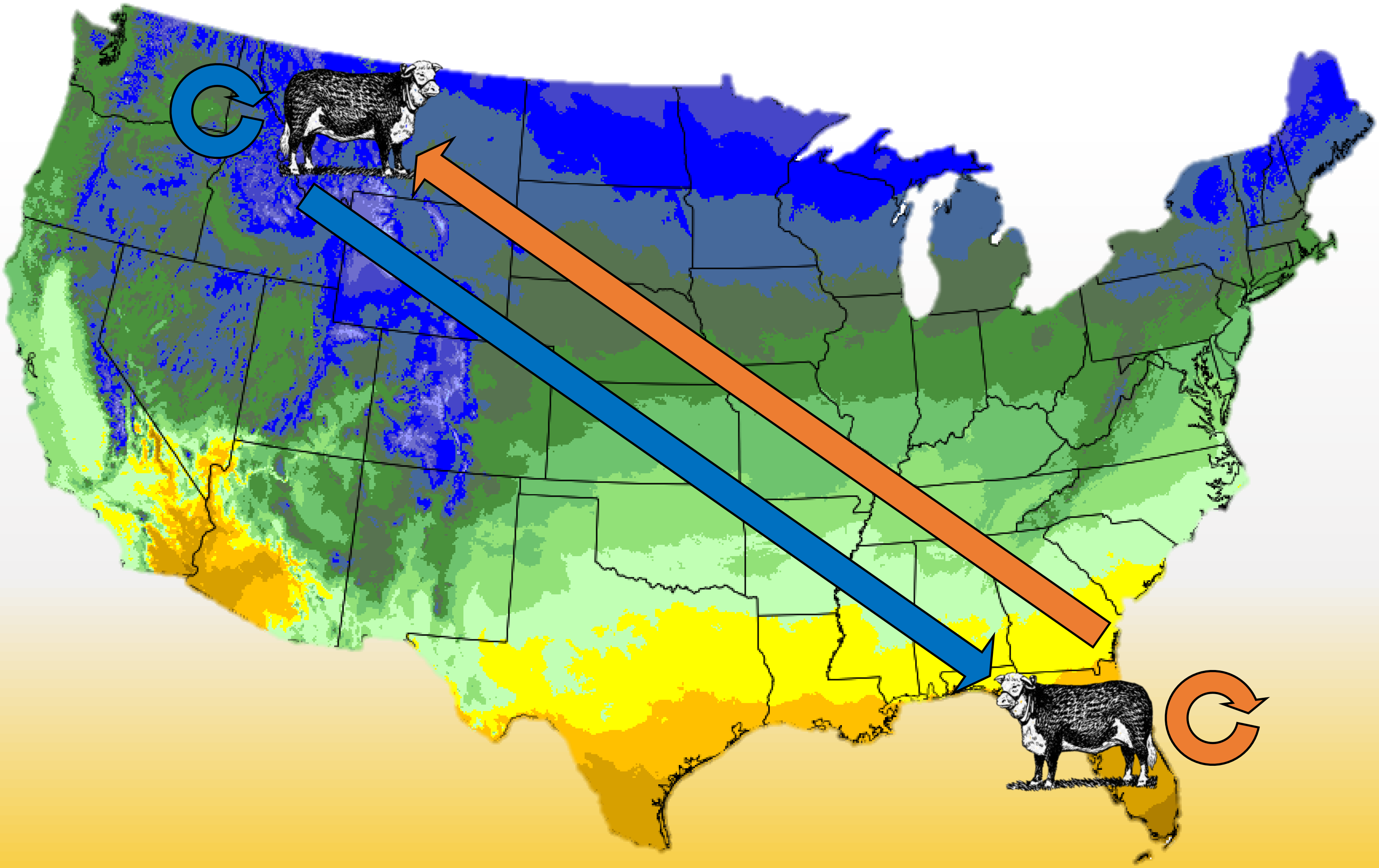

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TABLE 4. REPRODUCTIVE PERFORMANCE OF LINES M_1 AND F_4 AT EACH OF THE TWO LOCATIONS DURING PHASE 2 OF THE STUDY

Group or item	No. of matings	Pregnancy rate, %	Calf survival, %	Weaning rate, %
Subgroups				
M_1 in MT	398	83.0 ± 2.2	90.5 ± 1.9	75.1 ± 2.2
F_4 in MT	93	80.9 ± 4.3	86.8 ± 3.7	70.2 ± 4.7
M_1 in FL	98	55.0 ± 4.1	86.8 ± 4.4	47.7 ± 4.5
F_4 in FL	370	76.1 ± 2.2	89.1 ± 2.0	67.8 ± 2.3

21 to 28 percentage points lower than the other subgroups!!!

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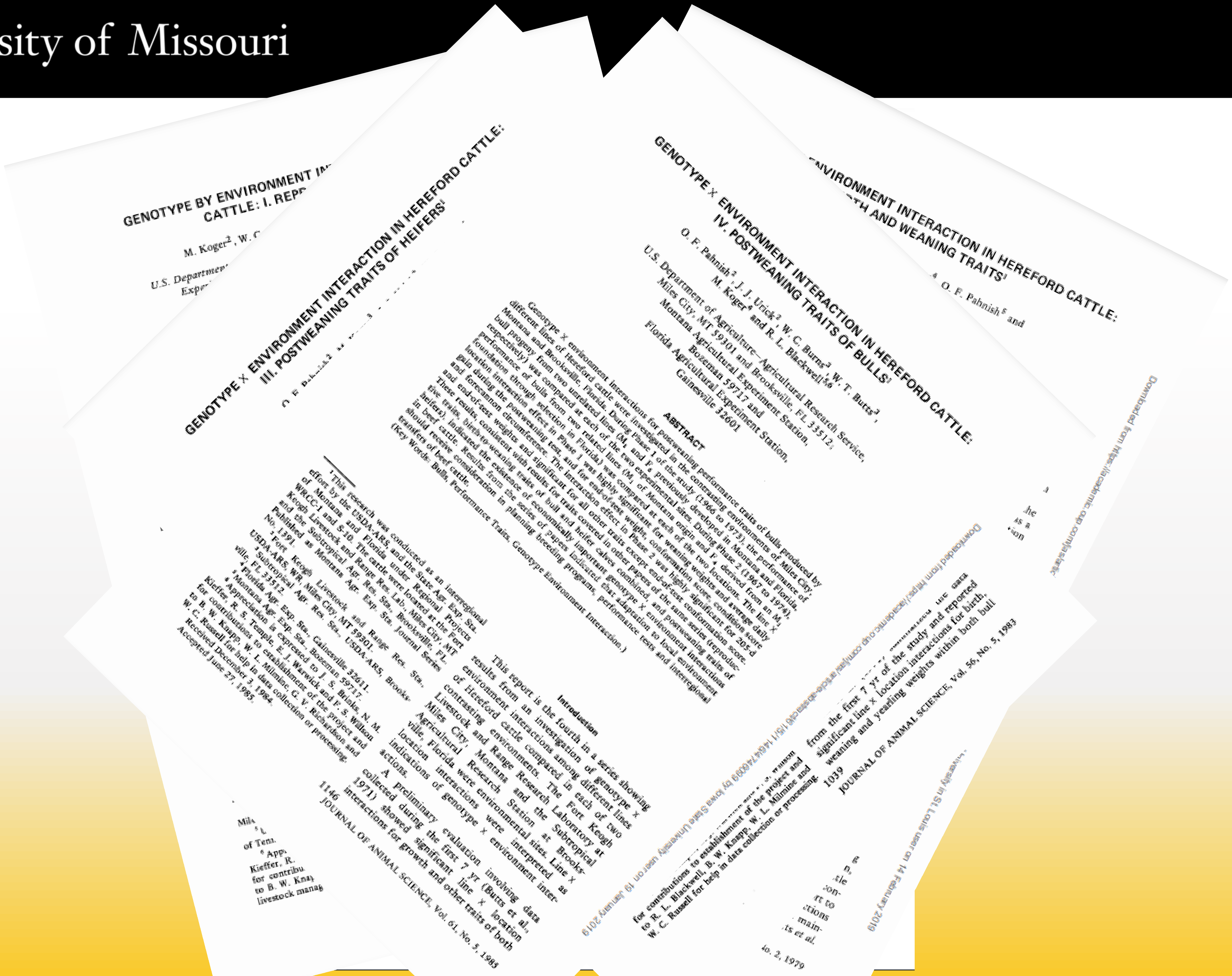

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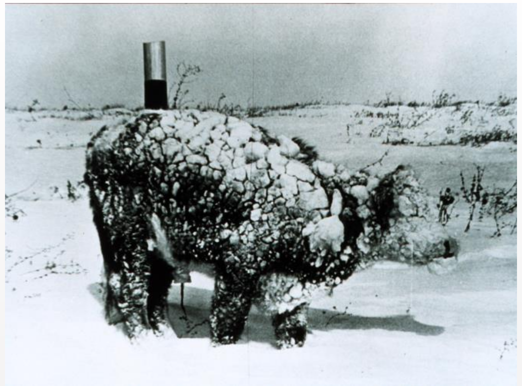
United States Department of Agriculture
National Institute of Food and Agriculture

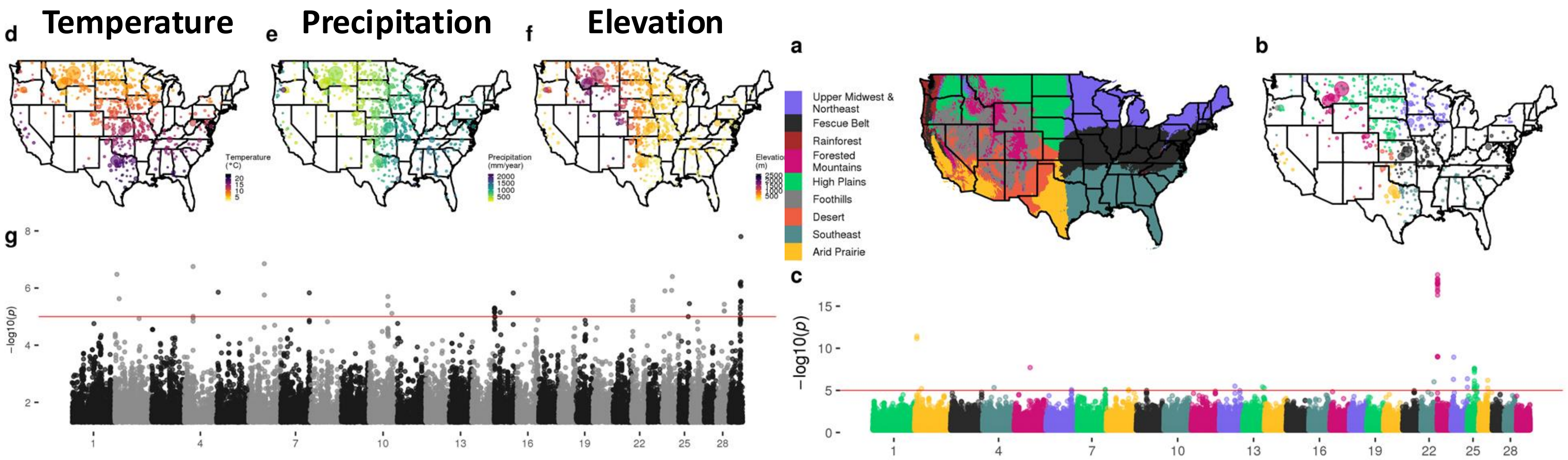


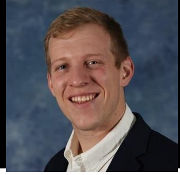
Funding from 3 USDA Grants

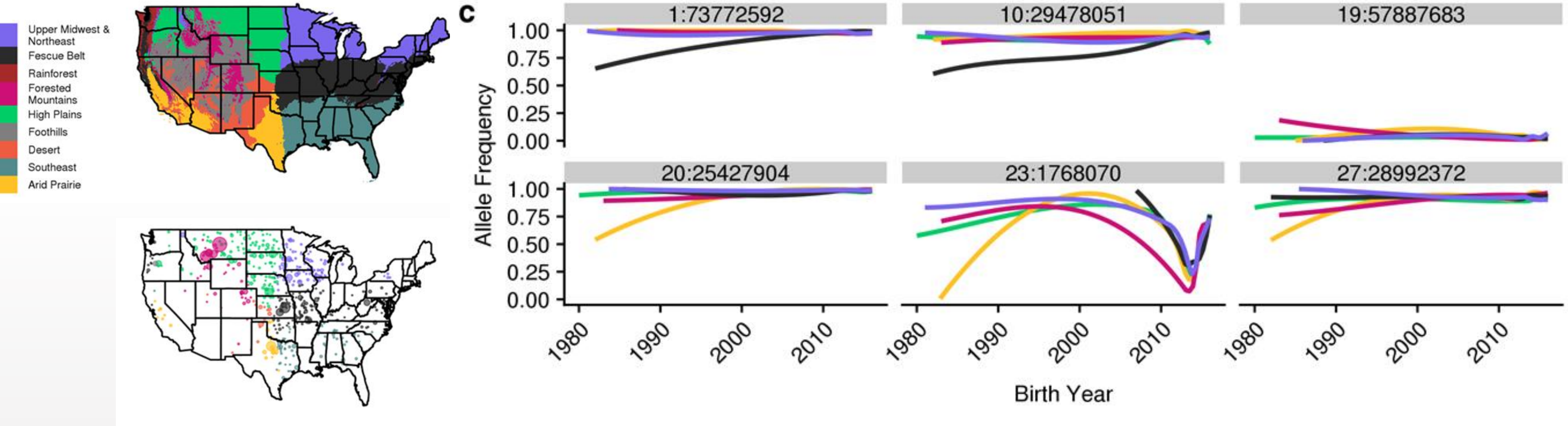
Environmental Interactions

In GxE growth trait GWAS or environmental adaptation scans

- Blood vessel constriction/dilation
- Metabolism
- Immunity







We find dozens of loci associated with environmental selection in cattle. However, most allele frequencies are converging to the breed average.

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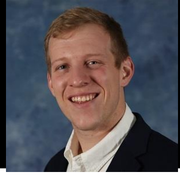
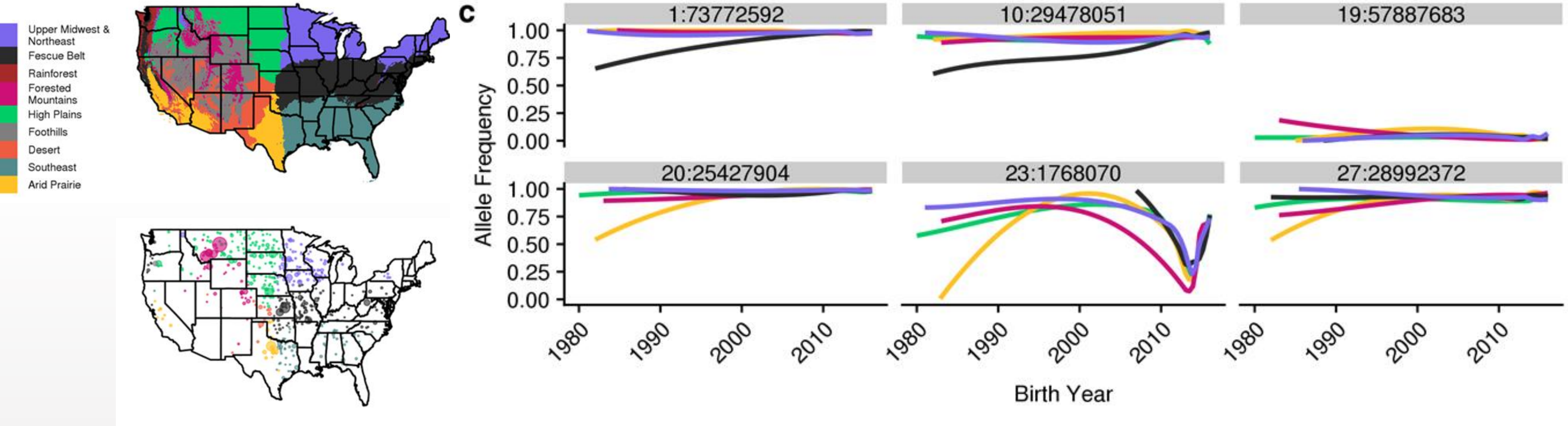




We find dozens of loci associated with environmental selection in cattle. However, most allele frequencies are converging to the breed average.

We are likely losing local adaptation due to the lack of *tools to select for it*.

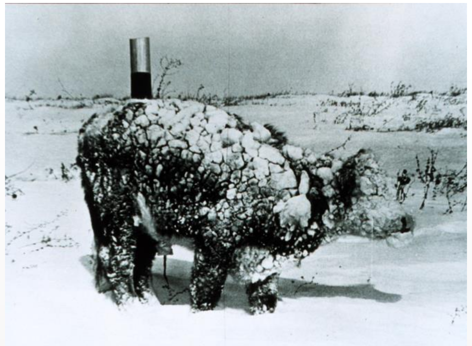
Rowan et al. *PLOS Genetics* 2021 https://doi.org/10.1371/journal.pgen.1009652

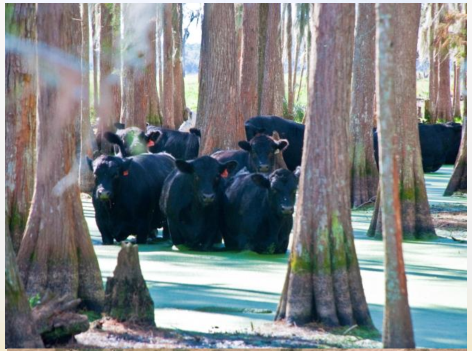
Matching Cattle Genetics to the Environment

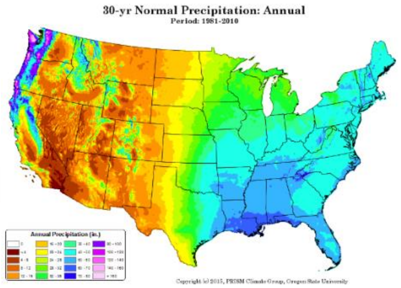
How do we match cow genetics to our environment?

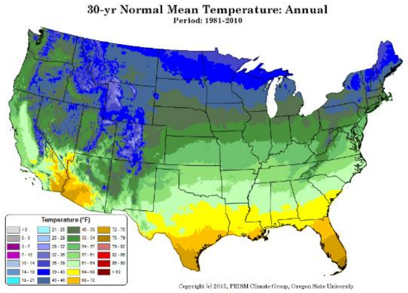
Low Tech

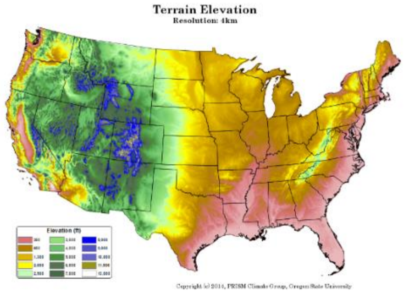
Purchase cattle from similar ***environment and management***

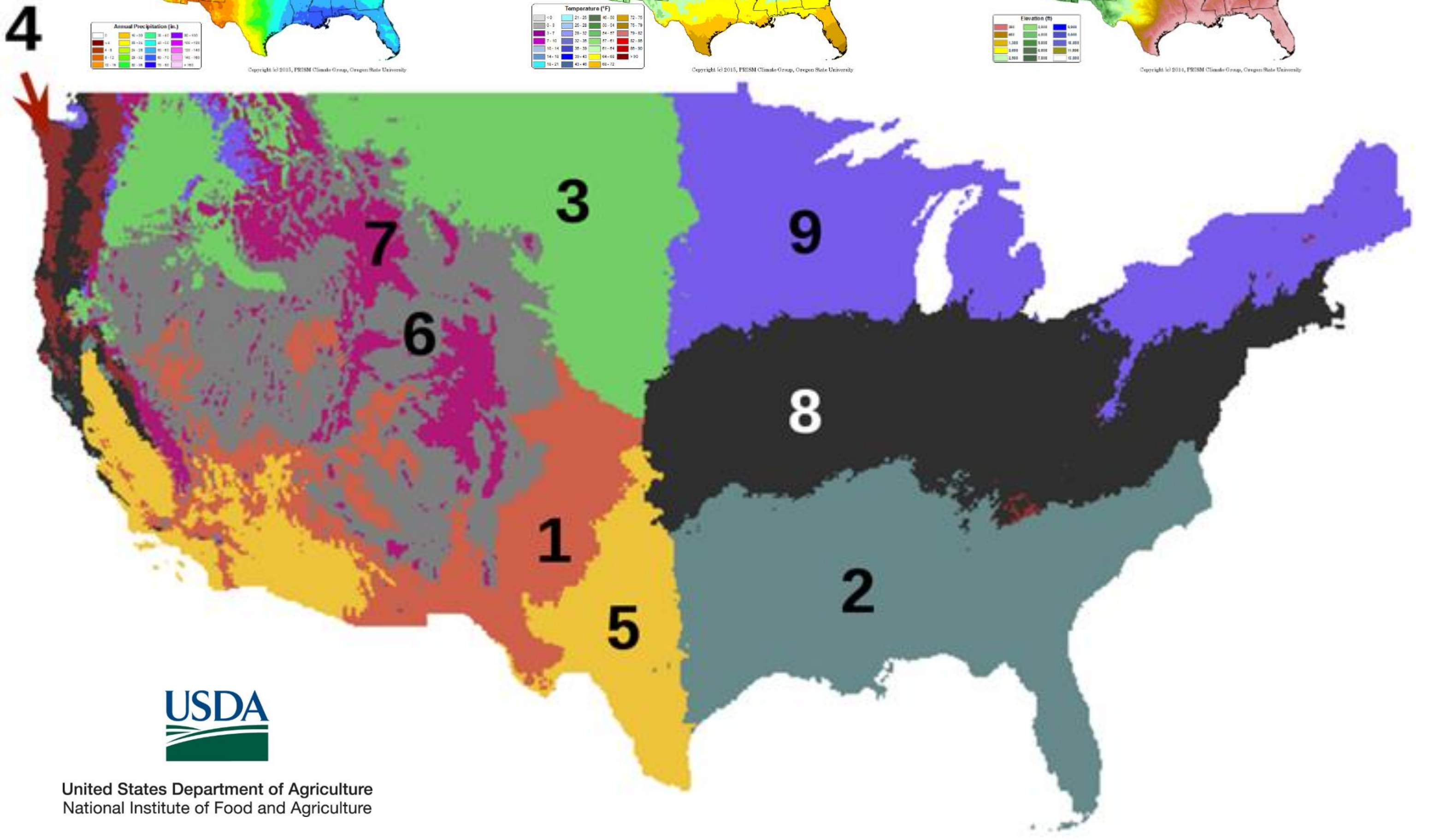












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Indirect

What traits suffer the quickest under environmental stress?

Indirect

What traits suffer the quickest under environmental stress?

- Reproduction

- Body Condition and Metabolism

Indirect

What traits suffer the quickest under environmental stress?

- **Reproduction**
  - EPDs
    - Heifer Pregnancy
    - Stayability
    - More in development!
- **Body Condition and Metabolism**
  - EPDs
    - Fat Thickness
    - Mature Cow Weight (select smaller cows)
    - Feed Intake

Indirect

What traits suffer the quickest under environmental stress?

Crossbreed!

- Reproduction
  - EPDs
    - Heifer Pregnancy
    - Stayability
    - More in development!
- Body Condition and Metabolism
  - EPDs
    - Fat Thickness
    - Mature Cow Weight (select smaller cows)
    - Feed Intake

High Tech & Direct?

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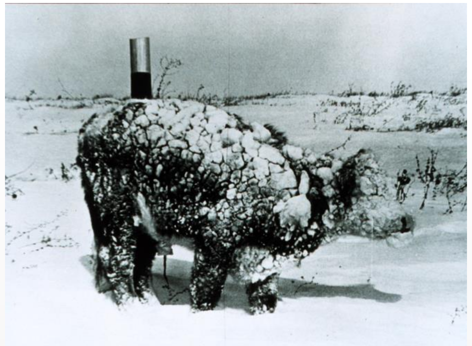

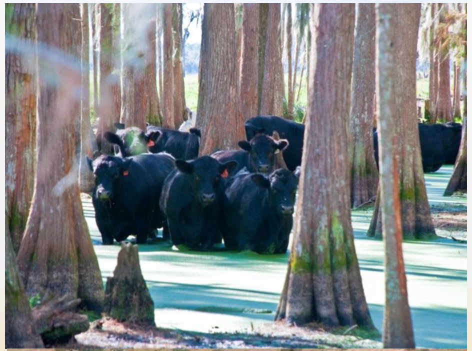

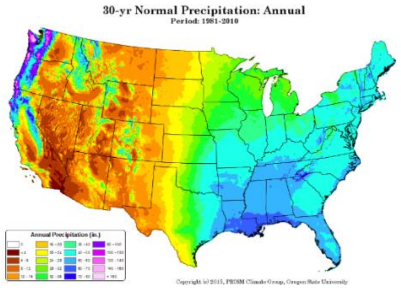

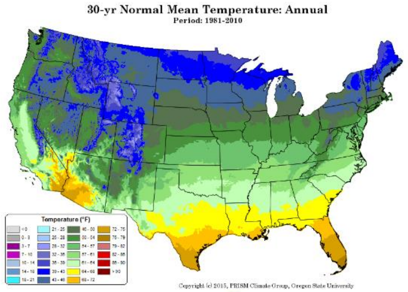

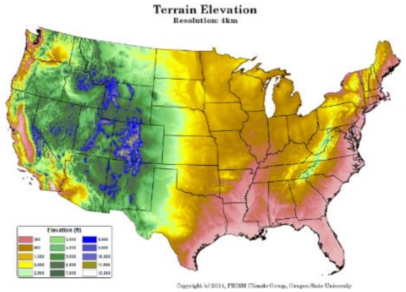

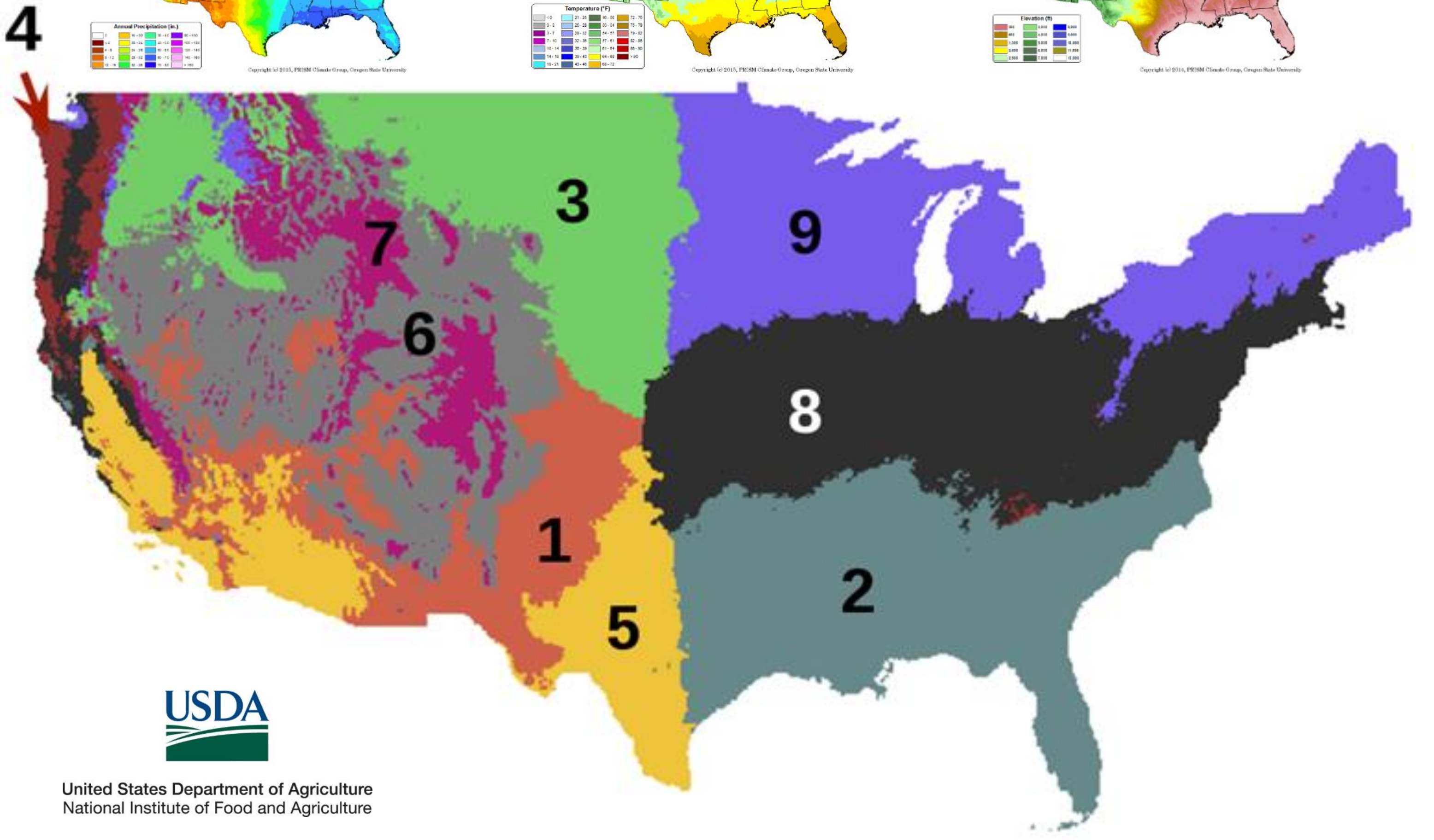

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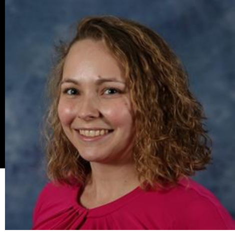
Ecoregion-Specific Genomic Prediction

Spoiler Alert: This is hard and hasn’t worked well.



Genotype-by-environment accounts for 3% to 33% of variation in traits

Birth Weight

Model	h^2	V(GxE)/ V(P)
No CG	0.21	0.22
Fixed CG	0.26	0.10
Fixed CG, Mat	0.35	0.05
Random CG, Mat	0.38	0.03

Weaning Weight

Model	h^2	V(GxE)/ V(P)
No CG	0.15	0.32
Fixed CG	0.17	0.10
Fixed CG, Mat	0.19	0.09
Random CG, Mat	0.26	0.06

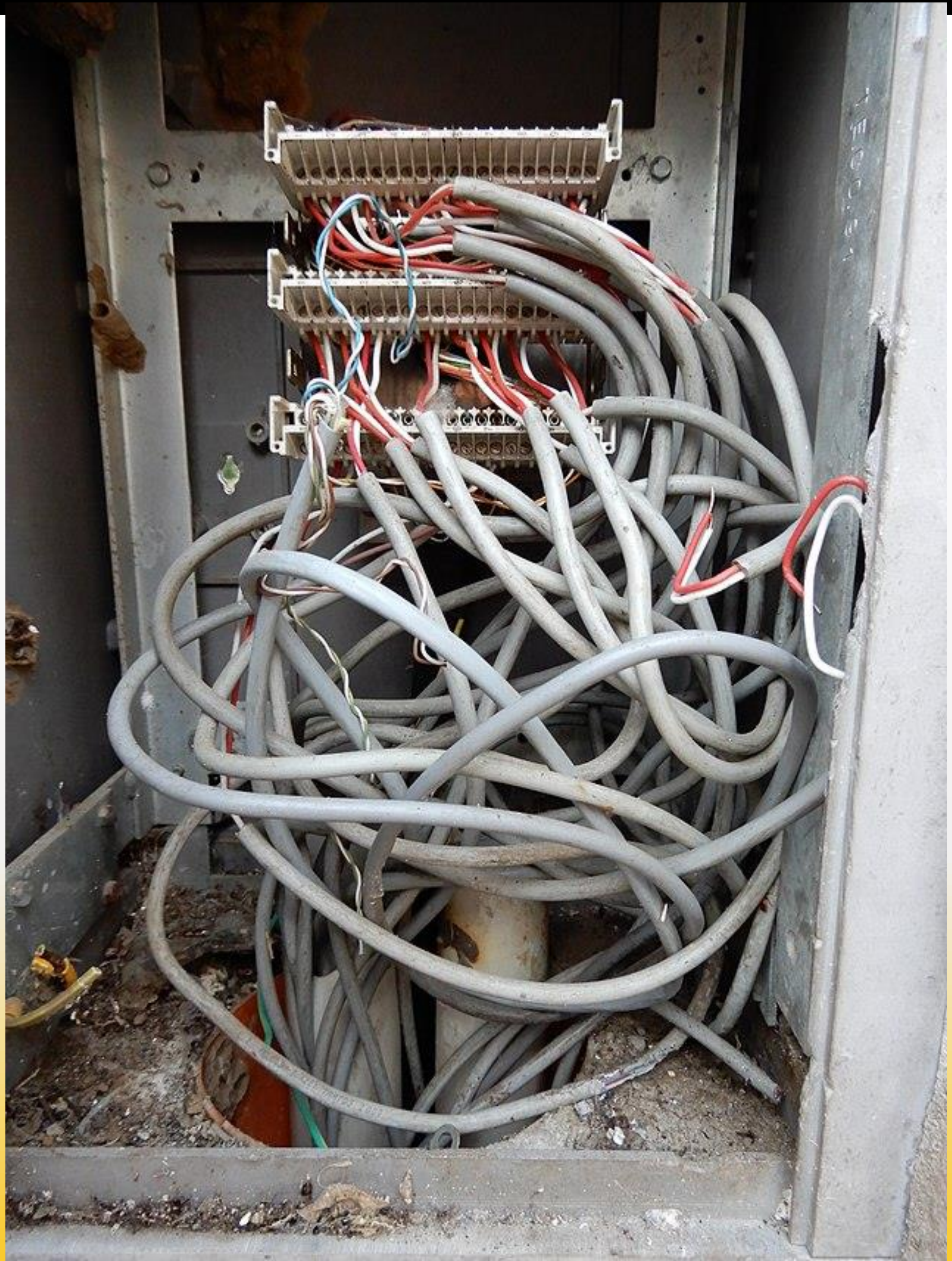
Yearling Weight

Model	h^2	V(GxE)/ V(P)
No CG	0.27	0.33
Fixed CG	0.30	0.12
Random CG	0.40	0.05

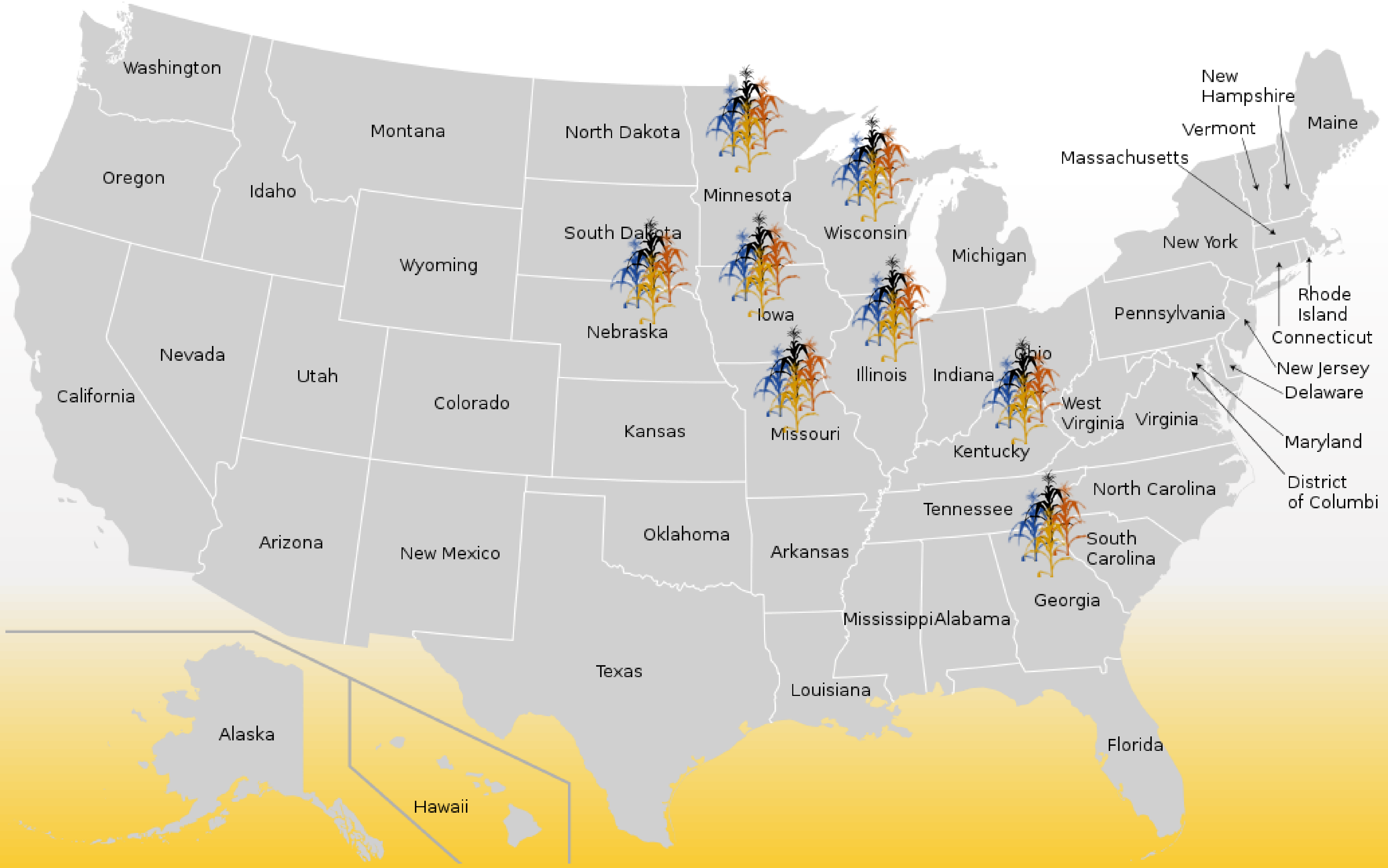
Sustainability

- As we work to increase efficiency, some producers will work to decrease inputs.
- Do we have genetics that will work under fewer inputs???

Environment and Management



Plant genotype is replicated across environment



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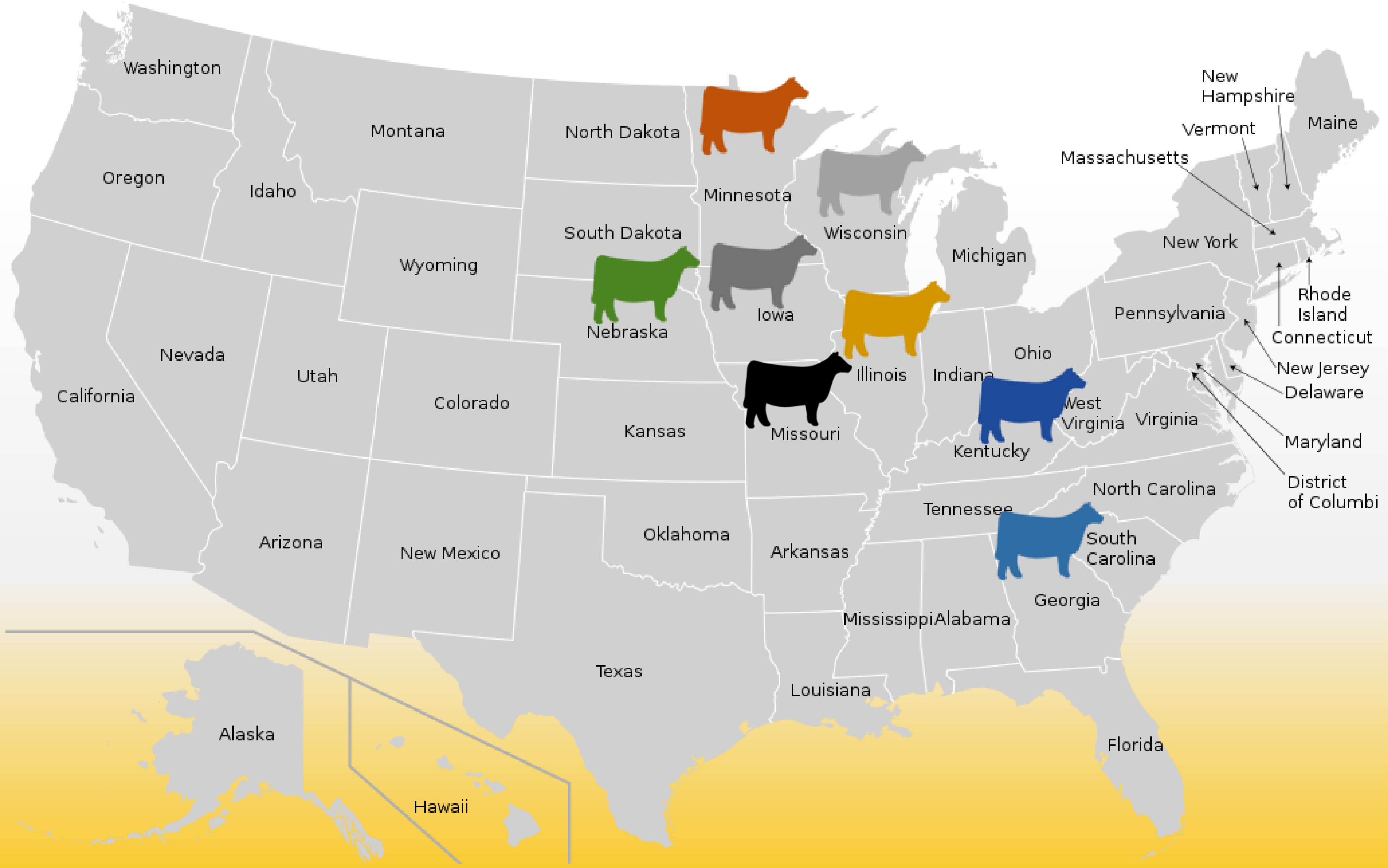
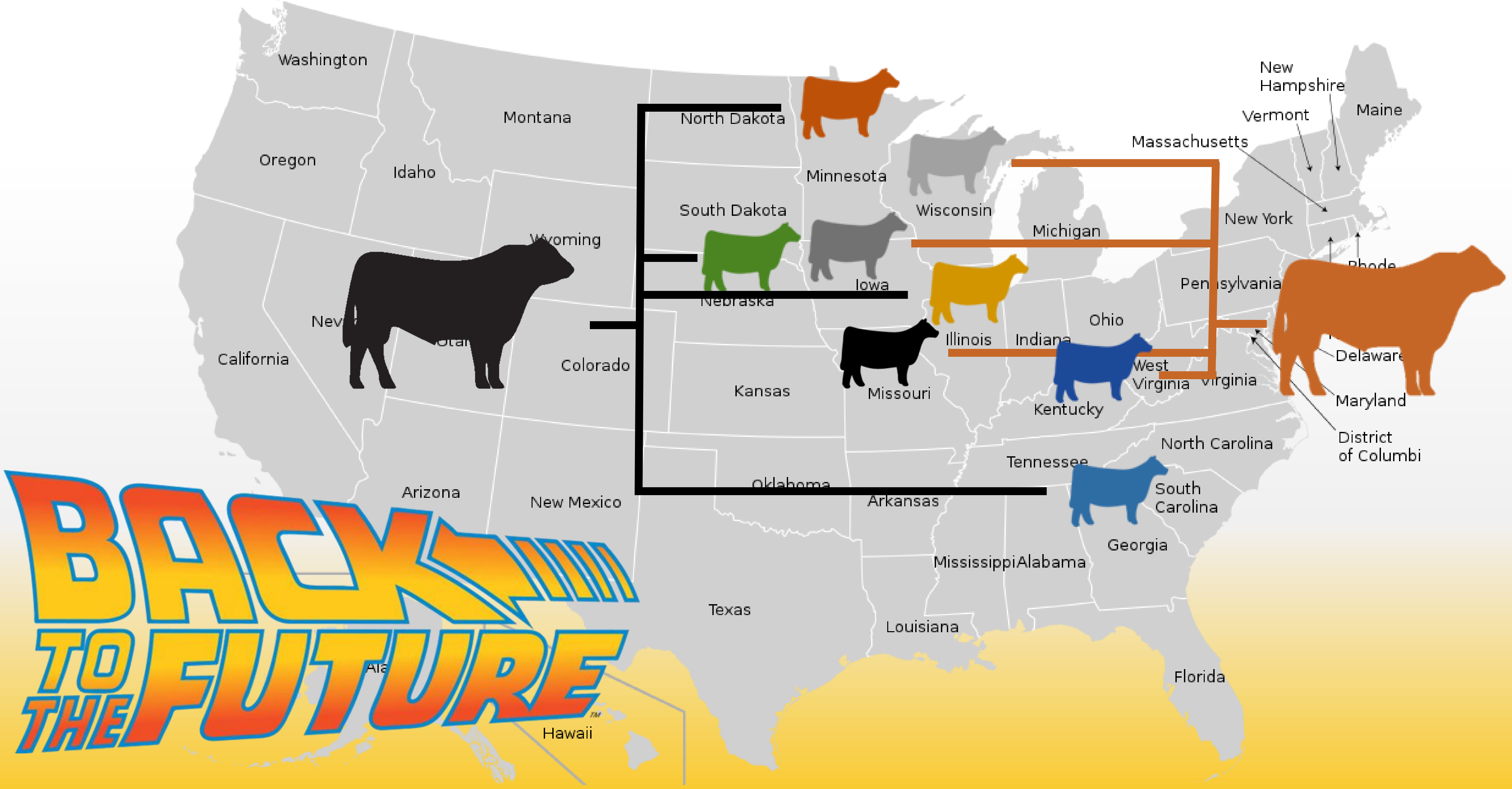
Animal genotype is ***not*** replicated across environment



Sire genotype ***is*** replicated across environment!



New Traits for Environmental Resilience

PAP

PHOTO COURTESY OF JOE NEARY

Lower EPD values are favorable

Selection Tools for Pulmonary Arterial Pressure

ANGUS
THE BUSINESS BREED

Research Report: Selecting Against High Altitude Disease

On May 29, 2020, the American Angus Association® and Angus Genetics Inc. (AGI) officially released expected progeny differences (EPDs) for high altitude pulmonary arterial pressure (PAP). The EPD predicts the genetic differences in PAP score with lower EPDs being more favorable. PAP is an indicator for animals with lower risk of developing high altitude disease (HAD), which in most cases results in congestive right heart failure. Researchers and veterinarians at Colorado State University (CSU) have been studying the disease and its onset for decades and have developed PAP tests in order to select animals to avoid pulmonary hypertension. This disease, most commonly found in cattle living at elevations of 5,000 ft. or greater, is a result of cattle living in hypoxic environments challenging heart and lung function. Symptoms of the disease include lethargy, diarrhea, weakness, brisket edema, right heart failure and eventual death.

While hard to quantify the economic deficit to the industry, it is known to be detrimental to high-altitude herds as onset can occur at any age, can be further exasperated by other events such as bovine respiratory disease (BRD), and in almost all cases is fatal to the animal. The PAP procedure is helping operations to remove high-risk high-risk HAD individuals earlier in life, not only to be removed from the herd, but also to select breeding animals for the next generation. In order to take high-altitude PAP measurements on individual groups, animals need to be living at elevations at 5,500 feet or higher for at least a 4-6 week period before scores are taken. This warm-up period allows for the cattle to adjust to the environmental settings, allowing accurate scoring.

Research in the area reports PAP score is a moderately heritable measurement. A collaboration with the Association, CSU and AGI laid the fundamental groundwork for a PAP genetic evaluation. A recent study investigated the relationships of scores taken at differing elevations. The study by Pauling et al. (2018) concluded a high positive correlation (r=0.83) between PAP measurements taken at high altitudes (5,250 ft. or greater) and moderate altitudes (4,000-5,250 ft.). This reveals PAP scores taken at moderate altitudes can be an informative indicator trait of measurements taken at higher altitudes.

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Winter Hair Shedding

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Hair Shedding

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Hair shedding measures the approximate amount of winter hair coat that is lost from the whole body during the spring and summer months. Hair shedding does not indicate hair length or type.

Contents hide

Phenotype

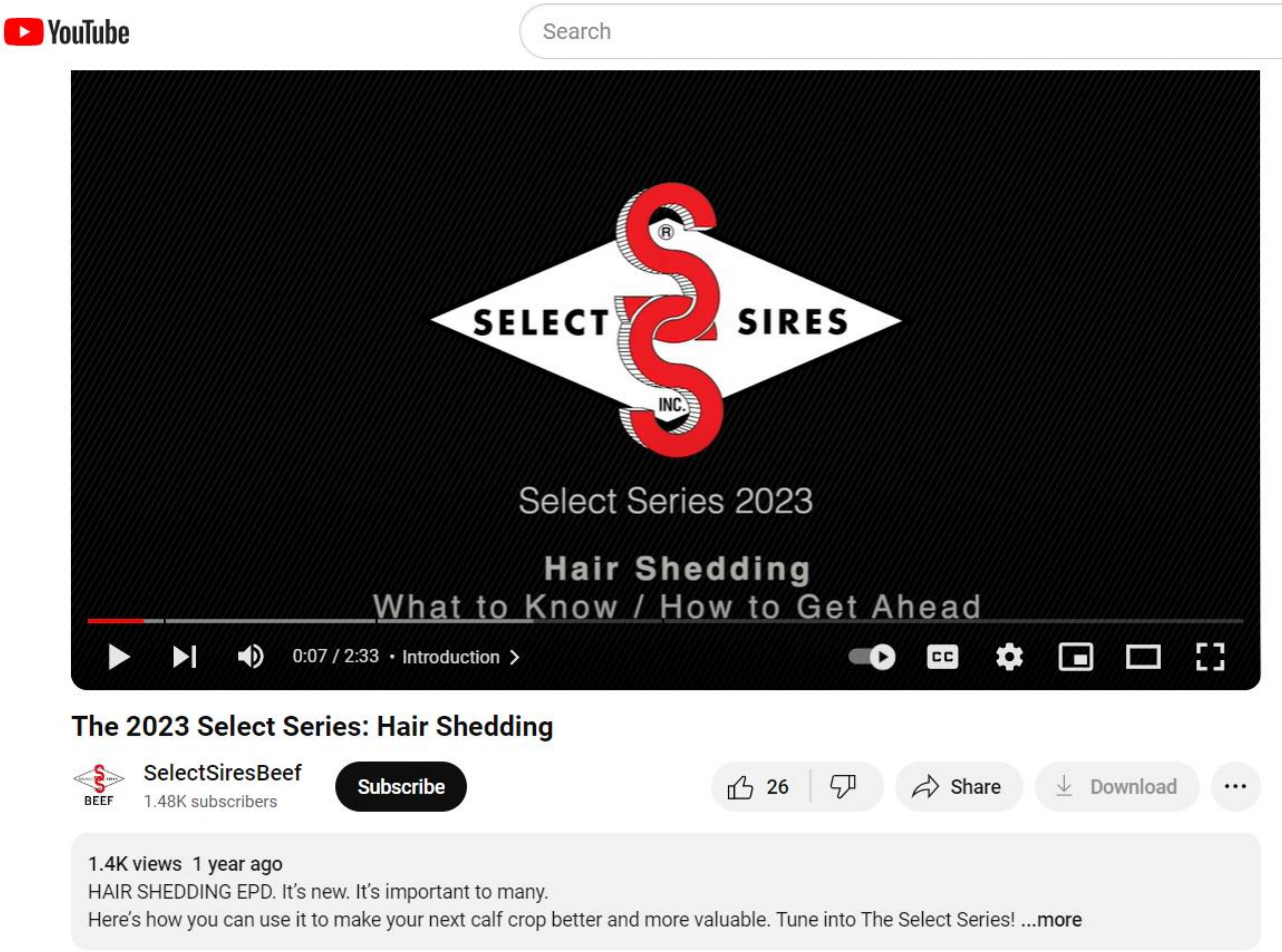
Hair shedding scores can be taken monthly from March to July. In most regions of the U.S. it is recommended that the herd be evaluated during the month of May. This time period seems to correlate when most cattle have initiated the process of shedding and when most variation occurs within the herd. This could vary in different regions of the U.S.

Hair shedding scores are based on a 1 to 5 scale with a score of 1 being completely shed or having a slick appearance and a score of 5 having not shed or having a rough hair coat appearance over the entire body. Percentage shedding is relative to the approximate amount of winter hair loss in relation to the body size of the individual.

Hair shedding scores can be taken on both sexes and animals of all ages. It is recommended to take scores at yearling during their first spring. The following table lists the scores, definition, and descriptions.

Description of hair coat shedding scores

Hair Shedding Score	Definition	*Description
5	Full winter coat (0% shed)	No hair shedding
4	Coat exhibits initial shedding (~25% shed)	Hair shed on neck and around tail head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HAIR SHEDDING EPD. It's new. It's important to many.
Here's how you can use it to make your next calf crop better and more valuable. Tune into The Select Series! ...more

Hair Shedding EPD

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- Research EPD released February 2020
- Production EPD released May 2022

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Why Hair Shedding?

This afternoon!

Advancements in Efficiency and Adaptability

ANR 103   2:30 – 3:15 pm

Practical application of hair shedding scores and EPD in your herd

Dr. Jared Decker, Wurdack Chair of Animal Genomics, and Dr. Jamie Courter, State Beef Extension Specialist University of Missouri

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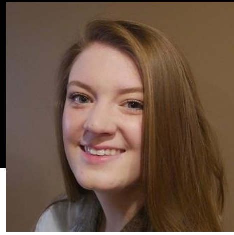
Hair shedding score is moderately heritable

Dataset	N scores	N animals	Avg. scores per animal	h^2	r
AGI	14,465	8,642	1.67	0.40	0.44
Full Mizzou	36,899	13,364	2.76	0.37	0.45
Angus Mizzou	8,674	3,953	2.19	0.37	0.42
Brangus Mizzou	1,829	984	1.92	0.40	0.40
Hereford Mizzou	2,857	1,235	2.31	0.32	0.40
IGS breeds Mizzou	10,996	4,713	2.33	0.41	0.48

- Turner & Schleger (1960) h^2 using 7-point scoring system: 0.63
- Gray et al. (2011) h^2 using same scoring system but pedigree only: 0.35



Prediction accuracy

Dataset	Number of Scores	Mean Model Accuracy	SD
Angus	8,674	0.594	0.006
Brangus	1,829	0.524	0.007
Hereford	2,857	0.520	0.013
IGS	10,996	0.663	0.007
Full dataset	36,899	0.665	0.006

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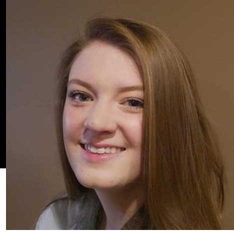

Dispersion ($b^{v}_{w,p}$)

Dataset	Mean Dispersion	SD
Angus	1.007	0.055
Brangus	1.014	0.072
Hereford	1.027	0.133
IGS	1.036	0.049
Full dataset	1.009	0.021

EPD decreases by 1 point = calf hair shedding decreases by 1 point

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Why Hair Shedding?

Heat Tolerance

Economically relevant trait (ERT) directly measuring heat stress

Adaptability

Appropriately Sensing and Responding to the Environment

Cows that work

- Cow efficiency is complex

http://www.bifconference.com/bif2015/proceedings-by-speaker/07MacNeil-et-al-pg69-77.pdf

- Hair shedding influences:
  - Maternal growth (a.k.a. milk)
  - Reproduction
  - Animal welfare

Indirect

What traits suffer the quickest under environmental stress?

- Reproduction
- Body Condition and Metabolism

EPDs for Reproductive Traits

How did we make progress for other traits?

- **High information traits**
  - Variation within contemporary groups
  - Quantitative measures
- **Multiple-trait models**
  - Borrow information across related traits
  - Account for biases in data reporting

Days Open

- **Calculated from ultrasound fetal age or calving date**
- **How much of the breeding season was the heifer open?**
  - Smaller values are better
  - Days Open = 0 means a heifer conceived on the first day of breeding season
- **Unlike Heifer Pregnancy, gives credit to heifers who conceive earlier in the breeding season**

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Red Angus Data

Breeding season, heifer pregnancy, and calf birth date
Used 4,004 genotyped heifers, plus 14,481 of their contemporaries

Genomic Prediction Model Accuracies*

- Heifer Pregnancy: 0.25 ± 0.05
- Days Open: 0.33 ± 0.03

EPD BIF Accuracy

Trait	Min	Mean	Max
Heifer Pregnancy	0	0.102	0.240
Days Open	0.040	0.238	0.423

*Specific to this dataset, does not reflect accuracy of National Cattle Evaluation accuracy

Matching Cattle Genetics to the Environment

Biological Rules and Laws

Rules and Laws

Bergmann's Rule

Moving away from the equator, animals tend to get larger

- Thermodynamics?
- Nutrient use?

Is there an advantage to lower surface-area-to-volume ratio cattle at higher latitudes?

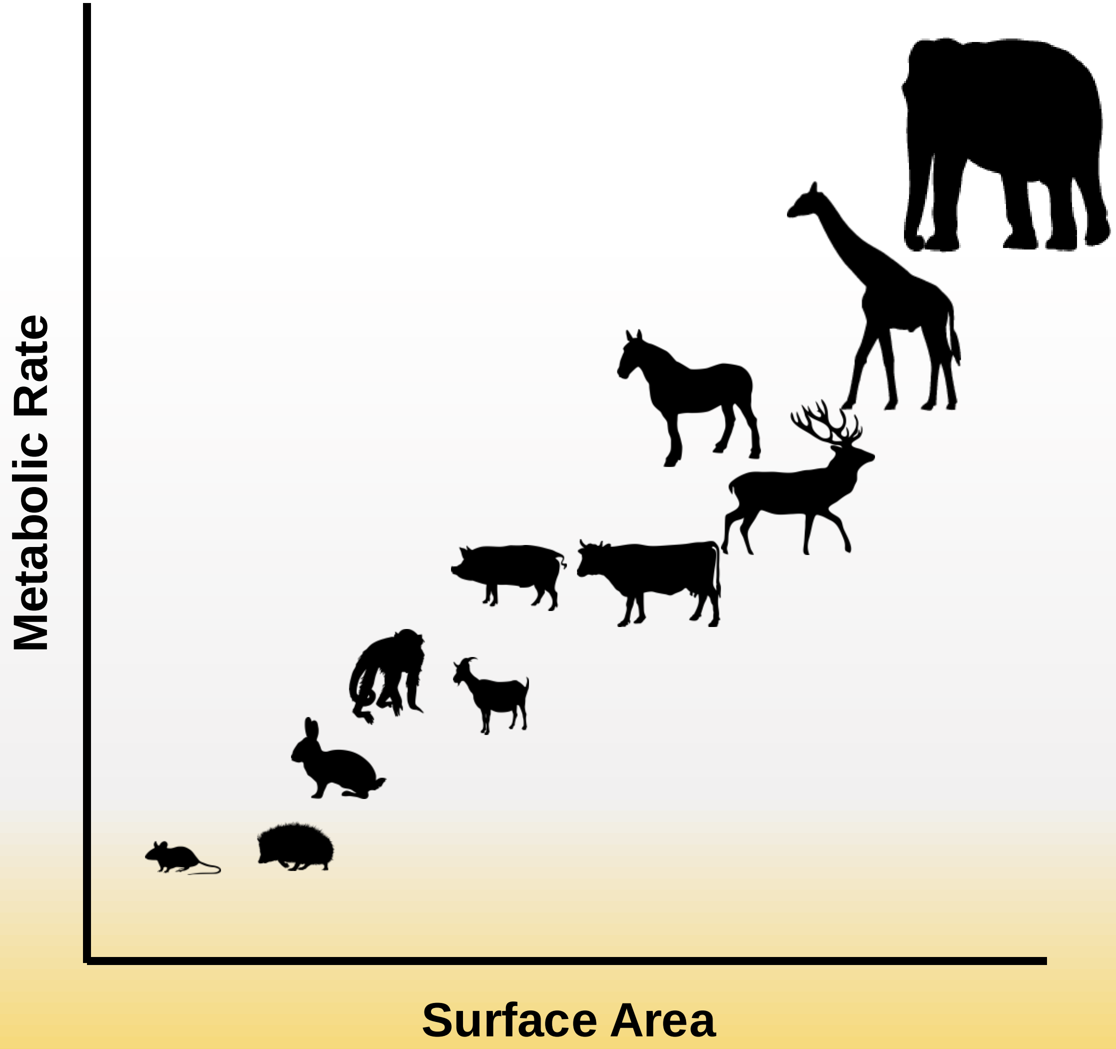
Is there an advantage to higher surface-area-to-volume ratio cattle at lower latitudes?

Rules and Laws

Surface Law

Differences in metabolism are largely driven by surface area

- Why do we measure weight?
- Metabolism driven by surface area and volume?



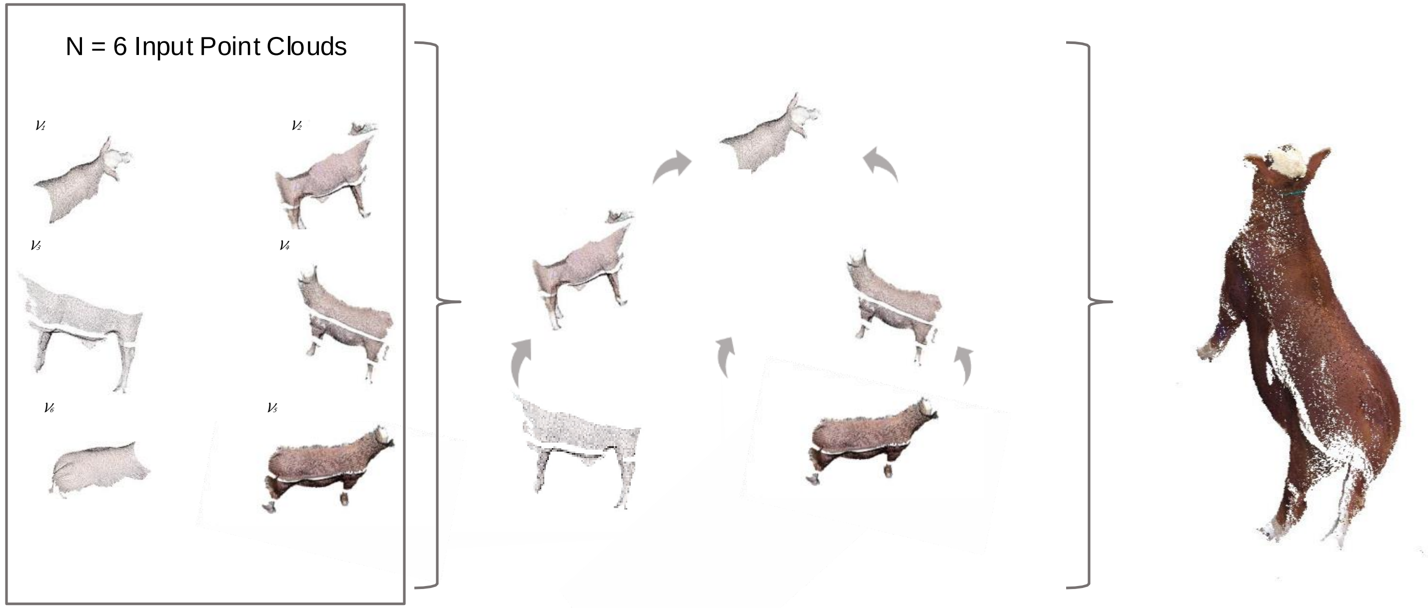
How does animal shape affect efficiency?

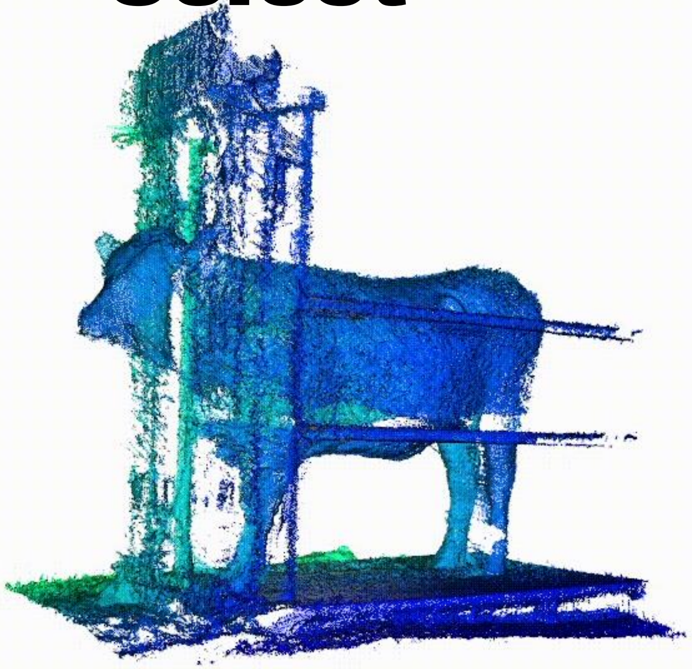
What would you do with accurate measures of surface area and volume?

Manage

Market

Select





Matching Cattle Genetics to the Environment

Measure and predict the *correct* traits *directly* connected to the *biology* of environmental stress

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American Gelbvieh Association

SimGenetics
PROFIT THROUGH SCIENCE
American Simmental Association

Ranch Tested. Rancher Trusted.
Red Angus

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Harly Durbin

Graduated 2020

Troy Rowan

Graduated 2020

Sara Nilson

Graduated 2022

Esdras Tuyishimire

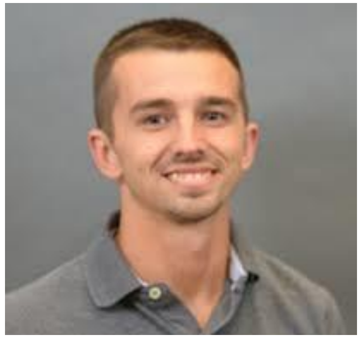
Graduated 2022

Bob Schnabel

Clint Bailey

MS Student

Caleb Grohmann



PhD Student

John Miraszek

PhD Student

SimGenetics PROFIT THROUGH SCIENCE American Simmental Association

American Gelbvieh Association

Ranch Tested. Rancher Trusted. Red Angus

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Recruiting Livestock Judging Coach/Instructor! Please share with potential candidates.

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USDA United States Department of Agriculture National Institute of Food and Agriculture

Durbin, et al. “Development of a genetic evaluation for hair shedding in American Angus cattle to improve thermotolerance.” *Genet Sel Evol* 52, 63 (2020). https://doi.org/10.1186/s12711-020-00584-0

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