# Implementation of genomic selection and crossbreeding in dairy cattle

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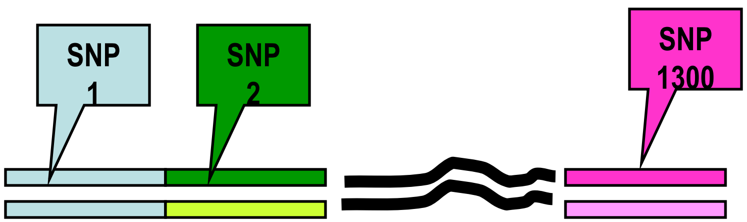
# Genomic Selection

- Extends our current quantitative selection approach – but revolutionary
- Still a “black box” approach to selection – do not know exact function of individual genes
- Not “ditching” old basic concepts just enhancing them
- Does not eliminate the need for data on important families & individuals

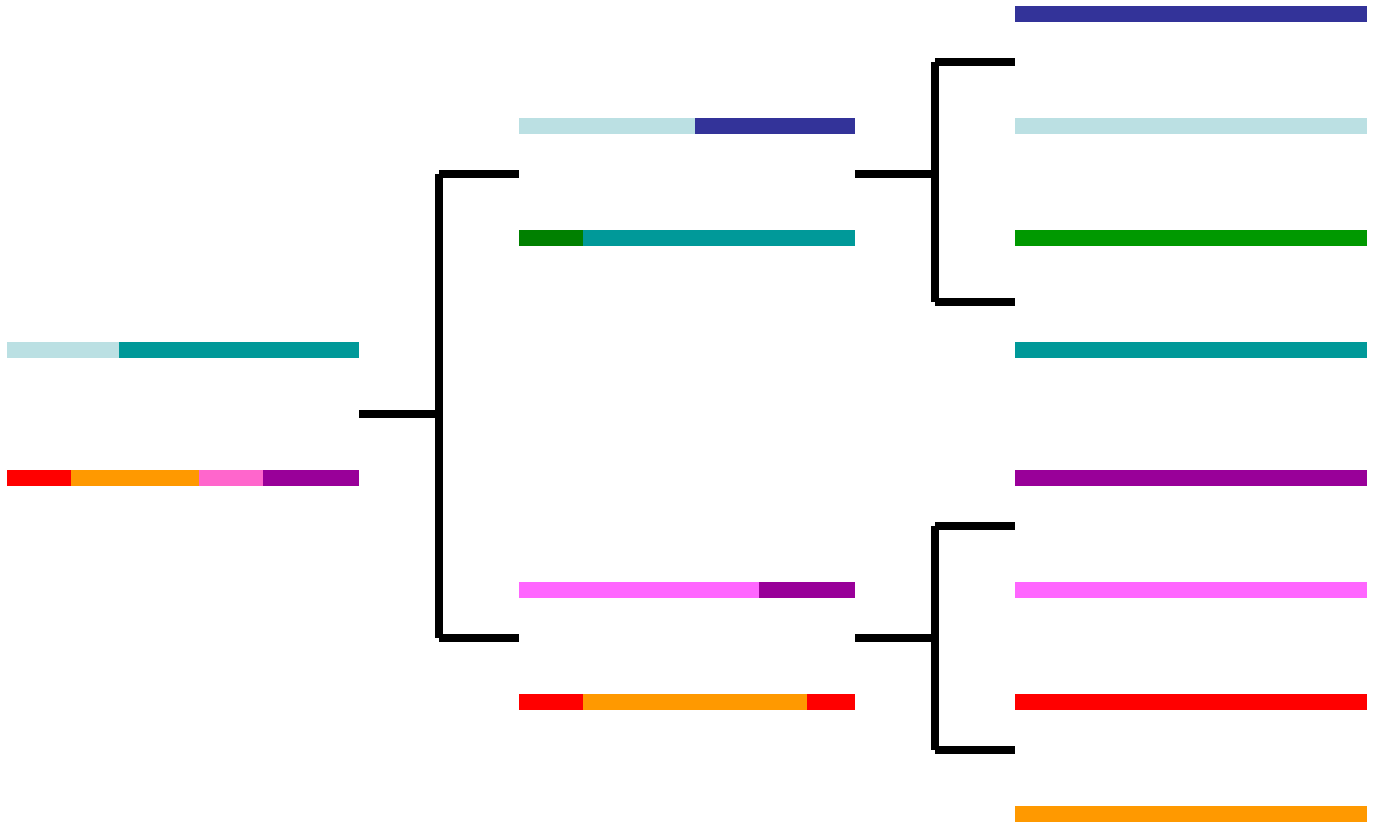
# Chromosomes, SNPs & "genomic" evaluations (estimated breeding values)

Example:1 pair of chromosomes




- Values for each SNP for each trait can be estimated
- Genomic evaluations for young animals are approximately:
  - SUM of all SNP values across all 30 pairs of chromosomes
  - Usually combined with parent averages/pedigree merit
- Genetic evaluations for older animals will include SNP and performance information

# Genomic Pedigree (1 pair of chromosomes)



Source - USDA

# Estimation of genetic values from SNPs

- Not trivial
- Need a reference population to estimate SNP effects
- Need thousands of SNPs for “genome wide selection” (50,000 SNP chip & moving to 800,000 SNP chip)
- Do not need to know “actual” value of all the genes located around all the SNPs
- SNP values need to be re-estimated frequently

## Genetic progress per year

Selection response/year = $i * r_{IA} * \sigma_B / L$

where,

$i$ = selection intensity

$r_{IA}$ = selection accuracy

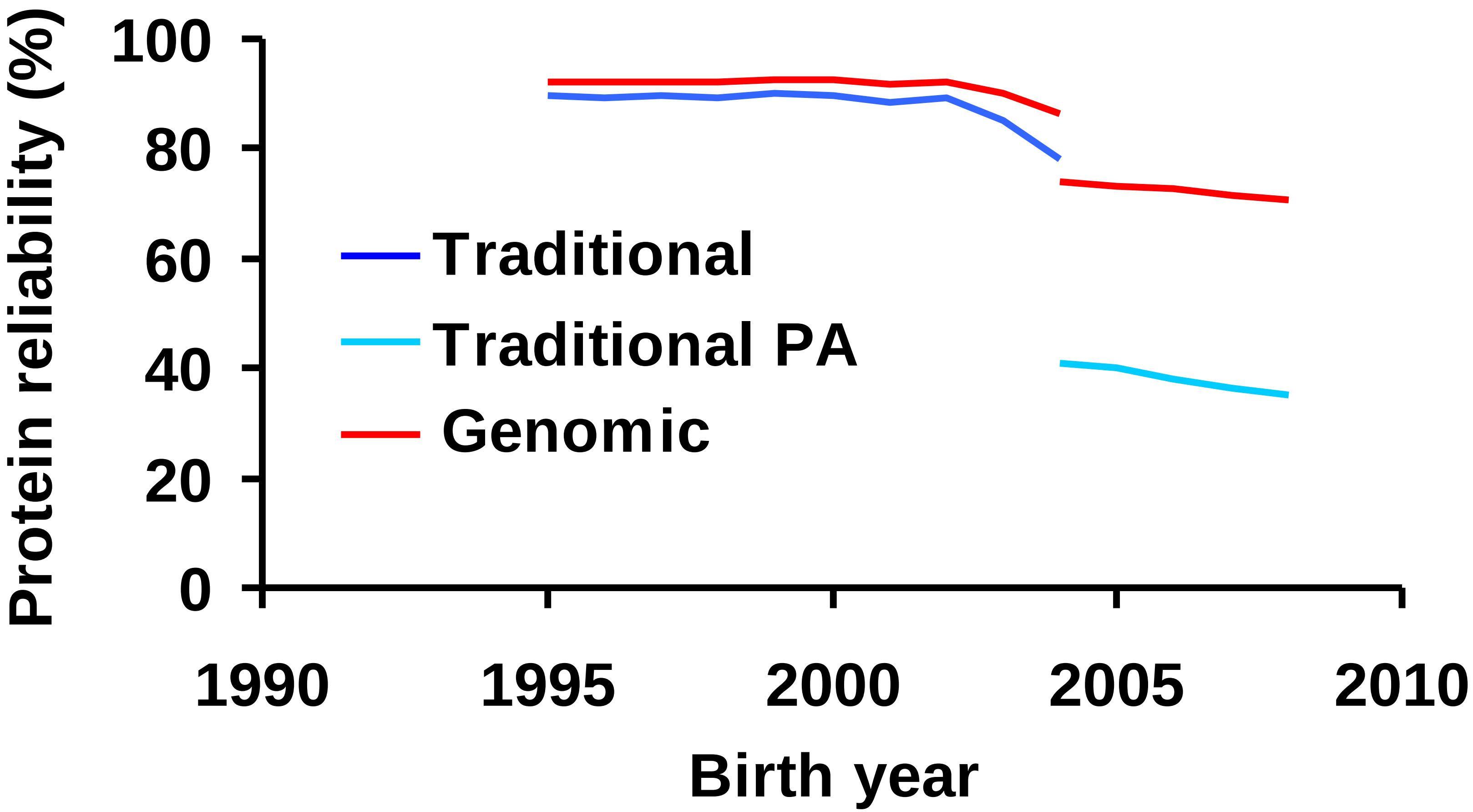
$\sigma_A$ = genetic standard deviation

$L$ = generation interval or age of parents when progeny are born

# Genomic Selection

- Increased reliability for genetic evaluations on young animals
  - Can get accurate genetic evaluations at birth (or before)
  - Increase in reliability equivalent to having >15 daughters
- Increased reliability for genetic evaluations on cows
- Possibly reduce generation interval by ½ or more in sire selection
- Could use AI bulls without daughters for:
  - breeding the entire dairy herd
  - breeding the next generation of young bulls to be used for AI
- Could use (more) heifers for next AI bulls

# Genomic vs. traditional reliability – protein




Source - USDA

# Enhanced genetic change from genomic selection

- Near future - a 5% to 15% increase in genetic gain
- Long term - a 50% increase in genetic gain – theoretical increase is higher

# Genomic Selection Issues

- Cost of program
- Population size & linkage disequilibrium
  - Larger reference population results in improved accuracy of genomic predictions
  - Highly selected populations have more linkage disequilibrium
- Reliability of prediction for lowly heritable traits has been disappointing (except DFS data)

# Genomic Selection Issues (continued)

- Potential increase in inbreeding (homozygousity)
  - Actual selection for the same SNPs (directly choosing animals with the same sequences/genes)
  - Those selected will be more homozygous than their pedigree will indicate
- Could allow use of some non-traditional or outcross families to reduce inbreeding?
  - No documented success yet
- Could use SNPs to decrease inbreeding

# Genomic Selection Issues (continued)

- Inbreeding from genomic selection could lead to an increase in crossbreeding in commercial herds
- Could use genomic selection to create inbred lines for crossbreeding
  - Maize & other important plants
  - Poultry & swine

# Implementation of genomic selection in populations

- Improved young bull selection & continue progeny testing
  - Geno, ABS Global, Select Sires, etc. current plan
- Change number of bulls progeny tested
- Use young bulls with genomic information like we currently use proven bulls (with daughter information)
  - Will get daughter information
  - Variable uptake by companies & herds
  - Risk differs compared with proven bulls
  - Team approach to bull usage

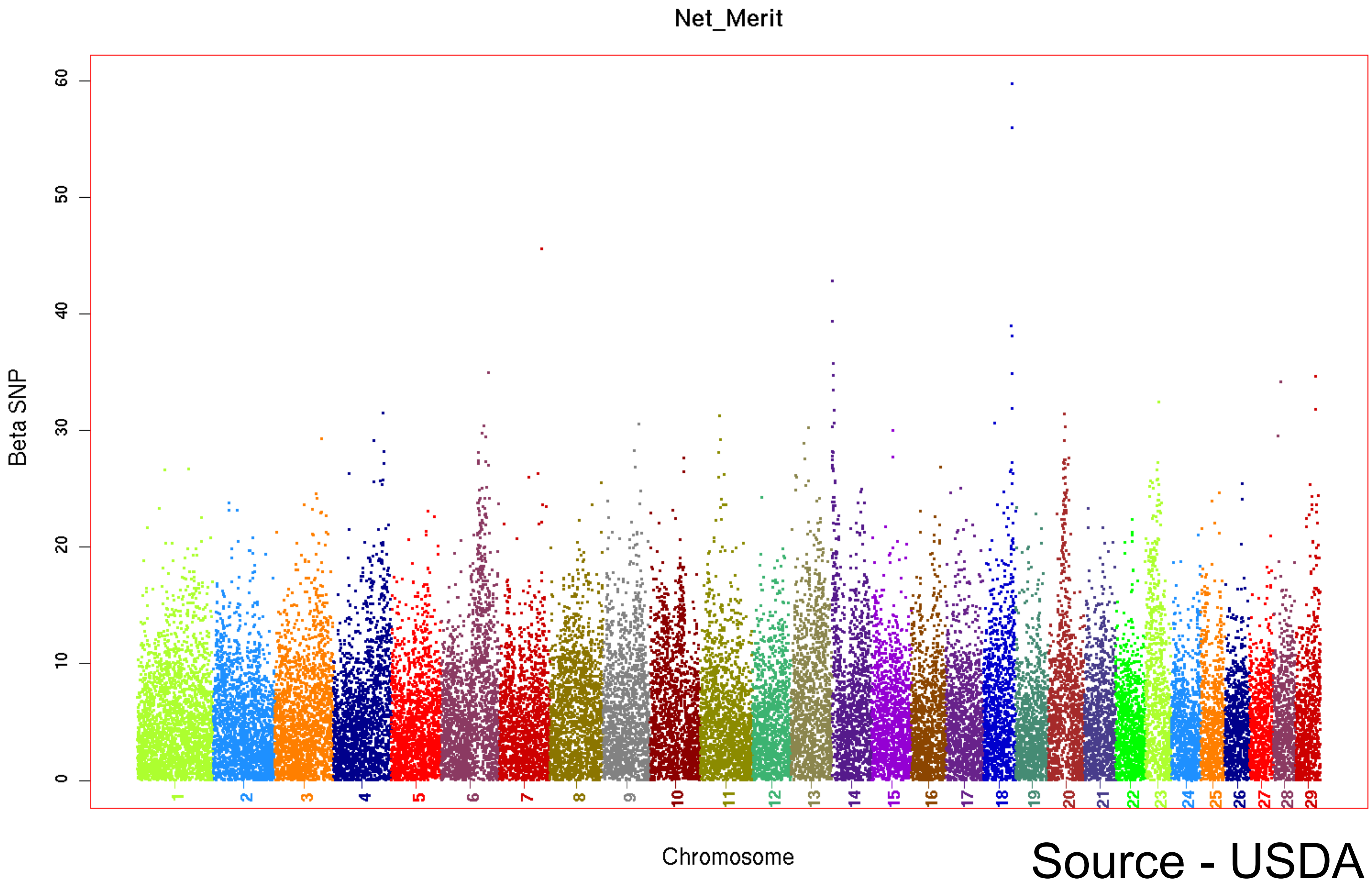
# Holstein Genotypes (reference bulls only)

Feb 2010

| Country | Reference bulls |
|---|---|
| Germany | 17,000 |
| Netherlands | 16,000 |
| France | 16,000 |
| Scandinavia (DFS) | 16,000 |
| United States | 9,300 |
| Canada | 8,800 |

Source - USDA

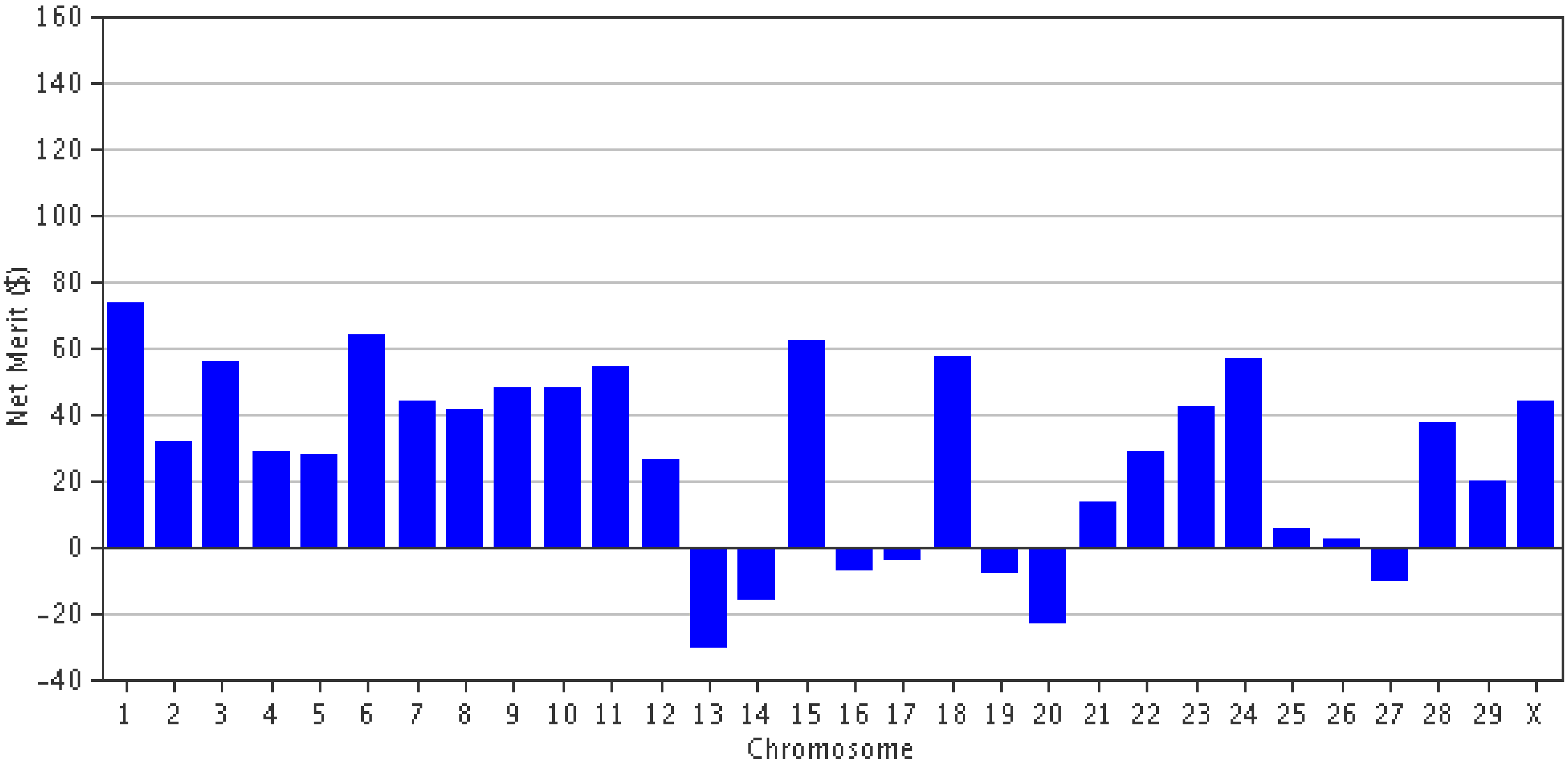
# SNP effects for US Net Merit




Source - USDA

# Net Merit by Chromosome

## O Man (7HO06417)




Source - USDA

# Summary on Genomic Selection

- Enhanced quantitative based selection
- Substantially increase rates of genetic improvement
- Require some changes in breeding programs to reap the benefits
- Take some time to be optimized
- Inbreeding must be properly considered

# Crossbreeding in the US & other countries

- Farm level economics has changed
- Successful genetic improvement in yield (genetic antagonism with reproduction, diseases & mortality)
- Selection for thinner cows
- Inbreeding

# Crossbreeding around the world

- New Zealand – 30% to 50% crossbred cows
- Australia
- Europe
- US - 9.1 million dairy cows – 53,000 herds
  - Approximately 80-90% Holstein genes
  - Many Jersey X Holstein crosses (>6% of cows in national recording)
  - >600,000 crossbred cows of milking age
  - Perhaps 1 million crossbred dairy cows in US very soon

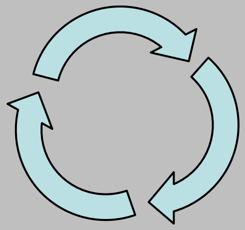
- Benefits of crossbreeding in "commercial herds"
  - Higher farm profit (cheaper cost of production)

  - Hybrid vigor (heterosis) & relief for inbreeding
  - Healthier cows with improved reproduction & survival
  - Improved calving performance
  - Improved genes for some traits from a different breed
  - Can simplify some aspects of mating system (no worry over inbreeding when mate cows)

- Potential negative aspects of crossbreeding
  - Change in traditional breeding policy
  - Identifying the appropriate breeds to use

# CROSSBREEDING MANAGEMENT SYSTEM

Rotational Crossbreeding with 3 breeds primarily



Holstein, Jersey and Norwegian Red

- Could involve Brown Swiss and other breeds in some circumstances

# 3 breed rotational crossbreeding

## (begin with Holstein cow)

Jersey sire (J) X Holstein cow (H)

→ Get JxH cow

Norwegian Red sire (N) X JxH cow

→ Get NxJxH cow

Holstein sire (H) X NxJxH cow

→ Get HxNxJxH cow

↑ Start rotation over with J sire on HxNxJxH cow geno

# Creative Genetics of California & Select Sires

PROCROSS

MONTBELIARDE / HOLSTEIN / SWEDISH RED
SWEDISH RED / HOLSTEIN / MONTBELIARDE

# Preliminary Results (April 2010) - 8 US herds –

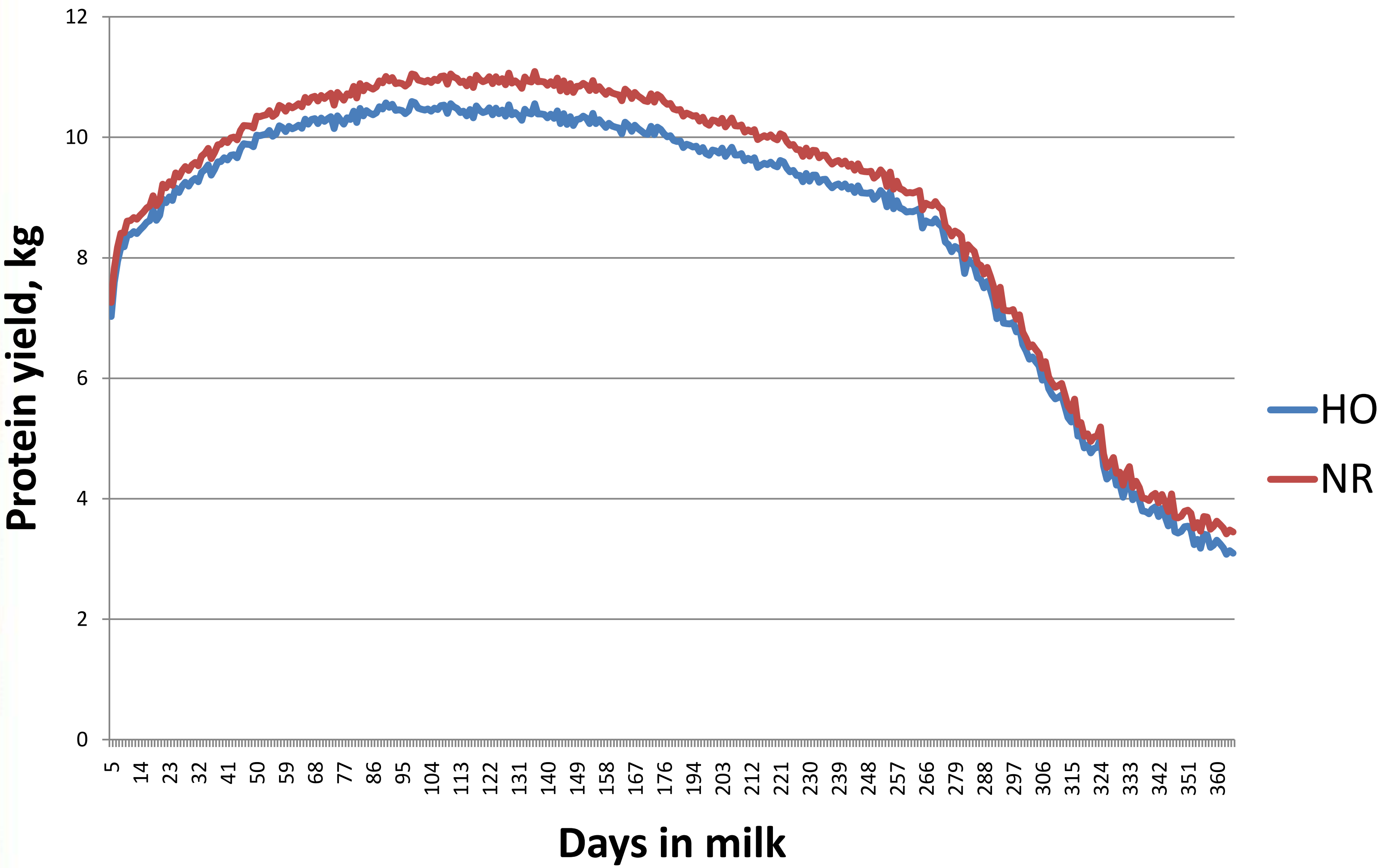
## 1st Lactation projected 305 d records (min 50 days in milk)

## Least squares means

| | Holstein | NRF sired crosses | Jersey sired crosses |
|---|---|---|---|
| # cows | 987 | 72 | 159 |
| Milk (lbs.) | 18,671[a] | 17,950[ab] | 17,194[b] |
| Fat (lbs.) | 736 | 709 | 746 |
| Protein (lbs.) | 589[a] | 589[ab] | 553[b] |
| SCS | 2.65[b] | 1.97[a] | 2.80[ab] |

[a,b] Least squares means with different superscripts differ *P*<.05

# Breed of sire effect on daily protein (kg/day) 60 Canadian herds - preliminary results U of Guelph (June 2010)



# Canadian project (60 herds) – June 2010
# Preliminary results – U of Guelph
# Reproduction in 1st lactation

| | Holstein | Norwegian Red X Holstein |
|---|---|---|
| # cows | 3036 | 117 |
| Non-return rate | .59 | .69 |

# NRF crosses in the USA

# Crossbreeding approaches & spreadsheet

Version 5 - Author Gary W. Rogers

Introductory comments - move cursor here for note

| **Partial Budget (12 mo basis - steady state - replacement enterpise excluded)** | **Input Column** | | | TWO | BREED | CROSSES | |
|---|---|---|---|---|---|---|---|
| | | Holstein | Jersey | JE X HO | BS X HO | NR X HO | MO X HO |
| Income minus expense/year | | 437,180 | 364,240 | 577,503 | 501,825 | 567,734 | 468,206 |
| Income minus expense/cow/year | | 437 | 364 | 578 | 502 | 568 | 468 |
| Number of cows | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Deviation from 1st lact Holsteins in very high producing herds | | | 6300 | 2650 | 1150 | 1300 | 1500 |
| Modifier for deviation from Holstein | 0 | | 6300 | 2650 | 1150 | 1300 | 1500 |
| 1st lactation 305 day milk mean (Holstein base for input) | 20,000 | 20,000 | 13,700 | 17,350 | 18,850 | 18,700 | 18,500 |
| 2nd lactation 305 day milk mean | | 24000 | 16440 | 20820 | 22620 | 22440 | 22200 |
| 3rd and later 305 day milk mean | | 26000 | 17810 | 22555 | 24505 | 24310 | 24050 |
| Weighted mean 305 day milk | | 23300 | 15960.5 | 20212.75 | 21960.25 | 21785.5 | 21552.5 |
| Adjustment for calving interval on annualized milk | | 0.975 | 0.982 | 0.984 | 0.980 | 0.984 | 0.984 |
| Annualized milk sold per cow | | 22727 | 15667 | 19885 | 21532 | 21432 | 21203 |
| Average pounds milk/cow/day for all cows | | 62.3 | 42.9 | 54.5 | 59.0 | 58.7 | 58.1 |
| Fat percentage (Holstein base for input) | 3.654 | 3.654 | 4.583 | 4.119 | 3.827 | 3.777 | 3.777 |
| Protein percentage (Holstein base for input) | 3.006 | 3.006 | 3.559 | 3.2825 | 3.1595 | 3.113 | 3.113 |
| Other solids percentage | | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 |
| Fat value $/pound | $1.40 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| Protein value $/pound | $3.00 | 3 | 3 | 3 | 3 | 3 | 3 |
| Other solids value $/pound | $0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Milk value $/100 pounds | | 14.42 | 17.38 | 15.90 | 15.12 | 14.91 | 14.91 |
| Net value of PPD, ovr ord prem, chkoff, oth deducts & haul $/cwt | $1.00 | 1 | 1 | 1 | 1 | 1 | 1 |
| Net milk value $/100 pounds | | 15.42 | 18.38 | 16.90 | 16.12 | 15.91 | 15.91 |
| Milk value $/cow/day | | 9.60 | 7.89 | 9.21 | 9.51 | 9.34 | 9.24 |
| Average 4% fat corrected milk per cow per day | | 70.6 | 55.9 | 66.4 | 68.8 | 67.9 | 67.2 |
| Average cow weight (Holstein base for input) | 1395 | 1395 | 990 | 1193 | 1395 | 1316 | 1418 |
| Dry matter intake for milking cows based on NRC equations | | 52.6 | 41.1 | 48.1 | 51.9 | 50.5 | 51.7 |

# Summary

- Crossbred cows will return more net revenue per cow per year than pure Holsteins in most herds in the US
- Various crossbreeding schemes are in use
- Three breed rotations:
  - Holstein, Nordic Reds and Jersey (likely most profitable in most US herds)
  - Holstein, Nordic Reds and Montbeliarde or Fleckvieh or Brown Swiss
  - Other combinations