Going Wireless: Fe(III) Oxide Reduction without Pili by Geobacter sulfurreducens Strain JS-1

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Previous studies have demonstrated that the electrically conductive pili of Geobacter sulfurreducens strain DL-1 are essential for optimal extracellular electron transfer to Fe(III). G. sulfurreducens strain KN400 reduces poorly crystalline Fe(III) oxide more rapidly than strain DL-1. In order to further study the mechanisms for Fe(III) oxide reduction in KN400, the gene for PilA, the structural pilin protein, was deleted. Deletion of the PilA gene inhibited Fe(III) oxide reduction. However, slow rates of Fe(III) reduction were detected after extended (> 30 days) incubation in the presence of Fe(III) oxide. After seven consecutive transfers the adapted PilA-deficient strain, designated strain JS-1, reduced Fe(III) oxide as fast as the wild type. Microarray, proteomic, and gene deletion studies indicated that this adaptation was associated with greater production of the c-type cytochrome PgcA, which was released into the culture medium. Multiple lines of evidence suggested that PgcA acted as an electron shuttle, promoting electron transfer from the outer cell surface to Fe(III) oxides in strain JS-1. In contrast, PgcA was not required for effective Fe(III) oxide reduction in the wild-type strain. Strain JS-1 competed well with the wild-type strain when both were grown together on Fe(III) oxide. However, when 50% of the culture medium was replaced with fresh medium every three days, the wild-type strain out-competed strain JS-1. This result was attributed to the need for JS-1 to continuously replace the PgcA being removed from the medium, putting JS-1 at a competitive disadvantage, similar to the apparent selection against electron shuttle producing Fe(III) reducers in most soils and sediments. The long period necessary for the PilA-deficient strain of KN400 to adapt for effective Fe(III) oxide reduction, and the fact that deleting the gene for PgcA in the wild-type had no impact on Fe(III) oxide reduction, suggest that pili-mediated Fe(III) oxide reduction is more representative of the mechanism by which G. sulfurreducens reduces Fe(III) oxide in soils and sediments. The ability of KN400 to adapt to the loss of pili demonstrates that caution may be warranted in extrapolating to natural environments the mechanisms for Fe(III) oxide reduction elucidated in studies with cultures maintained for long periods under laboratory conditions that do not mimic those found in soils and sediments. The substantial plasticity encoded in the genomes of microorganisms capable of extracellular electron transfer, coupled with unnatural laboratory selection pressures, have the potential to lead to physiological responses that might not be found in natural environments.