Study shows how a single gene drives aggression in wild songbird

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White-throated sparrows come in two different morphs, the white-striped (left) and the tan-striped (right). The morphs have both different plumage and behaviors, making these wild songbirds a good model organism for the genetic basis of behavior. Credit: Jennifer Merritt

A new study shows how differentiation of a single gene changes behavior in a wild songbird, determining whether the white-throated sparrow displays more, or less, aggression. The *Proceedings of the National Academy of Sciences (PNAS)* published the research, led by neuroscientists at Emory University.

The researchers singled out an estrogen receptor from a complex of more than 1,000 genes known as a "supergene," or genetic material inherited together as a block. The work provides a rare look at how genomic divergence can lead to behavioral divergence in a vertebrate.

"Evolution has tinkered with the DNA sequence of a gene of this songbird, and we demonstrated that those little changes affect both the expression of the gene and the bird's behavior," says Emory graduate student Jennifer Merritt, first author of the paper.

Merritt is a Ph.D. candidate in the lab of Donna Maney, senior author of the paper and an Emory professor of psychology.

"White-throated sparrows are common backyard birds found through most of North America," Merritt says. "What's remarkable about them is that they occur in two different morphs that have not only different plumage, but also different strategies for maximizing reproductive output. Both types of differences are caused by genetic differentiation of only one region of a single chromosome, and we know exactly where it is."

At some point during the evolution of a species, a chromosome can break and flip. This process, called an inversion, isolates the genes that are trapped inside, producing a supergene. In some cases, supergenes have led to distinct morphs within a single species—individuals with the supergene and those without it.

In the case of the white-throated sparrows, the white-striped morph sports bright yellow, black and white stripes on its crown while the tan-striped morph has more muted, tan and grayish stripes. The white-striped birds, which all possess at least one copy of the rearranged chromosome, tend to be more aggressive and less parental than the tan-striped birds, which do not have the rearranged chromosome.

"Scientists have hypothesized for 100 years that inversions are important for the evolution of some of the complex behaviors that we see in nature," Maney says. "But inversions are challenging to understand because, when they turn into supergenes, all of the genes are inherited together. We already knew a lot about the natural history of the white-throated sparrow, as well as the biological mechanisms underlying its aggression. Using that knowledge, we were able to finally show the evolutionary role of a supergene at the molecular level."

The current paper builds on previous work by the Maney lab, a leader in connecting gene sequence with behavior in free-living animals. In 2014, the lab identified a hormone receptor—estrogen receptor alpha (ER-alpha)—that appeared connected to the differences in the sparrows' aggression and parenting behaviors in the wild. The white-striped birds express this receptor at much higher levels than the tan-striped birds, and the more the expression, the more aggressive the bird.

"For this paper, we wanted to follow the genetic variation of ER-alpha all the way up to where it's expressed in the brain, and then to behavior, to see if we could trace the behavioral variation to variation in this one gene," Merritt says.

The birds sing to establish a territory. The rate at which they sing gives a measure of their level of aggression, along with the frequency at which they charge, or 'attack,' animals encroaching on what they consider their territory.

In field studies of white-throated sparrows in their natural habitat, the researchers showed that the more a bird expresses the supergene version of the estrogen receptor, the more vigorously it defends its territory.

The researchers then moved beyond the correlational work by taking an experimental approach. White-throated sparrows in the lab were given a

substance to block expression of the ER-alpha gene and their aggression levels were measured. The results showed that when expression of that one gene was blocked, the aggression of the white-striped birds went down so they behaved like the tan-striped ones.

"We believe this is the first demonstration of how a single gene within a supergene drives changes in a social behavior in a wild vertebrate," Merritt says. She gives an analogy for the challenge involved: "Imagine each of the genes within a supergene as tributaries converging into a river, the behavior. And then taking a sample of water from the river and determining which tributary the sample came from."

The Maney lab is continuing to investigate a suite of other neuroendocrine genes captured by the chromosome rearrangement in the white-throated sparrow that are thought to be important players in the regulation of social behavior.

More information: Jennifer R. Merritt et al. A supergene-linked estrogen receptor drives alternative phenotypes in a polymorphic songbird, *Proceedings of the National Academy of Sciences* (2020). DOI: 10.1073/pnas.2011347117

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