

Types of substrates used by methane produced	G ⁰ kJ/mole methanogens
H ₂ - CO ₂	-135.6
Formate	-130.1
Methanol	-104.9
Methylamines	~-74
Acetate	- 31.0

Methanogenesis from methanol, methylamines in the absence of hydrogen - methyl group must be dismutated to carbon dioxide and methane

Ability to make methane from acetate is dependent on the ability of the cell to cleave acetate and reduce methyl equivalent & oxidize the carboxyl equivalent. Energy yield is low. Acetate using methanogens are typically slow growing with doubling times ranging from 9 hours to 65 hours or more.

Hydrogen and formate can be metabolized simultaneously by cells capable of using both when the concentrations of each are appropriate. Also methanol and hydrogen/carbon dioxide use can occur at the same time. However, in cell which can metabolize acetate and also can metabolize one of the other substrates, the other substrate will be preferred and will give a diauxic growth pattern.

The dismutation of methanol, methylamines, and acetate in absence of hydrogen require system of electron carriers.

The family Methanosarcinaceae, the only family capable of using methanol, methylamines, acetate as substrates is also the only family of methanogens shown to contain membrane bound cytochromes.

The one member of this family which required hydrogen to grow on methanol contains no cytochromes - presumably reducing equivalents for reduction of methanol generated by a hydrogenase.

Energy conservation in methanogens thought to involve a chemiosmotic gradient (perhaps also substrate level phosphorylation in some cases).

In hydrogen using methanogens, chemiosmotic gradient may be generated by membrane bound hydrogenase.

Most methanogens cannot take up sugars, most can use acetate as carbon source. Autotrophic methanogens - first known CO_2 fixation product is formyl-MFR, acetyl - CoA is formed. Sugars synthesized via gluconeogenesis.

Nitrogen metabolism - methanogens use ammonia and some organic nitrogen sources. Also, some can fix molecular nitrogen.

Most methanogens lack assimilatory sulfate reductases and can't use sulfate as sulfur source. Usually, sulfide can be used or organic sulfur compounds.

Methanogens require low reducing potential to initiate growth $E_h < 250 \text{ mV}$. Have to add reducing agents to medium prior to inoculation (sulfide, cysteine, titanium III, etc.) Use of sulfide, cysteine, or sulfide/cysteine mixture as a reductant can also act as sulfur source.

Reductants