

20.106J – Systems Microbiology  
Lecture 3  
Prof. DeLong

- Reading for today: Chapter 5 and Chapter 17 (533-555)
- Reading for next class: Chapter 6 – Microbial Growth
- For today: Bioenergetics and physiological diversity
  - Finish up chemotaxis
  - Basic modes of energy generation
  - Thermodynamics of growth
  - Diversity in energy acquisition
  
- Chemotaxis
  - Flagella rotate counterclockwise, driving the microbe forward
    - When it switches to clockwise, the flagella all fly apart – change location – tumble
    - To choose direction, they can't really sense space, but over time they sense the concentration of particular chemicals
      - They do this with receptors on their surface
      - Che A auto phosphorylates Che Y to cause motor to drive, in the presence of the right concentration
      - As the concentration rises over time, the cell makes a net motion along the concentration gradient
      - This is a complex feedback mechanism
      - A fully methylated receptor is not able to respond to an attractant
      - Read Chapter 8.13 in the text to understand this
  - Pili – another structure that's involved in attachment and motility
  
- For growth and biosynthesis cells need:
  - Energy, in the form of ATP
  - Reducing power, in the form of NADH
  - Basic macronutrients: C, N, P, S (nmol to mmol in the environment)  
Mg<sup>++</sup>, K<sup>+</sup>, Na<sup>+</sup>, Ca<sup>++</sup>
  - Micronutrients: Fe, Mn, B, Cr, Cu, Mo, Ni, Se, W, V, Zn
  
- Where do organisms get their energy?
  - Light, or chemical energy (phototrophs vs. chemotrophs)
  - Both exist in the microbial world
  - Microbial chemotrophs: chemolithotrophs (oxidize inorganic compounds) vs. chemoorganotrophs (oxidize organic compounds)
  - Microbial chemoorganotrophs can reduce elements other than oxygen. They can use Iron, or Nitrate.
  - In general, microbes are different from eukaryotes because they can oxidize and reduce a much broader variety of different chemicals

- Free energy and bioenergetics

- For the chemical reaction  $A \rightarrow B$ ,

$$\text{Gibbs Free Energy} = \Delta G = G_{\text{products}} - G_{\text{reactants}} = G_B - G_A$$

- Negative  $\Delta G$ : reaction releases energy, and is exergonic
- Positive  $\Delta G$ : reaction absorbs energy, and is endergonic
- For the reaction  $aA + bB \rightleftharpoons cC + dD$ ,

$$\Delta G = \Delta G_o + RT \ln \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

- $\Delta G_o$  is a constant called the Gibbs Standard Free Energy: you can look it up (1M, 25°C, pH 7, 1atm)

- $\Delta G_o' = -nF \Delta \epsilon_o'$

- $n$ : number of electrons involved in reaction
- $F$ : Faraday constant
- $\epsilon_o'$ : Standard reduction potential at 1M, 25°C, pH 7, and 1atm

- With these equations, you can calculate which reactions will release energy, and from this you can predict which kinds of microbes will exist

- $\Delta \epsilon_o' = \epsilon_o'(\text{electron acceptor}) - \epsilon_o'(\text{electron donor})$

- $4H_2 + SO_4^{2-} \rightleftharpoons S^{2-} + 4H_2O$

$$\Delta \epsilon_o' = \epsilon_o' - \epsilon_o' = -0.21 - (-0.414) = +0.204V$$

Therefore  $\Delta G$  is positive, energy releasing

- $\Delta G_o' = -nF \Delta \epsilon_o' = -8(93.67 \frac{kJ}{mol})0.204V = -152.9kJ$

- However, a 1 atm concentration of hydrogen is unrealistically high.

Therefore:

$$\Delta G = \Delta G' + RT \ln \frac{[\text{products}]}{[\text{reactants}]}$$

$$\Delta G = -152.9 + (8.314 \times 10^{-3} \frac{kJ}{mol K} (298^\circ K)) \ln \frac{[1]}{(10^{-6})^4 [1]}$$

$$\Delta G = -15.9$$

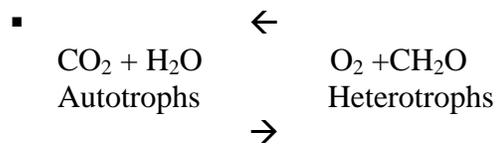
$$(H_2 = 10^{-6} atm)$$

- Aerobic respiration:  $O_2$  is the terminal electron acceptor

- Diagrams of energy production

- Modes of nutrition

- Where does the carbon come from? (heterotrophs vs. autotrophs)
- Where does the energy come from?
- What molecule is the electron donor?
- What molecule is the electron acceptor? (aerobic vs. anaerobic respiration)



- Bacterial photosynthesis
  - Anoxygenic bacterial photosynthesis came first
    - Uses bacteriochlorophyll, not chlorophyll
    - Does not produce oxygen
    - Does not split water
  - Photoautotrophs (use  $\text{CO}_2$ ) vs. photoheterotrophs (use organic compounds)
  - The Z scheme/oxygenic photosynthesis (noncyclic photosynthesis because electrons are not “recycled”) vs. cyclic photosynthesis
  - The Calvin cycle