Design of Breeding Programs
Decisions in breeding programs

Where to go?
- breeding objective (which traits)

Who and what to measure?
- performance, DNA test
  - genetic evaluation

Who to select and mate?
- reproductive technol.
  - gains vs inbreeding
Animal Breeding in a nutshell

Breeding objectives

Where to Go?

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
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

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

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

- One-tier breeding program

- Select and replace

- Breeding males (few)

- Breeding females (many)

- Male progeny

- Female progeny

- Select and Replace
Design Examples

One-tier breeding program

Nucleus

Genetic improvement
Measurement
Design Examples

Two-tier breeding program

Genetic improvement
measurement
dissemination

Nucleus

Breeding bulls

Genetic lag

Commercial producers
Genetic merit of Nucleus versus Commercial

Rate of gain is the same in all tiers
Design Examples

3-tier breeding program

- **Nucleus**: 100k cows
- **Multipliers**: 1 million cows
- **Commercial producers**: 10 million cows

Genetic improvement and measurement

Breeding bulls
Design Examples

3-tier breeding program

Nucleus

Multipliers

Commercial producers

Genetic improvement
measurement

dissemination

dissemination

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
  - 1 pedigree male
  - 10 pedigree females
  - x 15
  - Chicks/female: 150
  - x 40
  - 6000
  - x 40
  - 240,000
  - x 120
  - 28,800,000
  - x 2 kg x 69%
  - 39,744 T meat

Year 0

Year 3

Year 4-5
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)
Central Nucleus
(dairy)

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: dairy
selection of sires for sires
top AI sires

Elite matings
dams for sires
bull dams

Normal matings
sires for cows
average AI sires

Normal matings
dams for cows
normal cows

Commercial producers
Design Examples

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

- Sire of Sires
- Dams of sires
- Sires of Cows
- Dams of Cows

Nucleus Breeders

Genetic lag

AI bulls

Commercial producers
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
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)

Truncation Point

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

- Effect of selection in commercial

- Generation

- Commercial

- Nucleus
Contributions of pathways

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

2 pathways

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

<table>
<thead>
<tr>
<th>Contribution to dG</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Selection of sires for sires</td>
<td>39%</td>
</tr>
<tr>
<td>Selection of sires for cows</td>
<td>38%</td>
</tr>
<tr>
<td>Selection of dams for sires</td>
<td>22%</td>
</tr>
<tr>
<td>Selection of dams for dams</td>
<td>1%</td>
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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*  → 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

Reproductive rates affect all of the above!

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

- Increases selection intensities
- Increases accuracy of EBVs
- Decreases generation intervals
- Increases inbreeding
Adult dairy MOET scheme (1983)

Cow:

MOET progeny:

Normal progeny:

Birth
not selected

Months:

0
Birth

15
Mate

24
Birth

34 35
Get record
Select & MOET

44
MOET Birth

Generation interval 44 months

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