Genomic Selection in Dairy Cattle

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Current status

Challenges

Opportunities

Larry Schaeffer. 2006, J. Anim. Breed. Genet.

Table 1 Schedule of progeny testing activities

Time (months)	Activity
0	Elite dams chosen and bred.
9	Bull calves born from elite dams
21	Test matings of young bulls made
30	Daughters of young bulls born
45	Daughters of young bulls bred
54	Daughters calve and begin first lactation
57	First estimated breeding values for young bulls from test day model
64	Daughters complete first lactations, keep or cull young bulls

Table 2 Four pathways of selection, progeny testing

$\Delta G = 4.68 / 21.75 = 0.22\ \sigma_g/yr$

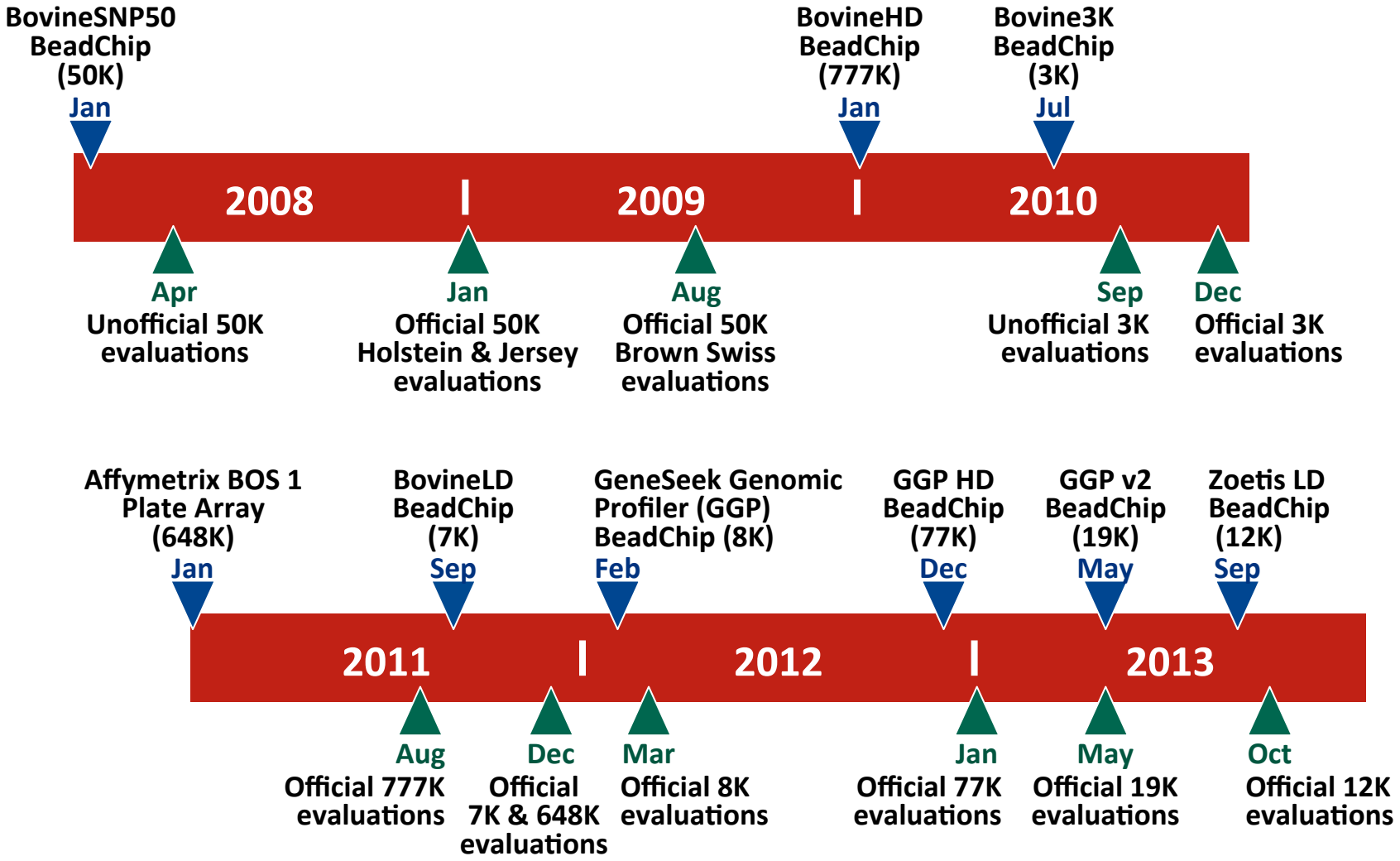
		Accuracy		Generation	
Pathway	Selection %	i	r_{TI}	Interval, L	$i \times r_{TI}$
Sire of bulls	5	2.06	0.99	6.5	2.04
Sire of cows	20	1.40	0.75	6	1.05
Dams of bulls	2	2.42	0.60	5	1.45
Dams of cows	85	0.27	0.50	4.25	0.14
Total				21.75	4.68

Table 3 Four pathways of selection, genome-wide strategy

$\Delta G = 4.55 / 9.75 = 0.47\ \sigma_g/yr$

		Accuracy		Generation	
Pathway	Selection %	i	r_{TI}	Interval, L	$i \times r_{TI}$
Sire of bulls	5	2.06	0.75	1.75	1.54
Sire of cows	20	1.40	0.75	1.75	1.05
Dams of bulls	2	2.42	0.75	2	1.82
Dams of cows	85	0.27	0.50	4.25	0.14
Total				9.75	4.55

Progression of chips and genomic evaluations



Why genomics works for dairy cattle

- Extensive historical data available
- Well-developed genetic evaluation program
- Widespread use of AI sires
- Progeny-test programs
- High-value animals worth the cost of genotyping
- Long generation interval that can be reduced substantially by genomics

How is Genomic Selection changing dairy breeding?

X

Embryo Transfer

Superior progeny-tested bull

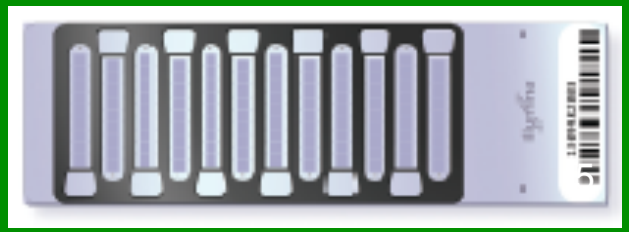
5 yrs & $$$$$$ later

Pro-geny Testing

DNA sam-ples

Superior genome-tested young bull

< 6 mo & $$ later



Illumina Bovine 50k Beadchip

Holstein prediction accuracy

Trait	Bias*	Reliability (%)	Reliability gain (% points)
Milk (kg)	–80.3	69.2	30.3
Fat (kg)	–1.4	68.4	29.5
Protein (kg)	–0.9	60.9	22.6
Fat (%)	0.0	93.7	54.8
Protein (%)	0.0	86.3	48.0
Productive life (mo)	–0.7	73.7	41.6
Somatic cell score	0.0	64.9	29.3
Daughter pregnancy rate (%)	0.2	53.5	20.9
Sire calving ease	0.6	45.8	19.6
Daughter calving ease	–1.8	44.2	22.4
Sire stillbirth rate	0.2	28.2	5.9
Daughter stillbirth rate	0.1	37.6	17.9

*2013 deregressed value – 2009 genomic evaluation

Holstein prediction accuracy

Trait	Bias*	Reliability (%)	Reliability gain (% points)
Final score	0.1	58.8	22.7
Stature	–0.2	68.5	30.6
Dairy form	–0.2	71.8	34.5
Rump angle	0.0	70.2	34.7
Rump width	–0.2	65.0	28.1
Feed and legs	0.2	44.0	12.8
Fore udder attachment	–0.2	70.4	33.1
Rear udder height	–0.1	59.4	22.2
Udder depth	–0.3	75.3	37.7
Udder cleft	–0.2	62.1	25.1
Front teat placement	–0.2	69.9	32.6
Teat length	–0.1	66.7	29.4

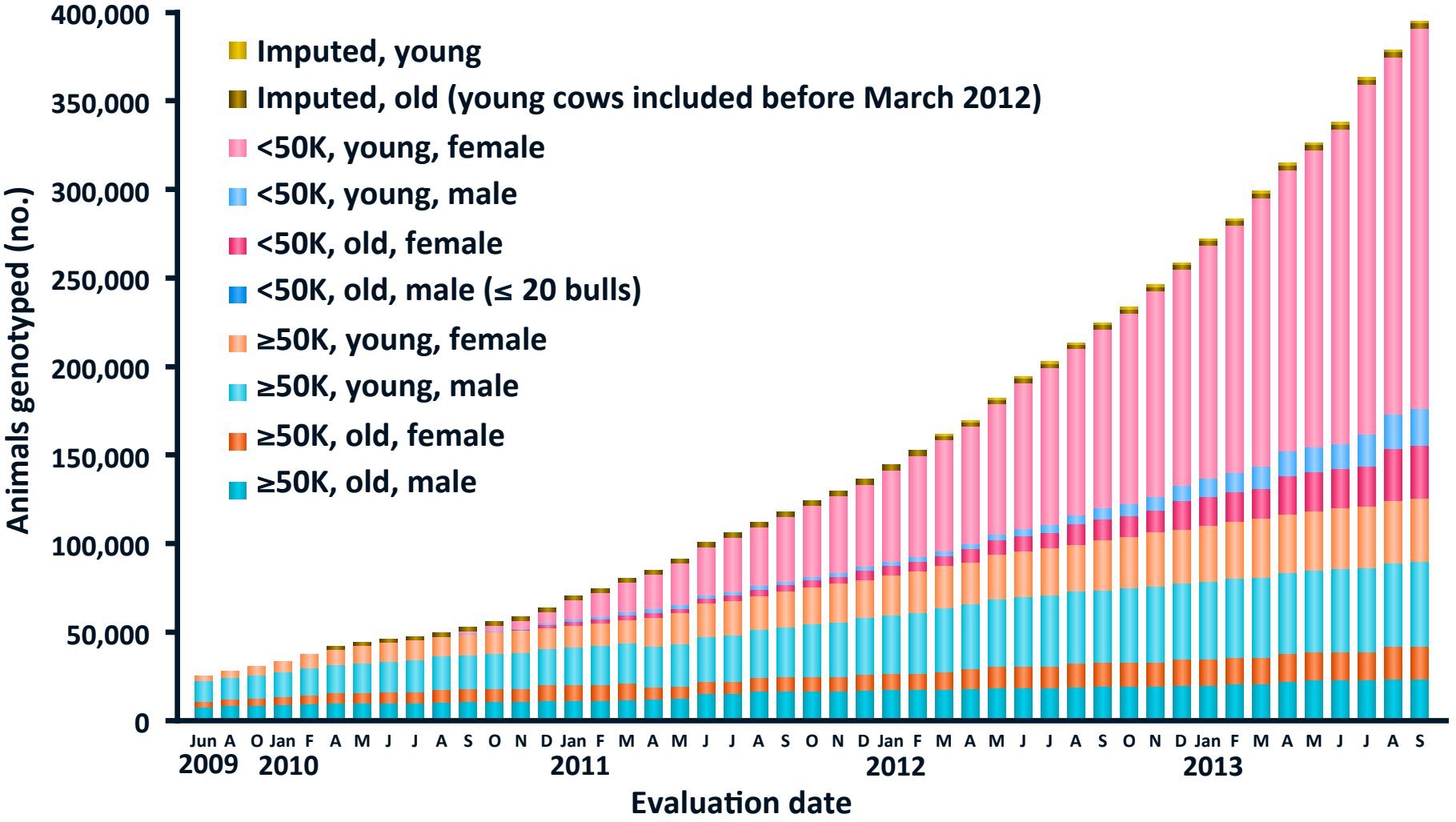
*2013 deregressed value – 2009 genomic evaluation

Reliability gains

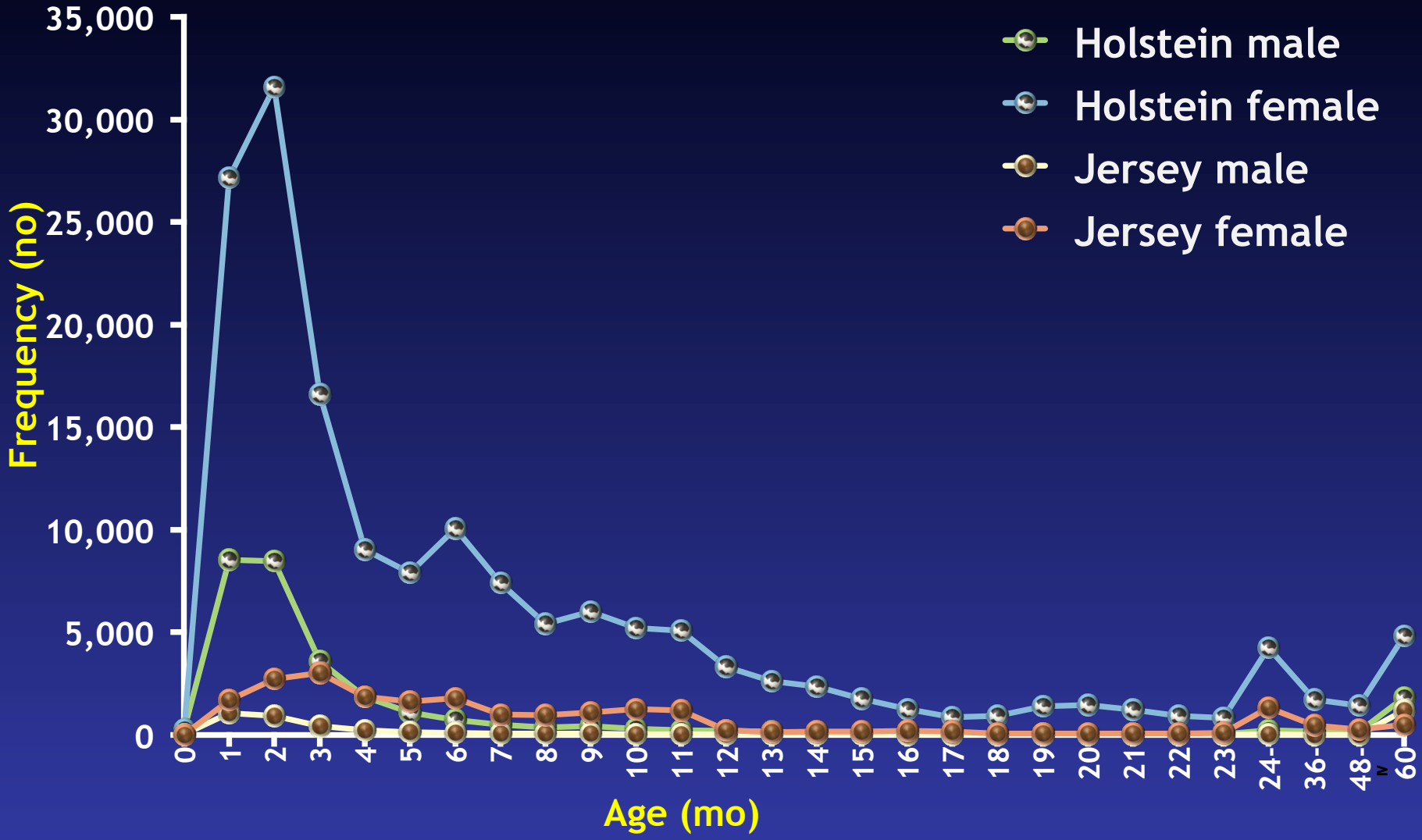
Reliability (%)	Ayrshire	Brown Swiss	Jersey	Holstein
Genomic	37	54	61	70
Parent average	28	30	30	30
Gain	9	24	31	40
Reference bulls	680	5,767	4,207	24,547
Animals genotyped	1,788	9,016	59,923	469,960
Exchange partners	Canada	Canada, Interbull	Canada, Denmark	Canada, Italy, UK

Source: VanRaden, Advancing Dairy Cattle Genetics: Genomics and Beyond presentation, Feb. 2014

Genotypes evaluated



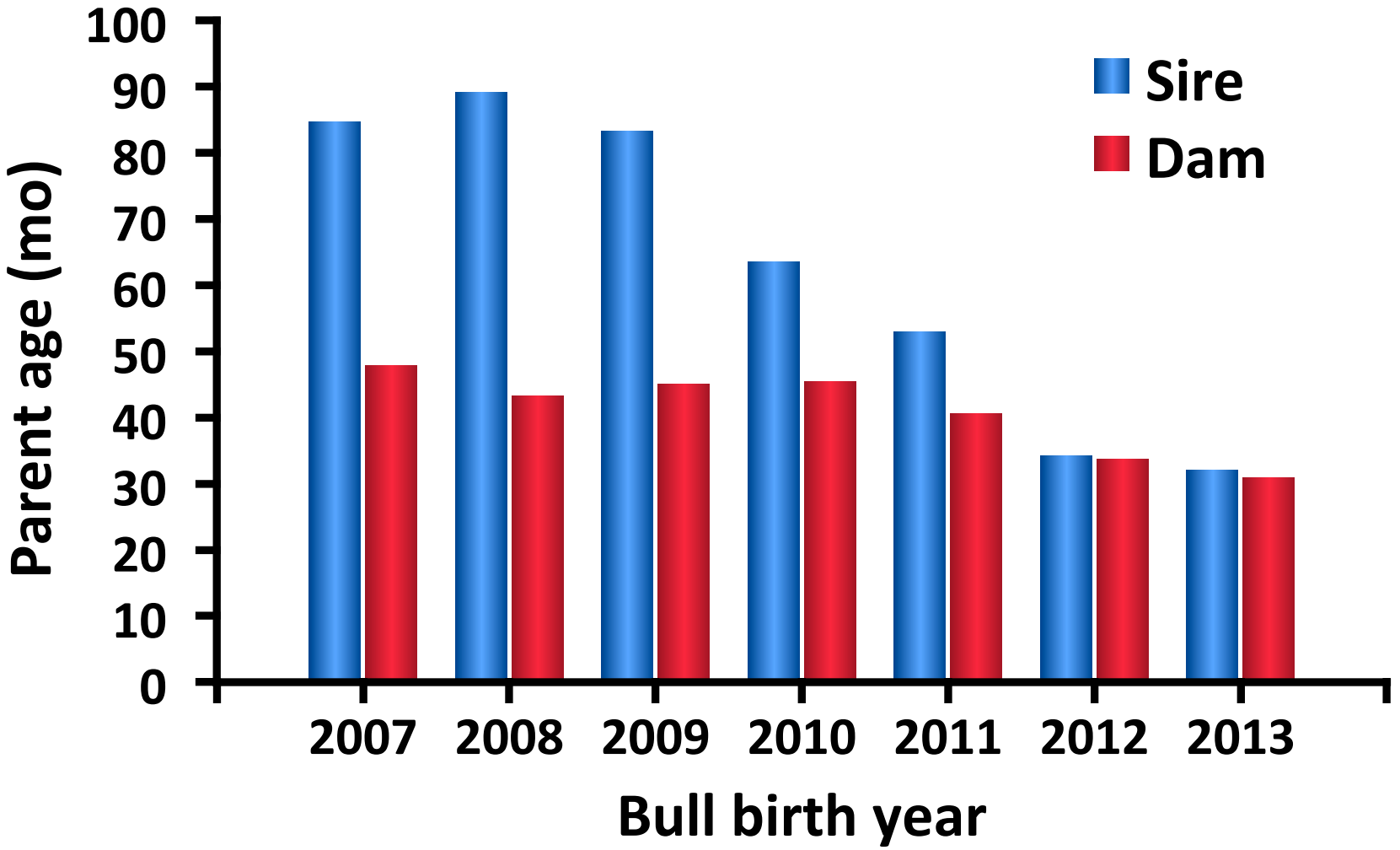
Genotypes by age (last 12 months)



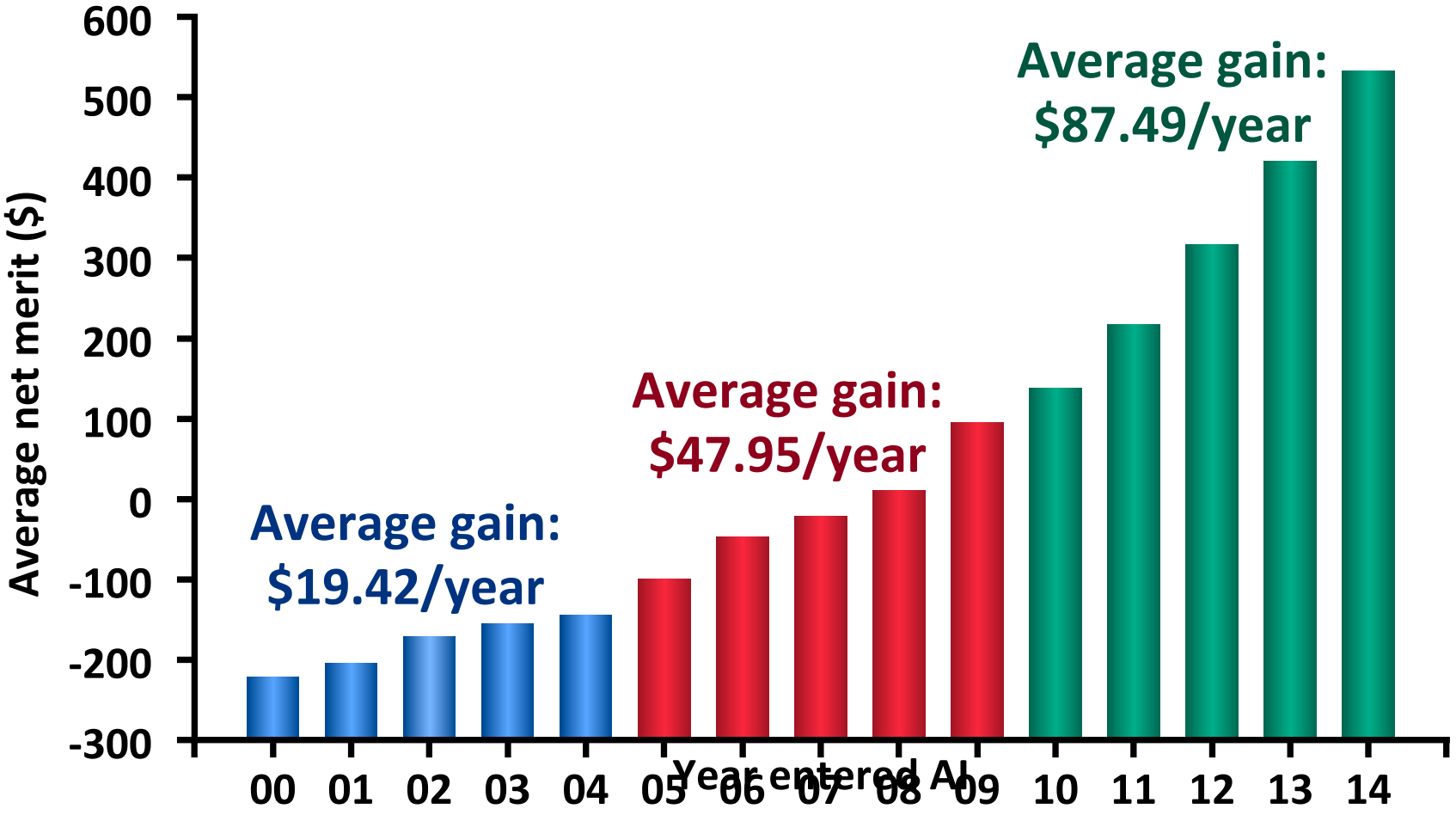
Marketed Holstein bulls

Year entered AI	Traditional progeny-tested	Genomic marketed	All bulls
2008	1,768	170	1,938
2009	1,474	346	1,820
2010	1,388	393	1,781
2011	1,254	648	1,902
2012	1,239	706	1,945
2013	907	747	1,654
2014	661	792	1,453

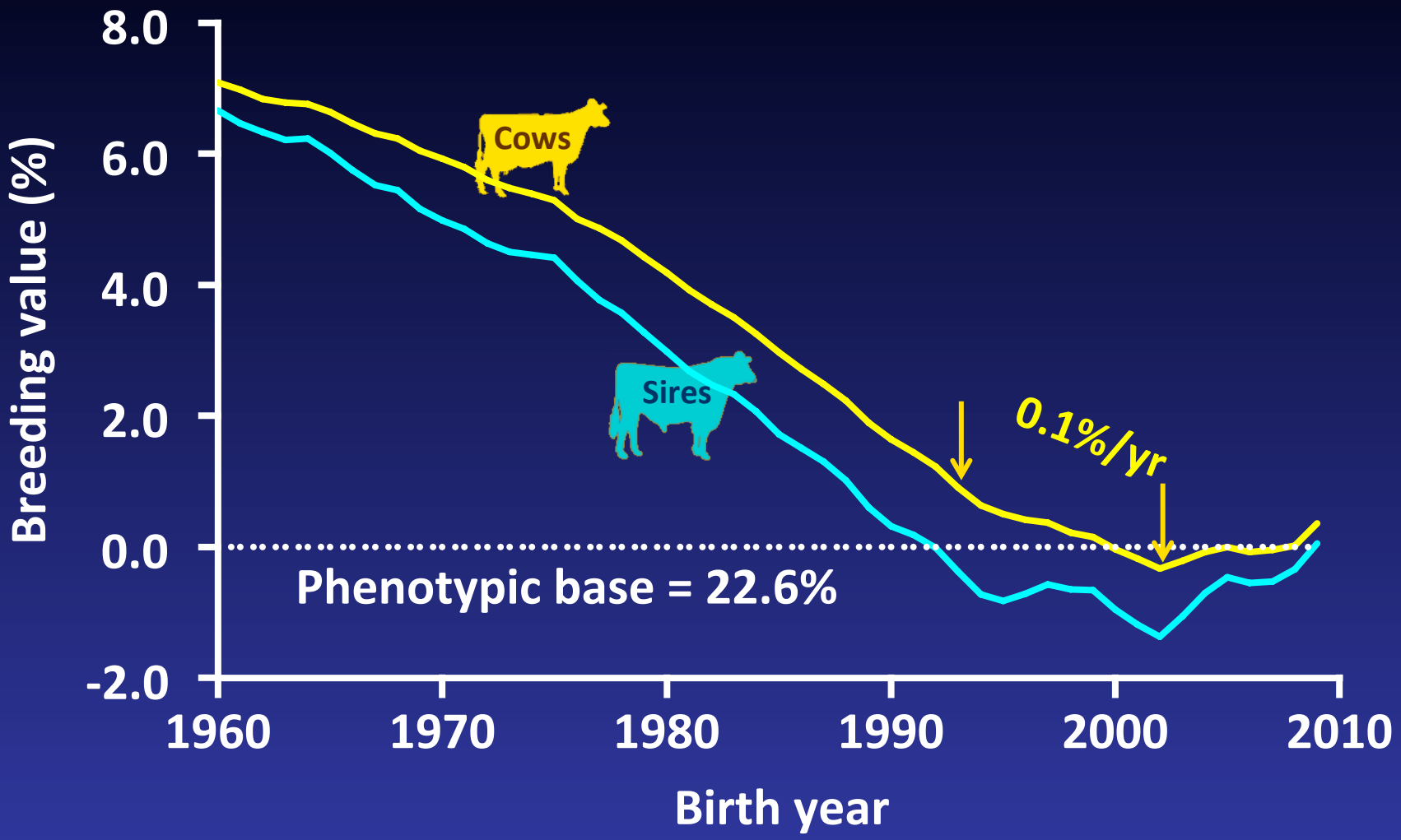
Parent ages for marketed Holstein bulls



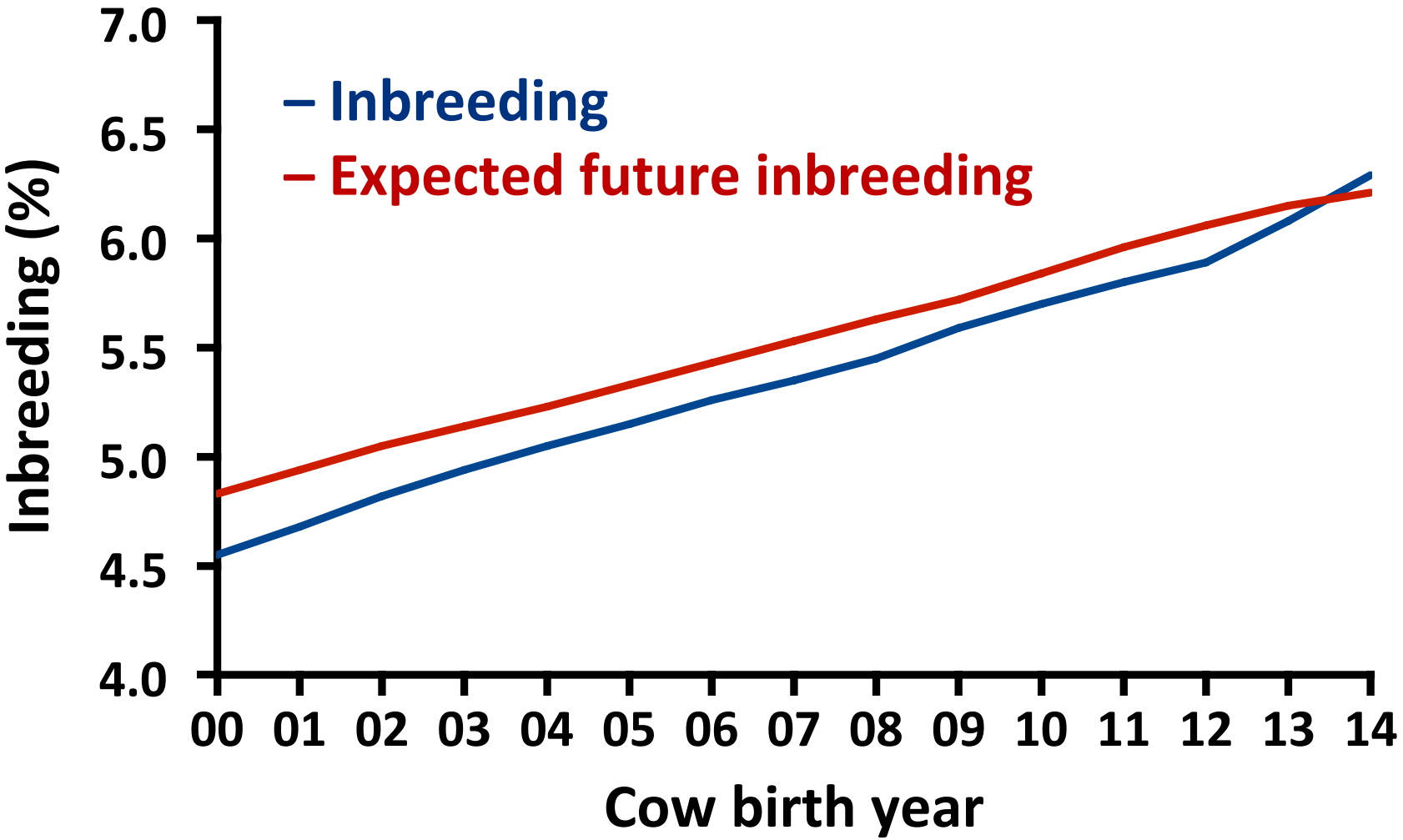
Genetic merit of marketed Holstein bulls



Holstein daughter pregnancy rate (%)



Inbreeding for Holstein cows



How is Genomic Selection changing Dairy Cattle Breeding?

- AI Studs market
  young bulls / bull teams
  selected on Genomic EBV
- These young bulls will be from ET flushes of heifers contract-mated to young bulls
  selected on Genomic EBV
- Need for progeny-testing will decrease?
- Easier for new organization to enter the market?

X

The Future of Dairy Cattle Breeding . . . .

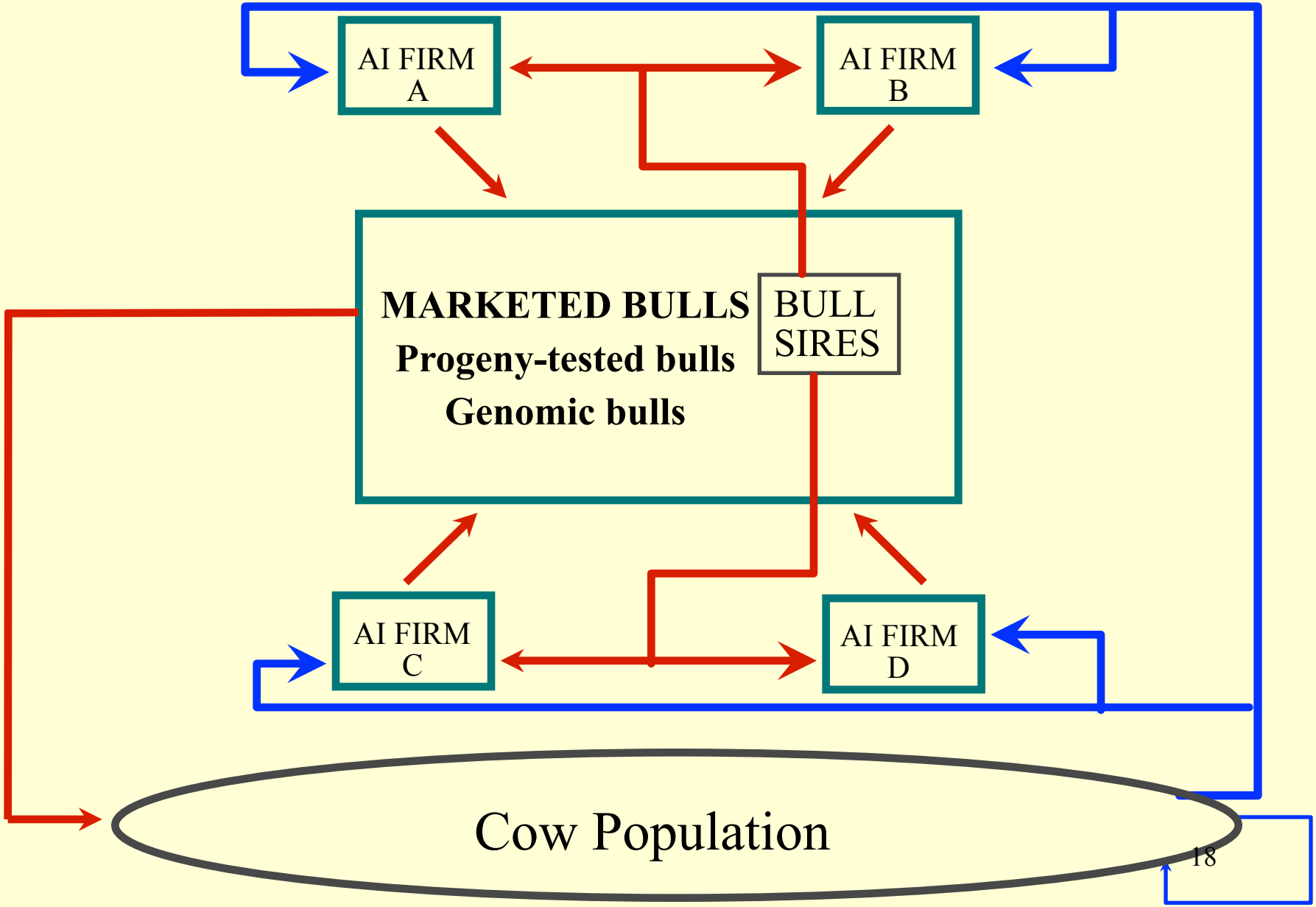
How can AI companies maintain market share?

When Everyone . . . .

- **has access to superior genetics**
- **can identify such genetics using genomics**
- **and market that genetics using genomics**

How to differentiate/protect your product?

A Competitive Global AI Industry



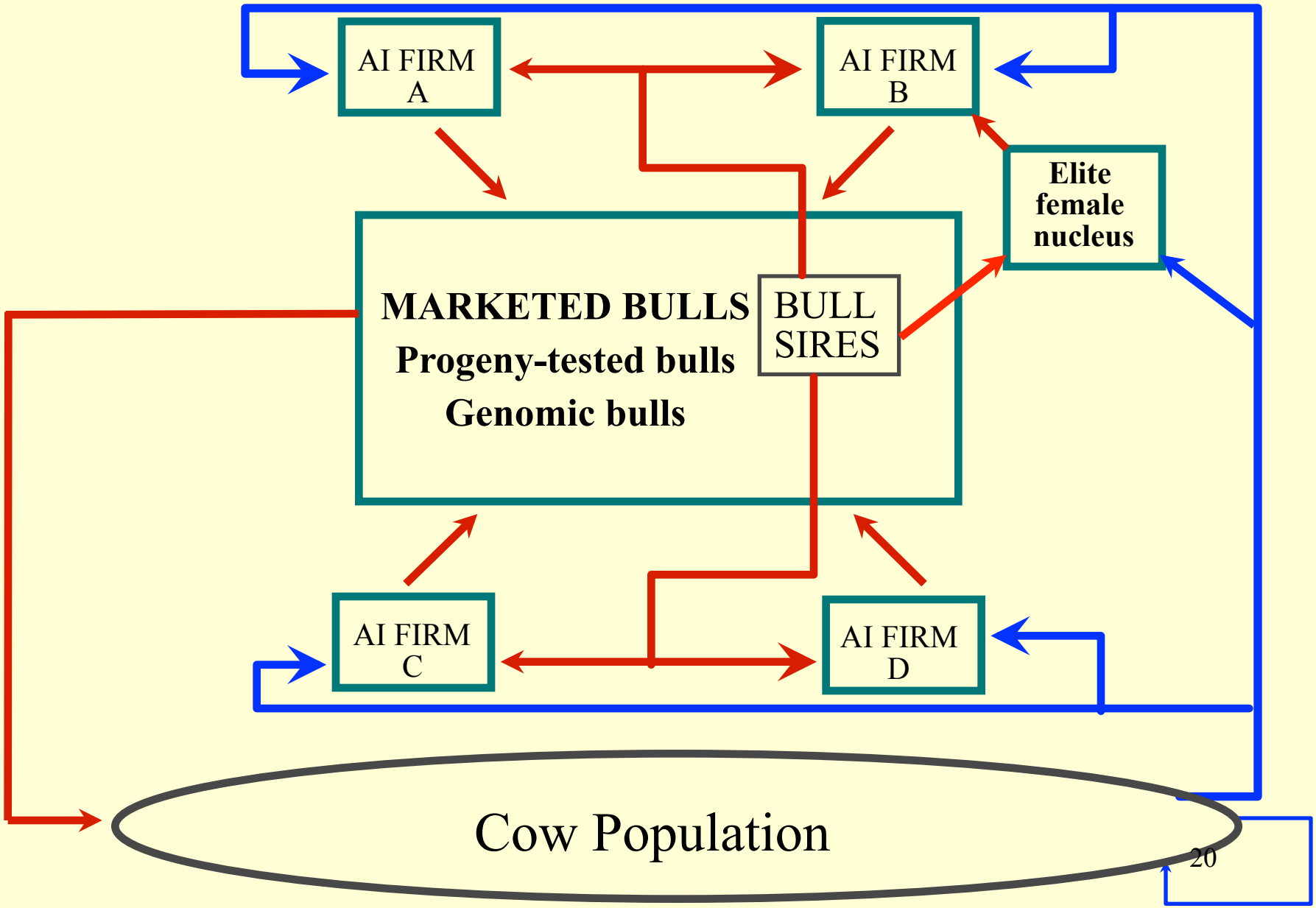
The Future of Dairy Cattle Breeding . . . .

How can AI companies maintain market share?

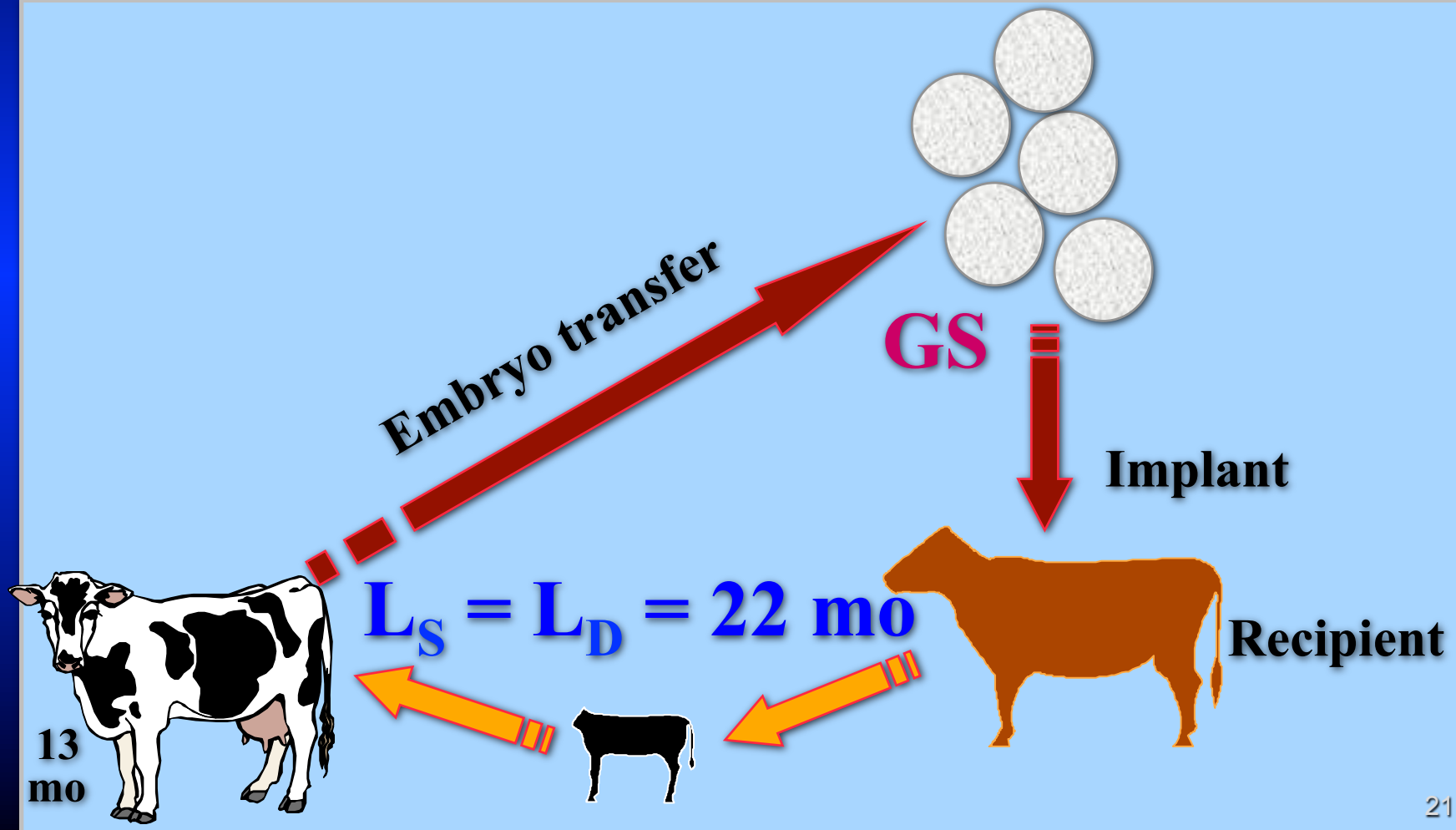
How to differentiate/protect your product?

- **Protect elite germplasm**
  - Elite nucleus herds with integration of genomic and reproductive technologies

Protecting Elite Germplasm



Reducing generation intervals
Integrating Genomics and Reproductive Technologies



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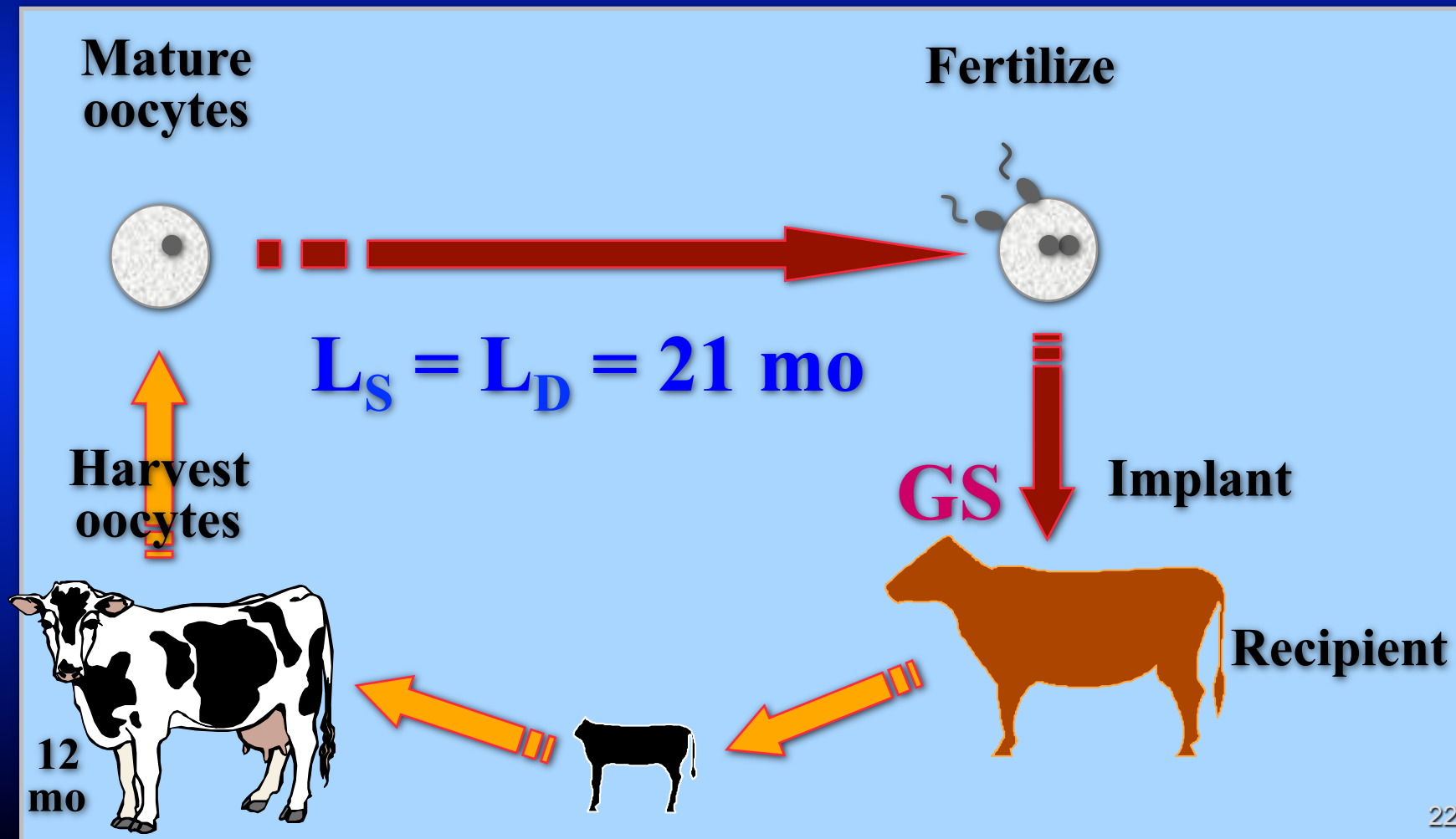
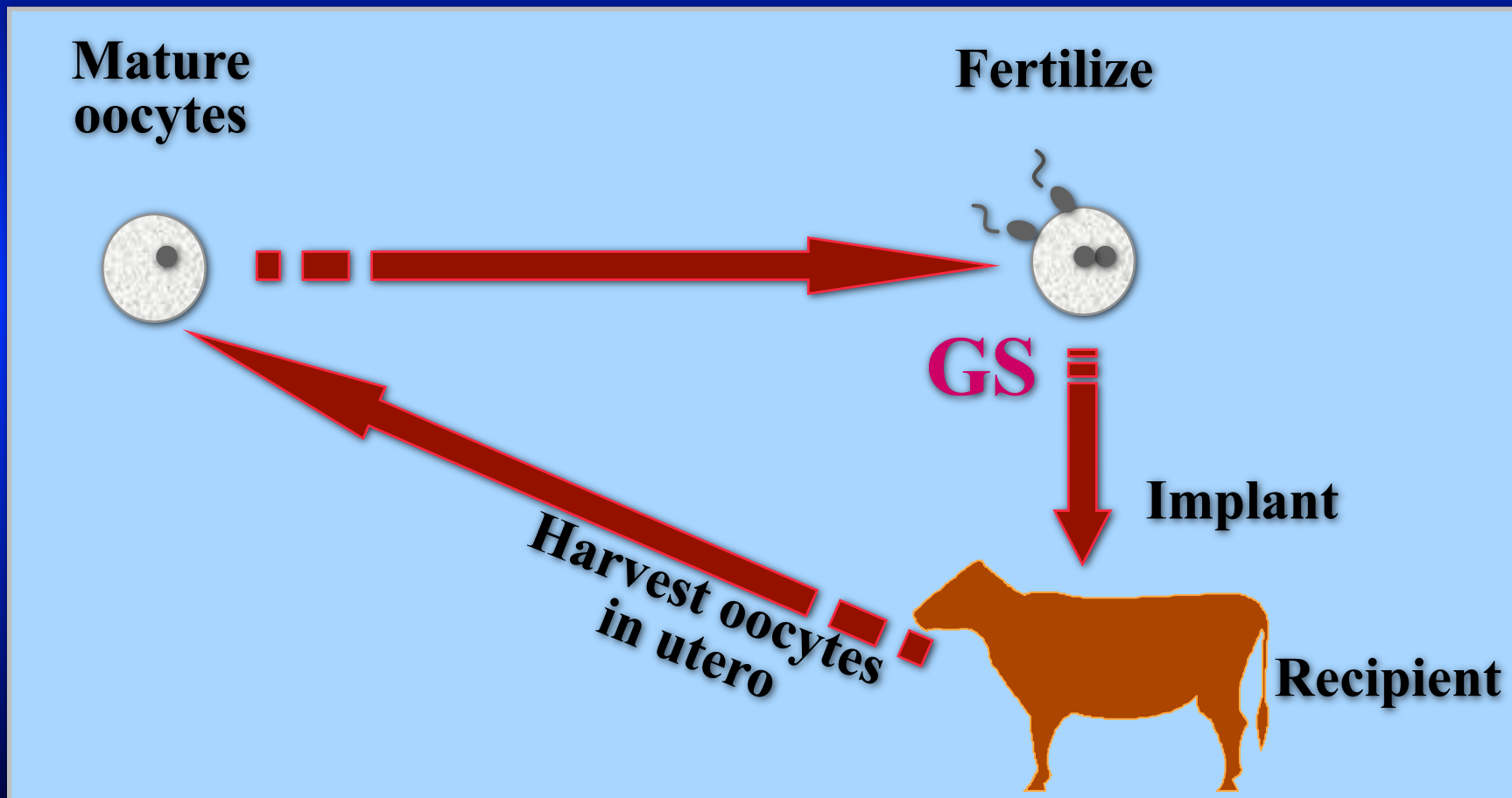


Integrating Reproductive and Molecular Technology

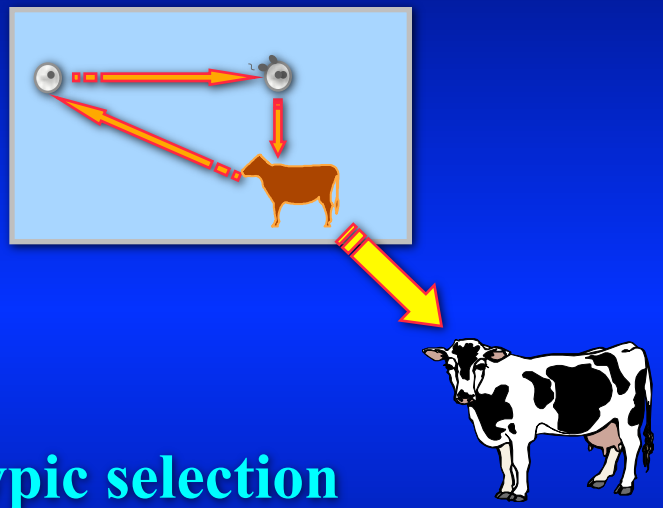


MAS + Reproductive Technology

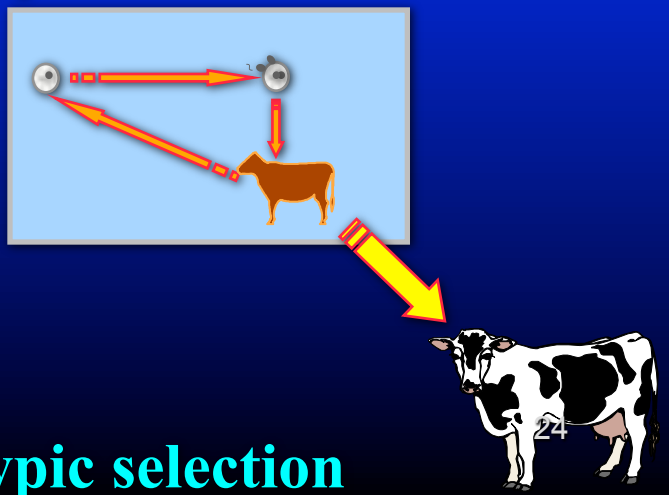
Velogenetics *(Georges,Massey '91)*

Generation

1 genotyping - MAS
2 genotyping - MAS
3 genotyping - MAS

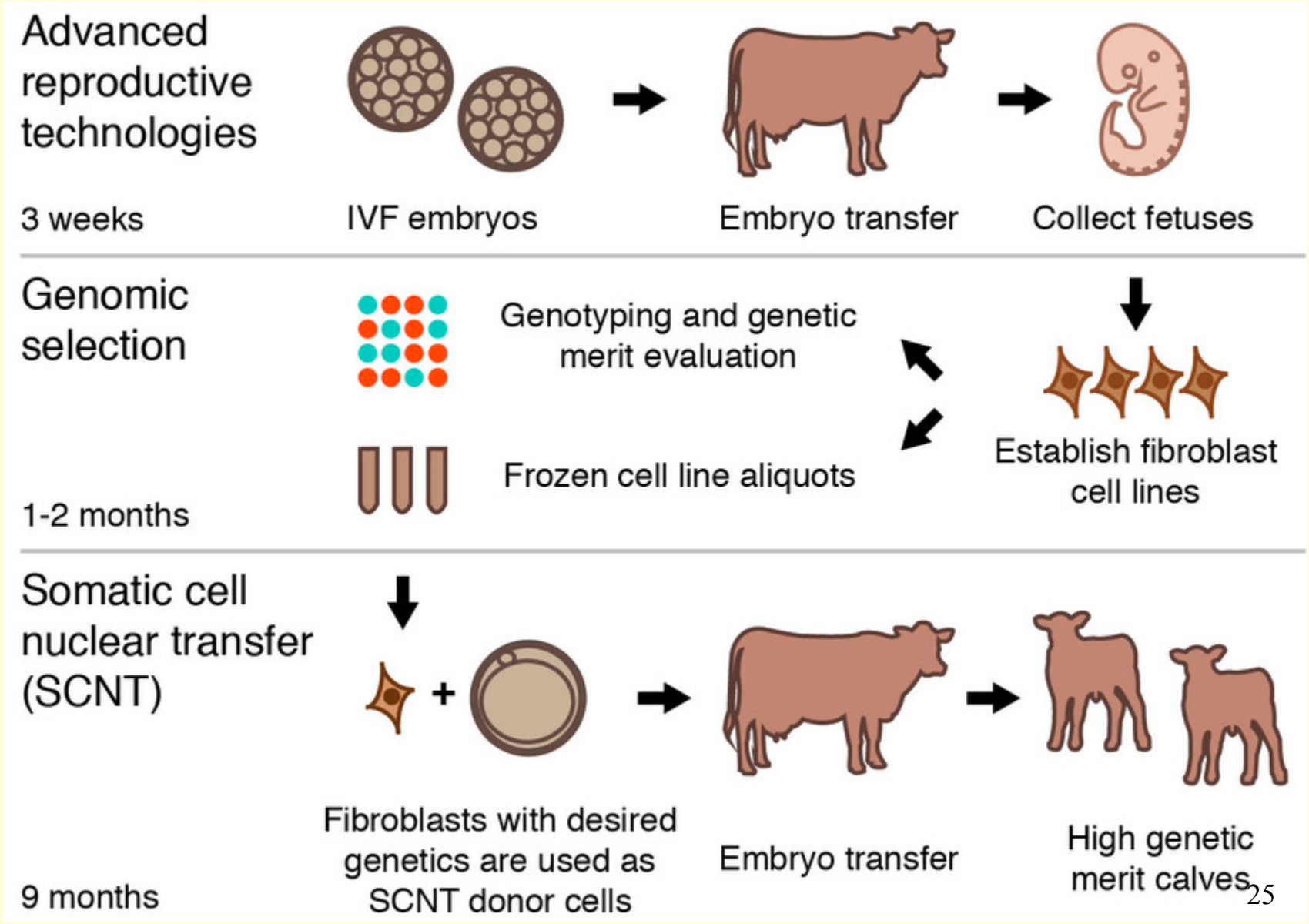


4 phenotyping - phenotypic selection
5 genotyping - MAS
6 genotyping - MAS
7 genotyping - MAS



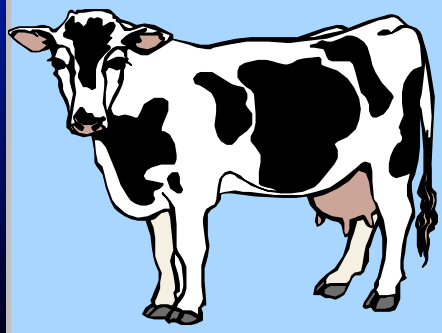
8 phenotyping - phenotypic selection

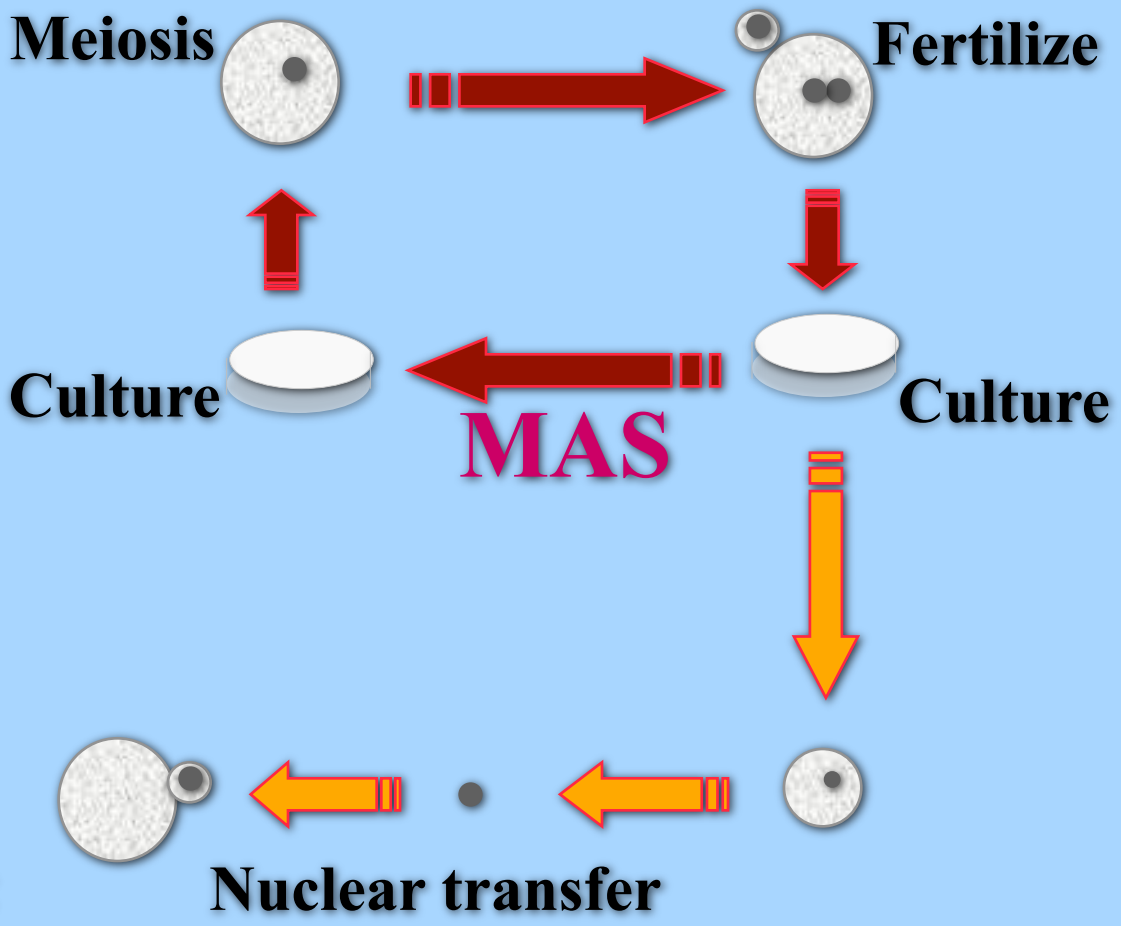
Combining genomic prediction with advanced reproductive technologies



Nuclear Whizzogenetics

(Haley and Visscher, 1998)





MAS + Reproductive Technology

Whizzogenetics

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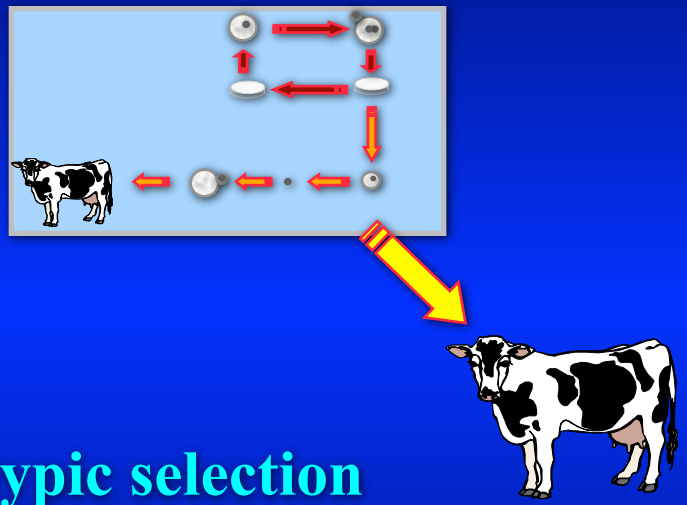

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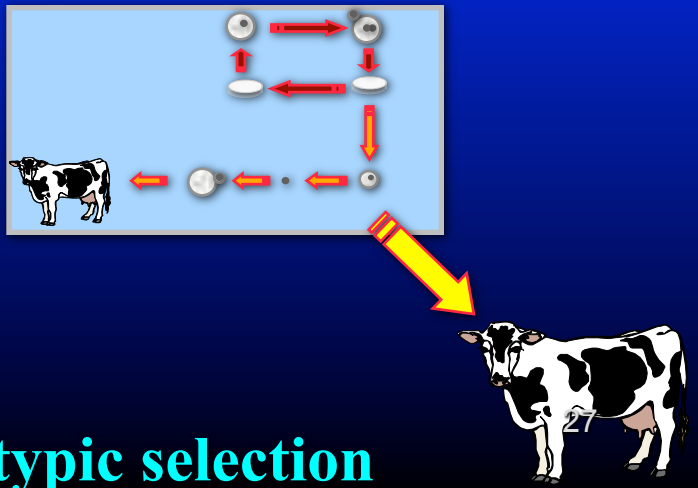


8 phenotyping - phenotypic selection

The Future of Dairy Cattle Breeding . . . .

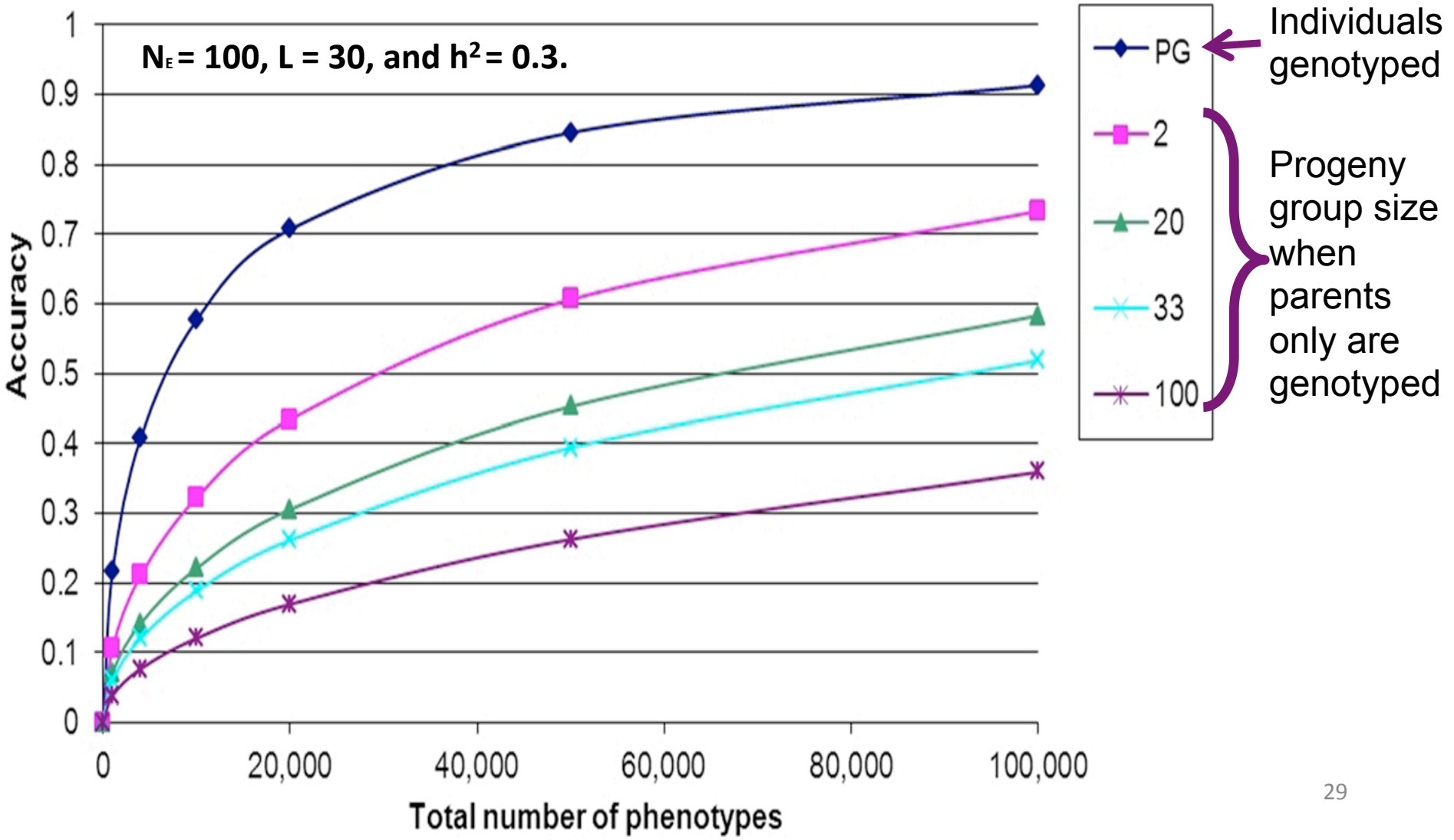
How can AI companies maintain market share?

How to differentiate/protect your product?

- **Protect elite germplasm**
  - Elite nucleus herds with integration of genomic and reproductive technologies
  - Disseminate germplasm as crossbred embryos
- **Provide information on new traits**
  - Feed efficiency
  - Disease resistance
    - Collected in information nucleus herds for genomic prediction

Reference Population for 'New Traits'

If # phenotypes is limited and genotyping is not:
Genotype individuals with phenotype, rather than parents
Grevenhof, Bijma, van Arendonk GSE 2012



Summary/conclusions

- **Genomic selection is revolutionizing dairy breeding**
- **Integration of genomic and reproductive technologies is reducing generation intervals**
- **Keys for the future:**
  - Maintaining and further developing phenotype recording programs
  - Finding ways to protect elite germplasm in order to develop a competitive advantage