Can You Afford to Avoid Crossbreeding?

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Genetic Improvement

- Selection
  - Improve additive genetic value through utilization of EPD
- Mating systems for commercial producers
  - Optimize heterosis
  - Take advantage of breed complementarity

Why Crossbreed?

Heterosis

- Individual heterosis
- Maternal heterosis

Breed Complementarity

- Selection of breeds for core traits that fill the other breed(s) shortcomings

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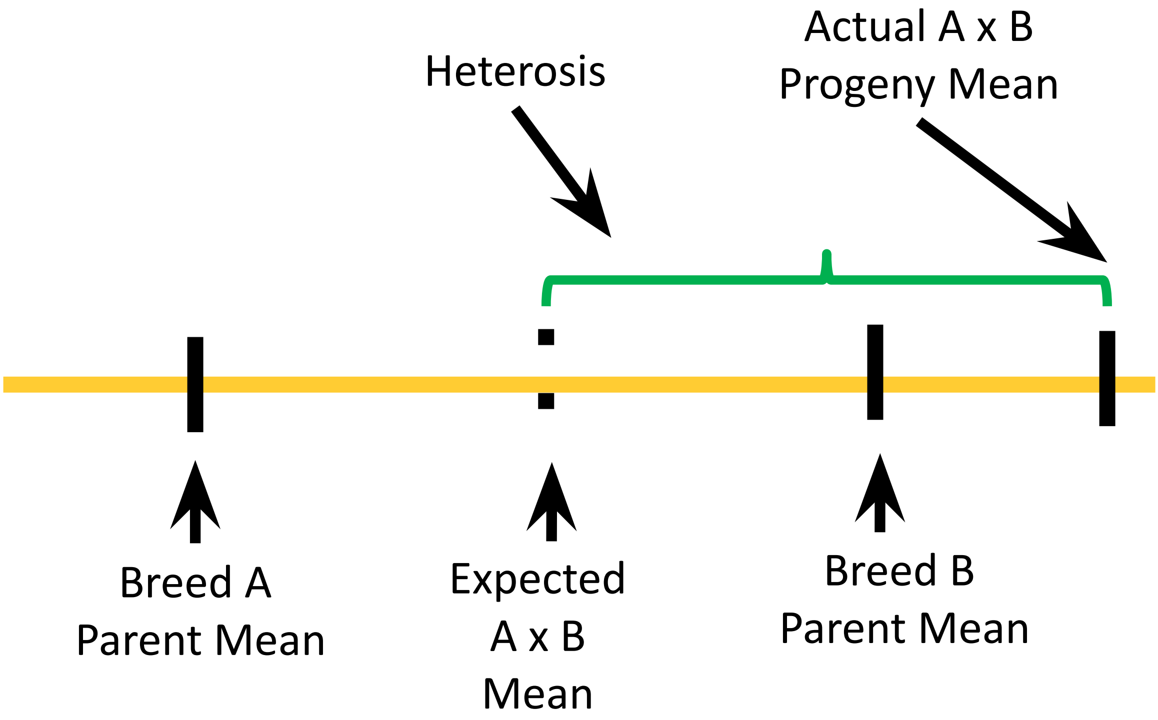
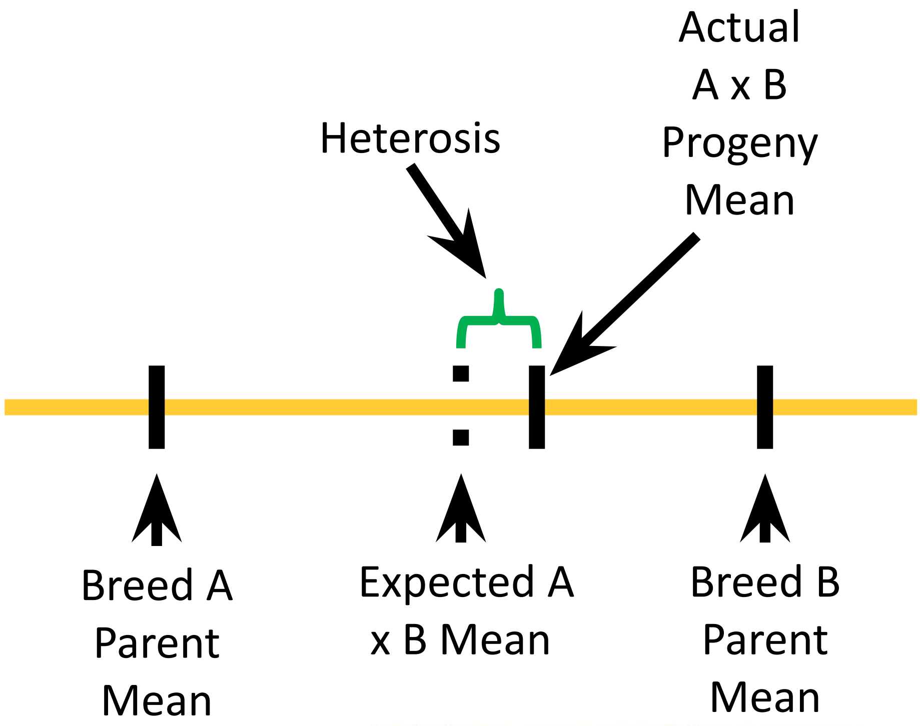
What is Heterosis?

- Hybrid Vigor
- Superiority of a crossbred animal as compared to the **average** of its straightbred parents
- More divergent parental lines = more heterosis





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Genetic Basis

- Increased heterozygosity: more Aa and less AA or aa
  - The inverse of linebreeding/inbreeding
  - Less favorable alleles TEND to be recessive both for major gene traits and polygenic traits
  - What happens if the less favorable allele was dominant?
  - Example with lethal allele

    AA = dead

    Aa = dead

    aa = survives

    Example with polygenic trait

    AA = 5 lbs less WW

    Aa = 5 lbs less WW

    aa = average WW

Genetic Basis Example

- Breed 1 has a recessive embryonic lethal allele at gene A (so aa die early in development)
  - Some percentage of Breed 1 animals are Aa, so when mated together produce ¼ aa embryos that die

	½ A	½ a
½ A	¼ AA normal	¼ Aa normal
½ a	¼ Aa normal	¼ aa lethal

Genetic Basis Example

- Breed 2 has a different recessive embryonic lethal allele at gene B (so bb die early in development)
  - Some percentage of Breed 1 animals are Bb, so when mated together produce ¼ bb embryos that die

	½ B	½ b
½ B	¼ BB normal	¼ Bb normal
½ b	¼ Bb normal	¼ bb lethal

Genetic Basis Example

Breeds have different allele frequencies at different genes; that's what makes breeds different.

Breed 1 allele frequencies are 0.8 for allele A and 0.2 for allele a

Breed 1 is homozygous normal for gene B, all animals are BB

Purebred Breed 1

	0.8 AB	0.2 aB
0.8 AB	0.64 AABB normal	0.16 AaBB normal
0.2 aB	0.16 AaBB normal	0.04 aaBB lethal

4% pregnancy loss

Genetic Basis Example

Breeds have different allele frequencies at different genes; that's what makes breeds different.

Breed 2 allele frequencies are 0.9 for allele B and 0.1 for allele b

Breed 2 is homozygous normal for gene A, all animals are AA

Purebred Breed 2

	0.9 AB	0.1 Ab
0.9 AB	0.81 AABB normal	0.09 AABb normal
0.1 Ab	0.09 AABb normal	0.01 AAbb lethal

1% pregnancy loss

Genetic Basis Example

Breeds have different allele frequencies at different genes; that's what makes breeds different.

Breed 1 allele frequencies are 0.8 for allele A and 0.2 for allele a, homozygous BB

Breed 2 allele frequencies are 0.9 for allele B and 0.1 for allele b, homozygous AA

Cross Breed 1 and Breed 2

	0.8 AB	0.2 aB
0.9 AB	0.72 AABB	0.18 AaBB
0.1 Ab	0.08 AABb	0.02 AaBb

0% pregnancy loss

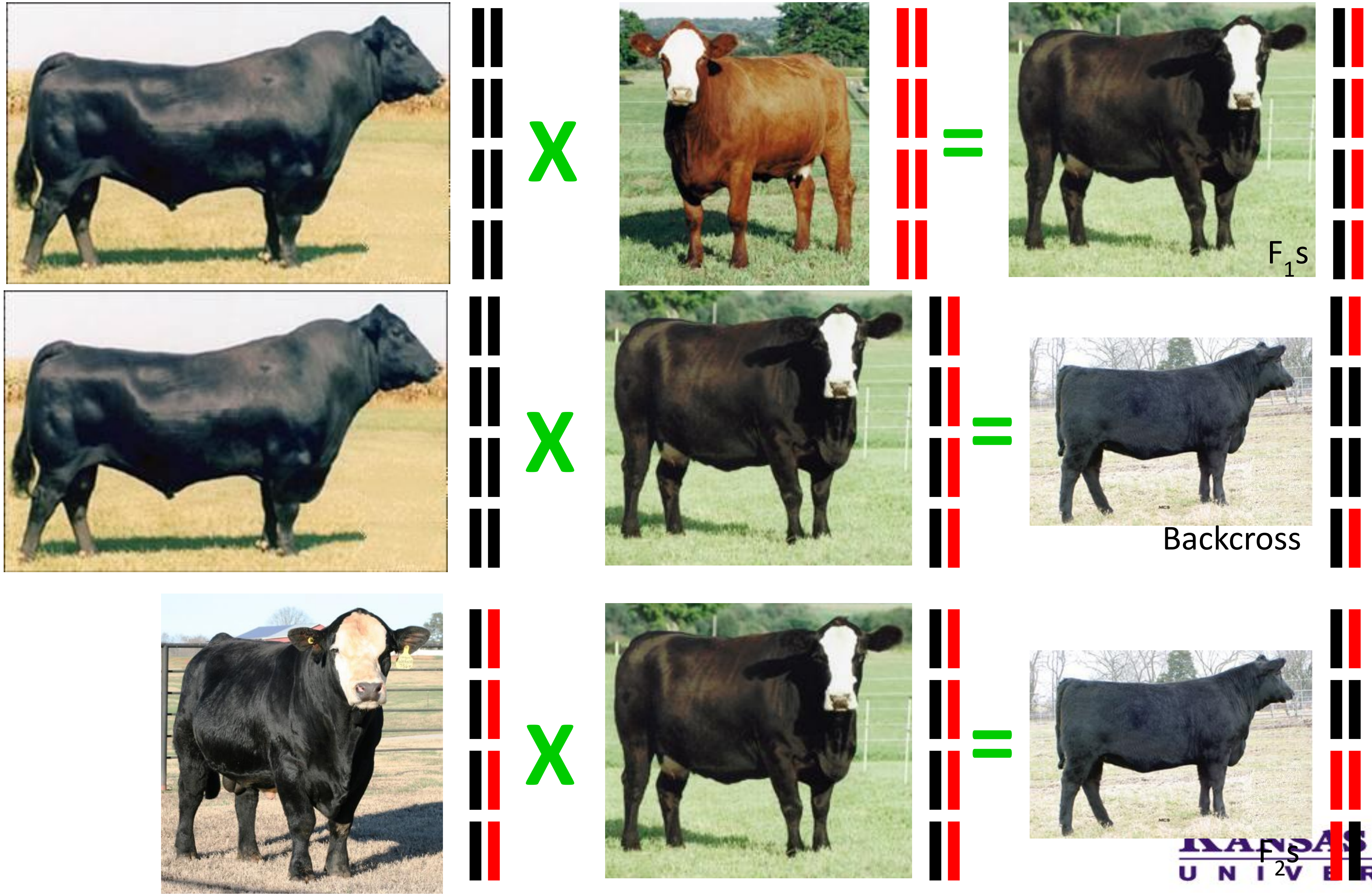
Origins of Heterosis

Breed 1 Breed 2 F_1

Retained Heterosis

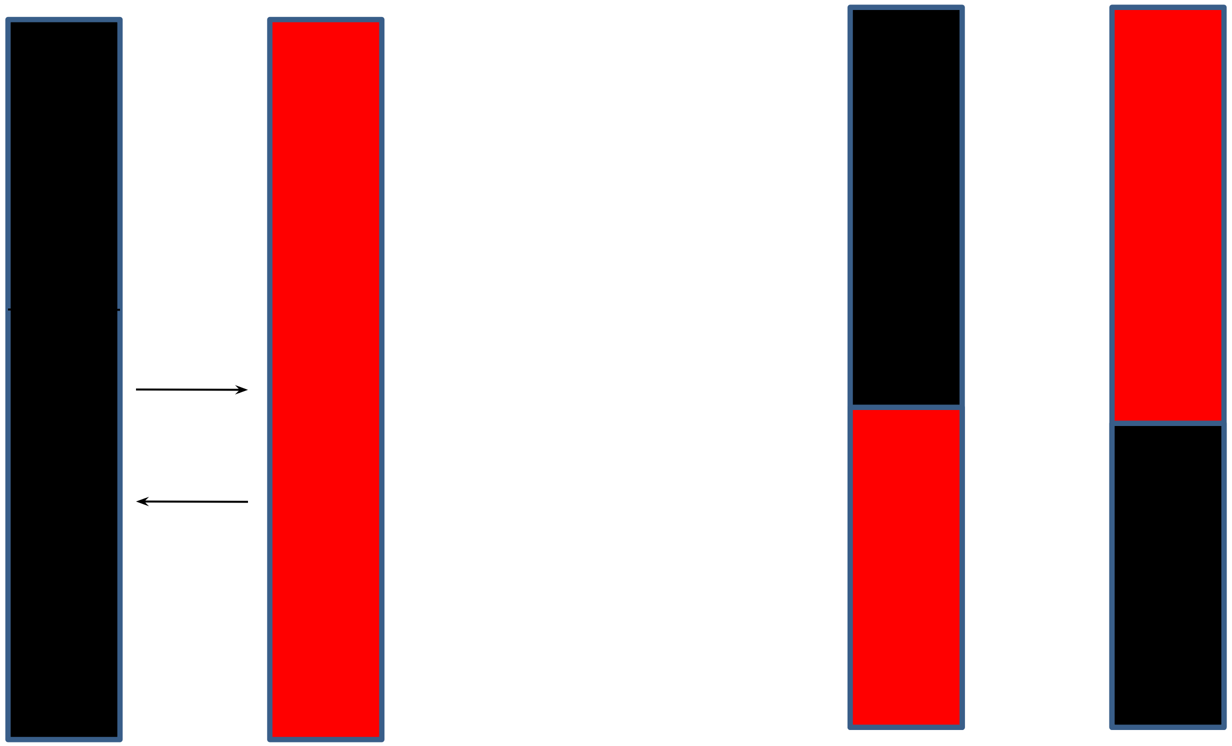
- Mating of crossbred animals leaves you with 0 heterosis…**WRONG**
- Heterosis is retained in future generations

Retained heterosis



Retained heterosis

Recombination is when homologous chromosomes break and switch bits with each other in the process of making sperm or eggs.



Retained Heterosis

- Related to the probability of alleles from different breeds pairing together
  - Note that expected and realized heterosis may differ due to the relationship of breeds
  - Retained heterosis is an average, individual animals may be more or less than average due to random segregation and recombination during sperm and egg formation

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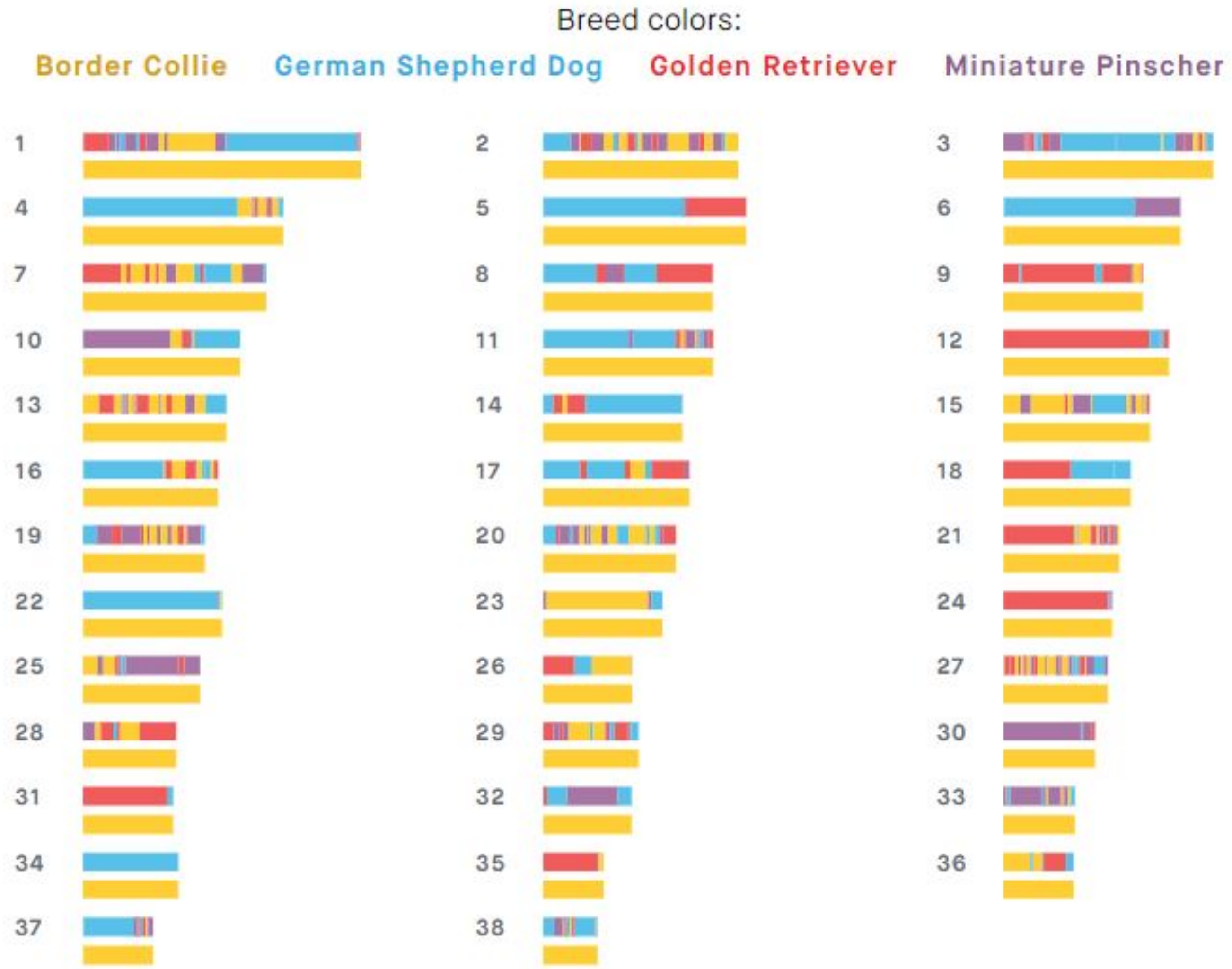
DNA Breed Origins

WHAT'S THIS?



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DNA Breed Origins

WHAT'S THIS?

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Heritability and Heterosis: Inversely Related

Trait	Heritability	Heterosis
Reproduction (fertility)	Low	High
Production (growth)	Moderate	Moderate
Product (carcass)	High	Low

Relative Economic Weights

Reproduction:Growth:End Product

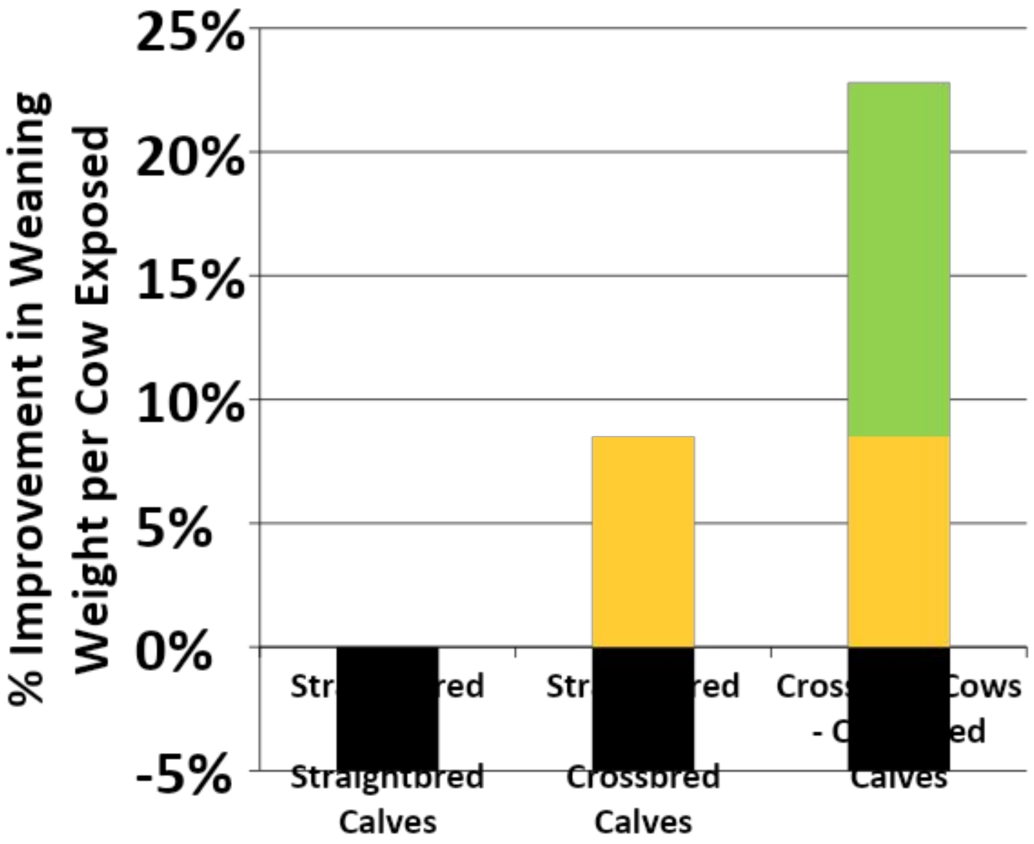
Traditional beef system = 10:5:1

Integrated beef firm = 2:1:1

(Melton, 1995)

Benefits of Heterosis

- Heterosis increases production 20 to 25% per cow in *Bos taurus x Bos taurus* crosses
- More than half of this effect is dependent on use of crossbred cows



Jenkins, MARC

Advantages of the Crossbred Cow

Trait	Observed Improvement	% Heterosis
Longevity	1.36	16.2
Cow Lifetime Production:		
No. Calves	0.97	17.0
Cumulative Wean. Wt., lb.	600	25.3

Adapted from Cundiff and Gregory, 1999.

Advantages of the Crossbred Calf

Trait	Observed Improvement	% Heterosis
Calving rate	3.2	4.4
Survival to weaning	1.4	1.9
Birth weight	1.7	2.4
Weaning weight	16.3	3.9
ADG	0.08	2.6
Yearling weight	29.1	3.8

Adapted from Cundiff and Gregory, 1999

How Big is the Effect?

Table 2. Estimates of biological type heterosis (SE) (British x British, British x Continental and Continental × Continental) for birth, weaning and yearling weight (Model 1)

Covariate[1]	BWT[2], kg	WT205D[2], kg	WT365D[2], kg
B × B	0.47 (0.37)	6.43 (1.80)**	17.59 (3.06)**
B × C	0.75 (0.32)*	8.65 (1.54)**	13.88 (2.63)**
C × C	0.73 (0.54)	5.86 (2.57) *	9.12 (4.34) *
Maternal heterosis	0.41 (0.31)	0.34 (1.84)	3.44 (2.66)

[1]B = British, C = Continental.

[2]BWT = adjusted birth weight, WT205D = adjusted weaning weight, WT365D = adjusted yearling weight.

*$P < 0.05$.

**$P < 0.01$.

Schiermiester et al., 2015 JAS

Aren't purebreds more uniform?

Coefficient of Variation

Trait	Purebreds	Composites
Birth weight	0.12	0.13
Wean weight	0.10	0.11
Carc. weight	0.08	0.09
Retail Product %	0.04	0.06
Marbling	0.27	0.29
Shear Force	0.22	0.21

Adapted from Cundiff and Gregory, 1999; Gosey, 2005

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Breed Complementarity

- Harvest the core strengths of breeds
- Crossing breeds to combine direct and maternal heterosis and breed effects to *optimize* performance levels
- Match cows to environment, calves to market….
- As breeds have become more alike, do we still have complementarity?

Crossbreds are always better? NO

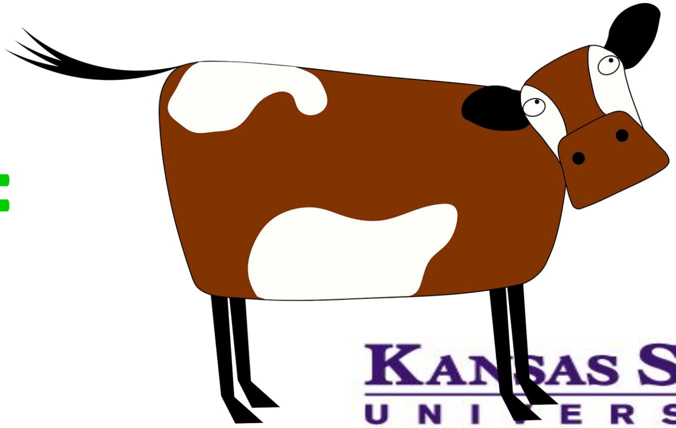
- Crossbreeding is not a substitute for selection, it's a complement

X

=

X

=



Basic Model

$$P = \mu + G + E$$

Phenotype

Contemporary Group
and Other Effects

Genetic
Merit

Unexplained
Variation

Basic Model

$$P = \mu + G + E$$

$$G = A + D + I$$

A = Breeding value (Additive gene effects) **EPD**

D = Dominance effects (pairing of genes effects) **Heterosis**

I = Epistatic (interactions among genes)

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Having Your Cake and Eating it Too

- Commercial cattlemen SHOULD care about BOTH additive and non-additive effects.
- Seedstock producers SHOULD focus on additive genetic merit and put it in a package that helps clientele exploit non-additive effects.

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Crossbreeding Systems

The F_1 cross of 2 purebreds has maximum heterosis.

If retaining replacement heifers, what do you breed her to?

A third breed? Eventually you will run out of breeds.

If retaining replacement heifers, cannot keep maximum heterosis.

Crossbreeding Systems

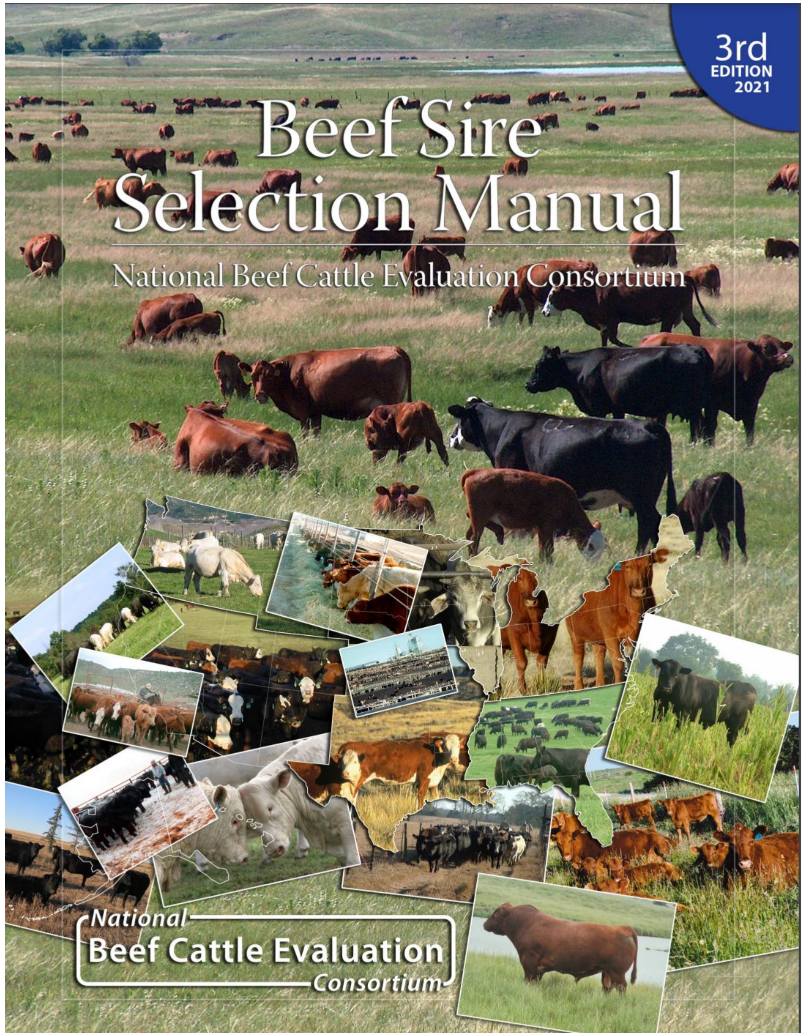
- Herd size
  - Efficient bull utilization
- How do I generate replacement heifers?
- How do I market calves?
  - Manage variation in marketing groups
- Constraints
  - Environment
  - Management

Crossbreeding Systems

- Rotational 2 or more breeds
  - Requires 2 or more breeds of sire
- Terminal
  - Source outside replacement heifers and market all calves
- Composite Seedstock

- Goals:
  - Optimize retained heterosis
  - Have uniform (breed composition) lots of calves to sell
  - Be sustainable over generations

Crossbreeding Systems



www.nbcec.org

Genetic Improvement

- Selection
  - Improve additive genetic value through utilization of EPD
- Mating systems for commercial producers
  - Optimize heterosis
  - Take advantage of breed complementarity
- Questions?

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Suggested Mating System Goals

Optimize	Utilize	Minimize	Technology
Optimize the utilization of calf and maternal heterosis	Utilize breed complementarity to match cows to their environment and their progeny to market targets	Minimize variation in progeny phenotypes by stabilizing breed inputs	Use Adv. Repro tech to help structure mating system (e.g. gender sort semen, estrus synch, etc.)

Crossbreeding Systems

SIMPLE

- Choose a system that will work with your inputs without being too complex to manage

STRUCTURED

- Build a plan – set attainable goals
- Considerations
  - Marketing end points
  - Replacement females (cows must have heterosis)
  - Environment
  - Management

SUSTAINABLE

- Stick to it!
- Improved cowherd production efficiency

SUCCESSFUL

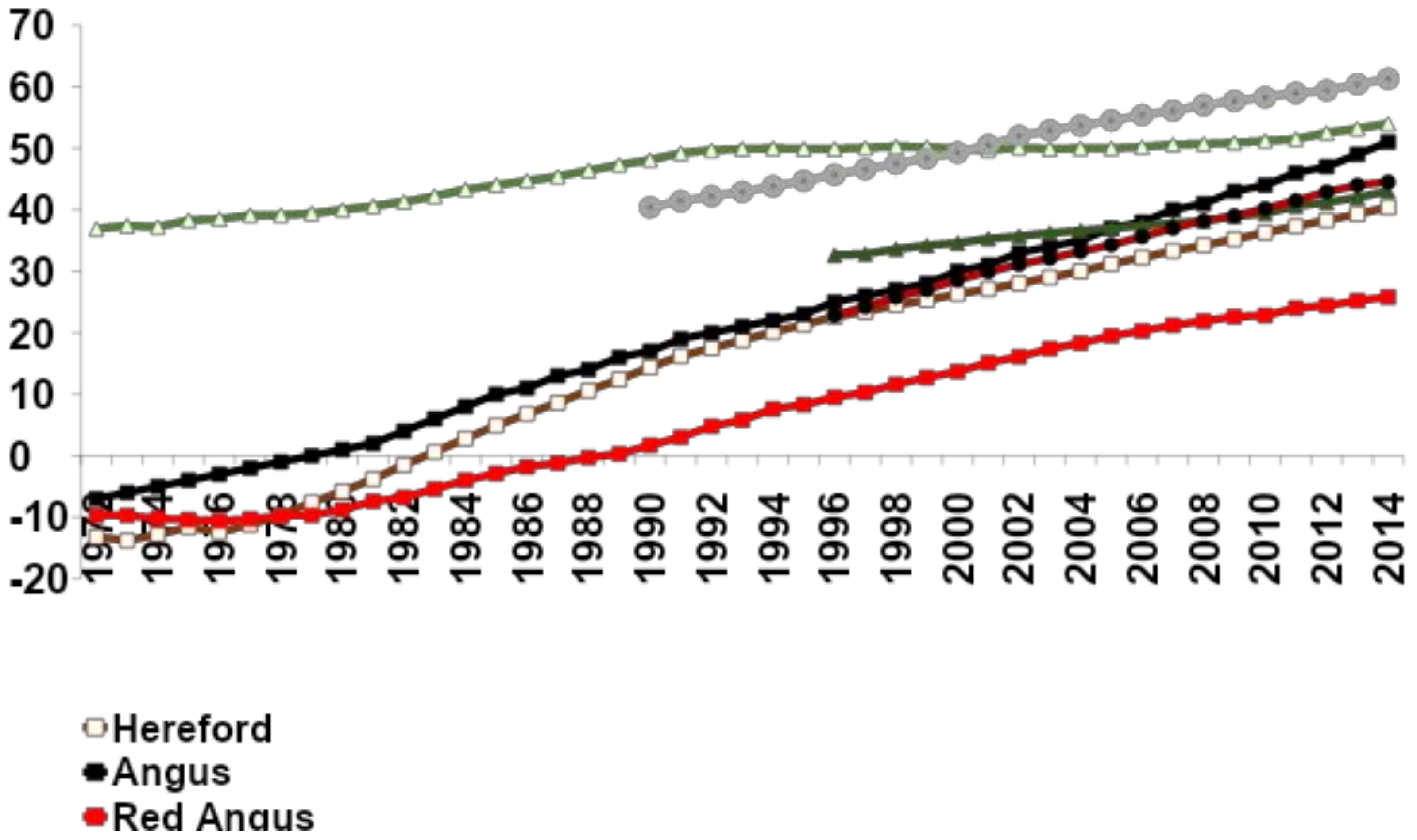
- Increased revenue stream (Weaning Wt/cow exposed)

Systems, Benefits, Constraints

Table 7. Summary of crossbreeding systems by amount of advantage and other factors.[a]

Type of System		% of Cow Herd	% of Marketed Calves	Advantage (%)[b]	Retained Heterosis (%)[c]	Minimum No. of Breeding Pastures	Minimum Herd Size	No. of Breeds
2-Breed Rotation	A*B Rotation	100	100	16	67	2	50	2
3-Breed Rotation	A*B*C Rotation	100	100	20	86	3	75	3
2-Breed Rotational/ Terminal Sire	A*B Rotational	50	33			2		
	T x (A*B)	50	67			1		
	Overall	100	100	21	90	3	100	3
Terminal Cross with Straightbred Females[d]	T x (A)	100	100	8.5	0[e]	1	Any	2
Terminal Cross with Purchased F_1 Females	T x (A*B)	100	100	24	100	1	Any	3
Rotate Bull every 4 years	A*B Rotation	100	100	12-16	50-67[f]	1	Any	2
	A*B*C Rotation	100	100	16-20	67-83[f]	1	Any	3
Composite Breeds	2-breed	100	100	12	50	1	Any	2
	3-breed	100	100	15	67	1	Any	3
	4-breed	100	100	17	75	1	Any	4
Rotating Unrelated F_1 Bulls	A*B x A*B	100	100	12	50	1	Any	2
	A*B x A*C	100	100	16	67	1	Any	3
	A*B x C*D	100	100	19	83	2	Any	4

Genetic Trends for Weaning Wt., lb



Adapted from Spring 2016 Genetic Trends from Breed Associations and 2016 AB-EPD factors (Kuehn et al., 2016)

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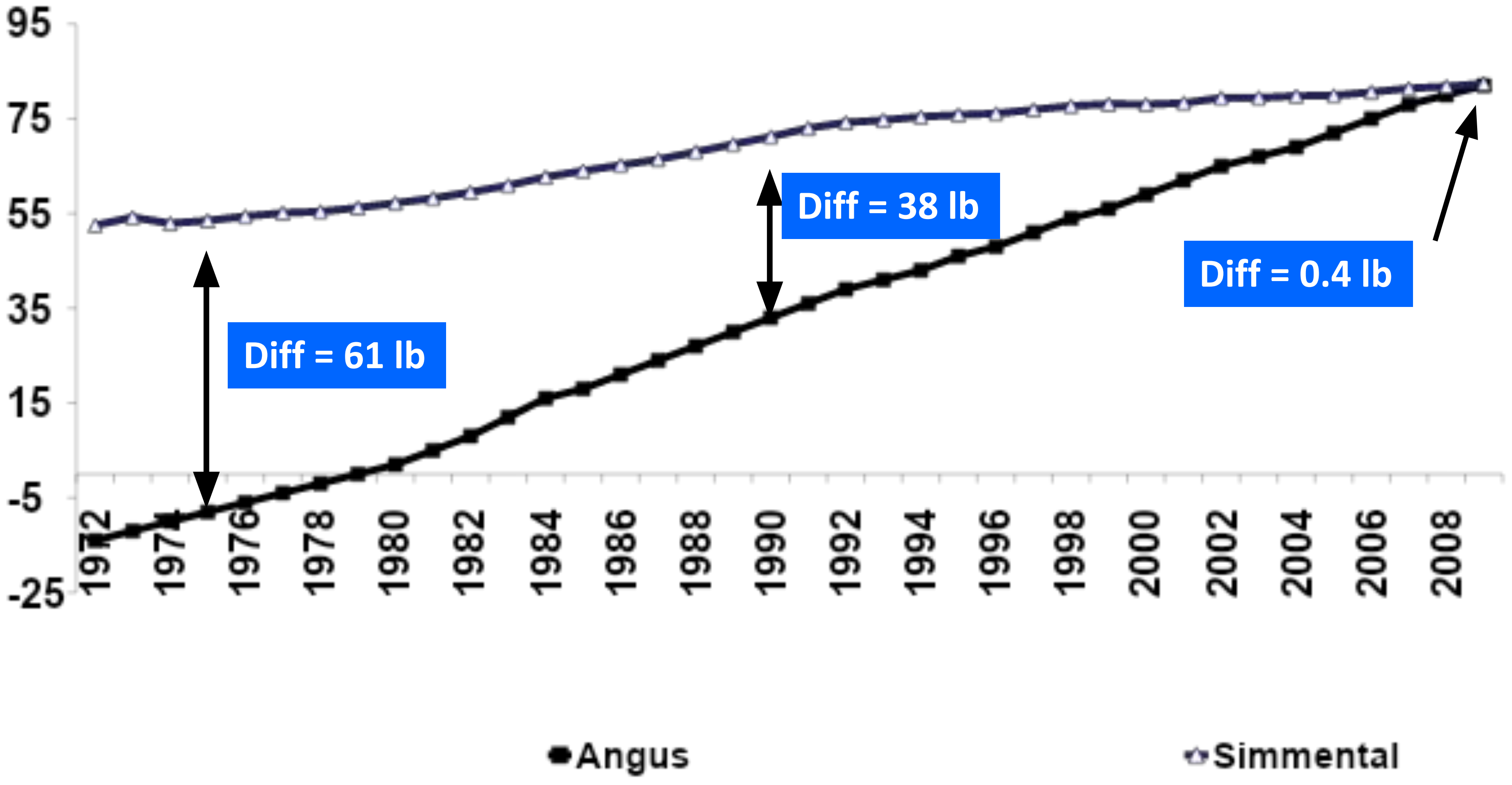
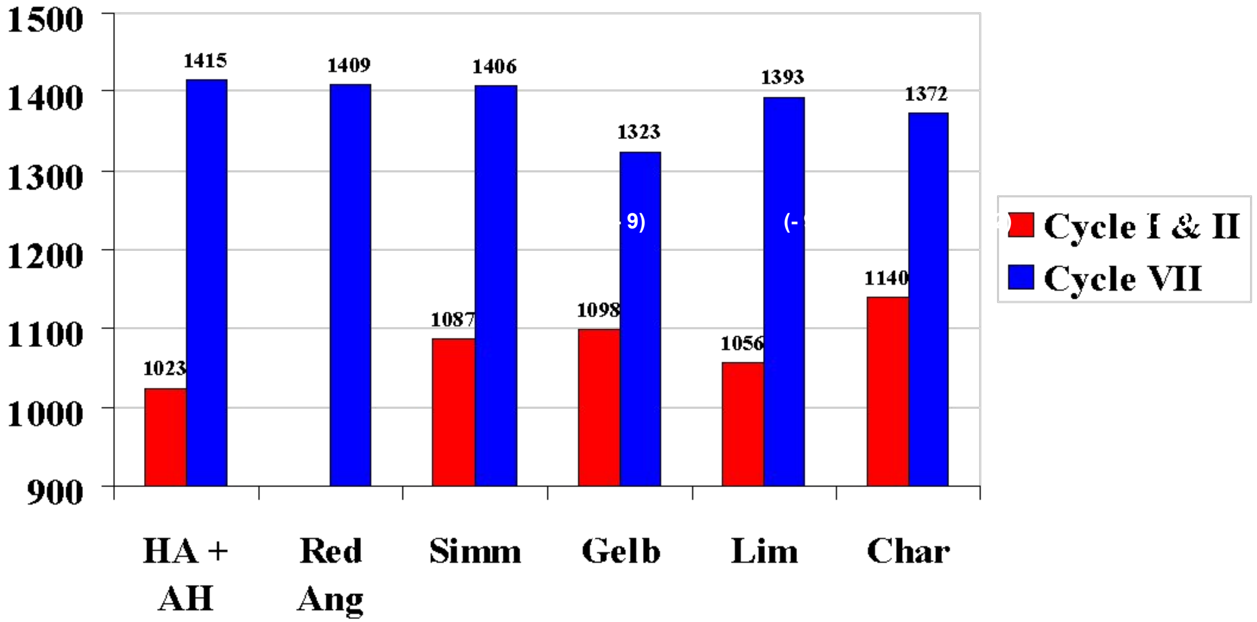
Genetic Trends for Yearling Weight, lb



Adapted from Spring 2009 Genetic Trends from Breed Associations and 2011 AB-EPD factors

BREED GROUP MEANS (DEVIATIONS FROM HA & AH) FOR MATURE WEIGHT (ADJUSTED TO CONDITION SCORE OF 5.5) OF F1 CROSS COWS IN CYCLES I AND II (BIRTH YEARS: 1970-74) COMPARED TO CYCLE VII (BIRTH YEARS 1999-2000), lb



LSD ≤ 26

How Valuable is the Improvement?

- Heifer Pregnancy
  - **Easy:** Heterosis: +7% FSCR, +5% HP (45 d)
  - **Difficult:** Selection: +8% (avg. vs top 1% HP RAAA)

- Longevity
  - **Easy:** Heterosis: +16% (~1.4 years)
  - **Difficult:** Selection: +9% (avg. vs top 1 % STAY ASA)
    - 9% fewer replacements-~$20,000 cost savings per 100 cows…that's $200 per cow/lifetime

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The Dollars of Heterosis

100 cows, 80% Weaning Rate, 575 avg. weaning weight, 10 year horizon

Calf Survival to Weaning (6%) = 48 hd.
Weaning wt. (4%) = +18,400 lb.

Weaning wt. per cow exposed (23%) = **+105,800 lb.**

…or the equivalent of 18 more 575 lb. calves/year

Heterosis is worth ~$150/cow/year

($1.50/lb for 5-6 cwt calves)

Decreases breakeven by $0.28/lb…straightbred would have to generate an additional *$198* per head to be equivalent

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What about end-product traits?

- Highly heritable so little effect of heterosis
- Some breeds compliment each other very well
- "Combination of quality and yield grade"

Sire Breed	% YG 1&2	% Choice & Prime	YG 4	Standards
British (AN,AR,HF)	33.7	86.1	22.9	0.0
Continental (SM,GV,LM,CH)	69.8	57.6	3.3	0.3

"For most marketing "grids", crossbred steers with a 50:50 ratio of Continental European to British breed inheritance are likely to produce a more optimum balance between carcass quality grade and yield grade than crossbred or straightbred steers that represent either 100% British breed, or 100% Continental European breeding."

Cundiff et al., 2004

Impact of Increased Reproductive Rate

- Increase % Calf Crop Weaned
- Increase revenue
  - Let's assume a 7% increase, 83-90%, 100 cows
  - 7 hd. of 500 lb calves, $145/cwt, grosses $5,075
  - Equivalent to increasing revenue by $61.44/hd
  - Decrease breakeven by $11.27/cwt
- No matter how you sell calves, pay wt. drives the bus (#head * avg. wt)

Crux of Straight-breeding

Do the benefits of selection for economically important/convenience traits within breed (straight-breeding) outweigh the improvement of lowly heritable traits via heterosis (especially maternal)?

Selection should be for **BOTH** additive and non-additive genetic merit.

Improvement of Herd Efficiency

- [Dam Weight*Lean Value of Dam + **No. Progeny***Progeny Weight*Lean Value of Progeny] - [Dam Feed*Value of Feed for Dam + **No. Progeny***Progeny Feed*Value of Feed for Progeny].

- By simply increasing number of progeny per dam through either selection, heterosis from crossing, or better management, we will increase efficiency of production.

Adapted from Dickerson 1970