BIOLOGY

Mammoth mangrove bacterium has complex cell

"Eye-opening" discovery challenges evolutionary thinking on microbes

By **Elizabeth Pennisi**

By definition, microbes are so small they can only be seen with a microscope. But a newly described bacterium living in Caribbean mangroves shatters that rule. Its threadlike single cell can be the length of a peanut—up to 2 centimeters long, 5000 times bigger than many other microbes. And whereas the genetic material of other bacteria floats freely within the cell, the huge genome of this giant is encased in a membrane, like that of more sophisticated cells including those in the human body.

Unveiled in a preprint posted bioRxiv last month, the organism drew astonished reactions. "Fantastic and eye-opening," says Victor Nizet, a physician scientist at the University of California, San Diego, who studies infectious diseases. "When it comes to bacteria, I never say never, but this one for sure is pushing what we thought was the upper limit [of size] by 10-fold," adds Verena Carvalho, a microbiologist at the University of Massachusetts, Amherst.

Aside from breaking size records, the bacterium, with its elaborate internal structure, "could be a missing link in the evolution of complex cells," says Kazuhiro Takemoto, a computational biologist at the Kyushu Institute of Technology. Researchers have long thought that only eukaryotes, from yeast to most forms of multicellular life, package their DNA in a nucleus and compartmentalize various cell functions into vesicles called organelles.

When Olivier Gros, a marine biologist at the University of the French Antilles, Pointe-à-Pitre, came across the strange organism growing as thin filaments on decaying mangrove leaves in a local swamp a decade ago, he had no idea what it was. Not until 5 years later did he and colleagues examine its DNA and realize the filaments were actually bacteria. And they didn't appreciate how special the microbes were until more recently, when Gros's graduate student Jean-Marie Volland took up the challenge of trying to characterize them.

Other microbes, such as slime molds and blue-green algae, form similar filaments, made up of many cells stacked together. But a variety of microscopy and staining methods made it clear the mangrove filaments were each just one enormous cell. This "was something we didn't believe … at first," recalls Volland, now a marine biologist at Lawrence Berkeley National Laboratory.

The largest specimen of this new bacterium so far stretched 2 centimeters, but Carvalho thinks they could grow even bigger if not trampled, eaten, blown by wind, or washed away by a wave. Volland and his colleagues also found that each cell includes two membrane sacs, one of which contains all the cell's DNA, like the nucleus of a eukaryotic cell.

A new bacterium's single-cell filaments are visible next to a dime.

"Perhaps it's time to rethink our definition of eukaryote and prokaryote!" says Petra Levin, a microbiologist at Washington University in St. Louis.

The other sac may be the key to the microbe's size. Microbiologists used to think bacteria had to be small, in part because they rely on diffusion, which only works over short distances, to carry out respiration, transport nutrients into and around the cell, and get rid of toxins. Eukaryotes, in contrast, actively transport molecules through molecular pumps and channels.

Then in 1999, researchers discovered a giant sulfur-eating microbe roughly the size of a poppy seed off Namibia's coast. Its cellular contents are squished up against its outer cell wall by a giant water- and nitrate-filled sac. The sac means the bacteria's essential molecules only need to diffuse short distances because "only [along the edge] is the cell living," says Carvalho, who worked on this group of bacteria.

The new mangrove bacterium also has a huge sac—presumably of water—that takes up 73% of its total volume. That similarity and a genetic analysis led the research team to place it in the same genus as most of the other microbial giants and propose calling it *Thiomargarita magnifica*.

"What an excellent name!" says Andrew Steen, a bioinformatician at the University of Tennessee, Knoxville, who studies how microorganisms affect geochemical cycles. "Reading about it makes me feel exactly the same way as when I hear about an enormous dinosaur."

Its DNA proved extraordinary as well. When researchers at the Department of Energy Joint Genome Institute sequenced it, they found the genome was enormous, with 11 million bases harboring some 11,000 clearly distinguishable genes. Typically, bacterial genomes average about 4 million bases and about 3900 genes.

By labeling the DNA with fluorescent tags, Volland determined the bacterium's genome was so big because it includes more than 500,000 copies of the same stretches of DNA. No one really knows why. Protein production factories called ribosomes nestled inside the DNA-filled sac as well, likely making the translation of a gene's code into a protein more efficient. It's yet another way *T. magnifica* defies preconceptions about bacteria, says Chris Greening, a microbiologist at Monash University, Clayton.

"All too often, bacteria are thought of as small, simple, 'unevolved' life forms—so-called 'bags of proteins,'" Greening adds. "But this bacterium shows this couldn't be much further from the truth." ■

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