Genetic Improvement of Cattle and Sheep

*Focus on The Future*

Dorian Garrick

AL Rae Centre for Genetics & Breeding, New Zealand  D.Garrick@massey.ac.nz

Theta Solutions LLC  dorian@ThetaSolutionsLLC.com
A Pool of Selection Candidates

Selection “moves the cloud”

One economically important trait

Genetic change in offspring performance only occurs if Breeding Values (BVs) of parents are not average
American Hereford Association Genetic Trends

Yearling Weight

EPD (lb) or (approx) EBV (kg)

Year of Birth


1.4 kg/yr
0.9 kg/yr

Weaning Direct
American Hereford Association Genetic Trends

Yearling Weight

- Ultrasound
- 1.4 kg/yr

Weaning Direct

- 0.9 kg/yr

EPD (lb) or (approx) EBV (kg)

Year of Birth

- 1975
- 1980
- 1985
- 1990
- 1995
- 2000
- 2005
- 2010
- 2015
- 2020
American Angus Association Genetic Trends

- Yearling Weight: 2.4 kg/yr
- Weaning Direct: 1.3 kg/yr
- Carcass Wt: 1.2 kg/yr

EBV (kg) vs Year (1980-2015)
An average 2017-born steer earns $103/head more than a 1980 steer

Admirable progress on terminal traits

June 2018
An average 2017-born daughter eats $57 more feed per year than an average 1980 daughter.

$EN
Cow Energy Savings
$/daughter/year

Undesirable progress on maternal traits

June 2018
American Angus Trends for cow-calf system

• An average 2017 daughter eats $57 more feed per year than an average 1980 daughter
  • Heavier liveweight
  • Higher milk production
  • Higher maintenance requirements
  • All of these costs are carried by the cow-calf operator

• An average 2017 feedlot offspring earns $103 more at slaughter due to improved postweaning performance and carcass characteristics
  • But cows don’t produce feedlot offspring every year!
  • At least some of this benefit is captured by the feedlotter

• Collectively, for the cow-calf operator this is genetic change not improvement
What do you measure?

• Calving Traits
  • **Calving Ease** and **Birth Weight**
• Early Growth Traits
  • **Weaning Weights**
  • **Yearling Weights**
• Reproduction
• Ultrasound predictions of carcass traits
• Mature Cow Weights and Condition Scores
• Actual Carcass Characteristics
• Actual Feed Intake

**Measure it**
**Store it**
**BLUP it**
**Report it**
**Market it**

Principally tangible traits that are easy to measure and heritable so see in the next generation
Logical Approach to Design of a Breeding Program

What you want to achieve

Goal → Breeding Objective → Selection Criteria

Economic Analysis

Breeding Scheme Design

Mating Plan → Dissemination System
Goal

*If you’re not farming for profit, we’d like to wish you well with your hobby*

*Livestock Improvement Corporation (LIC) in 1990’s*
Goal

*If you’re not farming for sustainable prosperity, do something else*
Logical Approach to Design of a Breeding Program

What you want to change

Goal

Breeding Objective

Selection Criteria

Breeding Scheme Design

Mating Plan

Dissemination System

Comprises a:
- List of traits (these will be the EBVs) and their
- Relative Emphasis (these define the index)
Logical Approach to Design of a Breeding Program

Goal

Breeding Objective

Selection Criteria

Breeding Scheme Design

Economic Analysis

Mating Plan

Dissemination System

What you measure to produce the EPDs
Logical Approach to Design of a Breeding Program

Goal → Breeding Objective → Selection Criteria → Breeding Scheme Design → Dissemination System → Mating Plan → Economic Analysis

Who you measure to produce the EPDs and generate selection candidates
Logical Approach to Design of a Breeding Program

- Goal
- Breeding Scheme Design
- Mating Plan
- Dissemination System
- Economic Analysis
- Breeding Objective
- Selection Criteria

What you do with the ones you select
Logical Approach to Design of a Breeding Program

Goal → Breeding Objective → Selection Criteria → Breeding Scheme Design → Dissemination System → Mating Plan → Economic Analysis → Goal

How you choose the mates
Logical Approach to Design of a Breeding Program

- Goal
- Breeding Objective
- Selection Criteria
- Breeding Scheme Design
- Dissemination System
- Mating Plan
- Economic Analysis

What are the overall benefits and the overall costs?
Who are the beneficiaries of change?
Who pays to achieve it?
Breeding Objective - Traits we want to change

- Reproduction and longevity

- Income over feed costs
  - Growth (Sheep & Beef Cattle)
  - Milk (Dairy Cattle, Dairy Sheep)
  - Food Product Quality
    - Eating quality including meat tenderness
    - Human healthfulness of meat or milk
  - Maternal, terminal and replacement feed costs

- Animal welfare

- Environmental “hoof” print
Traits we are doing a good job of selecting

- Reproduction and longevity

- **Income** over feed costs
  - **Growth** (Sheep & Beef Cattle)
  - **Milk** (Dairy Cattle, Dairy Sheep)
  - Food Product Quality
    - Eating quality including meat tenderness
    - Human healthfulness of meat or milk
  - Maternal, terminal and replacement feed costs

- Animal welfare

- Environmental “hoof”print
Traits we are doing a **better** job of selecting

- **Reproduction** and **longevity**

- Income over feed costs
  - Growth (Sheep & Beef Cattle)
  - Milk (Dairy Cattle, Dairy Sheep)
  - Food Product Quality
    - Eating quality including meat **tenderness**
    - Human **healthfulness** of meat or milk
  - Maternal, terminal and replacement **feed costs**

- **Animal welfare**

- **Environmental “hoof”print**
Why aren’t traits being adequately considered?

• Not selecting on the total merit indexes (e.g. for maternal systems)
• Not measuring enough of the less tangible attributes
  • Cannot be measured in production setting (e.g. carcass on breeding animals)
  • Hard to measure in production setting (e.g. intermittent disease)
• Too expensive or too labor intensive?
  • New devices (Internet of Things – IoT) will change this
• Don’t see a demand for them?
• Don’t believe in them?
• Don’t see the value proposition?
  • But prepared to invest in testing for genetic defects, or for genomic prediction
Value Proposition

• Among the ram or bull breeding sectors
  • Too many animals being recorded
  • Not enough traits being recorded
    • Traits not being measured or recorded accurately or with enough precision
  • Not being rewarded by ram or bull buyers – market failure
    • In terms of price or demand for less tangible traits (e.g. efficiency and consumer quality)
  • Breed Association structure might be impeding innovation
    • Routine EBVs provided on all animals regardless of phenotypic measurement or not
      • Exacerbated by use of genomic prediction relative to pedigree parent-average EBV
    • Disincentive for individual breeders to be an early investor in infrastructure
How might more balanced selection occur?

• New technologies for measuring
• Subsidies by government or levy payers (e.g. Australia, Canada)
• Local Regulations
  • Such as nutrient excretion limits or welfare codes
• Market Requirements
  • Specifications for access to markets (especially export markets)
• New business structures to capture value
  • Small collectives of like-minded entrepreneurs
  • Vertical integration
Traits we are doing a better job of selecting

- **Reproduction and longevity**

- Income over feed costs
  - Growth (Sheep & Beef Cattle)
  - Milk (Dairy Cattle, Dairy Sheep)
  - Food Product Quality
    - Eating quality including meat **tenderness**
    - Human **healthfulness** of meat or milk
  - Maternal, terminal and replacement **feed costs**

- **Animal welfare**

- **Environmental “hoof”print**
Feed required to produce one kilogram of meat or dairy product

Quantity of animal feed required to produce one kilogram of meat, egg or milk product. This is measured as dry matter feed in kilograms per kilogram of edible weight output.

- **BEEF**: 25 kilograms
- **LAMB**: 15 kilograms
- **Pork**: 6.4 kilograms
- **Poultry**: 3.3 kilograms
- **Eggs**: 2.3 kilograms
- **Whole Milk**: 0.7 kilograms

Source: Alexander et al. (2016)

[OurWorldInData.org/meat-and-seafood-production-consumption/ • CC BY-SA]
Energy efficiency of meat and dairy production

The energy efficiency of meat and dairy production is defined as the percentage of energy (caloric) inputs as feed effectively converted to animal product. An efficiency of 25% would mean 25% of calories in animal feed inputs were effectively converted to animal product; the remaining 75% would be lost during conversion.

- Whole Milk: 24%
- Eggs: 19%
- Poultry: 13%
- Pork: 8.6%
- Lamb/mutton: 4.4%
- Beef: 1.9%

Source: Meat conversion efficiencies - Alexander et al. (2016)  OurWorldInData.org/meat-and-seafood-production-consumption/ • CC BY-SA
Protein efficiency of meat and dairy production

The protein efficiency of meat and dairy production is defined as the percentage of protein inputs as feed effectively converted to animal product. An efficiency of 25% would mean 25% of protein in animal feed inputs were effectively converted to animal product; the remaining 75% would be lost during conversion.

Source: Meat conversion efficiencies - Alexander et al. (2016)  OurWorldInData.org/meat-and-seafood-production-consumption/ • CC BY-SA
### Greenhouse gas emissions per gram of protein, by food type

Average greenhouse gas emissions per unit protein, by food type measured in grams of carbon dioxide equivalents (CO₂e) per gram of protein. Average values are based on a meta-analysis of studies across 742 agricultural systems and over 90 unique foods.

<table>
<thead>
<tr>
<th>Food Type</th>
<th>GHG per unit protein (gCO₂e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef/Mutton</td>
<td>221.63 gCO₂e</td>
</tr>
<tr>
<td>Fresh Produce</td>
<td>37.17 gCO₂e</td>
</tr>
<tr>
<td>Pork</td>
<td>36.33 gCO₂e</td>
</tr>
<tr>
<td>Dairy</td>
<td>35.07 gCO₂e</td>
</tr>
<tr>
<td>Poultry</td>
<td>31.75 gCO₂e</td>
</tr>
<tr>
<td>Eggs</td>
<td>24.37 gCO₂e</td>
</tr>
<tr>
<td>Rice</td>
<td>21.16 gCO₂e</td>
</tr>
<tr>
<td>Wheat</td>
<td>4.62 gCO₂e</td>
</tr>
<tr>
<td>Maize</td>
<td>4.42 gCO₂e</td>
</tr>
<tr>
<td>Pulses</td>
<td>0.58 gCO₂e</td>
</tr>
</tbody>
</table>

Source: Clark & Tilman (2017)

OurWorldInData.org • CC BY-SA
Most of the increase is in pork and poultry.
Per capita meat consumption by type, kilograms per year, United States

Average per capita meat consumption broken down by specific meat types, measured in kilograms per person per year. Data is based on per capita food supply at the consumer level, but does not account for food waste at the consumer level.

Source: UN Food and Agricultural Organization (FAO)
NZ Meat Consumption Trends – last decade (kg carcass weight equivalent)

### Per capita consumption

<table>
<thead>
<tr>
<th>CWE (kg)</th>
<th>2006-7</th>
<th>2017-17</th>
<th>10 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>28</td>
<td>17</td>
<td>-39%</td>
</tr>
<tr>
<td>Sheep</td>
<td>11</td>
<td>6</td>
<td>-41%</td>
</tr>
<tr>
<td>Pork</td>
<td>21</td>
<td>24</td>
<td>+10%</td>
</tr>
<tr>
<td>Poultry</td>
<td>35</td>
<td>47</td>
<td>+35%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>95</td>
<td>94</td>
<td>-1%</td>
</tr>
</tbody>
</table>

### Retail Price US$

<table>
<thead>
<tr>
<th></th>
<th>2007-8</th>
<th>2017-18</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>$8.40</td>
<td>$11.90</td>
<td>42%</td>
</tr>
<tr>
<td>Sheep</td>
<td>$8.05</td>
<td>$10.50</td>
<td>30%</td>
</tr>
<tr>
<td>Pork</td>
<td>$8.05</td>
<td>$8.40</td>
<td>4%</td>
</tr>
<tr>
<td>Poultry</td>
<td>$5.60</td>
<td>$5.60</td>
<td>0%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$22.05</td>
<td>$30.40</td>
<td>36%</td>
</tr>
</tbody>
</table>

NZ has had 41% domestic population increase (immigration)
Moving the Cloud

• **Reproduction** and **longevity**

• **Income** over feed costs
  - **Growth** (Sheep & Beef Cattle)
  - **Milk** (Dairy Cattle, Dairy Sheep)
  - Food Product Quality
    - Eating quality including meat **tenderness**
    - Human **healthfulness** of meat or milk
  - Maternal, terminal and replacement **feed costs**

• **Animal welfare**

• **Environmental “hoof”print**
Summary

• We really need to improve efficiency of sheep and cattle production
  • Reproductive Efficiency
  • Birth to Finish Efficiency
  • Doing so involves a number of traits, many not being adequately considered

• Selection is a proven and cost-effective mechanism for improvement
  • Needs to be based on whole-system index(es)
  • Comprising EBVs for economically-relevant traits based on sensible phenotyping strategies combined with the use of genomics
  • Will need to be led by organisations like ICBF & SI and innovative breeders