# Jiggling Genes

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ALPACA BREEDING - CONCEPTS AND BASICS

Genetics is the science of how traits pass down generation to generation. Many people think that genetics can be a predictive science - accurately predicting the next baby to hit the ground. Alas, genetics does not work that way. Instead, genetics can be viewed as a science of possibilities. Genetics can help with predicting the overall range of expected types within the offspring of certain pairs. It is pretty good at predicting what will happen over the next 100 babies, but not very good (in most instances) at predicting the details of the next one. Knowledge of genetics is an extremely powerful tool for animal breeders, although its strengths and weaknesses both need to be appreciated for it to yield the greatest benefits.

HOW GENES WORK

Genes, with few exceptions, work in pairs. This is an essential concept. Each individual gets one member of the pair from its sire, one from its dam. Each individual, in its own turn, donates one of each pair to its offspring. Genetics "works" on the basis of these pairs, and the interactions of the members of each pair, as well as the interactions of the different pairs with each other.

Each individual is the result of genes and environment, and the genetic component is the sum total of all those pairs. If the genes are considered to be the units of interest, then the population can be imagined as a "jiggling" of the genes down through the generations as they are mixed up and recombined into new combinations at each generational step. The animal breeder's task is to use the favorable combinations more heavily than the unfavorable ones, so that the "jiggling" goes in a positive direction. Differential reproduction (some animals more than others) is the essence of selective breeding.

The pairs of genes can interact in different ways. Members of the pair can either be identical or different. If identical, then obviously that is the character (phenotype) that is expressed. If different, then a few different things can happen. One is that only one (a specific one) of the pair is expressed, and the other is hidden. In this case the one that is expressed is called "dominant" and the one not expressed is called "recessive". This is a key issue - dominant genes essentially cover up recessive genes. This means that recessive genes can trail along for many generations without being expressed, until they are paired up with another identical recessive gene and are therefore able to be expressed. As a result, recessive phenotypes (what is expressed) tend to show up as surprises, and tend to not reproduce themselves very well unless mated to the same recessive phenotype, or a dominant phenotype that carries the recessive.

In some situations where members of the gene pair are different, each member shows up in the phenotype. These situations are called incompletely dominant, or co-dominant. Blood types are a great example of a co-dominant system - everything is expressed, nothing is hidden. Good examples of incomplete dominance are not documented in alpacas, but are common in other species. Palomino horses are a good example - if both genes are "normal" or dark, the horse is chestnut (reddish). If one "dark" and one "light" gene are present, the horse is palomino (yellowish). If two doses of the "light" gene are present, then the horse is cream with blue eyes.

The critical concept for the way genes interact is that various mechanisms exist for hiding portions of the genome. The hidden parts may be good or may be bad, and breeding strategies can use them to advantage if carefully constructed.

A very common misconception is that common phenotypes are dominant, and uncommon ones are recessive. The relative frequency of a trait is simply a matter of gene frequency, or how many copies of a specific gene are represented in a population. The relative frequency has absolutely nothing to do with the dominance or recessiveness of a system. A good example is white horses. White in horses is dominant, and yet this color is very, very rare due to the gene having a very low frequency among horse populations.

BREEDING PHILOSOPHY

A crucial first step for breeding programs is to decide upon a philosophy. Philosophies include conservation, improvement, and a host of others. A conservation philosophy is going to dictate different goals and actions than a strict animal improvement philosophy, which is also going to be different than a companion animal philosophy. No single philosophy is wrong, just they are each different. Many discussions, and even some heated arguments, can stem from different breeders having different philosophies. The variety of philosophies is probably good for the overall health of the genetic resource, since each breeder is doing something slightly different and this helps the population have desired levels of genetic diversity.

Philosophy drives goals. Why are animals being bred, and what is the mental picture of the ideal animal? Is the goal show wins? Conformation? Certain fiber characteristics? Certain colors? Without answering these questions (honestly) very little progress is possible in a breeding program. Progress is difficult enough as it is - and is definitely enhanced by acknowledging a philosophy and the goals that go along with it.

SELECTION

Selection simply means that some animals get to reproduce more than do other animals. Selection differential indicates the relative proportion of animals that do reproduce. In alpacas the selection differential for females is pretty high, close to one hundred percent. That is, nearly every female is used for reproduction and therefore gets a chance to pass along her genes for good or ill.

For males the selection differential is smaller, but how much smaller varies with individual breeders. The selection differential for dairy bulls is probably the smallest of the common domesticated species, since by artificial insemination only one bull in thousands is used. The point of selection differentials is that these are what dictate the form of the succeeding generations. Selection determines which traits get passed along and which do not. The results of selection are easy to demonstrate for Peruvian versus North American alpacas. While certainly individual breeder's goals differ in both locations, the general trend is that Peruvians favor white, and favor huacaya fiber. In North America the opposite is generally true (with exceptions, of course). The result of the selection exerted in the two areas is that the gene frequencies, and phenotypic frequencies, of the two alpaca populations are going to differ because the selection pressures are different.

What selection does is change gene frequencies, and that limits the component genes in the population that can jiggle down to the next generations. The desirability of this is hardly debatable for disease traits (get rid of the genes, get rid of the disease), but is more subjective for other traits such as color and fleece variants.

BREEDING STRATEGIES

Breeding strategies include inbreeding and out-breeding. There are varying levels of these, and each has an appropriate place in a healthy population structure. Each does something different, and each has a place. They are value neutral - being good or bad in different situations and for different goals.

Inbreeding includes any mating in which the mated animals have ancestors in common. That is, the mating "doubles up" on certain ancestors. This can happen to varying degrees. When first-degree relatives (parent to offspring, sibling to sibling) are mated, the result is generally regarded as inbreeding. When more distant matings are accomplished (grandparent to grand-offspring, aunt to nephew) the matings are more likely to be considered line-breeding. There is no magic point at which the boundary between inbreeding and line-breeding is drawn.

Inbreeding tends to make animals more genetically uniform. That is, the pairs of genes are more likely to be similar than they are likely to be different. This has a variety of consequences, which can be good or bad depending on what goes into the mix. That is, good things become consistent, or bad things become consistent. Therefore, inbreeding must be accompanied by selection. Very, very good and consistent populations of animals in a variety of species have been accomplished by inbreeding to varying degrees. The key strength of an inbred or linebred animal is that since the gene pairs are generally alike, the animal produces very uniform offspring. This is one of the main strengths of a linebred animal - predictability.

A very important aspect of inbreeding is that as it proceeds and the gene pool gets narrower and narrower, traits of general fitness tend to suffer in a population. These include reproductive traits, milk production, growth rates, and size traits. Also disease resistance traits may well suffer, although this is going to vary. The point here is that inbreeding, especially if not associated with selection, has consequences that may not be all that good.

Out-breeding tends to do the opposite of inbreeding. It tends to make populations more variable by matching up unlike members in the gene pairs. Out-bred animals, since they have unlike gene pairs, tend to produce variable offspring.

Out-bred matings are those that do not have ancestors in common. Out-breeding or out-crossing can vary in extent, just like inbreeding. The widest out-breeding is to mate an alpaca to a llama, guanaco, or vicufia. The trick to out-breeding is that the products of the initial cross are very likely to be very uniform. If 100 babies were produced, they may actually end up looking like near copies of one another (to the extent possible in any animal related endeavor). So where is the variability? It is locked up in the fact that for each of these out-bred animals the gene pairs are unlike, and so when these uniform animals are used for reproduction they in turn produce extreme variability.

Out-bred animals can therefore be very, very productive animals. The initial out-bred product can be uniform, and they also have excellence for those very traits that suffer under inbreeding: vitality, reproduction, and growth. The peculiar qualities of inbreeding and out-breeding are used to great advantage in some animal industries. Egg laying chickens, for example, are the result of crossing inbred parental or grandparents lines. The resulting hens are uniform as a consequence of the line-breeding behind the parents, which constrains each gene pair to be one each of specific genes. They are also vigorous since the gene pairs are unlike. And - they are useless for anyone else to breed from, since they will produce uneven offspring. This tactic protects the investment of the breeder companies, since it does not matter into whose hands the actual laying hens fall.

So which is best - inbreeding or out-breeding? Depends entirely on the breeder's goals. Inbreeding tends to bring recessive genes to the light of day by forcing them into pairing with one another. That can be good or bad, depending on the trait and the selection imposed on it.

Alternatively, out-breeding tends to hide recessive genes. Note well, though, that these genes are still in the population, and in a form against which selection cannot occur since they are not expressed. Some deleterious genes could therefore become very widespread in a population before even discovered. A good example is the combined immunodeficiency of Arabian foals. About 20% of Arabian horses carry this gene, resulting in about 4% affected foals being born. The gene was allowed to get to this high frequency by lack of selection on the part of breeders.

COLORS

Color is a reasonably complicated trait. Alpaca breeders are proud to have 22 natural colors of fiber. These are wonderful, but the first thing to realize is that there is not a one-to-one correspondence of certain genetic combinations and certain of those 22 colors. That is, within one of the color classifications there will be animals of different genotypes. And, within a single genotype there may well be animals of different color classifications.

Color is the result of pigment being placed into fibers (and skin). The pigments occur in two types. One of these is eumelanin, and this is black or derivatives of black (black, grey, flat chocolate brown). The other is pheomelanin which is tan or its derivatives (fawn, red, tan, richer redder chocolate brown). While these two are usually easy to distinguish, this is not always so at the darker end of the color range. At that point (the darker browns) the two can be very difficult to separate.

White is the absence of color. For some reason pigment simply did not get put in the fiber. This phenomenon has two basic causes, either of which (or both) can result in a white animal. One of these is "white spotting."

White spotting simply means that some regions in the alpaca failed to get pigment cells, and so they are unavailable to stick pigment in the fiber. This is frequently only parts of animals, so that some regions grow white fiber and others grow colored fiber. Other animals can be considered one big white spot - on which there are no pigment cells. The second major mechanism for producing white, or pale colors, is dilution. With dilution the pigment cells are present but are ineffective at putting pigment in the fibers. This varies from complete to incomplete, so that some mechanisms yield very white results, some yield nearly white results, and some results are pale, but obviously pigmented.

One of the challenges in understanding color in alpacas is to understand that every alpaca has genetic machinery to produce color. On many, though, the whiteness has been superimposed either completely or partially. Therefore, white animals hold lots of hidden surprises for the alpaca breeder. These surprises can be used to good advantage by astute breeders.

The exact genetic control of color in alpacas has never been elucidated. Part of the reason for the lack of information is that most research has focused on fleece color. Fleece color alone does not reveal the genetic intricacies relating to the overall alpaca. As an example, imagine that bay and chestnut horses were alpacas - both would grow red-brown fleece, but the genetic control leading to that final color is distinct, and each will behave very differently in a breeding program. The lesson here is that it is important to look at the entire animal to evaluate the color phenotype, which can then be used to estimate the underlying color genotype.

My basic approach to understanding the color of any animal is to first try to remove the white. This is clearly impossible for white or nearly white individuals. Looking at color is important, and the important questions to be answered include deciding which pigments are present, their locations on the animal, and their relative intensity. My experience with alpacas is not as vast as mine with sheep and goats, but my experiences so far indicate that the following are the basic options for colors.

Basic intense colors:
Black that does not fade or sunburn
Black that fades or sunburns to reddish brown at the tips
Black with a light belly (these are tough to spot in fully fleeced animals)
Red/brown with no black trim
Red with black trim (nose, eyes, lower legs but maybe only toes)
Brown or chocolate with black trim
Shaded colors with pale lower areas, darker top areas (usually on a reddish tan)

These appear to be the basic patterns available, with other colors derived from these basic ones. The control of these is going to be complicated, and that is because several different loci (or genetic addresses, each with a few choices at that address) can control the final outcome. The several different loci can be imagined to be a series of switches. The switch choices are the different alleles at each locus, and the sum of these choices gives the final outcome. The beauty of this system is that a relatively few loci, with few choices at each location, can give a whole wide range of final colors. That, alas, makes predictions somewhat difficult.

The main source of color control is two separate loci, one called Extension and the other called Agouti. These two have a complicated interaction, and may or may not be present in the alpaca.

ExtensionAgouti
- black - dominant (called dominant blackred) with black trim dominant
- wild type - allows expression of Agoutired with extensive black trim
- red - recessive or chestnut red, no black hair, black and tan (tan belly on black
- black) - recessive black

Extension
- Black - dominant (called dominant black) wild type - allows expression of
- Agouti red - recessive or chestnut red
- No black
- Agouti
- Red with black trim dominant
- Red with extensive black trim
- Black and tan (tan belly on black) hair
- Black - recessive black

The take home message is that black alpacas may well come from two different mechanisms, and you cannot tell by looking which mechanism is responsible for which black animal. That determination may have to come from knowing the parents or other background on the animal. Likewise for totally red animals - they might be dominant at Agouti, or recessive at Extension. The intermediate Agouti patterns are more obvious, since they have to have the wild type Extension allele in order for there to be expression at all.

The Brown locus can modify the Extension-Agouti colors to make all the black areas chocolate brown. This is the brown of retrievers or spaniels, and lacks redness to its shade. If this is present in alpacas it appears to me to be very, very rare. The problem in alpacas is that a very dark red can look like a true chocolate visually, and only biochemical testing can distinguish these. The choices at Brown for most species are that wild type (black) is dominant to brown. The interactions are important here, so that with the brown modification a "red with black trim" would become a "red with brown trim", which is hardly a dramatic difference in regards to fleece color.

Modification of Brown on the Basic Colors

basic colorbrown modification
blackchocolate brown
black with tan bellybrown with tan belly
red with black trimred with brown trim
red without black trimno change

If alpacas are like other critters (and they probably are) then the blacks can be grouped into two basic types. Some of these sunburn to reddish brown at the tips, and others do not. In other species the fading or off-black types include the dominant blacks (so if you have been thinking that these are "jet black", then think again), or possibly that they are recessive black carrying one dose of the recessive aliele at the brown locus.

Other changes include the imposition of shading over the base color. I have only seen this on the reds, and the result is a red that shades from darker on the top of the animal to pale on the belly. This is very typical of guanacos and vicunas. This modification may reside relatively high at the Agouti locus, or may be like horses, where it is a totally separate factor.

Dilution of basic colors is important in alpacas, and seems to follow a few rules. In most species there are several different mechanisms for dilution of color. These mechanisms are each distinct genetically, although they may end up looking similar by visual inspection. That is, multiple genetic mechanisms may well give similar final results. The usual rule appears to be that red pigment is diluted, but black is not. Red can be diluted to a wide range of shades of tans and fawns, all the way to ivory or white. If black were diluted, the expectation would be solid and uniform blue-greys, which if present in alpacas are quite rare.

White spotting includes any process that removes pigment cells from skin and hair follicles. A few patterns are easily distinguished, and each is independent in genetic control.

Roan is the most common spotting pattern, and is the cause of grey (on a black background) or rose grey (on a red or tan background). Roan is a mixture of white and pigmented fibers, and this mixture is usually uneven or variable. This is especially noticeable when animals are shorn, for the short fibers reveal lighter and darker areas over the animal. In addition, most or all roans have white crowns on their heads. Roan appears to be a dominant, such that every roan has a roan parent. The only exceptions might be some very light, or white, animals, which can hide roan due to their pallor. It may also be true that no animals have two doses of roan, so that all are capable of producing roan and nonroan offspring.

Pinto is usually used to describe irregular white spotting, usually that which encircles the neck at some point. This appears to be a recessive pattern, so that it can pop up as a surprise where least expected. The result is white and colored fiber from a single animal.

A pattern that the South Americans call caped, and that I have called tuxedo, is a very distinctive pattern in which white is ventral on the animal. The white nearly always involves the front/lower half of the neck. The result is that the face may be white, but the ears and back of the neck are usually colored. When extensive in degree the animals may be very white, but always seem to retain the distinct lower relationship of white and upper relationship of color. This pattern appears to be dominant to me.

I have also seen one “flowery” or “speckled” alpaca, in which the white spotting took the form of small flecks and spots of white, generally on the neck and chest. This, if analogous to sheep and goats, is probably a dominant pattern. It minimally affects fleece color or classification due to its location.

Finally, white alpacas are a conundrum, and selection in South America greatly favors these animals. White can result from dilution (very, very pale) or white spotting (one big white spot). The key point is that any mechanism leading to whiteness will save an animal’s life in South America (well, most of the time), so that various mechanisms do exist. Many white animals are expected to be combinations of white spotting and dilution, since anything adding to whiteness is a positive for survival. From anecdotal evidence it seems that some mechanisms for whiteness are dominant (passed on to offspring from colored mates) while others are recessive (not passed on as white to offspring from colored mates). Unraveling the thread of all of these mechanisms will take a great deal of work.

BLUE EYES

Blue eyes are controversial in many livestock species, and alpacas are no exception. Many blue eyed animals appear to be perfectly normal (me among them....). Blue eyes are sometimes just the odd variant in an otherwise unremarkable animal. That is, the animal is fully pigmented and normal, just that it has blue eyes.

Many instances of blue eyes are related to white spotting patterns in a variety of species. In some of these species certain of these patterns are associated with blindness, night-blindness or deafness. This is a long way from saying that all blue eyes are defective, but only indicates that certain instances of blue eyes can be associated with defects. The main issues surrounding blue eyes are whether or not there are associated defects, and if so, what to do about it.

If blue eyes are not associated with defects (and this is most likely the case with dark coated animals that have blue eyes), then the best thing to do is to ignore them. In a few cases some white coated blue-eyed animals appear to be deaf. Again, this is probably only certain animals, and not all. A very, very important question for these animals is whether or not this matters. If the deaf animals are able to receive and give enough social signals to have relatively normal lives in a herd situation, then I would personally not worry too much about them. The question is: Does this condition matter to the animal?" If the answer is "no", then don't worry about it, for the animal does not. If the trait does adversely affect the animal in its intended use in its intended environment, then take steps to eliminate the trait. Most people with deaf alpacas relate that the animals appear to be fully competitive with their peers, and so this trait probably does not matter to the alpacas in most situations.

The impact of blue eyes in breeding decisions is somewhat different. Different philosophies are possible on this one. An extreme philosophy would be to cull them from breeding. The opposite extreme is to ignore them and mate them while ignoring their eye color status. A middle route would be to avoid the mating of blue eyed animals to one another. This approach is likely to mitigate any suboptimal baggage that the trait might have, simply because the breeder is avoiding the mating together of extreme animals.

FIBER CHARACTERISTICS, QUALITY

Fiber characteristics are very important to alpacas, especially if they are to enter mainstream production agriculture. The alpaca fiber is unique, and its uniqueness is important to foster and enhance. Fleece quality varies in a host of ways, many of them strongly influenced by genes. The main list of traits that are largely genetic includes growth rate, density, fineness, uniformity, handle (texture, feel), and color. Color is the easiest, but the most important traits are probably growth rate, density, uniformity, and fineness. All of these are affected by environment as well as by genes, but fortunately the genetic component is relatively large and so selection can be based on individual performance. That is, looking at the animal itself is accurate enough, and progeny testing does not add much.

SURI

The suri fleece variant is a most interesting variant, since the resultant fleece is unlike any other mammalian fiber. As a spinner I find it something like silk, and very different from other mammalian fibers. The suri variant is inherited as a dominant trait, meaning that huacaya to huacaya should never (and one is reluctant to use that word) produce suris, while suri to suri could well produce a proportion of huacaya offspring.

A few important issues surround the breeding of the suri fleece type. One issue is that while this is a very desirable fleece for hand-spinners, it presents technical problems that make it very much less useful for industrial use. As a result, it is a specialty fiber that will probably never become common nor incredibly valuable through mainstream industrial channels in the international fiber market. This does not, however, detract from its beauty, utility, and economic attractiveness as a specialty fiber.

The unanswered questions surrounding Suri are the relative importance of the single gene versus the numerous slight modifications from other genes at other loci. Put another way, how important is the single gene to the production of first-rate suri, and how important are all the other genes which are probably only expressed on suris. The reason this question is important is that the breeding of suris could be characterized as either simple or complicated, and we just don't yet know which is true. If the "simple" route is true, then it is rational and appropriate to cross suri to huacaya, and expect at least 50% decent suri offspring. This is "simplistic" and unlikely, but still could be true. The alternative "complicated" issue would mean that such crossing merely disrupts the host of modifiers needed to produce an excellent suri. If this is true, then the routine crossing of the two types in an attempt to produce more suris is probably shortsighted since the overall quality may not be there. However such crosses would still be indicated and useful in certain situations.

Many questions need to be answered on this issue, such as how fineness, density, length, and uniformity are related across the two types.

DEFECTS

A variety of physical defects occur in alpacas, and are important to breeders of alpacas since the production of defective babies has two negative aspects. One negative is the loss or suffering of the baby. The second loss is the tarnished image of the parents producing the defective baby. Few (if any) defects have yet to be proven genetic in origin, but certainly some are very good candidates: choanal atresia, angular limb deformities.

In the event that some defects are shown to be due to simple single genes, then selection becomes pretty easy. The affected animals can be culled, and with modern genetic techniques it is reasonable to expect there to be blood or DNA tests developed to spot carriers. Carriers can then be used wisely in reproduction. If a carrier is only average, the best idea is to cull. If a carrier has some other excellent traits, then the carrier could be used on a limited basis, hoping to replace the carrier with a non-carrier offspring that is excellent. The key to the single gene traits is that on average half of the offspring will be carriers, but the other half will not. A single gene can therefore be tracked, and eliminated with careful breeding practices.