20.106J – Systems Microbiology
Lecture 13
Prof. DeLong

- Genome Evolution and Ecology
  - LGT and Genome Evolution
  - Genomics of Endosymbionts
    - Live inside of other organisms, thus they're protected from the outside environment
  - Environmental Genomics (Meta-genomics)
    - Looking at genomes in the environment

- Mechanisms and consequences of lateral gene transfer
  - Three methods:
    - DNA transfer by phage
    - DNA transfer by conjugation (uses pili)
    - DNA transfer by transformation
  - These methods of transfer can all speed up the rate of mutation enormously
  - Thus huge genetic variation exists among these organisms
    - Remember, only around 40% of E. coli DNA is shared among all three major E. coli strains
  - Map of genetic differences between Uropathogenic and enterohaemorrhagic E. coli
    - Transfer RNAs are a place of frequent insertions
  - Molecular phylogenetics
    - Making Phylogenetic trees – simply based on the number of sequence differences
    - Requires certain conditions:
      - You must be comparing homologous sites and homologous sequences
      - Watch for paralogous genes – the result of a gene duplication within a cell, so that one form can develop a different function, inside the same organism
      - Homologous, on the other hand, implies the same gene function in different species
    - These gene phylogies can be misleading if lateral gene transfer has occurred
    - Phylogenic diagram showing lateral gene transfer
  - We can't just think about the genes that are inherited from parent cells – the genes that microbes pick up from other microbes by lateral transfer is also prominent – it's a way of rapidly acquiring new traits
    - It has big implications for the evolution of these organisms, particularly with antibiotic resistance.
  - Detecting horizontal transfers
    - Not all genes are easily transferred

        - For example, ribosomal DNA is too complex a machinery to move around easily
            - Thus you can use ribosomal DNA to map a cell's genetic descent, ignoring lateral transfers.
        - You can also detect later transfer by comparing operons – conservation of gene order
        - Anomalous DNA composition is also relevant – if there's a block of much higher AT or GC composition, for example

- Genome Evolution in the context of natural history and the organism. We'll focus on one system that is particularly well understood – the aphid.
    - They poke holes in plants and eat the flow
    - This food is very nutritionally poor mostly carbohydrates – no amino acids, very little nitrogen.
    - The only reason they're able to survive this way is that they have bacterial endosymbionts that produce amino acids for them.
    - Essential amino acids – there are ten amino acids that we have to get in our diet, because we can't produce them ourselves
    - Back in the 1900s, with light microscropy, scientists could see that many insect cells contain packaged organelles called bacteriomes that are just stuffed full of bacteria – obligate endosymbionts
    - These endosymbionts were providing the insects with amino acids
    - A map of co-evolution: symbiont phylogeny mirrors host phylogeny
        - This doesn't show time though
        - However, there's a fossil record for aphids, showing that it looks like aphids arose together with their sybionts around 150 million years ago
    - You can extract the DNA of these symbionts and assemble the whole genome
        - The genome is a lot smaller, since they don't have to live out in the environment
        - Somewhere around 400 kilobase pairs
    - These Buchnera endosymbionts are derived from E. coli
        - We can reconstruct a common ancestor, which would have looked very much like E. coli
        - The gene loss must have happened very rapidly
        - This process is described in a paper by Siv Andersson
        - After 70 million years, there are no chromosomal rearrangements or gene acquisitions
        - But considerable sequence divergence does occur
        - They're changing around 2000 times faster
        - Accumulation of pseudo-genes restrict the diet of the aphids
        - The evolutionary dynamic is very different – there isn't any rearrangement
        - Many fewer non-synonymous substitutions occur
        - Also very few repeats

        - This sort of genome reduction can get really extreme, as long as the host relationship is stable enough
        - The symbiont has lost the ability to regulate its own gene control – it doesn't have the mechanisms that free-living bugs like E. coli have, so it can't make more or less amino acids depending on the diet that the aphid is on

- Another system: Baumannia and Sulcia in the Glassy-winged Shapshooter
    - The genomes are pretty similar to Buchnera
    - You have to think of the insect like an ecosystem
    - One wonders: how much are there similar things going on in out own systems?
    - For example, it looks like human genetics determines which bacteria live in our stomach and intestines, which influences obesity.