20.106J – Systems Microbiology
Lecture 15
Prof. DeLong

- Exam this week:
- Lectures Oct 23 (techniques of genomics), 25 (comparitive genomics), 29 (lateral gene transfer and how genomes evolve), and Nov 1 (Nitrogen cycle from a global perspective, rhizobium and agrobacterium)
- Brock Chapters 15 (all), 17(586-591), 19 (656-666), and 31 (989-991)
- Today's lecture won't be on the exam.

- Environmental Genomics and Microbial Ecology
  - Natural microbial diversity
  - Molecular microbial ecology techniques
  - Environmental Genomics

- Methods for trying to understand bacterial communities – we don't normally get pure cultures
  - If you get a pure culture, it's much easier to describe
  - But then you have to be able to describe how it interacts with the larger mixed environment that it came from
  - Counting:
    - Seawater plate count (hundreds of cells per ml)
    - Direct count – fluorescence (millions of cells per ml)
    - Why do we get this difference?
    - If there are all these microbes that won't grow on a plate culture in the lab, then how can we characterize and study them?
  - Microbial evolution and phylyogeny
  - Cultivation independent surveys – Phylogenetic relationships
    - Polymerase Chain Reaction was invented since this process was come up with – it allows you to amplify a particular gene from a complex DNA mixture
    - That helps with Phylogenetic analysis
  - Known Bacterial Phylogenetic Divisions – in 1987, there were only 12. Now there are around a hundred, most of which we haven't been able to culture.
  - The diversity is enormous – but how does that help us understand their properties and function?
  - Remember, Phylogenetic trees are simply measures of genetic difference
  - Secondary structure of a small subunit of rRNA – you can design an oligo-nucleotide probe
  - Fluorescent In Situ Hybridization – a species-specific DNA probe – we can identify cells even at the single-cell level
    - Beyond just identifying cells, you can start to recognize specific patterns of environmental interaction

- These techniques are really important for understanding microbes that we haven't been able to culture in a lab yet
- These techniques are far more effective than microscopy, which turns out to be more of an art than a science
- Remember Buchnera – it's an obligate symbiont – the only thing that can grow it is an aphid
- Genomic DNA libraries: variations on a theme:
  - Small inserts versus larger inserts
- Microbial diversity in seawater
  - Every drop has 10^6 bacterial cells per ml
  - Every drop has 10^7 viruses per ml
- "SAR86" 130kb Genome Fragment – we found a proteorhodopsin, which had never been found in bacteria before (it had been in archea)
  - Rhodopsins are photoproteins – they absorb photons
  - Looking at it on a Phylogenetic tree doesn't help so much in terms of function
  - But you can look at its secondary structure, and you can see that it retains the elements from functional sensory rhodopsins
  - Light-driven proton pumping
  - This looks like a new way that microbes can get energy from light
- Understand the process of looking at an organism from the environment and then understanding their function by using all these processes
- Once you know that a particular gene or organism exists, you can go back out into the environment and ask questions about it.
- Population biology, gene distributions, and speciation – hard to do on a macro-scale
- It was really a surprise when people realized that different strains of E. coli can vary by a whole megabase.
- Now that we know that these bacteria have this kind of rhodopsin, when we look for it we find it all over the place in the ocean
  - The rhodopsin varies by depth
- Lesson: we've barely explored microbial sequence space at all: six years ago we didn't even know this rhodopsin existed, and now we know it's one of the most common bacterial genes in the ocean.
- Mapping organisms to their habitat
  - Which genes are found at which depth in the ocean? It's not random.
  - Genes associated with flagella and chemotaxis were more highly represented in the shallow water
  - Biosynthesis, pili, and attachment genes were more common at the greater depths
  - Look at clusters of orthologous genes
  - Transposases increase with depth – we don't know why this is, but it looks like a real trend

        - These transposases don't just all come from one family or one organism – this trend is spread out across a wide variety of transposases.
- A lot of the viruses in this ocean sample came from cyanophage
- Samples from the Sargasso Sea
- We're learning a lot about how these organisms evolve, how they adapt to their environment, and how they pick up variability
- Genomics doesn't just lead us down a reductionist path – it allows us to zoom out and look at the larger picture.