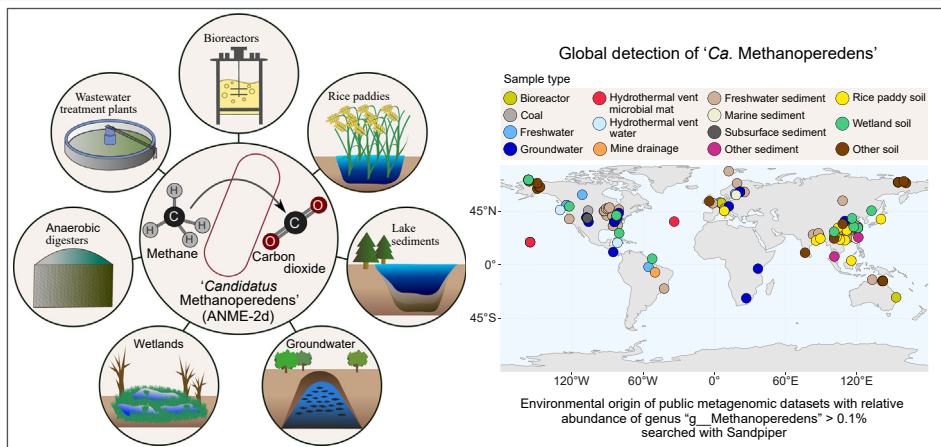


'Candidatus Methanoperedens'

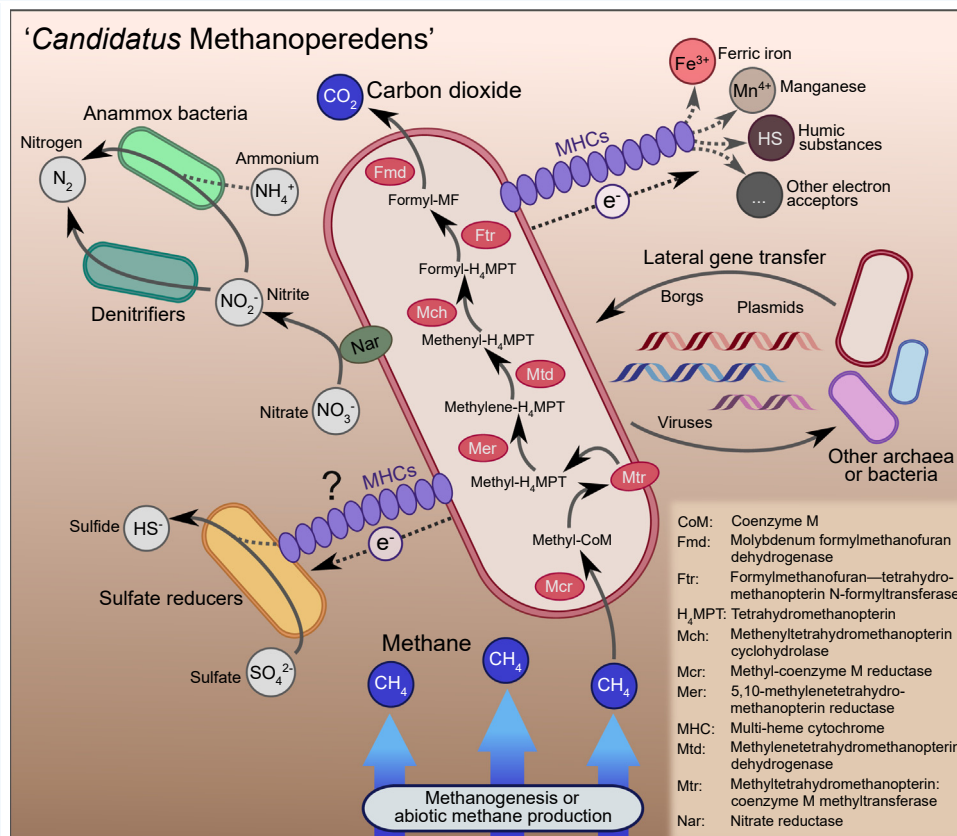
Hanna Zehle¹ and Marie C. Schoelmerich^{1,*}

¹Department of Environmental Systems Science, Institute for Biogeochemistry and Pollutant Dynamics, Environmental Microbiology Group, ETH Zürich, 8092 Zürich, Switzerland



Trends in Microbiology

'Candidatus Methanoperedens' is a genus of strictly anaerobic methanotrophic archaea (ANME). ANME mitigate the release of methane to the atmosphere by oxidizing this potent greenhouse gas to the less potent carbon dioxide. 'Ca. Methanoperedens', also known as ANME-2d, is the only ANME clade thriving primarily in freshwater ecosystems, while the other ANME clades are associated with marine environments. Sequences of 'Ca. Methanoperedens' have been reported in various anoxic freshwater habitats, including groundwater, lake and river sediments, wetlands, and wastewater treatment systems.



Trends in Microbiology

KEY FACTS:

'Ca. Methanoperedens' archaea couple anaerobic methane oxidation to the reduction of diverse electron acceptors in freshwater environments.

'Ca. M. nitroreducens' was the first enriched species of the genus, growing at mesophilic temperatures (22–35°C) at neutral to slightly basic pH (7–8).

'Ca. M. nitroreducens' can switch between existing as microcolonies or as planktonic single cells, which could facilitate cell dispersal and survival.

'Ca. Methanoperedens' can adjust to high salinity levels by augmenting the expression of selective ion channels and producing osmolytes, making them able to survive in marine environments.

This adaptability and metabolic flexibility of 'Ca. Methanoperedens' archaea is associated with lateral gene transfer with both bacteria and archaea and diverse extrachromosomal DNA elements.

TAXONOMY AND CLASSIFICATION:

- DOMAIN:** Archaea
- PHYLUM:** Halobacteriota
- CLASS:** Methanosarcinia
- ORDER:** Methanosarcinales
- FAMILY:** Methanoperedenaceae
- GENUS:** Methanoperedens (GTDB R220)

*Correspondence: marie.schoelmerich@usys.ethz.ch (M.C. Schoelmerich).



Unlike all other ANME, 'Ca. Methanoperedens' can use a wide range of electron acceptors as electron sinks. While marine ANME shuttle electrons from methane oxidation to a sulfate-reducing bacterial (SRB) partner, 'Ca. Methanoperedens' does not require such a symbiotic relationship. Some species, including 'Ca. M. nitroreducens', encode a terminal reductase for the reduction of nitrate to nitrite, directly linking the carbon and nitrogen cycles. Toxic nitrite is then often removed by nitrite scavengers like nitrite reducers or anammox bacteria, which are frequently found colocalized with 'Ca. Methanoperedens' in the environment. 'Ca. Methanoperedens' can also use diverse iron compounds as electron acceptors, for example, 'Ca. M. ferrireducens', which reduces ferric iron. Meanwhile, 'Ca. M. manganicus' and 'Ca. M. manganireducens' shuttle electrons to manganese. Highly toxic arsenic and hexavalent chromium, as well as humic substances omnipresent in sediments and soil, have also been reported as suitable electron acceptors. Other potential electron acceptors include selenate and elemental sulfur.

Diverse electroconductive multi-heme cytochromes (MHCs) encoded in their genomes facilitate the versatility of electron acceptors that 'Ca. Methanoperedens' archaea can use. These MHCs were experimentally shown to shuttle electrons to metals and electrodes. MHCs could also confer electron transfer from 'Ca. Methanoperedens' to syntrophic SRBs. This process has been proposed to occur in the anoxic, sulfate-rich sediments of Lake Cadagno, Switzerland, based on co-abundances of 'Ca. Methanoperedens' and Desulfobacterota. While such a relationship still awaits experimental confirmation, the potential for syntrophic interactions, so prevalent in their marine relatives, seems preserved in 'Ca. Methanoperedens'.

Members of the genus 'Ca. Methanoperedens' clearly stand out among all ANME for exhibiting the highest metabolic flexibility. What are the genetic reasons behind this flexibility? 'Ca. Methanoperedens' archaea exhibit a high rate of lateral gene transfer, through which genes for different reductive pathways were likely acquired. Furthermore, diverse extrachromosomal DNA (ecDNA) elements associated with 'Ca. Methanoperedens' have been discovered in metagenomic datasets. These include extraordinarily large linear ecDNA elements called Borgs, which are unlike previously known archaeal viruses and plasmids. Borgs can carry essential metabolic genes of 'Ca. Methanoperedens', including numerous MHCs. Other ecDNA elements likely associated with 'Ca. Methanoperedens' include plasmids, mini-Borgs, viruses, and still unclassified elements. These diverse ecDNA elements may play an important role in the adaptability and therefore survival of their hosts. Future studies, especially focused on cultivation, are required to illuminate the exact modes of interaction, potential metabolic modulation, and coevolution between 'Ca. Methanoperedens' and associated ecDNA elements. Such studies are crucial for fundamental science and might also lead to applications for mitigating methane release to the atmosphere.

Acknowledgments

This work was supported by Swiss National Science Foundation Grant 10001203 and by the ETH Zürich.

Declaration of interests

The authors declare no competing interests.

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