Coat Color in SimGenetic Cattle

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Coat color is an important trait with many sought-after varieties. Some breeders take advantage of the Certified Angus Beef program and breed mainly black cattle. Other breeders develop heat tolerant cattle with black hides and red hair. No matter your preference, coat color is one of the first things we notice about cattle. Here we dive into the physiology of coat color and the genetic control of various coat color phenotypes.

The Physiology of Coat Color

The coat color that we see in an adult animal is the result of many physiological steps that have to occur correctly beginning in the developing fetus. Early in pregnancy, cells called melanoblasts migrate from the neural crest of the fetus to the base layer of the skin or the hair follicle. Melanoblast migration is under the control of many different signals and is the first step in the future coat color phenotype — if these cells don't make it to the hair follicles throughout the body then those places will be white. The melanoblasts eventually mature into melanocytes, the cells responsible for coloring (pigmentation) the skin and hair. Melanocytes produce melanin through a process called melanogenesis. Melanin is a generic term for the chemicals responsible for coloring hair and skin. There are two melanins, pheomelanin makes yellow to red colors and eumelanin makes black/brown coloring. After the melanins are made they are transferred to hair follicle (a process called pigment transfer). In summary, colored hair — red, black, or anywhere in between — requires the following chain of events 1.) melanoblast migration, 2.) melanoblast maturation to melanocytes, 3.) melanogenesis (making of pheomelanin or eumelanin), 4.) distribution of the melanins to the follicles 5.) maintaining a healthy population of melanocytes. Disruption anywhere along this chain results in white hair.

Coat color in cattle has two main categories 1.) the basic solid color from black to white and 2.) patterned color that alters the basic coat color (blaze, brindle, brockle, spotting, etc.). The basic coat color depends on the ratio between the two melanins, pheomelanin and eumelanin. Black animals have more eumelanin production and red animals have more pheomelanin production (see how in the next section). There are dilution mutations that can alter the base color uniformly across the entire body. The dilution gene in Simmental cattle is dominant or semi-dominant meaning it only takes one copy to alter the phenotype. The dilution gene affects the eumelanin transfer to the hair follicle and is typically noticed in genetically black animals (change from black to grey). Charolais cattle have a different mutation on this same dilution gene (PMEL-17) fixed in their population that results in the light coat color typical of the Charoloais breed. White patterning in blazed faced, spotted, belted, or brockled cattle is usually caused by genes involved in melanocyte migration or survival.

The Gene Players

In order to understand the genetic control of coat color, you need to understand some basic principles in genetics. A gene refers to a specific sequence of DNA on a specific location of a chromosome that makes a specific protein in the cell. Variations in the sequence of DNA can have either no change to the resulting protein, slight change in the shape of the protein, or make the protein non-functional. Each animal carries two copies of every gene and each gene can have different DNA sequences called alleles which result in different proteins. The main gene involved in coat color in cattle goes by several names, the extension locus, melanocortin 1 receptor (MCR1), or melanocyte stimulating hormone receptor (MSHR). This gene has three alleles (variants in DNA sequence) ~ black (E), red (e), and wild type (E+).

Most of us have a pretty solid understanding of black coat color vs. red coat color but there is quite a bit of confusion when it comes to the wild type variant. First of all, "wild type" has nothing to do with an animal's disposition. Wild Type is a generic term in genetics referring to the normal allele or in this case the original allele. In the extension locus, the wild type variant is the original DNA sequence and the black and red variants are mutations of the wild type sequence. The black allele is a mutation that causes the pathway for eumelanin to be constantly active resulting in black pigmentation. The red allele has a mutation that results in a non-functional protein important in eumelanin production. Without this protein, eumelanin cannot be made and the animal will only produce pheomelanin resulting in a red coat color. Wild type animals have a functioning protein to make eumelanin

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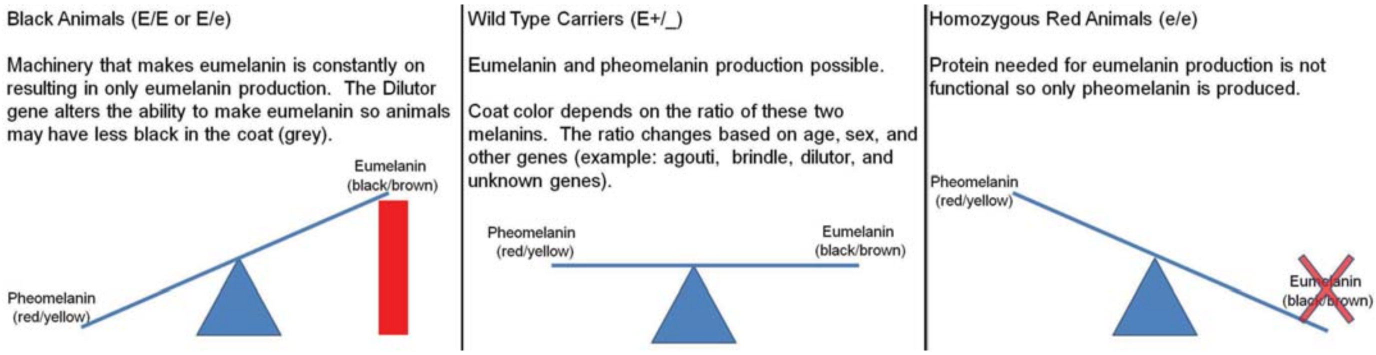

Coat color depends on the ratio of Eumelanin and Pheomelanin production. More Eumelanin leads to blacker pigmentation and more Pheomelanin results in red to yellow coat color.

(black) but this protein is susceptible to other signals to either increase eumelanin production for darker pigmentation or increase pheomelanin production for redder coat color. In other words, wild type coat color can be varying degrees of red/yellow to brown/black.

The order of dominance for these alleles is thought to be E > E+ > e, in other words black is dominant to wild type which is dominant to red. However, a new study suggests in some cattle, particularly in *Bos indicus* x *Bos taurus* crosses, black is not completely dominant to wild type. Hulsman Hanna and colleagues published an article (Genetics Selection Evolution, 2014) on the genetic control of coat color in over 200 heterozygous (E/E+) Angus-Nelore cross cattle. Based on the previous thinking, we would expect all these heterozygotes to be black as black is dominant to wild type and red alleles. However, there were varying degrees of pigmentation in these 200 cattle from black all the way to red. This study found some potential secondary genes that could cause the E/E+ cattle to have reddish coat, and it presented strong evidence that the black allele is not completely dominant to the wild type allele in *Bos indicus* x *Bos taurus cattle*.

SimAngus Bull (3/4 Simmental, 1/4 Red Angus) that is a wild type carrier (E+/e).

Jersey, Brown Swiss, Tarentaise, Texas Longhorn, Brahman, and other Zebu cattle carry the wild type allele but it is not limited to these populations (note picture of the E+/e SimAngus Bull). Due to its prevalence in the Brahman breed, Simbrah cattle frequently carry the wild type variant. As wild type animals have the ability to make both red or black hair, their coat color can be more variable. Homozygous wild type cattle range in coat color from yellow to black although the most common coloration is reddish brown or brownish black. Frequently wild type animals become darker as they age and wild type bulls are typically darker pigmented than wild type cows (see pictures for examples). Wild type animals commonly have darker pigmentation at the feet, head, and neck and have a tan ring around the muzzle.

As wild type animals can make black or red hair, other genes that affect the ratio of pheomelanin to eumelanin production will affect wild type animals but not black or true red (ee) cattle. The Agouti gene is one such gene with three different variants. The agouti gene makes a protein that can modify the ratio of eumelanin and pheomelanin in wild type cattle. Variants in the agouti gene can make a Wild type animal almost completely black, and may control the darker pigmentation associated with the head, neck, and feet in some E+ cattle. The brindle gene is another case where the gene has no affect on either red (ee) or black (E/_) cattle but can cause black stripes in wild type cattle.

Cattle can be blazed, spotted, brindled, roan, brockle, belted, diluted, dun, and the list goes on and on. There are many genes involved in these variations of coat color. With the genomic era, scientists are digging deeper into these variations and adding to the list of gene players continually. While the above information may be viewed as the tip of the iceberg when it comes to coat color control, hopefully this provides you with a little better understanding of the physiology and genetic control of hair pigmentation.

Simbrah cow on the left is a Wild type carrier (E+/e). Her bull calf, a likely wild type carrier, started with a similar reddish color (left) but developed a darker pigmentation especially on the head and neck and feet as he aged (right).

Simbrah heifer homozygous for the wild type coat color allele (E+/E+).

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