Investigating the origins of phototrophy in Proteobacteria using genomic data

Context:

Phototrophy is the capacity to produce **cellular energy from light**. It is an **ancient** metabolic capacity dispersed throughout the tree of life (algae, plants, Cyanobacteria, several bacterial lineages). The phylum of Proteobacteria gathers several scattered lineages of phototrophs that are physiologically separated in two classes: the P(N)SB that do not produce energy from light when O_2 concentrations are high (anaerob phototrophs) and the AAPB that can produce energy from light in the presence of O_2 (aerob phototrophs). Intriguingly, AAPB and P(N)SB have intricate phylogenetic relationships between themselves, but also with non-phototrophic lineages. Some hypothesized that the **ancestor of Proteobacteria** could have been an anaerob phototroph [2], and others showed that the cluster of genes responsible for phototrophic metabolism ("PGC" for photosynthetic gene cluster) can be exchanged between bacteria via **lateral gene transfer** and plasmids [3]. Despite a large corpus of literature on their physiology and environmental distribution, the distribution of P(N)SB and AAPB across Proteobacteria has not been systematically investigated in the diversity of genomes currently available [1] and their **relative origins and relationships** remain enigmatic. All these questions have to be re-evaluated in the light of the massive number of genome data now available.

Keywords: phylogenomics; microbial evolution; genome annotation; bioinformatics; metabolism; omics data analysis

Varied pigment colors of chlorophototrophic bacteria: selected P(N)SB, taken from [1].

Master 2 project:

In order to clarify the origins and evolution of phototrophy in Proteobacteria, we propose to (i) extract reference sequences for the photosynthetic gene cluster and develop a genome annotation tool to identify it in genomes, (ii) mine publicly available genomic data (first complete **genomes**, and then **metagenome assembled genomes**) for the presence of the PGC and (iii) build a phylogenomic tree of the PGC and compare it to the species tree of Proteobacteria to provide a **scenario to explain the distribution of phototrophy throughout Proteobacteria in terms of vertical or lateral inheritance**. Finally, markers for different **energy metabolisms** studied in the lab will be incorporated in the analysis, to provide a comprehensive evolutionary scenario for phototrophy across Proteobacteria, and make sense of it in the context of **varying O_2 concentrations** over Earth history [4].

During this project, the intern will create **scripts and workflows** (Python, Snakemake, shell, awk, contribution to the Github lab repo…), use specialized programs to manipulate, **annotate and analyse large and diverse (meta-)genomics data** and build phylogenetic trees (using programs such as blast, HMMER, IQ-Tree, MacSyFinder…). This approach will enable to gain new insights on the evolution of phototrophy, a crucial energy metabolism that appeared on Earth > 3 billion years ago [4].

Profile of the candidate: Ideally, the candidate will have followed a training in bioinformatics and programming, and have an interest in addressing biological questions in link with evolution.

The TREE team @TIMC lab (CNRS, Université Grenoble Alpes): We are part of a highly inter-disciplinary team, gathering biochemists, biophysicists, molecular microbiologists, biostatisticians and bioinformaticians, with a common strong interest in microbial evolution. The lab is located on the Campus of La Tronche, in close vicinity to Grenoble (Tram B).

- The team website: http://www.timc.fr/en/tree
- The computational biology group website: https://tree-timc.github.io/compbio

References:

[1] Thiel V, Tank M, Bryant DA (2018). Diversity of Chlorophototrophic Bacteria Revealed in the Omics Era. *Annual Review of Plant Biology*

[2] Woese CR (1987). Bacterial Evolution. *Microbiological Reviews*

[3] Brinkmann H, Göker M, Koblížek M, Wagner-Döbler I, Petersen J (2018). Horizontal operon transfer, plasmids, and the evolution of photosynthesis in Rhodobacteraceae. *ISME Journal*

[4] Fischer WW, Hemp J, and Johnson JE (2016). Evolution of Oxygenic Photosynthesis. *Annual Review of Earth and Planetary Sciences*

To apply: Please send an email to the contacts listed, attach a CV, a transcript of grades, and a statement to explain your interest in the internship. *Informal enqueries are welcome, as well as a simple email to obtain the above publications should they be pay-walled.*

Contacts:

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