Beef cattle improvement in the genomics era

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Outline

- Introduction to cattle breeding
- Genomic selection
- Practical questions for breeders
  - Dairy Industry as a genomic selection success story
  - Beef Industry as an “opportunity for improvement”
- What does the future hold

Genetic improvement

- Genetic change - use animals better than the average as parents of the next generation
- Key to genetic change: selection

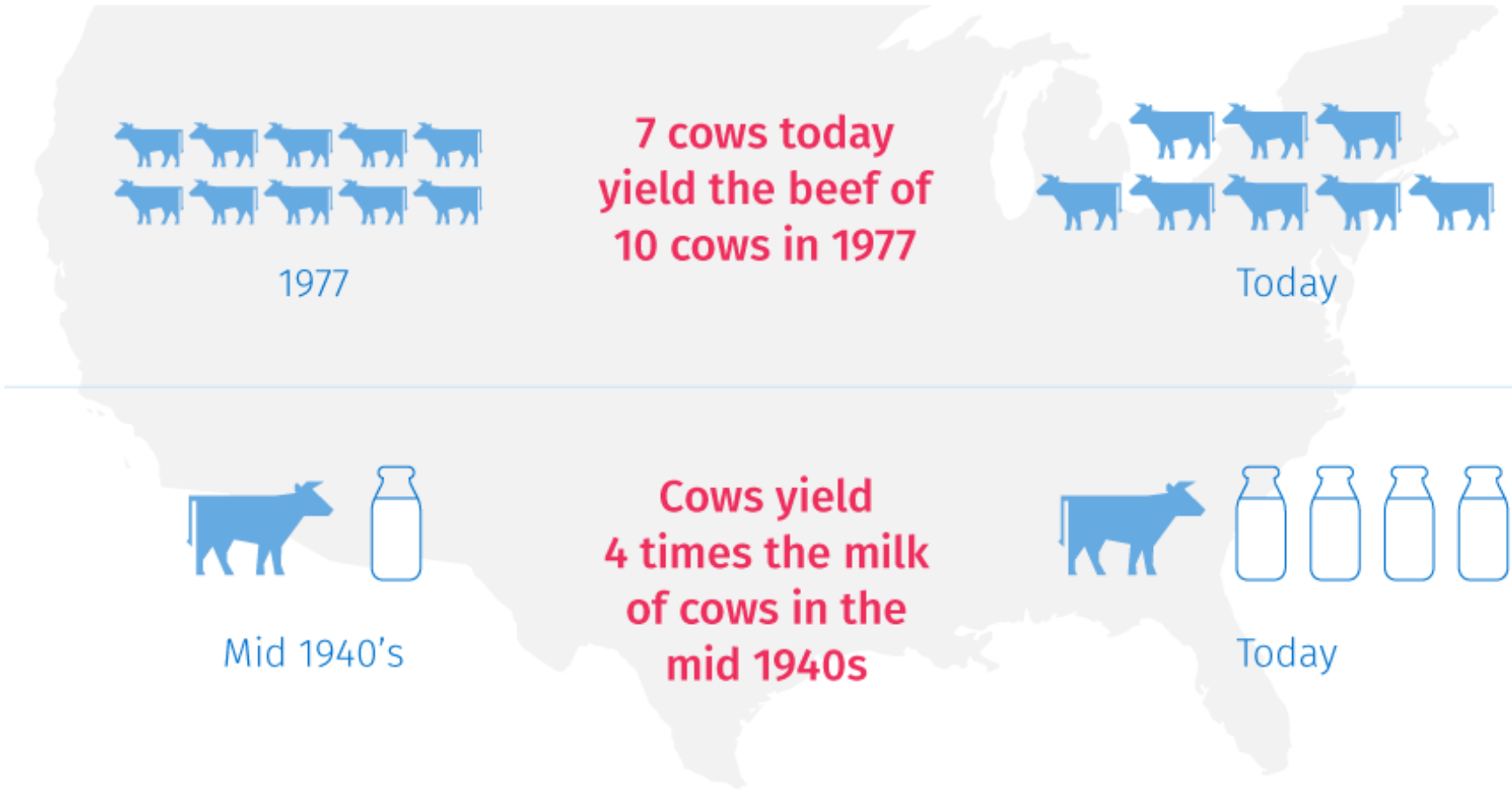
Traditional Animal Breeding

- Selective breeding for economically important traits
- Traditionally based on phenotypic recording
  - Estimation of breeding values from phenotypic records and pedigrees
  - Knowledge of heritability of each trait
- Successful
  - but slow process especially for certain traits

Fed identical diets, kept in similar conditions for 56 days.

Strains:	1957	1978	2005
56-d weight:	905g	1,808g	4,202g

Impact of innovation in US



Capper et al. 2009, Capper 2011

Slow/Difficult to improve traits

- Traits measured in **only one sex** (milk yield)
  - Need phenotypic records on relatives (progeny)
- Traits measured **late** in life (longevity) or **after death** (meat quality)
- Measuring the traits is **expensive** or **difficult** (feed efficiency, disease resistance)

Rate of genetic change

- Depends on 4 factors:
  - Selection **intensity**
  - **Accuracy** of genetic prediction
  - **Generation interval**
  - Amount of **genetic variation** in the trait

How to achieve high accuracy?

Historically:

- Number of records: large number of animals and high-quality phenotypic records
- Trait is highly heritable

Slow/Difficult to improve traits

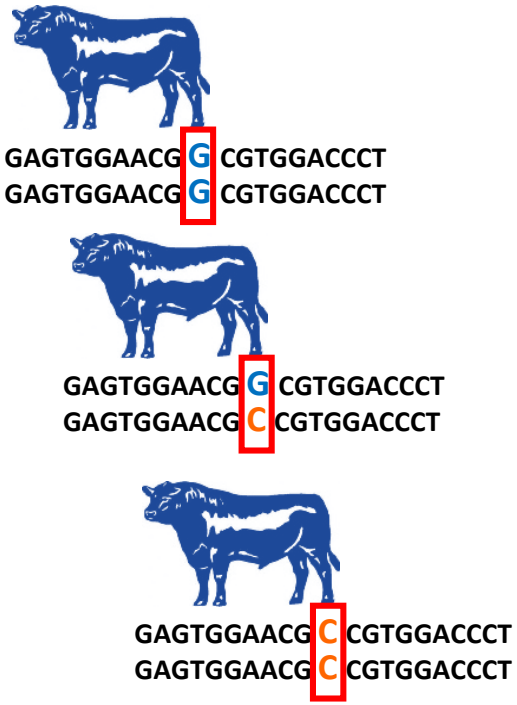
- Traits measured in **only one sex** (milk yield)
  - Need phenotypic records on relatives (progeny)
- Traits measured **late** in life (longevity) or **after death** (meat quality)
- Measuring the traits is **expensive** or **difficult** (feed efficiency, disease resistance)

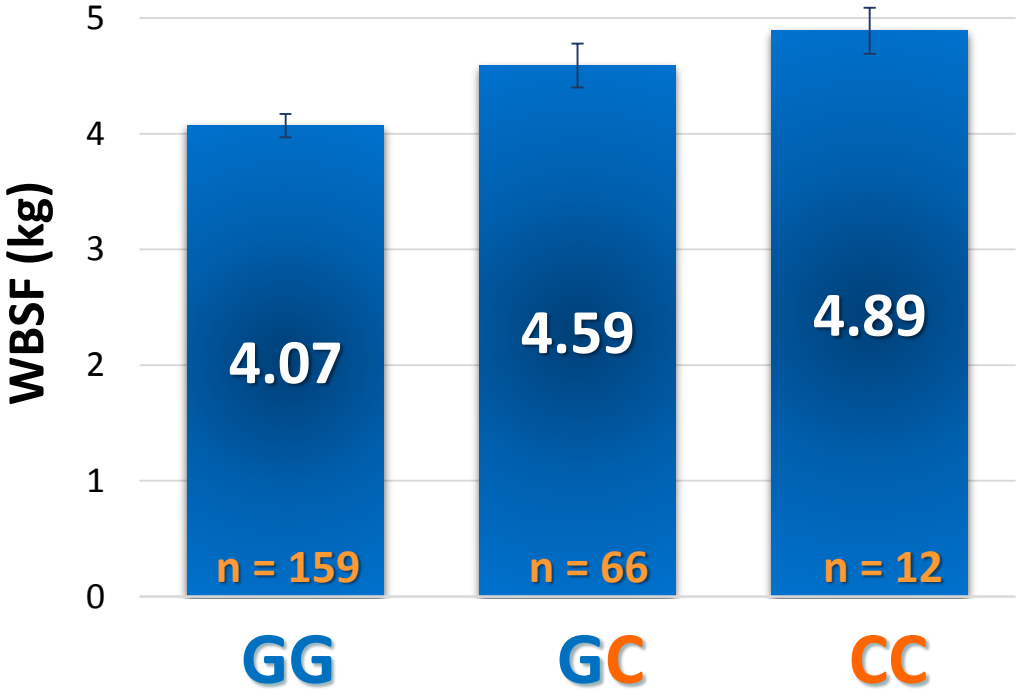
MAS – marker assisted selection

- Since 1990s – DNA information can increase the rate of genetic improvement.
- Challenges:
  - The effect of individual markers (QTLs) on complex traits is small
  - A large number of markers (QTLs) are necessary to explain the genetic variation
  - Marker information in outbreeding species is limited – linkage phase between marker and QTL (gene) must be established for every population

Tenderness - calpain

- CAPN1-316 = marker for tenderness
- One of the SNPs in the **GeneStar** Tenderness test
  - **GG** was **1.10** kg **tougher** than GC *(Pinto et al., 2010)*
  - **GG** was **0.36** kg **tougher** than GC *(Curi et al., 2010)*
  - **CC** is **1.23** kg **tougher** than CG *(UF multibreed pop., Casas et al., 2010)*





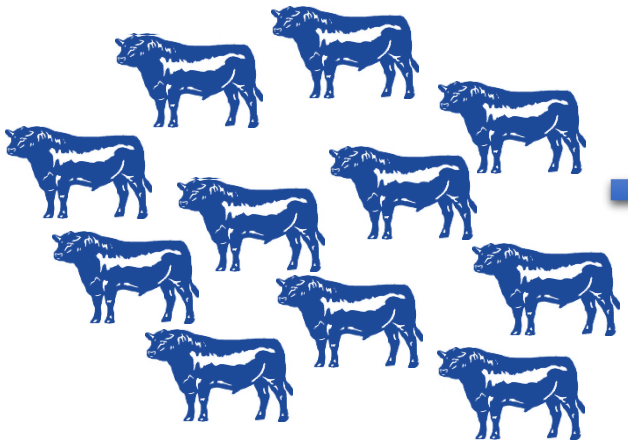
Genomic Selection

- Trace all segments of the genome with markers
  - Divide genome in chromosome segments based on marker intervals
  - Capture all QTLs = all genetic variation
  - Marker density must be sufficiently high to ensure at least one marker for each QTL/gene with an effect on the trait

Principles of Genomic Selection

Large Training Population

- Phenotyped
- Genotyped

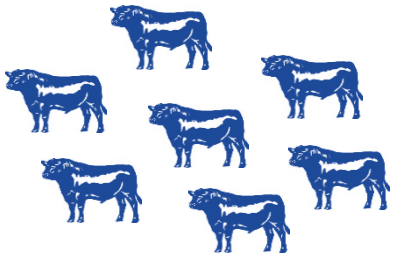


Prediction equation

Genomic breeding value = $w_1x_1 + w_2x_2 + w_3x_3$.....

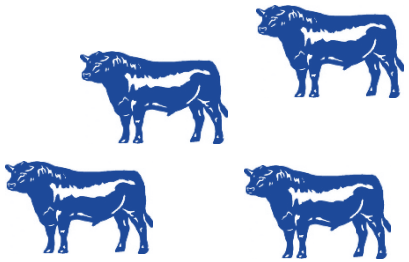
Selection Candidates

- Genotypes used to predict genetic merit



- Training Pop: many animals with phenotypes and genotypes
- Estimate effect of each marker, generate a prediction equation
- Apply the prediction equation to a group of animals with genotypes

Not predictive in other breeds/lines



Selected breeders

- Based on genomic breeding values

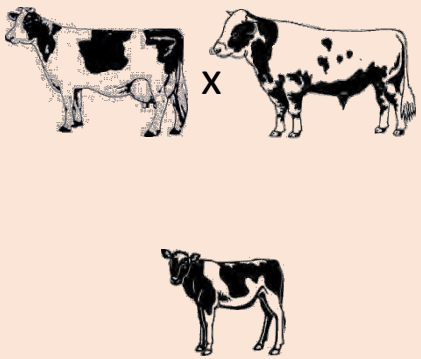
Adapted from Hayes and Goddard. 2009. Nature Reviews Genetics 10, 381-391

Dairy industry - as an example

- Dairy industry is well suited to whole genomic selection (different than beef)
  - High use of AI
  - Clear selection goal
  - One breed used extensively
  - Large number of high accuracy AI sires for training
  - Extensive, uniform collection of data on traits
  - Central evaluation (AIPL) receiving genotypes
  - Obvious way to increase rate of genetic change
  - AI companies funding the genotyping because they get a clear cost saving in terms of young sire program

Breeding value prediction in dairy

Young Sire
Parent Average

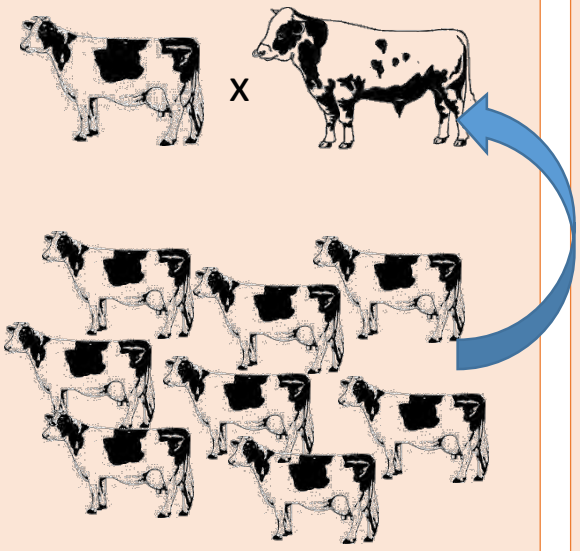


Birth

Genetics inherited from sire and dam (half of sire and dam genetics)

Accuracy: **0.20**

Young Sire
Progeny Test

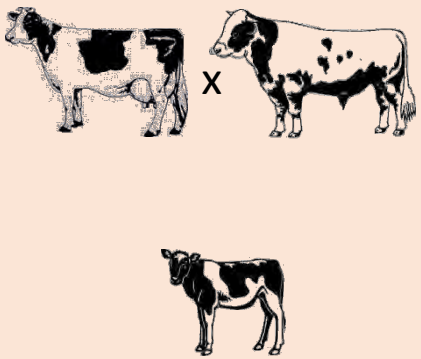


5 years; $50,000 cost

Genetics inherited from sire and dam (half of sire and dam genetics)

Accuracy : **0.80**

Young Sire
Genomic Selection



Birth; <<< $50,000 cost

Genetics inherited from sire and dam (half of sire and dam genetics)

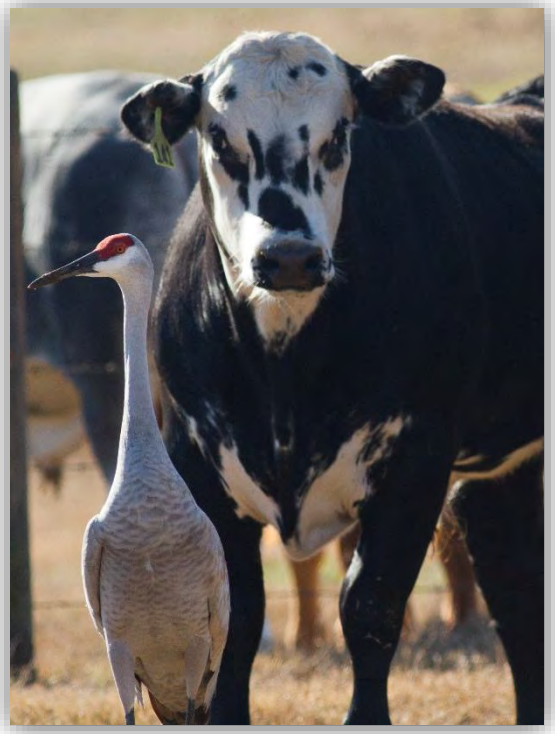
Accuracy : **0.65**

Benefits of genomic selection

- Genomic selection can help breeders identify superior individuals (higher genetic merit) at a young age
  - Selection **intensity**
  - **Accuracy** of genetic prediction **Increased**
  - **Generation interval** **Decreased**
  - Amount of **genetic variation** in the trait

How about the Beef Cattle Industry?

- Little use of AI
- Relatively few high accuracy sires for training
- Multiple competing selection goals – cow/calf, feedlot, processor – little data/value sharing between sectors
- Few/no records on many economically-relevant traits
- Many breeds, some small with limited resources
- Crossbreeding is important
- No one wants to pay, as value is not recovered by breeder



Beef Industry Prosperity

"The path to sustainable, profitable growth begins with creating more promoters [happy customers] and few detractors [unhappy customers]…
It's that simple and that profound."

Frederick Reichheld, Harvard Business Review, Dec., 2003

The cornerstone of **prosperity** for any industry depends on final **consumer demand**

Challenges and Opportunities

- **Challenge**: Beef 's competitive advantage is pressured by rising concerns about diet and health.
- **Opportunity**: Strong "**high-quality**" branded beef programs
  - Consumers are willing to pay for assured quality
- Important to maintain and increase current consumers brand loyalty (meeting and exceeding quality expectations)
- Important to **expand** consumer base
- Improving quality – critical for beef industry
- **Tenderness** – the most important sensory attribute

Genomics as a management tool

- Data from project supported by FL Beef Council
- 200 animals from UF multibreed herd
  - genotyped with 150K SNP chip
  - impute 150K genotypes on another 200 animals
  - **418** Brahman/Angus animals with **150K** genotypes and **WBSF**
- Used in a discriminant analysis
  - Identify a subset of carcass and meat quality traits and markers with the highest **predictive accuracy** across tenderness classes
- 3 tenderness classes:
  - **Tender1** (**tender**) if WBSF < **3.5**
  - **Tender2** (**moder. tender**) if WBSF between **3.5 - 4.5**
  - **Tender3** (**tough**) if WBSF > **4.5**

Best carcass traits, SNP, carcass+SNP

Best carcass traits model
Marb, REA

Error Estimates for tenderness classes				
	Tender	Moder.	Tough	Total
Error Rate	46.2	82.1	36.6	54.9

Best SNP (marker) model
17 SNP

Error Estimates for tenderness classes				
	Tender	Moder.	Tough	Total
Error Rate	40.1	61.7	30.3	44.0

Group 1: tender (WBSF < **3.5**)
Group 2: moderately tender (**3.5** > WBSF < **4.5**)
Group 3: tough (WBSF > **4.5**)

Best carcass + SNP model
Marb, LM, DP + 17 SNP

Error Estimates for tenderness classes				
	Tender	Moder.	Tough	Total
Error Rate	37.1	56.4	32.4	41.9

Future outlook / Summary Points

- Genomic information (SNPs)
  - Increase the accuracy of EPDs
  - Add “novel” traits to our suite of available EPD (feed efficiency, healthfulness, nutritional value, disease resistance, thermotolerance)
- Large resource populations with phenotypes are required for discovery and validation.
- Need breed specific prediction equations.

Genomics - technology to accelerate genetic progress.

Questions?

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Challenges facing beef industry

- Beef ’s competitive advantage is pressured by rising concerns about diet and health.
- Negative consumer perception regarding beef products is creeping into the marketplace and impacting buying behavior.
- The Consumer Climate for Red Meat Study (1985, Yankelovich, Skelly and White) reported a marked and significant shift in consumer preferences.

Industry's efforts to identify shortfalls

- The National Cattlemen's Association (NCA) initiated a "War on Fat" campaign (NCA, 1990) aimed at reduction of excess fat at the production level; it was the industry's first unified step towards aligning production practices with some measure of consumer preferences.
- The first and second National Beef Quality Audit (NBQA 91 & NBQA 95) showed:
  - successful in attacking production of excess fat
  - new concerns about beef 's palatability and price/value relationships had developed.
- Low overall uniformity and consistency" was identified in 1991 and remained the number one concern in 1995 and 2000 (and second in 2005).

Industry's challenges

- Unfavorable wellness/health perceptions of beef
- Product inconsistency
- Eroding palatability attributes
- Lack of preparation convenience;
- Its costs were disproportionately rising compared to its competitors.
- Meanwhile, the pork and poultry industries improved their respective perceptions among consumers while also becoming more and more efficient.
- Subsequently, the beef industry found itself with weakening perceptions of its price/value relationship in the mind of consumers (a critically important concept)