Optimizing Breeding Programs

COST-BENEFIT
Cost - Benefit of breeding programs

Cost of breeding programs for genetic improvement

Fixed costs (logistics, scientists etc. etc.)

Cost related to breeding strategy
• cost of phenotyping
• cost of genotyping
• cost of reproduction

Benefits

Benefit of more genetic gain
Market share
Benefits of genetic gain

• Assuming the benefit is expressed by the breeding objective (economic values of trait improvement).

• Variation in breeding objective is variation in genetic merit for profit.

Difference between best and worst is about $6 \sigma_H$. 
Benefits of genetic gain

- Benefit is transmitted is multiplied over many animals

[Diagram: Pyramid with tiers labeled Nucleus (50,000 cows), Multipliers (1 million cows), and Commercial producers (20 million cows).]
Benefits of genetic gain

- Benefit is cumulative

<table>
<thead>
<tr>
<th>yr1</th>
<th>yr2</th>
<th>yr3</th>
<th>yr4</th>
<th>yr5</th>
<th>yr6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

= $\text{dG/yr}$
Benefits of genetic gain

Benefit is
- Cumulative
- Multiplied over many

Benefits can be expected to be large

• But:
  - Are they achieved?
  - Who gets the benefit?
    • Breeders, Producer? Retail? Consumer?
Economic value of genetic improvement

– Value difference between two bulls
– Value of selecting better bulls
  – Bulls sold to Commercial
  – Bulls used in Stud

– Value of genetic improvement – whole herd
Two Commercial Bulls

<table>
<thead>
<tr>
<th>EBV YWT</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bull 1: Kevin</td>
<td>+10 kg</td>
</tr>
<tr>
<td>Bull 2: Tony</td>
<td>+15 kg</td>
</tr>
</tbody>
</table>

| Nr Progeny: | 100 |
| Value of 1 kg YWT | $4  |
| Difference in progeny | 2.5 kg |

Difference in value: \[ 5 \times \$4 \times 100 \times 0.5 = \$1000.\]
Two Commercial Bulls

$Index

<table>
<thead>
<tr>
<th>Bull</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kevin</td>
<td>+190</td>
</tr>
<tr>
<td>Tony</td>
<td>+180</td>
</tr>
</tbody>
</table>

Nr Progeny: 100

Difference in progeny $5

Difference in value: $10 * 100 * 0.5 = $500

= $500.-
Selecting Better Bulls

Average of 100 rams sold:  With Genomics +182
No Genomics +180

Nr Progeny:  100 per bull

Difference in progeny $1.0

Difference in value:  
$2  * 100
as commercial bulls

Selection
Difference

Nr of
Progeny

Expression
per progeny

= $100.- * 100 rams = $10,000.
So principles are

Value of a superior bull

\[ = \text{Selection Difference} \times \text{Nr. Progeny} \times \text{expressions per progeny} \]

We look at all expressions in commercial progeny

To evaluate benefit we need to predict

- the extra Selection Difference we can get
  
  *this will depend a lot on extra accuracy*

- the number of expressions
How about selection of stud bulls?

Value of a superior bull

\[ \text{Value of a superior bull} = \text{Selection Difference} \times \text{Nr. Progeny} \times \text{expression per progeny} \]

Progeny in commercial, so for a stud bulls these are actually grand progeny, great grand progeny, etc.
(allele) frequency of one unit of superiority as expressed in commercial herd

The fate of superiority from commercial bull vs a stud bull

Noting that a commercial bull also transmits the superiority from a stud bull
**GENEFLOW**

Donors of genes

<table>
<thead>
<tr>
<th>Sires of Nucleus</th>
<th>Dams of Nucleus</th>
</tr>
</thead>
<tbody>
<tr>
<td>P matrix</td>
<td></td>
</tr>
<tr>
<td>1    2   3   4   5</td>
<td>1    2   3   4   5</td>
</tr>
<tr>
<td>1 0 0.5 0 0 0 0</td>
<td>0 0.166667 0.166667 0.166667 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>2 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>3 0 1 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>4 0 0 1 0 0 0</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>5 0 0 0 1 0 0</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
</tbody>
</table>

Recipients of genes

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<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>5 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>6 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>7 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
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<td>8 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
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<tr>
<td>9 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>10 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
</tr>
</tbody>
</table>

**Predict more precisely when benefits occur**
GENEFLOW

Donors of genes

<table>
<thead>
<tr>
<th>Sn</th>
<th>Dn</th>
<th>Sc</th>
<th>Cm</th>
<th>Cf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn&lt; Sn</td>
<td>Sn&lt; Dn</td>
<td>Sn&lt; Sc</td>
<td>Sn&lt; Cm</td>
<td>Sn&lt; Cf</td>
</tr>
<tr>
<td>Dn&lt; Sn</td>
<td>Dn&lt; Dn</td>
<td>Sf&lt; Sc</td>
<td>Dn&lt; Cm</td>
<td>Dn&lt; Cf</td>
</tr>
<tr>
<td>Sc&lt; Sc</td>
<td>Sc&lt; Sc</td>
<td>Sc&lt; Sc</td>
<td>Sc&lt; Cm</td>
<td>Sc&lt; Cf</td>
</tr>
<tr>
<td>Cm&lt; Sc</td>
<td>Cm&lt; Dn</td>
<td>Cm&lt; Sc</td>
<td>Cm&lt; Cm</td>
<td>Cm&lt; Cf</td>
</tr>
<tr>
<td>Cf&lt; Sc</td>
<td>Cf&lt; Dn</td>
<td>Cf&lt; Sc</td>
<td>Cf&lt; Cm</td>
<td>Cf&lt; Cf</td>
</tr>
</tbody>
</table>

Sn Sires of Nucleus
Dn Dams of Nucleus
Sc Stud born males to sire commercial
Cm Commercial born males
Cf Commercial born females

Recipients of genes

Nucleus

Commercial
## GENEFLOW

### Donors of genes

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<thead>
<tr>
<th></th>
<th>Sires of Nucleus</th>
<th>Dams of Nucleus</th>
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<th>Commercial born males</th>
<th>Commercial born females</th>
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<tr>
<td>Sn</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cf</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

\[
P = \text{matrix describing transmission of genes}
\]
GENEFLOW

- \( R \) = a matrix defining gene transmission of some superiority (or particular allele)

- \( Q \) = a matrix describing aging

- \( P \) = matrix describing transmission of genes
  - \( P = R + Q \)

- \( m \) vector of allele frequency in each age class

- \( n \) vector to describe inserting allele or superiority
## GENEFLOW

### Allele frequency in the limit, from on ‘insertion’ of superiority (or an allele) = 1/(L_m + L_f)

Geneflow mainly useful for initial part of an action, otherwise can use Rendel and Robertson
Cumulative Discounted Expressions  CDE

Value (V) in year t is worth now $V \cdot c$ where $c = 1/(1+d)^t$

d = discount rate

c = discount factor

Expression in age class i in year t is $m(i)_t = E_{it}$

Net Present Value of Sum of expression over 25 years

$$CDE = \sum_{t=1}^{25} \sum_{i=1}^{nac} E_{it} c_t$$
(allele) frequency of one unit of superiority as expressed in commercial herd

The fate of superiority from commercial bull vs a stud bull

Noting that a commercial bull also transmits the superiority from a stud bull ?!
(allele) frequency of one unit of superiority as expressed in commercial herd

<table>
<thead>
<tr>
<th>Discount rate</th>
<th>CDE comm bulls</th>
<th>CDE stud sires</th>
<th>Sum of all future expressions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.99</td>
<td>3.93</td>
<td></td>
</tr>
<tr>
<td>0.05</td>
<td>0.78</td>
<td>1.96</td>
<td></td>
</tr>
<tr>
<td>0.08</td>
<td>0.68</td>
<td>1.37</td>
<td></td>
</tr>
</tbody>
</table>

Cumulative Discounted Expressions - CDE

Effect of discounting
## Value of selecting Stud Sires and Comm bulls

### Value of a superior bull

\[ \text{Value} = \text{Selection Difference} \times \text{Nr. Progeny} \times \text{expression per progeny} \]

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Comm bull</td>
<td>+ 1.4</td>
<td>100</td>
<td>0.68</td>
<td>$95</td>
</tr>
<tr>
<td>Stud Sire</td>
<td>+ 3.0</td>
<td>400</td>
<td>1.37</td>
<td>$1,644</td>
</tr>
</tbody>
</table>

Sum of all future expressions:
Cumulative Discounted Expressions
Can also use simple method: \( \frac{dG}{\text{year}} \), and cumulate

<table>
<thead>
<tr>
<th>yr1</th>
<th>yr2</th>
<th>yr3</th>
<th>yr4</th>
<th>yr5</th>
<th>yr6</th>
</tr>
</thead>
</table>

\[
\text{selection round 1} \quad \text{selection round 5}
\]
\[
\text{selection round 4}
\]
\[
\text{selection round 3}
\]
\[
\text{selection round 2}
\]
\[
\text{selection round 1}
\]

\[
= \frac{dG}{\text{yr}}
\]
Cost - Benefit of a breeding program

- **Nucleus**
  - 50,000 ewes
  - No GS
  - Cost/head $10
  - Cost $0.5 M
  - dG/ewe $2
  - Benefit $20 M

- **Multipliers**
  - 0.5 million ewes

- **Commercial producers**
  - 10 million ewes

Genetic lag

Genetic improvement

Dissemination
Economic evaluation of breeding programs

Benefit: \( dG.N \) accumulates each year

Cost: \( C \)

Future returns are discounted: \( 1/r^t \) in year \( t \)

\[(N.t.dG - C)(1/r^t)\]

<table>
<thead>
<tr>
<th>year</th>
<th>Genetic Mean ($)</th>
<th>Benefit (M)</th>
<th>Cost (M)</th>
<th>discount factor</th>
<th>NPV (M$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
<td>1.00</td>
<td>-0.50</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>20</td>
<td>0.5</td>
<td>0.95</td>
<td>18.57</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>40</td>
<td>0.5</td>
<td>0.91</td>
<td>35.83</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>60</td>
<td>0.5</td>
<td>0.86</td>
<td>51.40</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>80</td>
<td>0.5</td>
<td>0.82</td>
<td>65.40</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>100</td>
<td>0.5</td>
<td>0.78</td>
<td>77.96</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>120</td>
<td>0.5</td>
<td>0.75</td>
<td>89.17</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>140</td>
<td>0.5</td>
<td>0.71</td>
<td>99.14</td>
</tr>
</tbody>
</table>

Example:
Comm = 10 Million sheep
\( dG = \$2/\text{head}/\text{annum} \)
Cost = 500k
Cost - Benefit of a breeding program

Commercial producers
10 million ewes

Multipliers
0.5 million ewes

Nucleus
50,000 ewes

Genetic lag
Genetic improvement

No GS With GS

Cost/head $10 $50
Cost $0.5 M $2.5 M

dG/ewe $2 $2.2
Benefit $20 M $22 M
Cost-Benefit industry wide

3 tier benefit

Cost-Benefit Industry graph

No GS
Cost
$0.5 M

dG
$20 M

GS
Cost
$2.5 M

dG
$22 M

50k Nuc cows
20M Comm

NPV Industry

- 0 2 4 6 8 10 12 14 16 18 20
- 50,000,000 100,000,000 150,000,000 200,000,000 250,000,000

noGS

GS
Cost-Benefit Stud

2 tier benefit

<table>
<thead>
<tr>
<th></th>
<th>No GS</th>
<th>GS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>$5 k</td>
<td>$17.5 k</td>
</tr>
<tr>
<td>dG</td>
<td>$20 k</td>
<td>$22 k</td>
</tr>
</tbody>
</table>

NPV Stud

500 Nuc cows
10k Comm
Comparing simply dG/yr vs GFLOW
Cost - Benefit of breeding programs

- **Commercial producers**: 20 million cows
  - **Nucleus**: 50,000 cows
  - **Multipliers**: 1 million cows

<table>
<thead>
<tr>
<th></th>
<th>No GS</th>
<th>GS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost/head</strong></td>
<td>$10</td>
<td>$60</td>
</tr>
<tr>
<td><strong>dG/cow</strong></td>
<td>$2</td>
<td>$2.2</td>
</tr>
</tbody>
</table>

**Genetic lag**

**Genetic improvement**

**Dissemination**
Cost-Benefit industry wide

3 tier benefit

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<thead>
<tr>
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<th>GS</th>
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<tbody>
<tr>
<td>Cost</td>
<td>$0.5 M</td>
<td>$1.65 M</td>
</tr>
<tr>
<td>dG</td>
<td>$40 M</td>
<td>$44 M</td>
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</table>

NPV Industry

50k Nuc cows
20M Comm
Cost-Benefit Stud

2 tier benefit

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</table>

NPV Stud

500 Nuc cows
10k Comm
summary

• Can calculate additional gain on a per bull basis, assuming returns in commercial progeny

• Those figures depend on
  – Additional accuracy
  – Age structure
  – Herd parameters such as weaning rate, mating rate, prop. Sold