# Time Series Analysis of Bacterial Community Composition

Software Engineering for Data Scientists (CSE 599 B1) Project Saghar Hosseini, Yuan Gao, Janet Matsen, Pearl Philip

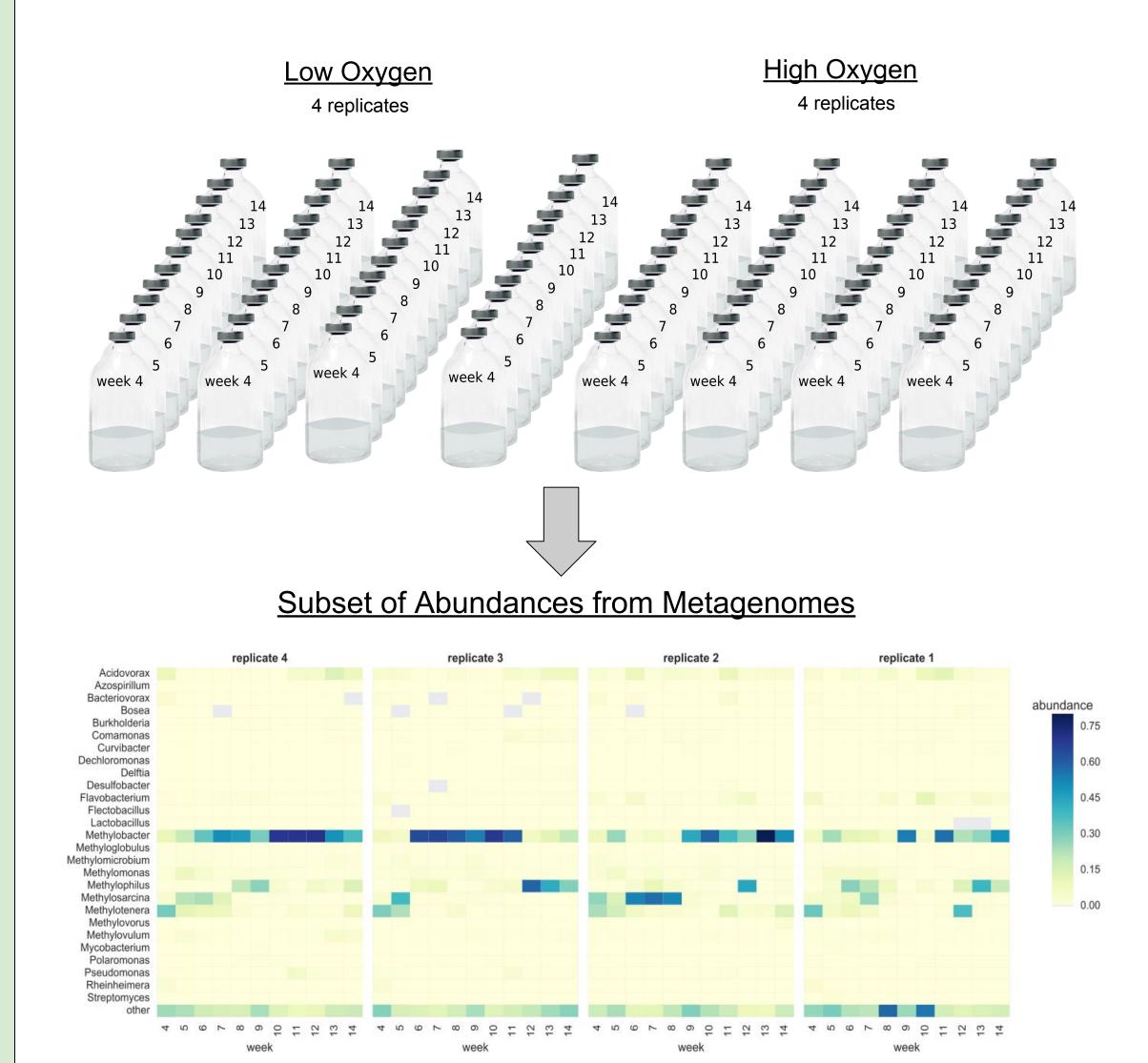


# Background

How do bacteria cooperate to remediate methane in Nature? We can discover their interactions by observing population dynamics.



Lake sediment was collected from a 180-foot deep study site in Lake Washington using this sediment corer. The samples were propagated with methane, and either high or low oxygen for 14 weeks. Metagenomes were sampled for weeks 4-14. Relative abundances of bacteria were inferred from this 5 terabyte sequencing data set.



#### Methods

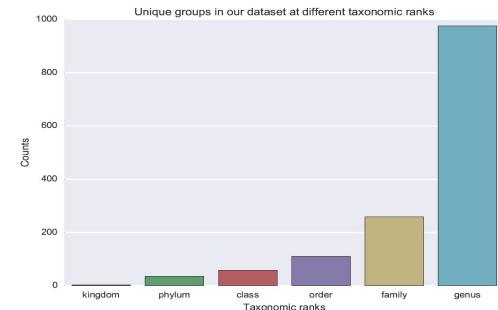
#### **Dynamic Mode Decomposition (DMD)**

- Powerful tool for analyzing the dynamics of nonlinear systems
- Given a sequential time series of data, DMD computes a linear mapping A, relating the snapshots:

$$egin{bmatrix} egin{bmatrix} \vdots & \vdots & \vdots & \vdots \ x_1 & x_2 & \dots & x_{t+1} \ \vdots & \vdots & & \vdots \end{bmatrix} = A egin{bmatrix} \vdots & \vdots & \vdots \ x_0 & x_1 & \dots & x_t \ \vdots & \vdots & & \vdots \end{bmatrix}$$

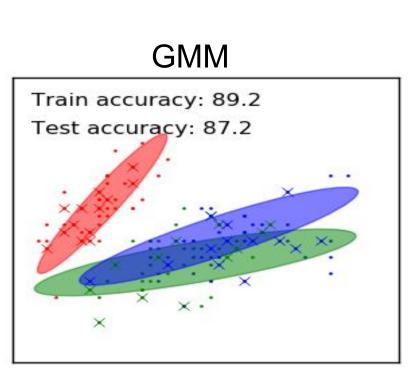
## **Clustering algorithms**

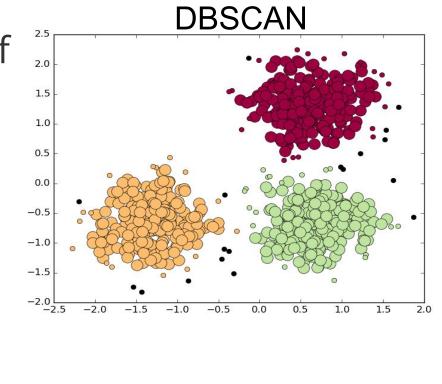
- . Gaussian Mixture Models: Generates data points from weighted sum of Gaussian component densities.
- 2. DBSCAN: Clusters points that are closely packed, marking as outliers points that in low-density regions.
- 3. Clustering through logical taxonomic reduction: Summing abundances across the sample space below a cutoff taxonomic rank to reduce data size.

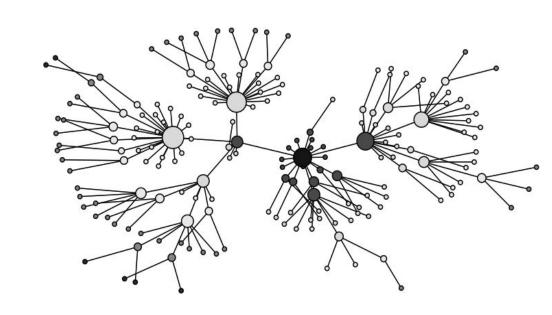


## Visualization tools

 NetworkX:Creation, manipulation, and study of the structure, dynamics, and functions of complex networks.

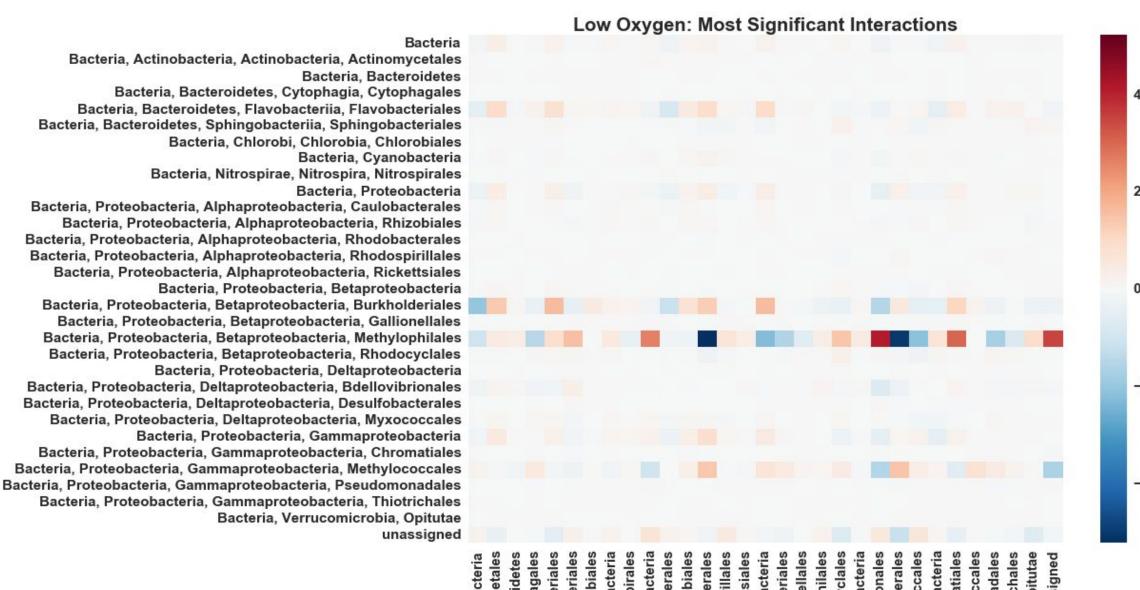




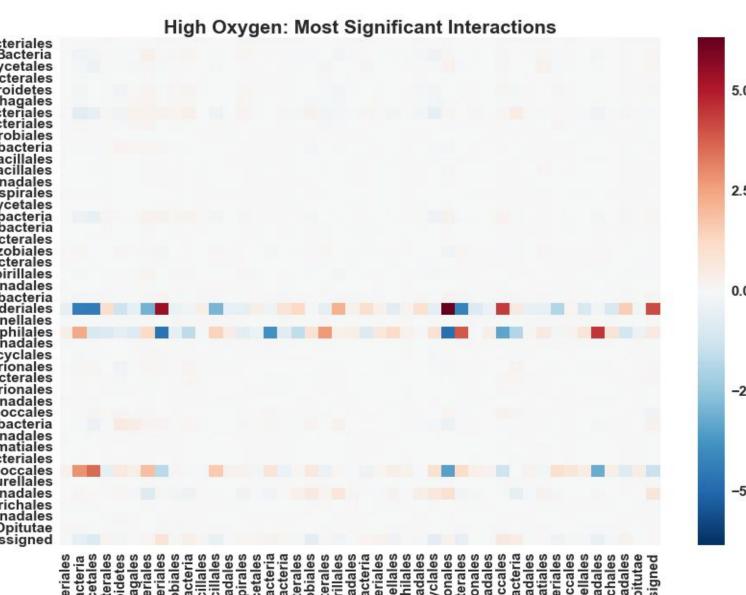


## Results

#### **Bacterial Correlations from Interaction matrices**



Bacteria, Actinobacteria, Actinobacteria, Actinomycetales
Bacteria, Bacteria, Bacteroidetes, Cytophagia, Cytophagiales
Bacteria, Bacteroidetes, Flavobacteriales
Bacteria, Bacteroidetes, Flavobacteriales
Bacteria, Bacteroidetes, Sphingobacteriales
Bacteria, Cyanobacteriales
Bacteria, Cyanobacteriales
Bacteria, Proteobacteria, Alphaproteobacteria, Caulobacteriales
Bacteria, Proteobacteria, Alphaproteobacteria, Rhizobiales
Bacteria, Proteobacteria, Alphaproteobacteria, Rhodobacteriales
Bacteria, Proteobacteria, Alphaproteobacteria, Rhodobacteriales
Bacteria, Proteobacteria, Betaproteobacteria, Burkholderiales
Bacteria, Proteobacteria, Betaproteobacteria, Gallionellales
Bacteria, Proteobacteria, Betaproteobacteria, Gallionellales
Bacteria, Proteobacteria, Betaproteobacteria, Methylophiiales
Bacteria, Proteobacteria, Betaproteobacteria, Gallionellales
Bacteria, Proteobacteria, Deltaproteobacteria, Gammaproteobacteria, Bacteria, Proteobacteria, Deltaproteobacteria, Gammaproteobacteria, Chromatiales
Bacteria, Proteobacteria, Gammaproteobacteria, Methylococcales
Bacteria, Proteobacteria, Gammaproteobacteria, Methylococcales
Bacteria, Proteobacteria, Gammaproteobacteria, Thiotrichales



Archaea, Euryarchaeota, Halobacteria, Halobacteria Bacteria Bacteria, Actinobacteria, Actinobacteria, Solirubrobacteria Bacteria, Actinobacteria, Solirubrobacteria Bacteria, Bacteria, Bacteria, Bacteria, Bacteria Bacteria Bacteria Bacteria Bacteria Bacteria Bacteria, Sphingobacteria; Spacia; Cyanobacia Bacteria, Firmicutes, Bacilli, Bacilla Bacteria, Firmicutes, Bacilli, Bacilla Bacteria, Planctomyceta, Planctomyceta, Planctomyceta Bacteria, Proteobacteria Bacteria, Proteobacteria, Alphaproteobacteria, Caulobactera Bacteria, Proteobacteria, Alphaproteobacteria, Rhodobacteria Bacteria, Proteobacteria, Alphaproteobacteria, Rhodobacteria Bacteria, Proteobacteria, Alphaproteobacteria, Rhodobacteria Bacteria, Proteobacteria, Betaproteobacteria, Betaproteobacteria, Bacteria, Proteobacteria, Betaproteobacteria, Gallionella Bacteria, Proteobacteria, Betaproteobacteria, Gallionella Bacteria, Proteobacteria, Betaproteobacteria, Gallionella Bacteria, Proteobacteria, Deltaproteobacteria, Desulforbriona steteria, Proteobacteria, Deltaproteobacteria, Desulforbriona iteria, Proteobacteria, Deltaproteobacteria, Gammaproteobacteria, Chromatia cteria, Proteobacteria, Deltaproteobacteria, Gammaproteobacteria, Chromatia cteria, Proteobacteria, Gammaproteobacteria, Aberenia, Proteobacteria, Gammaproteobacteria, Proteobacteria, Gammaproteoba