Lecture 3

1. Diversity among microbes

1.1 How diverse are microbial communities ?

- Diversity of habitats which selects for biodiversity of microbial communities. Characteristic microbes from specific ecosystems.
- Spacial heterogeneity: patterns of microbial diversity in soils.
- Temporal changes of community composition: patterns of diversity in time.
- Regulation of organismic ecosystem structure: how bacteriaplankton is regulated.
- Amounts of microbial biomass on earth: human gut contains more prokaryotic cells than the entire body consist of eukaryotic cells.
- Biogeography and co-evolution of bacterial diversity.

1.2 How can microbial diversity be sampled and quantified?

- Diversity based on cultivation vs. diversity based on molecular phylogenetic techniques.
- Basic molecular techniques: PCR of rDNA, cloning and sequencing, single-cell hybridization, etc.
- Designing primers which anneal to group specific and to universally conserved sequences of 16S-rRNA-genes.
- Analysis of sequence information: software packages for statistical methods.
- Known and unknown diversity: how to account for not yet culturable microorganisms.

1.3 Developments in molecular ecology

- 1970s: Discovery of a hidden diversity, the Archaea domain (kingdom).
- 1980s: Use of microbial models to test evolutionary hypotheses.
- 1990s: Application of molecular tools to study microbial diversity in ecosystems: RFLP, T-RFLP, DGGE, FISH, etc.
- 2000s: Microbial community analyses reveals large numbers of unknown microorganisms.
- 2003s: Mathematical modelling approaches to analyze interactions on cellular and complex microbial ecosystem levels.

Lecture 4

3. Phylogenetics: Evolution of microbial diversity

3.1 Evolutionary driving forces

- Mutations, horizontal gene transfer (conjugation, transformation, transduction) , selection, symbioses, cellular compartmentalization.
- Consequences of lateral gene transfer on phylogeny, plasmid structures and plasmid propagation, transposable elements.
- Prerequisits for rapid expression of new traits: haploid chromosome, plasmids, DNA-exchange and insertion mechanisms, small genome size (500kb to 10mb), rapid growth rate.
- Evolutionary experiments with microbes.
- Ecology of spreading genes and selection of microbes that carry them.
- The role of temperatures for early evolutionary processes. Was it hot, warm or cold ?
- Evolution of microbial symbioses, incl. symbioses in eukaryotic cells.

3.2 Genomic and proteomic data collections

- Biological databases for the study of microbial evolution: physiology, genomics, phylogeny.

- Molecular records of the biosphere: databases containing genome and protein sequences.
- Evolutionary models based on functional bioinformatics.
- How large is the essential genome ?

3.3 Phylogenetic developments
- The three domains (kingdoms) of organisms: Bacteria, Archaea and Eukarya.
- What are the forces that select for differentiated cells and not for the unified cell ?
- Criteria defining evolutionary relatedness: what distignuishes the three domains (kingdoms) of life ?
- Phylogenetic trees based on 16S-rRNA, backgrounds and construction.
- Phylogeny and taxonomy: metabolic genomics beyond phylogenetic trees.
- Metabolic phylogeny in the Archaea domain (kingdom), in the Bacteria domain (kingdom).
- Phylogeny of microbial eukaryotes from anoxic environments.
- Environmental evolutionary driving forces: effects of mass extinction phases, new radiations in the tree.

3.4 Genome analysis of bacterial communities
- Strategies and methods to analyze mixed population DNA.
- DNA/DNA hybridization for analyses of microbial communities: FISH and Checkerboard-Hybridization.
- Environmental genomics, novel organisms.

Exercises III: To topics from

8. Simulation of ecological determinants for the cultivation of microorganisms

8.1 Taming and domesticating microbial diversity
- Enrichment and isolation strategies.
- Composition of microbial diets (media).

8.2 Simulating conditions for growth in culture
- Static vs. continuous growth.
- Natural enrichments as sources for microorganisms.
- Evaluating diversity through enrichment culturing.
- Active in nature but not culturable yet: a consequence of our limited knowledge of microbial ecology.

Exercises IV: To topics from

2. Phenotypic characterization of metabolic versatility

2.1 Metabolic versatility
- Understanding metabolic diversity in Bacteria, Archaea and microbial Eukarya.
- Re-inventing the prokaryotic cell.
- Assimilative carbon autotrophy and pathways for CO_2-fixation.
- Energetic lifestyles: photo- and chemotrophy.

2.2 Levels of diversity
- Criteria for phenotypic characterization of Bacteria and Archaea (taxonomy acc. to Bergey's manual).

- Diversity at the level of electron donors and electron acceptors.
- Diversity in pathways for carbohydrate catabolism and the creation of basic metabolites for anabolism.
- How diverse membrane topologies fulfill the same chemiosmotic function.
- Functional diversity within genotypically unique groups.Genotypes, phenotypes, phylotypes and ecotypes.