

ANAEROBIC DIGESTION AND BIOGAS

Microbiology

Microbiology of biogas

- Anaerobic digestion utilizes a consortium of microbes in four distinct phases
- Products of one phase are feedstocks for next phase (serial process)
- For optimal performance, each rate keeps up with previous
- Microbial populations are ever-evolving

What is anaerobic digestion?

(Biochemistry perspective)

- Aerobic organisms use oxygen as their electron acceptor
- Anaerobic organisms utilize alternative electron acceptors
- Facultative organisms are aerobic or anaerobic

What is anaerobic digestion?

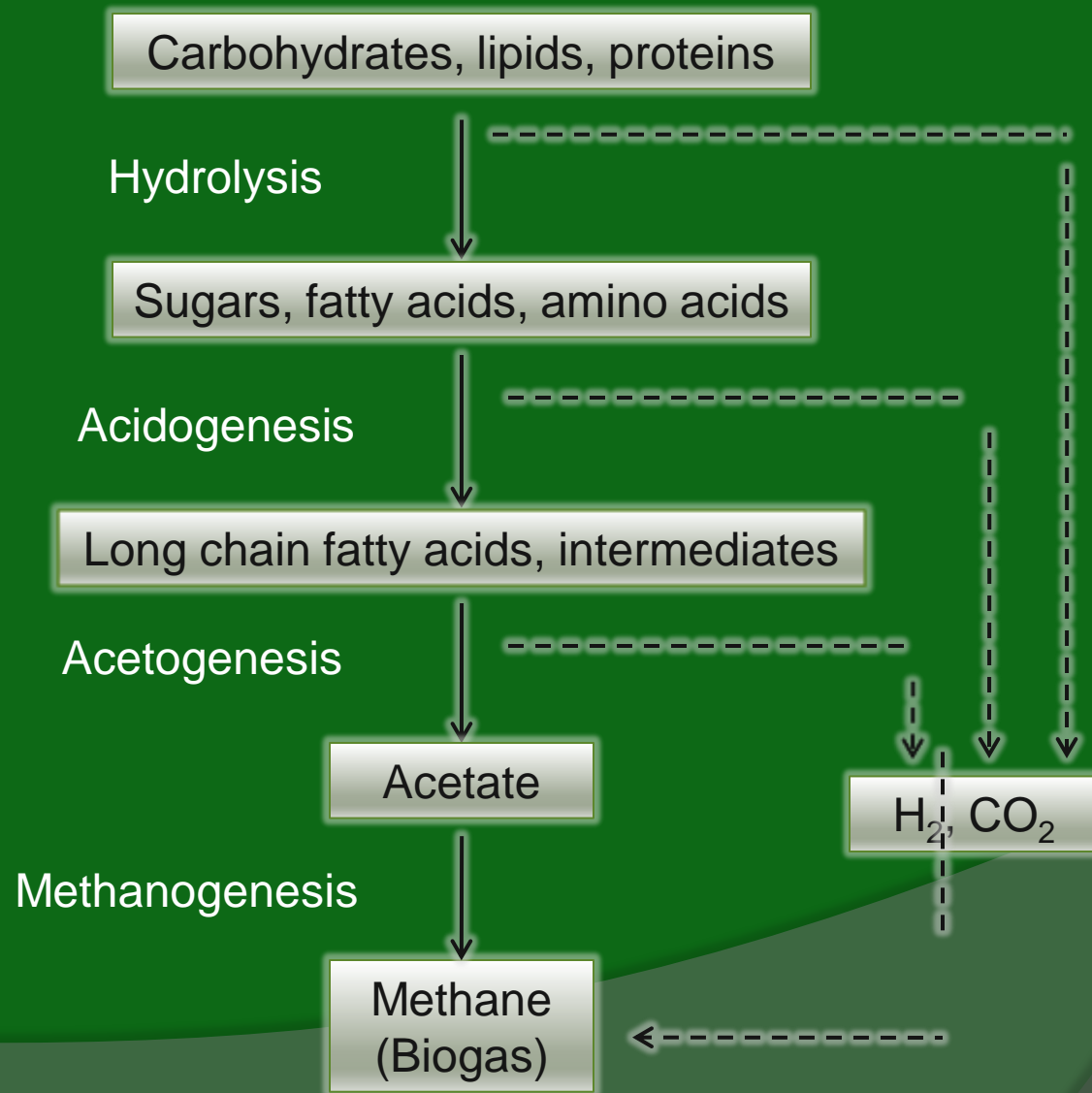
(Biochemistry perspective)

- ⦿ Anaerobic electron acceptors (oxidizers)
 - NO_3^- , Fe^{3+} , Mn^{3+} , SO_4^{2-} , CO_2
- ⦿ Significantly different energy output
 - 30 ATP (aerobic) vs. 2 ATP (anaerobic)
- ⦿ Anaerobic metabolism occurs throughout nature (hydric soils, ruminants, etc.)

Phases of digestion

- ④ Hydrolysis
- ④ Acidogenesis
- ④ Acetogenesis
- ④ Methanogenesis

Digestion Process



Hydrolysis

- Large organic compounds are broken down into simpler compounds
- Performed by many organisms
 - Bacteria, fungi, protists
- Facilitated by extracellular enzymes
- H_2 and CO_2 also produced



Vibrio



Hartmanella

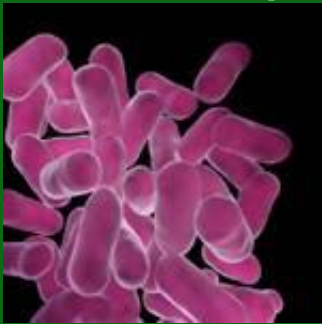
Carbohydrates, lipids, proteins



Sugars, fatty acids, amino acids

Acidogenesis

- Products of hydrolysis are fermented into volatile fatty acids
- Also termed fermentative bacteria
- Trace oxygen consumed by facultative bacteria
- Also produces acetate, H_2 , and CO_2



Lactobacillus



Propionibacterium

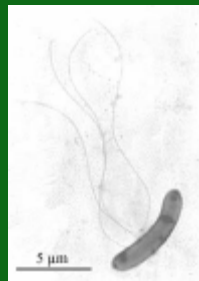
Sugars, fatty acids, amino acids



Long chain fatty acids, intermediates

Acetogenesis

- Long-chain volatile fatty acids are converted to acetate, H_2 , and CO_2
- Metabolizes intermediates (propionate, butyrate)
- Two groups of acetogens
 - Obligate hydrogen-producing acetogens (OHPA) – more dominant
 - Homoacetogens – less dominant



Syntrophomonas

Long chain fatty acids, intermediates



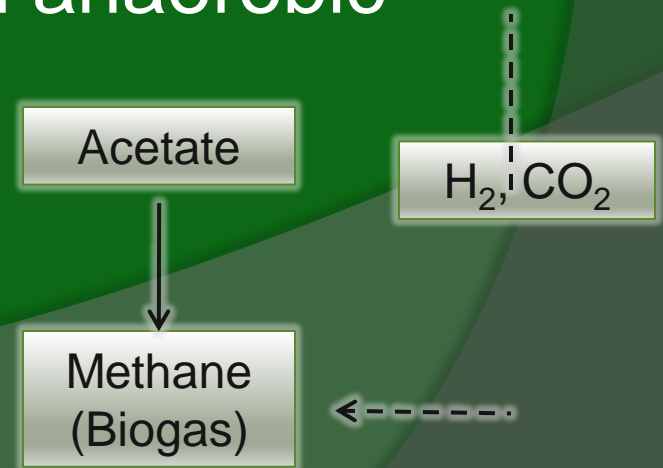
Acetate, CO_2 , H_2

Acetogenesis (OHPA)

- Produce acetate, CO_2 and H_2 from fatty acids
- Metabolize in low- H_2 environments
- Mutualistic relationship with methanogens (Syntrophy)
 - Methanogens consume H_2 , OHPA produce acetate and consume fatty acids
- Positive feedback cycle if balance disturbed
- Homoacetogens produce acetate from CO_2 and H_2
 - Also assist in reducing H_2

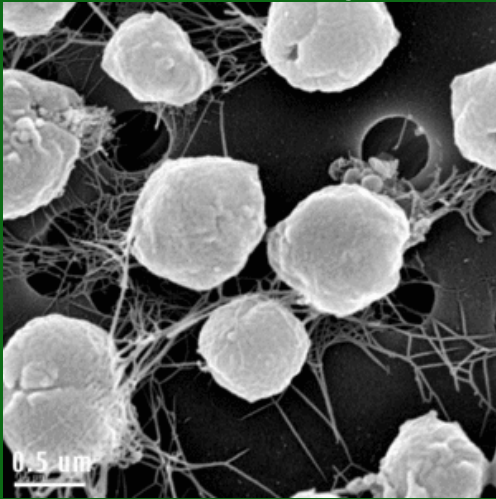
Methanogenesis

- Final metabolic phase
- Methanogens produce methane gas from acetate, H_2 and CO_2
- 2/3 of methane produced is derived from acetate
- Often the rate limiting step in anaerobic digestion
 - Can lead to accumulation of acids

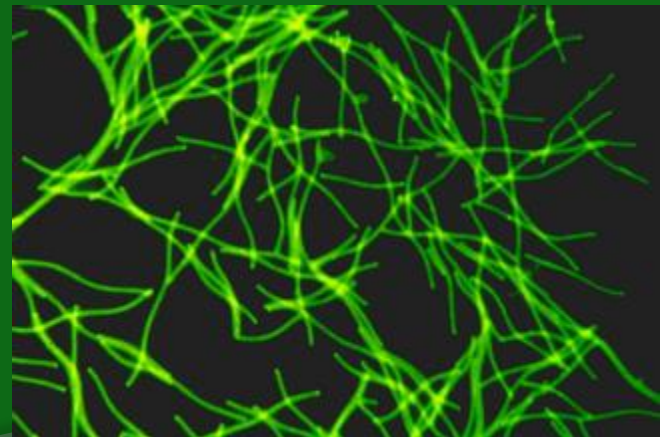


Methanogens

- All are Archaeobacteria
- Obligate anaerobes
- Optimum performance at neutral pH (7)
- Many genera convert H_2 and CO_2 to methane (Hydrogenotrophic)



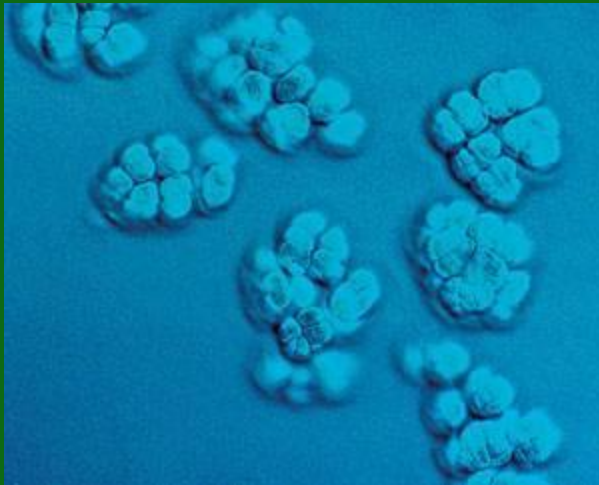
Methanococcus



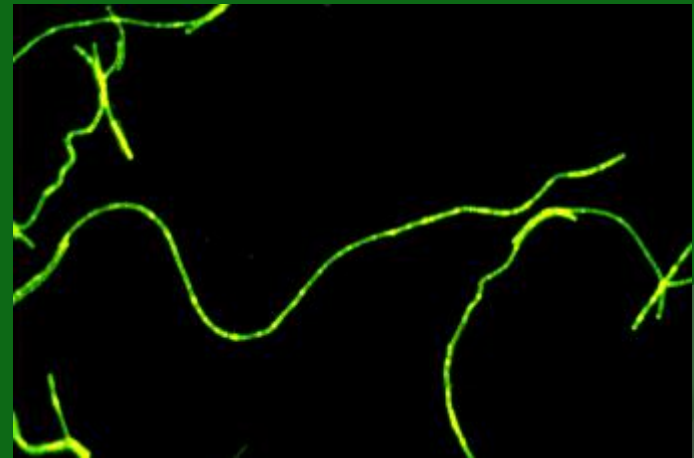
Methanospirillum

Methanogens

- Two known genera convert acetate to methane (Acetoclastic)
 - Methanosarcina – Favor high concentration
 - Methanosaeta – Favor low concentration



Methanosarcina



Methanosaeta

Questions?