Related to the last lecture:
  o 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.
  o Life on Earth today: the foundation
    - CO₂/O₂ cycle

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

Shape and Appearance – not where the interesting stuff is regarding microbes
  o They don’t bring in solid food – they bring in dissolved substrates.
    - Surface area to volume:
      \[
      \frac{SA}{V} = \frac{4\pi r^2}{\frac{4}{3}\pi r^3} = \frac{3}{r}
      \]
  o “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
    o 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
    o Archea – S-layers, pseudo peptidoglycan

• Motility
  o Flagella – moves like a propeller in bacteria, not like a whip – they’re rigid
    ▪ Video clip: *E. coli* moving with rotating flagella
    ▪ \( \frac{\text{Inertial Forces}}{\text{Viscous Forces}} \approx \frac{\text{a} \times \text{v}}{\eta} \) ← Fluid Density
    ← Fluid Viscosity
    ▪ The movement is dominated by viscosity
  o 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
  o Flagella are hollow on the inside
    ▪ Made of one protein: flagellin
    ▪ It grows from the inside-out
    ▪ Very complex
  o Going counter-clockwise they drive the cell forward
    ▪ Going clockwise, they fly out in a tumble
  o By changing the frequency, you get longer or shorter runs