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# ABSTRACT

The lanthanide metals (Ln) exhibit strong Lewis acidity, conducting, magnetic and, fluorescent properties, and redox chemistry, making them indispensable for modern and emerging technologies (1). The low aqueous solubility of Ln in natural environments led enzymologists and chemists to reason that their bioavailability was limited. However, a direct link has recently been established for Ln in methylotrophic bacteria, via pyrroloquinoline quinone (PQQ)-dependent methanol dehydrogenase (MeDH) during methane and methanol oxidation (2, 3) or via ethanol dehydrogenase (EtDH), ExaF (4) during methanol and ethanol growth.

Our work focuses on the impact of Ln on methylotrophic metabolism of Methylobacterium extorquens AM1. Using RNAseq analysis, we identified genes encoding two PQQ-dependent alcohol dehydrogenases that were upregulated in the presence of Ln, XoxF-MeDH and ExaF-EtDH. We have purified and biochemically characterized these enzymes, showing that they incorporate Ln metals in the active site, and that their catalytic properties are altered by different Ln ligands. XoxF-MeDH exhibits methanol oxidation capacity similar to reported non-Ln-dependent enzymes. ExaF, however, is the most efficient PQQ-dependent EtDH reported to date, extending Ln-dependent enzymes to multicarbon metabolism. Both enzymes also have the capacity to oxidize formaldehyde with relatively high efficiency, suggesting a secondary role in methylotrophy. In concert with our biochemical characterizations, in vivo growth experiments indicate that XoxF and ExaF can utilize a variety of Ln to differing degrees for catalysis and growth with methanol. The discovery of Ln-dependent enzymes such as XoxF and ExaF demonstrate that Ln play an integral role in methylotrophy and multicarbon metabolism. We are currently investigating methods to identify Ln-dependent enzymes in methylotrophic and non-methylotrophic bacteria, including structural analysis of XoxF and ExaF.

REFERENCES

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4. N. M. Good et al., Pyrroloquinoline Quinone-Containing Ethanol Dehydrogenase in Methylobacterium extorquens AM1 Extends Lanthanide-Dependent Metabolism to Multi-Carbon Substrates. J. Bacteriol. 198, 3109–3118 (2016).

# COMMUNICATION OUTCOMES

I work with a team of microbial physiologists studying metabolism of methylotrophs, microbes that can use one-carbon compounds as a sole source of carbon and energy. Recently, it was discovered that these microorganisms use rare earths, specifically lanthanides, during methane and methanol metabolism. This observation is very exciting because lanthanides are highly insoluble, scarce in pure form and were not thought to be involved in bacterial metabolism. I am very much looking forward to introducing the Wind River audience to lanthanide-dependent microbial metabolism.

Our lab is poised to define the metabolic network necessary and biochemical role of these metals during growth of Methylobacterium extorquens, a microbe capable of metabolism one-carbon compounds such as methanol. I have defined the transcriptomic profile under lanthanide-dependent methanol growth from which I was able to identify lanthanide-dependent enzymes that have never been described. I then kinetically characterized one of these enzymes, an alcohol dehydrogenase named ExaF. A significant contribution of my work is that through kinetic analysis I was able to define that lanthanide-biochemistry is not unique to one-carbon metabolism, as ExaF is an ethanol dehydrogenase. I have shown that lanthanides increase catalytic efficiency of ExaF, and I am now exploring their oxidation capacity. I have also purified a methanol dehydrogenase, XoxF1 and have kinetically characterized the effect of diverse lanthanides on the enzyme. Further, I have established a collaboration with Dr. Jian Hu in the Biochemistry department here at MSU and together we already obtained a crystal structure.

These results are very recent, and as methylotrophy is a relatively small field of study, our work has had limited exposure. Further, lanthanide-dependent metabolism is a new area of study in microbiology, and attending Wind River 2017 will provide me the opportunity to share our most recent work with the general Prokaryotic Physiology community. By giving a research talk at the conference I will practice my communication skills with a broad, diverse, highly knowledgable audience, and excite other scientists, young and old, to discuss the impacts of lanthanides on microbial metabolism. Wind River is highly appealing to me precisely because the audience is comprised of prokaryotic biologists with a wide-range of expertise. Lanthanides are of interest beyond prokaryotic biology and we have ongoing research projects using plant-microbe model systems and biometallurgy applications, and I believe these applications will pique the interest of attendees as well. Finally, through discussing my projects with the attendees at Wind River, I will strengthen existing professional connections (i.e. plenary speaker Dr. Matt Parsek, who was on my Ph.D. committee) as well as make new ones. Overall, my hope is that by the end of the conference I will have insipred many of the attendees to add lanthanides to their culture media and observe what happens next.