



Agriculture and
Agri-Food Canada

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Government of Alberta

Canadian Bovine Genomics Workshop

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Genomic Applications in Dairy Cattle: Now and in the Future

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Introduction

- **Canada is a world leader in the development of superior dairy cattle genetics**
 - Twice as much semen exported as used domestically
- **Large proportion of productivity improvement in Canada is due to improved genetics**
- **Key success factors: industry cooperation, coordinated research, structures for the rapid application of research results**

What is Genomics?

- **Genetics:**

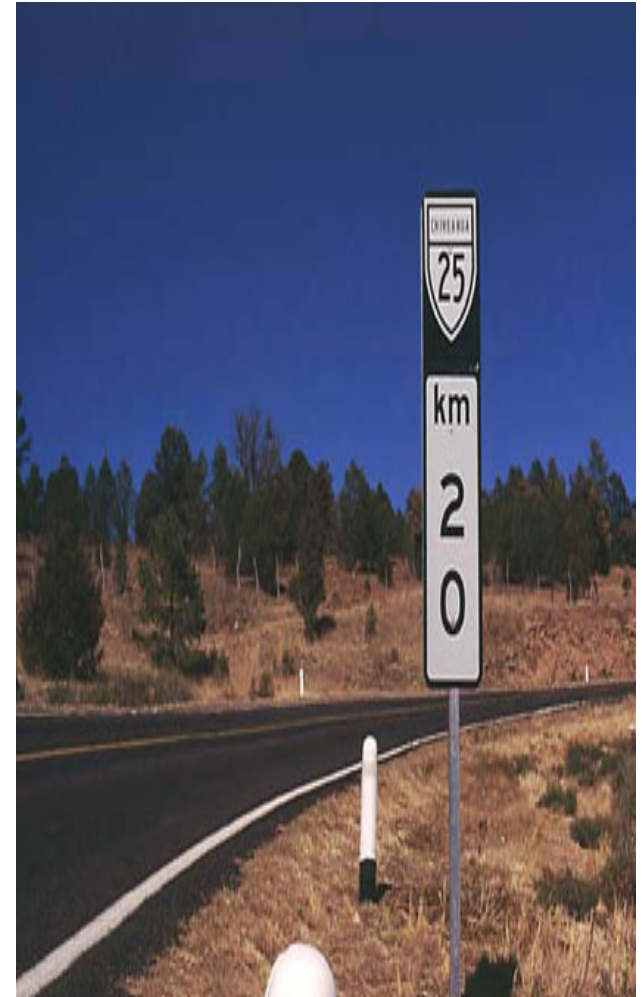
- Study of the hereditary transmission of traits expressed by individuals
- Basis is pedigree and performance data

- **Genomics:**

- Study of the genome and its components, namely DNA molecules
- DNA is unique for each individual/animal
- Logical to use for genetic improvement but other major uses also exist

DNA Genotyping

- Currently using a panel with 58,000 markers, labelled “50K panel”
- Each marker is equally spaced along the genome like posts beside our highways to indicate each kilometre
- If the genome was stretched to be the distance from St. John’s to Victoria (7,200 km), this would equate to a post every 125 m
- Genotyping process identifies if the animal carries 0, 1 or 2 copies of the gene at that specific location
- 0 and 2 = homozygous while 1 = heterozygous



Genotype Data for Elevation

Chromosome 1



1000111220020012111011112111101111001121100020122002220111
1202101200211122110021112001111001011011010220011002201101
1200201101020222121122102010011100011220221222112021120120
2010020220200002110001120201122111211102201111000021220200
0221012020002211220111012100111211102112110020102100022000
2201000201100002202211022112101121110122220012112122200200
020020202012221100222222002212111121002111120011011101120
0202220001112011010211121211102022100211201211001111102111
2110211122000101101110202200221110102011121111011202102102
1211011022122001211011211012022011002220021002110001110021
1021101110002220020221212110002220102002222121221121112002
0110202001222222112212021211210110012110110200220002001002
0001111011001211021212111201010121202210101011111021102112
2111111212111210110120011111021111011111220121012121101022
202021211222120222002121210121210201100111222121101

The Genomics “Tsunami”

- **Bovine Genome Sequencing Project**
 - Completed by end of 2006
 - Mapped the entire bovine genome across all 30 pairs of chromosomes (known order of DNA molecules)
- **Advances in genotyping technology**
 - Faster throughput and lower cost (\approx \$250 US)
- **The race is on to capitalize on these advances**
- **Canada is in the leader’s pack for application of genomics for genetic evaluation but a national dairy industry strategy is required to take full advantage of this technology**

Value of Genomics for Genetic Improvement

- A North American dairy cattle DNA repository was started more than 15 years ago with major A.I. companies providing semen for all new young bull purchases, most of which are now progeny proven
- USDA started research in 2007 with Canadian collaboration (U. of Guelph and CDN involved since 2008)
- First step was genotyping the DNA of many proven Holstein sires

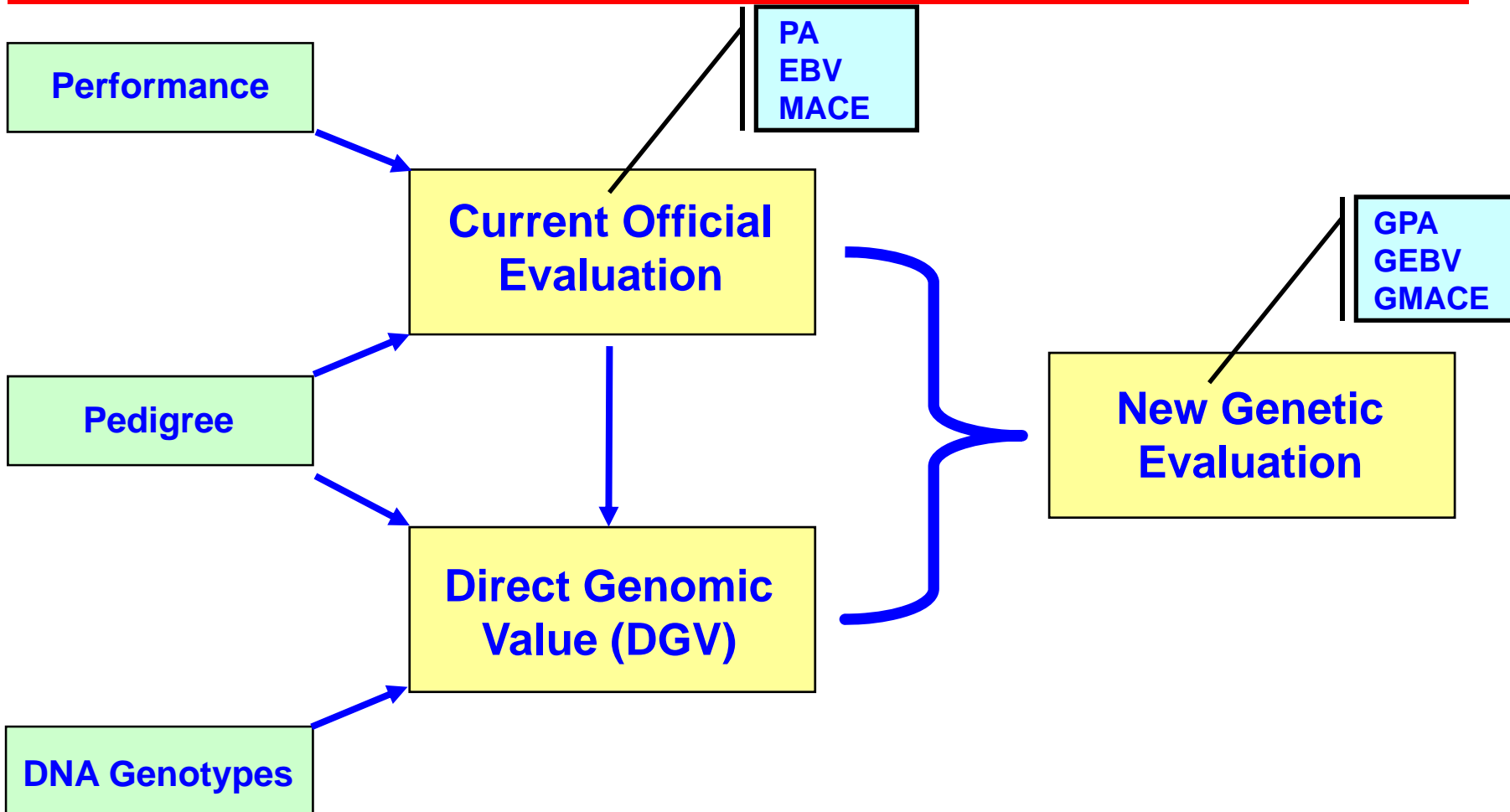
Genomic Evaluation Services

- **USDA started providing regular unofficial services in the US during 2008**
- **Official genomic evaluations provided for Holsteins and Jerseys in January, April and August 2009 (also included Brown Swiss)**
 - Provided regular genomic updates in between
- **CDN provided unofficial genomic evaluations to owners in April, June and July 2009**
 - Official implementation for HO on August 18th, 2009
 - Monthly genomic updates starting September 2009

Estimation of SNP Effects

- **Total of 28,042 animals genotyped (Aug'09)**
 - 2,375 progeny proven sires in Canada
 - 5,123 foreign progeny proven with MACE in Canada
 - 13,148 other males (mainly young bulls)
 - 7,396 cows and heifers
- **Only progeny proven males, on a trait-by-trait basis, are used to estimate SNP effects**
- **Total of 63 traits/indexes analyzed including the Lifetime Profit Index (total merit index) and its three main components**

Incorporating DGVs into New Official Genetic Evaluations



Gains in Published REL

- LPI by Sub-Group -

| Sub-Group | Average Reliability (%) | | | Blending Weight in DGV |
|--------------------------------------------------------------|-------------------------|----------|------|------------------------|
| | Traditional | Genomics | Gain | |
| Young Bulls and Heifers (2007-2009) | 34 | 54 | 19 | 61% |
| Younger Cows in 1 st or 2 nd Lactation | 52 | 62 | 10 | 54% |
| Foreign Cows with MACE in Canada | 42 | 57 | 15 | 58% |
| 1 st Crop Proven Sires in Canada | 85 | 88 | 3 | 51% |
| Foreign Sires with MACE in Canada | 69 | 77 | 7 | 53% |

Genomic Evaluation Details

| | | | |
|------------------------------------|------------------------------------|-------------|------------|
| HOCANF7639268 | MISTY SPRINGS SHOTTLE SATIN | %INB | %R |
| Born 30-OCT-05 | ET BW | 8.82% | 14% |
| Sire: HOGBRM598172 | PICSTON SHOTTLE-ET | 23-JUL-99 | 6.37% 15% |
| Dam: HOCANF7419914 | WILLSONA FREELANCE SIZZLE | 04-FEB-04 | 7.66% 14% |
| MGS: HOCANM6962003 | BRAEDALE FREELANCE | 21-MAR-98 | 15.03% 17% |

| Official Genomic Evaluation | Reliability (%) | Reliability Increase with Genomics | Direct Genomic Value (DGV) |
|-----------------------------|-----------------|------------------------------------|----------------------------|
|-----------------------------|-----------------|------------------------------------|----------------------------|

| LIFETIME PROFIT INDEX | GEBV 09*AUG | | | |
|-----------------------|-------------|-----------|------------|-------------|
| GLPI | 3351 | 63 | +10 | 3107 |
| PRODUCTION | 2129 | 67 | +10 | 1950 |
| DURABILITY | 1145 | 61 | +13 | 970 |
| HEALTH & FERTILITY | 77 | 52 | +18 | 187 |

| PRODUCTION | GEBV 09*AUG | | | |
|-----------------------|-------------|----|-----|------|
| Milk Yield (kg) | 1991 | 69 | +7 | 1741 |
| Fat Yield (kg) | 120 | 68 | +9 | 114 |
| Protein Yield (kg) | 65 | 67 | +10 | 58 |
| Fat Deviation (%) | 0.46 | 68 | +9 | 0.50 |
| Protein Deviation (%) | 0.00 | 67 | +10 | 0.01 |

| CONFORMATION | GEBV 09*AUG | | | |
|----------------|-------------|----|-----|----|
| Conformation | 16 | 64 | +10 | 13 |
| Mammary System | 14 | 64 | +11 | 11 |
| Feet & Legs | 13 | 59 | +13 | 11 |
| Dairy Strength | 12 | 67 | +6 | 7 |
| Rump | 9 | 61 | +9 | 9 |

| FUNCTIONAL | GPA | 09*AUG | | | |
|--------------------------|------|--------|----|-----|------|
| Herd Life | GPA | 102 | 52 | +20 | 105 |
| Somatic Cell Score | GEBV | 2.96 | 61 | +21 | 2.86 |
| Lactation Persistency | GPA | 105 | 56 | +17 | 105 |
| Daughter Fertility | GPA | 102 | 51 | +17 | 105 |
| Milking Speed | GPA | 103 | 55 | +17 | 103 |
| Milking Temperament | GPA | 105 | 49 | +14 | 105 |
| Calving Ability | GPA | 106 | 64 | +22 | 111 |
| Daughter Calving Ability | GPA | 103 | 51 | +16 | 107 |

Genomic Evaluation Details

www.cdn.ca

Value of Genomics to the Dairy Cattle Industry

Genomics does not just benefit elite breeders and the A.I. industry.

While genomics will clearly revolutionize genetic evaluation systems and selection strategies ...

there are many other benefits that genomics will provide to the dairy industry!

Value of Genomics to the Dairy Cattle Industry

■ Animal Health and Disease Surveillance

- The health status of the Canadian dairy cattle and livestock industries is critical for access to export markets
- Various diseases are currently high on the “radar”, including Johne’s, Leukosis, BSE, etc.
- In 2007, industry implemented a national system for collecting incidence data for 8 key diseases in dairy cattle plus two for heifers
 - Includes mastitis, lameness, metritis, cystic ovaries, displaces abomasum, retained placenta, milk fever, ketosis, calf diarrhea, calf pneumonia

Value of Genomics to the Dairy Cattle Industry

■ Animal Health and Disease Surveillance

- CanWest DHI (milk recording agency for Ontario and western provinces) now offering a DNA-based milk sample test for mastitis (staph. aureus)
 - Tests for detection of DNA for the specific bacteria that causes this form of mastitis
 - Automatically part of standard milk sample testing process, therefore convenient and cost-effective
- DNA will increasingly become the tool for testing the presence of disease in animals
- Genetic selection using genomics will become important for disease resistance

Value of Genomics to the Dairy Cattle Industry

■ Human Nutrition and Health

- Milk from dairy cows is recognized as a highly nutritious and safe product
- Industry has not fully capitalized on the potential to increase the concentration of valuable components of milk related to human health
 - Some with anti-carcinogenic properties
 - Recent effort in DHA Omega-3, other fatty acids, CLA, cholesterol, etc.
- Genomics is an important tool to identify genes/DNA profiles associated with such desirable components

Value of Genomics to the Dairy Cattle Industry

■ Parentage Testing

- Reported error rates in the US dairy sector are as high as 25%
- Much lower in Canada at less than 5%
- New technology offers solutions for a systematic approach for animal identification and recordation of parents/lineage
 - Applies to all livestock species not just dairy cattle

Value of Genomics to the Dairy Cattle Industry

■ Traceability

- DNA is natural and unique source of identification for each animal
- DNA allows for complete tracing from birth to death and even into food products
- DNA will clearly become an integral part of all livestock traceability systems
 - Ideally, requires collection and storage of a DNA sample for all livestock animals
 - Dairy cattle industry is heading down this road

Linking Animal ID and DNA

- Dairy Cattle Tagging Pilot Project -

- **Tissues for extracting DNA**
 - blood, hair, semen, ear tissue, nasal swabs, ...
- **Ear tissue was deemed best, because**
 - Ultimate objective = integrate to RFID tags
 - Same tag set with RFID in one ear and DNA tag in the other ear
 - Less ID errors since tag and sample numbers always match

Linking Animal ID and DNA

- Dairy Cattle Tagging Pilot Project -

- **Caisley DNA tags:**
 - Tamper evident and easy to apply
 - Metal cutting edge gives higher retention rate
 - Cost: \$2.00 for pilot, but marginal cost of \$0.25 over current tag price for high volumes
 - Can keep tissue at room temperature for up to 6 months
 - Now approved by CCIA
- **Other companies now developing similar technology**

DNA Ear Tags



DNA Collection Pilot Project

- Tagging Success and DNA Amount -

- **96% of animals tagged successfully**
- **Pilot: no repeated attempts, older animals**
- **Much higher rate expected with young animals (ex. Switzerland)**
- **Enough DNA for genomics (30 times the amount required for 50K genotyping)**
- **Well received by producers and DHI technicians**

DNA Collection Pilot Project

- Conclusions -

- The technology is there and works
- One integrated system for all needs would be better than several parallel systems
- Canadian dairy industry is moving forward in this direction
- Industry has approved a ***National Dairy Cattle Genomics Initiative*** and currently seeking government support

National Dairy Cattle Genomics Initiative

- **Animal ID and Traceability**

- Contribute to the development of effective DNA-backed systems for animal identification and traceability

- **Research**

- Provide resources for state-of-the-art research in genomics and genetics

- **Genetic Improvement**

- Develop tools for the application of the research by the industry, mainly CDN

Summary

- **Genomics is a new technology that has hit the dairy cattle industry extremely fast**
- **CDN, its members and collaborators have developed a national Genomic Evaluation System that became official in August 2009**
- **Genomics (more specifically DNA) has major benefits to the dairy industry in addition to genetic improvement**
- **Dairy cattle industry has developed a longer term strategic plan to capitalize on the use of DNA and genomics**

Application of Genomics

- **Take Home Message #1:**

GENOMICS IS HERE!

- **Take Home Message #2:**

GENOMICS IS HERE NOW!!

- **Take Home Message #3:**

GENOMICS IS HERE TO STAY!!!