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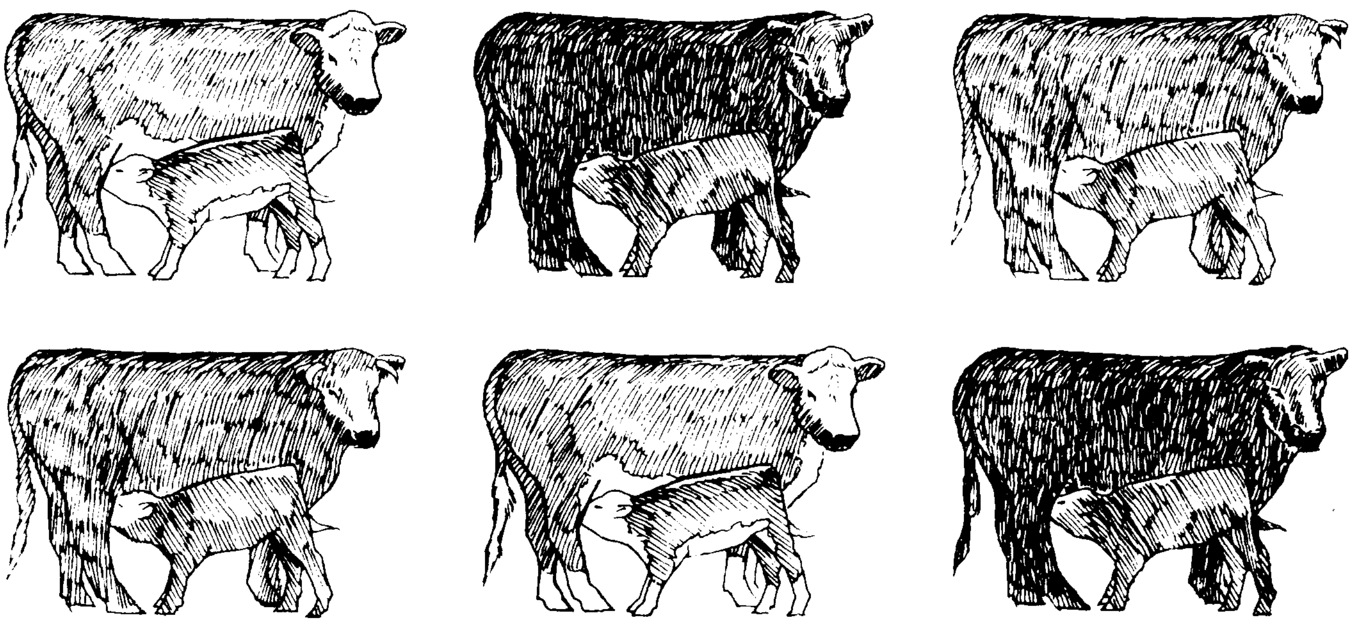

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PRINCIPLES OF BEEF CATTLE GENETICS

M. A. Kirkeide

During the past century, remarkable progress has been made in breeding better beef cattle — animals that are more efficient and produce cuts of meat that more nearly meet the rquirements of the consuming public. The early, semi-wild animals were built for stamina, had the ability to fight and furnish their own transportation, and produced tough, stringy meat. They have been replaced today by earlier-maturing steers that grade good and choice.

Despite past progress, much remains to be done. However, the present knowledge of genetics, although incomplete, should now make progress faster and more certain. In the past, cattle breeding was an art; in the future, it should be both an art and a science.

Mendel's Contribution

The modern science of genetics was founded by Gregor Johann Mendel, an Austrian monk who gardened because of his obesity. He conducted breeding experiments with garden peas from 1857 to 1865, about the time of the Civil War in the United States.

The essence of Mendelism is that inheritance is by particals or units called genes, that these genes are present in pairs — one member of each pair having come from each parent — and that each gene maintains its identity generation after generation. Mendel's work with peas laid the basis for two of the general laws of inheritance: (1) the law of segregation, and (2) the independent assortment of genes. Later genetic principles have been added, but all the phenomena of inheritance, based on the reactions of genes, are generally known under the collective term of Mendelism.

Heredity

Heredity is the transmission of biological traits from ancestors to descendents. Heritability is often described as that portion of the difference between individuals that is transmitted to the offspring. Stated another way, it is that portion of the difference between two animals that is due to genetic make-up and not to such environmental effects as feeding and management.

An estimate of the heritability of certain traits has been compiled from the results of many experiments. Heritability estimates for some of the most important economical traits of beef cattle are:

	Percentage
High	
Yearling weight	60
Feedlot gain	45
Ribeye area	70
Tenderness	60
Birth weight	40
Feed efficiency	40
Cow Maternal Ability	40
Moderate	
Weaning weight	30
Pasture gain	30
Carcass grade	30
Cancer eye susceptibility	30
Low	
Weaning grade	25
Calving interval	10

Note that these heritability estimates vary greatly from one trait to another. While all traits in beef cattle are inherited, the degree to which they are expressed is influenced by the environmental influences of feeding, management and disease. Some traits are influenced by environmental effects to a greater degree than others. For example, calving interval has a low heritability. This means that only a small amount of the difference observed is due to inheritance. A much higher portion may be due to feed, disease, injury at calving or other factors. With such traits as yearling weight, on the other hand, the heritability estimate is relatively high.

The magnitude of the heritability estimate for a given trait gives some idea of the rate of progress that can be expected when selection is made for this trait. For example, improvement in weaning weight may be obtained much more slowly than in a more highly heritable trait such as growth rate. Good results and improvement can be expected with traits that have a moderate to high heritability (over 30 per-

Kirkeide is Extension animal husbandman.

cent) if these traits are selected for intensely. With traits of low heritability, much of the difference we see is due to environmental effects which are not passed on to the offspring. However, some traits that are only moderately heritable, such as weaning weight, are so important from an economic standpoint that they receive major emphasis in a selection program even though rate of progress is slow.

Environment

Environmental effects result from surroundings, care, feed, etc. Heredity and environment are the two basic things that affect every living thing. Heredity and environment are complementary; that is, one is as important as the other in the completion of the life cycle. On the other hand, heredity and environment play varying roles in the development of different parts and processes of the living organism. For example, determination of coat color and markings in cattle is due almost entirely to heredity, except that sunlight and other weather conditions cause a fading of color in some animals. On the other hand, milking ability of a cow has been determined to be about 28 percent due to heredity and 72 percent due to environment.

Genes: Units of Heredity

Genes, the fundamental units of genetics, determine all the hereditary characteristics of animals, from body type to hair color.

The bodies of all animals are made up of millions or even billions of tiny cells which are microscopic in size. Each cell contains a nucleus in which there are a number of paired strand-like bodies called chromosomes. In turn, segments of the chromosomes are called genes, which are the basic hereditary units. The number of chromosome pairs is specific for the species: cattle have 30 pairs, swine have 19 and humans have 23. While the nucleus of each body cell of cattle contains 30 pairs of chromosomes, a total of 60, there are perhaps thousands of pairs of genes.

The modern breeder knows that the job of transmitting qualities from one generation to the next is performed by germ cells — a sperm from the male and an ovum or egg from the female. All animals are the result of the union of two such tiny cells, one from each of the parents. These two germ cells contain all the anatomical and physiological characters that the offspring will inherit. They determine whether a calf will be polled or horned, black or white, a bull or a heifer, etc.

Each of the chromosomes is duplicated in the body cells of an animal. But in the formation of the sex cells, the egg and the sperm, a reduction division occurs and only one chromosome and one set of genes of each pair goes into a sex cell. This means that only half the number of chromosomes and genes present in the body cells of the animal go into each egg and sperm. Each reproductive cell of cattle, then, has 30 chromosomes. Each sperm or egg cell has a gene for every characteristic of its species. When mating and fertilization occur, the single chromosomes from the germ cell of each parent unit to form a new pair, and the genes are again present in duplicate in the body cells of the embryo.

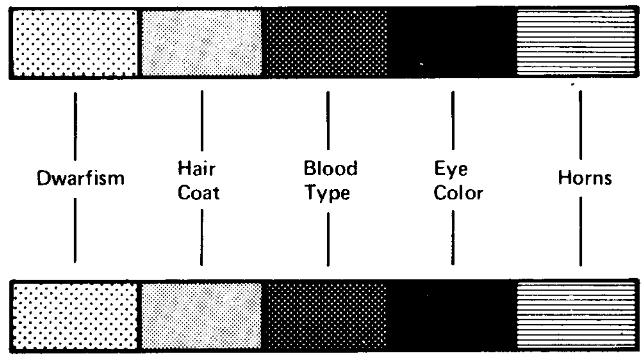


Figure 1. Graphic presentation of the way that chromosome pairs carry identical pairs of genes.

All the possible combinations in 30 pairs of chromosomes and the genes that they carry means that any bull or cow can transmit over a billion different samples of its inheritance. The combination from both parents makes possible a billion times a billion genetically different offspring. It is not strange, therefore, that no two animals within any breed (except identical twins from a single egg split after fertliization) are alike. It is more remarkable that the members of a given breed resemble each other as much as they do.

Even between such closely-related individuals as full brothers or sisters, it is possible that there will be wide differences in size, growth rate, temperament, conformation and almost every conceivable character. Many of these differences may be due to undetected differences in environment, but much of the variation is due to hereditary differences. A bull, for example, will sometimes transmit much better inheritance to one offspring than he does to most of his get, simply as the result of chance differences in genes that go to different sperm at the time of the reduction division. Such differences in inheritance have been called both the hope and the despair of the livestock breeder.

Homozygous and Heterozygous

If an animal gets similar genes or determiners from each parent, it will produce uniform germ cells because any half of its inehritance is just like the other half. Such animals are called homozygous. Few, if any, animals are in this hereditary state. Instead of being homozygous they are heterozygous, which explains why there may be such wide variation within the offspring of any given sire or dam.

Variation among the offspring of animals that are not pure, or homozygous, is not to be marveled at but rather to be expected. If a person were drawing a random sample of 30 apples from a barrel containing 40 red apples and 20 yellow ones, he would not expect to get exactly 20 red apples and 10 yellow ones every time. If enough samples were drawn, he would expect to get about that proportion of the average, although individual drawings might vary widely.

Exactly the same situation applies to the relative numbers of "good" and "bad" genes that may be present in the same animal. Because of this situation, mating a cow with a fine show record to a bull that usually produces good offspring will not always produce calves of equal merit to the parents. The calves could be considerably poorer than the parents or, happily, might be better than either parent.

Selection and close breeding are the tools the cattle breeder can use to obtain bulls and cows whose genes contain similar hereditary determiners — animals that are genetically more homozygous.

A completely homozygous condition is rarely, if ever, found in farm animals. While Angus cattle are usually black, the occasional red calf indicates the presence of an infrequent recessive red gene in the gene pool of the breed. The usual differences in color between breeds of cattle are due to the differing frequencies of the contrasting alleles (pairs of genes) that determine color, color markings, presence or absence of horns, etc.

Those characters of economic importance such as rate of growth, loin eye area and marbling are due to the combined effect of genes at any different loci. Again, we do not expect breeds or individuals to have only the desirable allele at every locus. These differences are due to differing frequency of the desirable and undesirable alleles.

Actually, a completely homozygous state would be unfortunate, because economic and environmental changes are apt to dictate changes from time to time. With complete homozygosity, changes would be impossible except through the slow and uncertain process of mutations. Fortunately, there is enough heterozygosity in our breeds to give the breeder flexibility to make changes in his herd. In fact, there is enough heterozygosity to make it nearly impossible to fix complete homozygosity.

Mutations

Gene changes are technically known as mutations. A mutation may be defined as a sudden variation which is later passed on through inheritance resulting from changes in a gene or genes. Mutations are rare, and a particular kind of mutation cannot be induced. For all practical purposes, genes can be thought of as unchanged from one generation to the next. Observed differences between animals are usually due to different combinations of genes being present rather than to mutations.

Once in a great while a mutation occurs in a farm animal that produces a visible effect in the animal carrying it. These animals are occasionally of practical value. The occurrence of the polled characteristic in the Hereford and Shorthorn breeds is an example of a mutation of economic importance. Out of this mutation came the Polled Hereford and Polled Shorthorn breeds of cattle.

Simple Gene Inheritance

In the simplest type of inheritance, only one pair of genes is involved. For example, one pair of genes is responsible for the color of Shorthorn cattle.

In Shorthorns, an animal carrying two genes for red (RR) is actually red in color, and an animal carrying two genes for white (rr) is white in color. On the other hand a Shorthorn which has one gene for red (R) and one for white (r) is neither red nor white but roan (Rr), which is a mixture of red and white. Matings of red and white cattle, then, usually produce roan offspring. However, if the gene for roan is not present the color would be red and white spotted rather than roan.

Roans, with one gene for red and one for white, don't breed true. If roans are mated, they will produce offspring in the proportion of one red, two roans and one white. If a roan animal is bred to a red one, half the offspring will be red and half roan. Likewise, when a roan animal is bred to a white one, approximately equal numbers of roan and white calves will be produced. The most certain way to produce roans is to mate red animals with white animals.

This example illustrates the most important principles of inheritance: (1) genes occur in animals in pairs because one of each pair comes from each parent, and (2) each reproductive cell contains a sample half of the genes of that animal.

There is no way to sort out the numerous genes to get the most desirable ones into the same reproductive cell except as occurs by chance during the formation of eggs and sperm. The various gene combinations occur at random, and the various colors will appear in the proportions indicated only when

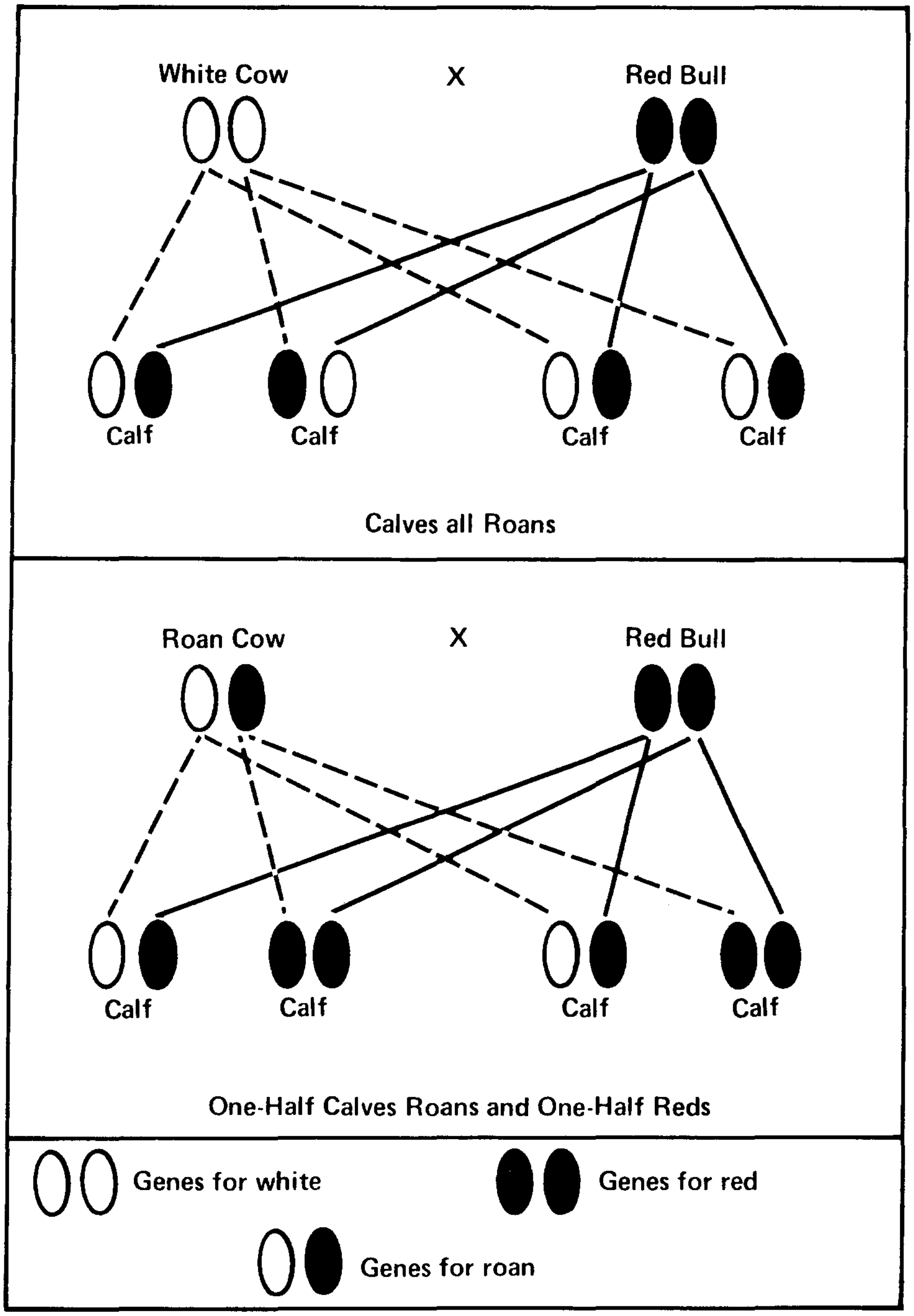


Figure 2. Calf color combinations to expect when red sires are crossed with white or roan dams.

relativley large numbers are involved. The possible gene combinations are governed by the laws of chance in much the same manner as the results obtained from flipping a coin.

If a coin is flipped often enough, the number of heads and tails will come out even. However, with the laws of probability in operation it is possible that out of four tosses all heads, all tails or three and one might come up. In exactly the same manner, a Shorthorn breeder might get four red calves in a row from mating roan cows and a roan bull, and then get four white calves from the same matings.

In addition to the hair color, other examples of simple gene inheritance (sometimes called qualitative traits) in cattle include color of eyes, presence or absence of horns, blood type and lethal traits.

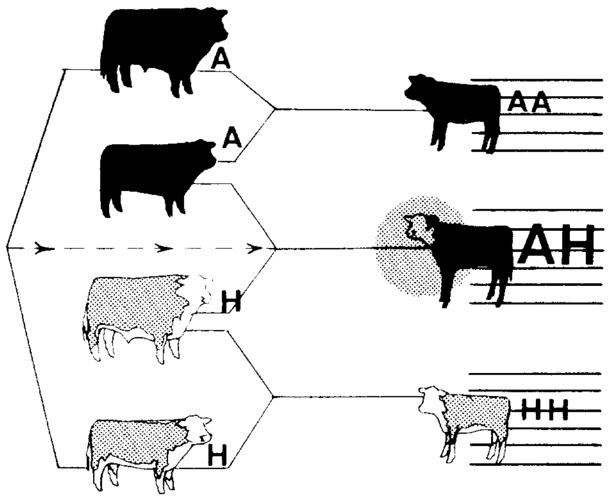


Figure 3. Calf color to expect when mating Angus-to-Angus, Angus-to-Hereford and Hereford-to-Hereford.

Non-Additive Genes

Non-additive gene effects refer to the kinds of gene actions that exist with regard to the many gene pairs that are involved in determining a particular performance trait. These effects fall in two categories:

Nonadditive gene effects that are expressed by individual gene pairs (due to level of dominance that exists between different genes that can be present at that particular locus). The levels or kinds of dominance that can exist between two different genes at a locus is illustrated in Figure 4. In this illustration the more favorable gene (the one having the biggest effect on increasing performance level for the trait) is symbolized as A and the less desirable gene (the one having a smaller effect) is symbolized as a. The non-additive gene effects at individual loci (gene pairs) can be caused by complete dominance, partial dominance, or overdominance. If gene effects are strictly additive, the effect of the heterozygote (Aa) is exactly intermediate between the effects of the two homozygous genotypes (AA and aa) as illustrated in Figure 4. Loci (gene pairs) with this kind of gene action will not make any contribution to heterosis. Complete dominance is a very common genetic property that exists when the effect of the heterozygote is closer to that of one of the homozygotes without being exactly the same. Overdominance describes the situation whereby the heterozygote has a more extreme effect than either homozygote. (As illustrated in Figure 4, the effect of Aa exceeds that of both aa and AA). To whatever extent they occur, gene pairs that exhibit overdominance would have a relatively large effect on the amount of heterosis exhibted by a trait. It is not really known, however, how prevalent gene pairs exhibiting overdominance are among the many loci that control livestock performance traits. Although some examples of overdominant gene pairs are known for traits involving only a single gene pair (qualitative traits), this phenomenon is not nearly as frequently encountered as is the case with partial to complete dominance.

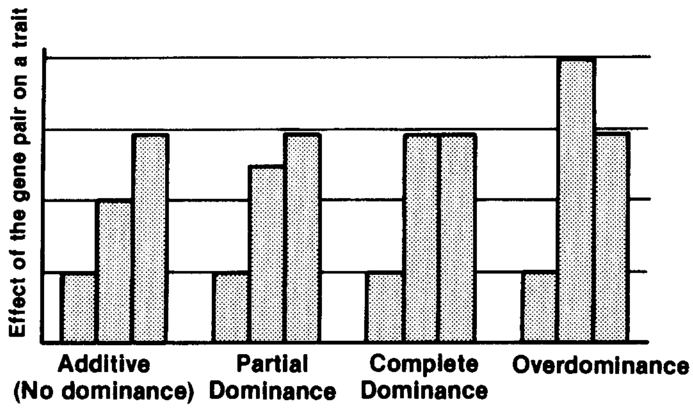


Figure 4. Illustration of kinds of gene action that can occur at a particular locus (gene pair).

Dominant and Recessive

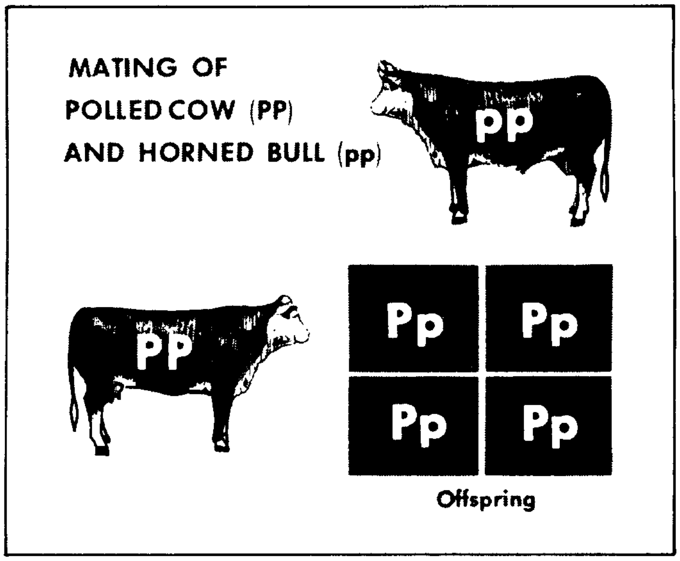
In the example of Shorthorn colors, each gene of the pair (R and r) produced a visible effect, whether paired as identical genes (two red or two white) or as two different genes (red and white producing a roan).

This is not true of all genes. Some have the ability to prevent or mask the expression of others. The genetic makeup of such animals cannot be recognized with perfect accuracy.

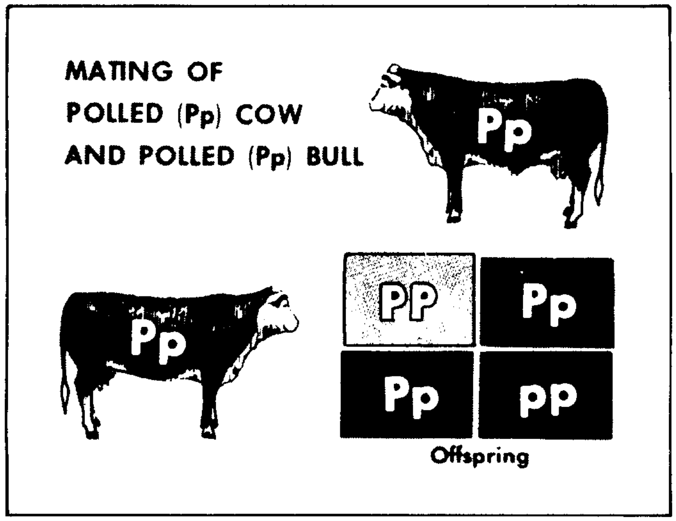
The ability to cover up or mask the presence of one member of a pair of genes is called dominance. The gene which masks the other is the dominant gene, and the one which is masked is the recessive gene.

In cattle, the polled character is dominant to the horned character. If a pure polled bull is used on horned cows (or vice versa),the resulting off-spring are not midway between the two parents but are polled. However, not all hornless animals are pure for the polled character. Many of them carry a gene for horns in the hidden or recessive condition.

Animals that carry two genes for the polled characteristic would be termed homozygous for this trait; those with one dominant (polled) and one recessive (horned) factor are termed heterozygous. It is impossible to determine whether a polled bull is homozygous or heterozygous. The test consists of mating the polled bull with a number of horned cows. If the bull is pure for the polled character, all of the calves will be polled. If he is impure or heterozygous, half the offspring, on the average, will be polled and half horned.

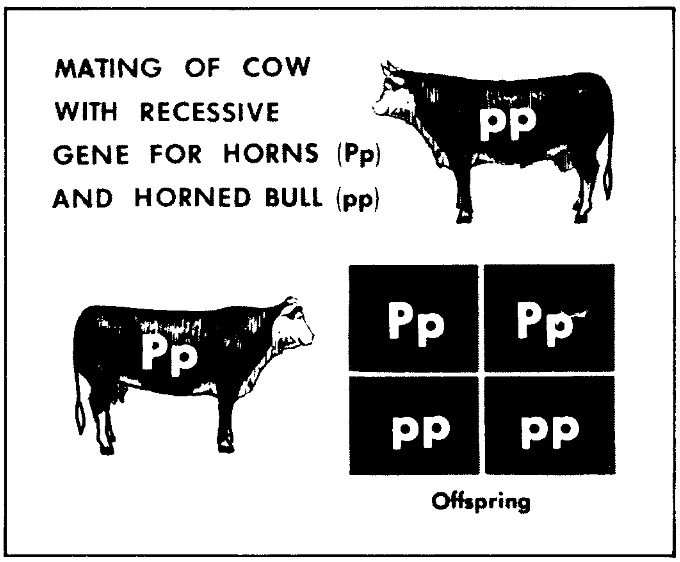


	P	P
p	Pp	Pp
p	Pp	Pp



Pp x Pp

	P	p
P	PP	Pp
p	Pp	pp



Pp x pp

	p	p
P	Pp	Pp
p	pp	pp

Figure 5. Expected results from different mating conditions.

A dominant character will cover up a recessive, so an animal's breeding performance can't be recognized by its phenotype (what it looks like). This fact is of great significance in practical breeding.

Dominance often makes it a difficult task to identify and discard all animals carrying an undesirable recessive factor or gene. Recessive genes can be passed on from generation to generation, appearing only when two animals which both carry the recessive factor happen to mate. Even then, only one out of four offspring, on the average, will be homozygous for the recessive factor and show it.

In Angus cattle, the gene for black color is dominant. The red color in the Angus breed is an example of a recessive factor.

Black polled cattle have been known in Scotland since 1523, and black has always been the accepted color of the Angus breeed. Yet, down through the years a recessive factor for red coat color has persisted in the breed. For this reason, a red calf occasionally and unexpectedly shows up in a purebred Angus herd. This occasional appearance of a red calf does not signify any impurity of breeding but is merely the outcropping of a long-hidden recessive gene.

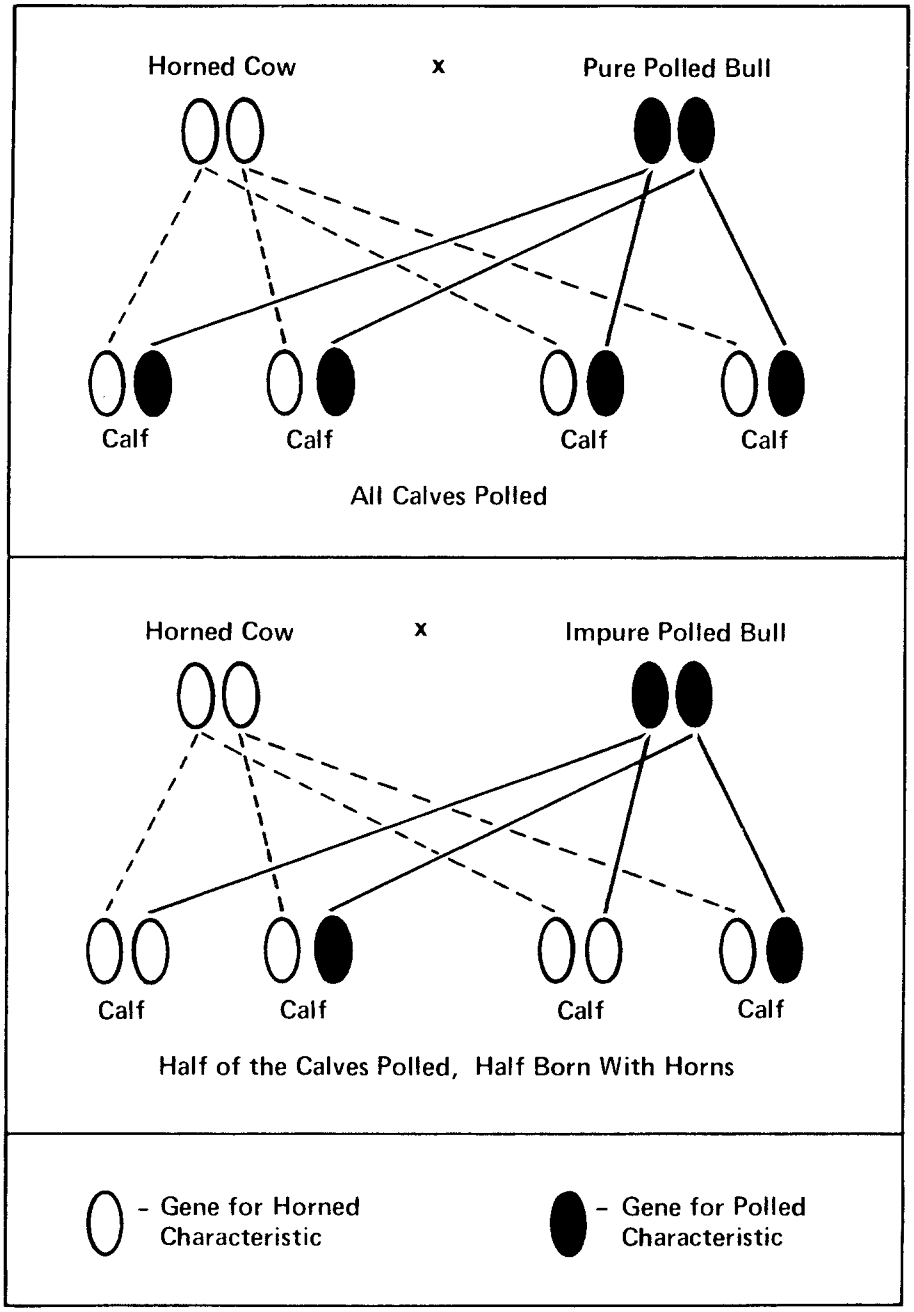


Figure 6. Expected results from mating polled-to-horned, and when mating polled (with recessive gene for horns)-to-horned.

When a red calf does appear, it is certain that both the sire and the dam carry the recessive gene for red color. As the factor for red is recessive, red animals are pure for color, and the mating of two red animals will always produce red calves.

Other examples of recessive are red color in Holstein cattle and dwarfism in cattle.

A Dihybrid Cross

A dihybrid cross is one that is heterozygous for two pairs of allelic genes. A cross between Angus and red Shrothorn cattle is such a cross.

Th Angus are black and polled; the Shorthorns red and horned. All first-cross animals will be black and polled. However, when these F_1 (first cross) animals are interbred the expected proportion would be nine black polled, three black horned, three red polled and one red horned out of 16 offspring.

A Trihybrid Cross

A trihybrid is one that is heterozygous for three pairs of genes. A cross between Angus and Hereford cattle represents such a cross.

In this situation, the cross is Angus (polled, black body, black face) and Hereford (horned, red body, white face). In the first cross between these breeds all three dominant characteristics will be in evidence, so all first-cross animals will be polled with a black body and white face. However, when these F_1 animals are interbred, the expected results out of 64 offspring would be:

27 polled with black body and white face
9 polled with black body and black face
9 polled with red body and white face
9 horned with black body and white face
3 polled with red body and colored face
3 horned with black body and black face
3 horned with red body and white face
1 horned with red body and colored face.

Epistatic gene action involves gene combinations at one locus (gene pair) interacting with the effects of gene combinations at other loci (gene pairs). There are many different kinds of epistatic effects but their relative influence has been very difficult to measure because of their complexity. It seems doubtful that these epistatic effects would be the primary cause of heterosis in the case of most traits.

It has not been possible to experimentally determine which of these kinds of non-additive effects are most important. In reality, all types of non-additive effects are probably involved in most traits and their relative influence varies from trait to trait. Knowing which kind of non-additive gene effects are most important in determining heterosis for important beef production traits would have an impact on the kind of breeding strategy which would be used to maximize production. In the case of overdominance, for example, the objective would be to maximize the number of heterozygous gene pairs in the crossbred.

Multiple Births

The tendency to produce twins is inherited to some extent, so more twins are produced in some breeds and some families within breeds than in others. But factors other than heredity play a major part in determining multiple births.

Most cattlemen prefer single births to twins due to the high incidence of freemartins (sterile heifers) in twins of opposite sexes, the higher mortality rate of twins, and the tendency toward lowered conception rates following multiple births.

Twins may be either fraternal or identical. Fraternal twins are produced from two separate eggs that are fertilized by two different sperm. Identical twins result when a single fertlized egg, very rarely in its embryology, divides into two separate individuals. Such twins are always of the same sex and alike genetically — they are 100 percent related. In humans, nearly half of the like-sexed twins are identical, while in cattle only 5 to 12 percent of such births are identical.

Geneticlaly, fraternal twins are no more alike than full brothers and sisters born at different times. They are only 50 percent related. They usually resemble each other more than non-twin brothers and sisters, however, because they were subjected to the same intrauterine environment before birth and are generally reared under much the same environment.

How Sex Is Determined

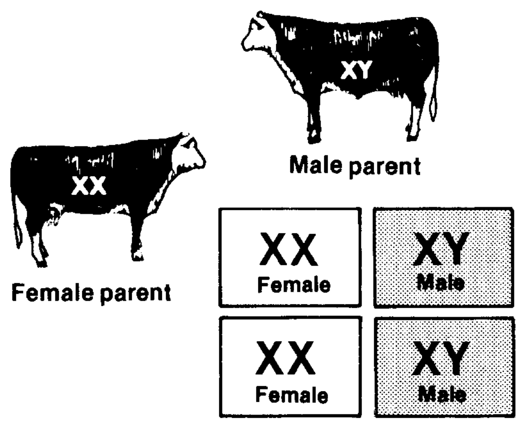
The most widely accepted theory of sex determination is that sex is determined by the chromosomal make-up of the individual. One particular pair of chromosomes is called the sex chromosomes.

In farm animals, the female has a pair of similar chromosomes (usually called X chromsomes), while the male has a pair of unlike chromosomes (usually called X and Y chromosomes). This condition is reversed in birds, with females having the unlike pair and males the like pair.

These pairs of chromosomes separate when the germ cells are formed. Each germ cell (ovum or egg) produced by the cow contains one X chromosome. Half of the germ cells (sperm) produced by the bull contain an X chromosome and the other half a Y chromosome. Since the egg and sperm at conception unite at random, half the progeny will have the chromosomal makeup XX (females) and the other half YX (males).

Researchers have employed many techniques attempting to separate the X-bearing and Y-bearing sperm of males, including specific gravity, electrical potential, reaction to acid and alkaline media, and speed of movement through the reproductive tract. To date, none of these techniques has been successful in controlling the sex of offspring. Research continues, and a successful method of sex determination may eventually be found.

HOW SEX IS DETERMINED



One-half of the offspring would be female and one-half would be male.

Figure 7. In beef cattle, the sire determines the sex of the off-spring.

Abnormalities in Cattle

Some abnormalities are a result of inheritance, but some others may result from nutritional deficiencies or "accidents" of development. Accidents include those which seem to occur sporadically with no well-defined reason. When only a few defective individuals occur within a herd, it is often impossible to determine if they are due to heredity, defective nutrition or merely to accidents of development. If the same defect occurs in any appreciable number of animals, however, it is probably either hereditary or nutritional. Diagnosis is not always a simple matter.

Conditions tending to indicate a hereditary defect include appearance of a defect known to be hereditary in the same breed, more frequent occurrence within certain families or appearance when there has been inbreeding. Occurrence in more than one season and when different rations have been fed also indicates a hereditary problem.

Abnormalities due to nutrition are indicated if the abnormality is known to be due to a nutritional deficiency, if the defect is restricted to a certain area, if it occured when the mother was known to be on a deficient ration, and if incidence of the abnormality disappears when an improved ration is fed.

Assuming that a hereditary defect or abnormality is present in a herd and that it is recessive in nature, the breeding program to follow to reduce or eliminate its future occurrence will depend somewhat on the type of herd involved. In a commercial herd, the breeder can usually guard against a reappearance of the undesirable recessive gene by using an outcross (unrelated) sire within the same breed, or by crossbreeding. With this system, the breeder is fully aware of the recessive being present, but he has taken action to prevent it from showing up.

On the other hand, if an undesirable recessive appears in a registered herd, the action should be more drastic. A reputable seedstock producer has an oblitation to purge his herd of undesirable genes and lethals.

This can be done by eliminating bulls and cows known to have transmitted the undesirable character. Both the abnormal and normal offspring produced by these cattle should also be eliminated, because about half of the normal animals will carry the undesirable character in the recessive condition. Breeding a prospective herd sire to a number of females known to carry the recessive gene will produce more assurance that the new sire is free of the undesirable character.

Such action in a purebred herd is expensive, but it is the only way purebred livestock can be freed from such undesirable genes.

Dwarfism

The genetic factors that cause dwarfism are recessive. This means that both the sire and the dam are responsible when a dwarf calf is born. Since dwarfism is inherited as a recessive, animals that transmit the factor appear normal and can't be distinguished from dwarf-free animals by appearance.

On the average, 100 carrier cows mated to carrier bulls would produce 25 dwarfs, 50 carriers and 25 normal, non-carrier calves. If carrier cows are mated to dwarf-free bulls, all the calves will appear normal, but, on the average, half the calves will be carriers.

Purebreeding

A purebred animal may be defined as a member of a breed in which the animals possess a common ancestry and distinctive characeristics, and are either registered or eligible for registry in the herd book of that breed.

Purebreeding and homozygosity may have very different connotations. The term "purebred" refers to animals whose entire lineage traces back to the foundation animals accepted by the breed or to any animal susbsequently approved for infusion. On the other hand, homozygosity, or genetic "purity," refers to the likeness of the genes.

There is some relationship between purebreds and homozygosity. Because most breeds had a relatively small number of foundation animals, the unavoidable inbreeding and linebreeding during the formative stage resulted in a certain amount of homozygosity.

Inbreeding

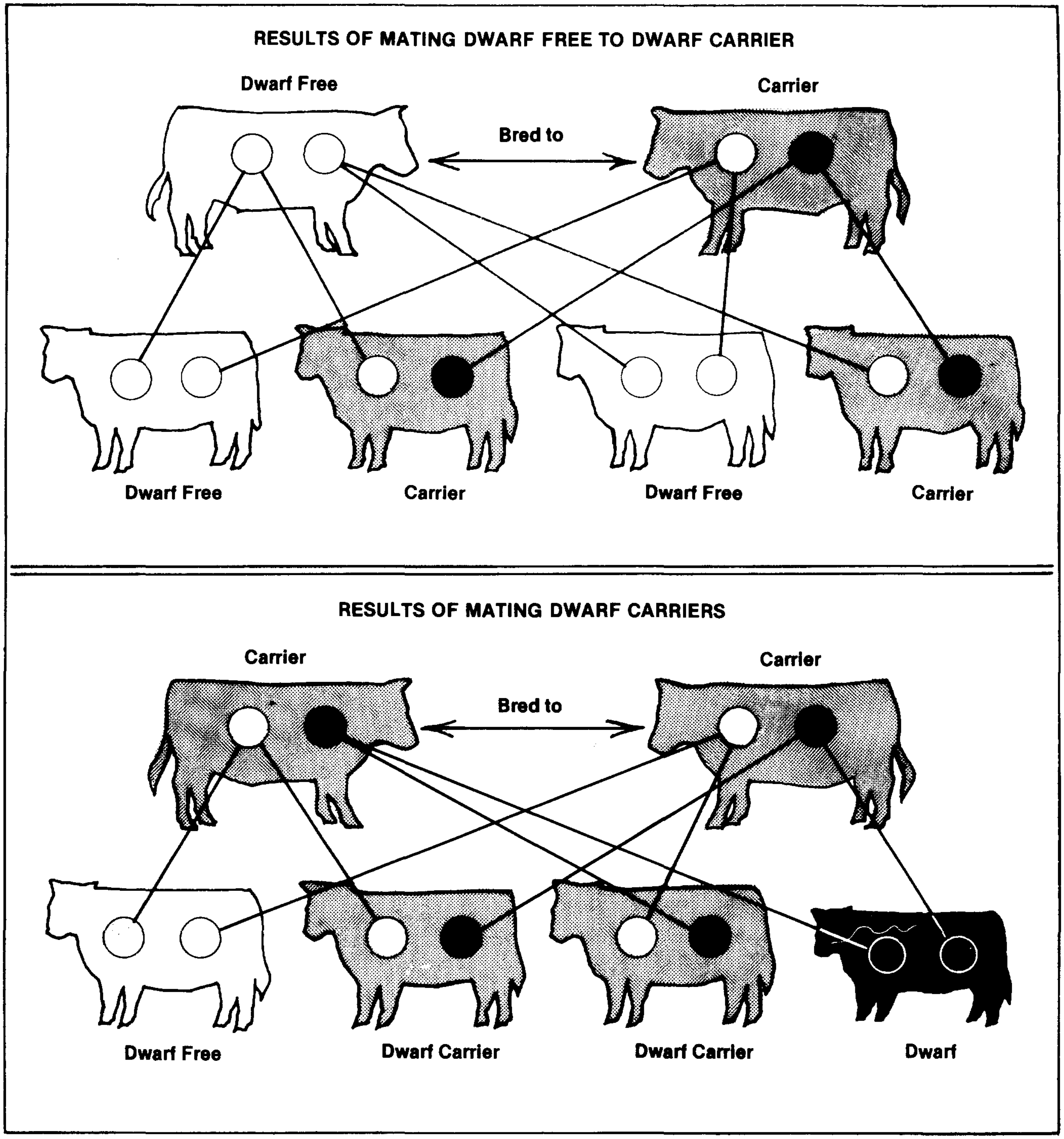
Inbreeding is the mating of animals more closely related than the average of the population from which they come.

In an inbreeding system, closely related animals are mated, so there is a minimum number of different ancestors. In the repeated mating of a full brother and sister, for example, there are only two grandparents instead of four, only two great-grandparents in stead of eight, and only two different ancestors in each generation farther back instead of the theoretically possible 16, 32, 64, 128, etc.

Closebreeding and linebreeding

Closebreeding is the mating of closely related animals such as sire to daughter, son to dam and brother to sister.

Linebreeding is the mating of animals more distantly related than in closebreeding, with the



Key

Genes
○ Snorter dwarf free (dominant)
● Snorter dwarf genes (recessive)

Figure 8. When dwarf-free animals are mated to dwarf carriers (upper), on the average 50 percent of the offspring will be dwarf-free and the other half will be dwarf carriers. When both parents are dwarf carriers (lower), on the average 25 percent of the offspring will be dwarf-free, 50 percent will be dwarf carriers, and the other 25 percent will be snorter dwarfs.

matings usually directed toward keeping the offspring closely related to some highly admired ancestor such as an outstanding sire or dam.

From a biological standpoint, closebreeding and linebreeding are somewhat similar, but linebreeding has a more planned breeding program. In general, closebreeding has been frowned upon by stockmen, but the less intensive linebreeding has been viewed more favorably.

In a linebreeding program, the relationship is not closer than half-brother and half-sister or more distantly related matings, such as cousin matings or grandparents to grand offspring.

Linebreeding is usually practiced to conserve and perpetuate the good traits of some outstanding sire or dam. Because the descendents are of a similar lineage, they have the same general genetic makeup and usually exhibit a high degree of uniformity.

Outcrossing

Outcrossing is the mating of animals that are members of the same breed but show no relationship in the pedigree for at least four or six generations.

Most purebred animals are the result of outcrossing. It is a relatively safe system of breeding, for it is unlikely that two such unrelated animals will carry the same "undesirable" genes and pass them on to their offspring.

Grading Up

Grading up is a system of breeding in which purebred sires of a given pure breed are mated to grade females. The purpose is to develop uniformity and quality and improve performance in the offspring.

The greatest single step toward improved quality occurs in the first cross. Subsequent crosses increase quality further, but to a less marked degree.

After the third and fourth cross, the offspring compare very favorably with purebred stock in conformation and quality, and only exceptionally good sires can bring about further improvement.

Crossbreeding

Crossbreeding is the mating of two animals which are both purebreds but members of different breeds. In a broad sense, crossbreeding also includes the mating of purebred sires and grade females of another breed. Crossbred animals generally possess greater heterozygosity than straightbreds with the added virtue of hybrid vigor. As in outcrossing, recessive and undesirable genes remain hidden in the crossbred animal. Hybrid vigor results from favorable combinations of genes brought about by specific crosses.

Crossbreeding programs usually consist of two types: (1) maintaining a herd of purebred females that are mated to a purebred sire of a different breed, and (2) maintaining crossbred females generation after generation with matings to purebred sires of different breeds on a rotation basis.

In the first system, the producer is sooner or later faced with the problem of breeding the females back to a sire of the same breed to obtain replacement females. This system allows for a limited opportunity to build up the quality of the cow herd.

In the second system, the rotation of sires is often a problem, and the females and offspring will almost inevitably vary in type and color. Even though a crossbred herd may contain superior individuals, they may be penalized when sold because of their lack of uniformity.

Crossbreeding has a place in beef production from the standpoint of increased vigor, growth rate and efficiency of production. To be successful, however, a crossbreeding program must be carefully planned and make use of superior seed stock.

Heterosis Defined. Heterosis is the phenomena of the superior level of performance for certain traits attained by crossbred individuals over and above the average performance of their straightbred parents. Heterosis is measured experimentally as the difference in performance of crossbred animals from the average contemporary performance of straightbred animals of the breeds involved in the cross. This difference is usually expressed as a percentage of the average performance of the straightbreds. It is calculated by the following formula:

$$\frac{\%\ \text{Heterosis} = \text{Crossbred ave.} - \text{Straightbred avg.} \times 100}{\text{Straightbred average}}$$

For example, if average weaning weight of the straighbred calves of breed A was 455 lbs. and for breed B calves was 445 lbs., the average of the straightbreds would be 450 lbs. If average weaning weight of the crossbred calves was 470 lbs., the percent heterosis would be estimated as $(470-450) \div 450 \times 100 = 4.4\%$

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