Chapter 4

Animal Breeding

Improving production efficiency and product desirability through each segment of the beef cattle industry rests with purebred breeders and commercial cattle producers. They determine the matings that produce beef and replenish breeding stock. Therefore, they should have a working knowledge of genetics, or the science of heredity, an appreciation of the traits of economic importance throughout the beef cattle industry and an understanding of the procedures for measuring or evaluating differences in these traits.

Basis for Genetic Improvement

Differences among animals result from the hereditary differences transmitted by their parents and the environmental differences in which they are developed. With minor exceptions, each animal receives half its inheritance from its sire and half from its dam. Units of inheritance are known as genes which are carried on threadlike material present in all cells of the body called chromosomes. Cattle have 30 pairs of chromosomes. The chromosomes and genes are paired with each gene being located at a particular place on a specific chromosome pair. Thousands of pairs of genes exist in each animal, and one member of each pair in an animal comes from each parent.

Tissue in the ovaries and the testicles produces the reproductive cells, which contain only one member of each chromosome pair. The gene from each pair going to each reproductive cell is purely a matter of chance.

The female is born with all of her potential eggs already produced and stored in the ovaries. Once she reaches puberty, one egg, sometimes two, will be released from the ovaries during each estrous cycle throughout the remainder of her reproductive life. The male, on the other hand, does not produce sperm cells until he reaches puberty. Sperm are then produced in the testicles by a process that requires about 60 days. Because beef cattle have 30 pairs of chromosomes and only one chromosome from each pair is contained in each sperm cell, there are 1.1 billion different combinations of chromosomes that may be contained in the sperm cells.

When a reproductive cell, or sperm cell, from a male fertilizes a reproductive cell, or egg, from the female, the full complement of genes is restored. Some reproductive cells will contain more desirable genes for economically important traits than will others. The union of reproductive cells that contain a high proportion of desirable genes for economically important traits results in a superior individual and offers the opportunity for selection. However, the chance segregation in the production of reproductive cells and recombination upon fertilization results in the possibility of genetic differences among offspring of the same parents.

The genetic merit of a large number of offspring will average that of their parents. However, some individuals will be genetically superior to the average of their parents and others will be inferior. Those that are superior, if selected as parents of the next generation, contribute to improvement.

Factors Affecting Rate of Improvement From Selection

Factors that affect rate of improvement from selection include (1) heritability [h^2], (2) selection differential [SD], (3) genetic correlation or association among traits and (4) generation interval [GI]. The amount of improvement for a single trait may be calculated as Rate of Improvement = (h^2 x SD) ÷ GI. If selection is based on more than one trait, the genetic association between traits becomes important.

Heritability

Heritability is the proportion of the differences between animals that is transmitted to the offspring. Thus, the higher the heritability for any trait, the greater the possible rate of genetic improvement. When evaluating animals, every attempt should be made to subject all animals from which selections are made to as nearly the same environment as possible. This results in a large proportion of the noted differences among individuals being genetic and will increase the effectiveness of selection.

The average heritability levels for some of the economically important traits in beef cattle are presented in Table 4-1. The heritability of any trait can be expected to vary slightly in different herds depending on the genetic variability present and the uniformity of the environment. Based on heritability estimates, selection should be reasonably effective for

TABLE 4-1. Percent Heritability Levels for Various Traits	
Low (h^2 less than 20%)	
Twinning	3
Calf Survival Ability	5
Conception Rate	10
Calving Interval	10
Medium (h^2 20%-45%)	
Birth Weight	40
Gain Birth to Weaning	30
Weaning Weight	30
Feedlot Gain	45
Feed Efficiency	40
Pasture Gain	30
Conformation Score at Weaning	25
Yearling Body Length	40
Carcass Grade	40
Fat Thickness – 12th Rib	45
High (h^2 greater than 45%)	
Yearling Weight	50
Yearling Hip Height	60
Yearling Wither Height	50
Dressing Percentage	50
Ribeye Area	70
Mature Weight	60

most performance traits, but these traits vary in heritability and economic importance. Thus, the rate of expected improvement and the emphasis each trait should receive in a selection program will also vary considerably.

The heritability estimates for each trait combined with the trait's economic value to that particular cattle producer should determine the relative emphasis each trait receives in the selection program. If a trait is medium to high in heritability, the purebred producer may select animals that are superior in that trait and expect reasonable progress to be made toward the goal. If the trait is low in heritability, little progress will be made by selection; however, considerable improvement may be made in traits with low heritabilities by utilizing crossbreeding. Thus, a commercial producer benefits in traits (primarily reproductive traits) that are low in heritability by crossbreeding while improving traits that are medium to high in heritability by purchasing bulls from a purebred producer who has been selecting for improvement in those traits.

Selection Differential

Selection differential is the difference between selected individuals and the average of all animals from which they were selected. For example, if the average weaning weight of a herd is 450 pounds and those selected for breeding average 480 pounds, the selection differential is 30 pounds. The average cattle producer who produces their own replacements saves from 30 to 40 percent of the heifers each year while retaining only 2 to 5 percent of the bull calves. Because of these differences in replacement rates, the greatest selection differential will be on the bull's side. Up to 90 percent of the genetic improvement in a trait over four generations is due to the sire used. Every effort should be made to obtain the maximum selection differential possible for the trait or traits of greatest economic importance and highest heritability, ignoring traits that have little bearing on either efficiency of production or carcass merit.

Genetic Association Among Traits

A genetic relationship among traits is the result of genes favorable for the expression of one trait tending to be either favorable or unfavorable for the expression of another trait. Genetic associations may be either positive or negative. If the genetic association between two traits is positive as is the case between birth weight, pre-weaning gain, post-weaning gain and eventual mature size, then selection to increase one of these traits would also cause some increase in the other traits. When two traits are negatively correlated, such as rate of gain and carcass quality, selection to increase one will cause the other trait to decrease.

Generation Interval

The fourth major factor that influences rate of improvement from selection is the generation interval – that is, the average age of all parents when their progeny are born. Generation interval averages approximately 4½ to 6 years in most beef cattle herds. Rate of progress is increased when the generation interval is shortened. This can be accomplished by vigorous culling of the cow herd based on their production, calving heifers as two-year-olds and using yearling bulls on a limited number of females.

Mating Systems

The five fundamental types of mating systems are (1) random mating, (2) inbreeding, (3) outbreeding, (4) assortative mating and (5) disassortative mating.

Random mating is mating individuals without regard to similarity of pedigree or similarity of performance.

Inbreeding is mating individuals that are more closely related than the average of the breed or population. Linebreeding is a special form of inbreeding and refers to the mating of individuals so the relationship to a particular individual is either maintained or increased. Linebreeding results in some inbreeding because related individuals must be mated.

Outbreeding is mating of individuals that are less closely related than the average of the breed or population. The term outcrossing is also used to mean outbreeding when matings are made within a breed. Crossbreeding is a form of outbreeding.

Assortative mating is the mating of individuals that are more alike in performance traits than the average of the herd or group. This mating system is often used when establishing uniformity within a herd.

Disassortative mating is the mating of individuals that are less alike in performance traits than the average of the herd or group. This mating system is used to correct deficiencies within a herd.

Crossbreeding for Commercial Beef Production

Crossbreeding can be used in commercial beef production to realize heterosis, or hybrid vigor, and complementary combinations of breed characteristics and to match market requirements, feed and other resources available in specific herds.

The effect of heterosis on some performance traits is important. Productivity in some traits is greater in crossbred animals than the average of the two parents due to heterosis. The effect of heterosis is inversely proportional to heritability. For example, high heritability traits such as post-weaning growth rates, feed efficiency and carcass composition are affected less by heterosis than low heritability traits such as livability and fertility.

More than 50 breeds are available in significant numbers to cattle producers through either natural breeding or artificial insemination. These breeds vary greatly in performance traits. Because offspring resulting from crossbreeding tend to be a blend of both parents, crossbreeding can be used to obtain a performance goal in one or two years that would require several years to accomplish through selection for genetic change within one breed.

Also, by matching the sire breed and the dam breed in proper combination, complementary traits can be obtained in the offspring through crossbreeding. For example, a cow selected for its small size, quick maturity, high fertility and low maintenance cost can be matched with a sire breed selected for faster growth rate and a lean muscular carcass.

Crossbreeding Systems

For most livestock species, crossbreeding is an important aspect of production. Intelligent crossbreeding generates **hybrid vigor** and **breed complementarity**, which are very important to production efficiency. Cattle breeders can obtain hybrid vigor and complementarity simply by crossing appropriate breeds. However, sustaining acceptable levels of hybrid vigor and breed complementarity in a manageable way over the long term requires a well-planned crossbreeding system. Given this, finding a way to evaluate different crossbreeding systems is important. The following is a list of seven useful criteria for evaluating different crossbreeding systems:

1. Merit of component breeds
2. Hybrid vigor
3. Breed complementarity
4. Consistency of performance
5. Replacement considerations
6. Simplicity
7. Accuracy of genetic prediction

Merit of Component Breeds

For any crossbreeding system to be effective, the breeds in the system must be well chosen. Each breed included in a crossbreeding system must bring favorable attributes to the cross. Determining the appropriate breeds to use in a crossbreeding system can be challenging. Another challenge is the availability of animals of those breeds.

Hybrid Vigor

Generating hybrid vigor is one of the most important, if not the most important, reasons for crossbreeding. Any worthwhile crossbreeding system should provide adequate levels of hybrid vigor. The highest level of hybrid vigor is obtained from F1s, the first cross of unrelated populations. To sustain F1 vigor in a herd, a producer must avoid **backcrossing –** not always an easy or a practical thing to do. Most crossbreeding systems do not achieve 100 percent hybrid vigor, but they do maintain acceptable levels of hybrid vigor by limiting backcrossing in a way that is manageable and economical. Table 4-2 lists expected level of hybrid vigor or heterosis for several crossbreeding systems.

Breed Complementarity

Breed complementarity refers to the production of a more desirable offspring by crossing breeds that are genetically different from each other but have

TABLE 4-2. Expected Heterosis Levels and Breed Complementarity Attributes of Several Crossbreeding Systems			
	Expected Heterosis		
Crossbreeding System	Offspring	Dam	Breed Complementarity
Two-breed terminal cross	100	0	maximum
Three-breed terminal cross (using F1 females)	100	100	maximum
Two-breed rotation	72	56	some
Three-breed rotation	91	70	minimal

Definitions

hybrid vigor – An increase in the performance of crossbred animals over that of purebreds, also known as heterosis.

breed complementarity – An improvement in the overall performance of crossbred offspring resulting from the crossing of breeds of different but complementary biological types.

backcrossing – The mating of an individual (purebred or hybrid) to any other individual with which it has one or more ancestral breeds or lines in common.

complementary attributes. In beef cattle breeding, it is often stated as "big bull X small cow" complementarity. The big bull contributes growth and leanness to the offspring, and the small cow requires less feed to maintain herself. The result is a desirable market animal economically produced.

Consistency of Performance

A crossbreeding system should ideally produce a consistent product. It is much easier to market a uniform set of animals than a diverse one. It is also much easier to manage a female population that is essentially one type than one made up of many types, each with its own requirements. Crossbreeding systems vary in their ability to provide this kind of consistency.

Replacement Considerations

In terms of hybrid vigor, the ultimate female is an F1. Commercial producers would like to have entire herds of F1 females. How can you produce a continuous supply of F1s? One way is to maintain purebred parent populations to cross to produce F1s. A second way is to purchase all the replacements needed from a third party. Neither of these methods is optimum for most producers. A number of crossbreeding systems manage to overcome the replacement female dilemma by allowing breeders to produce replacement heifers from their own **hybrid** populations. However, this convenience comes at a price, a price typically paid in loss of hybrid vigor, breed complementarity and simplicity.

Simplicity

Crossbreeding systems should be relatively simple. Expensive systems or complex systems that require an unrealistically high level of management are unlikely to remain in place for very long. More complex breeding systems often conflict with important management practices unrelated to breeding. For example, beef cattle crossbreeding systems that require many breeding pastures make grazing management difficult. It is important that crossbreeding systems fit with other aspects of cattle production. This means that crossbreeding systems should be kept simple.

Accuracy of Genetic Prediction

The higher the accuracy of genetic prediction, the lower selection risk and more predictable the offspring. Because relatively little performance information on commercial animals is recorded and even less is reported for analysis, accuracy of prediction in a commercial operation refers to accuracy of prediction for seed stock inputs to the crossbreeding system – typically sires. In many cases, accurate **EPDs** are available for purebred sires, and crossbreeding systems using purebred sires benefit as a result.

Definitions

hybrid – An animal that is a cross of breeds within a species.

EPD – Expected progeny difference.

Example Crossbreeding Systems

Terminal Cross

The simplest form of crossbreeding is a terminal cross. In this system, all offspring are marketed, making it necessary to purchase replacement heifers. If F1 replacement heifers (females that have 100 percent hybrid vigor for maternal traits) are purchased and are bred to bulls of a different breed, both cows and calves take advantage of maximum heterosis. This system also allows the most flexibility in choosing breeds to use. Replacement heifers can be purchased that are comprised of "maternal" breeds and bred to terminal or high-growth breed bulls. This type system is optimal for many cow-calf producers. This system is illustrated in Figure 4-1.

An even simpler form of this system just uses two breeds. Bulls of breed A are bred to females of breed B to produce F1 A X B offspring. These offspring will exhibit maximum heterosis, but since the females that produced these calves were not crossbreeds, the offspring were not able to take advantage of any maternal heterosis.

Rotational Cross

Spatial Rotations – The classic form of a rotational crossbreeding system is a spatial rotation. In spatial rotations, all breeds are used at the same time but are separated specially. This system requires multiple mating pastures, one for each sire breed. In a two-breed rotation (see Figure 4-2 for an example), two breeding pastures will be needed. A three-breed rotation would need three breeding pastures. This

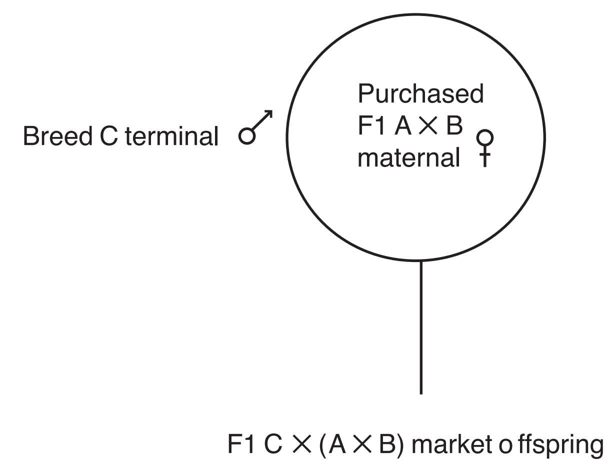


FIGURE 4-1. Example of a terminal crossbreeding system using purchased F1 females.

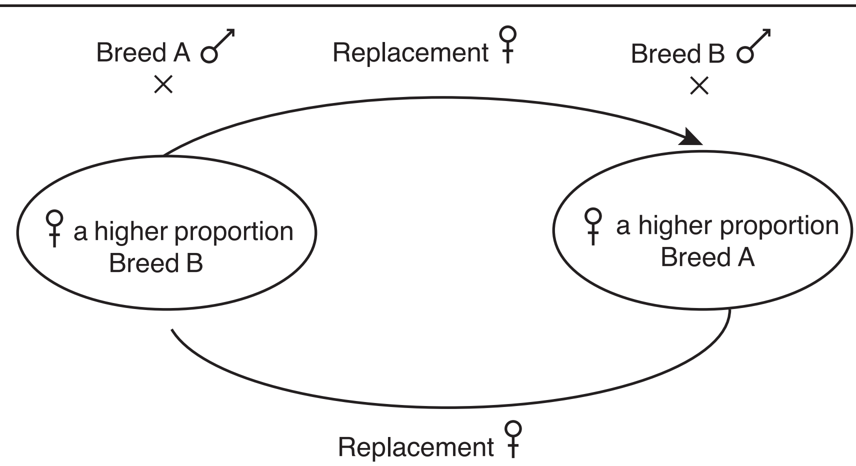
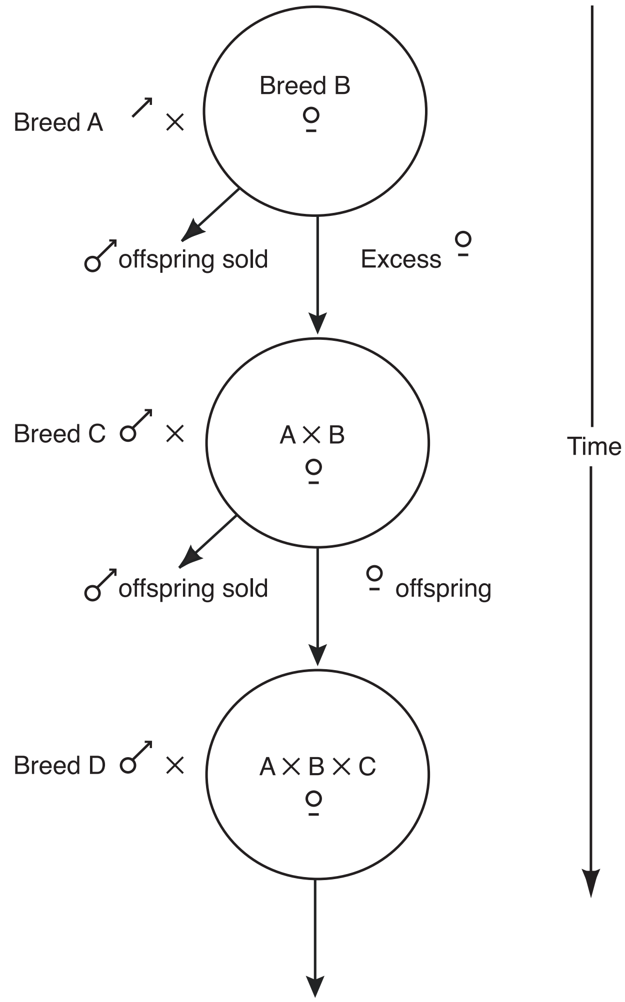


FIGURE 4-2. Example of a spatial rotation using two sire breeds.

system is designed to produce replacements. Replacements leave the group into which they were born to join the other breeding group as a replacement. As seen in Figure 4-2, replacements out of sire breed A move to the group that is to be bred to sire breed B and replacements out of sire group B move to the group to be bred to sire breed A. The more breeds that are included in the rotation, the greater amount of heterosis. Each breed added also increases the level of management needed to keep the system operational.

Rotation in Time – Another commonly used form of rotational crossbreeding is rotating sire breeds across time. In this system, only one breed of sires is used at one time. Typically, sire breeds are rotated every one or two breeding cycles. This system is simpler to manage than a spatial rotation, but the level of observed heterosis is somewhat less due to increased backcrossing. This system is illustrated in Figure 4-3. The major problem with utilizing this system is that over time the groups of breeding females become very inconsistent in their breed makeup and performance. This introduces inconsistency in their offspring. This variation in calf performance can be a hindrance during marketing of the offspring.



Continue rotation with another breed or breed back to Breed A and start the rotation again.

FIGURE 4-3. Example rotation in time system using three breeds.

Genetics and the Environment

In Arkansas, beef production requires compromise at intermediate levels among the traits of mature size, maturing rate and milk production in the cow herd, if best use of feed and forage resources on the farm are realized. These traits are factors that determine energy requirements. Feed and forage resources vary among farms; therefore, the optimum level of these characteristics must vary as well if the best choice of cattle is made to match the feed and forage resources. How well the cow herd matches the resources or how nearly the forage resources can meet the requirements of the cattle will be reflected in the supplementary feed that must be provided. Failure to provide needed supplementary feed for a cow herd that is mismatched with the forage resource will be reflected in increased ages at puberty, reduced reproduction and weaning rates and higher maintenance costs of cows. The size and maturing rate of the parents also influence carcass leanness and marbling at acceptable market weights.