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Conference Abstract

# Non-Deterministic Factors Affect Competition Between Thermophilic Autotrophs from Deep-Sea Hydrothermal Vents

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## Abstract

Hydrothermal vents provide windows into the rocky subseafloor on Earth and serve as terrestrial analog sites for extraterrestrial environments. By studying patterns of community assembly in hydrothermal vents and using geochemical models, we can better understand how the deep-sea biosphere contributes to local and global biogeochemical cycling and gather valuable information about how similar communities may arise on Earth and beyond Earth. One prevailing thought is that vent microbial community assembly is driven by deterministic factors such as the thermodynamic favorability of redox reactions. We hypothesized that subsurface microbial communities may also be significantly influenced by other factors, such as differential cell yields, varying optimal growth temperatures, and stochasticity.

At Axial Seamount in the Pacific Ocean, $H_2$-consuming methanogens of the genera *Methanocaldococcus* ($T_{opt}$ 82°C) and *Methanothermococcus* ($T_{opt}$ 65°C) and $H_2$-consuming sulfur reducers of the genus *Desulfurobacterium* ($T_{opt}$ 72°C) are the most abundant autotrophs that grow optimally at or above 65°C (Fortunato et al. 2017). At one low-temperature hydrothermal vent site, Marker 113, methanogens are the predominant thermophilic autotrophs while at another site, Marker 33, thermophilic autotrophic sulfur reducers predominate. There is no apparent geochemical or thermodynamic explanation

for the differences in community composition. In this study, we performed a series of co-culture competition experiments using *Methanocaldococcus jannaschii*, *Methanothermococcus thermolithotrophicus*, and *Desulfurobacterium thermolithotrophum* HR11 as representative methanogens and sulfur reducers common to hydrothermal vents to explain the variations in community composition between thermophilic autotrophs.

*M. jannaschii* increases its cell yield (cells produced per mole of $CH_4$ produced) when grown on very low $H_2$ concentrations as part of a growth rate-growth yield tradeoff (Topçuoğlu et al. 2019). This increase in cell yield could provide methanogens with a competitive growth advantage over $H_2$-consuming sulfur reducers, who otherwise catalyze a more thermodynamically favorable growth reaction. Competition co-culture experiments were conducted between *M. jannaschii* and *D. thermolithotrophum* at 72°C and between *M. thermolithotrophicus* and *D. thermolithotrophum* at 65°C, both at 1:1 ratios and initial aqueous $H_2$ concentrations of 1.2 mM (high $H_2$) and 85 µM (low $H_2$) to determine the effects of temperature and $H_2$ availability on autotroph competition. For both methanogens, the growth rate, maximum cell concentration, and total $CH_4$ produced decreased when they were grown in co-culture, at low $H_2$, or both relative to monocultures grown with high $H_2$. The methanogen cell yields generally increased in co-culture and at low $H_2$. At both experimental temperatures, the growth rate of *D. thermolithotrophum* remained unchanged in co-culture and at low $H_2$ relative to monocultures but the maximum cell concentration decreased in co-culture relative to monocultures at both $H_2$ concentrations. However, at low $H_2$, both in mono- and co-culture, there was no detectable $H_2S$ produced by the sulfur reducer suggesting a significant shift in growth yield. At both temperatures and $H_2$ concentrations, the sulfur reducer reached higher cell concentrations than the methanogens.

Stochasticity or vent fluid chemistry could lead to early colonization of a vent by methanogens followed by niche exclusion of autotrophic sulfur reducers due to a numerical advantage of the methanogens. Therefore, competitive co-culture experiments were run as before at high $H_2$ with varying initial methanogen:sulfur reducer ratios. At 72°C, *D. thermolithotrophum* reached the same maximum cell concentration and produced the same amount of $H_2S$ in monoculture and co-culture even when the methanogens initially outnumbered the sulfur reducer up to 10,000-fold. *M. jannaschii* reached a lower maximum cell concentration and produced less $CH_4$ in all co-cultures relative to growth in monoculture. At 65°C, *D. thermolithotrophum* reached the same maximum cell concentrations and produced the same amount of $H_2S$ in monoculture and co-culture when the methanogens initially outnumbered the sulfur reducers up to 100-fold. However, when the methanogens initially outnumbered the sulfur reducers 1,000-fold, *M. thermolithotrophicus* grew as well as in monoculture and the maximum cell concentration and amount of $H_2S$ produced by *D. thermolithotrophum* was significantly lower than in monoculture and the other co-culture conditions.

In conclusion, both methanogens and sulfur reducers shift their redox reactions away from $CH_4$ and $H_2S$ production, respectively, and towards biomass production when $H_2$ is limiting. This should be accounted for in thermodynamic predictive models. Furthermore, a combination of growth temperatures lower than the optimum of sulfur reducers and high initial methanogen cell concentrations relative to sulfur reducers can lead to a long-term predominance of methanogens over autotrophic sulfur reducers in vent environments through niche exclusion.

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## Presented at

Oral

## Conflicts of interest

The authors have declared that no competing interests exist.

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