

Elementary Genetics

The subject of genetics, gene action, genetic expression, inherited traits, etc. can be so confusing that it is just easier to follow the KISS rule – keep it super simple (some say keep it simple stupid). Two common beliefs relating to genetics that most cattle breeders adhere to is #1 - that crossbreeding is always better due to hybrid vigor and #2 you don't breed a bull to his daughters. Depending on what your goals are, perhaps the KISS rule is appropriate for your situation, but if you will equip yourself with knowledge, you will be better able to distinguish fact - from fiction - from general hearsay.

Understanding heredity and how genetic traits are passed from parents to offspring, at least on a basic level, should be the goal of anyone who intentionally breeds animals; otherwise it is just another roll of the dice. How can one become a reputable breeder with those odds? The purpose of this article is to provide some basic steps towards that understanding. So instead of going right for Genetics 101, let us start with some Elementary Genetics.

Let me begin with a brief explanation where heredity begins. Beginning at the molecular level, varying combinations of three, out of a possible four, nitrogen-containing bases make up the triplet codes that are the building blocks for a **gene**. The gene is the smallest biological unit of inheritance. They are arranged into a double stranded helix structure, which resembles a twisted ladder, known as **DNA**. Hundreds and possibly thousands of genes are the structural part of each chromosome. **Chromosomes** are threadlike bodies contained within the nucleus of each cell. Each species of animals has a characteristic number of chromosomes.

Chromosomes as well as genes occur in pairs in the body cells and half pairs in the gametes (egg and sperm). Each body cell normally contains two chromosomes known as the sex chromosomes and they are involved in the determination of the sex of the individual. In mammals, the sex chromosomes are called the X and the Y, the X chromosome being much larger and longer than the Y. The body cells of females are XX in composition, whereas the males are XY. Domestic cattle have a total of 60 chromosomes governing inheritance, two of which are the sex chromosomes.

Of each pair of genes, the individual receives one from the mother and one from the father; and to each of his/her offspring the individual will give one member of the pair. Thus for every pair of genes, each offspring receives a sample one-half of its inheritance from each parent. Since there are so many pairs of genes, and some are in the homozygous or heterozygous state in the individual, the sample may be quite different for any two.

Variations in individuals are due to differences in genes and are the raw material with which the animal breeder must use to accomplish goals. The animal breeder cannot create new genes, but must work with the genetic variation that already exists in his or her animals. The role of the animal breeder is to identify those animals that possess desirable genes and characteristics or combinations of genes and concentrate in his herd as many of these as possible.

To understand genetics, one needs to understand the terms **dominant, recessive, homozygous and heterozygous**. When one gene has the ability to block out or cover the expression of the other gene that it is paired with, the gene is said to be dominant. The gene that takes the back seat or is blocked out is recessive. When two genes affecting a character in different manners occur together, that animal is said to be heterozygous for that trait. When the two genes affect the character in the same manner, that animal is said to be homozygous.

Example: Absence of horns (P) is a dominant trait in cattle. The presence of horns (p) is recessive. If you breed a polled bull (PP) to a horned cow (pp), all the

offspring will be polled but carry the gene for horns (Pp). If you breed a polled bull (Pp) to a polled cow (Pp), the possible combinations are as follows.

Pp X Pp
1 PP Pure for polled (homozygous)
2 Pp Polled (heterozygous)
1 pp Pure for horns (homozygous)

The genetic construction is called the **genotype**. The expression of the genotype is called the **phenotype**. The PP and pp individuals are said to breed true, or be pure, since they are homozygous and can pass on only one kind of gene to their offspring. The Pp individuals, however, never breed true; that is they do not have 100% Pp offspring because they are heterozygous and pass two kinds of genes through their sex cells to their offspring.

Hopefully you now have a general understanding of genes as the mechanism for heredity. The next step is to learn the basic concepts of breeding and how the different methods work.

Inbreeding is a tool (**to be used with selection**) that the cattle breeder may use for the improvement of his or her livestock. Inbreeding is a mating system in which progeny are produced from parents more closely related than the average of the population from which they came.

Most livestock producers may be familiar with or have been led to believe that inbreeding is associated with genetic defects and a general over-all decline in vigor and performance.

The desire on the part of the animal breeder to avoid inbreeding has resulted in many good sires being shipped to market when their daughters become old enough for breeding. Actually, the production records or the daughters of the sire are a means of indicating his breeding ability, and sires that prove to be superior should be used for breeding purposes as long as they retain the ability to reproduce. Many herds today could profit from the use of superior sires by taking advantage of inbreeding if the owners understood the effects and possible consequences of this system of mating.

Studies of both plants and animals show that inbreeding is not always detrimental. Many of our present-day breeds of different farm animals were established by making use of inbreeding and many outstanding herds in the past were developed by this system of mating.

The genetic effect of inbreeding is that it makes more pairs of genes in the population homozygous regardless of the kind of gene action involved. All phenotypic effects of inbreeding result from this one genetic effect.

Inbreeding does not increase the number of recessive **alleles** (genes that affect the same characteristic but in a different manner are alleles of each other) in a population but merely brings them to light by the increasing homozygosity. In other words, the proportion of recessive genes in the original population is the same as even in the fourth generation, but they are hidden by being paired with a dominant gene. Undoubtedly, there are many hidden recessive genes in outbred populations.

From the physiological standpoint, dominant genes usually (not always) have a favorable effect whereas recessive genes have an unfavorable one. Culling the less desirable animals should result in an increase in the frequency of the dominant or favorable genes in a population.

Inbreeding fixes traits in the inbred population through increased homozygosity whether or not the effects are favorable or unfavorable and the animal breeder who uses this method must be prepared to cull a large proportion of the less desirable individuals

from the herd. This requires that a large number of animals be produced in developing a line and for this reason could be very costly and not too practical in some instances.

Since inbreeding makes more pairs of genes homozygous, the offspring are more likely to resemble the parent from which they receive the dominant gene, and because of this are more likely to resemble each other. This is another way of saying that inbred parents are more likely to be prepotent than noninbred parents, at least for traits conditioned by dominant genes.

When mated to nonrelated animals, inbred animals should breed better than they look, whereas noninbred animals are often disappointing from the breeding standpoint because they look better than they breed.

Inbreeding may be used to determine the actual genetic worth of an individual animal. It could be used in a practical way to select against a recessive gene that is of economic importance. Since inbreeding brings out the hidden recessive genes, the homozygous animals as well as many of the heterozygotes could be identified and culled. But again, this would require severe culling and might be too costly under many conditions.

Inbreeding should be used only for the production of seed stock. Many livestock producers have the mistaken opinion that inbred parents transmit less desirable genes to their offspring than those that are not inbred. A most practical use of inbreeding could be to develop lines that can be used for crossing purposes.

Linebreeding is a system of mating in which the relationship of an animal or animals is kept as close as possible to some ancestor in the pedigree. The ancestor is usually a male rather than a female, because the male produces many more descendants than a female and this allows a greater opportunity to prove merit by means of a progeny test.

Linebreeding is a special form of inbreeding but differs from inbreeding because inbreeding itself is a system of mating, which related parents are mated with no particular attempt to increase the relationship of the offspring to any particular ancestor in the pedigree.

The genetic effects of linebreeding are the same as inbreeding. Linebreeding tends to make the pairs of genes carried in the heterozygous condition in the ancestor more homozygous in the linebred offspring. In addition, linebreeding increases the probability that the linebred offspring will possess the same genes at the ancestor to which linebreeding is directed. If the ancestor possessed many desirable genes, the offspring are more likely to possess these same desirable genes. If he possessed detrimental recessive genes in the heterozygous state, the offspring are more likely to possess those as well. Linebreeding will bring some of these recessive genes together in the homozygous state in some offspring. This serves to emphasize the importance of linebreeding to an ancestor that is superior genetically and carries a minimum of detrimental recessive genes. Accurate and adequate progeny tests help to identify such individuals.

Linebreeding is often looked upon with favor by breeders, but inbreeding is not, probably because linebreeding is not so intense and when it is used, the inheritance of truly outstanding animals is concentrated in the pedigree.

As a general rule, a sire is not mated to his own daughters when linebreeding is practiced, but half-sib matings are made among the offspring of this particular sire. Mating a sire to his daughters can and will concentrate his favorable qualities on those offspring, but care must be exercised to identify detrimental traits and rigid culling practiced to stop regression.

There are different systems of linebreeding that are done according to kinship of the animals being mated and they are all practiced with the main objective of

concentrating genes of a particular ancestor in the herd or flock. Any linebreeding program requires a planned, systematic mating schedule. If practiced for a long period of time, linebreeding sooner or later must be directed through one or more of the ancestor's sons or other descendants.

A word of caution about linebreeding is appropriate. It will be most successful when used by breeders who recognize its potentialities and its limitations and by those who have made a detailed study of the principles of breeding. Even in these instances, success will depend upon the breeder's ability to find and recognize individuals of outstanding merit. Nevertheless, the industry could and should make more use of this system than it has in recent years.

Crossbreeding is the mating of animals of two or more different breeds.

Outcrossing is the mating of unrelated animals within a breed. Although crossbreeding is more extreme than outcrossing, the genetic effects of both are similar.

The genetic effects of outcrossing and crossbreeding are exactly the opposite of those of inbreeding or linebreeding. Whereas inbreeding tends to make more pairs of genes homozygous, outcrossing and crossbreeding tend to increase heterozygosity in the genes for which the parents possess different alleles.

Outcross or crossbred animals are less likely to breed true than are inbred or linebred animals. This is due to heterozygosity and means that they are less likely to transmit the same genes to all of their offspring.

Groups of outcross or crossbred animals in the F1 generation are likely to be uniform in traits related to physical fitness, especially if the parents are homozygous in opposite ways for the two alleles of a particular pair. If the outcrossed or crossbred parents are not homozygous and the F1 progeny are outcrossed/crossbred again, that resulting progeny from that mating will most likely not be uniform and their performance is unpredictable.

Some traits but not others express heterosis, also referred to as hybrid vigor. Heterosis cannot be estimated accurately for a single mating because nongenetic factors may cause a great deal of variation in a particular trait in a single mating.

Dominance is responsible for heterosis and it should be theoretically possible to capture this superiority in a single line by making individuals homozygous dominant for all pairs of genes. However, with outcrossing and crossbreeding, these homozygous dominants would be difficult to distinguish, for they would resemble the heterozygous in phenotype. In addition, it is very likely that there are many more than two pairs of genes involved and these would further complicate efforts to establish homozygous dominance.

It is difficult if not impossible to fix heterosis; this is, to attempt to maintain heterosis by mating those individuals having the highest degree of heterosis. The most practical procedure of making use of heterosis is the formation of distinct lines or breeds and then crossing them to find those, which give the greatest hybrid vigor.

Not all traits in farm animals are affected to the same degree by heterosis. Those traits that are expressed early in life, such as survival and growth rate to weaning, seem to be affected the most, whereas feed-lot performance, as measured by rate and efficiency of gain after weaning, is only moderately affected. In general, heterosis seems to have very little influence of carcass quality in cattle and other farm animals.

Evidence also indicates that the degree of heterosis depends upon the degree of genetic diversity of the parents that are crossed. Thus, a higher degree of heterosis should be obtained when different breeds are crossed than when lines within the same breed are crossed. Furthermore, crossing breeds having greater differences in their genetic backgrounds should give more heterosis than crossing breeds with similar genetic backgrounds.

Outcrossing is the system of mating used by many livestock breeders for the production of purebreds at the present time. For some reason many feel they can purchase from other breeders males of higher quality than they can produce in their own herds. One contributing factor to the widespread use of outbred sires has been the extreme importance placed on show-ring winnings. The breeders feel that they must obtain a certain amount of advertising for their own herds by purchasing progeny of grand champion sires. This does increase the chances of bringing more desirable show-ring type into the herd, but the chief advantage is that a well-known name appears on one side of the pedigree of the young stock they have for sale. This has resulted in more attention being paid to names than merit and show-ring qualities in most cases aren't the same as efficiency and performance in the pasture.

In summary Inbreeding or linebreeding is the most effective way to create prepotent seed stock. A main reason for developing inbred lines is to use two or more of them for crossing. The ones crossed year after year should be those that give the best performing linecross progeny. Such parents are said to have superior combining ability. Once inbred lines are formed, matings must continue to be made within the inbred line to keep it pure. The development of superior inbred lines and crossing those with the best combining ability could considerably increase the efficiency of livestock production.

Outcrossing is the form of mating most often used by present-day purebred breeders in the production of purebreds. Its popularity will most likely continue but the trade-off for heterosis is the loss of prepotency and genetic predictability. In outcrossing, the breeder must attempt to use the best genetic material he or she can find and afford, and in addition try to find a male that is superior to the females in the herd.

It is wise for the purebred breeder to purchase older males, or in the case of AI – use the semen from older males, that have been progeny tested and proved of superior genetic worth. Often the older male of outstanding breeding ability is sold because he has so many daughters in the herd that the owner would be forced to use inbreeding if he were kept in the herd. Superior genotypes of this kind should be used in someone's herd as long as the animal remains fertile, in order to improve the overall production of the herd and breed.

Crossbreeding is the mating system that should be used by the livestock multiplier or the commercial livestock producer. The class of livestock may be important, however; crossbreeding is useful in swine, but may not be useful in dairy cattle. Crossbreeding effects are the opposite of inbreeding and linebreeding effects. Although hybrid vigor has its purpose, the breeding worth of the individuals are lessened to a certain degree because they are heterozygous and do not breed as uniformly and true as inbred animals.

Some livestock producers become so enthusiastic about crossbreeding that they may forget that some traits in farm animals do not show heterosis. Thus it is important for the breeder to be familiar with the traits that show heterosis and which ones do not.

In conclusion, it is well to emphasize that, for the greatest improvement in livestock breeding; the breeder must not only be familiar with the raw material but also the tools available to mold this raw material. He or she must become familiar and know how to use both to the greatest advantage.