The Genetics of Gray Alpacas

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With all the discussion about gray alpacas taking place online on the various alpaca chat forums, I thought it would be worthwhile to reiterate my current understanding of the different kinds of grays and how their phenotypes are passed on. I would suggest that there are at least four kinds of alpacas that are called grays.

1. The majority of grays in my database are what I call "Classic Grays," also called "Tuxedo Grays" or "Tux Grays." I think tuxedo gray is misleading, as a tuxedo is not required for the phenotype, just white markings at any of the extremities, no matter how small.
2. A small percentage of grays have no white on them, and dark heads and legs. These are what I call "Dark-Headed Roan Grays."
3. A small percentage of grays have no white on them, but have speckles on the face and often throughout the blanket. I call these "Harlequin Grays."
4. Lastly, there are some animals that are gray, with no white on them, no spots, no dark points, and these often may end up in the "indefinite" classes. These are the types I have recognized, and have been collecting data on, in order to determine the inheritance patterns of the genes causing these phenotypes. The data comes from the Alpaca Registry, Inc (ARI) and Australian Registries. We looked up pictures of as many animals as possible, and categorized them into these four types. I have had students tallying all the outcomes, by sex, from all the gray males in the ARI database, and trying to find pictures or descriptions that say whether or not they have white on them, and if not, which kind of gray they are likely to be. Liz Paul in Australia has also tallied all the gray data from the Australian herd books.

Classic Grays

These are gray animals with white markings at some or all of the extremities (face, head, neck, legs, feet, tail, and/or groin). It does not matter how small the white markings are, so long as they are at one or more of the extremities. The most common variant of this is the tuxedo gray, which has a white face and front of the neck and bib and white stockings and feet. The back of the topknot is often much darker than the rest of the animal. Classic grays very often have brown or black spots on their bodies. Silver Grays and Rose Grays are both part of this phenotype. This phenotype is caused by two genes. The first I call the "White Spot Gene," and that is the gene that puts white or gray on the animal. The second gene I call the "Base Color Gene," and it determines the base color. Silver grays are black animals at the base color gene, with two copies of the black allele (bb), and they have one gray allele of the white spot gene and one solid allele of the white spot gene (GS). Think of it as a black animal that has been grayed. Rose grays are beige, fawn or brown animals that have been grayed, so at the base color gene they are one of many combinations of alleles that make beige, fawn, or brown and at that the white spot locus they have one gray allele and one solid allele (GS).

Lethal Homozygous Classic Gray

I believe that the gray phenotype (white at the extremities and gray fleece everywhere else) is coming from one dominant allele of the white spot gene. I also believe, as suggested by Liz Paul, that two copies of the gray allele of the white spot gene is lethal, and those animals with two copies are not born. Perhaps they would have been blue-eyed whites if it were not a lethal combination, as all other combinations of two white spot alleles create blue-eyed whites. Since classic gray to classic gray breeding almost never makes blue-eyed whites, I assume it is lethal. The fact that there are no herd sires in the ARI database with large numbers of crias that have ONLY made grays or whites, no matter what they are bred to, means there are no homozygous dominant grays. There should be many homozygous dominant grays by now if it were not lethal, as many breeders have bred gray to gray over the years. They do not exist, and the only explanation that is plausible is that homozygous classic gray is lethal. The growing body of anecdotal evidence shows that many get reabsorbed or aborted at or before five months for those pregnancies that we know took hold. I suspect most are lost almost immediately though. The other evidence for lethal gray is circumstantial population genetic data. There are three scenarios for a breeding between two gray alpacas:

- If two copies of gray makes gray, then there should be 75% or more gray offspring from gray to gray breeding, and some (homozygous) animals should produce gray no matter what color they are bred to.
- If two copies of gray make a blue-eyed white, then 25% of gray to gray breedings should yield BEWs.
- If two copies of gray is lethal, then we are left with 1/4 not born homozygous grays, 2/4 gray, and 1/4 solid animals (or 66% gray and 33% solid animals born).
- For example: in a mating between a tuxedo gray female with a solid tuxedo gray sire:
  G = tuxedo gray allele
  S = solid allele
  GG = ??? [scenario 1 = gray, scenario 2 = BEW, scenario 3 = lethal]

		Female Gamete	
		S	G
Male Gamete	S	S/S	S/G
	G	G/S	G/G

A partial summary of the ARI database and a complete tally of the Australian registry show pretty close to 65% gray crias when two grays are bred, exactly as predicted if the lethal gray theory is correct.

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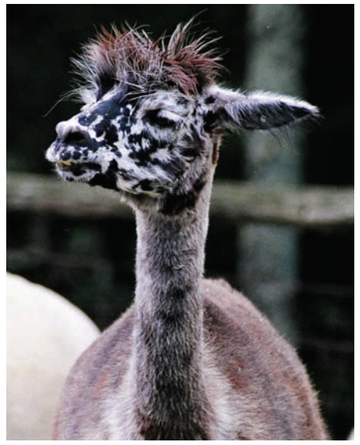
Classic or Tuxedo Gray



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Harlequin Gray

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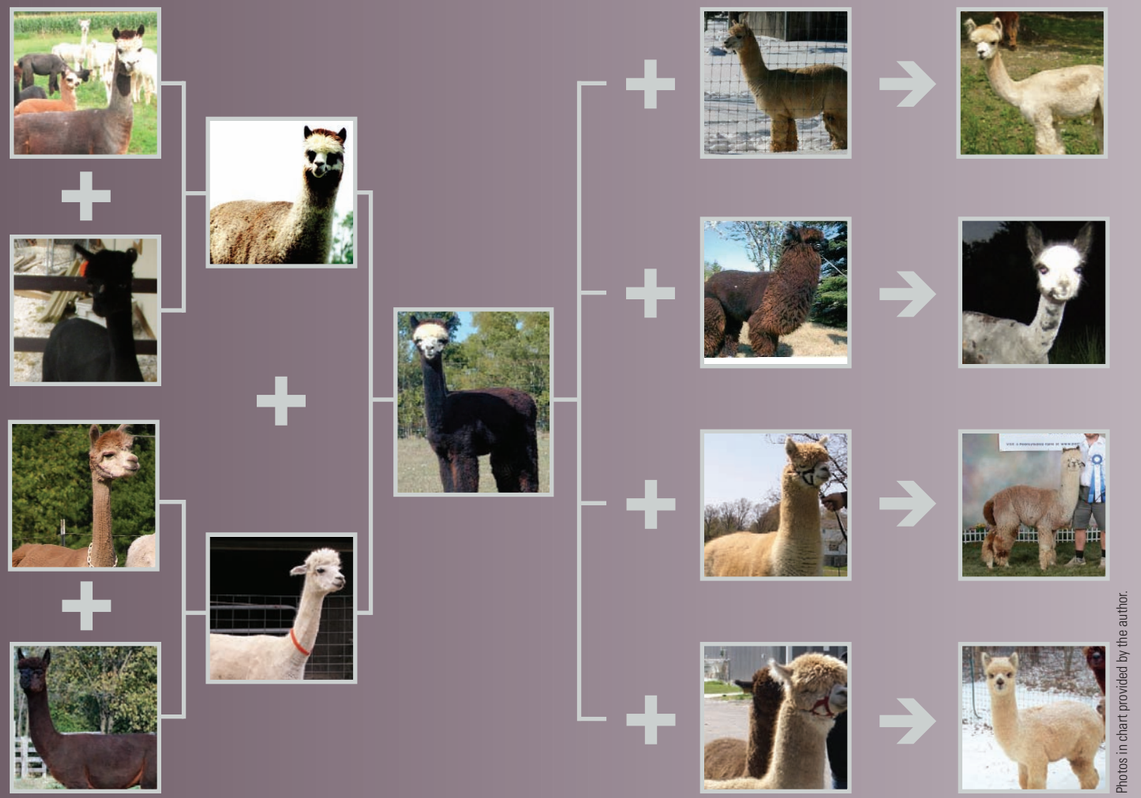
Dark-Headed Roan Gray



Photos in chart provided by the author.

Variable Expressivity through four generations.

Blue-Eyed Whites and Grays

Blue-eyed white alpacas (BEWs) are often deaf, and are created by breeding two animals together that have white markings at the extremities. This can include classic grays bred to non-gray animals with white markings. Such breedings will yield BEWs 25% of the time. It also means that some BEWs can actually make gray cria if they are bred to solid, non-white mates. Indeed, these BEWs out of classic grays should make classic grays 50% of the time (on average) and white marked animals the other 50% of the time.

Expressivity of Classic Gray Features

Expressivity refers to the level of expression of a trait. For grays, the level of expressivity varies wildly for the three traits that make up a classic gray: the amount of gray on the animal, the amount of white on the animal, and the number and size of dark spots on the animal. The first two are linked together, in that the white markings are created by incomplete migration of the melanocytes in the embryo. The melanocytes migrate from the core outward and wherever they do not reach is white, and wherever they reach is pigmented. That is why white markings are at the extremities. If the pigment migrates from the body core to half-way down the legs, you have white feet and stockings. If it does not migrate all the way up the neck, you get a white head, etc. Therefore, the amount of gray and the amount of white can be caused by the same phenomenon (migration of melanocytes during embryogenesis). Several genes are involved in melanocyte migration and these are candidate genes for the white spot locus. There are grays with only a white mask, and grays with the full-blown tuxedo look, but they are both the same thing. They are just variations in how far the pigment migrated.

The range of expressivity means that some animals that are genetically gray, may not end up characterized as gray, or meet the AOBA show definitions of gray. Very light animals that are grayed can be harder to detect as well. The fawn-looking cria in the upper right corner of the Variable Expressivity figure above is likely a poorly-expressed light rose gray, just as his mother (in the middle) is a poorly-expressed, very dark silver gray. She showed in black and even took second place at the AOBA nationals as a black juvenile many years ago, but had grayed down the neck and into the blanket by one year of age and is now much more obviously a gray rather than a black as AOBA color-checked her.

Bred to solid four times, Pistol, the dam in the middle of the figure, made two obvious grays with white markings, one fawn and one that is likely a poorly-expressed light rose gray. The upper right male had a light forelock and dark back of the head and dark fibers throughout the fleece. He showed in light fawn a number of times and indefinite a few times. We will see what he produces in a year or two. I predict 50% grays bred to solid non-whites.

Dark-Headed Roan Grays

I believe this is caused by a different gene than the classic grays. It seems to behave as a recessive, as most dark-headed roans have NO ROAN PARENTS. This is the classic sign of a recessive trait. For dominant traits, if you have the allele, you have the trait. Clearly, this is not the case for dark-headed roans. Breeding two dark-headed roans together should always yield more dark-headed roans (if it is a simple recessive trait). So far, I have seen no outcomes from such a breeding, but a number have been undertaken, so 2010 should yield some data. This also means that Dark-Headed Roans rarely reproduce their phenotype, and the registry backs this up, with very few gray crias out of dark-headed roans, unless they were bred to classic grays. Any animal can make gray bred to classic gray. However, if you can identify carriers of the roan allele and breed them to roan grays, they should make roan grays 50% of the time. Carriers would be any non-gray animal that made a dark-headed roan gray cria and any cria of dark-headed roans.

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Silver Grays and Rose Grays are both part of the Classic or Tuxedo phenotype.

Possible carriers would be siblings of dark-headed roans. Dark-headed roans have no white on them typically, and are thus not a risk for making BEWs. They also lack the dark spotting typical of both classic grays and harlequin grays.

The Harlequin gene is likely a different gene than any of the other kinds of grays. The inheritance pattern is not clear for harlequin grays.

Harlequin Grays

These are grays with dark spots or speckles over the face and often over the whole body. They do not typically have any white on them, and are thus not a risk for making BEWs. Again, this is likely a different gene than any of the other kinds of grays. The inheritance pattern is not clear for harlequin grays. Harlequins are fairly common in suris, due to the large influence of Condor and Romantico on the U.S. suri herd. They have produced many harlequin grays. It could be dominant or recessive. I am still investigating these. Right now, the number of crias from crosses is too low to make any kind of meaningful guess, but hopefully, we will collect enough breeding data to say dominant or recessive soon.

Caveat: As each of these kinds of grey is caused by a different gene, it is possible for an animal to be more than one kind of grey. While rare, this can arise from breeding different kinds of greys together. For example, an animal could be both roan grey and classic grey. Adding to the confusion, a roan grey could also get a copy of a white spot allele from a parent with white spot. Neruda may be like this, as some have reported he has a white marking, but he is clearly a dark headed roan phenotype, and has very rarely made classic greys unless bred to them.

Indefinite Grays

I am not sure what to call these animals, but they are the ones which have a uniform color without white or dark spotting, but white or black fibers throughout the fleece. I am also not sure of the inheritance pattern, nor how these relate to indefinite-fleeced animals that are not classified as grays. More data is needed to sort out the inheritance pattern(s) of these animals.

How to Breed for Gray

My recommendations for how to breed for a gray cria depends on which kind of gray you are starting with and your preferences for silver versus rose gray, spots or no spots, and white markings or not. For classic gray, I recommend only breeding to solid non-whites. You should get 50% gray crias (on average) from such crosses. While gray to gray breedings yield 65% gray crias, they also represent a 25% increased risk of loss due to the lethal gray phenomenon. Further, you typically get a MUCH bigger fleece boost breeding gray to fawn than you can get breeding gray to gray. It does not matter which partner is solid and which is gray. If you only like silver grays, then breed silver grays to blacks and you should get 50:50 silver grays and blacks (on average).

If dark-head roan gray is a simple recessive gene, then dark-headed roans bred to the other dark-headed roans should make dark-headed roan crias almost all the time. Otherwise, dark-headed roans should be bred to carriers of the roan allele for a lower percentage outcome of roans, but possibly a bigger fleece boost.

For harlequin grays, breeding two together would seem a good bet, but until we figure out the inheritance pattern of the gene, it is just a guess. The same holds true for Indefinite Grays.

Help with Research

Good luck. If you wish to help with my research, please call or send an e-mail to me for more information. We are sequencing candidate genes for color and pattern (Mit-f, Agouti, ASIP, MC1r, and KIT, among others) and also mapping the genes for color and pattern using STR loci developed by the Alpaca Genome Project. You can send blood samples from your gray crias and the parents that made them to help with my research. Blood should be drawn into EDTA vacutainers (purple tops) and overnight-mailed with a blue-ice pack to:

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