THE GENETIC SUPERCOW ISN’T IN SIGHT

Chad Dechow
• Selection limits
• Locked and lost genetic variation
• Selection goals
• How do we get there?
SELECTION LIMIT ESTIMATES IN DAIRY CATTLE

- USDA scientists evaluated genotypes for Holstein, Jersey and Brown Swiss
- Pluck the best chromosomes
  - Lower limit
- Pluck the best gene
  - Upper limit
Chromosomal PTA for EVER-GREEN-VIEW MY 1326-ET (HOUA000061853387, F)

PTA Milk (lbs.): +504, Rel Milk: 85%

How do I interpret and use the values in this figure?
GOOD LUCK!!

- 2 copies of each chromosome (one from sire, one from dam)
- Chance of passing the best of each?
  - $(\frac{1}{2})^{30} = 0.00000009\%$
  - One in 1,073,741,824
  - Bulls: 1 in 536,870,912
- Assumes no recombination
EBV Milk = PTAM * 2

- Brown Swiss
- Holstein
- Jersey

Cole et al., 2010
GLASS HALF FULL?

PTA Milk = 503
EBV Milk = 1006
78,170 + 76,262 = 154,432
Lower bound = 101,392

PTA Milk = 475
EBV Milk = 950
77,480 + 76,318 = 153,798
Lower bound = 101,758
Brown Swiss

Holstein

Jersey

EBV DPR

Lower Bound

Upper Bound

Cole et al., 2010
What are the limits if we begin to synthesize genomes from multiple breeds?

Current rate of progress: $155/year

Only 46 years until the lower limit is reached!

1.5 centuries for the upper limit

Cole et al., 2010
• + 60,630 lbs EBV Milk
  88,500 lbs milk
• + 3,032 lbs EBV Fat
  4,100 lbs fat (4.6%)
• + 2,274 lbs EBV Protein
  3,150 lbs pro (3.6%)
• Hold the line on everything else

• EBV $NM = $20,000
  ▪ PTA $NM = $10,000
Expected progress = correlation * genetic SD of trait * $NM$ change
<table>
<thead>
<tr>
<th>Trait</th>
<th>Lower Limit of $NM</th>
<th>Upper Limit of $NM</th>
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<tbody>
<tr>
<td>Milk</td>
<td>11,215</td>
<td>36,433</td>
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<tr>
<td>Fat</td>
<td>653</td>
<td>2,121</td>
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<tr>
<td>Protein</td>
<td>418</td>
<td>1,358</td>
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<tr>
<td>PL</td>
<td>60</td>
<td>195</td>
</tr>
<tr>
<td>SCS</td>
<td>-2</td>
<td>-7</td>
</tr>
<tr>
<td>BWC</td>
<td>-8</td>
<td>-26</td>
</tr>
<tr>
<td>Udder composite</td>
<td>7</td>
<td>21</td>
</tr>
<tr>
<td>Feet/leg composite</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>DPR</td>
<td>19</td>
<td>62</td>
</tr>
</tbody>
</table>
Genetic Limits vs Biological Limits
Cunningham’s Paradox: Genetic merit is higher, average has improved, top times are not changing.

From 1949 to 2013, the trend for Derby winning times is completely flat.
WHAT IS THE BIOLOGICAL LIMIT?

- We won’t know until long after we’ve arrived
  - New mutations or recombination
- Potential yield limits
  - Limit to nutrient intake & digestive capacity
  - Metabolic capacity
  - Udder capacity
    - More frequent milking can help overcome
Some favorable genes are physically linked to unfavorable genes
  - Need recombination to unlock

- Eliminated from the population and we’ll never know
  - Short term versus long term selection response
AVERAGE NUMBER OF RECOMBINATION EVENTS = ONE / CHROMOSOME

VanRaden, 2008
IDEAL CHOICE

OR
Recombination—the Making of New Allele Combinations

The best combinations in the future will depend on a broad selection of cow and sire lines from our breed.

Part of the excitement of the holiday season is the thrill of unwrapping a beautiful present from under the Christmas tree. Often a gift will be packaged with fancy paper and a beautiful bow—and inside it'll contain something wonderful. Well, in dairy cattle breeding, we also need to think about how the genetics of our elite animals is presented to the next generation. The genetic merit of the animal, i.e., the sum of all of the alleles that the animal possesses, is the content of the package. The packaging of these alleles is done with per pair of chromosomes. For example, with Chromosome 3, 41 percent of the time there will be one crossover between the inner pair of chromosomes. 27 percent of the time there will be 2 crossovers, and 9 percent of the time there will be 3 or more.

What's particularly fascinating about this repackaging of our genetic material is

<table>
<thead>
<tr>
<th>Bulls</th>
<th>Crossovers per gamete</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>BALISTO, O-STYLE, SUPERSIRE, KINGBOY, LITHIUM</td>
<td>28</td>
<td>High</td>
</tr>
<tr>
<td>MCCUTCHEN, MOGUL, FREDDIE, SHAMROCK, SUPERSTITION, PLANET</td>
<td>25</td>
<td>Medium</td>
</tr>
<tr>
<td>SHOTTE, BOLTON, G W ATWOOD, TANGO, GOLDWYN</td>
<td>22</td>
<td>Low</td>
</tr>
</tbody>
</table>
SELECTION GOALS WILL CONTINUE TO EVOLVE

TPI 2005

Protein | Fat | PTAT | Dairy Form | Udder | Feet & Legs
SCS | DPR | DCE
PL

TPI 2017

Protein | Fat | PTAT | Dairy Form | Udder | Feet & Legs | SCS | Fert. Index | DCE | PL | FE | Livability
DSB
WHAT TRAITS WILL BECOME IMPORTANT?

• More precise feed utilization?
• Properties of milk?
  ▪ Processing characteristics
  ▪ Human health
• Immune function?
• Recombination & genome structure?
WHAT TRAITS WILL BECOME IMPORTANT?

• Stress resistance?
  ▪ Heat tolerance
• Precise cows for precise management systems?
• Additional functional traits?
  ▪ Hoof health, mobility
• Environmental sustainability?
HOW WILL WE GET THERE?

• Gene Editing
  ▪ Suitable for traits such as polled, slick hair, A2
  ▪ Yield is infinitely more complicated

• Advances in genomic methodologies
  ▪ Whole genome sequence
  ▪ Functional understanding of the genome
HOW WILL WE GET THERE?

• Advanced embryo production technologies
  ▪ Embryos as parents of embryos

• Beyond the DNA sequence
  ▪ Epigenetics

• Recapturing lost genetic diversity

• Continued development of new traits
THANKS FOR YOUR TIME!
WE’VE GOT A LOT OF WORK LEFT!