BREEDING FOR COLOR by Sonya Sokolow, Leah Brault and Cecilia Penedo

INTRODUCTION

The topic of coat color and coat patterns is of great interest to horse breeders. Color can substantially increase a horse's marketability. All else being equal, a buyer is often willing to pay more for a horse with an attractive color pattern. This has led to a wide variety of colors and patterns in many breeds, and an increase in the number of breeders interested to include coat color in their breeding programs.

However, color should not be the sole objective of a breeding program. The desire to add a particular color gene to a herd may lead to selection of breeding stock for their color first, rather than for good conformation or a proven performance record. Over time, breeding programs that focus too intently on color may compromise quality, if care is not taken to select for other important traits at the same time. Additionally, certain colors or patterns are associated with health or medical problems, which can then be disseminated within the population.

The incredible advancements in the field of genetics, and equine genetics in particular, over the last fifteen years have allowed researchers to identify many genes and mutations responsible for coat colors and patterns in the horse. These discoveries led to the development of DNA tests for color genes which breeders can use to make informed decisions about their breeding stock and to increase the chances of producing foals with desirable colors and patterns. The diagnostic genetic tests have the added benefit of allowing breeders to identify color traits in their breeding stock that could have detrimental effects. These tests are an important tool that breeders can use to breed horses responsibly while still incorporating desirable colors and patterns into their herds. Genetic tests for horse coat color genes are available through laboratories that offer such diagnostic services such as the Veterinary Genetics Laboratory (VGL) at the University of California, Davis.

BREEDING FOR COLOR

Most coat color genes associated with particular color phenotypes (color which is visible to the eye) have no harmful effects. Examples of these genes include those that determine the base colors (chestnut, bay, black, brown) and the modifications of these such as cream, dun, champagne and tobiano. As long as diversity within a herd is maintained and breeding choices are made responsibly, there is no reason to expect detrimental effects from propagating these colors throughout a breeding program. Breeders can easily incorporate specific colors into their herds by simply selecting quality breeding stock that also have the colors of interest. Genetic tests, now available for nearly all of the major coat color genes, can be utilized by breeders wishing to identify potential carriers of colors of interest. However, there remain several coat color patterns for which the specific genes or mutations have not been identified, including: dun, roan, white spotting (Appaloosa, splash white and some forms of sabino), and flaxen chestnut.

Flaxen chestnut represents one example of a coat color with no known detrimental effects. It is characterized by a white, blond, or silver mane or tail (or both) and is only expressed on chestnut horses. The flaxen mane and tail are often very striking and are considered desirable by certain breeders. The flaxen trait appears to result from a different gene, or set of genes, from those already known to produce blond to nearly-white mane and tail phenotypes such as the Cream or Silver dilution

genes. Flaxen chestnut is currently under study at the Veterinary Genetics Laboratory (VGL), University of California, Davis. This research is focused on the Morgan breed and involves pedigree analyses to determine the mode of inheritance of the trait as well as molecular research using DNA samples collected from flaxen and non-flaxen chestnuts. Results may help breeders to identify stock that can produce flaxen foals. Preliminary results from the pedigree analyses are summarized in Figures 1 and 2.

A few coat color genes have been found to be associated with health problems, and it is therefore important for breeders to educate themselves about the risks involved with these traits. One of the best-known examples is that of Overo Lethal White Foal Syndrome (OLWFS), which is most often associated with the frame overo pattern. Frame overos are common in Paint Horses, but the pattern can also be found in a few other breeds. Frame overo usually manifests as irregular white patches along the neck and barrel of the horse but the pattern is highly variable, with some horses being so minimally marked that they appear to be solid. Horses homozygous for frame overo (those that receive the mutation from both parents) are born completely white and suffer from intestinal abnormalities that prevent the passage of food (due to a lack of important structures called "enteric ganglia"). Affected foals usually die within days of birth. A genetic test for OLWFS is available through the VGL so breeders can test their horses prior to breeding. When two overo horses that carry the OLWFS mutation are bred together, the risk of producing an affected foal is 25%. Therefore it is recommended that horses with any overo in their pedigrees be tested for this mutation before breeding in order to avoid producing a lethal white foal, especially because the frame overo pattern does not always express itself with loud markings and OLWFS carrier status cannot be determined based on spotting pattern alone. Breeding a frame overo to a solid horse offers the same chance of producing frame overo foals as breeding two frame overos to each other but without the risk of a lethal white foal, so breeders can make responsible choices about breeding for frame without decreasing their probability of producing frame overo foals. (See Figures 3 and 4.)

Another example of a coat color gene associated with health problems is the silver dilution, which can be associated with an eye defect known as Anterior Segment Dysgenesis (ASD). ASD is a genetic malformation of the anterior segment of the eye that causes development of cysts, misshapen pupils, and defects of the iris, cornea, and lens. The association between the silver gene and ASD has been documented and studied in the Rocky Mountain Horse breed in which silver-diluted colors are prevalent. Silver dilution is also present in other horse and pony breeds such as Miniature, Icelandic, Morgan, and Shetland, and there are indications that ASD may not be restricted to Rocky Mountain Horses. While there is a clear association between the silver gene and ASD, the specific mechanism leading to the eye defect is not known. It is hypothesized that ASD is caused by a gene located near the gene controlling the silver dilution, and that selection for silver-colored breeding pairs increased the incidence of ASD over time through a "hitch-hiking" effect. Because the silver color is highly desired in the Rocky Mountain breed, ASD presents a particular challenge to these breeders. While the silver gene may not directly cause ASD, the silver coat color is associated with ASD in Rocky Mountain Horses, perhaps because the gene causing ASD is located near the silver gene and has been propagated with the color in this breed. A genetic test for silver is available through the VGL, but because the genetic basis of ASD has not been identified, horses cannot yet be DNA tested for the disease itself.

There is a great deal of future research needed regarding the diseases associated with coat color in horses. Horses with the Appaloosa pattern, for example, are prone to night blindness, and gray horses have a high risk of developing skin melanomas. The reasons for these associations and the mutations that led to them are still being studied and may someday be elucidated. Hopefully this will lead to the development of additional genetic tests that will be at the disposal of horse owners looking to breed for particular colors without compromising health.

CONCLUSION

Production of horses with attractive coat color patterns is part of horse breeding culture and is prevalent within the industry. While breeding for color alone can sometimes be problematic, many problems can be avoided by a combination of breeder education and continued research. Additional knowledge about the genetic basis of equine coat color will enable better diagnostic and predictive tests for color and associated traits. The more that is learned about the horse genome, the more breeders can be assured that a particular mating will not produce an undesirable result. With an eye for quality stock and the implementation of rational and responsible genetic testing, there is no reason that a breeding operation cannot introduce new colors and patterns into a herd while maintaining diversity and herd health.

If you own a flaxen Morgan Horse and would like to participate in the research conducted on this trait, please send a photo of your horse, with registered name and registry number, to Sonya Sokolow at sonya@thesokolows.com. *Please ensure that the photo clearly shows the mane and tail and is taken in good lighting.*

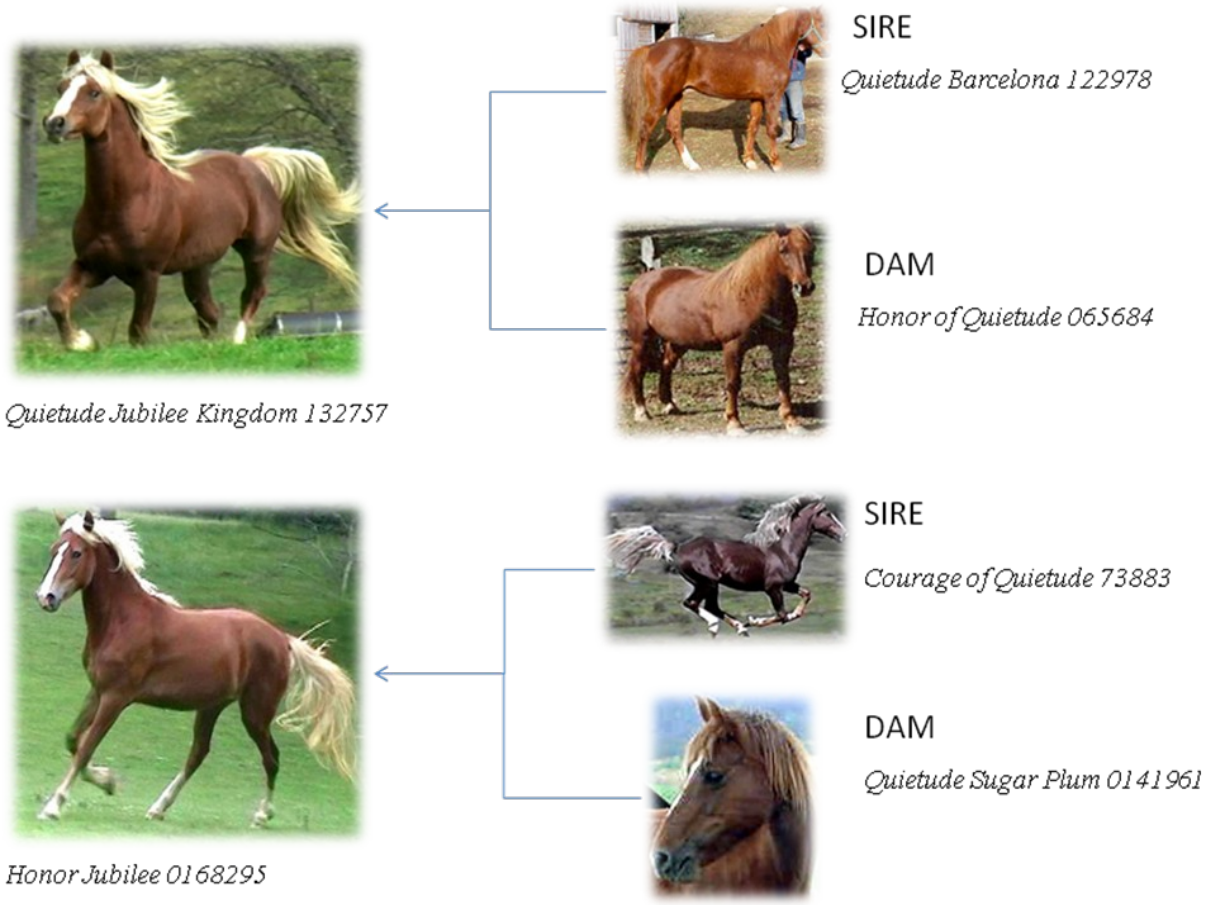

Figure 1. **FLAXEN INHERITANCE PATTERNS IN CHESTNUT MORGAN HORSES: The preliminary results found that a flaxen chestnut sire mated with a flaxen chestnut dam consistently produces flaxen chestnut offspring, while a non-flaxen chestnut sire mated with a non-flaxen chestnut dam consistently produces non-flaxen chestnut offspring. The expression of the trait among parents and offspring is highly variable (see photos above), and the inheritance mode appears to be more complicated than a simple recessive when a flaxen mates with a non-flaxen or when non-chestnut horses are involved. The genetics of the flaxen trait in Morgans are still not well understood.**

Seasons Fleetson 167636

SIRE

EF Hot Wheels 124892

Seasons Fine N Dandy 176461

DAM

Season's Midnight Majoret 0140369

Figure 2. **NON-FLAXEN PARENTS MAY PRODUCE FLAXEN CHESTNUT OFFSPRING: The two flaxen chestnut Morgan offspring above are among the progeny of the bay sire and black dam. Neither parent show the flaxen trait, yet they produced three very flaxen chestnut offspring, which are this mare's only offspring. With other mares, the stallion produced 9 other chestnuts, but none were flaxen. It is known that the flaxen trait is expressed only in horses with red (chestnut) body hair pigment, not black or bay body colors, but the trait may be hidden within the sire's and dam's genetic code and can be passed on to offspring.**

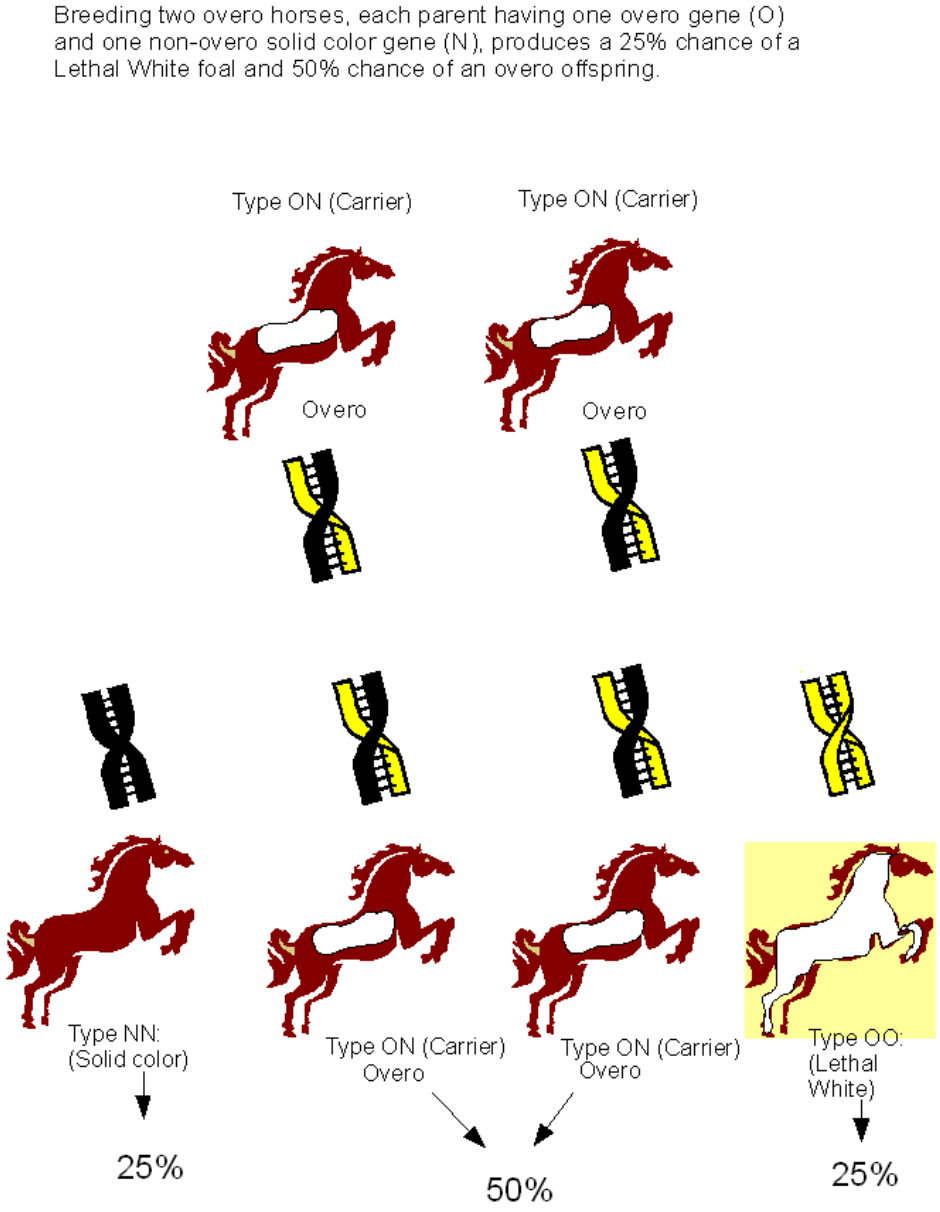

Figure 3. **Breeding of two overos producing a 25% chance of Lethal White offspring and 50% overo.**

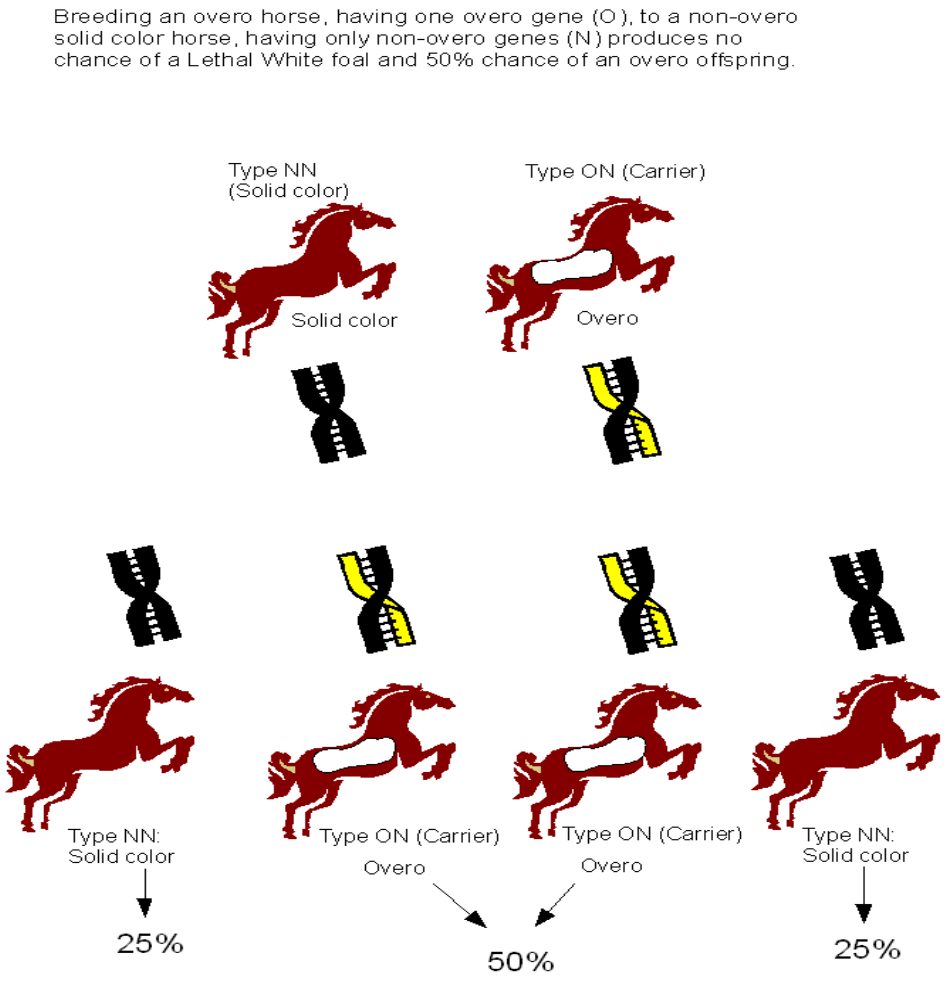

Figure 4. **Breeding of overo with non-overo solid color also produces 50% overo but with no risk of Lethal White.**