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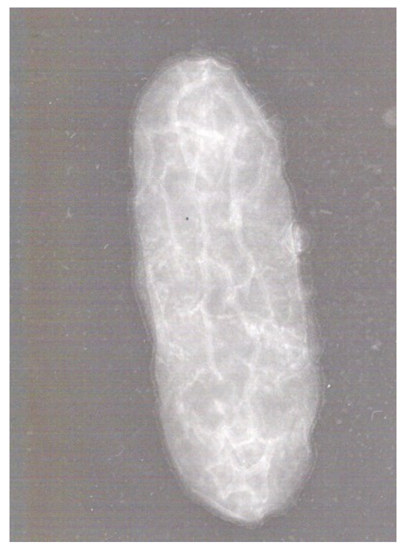
The Institute for Genomic Research

Scientists decipher genome of bacterium that remediates uranium contamination, generates electricity

Analysis of Geobacter sulfurreducens genes reveals new capabilities

Rockville, MD – Shining new light on the molecular secrets behind a microbe's capability to generate electricity and to help clean up radioactive contamination, scientists at The Institute for Genomic Research (TIGR) and collaborators have deciphered and analyzed the genome of Geobacter sulfurreducens.



bacterium Geobacter sulfurreducens

PHOTO CREDIT: University of Massachusetts

Full size image available through contact

The report, published in the December 12th issue of *Science*, found that the bacterium – a member of a family of organisms that can remove dissolved uranium from groundwater – possesses extraordinary capabilities to transport electrons and "reduce" metal ions as part of its energy-generating metabolism. The authors conclude that Geobacter "clearly has potential for bioremediation of radioactive metals and electricity generation."

Reduction is a chemical process during which electrons are added to metal ions. As a result, the metals become less soluble (dissolvable) in water and precipitate into solids, which are more easily removed. Small charges of electricity are also created through the reduction process.

Geobacter's capacity for reduction is enhanced by more than 100 of its genes that appear to encode for various forms of c-type cytochromes. Those are proteins which facilitate electron transfers and metal reduction during the organism's energy metabolism. The presence of those c-type cytochrome genes – the most and the greatest variety found so far in a bacterial species – are thought to give G. sulfurreducens a significant capacity and flexibility to reduce metals or create electricity.

By analyzing the genome, scientists discovered that the microbe has genes that give it the capacity to move towards metallic compounds. In addition, G. sulfurreducens – which scientists had previously regarded as an anaerobic organism (living in environments without oxygen) – also has genes that could allow it to function in the presence of oxygen under certain conditions.

"We've provided a comprehensive picture that has led to fundamental changes in how scientists evaluate this microbe," says Barbara Methé, the TIGR researcher who led the genome project and is the first author of the Science paper. "Research based on genome data has shown that this microbe can sense and move towards metallic substances, and in come cases can survive in environments with oxygen."

TIGR's collaborator on the project was Derek Lovley, a professor of microbiology at the University of Massachusetts, Amherst, who discovered the Geobacter family of bacteria and has led projects to assess their biology and their potential for bioremediation. The first Geobacter species to be discovered, G. metallireducens, was isolated from Potomac River sediments in 1987. G. sulfurreducens was isolated later from a soil sample in Oklahoma that was contaminated by hydrocarbons.

Lovley says, "Sequencing the genome of Geobacter sulfurreducens has radically changed our concepts of how this organism functions in subsurface environments." The genome analysis, he says, "revealed previously unsuspected physiological properties" of the bacterium and also gave scientists insight into the metabolic mechanisms that the organism uses to harvest electricity from the environment.

In a paper published earlier this year in Applied and Environmental Microbiology, the University of Massachusetts team reported that G. sulfurreducens – by means of reduction – could convert uranium that is dissolved in water to a solid compound called uraninite, which can then be removed. Scientists achieved that result by first mixing acetate, a food source for the bacteria that allowed them to multiply. After 50 days, the bacteria had removed about 70% of the uranium from a contaminated underground aquifer in this manner.

The G. sulfurreducens sequencing project was sponsored by the Natural and Accelerated Bioremediation Research and Microbial Genome Programs of the U.S. Department of Energy's Office of Science. The genome sequence is now serving as the basis for detailed investigations, supported by the Department's Genomes to Life program, into the ability of Geobacter to reduce radionuclides and metals and to generate electricity.

"The genome of this tiny microorganism may help us to address some of our most difficult cleanup problems and to generate power through biologically-based energy sources," says Secretary of Energy Spencer Abraham. "Geobacter is an important part of Nature's toolbox for meeting environmental and energy challenges. This genome sequence and the additional research that it makes possible may lead to new strategies and biotechnologies for cleaning up groundwater at DOE and at industry sites."

Comparing the Geobacter genome to that of another metal-reducing microbe, Shewanella oneidensis, the scientists found that they shared only two genes that have not yet been found in another species, and that about half of the electron-transport proteins in Geobacter have no direct counterpart in Shewanella. The results indicate that the expansion of gene families and the presence of novel genes are probable mechanisms involved in the advancing Geobacter's capabilities for metal reduction and electricity generation.

Last year, the U. Mass. team had reported in *Science* that Geobacter sulfurreducens and other

Geobacter species have the novel ability to harvest electricity from mud and other forms of waste inorganic matter. Scientists say that capability shows promise for such uses as powering electronic devices in remote locations such as the bottom of the ocean, as well as the conversion of sewage and renewable biomass to electricity and the development of improved microbial fuel cells.

One of the surprises from the G. sulfurreducens genome was the high percentage of its genes devoted to sensing environmental conditions and then regulating its metabolism in response to changes in the environment. Scientists say that sheds light into why Geobacter species are so successful in rapidly colonizing changing environments. The finding also suggests that Geobacter species are ideal candidates for the development of novel biosensors.

"Genomics is vital to the understanding of the molecular basis of energy production and bioremediation by microbes," says Claire M. Fraser, Ph.D., president of TIGR. "This project, as well as other TIGR genome studies of organisms of interest to environmental cleanup and energy production, provide the foundation for a wide range of useful research."

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The Institute for Genomic Research (TIGR) is a not-for-profit research institute based in Rockville, Maryland. TIGR, which sequenced the first complete genome of a free-living organism in 1995, has been at the forefront of the genomic revolution since the institute was founded in 1992. TIGR conducts research involving the structural, functional, and comparative analysis of genomes and gene products in viruses, bacteria, archaea, and eukaryotes.

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