Energy Metabolism and Uranium (VI) Reduction by *Desulfovibrio*

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Abstract

Sulfate reducing bacteria (SRB) of the genus *Desulfovibrio* can reduce uranium (VI) to uranium (IV) enzymatically. The reduction of U(VI) to U(IV) alters the solubility state of the uranium ion from a soluble to an insoluble, and therefore less biologically available, species. Because SRB are commonly found in uranium contaminated groundwater and soil, it is theoretically possible that we could use them to bioremediate uranium contaminated environments. However, before we attempt to manipulate the system, we must first understand the SRB genes and enzymes involved in uranium reduction and energy metabolism. Previous *in vitro* work by Lovley and coworkers suggested that the biochemical pathway for U(VI) reduction by *Desulfovibrio* was hydrogenase-to cytochrome c_3-to U(VI). In this pathway, cytochrome c_3 was suggested to be the sole U(VI) reductase. First, we tested this model *in vivo* with strains carrying mutations in the dominant Fe-hydrogenase or cytochrome c_3. We determined that the Lovley model is the primary pathway for U(VI) reduction *in vivo* when hydrogen gas is the electron donor; however, alternate pathways utilizing lactate or pyruvate for U(VI) reduction exist. In addition, at least one other cellular protein must be capable of acting as a U(VI) reductase in cytochrome c_3-lacking cells. Second, we grew *Desulfovibrio desulfuricans* G20 in the presence of a non-lethal concentration of uranium in order to

understand some of the effects of uranium on its physiology. By doing so, we showed that G20 cells grown in the presence of uranium are impaired for U(VI) reduction. While exploring this observation, we found that the electron carrier protein cytochrome c_3 tightly adsorbs to insoluble uranium (IV) oxide, as well as copper oxide and iron oxide. Finally, we observed that sodium ions play an important role in energy metabolism and antibiotic resistance of *Desulfovibrio* when grown on lactate sulfate medium. We speculate that *Desulfovibrio* is capable of coupling lactate, but not pyruvate, oxidation and subsequent electron transport to the generation of a transmembrane sodium gradient. We propose that *Desulfovibrio* uses this "sodium circuit" to complement the proton motive force, for growth and for the efflux of some toxic compounds.