Hair Color

by [Sue Ann Bowling]

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The Norwegian elkhound is one of the breeds of dog with unusually pronounced agouti (banded) hair.

If you have a dog, or a horse, or even a cat, this is the time of year that their hair is everywhere -- long hair, short hair, straight stiff hair, fine wavy hair, black hair, brown hair, white hair, even striped hair. The combination of increasing day length and warmer temperatures triggers the massive shed that most animals go through in the spring.

Look at a single hair, preferably one of the straight outer hairs, with a magnifying glass. It will taper to a fine point at one end, the first end to grow out of the animal's skin, and have a slight thickening at the other end, the hair base. Many hairs have deeper color at the tip than near the base, and some are black at the tip and have one or more bands of brown, red, yellow or cream color as you move toward the base of the hair. This kind of banded hair color is called agouti, after a South American rodent with banded hair. It occurs to varying degrees in at least some hairs of many dogs, cats, horses, and the majority of wild animals of brownish or greyish color. (Human beings and higher primates generally seem to have lost the agouti gene, so banded hair in people occurs only when a trip to the hairdresser is overdue and dyed or bleached hair is growing out.)

We don't fully understand what happens in nature to produce bands of different color in the same hair, but we have a pretty good idea. The key lies in specialized cells called melanocytes, which are derived from the same embryonic structure as our backbones and nervous systems. These cells migrate into the skin fairly early in development (at about eleven weeks in a human pregnancy). Some remain in the skin, while others move into the developing hair bulbs -- the structures which produce hair.

Melanocytes act as factories for the production of granules of the pigment, melanin. Those in the skin inject melanin (usually eumelanin, the black or dark brown version) into the dividing cells at the base of the skin. Their action is stimulated by ultraviolet radiation, leading to tanning in human beings. In furred animals, this leads to dark skin on noses and around eyes, and sometimes to dark areas where hair has been shaved. The number of melanocytes doesn't seem to vary much by race in human beings, but their level of activity does.

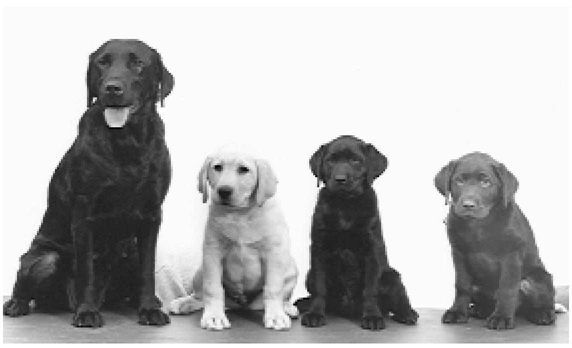
The melanocytes that migrate into the hair bulbs inject their pigment directly into the developing hair shaft. Their activity tends to be highest as the point of the new hair is first being formed, which is probably why many reddish animal hairs are darker at the tip than at the base. Once the hair is visible above the skin, the color of that part of the hair is fixed. In other words, if hair turned white overnight, you wouldn't see it the next morning, but only as white appearing gradually at the base of the growing hair, just like dark hair showing at the base of the hairs as a bleach job is growing out.

The agouti gene produces banded hair by periodically changing the kind of pigment (eumelanin or a reddish pigment called phaeomelanin) produced by the melanosomes that are injecting pigment cells into the base of the hair. The change is observed to take place very rapidly along the hair, and on a given animal affects only certain kinds of hair. On bay horses, for instance, the coarsest hairs (mane, tail, lower legs and whiskers) are black, the softer body hairs are red-brown, and variable numbers of black-tipped red hairs appear along the back, sometimes producing shadings down the sides. Tabby cats have solid black hairs in the dark stripes and banded ones in the light stripes. Agouti coloring in domestic dogs ranges from fawn with a few black-tipped hairs (great Danes and boxers) to dogs with black guard hairs and a tan undercoat (my Shelties) to dogs with several bands per hair of black and very pale cream (Norwegian elkhounds). Wolves, coyotes, rabbits, mice, and most other wild animals have a high percentage of banded hair.

If you don't have a pet, try your parka ruff. You may be surprised at the complex pattern the melanocytes can produce.

What Color is that Puppy in the Window?

Labrador retriever litter with a black mother and a yellow, a black and a chocolate puppy. This sire of this particular litter was a chocolate, but a black sire carrying the right genes



for yellow and chocolate could have produced a similar array of colors. Photo by Jim Coccia, litter bred by Sally Berry.

Two black Labs are mated, and nine weeks later the puppies arrive: some blacks, of course, but some chocolates and yellows as well. Has something gone wrong? No, the litter is merely demonstrating Mendel's laws in action.

Gregor Mendel was an Austrian monk of the nineteenth century who, as a result of experiments in cross-breeding plants in his monastery garden, formulated the laws of heredity now known by his name. In modern terms, these laws state that every hereditary characteristic is controlled by a pair of genes in each individual. During reproduction, each parent provides just one gene for each character to the offspring, and which of the parent's pair is passed on is a random process. In some cases, there are several different variants of the gene for a particular trait. If both genes in an individual are of the same form, the individual will show the characteristic determined by that form of the genes. If the two genes in a pair differ, one may dominate over the other, and the individual will appear as if both its genes for the trait are the dominant gene.

Our Labrador Retriever litter illustrates the effects of genes for two different traits. One of these traits is thought to concern the protein that makes up the dark pigment granules in the dog's hair. If these granules are large and heavily pigmented, dark pigment appears black. If a different form of the protein is the only one that can be made, dark pigment occurs in smaller granules and appears chocolate brown -- not only in the hair coat, but in skin and eyes as well. If both kinds of genes are present, the black pigment will dominate and the dog appears black, but is able to pass the chocolate gene on to its puppies. The appearance of chocolate puppies in the litter is proof that both parents were carrying the chocolate gene, even though they appeared to be black.

The yellow puppies are due to a different pair of genes. Dogs, like most mammals, are able to produce a red-yellow pigment, phaeomelanin, as well as the dark pigment, eumelanin. In black and chocolate animals, only the dark pigment is produced. However, there is another pair of genes which determines whether the red-yellow or the dark pigment colors the hair coat. (The skin and eyes produce dark pigment in any case.) In this case, the gene for determining dark pigment in the coat is dominant over the gene for a red-yellow coat. So, a dog with one gene for dark pigment and one for red-yellow pigment will appear to be black or chocolate, depending on what genes are present to control black or chocolate color. Again, each of the parents of a litter which produces yellow puppies must have at least one gene for red-yellow pigment, so we know that the black parents of our mixed litter must each have had one gene for dark pigment and one for red-yellow pigment.

Note that if both parents are yellow then neither can carry the gene for dark pigment, so none of their puppies will be dark. They may, however, vary in their nose and eye color, which is dependent on what genes are present controlling black or chocolate pigment. A yellow puppy with one or both of these genes producing black will have dark skin pigment and fairly dark eyes. If the puppy has both genes for chocolate, however, the nose will be chocolate and the eyes lighter than normal.

Just to complicate things, yellow dogs in other breeds may not be due to the same genetic mechanism as that which controls yellow color in Labradors. Yellow or tan Collies and Boxers, for instance, are due to a group of genes which allows both black and yellow to get into the hair coat, but differs in where on the dog black and yellow occur. A yellow (technically, sable) Collie mated to a yellow Labrador would produce a litter of black puppies!

Many traits in dogs, and other mammals as well, are controlled by the interaction of many different pairs of genes. The kind of inheritance described above is an oversimplification for such complex traits as the shape of a nose or proneness to heart attacks. But the same heredity processes are still at work, in mice and men as well as in dogs, even though we do not fully understand all the genes involved.

"Ringstreaked, Speckled, and Spotted"

"I will pass through all thy flock to day, removing from thence all the speckled and spotted cattle, and all the brown cattle among the sheep, and the spotted and speckled among the goats: and of such shall be my hire."
-- Genesis 31: 32

This Algerian rock painting of a cattle herding scene, showing a heavily white-marked bull, is four to five thousand years old. White spotting seems to have occurred quite early during domestication of animals. Cover photo from the Cambridge Encyclopedia of Archaeology, reproduced with permission.

The first step in science, the one on which all the experiments are based, is simply playing with ideas. Granted, we don't usually publish this part of the scientific process, but both Larry and Neil have done it here in the past and that's what I'm going to do today. The topic? Why is white spotting so common in domesticated animals, and so rare in wild ones?

White markings do occur in wild animals -- white tails on deer and rabbits, white face markings in wolves, stripes on zebras, chest patches on mink, and warning white bands on skunks. But these markings are very consistent in location from animal to animal within a species, and they serve a purpose -- communication, breaking up the animal's outline, or warning potential predators. The variable blazes, stockings, white toes, chest patches, collars, and tail tips we see in some breeds of almost every domesticated mammal are extremely rare in wild mammals. (The "wild" horses of the west, which do have a wide array of white markings, are in fact feral, that is, descended from domesticated ancestors.)

So we really have two questions: why aren't white markings of the domesticated type seen in wild mammals, and why are they common in domestic stock?

One obvious answer to the first question in that white markings, at least for most of the year, make an animal more conspicuous to potential predators or prey. The persistence of white markings in feral horse herds argues against this being the only factor involved.

Many genes producing white markings or all-white animals also affect the animal in other ways, producing anemia, nervous system problems, or sterility. These genes would tend to die out rapidly in the wild.

Another possibility is color prejudice among wild animals. This isn't quite as crazy as it sounds; possibly the biggest difference between domesticated and wild animals is that domestic animals have been selected to breed very freely, while wild animals of both sexes (as witnessed by the frustration of zoos trying to breed them in captivity) are extremely choosy about their mates. Some insects and birds will refuse to breed with a potential mate whose color or markings are not "right" for the species; if mammals react the same way, the occasional piebald moose or white-spotted wolf probably never finds a mate to help pass on the genes for spotting.

White spotting in domestic animals goes back for at least several thousand years. Cretan wall paintings show spotted bulls, Egyptian frescoes show piebald chariot horses and spotted oxen, and of course the bargain between Jacob and Laban in Genesis presupposes the existence of spotted goats. I suspect at least part of the reason that white spotting is so common in domesticated animals lies in the process of domestication. Domesticated animals are descended entirely from those wild animals that were unchoosy enough about their mates to reproduce in captivity. (Zookeepers trying to maintain endangered species are worried that they may unintentionally be domesticating them in the process due to this effect.)

If a spotted animal occurred in a domestic herd, it would normally mate and produce offspring carrying the spotting genes. Furthermore, the spotted animals would be relatively visible to herders and readily identifiable as domestic, and might have been unconsciously favored for these reasons. (This would be particularly true of early herding dogs, which probably looked very much like wolves. A herding dog with white markings would be far less likely to be killed by a shepherd thinking he was defending an early flock than would one that looked just like a wolf.)

If a particularly desirable trait, such as high milk production, happened to occur in a spotted animal, that animal would be heavily used for breeding, and spots would multiply along with the desirable trait. It is even possible, through a phenomenon called linkage, that the offspring carrying the parent's improved trait would be the spotted ones.

If Jacob's wage agreement with his father-in-law were at all typical, herdsmen who had observed that offspring frequently resembled the sire would have encouraged the spotted males to breed as many females as possible, possibly even removing solid males selectively. And, of course, spotted animals may have been favored for the same reason that full white ruffs are favored in Collies today -- just because their owners thought they looked pretty.