My background – animal breeding

- Director - Centre for Genetic Resources, the Netherlands (CGN)
  - Plant Genetic Resources
  - Forest Genetic Resources
  - **Animal Genetic Resources**
- FAO Global Strategy: National Coordinator for Animal Genetic Resources
- Chair of European Regional Focal Point (ERFP) European Network of National Coordinators
Ethiopia - Dairy cattle breeding policy and strategy

1. Identification, characterization and selection of indigenous breeds for dairy production

2. Improving the genetic potential of indigenous animals through crossbreeding with exotic dairy breed/s

3. Establishing dairy cattle production and multiplication centers

4. Import and export of dairy animal breed/s shall be regulated
This presentation

- Which dairy animals and animal characteristics for which Ethiopian production system? - Breeding goal!

- Structure and implementation of breeding programs
  - Cross-breeding strategies
  - Improvement and maintenance of indigenous breeds

- Taking advantage of novel approaches and technologies

- Conclusions - pathways towards implementation of complementary strategies
Animal breeding

- Very simple....

- Select the *best* animals
- Use/mate the *best* animals in further breeding
- Disseminate the *best*
- But maintain genetic diversity

- What is *best*?
## The success of (Dutch) animal breeding programs

<table>
<thead>
<tr>
<th>Species</th>
<th>Trait</th>
<th>1960</th>
<th>2005</th>
<th>Δ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pig</td>
<td># weaned piglets/sow/year</td>
<td>14</td>
<td>21</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Meat %</td>
<td>40</td>
<td>55</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Kg meat/ mton feed</td>
<td>85</td>
<td>170</td>
<td>100</td>
</tr>
<tr>
<td>Broiler chicken</td>
<td># days to 2 kg</td>
<td>100</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Kg feed/kg live weight</td>
<td>3.0</td>
<td>1.7</td>
<td>43</td>
</tr>
<tr>
<td>Laying hen</td>
<td># eggs per year</td>
<td>230</td>
<td>300</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td># eggs/mton feed</td>
<td>5,000</td>
<td>9,000</td>
<td>80</td>
</tr>
<tr>
<td>Dairy cattle</td>
<td>Kg milk/cow/year</td>
<td>6,000</td>
<td>10,000</td>
<td>67</td>
</tr>
</tbody>
</table>
Breeding circle

1. Defining production system
2. Defining Breeding goal
3. Collection of information
   - Phenotypes
   - Family relationships
   - Genotypes
4. Determining selection criteria
   - Genetic model
   - Breeding value estimation
5. Selection and mating
   - Prediction of selection response
   - Consequences of mating
6. Dissemination
   - Structure of breeding program
   - Crossbreeding
7. Evaluation
   - Genetic improvement
   - Genetic diversity

Breeding program
Starting point

1. Defining production system

2. Defining Breeding goal

3. Collection of information
   - Phenotypes
   - Family relationships
   - Genotypes

4. Determining selection criteria
   - Genetic model
   - Breeding value estimation

5. Selection and mating
   - Prediction of selection response
   - Consequences of mating

6. Dissemination
   - Structure of breeding program
   - Crossbreeding

7. Evaluation
   - Genetic improvement
   - Genetic diversity

Breeding program
Ethiopia – range of climates and production systems

- Altitude
- Mean daily temperature
- Rainfall distribution throughout the year
- Feed availability
- Farm management
- Small scale farms
- Medium/large scale
Breeding goal

- Local circumstances and external factors:
  - Market (consumers, society)
  - Climate
  - Feed availability
  - Cost price

- Which traits are really important in the next 10-15 years?
  - Many options:
    - Milk yield
    - Fertility
    - Heat tolerance..
Figure 8.1. The use of a profit function to derive economic values. The economic value (EV) of a trait is the increase in profit that results from a single unit increase of the trait value.
Example: Higher milk production per cow and/or improved longevity

<table>
<thead>
<tr>
<th>Price per extra kg milk</th>
<th>Price in KES</th>
<th>Explanation and/or assumptions*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35</td>
<td>Milk price on market</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost of extra feed</th>
<th>Price in KES</th>
<th>Explanation and/or assumptions*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23</td>
<td>Feed costs of 30 KES per kg concentrates. 0,65 kg concentrates needed for 1.0 kg of milk extra</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Margin of extra kg milk</th>
<th>Price in KES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heifer raising costs or investment to purchase a heifer</th>
<th>Price in KES Case 1</th>
<th>Price in KES Case 2</th>
<th>Explanation and/or assumptions*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>300,000</td>
<td>300,000</td>
<td>To be calculated or estimated</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Productive life in years</th>
<th>Price in KES</th>
<th>Price in KES</th>
<th>Explanation and/or assumptions*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>5</td>
<td>Just two cases in a common range</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depreciation per year</th>
<th>Price in KES</th>
<th>Price in KES</th>
<th>Explanation and/or assumptions*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10,000</td>
<td>60,000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Margin of extra year longevity</th>
<th>Price in KES</th>
<th>Price in KES</th>
<th>Explanation and/or assumptions*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>+40,000</td>
<td>Less costs means higher margin</td>
</tr>
</tbody>
</table>
We don’t want this situation ...
Specialists and generalists

- Harsh & dynamic
- Average
- Well-controlled
Another example Netherlands: What type of cow is optimal – specialized dairy or dual purpose?

- Reduction of green house gas emissions / kg milk:
  - By increasing milk production
  - By increasing longevity

- HOWEVER!
  - Benefits of higher milk production are much lower when taking into account both milk and beef/veal production from dairy farms
  - Higher milk production per cow → lower beef/veal production → more import of beef/veal
  - Specialized beef production systems are less efficient!
  - Dual purpose breeds are endangered, but WHY?

Vellinga and de Vries, 2018
Example: Is the Dorper the superior breed?

Dorper: Fast growing

Red Maasai: Slow growing

Re-ranking: The Dorper is superior in semi-arid conditions, but the Red Maasai is superior in hot and humid areas.
Example: Is the Dorper the superior breed?

Dorper: big, but sensitive

Red Maasai: small, but heat resistant
Another dimension: Role of livestock: added value of livestock products or feed/food competition?
(H. van Zanten, 2016)
New protein efficiency traits in breeding goals?

**Human edible protein ratio** =

 Output of human edible protein / Input human edible proteins via feed

<table>
<thead>
<tr>
<th>Dairy production in</th>
<th>Ratio</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>1.8</td>
<td>Baldwin (1984)</td>
</tr>
<tr>
<td>Netherlands</td>
<td>3.4</td>
<td>Dijkstra et al. (2013)</td>
</tr>
<tr>
<td>Kenya</td>
<td>∞</td>
<td>CAST (1999)</td>
</tr>
</tbody>
</table>

(Van Zanten, 2016)

Centre for Genetic Resources, the Netherlands (CGN)
Change in bull selection index over time

<table>
<thead>
<tr>
<th>Year</th>
<th>Index</th>
<th>Relative weight of trait category (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>INET</td>
</tr>
<tr>
<td>1980</td>
<td>INET</td>
<td>100</td>
</tr>
<tr>
<td>1989</td>
<td>Stiersom</td>
<td>67</td>
</tr>
<tr>
<td>1999</td>
<td>DPS</td>
<td>67</td>
</tr>
<tr>
<td>2003</td>
<td>DPS</td>
<td>58</td>
</tr>
<tr>
<td>2007</td>
<td>NVI</td>
<td>40</td>
</tr>
<tr>
<td>2012</td>
<td>NVI</td>
<td>26</td>
</tr>
</tbody>
</table>

Example
the Netherlands

Change in breeding goal over time

Trait categories:

- INET: production index
- CONF: conformation (udder/legs)
- LONG: longevity or sustainability
- REPR: reproduction, incl. fertility and birth traits
- UH: udder health

Major shift around 2000
Collection of information → Breeding values

1. Defining production system
2. Defining Breeding goal
3. Collection of information
   - Phenotypes
   - Family relationships
   - Genotypes
4. Determining selection criteria
   - Genetic model
   - Breeding value estimation
5. Selection and mating
   - Prediction of selection response
   - Consequences of mating
6. Dissemination
   - Structure of breeding program
   - Crossbreeding
7. Evaluation
   - Genetic improvement
   - Genetic diversity
Which traits are important?

Breeding goal → Selection response

<table>
<thead>
<tr>
<th>Trait</th>
<th>Production</th>
<th>Functional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kg milk</td>
<td>-0.06</td>
<td>0</td>
</tr>
<tr>
<td>Kg fat</td>
<td>0.7</td>
<td>0</td>
</tr>
<tr>
<td>Kg protein</td>
<td>4.2</td>
<td>0</td>
</tr>
<tr>
<td>Longevity</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Udder Health</td>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td>Fertility</td>
<td>0</td>
<td>2.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trait</th>
<th>production</th>
<th>Functional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kg milk</td>
<td>263</td>
<td>-98</td>
</tr>
<tr>
<td>Kg fat</td>
<td>16</td>
<td>-8</td>
</tr>
<tr>
<td>Kg protein</td>
<td>12</td>
<td>-4</td>
</tr>
<tr>
<td>Longevity</td>
<td>-0.9</td>
<td>3.0</td>
</tr>
<tr>
<td>Udder Health</td>
<td>-0.3</td>
<td>2.6</td>
</tr>
<tr>
<td>Fertility</td>
<td>-1.8</td>
<td>1.7</td>
</tr>
</tbody>
</table>

What do we learn from this:
1. Sign of economic value is not always equal to sign of selection response (milk, fertility)
2. Index with only 3 traits influences nearly every trait (weighting factor of zero does not mean zero change)
### Example the Netherlands

**Change in breeding goal over time**

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**Change in bull selection index over time**

**Trait categories:**
- INET: production index
- CONF: conformation (udder/legs)
- LONG: longevity or sustainability
- REPR: reproduction, incl. fertility and birth traits
- UH: udder health

<table>
<thead>
<tr>
<th>Year</th>
<th>Index</th>
<th>INET</th>
<th>CONF</th>
<th>LONG</th>
<th>REPR</th>
<th>UH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>INET</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1989</td>
<td>Stiersom</td>
<td>67</td>
<td>33</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1999</td>
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<td>67</td>
<td>-</td>
<td>33</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2003</td>
<td>DPS</td>
<td>58</td>
<td>-</td>
<td>26</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>2007</td>
<td>NVI</td>
<td>40</td>
<td>27</td>
<td>8</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>2012</td>
<td>NVI</td>
<td>26</td>
<td>30</td>
<td>11</td>
<td>19</td>
<td>14</td>
</tr>
</tbody>
</table>

*Major shift around 2000*
ATLANTIC
Delta Atlantic

- Health specialist
- Add strength and capacity
- Good Feet & legs and Locomotion

Born: 30.06.2008  Al Code: 978797
AA Code: 234165  Sire ID: NL 439538423
Color: Black & White  Kappa Casein: AB

Breeding Values
- % Health: 9
- % Efficiency: 3
- Feed intake: 0.95
- Longevity: 515
- NVI: 240

Production traits
- 7,280 dtr, 2,419 herds, reliability: 99%
- Kg Milk: 193
- % Fat: -0.06
- % Protein: 0.19
- Kg Fat: 3
- Kg Protein: 23
- INET: 100

Conformation traits
- 4,018 dtr, 1,358 herds, reliability: 99%
  - Frame: 108
  - Dairy Strength: 107
  - Udder: 106
  - Feet & legs: 109
  - Total score: 111

Management/Health
- Udder health: 107
- SCC: 110
- Daughter fertility: 104
Genetic improvement

- Selecting the best animals as parents of the next generation
- Every generation again
- This leads to a stepwise (cumulative) genetic improvement

Genetic improvement $\varepsilon$

$$= \text{Accuracy} \times \text{Intensity} \times \text{Genetic standard deviation}$$

$$\text{Generation interval}$$
Example: mass selection and $\Delta G$

- **Growth in beef cattle**
  
  \[ h^2 = 0.35, \sigma_p = 0.2 \text{ kg/day} \]

  *generation interval* \( L = 5 \text{ years} \)

  selection of 25% of fastest growing individuals

- **Intensity**: \( p = 0.25 \rightarrow i = 1.271 \)

- **Accuracy** \( r_{IH,\text{mass}} = h = \sqrt{0.35} = 0.59 \)

- **Genetic std** \( \sigma_A = h \sigma_p = 0.59 \times 0.2 = 0.118 \text{ kg/day} \)

- \( \Delta G = \frac{ir_{IH}\sigma_A}{L} = 0.0177 \text{ (kg/day)/yr} \)
Factors determining success of selection decisions

- How heritable is the trait under selection (i.e. the trait in the breeding goal)?
- How much genetic variation for that trait is there in the population?
- What is the average accuracy of the EBV, and thus the accuracy of selection?
- What proportion of the animals will be selected for breeding?
- In case genetic gain is to be expressed per year, rather than per generation: how long is a generation?
1. **Sires to breed males (SS)**
   - Selection of the best progeny tested bulls to breed “young bulls”. (AI-company)

2. **Sires to breed females (SD)**
   - Selection of progeny tested bulls to breed cows on farms (AI-company + farmer)

3. **Dams to breed males (DS)**
   - Selection of the very best cows to breed “young bulls” (AI-company)

4. **Dams to breed females (DD)**
   - Selection of cows to breed the next generation of cows (farmer)
Evaluation

7. Evaluation
- Genetic improvement
- Genetic diversity

6. Dissemination
- Structure of breeding program
- Crossbreeding

5. Selection and mating
- Prediction of selection response
- Consequences of mating

4. Determining selection criteria
- Genetic model
- Breeding value estimation

3. Collection of information
- Phenotypes
- Family relationships
- Genotypes

2. Defining Breeding goal

1. Defining production system
Example: the Netherlands

Genetic improvement over time

Genetic merit trends over time

New traits in index
Holstein
CRV-breeding program
Netherlands

Inbreeding trends over time

IBD (%) vs Year

- $F_{PED}$
- $F_{ROH}$
- $HOM_{SNP}$

Change BG Intro OCS
Intro GS

Doekes et al., 2018 (GSE)
Parallel breeding strategies needed to achieve the national goal and to meet farmers needs

- Conservation and genetic improvement of the most valuable indigenous breeds
- Upgrading of indigenous cattle to more productive 50% crossbreds
- Development of synthetic indigenous-exotic breed
- Importing suitable breeds (semen, embryo’s, heifers, ...)

Some key questions, based on breeding goal discussion:

- What do farmers consider as the optimal blood level? 50%? 75%?...
- Upgrading of local animals to 50% exotic → what’s next?
Which breeds – How to make optimal use of the genetic resources pool – a broad genetic base
Livestock breeds – the global picture (FAO, 2015)

Changes in breed risk status between 2006 and 2014

- **Number of breeds**
  - 2006: 9000 breeds
  - 2014: 9000 breeds

- **At risk**: 57% in 2006, 58% in 2014
- **Extinct**: 7% in 2006, 7% in 2014
- **Not at risk**: 21% in 2006, 18% in 2014
- **Unknown**: 15% in 2006, 17% in 2014


Figure 118: Risk status of the world’s mammalian breeds in June 2014 – regional breakdown

<table>
<thead>
<tr>
<th>Region</th>
<th>Unknown</th>
<th>Critical</th>
<th>Endangered</th>
<th>Endangered-maintained</th>
<th>Not at risk</th>
<th>Extinct</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>571</td>
<td>986</td>
<td>840</td>
<td>443</td>
<td>201</td>
<td>80</td>
<td>115</td>
</tr>
<tr>
<td>Asia</td>
<td>107</td>
<td>337</td>
<td>239</td>
<td>172</td>
<td>94</td>
<td>76</td>
<td>166</td>
</tr>
<tr>
<td>Europe and the Caucasus</td>
<td>1</td>
<td>10</td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>10</td>
<td>7</td>
<td>338</td>
<td>6</td>
<td>0</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Near and Middle East</td>
<td>2</td>
<td>7</td>
<td>144</td>
<td>1</td>
<td>0</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>North America</td>
<td>33</td>
<td>43</td>
<td>466</td>
<td>21</td>
<td>21</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Southwest Pacific</td>
<td>80</td>
<td>303</td>
<td>602</td>
<td>21</td>
<td>1</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>International transboundary breeds</td>
<td>33</td>
<td>43</td>
<td>466</td>
<td>21</td>
<td>5</td>
<td>10</td>
<td>6</td>
</tr>
</tbody>
</table>

Total: 600 | 1,361 | 2,156 | 493 | 237 | 118 | 147 | 386 | 6,493
Threats to livestock genetic diversity (FAO, 2015)

1. Indiscriminate cross-breeding
2. Introduction/increased use of exotic breeds
3. Weak policies or institutions
4. Lack of profitability/competitiveness
5. Production system intensification
6. Diseases/disease management
7. Loss of pasture or production environment
8. Poor control of inbreeding

Genetic erosion
What happened in the Netherlands?

% change in population size 1979 - 2007

- Blaarkop
- Fries Hollands ZB
- Fries Hollands R
- MRY incl. Brandrood
Ethiopian breeds

How can we unlock the genetic potential of the existing local livestock breed types?
Breed population within a country

Status of the breed:
- population size and structure
- geographical distribution within the country
- populations of same breed in other countries

Breeds at risk

"Value" of the breed:
- genetic distinctiveness
- adaptive traits
- relative utility value for food and agriculture
- historical or cultural use

No conservation programme
- High risk of extinction
- In vitro conservation
- In vivo conservation

Conservation programme

Breeds potentially at risk

Potential for improvement:
- target traits (genetic diversity within population)
- preference of market and society

Genetic improvement programme
- Pure/straight breeding
- Cross-breeding

Breeds not at risk

No planned genetic changes
Crossbreeding? Advantages?

- Upgrading of less productive breeds
- Quickly trying to solve problems at farm level
- Making use of heterosis effects

→ Long term strategy?

**Heterosis estimates (cattle)**

<table>
<thead>
<tr>
<th>Trait</th>
<th>Heterosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>3%</td>
</tr>
<tr>
<td>Fertility</td>
<td>10%</td>
</tr>
<tr>
<td>Calving ease (direct)</td>
<td>10-15%</td>
</tr>
<tr>
<td>Stillbirth (direct)</td>
<td>5-10%</td>
</tr>
<tr>
<td>Calving ease (maternal)</td>
<td>10-15%</td>
</tr>
<tr>
<td>Stillbirth (maternal)</td>
<td>5-10%</td>
</tr>
<tr>
<td>Longevity</td>
<td>10-15%</td>
</tr>
<tr>
<td>Total merit</td>
<td>≥ 10%</td>
</tr>
</tbody>
</table>

*Sorensen et al. (2008)*
Rotational cross?

Rotational cross: $A \times (B \times (A \times B)))$

Starting at 50/50%, the rotation stabilises at 65/35% or 35/65%, giving 65% from the last sire line used.
International pool of genetic products (e.g. CRV)
Success comes from interaction of genetics, management and markets

- **Indigenous breeds**: highly adapted to harsh conditions; little potential to increase milk yield under better feeding.

- **Crossbreds**: respond to better feeding with increased milk yield; moderately well adapted

- **Exotic dairy breeds**: very high genetic potential for milk yield which is expressed under the most favourable conditions; poorly adapted
Milk production by animals with different proportions of exotic genotypes (%dairyness)

High grade cattle only showed substantially better milk yields than other grades in the highest production environment.
Daily milk production for different dairy groups of animals within countries

Lactation curves for animals were generally flat with no evidence of a peak in early lactation.

**Kenya**

**Uganda**
Crossbreeding adoption can be considered as part of an overall migration from a low-input/low-output system to a high-input/high-output system (Roschinsky et al., 2015). Under favorable conditions, crossbreeding schemes can be considered an effective strategy to reduce poverty among smallholders, through the increased animal performance and farmer benefits, to improve environmental efficiency, and as a trigger for innovation and development at the farm level. It can, however, not be recommended in extensive production systems unable to provide the necessary inputs. More than anything, the sustainability of a crossbreeding strategy requires a careful planning and long-term organization.
Synthetic?
FxA crosses (goal=50%)
Taking advantage of new technologies in breeding programmes

- DNA technology
- Reproductive technologies
Reproductive technologies

- AI versus Natural mating
  - Uptake of AI is low (so far)
  - Technical results should improve

- Novel technologies?
  - Keep it simple
Large scale SNP genotyping is available

...CAGTCAGT\textcolor{red}{C}GTACC\textcolor{red}{A}GTCT...  
...CAGTCAGT\textcolor{red}{A}GTACC\textcolor{red}{A}GTCT...
Determine breed composition

Combine production and SNP data to determine which breed/animal/combinations perform best under different conditions

Genomic selection
Kenya/Uganda - PCA results based on 566k chip - Admixture
Selecting the best animals, for instance:

animal 1
A A G T A T T A T C T T ...
A A G T A T T A T C T T ....

animal 2
A A G T A T T A T C T T ...
A A G A A T T A T C T T ...

This A gives +0.2 kg milk, -1 fertility, etc.
Genomic Selection – accelerating genetic progress

- Estimate SNP effects
- Genomic breeding values (GEBVs)
- Reference population
- Selection candidates

Genomic Selection
## Traditional versus genomic selection

### Impact on genetic improvement:

<table>
<thead>
<tr>
<th>Factors</th>
<th>Traditional</th>
<th>Genomic selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Intensity</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Genetic variation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generation interval</td>
<td>--</td>
<td>++</td>
</tr>
</tbody>
</table>

Traditional = Progeny testing
Can we use GS in developing countries where pedigree recording is lacking?

- Screen the population:
  - Select number of herds with information on performance on cows
  - Take a DNA sample on these cows

- Young bulls in your nucleus
  - Take a DNA sample
  - Estimate EBV based on DNA profile

- Select the best bulls for nucleus and dissemination

Link performance to EBV through DNA
Genomic selection in small populations or specific context? (Kariuki, 2017)
Inbreeding - risks for small populations
Loss of diversity due to selection

- Directly in the trait itself

  Reduction in Additive genetic variance after selection (Falconer Chapter 11)

<table>
<thead>
<tr>
<th>Proportion selected</th>
<th>0.90</th>
<th>0.70</th>
<th>0.50</th>
<th>0.30</th>
<th>0.10</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>22%</td>
<td>40%</td>
<td>57%</td>
<td>74%</td>
<td>91%</td>
</tr>
<tr>
<td>20%</td>
<td>30%</td>
<td>45%</td>
<td>61%</td>
<td>77%</td>
<td>92%</td>
</tr>
<tr>
<td>50%</td>
<td>43%</td>
<td>55%</td>
<td>68%</td>
<td>81%</td>
<td>94%</td>
</tr>
</tbody>
</table>

- Use of a small group of related individuals as parents reduces the genetic diversity

- Affects other traits as well
Loss of genetic diversity through genetic drift

- Change in frequency and loss of alleles by chance due to sampling of a limited numbers of individuals
  - Less individuals sampled -> more genetic drift
  - Loss of diversity is predictable, but which diversity is not predictable

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>White</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Yellow</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Green</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Blue</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Brown</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Red</td>
<td>5</td>
<td>-</td>
</tr>
</tbody>
</table>
Not only in “small populations”

Holstein

CRV-breeding program

Netherlands
On inbreeding

- Inbreeding depression: inbred individuals perform less well
- Genetic defects are more common in inbred individuals
- Inbreeding always increases in closed population
- The smaller the population the higher the inbreeding rate
- Uneven distribution of # offspring over parents causes more inbreeding
  - Use of few bulls
Measures

- **Two principles**
  - Larger population size
  - More even distribution of offspring over ancestors

- **Provide access to more unrelated bulls**
  - Gene banks

- **Avoid excessive use of single bulls**
  - Limit # inseminations / bull
  - Limit # sons available for breeding
Example Netherlands - Gene bank supports conservation of endangered breeds

Dutch Friesian Red and White
• < 400 purebred cows
• > 40 (old) bulls in gene bank
Collections @CGN – Dutch gene bank farm animals

- CGN Gene bank collections = reproductive material
  - Semen (+ embryo’s, oocytes/ovarian tissue)
  - Blood samples
  - “Core collections”/breed

<table>
<thead>
<tr>
<th>Species</th>
<th># breeds</th>
<th># donors/breed</th>
<th># straws</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>19</td>
<td>1 - 4,781</td>
<td>221,925</td>
</tr>
<tr>
<td>Chicken</td>
<td>31</td>
<td>1 - 20</td>
<td>18,828</td>
</tr>
<tr>
<td>Dog</td>
<td>5</td>
<td>1 – 8</td>
<td>342</td>
</tr>
<tr>
<td>Duck</td>
<td>3</td>
<td>14 – 34</td>
<td>1,588</td>
</tr>
<tr>
<td>Goat</td>
<td>4</td>
<td>1 - 33</td>
<td>5,555</td>
</tr>
<tr>
<td>Goose</td>
<td>1</td>
<td>7</td>
<td>76</td>
</tr>
<tr>
<td>Horse</td>
<td>8</td>
<td>1 - 37</td>
<td>25,769</td>
</tr>
<tr>
<td>Pig</td>
<td>21</td>
<td>1 - 69</td>
<td>75,081</td>
</tr>
<tr>
<td>Sheep</td>
<td>9</td>
<td>8 - 71</td>
<td>27,738</td>
</tr>
<tr>
<td>Rabbit</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusions – pathways towards implementation

- "National breeding program and national infrastructure" should support the relevant complementary strategies
  - Upgrading
  - Development of synthetic breeds
  - Conservation and improvement of indigenous breeds
- More effective and efficient AI delivery system needed
- AI centres should make available semen of 'exotic bulls', 'crossbred bulls' and 'indigenous bulls'
- Investment in performance recording will pay off in the long run → selection of best animals/bull dams at private farms for further breeding
Conclusions – pathways towards implementation

- Import of semen? or semen production in Ethiopia?
  - Importing 100% exotic semen or importing young bulls is probably economically more profitable than sourcing 100% exotic bulls for AI at Ethiopian (nucleus breeding) farms.
  - No need to buy the most expensive semen – probably not the best for Ethiopian farmer

- Use the national infrastructure of breeding and research farms for:
  - Conservation and improvement of selected indigenous breeds
  - Development of synthetic breeds
  - Performance recording and research
  - Selection of bull-dams/bulls for AI
  - Dissemination of natural mating bulls and heifers to farmers
Looking forward to discuss collaboration in dairy breeding