

# Covering the Basics

Several weeks ago some hobbyists and I were discussing horse color inheritance, and one of the participants asked why anyone involved in model horses would ever need to understand something as technical as genetics. After all, she commented, all a model horse shower needed to know was what colors were possible in the various breeds. So before I start this column, I think it would be appropriate to explain why having a basic understanding of coat color genetics is important to hobbyists.

It is true that unless you are involved in pedigree assignment you will not need any more information than my friend indicated; what color does this or that breed come in. But that is a far more complicated task than it might seem at first. It might not matter whether my Quarter Horse with a tan body and dark points is a buckskin or a dun, because both colors are found in the breed. But it might matter a great deal if I want to paint my new Connemara model grulla and I have found a picture of a tan, dark-pointed Connemara. If that picture represents a dun Connemara, and not a buckskin, then my grulla model is possible. But I have to be able to tell the difference between the two similar colors to be able to determine this. And contacting the breed registry will not help me, because the Connemara registry uses the term "dun" for a color that is actually buckskin.

A similar example of this problem is found in the Arabian breed. Their registry will allow horses to be registered as "roan". But Arabians don't come in true roan. Two patterns are found in the breed that look a little like roan (sabino and rabicano), but they are not the same as roan. The roan gene will give an even mix of dark and white hairs on the body, with a dark head, legs, mane and tail. Sabinos that look like roans will have white ticking throughout the coat, and extensive white markings. Rabicanos have white ticking primarily along the flanks, and white tail tops. But if you are not familiar with color genetics and don't know that these are three unrelated patterns, you could find a picture of a rabicano Arabian, and decide that the picture proves there are "roan" Arabians (after all the registry says "roans" can be registered). Then you could use a lovely reference picture of a true, dark-headed roan Quarter Horse as a guide for repainting your Classic Arabian Mare. But Arabians that color don't really exist!

Because model horse hobbyists tend to have an interest in horses that crosses breed lines (we often like, and own, models of many different breeds), we are particularly vulnerable to these inconsistencies in color names in the different breeds. Adopting the terms used by geneticists for the different colors can help to create a more "universal" language of color that can be used for all breeds. Once these terms are understood, it is possible to speak more precisely and accurately about horse color. These terms are not based on a given registry's designation of color, but rather on the different genes thought to be responsible for those colors. It is my intention to focus on a different color (gene) in each issue, with an explanation of how the gene is inherited and the effect it has on the horse's color. I will also try to make it easier to identify the color

when you see it, how to tell it apart from similar colors, and details to remember when painting the color. In these future installments of the column, I will avoid being overly technical, but in this first one, I will have to establish some basics involving genetics and horse color to avoid confusion later.

## Skin and Hair Pigment

Normally horses have black pigmented skin. This is visible in the areas where the hair is particularly fine--the muzzle, the genitals, and the inside of the ears. The black skin is why a grey horse that has turned white with age will seem to have a dark grey muzzle. The black pigmented skin shows through the sparse hair around the mouth and nostrils.

When a horse has white markings, the skin underneath will be pink. This is because white isn't really a pigment, but rather the lack of pigment, and the skin appears pinkish from the blood vessels underneath. A common mistake of beginning repainters is to use grey to shade a blaze, not realizing that there is white skin around the muzzle that gives it a pinkish, and not a greyish, tint. The same is true of hooves. If there is white on the leg touching the hoof, the hoof will be unpigmented (shell-colored), and black-skinned legs will have dark hooves. On grey horses that have turned white, the leg markings may no longer be visible, but the color of each hoof will show which legs once had white markings. Stripes on hooves are usually caused by skin that has white and black spots along the coronet band.

The above descriptions involve skin pigment. The pigment of the hair is a different matter entirely, and in this column, use of the term pigment (such as "black pigment") will refer to hair pigment unless otherwise noted. Pigmented hair is always either red or black (remember white is not a pigment, but rather the lack of pigment). This applies to the hair on the body and the points - mane, tail, lower legs. So horses are either red with red points (chestnut), or black with black points (black) or red with black points (bay). Chestnut, black and bay are the basic colors found in horses. All other colors and patterns are the results of modifiers working on these three colors.

## Modifiers

No matter how exotic a horse's color may appear, he will always be basically chestnut, black or bay. The variety of colors and patterns found in horses are the result of genes known as modifiers, which are all inherited separately from the basic color. Grey, palomino, roan, dun are all caused by modifying genes. But these genes work independently from the basic color. It is not a matter of "pinto is dominant to chestnut - the pinto gene has nothing to do with whether or not the horse inherits the chestnut color! It is a modifier to that chestnut color.

For example, if you breed a chestnut mare to a bay pinto stallion, it is not as if the foal can be either chestnut or bay pinto. The foal could be either bay or chestnut and either pinto or non-pinto. In this way, modifier genes are like on/off switches. The bay pinto stallion in

the example is carrying a gene for spotting ("on"), and the chestnut mare has the gene for non-spotting ("off"). The resulting foal may have the pinto gene either "on" or "off". Of course, most pinto breeders will hope it is on!

Now imagine all the possible modifiers a horse can have (pinto patterns, greying, roaning, dilutions, appaloosa patterns - everything!) as a long row of switches, one switch for each possible modifier. Any combination of these switches can be on or off, depending on what combination of genes the horse inherited. The gene can be roan or notroan, or tobiano or not-tobiano, etc. Any of those switches that are "on" will modify the horse's basic color.

### Ways That Modifiers Work

Modifiers, like the name suggests, alter the appearance of the basic coat color of the horse. Any given modifier will work differently. Some modifiers are specific to one kind hair pigment, either red or black. A modifier that was specific to red hair would change any red hairs on a horse, but wouldn't affect any black hairs. Other modifiers are location specific. These modifiers will only affect the body color, or only the point color. Some modifiers are not specific at all, and will affect both red and black pigment and all locations (body and points). Knowing how each modifier works is essential to understanding color.

### A Word About Dominance

Probably the term that most often leads to confusion about color inheritance is "dominance." What exactly is meant when a gene is dominant?

Going back to the very basics, all horses will inherit two genes for any given trait, one from each parent. Colors or patterns that are visible even when the horse only inherits the gene from one parent are said to be dominant. If the horse must inherit the same gene from both parents for the color or pattern to be visible, it is said to be recessive. Colors that look one way when the horse inherits a gene from one parent, and look different still when the color is inherited from both parents are said to be "incompletely dominant." Palomino is a good example of incomplete dominance: if one gene is inherited, the horse will be palomino, but if two are inherited he will be cremello. Dominance does not refer to the frequency with which the color will be inherited. No matter how dominant a gene might be, the horse never has more than a 50/50 chance of inheriting any one gene! It also has nothing to do with how common a particular gene is in the general horse population; there are many dominant genes that are extremely rare!

Dominance refers to how the gene interacts with its opposite. For example, the ability to form black pigment (black) is dominant to the inability to form black pigment (chestnut). If a horse carries both genes (black and chestnut) he will be black and his offspring have an equal chance of inheriting either black or chestnut from him. The concept of dominance comes in when that one gene he gives is paired with the other parent's one gene. If he gives his foal the ability to form black pigment (black), that foal will be black, because the ability to form black is stronger ("dominant") to the inability to form black pigment. By the same token, if he gives his foal the inability to form black pigment (chestnut), it will not affect the color unless the other parent gives the same inability to form black (chestnut), because this trait is weaker ("recessive") than the ability to form black. So dominance doesn't make the gene more or less likely to be passed on to offspring, but rather determines which of the two genes inherited will be visible when you look at the horse.

Please note that this is all very simplified, and that the actual genetics involved are far more complicated. Many genes and their effects are not fully understood, even by experts. But the concepts presented here will work for a basic understanding. The important thing to remember is that color inheritance is not as random as it might seem. It is complicated, and at times convoluted, but not random. It really can be understood, even if you don't like things that are "too technical"!

Next issue we will start with the first of the modifying genes.



*These two horses are genetically the same color - bay - but look very different due to the presence of different modifying genes. The top horse has the dun and frame overo modifiers, while the pony on the bottom has the cream (buckskin) and silver modifiers.*

All text and images are © 2005 Lesli Kathman. This article is part of a series on horse color that originally appeared in The Hobby Horse News, a magazine for the model horse collecting community that is no longer published. The articles may be copied for personal, non-commercial use. Individuals may also offer the files for downloading provided they are properly attributed, but inclusion in commercial publications (magazines, newsletters, books) is forbidden unless written permission is obtained from the author.

To further explain the "switches" analogy, take "Fred", an imaginary horse of a color typical of models: a grulla-going-grey tobiano.

His genetic "code" could be: GgEEaaDdToto

Now think of these letters, which represent genes, as switches which come in pairs. Capital letters are **on** switches (dominant). Lower case letters are **off** switches (recessive). It only takes one uppercase letter for the overall effect to be "on".

Breaking Fred down gene by gene, we have the 'G' gene, which is the greying gene. For Fred the grey switches are **on** and **off** - 'Gg' - and because it only takes one **on** for grey, Fred is going to prematurely grey. And if we breed Fred, half his offspring will get 'G' (grey **on**) and half will get 'g' (grey **off**). Now if our Fred had two **on** switches ('GG') instead of 'Gg', all his offspring would be grey, because it only takes one 'G' (dominant) to make a horse grey, and Fred would be giving one 'G' to all his foals.

Now for the next two pairs of genes, which decide whether Fred is chestnut, bay or black. Because genes cannot be anything more than **on/off**, we cannot actually have a "chestnut gene" or a "bay gene." What we have are two pairs of switches that end up giving us those three results. In Fred's case, these switches give us black as a base color.

Of these two genes, the first is 'E', which means the horse can form black pigmented hair. Because Fred is 'EE', his offspring will all be able to have black pigmented hair. For Fred, the black switches are both **on**. If both switches were off, Fred would be chestnut ('ee').

The other gene is 'A'. The A gene says whether the horse's black pigment is restricted to the points (legs, mane and tail) or not. If this restriction is **on**, the horse can only have black hair on the points, and is bay. But Fred's switches are both **off**, so his black hair is not restricted at all. He is all black. If Fred had two 'ee'

genes (no black hair at all) then his 'A' genes - whatever they were - wouldn't matter because he wouldn't have any black to restrict. But the switch is still there. It is just like if you turned the breaker box off - it doesn't mean your light switch cannot be in an on or off position, it just means that it doesn't have a visible effect when you flip it.

By this same token, our Fred could have had the 'Cr' gene (palomino), but we'd not have known it without examining his parents or his offspring. This is because even if the dominant Cr gene was **on** ('CrCr'), we would never see it because 'Cr' lightens red hair, but not black. And all poor Fred has is black hair. So his 'Cr' switch could be on all this time, and we'd be none the wiser.

But we can see that Fred is grulla, because he carries the dun ('D') gene. Fred's dun is **on**, because he is 'Dd'. If Fred were dd he would be not-dun, like the vast majority of horses. 'D' is the dun gene (on) and 'd' is the not-dun gene (off). The 'D' gene dilutes the body color, but leaves the points undiluted. It does not matter how Fred's other switches are positioned, it is just going to take the results and lighten the body. So because Fred ended up black, it's going to lighten his body (making it mousy colored) and leave his legs, mane and tail black. If Fred had ended up bay instead, this gene would have made him yellow dun.

Finally, Fred also has one Tobiano gene **on** ('T') and one **off** ('t'). So he is tobiano spotted to some extent, and just like his grey gene, half his offspring will get this on switch as well.

What geneticists don't know is why Fred might end up a tobiano with a lot of white, or just a little hint of the tobiano pattern. And this is true of all the patterns - what is confusing is what genes, or combination of genes, cause the patterns or markings to look different. And some patterns that may seem like "one switch" may in truth be a set of switches that often go together. But the basic idea of on/off switches still applies.