Gene Expression in Cadmium Sulfide Biological-Nanoparticle Hybrids

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Abstract

Through millions of years of evolution, bacteria have developed unique and complex ways to survive, allowing them to inhabit ecosystems all over the Earth, including places with high metal ion concentrations. Bacteria have developed many survival mechanisms to evade metal ion toxicity. Survival mechanisms to evade metal toxicity include the ability to transform metal ions into nanoparticles. When metal ions bind to other constituents to form nanoparticles, the metal ion concentrations in the environment can be lowered, in turn lessening the likelihood of cells encountering toxic concentrations of metals. These nanoparticles can be expelled by the bacteria into the environment, remain inside the bacteria, or attached to the cell surface.

Bacteria and metal nanoparticles have many useful functions on their own. Furthermore, these functions can be combined when the two come together. Cells that produce metal nanoparticles that remain attached to their surface are referred to as biological-nanoparticle hybrids (bionanohybrids), as shown in the scanning electron image in Fig. 1. Surface-associated nanoparticles (SANs) can enhance biological functions, enabling a variety of new applications related to bioremediation, energy production and storage, and agricultural and medical advances. Bionanohybrid research also creates new opportunities to investigate microbial communities, synthetic biology, and the origins of life.

Metal-sulfide SANs are of particular interest due to their semi-conductor abilities and examples of their generation by multiple bacterial species. This includes bacteria inhabiting metal-rich extreme environments like the Mariana Trench, to bacteria found in the human gut (such as *E. coli*). While these bacteria are very different, they do share in common the cysteine desulfhydrase enzyme—which plays a crucial role in the formation of metal-sulfide bionanohybrids. Cysteine desulfhydrase converts the amino acid cysteine into sulfide that then reacts with environmental metal cations to create metal sulfide nanoparticles (Raouf Hosseini and Nasiri Sarvi 2015). Under the right conditions (e.g., optimal ratios of metal and cysteine to cell density and growth phase), the resulting nanoparticles remain attached to the surface of the cell, as shown in Fig. 1 (Barnes et al. 2022).

Despite the emergence of bionanohybrid applications, very little is known about how the bionanohybrid lifestyle impacts cells. This project aims to uncover some of the fundamental questions regarding bionanohybrid gene expression by analyzing the RNA transcripts from *E. coli* K-12 cells with different degrees of cadmium sulfide (CdS) SAN coverage. Gene expression studies may reveal fundamental differences between bionanohybrids and uncoated bacteria, potentially informing development of industrially advantageous bacteria strains that can produce more SANs.

Gel electrophoresis and/or density gradient centrifugation will be used to separate cells that are uncoated, lightly coated, medium coated, and heavily coated proir to RNA isolation and purification. Scanning electron microscopy will confirm SAN coverage in these different fractions. RNA sequencing will indicate if there are any differences in gene expression between uncoated cells and bionanoybrids, as well as examine if SAN cell coverage has any relationship to gene expression. This research promises to open doors to new applications related to bionanohybrids while expanding our knowledge of microbial biology.

Keywords

Microbiology, Nanoscience, Transcriptomics, Microbe-metal interactions

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Conflicts of interest

The authors have declared that no competing interests exist.

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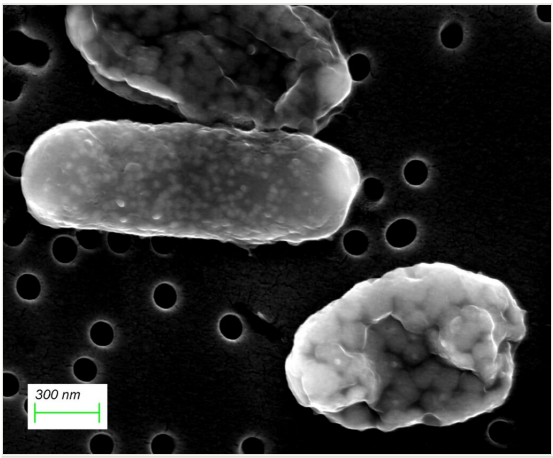

Figure 1.

SEM image of three *E. coli* K-12 bionanohybrids covered in CdS SANs.