Coffee genome sheds light on the evolution of caffeine

Enzymes that help produce caffeine evolved independently in coffee, tea and chocolate, say scientists who have newly sequenced the coffee plant genome

By Cory Nealon

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Summary:

- An international research team has sequenced the genome of the coffee plant *Coffea canephora.*
- By comparing genes in the coffee, tea and chocolate plants, the scientists show that enzymes involved in making caffeine likely evolved independently in these three organisms.
- More than 8.7 million tons of coffee was produced in 2013; it is the principal agricultural product of many tropical nations.
- The study was led by the French Institute of Research for Development, the French National Sequencing Center (CEA-Genoscope) and the University at Buffalo. The findings appear in the journal Science.

BUFFALO, N.Y. — The newly sequenced genome of the coffee plant reveals secrets about the evolution of man's best chemical friend: caffeine.

The scientists who completed the project say the sequences and positions of genes in the coffee plant show that they evolved independently from genes with similar functions in tea and chocolate, which also make caffeine.

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Victor Albert

"The coffee genome helps us understand what's exciting about coffee — other than that it

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In other words, coffee did not inherit caffeine-linked genes from a common ancestor, but instead developed the genes on its own.

The research appears in the journal Science on Sept. 5. A video explaining the findings is here:
http://bit.ly/1lD4LNQ.

wakes me up in the morning."

Victor Albert, professor of biological sciences
University at Buffalo

Why coffee?

With more than 2.25 billion cups consumed daily worldwide, coffee is the principal agricultural product of many tropical countries. According to estimates by the International Coffee Organization, more than 8.7 million tons of coffee were produced in 2013, revenue from exports amounted to $15.4 billion in 2009-2010, and the sector employed nearly 26 million people in 52 countries during 2010.

"Coffee is as important to everyday early risers as it is to the global economy. Accordingly, a genome sequence could be a significant step toward improving coffee," said Philippe Lashermes, a researcher at the French Institute of Research for Development (IRD). "By looking at the coffee genome and genes specific to coffee, we were able to draw some conclusions about what makes coffee special."

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Lashermes, along with Patrick Wincker and France Denoeud, genome scientists at the French National Sequencing Center (CEA-Genoscope), and Victor Albert, professor of biological sciences at the University at Buffalo, are the principal authors of the study.

Scientists from other organizations, particularly the Agricultural Research Center for International Development in France, also contributed, along with researchers from public and private organizations in the U.S., France, Italy, Canada, Germany, China, Spain, Indonesia, Brazil, Australia and India.

The team created a high-quality draft of the genome of *Coffea canephora*, which accounts for about 30 percent of the world's coffee production, according to the Manhattan-based National Coffee Association.

Next, the scientists looked at how coffee's genetic make-up is distinct from other species.

Compared to several other plant species, including the grape and tomato, coffee harbors larger families of genes that relate to the production of alkaloid and flavonoid compounds, which contribute to qualities such as coffee aroma and the bitterness of beans.

Coffee also has an expanded collection of N-methyltransferases, enzymes that are involved in making caffeine.

Upon taking a closer look, the researchers found that coffee's caffeine enzymes are more closely related to other genes *within* the coffee plant than to caffeine enzymes in tea and chocolate.

This finding suggests that caffeine production developed independently in coffee. If this trait had been inherited from a common ancestor, the enzymes would have been more similar between species.

"The coffee genome helps us understand what's exciting about coffee — other than that it wakes me up in the morning," Albert said. "By looking at which families of genes expanded in the plant, and the relationship between the genome structure of coffee and other species, we were able to learn about coffee's independent pathway in evolution, including — excitingly — the story of caffeine."

Why caffeine is so important in nature is another question. Scientists theorize that the chemical may help plants repel insects or stunt competitors' growth. One recent paper showed that pollinators — like humans — may develop caffeine habits. Insects that visited caffeine-producing plants often returned to get another taste.

The new Science study doesn't offer new ideas about the evolutionary role of caffeine, but it does reinforce the idea that the compound is a valuable asset. It also provides the opportunity to better understand the evolution of coffee's genome structure.

"It turns out that, over evolutionary time, the coffee genome wasn't triplicated as in its relatives: the tomato and chile pepper," Wincker said. "Instead it maintained a structure similar to the grape's. As such, evolutionary diversification of the coffee genome was likely more driven by duplications in particular gene families as opposed to *en masse*, when all genes in the genome duplicate."

This stands in contrast to what's been suggested for several other large plant families, where other investigators have noted correlations between high species diversity in a group and the presence of whole genome doublings or triplings.

"Coffee lies in the plant family Rubiaceae, which has about 13,000 species and is the world's fourth largest; thus, with no genome duplication at its root, it appears to break the mold of a genome duplication link to high biodiversity," Denoeud said.

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