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Shipworm enzyme could produce cellulosic ethanol

By Ryan C. Christiansen

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Scientists have received \$4 million from the National Institutes of Health to study an enzyme in clams – and to determine if that enzyme could be used to produce cellulosic ethanol.

A group of Philippine and American scientists led by Oregon Health and Science University will examine, among other things, whether the bacteria inside the gills of a worm-like marine clam in the Philippine archipelago include an enzyme that can be used in the production of cellulosic ethanol.

The National Science Foundation and the U.S. DOE also sponsored of the grant.

The researchers are studying the enzymes that come from bacteria that live inside the cells of *Lyrodus pedicellatus*, known as the shipworm. The bacteria produce enzymes that help the shipworm to digest wood. Those enzymes might prove useful for converting cellulosic biomass into ethanol, according to Daniel Distel, executive director for the Ocean Genome Legacy, a non-profit organization in Ipswich, Mass., which is putting together a database of the DNA blueprints of endangered marine organisms.

"We know that the shipworms produce a whole variety of enzymes," Distel said. "There are a number of different bacteria involved in the process, all of which are intracellular, which means they actually live inside the cells of the shipworm's body."



Researchers are studying the enzymes that come from bacteria that live inside the cells of *Lyrodus pedicellatus*, known as the shipworm. The bacteria produce enzymes that help the shipworm to digest wood and could be useful in converting cellulosic biomass into ethanol./PHOTO: DR. RUTH TURNER, HARVARD UNIVERSITY.

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So far, Distel and his colleagues have completed the DNA sequence of one shipworm bacteria, *Teredinibacter turnerae*, which can be grown in the lab. "We know that this is just one of the bacteria present," he said, "and this bacterium produces a large number of different enzymes involved in the





breakdown of wood cellulose and hemicellulose components." He said the isolated bacterium contains approximately 100 enzymes that can break down wood.

Distel said there are three classes of enzymes that can break down cellulose and one of the *T. turnerae* bacterium's 100 enzymes is unusual, because it can perform the same chemical reactions as two of those classes.

Enzymes from shipworm bacteria might enable an integrated cellulosic ethanol production process to break down feedstock using less-harsh pretreatment, Distel said. "The shipworm is a complete wood degrading factory," he said. "It actually does some pretreatment—it chews the wood, it grinds the wood into small bits—but the shipworm manages to digest wood without boiling it or steam-exploding it, and presumably without any harsh acids or bases."

Shipworms are an interesting study, Distel said, because they consume a material that few other organisms in the ocean or on land are able to consume. "Terrestrial wood is very distinct from anything that naturally grows in the ocean with the possible exception that some types of trees grow with their roots in the water, such as mangroves. We believe that these organisms evolved the ability to use a terrestrial waste product."

The organism is called a shipworm because of its ability to consume the wreckage of wooden ships, but there is plenty of other wood to be consumed, Distel said. "Enormous quantities of wood enter the ocean every year," he said. "Erosion along the coasts and on rivers cause trees and other materials to fall into the water and they are carried by rivers, sometimes carried hundreds of miles, and so even before man was around to toss his waste in and build wooden boats, as long as there has been trees there has been wood in the oceans."

Distel said the project—named the Philippine Mollusk Symbiont International Cooperative Biodiversity Groups project—is unique because the scientists are not only looking for enzymes for energy research, but also for anti-cancer agents—and the two components are related.

"The project is looking both for compounds that may be useful for drug development and for bioenergy development," Distel said. "The combination sprang out of an accidental discovery that we made. This bacterium from the shipworm is actually closely related to another bacterium from an organism called a bryozoan. It turns out that this bacterium from the bryozoan *Bugula neritina* produces [bryostatin], which is under investigation as an anti-cancer agent. That was a big surprise." The anti-cancer agent was discovered by Margo Haygood, a professor of marine and biomolecular systems in the Department of Science and Engineering in the OHSU School of Medicine. She is the lead investigator for the overall Philippines mollusk project.

Distel said the researchers discovered that the genome of the shipworm bacterium also contains genes that are very similar to the genes that are involved in the production of the anti-cancer agent. "That led to the realization that there may be other interesting drug-lead compounds in this bacterium and in other bacteria like it in marine mollusks," he said.

The Philippines mollusk project team includes scientists from OHSU, the University of the Philippines, the University of Utah, the Academy of Natural Sciences in Philadelphia, and also the Ocean Genome Legacy.

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