20.106J – Systems Microbiology
Lecture 2
Prof. DeLong

- Reading for next week: Chapter 5 (Biol. Energy, Couscku)
- Problem Set #1 due next week
- Reading for today: Purcell, Berg, and Pace

- Related to the last lecture:
  - Life's history on Earth – Evidence
    - Phylogenetic tree
    - The same machinery for making proteins – with ribosomes – is used all over Earth.
    - You can map how different the ribosomal RNA is in each species on Earth.
      - In this way we can compare microbes to eukaryotes.
    - A lot of the Eukarya tree (our own tree) is dominated by microbes – Archaea.
    - Chloroplast RNA falls right next to cyanobacteria on that tree
      - This supports the endosymbiont hypothesis – chloroplasts derive from cyanobacteria.
    - Similarly, mitochondrial RNA falls by agrobacteria – α proteobacteria.
  - Life on Earth today: the foundation
    - CO_2/O_2 cycle

- To be covered today: Structure, Function, Motility
  - The nature of being small
  - Cell membranes and cell walls
  - Flagella

- Shape and Appearance – not where the interesting stuff is regarding microbes
  - They don't bring in solid food – they bring in dissolved substrates.
    - Surface area to volume:

$$\frac{SA}{V} = \frac{4\pi r^2}{4/3\,\pi r^3} = \frac{3}{r}$$

  - "Prokaryote" vs. Eukaryote
    - In eukaryotes, there are organelles and a nucleus – quite a lot of communication and transport is going on.
    - In prokaryotes, transcription and translation all occur together in the cytoplasm

        - However, “Prokaryote” is in quotes because it is only a negative definition – they are defined only by the lack of a membrane-bound nucleus.
        - One group of microbes – Archaea – are a lot more like eukaryotes than they are like bacteria.
            - Their informational machinery – RNA polymerase, promoters – are more similar to those of eukaryotes.
        - Hence there are Three large branches of life: Bacteria, Archaea, and Eukarya (the two-branch representation of life as prokaryote vs. eukaryote is less accurate).

- Cell membranes: phospholipid bilayer
    - Main permeability barrier
    - Embedded integral membrane proteins – communication, transport
    - Membrane structure
        - Bacteria, eukaryotes
        - Archaea
    - Archaea can still make lipid bilayers – though sometimes they hook them directly together, making a lipid monolayer.
        - This is much more structurally rigid.
        - This is never found in bacteria or eukaryotes.
    - Membranes act as a protein anchor.
    - Also energy conservation – protein motive force.
    - Membrane permeability to various molecules:
        - Simple transport: let a proton down the gradient in order to move things.
        - Group translocation: chemical modification of transported substance driven by phosphoenolpyruvate.
        - ABC system: periplasmic binding proteins are involved and energy comes from ATP.
    - Transport method:
        - Uniporter: one thing comes in.
        - Antiporter: one thing in, one out.
        - Symporter: two in at once.
    - Gram-positive bacteria have one phospholipid bilayer.
        - With a thick peptidoglycan layer outside.
    - Gram-negative bacteria have two bilayers
        - There is periplasm in between.
            - Most of the binding proteins are located here.
        - The outer membrane (lipopolysaccharide and protein)
            - Antibiotic resistance occurs here – resistance thus occurs more easily in gram-negative bacteria.
        - There is a peptidoglycan layer in the middle of the periplasm, but it’s very thin.
            - It forms a net-like structure, with a single molecule of peptidoglycan that acts as a nylon stocking.

        - This maintains structure, shape, and integrity.

    - Lipopolysaccharide chains outside – can often make people sick
  - In penicillin, lysozyme chews up peptidoglycan
    - Then water all rushes in, causing lysis
    - Penicillin inhibits the crosslinks
    - Therefore penicillin only works on cells that are growing
  - Archea – S-layers, pseudo peptidoglycan

- Motility
  - Flagella – moves like a propeller in bacteria, not like a whip – they're rigid
    - Video clip: *E. coli* moving with rotating flagella
    - $\frac{Inertial\ Forces}{Viscous\ Forces} \approx \frac{a v \rho}{\eta}$ ← Fluid Density ← Fluid Viscosity

    - The movement is dominated by viscosity
  - Clamshell hypothesis: reciprocal motion doesn't work at low Reynolds number – instead it's a rotary motor
    - Proton motive force turns a ring that drives the motor
  - Flagella are hollow on the inside
    - Made of one protein: flagellin
    - It grows from the inside-out
    - Very complex
  - Going counter-clockwise they drive the cell forward
    - Going clockwise, they fly out in a tumble
  - By changing the frequency, you get longer or shorter runs