Welcome to the Mississippi Master Cattle Producer Program Self-Study Program Breeding and Genetics training module. This program is administered by the Mississippi State University Extension Service. For answers to questions about this training program, contact Dr. Jane Parish, MSU-ES Extension Beef Cattle Specialist.

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Mississippi Master Cattle Producer Program

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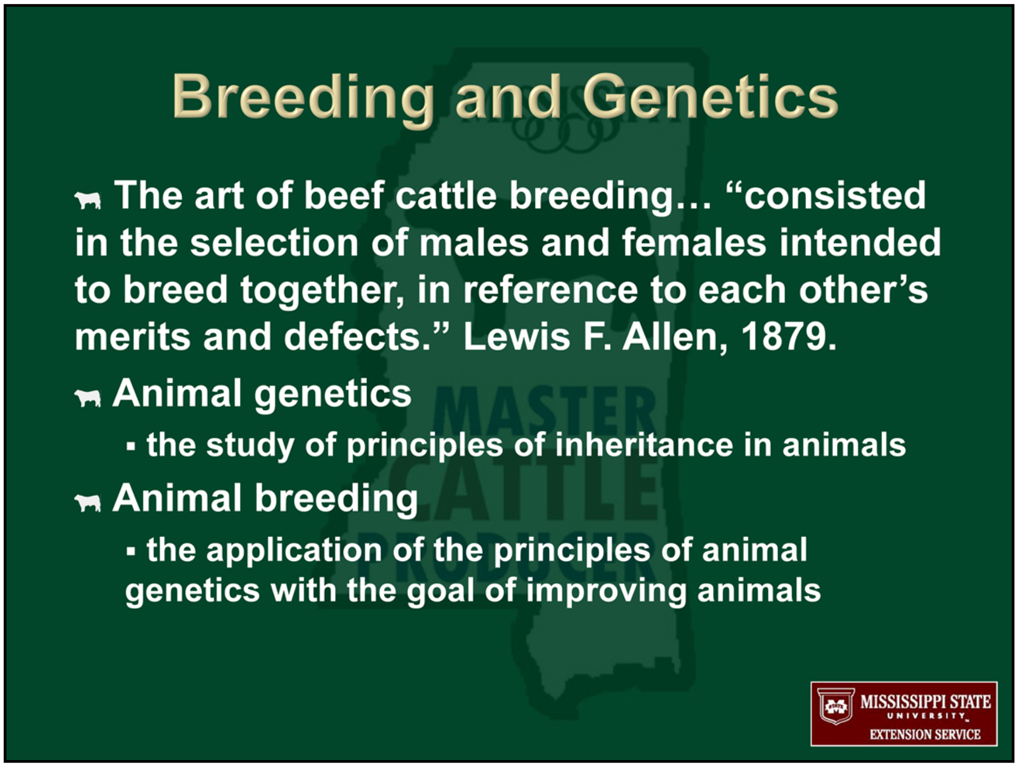
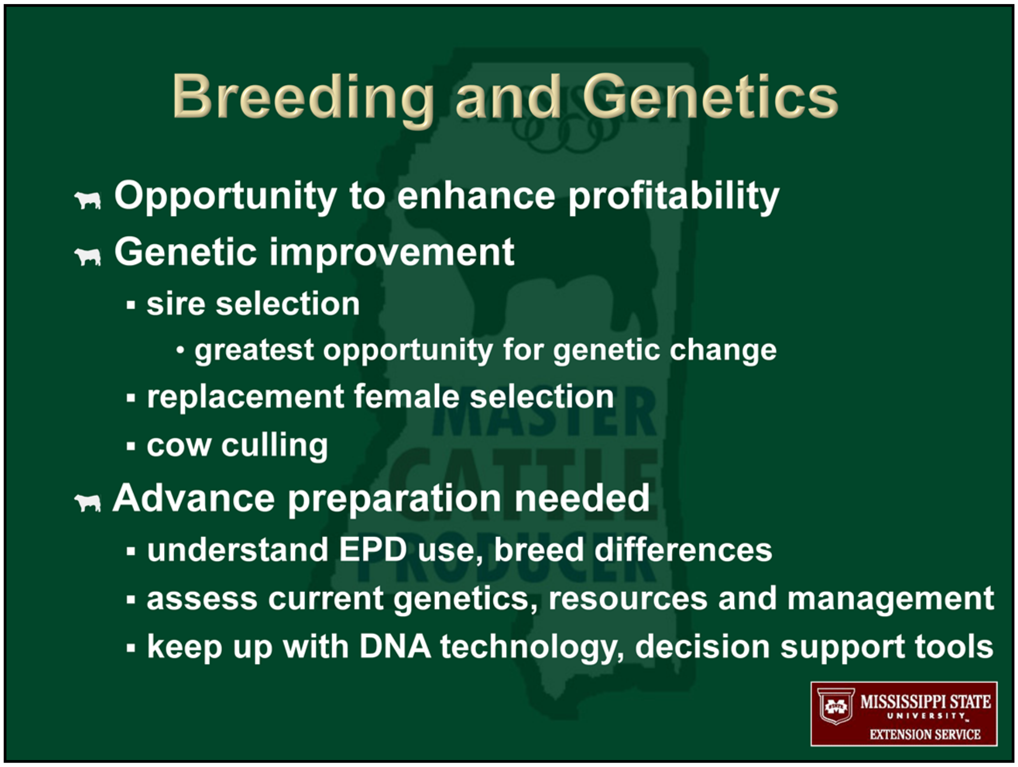


Beef cattle genetics is the study of the principles of inheritance in cattle. Beef cattle breeding is the application of the principles of genetics with the goal of improving cattle. Persons applying beef cattle breeding practices are referred to as breeders. More commonly, the term breeders is used in reference to seedstock operations. Beef cattle breeding is described as an art by some but is based on the scientific principles of animal genetics and trait data collection, reporting, analysis, and interpretation within the beef industry.



Beef cattle breeding and genetics presents an important opportunity to enhance the profitability of the beef production enterprise. Genetic change in cow-calf operations can occur both through sire selection and through replacement female selection in conjunction with cow culling. However, sire selection represents the greatest opportunity for genetic change. Because a relatively few bulls will service a large number of cows, producers can select bulls that are fairly elite even when natural mating. Use of artificial insemination allows commercial producers to use some of the most outstanding bulls in the world at a reasonable cost, allowing for enormous amounts of genetic change, if desired. Finally, selection of bulls is more accurate than female selection. Seedstock breeders provide genetic information in the form of Expected Progeny Differences (EPDs), which allow for direct comparison of potential sires across herds and environments.

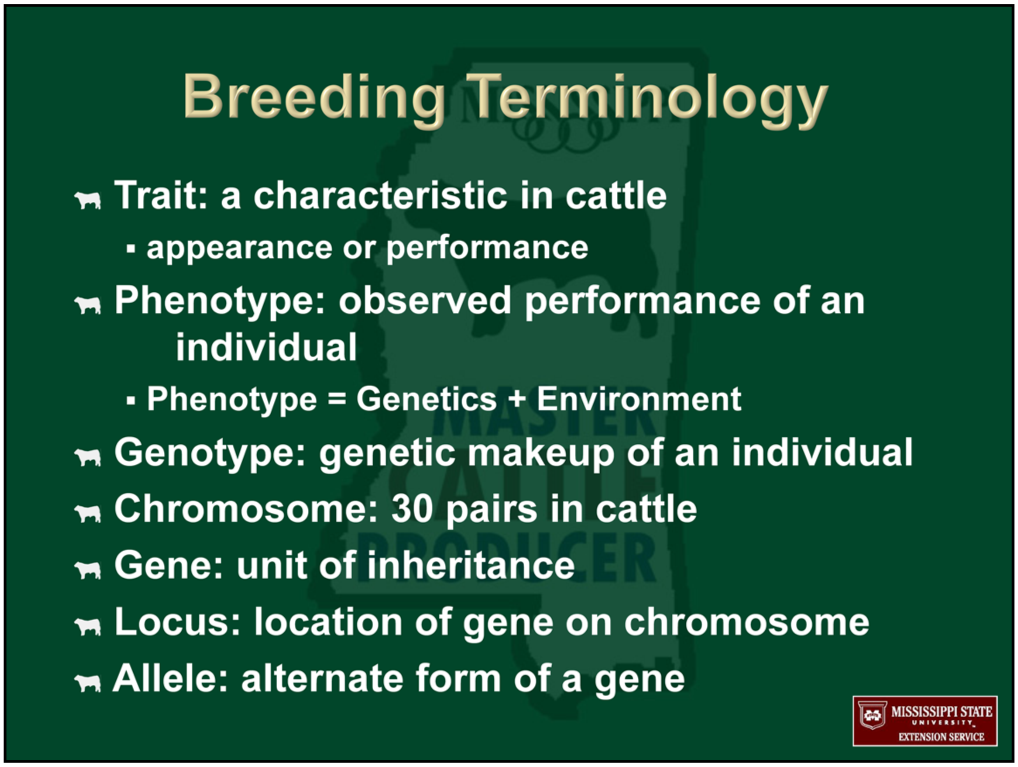
Bull selection is one of the most important producer decisions and, as such, requires advance preparation and effort to be successful. To effectively select sires, producers must not only be well versed in the use of EPDs and understand breed differences, but they must also accurately and objectively assess their current genetics, resources, and management. Furthermore, recent advances in DNA technology and decision support tools add complexity to selection but will ultimately enhance selection accuracy. Producers who stay up to date on advances in beef cattle genetics should profit from enhanced revenue and reduced production costs, as they best match genetics to their production situation.

Long-term Effects of Selection Decisions

Year	Seedstock Herd	Commercial Herd
1	✓Bull selection/purchase decision made ✓Bulls mated to selected cows	
2	✓Offspring of first mating born ✓Calves weaned, replacement males and females developed	
3	✓Replacement females chosen, bulls sold to commercial customers ✓Replacement heifers mated	✓Bull purchase ➔Bulls used in commercial herds
4	✓Offspring of replacement females born ✓Heifers' offspring weaned, replacements selected, culls enter the feedlot (seedstock heifers may remain in the herd for 12+ years)	✓Commercial bulls' offspring born ✓Commercial bulls' offspring weaned and sold (first potential income for commercial producer that resulted from a mating 3 years earlier in the seedstock herd)
5		✓Commercial bulls' offspring finished and harvested (first potential income if producer retains ownership of calves through feedlot)

Most producers do not consider the long-term effects of a selection decision, but rather consider what that particular sire will add to next year's calf crop. The potential time-span for a single selection decision from the perspective of a seedstock breeder and that seedstock breeder's commercial customer is illustrated in the figure above. The seedstock breeder makes a selection and mating decision in spring; the offspring are born the following year and weaned. Bull calves are selected for development in that same year. The year after, year 3, the bulls chosen for development are sold and used in the commercial herd. The offspring of these commercial matings are born in year 4. If those offspring are sold as weaned calves, the first income for the commercial producer arrives four years after the seedstock breeder's original selection decision. If the commercial producer retains ownership of the calves, the *first income may not be realized until year 5*. A mating in a seedstock herd made this year may not realize income for the commercial producer until year 5.

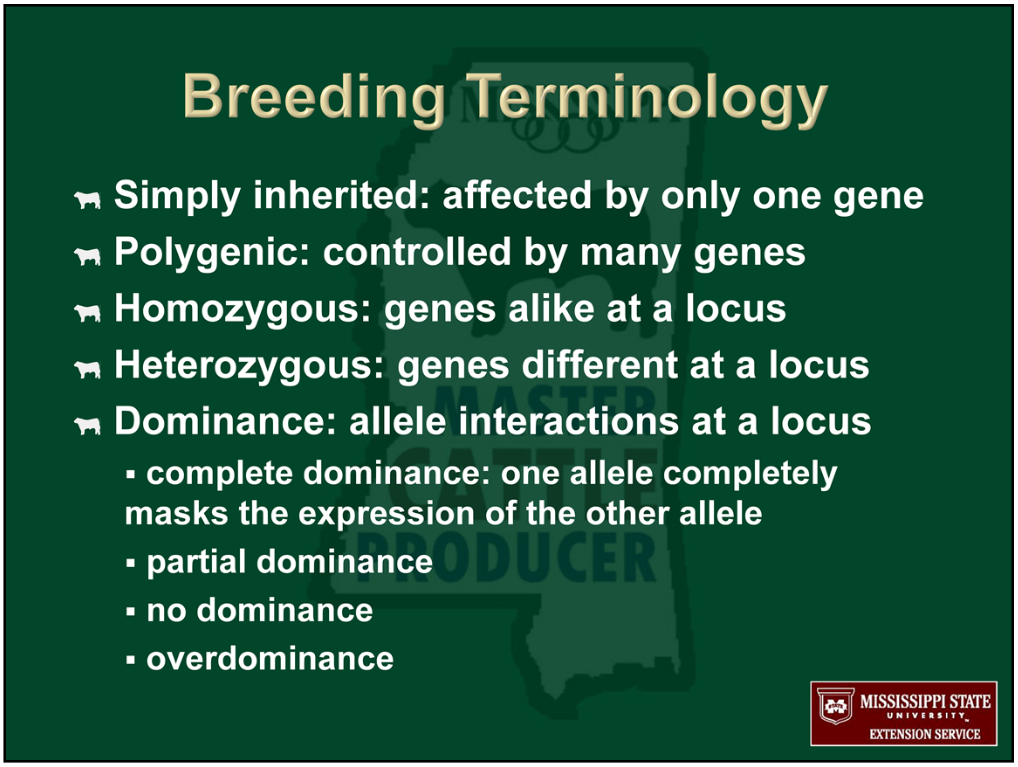
This does not begin to consider the long-term effects of replacement females kept in the seedstock or the commercial herd. Assuming cows may reach 12 years of age before being culled, the original selection decision in year 1 may influence calves produced 16 years after the seedstock breeder's original decision. Good selection decision tools consider the long-term effects of selection decisions.



Trait is the term used to describe a characteristic in cattle. This can refer to either the appearance or performance of an animal and can also be referred to as the *phenotype*; for example, black coat color, horned, 575-lb weaning weight, etc. For most performance traits (e.g., weaning weight), the phenotype of an animal is controlled by two factors: the environment in which the animal lives and the animal's genetic makeup or *genotype*. The *environment* consists of not only the weather but also how the cattle are managed. Creep feed, forage quality and quantity, and health programs are examples of environmental effects. Environmental effects on economically important traits are controlled through management techniques such as nutrition and health programs.

The genetic component of all living things is expressed through the production of proteins at the cellular level. Cells can turn on or turn off the production of proteins through signals from other cells, environmental changes, age, or other factors. The code for this protein production is found in DNA (deoxyribonucleic acid), which comes in long strands that form *chromosomes*. Cattle have 30 pairs of chromosomes; humans have 23. Each animal inherits one of each pair from its sire and the other from its dam.

The term *gene* refers to the basic unit of inheritance. It is a particular segment of the chromosome that codes for a specific protein. There are also parts of the chromosome that are thought to play no role in inheritance. The location of the gene on the chromosome is called the *locus*. The term *allele* refers to one of the chemical or functional possibilities that can be present at a locus (i.e., coat color has two possible alleles: red and black).



In terms of genetics, traits are usually referred to as either *simply inherited* or *polygenic*. Simply inherited traits are usually affected by only one gene. The two most commonly recognized simply inherited traits in beef cattle are red/black coat color and horned/polled. Some genetic disorders are also simply inherited. Simply inherited traits are typically observed as either/or: either the animals have horns, or they are polled. Additionally, simply inherited traits are affected little by the environment. If an animal has the genotype for black coat color, environmental conditions are not likely to make it red.

As implied in the name, polygenic traits are controlled by many genes. The number of genes involved depends on the trait, and there is currently little information on just how many genes are involved for particular traits. Examples of some common polygenic traits in cattle are birth weight, weaning weight, milking ability, marbling, tenderness, etc. Besides being controlled by many genes, polygenic traits are also controlled by the environment.

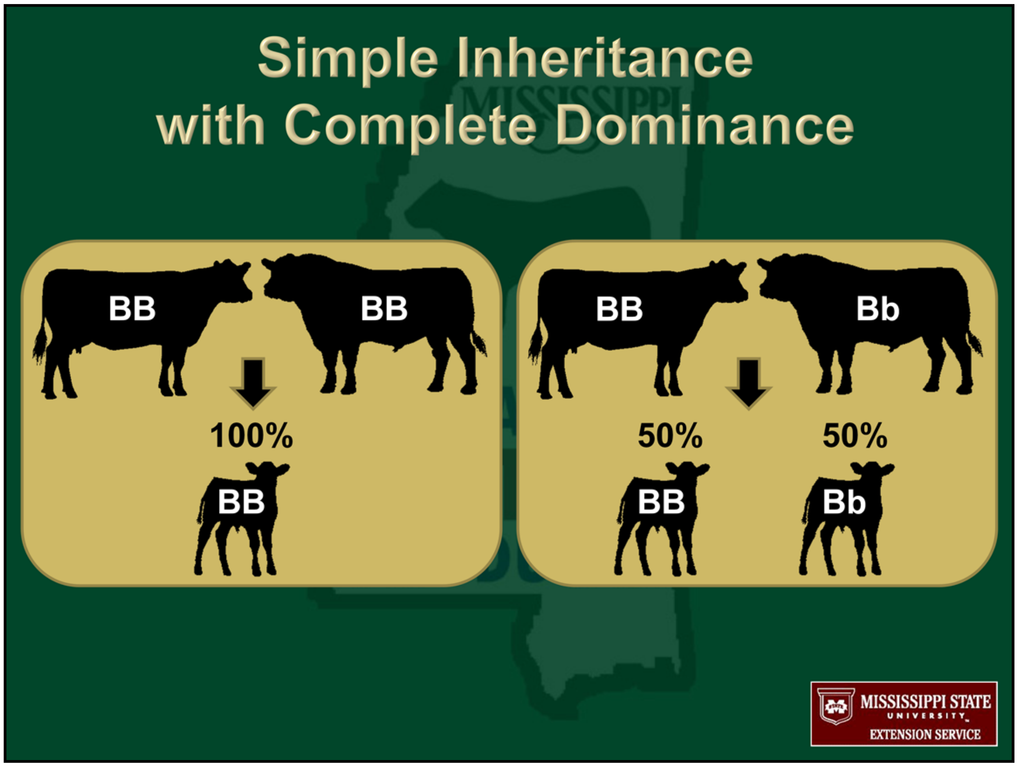
Alleles at a locus can have an effect on the trait by themselves but can also affect the phenotype through interactions with other alleles. Alleles can interact in two ways, referred to as *dominance* and *epistasis*. Dominance is a way to describe how alleles interact with each other at a particular locus. There are varying degrees of dominance. This refers to how the two alleles that an animal has at a particular locus interact. The classic form of dominance is complete dominance. With complete dominance, one allele can completely mask the expression of the other allele. This results in heterozygote animals having the exact phenotype as homozygote dominant animals. This is the type of dominance we see in red/black coat color, where black is dominant to red. Cattle that have two black alleles are black (*homozygous* dominant), cattle that have one black and one red allele are also black (*heterozygous*), and red animals are the result of having two red alleles (homozygous recessive). When dealing with traits with complete dominance, heterozygous animals are often called carriers because they are carrying the allele and can pass it to their offspring even though they do not express the trait themselves. It is possible to breed two black cattle and get a red calf because each parent was a red allele carrier.

Besides complete dominance, there are other types of interactions between the two alleles at a locus, including: partial dominance, no dominance, and overdominance. As implied by their names, partial dominance means that the heterozygote favors the dominant characteristic but does not express to the full extent as the homozygous dominant. No dominance means that the heterozygote is the average of the homozygote dominant and recessive and is also referred to as additive because the phenotype of the heterozygote is the sum of the effects of the two alleles individually. Overdominance is when the heterozygote is expressed at a greater level than the homozygous dominant.

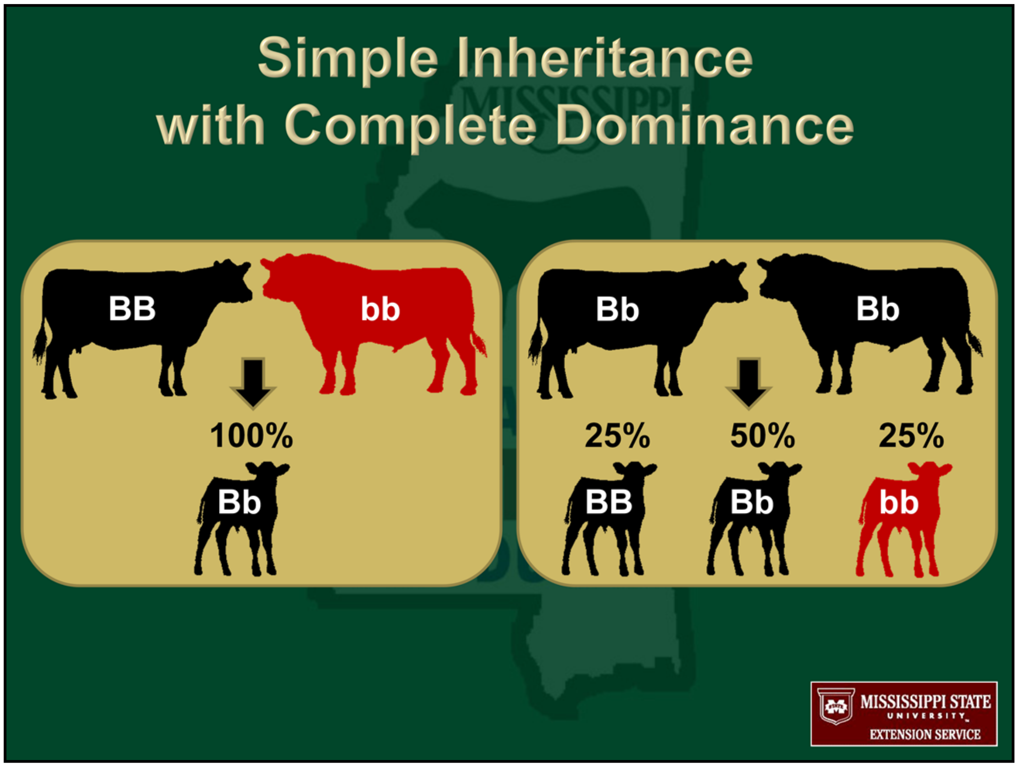
Traits Controlled or Largely Influenced by One Gene Pair

Trait	Type of Gene Action
Black, red color	Black (B) dominant to red (b)
Color in Shorthorns	Red (R) has no dominance over white (r)
Color dilution	Dilution (D) dominant to nondilution (d)
Pigmentation, albino	Normal pigmentation (A) dominant to albino (a)
Polled, horned condition	Polled (P) dominant to horned (p) in British breeds
Snorter dwarf, normal size	Normal size (D) dominant to dwarf (d)
Hypotrichosis (short hair/hairlessness), normal	Normal (H) dominant to hypotrichosis (h)
Hydrocephalus, normal	Normal (H) dominant to hydrocephalus (h)
Osteopetrosis (marble bone disease), normal	Normal (O) dominant to osteopetrosis (o)
Syndactyly (mulefoot), normal	Normal (S) dominant to mulefoot (s)
Arthrogryposis (palate-pastern syndrome), normal	Normal (A) dominant to palate-pastern (a)
Double muscling, normal	Normal (D) dominant to double muscling (d)

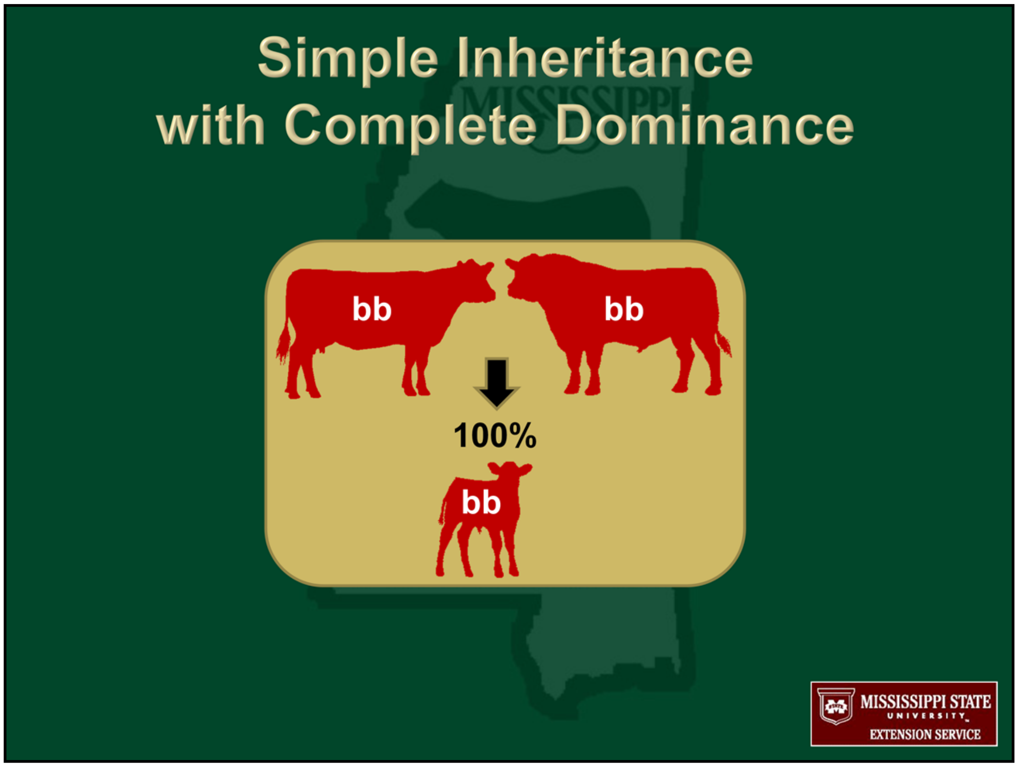
Several common cattle characteristics that appear to be controlled or largely influenced by a single pair of genes are listed in the table above. Black color is diluted to gray when DD or Dd exists with BB or Bb. Red color is diluted to yellow when DD or Dd exists with RR or Rr. This information is useful for selecting for a desired coat color or horn condition. It also helps in managing certain genetic defects such as snorter dwarfism, hydrocephalus, and others. With regard to double muscling, recessive inheritance shown here is typical of the British cattle breeds. In other breeds (for example, Piedmontese), the double muscling gene appears to be dominant. Other pairs of genes also modify the expression of double muscling.



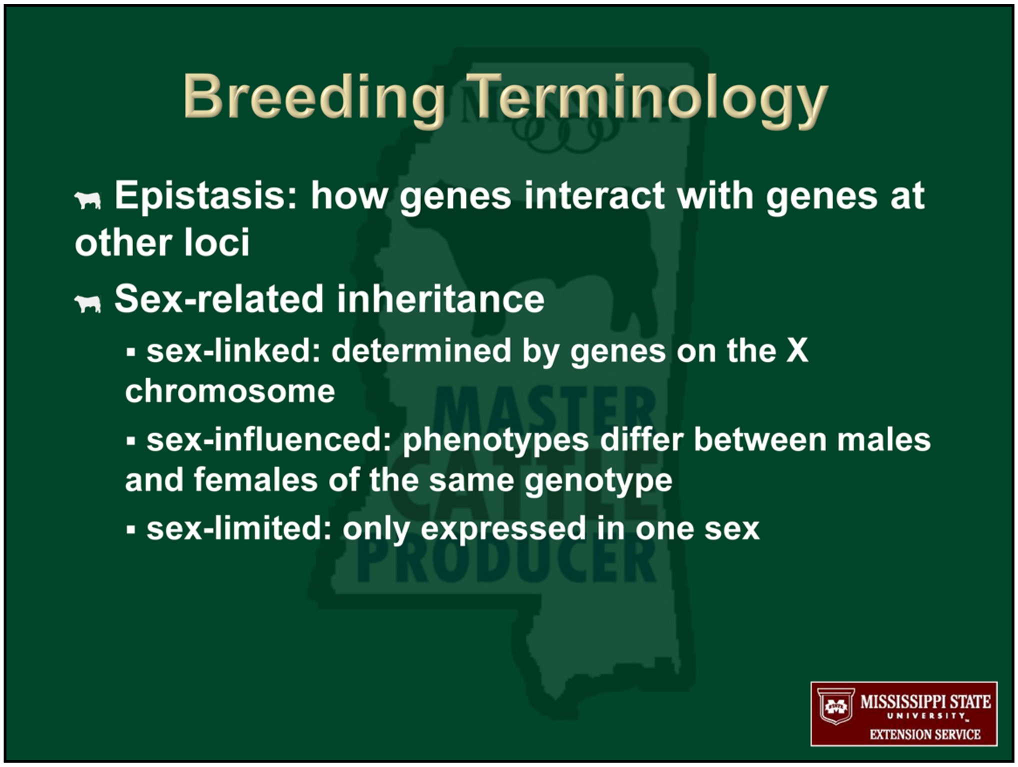
An example of simple inheritance with complete dominance is black versus red coat color in cattle. There are 3 different allele combinations possible in each parent: BB (homozygous dominant, black coat); Bb (heterozygous, black coat, carrier of red allele); or bb (homozygous recessive, red coat). If no red allele is present in either parent (BB x BB), then the mating will result in 100% of calves having a black coat phenotype and BB genotype. If homozygous dominant animal is mated to an animal with one red allele (BB x Bb), then the mating will result in 100% of calves having a black coat phenotype. However, 50% of these calves will have the BB genotype, and the other 50% will have the Bb genotype (red allele carriers). Note that the percentage breakdowns are based on probabilities and may differ slightly in a given calf crop. In addition, other pairs of genes also modify the expression of coat color.



If homozygous dominant animal is mated to homozygous recessive animal (BB x bb), then the mating will result in 100% of calves having a black coat phenotype and Bb genotype (red allele carriers). If two heterozygous animals are mated (Bb x Bb), then the mating will result in 25% of calves having the a black coat phenotype and BB genotype, another 50% having a black coat phenotype and Bb genotype (red allele carriers), and the remaining 25% having a red coat phenotype and bb genotype. Therefore, mating two cattle with black hair coats can result in calves with red coats if both parents are heterozygous for the black/red coat gene pair and both parents pass on the red allele to their offspring. Note that the percentage breakdowns are based on probabilities and may differ slightly in a given calf crop. In addition, other pairs of genes also modify the expression of coat color.

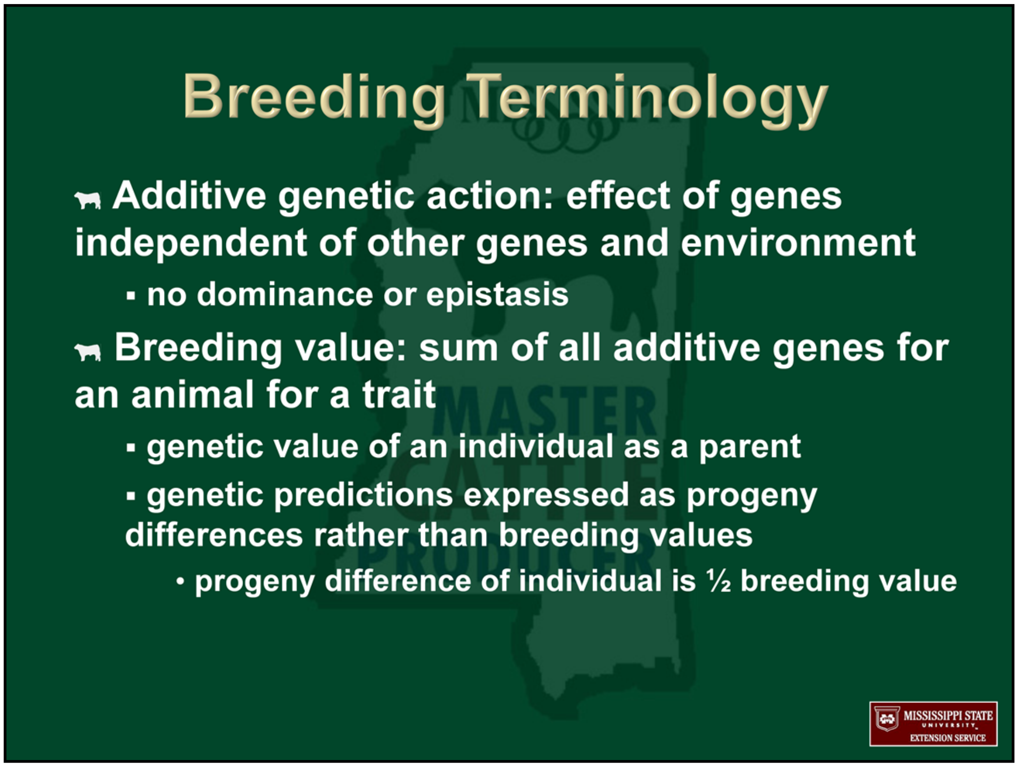


If both parents are homozygous recessive for the black/red hair coat gene pair (bb x bb), then the mating will result in 100% of calves having a red coat phenotype and bb genotype. Other genes, such as the diluter gene pair, may influence coat color phenotype beyond the influence of the black/red hair coat gene pair.

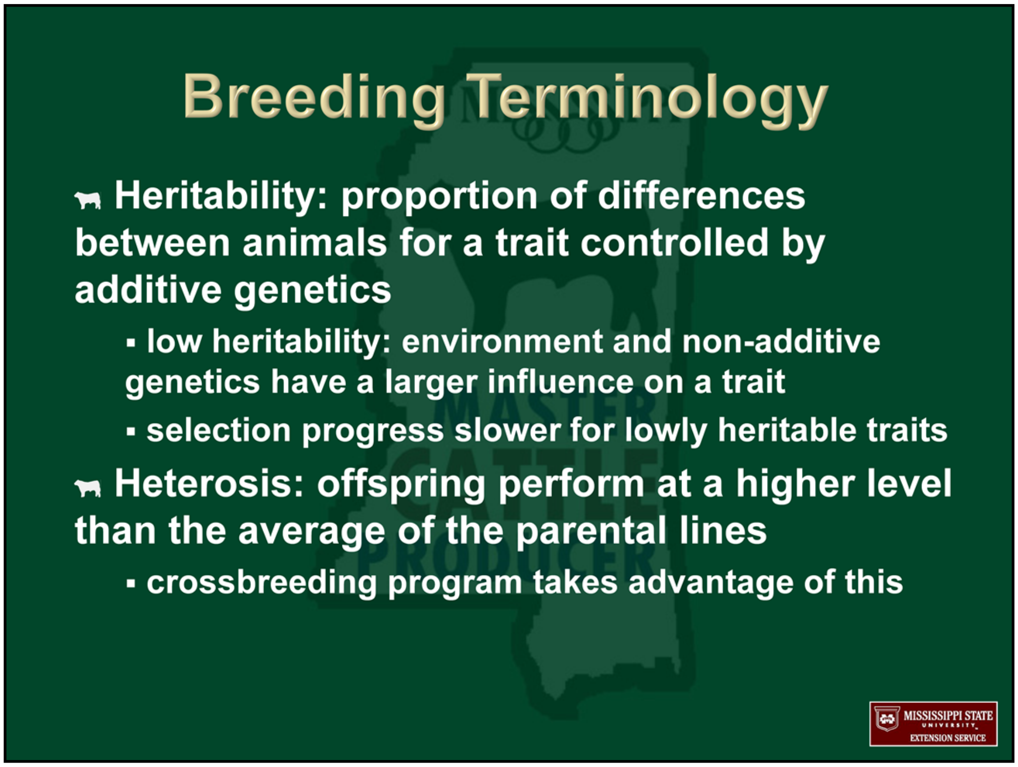


The term *epistasis* is used to describe how genes interact with genes at other loci. A classic example in cattle is the diluter genes in Charolais. When Charolais are crossed with red or black cattle, the offspring are off-white. This is the result of the diluter genes at different loci overriding the red/black genes.

Another type of inheritance interaction that can happen is *sex-related inheritance*. Sex-related inheritance can be categorized in three ways: sex-linked, sex-influenced, and sex-limited. *Sex-linked traits* are determined by genes located on the X chromosome. *Sex-influenced trait expression* occurs when phenotypes are different between males and females with the same genotype. An example in cattle of a sex-influenced trait would be scurs. In male cattle, the scur allele is dominant, and in female cattle it is recessive. Therefore, if a male or female are homozygous at the scur loci, then they will be scurred; if they are homozygous for the normal allele, then they will not be scurred. If they are heterozygous at the scur allele, then males will be scurred, but females will not. *Sex-limited traits* are those traits that can only be expressed in one sex or the other. Examples in cattle would be milking ability, which can only be expressed in females, and scrotal circumference, which can only be expressed in males.



All traits are controlled by two effects: genetics and environment. In actuality, the impact of genetics can be divided into two types of action: *additive* and *non-additive.* Most traits are controlled to some degree by both additive and non-additive genetic action. *Additive genetic action* refers to the effect of genes that is independent of other genes and the environment. There is no influence of dominance or epistasis. These genetic effects are additive in nature, which means for a polygenic trait, take one additive gene and add it to the effect of another additive gene, and so on, for all of the additive genes that influence that trait. The sum of all of those genes for an animal is called its *breeding value* for that trait. A breeding value is the transmissible genetic merit of an individual, or the value of that individual as a parent. In the United States and Canada, genetic predictions are expressed as progeny differences rather than as breeding values. Because any parent contributes only half the genes in any one offspring, the progeny difference of an individual is half of its breeding value. In beef cattle breeding, breeders can take advantage of additive genetics through selection decisions.



The proportion of differences observed between animals for a trait that is controlled by additive genetics is called *heritability*. For example, yearling weight has a heritability of 0.40, which means that 40% of the differences observed in yearling weights between cattle in a herd are caused by additive genetic effects. If a trait has a low heritability, this indicates that non-additive genetic effects and/or the environment have a much larger influence on that trait. High heritability indicates that additive genetics play a relatively large role in the trait. The level of heritability in a trait will have an impact on selection decisions. Progress tends to be much slower in lowly heritable traits when attempting change through selection. The higher the heritability, the more rapid progress can be made through selection.

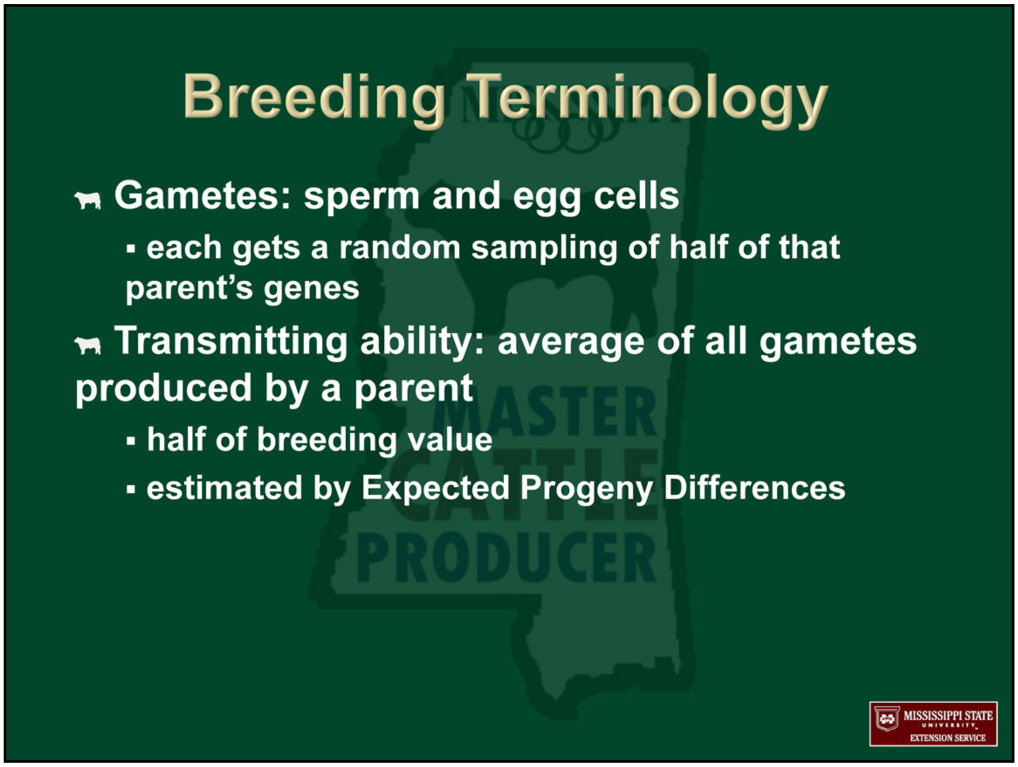
Epistasis and genetic-environmental interactions are difficult to account for, but dominance can be taken advantage of through a crossbreeding program. Pure breeds or lines of cattle have been developed over time through selection and inbreeding. Both of these practices increase the level of homozygosity in that breed; i.e., animals tend to have the same alleles at a locus. But this homozygosity will be different in other breeds or lines; i.e., animals in other lines tend to have a greater proportion of other alleles. Therefore, when these breeds or lines are crossed, there is a great increase in number of loci for which the offspring will be heterozygous. For polygenic traits, the dominant alleles are often the advantageous alleles. With complete dominance, there are no differences in performance between the homozygous dominant and heterozygous individuals. The result is that instead of the offspring performing average to the parental lines, as would be the case with additive genetics, they perform at a higher level than the average of the parental lines. The term for this increase in productivity is called *heterosis*. Heterosis tends to be highest for lowly heritable traits (such as reproduction) because these traits tend to have larger non-additive effects, and lowest for highly heritable traits (such as carcass traits). Crossbreeding might result in relatively small amounts of heterosis for a given trait, but these effects tend to accumulate to produce large increases in overall productivity. In some instances, a portion of this advantage is passed on to future generations, but to optimize the benefits, a crossbreeding program should be implemented.

Trait Heterosis and Heritability

Trait	Heterosis	Heritability
Maternal ability	High (10 to 30%)	Low
Reproduction		
Health		
Cow longevity		
Overall cow productivity		
Growth rate	Medium (5 to 10%)	Medium
Birth weight		
Weaning weight		
Yearling weight		
Milk production		
Carcass/end product	Low (0 to 5%)	High
Skeletal measurements		
Mature weight		

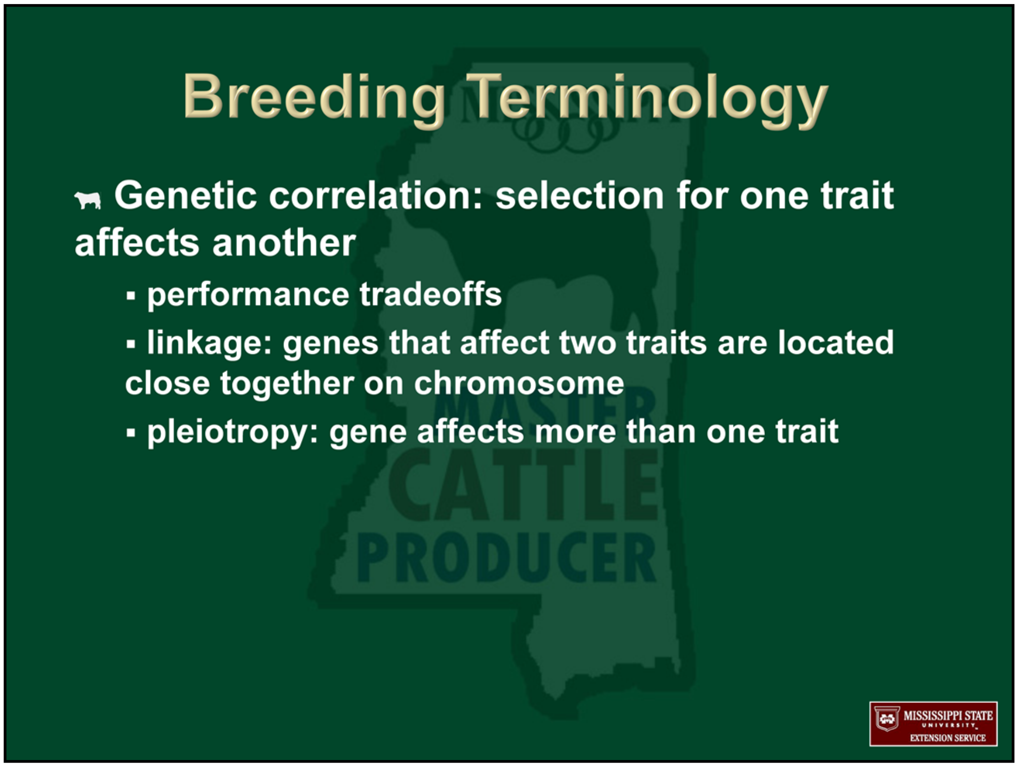
The table above shows the relative levels of heterosis and heritability for several biological traits of importance. Reproductive traits may be best improved through planned crossbreeding programs because of their high heterosis, but they may be more difficult to address through individual animal selection and culling due to their low heritability. Carcass traits, on the other hand, respond better to selection than crossbreeding programs because of their relatively low heterosis and high heritability.

Use selection in conjunction with crossbreeding to take advantage of both heterosis and heritability. To do this, select sires carefully in order to improve traits with high heritability. Then use a well-planned crossbreeding program in order to use heterosis effectively.



Both the sire and the dam pass on half of their genetics to their offspring. Sperm and egg cells are called *gametes*. Each gamete that a parent produces gets a random sampling of that parent’s genes. For a single gene, a heterozygous *Zz* animal produces 50% *Z gametes* and 50% *z gametes*. That means that there is variation in the genetic makeup of the gametes produced, which is termed *Mendelian sampling.* Mendelian sampling can be clearly observed by comparing full-sibs, and humans are perfect examples. The fact that male and female children can be born to the same parents is one example of Mendelian sampling. Now compare brothers and sisters within a family; there are often similarities because full sibs have half of their genes in common on average, but there are also differences, which can be dramatic. An example in cattle would be to compare flush-mates in an embryo transfer program; there is often variation in these full-sibs, even when raised in similar environments. Because only half of each parent’s total genetic material is in each gamete, then the average of all gametes produced is half of their breeding value. This is termed the parent’s *transmitting ability.*

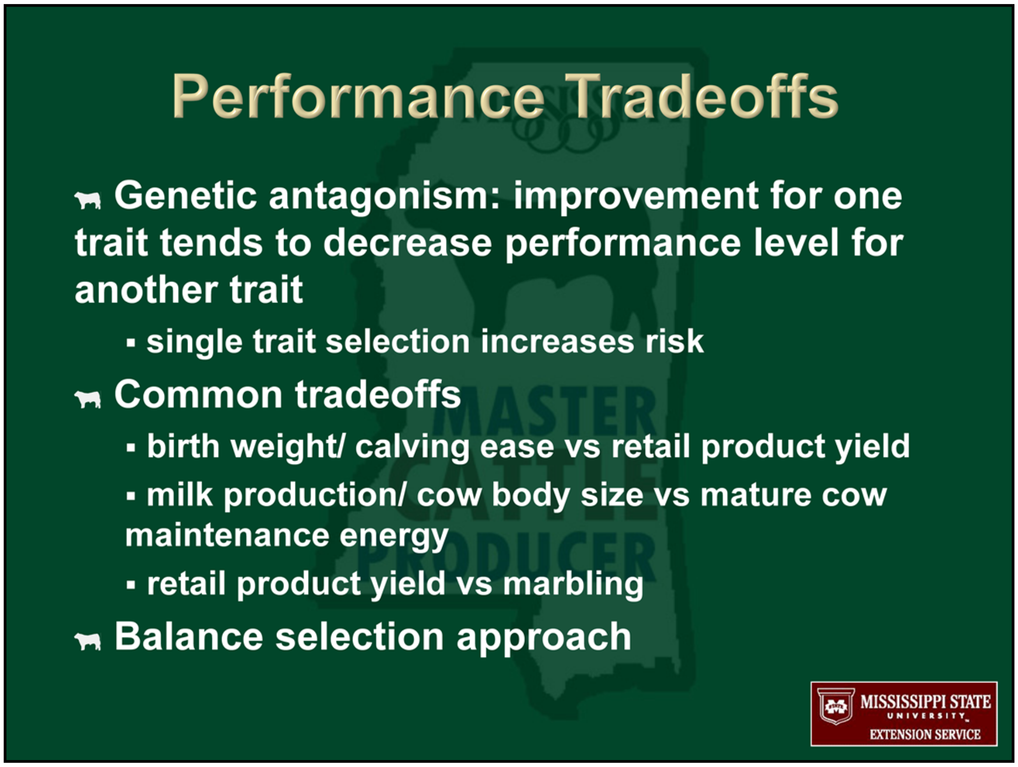
Expected Progeny Differences (EPD) are estimates of an animal’s transmitting ability and will be discussed in detail later. Selection decisions are made to change the additive genetics in the herd because additive genetics are passed on from one generation to the next; animals with high EPD tend to have alleles with positive additive effects on the trait for a larger number of loci.



Another genetic effect that is important when making selection decisions is *genetic correlations*. A genetic correlation occurs when selecting for one trait and another trait is affected. There are two ways that traits can be genetically correlated: linkage and pleiotropy. *Linkage* is when genes that affect two traits are located close together on the chromosome. In that case, they do not segregate randomly but tend to segregate similarly (the closer together, the less random the segregation). *Pleiotropy* is when a gene has an effect on more than one trait. It is easy to understand that some of the genes that impact weaning weight are also going to impact yearling weight and birth weight; this is an example of pleiotropy.

With a positive genetic correlation, successful selection for one trait will result in an increase in the other trait as well. With a negative genetic correlation, successful selection for one trait will result in a decrease in the other trait as well.

The effect of one trait on the other can be either complementary or disadvantageous. Here is an example of a complementary genetic correlation: as selections are made for increased weaning weight, yearling weight is also increased. An example of a disadvantageous correlation would be: as selections are made for increased weaning weight, birth weight also increases. Genetic correlations work the same, regardless of which trait is being selected for. In other words, as selections are made to decrease birth weights, weaning and yearling weights are usually decreased, too.

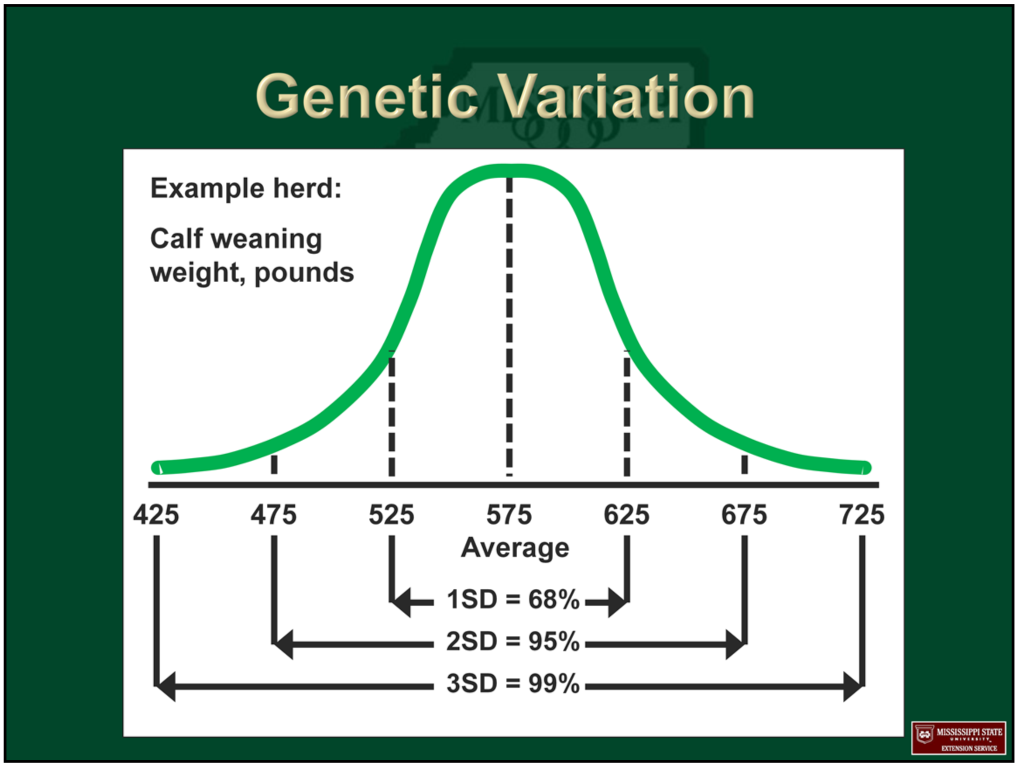


In addition to considering optimum levels of individual traits, it is important to be aware of performance tradeoffs among traits. There are genetic antagonisms in beef production where improvement for one trait tends to decrease the level of performance for another trait. Single trait selection puts the herd at risk for negative production consequences from genetic antagonisms. Common performance tradeoffs include birth weight/ calving ease versus retail product yield, milk production/ cow body size versus mature cow maintenance energy, and retail product yield versus marbling.

For genetic progress to be made within the herd, animal selection should not be based solely on one trait such as birth weight or calving ease. There are performance tradeoffs that must be considered. Birth weight is highly, positively correlated to weaning and yearling weights. Selection for increased growth rate may increase weight at all ages, including birth, while selection for low birth weight alone may decrease weaning and yearling weights. Make sure that, by selecting a calving ease bull, not too much ground is given up in these other economically relevant traits. Easy-calving, high growth sires are available that break the rules for the genetic antagonism between birth weight and growth. Try to strike a balance among several economically relevant traits, and avoid selecting for extremes.

Evaluating milk production versus mature cow maintenance energy is a commonly encountered selection decision where performance tradeoffs are considered. As milk production increases, more energy, protein, and other nutrients are leaving the beef female and being transferred to the suckling calf through the milk. This benefits the calf but also increases the dam’s nutrient requirements. If these increased nutritional needs are not met, then the lactating cow or heifer may lose body condition. In turn, reproductive rates can be negatively impacted if body condition drops below moderate levels.

As cow body size increases, larger quantities of nutrients are required. A higher milking cow, on the other hand, requires a diet that is higher in both quantity and quality. Because high-milking beef females often cannot consume enough extra low-quality forage and feed to meet added nutrient demands, high genetic milking potential may not match up well to a low quality diet. Of course, increased nutritional demands resulting from high milk production or larger body size can be met with a proper feeding program, but expenditures for forages and supplemental feedstuffs often increase to meet these demands. Optimizing milk production levels with nutritional program costs is a balancing act.



Many pairs of genes influence most economically important traits in beef cattle. This *genetic variation*, along with different environmental effects, causes considerable variation in cattle traits. High levels of production are possible with exceptional genetic and environmental conditions. These extremely high levels of productivity are usually not economically feasible because maximum profitability is reached before maximum levels of productivity. Differences in productivity are observable even under similar environmental conditions. It is not uncommon for there to be weaning weight differences of over 100 pounds in calves within the same herd.

Many economically important traits in beef cattle show continuous variation primarily because many pairs of genes control them. As these genes are expressed and as the environment influences these traits, large differences in the performance of cattle for any one trait are usually observed and measured. Traits that are continuous usually experience a normal distribution, meaning that when data are plotted, they form a bell-shaped curve.

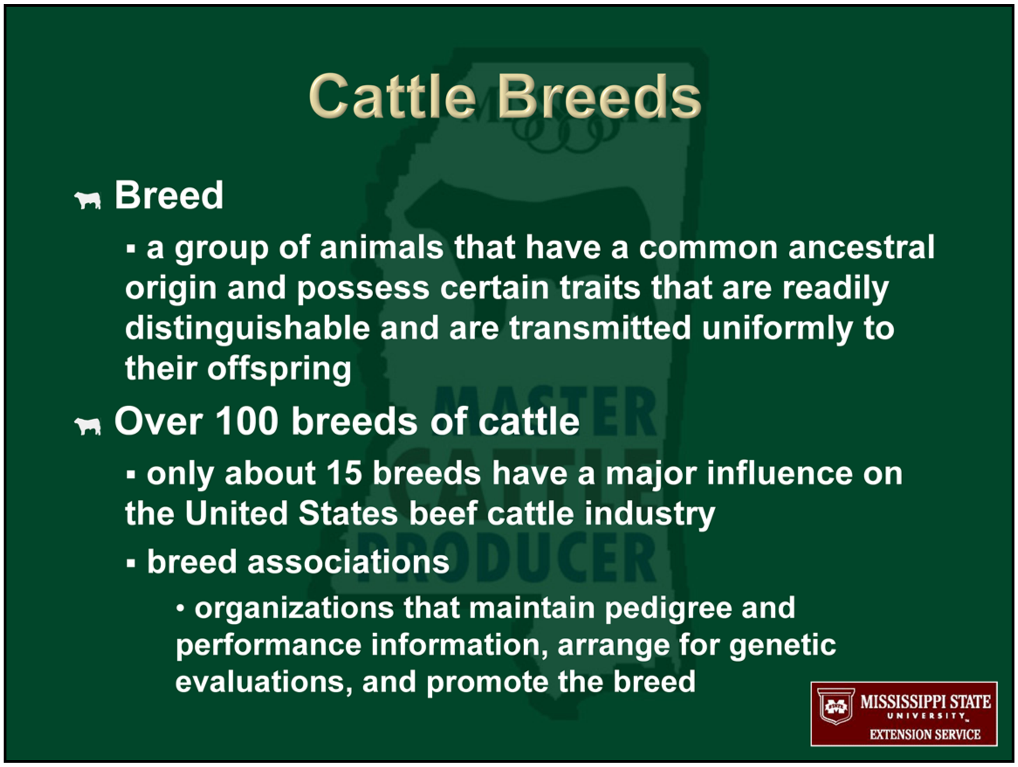
For example, if calves are weighed at weaning (approximately 205 days of age) in a single herd, there would be considerable variation in the calves' weights. Distribution of calf weaning weights would be similar to the example shown in the figure above. The bell-shaped curve distribution demonstrates that most of the calves are near the herd average (575 pounds), with relatively few calves having extremely high or low weaning weights when compared at the same age.

Standard deviation (SD) is a statistical measurement which describes the variation of differences in a data set. In the example above, the SD for weaning weight for this herd is 50 pounds. Using the herd average weaning weight and standard deviation, the variation in weaning weight is shown in the figure above.

575 lb ± 1 SD (50 lb) = 525 to 625 lb (68% of calf weaning weights are in this range)

575 lb ± 2 SD (100 lb) = 475 to 675 lb (95% of calf weaning weights are in this range)

575 lb ± 3 SD (150 lb) = 425 to 725 lb (99% of calf weaning weights are in this range)



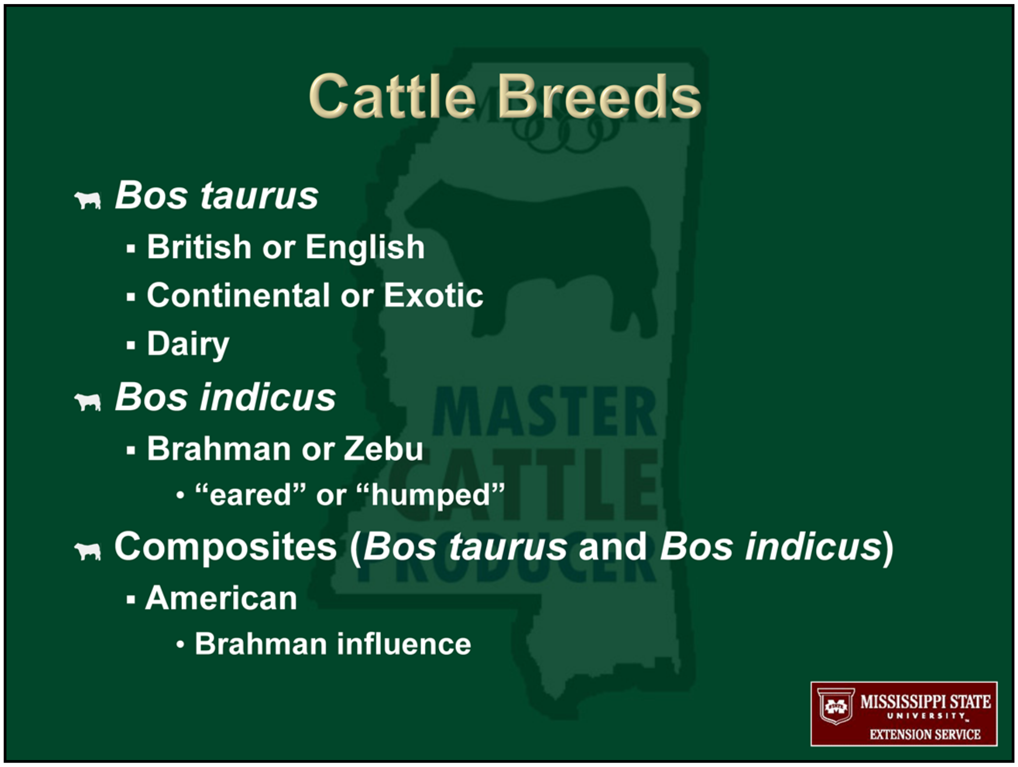
Breeds consist of animals with a common origin and selection history. Animals within a breed have physical characteristics that distinguish them from other breeds or groups of animals within the same species. Breeds offer important sources of genetic variation. Breed differences exist due partly to natural and artificial selection pressures. Each breed has something to offer for improved production and provides various uses under vastly different environments. There are over 100 breeds of cattle. However, only about 15 breeds have a major influence on the United States beef cattle industry. Detailed information on breeds of cattle is available at http://www.ansi.okstate.edu/breeds/cattle/. A breed association is an organization that maintains pedigree and performance information and arranges for timely genetic evaluation of animals within that breed. Breed associations also establish regulations for registration of animals, promote the breed, and advance the interests of breeder members.

Major U.S. Beef Breeds

Breed	2008 Registrations	1998 Registrations	1988 Registrations
Angus	333,766	252,969	143,520
Beefmaster	14,692	45,750	35,481
Brahman	8,500	15,000	16,425
Brangus	29,643	27,000	26,100
Charolais	65,954	49,223	39,605
Chianina	9,756	7,800	7,427
Gelbvieh	34,405*	29,252	17,545
Hereford	63,943	82,000	172,361
Limousin	28,928	61,462	53,136
Maine Anjou	10,386	10,513	4,909
Red Angus	48,061	37,428	14,004
Salers	6,552	10,286	18,482
Santa Gertrudis	7,500	11,000	18,003
Shorthorn	15,715	16,406	15,113
Simmental	45,500	51,390	75,273

*Source: National Pedigreed Livestock Council; *2007 data*

The National Pedigreed Livestock Council data from their member organizations show the 15 largest U.S. beef cattle registries recorded at least 6,500 animals each in 2008. Registrations of those 15 largest associations, and comparative numbers from 10 and 20 years ago, are shown above. Angus and Red Angus together had close to 50% of registrations. Breeds with the highest percentage increases from 1998 to 2008 were Charolais, Angus, Red Angus, and Chianina. Breeds with the highest percentage decreases were Beefmaster, Limousin, Brahman, and Salers. Purebred registrations are about 2% of the nation's beef cow numbers, which has not changed much over the years. According to the Council's 2007 report, the number of cattle registered per active association member is as low as 3 head. The larger associations generally register more per member. However, even the highest figure is 28 registered per member.



Bos taurus are a subspecies of cattle of western Asian origin but are often referred to as "European". Most breeds commonly found in the United States and Canada, and their European ancestors, belong to this group. *Bos taurus* cattle include British, Continental, and dairy breeds.

British or English breeds were developed in the British Isles. They are noted for moderate frame size, fleshing ability, carcass quality, and maternal ability. Examples of British breeds include Angus, Hereford, Red Angus, and Shorthorn.

Continental breeds include Charolais, Gelbvieh, and Simmental. Continental or exotic breeds are noted for high growth rates, heavy muscling, large frame, and carcass cutability or Yield Grade.

Dairy breeds can be used in crossbreeding programs to increase milk yield in replacement females or as sires bred to heifers for calving ease. They are also used as sires for niche markets such as Jersey-sired calves for rodeo stock. Holsteins are another dairy breed example.

Bos indicus are a subspecies of cattle of south Asian origin. They are often known as Zebu and have prominent humps forward of the shoulder. The Brahman breed is one example in the United States. Brahman or Zebu breeds are *Bos indicus* cattle noted for heat tolerance, mothering ability, and insect resistance. These breeds are often referred to as "eared" or "humped" cattle.

Bos indicus x *Bos taurus* crosses are viable, fully fertile, and exhibit large amounts of heterosis. American or Brahman composite "breeds" are composed of a combination of *Bos taurus* breeds and Brahman. American breeds are predominantly present in the southern United States. Examples of American breeds are Beefmaster and Santa Gertrudis.

Breed Performance Levels for Various Traits

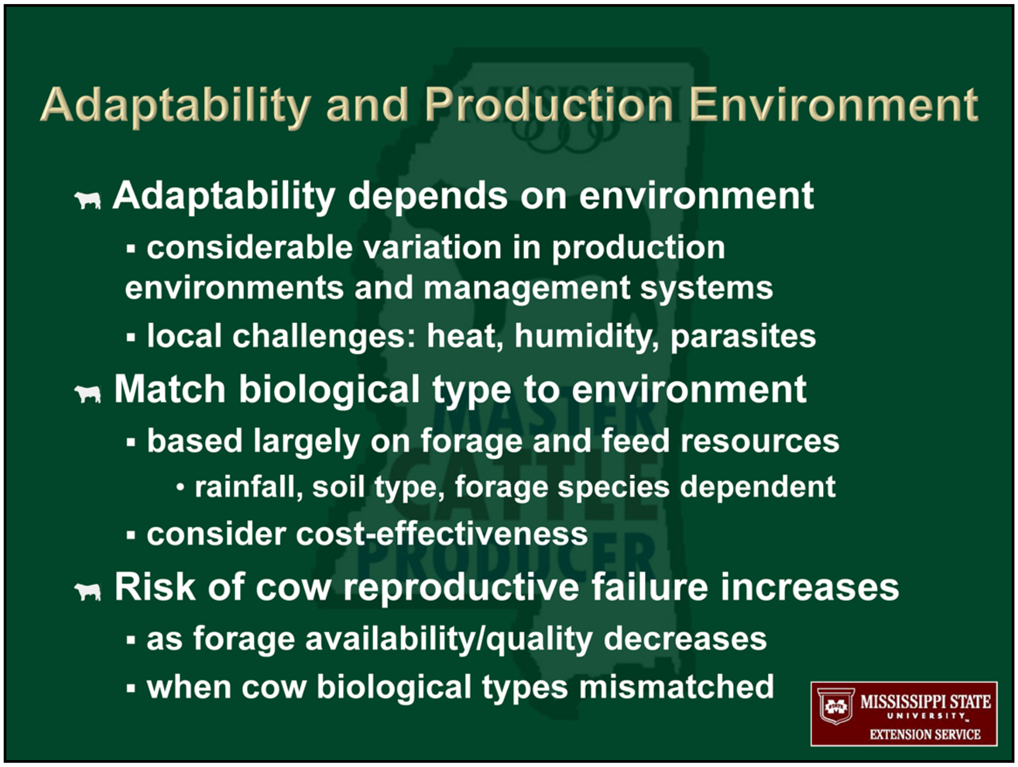
Breed	Growth and Mature Size	Lean to Fat Ratio	Marbling (Intramuscular Fat)	Tenderness	Age at Puberty	Milk Production	Tropical Adaptation
Angus	XXXX	XX	XXXX	XXX	XX	XXX	X
Beefmaster	XXXX	XXX	XX	XX	XXX	XXX	XXX
Brahman	XXXX	XXXX	XX	X	XXXXX	XXXX	XXXX
Brangus	XXXX	XXX	XXX	XX	XXX	XXX	XXX
Charolais	XXXXX	XXXXX	XX	XX	XXXX	XX	X
Chianina	XXXXX	XXXXX	XX	XX	XXXX	X	XX
Gelbvieh	XXXX	XXXX	X	XX	XX	XXXX	X
Hereford	XXXX	XX	XXX	XXX	XXX	XX	X
Limousin	XXX	XXXXX	X	XX	XXXX	X	X
Maine Anjou	XXXXX	XXXX	XX	XX	XXX	XXX	X
Red Angus	XXXX	XX	XXXX	XXX	XX	XXX	X
Salers	XXXX	XXXX	XX	XX	XXX	XXX	X
Shorthorn	XXXX	XX	XXXX	XXX	XX	XXX	X
Simmental	XXXXX	XXXX	XX	XX	XXX	XXXX	X

Increasing numbers of Xs indicate relatively higher value Source: Cundiff, 2003

Studies have been undertaken to examine the genetic merits of various breeds in a wide range of production environments and management systems. Researchers at the U.S. Meat Animal Research Center (MARC) have conducted the most comprehensive studies of sire breed genetic merit via their long-term Germplasm Evaluation (GPE) project. This project evaluated more than 30 sire breeds in a common environment and management system. One of the major outcomes of the GPE project was the characterization of sire breeds for a wide variety of economically important traits. Because all of the animals were in a common management system and production environment, the average differences observed in performance were due to genetic differences. The results of this project appear in the table above.

British breeds such as Hereford, Angus, Red Angus, and Shorthorn, are moderate in growth and mature size, are relatively higher in carcass fat composition, reach puberty at relatively younger ages, and are moderate in milk production. Continental European breeds, with a heritage that includes milk production, including Simmental, Maine-Anjou, and Gelbvieh, tend to have high growth rates, larger mature sizes, moderate ages at puberty, and relatively high levels of milk production. Another group of Continental European breeds, with a heritage of meat and draft purposes, including Charolais, Chianina, and Limousin, tend to have high growth rate, large mature size, older ages at puberty, very lean carcasses, and low milk production.

There is a wide amount of variation in performance within breeds. Therefore, even though a breed may tend to be higher or lower than another breed for a particular trait, there will be cattle in both breeds that defy these trends.



Environments and management systems vary tremendously throughout the U.S. beef cattle herd. Relocation of cattle exposes cattle to different environmental challenges and management schemes. Cattle genotype (genetic make-up) interacts with environment. In other words, within an environment, some cattle are better adapted to perform optimally in that environment. With the relatively high temperatures and humidity, parasite loads, and related production challenges common in Mississippi, adaptability is an important topic for Mississippi beef cattle producers.

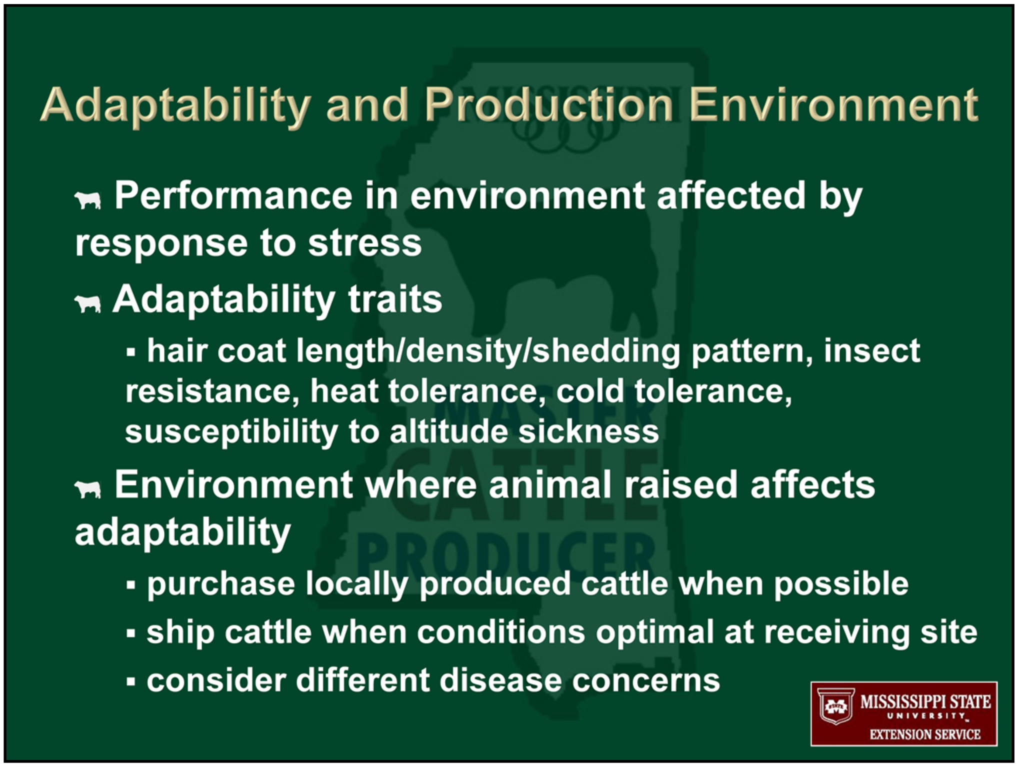
Adaptability of different biological types of cattle varies depending on the environment where they are expected to perform. For example, cows of large mature size and high milk production will likely have below average reproductive performance in a poor grazing system with low amounts of available forage and high quality forage. Breakeven prices of weaned would then be high. These cows are best adapted to an environment with large amounts of good quality forage (typically a high rainfall area such as the Southeastern U.S.) and may require supplemental feed to achieve satisfactory reproductive performance. As forage availability becomes more limited, the risk of reproductive failure increases due to mismatched biological type (for example, cows that are too large and/or milk too heavily for their production environment). Match biological types to their most cost-effective environments. Biological type varies both by breed and within breed.

Matching Genetic Potential to Production Environment

Production Environment		Traits					
Feed Availability	**Stress**	**Milk Production**	**Mature Size**	**Ability to Store Energy**	**Resistance to Stress**	**Calving Ease**	**Lean Yield**
High	Low	M to H	M to H	L to M	M	M to H	H
	High	M	L to H	L to H	H	H	M to H
Medium	Low	M to H	M	M to H	M	M to H	M to H
	High	L to M	M	M to H	H	H	H
Low	Low	L to M	L to M	H	M	M to H	M
	High	L to M	L to M	H	H	H	L to M
Breed role in terminal crossbreeding systems							
Maternal		M to H	L to H	M to H	M to H	H	L to M
Paternal		L to M	H	L	M to H	M	H

L = low, M = medium, H = high

One of the challenges of breed selection is the interaction of the animal's genotype with its production environment. The table above describes common production environments by level of feed availability and environmental stress and lists optimal levels of a variety of performance traits. Here, feed availability refers to the regular availability of grazed or harvested forage and its quantity and quality. Environmental stress includes parasites, disease, heat, and humidity. Ranges for mature cow size are low (800 to 1,000 lb), medium (1,000 to 1,200 lb), and high (1,200 to 1,400 lb). Clearly, breed choices should be influenced by the production environment in which they are expected to perform.

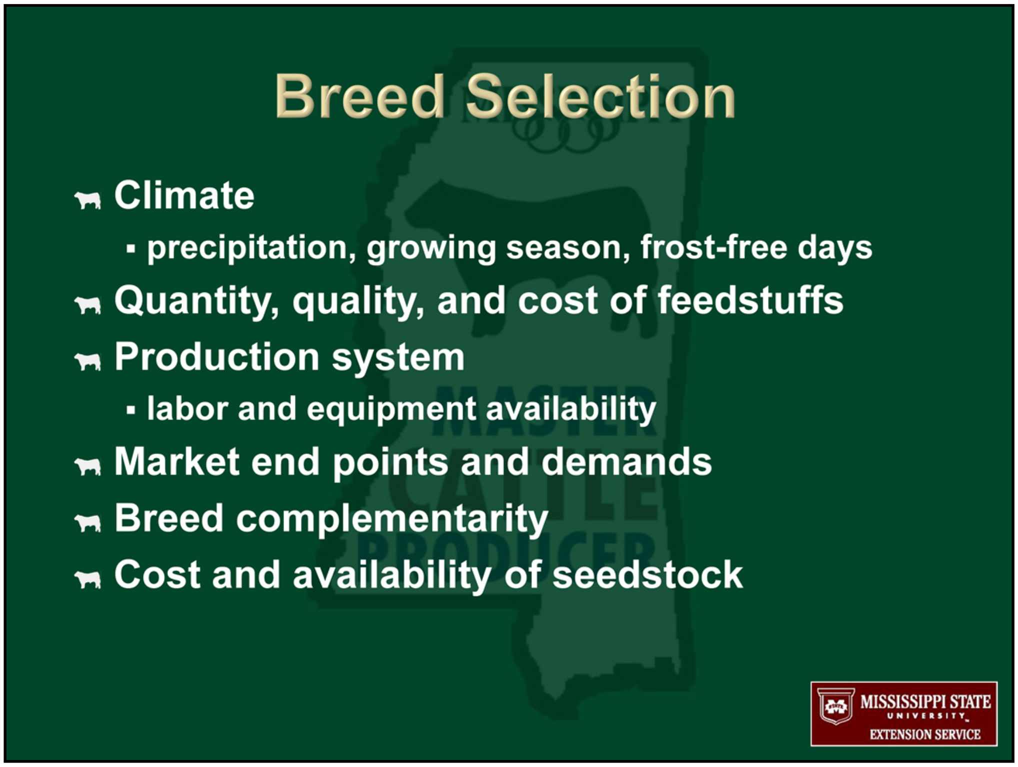


Cattle performance in an environment is affected by their response to stress. Stressors include nutrition, disease, weather/ climate, and topography. Nutritional stressors, for example, may include the presence of toxic plants in grazing areas and forage quantity or nutrient quality limitations. Adaptability refers to how well cattle handle these environmental stresses. Examples of traits of interest related to cattle adaptability include heat tolerance, hair shedding, and susceptibility to high-altitude disease. Both breed differences and differences among cattle within a breed are relevant when considering how "adapted" cattle are to an area. If resources used to support reproduction and survival are compromised, then rapidly increasing genetic potential for production could occur while decreasing genetic merit for adaptation. A focus on selection for adaptability is essential within current production systems and environments. Evidence supports the idea that a slick hair coat contributes to heat tolerance in beef cattle.

Specific steps can be taken to minimize the risk of adaptation problems in relocated cattle. First, purchase local produced cattle when possible. Do not sacrifice genetics when doing this. However, with use of artificial insemination and embryo transfer in many local herds, it is likely that there are sources of desirable and even superior cattle genetics nearby. Advantages to purchasing local genetics include reduced freight costs, local customer service, and adaptability benefits.

With regard to adaptability, numerous studies have shown real performance differences in cattle raised in a region compared with cattle introduced into a region. For example, comparisons of Florida-born Hereford bulls versus Montana-born Hereford bulls revealed that in Florida the locally born and raised bulls had a 33-pound advantage at weaning over the bulls introduced into Florida from Montana. Similarly, during the spring and summer months in Florida, bulls from Florida experienced lower decreases in testicular volume, semen volume, and sperm motility than Montana bulls. The Florida bulls increased sperm concentration, while the Montana bulls decreased sperm concentration. Thus, environment affected the reproductive development of Montana bulls in Florida.

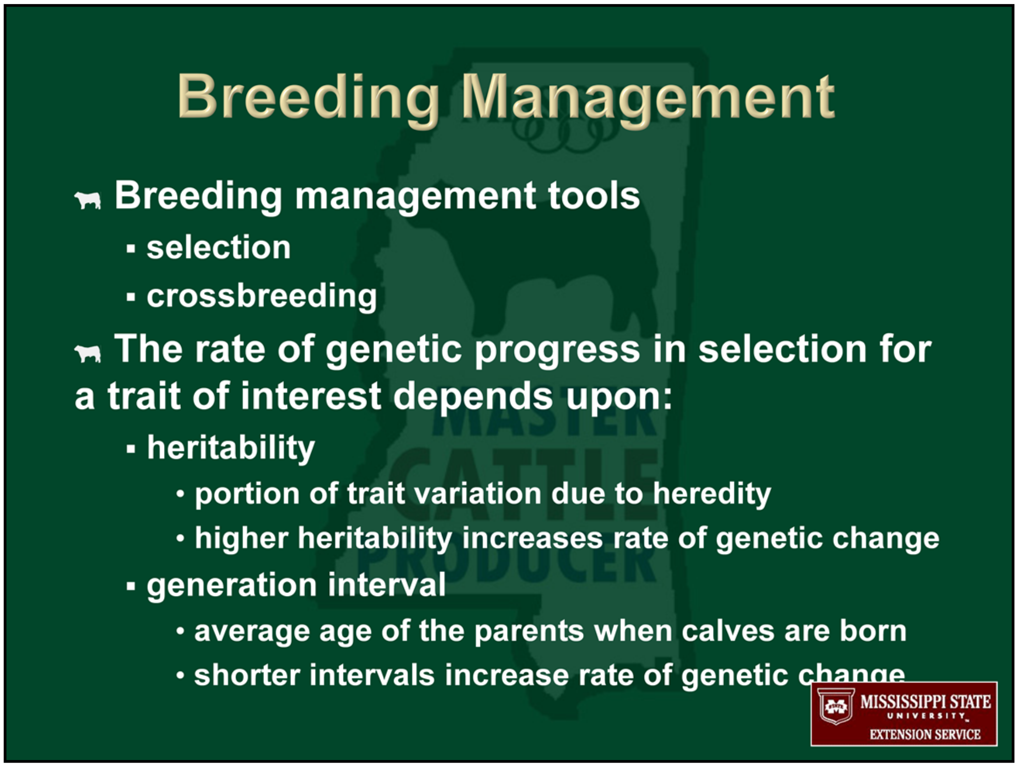
Try to ship cattle from other areas to the local ranch when conditions are optimal at the local site. For instance, bring cattle in during periods of high forage availability and quality and low parasite loads. Avoid transporting cattle to the local ranch during adverse weather conditions including periods of high ambient temperature. Introduce cattle to new environments slowly. Start by placing them in small pens or traps and then monitor them carefully as they move to larger pastures. When purchasing "unadapted" bulls consider buying yearlings and continue their development in the new environment. This allows for social adaptation as well. Consider the health programs and disease exposure of cattle from other regions before purchase. Disease risks in distance locations may be different from local disease concerns.



Selection of appropriate breeds for a particular production system can be a challenging task. Consideration during the selection process should be given to a number of criteria including:

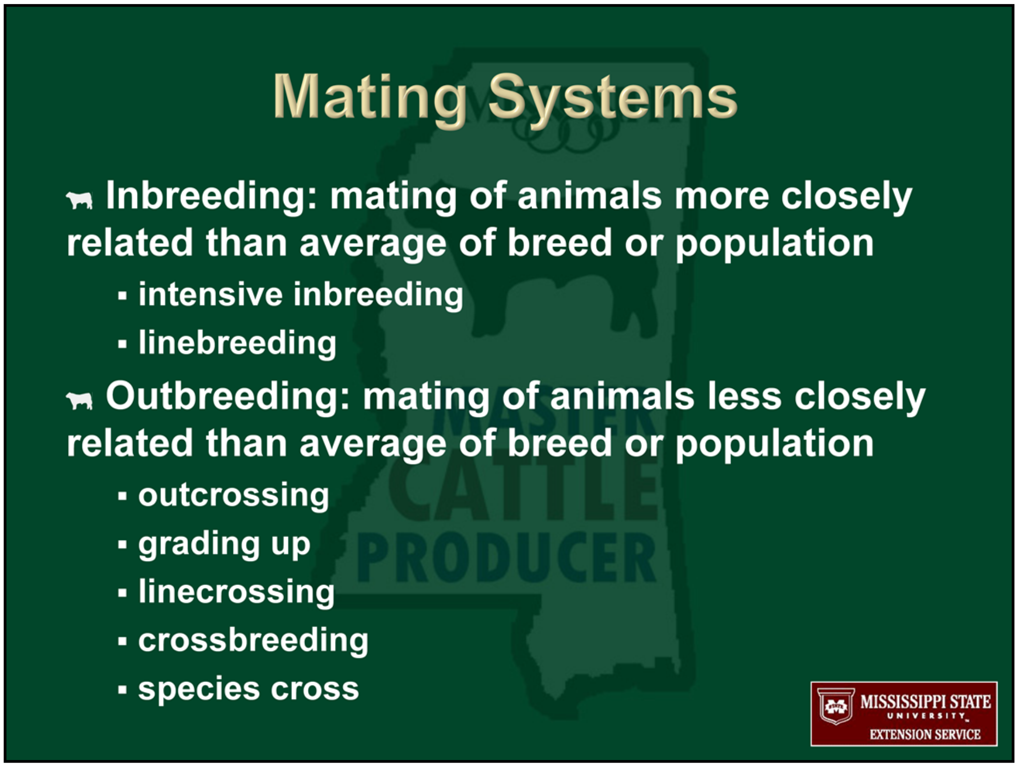
- climate (frost-free days, growing season, precipitation),
- quantity, quality, and cost of feedstuffs available,
- production system (availability of labor and equipment),
- market end points and demands,
- breed complementarity, and
- cost and availability of seedstock.

The selection of breeds and the genetics they contribute to the cowherd can have a large impact on profitability through the aggregate effects on each of the above criteria. Clearly, breeds need to be selected to fit a specific production system, whether that is selling replacement females, weaned feeder calves, or carcass components. For most producers, that production system should employ a structured crossbreeding system that utilizes two or more breeds. The breeds (and/or composites) chosen should produce calves that are appropriate for the market targeted. Moreover, the system and breeds included should provide a mechanism for the use of crossbred cows that are matched to the production environment in terms of mature size and lactation potential so as to capture the benefits of maternal heterosis. Selection of breeds that are too large and/or produce too much milk for the forage environment in which they are expected to produce may result in lower reproductive efficiency and increased supplemental feed costs. Selection of breeds provides an opportunity for the beef producer to impact both additive and non-additive genetics of the cowherd. Optimization of these two genetic components requires a disciplined approach to breed selection.



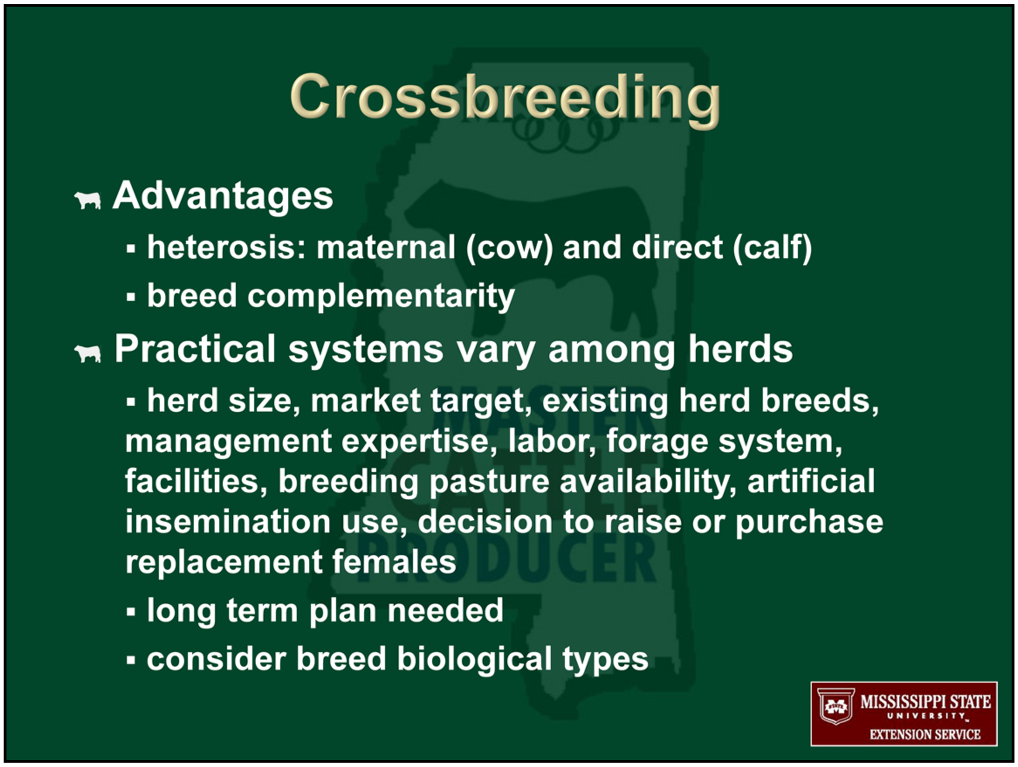
Breeding management tools include both selection and crossbreeding. The breeding management program of most seedstock producers is handled primarily through their selection practices. The exception would be seedstock producers who are producing F1 or composite sires. A sound breeding management program for most commercial cattle producers should include both selection and crossbreeding.

The rate of genetic progress or change in selection for a trait of interest depends upon the heritability of the trait and the generation interval. As heritability increases, the rate of genetic change improves. The generation interval is the average age of the parents when calves are born. Shorter generation intervals increase the rate of genetic change.



The two major systems of mating, based on relationship, are inbreeding and outbreeding. Inbreeding is the mating of animals more closely related than the average of the breed or population. The two different forms of inbreeding are intensive inbreeding and linebreeding. Intensive inbreeding is the mating of closely related animals whose ancestors have been inbred for several generations. Linebreeding is a mild form of inbreeding where inbreeding is kept relatively low while a high genetic relationship to an ancestor or a line of ancestors is maintained.

Outbreeding involves the mating of animals less closely related than the average of the breed or population. The five different forms of outbreeding are outcrossing, grading up, linecrossing, crossbreeding, and species cross. Outcrossing is the mating of unrelated animals within the same breed. Grading up is the mating of purebred sires to nondescript or grade females and their female offspring generation after generation. Linecrossing is the crossing of rather distinct lines (that may or may not be inbred) of the same breed. Crossbreeding is the mating of animals of different established breeds. Species cross is the crossing of animals of different species (for example, cattle to bison to result in beefalos).



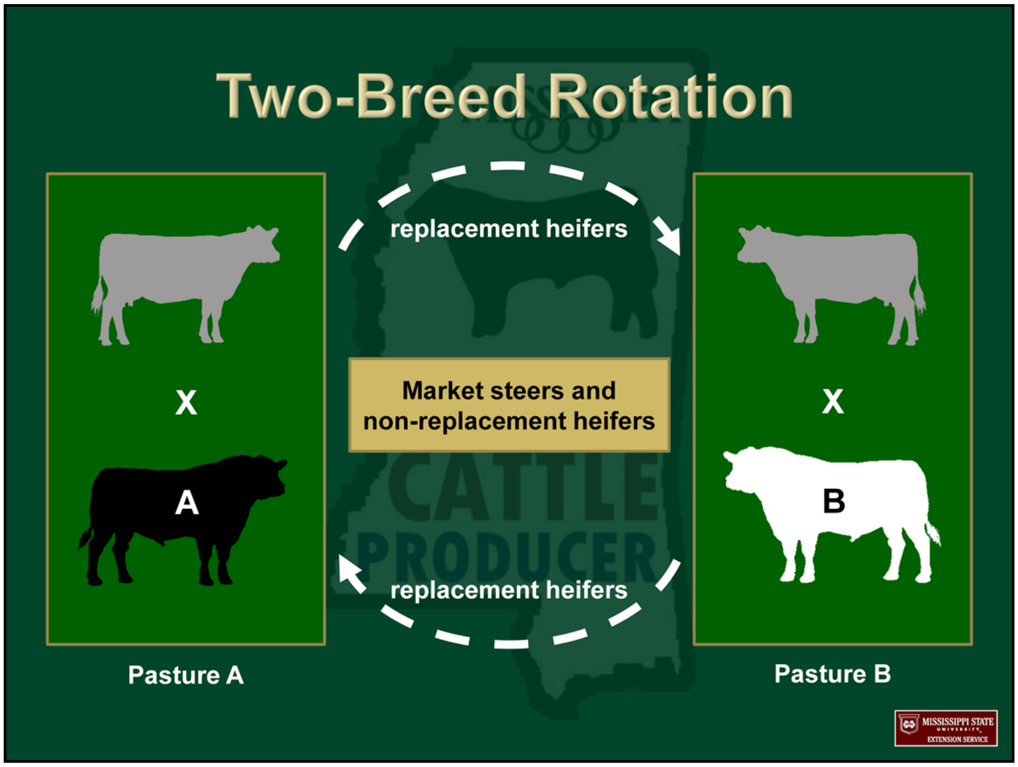
The use of crossbreeding offers two distinct and important advantages over the use of a single breed. First, crossbred animals have heterosis, or hybrid vigor. Second, crossbred animals combine the strengths of the parent breeds. The term “breed complementarity” is often used to describe breed combinations that produce highly desirable animals for a broad range of traits.

Heterosis refers to the superiority of the crossbred animal relative to the average of its straightbred parents. Heterosis generated through crossbreeding can significantly improve an animal’s performance for lowly heritable traits, such as reproduction and longevity. These traits respond very slowly to selection since a large portion of the variation observed in them is due to environmental factors and non-additive genetic effects, and a small percentage is due to additive genetic differences. Crossbreeding has been shown to be an efficient method to improve reproductive efficiency and productivity in beef cattle. Improvements in cow-calf production due to heterosis are attributable to having both a crossbred cow and a crossbred calf.

The production of crossbred calves yields advantages in both heterosis and the blending of desirable traits from two or more breeds. However, the largest economic benefit of crossbreeding to commercial producers comes from having crossbred cows. Maternal heterosis improves both the environment a cow provides for her calf as well as improves the reproductive performance, longevity, and durability of the cow. The improvement of the maternal environment, or mothering ability, a cow provides for her calf is manifested in the improvements in calf survivability to weaning and increased weaning weight. Crossbred cows exhibit improvements in calving rate of nearly 4% and an increase in longevity of more than one year due to heterosis. Heterosis results in increases in lifetime productivity of approximately one calf and 600 pounds of calf weaning weight over the lifetime of the cow.

Practical crossbreeding systems implemented in a commercial herd vary considerably from herd to herd. A number of factors determine the practicality and effectiveness of crossbreeding systems for each operation. These factors include herd size, market target, existing breeds in the herd, the level of management expertise, labor availability, grazing system, handling facilities and the number of available breeding pastures. In some instances the number of breeding pastures required can be reduced through the use of artificial insemination. Additional considerations include the operation’s decision to purchase replacement females or select and raise replacements from the herd. Purchasing healthy, well-developed replacement females of appropriate breed composition can be the simplest and quickest way for producers, especially small operators, to maximize maternal heterosis in the cowherd. Regardless of the crossbreeding system selected, a long-term plan and commitment to it are required to achieve the maximum benefit from crossbreeding.

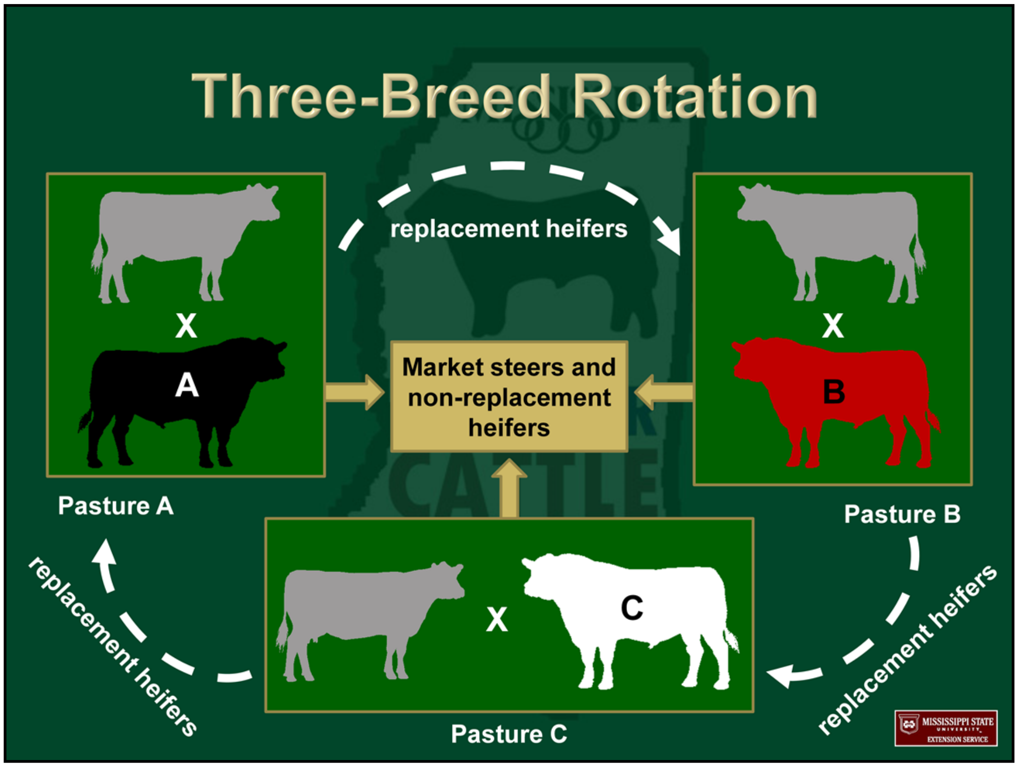
Breeds used in rotational systems should be of similar biological type to avoid large swings in progeny phenotype due to changes in breed composition. The breeds included have similar genetic potential for calving ease, mature weight and frame size, and lactation potential to prevent excessive variation in nutrient and management requirements of the herd. Using breeds of similar biological type and color pattern will produce a more uniform calf crop, which is more desirable at marketing time. If animals of divergent type or color pattern are used, additional management inputs and sorting of progeny at marketing time to produce uniform groups may be required.



A two-breed rotation is a simple crossbreeding system requiring two breeds and two breeding pastures. The two-breed rotational crossbreeding system is initiated by breeding cows of breed A to bulls of breed B. The resulting progeny (A*B) chosen as replacement females would then be mated to bulls of breed A for the duration of their lifetime. Note the service sire is the opposite breed of the female's own sire. These progeny are then one-quarter breed A and three-quarters breed B. Because these animals were sired by breed B bulls, they are mated to breed A bulls. Each succeeding generation of replacement females is mated to the opposite breed of their sire.

Initially only one breed of sire is required. Following the second year of mating, two breeds of sire are required. After several generations, the amount of retained heterosis stabilizes at about 67% of the maximum heterosis, resulting in an expected 16% increase in the pounds of calf weaning weight per cow exposed above the average of the parent breeds. This system is sometimes called a crisscross.

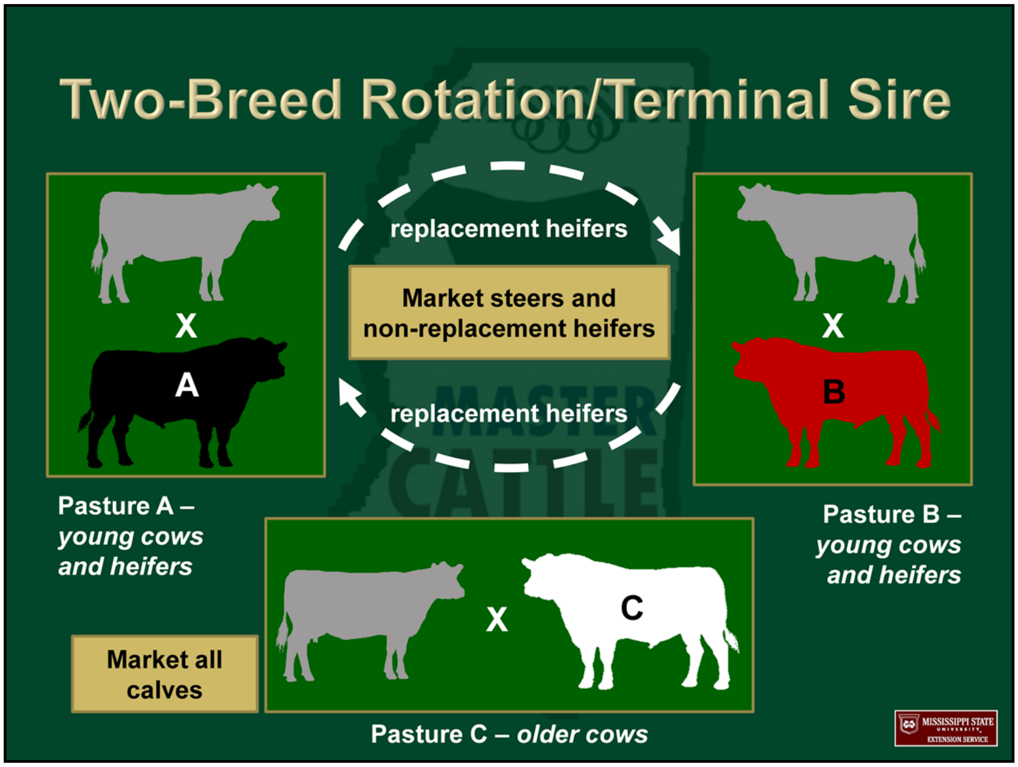
The minimum herd size is approximately 50 cows with each half being serviced by one bull of each breed. Scaling of herd size should be done in approximately 50 cow units to make the best use of service sires, assuming one bull per 25 cows. Replacement females are mated to herd bulls in this system, so extra caution is merited in sire selection for calving ease to minimize calving difficulty. Be sure to purchase bulls or semen from sires with acceptable calving ease (preferably) or birth weight EPD for mating to heifers. Alternatively, a calving ease sire(s) could be purchased to breed exclusively to first-calf heifers regardless of their breed type. The progeny produced from these matings that do not conform to the breed type of the herd should all be marketed.



A three-breed rotational system is very similar to a two-breed system in implementation with an additional breed added to the mix. A three-breed rotational system achieves a higher level of retained heterosis than a two-breed rotational crossbreeding system does. After several generations, the amount of retained heterosis stabilizes at about 86% of the maximum heterosis, resulting in an expected 20% increase in the pounds of calf weaning weight per cow exposed above the average of the parent breeds. Like the two-breed system, distinct groups of cows are formed and mated to bulls of the breed that represents the smallest fraction of the cows breed makeup. A cow will only be mated to a single breed of bull for her lifetime.

A minimum of three breeding pastures is required for a three-breed rotational system. Replacement females must be identified by breed of sire to ensure proper matings. A simple ear tagging system may be implemented to aid in identification. All calves sired by breed A bulls should be tagged with one color (e.g., red), the calves sired bulls of breed B should be tagged with a different color (e.g., blue), and the progeny of bulls of breed C tagged a third color (e.g., green). Then at mating time, all the cows with red tags (sired by breed A) should be mated to breed B bulls, cows with blue tags (sired by breed B) should be mated to breed C bulls, and, finally, all cows with green tags (sired by breed C) should be mated to breed A bulls.

The minimum herd size is approximately 75 cows with each one-third being serviced by one bull of each breed. Scaling of herd size should be done in approximately 75 cow units to make the best use of service sires, assuming one bull per 25 cows. Replacement females are mated to herd bulls in this system, so extra caution is merited in sire selection for calving ease to minimize calving difficulty. Be sure to purchase bulls or semen from sires with acceptable calving ease (preferably) or birth weight EPD for mating to heifers. Alternatively, a calving ease sire(s) could be purchased to breed exclusively to first-calf heifers regardless of their breed type. The progeny produced from these matings that do not conform to the breed type of the herd should all be marketed.



Two-Breed Rotational/Terminal Sire

The two-breed rotational with terminal sire system is sometimes called a rota-terminal system. It includes a two-breed rotational crossbreeding system of maternal breeds A and B. This portion of the herd is charged with producing replacement females for the entire herd, so maternal traits of the breeds included are very important. The remainder of the cow herd is bred to a terminal sire of a different breed. In this system, approximately half of the cow-herd is committed to the rotational portion of the breeding system and half to the terminal sire portion. This system retains about 90% of the maximum heterosis and should increase weaning weight per cow exposed by approximately 21%.

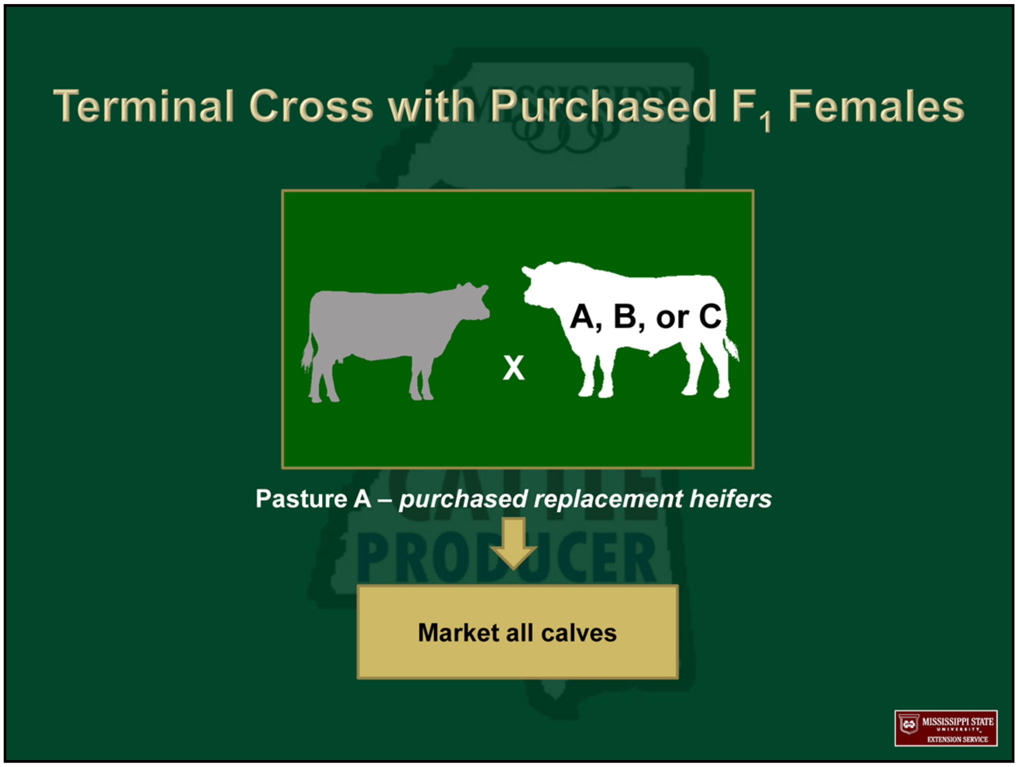
This system requires a minimum of three breeding pastures. Females in the rotational portion of the system must be identified by breed of sire. Minimum herd size is approximately 100 cows. Given the complexity of the breeding system and identification requirements, this system requires more management and labor to make it run effectively than some other systems do. The trade-off in systems that are easier to manage is that they typically yield lower levels of heterosis. If management expertise and labor are readily available, this system is one of the best for maximizing efficiency and the use of heterosis.

The females in the rotational portion should consist of the youngest females, namely the 1-, 2-, and 3-yearolds. These females should be bred to bulls with both good calving ease and maternal traits. Calving ease and maternal traits are emphasized here because the cows being bred are the youngest animals where dystocia is expected to be highest. Additionally, replacement Females for the entire herd will be selected from the progeny of these cows, so maternal traits are important. The remainder of the cow herd consists of mature cows that should be mated to bulls from a third breed that excel in growth rate and muscularity. The proportion of cows in each portion of the breeding system should be adjusted depending on the number of replacement females required. When fewer replacements are needed, a smaller portion of the herd will be included in the rotational system. Be sure to keep the very youngest groups in the rotational system to avoid dystocia problems. If ownership of calves will be retained through harvest, some consideration should be given to end product traits such as carcass weight, marbling, and leanness.

One drawback of the system is that there will be two different types of calves to market: one set from the maternally focused rotational system and one from the terminal sire system. Sorting and marketing can typically help offset this problem. The benefits of the rota-terminal system are usually worth the limitations.

Two-Breed Terminal Sire

A two-breed terminal cross system uses straightbred cows of one breed and a sire(s) of another breed. No replacement females are kept, and therefore all must be purchased. Because all calves are marketed, it is a terminal sire system. Charolais or Limousin sires used on Angus cows would be a common example. Implementations of two-breed terminal sire systems are not desirable or recommended as they do not employ any benefits of maternal heterosis as the cows are all straightbred. Remember most of the benefits of heterosis arise from the enhancement of reproduction and longevity traits of crossbred cows.



The terminal cross system utilizes crossbred cows and bulls of a third breed. This system is an excellent choice as it produces maximum heterosis in both the calf and cow. As such, calves obtain the additional growth benefits of hybrid vigor, while heterosis in the cows improves their maternal ability. The terminal sire system is one of the simplest systems to implement and achieves the highest use of heterosis and breed complementarity. All calves marketed will have the same breed composition. A 24% increase in pounds of calf weaned per cow exposed is expected from this system when compared to the average of the parent breeds.

The terminal cross system works well for herds of any size if high-quality replacement females are readily available from other sources. Only one breeding pasture is required. No special identification of cows or groups is required.

Because replacement females are purchased, care should be given in their selection to ensure that they are fit to the production environment. Their adaptation to the production environment will be determined by their biological type, especially their mature size and lactation potential. Success of the system is dependent on being able to purchase a bull of a third breed that excels in growth and carcass traits. Virgin heifers should be mated to an easy calving sire to minimize dystocia problems. Disease issues are always a concern when introducing new animals to your herd. Be sure that replacement heifers are from a reputable, disease-free source and that appropriate biosecurity measures are employed. Johne's, brucellosis (Bangs), tuberculosis (TB), and bovine viral diarrhea (BVD) are diseases to be aware of when purchasing animals.

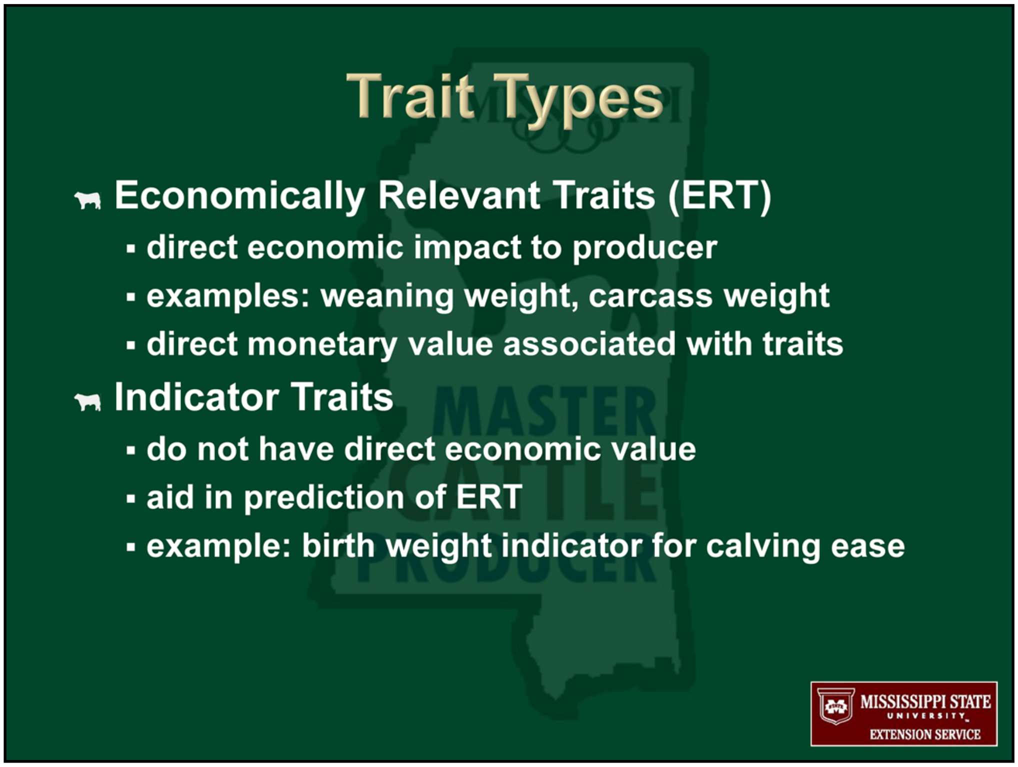
Another consideration and potential advantage of the terminal cross system is that replacement females do not need to be purchased each year depending on the age stratification of the original cows. In some cases, replacements may be added every two to five years, providing an opportunity to purchase heifers during periods of lower prices or more abundant supplies. Heifers could also be developed by a professional heifer development center or purchased bred to easy calving bulls.

The use of composite populations in beef cattle has seen a surge in popularity recently. Aside from the advantages of heterosis retention and breed complementarity, composite population breeding systems are as easy to manage as straightbreds once the composite is formed. The simplicity of use has made composites popular among very large, extensively managed operations and small herds alike. When two-, three-, or four-breed composites are formed, they retain 50%, 67%, and 75% of maximum heterosis and improve productivity of the cowherd by 12%, 15%, and 17%, respectively. Thus, these systems typically offer a balance of convenience, breed complementarity, and heterosis retention.

This system requires either a very large herd (500 to 1,000 cows) to form a composite or a source of composite genetics. In closed populations, inbreeding must be avoided as it will decrease heterosis. To help minimize inbreeding in the closed herd where cows are randomly mated to sires, the foundation animals should represent 15 to 20 sire groups per breed, and 25 or more sires should be used to produce each subsequent generation . In small herds, inbreeding may be avoided through purchase of outside genetics that are unrelated to the herd. Due to the ease of use once the composite is established, composite systems can be applied to herds of any size or number of breeding pastures.

Clearly, availability of outside seedstock is the limiting factor for most producers. However, with emerging popularity of structured, stabilized half-blood systems (*inter se* mated F1 animals) such as SimAngus, Balancer, and LimFlex, availability is much easier for these British x Continental crossbreds. Other composites have been formed and include MARC I, MARC II, MARC III, Rangemaker, Stabilizer, and others.

Mississippi State University Extension Service Publication 2755, “Crossbreeding Systems for Beef Cattle” discusses crossbreeding in detail.



Economically Relevant Traits (ERT), as the name implies, are those traits that have a direct economic impact to the producer. Most ERTs classified under reproductive performance, weaning weight, yearling weight, feed efficiency, carcass merit, longevity, conformation, freedom from genetic defects, disposition, and environmental adaptability. Traits such as weaning weight and carcass weight are ERTs because there is a direct monetary value associated with these traits. Other traits, such as birth weight, do not have a direct economic value associated with them. For instance, an increase in 1 lb of weaning weight increases the producer's income, but a decrease in 1 lb of birth weight does not directly affect the income or expense of a producer. Instead, birth weight is used to indicate the probability of dystocia, or calving difficulty, which does have an economic impact. For this reason, birth weight is not an ERT but is what is called an indicator trait. Indicator traits do not have direct economic importance but aid in the prediction of ERT. Newer EPDs, such as direct and maternal calving ease, are the ERT for which birth weight is the indicator.

The difference between indicator traits and ERTs and the ability to distinguish between the two are key to improving profitability. By identifying the ERTs, selection focus can be narrowed, resulting in faster genetic improvement and improved profitability. In the end, the goal of focusing selection on ERT is to increase the probability that breeders will make selection decisions that make their operation more profitable. The easiest way to distinguish between ERTs and indicator traits is to ask a specific question about the trait of interest: if that trait changes one unit, either up or down with no changes in any other traits, will there be a *direct effect* on income or expense?

ERTs and Associated Indicators

Economically Relevant Traits	Indicators
Sale weights: weaning weight, weaning maternal, yearling weight, carcass weight, pounds of retail yield	Birth weight, 205-day weight, 365-day weight, carcass weight, fat thickness, ribeye area
Likelihood of calving ease	Calving ease score, birth weight, gestation length
Feed requirements for maintenance	Mature cow weight, body condition score, milk production, internal organ weight
Productive life or stayability	Calving records, days to calving, milk production, calving interval
Likelihood of heifer pregnancy	Pregnancy diagnosis, scrotal measures
Tenderness	Shear force, marbling, color analysis
Feed efficiency	Feed consumption
Docility	Docility or chute scores

The chart above lists many economically relevant traits and associated indicator traits. Genetic predictors such as expected progeny differences are available for many ERTs and indicator traits.

Birth weight (BW) should be collected as soon after birth as possible and needs to be adjusted for age of dam before being included in a genetic evaluation. The age of dam adjustment will compare all calves on a mature cow equivalent basis. Most associations ask that breeders submit the raw data, and they will make the appropriate adjustments, using their own breed-specific adjustment factors.

The next information to collect on a bull, heifer, or steer is weaning weight (WW). A group of calves should be weighed when the average of the group is near 205 days of age. The Beef Improvement Federation recommends that all calves be between 160 and 250 days old, or they need to be split into two contemporary groups and weighed on two different days. However, each breed association's particular guidelines for age at weaning may be slightly different. Any calf that is outside the prescribed range when weighed will not be included in a national genetic evaluation. Contemporary group criteria typically include all those for birth weight, plus birth-to-wean management code (which includes creep versus no-creep), date weighed, and sex (some calves that were bulls at birth may be steers by weaning). Weaning weight should be adjusted for age of dam and for age of calf. Weaning weights are used by breed associations to calculate weaning weight, maternal milk, and total maternal EPD. The genetic correlation between weaning weight and other weight traits makes it possible to use weaning weights to help calculate EPD for the other weight traits.

Yearling weight (YW) should be collected on all animals and adjusted for age and age of dam. Adjusted yearling weights are used to calculate yearling weight EPD. Depending on the association, yearling weight may also be used as indicator traits to help calculate other EPD, such as mature weight. Many animals that have birth and weaning records go into the feedlot and will not contribute a yearling weight record. This could lead to selection bias for yearling weight EPD. However, most associations use a multiple trait animal model that includes birth, weaning, and yearling weights. This uses genetic correlations between the trait to account for selection and avoid bias.

Frame score is a measurement that describes skeletal size. Larger-framed cattle tend to be later maturing, and smaller-framed cattle tend to be earlier maturing. Tables are available to convert the hip height measured in inches into a frame score. Hip height can be measured at any time from 5 to 21 months, but many producers choose to do it at yearling time because of convenience. Hip height or frame score can be used by associations to calculate EPD for mature weight or height. Check with the association for acceptable age ranges for submission of data.

Depending on the association, cow weights can be used to calculate mature cow weight EPD. Also, cow weight and body condition are important components of the new EPD being developed for cow efficiency and cow maintenance. Cow hip height is also used to calculate a mature height EPD.

In beef cattle, the dam makes at least two contributions to offspring phenotypic values. These contributions are the sample half of her genes passed directly to the offspring and the maternal effect she provides her calf. A maternal effect is defined as any environmental influence that the dam contributes to the phenotype of her offspring. The contribution of the dam is environmental with respect to the calf (mothering ability, milk production, environment, maternal instinct). The genetics of the dam allow her to create this environment for her calf. Maternal effects are important during the nursing period with diminishing effects through post weaning.

Milk production is not measured directly but is instead estimated from weaning weights. Udder conformation is a subjectively measured. Udder and teat quality are among the most important functional traits of beef females. Unsound udders and teats are associated with reduced productive life and inferior calf performance, and poor udder and teat conformation is a major reason why cows are culled from the breeding herd. The scoring system described below is designed to help producers evaluate differences in udder and teat quality of beef cows. Udder suspension and teat size scores are numerical values that reflect differences in udder and teat quality. Udder suspension scores are subjective assessments of udder support and range from 9 (very tight) to 1 (very pendulous). Teat size scores are subjective assessments of teat length and circumference and range from 9 (very small) to 1 (very large). Udder and teat scores should be taken within 24 hours after calving, preferably by one person and on the weakest quarter.

Reproductive performance, measured as percent calf crop, has the highest economic importance for cow-calf operations when compared with growth and carcass traits. Most cow-calf producers have a goal for percent calf crop weaned (the number of calves weaned per cow exposed to breeding) of 85% or higher. Other reproductive goals typically include each cow calving every 365 days or less and for calving seasons to be controlled (typically 90 days or less).

Many reproductive traits, such as calving interval, are lowly heritable. These traits can be most effectively improved by changing the environment (for instance, improving herd nutrition and health programs). Rebreeding rate is best improved via management due to its low heritability. Reproductive performance can be improved through breeding methods by crossbreeding to obtain heterosis for percent calf crop weaned. Currently there are few measures of genetic merit for reproduction, but breed associations are working to provide producers with EPD for fertility traits. Having complete breeding records will allow a producer to take advantage of these EPD as soon as they are developed.

Once a female makes it into the breeding herd, there are several records that should be collected every year. All replacement heifers and cows should be checked for pregnancy after the breeding season. Besides being a management tool to cull open females, some breeds are now collecting pregnancy data on heifers to calculate a heifer pregnancy EPD.

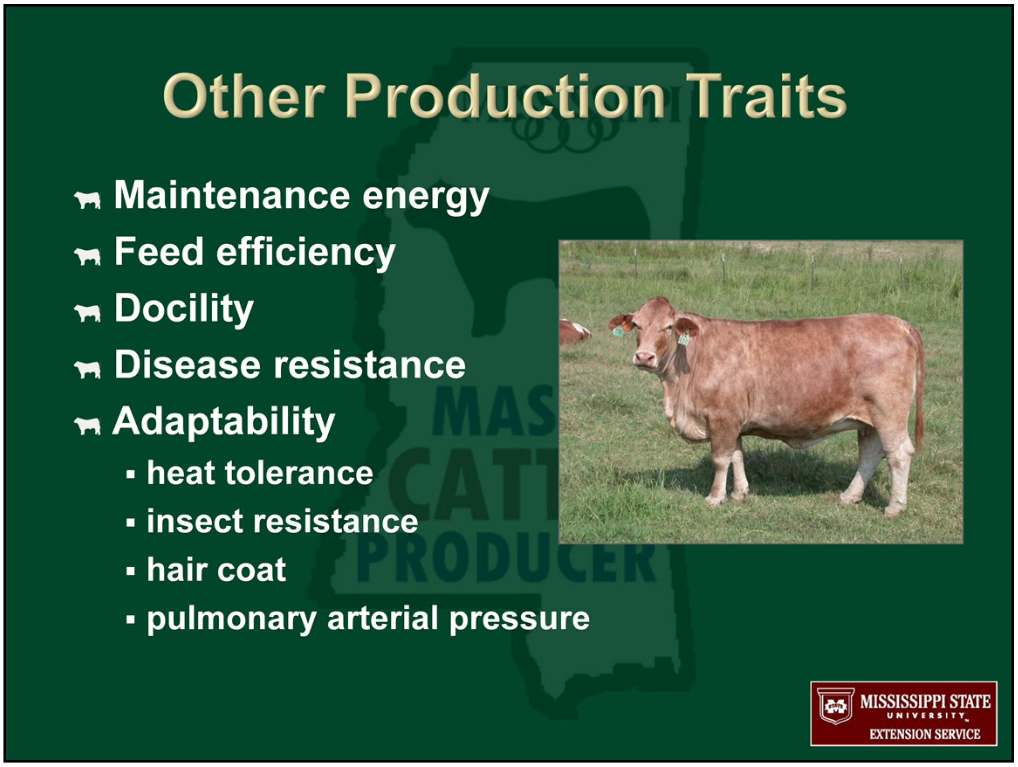
At calving, birth dates, birth weights, and calving ease score should be recorded. These are necessary to document calf performance (as discussed previously) but also to document cow performance. To record calving ease, use the scale recommended by the respective breed association, or the BIF-recommended scale: 1) No difficulty, no assistance; 2) Minor difficulty, some assistance; 3) Major difficulty, usually mechanical assistance; 4) Caesarean section or other surgery; 5) Abnormal presentation. Both birth weights and calving ease measurements are used to calculate calving ease direct (genetic merit of the calf) and calving ease maternal (genetic merit of the dam) EPD. Selection for calving ease can decrease calving difficulty.

Stayability EPDs predict how long a cow will stay in the herd. This is based on reporting whether a cow is in the herd after 6 years of age. It is important to record AI or exposure dates on the breeding herd. At weaning, cow weight and body condition score should be collected along with calf weaning weight.

Pelvic area can be measured on bulls and heifers at yearling time. While most breed associations are not calculating EPD for pelvic area at this time, it can be a useful culling tool within a herd. Heifers with small pelvic areas are more likely to experience calving difficulty. It may be beneficial to measure yearling bulls as well, because bull pelvic area is moderately correlated with heifer pelvic area.

Scrotal circumference is measured at yearling age and is an indicator of a bull’s fertility, and it has a relationship with his daughters’ age at puberty. Larger scrotal circumference is associated with younger age at puberty for the bull and his daughters. Most associations are using scrotal circumferences to calculate EPDs for scrotal circumference and may use it as an indicator trait for heifer pregnancy EPDs.

An experienced technician can palpate a heifer to determine the maturity of her reproductive tract and to determine if she has begun cycling. This information is not used in national genetic evaluations but can be a useful management tool. Heifers with immature reproductive tracts should be culled before the breeding season. Reproductive tract score is approximately 30% heritable and will respond to selection.



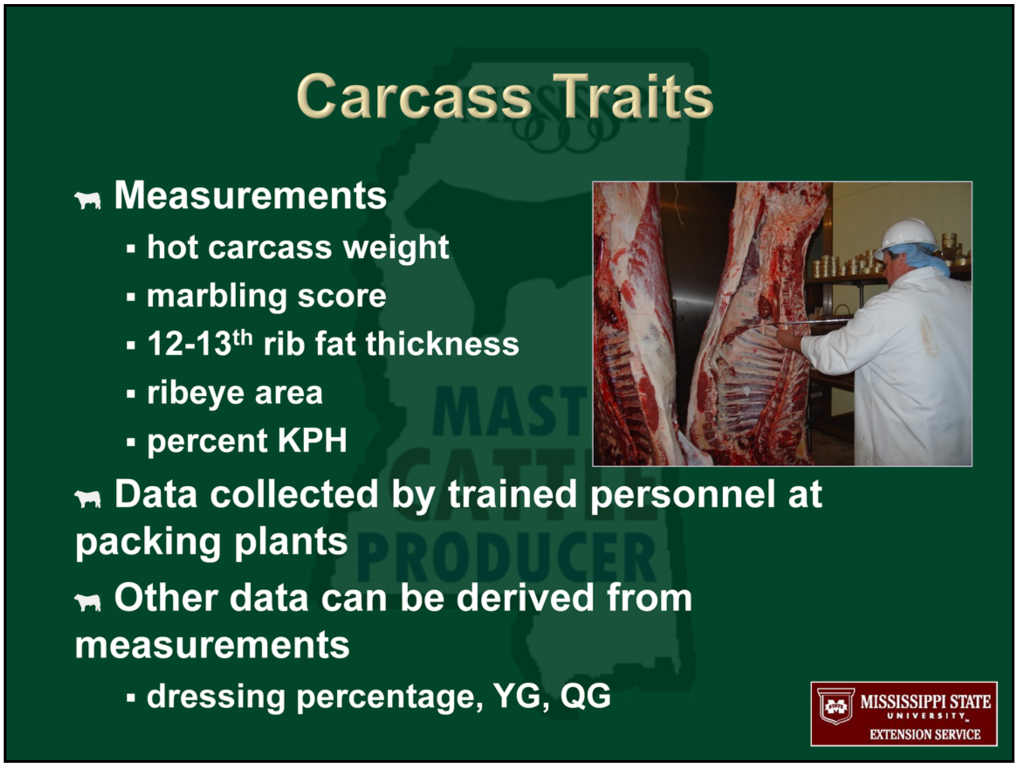
Maintenance energy is the amount of feed energy required per day by an animal to maintain its body weight and support necessary metabolic (body) functions. Cow weight and body condition are important components of new EPDs being developed for cow efficiency and cow maintenance.

Genetic evaluation programs for feed intake and efficiency are developing, recognizing the economic relevance of cost-stream input traits to genetic improvement in profitability. The economic importance of intake as the largest non-fixed cost of beef production is well known. However, the phenotypic definition of feed efficiency remains somewhat debatable. One potential measure is residual feed intake (RFI), which is the difference between the actual and expected feed intake.

Disposition (docility or temperament) refers to the level of calmness or excitability of cattle. Chute scores and pen scores are used to subjectively evaluate disposition. Some breeds have docility EPDs to assist in selection for this trait. Both the genetic makeup of cattle and the environmental conditions to which they are exposed determine disposition. Poor animal handling can contribute to disposition problems. Cattle with very poor disposition are a safety hazard to human handlers and other animals and should be culled from breeding populations.

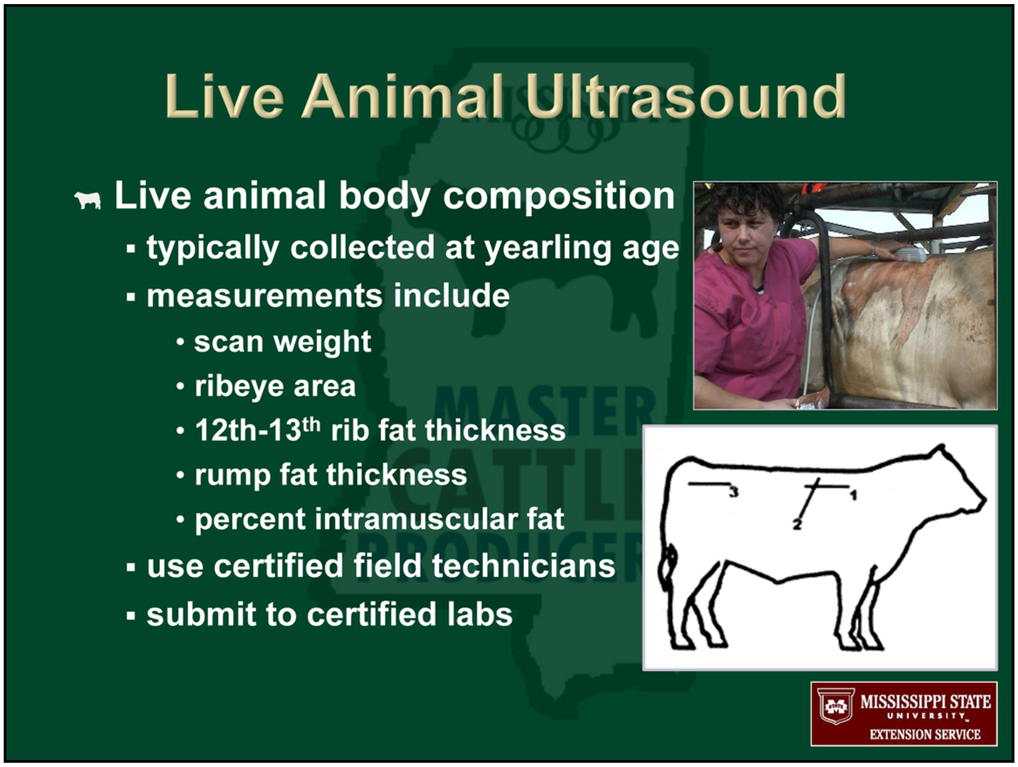
Herd health and feedlot health problems are widespread and very costly to the beef cattle industry. There is documented variability in susceptibility or resistance to cattle health problems. Thus, selection for improved resistance to disease and other health concerns is possible.

Traits related to adaptability of cattle to their environments include heat tolerance, insect resistance, hair coat density and shedding pattern, and pulmonary arterial pressure score as it relates to susceptibility to altitude sickness or brisket disease.



Steers and cull heifers can be used to provide carcass data. Carcass data must be collected by trained personnel in conjunction with a packing plant. Many breed associations have structured carcass tests in place that do much of the groundwork for producers. Contemporary grouping for carcass data includes weaning contemporary group, feeding management group, and slaughter date. Within a plant, the day, and even the shift, that the cattle are processed can have a large effect on the carcass data. Data should be adjusted to an age-constant or weight-constant basis. Each breed association has its own guidelines to do this. Data collected include hot carcass weight, marbling score, 12-13th rib fat thickness, ribeye area, and percent kidney, pelvic, and heart (KPH) fat. Additional data can be collected including financial data, and additional traits can be calculated or determined such as dressing percentage, Yield Grade, and Quality Grade. Marbling score measures the quality of the carcass. Depending on market conditions, highly marbled carcasses can receive significant premiums. Marbling score is related to Quality Grade.

Most breeds report EPDs for carcass weight, marbling, ribeye area, and fat. In addition, they may include an EPD for yield or percent retail product. These EPDs are intended to indicate the amount of lean meat in the carcass, and they use measurements of 12-13th rib fat, kidney pelvic and heart fat, ribeye area, and hot carcass weight.



Many breed associations are now using ultrasound data collected on bulls and heifers to calculate EPD for body composition. Each association has its own specifications for when data should be collected. In general, bulls on gain test should be measured around a year of age. Some associations will use data from forage-raised bulls that are measured later than one year of age. Developing replacement heifers are typically scanned between 12 and 15 months of age, but there is variation among associations. Contact the respective breed association to get its requirements for age of scanning. Different associations have different requirements for ultrasound contemporary grouping. If scanning is done the same time as other yearling measurements, contemporary grouping is often the same as for yearling weight. If done at a different time, contemporary group criteria may include weaning weight contemporary group, yearling management group, and scan date. Check with a particular association for its contemporary grouping guidelines. The Beef Improvement Federation recommends that all calves in a scanning contemporary group be within 60 days of age with each other, but some associations may allow a wider age range. Ultrasound data need to be adjusted to a common endpoint of either age or weight. Each breed has its own endpoints and adjustment factors. Some breeds may include steer ultrasound data in their genetic evaluations. Check with the respective breed association for specific recommendations regarding scanning steers. It is important to use a certified technician to scan cattle if these data are to be included in a national genetic evaluation. Breed associations have a list of certified technicians from whom they will accept data.

Measurements taken at scanning include scan weight, ribeye area, 12-13th rib fat thickness, rump fat thickness, and percent intramuscular fat. EPD for scan weight, ribeye area, fat thickness, and percent intramuscular fat are produced from those measurements. Ribeye area and fat are indicators of the amount of carcass red meat yield. Percentage intramuscular fat is highly correlated with the amount of marbling in the carcass. Measurements of 12-13th rib fat thickness and rump fat thickness are combined to develop an EPD for fat. Some breeds combine weight, fat, and ribeye area into an EPD for yield or percent retail product.

For more information on ultrasound scanning, refer to Mississippi State University Extension Service Publication 2509, “Ultrasound Scanning Beef Cattle for Body Composition”.

One of the challenges in beef cattle selection and culling involves finding optimum levels of individual traits for the herd. Optimum does not necessarily mean maximum. With many evaluated traits in beef cattle production, it is advisable to avoid extremes. For illustration, too much milk production in a herd can have some negative consequences. Likewise, too little milk production in a beef herd can result in lighter weaning calves. The level of milk production in a cow-calf herd must fit the forage and feed environment to ensure that nutrient requirements of lactating cattle are met and rebreeding is not hindered by inadequate nutrition.

Nutritional and other environmental factors will affect the degree to which the genetic potential for milk production is expressed. Even when the genetic potential for a particular level of milk production is present within an individual or herd, it does not mean that this level of milk production will be achieved. Both genetic and environmental influences on milk production can ultimately affect calf weaning weights and cow reproductive rates.

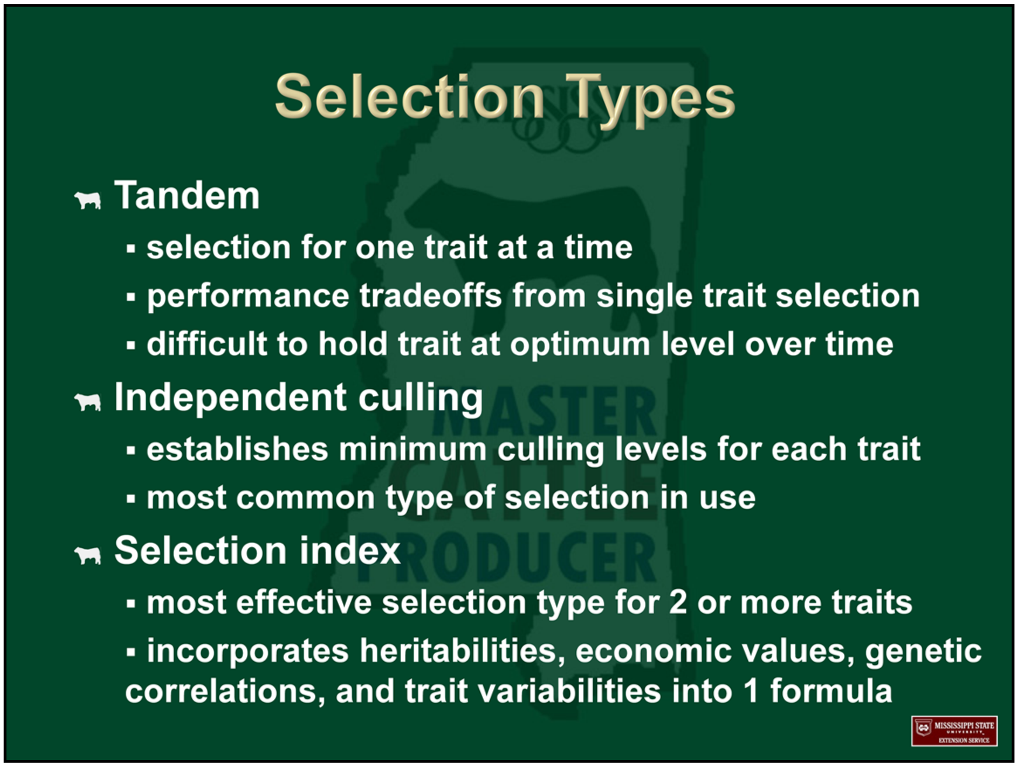
As nutrient costs increase, heavy milking or larger cattle may be less desirable in a cow-calf operation. In contrast, reasonably priced feed favors heavier calves from higher milking dams in cow-calf production and lighter weight calves fed over a longer period in the feedlot. Increasing milk yield has been shown to increase both weaning weights and efficiency to weaning in the cow-calf sector, with mixed results on efficiency to harvest. Therefore, for strictly cow-calf producers, increasing milk and size may be practical for increasing weaning weights and optimizing production when feed prices are reasonable. However, for producers retaining ownership of calves through post-weaning phases, maximizing profit by increasing weaning weights via milk production works in some cases and not in others.

Genetic potential for milk production can vary widely among cattle. An efficient level of milk production and mature body size for the herd may vary from one farm to the next. A moderate level of milk production is generally most appropriate. However, low to high milk production levels can be applicable depending on production and market conditions. In general, larger body size is more suitable with larger quantities of forage, and high milk production fits better with adequate levels of high quality forage.

Some traits such as scrotal circumference are threshold traits. There is no apparent advantage in increasing scrotal circumference beyond 38 to 40 cm despite advantages to increases in scrotal size below this threshold.

A well-designed breeding program has definite selection goals. Cow-calf operations across the state have different goals and different resources. Yet sire selection goals for any cow-calf herd should target an acceptable combination of traits that complement the strengths and weaknesses of the cow herd and match target markets. When selecting a bull, consider the needs of the cow herd. Ask questions that will help match a bull to the cow herd. Do weaning weights need to be improved? If so, then growth performance is a priority in the selection process. Does calf crop color uniformity need improvement? If so, then color pattern inheritance is an important consideration in sire selection. Will the bull be bred to heifers and is limited labor available to assist with calving? If either is the case, then calving ease is a priority. Are there plans to retain ownership of calves beyond the feedlot and market them on a value-based pricing grid? If so, then attention needs to focus on yearling weights and carcass traits in selecting breeding animals.

Other factors to consider in sire selection include structural soundness, conformation, libido, disposition, scrotal circumference, sheath, frame size, muscling, breed, and horn presence or absence. Try to strike a balance among economically relevant traits and avoid extremes. The type of bull selected also needs to be based on the purpose of the bull in the breeding herd. Will the bull be used as a terminal sire on mature cows, will he be bred to heifers, or will he be used to sire replacement heifers? The answers to these questions will impact the emphasis that needs to be placed on maternal traits. Use a similar approach when defining selection goals for replacement females.

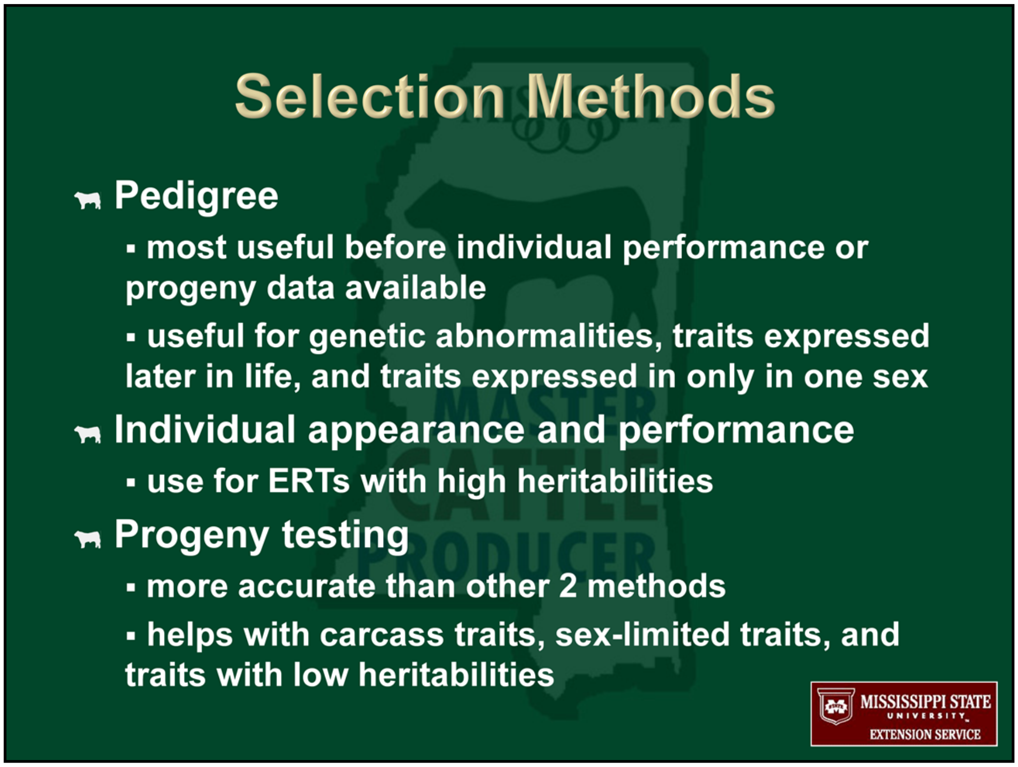


Three types of selection are tandem, independent culling level, and selection index.

Tandem is selection for one trait at a time. When the desired level is achieved in that one trait, then selection is practiced for a second trait. Tandem is the least effective of the three selection methods. Because of negative genetic correlations, the prolonged selection for one trait may produce deficiencies in another. While progress in the selected trait may be significant in the short run, it is very difficult to hold a trait at an optimal level over time.

Independent culling level establishes minimum or maximum culling levels for each trait in the selection program. Even though it is not as effective as the selection index, independent culling level is the most common type of selection in use today. Its major disadvantage is that an animal slightly outside the maximum or minimum culling levels in one trait but highly superior in other traits would be culled.

The selection index is the most effective selection type when selecting for two or more traits. Exercise caution about genetic change when including many traits in the selection program. A selection index requires highly involved statistical methods in order to put the heritabilities, economic values, genetic correlations, and variabilities of several traits into a single formula.

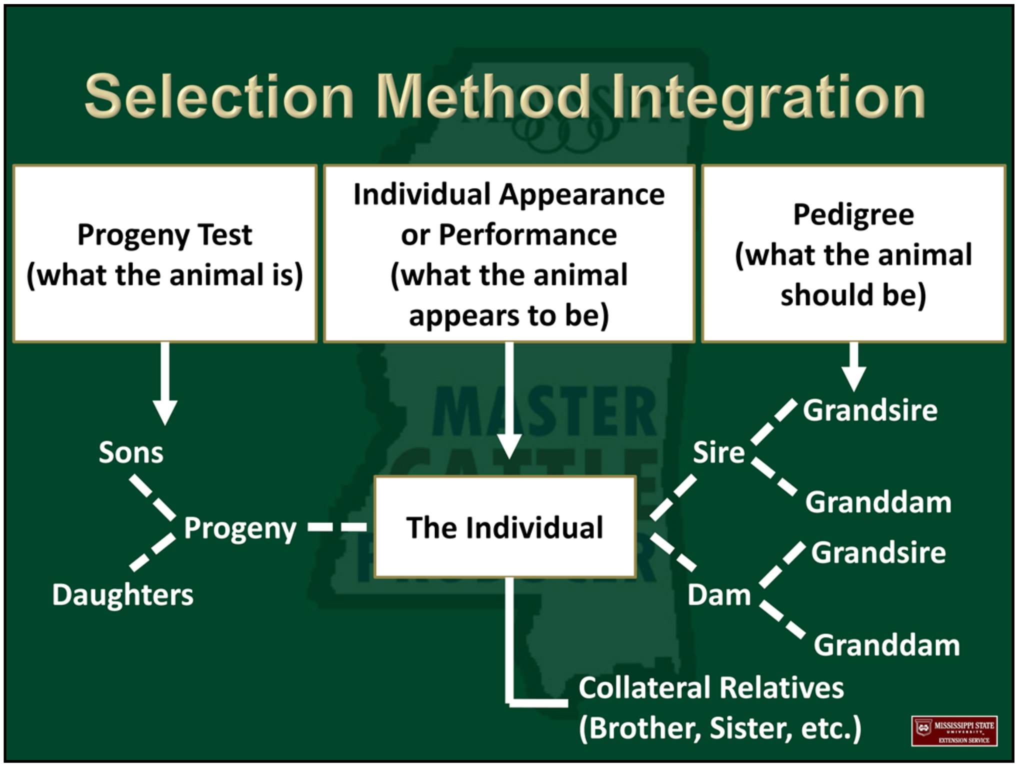


Three primary methods of selection are pedigree, individual appearance and performance, and progeny testing.

Pedigree information is most useful before animals have expressed their own individual performance or before the performance of progeny has been documented. Pedigree is also useful in assessing genetic abnormalities and traits expressed much later in life (for example, longevity), and in selecting for traits expressed only in one sex (for example, bull selection for milk production).

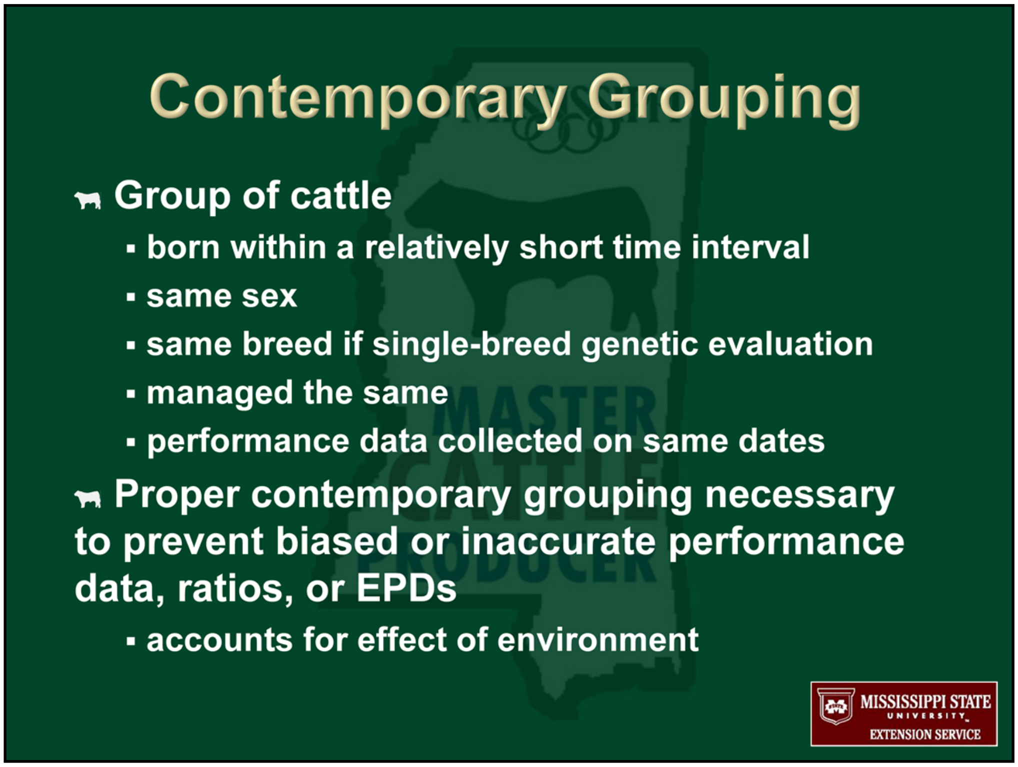
Practice selection on individual appearance and performance on traits that are economically important and have high heritabilities. One main advantage of selection on individual performance is that it allows rapid genetic turnover and thus shortens the generation interval.

Progeny testing is more accurate and useful than the other two selection methods. Such tests are particularly useful in selecting for carcass traits (where good carcass indicators are not available in the live animal), sex-limited traits (such as mothering ability), and traits with low heritabilities. Disadvantages of progeny testing include: only a limited number of animals can be progeny tested, a longer generation interval is required to obtain progeny information, and there is decreased accuracy in poorly conducted tests.



The three primary methods of selection (pedigree, individual appearance and performance, and progeny testing) can be used effectively together in a cattle breeding program. How these selection methods tie together is depicted in the figure above.

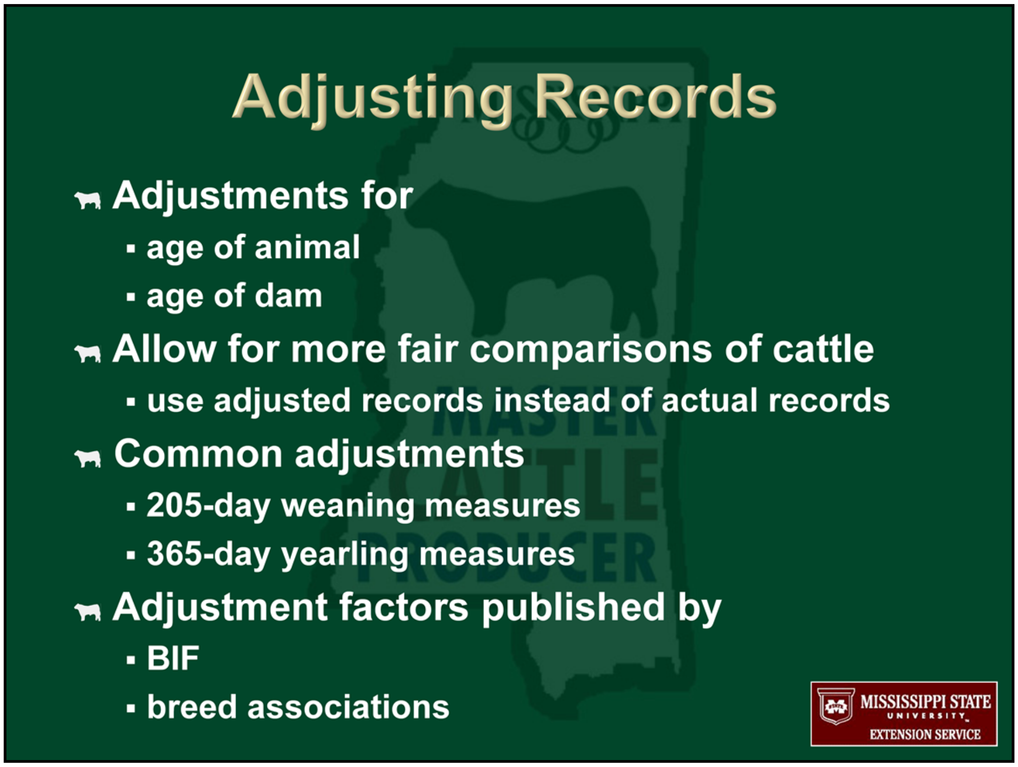
Genetic predictions are based in part on individual performance records. Performance data is collected at several points in the production process including: birth, weaning, post-weaning, yearling age, finishing period, harvest, and maturity.



The environment that a calf is exposed to can have a large effect on how well it performs for all of the economically important traits. By using contemporary grouping, we are better able to separate genetic and environmental effects. A contemporary group for a traditional, within-breed genetic evaluation is defined as a set of same-sex, same-breed calves that were born within a relatively short time interval and have been managed the same ever since. A contemporary group of cattle is born within the same birth management group (same management system, calf age group), managed together, and had performance data collected on the same dates. In multiple-breed genetic evaluation, calves in the same contemporary group can have different breed makeup. Regardless of what type of evaluation, every calf in the contemporary group should receive an equal opportunity to express its genetic merit. Once an animal has been separated from his contemporaries, he can never be put into that group again. Thus, the yearling contemporary group is equal to or smaller than the weaning contemporary group which is equal to or smaller than the birth contemporary group.

For example, a producer may decide to select one particular bull calf to put into a fall or winter sale. That calf and his mother are pulled into a separate pen, where they have access to shelter and the calf gets creep feed. When weaning weights are collected on the group of bull calves, the selected calf has the highest weight. The problem is that it is not known if that calf was genetically superior for weaning weight, or if his extra growth was due to the feed and shelter. This is an extreme example, but anything that is different in the environment or management between groups of calves may give some of them an unfair advantage and make comparisons impossible. Improper contemporary grouping can lead to biased and inaccurate EPDs.

Consider the size of the contemporary group when evaluating performance ratios. For example, a contemporary group of three does not provide information as useful as a contemporary group of 30. Generally, larger contemporary groups give better indications of cattle performance and associated performance comparisons than smaller contemporary groups. Many breed associations will not accept performance data for use in national cattle evaluations to produce EPDs if a minimum contemporary group size is not met.

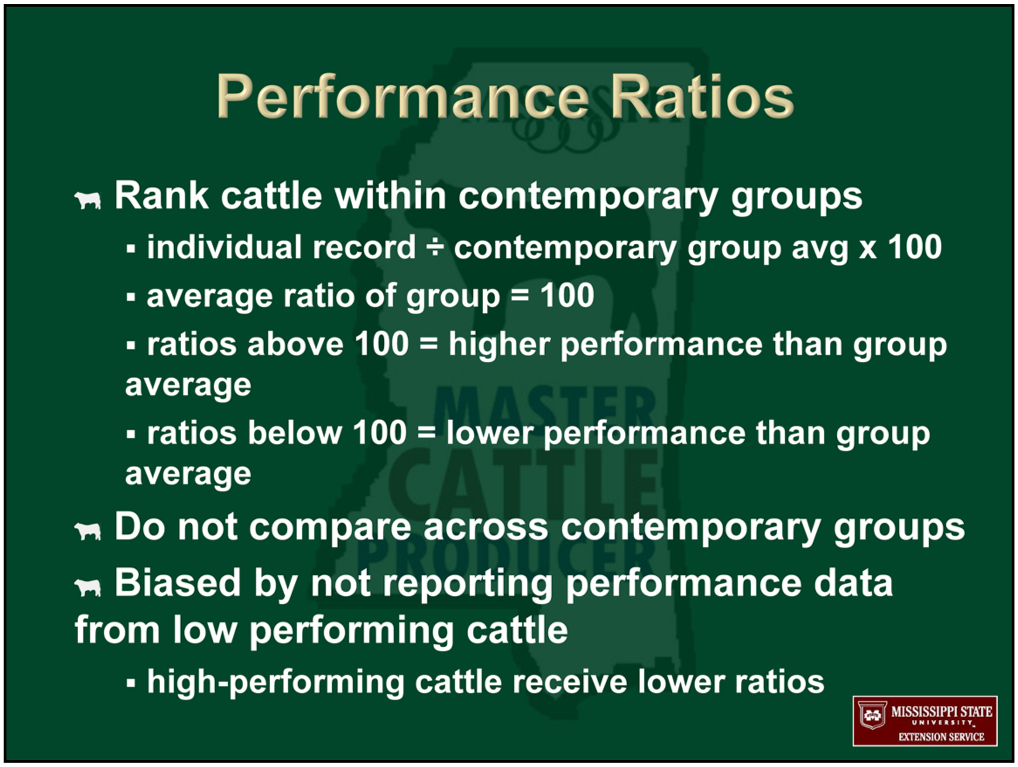


Many individual trait measurements are adjusted for age of the animal and age of its dam. This allows for more fair comparisons of cattle for these traits. For example, weaning weight is commonly adjusted to 205 days of age, and yearling measurements (weight, hip height, scrotal circumference) are typically adjusted to 365 days of age. When evaluating cattle for individual performance traits, be sure that adjusted performance levels are truly adjusted measurements and not, instead, actual performance values.

Calf age and cow age are two environment factors that are not accounted for by contemporary grouping. These effects are predictable from year to year and herd to herd, so the records can be adjusted to account for that variation. For example, all calves in the herd should not be weaned and weighed when they are exactly 205 days of age. It is important to keep contemporary groups as large as possible. If a producer weighed each calf individually when it was exactly 205 days of age, each calf would be in its own contemporary group. Single-animal contemporary groups are worthless as far as genetic evaluation goes. However, when all calves are weighed on the same day (when the average of the group is close to 205 days old), the younger calves will be at a disadvantage compared to the older calves. To get a fair comparison, the raw weights of calves weighed on the same day will be adjusted to the same age of 205 days. Basically, the adjustment figures out how much each calf is gaining per day and predicts what they will weigh (or did weigh) when they are (or were) exactly 205 days old.

The second type of adjustment is for age of dam. First-calf heifers generally have calves that are lighter at birth than calves from older cows, and they also produce less milk throughout lactation than older cows, leading to lower weaning weights. These are not genetic factors of the calf and should not be attributed to the calf 's performance.

The Beef Improvement Federation publishes adjustment factors and procedures. These are general adjustment factors that are appropriate for commercial cattle. Most breed associations have developed adjustment factors using their breed data. Purebred producers should use the adjustment factors and procedures of their association.



One way to compare calves within the same contemporary group is to use ratios. Individual performance ratios rank cattle within their contemporary groups. Ratios are calculated by dividing a calf's adjusted record by the average record of its contemporary group and multiplying by 100.

Ratio = (Individual Record ÷ Contemporary Group Average) x 100

This means that the average performing calf in the group will have a ratio of 100, poorer calves will be below 100, and better calves will be above 100 for traits where bigger is better. For traits where smaller is better, like birth weight, better (lighter) calves will be below 100, and poorer (heavier) calves will be above 100. Ratios measure an animal's percentage deviation from the average of its contemporary group. For example, an adjusted yearling weight ratio of 115 indicates that the animal's adjusted yearling weight was 15 percent higher than the average of its contemporary group. Likewise, an adjusted yearling weight ratio of 93 indicates that the animal's adjusted yearling weight was 7 percent lower than the average of its contemporary group.

Because of differences in management and mean genetic level between herds, ratios should not be used to compare animals across contemporary groups. Not reporting performance data from low performing (often cull) cattle will bias a contemporary group and performance results. If performance data from lower performing calves (culls) are not included in performance ratio calculations, then high-performing calves receive lower performance ratios. This results in incomplete contemporary group information and biased performance comparisons of individual calves within the contemporary group.

Whole Herd Reporting

- **Complete reporting is critical**
  - ratios and EPDs biased by not reporting performance data from low performing cattle
  - high-performing cattle receive lower ratios, EPDs

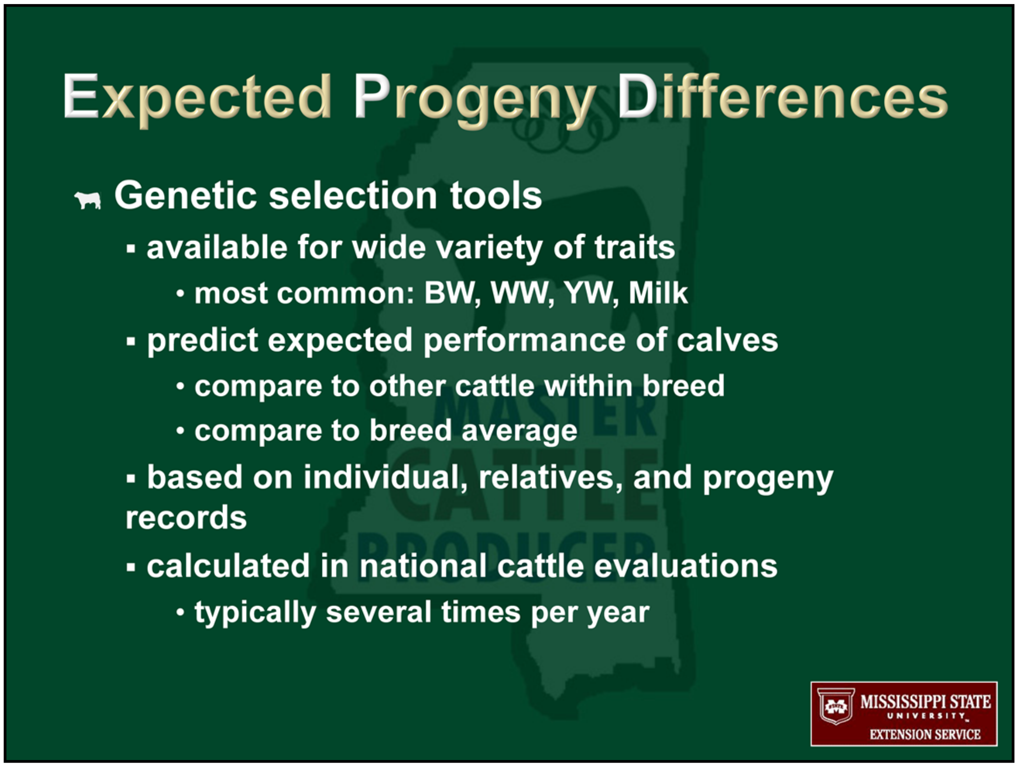
Contemporary Group Effect on Performance Ratios

Calves in Contemporary Group	Performance Data and Ratios		
	Adjusted Weaning Weight, pounds	**Adjusted Weaning Weight Ratio including all calves**	**Adjusted Weaning Weight Ratio without culls**
Calf 1	720	119.6	108.8
Calf 2	695	115.5	105.0
Calf 3	648	107.7	97.9
Calf 4	633	105.2	95.7
Calf 5	612	101.7	92.5
Calf 6 (cull)	574	95.4	—
Calf 7 (cull)	559	92.9	—
Calf 8 (cull)	557	92.5	—
Calf 9 (cull)	523	86.9	—
Calf 10 (cull)	498	82.7	—
Group Average	**601.9**	**100**	**100**

Traditionally, some breeders have only reported performance data on calves that they want to register. However, this leads to biased and inaccurate EPD. Complete reporting of every animal in the herd is critical to obtain the best estimates of genetic merit. By only reporting the best calves (for whatever trait), producers are not making their herd look better; they are inadvertently penalizing their highest-performing calves.

Consider the example in the table above. In this example, weaning weight ratios change when only the best calves are reported. Those high-performing calves (calves 1, 2, 3, 4, and 5) receive much lower ratios, and subsequently EPDs, than if they had been compared to their entire contemporary group. Incomplete reporting has the same effect on EPD that it does on ratios.

Another reason to use complete reporting, sometimes referred to as whole herd reporting, is to take advantage of genetic evaluations for cow stayability and fertility. As new genetic predictions of cow efficiency, maintenance, and fertility are developed, associations are going to need lifetime performance records on those cows to make the best estimates possible.

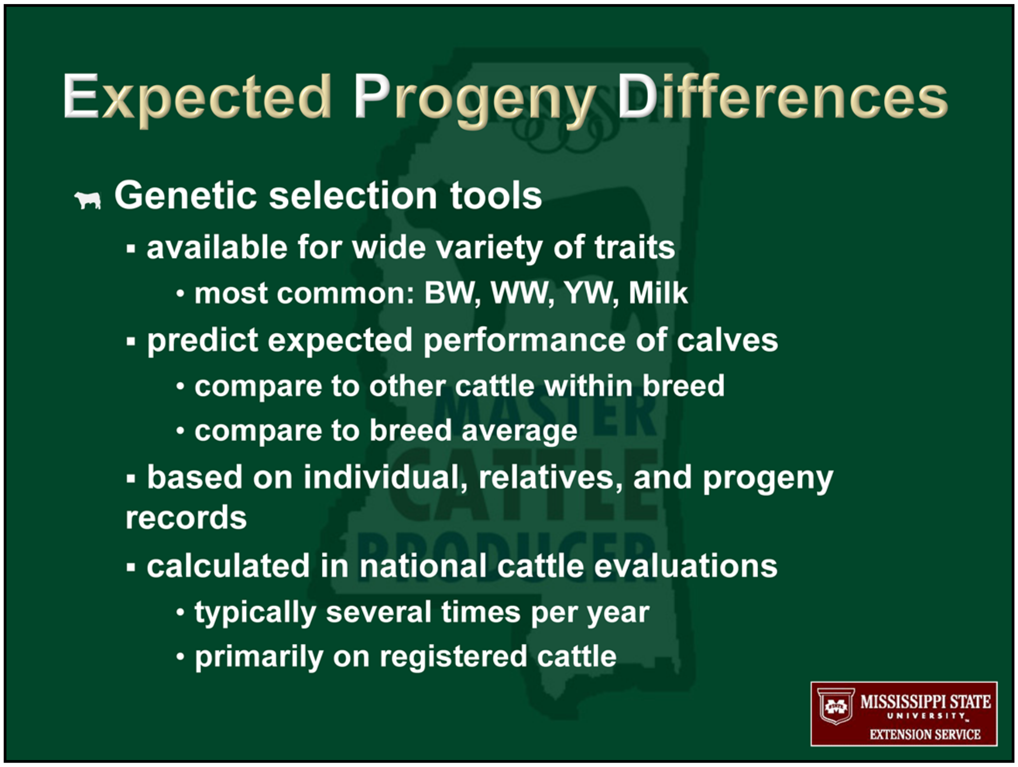


Expected progeny differences (EPDs) are useful genetic selection tools available for a wide variety of beef cattle traits. Expected progeny differences provide predictions of the expected performance for specific traits of the calves (progeny) sired by a particular bull (or out of a particular dam) compared to the expected performance of calves sired by another bull (dam) or group of bulls (dams). They are based on the performance records of an individual, its relatives, and its progeny.

Expected progeny differences are easily interpreted. They are expressed in various units depending upon the specific trait. For example, units for birth weight, weaning weight, yearling weight, and milk EPDs are pounds of calf. Units for scrotal circumference EPDs are centimeters. Contact the respective breed association for specific EPD definition and units. Expected progeny differences can be compared between animals or to a breed average.

Expected progeny differences are currently the best predictors of the genetic performance of an individual animal and are available for a growing number of economically relevant traits. Different breeds will have EPDs available for different traits. However, most breeds have basic EPDs such as birth weight, weaning weight, yearling weight and milk. Expected progeny differences can be used to make herd genetic improvement in both commercial and seedstock operations. National cattle evaluations, in which EPDs are reported, are typically calculated multiple times per year. This varies by breed, but it is important to make sure decisions are made using current EPD calculations. For instance, a bull sale catalog may be published before an upcoming national cattle evaluation is released, and the EPDs reported in that catalog could then be outdated relatively soon after its distribution.

The earliest developed EPDs for beef cattle were for birth weight, weaning weight, yearling weight, and milk. These are still the standard EPDs that are calculated for all breeds that conduct genetic evaluations. Even those breeds that have genetic evaluations and that report no other EPDs still report birth weight, weaning weight, yearling weight, and milk.



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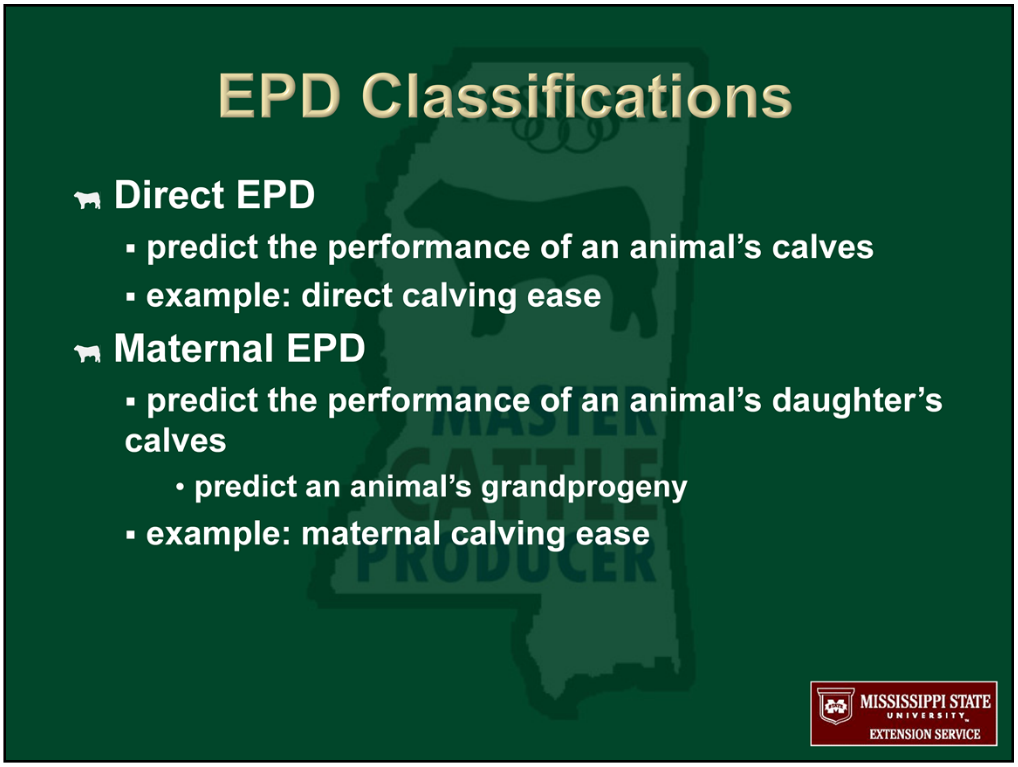
Expected progeny differences are easily interpreted. They are expressed in various units depending upon the specific trait. For example, units for birth weight, weaning weight, yearling weight, and milk EPDs are pounds of calf. Units for scrotal circumference EPDs are centimeters. Contact the respective breed association for specific EPD definition and units.

Expected progeny differences can be compared between animals or to a breed average. For illustration, calves sired by Bull A (yearling weight EPD = 82) are expected to be on average 18 pounds lighter at yearling age than calves sired by Bull B (yearling weight EPD = 100) when mated to similar females. This is determined by calculating the difference between the two EPD values; 82 – 100 = -18. Similarly, calves sired by Bull A can be expected to be on average 7 pounds heavier at yearling age than calves sired by all other bulls in that same breed when mated to similar females when the breed average yearling weight EPD = 75; 82 – 75 = 7.

Expected progeny differences are currently the best predictors of the genetic performance of an individual animal and are available for a growing number of economically relevant traits. Different breeds will have EPDs available for different traits. However, most breeds have basic EPDs such as birth weight, weaning weight, yearling weight and milk. Expected progeny differences can be used to make herd genetic improvement in both commercial and seedstock operations. National cattle evaluations, in which EPDs are reported, are typically calculated multiple times per year. This varies by breed, but it is important to make sure decisions are made using current EPD calculations. For instance, a bull sale catalog may be published before an upcoming national cattle evaluation is released, and the EPDs reported in that catalog could then be outdated relatively soon after its distribution.

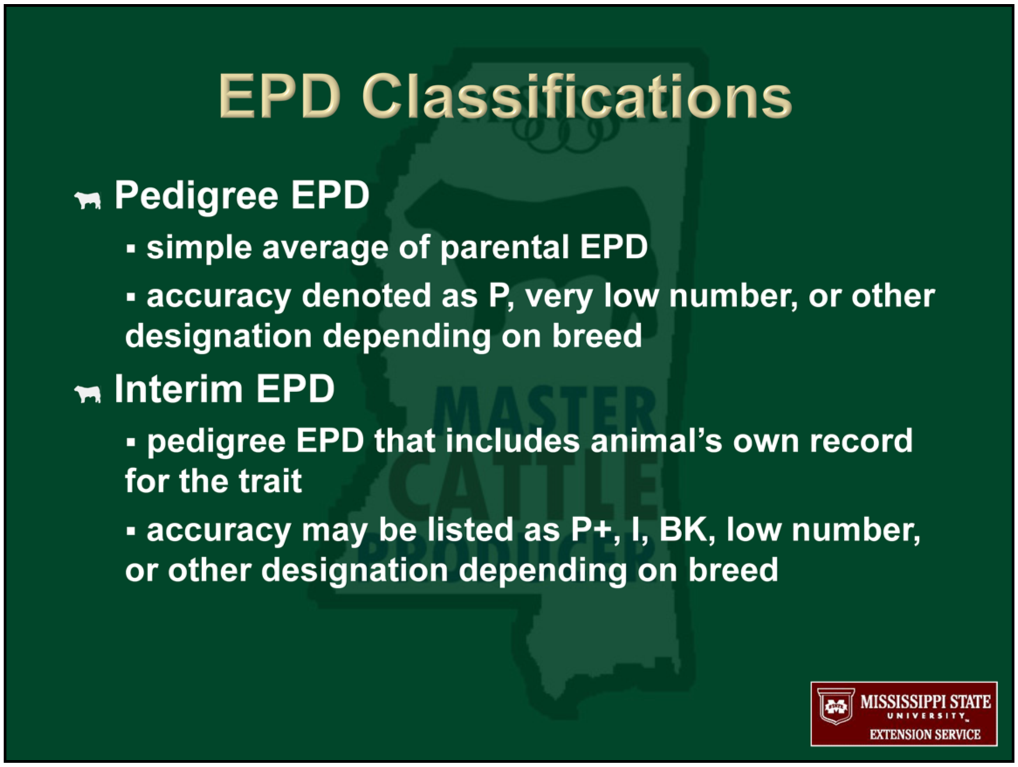
The earliest developed EPDs for beef cattle were for birth weight, weaning weight, yearling weight, and milk. These are still the standard EPDs that are calculated for all breeds that conduct genetic evaluations. Even those breeds that have genetic evaluations and that report no other EPDs still report birth weight, weaning weight, yearling weight, and milk.



Most EPDs are expressed in a direct form—meaning they predict an animal's future progeny performance. Others are maternal EPDs and predict an animal's grandprogeny. For instance, calving ease is expressed in two different EPDs, one direct and one maternal. Milk, which is known by many names, including maternal milk, milking ability, maternal, and maternal traits, is the oldest maternal EPDs available to producers.

Direct EPDs predict the performance of an animal's calves. Direct calving ease, for instance, is a prediction of calving ease when a bull's calves are born—a measure of dystocia experienced by the heifers to which he is bred. Other EPDs that are not explicitly referred to as direct or maternal can usually be assumed to be direct EPDs.

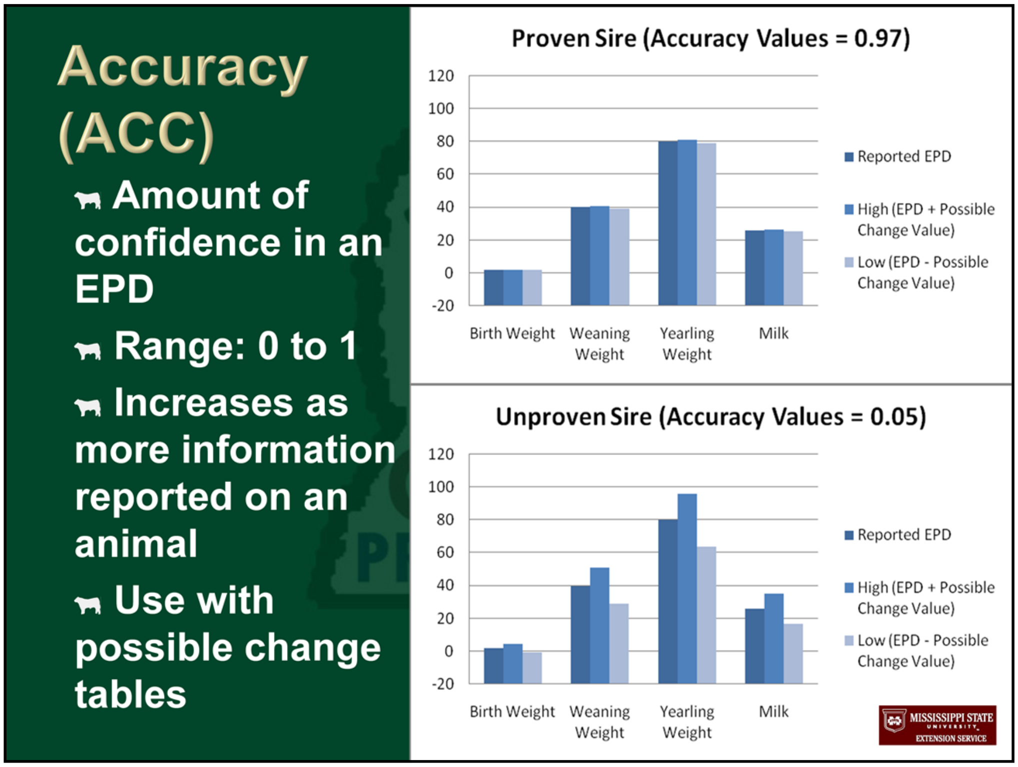
Maternal EPDs, on the other hand, predict the performance of an animal's daughter's calves. Maternal calving ease is a prediction of the ease with which a animal's daughters will calve as first-calf heifers. Greater values indicate the animal's daughters will calve with greater ease. Similarly, milk and total maternal EPDs help to predict the weaning weight of a animal's daughter's calves. Total maternal EPD (also known as milk + growth EPD and maternal weaning weight EPD) is expressed as pounds of calf weaning due to dam's milk production and maternal ability as well as the calf's genetics for growth.



Expected Progeny Differences are an estimate of the cumulative effect of the genes that an animal has and can pass on to its offspring. Because of this, until an animal has a record of its own, or even better, progeny of its own, it is difficult to know what genes it possesses. Without this information, the only way to estimate what genes an animal possesses is by averaging the parents. This means that all progeny of the same two parents will have the same EPD value until they have progeny of their own or records of their own. These EPDs that are simply averages of the parental EPDs are pedigree estimates and are referred to as pedigree EPDs.

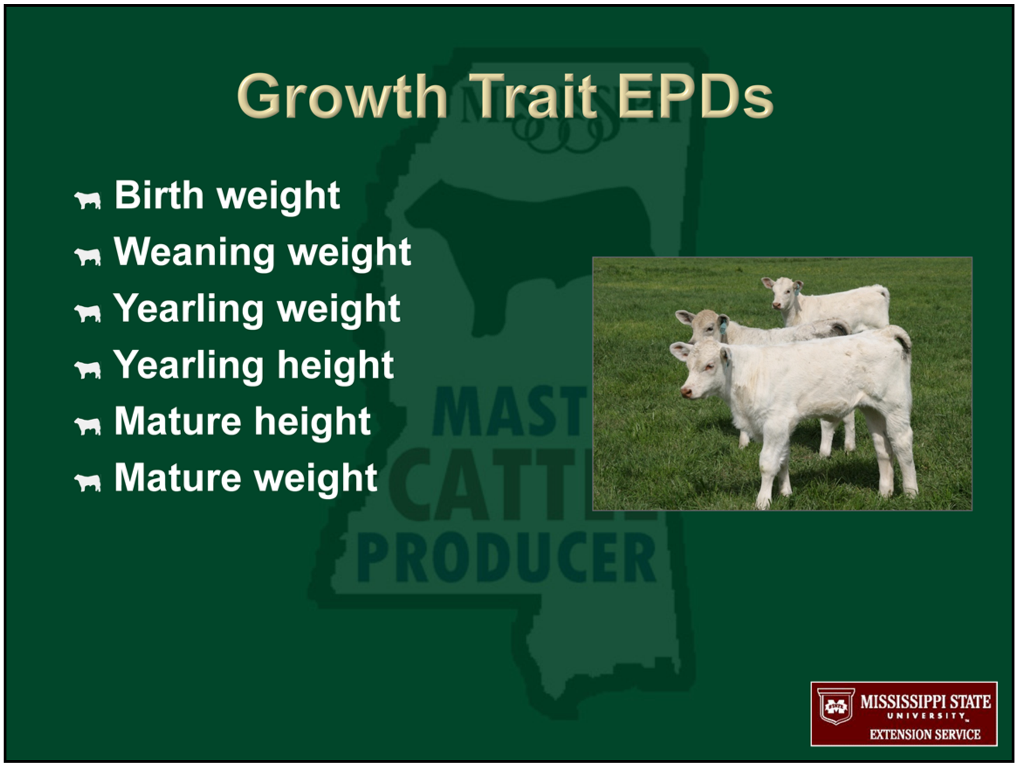
In most sire summaries, pedigree EPDs are easy to identify because, instead of a numerical value, their accuracy values are designated as either "I" or "P," again depending on the breed association supplying the value. Some breeds may publish actual accuracy values, but these will be extremely small in value, such as 0.05. An interim EPD is a pedigree EPD that also includes the animal's own record for that trait. In many cases, these EPDs have accuracies of "I+" or "P+."

The calf progeny has an EPD that is the average of its parents' EPDs until it has a record of its own from a valid contemporary group. Once the calf has its own record, the pedigree EPD is adjusted to include the animal's own record as well. The accuracy is then designated at "I+" (or "P+," depending on the breed association). This depends on the breed association. Some breeds do not identify accuracies with a "+", whereas others may report the actual low numerical value. It may be difficult to know, in these cases, if the animal's own record has been included or not. For those breeds that do not report the numerical accuracy with pedigree and interim EPDs, once the animal has progeny data reported, the accuracy value reported will be the actual numerical value. As more data are added, the accuracy of the animal's EPDs will increase in value.



Expected progeny differences can change over time as additional performance information is collected. Therefore, EPDs come with accuracy values that give an indication of the reliability of the EPDs. Accuracies range from 0 to 1, with values closer to 1 signifying higher accuracies. As more usable performance information becomes available for an animal and its relatives and progeny, its EPDs will become more accurate or reliable. Thus, a young, unproven bull with no calves will have lower accuracy EPDs than a proven sire with hundreds of calf records. Expected change tables are published by breed associations as part of national cattle evaluations to show how much variation can be expected for EPDs at specific accuracy levels.

For an illustration of accuracy values and their role in EPD interpretation, consider the following two bulls. The “Proven Sire” has high EPD accuracy values (ACC = 0.97) for birth weight, weaning weight, yearling weight, and milk EPDs, while the “Unproven Sire” has low EPD accuracy values (ACC = 0.05) for the same EPDs. Yet both bulls have the same EPD values reported for these four EPDs in the current national cattle evaluation. The chart of the “Proven Sire” shows that little change in EPD values is expected in the future as additional performance data is reported to the breed association. The low accuracy values of the “Unproven Sire” indicate that the reported EPDs are less reliable and subject to more possible change as additional performance data is reported to the breed association. While the “Unproven Sire” may currently display EPD levels that meet selection goals, the variability in these values may move its reported EPDs to levels in the future that may or may not meet selection goals. Low accuracy values simply mean more risk is involved in EPD use. However, even low accuracy EPDs might still be the best genetic prediction available for use in selection decisions.



Birth Weight: The birth weight EPD indicates the weight of an animal's calf at birth and is used as an indicator of the probability of dystocia when that calf is born. Because birth weight EPD is expressed in pounds of birth weight, higher birth weight EPD values indicate larger calves that could result in more calving difficulty. It is normally recommended to use low birth weight EPD sires, especially when breeding heifers. Very low birth weight calves may be unthrifty and will have to gain more weight to reach the same size as larger born calves.

Weaning Weight: The weaning weight EPD is measured in pounds of weaning weight and predicts the weight of an animal's calf at weaning. Because producers selling calves at weaning are often paid solely by pounds of calf, a higher value is more desirable. This EPD may be of little value for producers retaining ownership of calves beyond weaning, except for its correlated response to general growth, i.e., yearling weight and mature weight. For producers selling calves at weaning by the pound, this is one of the most important EPDs to consider when making selection decisions.

Yearling Weight: The yearling weight EPD is measured in pounds of yearling weight and predicts the weight of an animal's progeny at one year of age. Typically, a larger value is better. This EPD is of use if calves are going to be retained beyond weaning. For production scenarios where calves are sold at weaning or at some point before yearling, this EPD has little value as a prediction of yearling weight; however, its correlation with weaning weight and mature weight (if heifers are retained) can make it valuable.

More recently, other growth-related EPD have been developed by some breed associations. These are not reported by all associations.

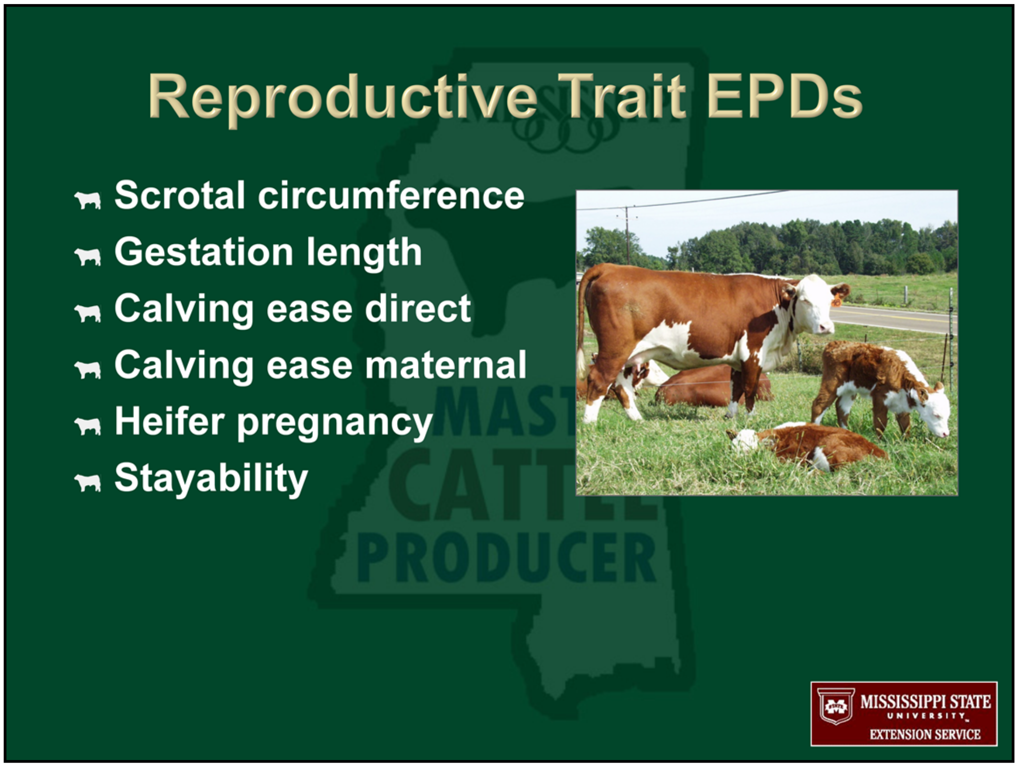
Yearling Height: Yearling height EPDs were developed as a frame size selection tool. This EPD is reported in inches of hip height at one year of age. Although intermediate values are usually more desirable, this EPD could also be used to increase the size so that a herd with mainly small-framed cattle can become more moderate. This EPD is useful for both terminal production systems and those systems where heifers are kept as replacements. Taller calves can be expected to take a longer amount of time on feed in order to reach the Choice grade. For replacements, yearling height is highly correlated with mature height, and this EPD could be used as an indicator for mature size.

Mature Height: Similar to yearling height, the mature height EPD was also developed as a frame size selection tool. In theory, selection for shorter cows will result in cows that require less feed inputs for maintenance. Therefore, this EPD, which is reported in terms of inches of hip height at maturity, could be used as an indicator of the amount of energy required to maintain heifer calves once they reach maturity. As a prediction of mature height, this EPD is of no use in a terminal situation where replacements are not retained. It is, however, useful as an indicator of yearling height due to the high genetic correlation between the two traits. Depending on the breed, this EPD is sometimes referred to as the daughter height EPD.

Mature Weight: The mature weight EPD is another indicator for maintenance energy requirements. In theory, when a cow weighs more, she should be expected to require more feed energy in order to maintain herself. Mature weight is reported in terms of the pounds of mature weight of an animal's daughters and is usually selected for reduced size. If replacement females are not retained, this EPD is not necessary in a selection program. Depending on the breed, this EPD is sometimes referred to as the daughter weight EPD.

Milk: The milk EPD is actually a by-product of the weaning weight EPD. The milk EPD is the maternal portion of weaning weight that is thought to be mainly due to the milk production of the dam. Because of this, the milk EPD is measured in pounds of weaning weight of an animal's grandprogeny due to the milk production of the animal's daughters. In areas where feed resources are abundant, selection for increased milk EPD should not be a problem, but in areas where resources are limited and females are retained, care should be taken not to use breeding animals with high milk EPDs. This is because a high milking female will require more feed energy for lactation and have less energy available to put on the condition necessary to rebreed.

Total Maternal: Like milk, total maternal EPDs are expressed in terms of weaning weight of a bull's daughter's calves. The EPD is calculated by taking half of the weaning weight EPD and adding the entire milk EPD. This accounts for the half of the weaning weight genetics that the grandprogeny will receive from its dam (the other half will come from the calf's sire) and all of the milk production of that calf's dam. Because this is an indicator of weaning weight (of grandprogeny), a higher value is better, similar to the weaning weight EPD. Because this EPD is used to predict the performance of the animal's grandprogeny, this EPD is of no use if heifer calves are not being retained as replacements. Depending on the breed association, this EPD is also referred to as the maternal weaning weight, maternal milk and growth, or milk and growth EPD.



Breed associations have placed an emphasis on developing EPDs for reproductive traits. These traits vary from association to association and are listed below.

Scrotal Circumference: Scrotal circumference is an indicator trait. The EPD for this trait is used as an indicator for the age at puberty, and consequently, heifer pregnancy of a bull's granddaughters. In theory, the larger a bull's scrotal circumference, the earlier his daughters will reach puberty. Therefore, the EPD can be used to select for the scrotal circumference of a bull's sons with implications on the daughters of those sons. The scrotal circumference EPD is expressed in centimeters with a larger number being more desirable. This EPD is of use only in situations in which heifers are retained as replacements.

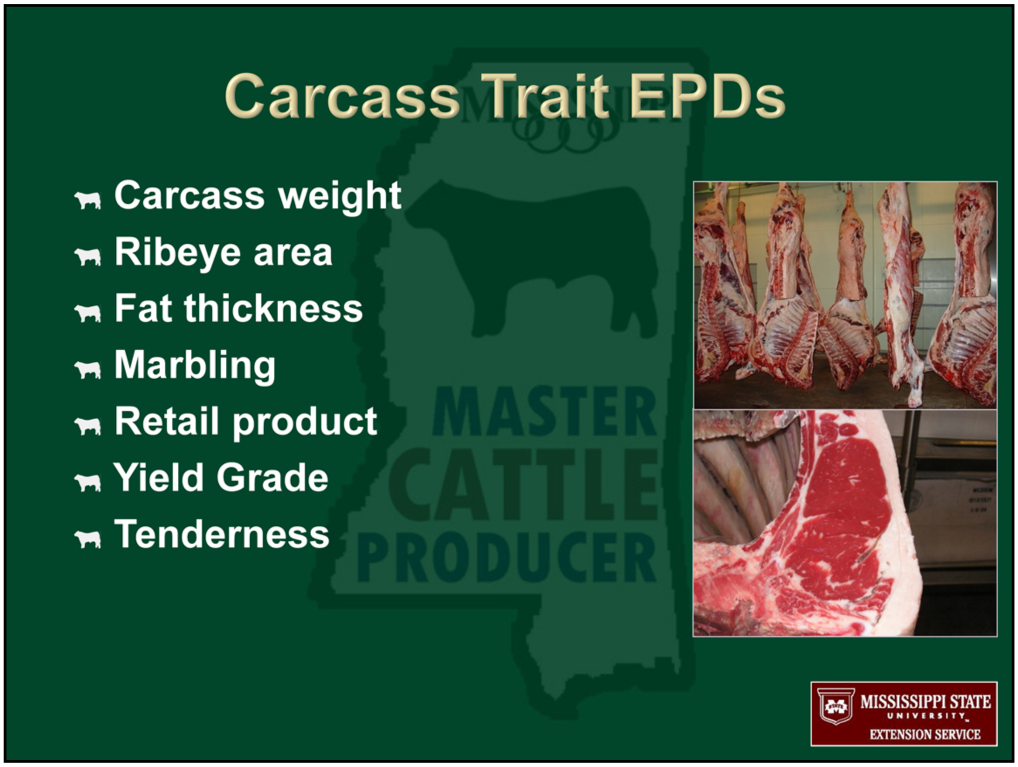
Gestation Length: Similar to birth weight, the gestation length EPD is another indicator of the probability of dystocia. This EPD is reported in terms of days in utero of an animal's calves. The longer a calf is in utero, the more that calf will weigh at birth and the higher probability of dystocia. This EPD is also used to provide cows with a longer postpartum interval before having to be rebred for the next year's calf. Therefore, the gestation length EPD with smaller values are more desirable.

Calving Ease Direct: The calving ease EPDs, both direct and maternal, are the ERTs that indicator traits, such as birth weight and gestation length, are attempting to predict. Calving ease direct EPDs are a measure of the ease at which an animal's calves will be born. This has to do mainly with size and shape of the calves. Calving ease direct EPDs are calculated using information from calvings of 2-year-old females only (no older calvings are included) and the birth weight information of the animal's progeny. In most cases, this EPD is reported as a percentage so that a higher value indicates a higher probability of unassisted calving but is sometimes also reported in ratio form (i.e., 104 versus 4%).

Calving Ease Maternal: Similar to the calving ease direct EPD, the calving ease maternal EPD is also an ERT for unassisted calving. Contrary to calving ease direct EPDs, however, the calving ease maternal EPD predicts the probability of an animal's daughters calving without assistance. This EPD is also expressed in terms of percentages with a higher value indicating that the animal's daughters are more likely to deliver a calf unassisted. Like other EPDs that are related to an animal's grandprogeny, this EPD is of no use unless heifers are retained as replacements. Depending on the breed association, this EPD is sometimes referred to as the calving ease daughters EPD.

Heifer Pregnancy: Heifer pregnancy is an ERT that indicator traits, such as scrotal circumference, predict. Heifer pregnancy EPDs report the probability that an animal's daughters will conceive to calve at two years of age. This EPD is also reported in percentages where a higher value indicates progeny with a higher probability of conceiving to calve at two years of age.

Stayability: Stayability is an indicator of longevity of an animal's daughters in the cow herd. This EPD is reported in percent and predicts the probability that a bull's daughters will remain in the herd through six years of age. The higher the EPD value, the higher the probability that the bull's daughters will remain in the herd through six years of age.



Carcass traits are another group of traits that have begun to be included in genetic evaluations. These EPDs are calculated on an age endpoint as if all cattle were slaughtered at a specific age. Some breed associations report carcass EPDs only, some report ultrasound EPDs only, and some report both. Even if an association reports only one type of EPD (i.e., carcass), both ultrasound and carcass information may go into the calculation of those EPDs because of the genetic correlation between the traits. For producers who are selling calves based strictly on weight with no premiums for carcass traits and not selling seedstock to customers concerned with carcass traits, both carcass and ultrasound EPDs are of limited benefit in selection schemes.

Carcass EPD: Carcass EPDs predict the genetic differences of animals on the rail.

Carcass Weight: Carcass weight EPD report the expected carcass weight, in pounds, of an animal's progeny when it is harvested at a constant age so that producers can select cattle that will produce calves within a certain weight range in order to avoid discounts. There is no ultrasound equivalent to this EPD.

Ribeye Area: Ribeye area EPDs are reported in square inches and indicate the area of the longissimus muscle between the 12th and 13th ribs of an animal's offspring when harvested at a constant age. Although bigger is usually better, some grids may discount for ribeyes that are too large. The ultrasound equivalent to this EPD is the ultrasound ribeye area EPD.

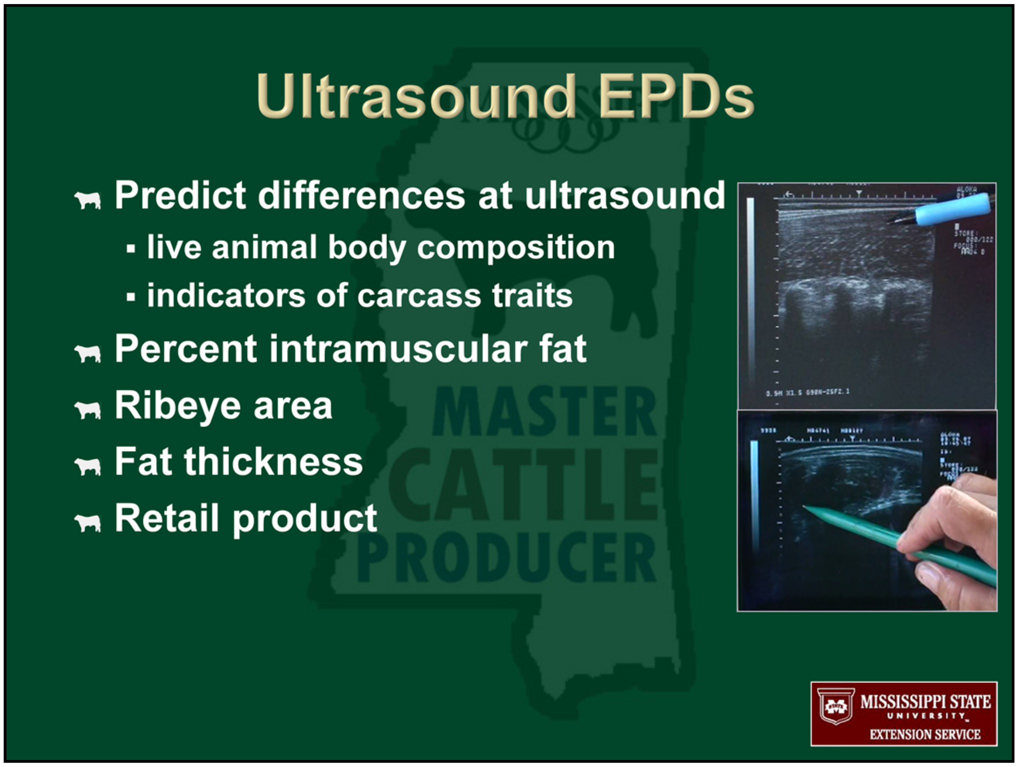
Fat Thickness: This EPD is measured in inches as the prediction of the 12th rib fat thickness of an animal's progeny when harvested at a constant age. A lower value is better to an extent. However, for breeds that are naturally lean, selecting against fat may result in progeny that are too lean, and consequently carcass quality is reduced. Depending on the breed association reporting the estimates, the fat thickness EPD is also sometimes referred to as the backfat EPD or just simply the fat EPD.

Marbling: The marbling EPD indicates the marbling of the ribeye of an animal's progeny when harvested at a constant age. Breed associations code marbling scores for analysis. For most breeds, marbling EPD values range from -0.50 to +0.50. This means that the difference in marbling expected between the progeny of a bull with a +0.50 and a bull with a -0.50 would be a full grade (i.e., Low Choice to Average Choice or Select to Low Choice). The ultrasound equivalent to this EPD is the percent intramuscular fat EPD.

Retail Product: This EPD is a prediction of the salable meat that the carcass of the progeny of an animal will yield. It is roughly equivalent to the yield grade EPD because it takes into consideration the same component traits: fat thickness, hot carcass weight, ribeye area, and percentage kidney, pelvic, and heart fat but weighs each component slightly different than for yield grade. The retail product EPD is expressed in percentage units with a higher value indicating that a greater proportion of the carcass is in the form of salable meat. The ultrasound equivalent to this EPD is the ultrasound retail product EPD. Depending on the breed association, this EPD is also called retail yield percent, percent retail, percent retail product, percent retail cuts, or retail beef yield percentage.

Yield Grade: Similar to the retail product EPDs, the yield grade EPDs are a measure of lean meat yield of the carcass. All of the same component traits are included in yield grade as in retail product, but each is weighted differently than for retail product. Although retail product is expressed in percent, yield grade is expressed in grade units. The lower the grade, the leaner the carcass, in contrast to retail product where higher values indicate a higher percentage of retail cuts. An animal receiving a calculated yield grade of 1.0 – 1.9 is a Yield Grade 1, an animal receiving a calculated yield grade of 2.0 – 2.9 is a Yield Grade 2, etc. The highest yield grade is 5, so any animal receiving a calculated yield grade of 5.0 or more is classified as a Yield Grade 5. There is currently no ultrasound equivalent to the yield grade EPD.

Tenderness: The tenderness EPD is measured in pounds of Warner Bratzler Shear Force so that a higher value indicates that more pounds of shear force are required to cut through the meat. Therefore, a lower value indicates more tender meat and is more desirable. There is no ultrasound equivalent to the tenderness EPD.



Ultrasound EPD: Ultrasound EPDs predict differences at ultrasound, which is an indicator of the carcass traits when it is on the rail.

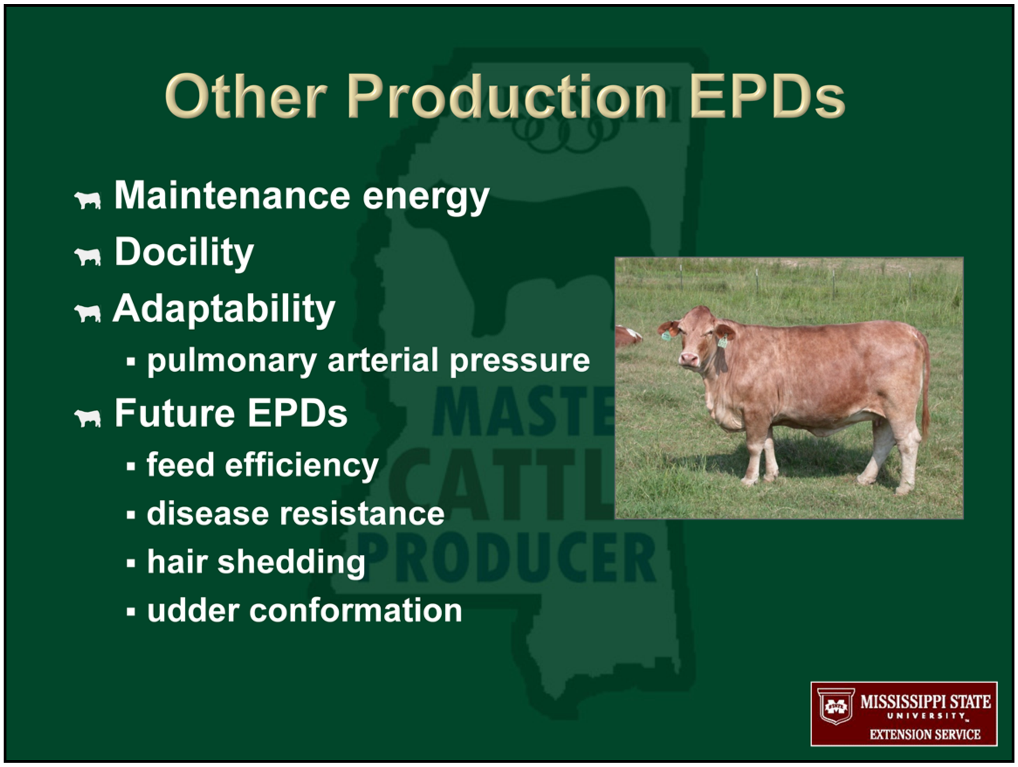
Percent Intramuscular Fat: The ultrasound equivalent of the marbling EPD is the percent intramuscular fat EPD. Like the carcass marbling EPD, a higher value indicates more marbling and is generally more desirable. Unlike the carcass marbling EPD, this EPD is measured in percentages.

Ribeye Area: The ultrasound ribeye area EPD is the ultrasound equivalent to the carcass ribeye area EPD. The ultrasound version is measured the same, in square inches, and it is also generally more desirable to have a higher value.

Fat Thickness: The ultrasound fat thickness EPD is comparable to the carcass fat thickness EPD and has the same limitations. In most cases, it is more desirable to select for less fat at the 12th rib, but selection to extremes can result in decreased carcass quality. Like the carcass equivalent, this EPD is measured in inches.

Retail Product: Similar to its carcass version, the ultrasound retail product EPD combines several component traits to determine the amount of salable meat in the carcass. A higher value indicates a higher proportion of the carcass is in the form of salable meat. This is measured in percent, like its carcass equivalent, but uses the ultrasound component traits.

In some cases, carcass and ultrasound data are combined into a single EPD.

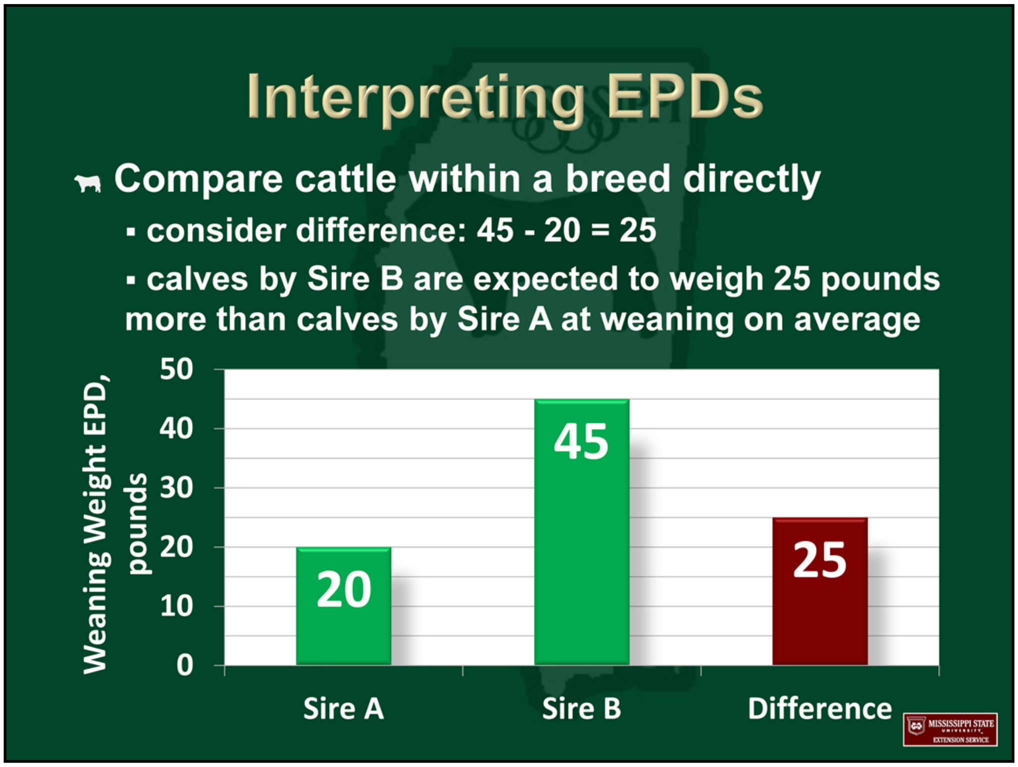


Maintenance Energy: The maintenance energy EPD is a predictor of the energy needed for a cow to maintain herself. Daughters of animals with lower maintenance energy EPD values will require less feed resources than will daughters of animals with higher values. Therefore, it is beneficial to select animals with lower maintenance energy EPD values. Maintenance energy EPD are measured in terms of megacalories per month. This EPD is of no use if heifer calves are not retained as replacements.

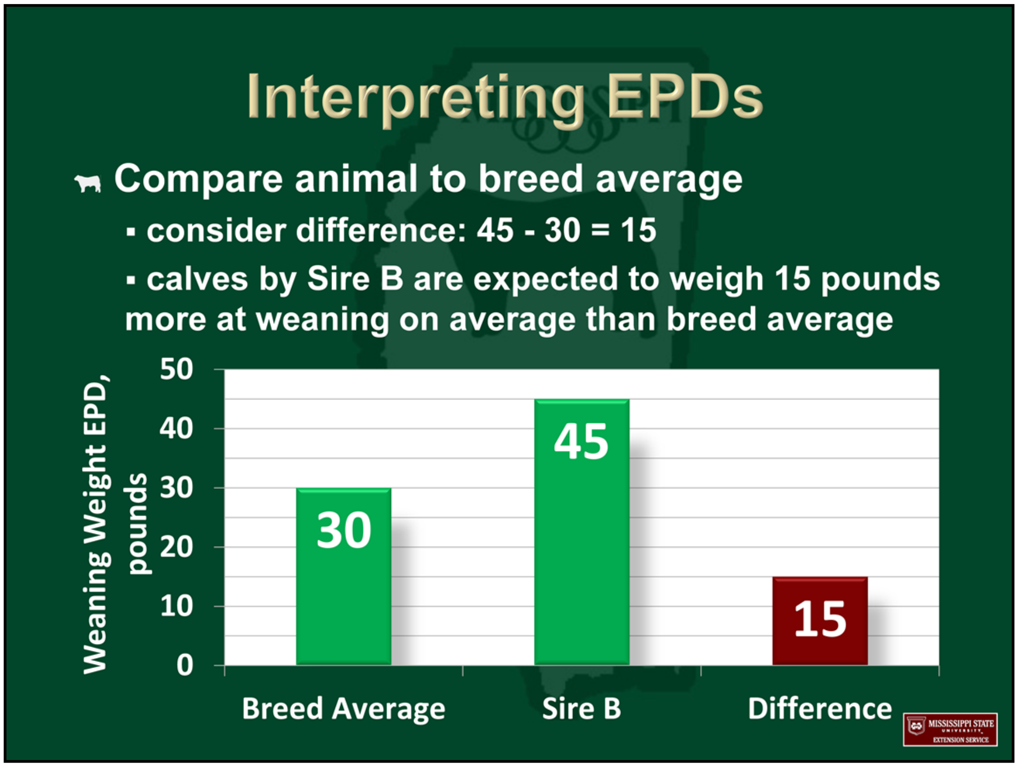
Docility: Docility EPDs are a measure of the behavior of an animal's calves as they leave the chute. Animals are evaluated by producers on a scale of 1 to 6, with 1 meaning docile and 6 indicating extremely aggressive behavior. Docility EPDs are reported as percentages so that animals with a higher docility EPD value will have a higher probability of producing calm animals.

Pulmonary Arterial Pressure: Pulmonary arterial pressure EPDs also provide another indicator for longevity in the cow herd. Animals with higher pulmonary arterial pressure are more susceptible to brisket (or high mountain) disease. Pulmonary arterial pressure EPDs are measured in millimeters of mercury, with a lower value being more desirable. Similar to stayability, because this EPD is an indicator of longevity, it is of no use in strictly terminal situations where heifer calves are not retained. This EPD is also not necessary for cattle that are not going to be in high elevations. The pulmonary arterial pressure EPD is not routinely calculated by any breed association but is calculated, by request, for some individual producers.

Future EPDs may address a wide variety of traits. Research and data collection are currently underway for several traits including feed efficiency, disease resistance, hair shedding, and udder conformation.



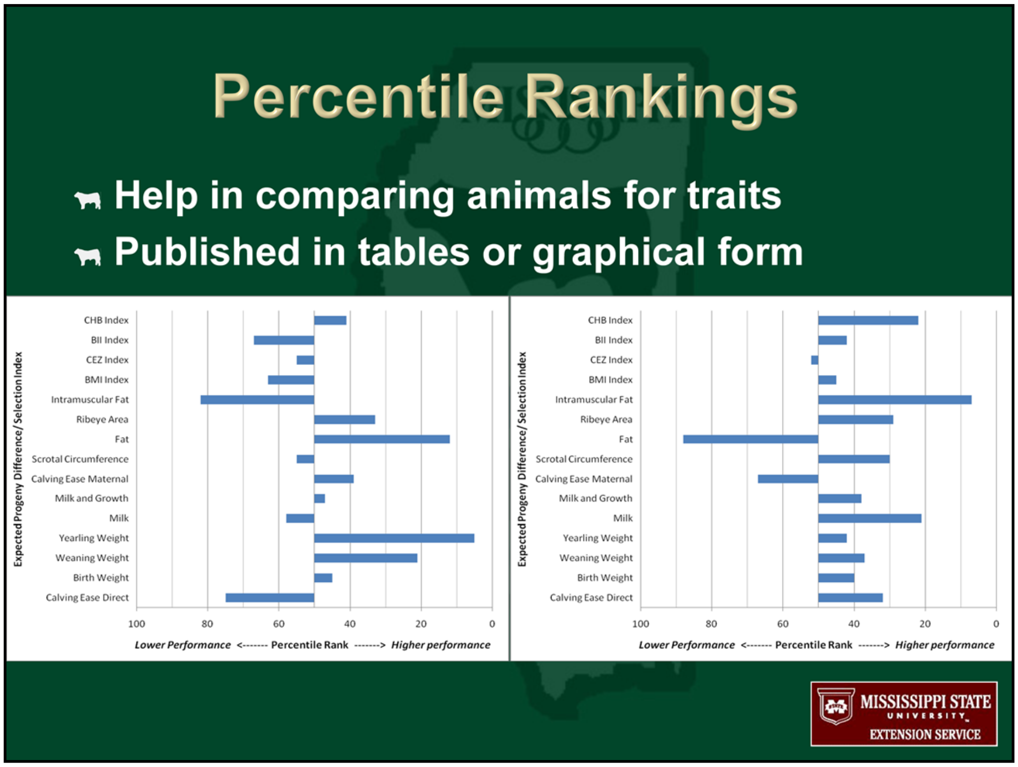
Expected progeny differences are often used to make direct comparisons of 2 or more animals within a breed. For illustration, calves sired by Sire A (weaning weight EPD = 20) are expected to be on average 25 pounds lighter at weaning age than calves sired by Sire B (weaning weight EPD = 45) when mated to similar females. This is determined by calculating the difference between the two EPD values; 20 – 45 = -25.



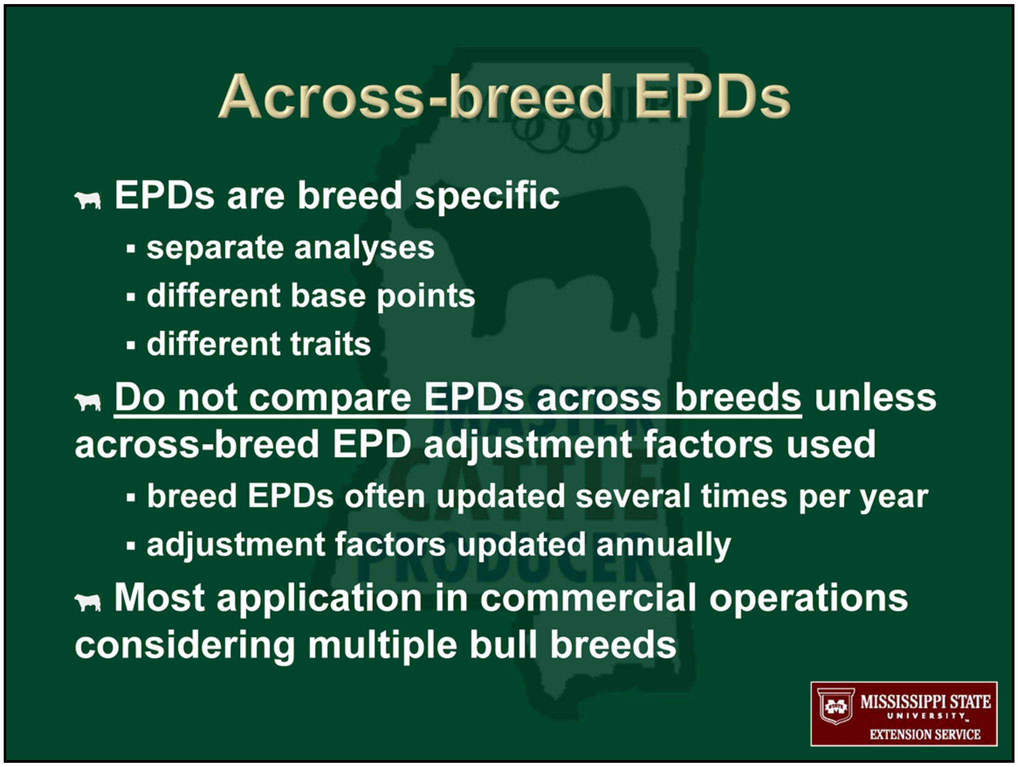
Similarly, EPDs are also used to rank cattle within a breed. Cattle are commonly compared against breed average values. For example, calves sired by Sire B can be expected to be on average 15 pounds heavier at weaning age than the average of calves sired by all other bulls in that same breed when mated to similar females when the breed average yearling weight EPD = 30; 45 – 30 = 15.

Breed average EPDs provide a benchmark against which to compare animals. Just as the name implies, they are the average EPDs for animals included in that run of the genetic evaluation. Many associations will also split the breed averages into those for active proven sires, young sires, dams, non-parents, etc.

Traditionally, breeds had a base year, and the average EPDs in the base year was set to zero, so that any difference from zero would correspond to a difference from the average in the base year, not the current year. Recently, however, some breeds have varied from the base year idea, so it is not as easy to determine what an EPD of zero equates to. What is common across all breeds, however, is that zero does not automatically mean breed average.

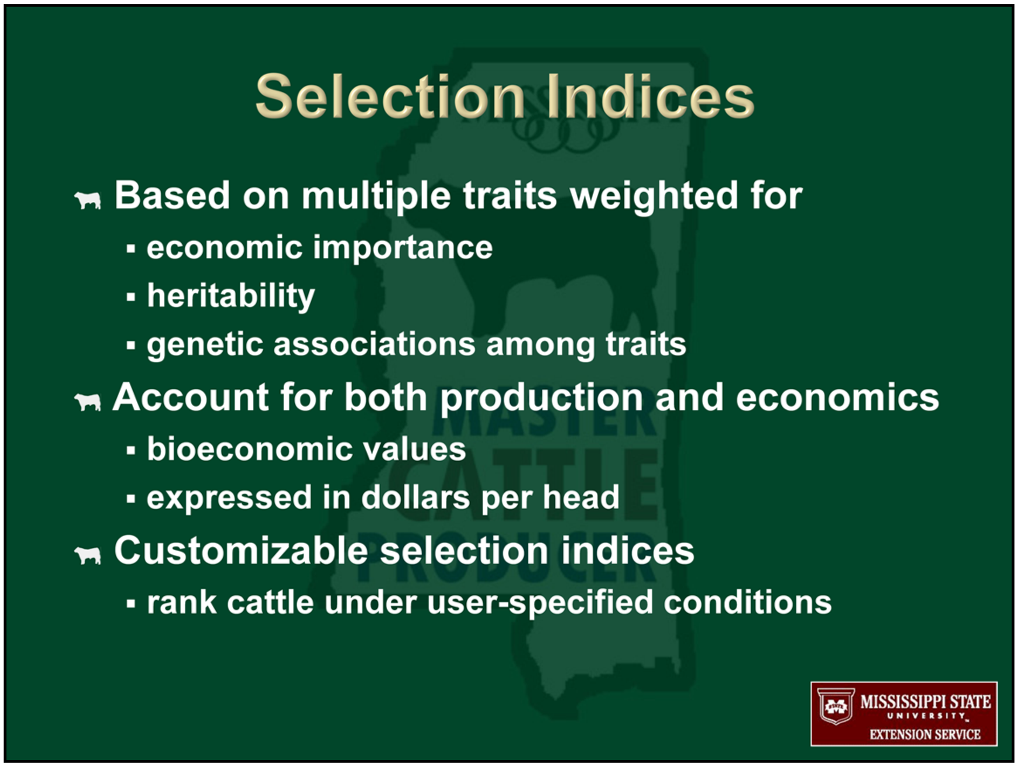


Percentile ranking tables allow EPD and selection index values from one animal to be compared to another animal within the same breed and breed averages. For example, percentile rankings of a bull within a breed provide a profile of the bull that can be readily assessed and compared to other bulls of that breed. Comparing the percentile rank profiles above, the bull profile on the left appears to be better suited to breeding to mature cows where no heifers are retained and calves are marketed at weaning or yearling. The bull profile on the right depicts a bull that may be appropriately used to breed to heifers or mature cows where replacement heifers could be retained and calves could best be marketed on value-based grids at harvest. Some breed association websites generate automatic EPD and selection index profiles similar to those depicted in above. Producers interested in bulls of breeds that do not do this can use the same concept to develop their own percentile rank profiles for comparison and selection purposes.



Expected progeny differences are breed-specific. The EPDs of bulls from different breeds cannot normally be compared because they are calculated in separate analyses and each breed has different base points for various EPDs. Therefore, direct comparisons of EPDs across breeds should not be made unless across-breed EPD adjustment factors are used. The USDA Meat Animal Research Center publishes annual updates of adjustment factors to add to EPDs of 16 beef cattle breeds to estimate across-breed EPDs. As a general rule, unless updated breed-specific adjustment factors are added to current EPDs, compare the EPDs of a particular animal to animals within the same breed.

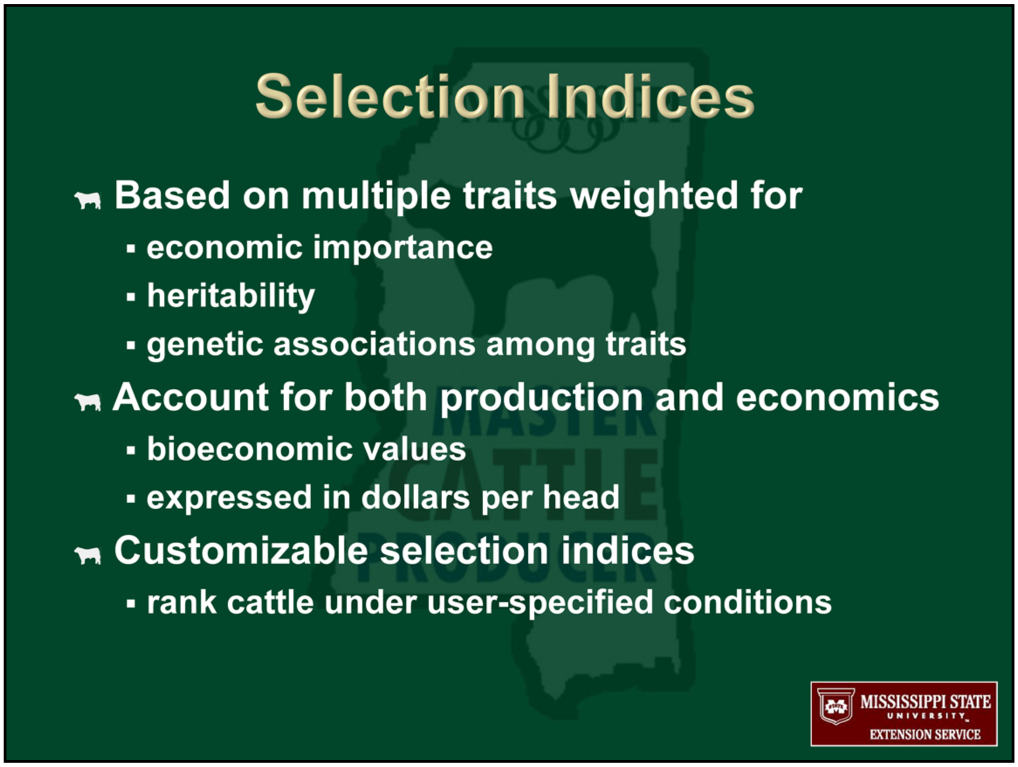
Across-breed EPDs have the most application for commercial cow-calf producers considering use of bulls of more than one breed in crossbreeding programs. Uniformity between generations may be improved by selection for similar across-breed EPDs. Many breed associations publish EPDs on individual animals in sire summaries and searchable internet databases. Breed associations also publish tables that show where individual animals rank within the breed for specific traits such as weaning weight or ribeye area.



Selection indices are based on multiple traits weighted for economic importance, heritability (the proportion of the differences among cattle that is transmitted to their offspring), and genetic associations among traits. In other words, a selection index is a selection tool that accounts for both biological production levels and economics. That is why selection indices are sometimes called bioeconomic values. Selection indices are expressed in dollars per head. A selection index may provide a balanced selection approach when selecting for more than one trait at a time. Yet, when using a selection index, it is valuable to know the traits included in it and the relative emphasis placed on these traits within the index calculation. This allows fine-tuning of selection index use within a specific herd. Definitions of specific selection indices are available from the respective breed associations.

Customizable selection indices provide breeders with the option to rank cattle according to production and economic conditions specified by the user. Several breed associations provide web-based versions of selection indices that allow the user to enter their own values for various inputs such as herd size, average cow weight, nutrition-related costs, and market prices. Customizable selection indices can be used to rank cattle for the specific production and economic environment in which they intend to be used. The end result is a simulation of ranch-specific production and marketing conditions in which potential breeding animals can be compared.

For more information on selection tools, refer to Mississippi State University Extension Service Publication 2491, “Expected Progeny Differences and Selection Indices for Beef Cattle Selection”.



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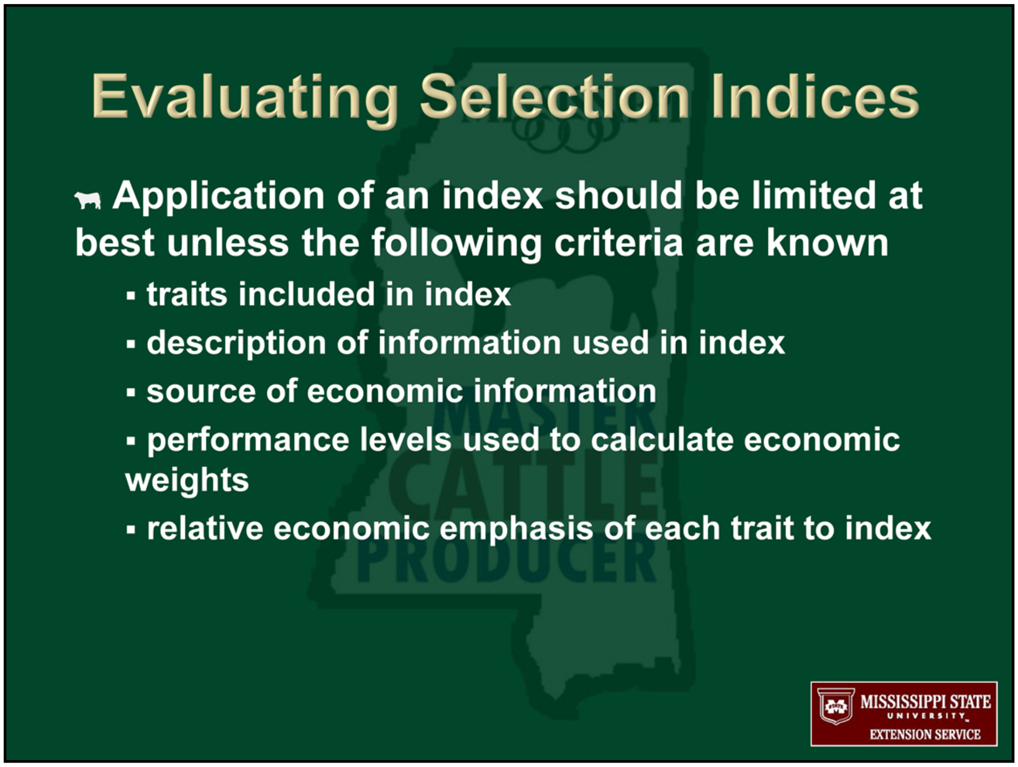
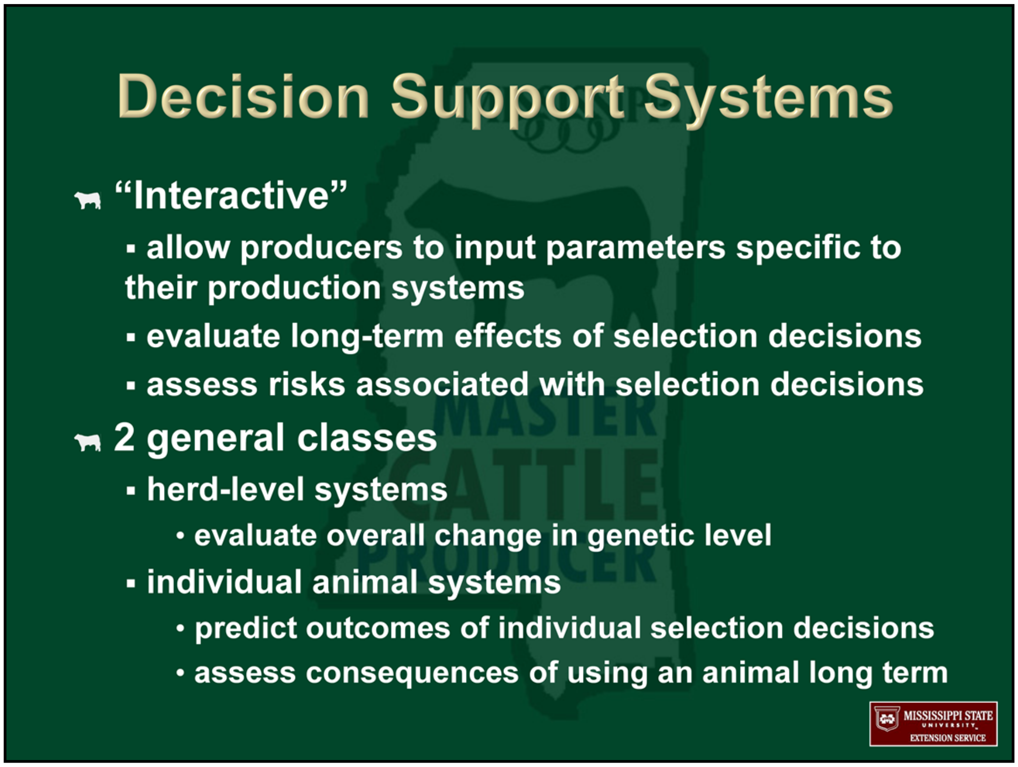
Customizable selection indices provide breeders with the option to rank cattle according to production and economic conditions specified by the user. Several breed associations provide web-based versions of selection indices that allow the user to enter their own values for various inputs such as herd size, average cow weight, nutrition-related costs, and market prices. Customizable selection indices can be used to rank cattle for the specific production and economic environment in which they intend to be used. The end result is a simulation of ranch-specific production and marketing conditions in which potential breeding animals can be compared.

For more information on selection tools, refer to Mississippi State University Extension Service Publication 2491, “Expected Progeny Differences and Selection Indices for Beef Cattle Selection”.



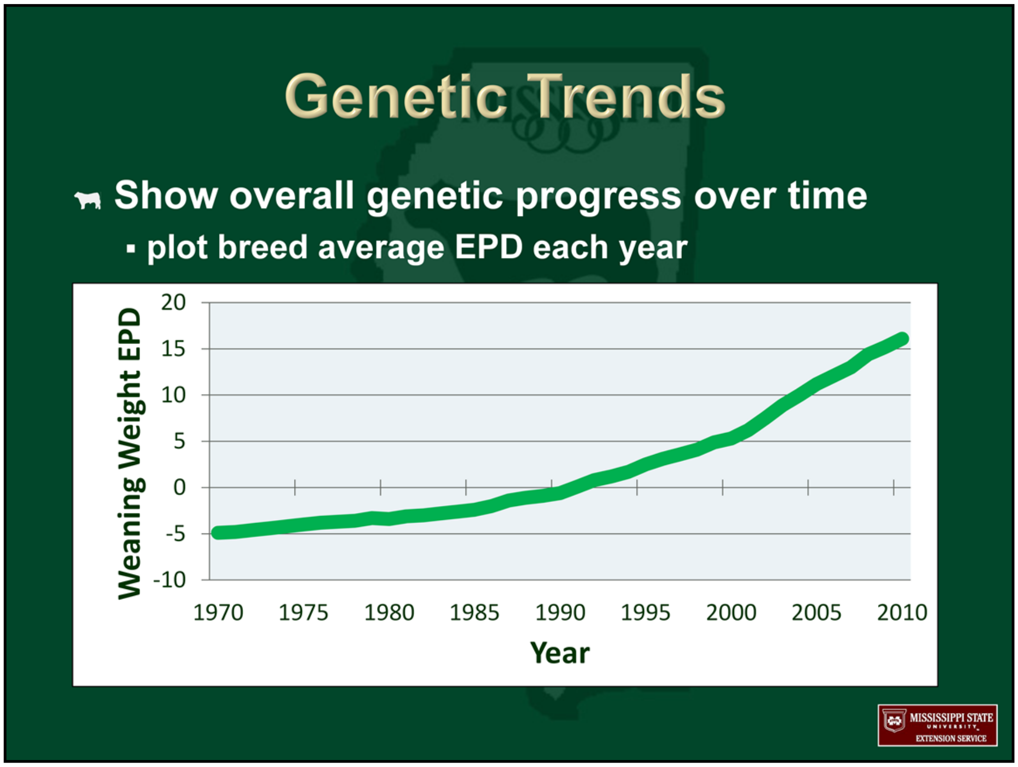
Many indices are produced by individual breed associations and may or may not include all of the traits that are economically relevant to a particular production system. When deciding on the use of generalized indexes, several criteria must be available for the breeder to evaluate utility of each index in his or her production system. If these criteria are not available, then application of those indexes should be limited at best. At minimum, a description of every index should include traits included in the index; a description of information used in the index, such as EPDs from a breed evaluation or individual phenotypic performance; the source(s) of economic information and performance levels used to calculate economic weights; and the relative economic emphasis of each trait to the overall index.

Without knowing the traits included in an index, a producer cannot decide whether its use is appropriate or not. In a perfect world, the index would contain all of the traits that are economically relevant for the breeder's system. Unfortunately, this scenario is unlikely, and the breeder should identify the index with the most traits in common with his or her list of economically relevant traits. Use of EPDs is always a more ac curate form of selection than use of phenotypic information. Use of similar economic values may not be appropriate among different breeders due to differences in input costs. It is important to have information on the relative importance of traits in an index—which trait is most emphasized, which is second, and so on down to the least emphasized trait. Economic weights can be expressed as a dollar value or as a relative weight indicating the emphasis placed on each trait. A breeder would not likely choose an index that puts most emphasis on a trait that is of little value to that production system or is already at an optimum level. This further refines the selection of the appropriate index.

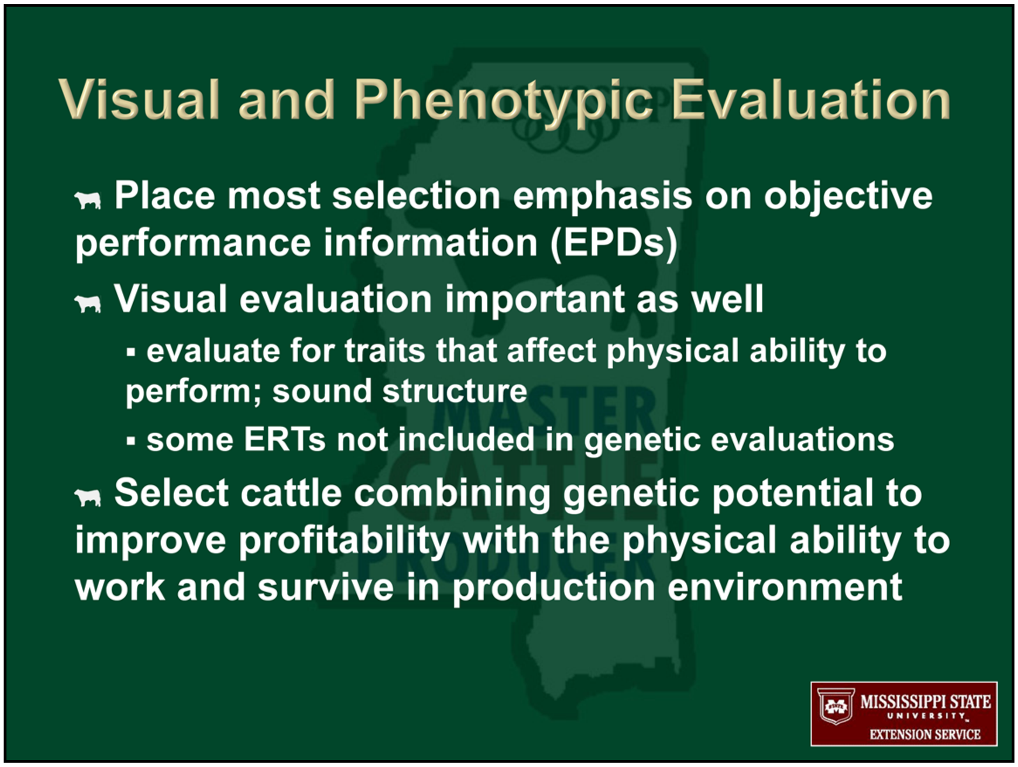


Interactive decision support tools overcome the weaknesses inherent in generalized indexes. The term "interactive" refers to systems that allow producers to input parameters specific to their production systems. These interactive systems offer increased flexibility to simulate individual breeders' production systems and allow evaluation of the long-term effects of selection decisions and evaluation of the risks associated with particular selection decisions.

There are two general classes of interactive decision support systems. The first are herd-level systems that require herd-wide biological inputs and costs and incomes of production and, in turn, return herd-wide results. These systems are designed to evaluate overall change in genetic level rather than to evaluate potential individual selection decisions and to uncover important interactions between genetic level and environment. Systems of the second type are animal based, and they predict outcomes of individual selection decisions and the potential consequences of using an animal (or animals with similar EPDs) over the long-term scenario. The second class of decision support systems is designed for evaluating individual animal selection decisions and the impact of those decisions on profitability. These systems are based on breeder-specific production and economic data.

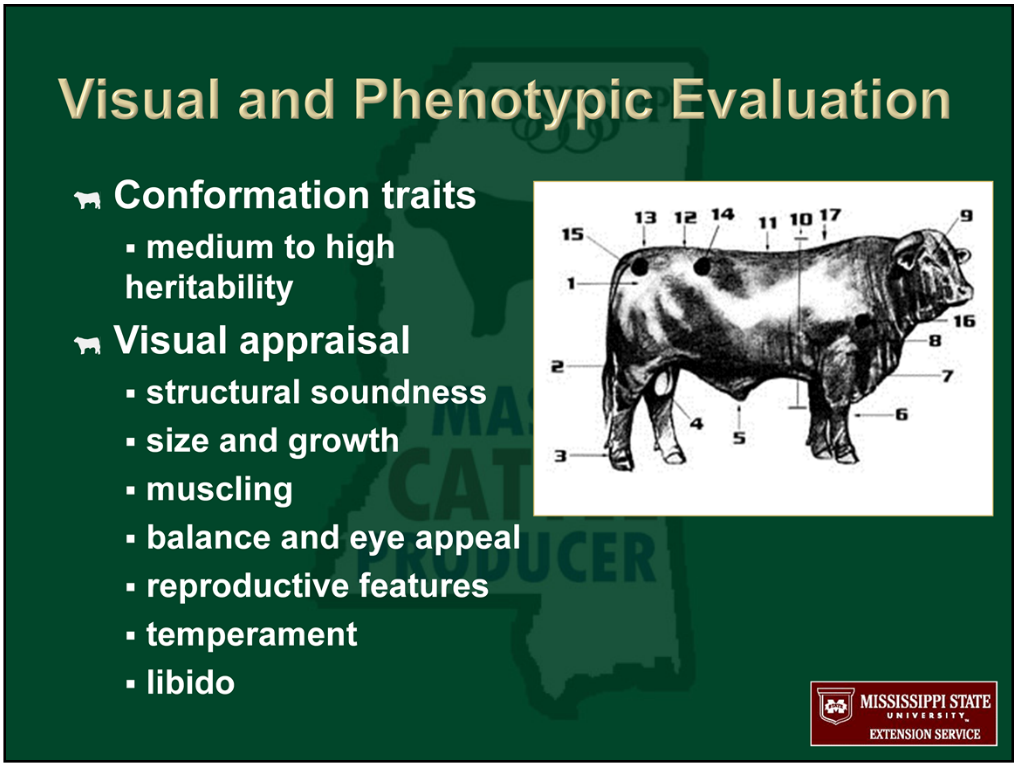


Genetic trends show the overall genetic progress for the breed over many years. This is done by plotting the breed average EPD for each year. These trends are typically depicted in graphs similar to the one shown in the figure above. This figure depicts a hypothetical genetic trend for weaning weight. It can easily be seen that weaning weight has increased over the past 40 years, most likely due to selection for the trait. It also appears that there has been a stronger emphasis placed on selection beginning in the mid- to late 1980s and continuing through today.



While a majority of the emphasis in cattle selection should be placed on objective performance information, visual and phenotypic evaluation remains important for two reasons. First, cattle must be evaluated for traits that affect their physical ability to perform. In addition, some traits of economic relevance are not included in genetic evaluation programs. Strive to select cattle that combine the genetic potential to improve profitability with the physical ability to work and survive in their production environment.

Prior to the advent of performance testing, producers used visual evaluation to predict the breeding value of bulls for traits like growth rate and carcass composition, with variable success. The first performance-tested herds provided adjusted weights and in-herd ratios to their bull buyers, increasing accuracy of selection within one herd’s offering. However, only with the availability of EPDs were bull buyers able to accurately compare animals from different herds. Focus on genetic evaluation results in the form of EPDs for selection whenever possible. Using the most current EPDs will most likely result in the desired genetic change. The animal with the most desirable actual performance will not necessarily produce the most desirable progeny (calves). “Adjusting” EPDs for the actual performance data or visual characteristics of the animal biases selection and results in less than maximum genetic progress with no reduction in risk. Expected progeny differences are the single best estimate of progeny performance. When EPDs are available, using the actual weights or ratios with or without the EPD decreases the accuracy of selection.



Conformation is the form, shape, and visual appearance of an animal. Most conformation traits are medium to high (30-60%) in heritability. Selection for them will result in genetic improvement. Placing some selection emphasis on conformation traits such as skeletal (particularly feet and legs), udder, eye, and teeth soundness is justified. Conformation can also affect animal marketability.

Visual appraisal should consider the “functionality” of an animal. Assess whether or not cattle have potential to do the job intended and whether or not they are physically appealing (important for marketability). Evaluate the following:

•Structural soundness

•Size and growth (in terms of frame and weight)

•Muscling (thickness)

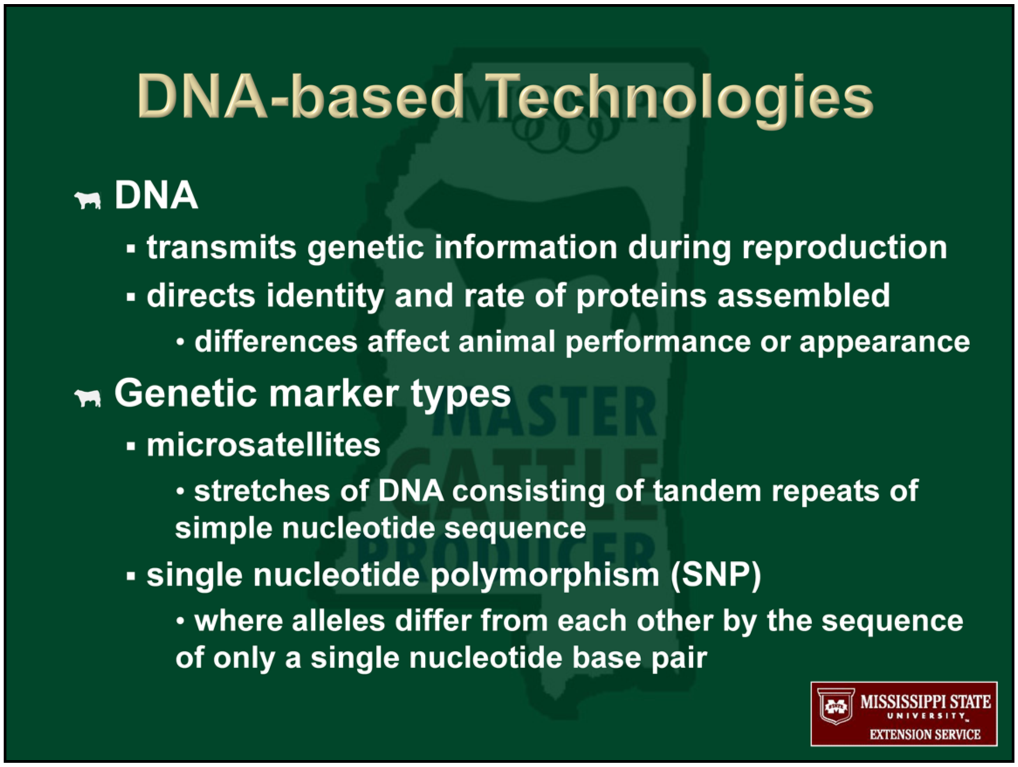
•Balance and eye appeal

•Reproductive “equipment” – A Breeding Soundness Exam is a must for any bull to be considered for purchase.

•Temperament (excitability or docility)

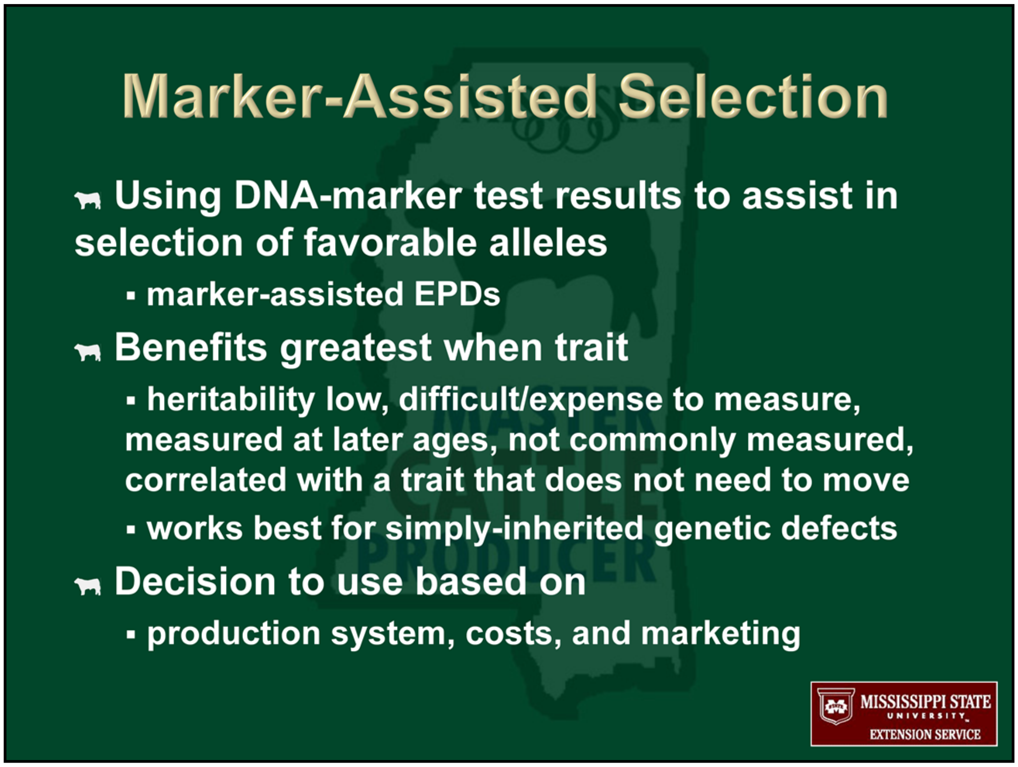
•Libido (sexual aggressiveness, desire to mate)

Some traits that affect, for example, the ability of natural service sires to successfully breed cows, like breeding soundness and skeletal structure, must be visually evaluated. The ability of a bull to walk freely and without discomfort is critical for both breeding and grazing behavior. The most critical details of soundness are correct slope and angle to the joints of the front and rear limbs. Bulls that are excessively straight-legged travel with short strides and are somewhat prone to stifle injuries during mating. Sound structured bulls, walking on smooth, level ground, will set their rear hoof down in the track of their front hoof. Straight-shouldered, straight-legged bulls will set their hind foot down in a position well behind where the front foot was set. Hocks and knees should be free of any swelling or inflammation. Structural problems in yearling bulls tend to become more severe as the bulls age and increase in weight. Likely the most important reason to evaluate prospective herd sires visually is to ensure they have the physical characteristics necessary to serve a large number of cows for a number of years.



Living organisms are made up of cells, and located on the inside of each cell is deoxyribonucleic acid (DNA). DNA is made up of pairs of four nucleotides abbreviated as "A", "C", "G", and "T". The entire genetic makeup, or genome, of an organism is stored in one or more chromosomes located inside each cell. DNA has two important functions; first, it transmits genetic information during reproduction, and, second, it continually spells out the identity and the rate of assembly of proteins. Proteins are essential to the structure and function of plants and animals. A gene is a distinct sequence of DNA that contains all of the instructions for making a protein. It is possible for the DNA sequence that makes up a gene or "locus" to differ between individuals. These alternative DNA sequences or forms of a gene are called alleles, and they can result in differences in the amount or type of protein being produced by that gene among different individual animals. This can affect the performance or appearance of animals that carry different alleles.

Recently scientists have started to identify regions of DNA that influence production traits. They have used the techniques of molecular biology and quantitative genetics to find differences in the DNA sequence in these regions. Tests have been developed to identify these subtle sequence differences and so identify whether an animal is carrying a segment of DNA that is positively or negatively associated with the trait of interest. These different forms of a genetic marker are known as DNA-marker alleles. There are several types of genetic markers. *Microsatellites* are stretches of DNA that consist of tandem repeats of a simple sequence of nucleotides (e.g., "AC" repeated 15 times in succession). The tandem repeats tend to vary in number such that it is unlikely two individuals will have the same number of repeats. To date, the molecular markers used to determine parentage have primarily utilized microsatellite markers. Another type of genetic marker is referred to as a *single nucleotide polymorphism or SNP* (referred to as "snip"), where alleles differ from each other by the sequence of only a single nucleotide base pair. SNP genetic tests focus on detecting precise single nucleotide base pair differences among the three billion nucleotide base pairs that make up the bovine genome.



Marker-Assisted Selection (MAS) is the process of using the results of DNA-marker tests to assist in the selection of individuals to become the parents in the next generation of a genetic improvement program. That is, instead of using only a traditional or EPD selection program to increase the proportion of favorable alleles for the genes that affect a certain trait, specific DNA tests are used to assist in the selection of those favorable alleles. Genotyping allows for the accurate detection of specific DNA variations that have been associated with measurable effects on complex traits. It is important to remember that markers for complex traits are associated with only those genes that are located in close proximity to the marker and do not identify favorable alleles for all the other genes that are associated with the trait. Selecting an animal that carries favorable alleles of a marker, which is the allele that is associated with a positive impact on the trait of interest, can result in an improvement in the observed phenotype for that trait. Although complex traits are influenced by a number of genes, the mode of inheritance of each genetic marker is simple. An animal gets one marker allele from its sire and one marker allele from its dam. The alleles of the marked genes, as well as the numerous other “unmarked” genes, and the production environment will determine an animal’s phenotype (e.g., weaning weight, marbling, etc.). EPD estimate the breeding value of all the genes (both “marked” and “unmarked”) that contribute toward a given trait; therefore, when EPD exist for a given trait, they should always be considered in selection decisions, even when marker data are available.

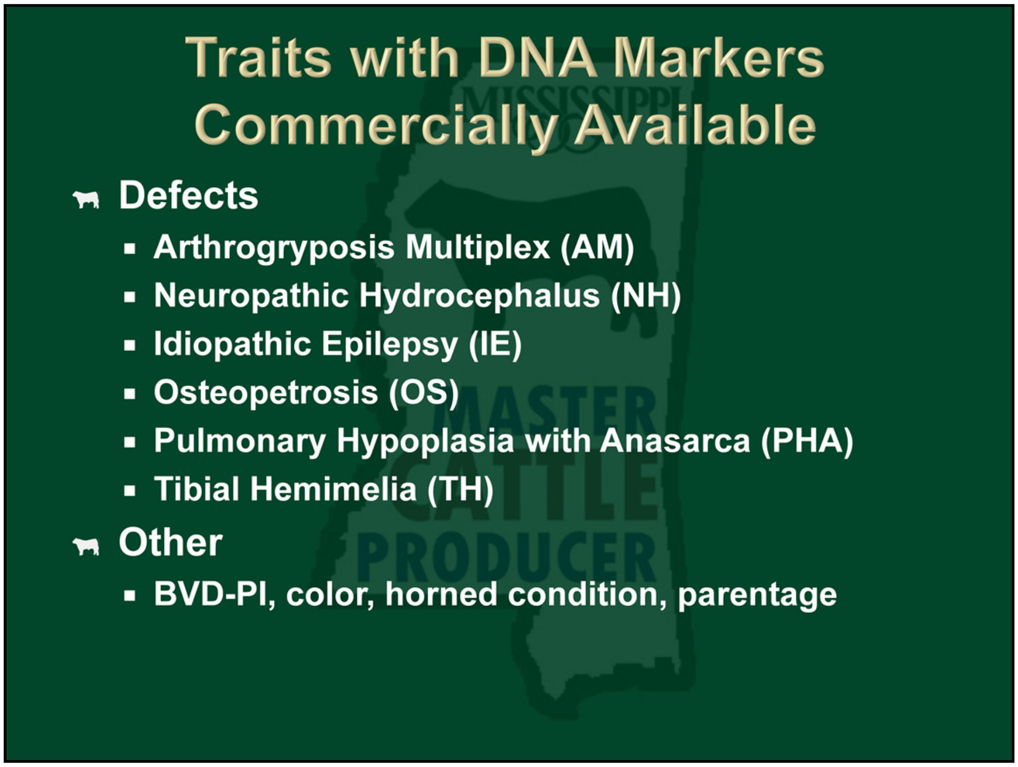
Potential benefits from marker-assisted selection are greatest for traits that have low heritability, are difficult or expensive to measure (e.g., disease resistance), cannot be measured until after the animal has already contributed to the next generation (e.g., reproduction or longevity), are currently not selected for because they are not routinely measured (e.g., tenderness), or are genetically correlated with a trait that does not need to increase (e.g., a marker that is associated with increased marbling but that is not also associated with those genes that increase backfat thickness).

The following categories of traits are ordered according to those most likely to benefit from marker-assisted selection to those least likely to benefit: 1. simply inherited genetic defects; 2. carcass quality and palatability attributes; 3. fertility and reproductive efficiency; 4. carcass quantity and yield; 5. milk production and maternal ability; 6. growth, birth weight, and calving ease.

Whether to use DNA-based marker-assisted selection in a breeding program is the most important question for producers and one that is not easily answered, as it will differ for every producer based on the production system, costs for obtaining the genetic information, and marketing considerations. The following questions should be asked when evaluating the use of marker-assisted selection in a breeding program:

1. Will marker-assisted selection make the operation money?
2. What impact does increasing the frequency of the marker allele have on the trait of interest in the herd?
3. Is it a single gene test, or are there results from more than one gene?
4. What form of the marker is wanted for the herd and production environment?
5. What is being given up to use animals that are carrying the marker of interest?
6. Could good progress in that trait be achieved without the expense of marker-assisted selection?

Once a decision has been made to use marker-assisted selection, the actual application of the technology is fairly straightforward. DNA samples should be collected from all animals to be tested. Common collection methods include a drop of blood blotted on paper (make sure to let the sample dry well before storing), ear tag systems that deposit a tissue sample in an enclosed container with bar code identification, semen, or hair samples (including the DNA-rich follicle or root).



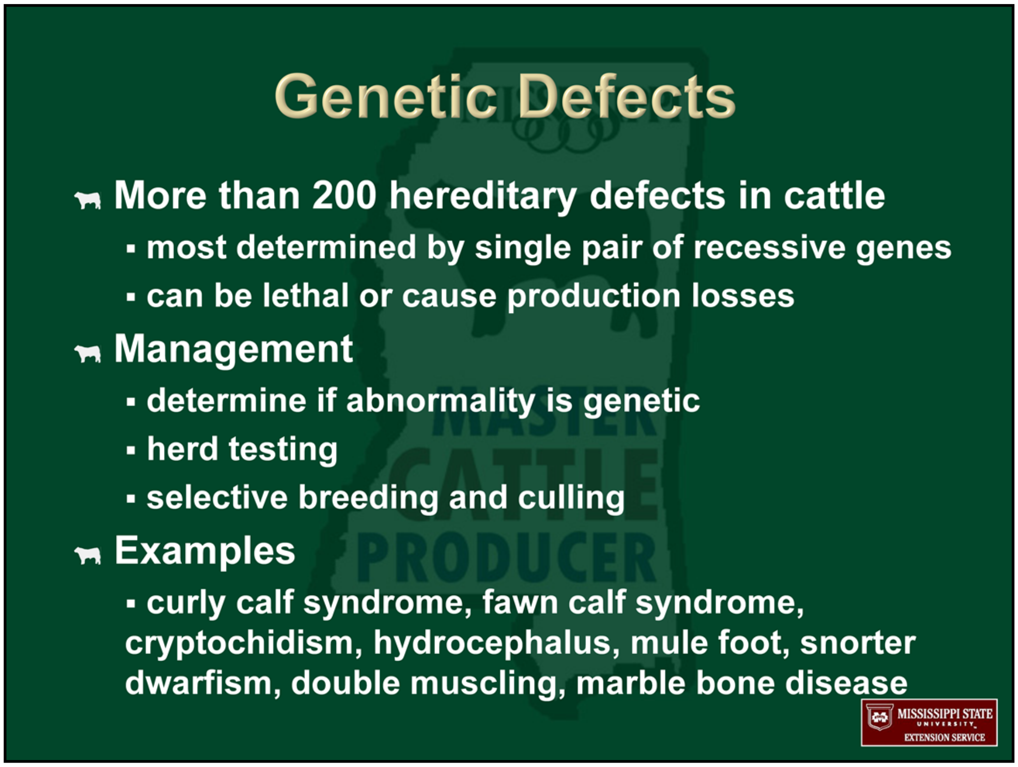
DNA marker is a term used to refer to a specific DNA variation among individuals that has been found to be associated with a certain characteristic (for example, increased tenderness). These different DNA or genetic variants are known as alleles. DNA marker testing or genotyping determines which alleles an animal is carrying for a DNA marker(s). The use of this genotype information from DNA marker tests associated with simple traits is relatively straight forward. Such traits are often controlled by a single gene, and a marker allele associated with that gene can perfectly predict the phenotype of that trait (the physical attributes of an animal). DNA tests for simple traits have been on the market for several years and include those for certain diseases, coat color, and horned status.

Most economically relevant traits are complex, meaning they are controlled by many genes and are also influenced by the environment. Examples of complex traits include carcass characteristics, growth traits, and reproductive performance. Any single DNA marker is associated with only one of the many genes that control complex traits. Genetic markers for many of these traits are commercially available.

The accuracy of a DNA test at predicting the true genetic merit of an animal for quantitative traits is primarily driven by the amount of additive genetic variation accounted for by the DNA test. Current estimates for this correlation and the proportion of the variation accounted for by existing marker tests are generally low (<0.1) with the exception of DNA tests for tenderness.

It is important to combine DNA test results which currently involve a relatively small number (<100) of SNP markers and typically explain a small proportion (<10%) of the genetic variation associated with the target trait) with other criteria, such as EPDs (which look at the effects of many "unmarked" genes and the animal's actual phenotype for the trait (if available), to ensure that selection is distributed over all the genes that contribute towards the trait of interest. Animals that have a good EPD for a given trait and yet are not carrying the favorable form of a marker for that trait should not be ignored. These animals are likely to be a source of good genes for the many other genes that contribute towards that trait. Ideally the information from genetic tests will become integrated into a genetic evaluation system that weighs all the information about an animal. In the future, DNA information may enable the development of EPDs and associated accuracy values for traits that have no phenotypic data because that are difficult or expensive to measure.

Several multiple-marker tests are commercially available. Some companies are also offering marker panels for marker-assisted management (MAM). Marker-assisted management is a relatively new term that refers to the process of using DNA marker information to make decisions on how to manage a particular animal or a specific group of animals.

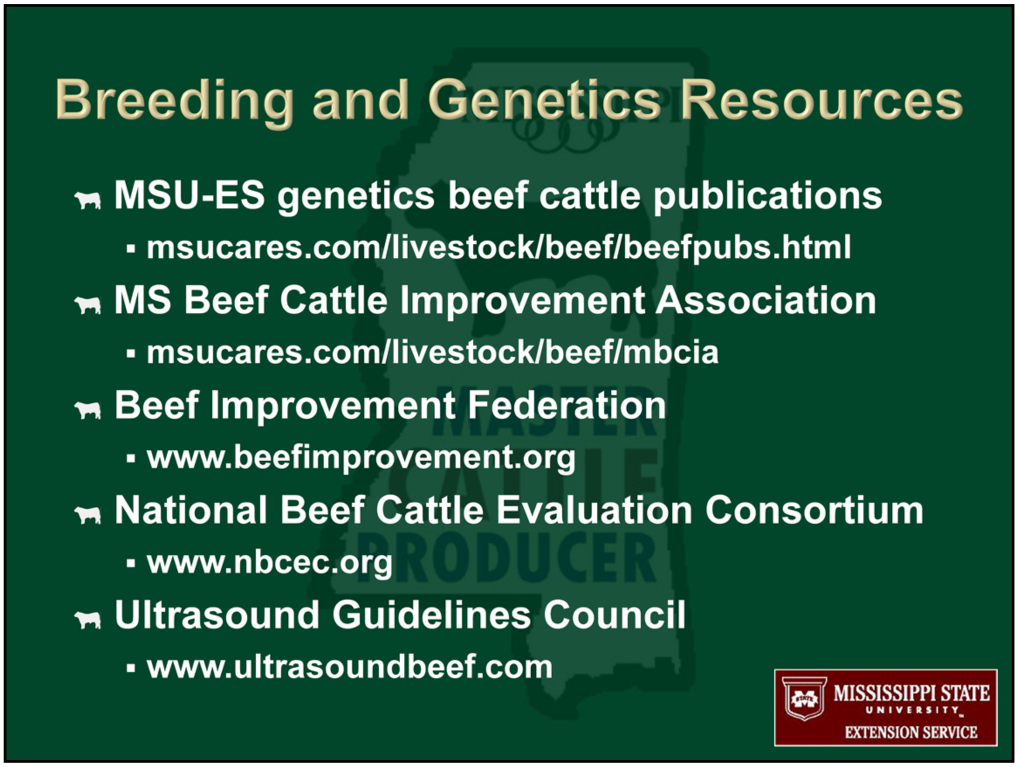


Over 200 different hereditary defects have been identified in cattle. Most of them occur infrequently and are of minor concern, but some increase in their frequency and need to be selected against. Most genetic defects are determined by a single pair of recessive genes.

When an abnormal calf is born, first try to determine if the abnormality is genetic. Recently, genetic tests for DNA markers associated with simple traits such as simply inherited genetic defects have become commercially available. Genetic tests for simple traits that are controlled by one gene are able to accurately assess whether an animal is a "carrier" (i.e., heterozygous) or will "breed true" (homozygous) for the marker alleles that result in a certain phenotype. Breed associations and genetic testing companies can provide testing protocols for genetic defects associated with a certain breed. Once carrier and affected animals are identified, producers can make selective breeding and culling decisions to manage a genetic defect within a herd. Breed associations may have rules regarding registration eligibility or required denotations on registration papers for animals carrying or affected with genetic defects.

Examples of genetic defects include: achondroplasia (bulldog dwarfism), alopecia, ankylosis, arthrogryposis (palate-pastern syndrome), arthrogryposis multiplex (AM, curly calf syndrome), brachynathia inferior (parrot mouth), cryptorchidism, dermoid (feather eyes), double muscling, fawn calf syndrome, hypotrichosis (hairlessness), hypotrichosis ("rat-tail"), neuraxial edema, neuropathic hydrocephalus (NH, "water-head"), osteopetrosis (marble bone disease), progressive bovine myeloencephaly (weaver calf), protoporphyria (photosensitivity), and syndactyly (mule foot).

Mississippi State University Extension Service Publication 2622, "Managing Genetic Defects in Beef Cattle Herds" discusses genetic defects in detail.



Mississippi State University Extension Service **beef cattle breeding and genetics publications** are available online at http://msucares.com/livestock/beef/beefpubs.html. This includes the publications referenced in this training module.

The **Mississippi Beef Cattle Improvement Association (MBCIA)** focuses on promoting performance records and encouraging good management practices while cooperating with other like-minded organizations to emphasize the economic importance of beef cattle production in Mississippi. The MBCIA encourages the production and identification of genetically superior animals by purebred breeders and promotes the purchase and use of these animals by commercial producers through various sale offerings. The MBCIA website is http://msucares.com/livestock/beef/mbcia.

The **Beef Improvement Federation (BIF)** was formed as a means to standardize programs and methodology and to create greater awareness, acceptance, and usage of beef cattle performance concepts. It represents over 40 state and national beef cattle organizations including MBCIA. The BIF website is http://www.beefimprovement.org/.

The **National Beef Cattle Evaluation Consortium (NBCEC**; (http://www.nbcec.org) is an organization of researchers, educators, producers, and industry leaders focused on genetic evaluation of beef cattle. The NBCEC's ***Beef Sire Selection Manual*** was used extensively as a reference for this training module. It can be viewed online at http://msucares.com/livestock/beef/sireselectionmanual.pdf***.***

The purpose of the **Ultrasound Guidelines Council (UGC)** is to insure data collected from beef cattle using ultrasound technology is of the highest quality and accuracy. Ultrasound field technicians and image processing labs are listed on the UGC website: http://www.ultrasoundbeef.com/.