Alpaca Color Genetics

Andy Merriwether, Ph.D. and Ann Merriwether, Ph.D.

Few topics generate as much interest among alpaca breeders as the subject of color genetics. No wonder, considering how many genes camelids have. Humans have 46 chromosomes (23 pairs). Each person receives 23 chromosomes from the mother (from the egg) and 23 chromosomes from the father (via the sperm that fertilizes the egg). In humans, they are numbered 1 through 22 (called the autosomes) and the 23rd chromosome is called the sex chromosome (either an X or a Y chromosome). So each person gets a chromosome “1” from his mother and a chromosome “1” from his father. A chromosome “2” from his mother and a chromosome “2” from his father, etc. Twenty-three pairs in all. Males get an X from their father and an X from their mother. Females get an X from each parent. All camels (including alpacas) have 74 chromosomes, 37 from the mother and 37 from the father. This means half of any individual’s genetic variation, and hence half of its appearance, is contributed by each parent.

**Dominance:** Some genetic traits are dominant. Dominant traits are not blocked or hidden by other traits. Since you get two copies of every gene (one from each parent), dominance is important. The two versions of a gene are called “alleles.” In humans, curly hair is dominant over straight (curly allele and straight allele). In alpacas, the color white is dominant over black (white allele and black allele). This means that if a cria gets a white allele from its mother via the egg, and gets a black allele from the father via the sperm, the cria will be white. This is because white is dominant over black. It masks or hides the non-dominant (recessive) alleles.

**Recessive:** Some genetic traits are recessive. If an animal inherits a version of a gene (allele) that codes for a recessive trait it will only be expressed in the presence of another recessive version of that same gene. In the presence of a dominant gene, this gene will not be expressed, it will be masked. This is how two white alpacas could have a black offspring (if each white parent were masking a black allele).

**Homozygous** means you have two alleles that are the same (one from the mother and one from the father). For example, a black animal has two black alleles and is described as homozygous for black. Another example, a white animal could have two copies of the white allele and would then be described as homozygous for white.

**Heterozygous** means you have two different versions of a gene. For example, a white animal could be heterozygous and have one white allele and one black allele. The animal would still be white (the recessive black allele would be masked).

Some examples of these concepts:

**Question:** How come when I repeatedly bred my white alpaca to a black alpaca all I ever got were white offspring?

**Answer:** One possibility is that both animals were homozygous.

In this example:

- b=gene for black (and is recessive)
- B=gene for white (and is dominant)

Winston is mated to a black dam b Wb. The dam had the one dominant white gene and one recessive (masked) black gene (the data showed that basic coat color gene). Certainly there are black herd sires that, when bred to whites, throw black. This means that basic coat color gene. Certainly there are black herd sires that, when bred to whites, throw black. This means that black traits are influenced by genes, but diet can be influenced by genes, but diet can influence the expression of traits. For example, a white animal could have two copies of the white allele and would then be described as homozygous for white.

**Myth #1:** There are strong genes.

For example, you might hear an alpaca owner say “My black herd sire has strong black genes.” Implying that somehow this animal’s black gene is so strong that it will be expressed no matter what. This is a myth. Genes may be either dominant or recessive. Black is recessive. A black herd sire throws one of his recessive black genes. Basic coat color depends on what the other gene combination the dam brought, or if there are other genes modifying or influencing that basic coat color gene. Certainly there are black herd sires that, when bred to whites, throw black. This means that white is dominant over black and has a 50% chance of passing that gene on! Blackie and Wilma’s son is a white (homozygous) animal. His dam was black.

**Myth #2:** The herd sire’s genes are more important (or stronger) than the dam’s.

This is a myth (probably linked to the strong gene myth). Each parent contributes 50% of the genes. Never underestimate either parent’s contribution. Certainly, very few males get to be herd sires and those that do are usually spectac-ular choices. Certainly, some traits are dominant (but very little is known about traits that influence head shape, top knot, fiber characteristics). Certainly you can get improvement by breeding a “not-so-great” female to an amazing male. It would work the other way as well (“not-so-great male” with an amazing female).

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some. Most traits are polygenic, mean-
ing multiple genes in multiple places on chromosomes (even multiple chro-
mosomes) are involved. In people, even
eye color is influenced by more than one
gene, (that is how we get hazel, green,
etc.). In alpacas, coat color is influenced
by more than one gene at more than one
location in the genome (locus). This
makes color prediction complicated.

Not much is known. There have been
genetic studies that actually
look at what genes might control this
(a candidate gene approach).

People have attempted to
look at existing data sets,
but colors are often
reported incorrectly.
(For example: Is a cria
really dark fawn, or is it
brown? Did an animal
have any white markings,
even a small dot on the lip?)

This makes answers to many
important questions difficult. Some
registries only provide info on the sires,
but not the dams for each individual.

There are certain concepts that we
think are true, but much more genetic
analysis is needed to confirm:

• White is dominant, black is recessive.

• As a rule of thumb, lighter colors
are dominant over darker colors.

• There are multiple genes involved.

• A white spot gene adds white color
to animals of any color.

Question: Why did I get a blue-eyed white
from breeding a grey to a black animal?

Answer: There is a “white spot” gene.
It is not the same gene that makes an
animal’s basic coat color (white, brown,
black, etc.). Combinations of alleles of
this gene lead to animals with a white
face, white spots, tuxedos, pinots, white
feet, silver grey and rose grey (roan-
ing), blue-eyed white animals, and
some non-blue eyed whites. Most alle-
les of this gene seem to be dominant.

If you get two copies of this gene you
get a blue-eyed white animal. Some-
times two copies of a dominant gene
cause a different effect than one copy
alone. This seems to be the case with the
“white spot” gene.

So, if you wanted to speculate on
probabilities of offspring with and with-
out white, you would say it is 50%.
Again Lady Luck has no memory, so each birth has a 50% chance of being
male or female. However, we probably all know of a family that has five sons or five daughters, and certainly we have
heard about a breeder that has had nine male births in a row. Any of these events is statistically unlikely, but possible.

This would yield 1/2 blue-eyed whites; 1/4 white faced blacks; 1/4 silver grey; 1/4 non-blue-eyed white (1/8 with white
spots with roan, and 1/8 true solid); and 1/8 solid black.

Now imagine how complicated it
gets if there are three or more
genes involved.

Some speculation

The adjoining allele could be a version of the
white spot gene OR it could be an allele
of a different gene that lies very
close on the same chromosome. Most
genes seem to have white spot
alleles, but colors are often
uncommon. There are not enough
breedings in the registry to sort out
the inheritance patterns yet.

Additive genes

Many traits are due to the effects of
many genes simultaneously. We believe
many fiber qualities may fall into this
category. For additive genes, we can
illustrate with an imaginary example:

Myth #2: An animal “pulls color” out of other animals or “lets the dam’s color
come through.”

This is related to Myths 1 and 2. The basic coat color genes don’t pull and push each other around. This basically means
that the herd sire has recessive alleles that are masked by the dam’s alleles. Any animal that has a black allele will “let
the dam’s color come through” since black is recessive to everything.

Myth #4: Some animals throw a higher percent of female offspring than others

Animals with two “X” chromosomes are female and animals with an “X” and a “Y” chromosome are male. Fathers deter-
mine the sex of the offspring. Mothers have two “X”s to pass but fathers contribute either an “X” or a “Y”. Sex is actu-
ally determined by the presence or absence of particular genes on the “Y” chromosome. The ratio of male to female
births in most species is approximately 50-50. Again Lady Luck has no memory, so each birth has a 50% chance of being
male or female. However, we probably all know of a family that has five sons or five daughters, and certainly we have
heard about a breeder that has had nine male births in a row. Any of these events is statistically unlikely, but possible.

On a positive note, you’ve had nine boys in a row, you still have a 50-50 shot at a girl cria the next time.
there may be three genes that control fineness, each has four alleles numbered 1 to 4 with 1 being the finest in each and 4 being the coarsest. The finest animal possible (the pre-Columbian vicuña population) would get eight “1” alleles (two from each parent from four loci): 1/1, 1/1, 1/1, 1/1. The coarsest animal possible (a guanaco crossed with a porcupine) would get eight “4” alleles: 4/4, 4/4, 4/4, 4/4. When two animals mate, each donates one of its two alleles at each of the four loci (loci are locations on the chromosome, and loci is the plural form of locus, a single location). The lower the total number, the finer the animal, the higher the total number, the coarser the animal.

Here’s another example. Consider flowers. Sometimes petal colors are additive. For example, W=white, w=red. WW = white petals, ww= red petals, but Ww = pink petals. The heterozygote Ww is half-way between white and red in color.

Intermediate colors
So what is the difference between beige and light fawn; between medium brown and dark fawn; and between dark brown and bay black? By now, virtually everyone has heard of animals that were assigned a color when they registered with the ARI, and then a color judge placed them in a different category when they were taken to a show. Animals change hue throughout the course of their lifetimes, greying as they age, but also darkening sometimes between birth and adulthood. Diet may play some role in color as well. If humans eat a lot (and we mean a lot) of carrots, their skin takes on an orange hue. Diet certainly plays a role in fiber fineness, with skinny animals having noticeably lower micron counts than obese animals. Regardless of all this, the evidence is weaker for dominance of color in between white and brown/black. We are not yet convinced that dark fawn is recessive to light fawn or to beige. Maybe these intermediate colors are due to a combination of additive and dominant/recessive genes. It may be, but the color assignments are not rigorous, so it is hard to trust the data to do the tests.

If you have questions about genetics, feel free to e-mail Andy Merriwether at andyon@umich.edu. Andy is currently an Assistant Professor of anthropology and of ecology and evolutionary biology at the University of Michigan. Andy is a member of the Center for Statistical Genetics and the Center for the Molecular and Clinical Epidemiology of Infectious Disease at the University of Michigan. Ann is a lecturer in Human Development and Psychology at the UofM. Andy and Ann will be moving to their new farm in Vestal, New York, in July 2003, and will be joining the facult-