Birds of a Different Color

THREE MAJOR GENES SET FEATHER HUE IN PIGEONS

Feb. 6, 2014 – Scientists at the University of Utah identified mutations in three key genes that determine feather color in domestic rock pigeons. The same genes control pigmentation of human skin.

“Mutations in these genes can be responsible for skin diseases and conditions such as melanoma and albinism,” says Michael Shapiro, associate professor of biology and senior author of the study published online Feb. 6 in the journal *Current Biology*.

“In humans, mutations of these genes often are considered ‘bad’ because they can cause albinism or make cells more susceptible to UV (ultraviolet sunlight) damage and melanoma because the protective pigment is absent or low,” says Eric Domyan, a biology postdoctoral fellow and first author of the study. “In pigeons, mutations of these same genes cause different feather colors, and to pigeon hobbyists that is a very good thing.”

Pigeon breeders have drawn on their centuries-long experience to produce about 350 distinct pigeon breeds, focusing particularly on beak shape, plumage color and feather ornaments on the head, feet, beaks and elsewhere. But until this study, the specific mutations that control color in rock pigeons (*Columba livia)* were unknown.

“Across all pigeon breeds, mutations in three major genes explain a huge amount of color variation,” Shapiro says.

Various forms of a gene named *Tyrp1* make pigeons either blue-black (the grayish color of common city pigeons), red or brown. Mutations of a second gene, named *Sox10,* makes pigeons red no matter what the first gene does. And different forms of a third gene, named *Slc45a2*, make the pigeons’ colors either intense or washed out.

The scientists discovered how pigeons’ feather color is determined by different versions of these three genes – known as variants or alleles – and by what are called “epistatic” interactions, in which one gene obscures the effects of other genes.

“Our work provides new insights about how mutations in these genes affect their functions and how the genes work together,” Shapiro says. “Many traits in animals, including susceptibility to diseases such as cancer, are controlled by more than one gene. To understand how these genes work together to produce a trait, we often have to move beyond studies of humans. It’s difficult to study interactions among the genes in people.”

“Both *Tyrp1* and *Sox10* are potential targets for treatment of melanoma,” he adds. “Mutations in *Slc45a2* in humans can lead to changes in skin color, including albinism (lack of skin color).”

Different versions of the three major pigeon-color genes affect the relative proportions of major forms of the melanin pigment − eumelanin and pheomelanin − and their distribution within cells. Eumelanin provides black and brown pigmentation, while pheomelanin provides red and yellow pigmentation of feathers. Interplay among the three major genes is complex, resulting in diverse coloration of pigeons.

“Mutations in one gene determine whether mutations in a second gene have an effect on an organism,” Domyan says. In other words, one gene can mask the effects of another in relation to pigeon color.

The three pigment genes don’t control how the colors are distributed in patterns on pigeons’ bodies, such as white patches of feathers on some breeds. The genetics of color patterns remains to be determined.

Shapiro and Domyan conducted the study with several University of Utah co-authors: human genetics professor Mark Yandell, biology lab technician Michael Guernsey, genetics doctoral student Zev Kronenberg, former Huntsman Cancer Institute researchers Sancy Leachman and Pamela Cassidy, and biology undergraduate student Anna Vickrey. Other co-authors were Shreyas Krishnan, Clifford Rogers and John Fondon III from the University of Texas at Arlington; and Raymond Boissy from the University of Cincinnati College of Medicine.

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Breaking the Color Code

The scientists showed that feather colors in 82 breeds of pigeons could be explained by various combinations of the three genes and their different versions.

“Color is one of the most important traits to breeders − it makes a pretty pigeon,” Shapiro says. Tinkering by breeders led to great color diversity in pigeons across the centuries, providing scientists with perfect specimens to study pigmentation genetics.

Shapiro and co-workers found that versions of the *Tyrp1* gene were responsible for determining three basic pigeon colors: blue-black, ash-red, and brown. Blue-black color of pigeons is considered “normal,” because neither *Tyrp1* nor the other two major color genes contain mutations in these pigeons. City pigeons typically are this color.

Even before the rise of genetics, “Darwin realized that blue-black was the ancestral pigeon color, and that the various domestic rock pigeon breeds represented a single species,” Shapiro says. When Darwin crossed pigeons of different colors, blue-black pigeons consistently appeared among the progeny.

Here’s how the three genes work:

– *Tyrp1* gene produces a protein that helps make the pigment eumelanin. Pigeons with blue-black feathers have normal *Tyrp1*. Ash-red and brown birds pigeons contain different mutations in the *Tyrp1* gene, which leads to less or different pigmentation.

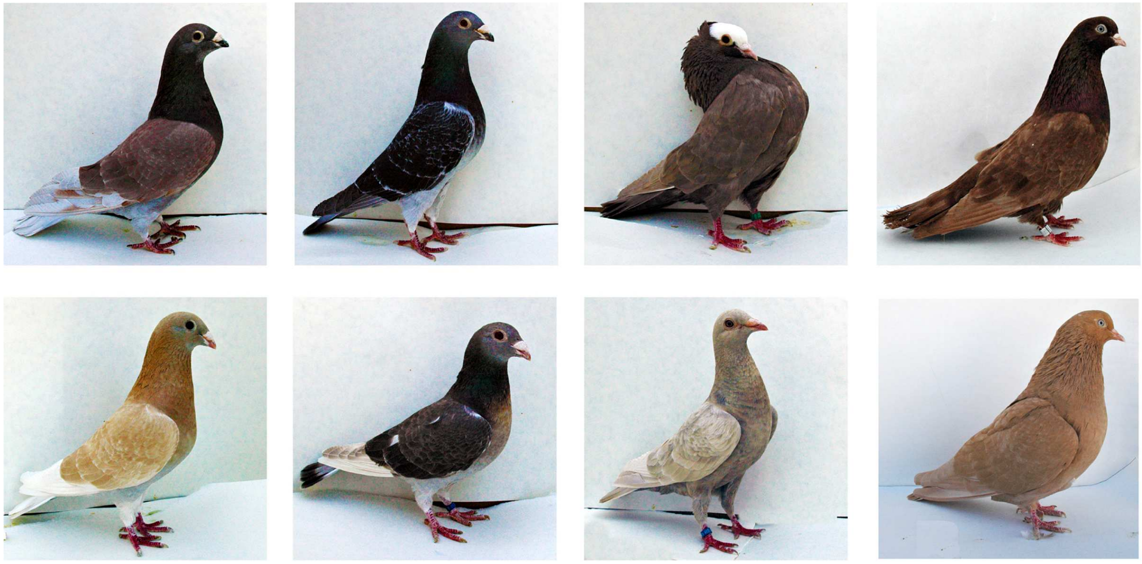
– Mutations that affect the *Sox10* gene override colors determined by various versions of the *Tyrp1* gene. Regardless of whether the *Tyrp1* version makes pigeons blue-black, ash-red or brown, mutations that regulate the *Sox10* gene result in red pigeons.

– Mutation of the *Slc45a2* gene decreases the intensity of colors determined by *Tyrp1*, *Sox10* and their mutants. Depending on the version of the *Tyrp1* gene – blue-black, ash-red, and brown − pigeons harboring the mutant *Slc45a2* gene still display the same colors, but in watered-down or diluted versions, less intense than those with normal *Slc45a2*. For example, a pigeon with both the ash-red version of *Tyrp*1 and the mutant *Slc45a2* gene has ash-yellow feathers. Pigeons with *Sox10* and *Slc45a2* mutations are yellow, which is the dilute form of red.

Most of the pigeon blood and feather samples used in the study were collected at pigeon shows in Utah, where breeders from across the country flocked to display their pigeons. After extracting and sequencing DNA from the samples, the researchers compared DNA sequences among the pigeons and observed that specific versions of genes associated with specific feather colors.

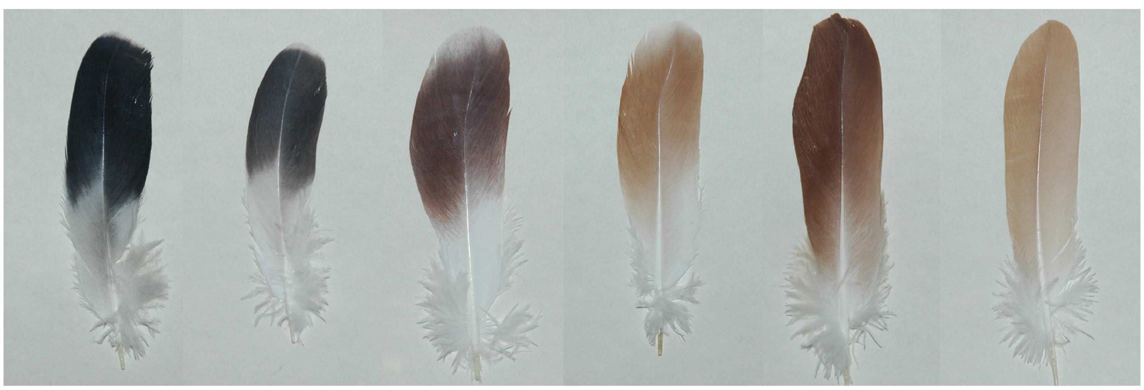
These English trumpeter pigeons – blue-black on the left and red on the right – display some of the great diversity of colors among some 350 breeds of rock pigeons. University of Utah biologists discovered three major genes explain color variations in rock pigeons. In the blue-black pigeon, none of the genes have mutations. The red bird is that color because it has a mutant version of a gene named Sox10. The same genes are involved in making some people susceptible to skin cancer and others develop albinism, or a lack of pigment.

Photo Credit: Sydney Stringham, University of Utah



University of Utah biologists identified three major genes that determine feather colors in common rock pigeons, of which there are some 350 breeds. Top row, first three images from left to right, show ash-red color from a mutant form of the Tyrp1 gene, blue-black from a normal Tyrp1 gene, and brown from another Tyrp1 mutant. The fourth photo, upper right, shows a pigeon that is red due to a mutant Sox10 gene. The pigeons in the bottom four images have the same form of the Tyrp1 or Sox10 genes as the corresponding birds in the top row, but their colors are diluted or watered-down because they also have mutant gene named Slc45a2.

Photo Credit: Eric Domyan, University of Utah



Biologists at the University of Utah showed how three pigment genes interact to cause a variety of colors among rock pigeons. From left to right: The first feather is blue-black because all three genes are normal. The second feather is dilute blue because the Tyrp1 and Sox10 genes are normal but the Slc45a2 gene is mutant, which dilutes the intensity of any color. The third feather from the left is ash-red because of a mutant Tyrp1 gene and normal Sox10 and Slc45a2. But if Slc45a2 also is mutant, the feather color is diluted to ash-yellow (fourth from left). The fifth feather from the left is red because the Sox10 gene is mutant, which overrides whatever color Tyrp1 normally would dictate. In the sixth feather, Slc45a2 also is mutant, making the feather yellow, which is the diluted form of red.

Photo Credit: Eric Domyan, University of Utah

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