EGU General Assembly 2020
Online | 7 May 2020

“Methanogenesis 2020 – An update”

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Well known processes of methane formation on Earth

Methanogenesis – traditional view

geological

Prokaryotes
Archaea

abiotic

biotic

anoxic

microbial

abiotic

biomass burning
fossil sources
energy production

industry

Ocean floor

rice paddies, mires, lakes, wetlands, landfills …

CO$_2$ + 4H$_2$ $\rightarrow$ CH$_4$ + 2H$_2$O

CH$_3$COOH $\rightarrow$ CH$_4$ + CO$_2$

$\text{n CO} + (2\text{n} + 1)\text{H}_2 \rightleftharpoons \text{C}_n\text{H}_{2n+2} + \text{n H}_2\text{O}$

Fischer-Tropsch-process

guts of ruminants or termites

n CO + (2n + 1) H$_2$ $\rightleftharpoons$ C$_n$H$_{2n+2}$ + n H$_2$O

Fischer-Tropsch-process
The final step of methanogenesis by archaea

\[ \text{Me-S-CoM} + \text{CoB-SH} \rightarrow \text{CH}_4 + \text{CoB-S-S-CoM} \]

The enzyme **Methyl-coenzyme M reductase** (MCR) catalyzes the final step in \( \text{CH}_4 \) formation...a phylogenetic marker

*Ellermann et al., Eur. J. Biochem, 1988*
Phylogenetic Tree of Life
Three domain system

[Phylogenetic Tree of Life taken from Wikimedia Commons]
Widespread formation of methane by *Cyanobacteria* in aquatic and terrestrial environments

*Bižić et al., Science Advances, 2020*
Reported formation rates - from culture experiments:

Bižić et al., Science Advances, 2020
Methanogenesis 2020

Bacteria
- Spirochetes
- Proteobacteria
  - Cyanobacteria
    - Planctomyces
  - Bacteroides
  - Cytophaga
  - Thermotoga
  - Aquifex

Archaea
- Gram positives
  - Methanosarcina
  - Methanobacterium
  - Methanococcus
    - T. celer
  - Thermoproteus
  - Pyrodictium
- Entamoebae
- Halophiles

Eukaryota
- Animals
  - Fungi
  - Slime molds
  - Plants
  - Ciliates
  - Flagellates
  - Trichomonads
  - Microsporidia
  - Diplomonads

[Phylogenetic Tree of Life taken from Wikimedia Commons]
Detailed pathways of non-archaeal methane formation have yet to be discovered...