Methanotrophs/Biofilters

Mary Lidstrom
University of Washington
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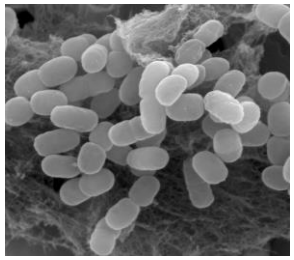
Introduction/Background

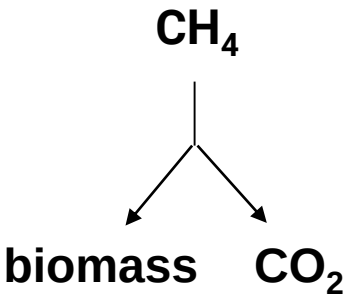
- Jungers Professor of Chemical Engineering
- Professor of Microbiology
- University of Washington, Seattle

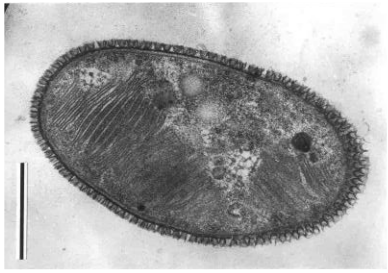
- For over 40 years, studied bacteria that grow on one-carbon compounds including methane and methanol
- Includes microbial physiology, genetics, genomics, metabolic engineering, microbial ecology, environmental communities

Methanotrophic Bacteria



methanotrophic bacteria





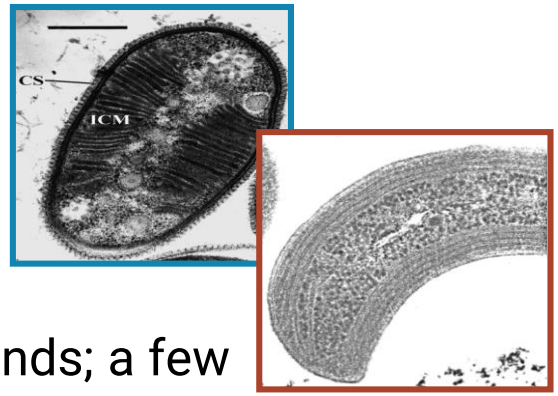
methanotrophic bacteria

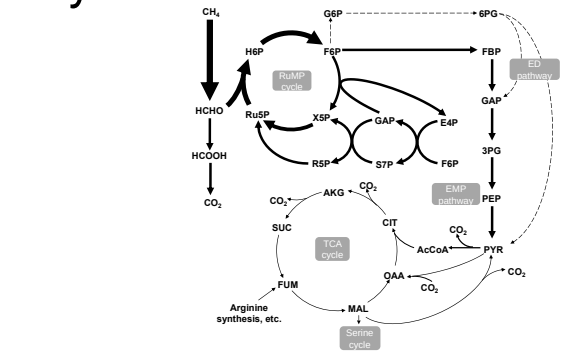
Anaerobic: --use nitrate or sulfate as electron acceptor
--slow growth

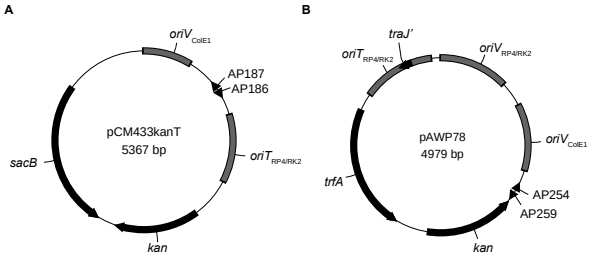
Aerobic: --use O_2 as electron acceptor and for activation of methane
--have specialized metabolic pathways and enzymes
--Alpha- and Gamma-proteobacterial strains
Methylomicrobium, Methylomonas, Methylobacter, Methylococcus, Methylosinus, Methylocystis
--verrucomicrobia, NC10

Aerobic Methanotrophs are Well-Studied

- Broad variety of strains available
  - High, medium, or low pH
  - High, medium, or low temperature
  - Salt-requiring or nonsalt-requiring
  - Most can only grow on one-carbon compounds; a few can grow on multicarbon compounds also
- Many grow very slowly; new strains grow well, easy to work with
- Metabolic pathways are well-known
  - Complete flux maps
  - Genome-scale metabolic models
  - Broad omics-level databases
- A variety of genetic tools and approaches



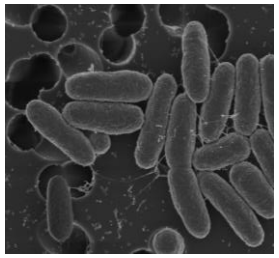




Methane Consumption in Nature

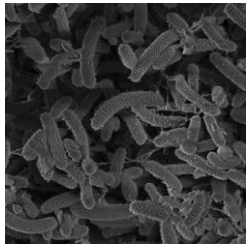
- Most habitats with some O_2 contain aerobic methanotrophs, consume methane
- Some strains adapted to low methane, some to low O_2
- In many soils and aquatic habitats, methane is consumed by a community of bacteria

CH_4 →



Methanotroph:
Methylobacter (gamma-prot.)

excreted CH_3OH ↓

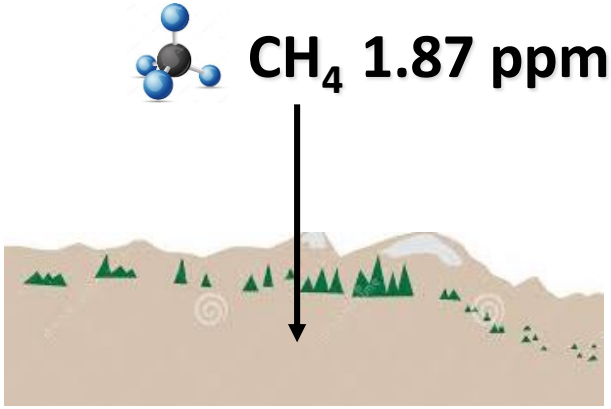


Non-methanotrophic methylotrophs:
Methylotenera
(beta-proteobacteria)

Oshkin et al., 2014. ISME J; Krause et al., 2017 PNAS

Methane Consumption From the Atmosphere

- Soils consume methane due to methanotrophs
- Some soils are net consumers from the atmosphere



  - Recently isolated *Methylocapsa* strains grow at atmospheric methane concentrations
  - Whole cell K_m for methane is similar to other methanotrophs (~1 μM)
    Tveit et al., PNAS 2020

Possibility: enhance by adding nutrients (biofertilizer)

Questions: duration, other ecosystem effects

Methane Capture to Reduce Atmospheric Methane

Major Challenges:

1) Scale
imbalance ~17 Tg/yr or 17 millions tons/yr
(Global Carbon Project)

2) Low concentration in the atmosphere
   1.87 ppm = 0.000187%
   dissolved in water ~ 2 nM
   best K_m ~ 1 μM

Consuming Methane From Above Emission Sources

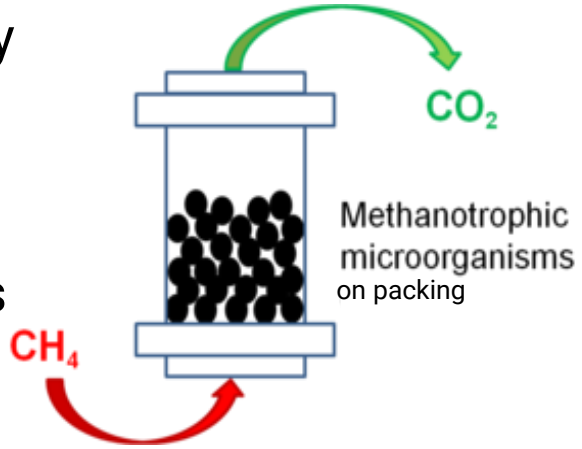
- Methane levels needed for stable methane consumption by known strains: ~500 ppm
  Yoon, Carey, Semrau. Appl Micro Biotech 2009
- Methane is enriched to 500 ppm over methane-generating entities
  - Landfills -- Natural gas extraction sites
  - Feedlots -- Sewage treatment plants
  - Coal Mines
- US alone has over 15,000 of such entities

Questions:
type of treatment system, cultures, optimal variables

Provides an approach to methane capture

Methane Biofilters

- Systems for removing methane from gas streams
- Use methanotrophs, usually in a community
- Many variables
  pH, temperature, flow rate, inlet gas %, residence time, water content, packing material, community composition, nutrients provided
- Generally, low cost, high removal >70-90%



Questions: optimal variables, durability (time of operation)

La et al, Biores Tech 2018

Methane Concentration vs. Treatment Options

- >5%: can be flared or used for energy
  - from digestors (sewage treatment, feed lots)
  - from piped landfills

- 1-5%: existing technology
  - factory sources
  - natural gas wells
  - coal mines

- <1%: need new technology
  - air over emission sites

SUMMARY

- Methanotrophs consume methane in natural environments
- Past decade has seen major advances in understanding of methanotrophs, their metabolism and enzymes, and their role in nature
- Opportunities exist for both natural and engineered systems to consume methane