The Findings of the Science Panel of the American Romney Breeders Association Regarding Moorit Romneys

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Introduction

The American Romney Breeders Association (ARBA) Science Panel is aware that there are a number of members who question the appearance of moorit*/brown Romney sheep within the US Romney flock. It was for this reason that we were tasked by the ARBA Board of Directors to delve into the science of color genetics to determine whether the genetics that produce moorit could, in fact, have remained hidden within the Romney genepool until the present time. Further, if the determination was that this could have occurred within the existing genepool, the Panel was to then recommend what steps, if any, the Board of Directors should consider in registering and/or tracking this trait - in much the same way that colored sheep are now tracked within the registry. This document contains the findings of the ARBA Science Panel on this topic.

Three Basic Points

We find that:

- Moorit pigment is distinct from black, producing brown coloring in sheep.
- Moorit in Romneys is theoretically possible from the existing genepool.
- Tracing of the genetics in moorit Romneys and their descendants with a notation on the registration is important for ARBA and the individual breeder. This allows members to embrace or refuse the inclusion of these genetics in their own flocks as they see fit.

Background: Black and Moorit/Brown Color Genetics

In the sheep, there exist two pigment alleles* at the Black/Brown locus*, each having a specific meaning and a specific notation acceptable to the Committee of Genetic Nomenclature of Sheep and Goats (COGNOSAG). At this locus

(a) The dominant* allele is B+ (denoting black pigment)
(b) The recessive* allele is Bb (denoting brown pigment)
(c) Three pigment allele pairings are possible:
    - B+B+ - homozygous* black, producing black pigment and a sheep whose color base lies in the black/gray spectrum
    - B+Bb – heterozygous* black and brown, producing black pigment and a sheep whose color base lies in the black/gray spectrum - but carrying a "hidden" brown pigment allele
    - BbBb - homozygous brown, producing brown or "moorit" pigment and a sheep whose color base lies in the brown/tan/ivory spectrum
(d) These three pigment pairings are possible in every sheep, regardless of color class: white, color-carrying white and NC.

For more information regarding the color genetics of sheep and specifically about the production of moorit coloring in sheep, resources are provided at the end of this document.

Pigment Options in Romney Sheep

When considering the black/brown color of the offspring of any two sheep, we must consider all of the options that may come together and the probabilities of various results. For the B-locus, the options are quite limited. If both the sire and dam are homozygous for black coloring (B+B+), then using a Punnet Square (Table 1), we can see that 100% of offspring will also be homozygous for the same trait (100% will be B+B+, as shown in the shaded portion of the table). If one of the pair is heterozygous (B+Bb) carrying moorit coloring but still evidently black, then 50% of the offspring will be black moorit carriers (B+Bb) and 50% will be homozygous black (B+B+) – again, shown in the shaded portion of Table 2. If *both* the sire and the dam are black moorit carriers (B+Bb), as shown in Table 3, it becomes possible that some of the offspring will be moorit (BbBb). The expected distribution* of lamb genotypes at the B locus from this union is 25% BbBb, 50% B+Bb, and 25% B+B+ (see shaded portion of Table 3). Finally, if both the sire and dam are moorit BbBb, then as in the first table, 100% of offspring from this pairing will be homozygous - in this case, moorit in coloring (BbBb) (See Table 4).

Table 1		
Both are homozygous B+B+		
Ram → / Ewe ↓	B+	B+
B+	B+B+	B+B+
B+	B+B+	B+B+

Table 2		
One parent is heterozygous B+Bb, the other is homozygous B+B+		
heterosygous → / homozygous ↓	B+	Bb
B+	B+B+	B+Bb
B+	B+B+	B+Bb

Table 3		
Both are heterozygous B+Bb		
Ram → / Ewe ↓	B+	Bb
B+	B+B+	B+Bb
Bb	B+Bb	BbBb

Table 4		
Both are homozygous BbBb		
Ram → / Ewe ↓	Bb	Bb
Bb	BbBb	BbBb
Bb	BbBb	BbBb

Identification of Moorit Coloring

It should be noted that the identification of moorit (BbBb) coloring cannot be made by fleece color. All color classes (pure white, B-factor, Extension dominant, and recessively colored) can be moorit or can carry the genetics for moorit coloring. There is no way at this time to identify whether any given black-based sheep does or does not carry moorit. A moorit sheep (BbBb) can be identified by the brown color of its points (eyeliner, lips, nose, tongue, hooves), which will be brown rather than black – and this brown can have a purplish tinge, in some cases. Moorit coloring can present as dark mahogany, brown, soft brown, rust, caramel, and a variety of other brown-based shades.

Statistically Speaking

Although throughout history the Romney has reflected the black pigment option, it cannot be definitively known that moorit genetics were *not* to be found among some number of members of the population. The question that arises then is whether the recessive option at B *could have been* present in some portion of the population. Or, phrased another way, "Under what circumstances could a recessive allele like Bb go unrecognized in the national flock of purebred Romneys?" The answer is "It depends on the carrier frequency but also on the distinctiveness of the homozygous recessive phenotype"

To look at how these two factors impact the recognition of this recessive allele, let's say the carrier frequency is 1% (meaning that 1 sheep in a hundred is B+Bb, while 99 are B+B+). The presence of Bb might never be recognized because there is only a 25% chance that a given lamb of two heterozygotes will be homozygous recessive.

If, as in this example, the carrier frequency is .01, then under independent assortment* only one union in ten thousand (.01 multiplied by .01) will be that of two carriers, and on the average only a quarter of progeny will be BbBb. In a colored population, BbBb is fairly easy to see, being brown rather than black. Yet, in a white population, it would be much more difficult to recognize – only the occasional off-color points would give an indication that there were unusual genetics at play. An occasional off-colored lamb, say one in 40,000, will be born and identified under the conditions outlined in this example. If it is not

wanted, however, it will be buried and hushed up, and the parents perhaps culled. At one in 40,000 births, and covered up, it is possible for people to say with a straight face "we never have brown sheep in the Romney flock."

If the carrier frequency is higher, let's say five times higher at .05, then twenty five unions in 10,000 will be of carriers and the proportion of brown-colored lambs born will be about 6 per ten thousand, 24 times higher than in our previous example. What was really quite rare is now more common. If the carrier frequency is higher yet at .1, then 1% of unions will be of carriers and about one lamb in 400 will be brown-colored. At this level, no longer can the presence of recessive brown color be denied.

Conclusion: It is the conclusion of this Science Panel that as the recessive option, brown pigment (Bb) could have been and probably was present in the Romney gene pool but not visible or recognized due to its very limited presence and its recessive nature. Now that members of the Romney population that carry the genetics for moorit have been identified, the production of this coloring no longer has to be random and can be produced by selective breeding.

The First Moorit Romneys?

It is important to note that in regards to the US Romney population, there have been discussions and reports of "caramel" noses since at least 2012 (based on email exchanges on both Romney Sheep and Romney Recessive Color Yahoo Groups beginning in May and continuing in July, 2012). Since moorit brown Romneys would necessarily have brown/tan/ivory coloring including points, and caramel coloring at the points is a common indicator of moorit coloring in white sheep of other breeds, it is possible that these white sheep with caramel points were earlier examples of moorit purebred Romneys in the US genepool. It is very difficult to identify a white moorit with a mottled nose (the topic of conversation in many of these postings), but any white sheep with a nose that is in the caramel, cinnamon, mahogany range would indicate a moorit sheep with white agouti* genetics (AwtA_) in other breeds. These could very well have been among the few random moorit Romneys produced by moorit carriers present but unrecognized in the US genepool.

Examples of Other "Hidden" Genes

- The Wishart trait (FecW) was not identified in sheep until about 15 years ago, but in retrospect had been in the Rinaultrie flock of purebred Romneys for forty years before that. This particular trait is dominant but of very low frequency outside the flocks that have historically had it and in which it presumably originated. Because of this low frequency, it was able to remain hidden – in spite of the fact that it is a dominant allele.

- Discussions of moorit Romneys within this Panel brought to mind Morris Culver's 'surprise' colored lamb and the trouble he had getting that accepted. His first colored lamb Mereoak US 8-72 (out of Mereoak 665-68 by RuRu 477-66, both imported) went back to the Mereoak flock,

which had spun off from Rinaultrie (see above bullet). Is it possible that Mereoak had an unusually high (for NZ) occurrence of colored lambs? Although there is no physical evidence of this, perhaps this is what led Morris to suspect there was a high gene* frequency of color in that flock and to gravitate to it for that reason.

- Several years ago, a Romney ewe appeared in the show pens at the Black Sheep Gathering who was identified by multiple breeders as carrying Swiss Markings – a fairly unusual allele in most breeds. Because this allele is fairly low in the agouti hierarchy, it is perfectly conceivable that this allele had lain dormant in the US Romney population for many years, only coming to the fore as more people began to produce and track recessive Romneys. Although great effort was exerted to purchase this sheep for breeding and further genetic study, it was reported that this animal was unfortunately sent to slaughter. It is likely, however, that there are more Romney sheep carrying the Swiss markings allele present in the US genepool, hidden in the population until such a time as the allele is paired with a darker, more recessive allele and evidence of its presence once again emerges.

The Presence of Moorit in the US Romney Genepool

It is important to keep science and reality in mind as decisions are made regarding the appearance of moorit in the Romney genepool. Because this is a recessive allele at this locus (and very much a separate issue from the production of "recessives" in the Romney), it can hide behind the dominant black allele in both white and colored sheep. Because at low frequencies, such a gene can remain hidden for a very long time, it is impossible to prove that it was not present previously or that it was introduced recently. One cannot prove that a recessive allele does not exist in a particular genepool without genetic testing that did not exist when the breed was created. As a result, the best that can be said is that it did not ***appear*** to be present. Yet, a recessive allele like this might not show itself until it spreads into a larger population or until it increases in frequency (as shown in the previous section). It is known that recessives can hide - and have effectively done so for millennia.

ARBA has been allowing for the importation of Romney sheep and semen from New Zealand for a very long time - and registering the lambs produced from these imports. Under these circumstances, it would be surprising if there has not already been the inadvertent importation of moorit genetics in this way over the years – and there is no way to know. When genetics are imported from a large genepool, it is not unusual to find that all of the many traits of the source genepool eventually find their way into the new region - in this case, it would not be unusual for the many traits of the NZ Romneys to slowly begin to appear more frequently here, even though not specifically looked for in the original business dealings.

Unless ARBA is willing to totally and permanently shut down any importation of semen (and/or animals) from countries that have moorit Romneys, that color likely has and will continue to seep into our genepool. It is not possible to prove a negative - it cannot be proven that moorit genetics have not been some percentage of the US Romney flock for many years and continue to come in occasionally in imports

Conclusion: It is the conclusion of this Science Panel that the best route forward at this time is to understand how to work with the moorit gene that has made its presence known in the Romney - to track it and either embrace or avoid it based on individual preferences, much as the introduction of recessively colored Romneys was handled by ARBA previously.

Moving Forward

When recessive genetics were brought together to produce colored Romneys, it was decided by ARBA to track not only these particular sheep by notation of their color on their registrations, but also to track any descendants of these colored lines. This allowed those members who were interested in avoiding colored bloodlines to do so by only working with Romney sheep without a B in the registration number. It is the recommendation of this Science Panel that ARBA track these newly identified moorit genetics in a similar manner. We would suggest including an MM prefix to the registration number of any ARBA registered moorit Romney, and a single M prefix to the offspring or any descendant of a moorit Romney, indicating that this could be a moorit carrier.

It should be noted that under these circumstances, if an MM Romney is bred to a black based Romney, its offspring will display the dominant black at its points but an "M" will precede its registration number, as it is a moorit carrier.

Thus, an ARBA member who wishes to embrace or to avoid the Moorit class will be able to be confident in the MM or M functioning as an alert.

It is extremely important that the M prefix carry on generation to generation. To drop it opens the door to enormous confusion. There are instances where dropping a B suffix (one related to an extension dominant ancestor) would not really do harm, though it is sloppy. Discarding an M prefix is different, because unlike the B suffix, the M prefix means "be on the alert for recessive." It is the breeder's responsibility when registering a moorit or moorit carrier to ensure correct prefixes. The registration secretary is not responsible for that. All potential buyers of purebred Romney sheep in the US are urged in future to study the pedigree of any Romney to see if there is an M prefix anywhere in it that has dropped out. An MM prefix can change in the next generation to single M but at least a single M prefix must go down the generations. It requires more attention even than the B suffix.

This is not to say that any purebred Romney with an M prefix is a moorit carrier. It is quite possible that the sheep is B+B+ , not a carrier at all, but had a B+Bb parent with an M prefix. Nevertheless, the M prefix has to be on that sheep ***and*** all of that sheep's progeny ***and*** their progeny, etc.

The Evolution of the US Romney

We believe that it is important that ARBA address the genetic foundational mechanisms that exist in the Romney and that allow our members to produce the variety of color product. It is only by understanding this information that members can make the most of the genetics they have in their flocks.

From the 1970s to the present day, ARBA has accepted a great many changes in what is an acceptable Romney. A time line reflects these changes well:

Sheep Classes in ARBA registry

- Pre 1972
    - white sheep with black points
- Post 1972
    - white sheep with black points
    - colored black-based sheep (designated B)
    - white sheep with black points with natural color ancestry (designated BW)
- 2004-2016
    - white sheep with black points
    - white sheep with black points with natural color ancestry (designated BW)
    - color patterned black-based recessives AND Extension dominant black-based natural colored (with no differentiation between these groups – both designated BB)
- Post-2016
    - white sheep with black points
    - white sheep with black points with natural color ancestry (designated BW and possibly M)
    - Color patterned black-based recessives AND Extension dominant black-based natural colored (with no differentiation between these – both designated BB and possibly M)
    - white sheep with brown points (designated MM)
    - white sheep with brown points with natural color ancestry (designated MM and BW)
    - color patterned recessives with brown points AND Extension dominant natural colored with brown points (designated MM and BB with no differentiation between these groups)

As this time line makes clear, more subgroups within the Romney genepool continue to develop with little detailed information made available to the breeder to understand these additions and/or changes. This fact does not help our members to feel safe nor to feel competent. It is the recommendation of this Science Panel that materials be made readily available to breeders that allow them to understand and utilize the color genetics available to them in their flock and within the breed. This would enable them to fully utilize the depth and breadth of the Romney and will bring our organization into a more up to date breed association status. The work product to provide this to the breeder can be quite short

(perhaps a triptych card), and should appear on the ARBA web-site as well as being hardcopy mailed to our membership.

Registering Moorit Romneys and Avoiding Non-Romney Genetics

Unless additional moorit Romney AI imports are accepted for registration, the membership should be made aware that at the current time, the moorit coloring in the US Romney traces back to RoseBank through IronWater. Moorit animals from these bloodlines will be registered with the previously mentioned MM or M designation. At the current time and until proven otherwise, any other bloodlines that randomly produce moorit Romneys should be considered suspect.

Other Sources for information regarding moorit brown genetics:

The Genetics of Sheep, Piper & Ruvinsky, CAB Internat'l, UK, 1997; D.P. Sponenberg, p.67-69

The World of Coloured Sheep, Lundie & Wilkinson, 2004; R. Lundie, p. 119-20

The Coat of Many Colors, M. Howard, 2012; p. 24-26; photos p. 105, 124.

I Am a Shepherd, M. Howard, 2015; p. 36-38

Icelandic Sheep: A Primer for Color Pattern Genetics. http://lavenderfleece.com/genetics.html, Accessed Aug. 16, 2016

Holly Schaltz. *Sheep Color Genetics Primer*. http://www.shaltzfarm.com/shcolprim.html, Accessed Aug. 16, 2016.

Black and Colored Sheep Breeders' Association of New Zealand. *Genetics of Coloured Sheep: the short and (relatively) simple version.* http://www.colouredsheep.org.nz/genetics.php , Accessed Aug. 16, 2016.

Black & Coloured Sheep Breeders Assn. of Australia (Vic.) Inc. *Basic Concepts of Colour Inheritance,* 2015. http://www.blackandcolouredsheep.com.au/genes.html, Accessed Aug. 17, 2016.

D. Phillip Sponenberg, DVM, PhD. *Color Genetics in Coopworth Sheep.* http://www.deerrunsheepfarm.com/genetics.html, Accessed Aug 17, 2016.

Glossary

agouti – In this context, this refers to the color pattern gene location in chromosome* 13. Proper use of this word could be "agouti genetics," "agouti expression," or "agouti locus."

allele – one member of a pair or a series of genes that occupy a specific position or location in a specific chromosome; one of a gene pair

B locus – the genetic location that determines whether the eumelanin* production within any given sheep will produce black (dominant – B+) or brown (recessive – Bb) eumelanin

chromosome – a structure found in the nucleus of the cell within an organism; this structure contains genes at specific locations that determine the characteristics of the organism.

dominant – adjective used to designate any allele of a pair that prevails in its specific display. In terms of this document and the B-locus, this term describes the black eumelanin that comes from the dominant allele B+.

eumelanin – the most common form of dark pigment in sheep; a melanin or pigment that is black or brown, depending upon its structure

expected distribution – The results that would be expected in a very large sample, not what will necessarily have been seen on a farm. Everyone knows that the expected number of heads in ten coin flips is five, but also that in any given ten flips, a different tally of heads may occur.

gene – the smallest unit used in the transmission of hereditary characteristics. A *gene* is a segment of DNA that occupies a specific place within a specific chromosome.

heterozygous – refers to differences existing between the genes of a pair; the differences between two alleles, e.g., B+Bb

homozygous – denotes the sameness of two genes of a pair; identical alleles, e.g., B+B+.

independent assortment – in this context means that the union is random with respect to genotype at the B locus and to any other traits that might be associated with that locus. It's like a very thorough shuffling of a deck of cards.

moorit – in sheep, brown coloring due to the recessive eumelanin option determined at the B-locus (must be homozygous, BbBb, at this location to be moorit/brown)

recessive - adjective that denotes an allele's relationship to a *dominant*. A recessive allele, though present, will not be expressed in the presence of a dominant allele. In this case, the recessive allele Bb (that creates brown coloring when homozygous) will not be expressed when in the presence of the dominant allele B+ that creates black coloring.