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RESEARCH NEWS

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Fruitfly Study Shows How Evolution Wings It

In the frantic world of fruitfly courtship, the difference between attracting a mate and going home alone may depend on having the right wing spots. Now, Howard Hughes Medical Institute researchers have learned which elements of fly DNA make these spots come and go in different species. Their studies have also uncovered surprising new evidence supporting the idea that evolution is an incessant tinkerer when it comes to complex traits.

The experiments are among the first to root out the deep mechanics of evolution that underpin complex traits, according to the study's senior author Sean Carroll, a Howard Hughes Medical Institute researcher at the University of Wisconsin-Madison. Carroll and his Wisconsin colleagues collaborated with researchers from the University of Cambridge and Stony Brook University on the studies, which were published in the April 20, 2006, issue of the journal *Nature*.

> "Researchers are now finding the actual 'smoking guns' of evolution by documenting specific evolutionary changes at the DNA level."
> **— Sean B. Carroll**

The researchers said their findings emphasize the evolutionary significance of pleiotropic genes - those with multiple on-switches that enable the expression of a single gene in different tissues or at different stages of development.

The wing spot on the fruitfly is a particularly good model because we know it constitutes a new feature that is gained or lost by evolution in different species, said Carroll. And, since it is a spatial pattern, it gives us a chance to analyze the evolution of a physical trait. Such traits have size, shape, and length, and they are more complicated than physiological traits. For example, eye color is not a tricky thing to figure out, since it can be reduced to single genetic changes. But evolutionary biologists want to understand how even complicated bits of anatomy and machinery - like the wing or the complex eye - are put together in the course of evolution.

Wing spots have evolved in different fruitfly species as part of the courtship displays that males present to females during mating. Thus, they can be under intense evolutionary pressure to appear and be maintained, depending on whether the females find them attractive, Carroll noted.

In their study, the researchers first organized 77 species of the fruitfly *Drosophila* into a fly family tree to reveal which species had gained or lost wing spots in comparison to their ancestors. The researchers then analyzed the genetic mechanisms that caused two of the species to gain wing spots independently in comparison to ancestral flies which did not have the wing spots. The researchers also performed similar analyses on two species of flies that had lost wing spots.

Their genetic studies focused on the role of DNA segments called *cis*-regulatory elements that were thought to be involved in the evolution of wing spots. *Cis*-regulatory elements (CREs) are DNA segments that nestle around DNA sequences that code for specific proteins and dictate where and when a gene is turned on or off in the body. By having different CREs, the gene's function can vary in different tissues between species.

In earlier studies, Carroll's team had shown that CREs regulating a gene called *yellow* played a central role in wing spot development. Their studies showed that when a CRE switches on the *yellow* gene, it produces a spot's black pigment. CREs are important targets for evolutionary experimentation because they can be mutated without compromising the basic function of the gene, said Carroll.

The researchers' comparison of the different species revealed that all the gains or losses of spots involved mutations that altered CREs for the *yellow* gene. The scientists found that losses of spots in two different groups of *Drosophila* species involved different, independent mutations in the same CRE. However, said Carroll, the bigger surprise came when they studied the gains of spots in different species.

The big stunner in this paper was that the two independent gains of spots we studied each resulted from mutations in distinct ancestral CREs, said Carroll. In the ancestor, one of these CREs controls the expression of the *yellow* gene in the wing blade and one in the vein.

This finding is informative because it shows that the wing pattern wasn't generated from scratch, said Carroll. The fly didn't use naïve DNA that had no job and invent this pattern out of thin air. It used a gene that was already active in the wing, already drawing some kind of pattern in the wing, and modified that pattern. We think that is strong clue to how nature invents, which is by using material that is already available. This demonstrates how evolution is a tinkerer, he said.

The findings also underscore an important role for pleiotropic genes in evolution. For example, a fly's body has pigmented bristles, mouth parts, thorax and abdomen. These different features are controlled separately, so the same *yellow* gene can be used in different parts of the body. So this pleiotropy gives evolution an artistic freedom to play with the regulatory elements in specific regions without making mutations that would affect the gene throughout the body.

Carroll said that his future studies will explore how evolution can tinker with the machinery of the fly's nervous system to affect behaviors such as male mating dances and courtship songs, as well as how those are perceived by the female.

More generally, these kinds of molecular studies are enabling new advances in understanding the machinery of evolution. These techniques are enabling dramatic progress in understanding the deep mechanics of evolution in more and more detail, he said. Researchers are now finding the actual `smoking guns' of evolution by documenting specific evolutionary changes at the DNA level.

And studies of phenomena such as fruitfly wing spots show how evolution is not some one-off process. It repeats itself over and over. They show that there is more than one way to tinker with the same gene, and by extension, to independently evolve the same trait, Carroll said.