Does carbon or energy limit chemosynthetic mixotrophic microbial growth?

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Microorganisms mediate many of the biogeochemical processes that control important ecosystem functions. The ability to accurately model these processes is paramount for elucidating the biogeochemical controls on microbial growth dynamics and function within populations and across communities. In dark subsurface environments, catabolic energy is derived from the oxidation of organic and/or inorganic electron donors (i.e., chemoorganotrophy and chemolithotrophy) coupled to the reduction of electron acceptors which fuels microbial growth (i.e., anabolism) and maintenance. Within a metabolism, catabolism is linked to anabolism via the microbial growth yield (Y) parameter, which can be predicted using bioenergetics-based semi-theoretical methods. Consequently, in energy-limited environments, bioenergetics can be implemented into biomass-explicit environmental (e.g. reactive transport) models to predict microbial growth and activity. To date, the ability to predict Y has only been demonstrated for single electron donor metabolisms. However, in the presence of multiple electron donors, microorganisms can gain energy by oxidizing a mixture of two or more electron donors. Here, we successfully adapted and applied our recently derived and validated Gibbs Energy Dynamic Yield Method (GEDYM) to predict Y values using published continuous culture studies of mixotrophic microorganisms grown on mixtures of electron donors. Moreover, we show that the relative rates of electron donor consumption regulate the carbon source used for growth (i.e., heterotrophy and autotrophy). Given that mixotrophic growth is likely a widespread microbial growth strategy, this work provides a flexible new theoretical framework to model carbon cycling and microbial growth in environments such as the terrestrial subsurface.