1.89, Environmental Microbiology
Prof. Martin Polz
Lecture 12

Energetics: biomass yield, ATP, NADH yield } optimized

$\Delta G^{o'}$ glucose $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

→ -2,869 KJ/mol

$\Delta G^{o'}$ benzene $C_6H_6 + \frac{15}{2}O_2 \rightarrow 6CO_2 + 3H_2O$

→ -3,265 KJ/mol

- Benzene appears to be more energetically favorable
- However, biomass formation using benzene is actually more costly
- Solubility of benzene is lower
- Benzene has longer half-life

Autotrophy

- CO_2 = carbon source
- ATP energy provided by light or oxidation of inorganic chemicals
- Oxidation of inorganic chemicals → gets reducing power from NADPH

CO_2 - fixation

- Several pathways
  a) Calvin Benson cycle: all plants, cyanobacteria & many other bacteria
    - Most important CO_2-fixation pathway
    - Runs ~ 6 times before fructose – 6 phosphate can be used for biosynthesis
    - Key enzyme: RuBisCo (Ribulose 1, 6-bisphosphate Carboxylase/Oxygenase)
  b) Reverse TCA cycle: green sulfur bacteria
  c) Acetyl-CoA pathway: anaerobic respirers when growing with H_2 as energy source
  d) Serine pathway: methanotrophs (oxidize methane)

Phototrophy

- 1st step: light is absorbed by photopigment
- Chlorophyll is most important pigment (chlorophyll is excited by light & donates e^-s, leading to generation of proton motive force)
    - o Chlorophyll a, plants, algae, cyanobacteria (all of these absorb between 450-700 nm)
    - o Other chlorophyll has different absorption ranges → plays a role in ecological differentiation

Accessory pigments

- Example: carotenoids
- Also capture light $\rightarrow$ energy transfer to chlorophylls

2 types of photosynthesis

1. Anoxygenic Photosynthesis $\rightarrow$ oxygen is not created as an end product
   - Anaerobic bacteria
   - Cyclic e^- flow
     - Excited chlorophyll
     - Donates e^- into e^- transport chain
     - Leads to generation of H^+ gradient
     - e^- ultimately reduces an oxidized chlorophyll molecule
   - NADPH generation occurs via "Reverse-flow"
     - Inorganic compounds (H_2S, S^o, Fe^{2+}, H_2) serve as electron donors & are oxidized (but many are too electropositive to directly reduce $NADP^+$ $\Rightarrow$ they are $\therefore$ oxidized by components of e^- transport chain)

Reducing power comes from H_2S, etc.

Quinines = e^- donors for $NADP^+$ (regenerate NADPH)

2. Oxygenic $\rightarrow$ oxygen is created as end product (Figure 15.19)
   - 2 photosystems (PS): PSI (analogous to anoxygenic PS) & PSII (replenishes e^- lost by PSI and uses H_2O as e^- donor (O_2 generated as result))
   - ATP generation occurs via cyclical e^- flow in PSI
   - NADPH generation occurs via "z-scheme" where PSII acts as an e^- donor for PSI (which is oxidized by $NADP^+$ reduction)
   - e^- in PSII replenished by $H_2O \rightarrow \frac{1}{2} O_2 + 2H^+$

Reducing power comes from H_2O

Lithotrophy

- Diverse group of bacteria which gain energy by oxidation of inorganic chemicals with molecular O_2 (or NO_3^-)
- Hydrogen oxidizers: $H_2 + \frac{1}{2} O_2 \rightarrow H_2O$
- Nitrifiers:
  2 types:
  1. Ammonia oxidizers $\rightarrow$ nitrite
  2. Nitrite oxidizers $\rightarrow$ nitrate

Biosynthesis: both processes are not very efficient, must use a lot of N substrate to get 1 mol $C_5H_7O_2N$

1. $55NH_4^+ + 76O_2 + 109HCO_3^- \rightarrow C_5H_7O_2N + 54NO_2^- + 57H_2O + 104H_2CO_3$

2. $400NO_2^- + \underbrace{NH_4^+}_{\text{biomass}} + 4H_2CO_3 + HCO_3^- + 195O_2 \rightarrow C_5H_7O_2N + 3H_2O + 400NO_3^-$

Energy:

1. $NH_4^+ + 3/2\, O_2 \rightarrow NO_2^- + 2H^+ + H_2O$

2. $NO_2^- + 1/2\, O_2 \rightarrow NO_3^-$

Note: denitrifiers use NO_3^- as electron acceptors & reduce it to N_2 gas.

- Anamox: $5NH_4^+ + \underset{e^- \text{ acceptor}}{3NO_3^-} \rightarrow 4N_2 + 9H_2O + 2H^+$

  wastewater treatment? – need exact stoichiomethry (no O_2, add NO_3^-)

Chemolithoautotrophs: All need reduced chemicals & oxygen or nitrate as e^- acceptors.