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Methanol bridges syntrophic symbiosis

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Methanogenic degradation of organic matter plays a vital role in the global carbon cycle. In methanogenic ecosystems, organotrophic bacteria and methanogenic archaea (typically hydrogenotrophic or acetoclastic methanogens) cooperatively drive chemical transformations via interspecies H_2/formate transfer or direct interspecies electron transfer to combat energetic and thermodynamic limitations, an interaction termed syntrophy. However, the ubiquity of methylotrophic methanogens in subsurface methanogenic ecosystems, implies the prominence of methylated compounds in the ecology and carbon cycling of such habitats, yet the origin of these chemicals remains enigmatic given that natural sources are often absent. Here, we discovered a novel formate metabolism in a subsurface-derived thermophilic anaerobe that generates methanol as its main product ("methanologenesis"), the first example of a catabolism that produces methanol *de novo* (*i.e.*, without methylated compounds as an input). Cultivation-based investigation showed that formate-driven methanologenesis is thermodynamically inhibited by accumulation of methanol but can overcome this limitation by handing off methanol to an obligately methylotrophic methanogen partner. This novel symbiosis represents a fourth mode of thermodynamically motivated cross-feeding ("syntrophy"), which has, thus far, been thought to only be mediated by three paths and shows an overlooked syntrophic role of methylotrophic methanogens in organic matter mineralization (Figure 1). The unusual metabolism and syntrophy provide unprecedented insight into the enigmatic presence of methylated compounds in subsurface methanogenic ecosystems and how organisms can symbiotically thrive at the thermodynamic limit.

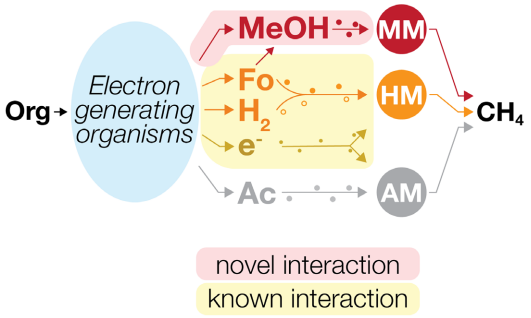

Figure 1. Schematic diagram of methylated compounds involving methanogenic organics degradation. Proposed formate-based methylotrophic pathway is shown in red. MM, methylotrophic methanogens; HM, hydrogenotrophic methanogens; AM, acetoclastic methanogens. Org, organics; MeOH, methanol; Fo, formate; Ac, acetate