Anaerobic Digestion Basics and Microbiology

Anaerobic Digestion

- The fermentation of organic matter in an oxygen free environment to produce an end product of Biogas
- Biogas is a biofuel composed of Methane and Carbon Dioxide with traces of Hydrogen sulfide and Ammonia

Benefits of Anaerobic Digestion

- Energy Production
- Nutrient recovery
- Combat Global Warming
- Conserve Energy
- Conserve Land
- Reduce odors
- Pathogen Reduction
- Manage waste
- Save the Earth!

Microbiology

- Anaerobic digestion is carried out by facultative and anaerobic organisms
- Anaerobic organisms are organisms that don't use oxygen for their oxidation metabolisms
- Aerobic organisms use oxygen for oxidation metabolisms
- Facultative microorganisms have both anaerobic and aerobic metabolic pathways

Aerobic vs. Anaerobic Metabolism

- Metabolic pathways have very different energy yields
- Aerobic respiration produces 30 ATP compared to the 2 ATP yielded from anaerobic respiration per glucose molecule

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ 2880kJ

$C_6H_{12}O_6 \rightarrow 2C_3H_6O_3$
120kJ

Alternative Electron Acceptors

- Electron acceptors are oxidizing agents i.e. they accept an electron from another compound to reduce itself and oxidize the other compound
- Oxidation describes the loss of an electron
- Reduction describes the gain of an electron
- Respiration uses electron acceptors to produce reduced compounds
- We aerobes use Oxygen as our electron acceptor

Anoxic Electron Acceptors

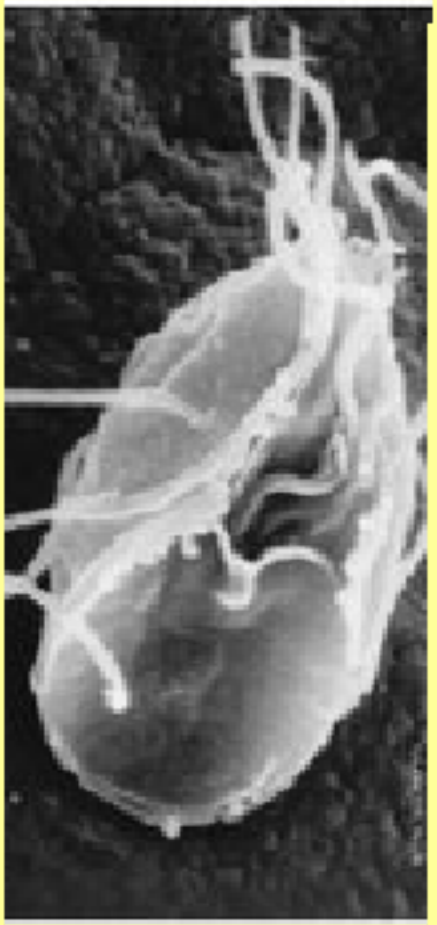
Oxidized	Reduced
NO_3^-	NH_4^+, N_2
Fe^{3+}	Fe^{2+}
Mn^{3+}	Mn^{2+}
SO_4^{2-}	H_2S
Carbon	CH_4

Anaerobic Digester Microbiology

- An Anaerobic Digester contains a synergistic community of microorganisms to carry out the process of fermenting organic matter into methane
- The process is carried out by Methanogens, Bacteria, Fungi, and Protozoa
- Anaerobic Digestion is mediated through the processes of Hydrolysis, Acidogenesis, Acetogenesis, and Methanogenesis

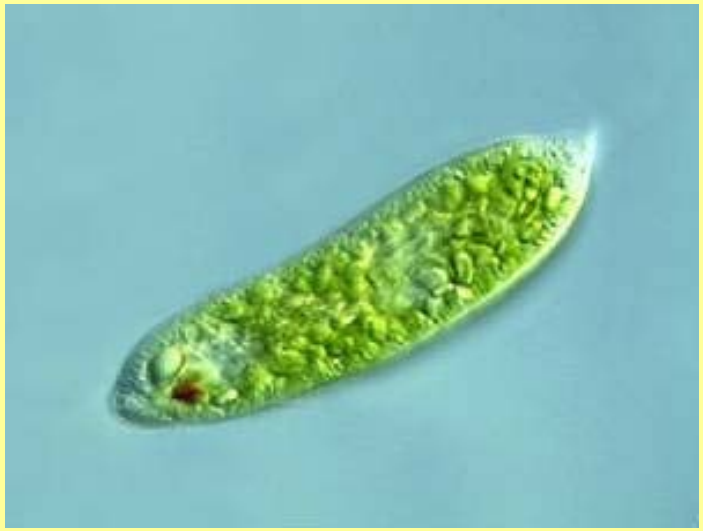
Hydrolysis

- The process of solubilizing complex organic matter
- Carried out by a number of bacteria, protozoa and fungi
- Carried out by exoenzymes i.e. Enzymes outside of the cell



Metamonad

Protists



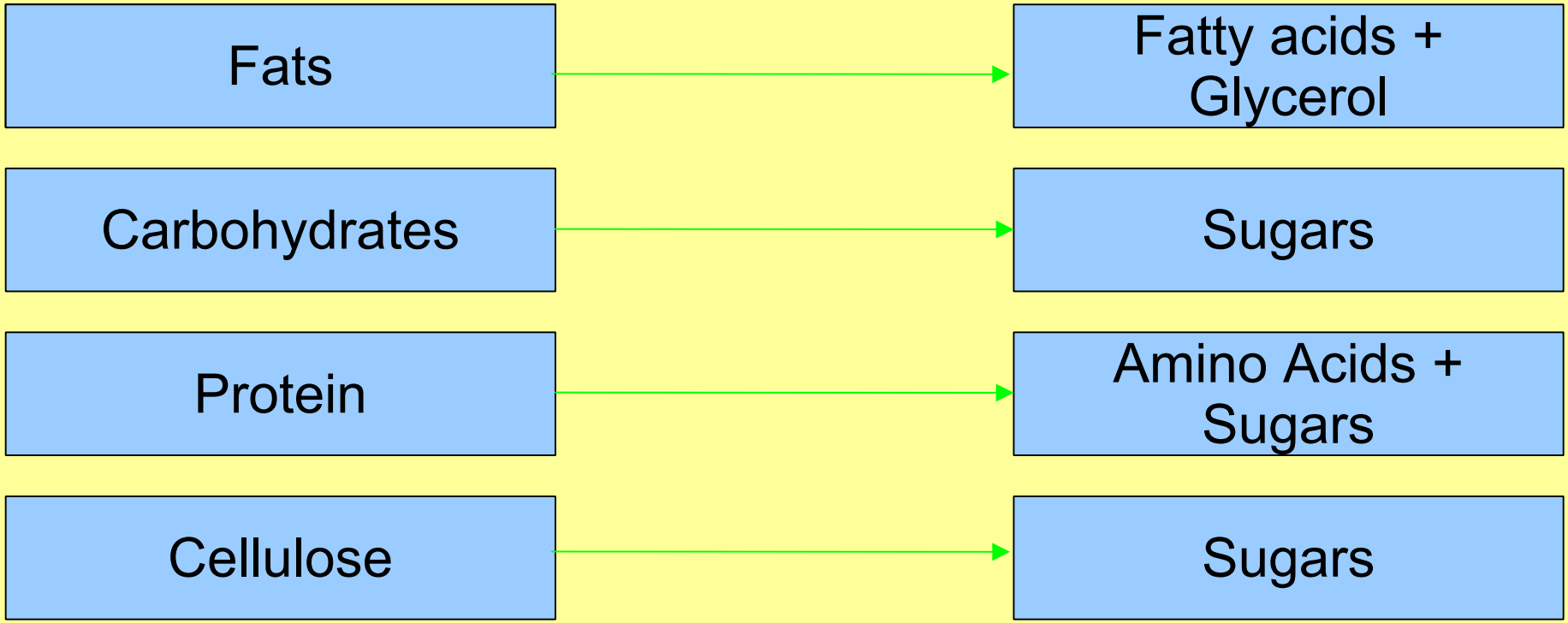
- Group of Eukarya
- Consist of animal like Protozoa
- Plant like Algae
- Fungus like Protists
- Questions of taxonomy

Termite Metamonads

Trichonympha

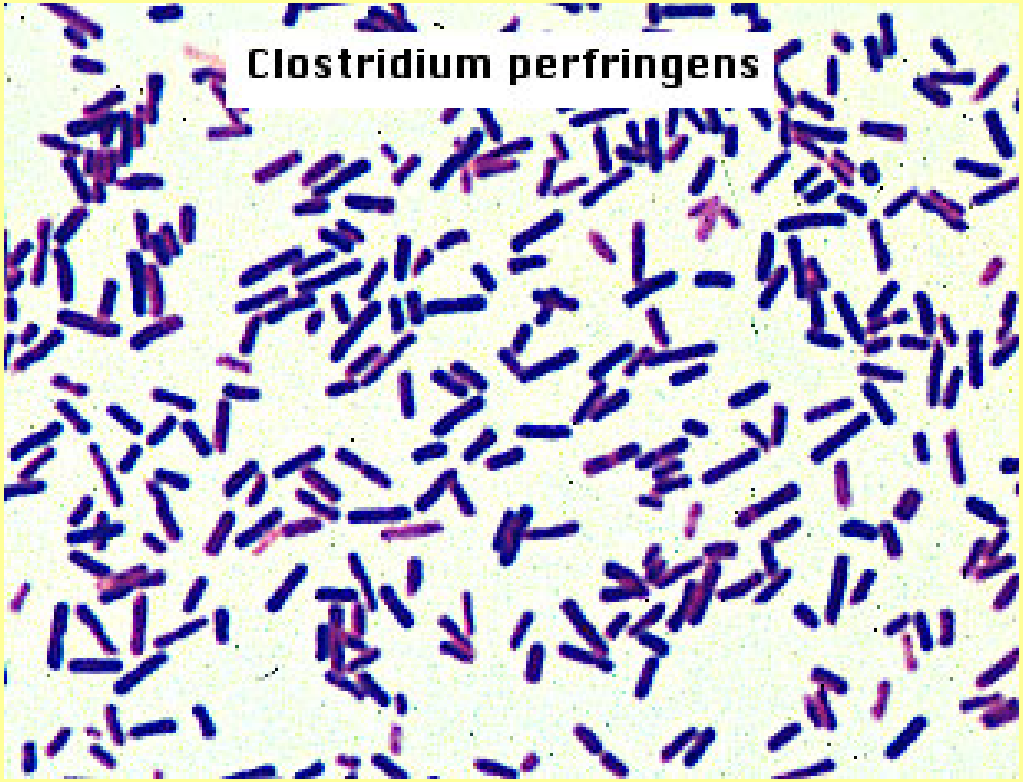
- Engulf cellulose
- Exoenzymes produced by a bacteria inside them
- Cellulases are end product
- Trichonympha is a species of Metamonad

Hydrolysis Intermediates



Acidogenesis

- Microbial process of metabolizing hydrolyzed organics material into organic acids and H_2 and CO_2
- Carried out by Bacteria



Clostridium

Acetogenesis

Acetobacterium

- Formation of acetate from byproducts of acidogenesis
- Also produces H_2 + CO_2
- Can be rate limiting step in Methanogen metabolism

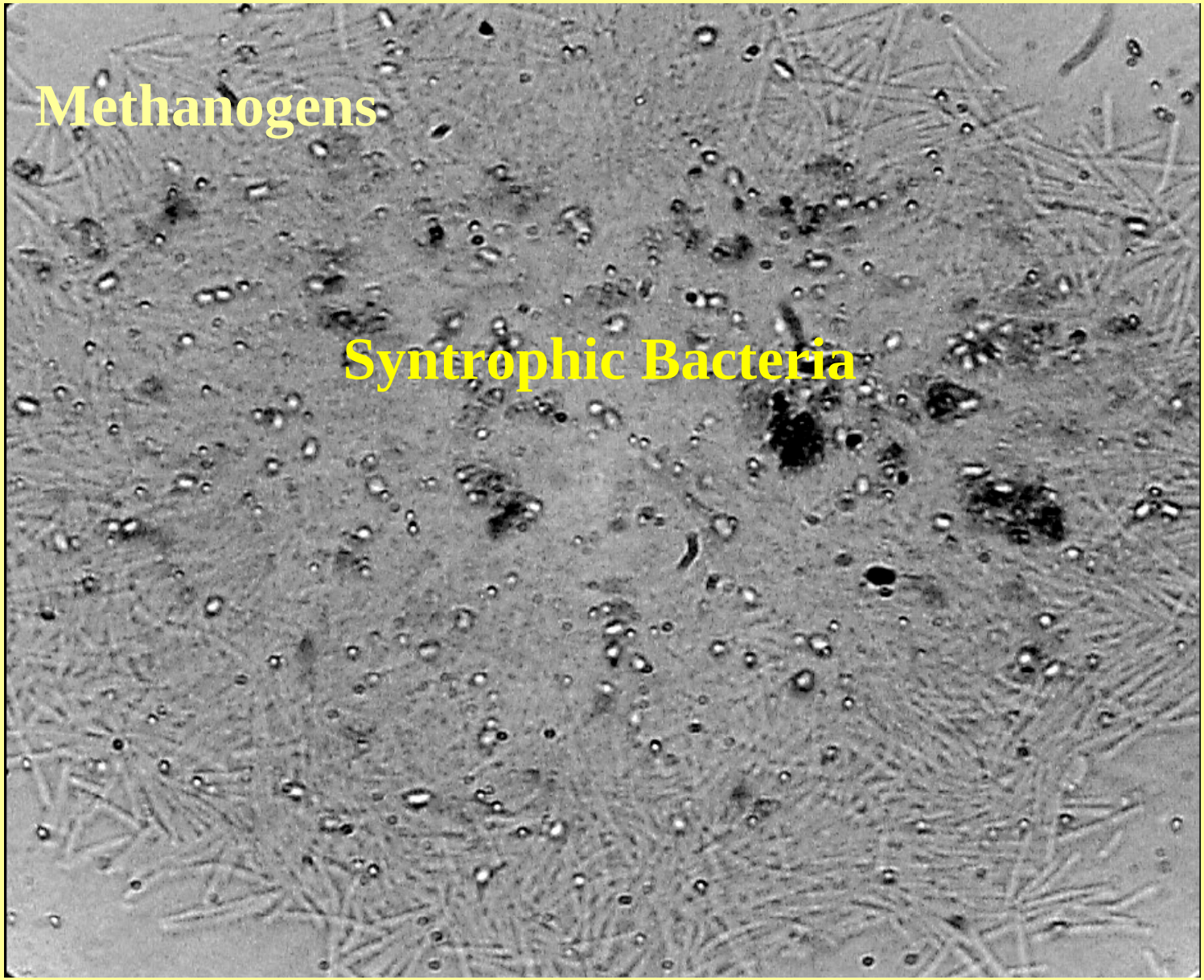
Hydrogen Producing Oxidation

- A soluble organic is oxidized in an anaerobic environment and produces H_2 as a byproduct
- The fermentation requires the reduction of NAD to NADH
- NADH cannot be regenerated in the presence of hydrogen
- The thermodynamic yield is negative in the presence of hydrogen, Positive when hydrogen is no longer present

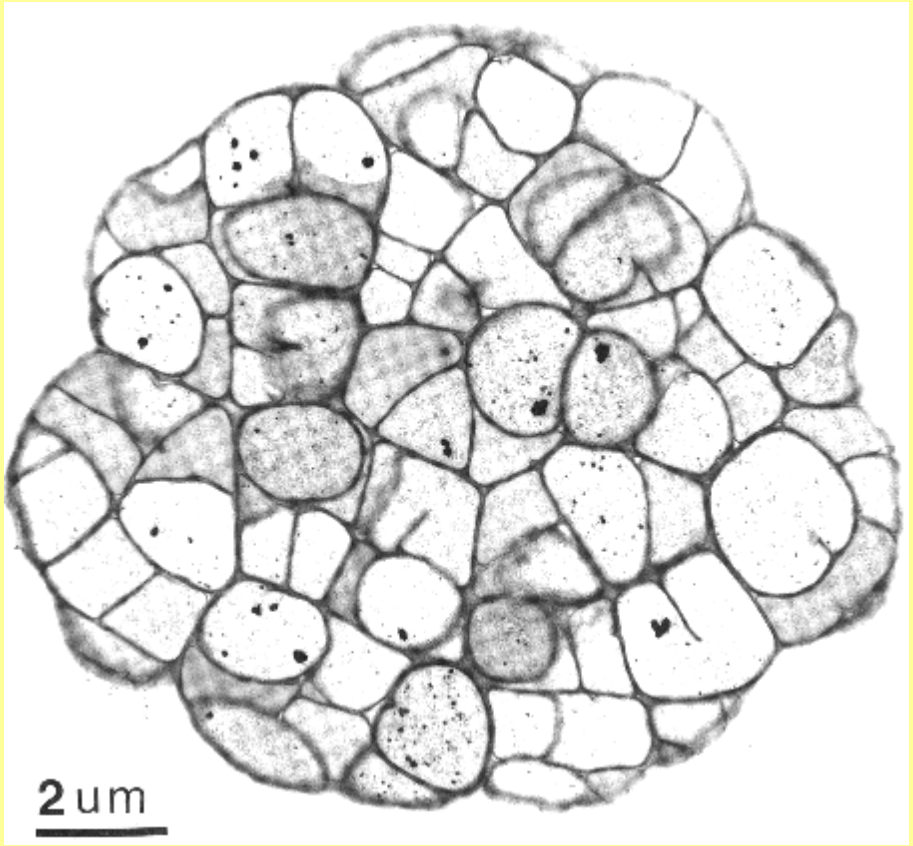
H_2 Producing Oxidation

- Only favorable kinetics in concert with uptake of $H_2 + CO_2$
- Low energy yield
- Ethanol + H_2O --> H_2 + acetate -19.36 kJ
- $H_2 + CO_2$ --> $CH_4 + H_2O$ 130.69 kJ

Syntrophic Community

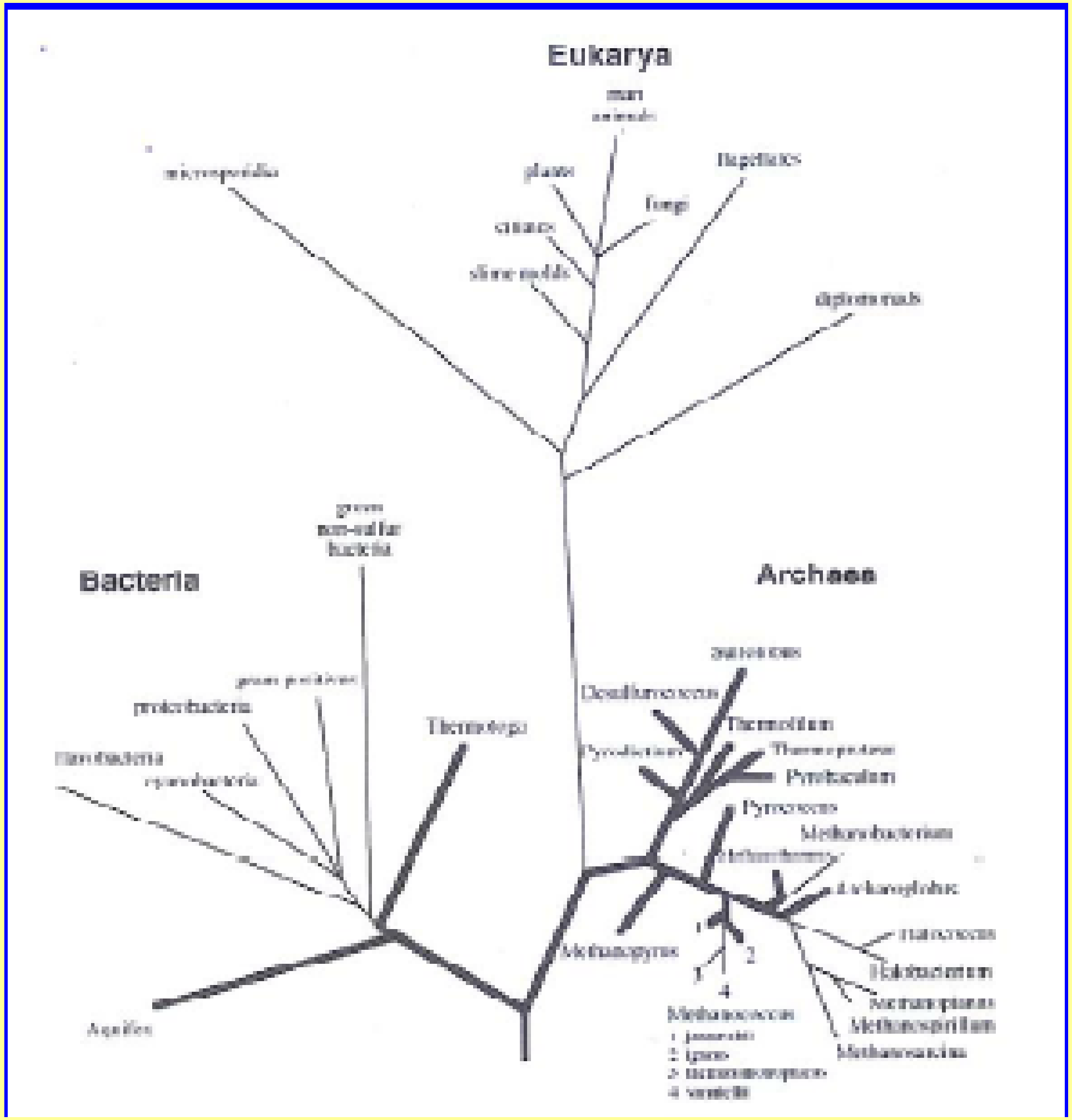


Methanogenesis



Methanosarcina

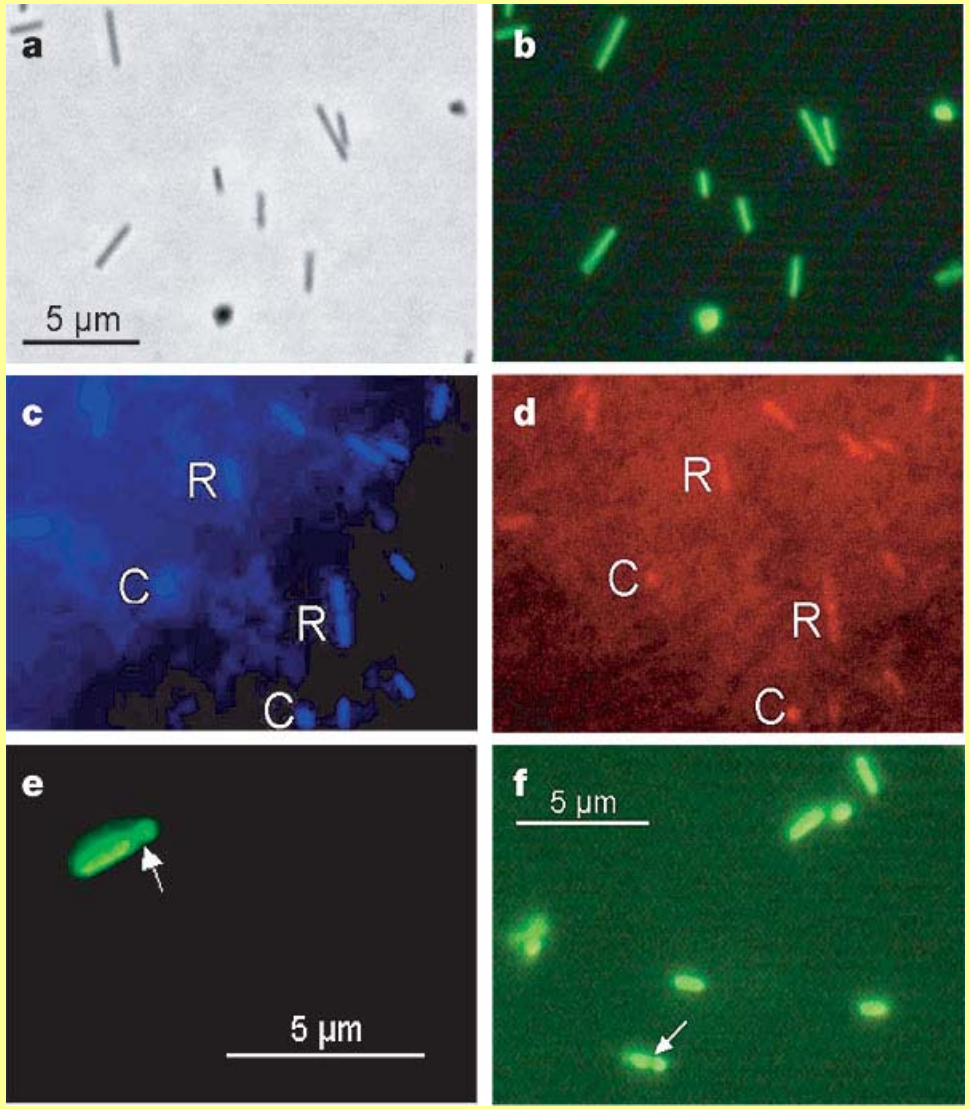
- Carried out by Methanogens
- Substrates for CH_4 production are Acetate, H_2 + CO_2, Formate, Methanol
- The metabolic end product of anaerobic digestion



Eukarya
man
microsporidia
plants
fungi
flagellates
slime molds
diplomonads
Bacteria
green
non-sulfur
bacteria
proteobacteria
Thermotoga
Aquifex
Archaea
Desulfurococcus
Thermofilum
Pyrodictium
Pyrobaculum
Pyrococcus
Methanobacterium
Methanopyrus
Halobacterium
Methanospirillum
Methanosarcina
Methanococcus
1
2
3
4

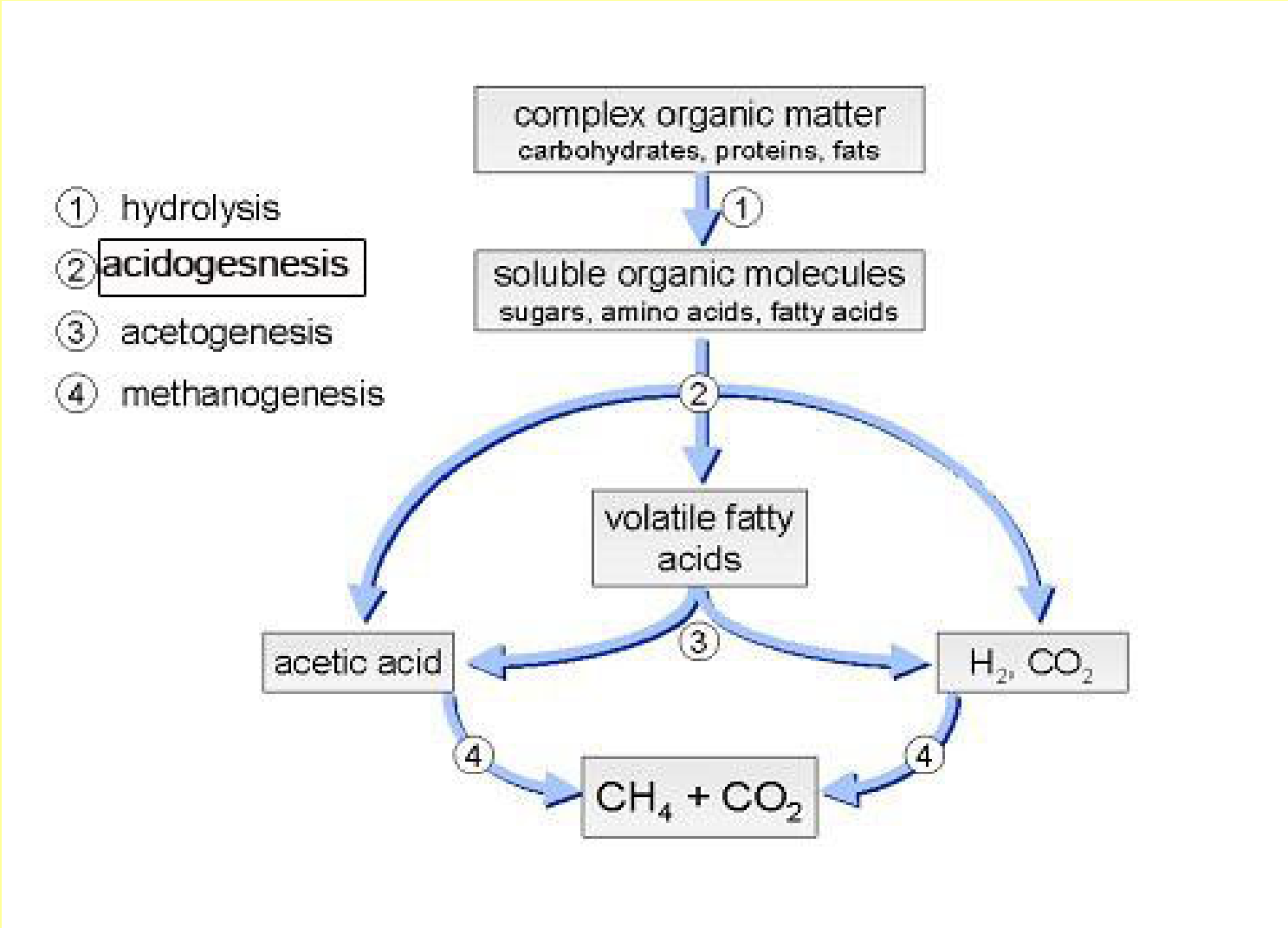
Methanogens

- Obligate Anaerobes from the Domain Archaea
- Divided into Hydrogenotrophic, Acetoclastic, and Methyltrophic depending on substrate
- Optimum pH is around neutral (7)

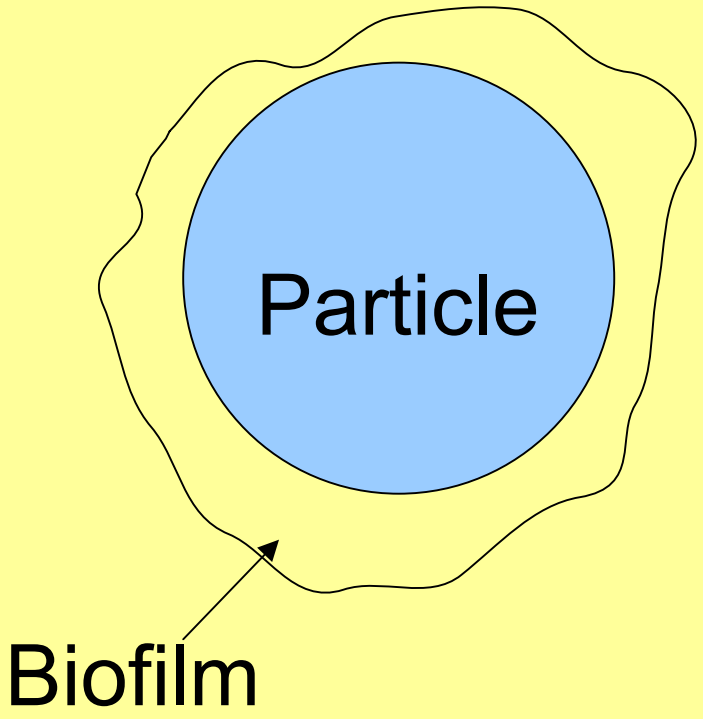


Various Methanogens

Anaerobic Digestion Microbiology



Biofilm Basics



- A biofilm is an attached community of microbes
- Benefits include proximity to maximize resource utilization, decreased competition, resist stress and increased metabolic activity

Review

- Review
  - Define Anaerobic Digestion
  - What are of the metabolic processes in Anaerobic Digestion?
  - Define each process
  - Who carries out the processes?

Thought Questions

- What might affect the Anaerobic Digestion process?
- How can we take advantage of the microbiology?