Genetic Underpinnings of Wood Digestion by Termite Gut Microbes Revealed

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When termites are chewing on your home, your immediate thought probably isn't "I wonder how they digest that stuff?" But biologists have been gnawing on the question for more than a century. The key is not just the termite, but what lives in its gut. A multitude of genes from the microbes populating the hindgut of a termite have been sequenced and analyzed, and the findings reported today in the journal *Nature*.

California Institute of Technology associate professor of environmental microbiology Jared Leadbetter led a team of researchers from other universities, private industry, and the Department of Energy (DOE) in uncovering the genetic underpinnings and the roles of bacteria in wood digestion by "higher termites." These insects abound in tropical and subtropical ecosystems. What the team found, says Leadbetter, is "a comprehensive set of blueprints for the bacteria that help dismantle wood."

Prior to this study, only one gene--in the insect itself--had been connected to the termite's rare ability to digest and nourish itself with wood, a substance that is energy-rich but hard to break down. It had also long been suspected that the 250 bacterial species that crowd the pinhead volume of a higher termite's hindgut might be directly involved in the process. But there was no way of knowing their roles for sure, because most of the organisms die quickly when removed from their host. Although the first bacterium genome was sequenced in 1994, it was a few years before scientists even considered sequencing entire communities of multiple species of organisms.

Leadbetter and his colleagues proposed to the DOE Joint Genome Institute (JGI) that the gut community of the Costa Rican termite Nasutitermes be examined because it is abundant and it plays significant roles in the wood degradation that helps to renew ecosystems. Leadbetter joined forces with collaborators at JGI, Verenium Corporation's San Diego facilities, and INBio, the National Biodiversity Institute of Costa Rica. They sequenced and analyzed more than 80,000 genes encoded by many of the hindgut bacteria species. "This was a fairly risky project when we proposed it," says Leadbetter, because "in these abundant tropical termites, there was no compelling evidence that these microbes play direct roles in cellulose degradation."

When the results started coming in, "we all breathed a big sigh of relief, because it turned out to be a gold mine in there," Leadbetter says. They found nearly 1,000 genes that underlie roles in breaking down two of wood's main components, cellulose and xylan, into their component sugars. The degradation of cellulose and xylan requires an arsenal of enzymes because of the huge diversity of biochemical bonds in wood. "This isn't some soft paper or grass we're talking about," says Leadbetter. "It's a hard substrate." Wood is made of three tightly intertwined compounds; taking it apart is a challenge, and termites are among the few known animals that can do it.

Leadbetter and his colleagues hope to eventually uncover exactly how each gene is involved in degrading wood, and where the energy the termite derives from the wood goes. This has recently become a focus of interest for those interested in developing an effective, industrial method to convert wood into ethanol. The challenge lies in events at the start of the process, like those involved in breaking down cellulose and xylan. Leadbetter and his colleagues believe that by investigating the genes that underlie these primary reactions, better ways of manufacturing biofuel can eventually be developed.

The study also identified nearly 100 different species of bacteria called spirochetes that belong to the genus Treponema. This membership makes them closely related to the bacterium that causes syphilis and to other spirochetes implicated in Lyme disease and gum disease. In termites, though, the findings show that these spirochetes actually benefit the health of their hosts. The genome sequencing also showed that the spirochetes are active in processes that generate hydrogen, an energy-rich gas, from wood. Certain genes also indicate that gut spirochetes can essentially taste or smell hydrogen and will swim either to or from its sources in the gut. In general, Leadbetter says, it looks like "these bacteria differ from those that dominate the gut tracts of humans and other mammals in their broad capacity to swim in response to diverse chemical stimuli. This behavior may be relevant to effective wood degradation."

Other Caltech authors of the paper are Eric Matson, a postdoctoral scholar in environmental science and engineering; Xinning Zhang, a graduate student in environmental science and engineering; and Elizabeth Ottesen, a graduate student in biology. Group leaders are Dan Robertson of Verenium Corporation, Phil Hugenholtz of the JGI, Giselle Tamayo of INBio, and Eric Mathur, formerly of Diversa (now at Synthetic Genomics).

Source: Caltech

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