Eukaryotic Phylogenomics Laboratory

Exploring Thylakoid Emergence:

Evolution of Membrane Biogenesis in Early-diverging Cyanobacteria

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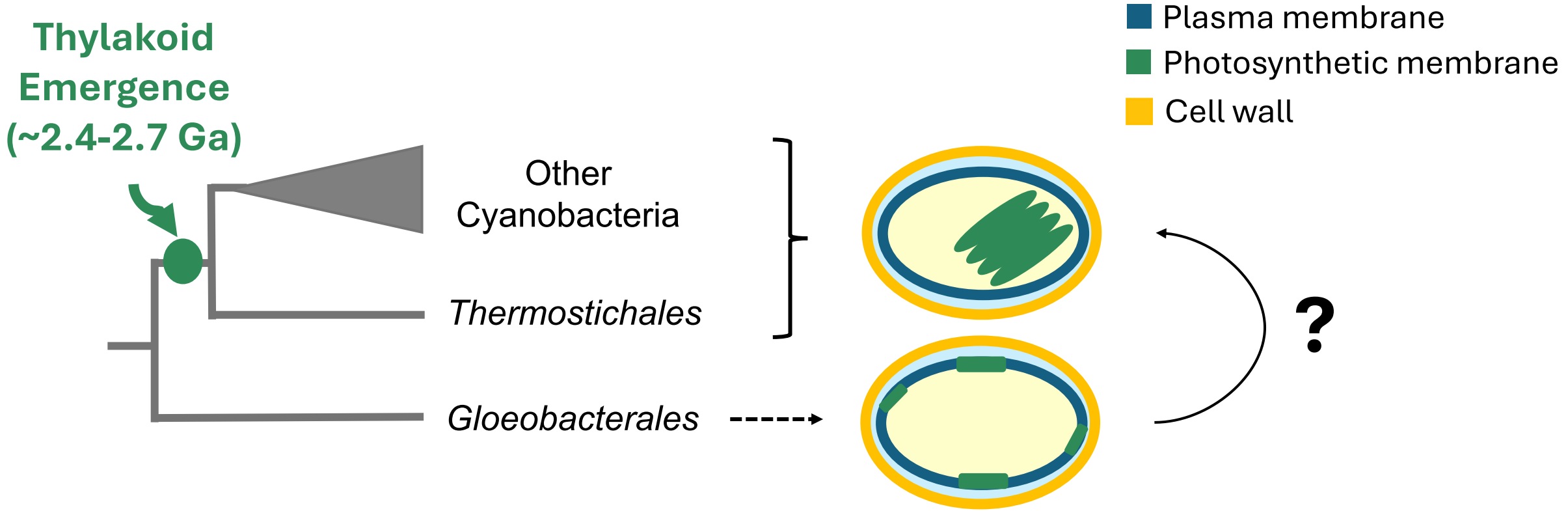
1946 watercolor by G. E. Fogg, FRS

Context & Research Question

Thylakoids = Photosynthetic membranes



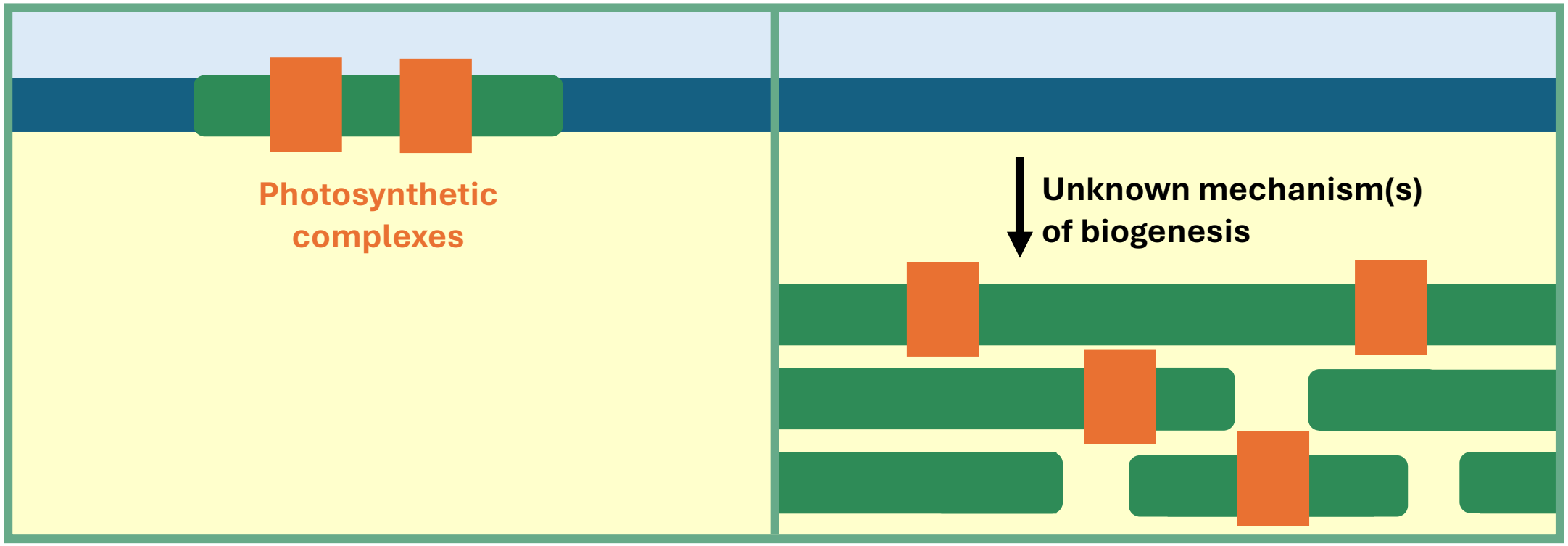
What **evolutionary changes** in **membrane biogenesis** and **protein integration** explain this transition ?

Context & Research Question

Tracking evolution to reveal **unresolved thylakoid biogenesis mechanisms**

Differences ?

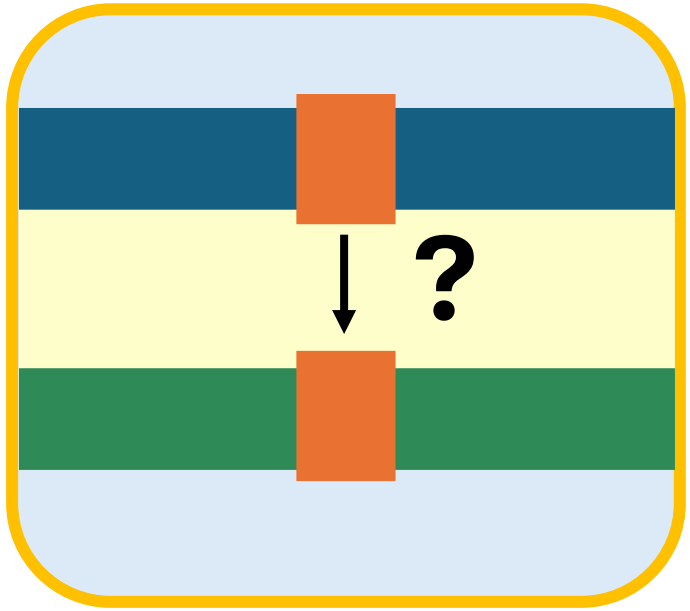
Gloeobacterales ≠ **Cyanobacteria with thylakoids**



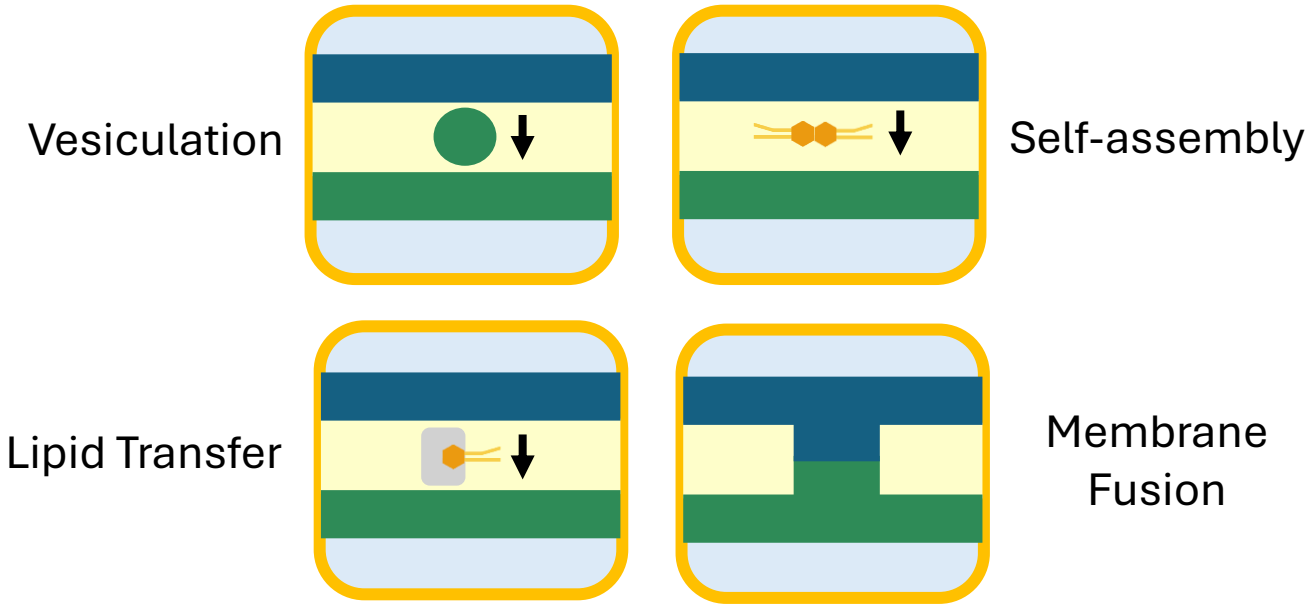
Context & Research Question

Mechanisms of thylakoid membrane biogenesis

❶ Assembly & Targeting of the photosynthetic complexes



❷ Generation of the membrane scaffold
→ **Four hypotheses**:

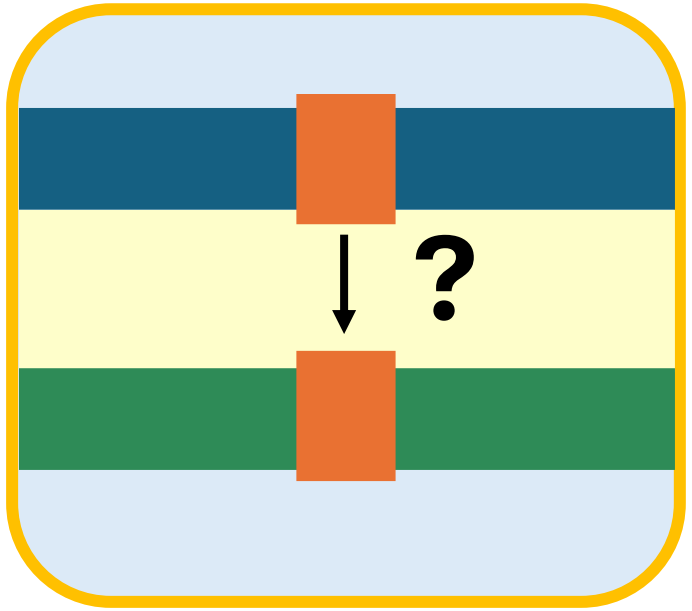


→ **Goal:** Track the evolutionary origins of 36 proteins involved in photosystem II assembly and **13 proteins involved in membrane dynamics** among **Cyanobacteria**

Context & Research Question

Mechanisms of thylakoid membrane biogenesis

❶ Assembly & Targeting of the photosynthetic complexes



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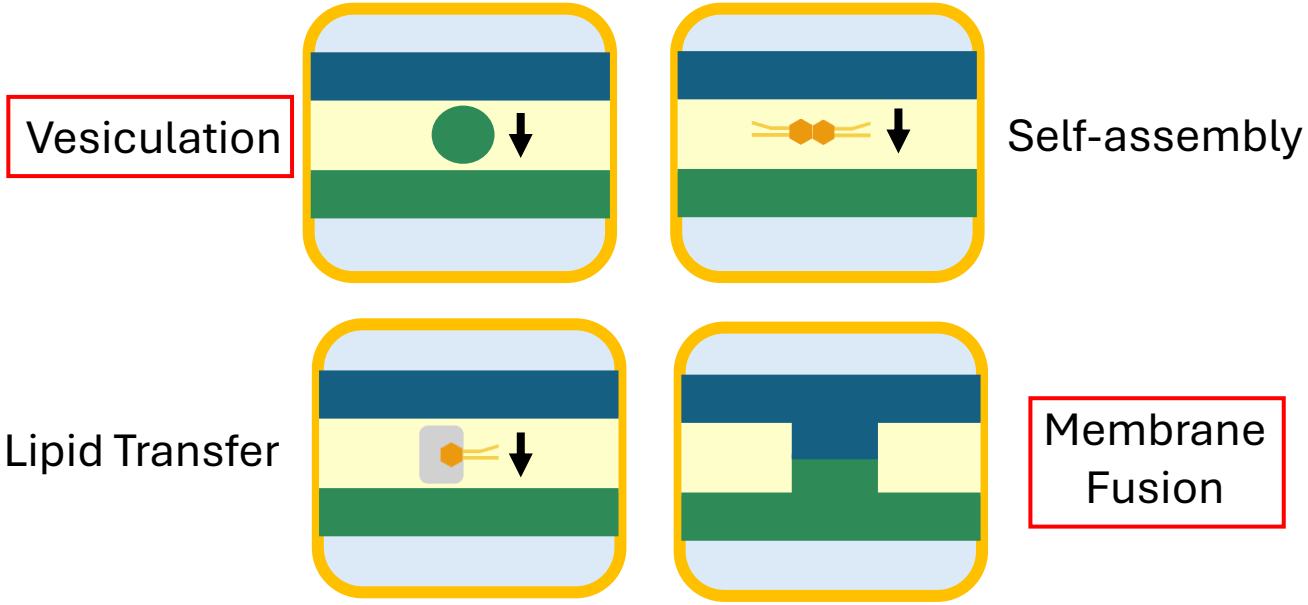


→ **Goal:** Track the evolutionary origins of 36 proteins involved in photosystem II assembly and **13 proteins involved in membrane dynamics** among **Cyanobacteria**

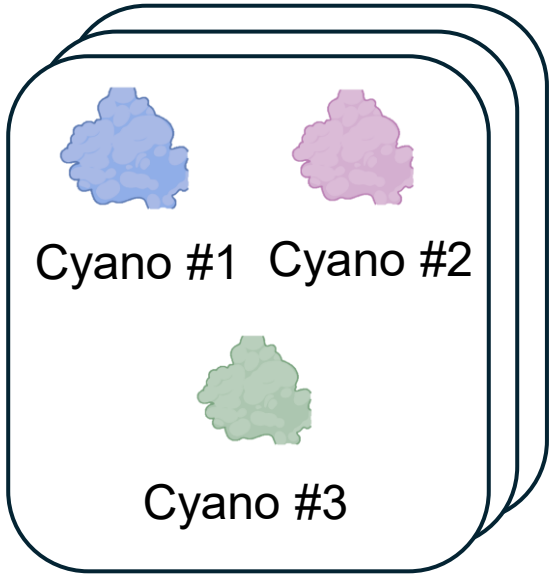
Methods

Dataset Selection

950 Terrabacterial genomes

- Quality filters
- Phylogenic diversity selection

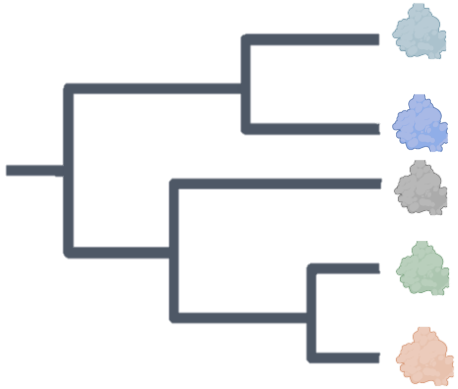
Orthology Inference



Orthologous groups

Phylogenetic Reconstruction

Orthologous group #1

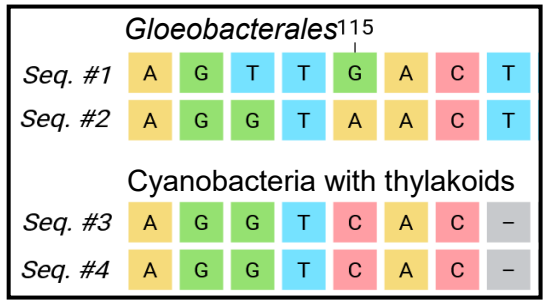


Types of analysis:

- Evoluationary history
- Taxonomic distribution within Cyanobacteria

Molecular Modeling structures

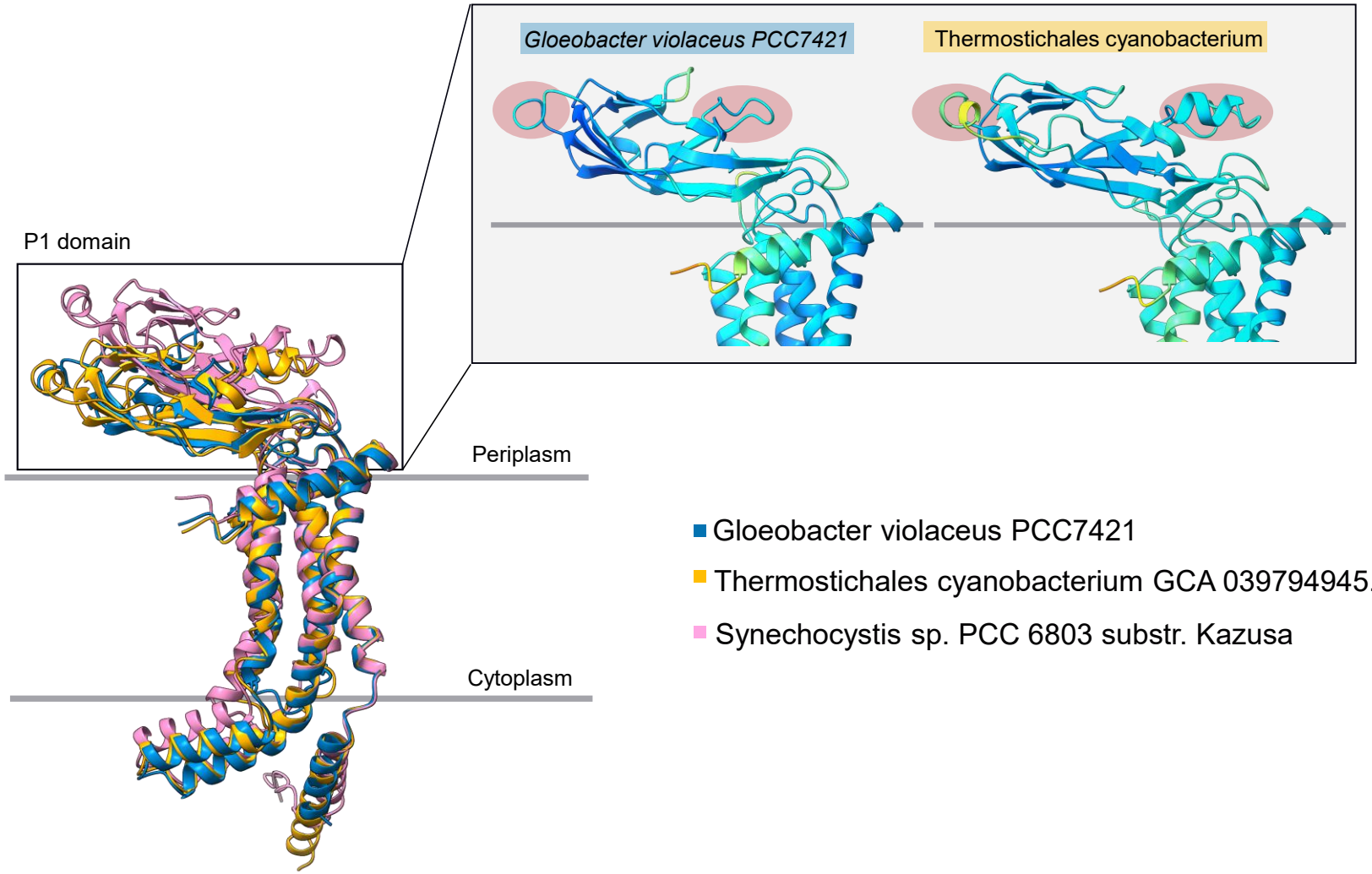
Multiple sequence alignment



3D structure prediction (AlphaFold)

Result #1

Structural changes in the translocase YidC



- Gloeobacter violaceus PCC7421
- Thermostichales cyanobacterium GCA 039794945.1
- Synechocystis sp. PCC 6803 substr. Kazusa

Translocase YidC:

- Integrate proteins within membranes
- Works in cooperation with the Sec machinery

Model Confidence:

- Very High (pLDDT > 90)
- Confident (90 > pLDDT > 70)
- Low (70 > pLDDT > 50)
- Very Low (pLDDT < 50)

Discussion #1

Structural changes in the translocase YidC

→ Periplasmic domains only found in Gram – Bacteria

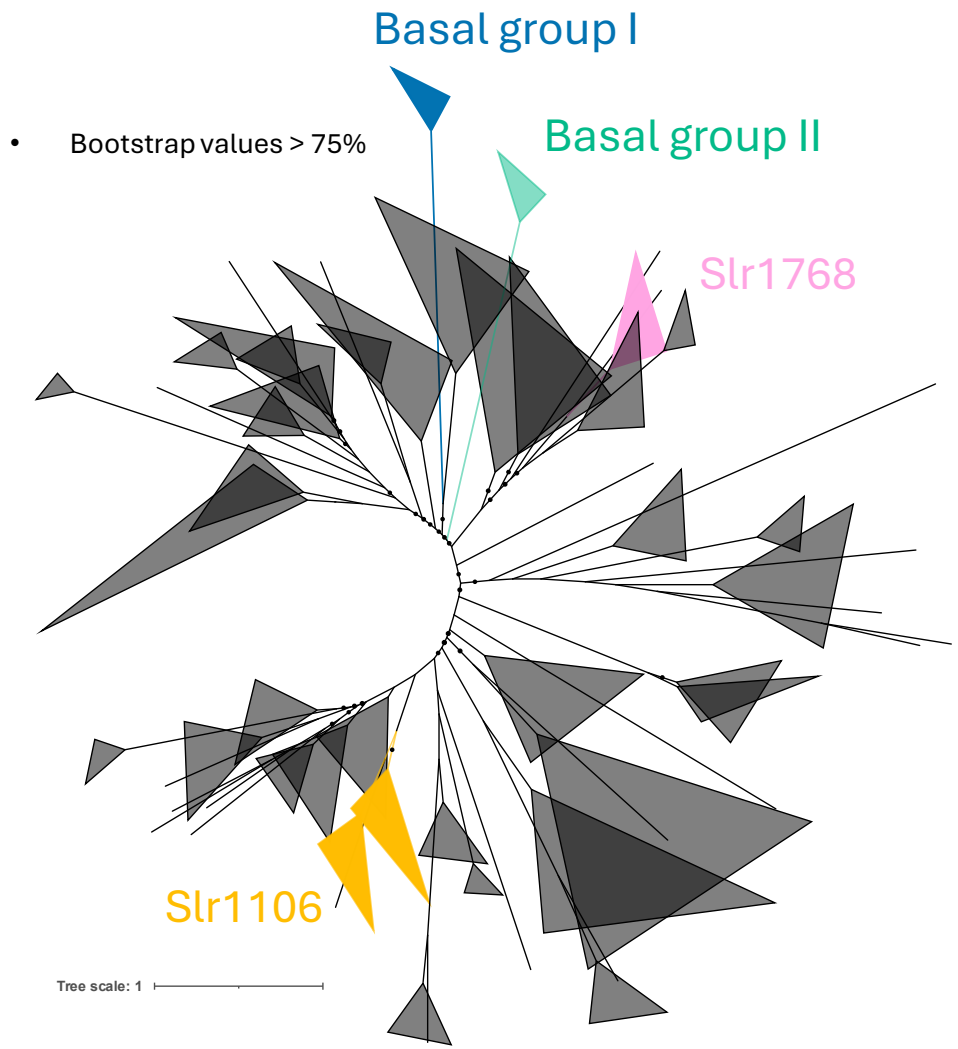
→ Unknown role of periplasmic domains

→ Structure conserved within Cyanobacteria

What is the role of **YidC periplasmic domain** in membrane **protein insertion** in Cyanobacteria?

→ Was YidC instrumental in the **redirection** of **protein targeting** during **thylakoid emergence**?

Result #2 Specific groups of prohibitins within basal lineages



Phylogenetic tree of the prohibitin family among Terrabacteria

Prohibin family

→ associated with lipid domains

	Gloeobacterales	**Cyanobacteria with thylakoids**
Slr1106	Absent	Conserved
Slr1768	Absent	Conserved
Basal Group I	Conserved	Conserved in basal clades
Basal Group II	Conserved	Conserved in basal clades

Comparative evolutionary distribution of prohibitin families within Cyanobacteria

Discussion #2

Phylogenetic dynamics of prohibitins: Gene acquisition and loss of prohibitins in Cyanobacteria

→ Lack of Slr1106 and Slr1768 in *Gloeobacterales*

→ Specific groups of basal Cyanobacteria within the prohibitin family tree

} Do **SPFH prohibitins** act as "scaffolds" to stabilize **photosynthetic active domains** in *Gloeobacterales*?

→ Could the **specialization** of the prohibitin families be the missing link that allowed the **relocation** from the **plasma membrane** to **thylakoids**?

Conclusion

- **Evolutionary Context:** Thylakoid emergence (2.4–2.7 Ga) represents a major structural transition in Cyanobacteria

- **Mechanistic Insights**: Their specific acquisition/loss patterns in basal clades might correlate with thylakoid membrane biogenesis

- **Perspectives:** Are these lipid and translocase differences the **pre-requisites** for, or the **consequences** of, thylakoid absence?

Acknowledgements

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