20.106J – Systems Microbiology
Lecture 1
Prof. DeLong

- Text: *Biology of Microorganisms*, by Michael Madigan and John Martinko, 11th edition.

- Grading based on:

Problem sets (~1 every 2 weeks)		25%
Midterms	I	20%
	II	20%
Final Exam		35%

- There will also be guest lecturers

- Slide of microscopic image of microorganisms: simply looking doesn't give a *lot* of information.
    - So how do we examine them?
    - What constitutes microbial diversity?
        - It has to do with what they can do with matter and energy → metabolism (on the other hand, diversity has more to do with tissue for higher organisms)
    - Why are microbes important? → ecology, health, engineering…

- Slide of biological levels from cell to ecosphere:
    - With microbes, we can skip the levels of tissue, organ, etc., all the way up to the levels of population and community → a whole chain of microorganisms are involved

- Slide of satellite shots of Earth showing chlorophyll from outer space:
    - You can see blooms of microorganisms → the movement of El Niño over the Pacific is visible via the changing growth of microbes.
    - Earth looks *really* different from outer space because of microbes.

- Microorganisms have been on Earth for about 3.8 billion years
    - That's the majority of Earth's existence as a planet.
    - Microbes can grow anywhere on Earth, in an astounding variety of conditions.

- Metabolic diversity
    - Microbes can eat and breathe just about anything – sulfates, nitrates, metals… (they can even eat rocks!).
    - From all this, they create biomass, which feeds the entire food chain.

- All of this is essential in terms of energy and the environment.

    - The vast amount of diversity on Earth exists in the microbial world.
    - Microbes represent more than 50% of biomass in the oceans.
    - They control all the elemental cycles that shape Earth's habitability.
    - They can live without us… but we can't live without them.
    - It used to be that microbes were the only way that nitrogen got into the atmosphere…
        - But now, with fertilizers etc., people are contributing to the nitrogen cycle more than microbes are.
    - Slide: photosynthesis and respiration
        - Plants ←→ Animals: both are codependent
    - Slide: Energy: The Anthropocentric perspective
        - We're using up all the oil, putting carbon dioxide in the atmosphere.
    - Slide: graph of atmospheric carbon dioxide over time, as measured at Mauna Loa.
        - Shows a steep, steady increase – we haven't seen an increase like this in a very long time – it doesn't look natural.
        - There are spikes of carbon dioxide every winter and lower areas every summer, because plants are photosynthesizing more in the summer.
        - This increase in carbon dioxide could have serious consequences as the greenhouse gas effect.

- Slide: "The Popular View of 'Bugs'"
    - People popularly think that microbes ("bugs") are somehow dirty or damaging, but the truth is that you *cannot* get rid of them – they're all over your body, and most of them are good for you.
        - It's a symbiotic relationship.
        - Slide: host bacterial symbiosis in the human intestine.

- Fundamentally, pathogenic microorganisms use the same machinery as nonpathogenic ones.
    - Short movie: bacteriophage infecting a cell.

- Biotechnology and biological engineering: research examples
    - Functional diversity in rhodopsin – in the presence of light, this will move a proton, creating an electrical gradient that allows ATP production
    - The functional parts of a cell: people are working on creating a registry of standard biological parts.

- Life on Earth: How did we (everything) get here? (Lessons in geobiological engineering).
    - Microbes seem to have originated about 3.8 billion years ago.
    - But it turns out that the oldest rocks on Earth are only about 4 billion years old (existing in Greenland, Australia, and South Africa).
    - Slide: "The Early Earth System," "The Evidence"

- It's hard to make all these inferences, because the earth looks so different now
    - The early earth had no oxygen, water only as steam, and lots of asteroid collisions.
- The origin of life on Earth:
    - In situ (originating here) or panspermia (coming from elsewhere via a collision)
        - Panspermia seems unlikely, though interesting, because outer space can destroy these organic molecules very quickly.
    - The Oparin ocean scenario, or hydrothermal vents?
- Determining the atmospheric composition of the early earth is still largely guesswork
    - This early atmosphere had mildly reducing conditions
    - As the earth cooled, H_20 dropped from the sky, and the oceans formed. These early oceans contained lots of sulfates and acids.

- Some scenarios for the origin of life:
    - The Miller Urey experiment: CH_4, H_2, NH_4, and H_2O, plus energy, will generate amino acids and simple sugars.
    - But how do you produce molecules that actually replicate?
        - Slide: ribosomal RNA – its folding, tertiary structure allows it to act as an enzyme: ribozyme.
        - Thus we have a single molecule that can reproduce itself *and* act as an enzyme, and hence this might be where life originated
        - There's also a clay that can create lipids, and once one of these ribozymes ended up inside one of these lipid vesicles, very interesting things could happen.
        - However, there are some problems – *we don't really know* – this is all speculative.

- The evidence for theories on the origin of life:
    - People look at very old rocks, and identify impressions that look like life, starting around 3.5 billion years back.
        - Microbes create macrofossils – stromatolites – microbial mats that create layers, building formations that look like big rock mushroom structures.

- Stable isotope analysis, organic geochemistry.
    - Look at the internal structure of an atom – there are different isotopes.
    - We know the normal stable isotope abundances.
    - Life changes these isotope abundances, because it uses light isotopes preferentially.
    - The delta value δ – comparing isotope ratios – measure using mass spectroscopy.

$$\delta_X = 1000\left(\frac{R_X - R_{Std}}{R_{std}}\right) \quad {}^{0}\!/_{00} \quad \text{(per mil)}$$

  - We breathe out more heavy oxygen than we take in
  - In plants, they preferentially incorporate the lighter carbon dioxide as well
  - All of this matters because we can measure the isotope ratios in fossils – old rocks – and they're really light!
    - This kind of chemical evidence is a lot more reliable than just examining these rocks visually – this is real evidence.

- Around 2.5 billion years ago something big happened, dropping huge amounts of oxidized iron – rust – into the earth in huge red bands → this represents the rise of oxygen in the atmosphere, as microbes and plants figured out how to split water.
  - That rise in oxygen is what set the stage for *us* – animals.