Chemical Engineering

We now know that some anaerobic bacteria gain energy through extracellular electron transport to natural minerals or synthetic electrodes that serve as electron acceptors for respiration outside the cells. In addition to the fundamental implications for physiology and microbial communication, a physics-based understanding of this extracellular respiration will impact the transmission of signals at hybrid living/synthetic interfaces.

But how can a bacterium transport electrons to an external surface? In contrast to solid-state systems (e.g. metals and semiconductors), where the charge transport physics is well understood, comparatively little is known about the physics of biological charge transport over cellular length scales. In this talk we will describe how bacteria organize redox sites on outer cell membranes, and along quasi-one-dimensional filaments known as bacterial nanowires, to facilitate long-range charge transport. The approaches taken include microfluidic fluorescence assays, gene expression profiling, kinetic Monte Carlo simulations, single-cell electrochemical measurements, scanning tunneling microscopy, and nanofabrication-enabled measurements of transport along individual bacterial nanowires produced by the bacterium Shewanella oneidensis MR-1. Based on these measurements, we propose that extracellular respiration is facilitated by an incoherent multistep charge hopping mechanism along redox chains. Finally, we will describe in vivo measurements demonstrating that the S. oneidensis MR-1 nanowires are lipid-based extensions of the outer membrane and periplasm that include the multiheme cytochromes responsible for extracellular electron transport. Redox-functionalized membrane and vesicular extensions may represent a general microbial strategy for electron transport and energy distribution.

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Moh El-Naggar is an assistant professor of physics and biological sciences at the University of Southern California. As a biophysicist, El-Naggar investigates energy conversion and charge transmission at the interface between living cells and synthetic surfaces. His work, which has important implications for cell physiology and astrobiology, may lead to the development of new hybrid materials and renewable energy technologies that combine the exquisite biochemical control of nature with the synthetic building blocks of nanotechnology. El-Naggar was awarded the Presidential Early Career Award for Scientists and Engineers (PECASE) by President Obama in 2014. In 2010, El-Naggar received a Department of Defense Young Investigator Program (YIP) Award, from the Air Force Office of Scientific Research. In 2012, he was named one of Popular Science's 'Brilliant 10', the magazine's annual honor roll of the 10 most promising young scientists whose innovations will change the world. More information about El-Naggar’s research can be found at http://nanobio.usc.edu

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