Genetic Gain, Inbreeding and Mating Programs

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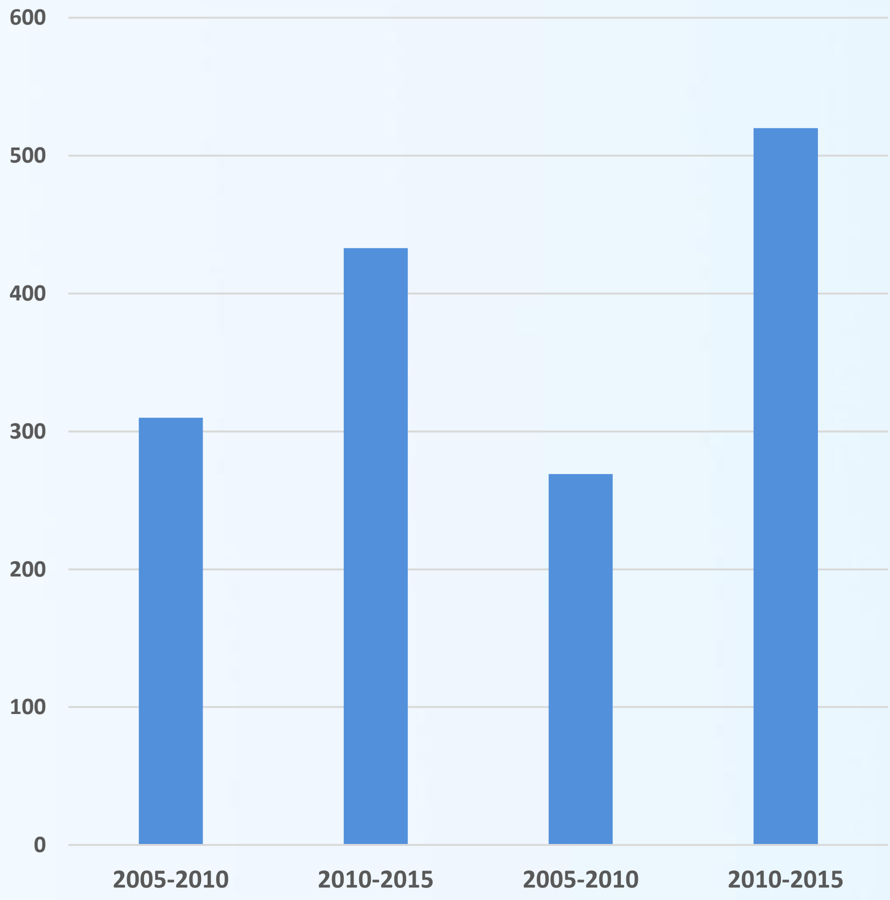
In the age of Genomics

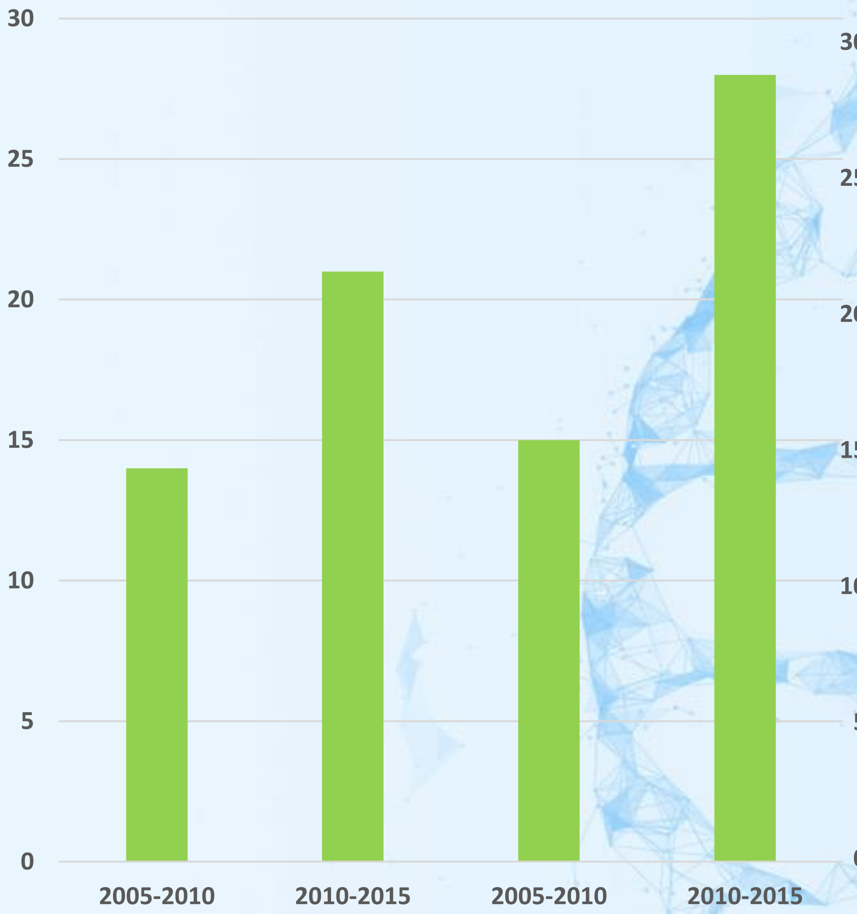
Additive Genetics – Inbreeding Depression = Economic Gain

Comparison Last Five Years Before and First Five Years After Introduction of Genomics
Production Traits

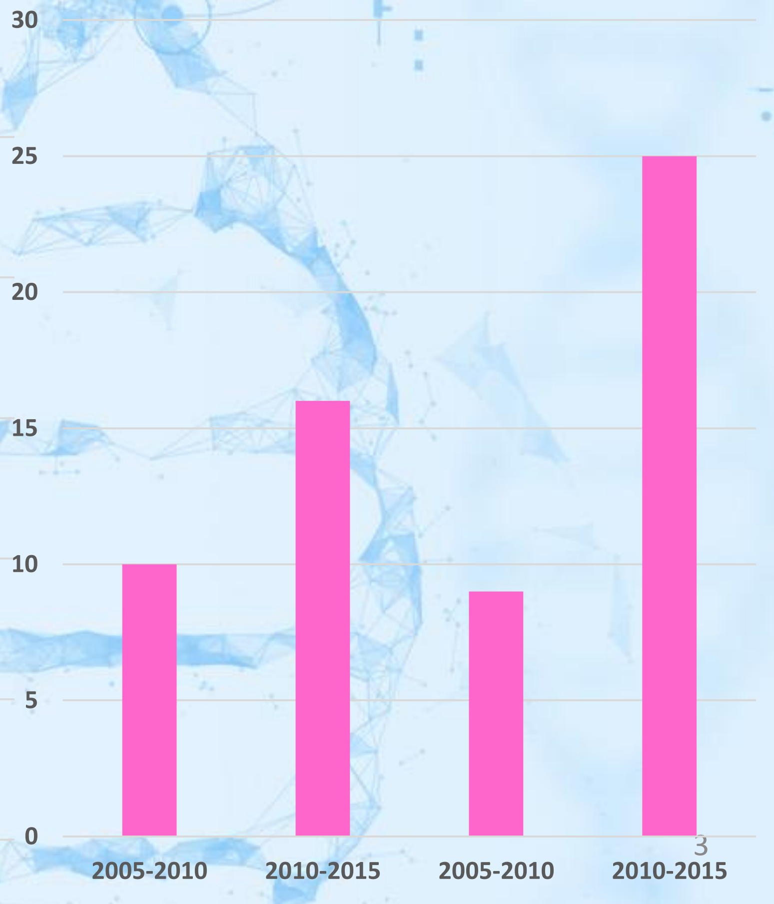
COW MILK BULL



COW FAT BULL



COW PRT BULL



Comparison National Holstein DHI Averages

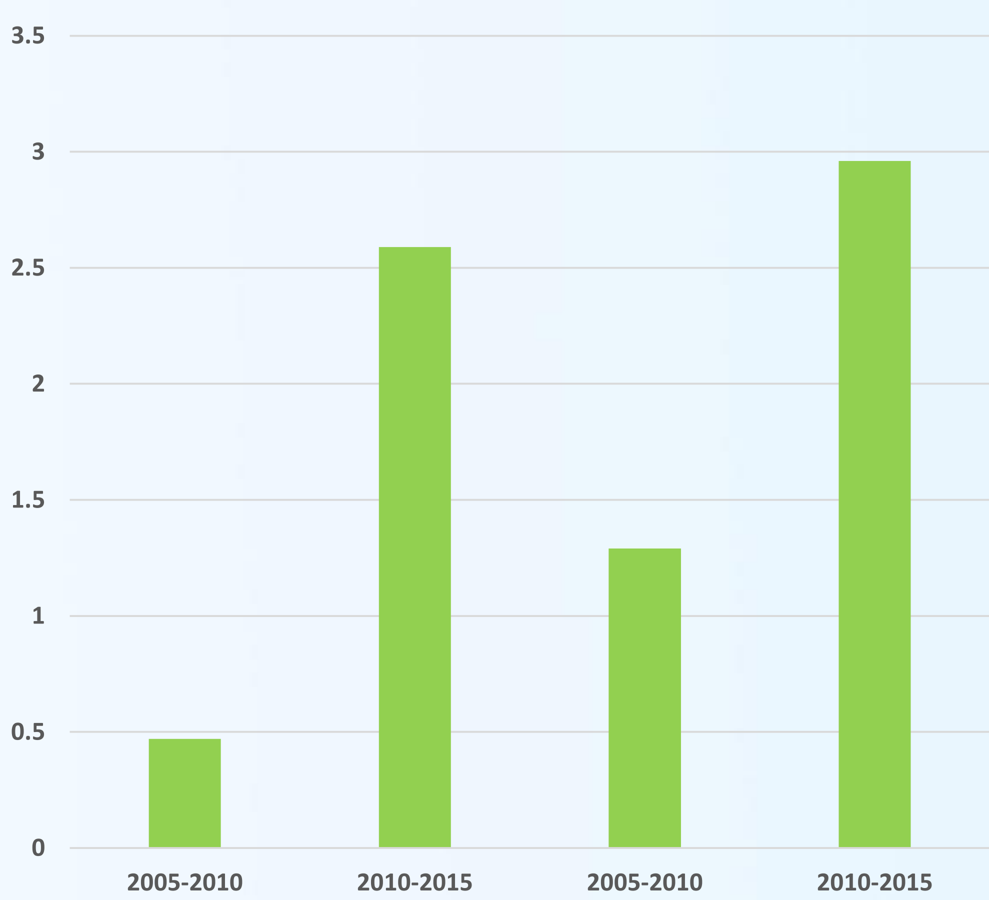
Test Plan	Number of Herds	Number of Cows	Average Number of Cow	Milk	Fat%	Fat	Protein %	Protein
All plans 2017	13,321	3,586,789	269	11,508 L	3.76	433 kg	3.11	358 kg
All plans 2015	14,662	3,642,037	248	11,343 L	3.68	417 kg	3.08	350 kg
All plans 2010	17,578	3,776,761	215	10,539 L	3.61	381 kg	3.06	323 kg

47% of US Dairy Cow Population is on DHI Test

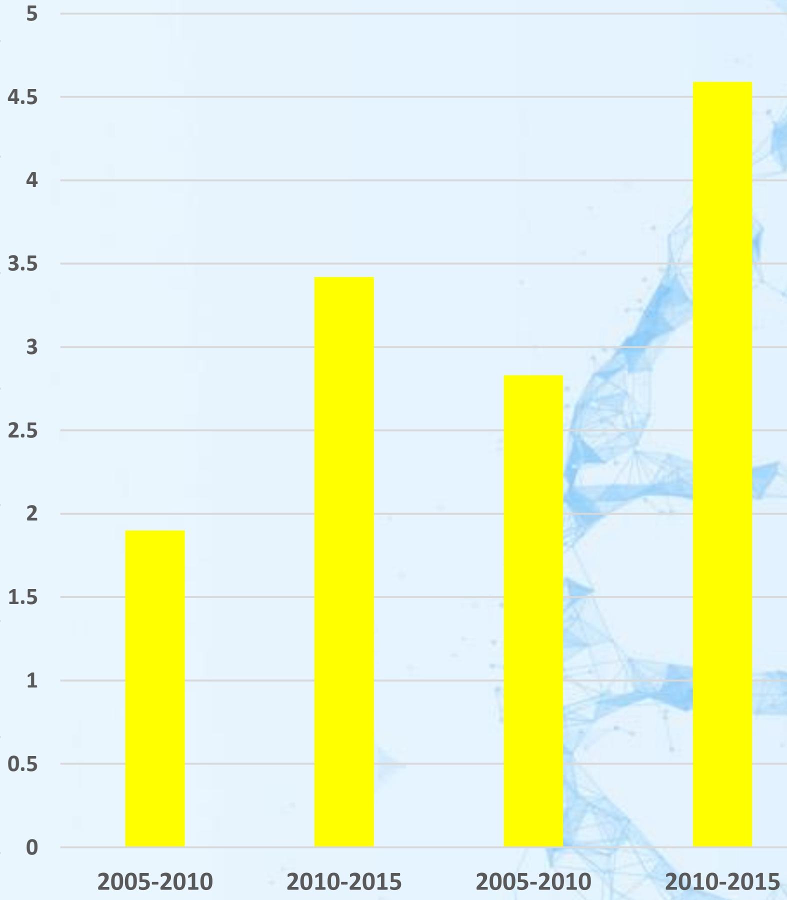
Source National DHI

Comparison Last Five Years Before and First Five Years After Introduction of Genomics
Fertility, Productive Life and Net Merit

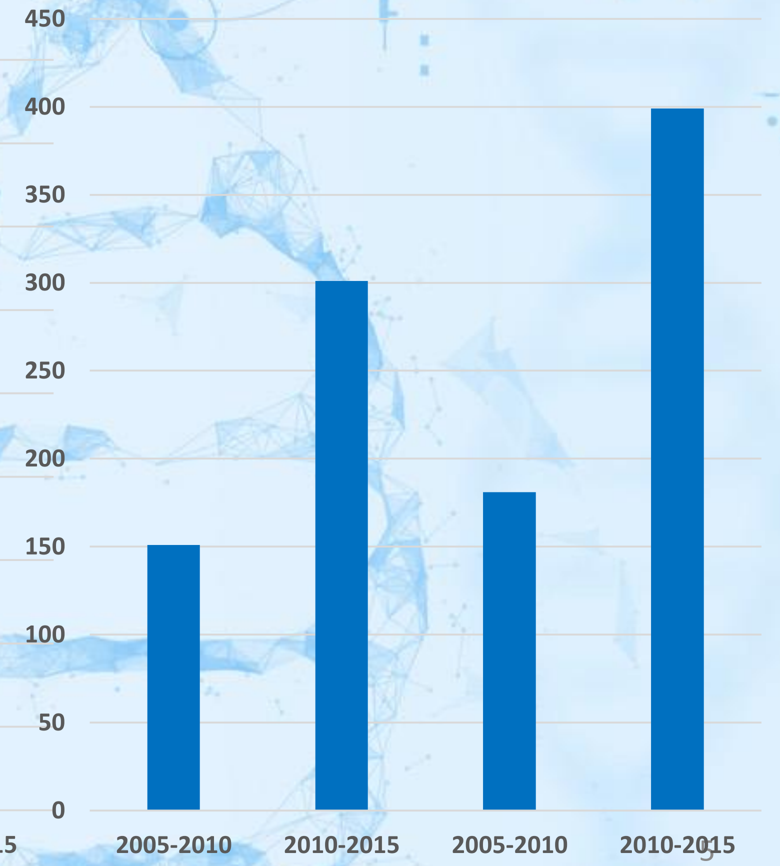
COW DPR BULL



COW PL BULL



COW NM$ BULL



Change in Pregnancy Traits Over Time in DHI Herds

Inseminations Per Pregnancy

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.4	2.4	2.3

Average Days from Calving to First Breeding

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
87	86	85	83	81	81	79	78	78	78	78	78

Average Days from Calving to Last Breeding

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
146	145	141	136	133	132	130	126	126	124	122	120

Average Calving Interval

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
423	423	418	417	412	409	408	404	403	401	399

Source DHI/CDCB

Improvement in Somatic Cell

Birth Year	Cows	SCS	BV	Rel	Sire BV
2015	834165	2.32	-0.18	0.36	-0.31
2010	854539	2.37	0.00	0.41	-0.05
2005	720088	2.74	0.09	0.41	0.12

Source USDA/CDCB

Comparison of Somatic Cell in DHI Herds Overtime

Year	Milk Per Day	Somatic Cell
2005	32.3 L	296
2006	32.3 L	288
2007	32.4 L	276
2008	32.6 L	262
2009	32.8 L	233
2010	33.0 L	228
2011	33.2 L	217
2012	33.7 L	200
2013	34.2 L	199
2014	34.6 L	200
2015	35.1 L	204
2016	35.5 L	203
2017	35.5 L	197
Annual trend	0.24 L	-7.61

Source DHI

Reasons Cows Leave herds DHI 2010 compared 2015

Termination code 2015	Parity 1	Parity 2	Parity 3	Parity 4	Parity 5	Parity 6+	All
Lactation ended normally	74.3	66.8	57.9	50.1	43.7	37.8	64
Lactation ended with abortion	0.3	0.3	0.3	0.2	0.2	0.2	0.3
Sold For Dairy	4.5	2.8	2.4	2.4	2.5	2.7	3.3
Locomotion problems	0.7	1.2	2	2.9	3.5	4	1.5
Low production	5	6.3	6.6	7.1	7.8	8.9	6.1
Reproduction problems	3.7	5	5.4	5.7	6.1	6.3	4.8
Unspecified reasons	6.4	8.8	12	14.7	16.8	19	9.9
Mastitis or high SCS	2	4.2	6.3	7.9	9	9.6	4.6
Died	3	4.6	7	8.9	10.5	11.5	5.5

Termination code 2010	Parity 1	Parity 2	Parity 3	Parity 4	Parity 5	Parity 6+	All
Lactation ended normally	76.8	69.6	61.1	53.1	46.9	40.8	66.3
Lactation ended with abortion	0.4	0.4	0.3	0.3	0.3	0.2	0.4
Sold For Dairy	4.4	3	2.6	2.5	2.4	2.6	3.3
Locomotion problems	0.7	1.3	2.2	3.1	3.8	4.1	1.7
Low production	3.7	4.7	5.3	5.7	6.2	7.1	4.7
Reproduction problems	3.6	5	5.3	5.6	5.9	6.6	4.8
Unspecified reasons	5.6	8	11	13.9	16	18.3	9.2
Mastitis or high SCS	1.7	3.3	5.1	6.5	7.7	8.5	3.9
Died	3.1	4.8	7.2	9.3	10.7	11.7	5.7

Source DHI/CDCB

Improvement in Livability

Birth Year	Cows	BV	Rel	Sire BV
2014	560028	1.19	0.24	1.64
2010	898760	0.00	0.28	0.31
2006	779028	-1.26	0.28	-1.77

Source USDA/CDCB

Comparison of Gain Between Registered Cows and Commercial Cows

peutics, veterinary care, and replacement animals (34).

SD. From 1985 to 2000, there was no clear trend in any of the four paths for SD of SCS (Fig. 2). In fact, the SD for the three more influential paths were all positive (worsening, because a lower value for the SCS is preferred) until 2005. The DC had slightly positive until 2005. The introduction of genomic selection produced a rapid and substantial increase in SD in the SB, SC, and DB paths. Most notably, the SD in the SB path increased by a factor of 10 between 2001–2005 and 2011–2015, from 0.26 to 4.07. This increase is due largely to the influence of a single bull, O-Bee

Table 1. Estimates of genetic change per year from segmented regressions of PBV on birth year for all cows (All Cows) or the subset of cows registered in the national herdbook (Registered cows) for six traits: milk, fat, and protein yields; SCS; PL; and DPR

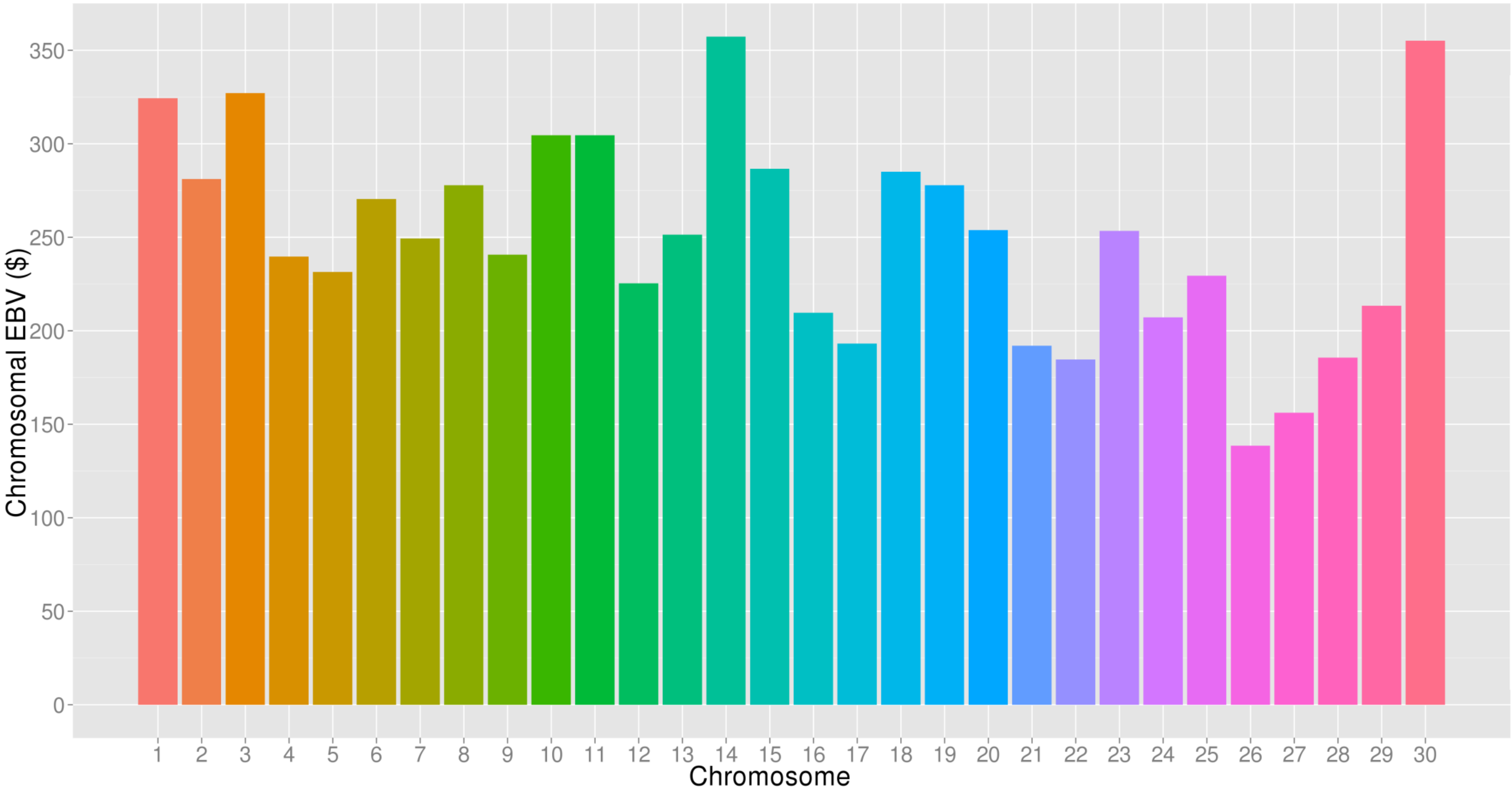
Group	Trait	1981–1985	1986–1990	1991–1995	1996–2000	2001–2005	2006–2010	2011–2015
All cows	Milk	74	79	85	74	64	55	67
	Fat	2.8	3.2	2.2	2.2	2.1	2.6	3.8
	Protein	1.8	2.6	2.6	2.6	2.1	1.8	2.6
	SCS	0.014	0.016	0.005	0.014	−0.002	−0.024	−0.035
	PL	0.25	0.14	0.17	0.03	0.16	0.45	0.88
	DPR	−0.46	−0.54	−0.52	−0.42	−0.20	0.06	0.28
Registered cows	Milk	66	74	66	61	54	50	109
	Fat	2.6	3.1	1.1	1.7	1.8	2.2	6.0
	Protein	1.7	2.8	1.9	1.8	1.8	1.6	4.1
	SCS	0.011	0.006	0.012	0.010	−0.001	−0.021	−0.044
	PL	0.01	−0.02	−0.01	0.00	0.07	0.41	1.17
	DPR	−0.46	−0.48	−0.39	−0.30	−0.27	0.02	0.26

Index changes over time

Relative emphasis in USDA index (%)

Trait	PD$ 1971	MFP$ 1976	NM$ 1994	NM$ 2000	NM$ 2003	NM$ 2014	NM$ 2016	NM$ 2018
Milk	52	27	6	5	0	−1	−1	-1
Fat	48	46	25	21	22	22	22	27
Protein	…	27	43	36	33	20	20	17
Longevity	…	…	20	14	11	19	14	12
SCS (mastitis)	…	…	−6	−9	−9	−7	−7	-4
Udder	…	…	…	7	7	8	8	7
Feet/legs	…	…	…	4	4	3	3	3
Body size	…	…	…	−4	−3	−5	−4	-4
Pregnancy rate	…	…	…	…	7	7	7	7
Calving	…	…	…	…	4	5	5	5
Heifer Conception	…	…	…	…	…	1	1	1
Conception rate	…	…	…	…	…	3	3	2
Health Trait Index	…	…	…	…	…	…	…	2
Livability	…	…	…	…	…	…	7	7

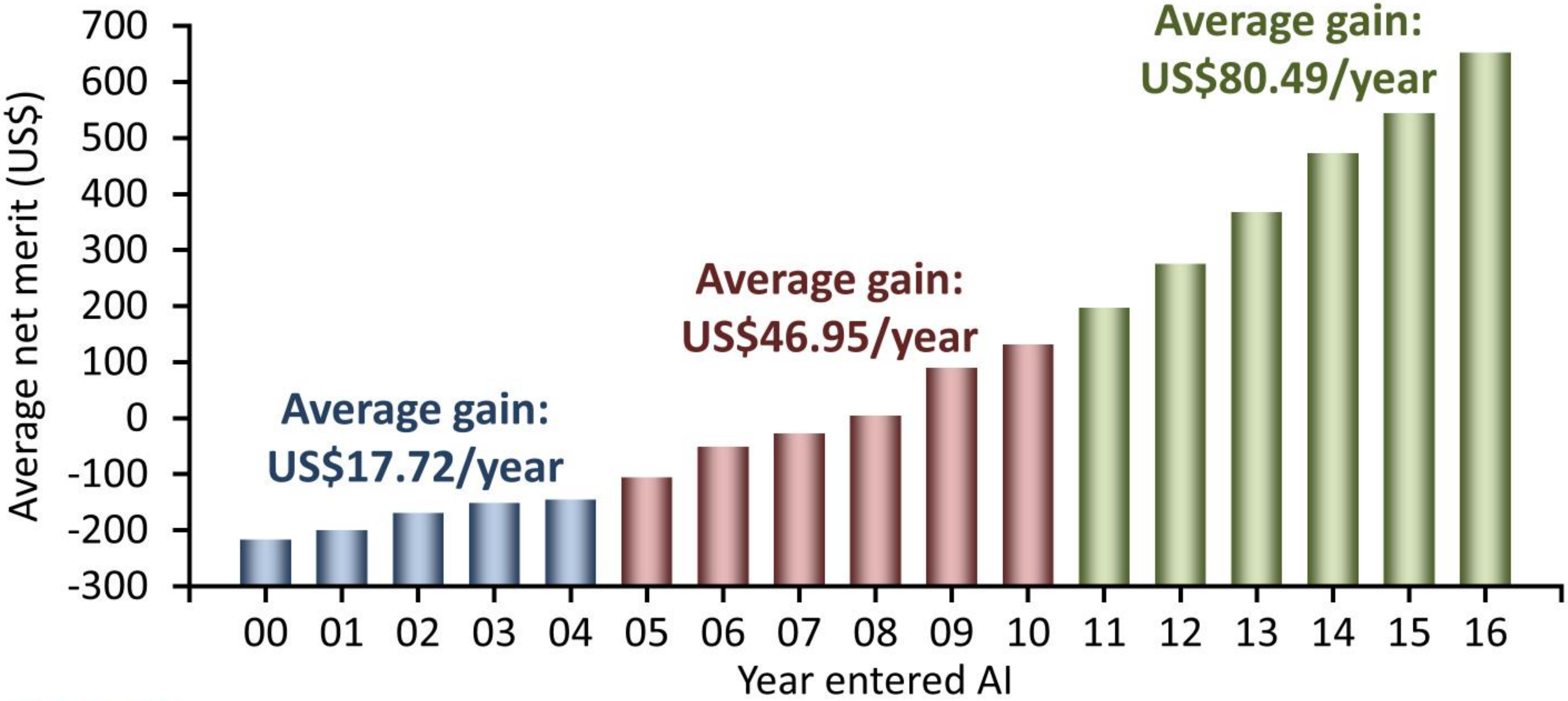
What’s the best cow we can make?



A “supercow” constructed from the best haplotypes in the Holstein population would have an EBV for NM$ of +$7,515 !

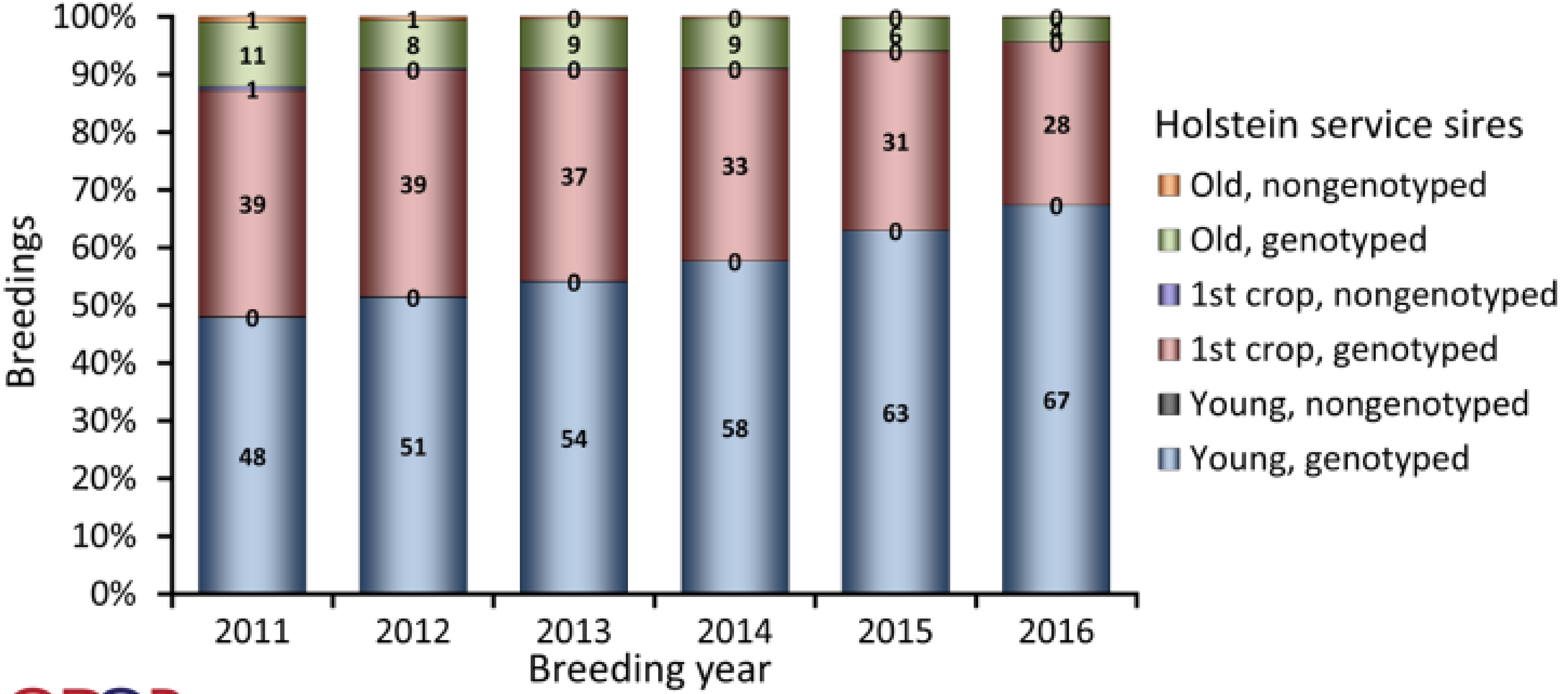
Additive Genetics – Inbreeding Depression = Economic Gain

Marketed Holstein bulls



CDCB
COUNCIL ON DAIRY CATTLE BREEDING

AI breedings to genomic bulls



Some Terms

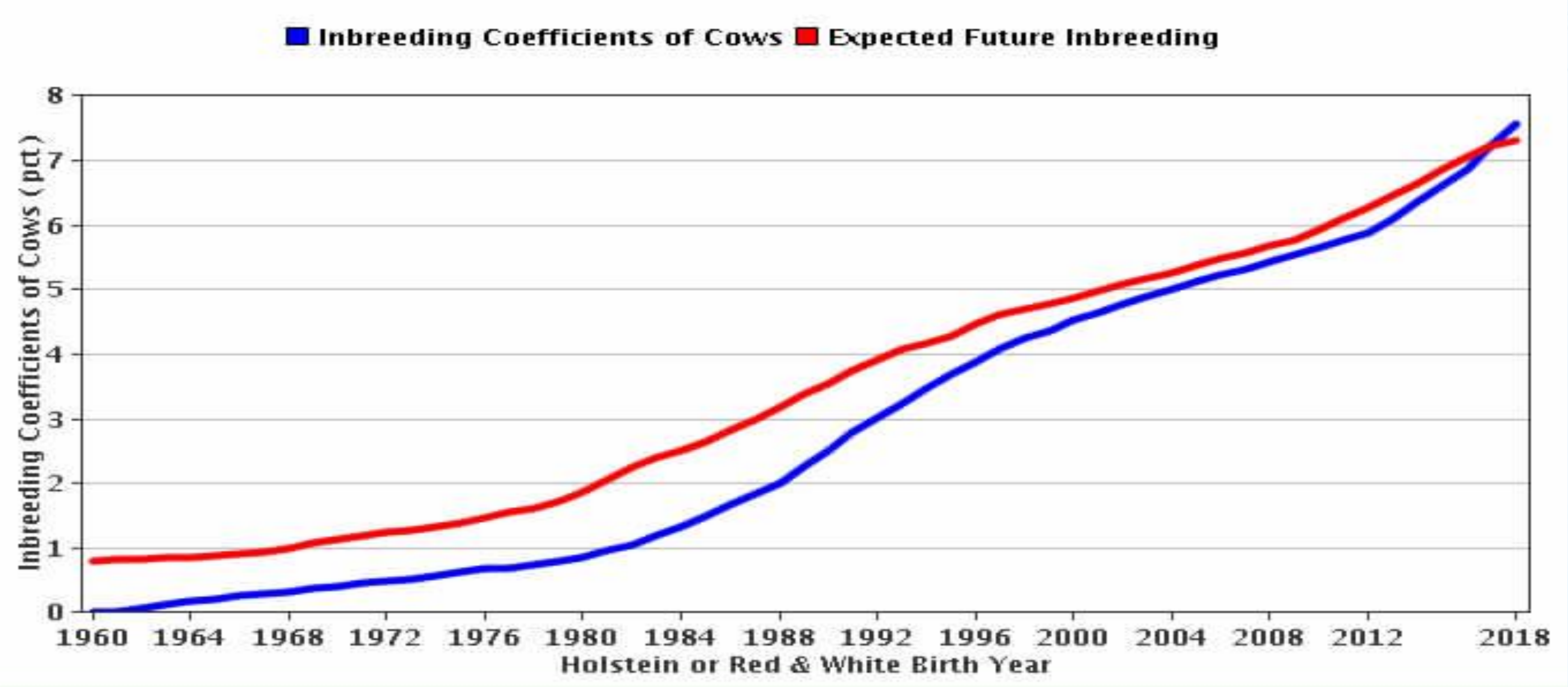
- Expected Future Inbreeding-Based on pedigree the expected future inbreeding level of an animal’s offspring when bred to the general population. If a cow has a EFI of 7.5% her offspring will be 7.5% inbred when bred to the average bull.
- Genomic Future Inbreeding-Based on the genomic relationship between an animal and other animals that have been genomically tested.
- Inbreeding-Based on pedigree the inbreeding level of an individual animal.
- Genomic Inbreeding-The actual inbreeding derived from their genomic evaluation.

Change in Inbreeding Cows

Birth Year	Cows	Percent Inbreeding	Expected Future Inbreeding
2018	1156042	7.60	7.36
2015	1861463	6.56	6.72
2010	1927372	5.67	5.93
2005	1659733	5.13	5.37

Source USDA/CDCB

Inbreeding Cows

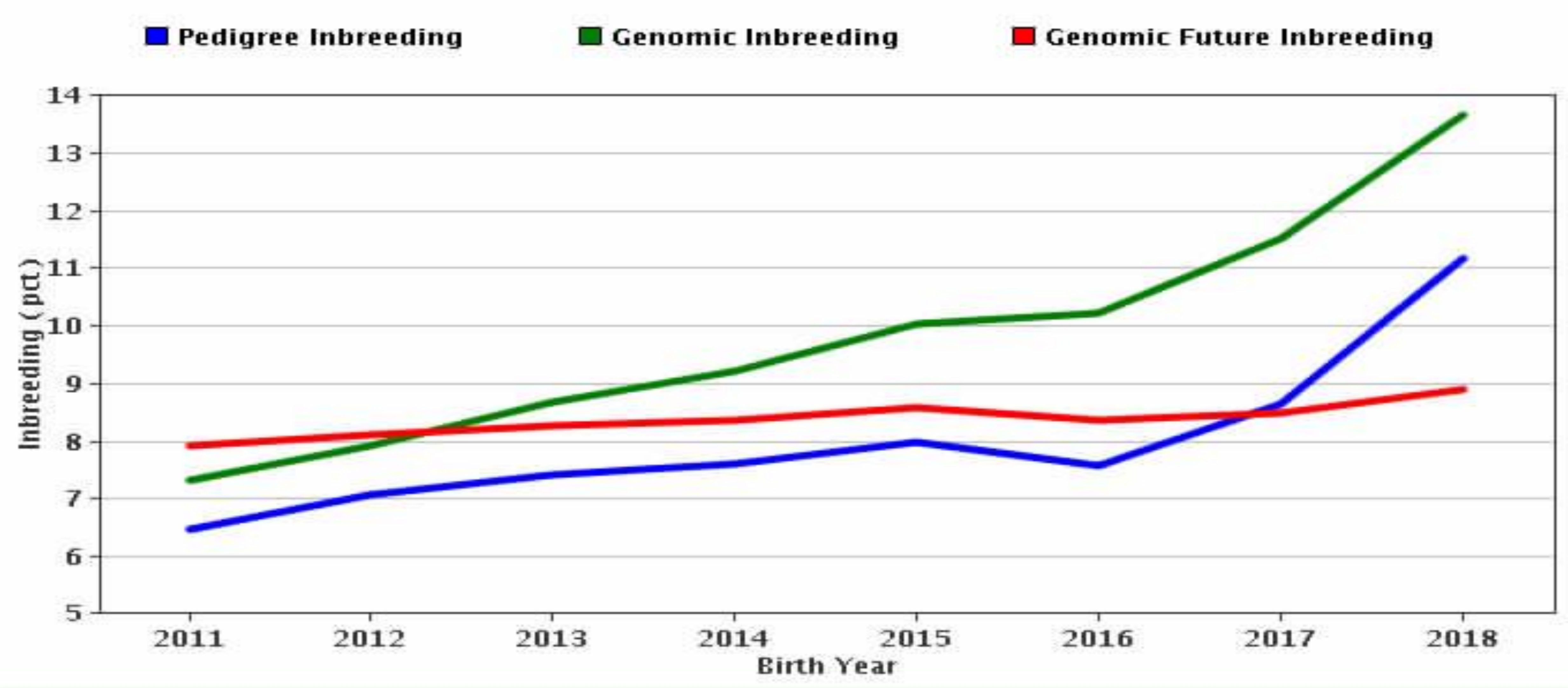


Change Inbreeding Genomic Tested Young Sires

Birth Year	Bulls	Pedigree Inbreeding	Genomic Inbreeding	Genomic Future Inbreeding
2018	14679	11.17	13.66	8.90
2017	24431	8.65	11.52	8.48
2016	23103	7.56	10.21	8.37
2015	20834	7.98	10.03	8.59
2014	18470	7.61	9.22	8.36
2013	15246	7.40	8.69	8.26
2012	17287	7.06	7.93	8.10
2011	11847	6.48	7.31	7.92

Source USDA/CDCB

Genomic Future Inbreeding Young Sires

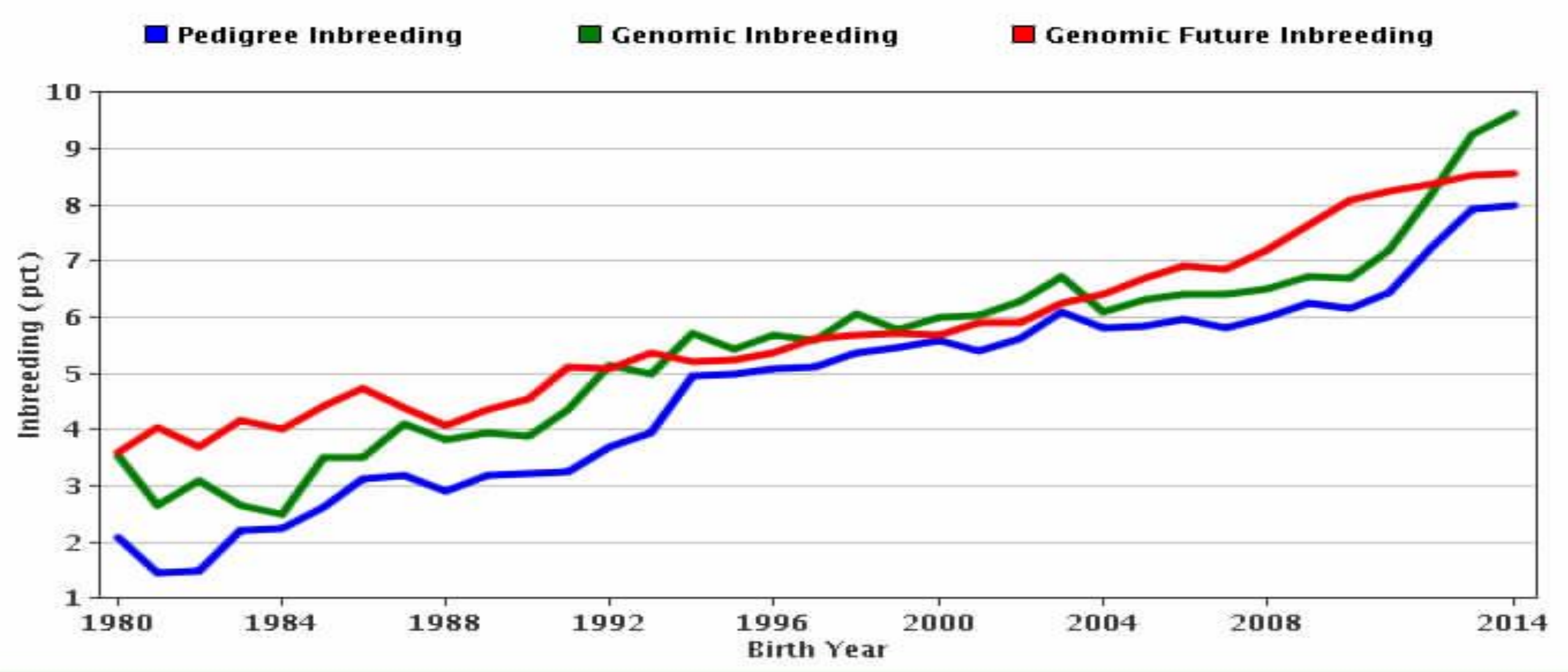


Change Genomic Inbreeding Proven Bulls

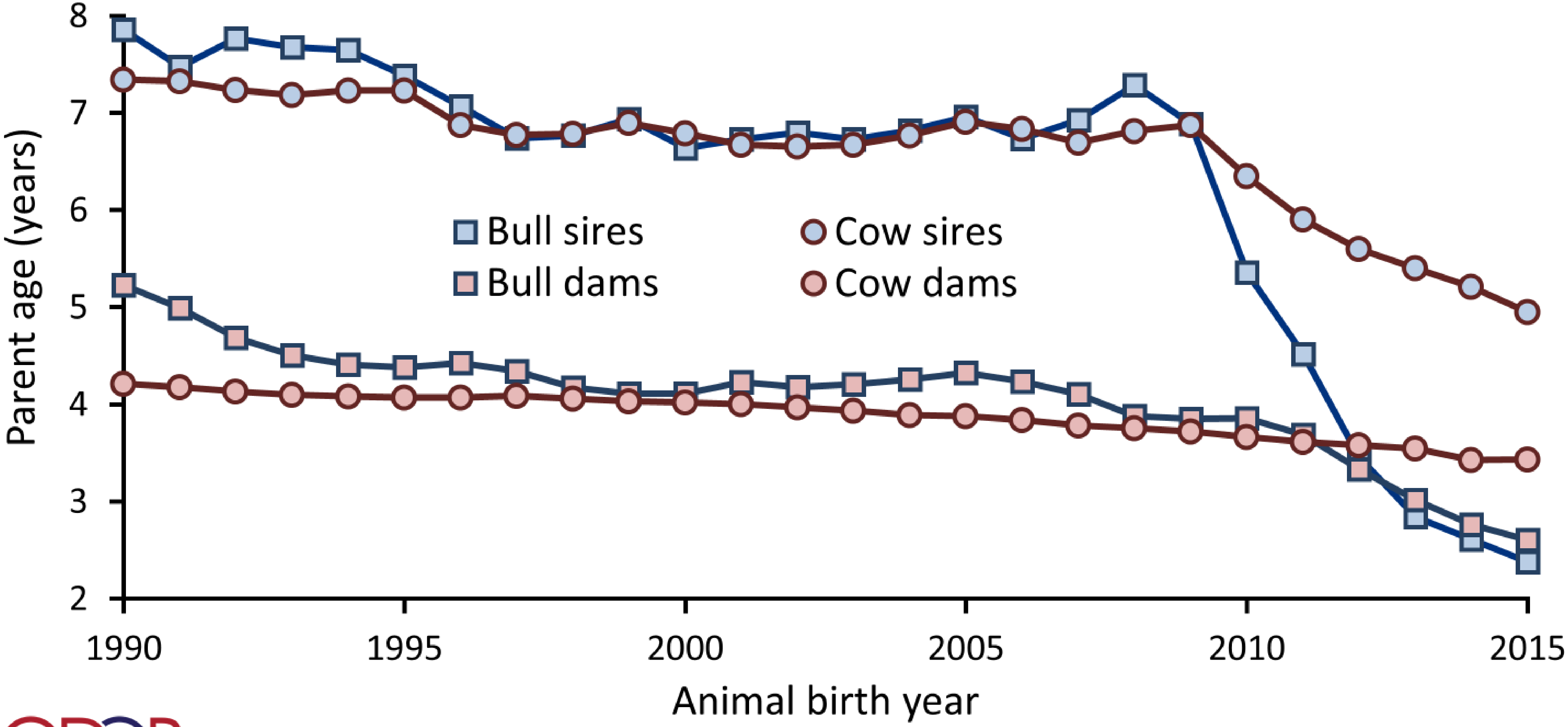
Birth Year	Bulls	Pedigree Inbreeding	Genomic Inbreeding	Genomic Future Inbreeding
2014	1168	8.17	10.13	8.73
2013	2020	7.96	9.51	8.63
2012	2700	7.24	9.27	8.55
2011	2234	6.49	7.34	8.00
2010	2392	6.14	6.76	7.88
2009	2056	6.27	6.85	7.50
2008	2040	6.02	6.64	7.16
2007	2290	5.80	6.51	6.92
2006	2332	5.98	6.49	6.91
2005	2124	5.86	6.42	6.69
2004	2000	5.82	6.21	6.40
2003	1369	6.09	6.83	6.27
2002	1351	5.63	6.39	5.95

Source USDA/CDCB

Proven Sires



Generation interval – Holstein



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Before Genomics six generations in 33 years

023HO00206	TRADITION	DOB: 08/18/1974	NM$ -349	gEFI 4.5%
001HO01464	CLEITUS	DOB: 10/26/1981	NM$ -214	gEFI 4.1%
011HO03073	LUKE	DOB: 05/07/1988	NM$ -573	gEFI 5.7%
011HO04623	HERSHEL	DOB: 07/30/1995	NM$ -203	gEFI 6.9%
029HO11111	BOLTON	DOB: 09/11/2001	NM$ +205	gEFI 6.8%
029HO14142	**DORCY**	DOB: 09/17/2007	NM$ +437	gEFI 7.1%
			NM$ +786	gEFI +2.6%

With Genomics Six generations in 12 years

- 029HO14142 DORCY DOB: 09/17/2007 NM$ +437 gEFI 7.1%
- 007HO11314 MOGUL DOB: 06/22/2010 NM$ +624 gEFI 8.1%
- 151HO00681 RUBICON DOB: 12/20/2012 NM$ +953 gEFI 8.2%
- 551HO03418 DYNASTY DOB: 09/10/2015 NM$ +980 gEFI 8.1%
- 551HO03600 NASHVILLE DOB: 07/04/2017 NM$ +1056 gEFI 8.6%
- HOUSA00023ETZ0353 DUE: 05/04/2019 NM$ +1094 gEFI 9.0%
- NM$ +657 gEFI +1.9%

Last three generations in 34 months

- **ART will further reduce the generation interval**

Additive Genetics – Inbreeding Depression = Economic Gain

U.S. PTAs are Adjusted for Inbreeding

Trait	Inbreeding depression/1%	Trait value in NM$	$ Value /1% F
Milk	–63.9	–0.004	-0.3
Fat	–2.37	3.56	–8.4
Protein	–1.89	3.81	–7.2
Productive life	–0.26	21	–5.5
Somatic cell score	0.004	–117	–0.5
Daughter pregnancy rate	–0.13	11	–1.4
Cow conception rate	–0.16	2.2	–0.4
Heifer conception rate	–0.08	2.2	–0.2
Cow livability	–0.08	12	–1.0
Net merit $	–25	1	–25

Source Paul Van Raden, CDCB Presentation October 2017 USDA-AGIL

An Example With Four Bulls

Unadjusted NM$	Percentage EFI	Adjusted NM$
1000 NM$	7%	825 NM$
1000 NM$	8%	800 NM$
1000 NM$	9%	775 NM$
1000 NM$	10%	750NM$

UK estimates of inbreeding depression

- Inbreeding depression per % inbreeding
- Starting from 5% inbreeding upwards
- Expressed as PTA
- Similar to estimates from other countries
- £PLI impact per % inbreeding
- Approx. -10 £PLI

	1%
Milk kg	-8
Fat kg	-0.3
Protein kg	-0.3
SCC	0.1
Calving Interval	0.1
NR56	-0.04
Fertility Index	-0.2
Life Span	-0.01
Calf Survival	-0.2

AHDB 2019

Genetics Selection Evolution 2014, 46:71

Identification of genomic regions associated with Inbreeding Depression in Holstein and Jersey Dairy Cattle

Jennie E. Pryce, Mekonnen Haile-Maram, Michael E Goddard, Ben J Hays

Terms you will begin to hear a lot

Runs of Homozygosity

Genomic Inbreeding Matrix

Percent of Homozygosity

Additive Genetics – Inbreeding Depression = Economic Gain

CHROMOSOMAL™
MATING

Creating the Most Profitable Herd

Mating Program Goals

What is the goal of a breeding a program?

Do develop a more profitable dairy farm

What improves profitability?

Increased production

Improved health traits

Longer Productive Life

Improved Fertility

How to achieve

Most important part of any mating program:

CHROMOSOMAL™ MATING

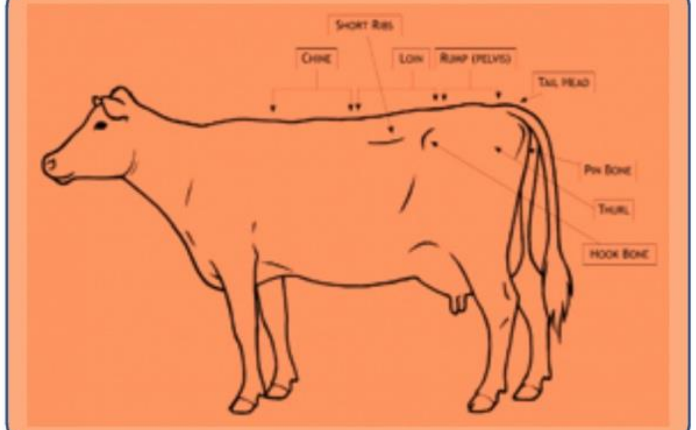
A well established science in a modern, efficient, flexible new suite!

The first mating programs were very basic:

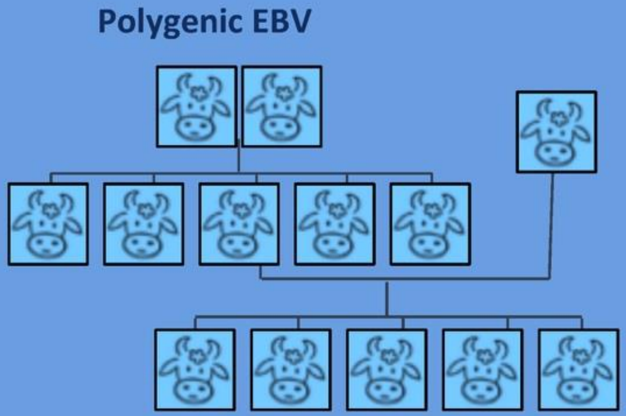
1. Focused on breeding wide bulls to thin cows and average strength bulls to average strength cows
2. The next generation of mating programs included more traits
3. Shallow uddered bulls were bred to deep udder cows
4. Straight leg bulls bred to cows with too much set
5. The problem with corrective mating programs was they did not consider genetics of the cow
6. Phenotype does NOT equal genotype
7. Pedigree matings became popular as they accounted better for genetics
8. This does not mean that animal evaluations are not needed
9. Cows must be scored to provide information for the genetic evaluations
10. Today genomic mating programs are rapidly growing in popularity as they provide the most accurate information

CHROMOSOMAL MATING

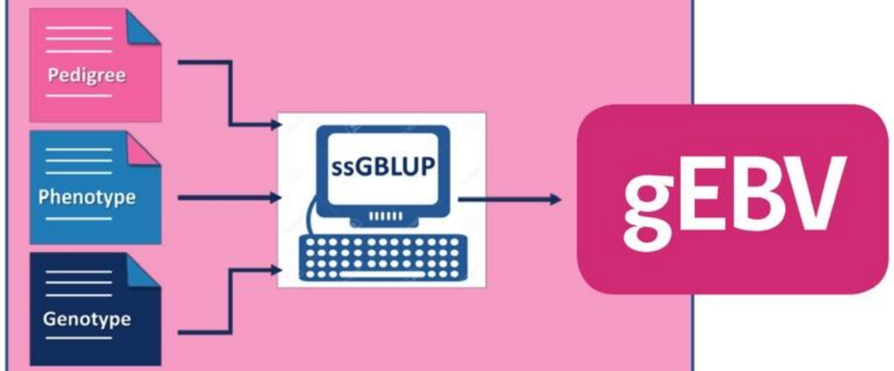
Phenotypic-based
(Linear Scoring)



Pedigree-based
(Parents' Averages)



Genomics-based



- One size doesn't fit all .
- A multi-functional program to meet the needs of markets in different countries and regions.
- Maximize herd GEBV.

- Optimize Whole Herd Profitability.
- Manage recessive disorders in a herd.
- Maximize the frequencies of beneficial haplotypes or genomic regions.

Accounts for the economic impact of inbreeding

SELECT THE CORRECT BULL TEAM

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Mating programs including genomic relationships and dominance effects

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Chromosomal Mating Provides the Predicted Producing Value of the Offspring or PPV

For most traits PPV is what is used for the first step in CMP

The equation is:

CowPTA + BullPTA +B*(cowEFI + bullEFI)-B*inbreeding of calf = PPV

Where B = inbreeding depression of selected Trait

Cow NM$ = 643 EFI 8.2

Bull NM$ = 818 EFI 7.8

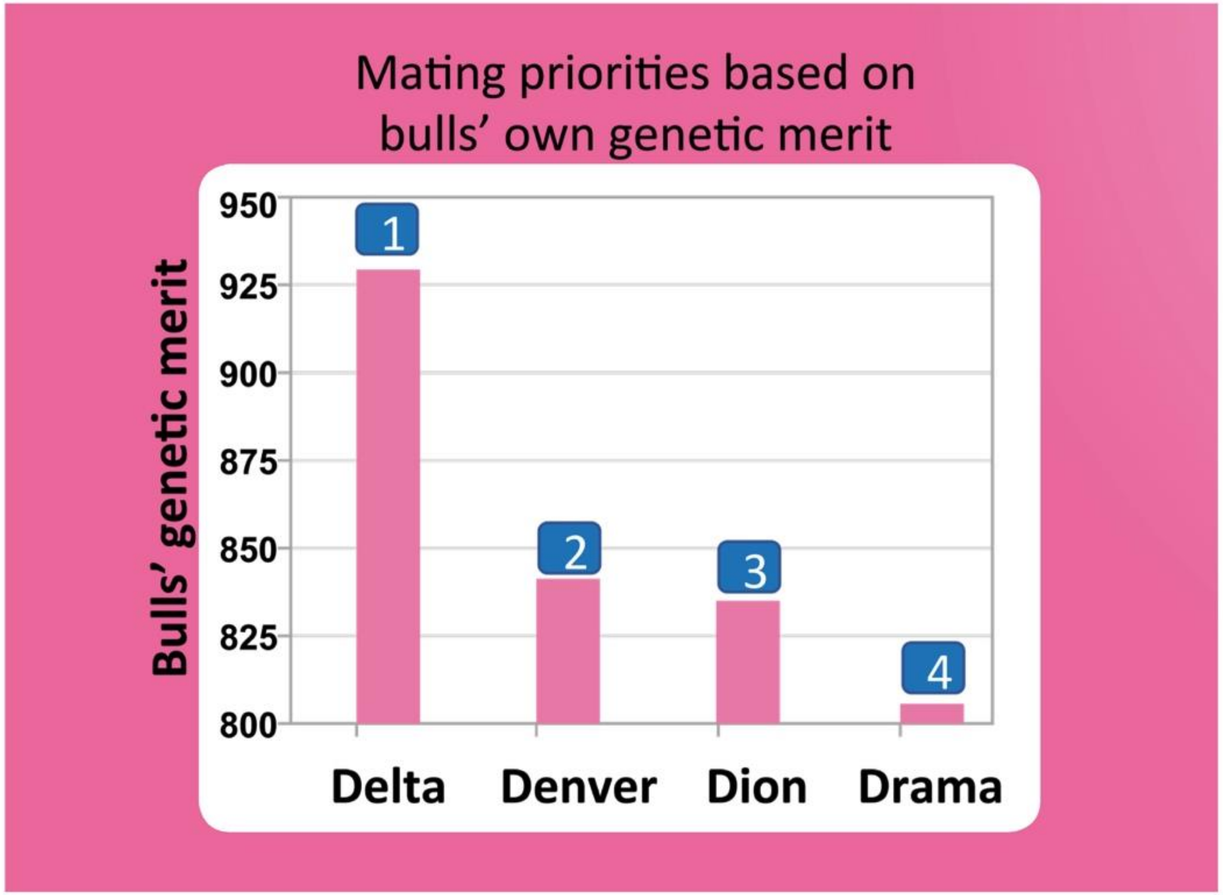
B = Net Merit 1% = $25

(643+818) +25(8.2 +7.8) -200 = 1661 NM$ PPV

Additive Genetics – Inbreeding Depression = Economic Gain

Comparing Mating One Cow with Four Full Brothers

CHROMOSOMAL MATING

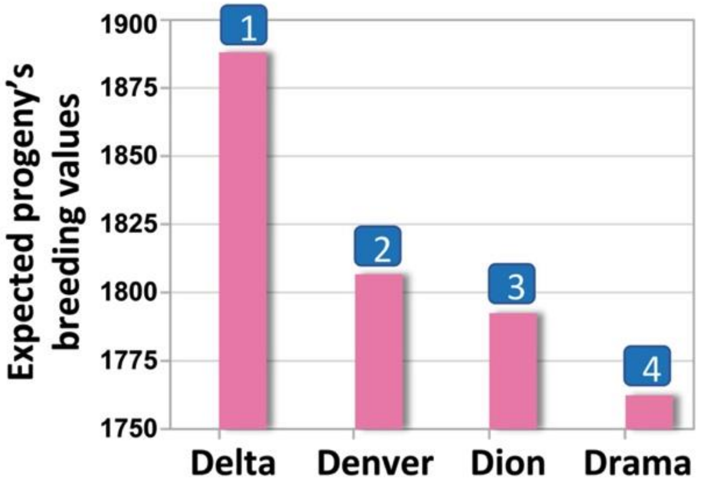


Comparing Mating One Cow with Four Full Brothers

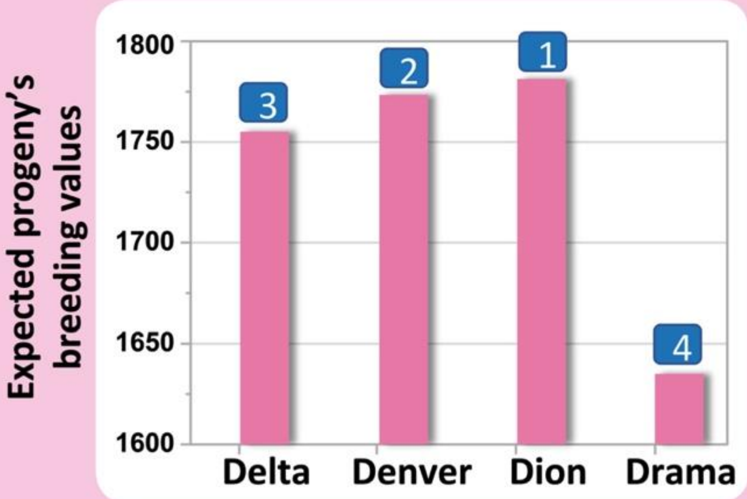
CHROMOSOMAL MATING

523HO1468 Delta	551HO00690 Denver	551HO00695 Drama	523HO01470 Dion
Own +928NM$	**Own +840NM$**	**Own +804NM$**	**Own +834NM$**
Progeny's performance	Progeny's performance	Progeny's performance	Progeny's performance
Pedigree +1,888NM$ IB **12.68%**	Pedigree +1,806NM$ IB **12.68%**	Pedigree +1,762NM$ IB **12.68%**	Pedigree +1,792NM$ IB **12.68%**
Genomic +1,755NM$ IB **18%**	Genomic +1,773NM$ IB **14%**	Genomic +1,634NM$ IB **17.5%**	Genomic +1,781 NM$ IB **13.1%**

Mating priorities using PEDIGREE BASED matings



Mating priorities using GENOMIC BASED matings



Genomic mating programs

- Reduce inbreeding using genomic instead of pedigree relationships
  - Genomic relationship of each live female to each marketed bull
  - File contains 1 million females × 5,000 males
- Genomic mating increases heifer calf value by
  - +$84 compared with pedigree mating (1.3% lower inbreeding)
  - +$214 compared with random mating (2.9% lower inbreeding)
- Also improves conception rates by avoiding recessive carrier matings
- Also reduces inbreeding of bull calves, promoting faster growth

What can genomics do on commercial farms?

- Traditionally, commercial farms create very little genetic progress on the female side
- This is due to selection restriction imposed by replacement rates
- Most genetic progress comes in through the male side (AI sires)
- So we have very small selection intensities and very low accuracies of selection

Example of introducing genomic selection bundled with sexed semen

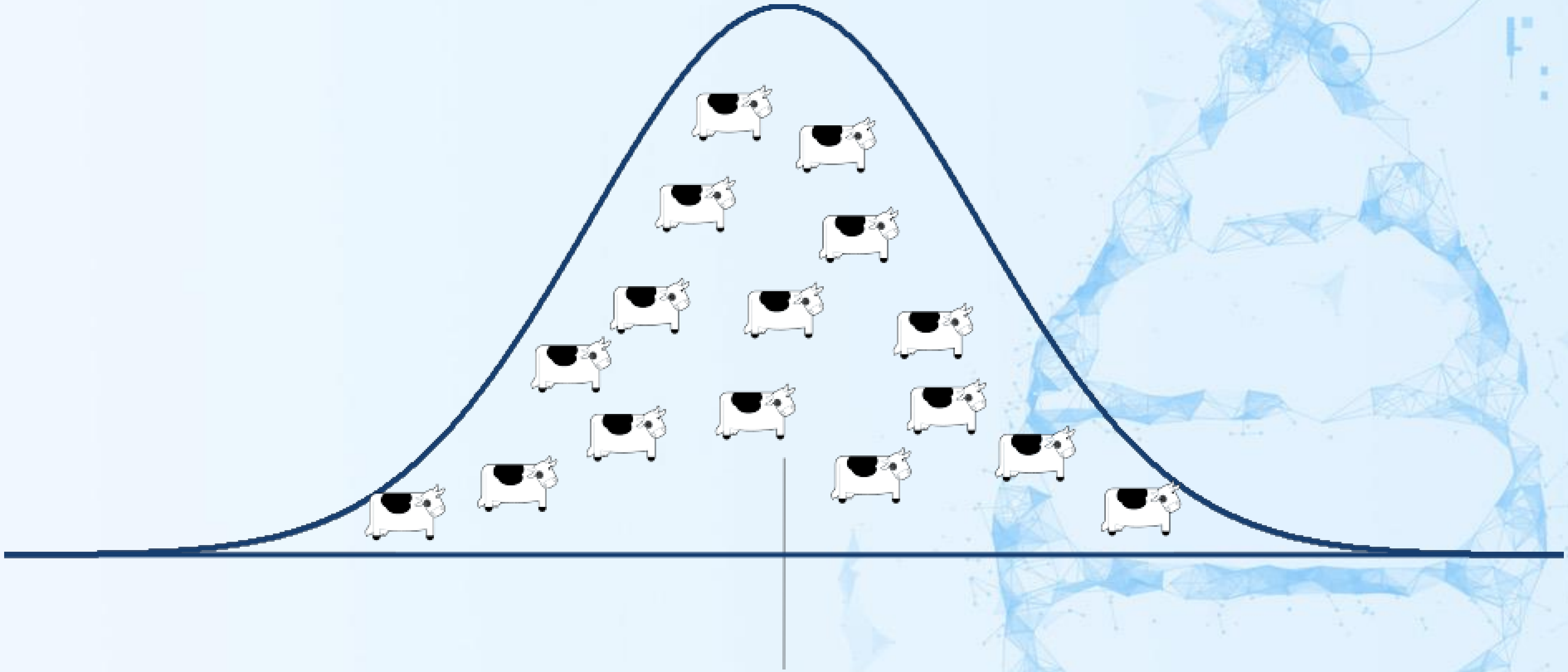
„Breeders Equation“

$$\Delta G = \frac{i * r * \sigma}{GI}$$

- **ΔG** = Genetic progress per year
- **i** = selection intensity
- **r** = accuracy of selection
- **σ** = additiv genetic standard deviation
- **GI** = generation interveral

- Sexed semen leverages selection intensity (i)
- Genomic prediction increases accuracy of selection (r)

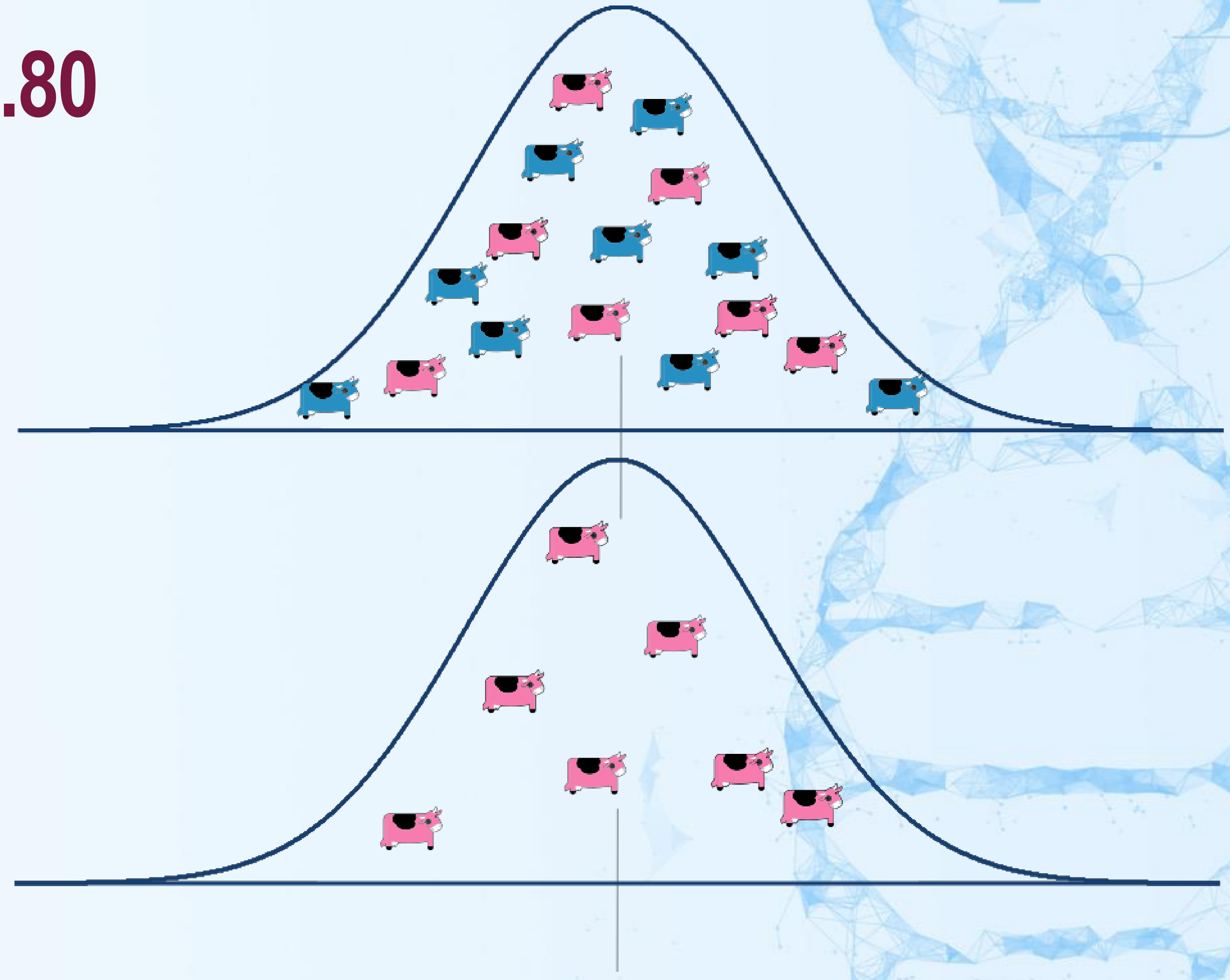
The cow population on a dairy farm



Example

Traditional	
σ	NM$197
i	0.35
r	0.40
GI	3.5
ΔG	NM$7.88

ΔG ≈ $7.80



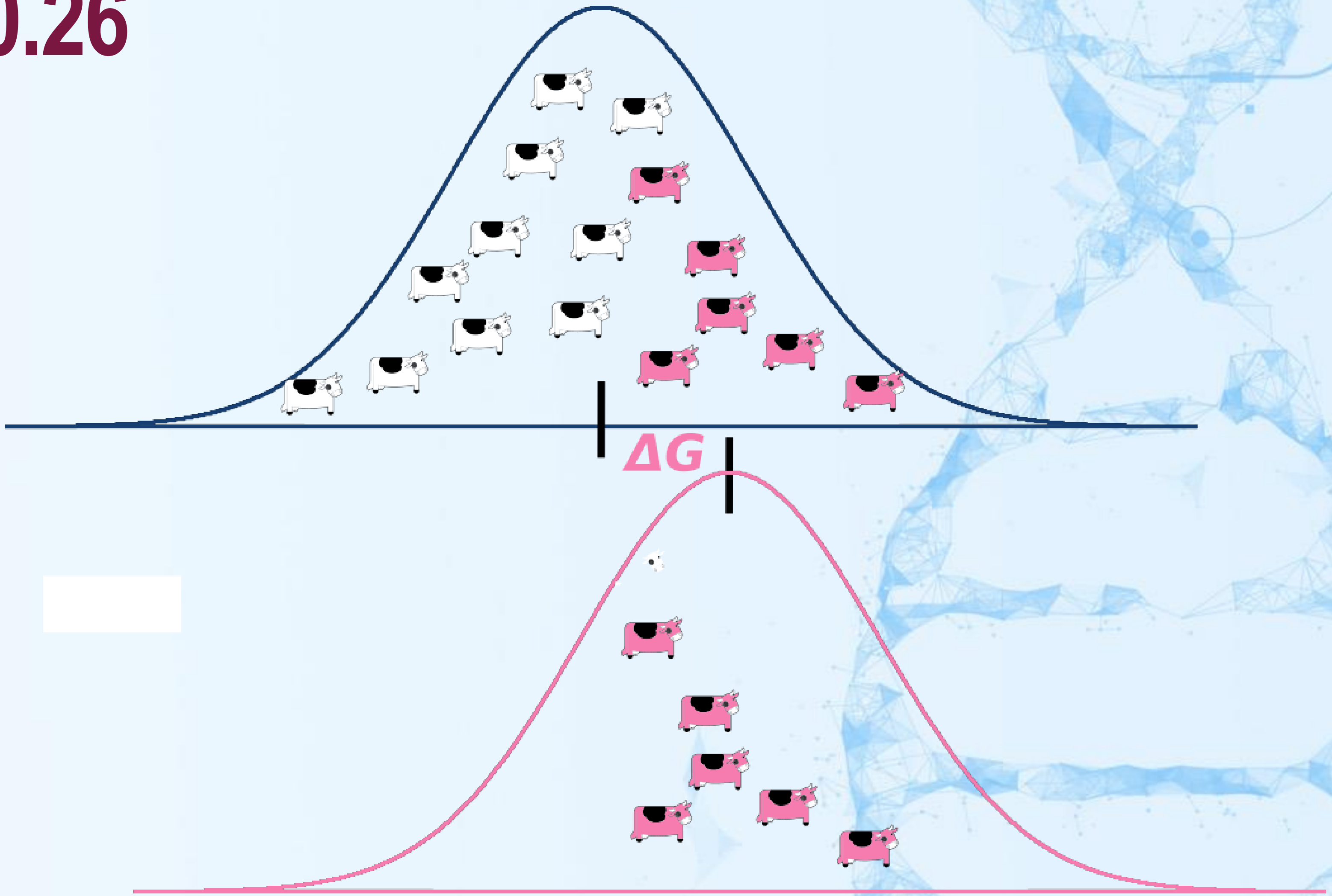
Example

1) Sexed semen – Select from more females and shorter generation interval.

Traditional	
σ	NM$197
i	0.35
r	0.40
GI	3.5
ΔG	NM$7.88

Sexed Semen	
σ	NM$197
i	0.96
r	0.40
GI	2.5
ΔG	NM$30.26

ΔG = $30.26



Example

1) Sexed semen – Select from more females and shorter generation interval.

2) Genomics – Select more accurately

Traditional	
σ	NM$197
i	0.35
r	0.40
GI	3.5
ΔG	NM$7.88

Sexed Semen	
σ	NM$197
i	0.96
r	0.40
GI	2.5
ΔG	NM$30.26

Sexed Semen + Genomics	
σ	NM$197
i	0.96
r	0.70
GI	2.5
ΔG	NM$52.95

The best way to predict the future is to *Create it*

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