Genetic Selection of Beef Cattle: Past, present, and future

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Phenotypic selection—show ring
Genesis of modern beef improvement in the U.S.

- 1930-35 “Genesis” of Performance Recording: US Range and Livestock Research Station, Miles City, MT
- 1935-45 Beginning of measurement in New Mexico and California
- 1941 Central Bull Testing: Balmorhea, TX
First Simmental Sire Summary

1971 (done at Boeing and led by Paul Miller)
BIF Guidelines

1st Edition 1970
measurement, adjustment
herd guidelines
central test guidelines

2nd Edition 1972
some initial thoughts on
sire evaluation
reference sires and
no. progeny
performance pedigree
Best Linear Unbiased Prediction (BLUP) Animal Model

\[
\begin{bmatrix}
  X'X & X'Z \\
  Z'X & Z'Z + K^{-1}a
\end{bmatrix}
\begin{bmatrix}
  \hat{b} \\
  \hat{a}
\end{bmatrix}
= \begin{bmatrix}
  X'y \\
  Z'y
\end{bmatrix}
\]

• This is the framework in which we have worked for decades.
Progeny Inform Us About Parents

Sire EPD +8 lb

(EPD is “shrunk”)

Sire EPD +8 lb

+30 lb
+15 lb
-10 lb
+ 5 lb
+10 lb

Progeny +10 lb
What Is a Selection Index?

- Selection on ‘aggregate merit’ (Hazel, 1943)
- List of traits that influence “satisfaction”
- Relative Economic Value (REV) of each trait
  - Increase in satisfaction with one unit change in a trait, all others held constant
- List of characteristics to be measured on animal
- Relationships between characteristics (phenotypes) and traits (genotypes)
Why Do We Need Selection Indexes?

“There is no easily accessible, objective way for breeders, particularly breeders in the beef and sheep industries where ownership is diverse and production environments vary a great deal, to use these predictions intelligently.”

-- R. M. Bourdon, 1998
What influences net profit?

- HCW = 59.5%
- DMI = 19.3%
- MS = 11.1%
- REA = 5.5%
- FAT = 4.6%
- What’s missing?

- Ochsner et al. (2017)
Gartner Hype Cycle

- Technology Trigger
- Trough of Disillusionment
- Slope of Enlightenment
- Plateau of Productivity
- Peak of Inflated Expectations
# Dark Ages

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Genomics

- 2004—First Marker-Assisted EPD
  - ASA--Tenderness
- 2009—Release of genomic enhanced EPD
  - AGI
  - A move away from “validation” to “evaluation”
- 2012—Genomic enhanced EPD for many breeds
Breeding Value Estimation

- Progeny receive half of their genetic material from each parent (PA)

\[ BV = \frac{1}{2} BV_{(sire)} + \frac{1}{2} BV_{(dam)} + \Phi \]

- \( \Phi \) = Mendelian sampling term
- Genomic data
  - Account for part of the Mendelian sampling term
Blending

$$EBV_i = \frac{1-R_i^2}{1-r_g^2 R_i^2} MBV_i + \frac{1-r_g^2}{1-r_g^2 R_i^2} EBV_i$$

Predictions of who is the better parent
Pedigree information was the primary method to incorporate relationship information into BLUP and is still the backbone.

- Usually deep
- Prone to errors ~10%
- Computationally feasible

Genomic data now augments pedigree, allowing for deviations from expected degrees of relationships:

- Cleans up pedigree errors
- Better estimates of relationships
- More computationally demanding
Pedigree Relatedness

- The **expected** (averaged across loci) relationship between individuals.

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Genomic Relatedness

- The **realized** (averaged across loci) relationship between individuals.
# Progeny Equivalents

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Increased Accuracy-Benefits

- Mitigation of risk
- Faster genetic progress

\[
\Delta_{BV} / t = \frac{r_{BV,EBV} i \sigma_{BV}}{L}
\]

- Increased accuracy does not mean higher or lower EPD/EBV!
  - Increased information can make EPD/EBV go up or down
Delta G should be thought of per $ invested!
Sequencing Is Just Beginning

- Best chance we have at:
  - Predicting across populations
    - Single variant (birth weight)—$r_g$ ranged between 0.17 and 0.34
  - Developing MAM products
    - An objective, but the highest hanging fruit
What is gene editing?

- A category of new methods that can be used to precisely edit or change the genetic code.
- Molecular scissors called nucleases are used to cut DNA at a specific location in the genome based on recognition of the target DNA sequence.
- This enables us to add, delete, or replace components of the genetic code.
What examples are there in livestock?

- Genetically hornless Holstein dairy cattle.
  - Holstein “horned” allele → naturally-occurring Angus “polled” allele
- Pigs with a single base deletion in a gene that may enable resilience to African Swine Fever Virus.
- Pigs protected from porcine respiratory and reproductive syndrome (PRRS) virus.
- Changes in the myostatin gene in sheep and cattle.
Does this replace “traditional” genetic selection?

- Can save time
  - Avoid the need to introgress using traditional backcross
  - This can also avoid the introgression of undesired mutations
- The majority of ERT are very polygenic
  - Potentially changes the intercept from which we make “traditional” progress.
- Even if disease resistance is achieved there are several other traits in the breeding objective
- Simply one tool to add to the toolbox
  - But potentially an important one.
Commercial Data is Important

- Improvements can be made by increasing the number of ERT that have EBV
  - Input traits
  - Fertility
  - Health
  - Carcass

- Genomic selection will only be fully realized when we collect traits for which genomics could be most helpful.
Clearly define breeding goals

- Emerging technologies should increase the rate of genetic change.

- The rate of "improvement" towards a specified goal should be the objective.

- This requires clearly defined goals whereby trait maximums or minimums may not be ideal.
Data

Data is constantly growing
(more animals, more traits, more genotypes, sequence data)

Knowledge

Requires turning data into tools
Everybody is talking about GEMS

- Genotype
- Environment
- Management
- Societal concerns
Body Temperature During Heat Stress ($h^2 = 0.68$)

Howard et al., 2013 & 2014
Iron Content in Beef ($h^2 = 0.35$)  
(Ahlberg et al., 2014)
Heritability Across OTUs

Histogram OTU Heritability

OTU Heritability

Count
Final thoughts

- Use the tools we have, and be aware of the advantages of emerging tools.
- SCIENCE and ECONOMICS should rule the day, not reckless bias based on opinion.
- IF you have not yet capitalized on existing genetic improvement tools, then the only way for you to benefit from new technologies is if someone takes decision making power from you.
- Do not make it harder than it need be.
- Be an educated livestock producer and educated consumer.
  - Consumer of science