Similar organisms deal with life in the extreme differently, research finds

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Life in extreme environments – hot acids and heavy metals, for example – can apparently make very similar organisms deal with stress in very different ways, according to new research from North Carolina State University.

One single-celled organism from a hot spring near Mount Vesuvius in Italy fights uranium toxicity directly – by eating the heavy metal and acquiring energy from it. Another single-celled organism that lives on a "smoldering heap" near an abandoned uranium mine in Germany overcomes uranium toxicity indirectly – essentially shutting down its cellular processes to induce a type of cellular coma when toxic levels of uranium are present in its environment.

Interestingly, these very different responses to environmental stress come from two organisms that are 99.99 percent genetically identical.

In a paper published this week online in Proceedings of the National Academy of Sciences, NC State researchers show that these extreme organisms – basic life forms called Archaea that have no nucleus and that are so tiny they can only be seen under a microscope – can teach us a lot about how living things use different mechanisms to adapt to their surroundings.

The researchers, led by Dr. Robert Kelly, Alcoa Professor of Chemical and Biomolecular Engineering at NC State, exposed two very close relatives of thermoacidophilic Archaea – they live in highly acidic environments with temperatures of more than 70 degrees Celsius, or about 160 degrees Fahrenheit – to pure uranium. One, *Metallosphaera sedula*, metabolized the uranium as a way to support its energy needs.

That in itself was surprising to Kelly and his fellow researchers, as it was the first report that an organism can directly use uranium as an energy source.

"This could be a new way to mine uranium using microorganisms to release the metal from ores – a process referred to as bioleaching," Kelly says of *M. sedula*.

Its genetic twin, *Metallosphaera prunae*, reacted very differently. When faced with pure uranium, it went into a dormant state, shutting down critical cellular processes that enable it to grow. When the toxic threat was removed, *M. prunae* rebooted its cellular processes and returned to its normal state.

Kelly hypothesizes that *M. prunae* is an offshoot of *M. sedula*, with just a small number of mutations, or changes, to its genome that allow it to react differently when faced with heavy-metal toxicity.

Kelly says the findings could also have implications for understanding how antibiotic resistance develops and operates in pathogens.

"We have come across a new model for how organisms learn how to live in an environment that would otherwise be deadly for them," he says.

Kelly adds that the study calls into question the ways that scientists classified living things before the rise of the genomic era.

"How do we classify microorganisms now that we can compare genomes so easily?" Kelly asks. "These are not different species by the classical definition because their genomes are virtually identical, but they have very different phenotypes, or lifestyles, when faced with stress."

More information: "Uranium extremophily is an adaptive, rather than intrinsic, feature for extremely thermoacidophilic Metallosphaera species" *Proceedings of the National Academy of Sciences*, www.pnas.org/cgi/doi/10.1073/pnas.1210904109

Abstract
Thermoacidophilic archaea are found in heavy metal-rich environments, and, in some cases, these microorganisms are causative agents of metal mobilization through cellular processes related to their bioenergetics. Given the nature of their habitats, these microorganisms must deal with the potentially toxic effect of heavy metals. Here, we show that two thermoacidophilic Metallosphaera species with nearly identical (99.99%) genomes differed significantly in their sensitivity and reactivity to uranium (U). Metallosphaera prunae, isolated from a smoldering heap on a uranium mine in Thüringen, Germany, could be viewed as a "spontaneous mutant" of Metallosphaera sedula, an isolate from Pisciarelli Solfatara near Naples. Metallosphaera prunae tolerated triuranium octaoxide (U3O8) and soluble uranium [U(VI)] to a much greater extent than M. sedula. Within 15 min following exposure to "U(VI) shock," M. sedula, and not M. prunae, exhibited transcriptomic features associated with severe stress response. Furthermore, within 15 min post-U(VI) shock, M. prunae, and not M. sedula, showed evidence of substantial degradation of cellular RNA, suggesting that transcriptional and translational processes were aborted as a dynamic mechanism for resisting U toxicity; by 60 min post-U(VI) shock, RNA integrity in M. prunae recovered, and known modes for heavy metal resistance were activated. In addition, M. sedula rapidly oxidized solid U3O8 to soluble U(VI) for bioenergetic purposes, a chemolithoautotrophic feature not previously reported. M. prunae, however, did not solubilize solid U3O8 to any significant extent, thereby

not exacerbating U(VI) toxicity. These results point to uranium extremophily as an adaptive, rather than intrinsic, feature for Metallosphaera species, driven by environmental factors.

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