# Pure Blood - Part III

By Mike Safley

The Quechua Indians are basically animistic in their religious beliefs. Their gods are called Apus and they have many, including a few Catholic saints who they throw in for good measure. Their Apus reside in earth, water, air, and animals. Let's pretend for a moment that we are the Alpaca Apu and we have been given the job of creating a mating plan for the North American alpaca herd which will allow the expression of its fullest genetic potential. In fact let's imagine that we are not only Alpaca Apus but trained geneticists as well. What should we do?

The first step to creating any future plan is to analyze the current circumstance. Today the United States alpaca industry is generally following a breeding system known as outcrossing. Breeders work hard to insure that their alpaca's pedigrees do not include any relatives. This may be the best plan, it may not, but before breeders decide which mating system is optimal they should understand all of their alternatives.

Every alpaca breeder makes two basic choices in their breeding program. First, they select the alpacas which make up their herd. We talked extensively about selection in Pure Blood Part II. Second, the breeder decides which alpaca they will mate with each of the alpacas in the herd and how many offspring each parent will have. The second decision they make, the mating system or whom to breed to whom, is every bit as important as their initial selection decision. Most breeders practice selection, but for many of them selection also substitutes for their breeding system.

CREATING A BREEDING PROGRAM

To create an effective mating plan, we must understand how the elements of selection fit into the plan and impact genetic gain. Selection is used to identify superior animals. A mating plan is used to consolidate and perpetuate the gains made from selection. Understanding this relationship, together with a thorough knowledge of how the various mating plans operate, will guide the creation of our breeding program and allow us to answer questions, such as:

1. Should I use a wide variety of males or a select few?
2. Should I use proven older males or unproven younger males?
3. How important is pedigree?
4. Should I buy replacements or breed them from my herd?
5. How many replacement females should I save?
6. Should I outcross, linebreed, mate like-to-like?
7. Is corrective mating important?

The answers aren't easy, but by understanding how selection impacts genetic gain, then combining that knowledge with our mating plan, we will begin to close in on effective breeding strategies, which will be discussed in great detail later in this article.

FOUR KEYS TO GENETIC CHANGE

Selection accuracy is important if any gain is to be made. This means the traits you are selecting for must be heritable and the animals you choose for parents must have high breeding value for the traits under selection.

For instance, if you are selecting for a heritable characteristic, such as fleece density, you must use stud males whose offspring have higher than average fleece weights. The same goes for fineness, crimp. staple length, etc.

If you are purchasing foundation stock, replacements, or breeding services and density is your goal, ask for records of shear weights for all of a male's offspring. Inspect as many of his offspring in a given environment as possible. The same goes for any heritable trait under selection. By inspecting the offspring, you are determining the breeding value of the parents. Parents with high breeding values assure a higher degree of selection accuracy for the progeny.

Selection intensity is a key element of the rate of genetic gain. If a breeder is highly selective and chooses only the offspring exhibiting superior traits for heritable characters, from parents who are consistently transmitting these traits, the breeding values will be high and the offspring should improve from generation to generation.

Breeders may decide to select animals scoring in the top twenty-five percent on their selection index. (See Pure Blood Part II.) If they later select only those alpacas scoring in the top twenty percent of the index, they would then be selecting more intensely. The higher the selection intensity, the higher the rate of gain.

Genetic variation is extremely important to the rate of gain. Assuming there are a wide variety of animals to choose from, a breeder has the choice of selecting alpacas with very different traits, such as ones with high or low fleece weights. If there is a high breeding value for a trait, such as density, progress can be rapid in the direction the breeder chooses.

On the other hand, if there is little genetic variation in a population of alpacas, it is very difficult to affect change. How could you expect to rapidly effect fleece weight if there was little difference between the high and the low? In other words, the more variation for a particular trait in a population, the more potential there is for change.

Generation interval is the final element that effects the rate of genetic change. Simply put, the more rapidly one generation replaces the other, the faster the potential gain. Mice reproduce more quickly than humans, producing one hundred and fifty generations in the time it takes humans to produce one. (Please note, this makes mice far easier to improve than humans and explains why mice are preferable over humans as laboratory animals.)

Generational interval is determined by the average age of the producing males and females in a given herd. Alpacas have a generational interval of four to six years for females and approximately five years for males. The interval will vary from herd to herd. Figure 1 identifies some common generational intervals for livestock.

**Figure 1: Common Generation Intervals**

| Species | Generation Interval (years) |
|---|---|
| Horses | 8 to 12 |
| Dairy Cattle | 4 to 6 |
| Beef Cattle | 4 to 6 |
| Sheep | 3 to 5 |
| Swine | 1.5 to 2 |
| Chickens | 1 to 1.5 |

The interaction of the four elements above combined with an effective mating plan will determine the direction and rate of gain in any herd. Selecting alpacas with high breeding values is a major key to success. Each of the five mating systems discussed will use these keys for genetic gain in differing degrees.

MATING SYSTEMS

The five types of mating systems are: random, outbreeding based on pedigree, like-to-like, or inbreeding based on pedigree, like-to-like based on phenotype, and unlike-to-unlike or corrective mating based on phenotype. Outbreeding involves joining alpacas which are less closely related by blood than would be the case with random mating. Inbreeding involves joining alpacas that are more closely related by blood than would be the case with random mating. The mating of like-to-like or the mating of unlikes, regardless of pedigree, is different from outbreeding and inbreeding.

Using some form of these five basic systems, together with selection, is the only way an alpaca breeder can change the inheritance pattern of their alpacas. It is important to know which changes will likely occur under each system. What are the strengths and weaknesses of inbreeding, outbreeding, mating like-to-like, and unlike-to-unlike. What does each system do, both poorly and well?

Any of these mating systems can be practiced in combination with any of the others. Each system is almost always accompanied by some degree of selection. This makes possible an almost infinite number of specific breeding plans. The consequences of each decision may be predicted in a general way, but the random nature of Mendelian segregation and recombination leaves room for surprising results in individual cases. Precise predictions about the outcome of breeding plans will never remove the sporting elements, of hope and chance, which have historically held the farmers' fascination and led many wealthy men to take up livestock breeding as a hobby.

The alpaca breeder can not change the laws of Mendelism, the number of genes which make an alpaca, or their inter-relationship. They can not change the expression of dominance or the negative effects of recessive genes. This leaves, as the practical means of controlling the heredity of animals, the decision about how many offspring each animal shall have and which alpaca shall be mated with which alpaca.

The following organizational chart lays out the five basic breeding systems. If you think about each of the breeding decisions you have made, you will find that they fall into one of these categories.

MATING SYSTEMS

- Mating Like-to-Like
  - By pedigree: Inbreeding, including line-breeding, sometimes called family breeding
  - As individuals: Mating big with big, dense with dense, fine fleece with fine fleece, black with black, heavy boned with heavy boned, vigorous with vigorous, etc
- Random Mating
  - Mates no more and no less alike, either as individuals or in pedigree, than if they had been mated by drawing lots from within the group elected to be parents
- Mating Unlikes Together
  - By pedigree: Outbreeding, ranging from species crossing through crossbreeding (such as suri to huacaya), crossing strains within the breed.
  - As individuals: Compensating for defects, crossing extremes to produce intermediates, mating large with small, coarse with fine, dense fleeced with light fleeced, knock knees with straight legs, etc.

RANDOM MATING

Random mating is a system in which mates are chosen at random. With truly random mating, all conceivable matings are equally possible. To make random matings, a breeder with a statistical inclination might assign each female a number from a random number table, then allocate those females with the lowest random numbers to one male, those females with higher random numbers to another male, and so on.  More typical procedures for random mating include “gate cutting” or sorting females according to the order they choose to approach a gate or turning a number of unselected males in with females and allowing nature to take its course, as they do in Peru.

Random mating is easy.  It requires no performance records or genetic predictions, and little time is involved in making mating decisions.  Random mating is often used in commercial breeding programs where there are so many animals that other approaches are impractical.  Few, if any, purebred breeders use random mating.

Random mating can be very helpful in the progeny testing of studs. If each sire is assigned to a large number of mates, and those mates are chosen at random, it is unlikely that the individual sire's evaluation will benefit from having good mates or suffer from having poor ones. An analysis of the progeny should be a reliable indicator of which sire is most desirable for the traits under selection.

There is no art in random mating. Many breeders feel that by using random mating they give up power over nature. But, random mating is underrated and it relinquishes less control than you might think. The "culls" that result from random mating are often balanced by superior specimens. There is no opportunity to use selection intensity or accuracy to impact the outcomes of random matings. Genetic variation can be enhanced using this system.

LIKE-TO-LIKE OR POSITIVE ASSORTIVE MATING

The like-to-like breeding system in the following discussion is based on phenotype, not genotype or pedigree. This system is also called positive assortive mating. A like-to-like system based on pedigree would be called inbreeding, which will be discussed later.

When alpaca breeders talk about mating like-to-like, they are often talking about selection. They usually mean breeding the best to the best. Most breeders don't mean that they would also breed their worst alpacas to their worst alpacas, as would be the case in true like-to-like breeding. They might breed their best stud to their worst dam, which is unlike-to-unlike mating, but they wouldn't breed their worst stud to their worst female. So, when alpaca breeders talk about breeding like-to-like, they may be talking about using selection as a substitute for a mating system.

An example of like-to-like mating would be the mating of the tallest males to the tallest females or the smallest to the smallest, the fastest to the fastest, and so on. Positive assortative or like-to-like mating tends to create more genetic and phenotypic variation in the offspring than would be found in a comparable randomly mated population. This is because the mating of the largest to the largest creates a portion of the herd which is much larger alpacas as opposed to the portion of the herd where the smallest was mated to the smallest and smaller alpacas were the result.

Uniformity for traits like fineness, crimp, and luster in alpacas or speed in horses are usually valuable to pure blood breeders. The increased phenotypic variation caused by true like-to-like assortative mating is normally considered a drawback of the strategy. However, the increased genetic variation obtained from like-to-like breeding can be beneficial from a selection standpoint. The greater the genetic variation, the faster the rate of genetic change.

Few breeders use like-to-like breeding for the express purpose of increasing genetic variation. They are more likely to mate their best males to their best females in order to increase the probability of producing superior offspring. They often use positive assortative mating to produce extreme individuals which makes sense if the breeding goal is to produce show animals.

Like-to-like mating is sometimes advocated in the belief that this will lead to a fixation of characters. When an animal's characters or traits are "fixed" or homozygous, they will breed true for these same characters. The problem is that like-to-like mating perpetuates characters, but does not fix them. Most of the benefits of like-to-like matings occur in the first few generations. After that, there are diminishing returns. This approach does facilitate both selection accuracy and intensity.

MATING UNLIKE-TO-UNLIKE OR NEGATIVE ASSORTIVE MATING
The reverse of mating like-to-like is the mating of unlikes or negative assortive mating. Again, this system is based on phenotype, not pedigree. One rationale for unlike mating is corrective mating. By compensating for faults in the parents you help ensure that they are not present in the offspring. For example, if your favorite alpaca dam is sickle-hocked (too much bend in the hind legs), you might correct the fault in her cria by breeding her to a stud that is post-legged (too little bend in the hind legs). The mating of unlikes should be regarded as a short-term expedient and breeders should attempt to move on to like-to-like mating as soon as possible. It is extremely important to avoid the mating of animals with similar faults.

With the use of unlike matings, the parent's faults may disappear from the offspring, but they will probably reappear in later generations. This is especially true if there is "over compensation," which happens when very good alpacas are mated with very poor alpacas.

Just as like-to-like mating tends to increase genetic and phenotypic variation in the offspring, unlike mating tends to decrease variation. Mating animals that are extreme in one direction to animals that are extreme in the opposite direction tends to produce more intermediate types and reduce the variability of the offspring.

Negative assortative mating is not a good strategy if you want to speed the rate and direction of genetic change. Reduced genetic variation decreases response to selection. However, if your chief goal is to increase phenotypic uniformity about some intermediate optimum, this mating strategy can be good. An example of unlike mating might be the pairing of roosters with high breeding values for egg size to hens that produce small eggs. This mating should tend to create layers producing moderate-sized eggs.

OUTBREEDING
Outbreeding or outcrossing is the opposite of inbreeding. It is the mating of individuals unrelated by pedigree. Because no animals within a population are completely unrelated, a more technically correct definition of outbreeding is the mating of individuals more distantly related than the average for the population. Any mating involving essentially unrelated individuals can be considered outbreeding. As a mating strategy, outbreeding often refers to crossbreeding or to linecrossing, which is the mating of sires of one line to dams of another line or breed. Mating suri males to huacaya females to create suri cria is the clearest example of crossbreeding in the alpaca industry.

The primary effect of outbreeding is an increase in heterozygosity. Most of the effects of outbreeding result from the increase of heterozygosity. By increasing heterozygosity, outbreeding tends to keep most bad genes in heterozygous form where they are not expressed. Geneticists say the expression of recessive alleles is "masked" in the heterozygote. That is why mutts exhibit fewer genetic defects than purebred dogs, and why outcross individuals in general appear to suffer from fewer genetic problems.

It is important to understand that outbreeding does not eliminate bad genes. It actually perpetuates them by masking their expression, making selection against them ineffective. If these recessive alleles occur at low frequencies, their impact on outbred populations is minimal.

## OUTBREEDING FOR HYBRID VIGOR

The most important genetic reason for outbreeding is to add hybrid vigor and genetic variation to a herd. Hybrid vigor is critically important to production in a number of species. It has major effects on fertility and survivability, it is manifested in traits like conception rate, litter size, and weaning rate -- traits that are very important economically. For this reason, crossbreeding, the most common form of outbreeding, is typically used to increase hybrid vigor. Outbreeding is practiced primarily by commercial producers who sell phenotypic value in the form of meat, milk, wool, or eggs. Because outbreeding boosts production and efficiency by adding hybrid vigor, it is an important breeding tool. (For a thorough discussion of hybrid vigor, see Suri Gene Supreme, a Cross Breeding Conundrum.)

## THE RISKS OF OUTBREEDING

Outbreeding systems risk half the merit of the offspring on the selection of the next sire to head the herd. If selection has already made the herd superior to the average of the breed, half of that superiority might be lost in the next generation unless selection is again as effective as it was before. Every breeder will occasionally make mistakes in his selections. The breeder who continually practices outbreeding can therefore expect to have the merit of his herd regress at times toward the average of the breed.

The breeder who wants to keep the quality of his herd far different from the average of the breed must put some kind of a pedigree barrier between it and the rest of the breed. This will ensure that the quality differences continually being produced will tend to accumulate and not be halved with each successive sire.

The following analogy, which is found in Jay L. Lush's famous animal breeding book, Animal Breeding Plans, makes the pedigree point clear. Water tends to seek its level. If there were no barriers in the way, the level of the water in all the lakes of the world would quickly seek the level of the ocean, just as the water in the rivers is continually doing.

The breeder who practices outbreeding is placing no barriers, except his own skill at selecting, in the way of his or her animals tending toward the average level of the breed. The breeder who practices linebreeding is to a considerable extent isolating his herd from the rest of the breed, and its merit tends toward that of the isolated group rather than toward that of the breed as a whole, just as the level of the water in Lake Erie remains nearly constant but several hundred feet above the level of the water in the ocean, even though water is steadily flowing into it and out of it again.

Breeders have a number of reasons for outbreeding. Sometimes they outbreed just to avoid the appearance of inbreeding. At other times they outbreed to cover the existence of lethal genes. Outbred individuals generally have low breeding values. This is the case even when outbreeding is combined with intense selection. The benefits of selection disappear quickly in outbred populations once selection is no longer practiced.

## LIKE-TO-LIKE MATING BASED ON PEDIGREE OR INBREEDING

The simplest definition of inbreeding is the mating of relatives. Because all animals within a population are related to some degree, a more technically correct definition of inbreeding is the mating of individuals more closely related than the average of the population.

The fundamental difference between inbreeding and the mating of like individuals together regardless of pedigree is that inbreeding is the mating of individuals who are apt to have the same genes and like-to-like mating is the mating of individuals which have similar characteristics, irrespective of common ancestors in their pedigree. Before we discuss the strengths and weakness of inbreeding in a calm, rational, scientific context (if that's possible) I would like to tell you a story.

It seems an old Syrian tribesman named Terah had three sons and a daughter. Their names were Nahor, Haran, Abram, and Sarai, respectively. Each was born of a different wife. Contrary to modern customs, the half-brother and sister, Abram and Sarai married, and their son married Nahor's granddaughter who was twice his first cousin, once removed, and they were known as Rebekah and Issac. Their son, Jacob, married two of his first cousins (great-granddaughters of Nahor, Terah's son) and had eight sons who became founders of the most persistently influential nation in human history, the ever miraculous Jewish race.

Apparently all of this worked so well that the Jews passed a law that established the tradition that they should not marry outside their race. That tradition survives in part today. Of the many charges brought against the Jews down through history, no one has ever accused them of feeble mindedness, degeneracy, or lack of vitality. One can only assume that old Terah and his three wives had great genes.

I am not sure why so many people are emotionally predisposed to reject inbreeding among animals. Mother Nature doesn't object if squirrels, deer, foxes, or frogs inbreed. Her only rule is survival of the fittest. Maybe humans associate the practice, on a moralistic level, with incest.

While I was researching the topic at our local library, I came across a book entitled The Incidence of Feeble Mindedness Among Inbred Mountain People. I guess it's fair to say that there are negative human examples of inbreeding. The human inbreeding problem is compounded by a certain lack of culling. On the other side of the coin, I remember reading somewhere that Cleopatra was the product of seven generations of brother-sister marriages among Egyptian royalty.

Enough talk of humans and their breeding practices. Let's turn our attention to what might happen if we inbreed alpacas.

## THE GENETICS OF INBREEDING

Inbreeding has a number of effects, but the chief one and the one from which all others stem is an increase in homozygosity, just as the primary effect of outbreeding is an increase of heterozygosity. There will be an increase in the number of homozygous loci in inbred individuals and an increase in the frequency of homozygous genotypes in an inbred population. Heterozygosity is uniformly reduced by inbreeding.

## THE NEGATIVE EFFECTS OF INBREEDING

One consequence of inbreeding is the expression of deleterious recessive alleles with lethal or negative effects, and it is this aspect of inbreeding that gives it a bad name. People associate inbreeding with genetic defect such as the spider leg condition in sheep, dwarfism in cattle, and various problems in dogs. It is true that defects caused by recessive alleles often surface in inbred populations. But inbreeding by itself does not create the problems. Inbreeding by itself simply increases homozygosity, and it does so without regard to whether the newly formed homozygous combinations contain good or bad genes. If negative recessive alleles are already present in a population, inbreeding increases the likelihood of these bad genes becoming homozygous and then expressing themselves.

For example, consider the problem known as diaphragmatic hernia, a congenital defect of the diaphragm in dogs. The recessive allele that causes the problem occurs at low frequency in the general population, so the probability is lower that a non inbred mating will produce the condition. However, if a dog that carries the recessive allele is mated to his daughter, there is much higher probability of producing an affected pup.

The fact that inbreeding increases the incidence of expression of simply inherited bad genes is a problem. But it is also possible to use inbreeding combined with selection to eliminate faulty recessive alleles from a population. The idea here is to inbreed within a small population, continually selecting against undesirable alleles, the result being the fixation of desirable dominant alleles and corresponding elimination of bad genes. This type of inbreeding can "purify" the herd.

INBREEDING DEPRESSION

The effect of inbreeding on the uniformity of polygenic traits, such as vigor, size, and fertility is less clear. There is always a fear that inbreeding will bring about a decline in the stamina of a herd. This phenomena is called "inbreeding depression" and is a possibility which should not be ignored. The loss of stamina is caused by the increasing homozygosity of the polygenes controlling health and vigor. The effect of any one of these alleles is small and will pass unnoticed in isolation, but the effect of homozygosity introduced by inbreeding, could result in individuals which appear sickly from no obvious cause or lag behind the growth of their siblings.

In the ordinary breeding population, these slightly deleterious polygenes will be present in heterozygotes and their existence would remain unsuspected until exposed by inbreeding. This is not to suggest that all alpacas carry these kinds of polygenes, or that inbreeding will inevitably produce weak stock. As a matter of fact, the inbreeding of inherently healthy normal animals will do no harm. Should inbreeding depression become too severe in spite of efforts to counteract its effects, the breeder must outcross to unrelated stock. If the outcross is good, it will be possible to preserve most of the better qualities of the strain, or at least not to lose too many. The first-cross progeny of inbreds are often remarkably hardy and vigorous.

THE POSITIVE EFFECTS OF INBREEDING

Historically, in most domestic species, inbreeding has been used as a way of increasing the uniformity of positive traits within a breed. This has been particularly true for simply-inherited traits like color, which have a noticeable effect on an animal's visual appearance. By inbreeding and allowing recessive alleles to express themselves, selection can reduce the frequency of or even eliminate from a population unwanted alleles for certain traits, such as red in Black Angus, or horns in sheep.

Inbreeding allows breeders to increase selection accuracy and use selection intensity to its maximum effect. The shorter the generation interval the faster the progress with inbreeding. One drawback to inbreeding is the loss of genetic variation.

The most positive consequence of the increase in homozygosity caused by inbreeding is prepotency. Individuals are said to be prepotent if the performance of their offspring is especially like their own or it is especially uniform. Because inbred individuals have fewer heterozygous loci than non inbreds, they cannot produce as many different kinds of gametes. The result is fewer kinds of zygotes and this ultimately means more uniform progeny.

An inbred individual is more likely to be prepotent if its homozygous loci contain chiefly dominant alleles. Their offspring will then have at least one dominant allele at each of these loci. If dominance is complete, the effect of these loci in the offspring will be the same as in the parent, regardless of what genes are controlled by the other parent. This is why the offspring will more closely resemble the inbred parent.

PREPOTENCY

The idea of "prepotency" is a breeder's concept. The term is often used where a given individual has the remarkable ability of producing offspring bearing a strong resemblance to itself. Males are usually referred to in these terms, partly because they have greater opportunity to reveal their potency than a female. The mystique of a "potent" stud has been the subject of many advertisements.

The interesting aspect of potency is that the more inbred an individual is the greater chance they have of being homozygous and therefore prepotent. An individual from an inbred or linebred strain will be more potent than one of heterozygous origin, even if the latter is superior phenotypically. The inbred animal will tend to transmit a uniform set of genes in every germ cell which is something a heterozygous individual cannot do.

CALCULATING THE PERCENTAGE OF INBREEDING

Different writers on the subject of inbreeding establish different standards to describe the difference between close inbreeding and milder forms, such as line breeding. Some forms of inbreeding are regarded as close, others as moderate, and still others as mild. The easiest way of measuring the degree of inbreeding is to decide that an animal above a certain percentage of inbreeding, say 25-30 percent, falls into the inbred category and an animal under this percentage is line bred. When using inbreeding as a mating system, the degree of inbreeding for the entire herd is far more relevant than for the individual. Inbreeding depression can begin to occur in a herd after the percentage exceeds say 25 percent.

Degrees of inbreeding can be worked out very simply. Each parent contributes a sample half of the chromosomes it carries to make the pairs of chromosomes in its offspring. For instance, full brothers and sisters have 50 percent of each parent. However, they may not have the same 50 percent. They will be similar in some respects, but the odds are as great that they will be totally different as they are that they will be entirely the same.

To work out the degree to which an animal is inbred, multiply the values of the fraction (or decimal) of each parent's relationship to the animal being considered. Full brother A and sister B are 50 percent related, in fractions 1/2 related, in decimals .5 related. The progeny of A X B is 1/2 x 1/2 = 1/4, or .5 X .5 = .25 or 25 percent inbred. Following this approach, the degree of various relationships works out as follows:


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| | |
|---|---|
| Sire and daughter | 1/4 or 25% |
| Full-brother and full-sister | 1/4 or 25% |
| Sire and Granddaughter | 1/8 or 12.5% |
| Half-brother and Sister | 1/8 or 12.5% |
| Nephew and aunt | 1/8 or 12.5% |
| Niece and uncle | 1/8 or 12.5% |
| Full first cousins | 1/16 or 6.25% |
| Half first cousins | 1/52 or 3.125% |

This approach to determining the percentage of inbreeding is open to a certain amount of criticism since relatives may have more in common than the average possible.

COEFFICIENT OF INBREEDING
The above calculations hold if the parents themselves are not inbred. However, if the ancestor is common to both parents and is itself from an inbred line of descent, this has to be taken into account. The inbreeding coefficient of an individual then becomes slightly larger, or 1/2 E [(1/2)n x (1 + inbreeding coefficient of the common ancestor)]. E stands for the sum of all lines of descent. N stands for the number of intervening gene segregations in a line of descent on which its sire and dam are related. Should more than one common ancestor of the parents be inbred, each will be accounted for when the calculation is made for the appropriate line of descent. Corrections made in this way account for very little once the ancestors are several generations behind the animal whose inbreeding is being calculated. (See Galton's Law, Pure Blood Part I.)

Another method of determining the coefficient of inbreeding is the path method which is a calculation that simulates the "path" taken by identical genes as they flow from ancestors to descendants. The method is simple and can be done by hand without a computer. Most genetic texts contain the "path" protocol used to determine the degree of inbreeding in an individual.

RATE OF INCREASE OF INBREEDING IN A HERD
The progression of inbreeding in a herd is very slow when more males are used. Some people have said the Accoyo herd is highly inbred but, based on the fact that Barreda uses over 100 sires on about 1,000 females, this assertion is doubtful, especially given that the Accoyo herd has only been closed since 1946. The fact that Don Julio has practiced rigorous selection, together with mild inbreeding, explains why his males breed true for so many positive traits.

LINE BREEDING
"Linebreeding" is a term commonly used by breeders of purebred stock. Linebreeding is the mating of animals related to a highly regarded ancestor. It is accomplished by using parents which are closely related to the admired ancestor but are little, if at all, related to each other through any other ancestors.

If a breeder says an animal is linebred, this instantly raises the question: "Linebred to what?" The answer is often that "this bull is a linebred Domino" or these "are linebred Accoyo alpacas" or "this horse is linebred to Secretariat."

Linebreeding differs from other forms of inbreeding primarily because it is directed toward maintaining a close relationship to a certain ancestor and secondarily, because it is less intense than extreme inbreeding. The relationship to the admired ancestor rather than intensity of inbreeding usually dominates the breeder's thought when they linebreed.

Linebreeding, more than any other breeding system, combines selection with inbreeding. In a certain sense, linebreeding is selection among the ancestors rather than among living animals. Often the ancestors being considered will have many offspring and be proven sires and proven dams. In this context, linebreeding can be considered selecting from among progeny tested ancestors.

The linebreeding advantage is partially offset by the fact that the individuals used to preserve the traits of their ancestors will vary in how much they are really alike. A breeder cannot depend entirely upon a pedigree in making selections. The linebreeding process involves deciding approximately which pedigree the next sire or dam of a sire must have, and then choosing, from among several different animals with the desired pedigree, the one which seems to be the best individual. If a breeder can progeny test several of the selected individuals and postpone the final decision of which sire will eventually carry on the breeding program, they will be on safer grounds.

The goal of linebreeding is to perpetuate the good traits of an outstanding sire or dam and increase the number of progeny they create without lessening their resemblance to the ancestor. The more superior a breeder's herd or flock is to the average merit of its breed the more reason he has to linebreed his very best animals to the best of their recent ancestors. The risk involved in linebreeding depends upon how much undesirable inheritance is in the herd when the linebreeding begins.

A breeder's linebreeding success depends on their selection skills, how much use they make of progeny tests before they decide whether to use a sire extensively, how large the herd is, and whether they work alone. If the breeder can cooperate with several other breeders who are linebreeding to closely related animals, they can get an occasional mild outcross from them without disturbing their entire breeding program.

In summary, linebreeding is a form of inbreeding directed toward keeping the offspring closely related to a highly admired ancestor. All inbreeding that's not necessary to maintain this relationship is avoided. That is why the intensity of inbreeding is usually moderate in linebreeding systems. The relationship to a chosen ancestor, usually a male, is the main feature which distinguishes linebreeding from other forms of inbreeding. More than one author of animal breeding books has commented that line breeding rarely results in problems. If there were problems, they would be attributed to inbreeding.

TO INBREED OR NOT INBREED

The dilemma of whether or not to inbred is not an easy one for most people to resolve. However, one thing is certain, if a breeder wishes to create a strain of excellent alpacas, with its own characteristics and uniformity of offspring, some degree of inbreeding is necessary. The reason is that a pure breeding largely homozygous strain cannot be developed by any other means. Selection alone will not do it.

Parents may have similar phenotypes because a certain type has been intensely selected. But what about their progeny? These may be variable, with only an occasional cria tending to resemble the parents. This is why, in the livestock breeder's jargon, inbreeding is necessary to "fix" the characters under selection.

There is no doubt that inbreeding is valuable in stabilizing the results of selection. It may be a good idea to defer inbreeding for a few generations to let selection have its maximum effect. The most significant advances with selection are usually accomplished during the initial stages. Eventually diminishing returns set in and it is more difficult to make further progress. This is where the inbreeding or linebreeding might begin.

Inbreeding also has financial or market considerations. The current alpaca market does not value inbreds. To the contrary, they may be considered defective. This brings us back to the question, are we breeding for "pure blood or pure money"?

SELECTION AND INBREEDING

The effects of selection and inbreeding or linebreeding are briefly contrasted below:

| Selection | Inbreeding/Linebreeding |
|---|---|
| Perpetuation of certain genes | Fixation of all genes |
| Small decrease of heterozygosity | Steady decrease of heterozygosity |
| Increasing phenotypic similarity | Increasing genotypic similarity |

At first glance, the consequences of selection and inbreeding appear to compliment one another. The comparison would suggest that all a breeder has to do is to select the right animals and inbreed closely, which will lead automatically to the fixation of advantageous genes and the breeding of high quality animals. The problem is that it is very difficult to concentrate all the desirable genes in a few animals. Another problem is that close inbreeding produces a situation where all of the genetic variability is used up quickly and further progress becomes impossible.

A compromise can be found in the form of moderate to mild inbreeding, or linebreeding. If a breeder decides to inbreed, they can not compromise their selection, which must be as intense as possible, after making allowance for the quality of the available stock. The breeder's goal is the fixation of positive genes, but progress can not be so rapid that both good and bad features are fixed before they have time to identify and weed out the bad genes.

In certain situations, selection and like-to-like mating with the minimum or absence of inbreeding may be the best plan. This is particularly true if the initial stock is poor. There are no quick and easy solutions.

HOW TO DO INBREEDING AND LINEBREEDING

There are several ways alpacas breeders, both large and small, can inbreed their stock. Three types of inbreeding are common: close inbreeding, linebreeding, and closed stud mating. But before anyone undertakes any of these approaches, there are a few steadfast rules that must be observed:

1. Only the highest quality foundation stock should be inbred.
2. Selection intensity should be high in inbred or linebred herds.
3. No alpacas with similar faults should be mated.
4. Remember that no stable is better than its mares. High quality females are every bit as important as highly selected males.
5. Before you inbreed you must have a clear picture of the breed standard that you wish to create. (There will be a thorough discussion of breed standards in Pure Blood Part IV.)

Alpaca breeders can begin inbreeding by simply buying a few superior females and then breeding them to their relatives. This is simple, since almost every alpaca in North American has a scientifically verifiable pedigree. Intense inbreeding on the sire's side, such as father to daughter, emphasizes the blood of the male. If it is repeated for several generations, the offspring will soon have almost none of the dam's genes. The same is true of son to mother mating, which is used when the dam's qualities are the breeder's objective. Full sister and brother matings are also considered close inbreeding, especially if they are repeated in subsequent generations.

As we discussed earlier, linebreeding involves focusing on the blood of an outstanding ancestor, generally a sire. A classic linebred mating which is used in many livestock breeds goes like this: let the sire of the sire be the grandsire on the dam's side. This breeding usually produces excellent stock down the line if the sire himself is excellent, without fault and his ancestors were the same. To see how a pedigree for this mating might be arranged, study the following diagram:

| | | | |
|---|---|---|---|
| | | | < A |
| | | < I -- | |
| | | | < B |
| | Sire M -- | | |
| | | | < C |
| | | < J-- | |
| | | | < D |
| Linebred Sire MM -- | | | |
| | | | < E |
| | | < K -- | |
| | | | < F |
| | Dam N -- | | |
| | | | < M |
| | | < L -- | |
| | | | < H |

As you can see, this breeding takes some planning. Three generations, seven matings, and fourteen individuals are involved. There are many variations to this approach. For instance, the sire of the sire might be the grandsire of the dam on the sire's side. Half sister-half brother matings are also common linebred pairings and so on.

Another form of inbreeding, the "closed stud" system, which is essentially the Accoyo method used by Julio Barreda, is detailed in many animal breeding textbooks. This is a flexible mating system which allows intense selection to be combined with linebreeding and mild inbreeding. When this system is working correctly, there is a steady decrease in heterozygosity, the elimination of negative traits, and a steady fixing of desirable traits.

Most closed studs operate with a high proportion of females to males. All replacement animals are selected from the closed herd. Ideally, replacement sires are progeny tested for prepotency before being widely used. This would involve at least ten test matings, preferably more.

By maintaining a closed stud and using females for several generations, a breeder can see which dam consistently produces outstanding cria. She should be highly valued and her male offspring preferred as replacements, all things being equal.

The coefficient of inbreeding can be kept at acceptable levels, in closed studs, say no more than 25%, by simply adding males. The 25% threshold is suggested because most stains exhibit little or no inbreeding depression at this level. If you are lucky and your foundation stock is pure, you may never experience inbreeding depression.

The closed stud, linebreeding, or inbreeding methods discussed above allow selection to be backed up by the power of genetics. The simplicity and strength of the ancestry allows good genes to be locked in and the "pulls" of the breeding system will all be in the right direction. If, on the other hand, you are working with flawed stock, the closed system of breeding lets you know sooner, rather than later. Nobody wants to perpetuate genetic defects.

Remember in a broad genetic context, homozygosity denotes genetic purity and heterozygosity denotes genetic impurity. If the genes you start with are free of negative recessive alleles, that purity will be enhanced by inbreeding. If not, and there are bad genes, the homozygotic herd can become pure for the bad genes as well.

Linebreeding or inbreeding is not going to be embraced by every alpaca breeder, nor should it be. The more diverse our collective mating plans and selection systems, the more progress we will make on a national level. Our common vision should be to breed the most productive alpacas in the world. Inbreeding is but one possible path to that goal.

## CREATING A STRAIN OR A BREED WITHIN A BREED

In 1991 I made my first trip to Peru. While I was there, my host, Alonso Burgos, invited me to visit the Colca Valley. We stopped on the way to visit Grupo Inca's breeding operation, Sallalli, where they had just purchased 24 male alpacas from Accoyo. As I inspected the males, I said to myself, "these must be a different breed of alpacas." Upon returning to Arequipa, I managed to meet Don Julio for the first time. I will never forget those 24 males (see photos B, C, and D). Since then, I have often dreamed about creating my own strain or breed of alpacas, much the same as Don Julio Barreda has done.

My dream prompts the question "what is a strain?" A breeder can assemble a few similar alpacas and maybe talk about a strain. This approach is encouraged by the registration of breeder identifiers with the Alpaca Registry, but there is much more to the term than that. Many years and a certain depth of pedigree needs to be created before it is legitimate to even speak of a blood line, let alone a breed within a breed. To be considered a strain, or a breed within a breed, the members of the exalted group must consistently breed true to their type.

In my dreams people talk about the quality Northwest Alpacas' animals. Maybe in the future the term strain or breed within a breed will be used to describe my alpacas. My dream will become reality when knowledgeable people remark, "that alpaca is from Northwest Alpacas. I can spot them every time." I believe that for a person to accomplish anything significant, they have "gotta dream."

## BLOODLINES

The word "bloodline" is often used by breeders and the term is found in many advertisements and is mentioned in many articles. It is rare, however, in books on animal breeding and still rarer in textbooks on genetics.

In general, bloodline is synonymous with pedigree, though not as definite. It indicates family. A breeder might test many animals in a breed to find out "which bloodlines are the most productive and valuable," or maybe they want to learn "which are the most prominent bloodlines of the breed."

Sometimes bloodline is used to convey the idea of relationship. It can be said that two animals "have nearly the same bloodlines." This implies that the two animals are closely related. It may imply that an animal is closely related to some famous ancestor. Usually the term makes the relationship seem much higher than it is in any genetic context.

Bloodline is also used to describe a linebreeding or an inbreeding program, which involves the mating together animals of similar but not identical bloodlines. The term conveys a vague idea of the inbreeding coefficient.

Because of its vagueness, bloodline is not a good scientific word. It is widely used in breeders' conversations and everyone thinks they understand, at least in a general way, what it means. The terms relationship coefficient, and inbreeding coefficient are not widely used and understood. They would often require a long translation or explanation. There is no way to make the term bloodline quantitative and it is only useful where a qualitative meaning is intended.

Once in a while bloodline is used to infer that a whole complex of inheritance is transmitted as a unit unchanged from parent to offspring, generation after generation. This misconception comes from studying pedigrees backward. A living, well regarded animal is often traced through his sire back to a grandsire or great grandsire, who was an outstanding individual. Looking at what happened in retrospect, we sometimes think we see an unbroken succession of outstanding genetic merit. This impression about an animal's "bloodline" could be formed even if most of the ancestors were essentially unrelated.

If we could turn the pedigree around and look forward from the first famous animal in the line, we might see a different picture. This outstanding individual, the first identified with the bloodline, was probably used in one of his era's the leading herds. He sired many sons and daughters and only the best of his sons were selected for use in other leading herds, where they were mated to better-than-average females. That son, whose offspring proved him to be the best, then became the leading sire of his generation and his supposedly best sons were eagerly sought and in turn were tried out in the leading herds of their time. This may have lasted several generations or at least as long as even one outstanding son of the original outstanding sire in each generation could be found. What really happened was nothing more fundamental than selection intensity operating to choose the best of the original sire's sons in each generation. The truth is the original sire's blood was probably fully diluted in very short order by mating the sons with unrelated females.

In the above example, the original sire becomes familiar to everyone who studies pedigrees of the breed, and many breeders will refer to the current relatives as having "very valuable bloodlines." Advertising will be used to reinforce this misconception. This claim of a superior bloodline is genetically dubious, but that won't stop claims of quality based on "bloodline."

USING THE FIVE MATING SYSTEMS

The mating systems we have discussed each serve a different purpose. None of them would be used in a vacuum. Each has its place. The North American alpaca industry currently places an emphasis on pedigree breeding. Most, if not all, breeders are raising breeding stock and are intent on improving the quality for use in breeding operations, not commercial herds. But breeding for small, uniquely colored pet alpacas with good dispositions or fine fleeced geldings for sale to the hand spinner market are also examples of legitimate alpaca breeding goals. The point is that breeders should use the mating plan most suited for their goal.

All the imported South American stock was the product of mating alpacas on a random basis. Many imported alpacas from small Indian herds were highly inbred. Very few of the South American alpaca breeders even practice selection, except for color and, maybe density, in the larger herds. Julio Barreda's Accoyo herd is a notable exception, since he selects for size, density, fineness, and a certain type or look, as well as color.

Once alpacas were selected by importers from herds in Chile, Bolivia, and Peru, and they made their way to the U.S., they have been bred using an outcross system. The result has been an increase in heterozygosity and hybrid vigor. Genes from many sources have been blended into the North American crias creating a wide band of genetic variability.

It should be clear that from here forward, based on the fact that our registry is closed, there will no longer be "breeds" based on country of origin. There never really was such a thing as Peruvian, Chilean, or Bolivian breeds. That concept is genetic nonsense. What we really have are alpacas with traits, characters, alleles, genes, gene frequencies, and gene combinations. None of these are identifiable in a genetic sense with a country of origin. This foundation stock is the genetic raw material of future generations of North American alpacas.

From our current base, there are a large number of breeding strategies available. For instance, breeders can decide to mate unrelated animals on a like-to-like basis, selecting for traits such as size, density, crimp, fineness, luster, or color. Once the breeder has produced or selected a population of animals which exhibit the traits they desire, they might begin to linebreed the alpacas with the sires exhibiting the best examples of these traits creating lines of animals which are homozygous for the traits under selection. The progeny of alpacas bred in this manner have the potential to become prepotent and breed true.

Once closely bred, or intensely selected, alpacas have become consistent and uniform for specific traits, they can be outcrossed with other lines to take advantage of hybrid vigor, creating an even higher frequency of favorable dominate gene combinations. Closely bred herds could use outcrosses to import favorable alleles for specific traits or to introduce hybrid vigor to the inbred line.

Pet breeders might use an outcross system to create unique individual alpacas. Breeders intent on creating extreme individual alpacas that will do well in the show ring might use like-to-like breeding. Each mating plan can serve a purpose.

None of this can be accomplished quickly. Breeding high quality animals is a long term prospect. I once asked Don Julio Barreda if he had any regrets about spending 60 years of his life breeding alpacas. "Yes," he said, "it is a great disappointment that I have only completed half the job."

Most exceptional herds of any breed are created over one or more lifetimes. This is especially true of large farm animals which reproduce slowly. Since the benefits of selection and pedigree can be dissipated very quickly (see Pure Blood Part I, Galton's Law) once a breeder dies or retires, the fruits of his lifetime can quickly disappear.

This means we need to get started immediately. Breeding purebred stock has maintained man's fascination for thousands of years. Breeders can rejoice in the successful application of the creative powers afforded them through the science of genetics.

A breeder doesn't need to spend fifty years to see results. By researching pedigrees, practicing selection, inspecting progeny, and making specific matings based on a plan, even the novice alpaca breeder can quickly begin to see the improvement. When breeders begin making mating decisions based on who the resulting progeny will be bred to, the results will follow. If their vision is true, the results will be good and the next breeding better.

Creating a breeding program involves the use of judicious selection and conscious choices according to a mating plan. Whether a breeder chooses to mate like-to-like, outcross, inbreed, or create a nucleus herd, the probability of reaching a specific goal increases when a precise plan is operating. Adjustments may need to be made, but the plan and its goals allow a breeder to check his progress. Another element in the overall plan is the animal standard or ideal which a breeder is attempting to attain. We will discuss breed standards in detail in *Pure Blood Part IV*.