# Horizontal Gene Transfers Underpin Ribose Heterotrophy and Central Carbon Metabolism Remodeling in Gloeobacteraceae

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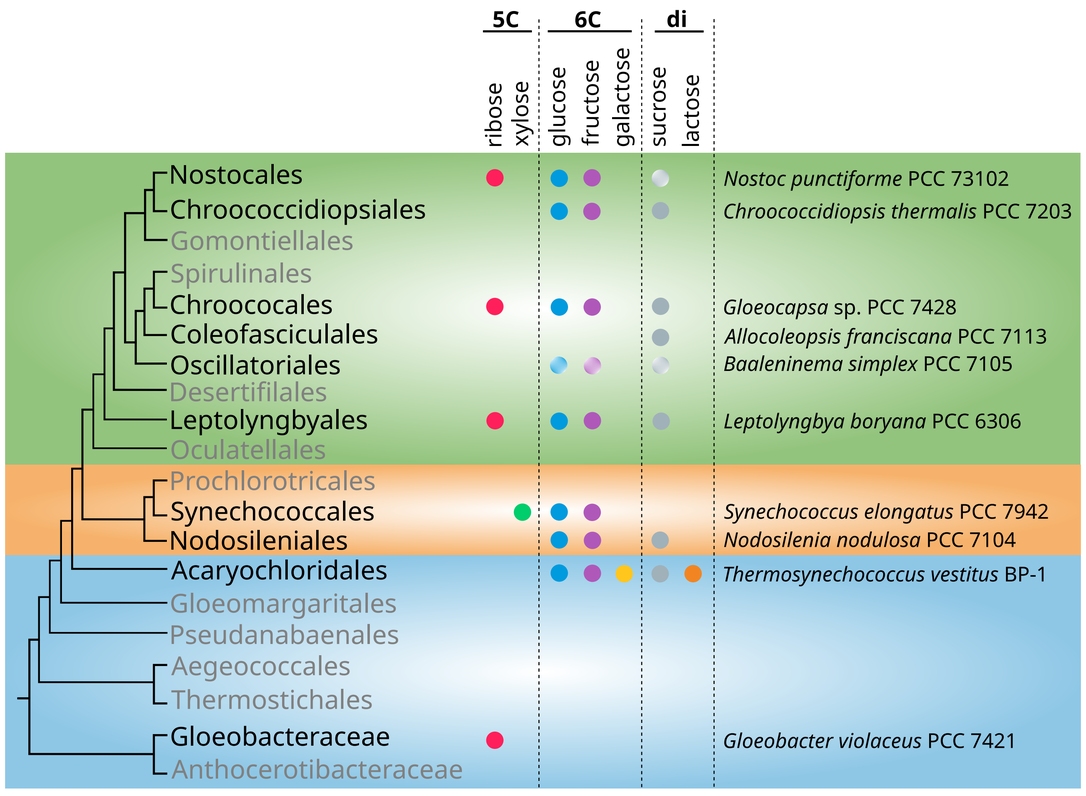
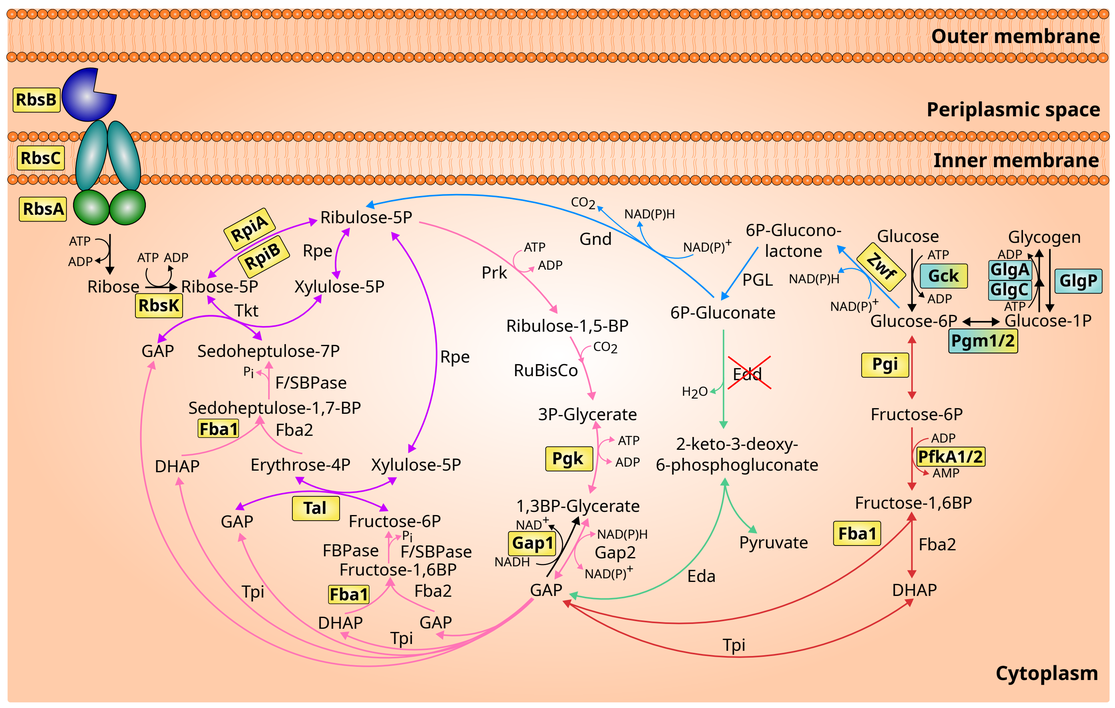
## Ribose Uptake and Metabolism in Gloeobacteraceae

- Cyanobacteria are traditionally regarded as strictly photosynthetic
- However, increasing evidence show that **photomixotrophy**—the ability to perform photosynthesis while assimilating additional carbon sources—is more widespread than previously assumed
- Gloeobacterales is unique among cyanobacteria due to their lack of thylakoid membranes
- We report the first genomic evidence of photomixotrophy within Gloeobacteraceae
- We identified three genes associated with an ATP-synthase Binding Cassette (ABC) transporter system that import ribose to the cytoplasm of Gloeobacteraceae
- We further identified ribose metabolism-related genes that allows integration into central carbon metabolism pathways
- These six genes are the product of horizontal gene transfers (HGTs) from diverse bacterial donors

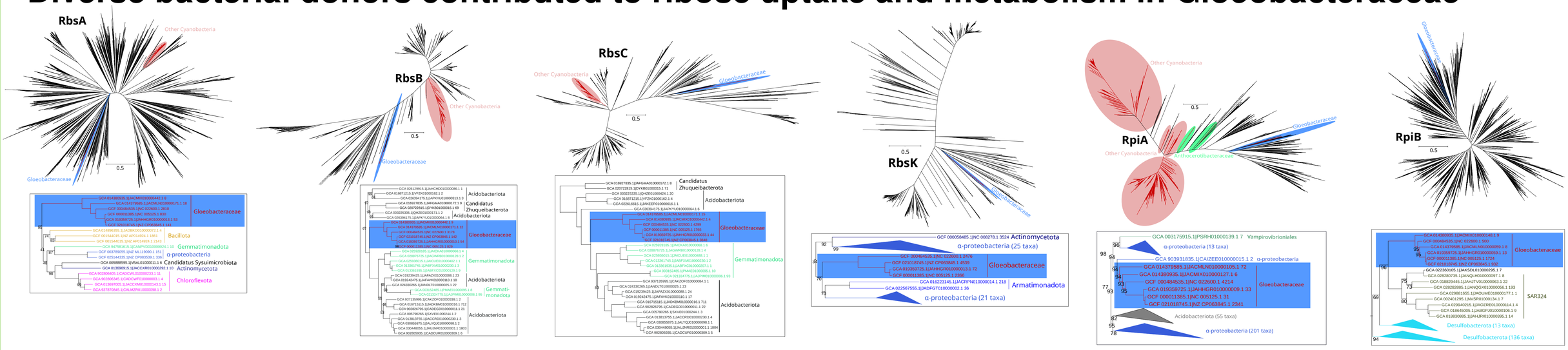


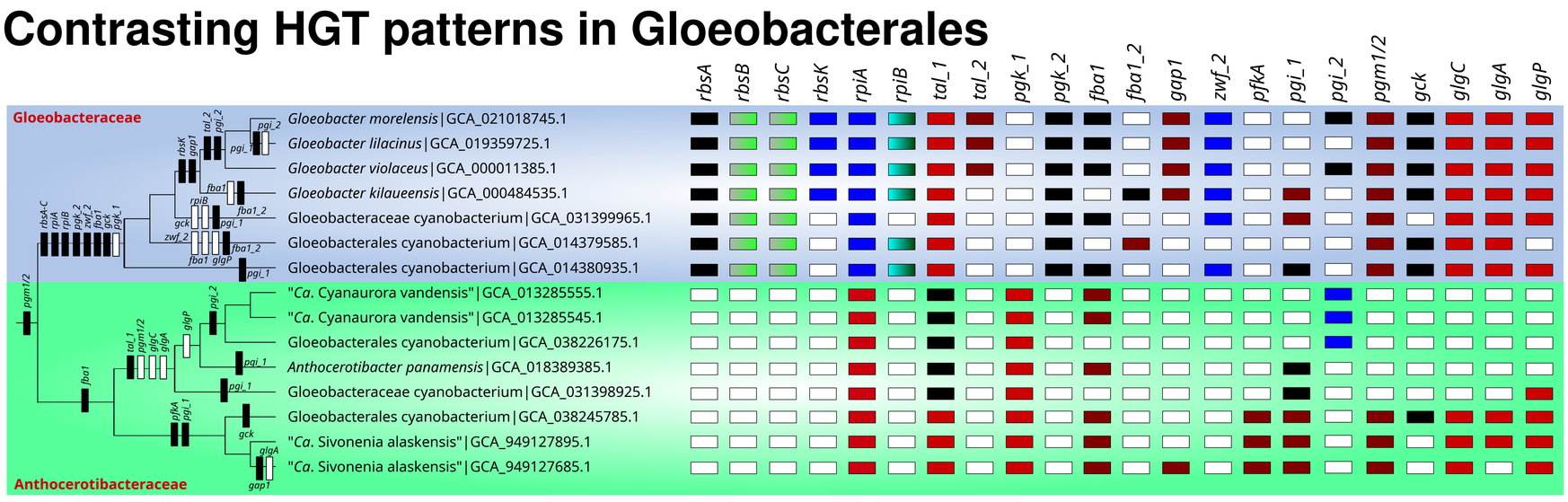

## Mosaic central carbon metabolism architecture in Gloeobacterales

- Several genes in the Calvin-Benshon-Bassham cycle, pentose phosphate pathway, and Embden-Meyerhof-Parnas pathway show signs of HGT
- In contrast, some genes are absent in subsets of Anthocerotibacteraceae
- Two genes show signs of HGT before being lost in Anthocerotibacteraceae
- The *edd* gene was absent from all cyanobacteria genomes, thus no full Entner-Douderoff pathway in cyanobacteria
- *pfkA* was detected only in three Anthocerotibacteraceae genomes, likely indicating a recent acquisition event
- HGT and gene loss are the major drivers of metabolic reorganization in the central carbon metabolism in Gloeobacterales

## Diverse bacterial donors contributed to ribose uptake and metabolism in Gloeobacteraceae




## Contrasting HGT patterns in Gloeobacterales




## Conclusion

- Ribose import and utilization genes enables Gloeobacteraceae to couple photosynthesis with external sugar imports
- This allow Gloeobacteraceae to persist in low-light and nutrient-variable habitats
- HGT also plays important roles in central carbon metabolisms of Gloeobacterales with varying degree across the two families