GENE FREQUENCY OF CHESTNUT BASE COAT COLOR

BY LORETTA BROWN

Author's Note: There will be some math and algebra in the article but one can just skip over that and go to the end, if to read just the "colorful" material!

During the last 20 years we have seen changes to the color categories that are available to one when registering a new Morgan. We have also seen an increase in several of the "rainbow" colors which the Morgan has in its gene pool. This may have led one to wonder if the base color of the Morgan has changed over the years. It did for me—hence this research article. *See sidebar for information about color choices and the Registry.*

Now for a bit of basic color background. When we look at all the color choices we have available to us, it may seem daunting to try and sort out any of it to make sense. However, the one point above all is that the base color of all horses involves only one gene and there are only 2 alternatives of that gene (alleles). That gene is for the base pigments which make a horse either a chestnut or "not a chestnut." Every horse one looks at will fall onto one of those two categories. The chestnut is the simplest one to think about. The "non-chestnuts" are those in the "black family."

Chestnuts include those that are visually (phenotypically) chestnut (including the dark/black chestnuts), as well as those that may be diluted—the palomino, cremello, chestnut dun.

We may also have chestnuts with modified colors or color characteristics, but the "chestnut" part may not be obvious unless the base color has been identified. For example, until recently, if one had a gray or a roan horse, there was only one choice for the color of that horse—gray or roan. But this didn't tell if the horse's base color was from the chestnut family or the black family. Since we cannot know to which it belongs, those horses cannot be used in the calculations. These would include gray, some dun, cream (crème), roan or silver dapple. If the base color was identified, the horse was placed in the appropriate category. Luckily, the number of these horses and those that had no color listed at all is few compared to the rest and deleting them will not, significantly, change the results.

In the "black family," we have black, bay, brown, buckskin, perlino, smoky black/brown, smoky cream, bay dun, black/brown dun (grulla). As with the chestnut, in the "black family" we may have some with modified colors or color characteristics but with the base color not identified. Again, if the base color was identified, it was placed in the appropriate category.

Fortunately, the new naming system no longer allows for one to register a horse as just gray, dun, roan, silver. *See sidebar for an explanation of the current color categories.*

Now we get into some math and shorthand notations. When looking at a population and wanting to know the frequency of a gene in that population, one has to start with an individual one can reliably identify as having a particular gene makeup. In population genetics, this is the recessive individual. As you may remember from your basic biology, horses (and people) have two copies of a gene in each individual. These two genes occupy identical sites on each of a pair of chromosomes. When there are different forms (alleles) of that gene, one may be dominant over the other. That is, an individual with one of each allele will look like only one of the types and not a combination of the two. In the gene for chestnut base vs. "black family," chestnut is recessive. That means a horse carrying a "black family" gene and a chestnut gene will look like a "black family" horse in color. We will not be able to tell by looking (phenotype) at him/her that there is a chestnut gene present. However, then, the chestnut must have the chestnut gene on both of his/her chromosomes. The state where an individual has the identical allele on both chromosomes is called homozygous.

Let's call the chestnut base gene "e" and the "black family" gene "E." Continuing, then, a chestnut would have to have an "ee" genetic makeup (genotypically). A "black family," however, could be "EE" or "Ee." We could not tell the genotype of the "black family" horse just by looking.

Now, since there are only two alternatives to this particular gene, the sum of the two must equal 100%. That is the frequency of E + e must equal 100 percent. In math or algebra, this is symbolized by the equation, $E + e = 1$.

Unfortunately, we have to go a bit further before we can get the frequency of the gene in the population—the value of E or e. We can use the chestnut to determine the frequency of "e" since the chestnut just has this form of the gene. Remember that each horse has a pair of each chromosome. That means that a chestnut horse has an "e" allele on each chromosome. We can symbolize the chestnut horse by the term "ee." Algebraically that means "e x e" or e^2. So to find the frequency of the gene "e" in the population we must take the square root of "ee."

Now, let's look at some data. The Morgans were grouped according to year foaled. The horses were divided into two categories—chestnut base and "black family." Chestnuts included chestnut, dark/black chestnut, palomino, cremello, chestnut dun and any of the modifier/characteristics colors if the base color was identified as chestnut. "Black family" included bay, black, brown, buckskin, smoky black/brown, perlino, smoky cream, bay dun, and black/brown dun (grulla) and any of the modifier/characteristics colors if the base color was identified as belonging to the "black family."

RESULTS

YEAR	1789–1899	1900-1950	1951-1980	1980-1990	1991-1999	2000-2009	TOTAL
COLOR							
Chestnut	1,397	6,019	40,502	23,496	12,934	9,660	**94,008**
Not Chestnut "Black Family"	3,352	6,181	19,822	19,378	16,424	17,928	**83,085**
TOTAL	4,749	12,200	60,324	42,874	29,358	27,588	**177,093**
% Chestnut	29.4%	49.3%	67.1%	54.8%	44.1%	35.0%	**53.1%**
% "Black Family"	70.6%	50.7%	32.9%	45.2%	55.9%	65.0%	**46.9%**
Freq. Chestnut ee (e^2)	0.294	0.493	0.671	0.548	0.441	0.350	**0.531**
Chestnut Gene frequency which equals the square root of ee (e^2) e	0.54	0.70	0.82	0.74	0.66	0.59	**0.73**

LOOKING AT THE RESULTS TABLE, we see that at the foundation of the breed (the Morgans foaled during the first approximately 100 years), the gene frequency of the chestnut gene was slightly more than half. Remember that $E + e = 1$ so that $E = 1 – e$.

But you may say—how can that be—there were just about only 30 percent chestnuts and 70 percent from the "black family." Remember that a horse can look like a "black family" in color but still carry a chestnut gene. So a "black family" horse can be "EE" or "Ee." For those interested in math, this can be symbolized by the equation: $E^2 + 2Ee + e^2 = 1$. Where "EE" represents those "black family" horses that are homozygous for "E" and "Ee" represents those "black family" horses that also carry a chestnut gene "e." Knowing the frequency of the chestnut gene and, therefore, the frequency of the "E" gene, we can substitute in the equation and come up with the number of "black family" horses (in a normal population) that would be carrying the chestnut gene without being visible. I will leave that for those so mathematically inclined to work it out if they wish.

So, as one can see, it appears that the chestnut gene increased in frequency through about 1980 and then decreased back toward where it started.

However, the size of these different populations is quite different. How can we know if there really is a difference between the years and that it didn't occur by chance? That's where statistics come in. There are tests that can be done on data to evaluate the question as to whether two populations are really the same or not.

One of these tests is the Chi-Square test which is commonly used in genetics.

In this test, one looks at what one would expect the numbers to be if the two samples were the same. For example—using 1789-1899 as the base we see that 29.4 percent are chestnuts and 70.6 percent are not. One then compares one of the other groups to see what the actual number of chestnuts or "black family" there would be if the same percentages were in effect. This is then compared to what was actually found. The expected vs. the observed are analyzed and given a number which then tells us the likelihood that the two populations are not different (the null hypothesis).

When this test is done for each of the year blocks, they are all, statistically, very significantly different from the 1789-1899 block. The level of significance goes down after 1980 but is still over the 0.01 level.

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HOW WE RECORD COLOR TODAY

Until recently, there were a very limited number of color options from which to choose when one registered a new Morgan. The color choices were black, bay, brown, chestnut, palomino, buckskin, gray, roan, dun. Later, dark or black chestnut was added to the group. Then, when the white rule was rescinded, the very dilute color of crème (cream) was added.

As time went on, we realized that there were many other "colors" that existed in our Morgans. These were not really new colors that hadn't existed before, but we were not aware of them as such. For example, when what looked like a black horse was crossed to a chestnut—sometimes one would get a palomino. This can be very surprising! And this may have contributed to the horse mistakenly being registered as a chestnut. What we now know is that the black horse was really a smoky black—a black horse that also had the cream dilution gene. But there was no way for the registry to obtain that information as there was no color option for smoky black.

This information prompted the Registry to evaluate and revamp the entire system that was used to designate the color of the Morgan being registered.

Now there is a choice of 10 colors from which all Morgans must choose—one and only one. These include black, bay, brown, chestnut, palomino, cremello, buckskin, perlino, smoky black and smoky cream.

Then there are several other options of color characteristics which include dilutions and other modifications of color. These include gray, dun, roan, silver, flaxen and pinto patterns. A horse may have one, more than one or none of these.

So now, one cannot register a horse as just gray. It has to first belong to one of the 10 of the first group. Then as many from the second group as appropriate could be added. Some examples: It could be a chestnut gray, or a black gray or a buckskin gray;. It could be a chestnut gray dun, or a buckskin gray pinto.

That means that there is less than a 1% chance that they represent identical populations.

So, the bottom line: yes the representation of the chestnut gene in registered Morgans has changed over the years but it has been reapproaching the early levels.

Why this may be happening will be left for further evaluations involving a more detailed look at the changes from year to year. In the first half of the 20th century, breedings were done on a more local scale as mares had to be physically brought to the stallion or visa versa. A single stallion has access to mares in herd situations. Later, with the use of transported semen, the "store" or selection of stallions available was not restricted by distance. Folks could go to stallions they might not have been able to use otherwise. Maybe herd situations declined. Also, there may have been a change in the base color of the majority of horses available via transported semen that were also very popular. Look at the horses offered in this year's Stallion Service Auction—of the individual offerings there are 29 bays, two blacks, two browns and only four chestnuts! There are, likely, other reasons for the changes in the frequency of the chestnut gene over the years as well.

What will happen in the future? That depends on people's whims. We can determine the actual genes the horse carries for many of the colors we now have from simple hair samples. These include the gene for chestnut vs. black family; within the black family—another gene to separate black/brown from bay. We can also identify the cream dilution gene, the genes for silver dapple, gray and one sabino (type of pinto) gene. There will likely be more in the near future. Now that one can actually determine the genotype of the horses involved to see if they are homozygous "EE" or heterozygous "Ee," it is conceivably possible to move all the "black family" horses to "EE" such that the only time one would get a chestnut was if one bred a chestnut to a chestnut—eliminating the heterozygous "Ee" animals from the gene pool. We will just have to wait and see what develops.

We can look at other trends—for example, the frequency of the bay vs. brown and black and at the frequency of the cream dilution gene in the modern Morgan population. Let's see where it takes us. We have some interesting times ahead. ■

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