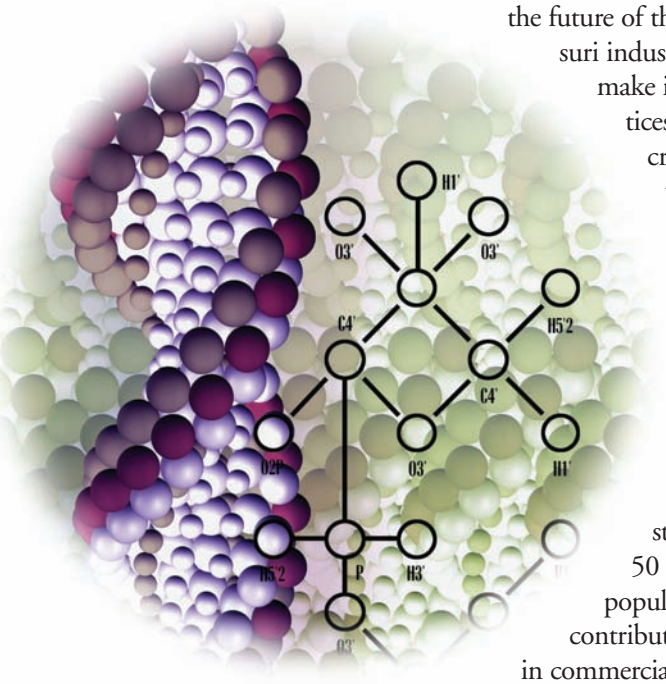
shaping the future
of the North American suri alpaca

by Dick Walker, MD

As suri breeders, our primary focus is the prized suri phenotype, or physical characteristics. Suris are judged by their appearance, and the greatest financial returns come from producing offspring that are superior in those traits that can be observed or measured. But there is far more to consider than meets the eye when it comes to making intelligent breeding decisions.

Photo by Ben Fisco/Humming Hill Suri Farm

Even more important in the long run is what we can't see in the breeding process: each suri's genotype, the individual genetic content that is created as the genetic makeup of each parent mixes and recombines in the progeny. Within the genotype are hidden variations that provide the raw material for new suri masterpieces. As such, they are our most precious assets, not only for individual successes, but also for the future of the North American suri industry. Choices we make in our breeding practices today will play a critical role in allowing this valuable genetic diversity to thrive in the years ahead.



One needn't be a scientist to appreciate the importance of genetic considerations when breeding livestock. Over the past 50 years, the field of population genetics has contributed to huge advances in commercial livestock production. Wool yields in sheep have quadrupled; milk production in dairy cattle has more than doubled; and body fat in swine has been halved while meat production has increased significantly.

It will be years before the alpaca industry can even approach this level of sophistication. Even so, we can apply the basic concepts of population genetics to help us create successful breeding programs and still maintain the genetic diversity necessary for the long-term vigor of the suri industry.

Population genetics applies genetic principals to groups of animals. Looking at suri breeding from the group perspective, rather than the individual perspective, is important because it is within groups of animals that systematic changes in genetic makeup occur, eventually resulting in the evolution of particular breeds. This is especially important at this stage of the North American suri industry, as most of us work to develop seed stock herds that will supply genetic material for multiple generations.

In the wild, random mating within groups, also known as natural selection, ensures a diverse population with widespread genetic variations. As most of us learned in high school biology, genes come in pairs, which can be identical or different. The members of each pair are known as alleles, which are homozygous if identical and heterozygous if different. Natural selection maintains many heterozygous gene pairs, thereby preserving genetic diversity in the wild.

Breeders, on the other hand, artificially attempt to change the frequencies of certain genes or combinations of genes by selecting and mating suris with superior phenotypes. The result can be a decrease in heterozygous gene pairs and therefore genetic diversity, depending upon the selection and mating systems breeders use. In addition, a phenomenon known as genetic drift also affects gene frequency. Understanding how mating systems and genetic drift work within a population of animals is the first step in equipping ourselves to make smart breeding decisions.

Selection and Mating Systems of Breeders

Three mating systems are most commonly employed by breeders. One is positive assortive mating, mating two phenotypically similar animals. Another is inbreeding, mating between relatives. The third is outcrossing, mating between unrelated animals within a breed.

When breeding pairs are chosen based on phenotype without regard to genotype, this is referred to as assortive or selective mating. If selective breeding is effective, there will be an increase in the alleles selected "for" and a decrease in those selected "against." Selecting breeding pairs that are phenotypically alike is called positive assortive mating. This, the most common form of selective breeding, increases the frequency of homozygous genotypes and decreases that of the heterozygous type. The net effect is to decrease genetic diversity within the herd.

Like positive assortive mating, inbreeding increases homozygous gene pairs and decreases heterozygous pairs, reducing the genetic diversity within a population. Unlike assortive mating, which affects only those genes on which mate selection is based, inbreeding affects all genes. When inbreeding, one inadvertently increases the homozygosity of all genes, the undesirable as well as those purposely selected for. In species like alpacas that regularly avoid inbreeding, close inbreeding is generally harmful. Detrimental effects of inbreeding, called inbreeding depression, are found in virtually every species. The more intense the inbreeding, the more harmful the effects, which can include genetic defects, a general overall decline in vigor and performance, and a larger proportion of prenatal and perinatal deaths. Recessive genes cause the majority of genetic defects.

Due to genetic drift, the offspring of our imported suris have less genetic diversity than was present in the population from which they were chosen.

Less apparent than prenatal and perinatal deaths, but perhaps equally harmful, are decreases in fertility, birth weights, viability, disease resistance, stress tolerance and multiple other factors affecting the economic value of virtually all heavily inbred lines of livestock. Despite the problems associated with inbreeding, it has been used at various levels in the early development of many breeds of livestock. It is quite likely that inbreeding has played a significant role in the evolution of the suri as well.

Photo by Linda Bader/Shady Hollow Suri Alpacas

The genetic effects of outcrossing are exactly the opposite of those of inbreeding. There is an increase in heterozygosity among the offspring, called heterosis or hybrid vigor. This happens because unrelated parents are less likely to possess the same harmful, even lethal, recessive genes. Therefore, the offspring are more likely to carry at least one normal (dominant) gene within many pairs, resulting in normal biological function. Hybrid vigor is associated with greater viability and faster growth rates. Advances in the swine, dairy, poultry and cattle industries are the result of hybrid vigor, and we can assume that similar benefits would occur in alpacas as well.

Photo by Brad Sprouse/Great Lakes Ranch

If one were to choose to breed only Peruvian colored suris…the genetic diversity in this population would be severely limited.

Genetic Drift

Genetic drift, random changes in gene frequency that occur within small populations, has had a major effect on the North American suri population. In large populations, gene frequencies reach a state of equilibrium and then change at a slow and predictable rate. In contrast, changes in gene frequencies in smaller populations like ours can happen more quickly and without warning, This happens when, by chance, most offspring receive a particular gene rather than its allele.

One type of genetic drift occurs when there is a significant variation in population size from one generation to the next. This could result from an environmental event like an epidemic or severe climatic condition that leaves a small surviving population. Or, as in our case, a small group of animals could become geographically isolated from a larger population by migration or importation to a new location. Additionally, economic factors for domestic livestock might favor only certain phenotypes, such as white suris, for breeding. When a population undergoes a temporary reduction in breeding numbers this causes a bottleneck between the present and all subsequent generations. The bottleneck is often severe when a small group leaves an established population and finds a new sub population. The random genetic drift associated with such an event is called the founder effect.

When a small group of animals becomes geographically isolated, any gene may either disappear or become fixed (homozygous) in a few generations. This occurs because the population is so small that even a slight change in the number of animals carrying a gene can cause a large change in the percentage of the total population having the gene or not having the gene. If this small, now isolated, population were closely related, then the change in gene frequency would be dramatic. Genetic drift, like inbreeding, causes decreased heterozygosity and increased homozygosity, with an overall result of diminished genetic variety in the new subpopulation.

Genetic drift is compounded when, for whatever reason, the number of males and females in a new subpopulation is unequal. This creates a peculiar sort of bottleneck because half of all alleles in any generation must come from each sex. If there are fewer males than females, these males then have a disproportionate effect on gene frequencies.

Clearly, the situation was ripe for genetic drift when suris were imported to North America. According to statistics from The Alpaca Registry, between 1991 and 1999 a total of 1,694 suris were imported into the United States. Of those, 1,456 were females and 238 were males. (These included 912 from Peru, 781 female and 131 male; 506 from Bolivia, 443 female and 63 male; and 276 from Chile, 232 female and 44 male.) The imported group represented only 1.4 percent of the 120,000 suris in all of South America, creating a very tight bottleneck certain to cause a founder effect in subsequent generations. Through this information and some related scientific calculations, we know that the offspring of the imported suris have less genetic diversity than was present in the population from which they were chosen. The impact of genetic drift on the North American suri must not be underestimated.

Imported & Domestic Male Production Data

	Imported	Domestic	Total
Males	214	2,376	2,590
% of Total	8%	92%	
No. of Crias Sired	3,969	903	4,872

What are the implications of this information for suri breeders? It allows us to objectively evaluate the selection and mating systems used in our own breeding programs and how they, combined with the effects of genetic drift, create potential benefits and risks with respect to genetic diversity. This can help both new and experienced suri breeders establish goals and objectives for breeding programs. Plotting the most appropriate course to reach those goals can help breeders choose the mating system that will maximize their chance of achieving specific breeding goals while minimizing any risks. Even breeders with pedigreed suris can benefit from understanding these concepts.

Country Pure

Breeding "country pure" is the practice of selecting mating pairs from only one country of origin, i.e., Bolivian x Bolivian or Peruvian x Peruvian. The most important risk with this style of breeding is a lack of genetic diversity significant enough to cause undesirable consequences. This is largely the result of inbreeding during the development of each line before importation and the inbreeding-like effects associated with importation. Breeding country pure serves to dramatically tighten the bottlenecks associated with importation and will undoubtedly cause problems if it is strictly adhered to. There simply is not enough diversity present within such a small population.

Breeding country pure appeals to breeders because its outcomes are predictable. Since sire and dam are more closely related than the population at large, the offspring are more likely to have phenotypes very much like their parents. They will therefore more likely breed true to type. Thus, breeding within country pure lines will cause an increase in phenotypic uniformity by causing a decrease in genetic diversity. This style of breeding can serve an important purpose. Country pure breeding, when practiced to maintain a line of suris to be used for outcrossing to other lines, can serve a valuable role in the future development of the North American suri. However, this must be done with full knowledge of its effects and possible consequences. It also necessitates rigorous selection and removal of inferior offspring from the breeding population to limit genetic defects.

Photo by Ameripaca Alpaca Breeding Company

Color Pure

Breeding color pure is the practice of selecting mating pairs using color as the major selection criteria. Using this style, breeders can potentially create yet another significant bottleneck in their breeding program. In South America, suris were uncommon and colored suris were very rare. Clearly, if a breeder chose a combination of country pure and color pure, the bottleneck could be extremely tight. For example, if one were to choose to breed only Peruvian colored suris, based on the extreme rarity of Peruvian colored suris in South America and in the imports, the genetic diversity in this population would be severely limited.

Little is known about the inheritance of color. Fortunately there appears to be significant color potential in the genome of phenotypic white suris. Breeding for color without selection for suri characteristics and without regard to fleece and other production traits could be a cause for future problems. Insisting on colored pedigrees three to four generations back would severely restrict the gene pool available for breeding.

Certain compromises may be necessary to restore color in our North American suris, but at this point there is no justifiable reason to outcross to huacayas for this purpose. Crossing suris with huacayas is not likely to produce long-term benefits and will decrease breed predictability in future generations. Capitalizing on the short-term financial opportunity of producing colored suris by crossing white suris with the more prevalent colored huacaya is therefore ill advised. Any breeder whose goal is to produce suri offspring from suri parents should seek a suri pedigree devoid of huacaya ancestors.

Outcrossing, Hybrid Vigor & Heterosis

A third breeding style to consider is outcrossing, the practice of selecting breeding pairs solely on the basis of suri character and production traits while mating across country lines, i.e., Peruvian x Bolivian or Bolivian x Chilean.

Statistical Breakdown of Male Production by Country of Origin

Number of crias per male	Peruvian		Bolivian		Chilean	
	# males	#cria sired	# males	#cria sired	# males	#cria sired
> 50	12	881 (36%)	4	273 (27%)	1	66 (13%)
40 – 49	8	359 (15%)	3	137 (13%)	0	0
30 – 39	10	328 (13%)	4	136 (13%)	1	30 (6%)
20 – 29	13	318 (13%)	8	205 (20%)	6	133 (26%)
<20	72	553 (23%)	35	272 (27%)	37	278 (55%)

Both country of origin and color are second considerations in this breeding system. This type of outcrossing maximizes the genetic diversity available to a breeding program and minimizes the possible effects of inbreeding depression on subsequent generations. Practiced as a predominant breeding style, it takes full advantage of heterosis and hybrid vigor and best utilizes the limited genetic diversity available to North American suri breeders. The payoff for accepting less predictability in phenotypic outcomes will be significant gains in physical fitness, fertility, viability, growth rate, mothering ability, and disease resistance, and an overall superior ability to cope with the environment. The gains in hybrid vigor, or suri vigor, if you will, can have a marked impact on the financial success of a breeding program.

The number and variety of bottlenecks that have occurred before, during and after importation have certainly challenged genetic diversity within the North American suri population. The question is, do we have enough genetic diversity to build a strong and healthy suri industry in North America? Despite the challenges brought on by bottlenecks the diversity is adequate if prudent breeding decisions are made with a full appreciation of existing limitations.

Photo by Ben Fisco/Humming Hill Suri Farm

Country pure breeding, when practiced to maintain a line of suris to be used for outcrossing to other lines, can serve a valuable role in the future development of the North American suri.

One important limitation that must particularly be addressed is the genetic bottleneck created by importing fewer males than females, which will have long lasting effects on the genetic diversity of North American suris. Of paramount importance to the future of the North American suri is how suri breeders have chosen to utilize these males. Ideally this limited and precious resource should be used in ways that maintain a diverse genetic base for the future evolution of the suri in North America. However, a review of the ARI data regarding the actual production of these males reveals a much different story.

As of June 2002, ARI had 2,590 registered suri males. Of those males, 214 or 8 percent are direct imports. These 214 imported males have sired 82 percent of all registered suris born in North America. Peruvian males accounted for 54 percent of all imported males and have sired 2,439 or 61 percent of all North American born suris. Bolivian males accounted for 25 percent of all imported males and have sired 1,023 or 26 percent of the offspring. Chilean males were 21 percent of the imported males and sired 507 or 13 percent of the offspring. If we select out those males that have produced 50 or more offspring we find 12 Peruvian, 4 Bolivian and 1 Chilean.

Looking more closely at utilization by country of origin reveals a troublesome trend. Among the Peruvian males, the top 12 (10 percent of Peruvian male imports) produced 36 percent of all crias by Peruvian males. The top 20 males (17 percent), account for 51 percent of crias and

the top 30 males (26 percent), have sired 64 percent of all crias produced by Peruvian males. A similar situation exists with Bolivian and Chilean production. With Bolivian males, 11 (20 percent) account for 53 percent of all production. In Chilean males, 8 (17 percent) account for 45 percent of all offspring sired by Chilean males.

When so few males account for such a large percentage of production, there should be significant concern among pure Peruvian breeders about the paucity of genetic diversity and the potential for inbreeding depression that could result. If a breeder's selection criteria are even more restrictive, for example, only Accoyo or only certain colors, then this issue becomes an even greater concern.

This situation points out very clearly the importance of maintaining genetic diversity within our industry. In the first 10 years, we have not made maximum use of the limited diversity available to us. It would appear that the risk of inadvertently exposing one's herd to the effects of inbreeding depression is the greatest when breeding country pure. The intense use of so few males and the under utilization of so many of the imported males serve to intensify this risk. Breeders who pursue a country pure breeding program should be very diligent in seeking out as much diversity as possible within their set parameters.

Thanks to the rigorous selection and screening criteria used for the importation of our suri, we have seed stock representing the best phenotypes from Peru, Bolivia and Chile. We are, at most, four-generation intervals past the first importation. The genome of every suri in North America is heavily influenced by that of our original imports and will continue to be for years to come. Future imports, especially if selected in similar ways, would not appear necessary or beneficial at this time; we would simply be importing more of what we already have. The suri genome may require a certain degree of guarding, but with informed and conscientious breeding to ensure continued genetic diversity, the North American suri will not only survive but will flourish. ❖

Dr. Walker and his wife, Nancy, have been breeding suri alpacas for seven years. Their ranch, Supersuris Alpacas, is located in Spokane, Washington. Dr. Walker's interest in genetics started while obtaining his Bachelor's Degree in Zoology and Animal Science at Iowa State University. He earned a Masters Degree in Preventive Medicine and a Doctoral Degree in Medicine at the University of Iowa. The Walker family has been involved in the fiber industry for three generations, "My Grandfather Walker had a mill in Connecticut that produced high fashion mohair garments." Nancy manages the alpaca business while Dick practices Emergency Medicine. Together they are dedicated to the future of the North American Suri Alpaca. (509) 238-3191; alpacas@supersuris.com

genetic terminology

Allele – either of a pair of genes located at the same position on both members of a pair of chromosomes and conveying characteristics that are inherited

Bottleneck – any point at which movement or progress is slowed up because so much must be funneled through it

Founder effect – random genetic drift associated with a small group becoming separated from an established population

Gene frequency – the relative abundance or relative rarity of a particular gene compared to other alleles in that population

Genetic drift – a random change in gene frequency within a small population, resulting in mutations, which, regardless of their adaptive value, become fixed within the group

Genotype – the individual genetic content that is passed on for generations

Heterosis or hybrid vigor – a phenomenon resulting from hybridization, in which offspring display greater vigor, size, resistance, etc. than the parents

Heterozygous – having two different alleles in regard to a given characteristic or characteristics

Homozygous – having two identical alleles in regard to a given characteristic or characteristics

Inbreeding – the breeding of closely related stocks

Inbreeding depression – the detrimental effects of inbreeding, which can include genetic defects, a general overall decline in vigor and performance, and a larger proportion of prenatal and perinatal deaths

Outcrossing – the breeding of stocks that are not closely related

Phenotype – the physical expression of genotypic traits under the influence of environmental factors

Population genetics – the study of genetic principles as they apply to groups of animals

Positive assortive mating – selecting breeding pairs that are phenotypically alike