Metal-loving microbes offer a green way to refine rare earth elements

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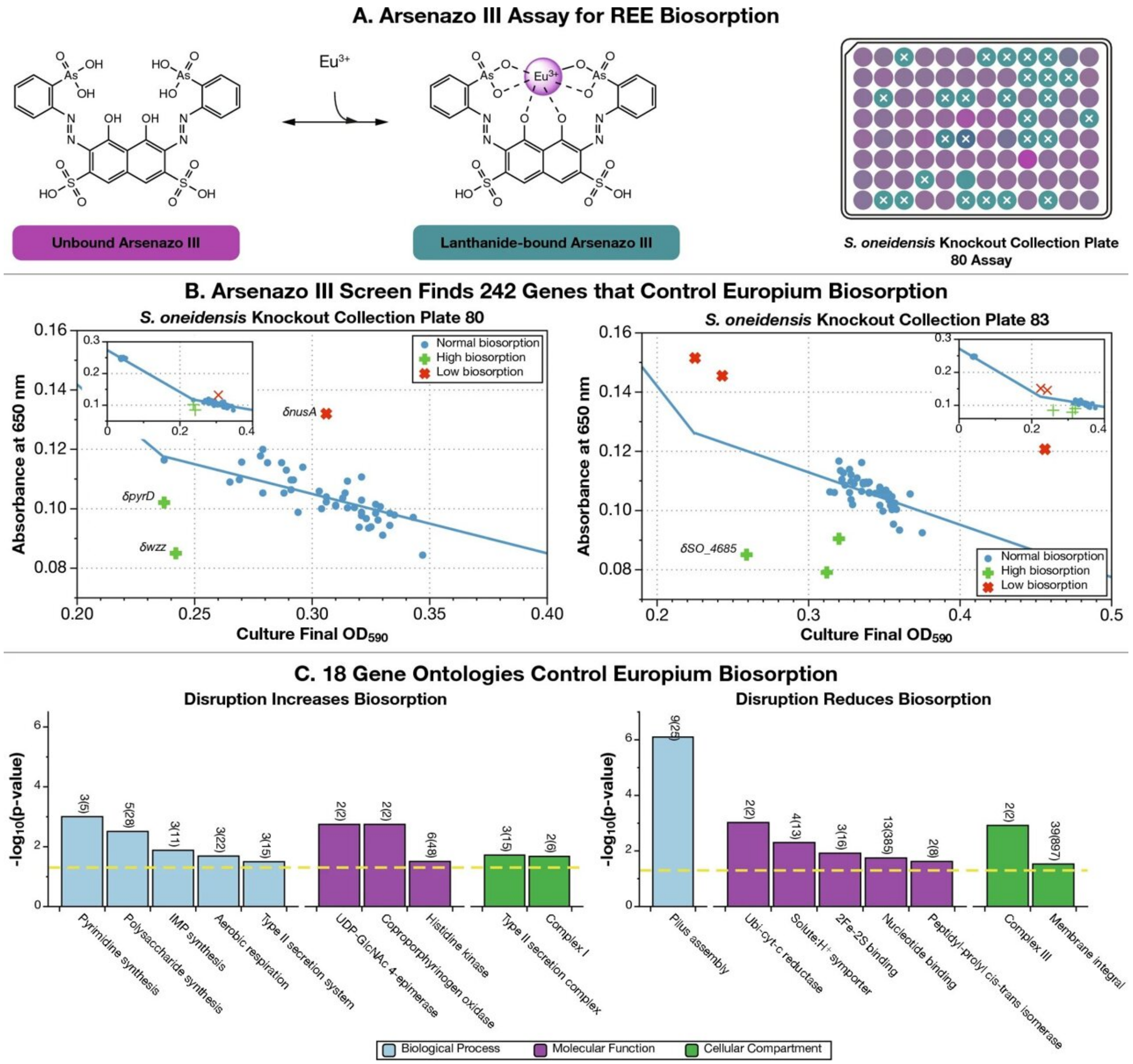

Screening the *Shewanella oneidensis* whole genome knockout collection finds

242 genes representing 18 gene ontologies that control Eu-biosorption. We used the Arsenazo III (As-III) competitive assay for europium- (Eu-) binding to screen 3,373 unique members of the *S. oneidensis* whole genome knockout collection to identify mutants with modified REE-biosorption capability. (**A**) Unbound As-III absorbance peaks at ≈ 530 nm (resulting in a cyan color), while Eu-bound As-III (proposed structure) absorbance peaks at ≈ 650 nm (purple). Right panel shows a computer-generated image of a sample assay plate derived from spectroscopic data. Higher biosorption by *S. oneidensis* results in a lower concentration of Eu-As-III and hence lower 650 nm absorption (the well will be more purple-colored) while lower biosorption results in a higher concentration of Eu-As-III (the well will be more cyan-colored). Additional information on the high-throughput screen is presented in Online Methods and Fig. S1. (**B**) The As-III screen found 242 genes that control Eu-biosorption (Dataset S1). The largest source of Eu-biosorption variability in the screen is due to bacterial density differences between mutants. For most mutants, the optical density of the culture at the start of the biosorption screen will map onto As-III absorption at 650 nm by a linear piecewise function (shown as a blue solid line). Mutants shown as red diagonal crosses had significantly less biosorption than the plate average. Mutants shown as green horizontal crosses had significantly higher biosorption than the plate average (mutants shown as blue dots are not significantly different from the average). (**C**) Gene ontology enrichment analysis found that 18 ontologies were enriched with mutants discovered by the As-III screen. The yellow dotted line indicates a *p*-value of 0.05. We only show results with *p*-values below 0.05 and gene ontologies with > 1 representative mutant. Numbers above each bar indicate the number of significant biosorption genes within each ontology in the screen results relative to the number in the *S. oneidensis* genome. Precise definitions of each gene ontology are shown in Dataset S2. IMP: inosine 5′-monophosphate; UDP-GlcNAc 4-epimerase: UDP-N-acetylglucosamine 4-epimerase; Ubi-cyt-c reductase: ubiquinol-cytochrome-c reductase. Credit: *Scientific Reports* (2023). DOI: 10.1038/s41598-023-42742-6

Rare earth elements are essential components of electric cars, wind turbines and smartphones. Retrieving these metals from raw ore requires processing with acids and solvents.

Now, Cornell scientists have characterized the genome of Shewanella oneidensis—a metal-loving bacteria with an affinity for rare earth elements—to replace the harsh chemical processing with a benign practice called biosorption.

Their research, "Genomic characterization of rare earth binding by Shewanella oneidensis," was published in *Scientific Reports*.

"The problem with the current methods of rare earth element purification is that they rely heavily on organic solvents and harsh chemicals," said senior author Buz Barstow, assistant professor of biological and environmental engineering in the College of Agriculture and Life Sciences. "These methods are costly and environmentally damaging. Here we have a green alternative that uses microbes to selectively adsorb and purify rare earth elements, eliminating the need for harmful chemicals. We're making the purification process greener."

The microbe selectively adsorbs—or clings—to these rare earth elements, making it an ideal candidate to carry out an eco-friendly purification procedure.

Generally, S. oneidensis prefers dining on the f-block elements residing in the sixth row of the periodic table, known as the lanthanides. Specifically, the microbe favors europium.

Characterizing the S. oneidensis's genome allows scientists to tweak its preference for processing the other rare earth elements.

The scientists screened 3,373 parts of the S. oneidensis genome and found 242 genes that influence it.

The mutant genes found in the bacteria by the scientists can reduce the length of that rare earth element purification process by almost onethird—compared with the wild variety of S. oneidensis—and offers a roadmap for honing this green method.

"Our work points to key genes that control membrane composition that are traditionally responsible for cell adhesion and biofilm formation in rare earth element biosorption," said lead author Sean Medin, a doctoral student in Barstow's lab and a founder of REEgen. "This work advances the mechanisms responsible for rare earth elements biosorption in S. oneidensis."

This work has the potential to make processing rare earths cleaner and scalable, Medin said. "Currently all the purification of rare earth elements is done abroad, due to stringent environmental regulations and high infrastructure costs of building a separations plant," he said. "Our process would make environmentally harmful solvents unnecessary."

"Our process potentially would be significantly less land- and capital-intensive to build," Medin said, "as our separations could be done with repeated enrichment through columns full of immobilized bacteria instead of mixer-settler plants that are miles long."

While the technology is still in development, the researchers are optimistic about potential impact. This technology could help develop a stable U.S. supply of rare earth elements for technology and defense applications, said Barstow, a faculty fellow at the Cornell Atkinson Center for Sustainability.

The group anticipates creating a pilot-scale purification system by 2028.

"This research gives us a genetic blueprint for making a microbe that lets allows us to purify rare earths in an environmentally friendly way," Barstow said. "If you want to reduce climate change, this allows us to build a sustainable energy infrastructure—things like improving electric vehicles, wind turbines, creating superconductors and offering high-efficiency lighting. That's the ultimate payoff."

More information: Sean Medin et al, Genomic characterization of rare earth binding by Shewanella oneidensis, *Scientific Reports* (2023). DOI: 10.1038/s41598-023-42742-6

Provided by Cornell University

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