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^{++}, K^{+}, Na^{+}, Ca^{++}
    - 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 $A \rightarrow B$,
      Gibbs Free Energy $= \Delta G = G_{\text{products}} - G_{\text{reactants}} = G_B - G_A$
    - Negative ΔG: reaction releases energy, and is exergonic
    - Positive ΔG: reaction absorbs energy, and is endergonic
    - For the reaction $aA + bB \rightleftharpoons cC + dD$,
      $$\Delta G = \Delta G_o + RT \ln \frac{[C]^c [D]^d}{[A]^a [B]^b}$$
        - ΔG_o is a constant called the Gibbs Standard Free Energy: you can look it up (1M, 25°C, pH 7, 1atm)
    - $\Delta G_o{}' = -nF\Delta \varepsilon_o{}'$
        - n : number of electrons involved in reaction
        - F : Faraday constant
        - $\varepsilon_o{}'$: 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
    - $\Delta \varepsilon_o{}' = \varepsilon_o{}'(\text{electron acceptor}) - \varepsilon_o{}'(\text{electron donor})$
    - $4H_2 + SO_4^{=} \rightleftharpoons S^{=} + 4H_2O$
      $\Delta \varepsilon_o{}' = \varepsilon_o{}' - \varepsilon_o{}' = -0.21 - (-0.414) = +0.204V$
      Therefore ΔG is positive, energy releasing
    - $\Delta G_o' = -nF\Delta \varepsilon_o' = -8(93.67 \frac{kJ}{mol})0.204V = -152.9kJ$
    - However, a 1 atm concentration of hydrogen is unrealistically high. Therefore:
      $$\Delta G = \Delta G' + RT \ln \frac{[\text{products}]}{[\text{reactants}]}$$
      $$\Delta G = -152.9 + (8.314 \times 10^{-3} \frac{kJ}{mol\ K}(298^{o} K)) \ln \frac{[1]^1}{(10^{-6})^4 [1]^1}$$
      $$\Delta G = -15.9$$
      $$(H_2 = 10^{-6} atm)$$

- 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)

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  CO_2 + H_2O O_2 +CH_2O
  Autotrophs Heterotrophs
  →

- Bacterial photosynthesis
  - Anoxygenic bacterial photosynthesis came first
    - Uses bacteriochlorophyll, not chlorophyll
    - Does not produce oxygen
    - Does not split water
  - Photoautotrophs (use 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