Wiring the cell wall: Surface multiheme *c*-type cytochromes from *Thermincola potens* and implications for dissimilatory metal reduction by Gram-positive bacteria

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Background

Almost nothing is known about the mechanisms of dissimilatory metal reduction by Gram-positive bacteria, although they have been shown to be the dominant species in some environments. Thermincola potens strain JR was isolated from the anode of a microbial fuel cell inoculated with anaerobic digester sludge and operated at 55 °C. Preliminary characterization revealed that T. potens coupled acetate oxidation to the reduction of hydrous ferric oxides (HFO) or an analog of the redox active components of humic substances, anthraquinone-2,6-disulfonate (AQDS). The genome of T. potens was recently sequenced, and the abundance of multiheme c-type cytochromes (MHCs) is unusual for a Gram-positive bacterium.

Results and Conclusions

We present evidence from trypsin shaving LC-MS/MS experiments and surface-enhanced Raman spectroscopy (SERS) that indicates the expression of a number of MHCs during T. potens growth on either HFO or AQDS and that several MHCs are localized to the cell wall or cell surface of T. potens. Furthermore, one of the MHCs can be extracted from cells with low pH or denaturants suggesting a loose association with the cell wall or cell surface. Electron microscopy does not reveal an S-layer, and the precipitation of silver metal on the cell surface is inhibited by cyanide, supporting the involvement of surface-localized redox-active heme proteins in dissimilatory metal reduction. These results are the first direct evidence for cell-wall associated cytochromes and MHC involvement in conducting electrons across the cell envelope of a Gram-positive bacterium.

Early Earth differentiation: Before and after Earth formation

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An increasingly long list of isotopic differences between Earth and most types of chondritic meteorites is straining the traditional model of a bulk Earth composition that has chondritic abundances of the refractory lithophile elements. Some isotopic differences (e.g. Cr, Mo, Ba) reflect an imperfect mix of the various nucleosynthetic contributions to the Solar nebula. Oxygen isotope differences between Earth and meteorites appear to reflect photochemically induced isotope variation in the nebula with differential sampling of volatile and refractory components by meteorites and terrestrial planets. Both causes of isotope variation point to chemical variability in the Solar nebula that was inherited by the terrestrial planets. The composition of the bulk-silicate-Earth predicted from the difference in ^{142}Nd/^{144}Nd between Earth and chondrites is most consistent with the loss of a component produced by low-pressure melting. Compared to chondritic Earth models, the calculated non-chondritic Earth composition has 30-35% lower concentrations of heat producing elements (U, Th, K), eliminating the need for ^{40}Ar retention in the mantle, and implying that incompatible element depleted material is the volumetrically dominant mantle component.

Variability in the relative abundance of daughter products (^{142}Nd, ^{182}W) of short-lived nuclides in Archean/Hadean rocks points to preservation of chemical heterogeneity within Earth's interior that was created by differentiation events occurring prior to 4.3-4.4 Ga. The declining ^{142}Nd variability between 3.8 and 3.5 Ga must reflect mixing within the silicate mantle. While this explanation might also apply to the recent discovery of ^{182}W variability, another option is that the W isotopic variability reflects addition of siderophile elements to Earth's mantle by continued late accretion. The composition of Hadean crust exposed in the Nuvvuagittuq greenstone belt and the inferred composition of the host rocks of the western Australia Hadean zircons point to the beginning of crust forming processes similar to those acting through the Archean within 100-200 Ma of Earth formation.