1.89, Environmental Microbiology
Prof. Martin Polz
Lecture 10

Electron Accepters: Metals

- Iron oxides
- Manganese oxides

} abundant in soils & sediments of terrestrial origin

$CH_3COO^- + 8Fe(III) + 4H_2O \rightarrow 2HCO_3^- + 8Fe(II) + 9H^+$

- More limited C-substrates: NO SUGARS!
  - o Acetate, lactate (simple organic acids) → Frequently incomplete oxidations (acetate as end-product)
  - o Simple alcohols
  - o Simple hydrocarbons
  - o H_2

- Can use a great variety of metals & metalloids
  → Cu, As, Mo, V, Cr, Se, Co
  - o Significance: metal solubility changes with oxidation state.
    Example: Fe-oxides are solids → sorbs many other chemicals
    → reduction can lead to solubilization (example: phosphate, arsenic)

- Sulphate
  2 types
  1. Complete oxidizers
     $CH_3COO^- + SO_4^{2-} + 3H^+ \rightarrow 2CO_2 + H_2S + H_2O$
  2. Incomplete oxidizers
     $2CH_3 - CHOH - COOH + SO_4^{2-} \rightarrow 2CH_3COOH + 2CO_2 + S^{2-} + 2H_2O$
     (Lactate)
  - o Similar substrates to metal reducers
  - o Significance is primarily marine (up to 80% of C-mineralization in anaerobic sediments by SRB (Sulfate Reducing Bacteria))

- Carbon dioxide
  - o Methanogenesis (methanogens ⇒ all archaea)

    2 types
    1. CO_2 only ⇒ $CO_2 + 3H_2 \rightarrow CH_4 + H_2O$
    2. acetodastic methanogens
       $CH_3COO^- + H_2O \rightarrow CH_4 + HCO_3^-$
  - o Acetogenic bacteria
    $4H_2 + 2HCO_3^- + H^+ \rightarrow CH_3COO^- + 4H_2O$

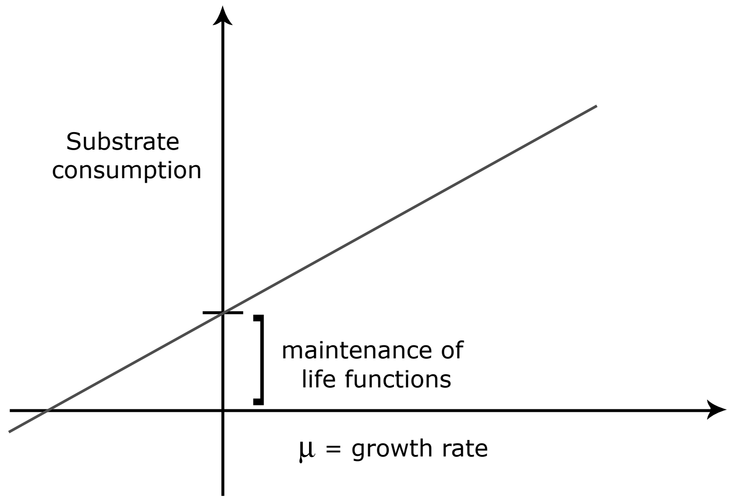
Energetic considerations

- Yield (Y): how much biomass/specific substrate can be made
- Theoretically need 35 mmol ATP/g all biomass, so 1 mol ATP → 30 g cells.

Experimental:

- o Streptococcus faecalis $Y_{glucose} = 22\ g/mol \rightarrow 2\ ATP\ /\ glucose$
- o Zymomonas mobilis $Y_{glucose} = 8.3\ g/mol \rightarrow 1\ ATP\ /\ glucose$

~ 10 g biomass/mol ATP



Aerobes: 5C:1N → more into biomass, less into respiration
Anaerobes: 5C:1N → more of this goes into respiration because lower yield of biomass
unclear

How is organic matter mineralized in aerobic vs. anaerobic environments?

Paradox: most organic C = polymers (proteins, DNA, structural polysaccharides)

- Yet anaerobic respirers can only use very simple C-substrates
- Why is H_2 usage so pervasive?

<u>Aerobic bacteria</u>
Specialized in respect to types of C-substrates used

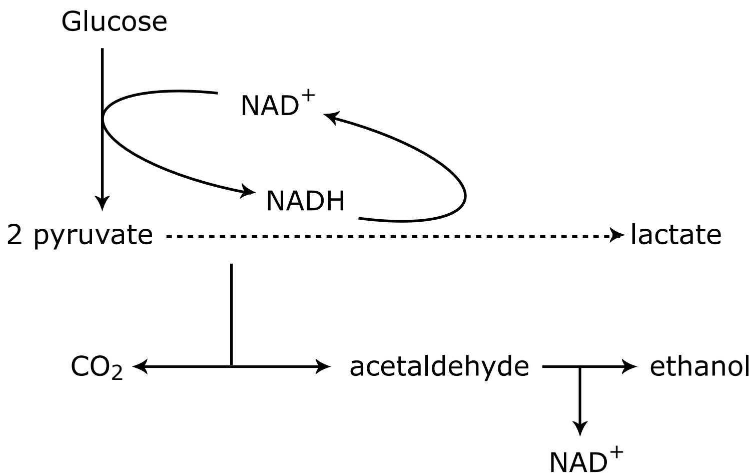
- Almost always mineralized to CO_2
- Some have wide substrate spectrum (generalists)
- Some have narrow substrate spectrum (specialists)

<u>Anaerobic bacteria</u>

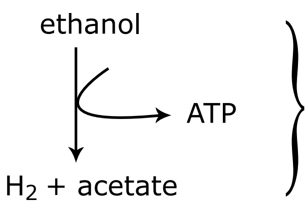
- Cooperation for mineralization
- Fermenters hydrolyze polymers & ferment monomers (example: sugars & amino acids)
  → Excrete simple fatty acids, Alcohols, H_2 } substrates for anaerobic respirers

Relationship between fermenter and anaerobic respirers = Syntrophy

Reexamine fermentation



But additional energy could be gained from reaction:



Problem is that this reaction has a positive $\Delta G^{o'}$

Standard conditions

$\Delta G^{o'} = +19.4\ KJ/mol$

$$2CH_3CH_2OH + 2H_2O \rightarrow 4H_2 + 2CH_3COOH + 2H^+$$

$\Delta G_{reaction}$ depends on H_2 partial pressure

→ anaerobic respirers have a high affinity for H_2

⇒ Close cooperation results in a crucial role of acetate & hydrogen in anaerobic environments

⇒ Anaerobic food chain