Design of Breeding Programs
Decisions in breeding programs

Where to go? breeding objective (which traits)

Who and what to measure? performance, DNA test

Who to select and mate? reproductive technol.

gains vs inbreeding
Animal Breeding in a nutshell

Breeding objectives

How to get there?

Trait measurement
- Which animals?
- Which traits
- Genotyping
- Reference population?
- ID and pedigree

Estimation of breeding value
- BLUP
- GBLUP, 1step, Bayes ABCD
- Multi trait

Reproductive technology
- Artificial Insemination
- MOET
- JIVET
- Cloning

Selection, Culling & Mating
- Merit, Inbreeding, Risk,
- Constraints, Crossbreeding

Where to Go?
Why do we need a design?

- **Genetic Improvement:**
  - Which animals to measure?
  - Where to select them?
  - Mating strategy
  - Reproductive and Genomic Technologies?

- **Dissemination of Genetic Superiority**

- **Inbreeding**
Basic Principle of making genetic progress

Mate the “best” to the “best”
and do that as quickly as possible

Genetic Gain/yr = \frac{\text{Genetic Superiority of parents}}{\text{Generation Interval}}

Genetic Gain/yr = \frac{\text{Sel Intensity} \times \text{Accuracy} \times \text{Genetic SD}}{\text{Generation Interval}}
Design Examples

- One-tier breeding program

Select and replace

Breeding males (few)

Breeding females (many)

Select and Replace

Male progeny

Female progeny
Design Examples

One-tier breeding program

Nucleus

genetic improvement measurement
Two-tier breeding program

- Nucleus
- Breeding bulls
- Genetic lag
- Commercial producers

Design Examples

Genetic improvement
Measurement
Dissemination
Genetic merit of Nucleus versus Commercial

Rate of gain is the same in all tiers
3-tier breeding program

- **Nucleus**
  - 100k cows
  - Genetic improvement
  - Measurement

- **Multipliers**
  - 1 million cows
  - Breeding bulls

- **Commercial producers**
  - 10 million cows
  - 1 million cows
Design Examples

3-tier breeding program

- Nucleus
- Multipliers
- Commercial producers

Genetic improvement
Measurement
Dissemination
Dissemination
Genetic lag
Genetic lag
Genetic lag
Genetic lag
Multiplication in Broiler Breeding Programs

Adapted from: Poultry Breeding and Genetics, Crawford (ed). Elsevier, 1990

From pure line with 200-500 females and 50--100 males

**Dam line**

<table>
<thead>
<tr>
<th>Generation</th>
<th>Quantity</th>
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</thead>
<tbody>
<tr>
<td>Pedigree</td>
<td>1</td>
</tr>
<tr>
<td>Pedigree</td>
<td>10</td>
</tr>
<tr>
<td>Male</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td></td>
</tr>
<tr>
<td>X 15</td>
<td></td>
</tr>
<tr>
<td>Chicks/female</td>
<td>150</td>
</tr>
<tr>
<td>X 40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6000</td>
</tr>
<tr>
<td>X 40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>240,000</td>
</tr>
<tr>
<td>X 120</td>
<td></td>
</tr>
<tr>
<td></td>
<td>28,800,000</td>
</tr>
<tr>
<td>X 2 kg x 69%</td>
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<td></td>
<td>39,744 T meat</td>
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</table>

**Year 0**

**Year 3**

**Year 4-5**

**Pure-line selection**

- Great-grandparent stock
- Grandparent stock
- Parent stock
- Broilers
- Consumers

39,744 T meat
Structure of Swine (Poultry) Breeding Programs

Within breed/line selection programs:
Testing, evaluation, and selection
- Elite breeder herds or breeding company

Genetic Improvement $\Delta G$
- Dissemination - multiply superior genetics and provide to the commercial sector
- Limited selection; some cross breeding

Production of market pigs
- Limited selection
- Extensive crossbreeding

MARKET
Design Examples

Two-tier breeding program

Central Nucleus
(pigs, poultry, some dairy)

or Dispersed
(sheep, cattle)
More uniform testing
Can test more traits (FI)
Easier to apply MOET
Nucleus: could be defined as "the mothers and fathers of the future bulls"

What defines the nucleus?

4 pathways:
- Selection of sires for sires: top AI sires
- Dams for sires: bull dams
- Sires for cows: average AI sires
- Dams for cows: normal cows

Commercial producers

Elite matings
Design Examples

Two-tier breeding program (can compare with 4 pathways)
Dispersed Nucleus

Nucleus: could be defined as
"the mothers and fathers of the future bulls"

Top studs
Delivering the genetics of the future bulls

Other studs
Acquire their genetic from top studs
Themselves being merely multipliers
Local ‘nucleus’ can in fact be a multiplier

Semen imports: with a lot of it the local nucleus is merely a multiplier

Examples:
- Angus Australia breeding program
- Holstein Australia Breeding program

Other Nucleus (USA)

Local Nucleus

Commercial producers
Nucleus Breeding Schemes

Closed Nucleus

Replacement animals for nucleus only from nucleus

Selection only permanently effective in nucleus.

Nucleus objectives impact on whole scheme.

Common in pigs and poultry
Nucleus Breeding Schemes

Open Nucleus

Replacement animals for nucleus but also some from base

Selecting from base requires measurement in base

More genetic improvement than closed scheme (~15%)

Common in dairy
Open nucleus systems

• Select the best animals from lower tiers to compete for being nucleus parents

• degree of ‘openness depends on
  ▪ difference between nucleus and commercial
  ▪ spread of their breeding values

• Open to nuclei
Open Nucleus

Difference in genetic mean between nucleus and base (~2 generations)

Selection of females for elite matings (e.g. 80% from nucleus, 20% from base)

Truncation Point

145 165 220

130 150 170

nucleus

base
Open Nucleus: *effect of more information in base*

- Difference in genetic mean between nucleus and base (~2 generations)
- Selection of females for elite matings (e.g. 70% from nucleus, 30% from base)
- More measurement in base, more spread of EBV, more selected from base
Benefit of selection in lower tier

Genetic Merit

Genetic lag
2 gen's here

nucleus

commmercial

Effect of selection in commercial
Contributions of pathways

$$R = \frac{i_m r_m + i_f r_f}{L_m + L_f} \sigma_A$$

<table>
<thead>
<tr>
<th>Selection</th>
<th>sel.int</th>
<th>sel.accur</th>
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<tbody>
<tr>
<td>Selection of sires</td>
<td>2</td>
<td>.5-.8</td>
</tr>
<tr>
<td>Selection of dams</td>
<td>0.5-1</td>
<td>.5-.6</td>
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</table>

- $S_{\text{sires}} : S_{\text{dams}}$ at least varies from 2:1 to 5:1
- Sire selection contribute more than 70%-90% to dG
Contributions of pathways

4 pathways in dairy

- Selection of sires for sires 39%
- Selection of sires for cows 38%
- Selection of dams for sires 22%
- Selection of dams for dams 1%

contribution to $\Delta G$
Why need a design?

• Genetic improvement

Need decisions on

- which animals to measure or genotype  
  *nucleus*  *males (females)*
- where to select them  
  *nucleus/base*
- mating strategy  
  *best to best*  \(\rightarrow\)  elite matings

• Dissemination of genetic superiority
  - Often a challenge when setting up a new program, esp in developing countries.
  - How to sell/give improved seedstock to local farmers

• Inbreeding
Making genetic progress is about

- Selecting only the very best
- Selecting accurately
- Keeping generation intervals short

\[ R = \frac{i_m r_m + i_f r_f}{L_m + L_f} \sigma_A \]

Reproductive rates affect all of the above!
Reproductive technologies

• Increases selection intensities

• Increases accuracy of EBVs

• Decreases generation intervals

• Increases inbreeding
Adult dairy MOET scheme (1983)

More offspring of top cow after testing it
1998: Note that this is a bad design - EBV from grandparents!
2015: Maybe it isn’t when we use genomics selection!
Development of Breeding Strategies

Summary

• Integration of the components of a breeding program into a structured system for genetic improvement, with the aim to maximize an overall objective (genetic gain, market share).

• Evaluate opportunities for improving upon current strategies.

• Evaluate the potential of new technologies.
  ◆ How can they best be incorporated into current strategies?
  ◆ Can their benefits best be capitalized on in a redesigned breeding structure?
Breeding Strategies - Summary

What tools are necessary to develop optimal strategies?

- Quantitative genetics theory
  - Predicting response to selection, selection index, inbreeding, etc.

- Systems analysis
  - Predicting and optimizing response in overall objective

- Common sense

- An open mind