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Inheritance of Color And The Polled Trait

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Introduction

All functions of an animal are controlled by the enzymes (and other proteins) produced by the genes the individual possesses. The way these enzymes metabolize nutrients into a wide range of products determines the specific growth rate, structural size, color, etc. for each individual. Since genes are passed from parent to offspring, the characteristics of the offspring can be predicted if enough is known about the parents.

Genes are small spots on the chromosomes. Each spot controls a specific function of the animal. Cattle have about 200,000 pair of genes on 30 pair of chromosomes. Each of the 30 pair of chromosomes is different and controls different functions of the animal. Genes that control a specific function are located at a unique spot on a certain pair of chromosomes. Each of the two chromosomes that make up a pair will have a gene for the same function at exactly the same spot and that gene cannot be any place else or on any other pair of chromosomes. Because of this, every animal has two (always two) genes for each of the 200,000 functions (except for the X and Y chromosome). For example, each animal has two genes for basic color, two genes to determine if they are polled or horned, etc.

When a bull produces a sperm or a cow produces an egg, the cell divides and one chromosome from each pair goes to the sperm or egg. Therefore, the sperm and egg have only one of the two genes for each function of the animal. When the sperm and egg unite, the new embryo gets 30 chromosomes from each parent to again establish the 30 pairs of chromosomes. In this way, the new offspring always gets half of its genes from each parent. Therefore, if you know what genes the parents have, you can predict what genes the offspring will have. This is what is done with estimated breeding values. From all the information that is available, we can estimate the genes each parent has and then predict the genetic ability of the offspring. It is much easier to predict (and often you know exactly) the gene involved in a simply inherited trait such as color or horned-polled.

Color

All cattle have a basic color of black, red or white (Shorthorn type of white). Since all cattle have two genes for basic color, this makes six genetic combinations. (Table 1).

Table 1. Combinations of the red, black, and white gene and the colors they produce.

Gene Combinations (Genotype)	Cattle Color (Phenotype)
2 black genes (R^bR^b)	**Black**
1 black, 1 red gene (R^bR)	**Black**
2 red genes (RR)	**Red**
1 black, 1 white gene (R^br)	**Black-roan**
1 red, 1 white gene (Rr)	**Red-roan**
2 white genes (rr)	**White**

The gene for black (R^b) is dominant to the gene for red (R). Cattle with one gene for black and one gene for red will be black. There is incomplete dominance between the gene for black (R^b) and the gene for white (r) so that an individual with one gene for black and one gene for white will be black-roan. There is also incomplete dominance between the gene for red (R) and the gene for white (r), producing the red-roan when these two genes are present. An individual with two genes for white (r) will be white.

Another set of genes determines if the color is diluted or not diluted. The gene for dilution (D) is dominant to the gene for nondilution (d). An animal that has one gene for dilution and one for nondilution will have a diluted color. An animal with two genes for dilution will also be diluted and one with two genes for nondilution will not be diluted. The dilution gene causes black to be diluted to gray and red to yellow. Of course diluted white is still white (Table 2). *Most Simmentals have the dilution gene* (probably over 80%).

Table 2. Combinations of the genes for color and the gene for dilution (two loci).

Gene Combinations (Genotype)	Cattle Color (Phenotype)
R^bR^bDD – Diluted black	Gray
R^bR^bDd – Diluted black	Gray
R^bR^bdd – Nondiluted black	Black
R^bR DD – Diluted black	Gray
R^bR Dd – Diluted black	Gray
R^bR dd – Nondiluted black	Black
R R DD – Diluted red	Yellow
R R Dd – Diluted red	Yellow
R R dd – Nondiluted red	Red
R^br DD – Diluted black-roan	Gray-roan
R^br Dd – Diluted black-roan	Gray-roan
R^br dd – Nondiluted black-roan	Black-roan
R r DD – Diluted red-roan	Yellow-roan
R r Dd – Diluted red-roan	Yellow-roan
R r dd – Nondiluted red-roan	Red-roan
r r DD – Diluted white	White
r r Dd – Diluted white	White
r r dd – Nondiluted white	White

These two sets of genes are of most interest to Simmental breeders. There are several sets that will also modify the color, such as the dominant inhibitor gene of the Charolais which inhibits color from forming.

There are also several sets of genes that determine color pattern. An example of this is the white face, solid color or spotted set of genes. It should be remembered that these genes for color have no influence on production or reproduction traits.

Examples and Probabilities:

Example 1. An Angus cow bred to Galant

	Parents	
	Cow	**Bull**
Genotype	R^bR^bdd	RRDD
Phenotype	Black	Yellow
Gametes	100% R^bd	100% RD
	Genotype	**Phenotype**
Calf	R^bR Dd	Gray

The Angus cow probably had two genes for black and two genes for nondilution; therefore, the eggs she produces will all have one gene for black and one gene for nondilution. Galant has two genes for red and probably two genes for dilution. His sperm will all have one gene for red and one gene for dilution. When these two gametes unite, the calf will have a gene for black and one for red to determine the basic color of black (black is dominant to red) and a gene for dilution and one for nondilution to produce a diluted color (diluted is dominant to nondiluted). Therefore, the calf will be a diluted black which we would call gray.

Example 2. The gray calf (assuming a heifer) from example 1 bred Abricot:

	Parents	
	Cow	**Bull**
Genotype	R^bRDd	RRdd
Phenotype	Gray	Red
Gametes	25% R^bD	100% Red
	25% R^bd	
	25% R D	
	25% R d	
	Genotype	**Phenotype**
Calf	25% R^bR Dd	Gray
	25% R^bRdd	Black
	25% RRDd	Yellow
	25% RRdd	Red

One-fourth of the eggs produced by the gray cow would have the gene for black and the gene for dilution, ¼ would have the gene for black and the gene for nondilution, ¼ would have the gene for red and the gene for dilution, and ¼ would have the gene for red and the gene for nondilution. All sperm from Abricot would have the gene for red and the gene for nondilution. When the sperm unites with eggs from the gray cow, there is a ¼ chance the calf will be gray, ¼ chance of black, ¼ chance of yellow, and ¼ chance of red.

Example 3. A Hereford cow bred to Galant:

	Parents	
	Cow	**Bull**
Genotype	RRdd	RRDD
Phenotype	Red	Yellow
Gametes	100% Rd	100% RD
	Genotype	**Phenotype**
Calf	RRDd	Yellow

The Hereford cow has two genes for red and two genes for nondilution so all the eggs she produces will have one gene for red and one gene for nondilution. Galant, as in example 1, will produce only sperm that have one gene for red and one for dilution. The calf will have two genes for red, one gene for dilution and one gene for nondilution. The calf will be yellow.

Terms Used For Color

The only common term that has been used in describing color is "Black factor". This indicates that the animal has the black gene and may or may not be diluted. Breeders should be very careful about advertising an animal as "black". Black indicates that the animal has two genes for nondilution. The typical Angus is black. If your Simmental is a lighter shade than the typical Angus, it has the dilution gene and should not be called black. It would be correct to say the animal has the "black factor".

Occasionally, an animal is referred to as "dark red". This also indicates that it has two genes for nondilution. Again caution should be used not to misrepresent your cattle.

Polled

Most traits involve large numbers of different genes. Very complex genes are responsible for a trait like weaning weight, (Environmental factors like nutrition must also be taken into account) but the polled trait depends on just one gene, expressed by the symbol "P". The opposite condition, the presence of horns, is expressed as the "p" gene.

The polled gene (P) is dominant to the horned gene (p). So when an animal inherits the dominant P gene from one parent and the recessive p gene from the other parent, it is the dominant P that shows up in the individual's appearance as the polled trait. The only time the recessive horn gene (p) can express itself is when the dominant P gene is not present.

There are three possible gene combinations involving the dominant polled gene (P). They are PP, Pp, and pp. Half of each combination is inherited from each parent.

The PP individual is said to be homozygous polled because it possesses two identical genes ("homo" means "the same"). It will have all polled offspring regardless of whether the other parent is horned or polled, because it has only the dominant P gene to pass onto its progeny. PP bulls are sometimes referred to as 100% dehorners.

The Pp individual, on the other hand, is heterozygous ("hetero" means "not the same"). The Pp individual possesses two different genes, so it won't breed true for the polled trait. Fifty percent of the time, the Pp individual will pass on the horn gene, p, to its progeny.

The pp individual is horned, and is also homozygous because it has two identical genes. The pp individual will always pass on the p gene to its progeny because that is all it possesses.

To date, most of the research on the polled characteristic has been with the British breeds. But scientists are reasonably certain that the modes of genetic inheritance in the Simmental breed are similar to British and other Northern European cattle, unless the individuals involved have been bred up from breeds with zebu ancestry, like Brahman, Santa Gertrudis, and others. An additional gene affects the inheritance of horns in zebu-type cattle, and complicates the issue somewhat.

A third factor that comes into play is, of course, the inheritance of scurs. Scurs and smooth polledness are separate traits from the horned and polled conditions. Inheritance of scurs is a separate process from inheritance of horns, and involves a different set of genes.

A) Testing Homozygosity of Polled Bulls

Polled cattle (either smooth or scurred) of European background can have either one gene for polledness (heterozygous polled) or two genes for polledness (homozygous polled). The bull with two polled genes will sire only polled (either smooth or scurred) calves. The number of polled genes a polled animal has cannot be determined by its outward appearance. Only through the offspring produced can the number of polled genes be determined. The best test of homozygous polledness is to mate a polled bull to horned cows.

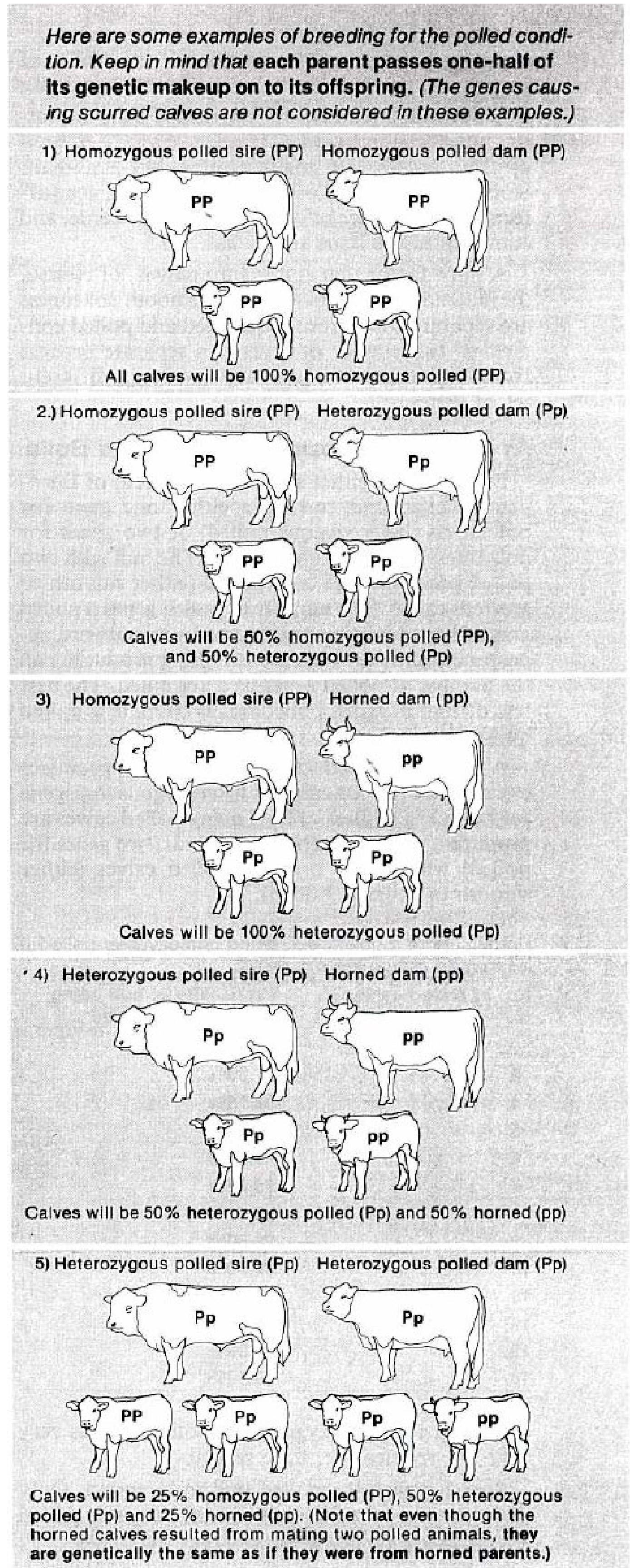
A polled bull bred to horned cows that produces one or more horned calves is heterozygous (one gene for horns) regardless of how many polled calves are produced. A homozygous polled bull (two genes for polled) will always produce polled calves (either smooth or scurred Polled).

Probability of a polled bull being homozygous polled if no horned calves are produced.

No. of polled calves From horned cows	Probability of bull being Homozygous Polled
2	75%
3	87.50%
4	93.75%
5	96.88%
6	98.44%
7	99.22%
8	99.61%
9	99.80%
10	99.90%
11	99.95%
12	99.98%
13	99.99%
14	99.99%

Testing for homozygosity of polled bulls is very easy but requires accurate records.

Step 1: Select the polled bull to be tested. Only bulls that are polled themselves can carry two



polled genes. But remember that bulls with scurs are polled. Any bull can be tested – Simbrah, Simmental, or other breed. He can be owned by you, or by someone else.

Step 2: Breed the bull to at least 10 (preferably 14 or more, see the chart) horned cows of European breeding (not zebu breeding.)* Do not use scurred or smooth-polled cows for the test. The cows can be bred by A.I., natural service, or embryo transplants.

Step 3: Check all calves – heifers, bulls and steers. If one or more calves has horns the bull carries the genes for horns and is heterozygous polled. (If parentage of the calves is questionable, have the bull, the cows and the calves blood-typed.) If no horned calves are found, keep the calves until they are yearlings, then check them again. You need to keep at least 8 calves, preferably 10 or more calves. (Remember that identical twins count as one calf, but non-identical twins count as two calves.) If you don't get enough cows bred the first breeding season, continue the next season with the same or different horned cows.

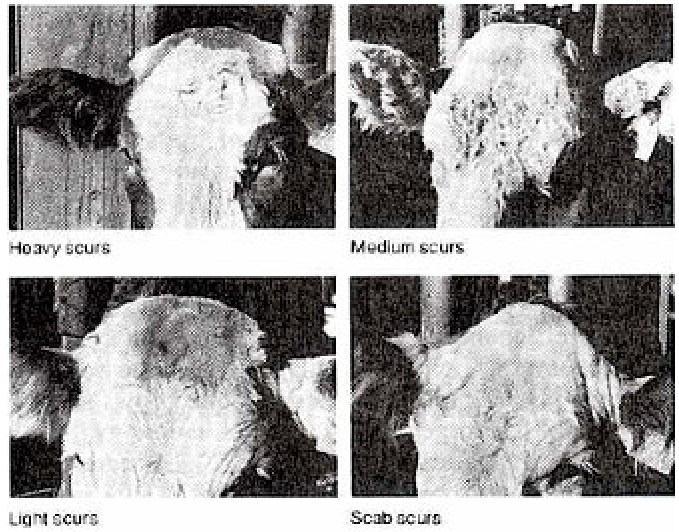
Remember, if a bull ever sires a horned calf, he carries the horn gene, even if the calf was from a cow not in the test. Once you are sure you have one horned calf, the test is complete. The bull carries the gene for horns.

B) Scurs

There are additional genes that affect hornlike growth on an animal's head. The major gene for scurs (S^c) is thought to involve an inheritance process that is separate from the processes that determine either polledness of the presence of the African horn. Absence of the scur gene is expressed by the symbol S^n.

Scurs are incompletely developed horns which are generally loose and moveable beneath the skin. In older animals, they may become attached to the skull. They range from tiny scablike growths to large protuberances almost as large - but not usually - as horns.

Because the gene for scurs is probably transmitted separately, it generally has no effect on the presence or absence of horns. Not all horned cattle carry the gene for scurs, and not all polled cattle lack the scur gene. In a horned herd, the presence of scurs is hidden by the horn growth, and does not show up until the horns are bred off. So scientists recommend that the cattleman at first ignores the scurred condition until he has achieved a polled herd. Then, after his animals are hornless, he can start a program to breed out scurs.



At present, scientists don't have enough information to be sure of the way scurs are inherited. Some feel that the gene is responsible for all types of scurs, no matter what their size, although that gene varies greatly in its expression. Others suggest that the scurred condition may be affected by more than one pair of genes, with the size of the scur determined by either (1) which pair of genes is involved, or else (2) the number of pairs of genes involved.

Scurred Inheritance Patterns

Genetic makeup Of animal	**Cows**	**Bulls**
S^cS^cPP	scurred	scurred
$S^cS^n PP$	smooth polled	scurred
S^nS^nPP	smooth polled	smooth polled

These patterns are true for polled animals that are either PP or Pp; pp animals will be horned, and the scurred condition (if it is present) will be covered up by the horn growth.

* Zebu breeds have different inheritance of the polled trait.

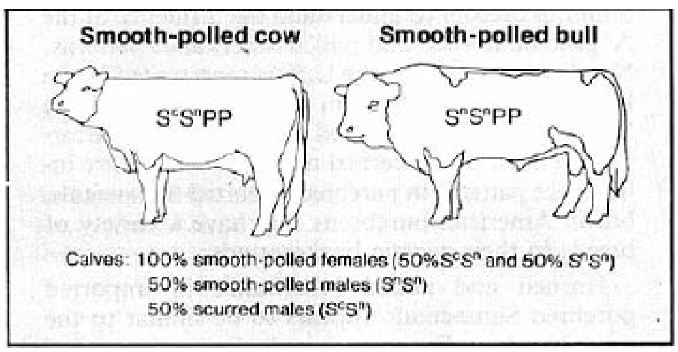
The way the gene for scurs (S^c) is expressed depends on the sex of the animal.

In males, the S^c gene is dominant. This means that the presence of a single S^c gene will cause a bull to be scurred.

In females, the S^c gene is recessive. So a cow must possess two S^c genes in order to be scurred. If she possesses only one S^c gene, she may pass the scurred condition onto some of her calves, but will not herself be scurred.

It is easy to detect the presence of the scur gene in a bull since, if he carries just one S^c gene, he will be scurred instead of smooth-polled.

However, a smooth-polled cow may carry a recessive S^c gene (S^cS^n), so eliminating scurs from your herd is a more complex process. But you can positively identify a smooth-polled cow that carries the scurred gene if she produces a scurred bull calf when mated to a smooth-polled bull:



The scurred condition is not easy to eliminate from a herd, and factors enter into scurred inheritance patterns that have no scientific explanation as yet. In time, however, a breeder can virtually eliminate scurs from his herd by exclusive use of smooth-polled bulls, and by selecting against all animals that have scurs or that are known to carry the gene for scurs. Of course, he would continue to select for performance in the other traits at the same time.

The most convenient time for a breeder to classify his animals as horned, polled, or scurred is at weaning (6-9 months). But breeders should note that occasionally what appears to be scurs at weaning may develop into horns by 15 months of age or even later, particularly with heifers. When this happens, the animal must be reclassified as horned.

The breeder who wants to be positive about the horned, polled, or scurred status of his Simmentals should continue to check polled animals for horn or scur growth up to three or four years of age, and report any changes in status to ASA so that breed records can be corrected.

C) Simbrah

Inheritance of horns in zebu-type cattle is different from that observed in the British breeds. The polled gene, P, and the scur gene, S^c, can both be present in American cattle with zebu ancestry. But another gene (the A^f gene) also affects inheritance of horns in these animals.

The A^f gene is rare in British cattle, and is usually called the African horn gene because it was first studied in cattle native to Africa. Absence of this gene is expressed by the symbol A^n.

It is important for the American Simmental and Simbrah breeder to understand the influence of the A^f gene on horned and polled inheritance patterns. Nearly every breed in the U.S. is represented in the base cow population from which Simmentals and Simbrah are being upgraded to purebred. So the cattleman must be concerned not just with genetic inheritance patterns in purebred imported Simmentals, but in American purebreds that have a variety of breeds in their genetic backgrounds.

Horned and polled inheritance in imported purebred Simmentals appears to be similar to the other Northern European breeds. But in the case of an upgrading program involving Brahman, or other breeds with zebu blood in their ancestry, the A^f gene can show up in an animal that has been bred up all the way to purebred Simmental.

Scientists are reasonably certain that the behavior of the A^f gene depends on the sex of the animal it appears in.

In males, the A^f gene is dominant to the polled gene, P. This means that the appearance of a single A^f gene will cause a male animal to be horned, even if he is Pp or PP.

In females, a single A^f gene is recessive to the polled gene, P. In order for the A^f gene to produce horns in a PP or Pp female, two A^f genes must be present.

In animals possessing the A^f gene in addition to the polled gene, P, the following inheritance patterns can be expected (note that for all the combinations below, the animal's genetic inheritance for polledness could be Pp instead of PP without changing the effect of the African gene):

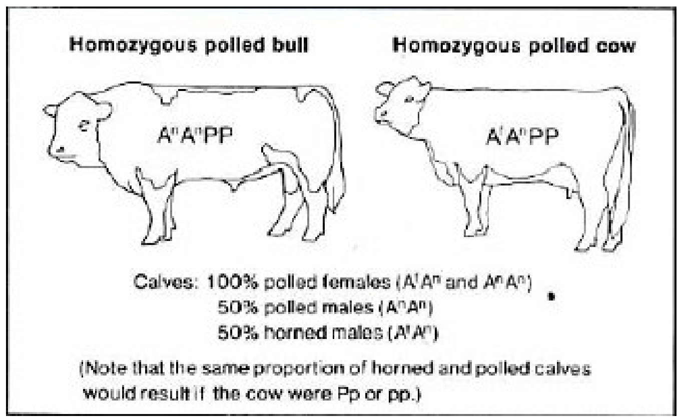
Genetic makeup of animal	**Cows**	**Bulls**
A^fA^f PP	horned	horned
A^fA^n PP	polled	horned
A^nA^n PP	polled	polled

Although the presence of the A^f gene complicates genetic inheritance patterns, it is actually easier to eliminate than the European horn gene, p.

Since the presence of a singe A^f gene causes a male to be horned, progeny tests of bulls are unnecessary. If a bull is polled, he does not carry the African horn. On the other hand, if he is horned when his genetic ancestry says he should carry the polled gene, P, he may carry the A^f gene which is covering up the expression of the P gene.

The breeder should keep in mind, too, that a proven homozygous polled bull will produce some horned calves if he is bred to horned or polled cows that carry the African gene (A^fA^n or A^fA^f). For example, a bull that does not carry the A^f gene (A^nA^n) and is also homozygous for polledness (PP) is a 100% dehorner under ordinary circumstances. But he will still produce some horned calves if he is bred to a cow that carries the A^f gene.

It is more difficult, of course, to identify cows that carry the A^f gene, since a cow has to have two A^f genes, in order to be horned. The best method is to select against all cows with horns, and all cows that throw a horned calf when bred to a proven homozygous polled bull.



The American Simmental Association expresses appreciation to the authors and the following regional committees – GPE Cattle Handbook, Western Regional Cattleman's Library, Southern Regional Beef Cow-Calf Handbook – for permission to reprint this factsheet.

There have been several advances in the understanding of color inheritance in cattle since the publication of Dr. Shalles' paper. The appendix below, developed by Sally Buxkemper, addresses the advancements:

TERMS USED FOR COLOR

The Extension (E) locus, which is responsible for much of the variation in cattle coat color, has been identified as the melanocyte stimulating hormone receptor (MSHR or MC1R). There are commercial DNA tests for the three alleles. ED for dominant black, E+ for wildtype, and e for the recessive red. The order of dominance is ED>E+>e and every animal will have one allele from each parent. The E+ allele allows for both red and black pigment to be produced.

The gene for roan(R) is not allelic in this series but is the Steel locus or Mast Cell Growth Factor. This gene causes a mixture of white hair with any basic color when heterozygous and produces an almost all white animal when homozygous. We will use the (r+) for the normal or non roan.

COMBINATIONS OF THE GENES FOR COLOR, SIMMENTAL DILUTION, AND ROAN (THREE LOCI).

EDEDDDr+r+= black diluted, gray	EDEDDDRr+=gray roan
EDeDdr+r+= black diluted, gray	EDeDdRr+=gray roan
EDEDddr+r+-=black nondiluted, black	EDEDddRr+=black roan
EDeddr+r+=black nondiluted, black	EDeddRR=white
EDE+ddr+r+= black nondiluted, black	EDE+ddRR=white
eeDDr+r+=red diluted or yellow	eeDDRr+=yellow roan
eeddr+r+=red nondiluted	eeddRr+=red roan
E+eddr+r+=wildtype(can have some black)	E+eddRr+=wildtype roan

There are more combinations of these three loci in Simmental cattle. Some Red Angus and Red Simmentals are E+eddr+r+ but are phenotypically called red. They usually have black skin. There are other genes that cause variations of color. Simmental recessive spotting gene is of concern to modern breeders. Since this spotting gene is recessive, it can be hidden for generations.