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Parallel evolution: proteins do it, too

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Wings, spines, saber-like teeth—nature and the fossil record abound with examples of structures so useful they've evolved independently in a variety of animals. But scientists have debated whether examples of so-called adaptive, parallel evolution also can be found at the level of genes and proteins.

In the June 11 issue of *Nature Genetics*, evolutionary biologist Jianzhi (George) Zhang presents evidence for one such instance in a gene for an enzyme that helps leaf-eating monkeys digest their food.

"We know that parallel, or convergent, evolution is very common at the level of morphology—birds can fly, insects can fly, bats can fly, and they've all evolved this capability independently. But at the DNA and protein sequence level, it's very rare to find parallel evolution. This paper provides a real example," said Zhang, an associate professor of ecology and evolutionary biology.

The new work builds on previous research in which Zhang showed that the duplication of a gene encoding a pancreatic enzyme helped Asian colobine monkeys cope with an unusual diet.

"Colobines are different from other monkeys in that they primarily eat leaves rather than fruit or insects, and leaves are very difficult to digest," Zhang said. The monkeys manage with a digestive system similar to a cow's. Bacteria in the gut ferment the leaves and take up nutrients that are released in the process. The monkeys, in turn, digest the bacteria to recover the nutrients, such as protein and ribonucleic acid (RNA), a particularly important source of nitrogen in leaf eaters.

Zhang focused his attention on RNASE1, a pancreatic enzyme that breaks down bacterial RNA. Most primates have one gene encoding the enzyme, but he found that the douc langur, a colobine from Asia, has two—one encodes RNASE1, and its duplicate encodes a new enzyme, RNASE1B. The duplicate enzyme, it turns out, works better than the original in the acidic conditions of the colobine small intestine, making it more efficient at recovering nutrients from bacteria.

Zhang's initial analysis showed that the duplication occurred about four million years ago, some nine million years after the two main groups of colobines—Asian and African—split into separate lineages. To confirm that the duplication occurred after the split, he analyzed DNA samples from an African colobine known as the guereza or colobus monkey.

"We sequenced the gene, and to our surprise we found not one, not two, but three RNASE1 genes," Zhang said. "Further analysis showed that the duplications in African monkeys and Asian monkeys were separate, independent events." Next, Zhang wanted to know if the duplications resulted in similar functional changes in the enzyme. Just as in the Asian colobine, the duplicated genes in African colobines functioned more efficiently at the typical acidity level of the colobine small intestine, he found.

"Then our question was whether the similar functional changes were due to identical amino acid changes at the protein sequence level," Zhang said. "Indeed, we found three amino acid changes that were identical in the two lineages. They occurred independently, but they were identical." Additional experiments confirmed that the three, independent, parallel amino acid changes were responsible for the change in enzyme function.

In both Asian and African colobines, the original, less efficient, gene is not discarded after duplication. But why, Zhang wondered.

"The guess is that the old copy is still doing something important," he said. "RNASE1 has another function, which is to degrade double-stranded RNA. Double-stranded RNA is not normally found in food, but it's found in some viruses, so the old gene may be useful in defending against viral infection." Zhang checked the new and old genes in both lineages and found the same pattern: the new genes have lost the ability to degrade double-stranded RNA, but the older genes have kept it.

"So it looks like, after gene duplication, there is a division of labor," Zhang said. "Before duplication, the gene is supposed to do both jobs: digestion and degrading double-stranded RNA. After duplication, one copy seems to retain the activity of degrading double-stranded RNA while the other copy has adapted to changed pH in the small intestine so it can better digest food."

Even after clearly demonstrating parallel evolution in this case, Zhang believes the phenomenon is uncommon at the protein sequence level. However, he proposes a list of criteria in the Nature Genetics paper that he and other researchers can use to test apparent examples in the future.

Source: University of Michigan