Genome inversion gives plant a new lifestyle

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The yellow monkeyflower, an unassuming little plant that lives as both a perennial on the foggy coasts of the Pacific Northwest and a dry-land annual hundreds of miles inland, harbors a significant clue about evolution.

Duke graduate student and native northern Californian David Lowry had become interested in how a single species could live such different lifestyles. He set out to find a gene or genes that would account for the monkeyflower (*Mimulus guttatus*) being a lush, moisture-loving, salt-tolerant perennial on the coast, but a shorter, faster-flowering, drought-tolerant annual inland.

What he found instead was that a large chunk of the plant's genome - 2.2 million letters of DNA and 350 genes - are working differently in each ecotype of the plant. The difference is called a genetic inversion, a long piece of DNA that has been clipped out of a chromosome at both ends and then reinserted essentially upside down.

"When you look at one plant species across a broad landscape with lots of different habitat conditions, you find differences in the genes from one place to the next," Lowry said. "The cause of these differences has been a source of contention among evolutionary biologists for decades as they've tried to figure out what mechanisms drive the origin of species."

A single species with a broad range of habitats like the monkeyflower can be expected to have a suite of genes available to help it adapt to the various conditions it would encounter within its range. But depending on where an individual plant finds itself, some of those genes aren't being used.

In the case of the monkeyflower, Lowry found that each ecotype has a large suite of adaptive genes carried within the inversion. The inland plants set about producing flowers and getting their reproduction done in the spring, before hot, dry weather arrives. The coastal plants grow a lot more foliage and flower much later without the threat of drought, leaving them better suited to overwinter and to compete for space in a riotous plant environment. Lowry showed that those adaptations lie within the inverted section: transplanted to the other environment, neither variety does well.

The inversion can be a driver of speciation. In the process of gene-shuffling during the formation of sex cells (known as recombination), an inverted region can't successfully swap genes with its counterpart chromosome precisely because it's backwards. Lowry's first clue was that crosses between the two ecotypes didn't produce any recombinations in the part of the chromosome where the inversion was eventually found.

Because they aren't reshuffled by recombination, the genes within the inverted stretch end up traveling through time as one large block of genes, rather than an assortment. "So the inversion sort of works like a super gene," Lowry said.

Inversions are particularly interesting to biologists who are trying to figure out how one species becomes two. Notably, many significant inversions have been identified between humans and chimpanzees. And one of Lowry's Duke advisors, biologist Mohamed Noor, has found inversions help separate new species of fruitflies.

"Inversions are going to be seen as an important part of local adaptation as more people look for them," said Duke biology professor John Willis, who was Lowry's thesis advisor and co-author. "This is an extremely important argument and could explain a lot of the inversions that people are finding."

To prove the adaptations were in the inversions, Lowry painstakingly put the annual spelling of the inversion into perennial plants and the perennial spelling into the annuals through a long series of crosses in the greenhouses at Duke. Then he took 1,600 of these carefully edited plants out to test plots across several habitats in the Pacific Northwest to see how they'd do in the 2009 growing season. "It was a huge amount of work," Willis said.

Not only will these hardiness differences help drive the two ecotypes apart, their different flowering times will help prevent pollen-swapping that would mingle their genes. With time, they should become separate species, "depending on which definition of species you want to use," Lowry quickly added. "They're not full species, but they're going in that direction."

This is the first time in a natural setting that anyone has shown inversions directly affecting adaptation to local conditions and a shift between annual and perennial life history in plants. "We actually showed through experimentation that the inversion contributes to adaptation and reproductive isolation," Lowry said.

It took Lowry five years of meticulous lab work repetitively cross-breeding the plants and tromping around in mud to nail the monkeyflower inversions down and prove they accounted for the lifestyle differences.

For his efforts, he got a successful dissertation and a 2010 Ph.D. in biology, as well as a publication in the Sept. 28 edition of *PLoS Biology* with his adviser, associate professor of biology John Willis.

More information: Lowry DB, Willis JH (2010) A Widespread Chromosomal Inversion Polymorphism Contributes to a Major Life-History Transition, Local Adaptation, and Reproductive Isolation. *PLoS Biol* 8(9): e1000500. doi:10.1371/journal.pbio.1000500

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