Bogs, Bugs, and Borgs:

Giant extrachromosomal elements with the potential to augment methane oxidation

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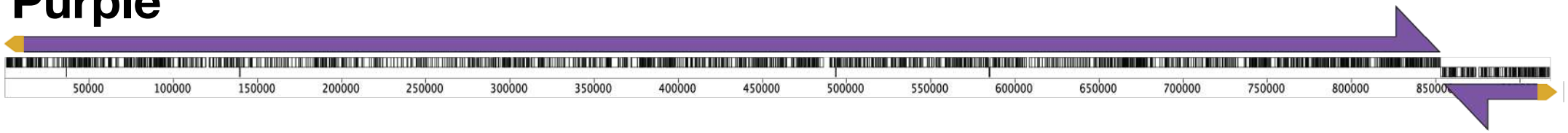
Bizarre giant linear DNA elements flanked by ~2kbp inverted terminal repeats

Purple

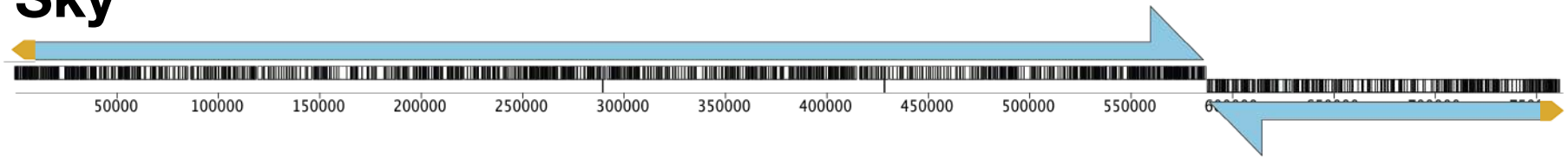


918 kb

Black

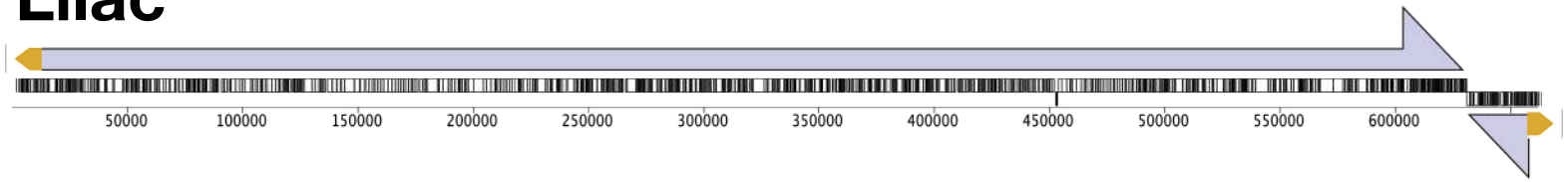
902 kb

Sky



763 kb

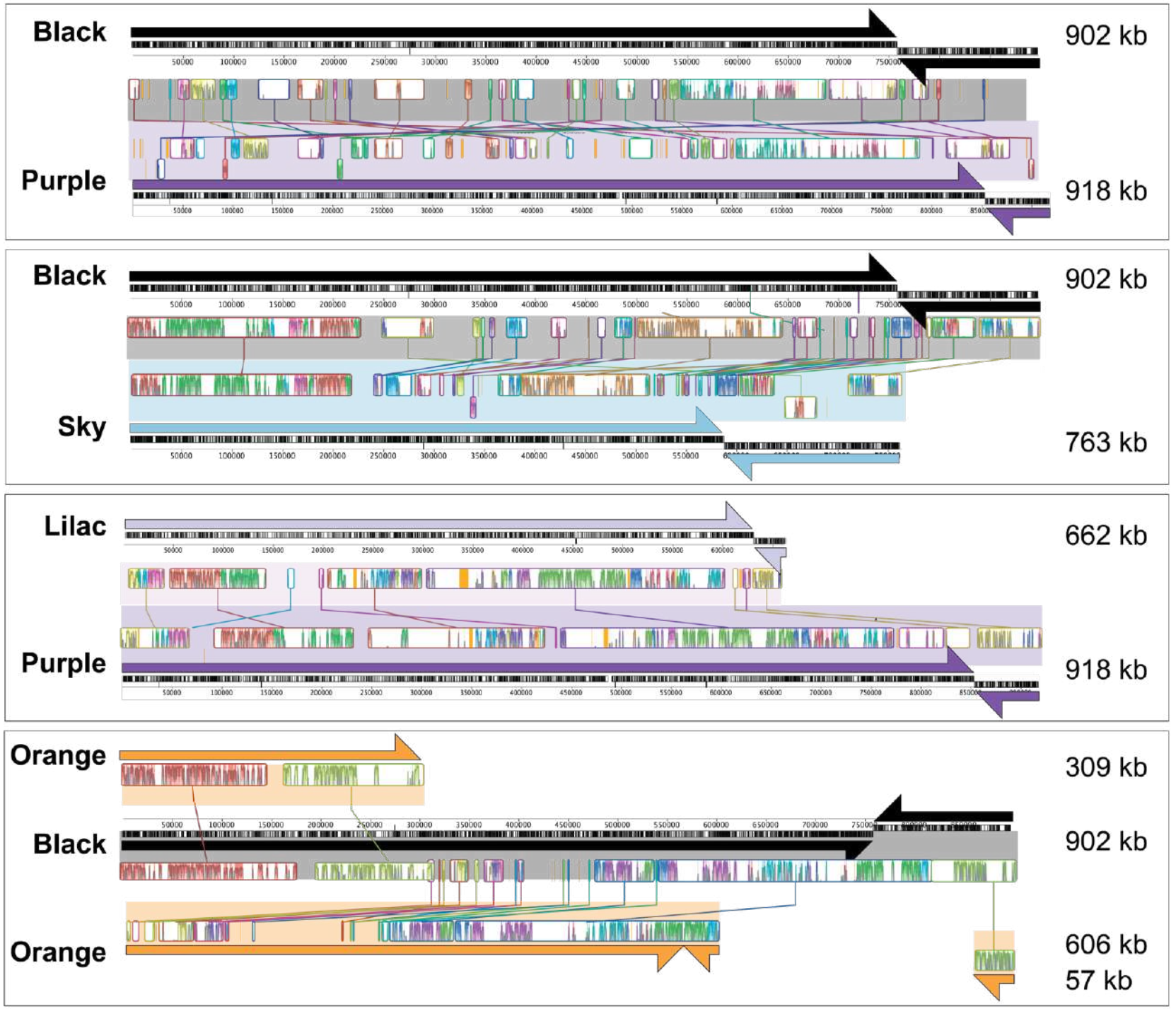
Lilac



662 kb

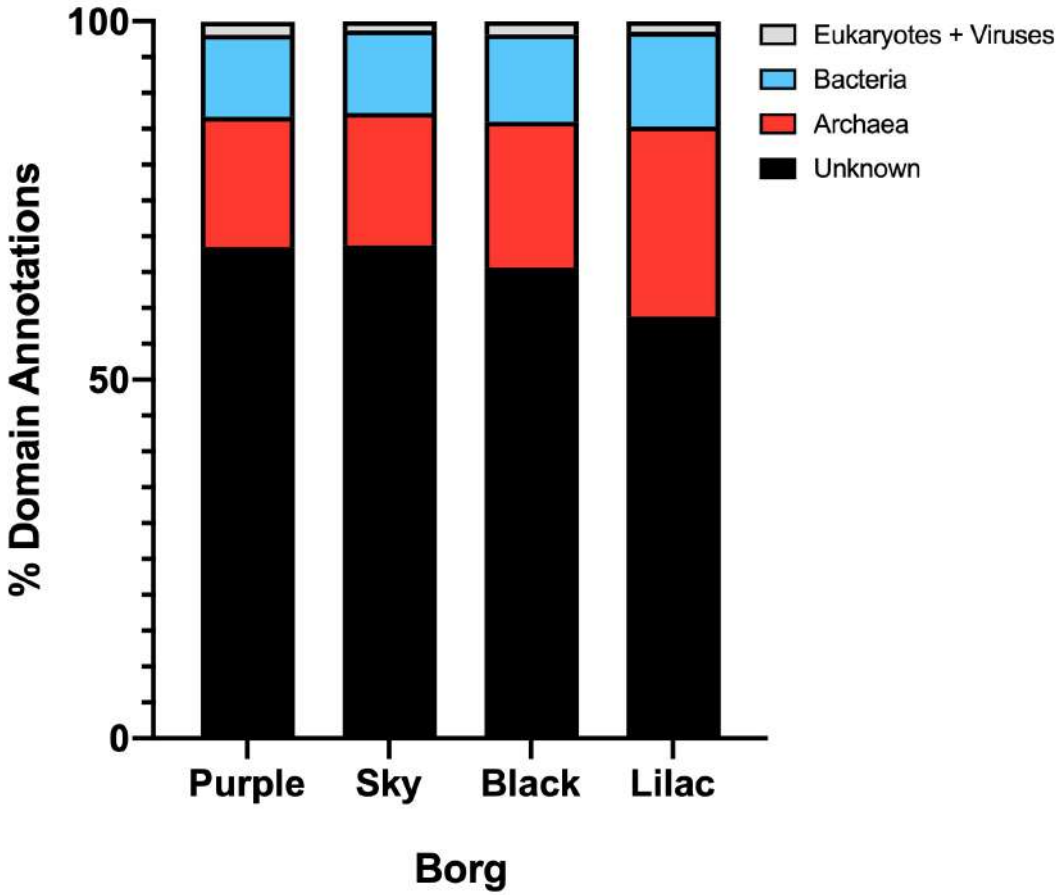
Al-Shayeb, *et al.* 2021, BioRxiv

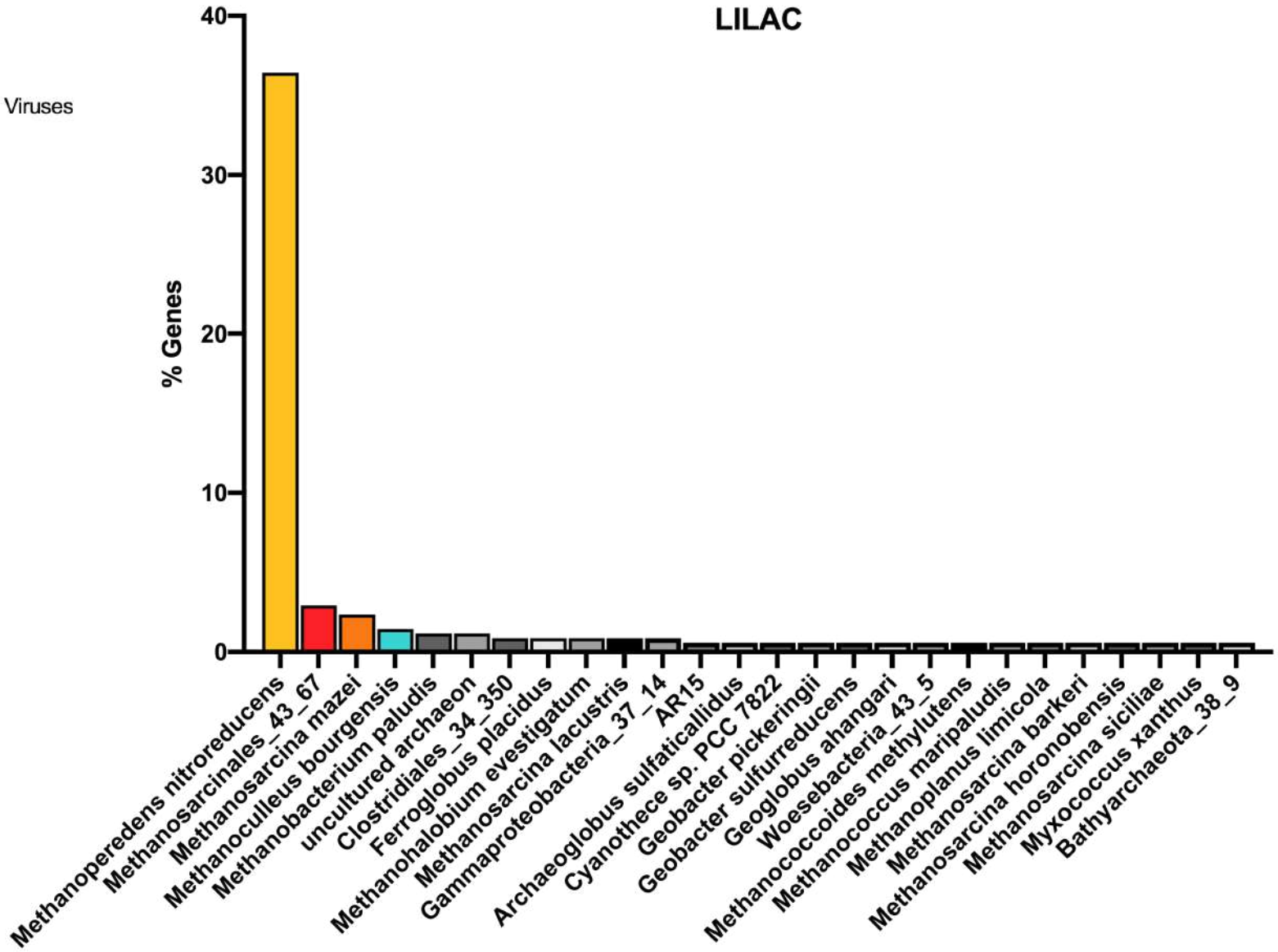
Different Borgs are syntenous (related)



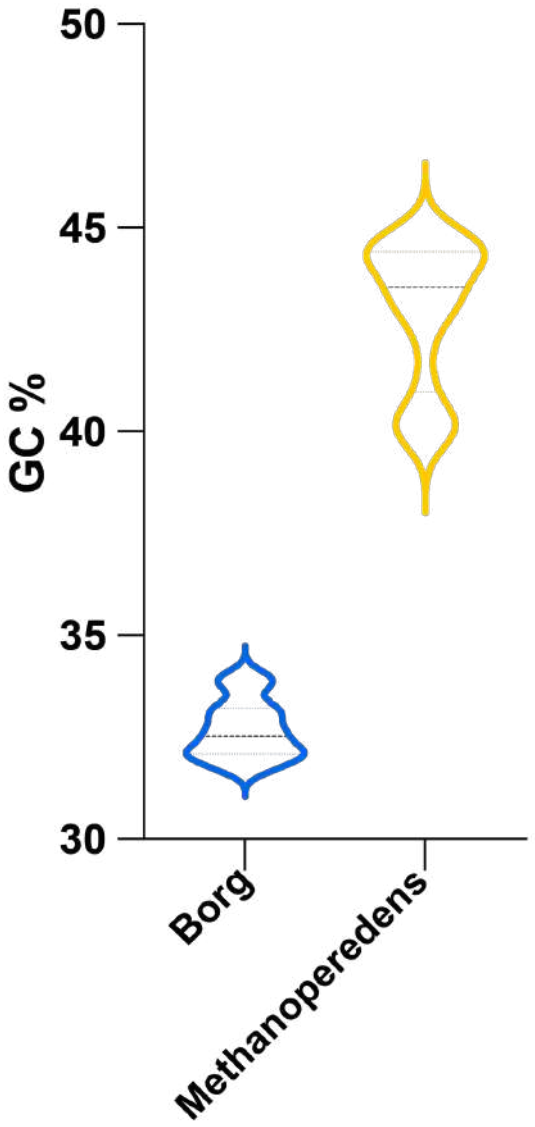
Al-Shayeb, *et al.* 2021, BioRxiv

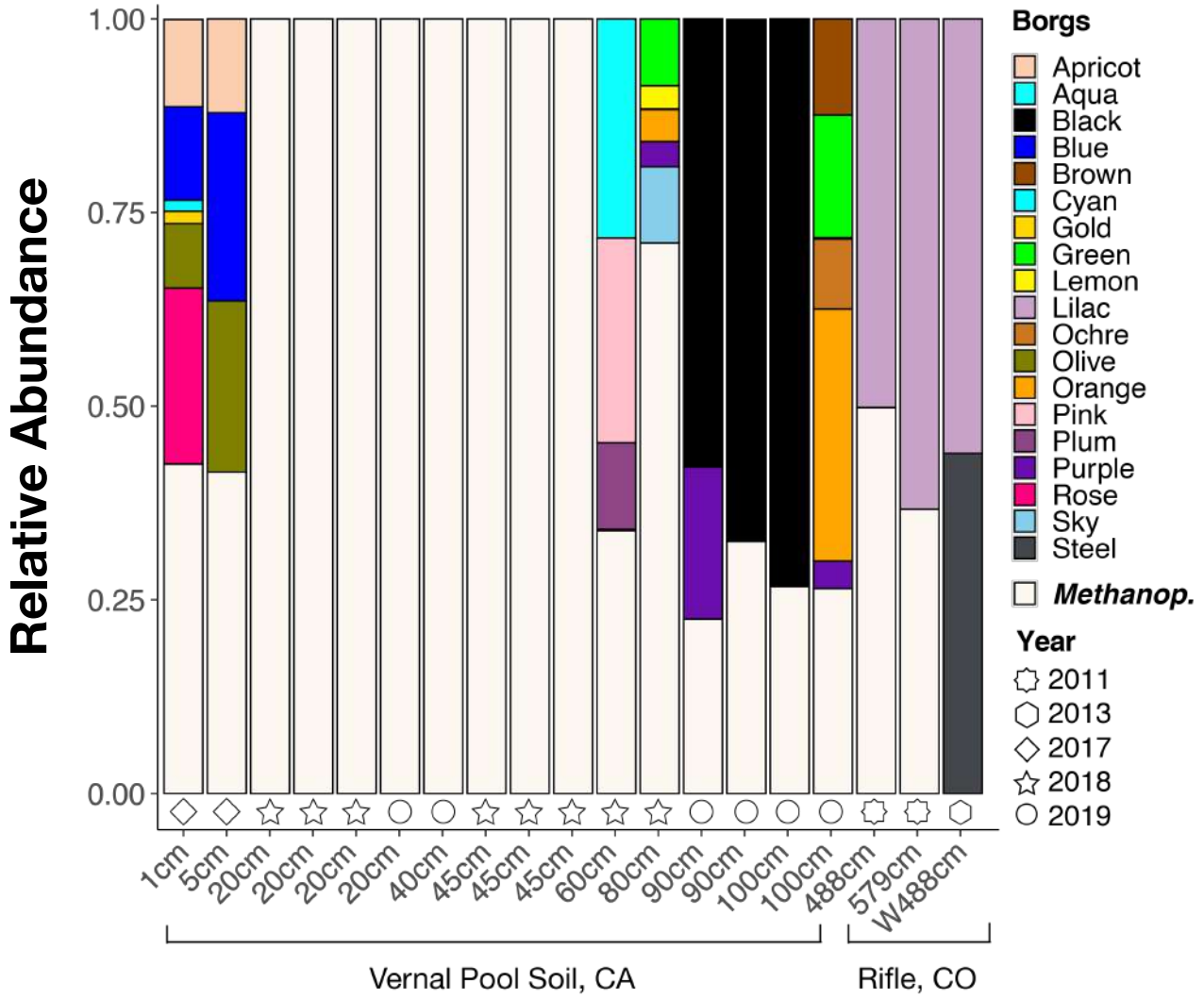
Borg genomes are most similar to archaea, namely *Methanoperedens spp.*





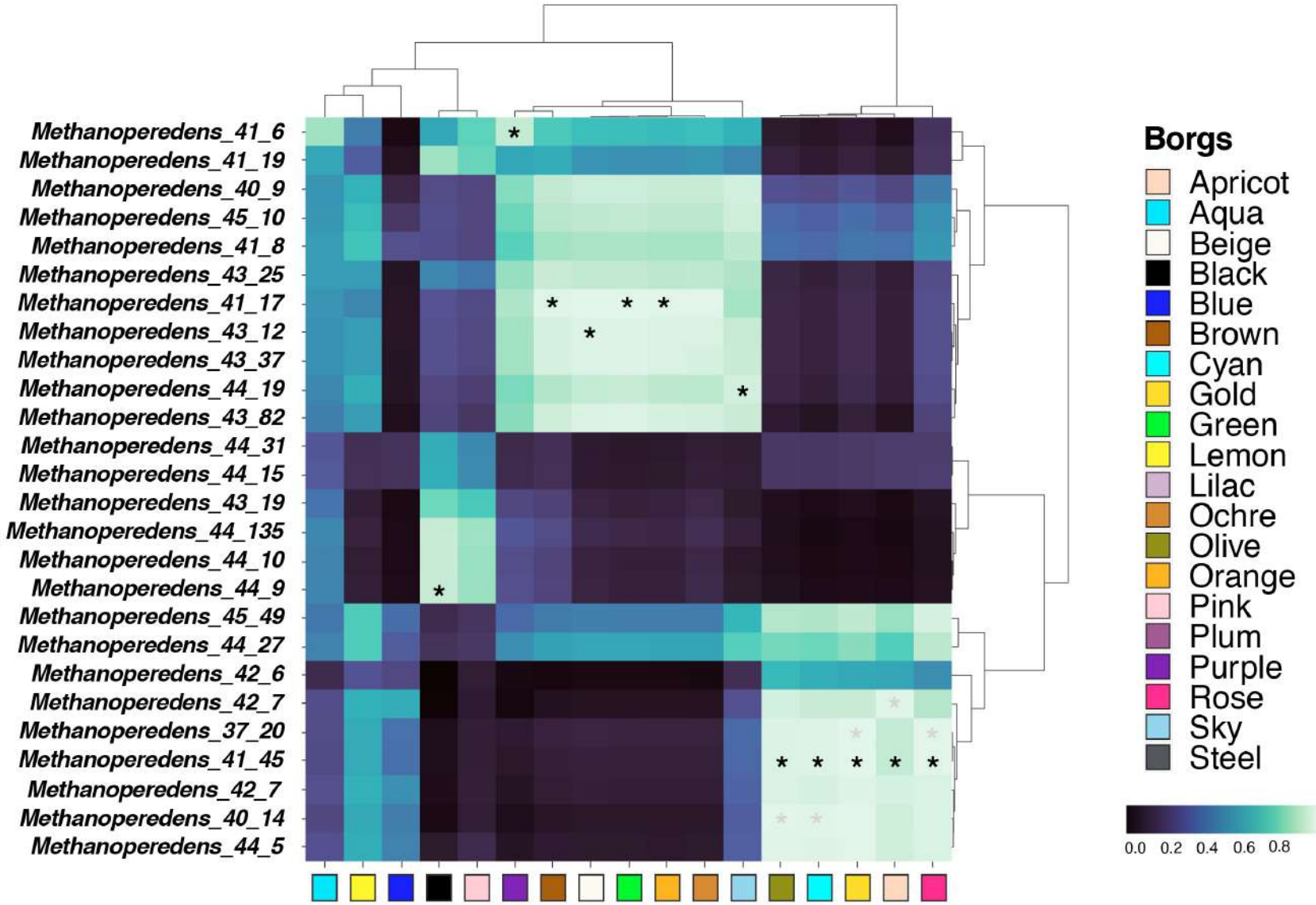
But Borgs are not part of the *Methanoperedens spp.* chromosome…

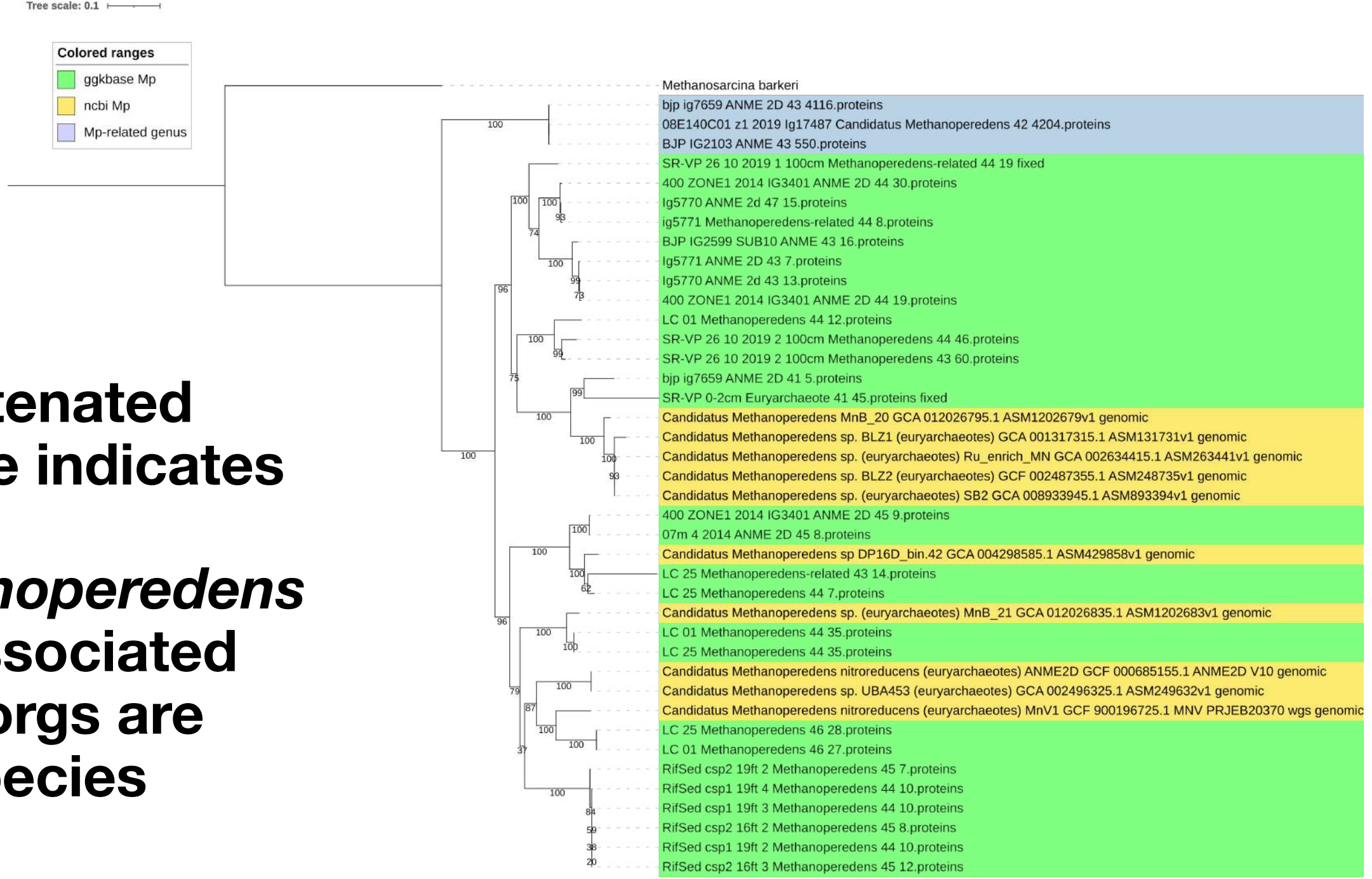




Al-Shayeb, *et al.* 2021, BioRxiv

Groups of related *Methanoperedens spp.* correlate with groups of Borgs within samples

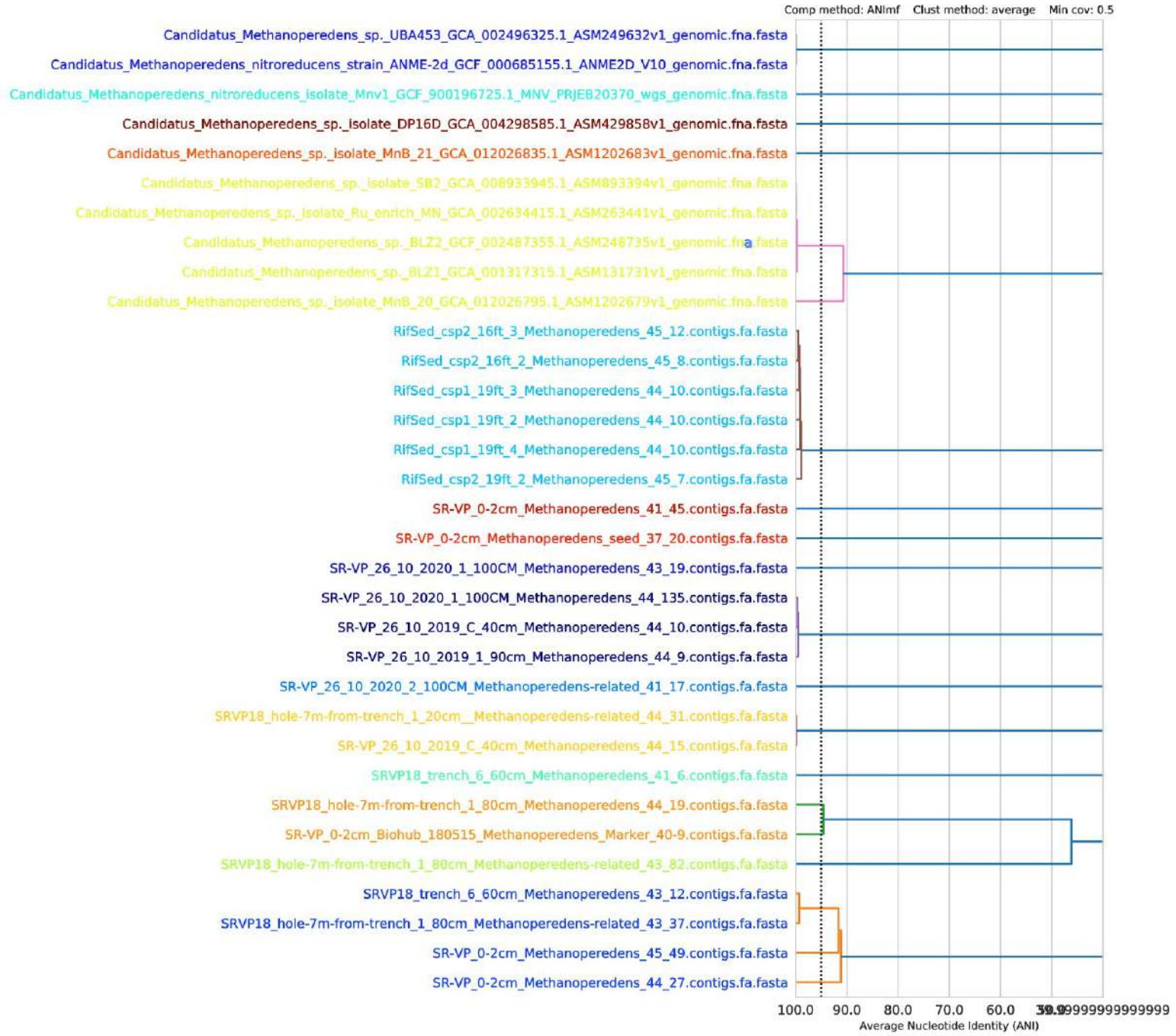




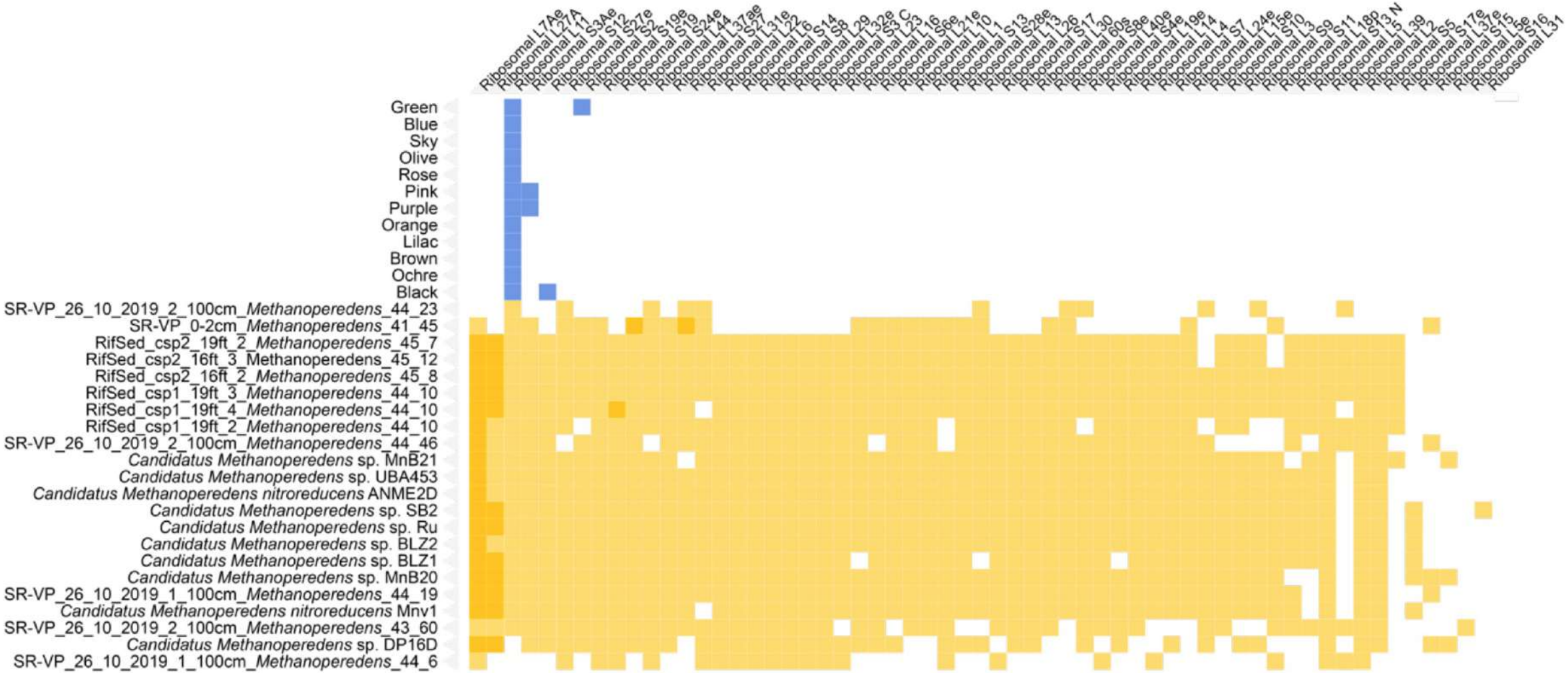
Concatenated RP Tree indicates that *Methanoperedens spp.* associated with Borgs are new species

Species-level ANI threshold = 95%

Average Nucleotide Identity Comparisons support that the *Methanoperedens* co-occurring with Borgs are different species



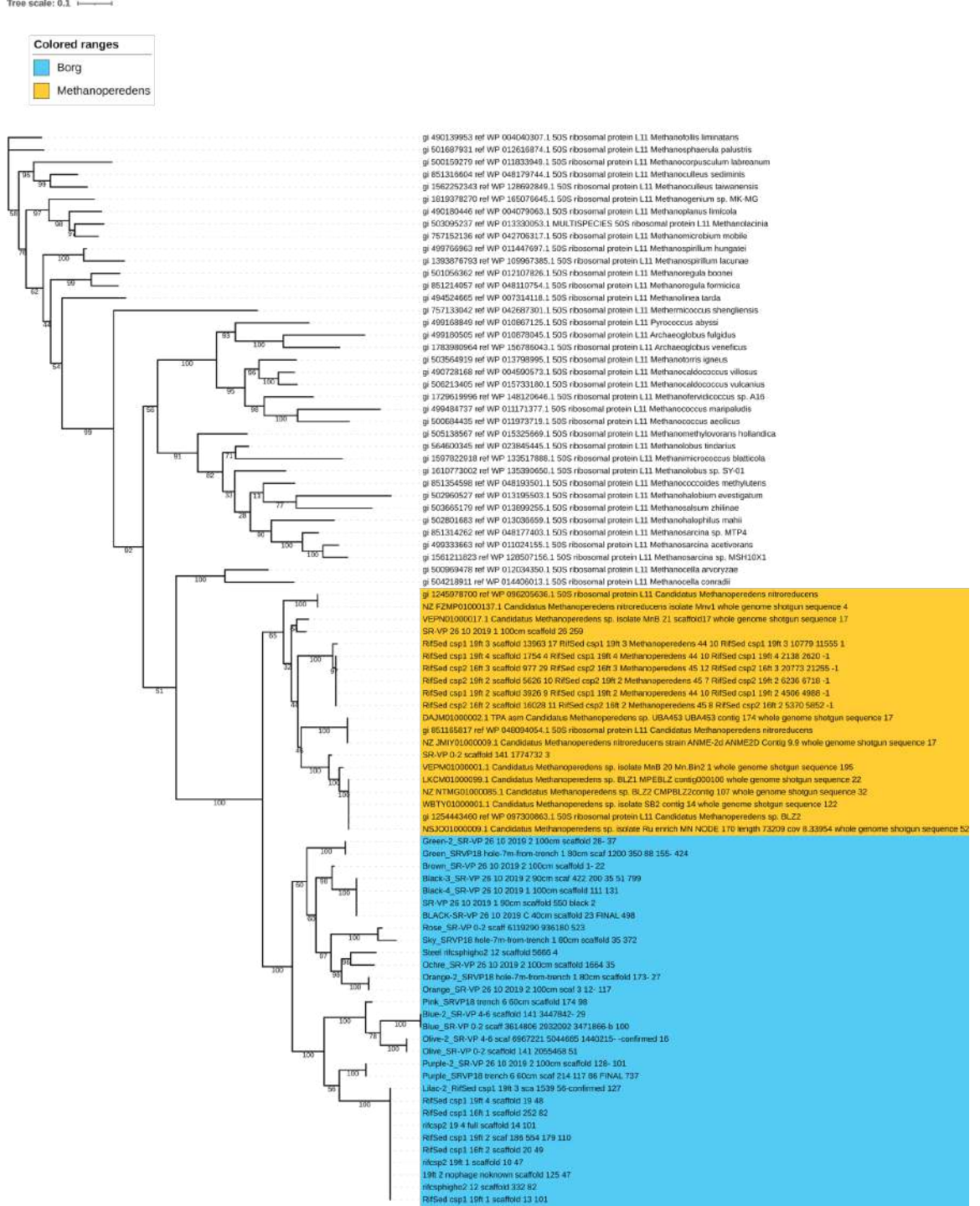
Borgs cannot be an independent Archaeal lineage



Al-Shayeb, *et al.* 2021, BioRxiv

Ribosomal Protein L11

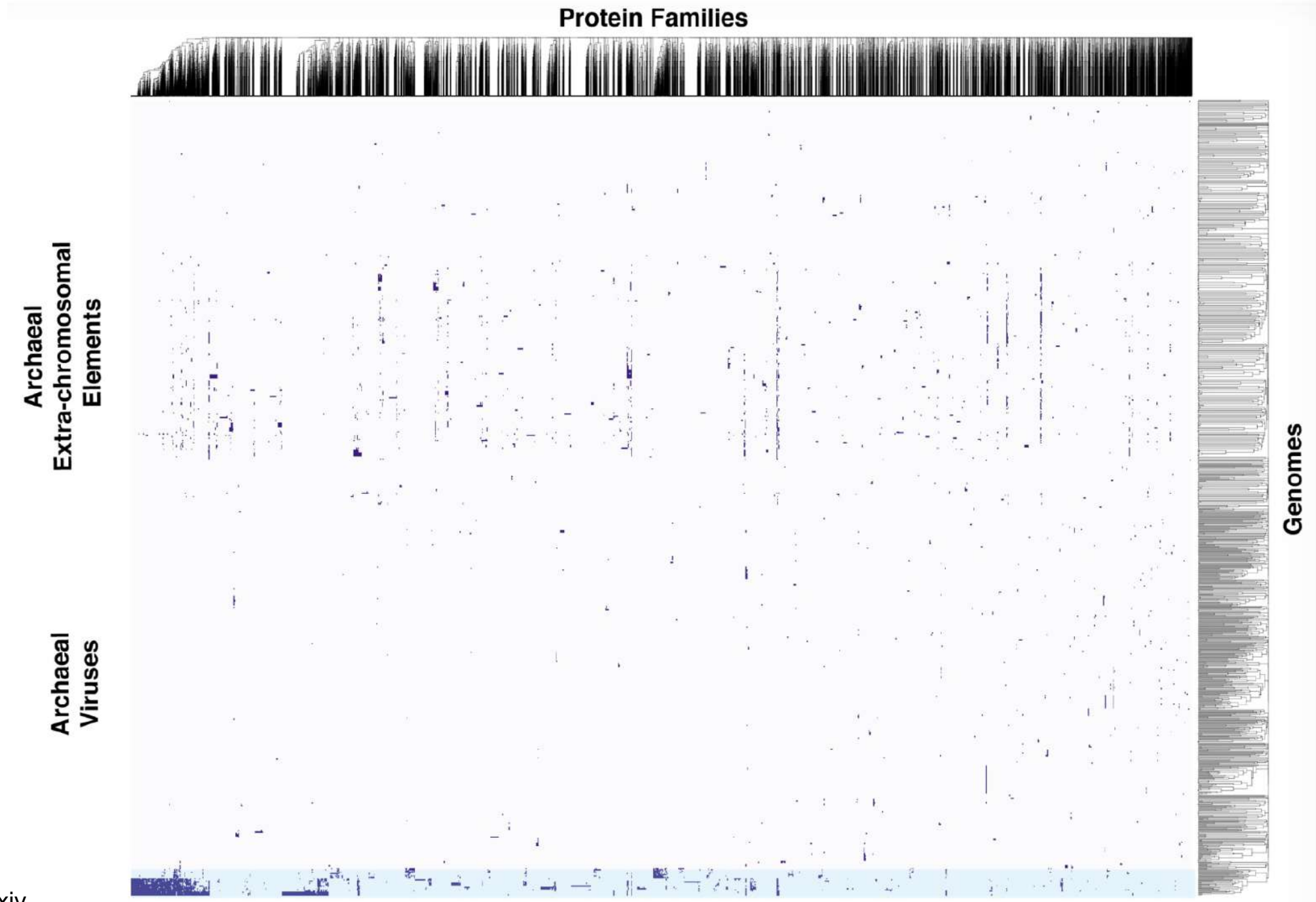
Ribosomal proteins found in Borgs are similar to, but distinct from, those in identified Methanoperedens species



Methanoperedens

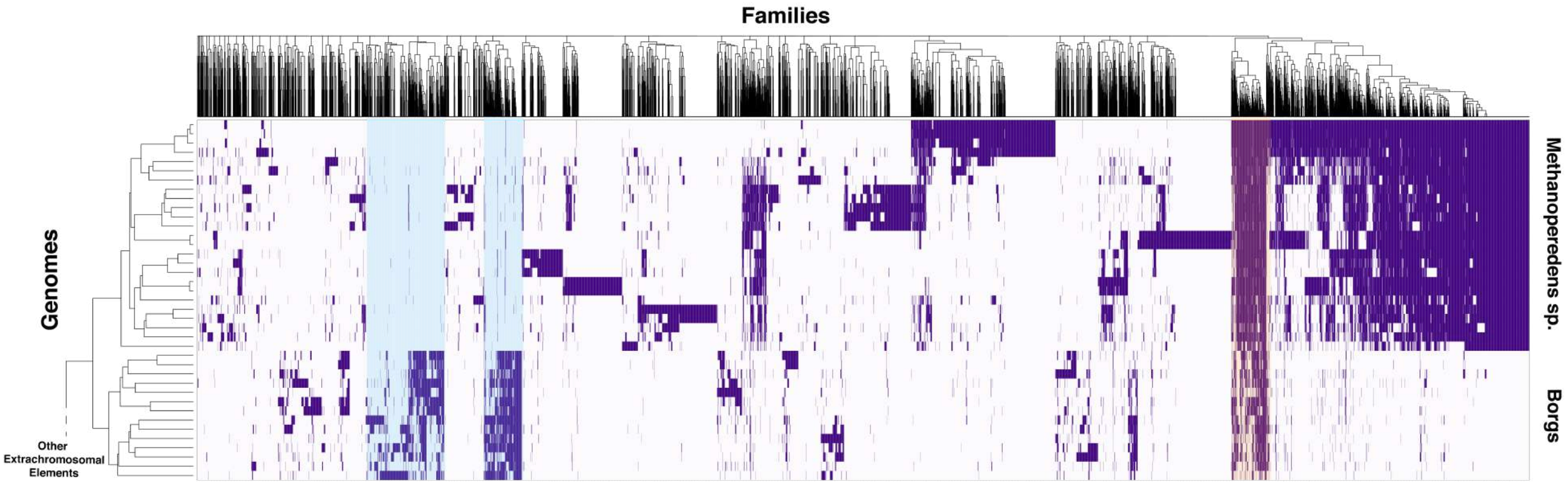
Borg

Borgs are distinct from other genetic elements



Al-Shayeb, *et al.* 2021, BioRxiv

Some protein families are Borg-specific, some are shared with their hosts



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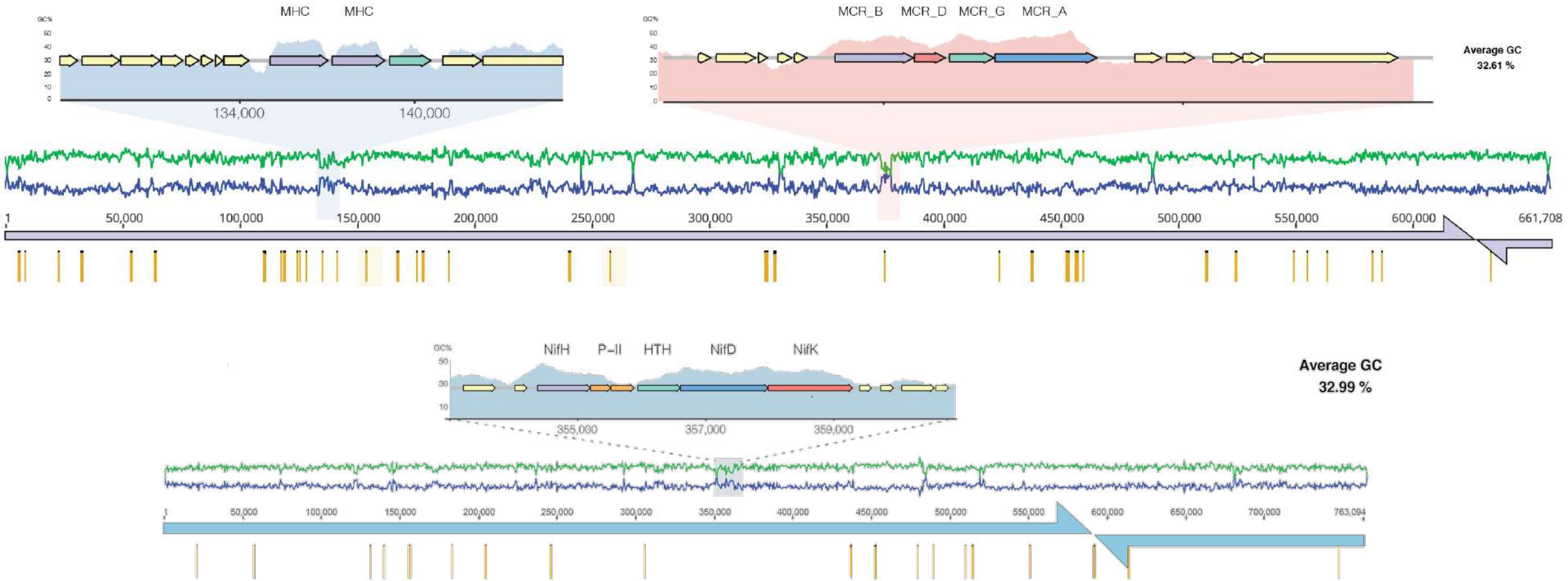
Borgs ‘assimilate’ genes from their hosts via horizontal gene transfer



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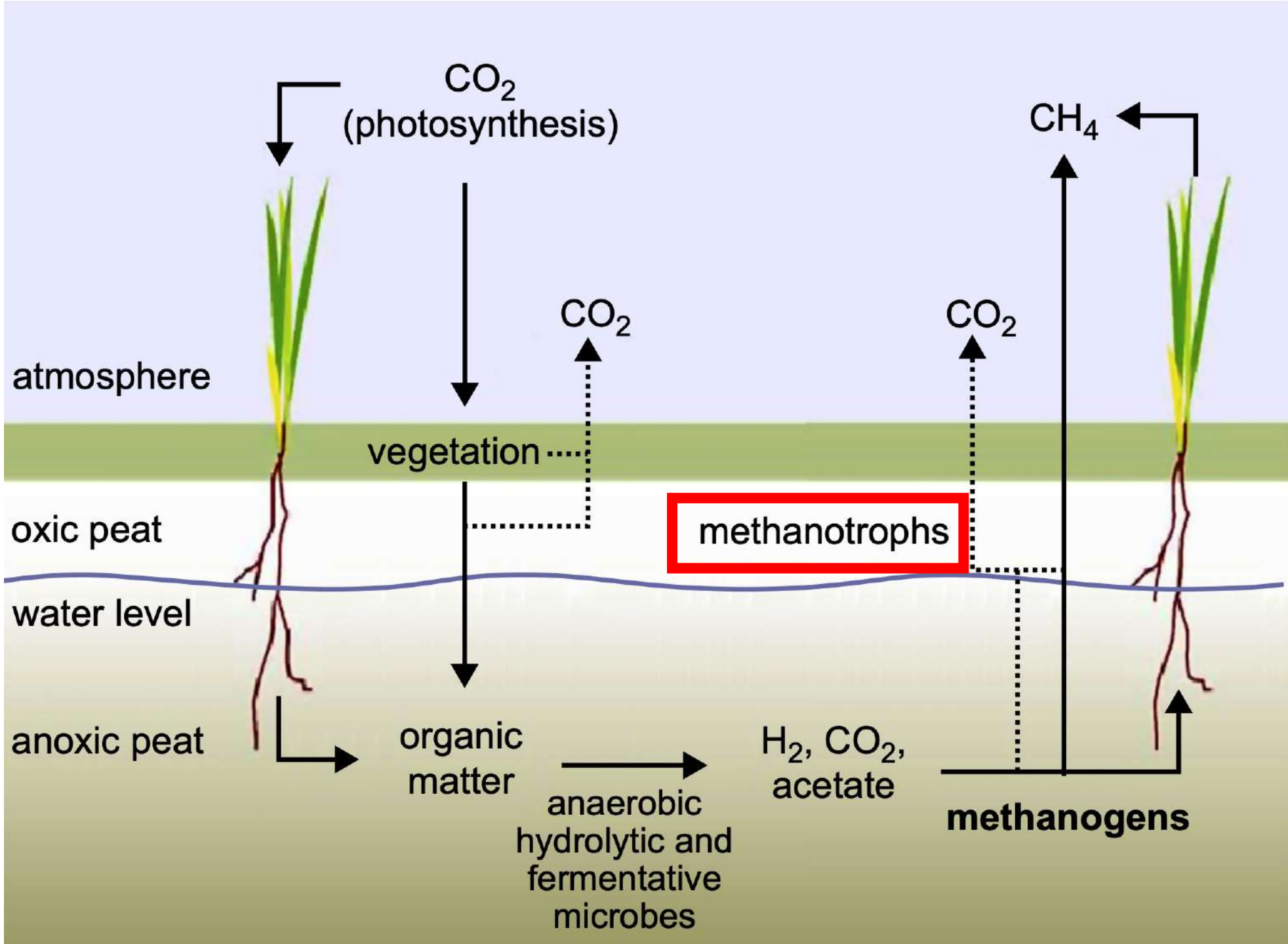
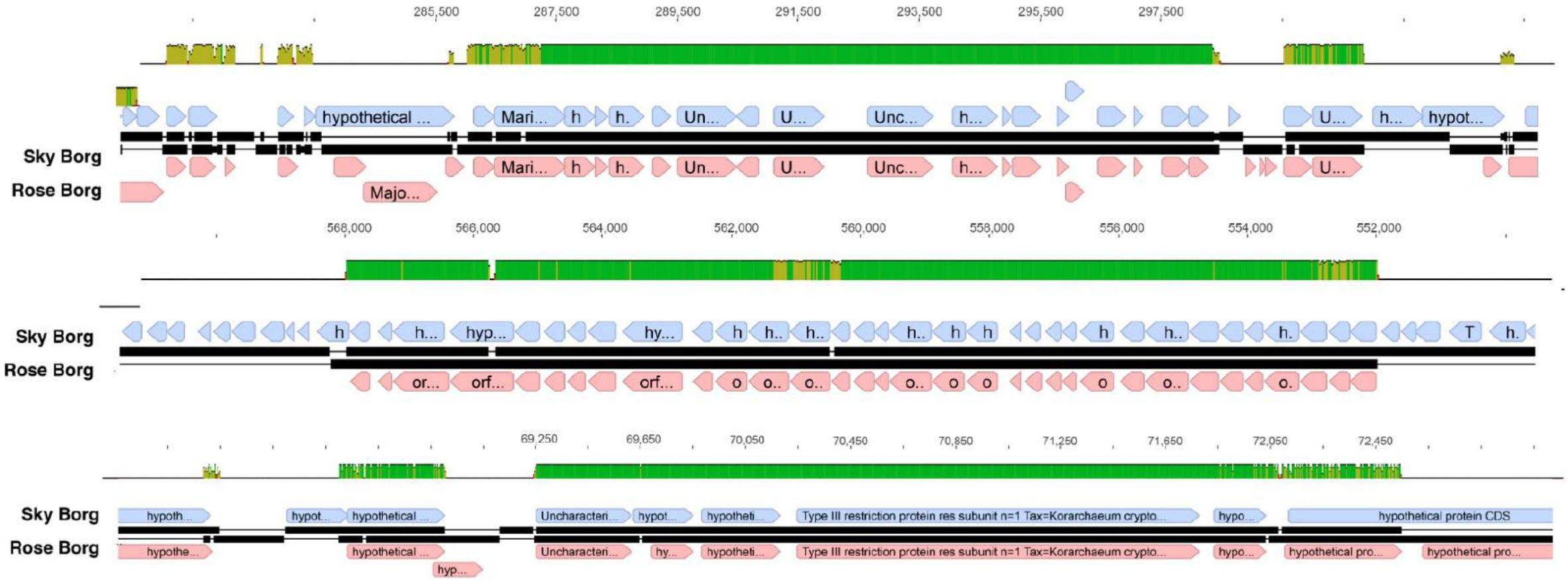
The Methane cycle may be most tightly linked to climate

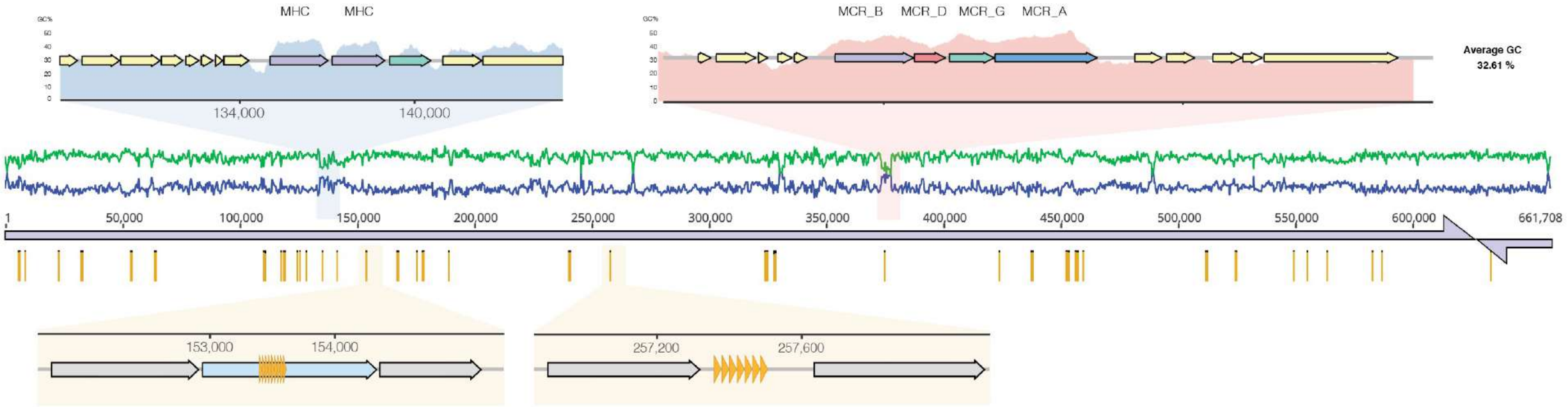


Some microbial lineages like ANME gain energy from the anaerobic oxidation of methane

Blocks of identical regions indicate possible recombination within same Mp Host cell



Borgs ‘assimilate’ genes from their hosts via horizontal gene transfer



Tandem direct repeats are found across Borg genomes

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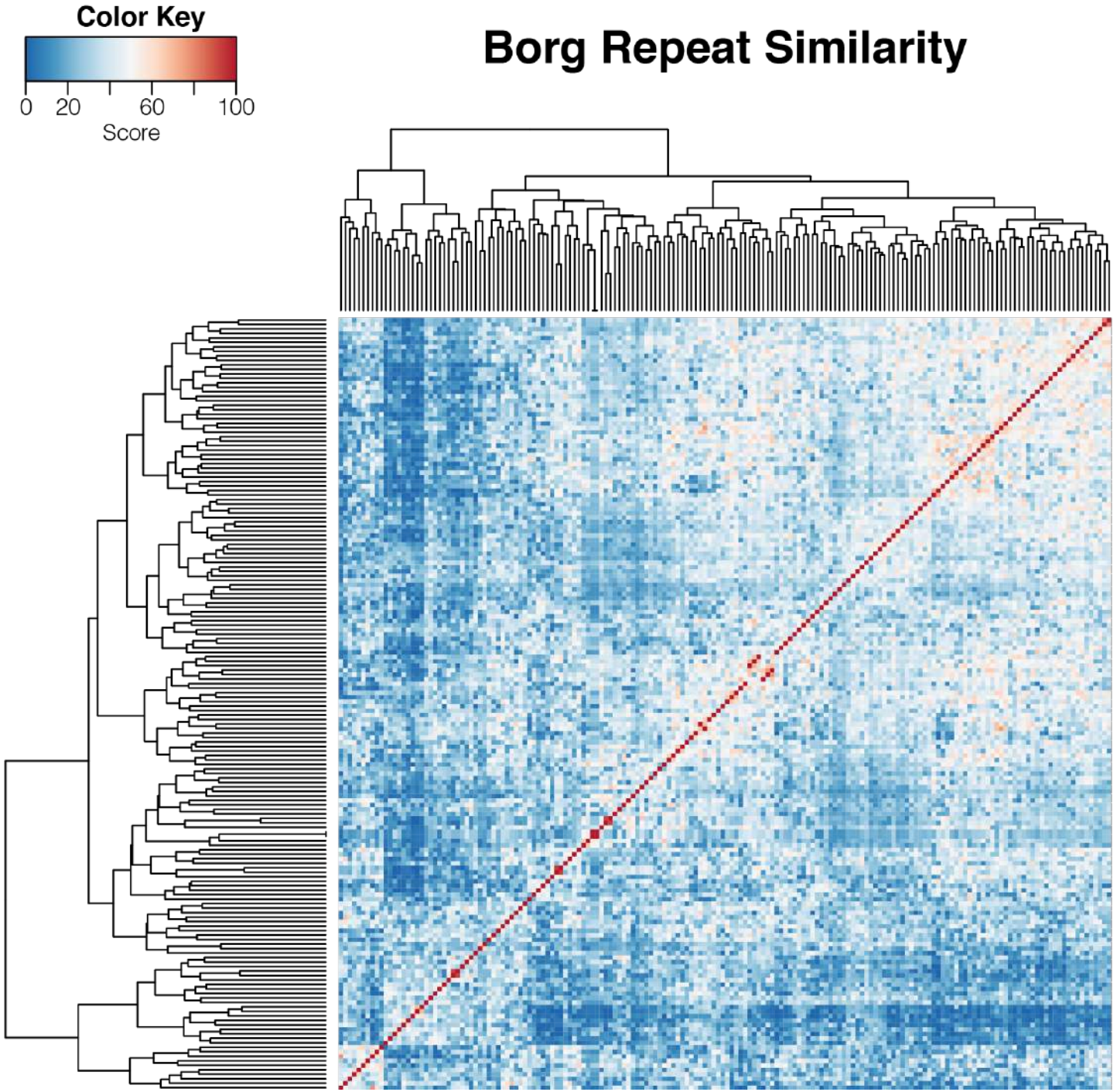
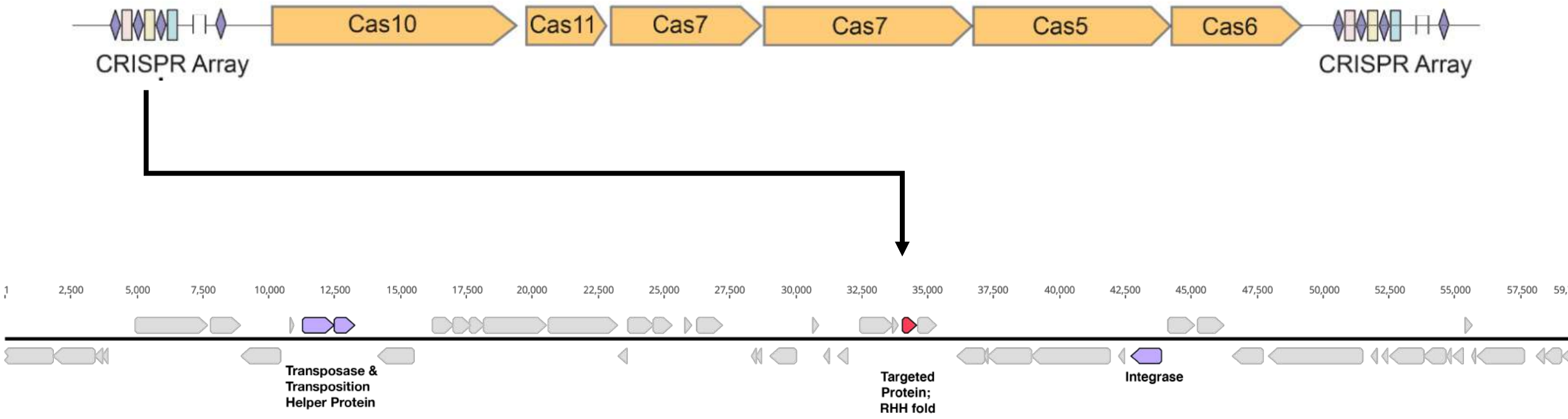
Repeats from different Borgs do not exhibit sequence conservation



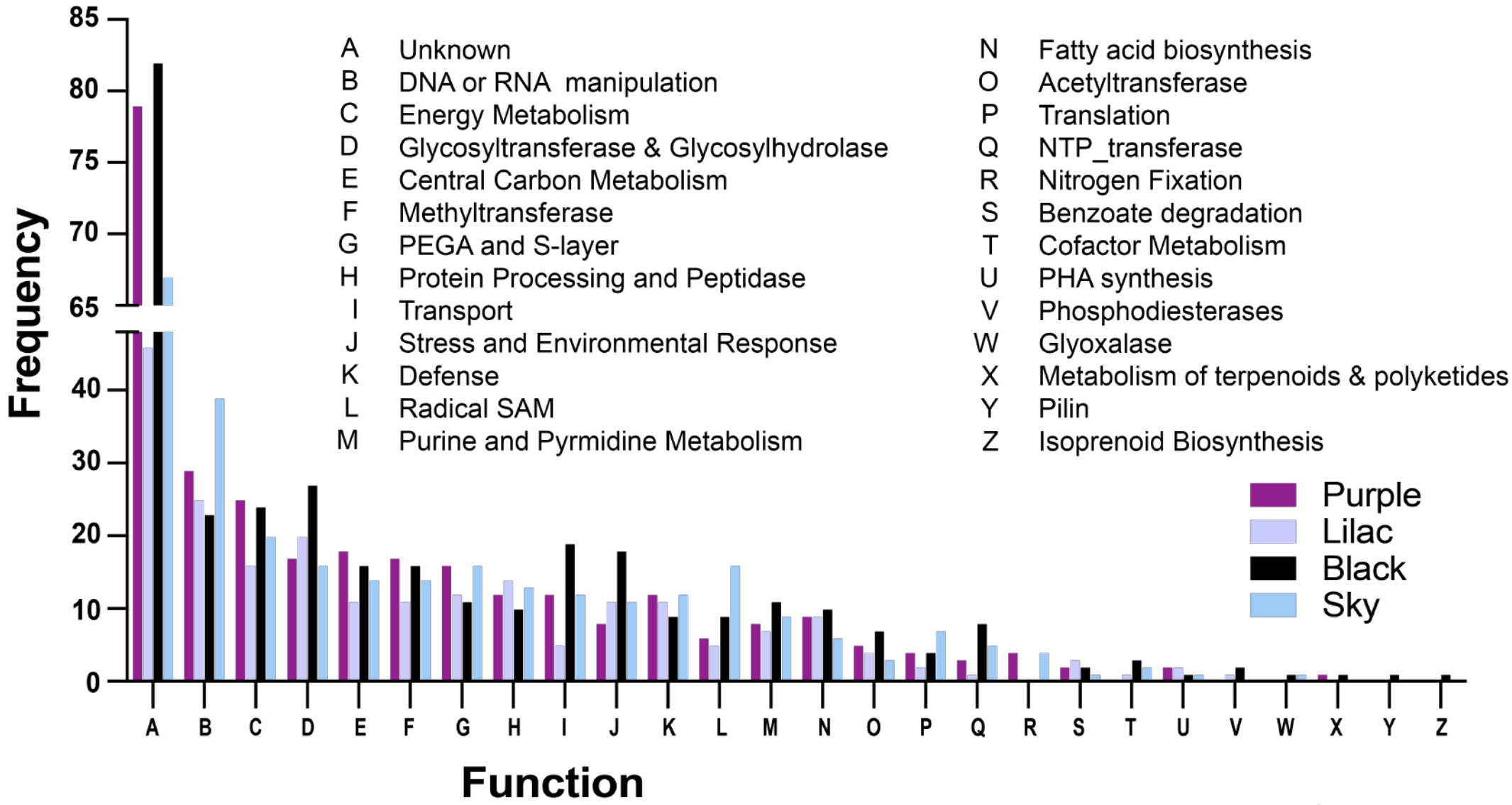
Borg CRISPR-Cas targets a *Methanoperedens* mobile element

Type III-A variant system, lacking acquisition machinery



CRISPR spacers match antisense strand coding for protein Methanoperedens Mobile Region
Remote homology to Antitoxin/ Nickel Regulator Proteins

Borgs likely affect many processes within their hosts



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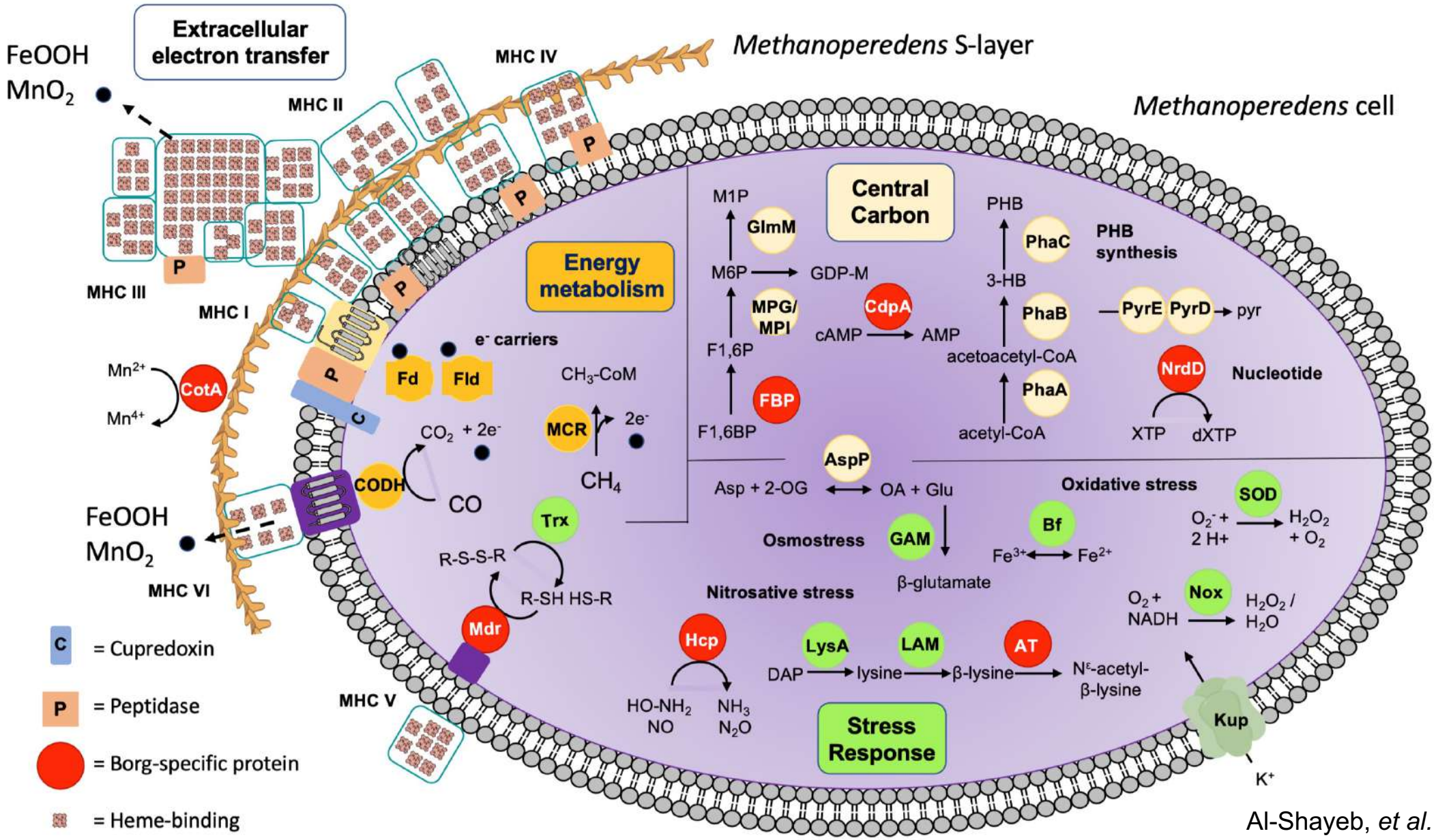
Borgs potentially augment methane oxidation and other biogeochemical cycles



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