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Genomic Selection for Performance and Health

Dr. Thomas Mark
 Animal Breeding, Quantitative Genetics and Systems Biology
 Dept. Veterinary Clinical and Animal Sciences
 Faculty of Health and Medicine
 University of Copenhagen
 E-mail: thm@sund.ku.dk

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Outline

- **Basics about (horse) breeding**
 - Breeding values and their accuracy
 - Bottlenecks in breeding of sport-horses
- **Genomic selection**
 - What it is
 - Consequences for sport-horse breeding
 - Requirements for successful implementation
 - Danish and other projects
- **Possibilities for international collaboration**
- **Conclusions**

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Differences in performance due to...

DNA (genetics)

Feeding Random events

Training Housing

Age Rider

Sex Disease pressure

- Only half of DNA (or **breeding value, BV**) is passed from a parent to its offspring (not feeding, training etc.)

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♀ $BV_{dam} = 110$

♂ $BV_{sire} = 134$

Possible egg-cells

14 12	20 13	17 12	24 12	14 12	25 12	17 12	25 12
46	49	51	54	56	59	61	64

Possible sperm-cells

16 23	19 23	21 23	19 23	16 29	19 29	16 26	26 23
58	63	64	65	69	70	71	76

Average = $55 = \frac{1}{2} \times BV_{dam}$ Average = $67 = \frac{1}{2} \times BV_{sire}$

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Possible egg-cells

14 20 46	17 20 49	14 25 51	17 25 54
14 20 56	17 20 59	14 25 61	17 25 64

X

Possible sperm-cells

16 19 28	21 19 33	16 19 29	16 26 23
21 19 29	21 26 25	16 26 29	21 26 29

Distribution of offspring:

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BV_{sire} × **BV_{dam}**

50 % of Genes from sire

50 % of Genes from dam

BV_{offspring} = 1/2 BV_{sire} + 1/2 BV_{dam} + "Mendelian sampling"

Predictable Random

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Estimated Breeding Values (EBV) and their accuracy

- EBV 'drawn' towards population average when accuracy is low
- True BV best reflected by EBV when accuracy is high
- Foal's EBV determined by parent's average EBV

Sire	Dam
Mendelian sampling	

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Larger Genetic Gain when...

- Higher accuracies of EBVs
 - Provided EBV used for selection
- Shorter generation interval
- Fewer horses used for breeding (best gets more offspring)
 - However, inbreeding must be controlled for long-term gain
- Larger difference between best and worst horses
 - Large pool where stallions can be selected from
 - Advantage with international collaboration

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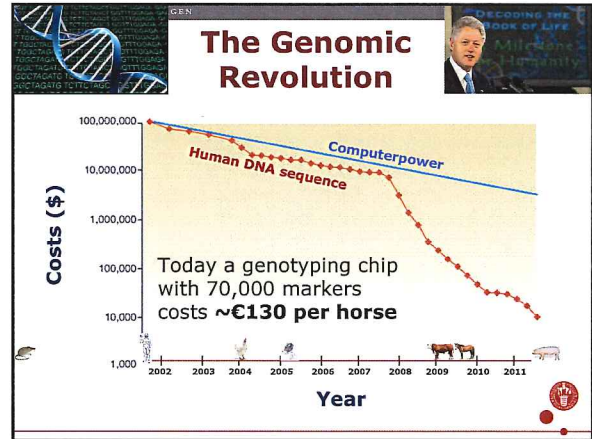
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Bottlenecks in current sport-horse breeding schemes

- Low accuracy of EBVs for mares and young stallions (especially for competition traits)
- Very long generation intervals
- No objective comparison between domestic and foreign horses
- EBVs are lacking for key traits (e.g. OCD, reproduction)

• Total-merit index lacking

• EBV's are not systematically used in practise



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How does Genomic Selection work?

Implemented successfully:

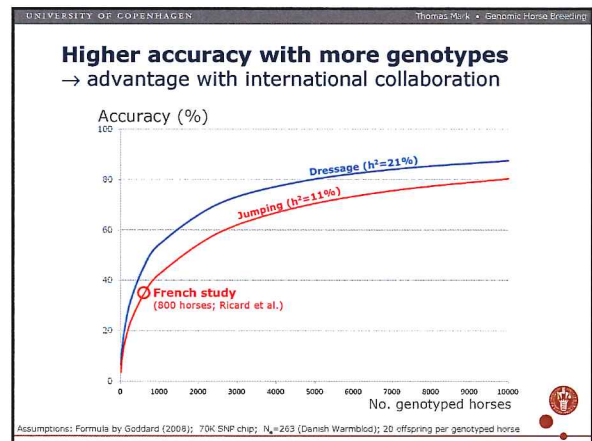
- ✓ Cattle
- ✓ Pig
- ✓ Poultry
- ✓ Fish
- ✓ Sheep
- ✓ Ryegrass
- ✓ Corn

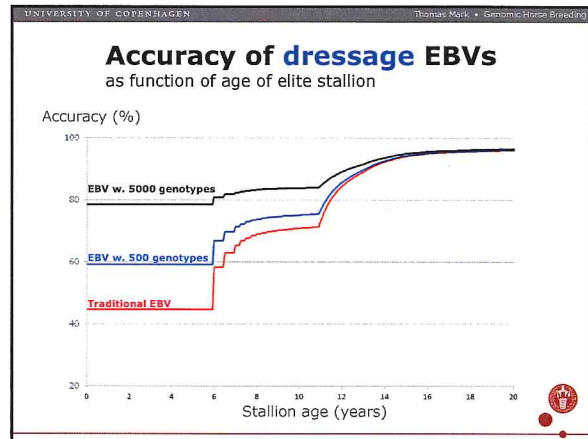
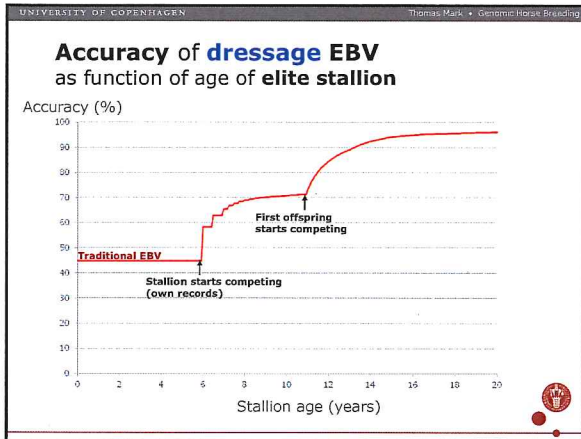
Reference population

Genotypes (DNA)
Phenotypic records

Prediction equation:
 $EBV = m_1 + m_2 + \dots + m_{70000}$

Gene effects





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- ### Advantages with genomic breeding
- **Higher accuracy of EBV in general**
 - But highest improvement for horses and traits that traditionally have low accuracy
 - Young stallions, mares
 - Foreign horses
 - Traits expressed late in life (competition)
 - Traits with few records or low heritability (health, reproduction)
 - **Less inbreeding** (same selection intensity)
 - **No. Phenotypic records can be reduced**
 - 'quite a few' records of good quality still needed for 'reference population'!

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- ### 2 Scenarios for Int'l Collaboration
1. Exchange of genotypes
 2. Joint genomic evaluations
genotypes, phenotypes (+pedigree)

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1) Exchange of Genotypes

Stallions used in RED country
R1
R2
B1

Stallions used in BLUE country
B1
B2
R1
B3
B4

Genomic evaluation based on RED phenotypes

Genomic evaluation based on BLUE phenotypes

- Larger reference population in both countries → higher accuracy
- Or lower genotyping costs

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2) Joint Genomic Evaluation

Stallions used in RED country
R1
R2
B1

Stallions used in BLUE country
B1
B2
R1
B3
B4

Joint genomic evaluation based on both RED + BLUE phenotypes

- Much higher accuracies
- Better correction for biases
- Possible to reduce costs...

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Cost Savings with Joint Evaluations


- **No/reduced need of recording young-horse and conformation traits**
 - In future most horses will probably be genotyped
 - Target traits can be predicted accurately for all genotyped horses without indicator traits
- **More efficient use of human resources**
 - One common computation site rather than one per country/association
 - Ensure data access to all researchers with relevant agenda

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Beneficial to...


- **harmonize traits across countries**
 - Performance in sport competitions
 - Health
 - Reproduction
- **store blood and/or tissue samples to allow future genotyping**
 - Especially founders
- **have as many countries participate as possible**
 - Good with large populations, but not required
 - Genotypes provide genetic links (connectedness)

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If you can't join them... beat them

Uffe Ellemann-Jensen, 1992



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Danish project

- ~500 genotypes
 - Illumina 70K SNP chip
- Primary aim is dressage
 - But also jumping and osteochondrosis
- Method that considers phenotype, pedigree and genotypes (all data) simultaneously
 - Great advantage when most horses are non-genotyped
 - Challenges with proper scaling (need to ensure fair comparisons, e.g. young vs. old, genotyped or not)
- Research project 2013 – 16 (Lina Jönsson)
- Willing to collaborate (win-win)
- Similar efforts in other countries
 - FRA, SWE, NLD, DEU,...?


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Conclusions


- **Great potential in genomic selection**
 - More genetic gain with more genotypes
 - And less inbreeding with genomic selection
 - Accurate assessment of foal's potential (sport, health etc.)
- **Research ongoing in a few countries**
 - Small national reference populations
- **Advantage with international collaboration**
 - Especially for small populations
- **Organizational implications**
 - Recording of traits (more emphasis on target traits)
 - Internationalization




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Traditional breeding



Genomic breeding





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The big picture

- Those with best breeding program ... will breed best horses
- Best breeding program requires
 - Systematic recording of high-quality phenotypic data
 - **Genomic selection**
 - Breeding plan (incl. inbreeding control)
 - Breeders should be loyal to breeding plan



Thanks for your attention!

