Science

A geological timescale for bacterial evolution and oxygen adaptation

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Journal Club

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Bioinformatics

TITLE	CITED BY	YEAR
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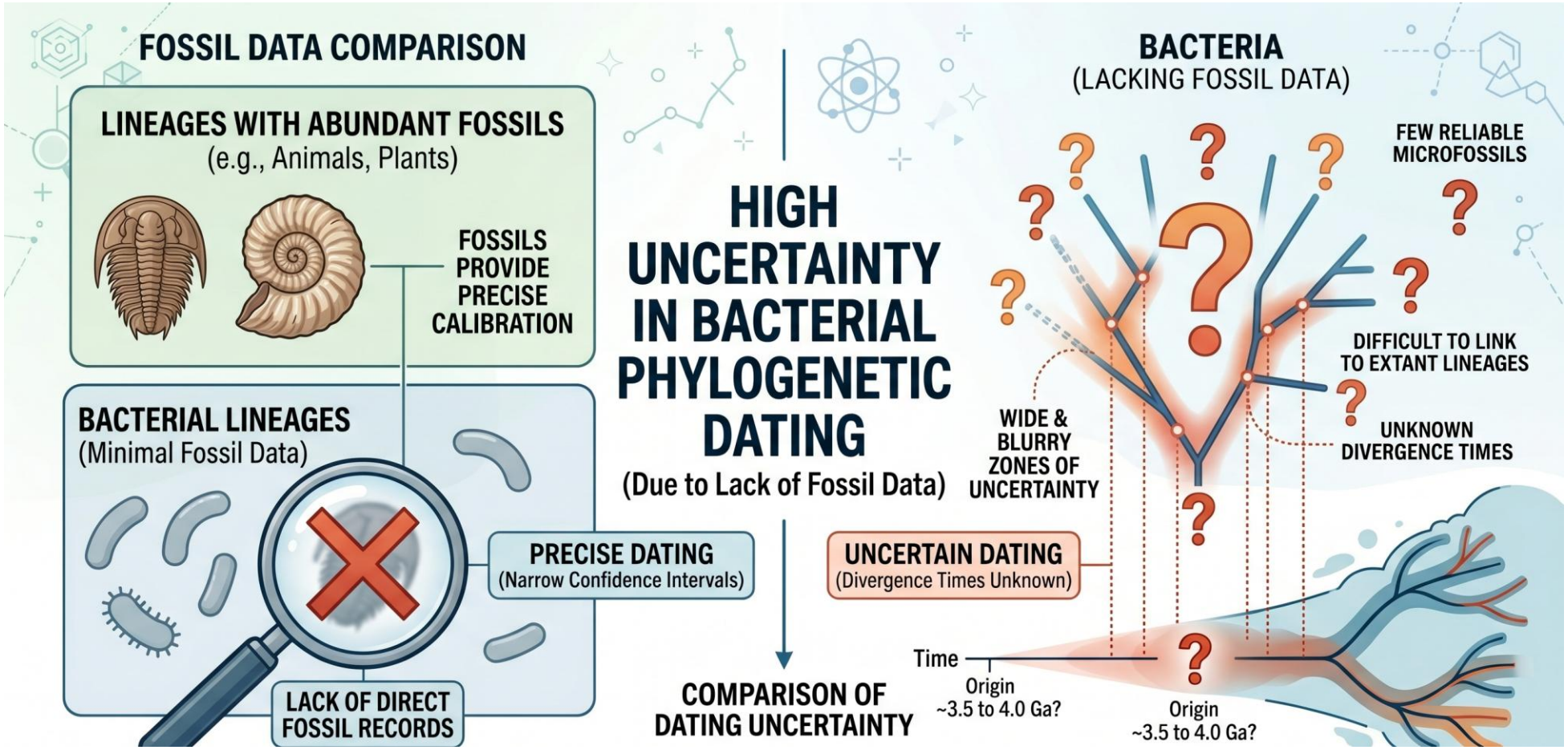
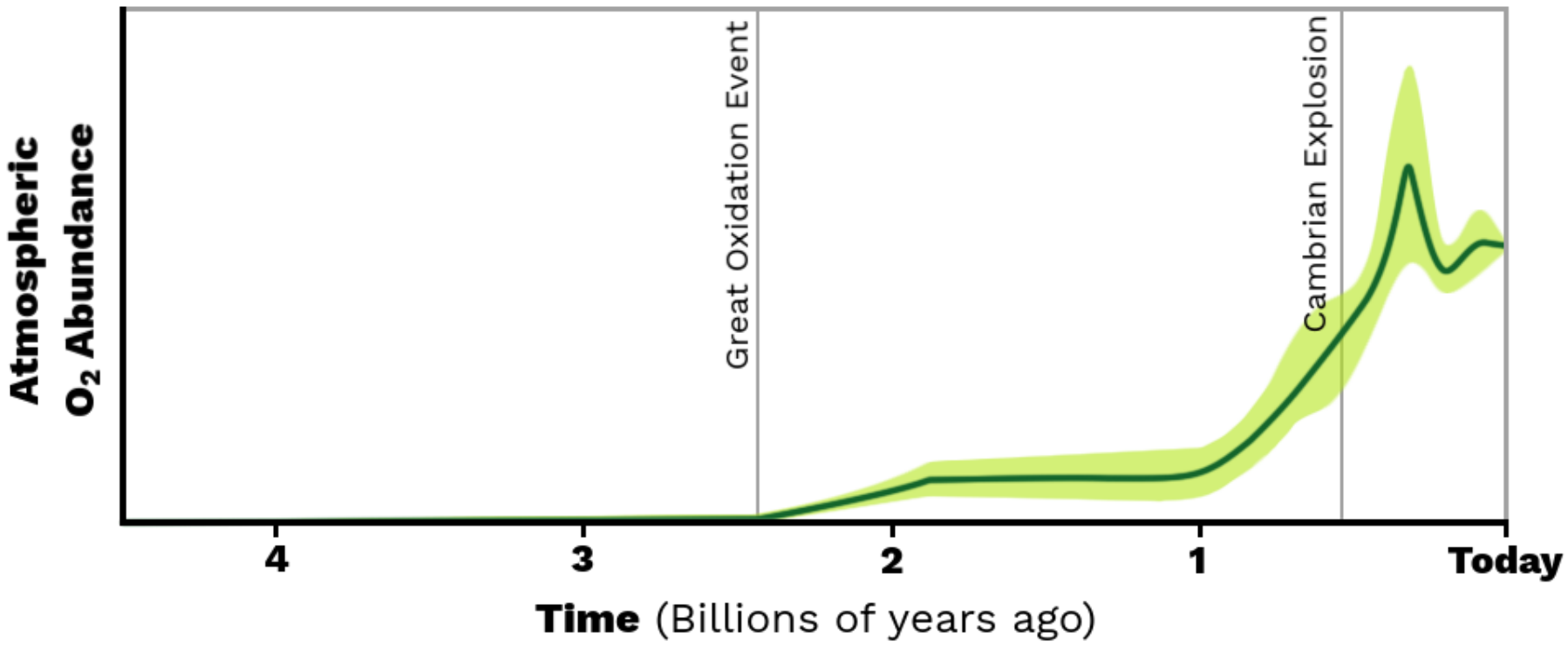
Problem in bacteria phylogeny : no fossil, no dating landmark

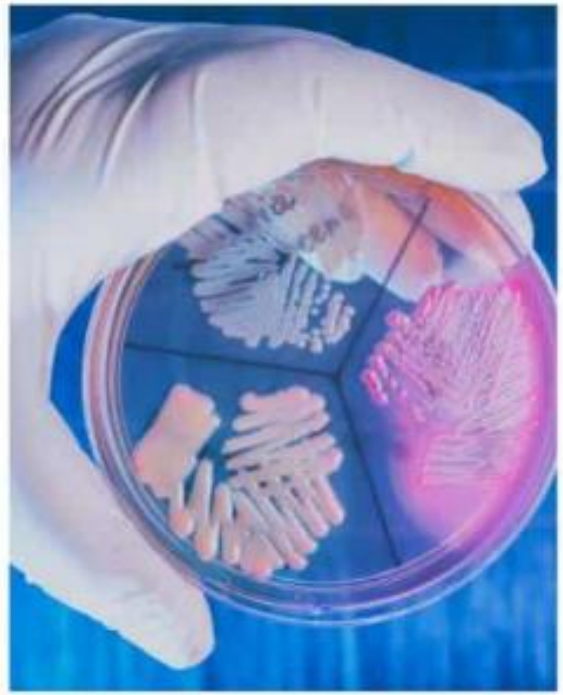


The Great Oxygenation Event 2400 Mya



Aerobic Bacteria

Aerobic bacteria are bacteria that require oxygen for their survival and without oxygen, they will die.



Anaerobic Bacteria

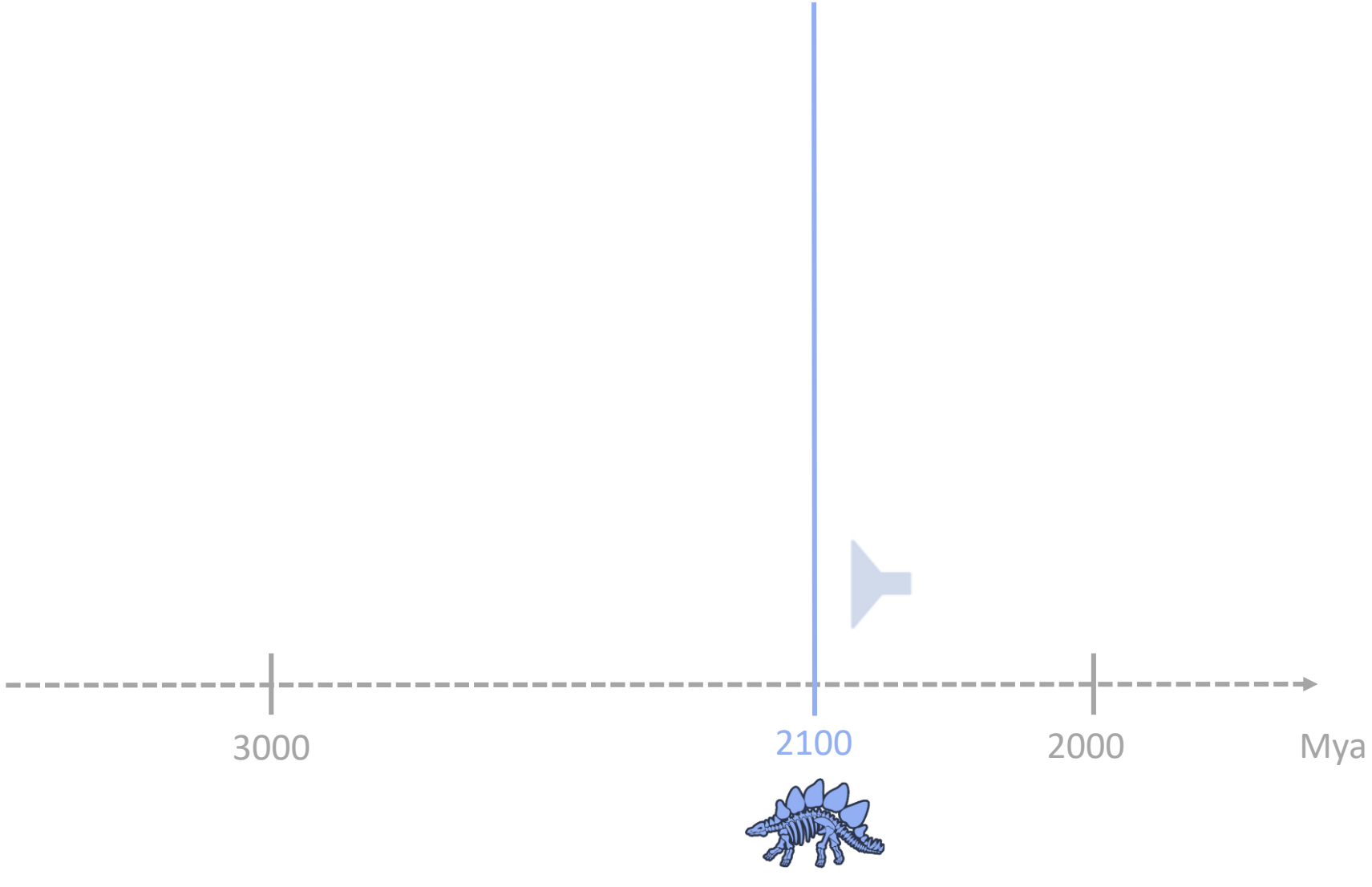
Anaerobic bacteria is another type of bacteria that is just the opposite of aerobic bacteria.

Date the ancestor：

Sequence only:
Roughly 3000-2000 Mya

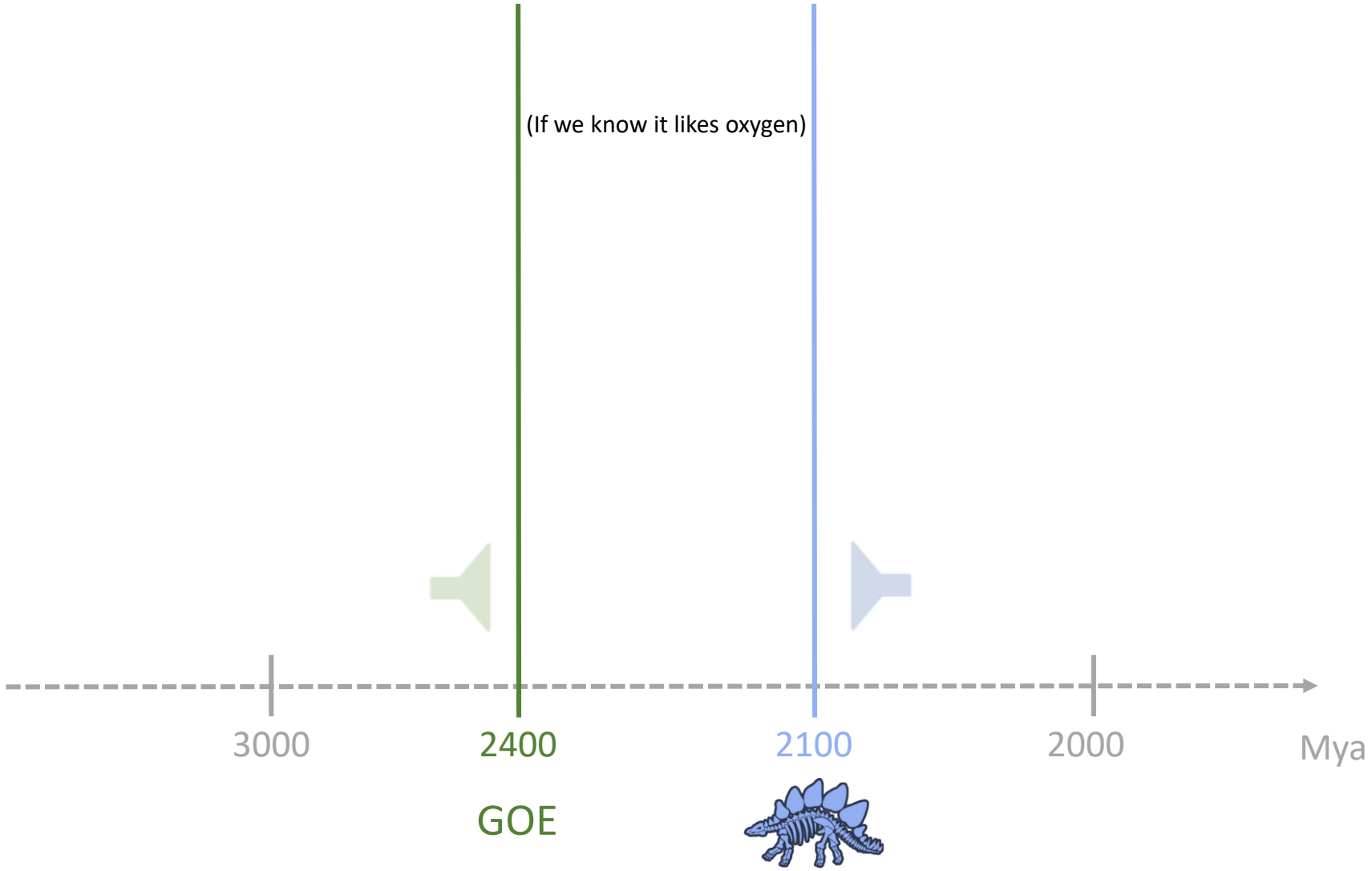
Sequence + Fossil

Roughly after 3000 and definitely before 2100 Mya



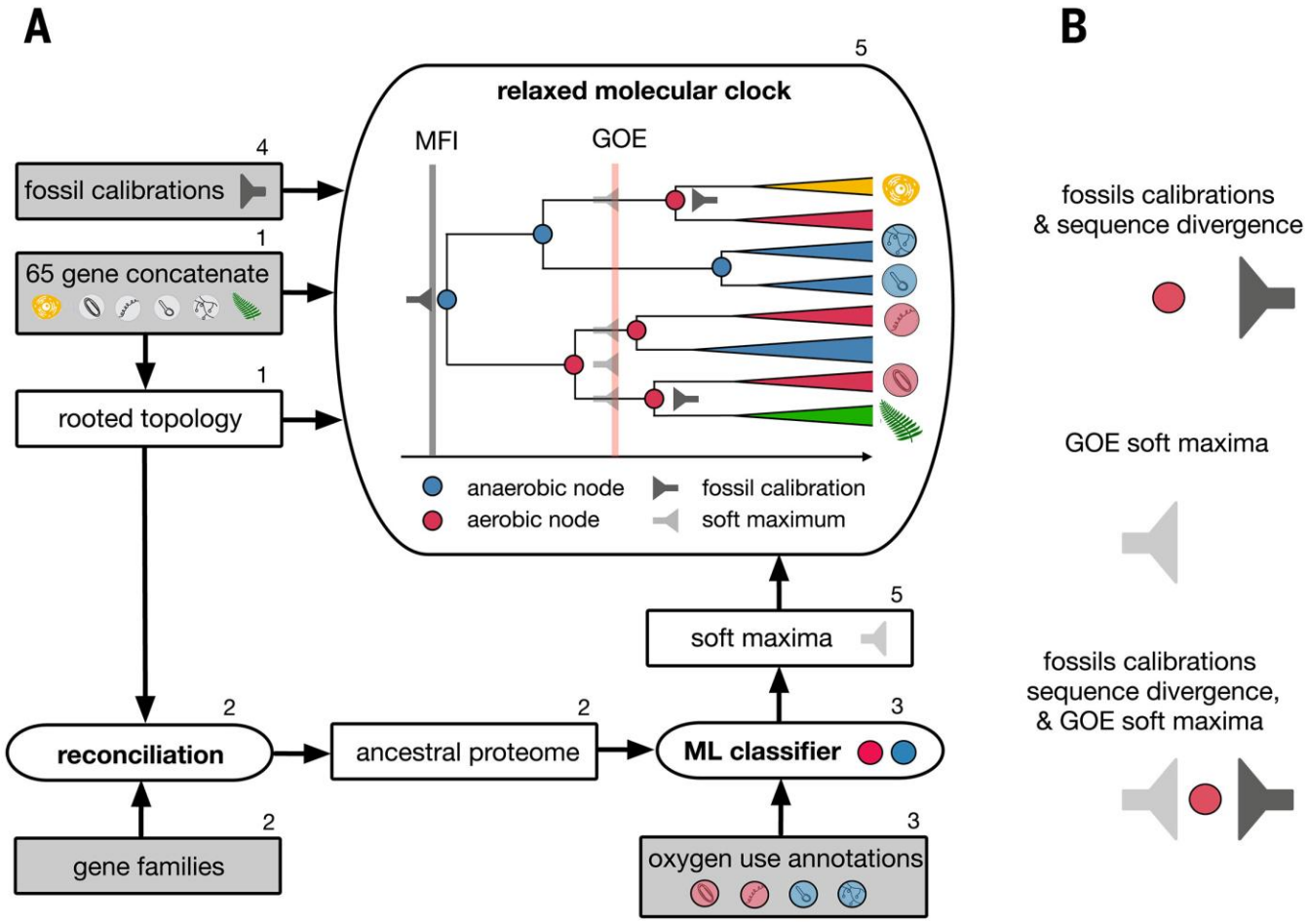
Sequence + Fossil + GOE

Likely after 2400 and definitely before 2000 Mya



integrate GOE to date the nodes

Underlying hypothesis: aerobic species are more likely to appear after GOE



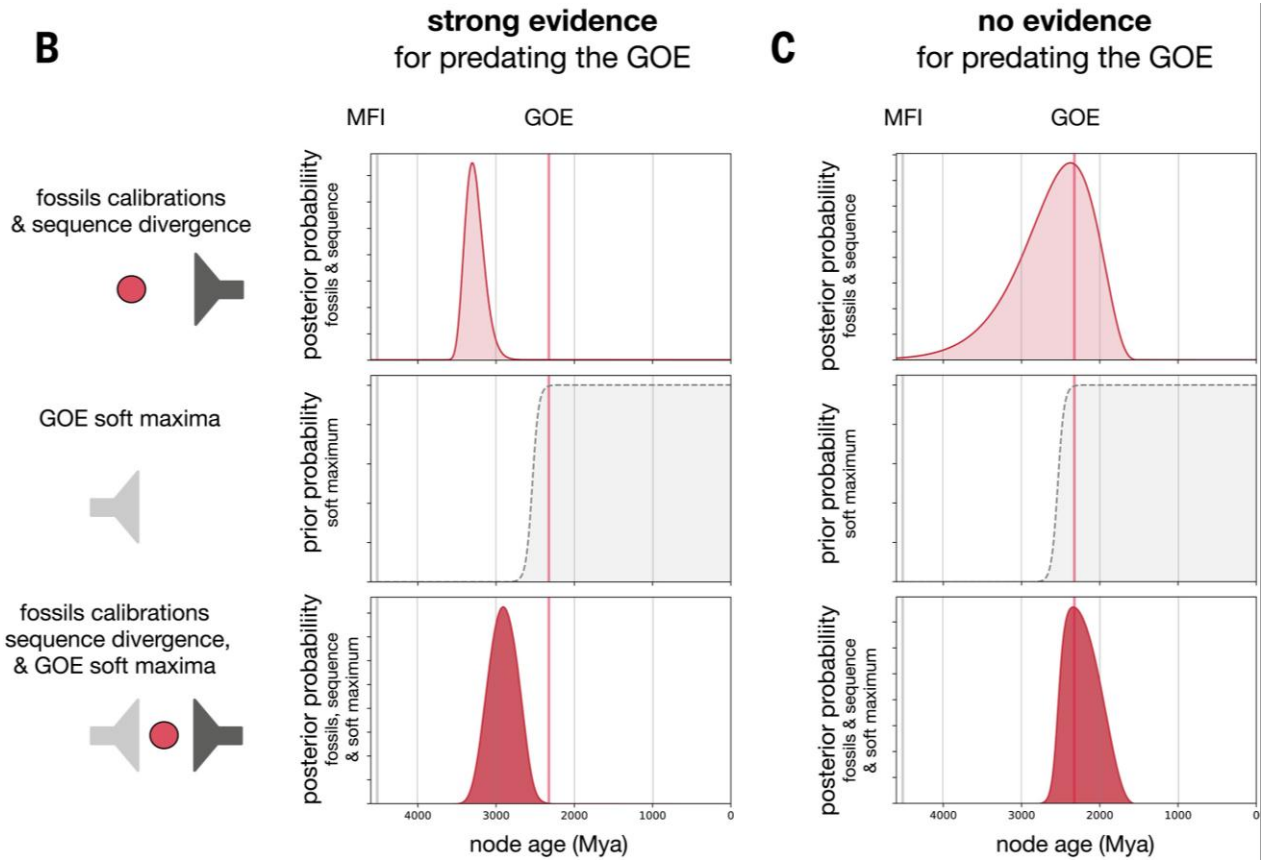
1.Build a tree

2.Build ancestral proteome

3.ML classification: aerobic or anaerobic?

If aerobic: try pushing the node toward a post-GOE age

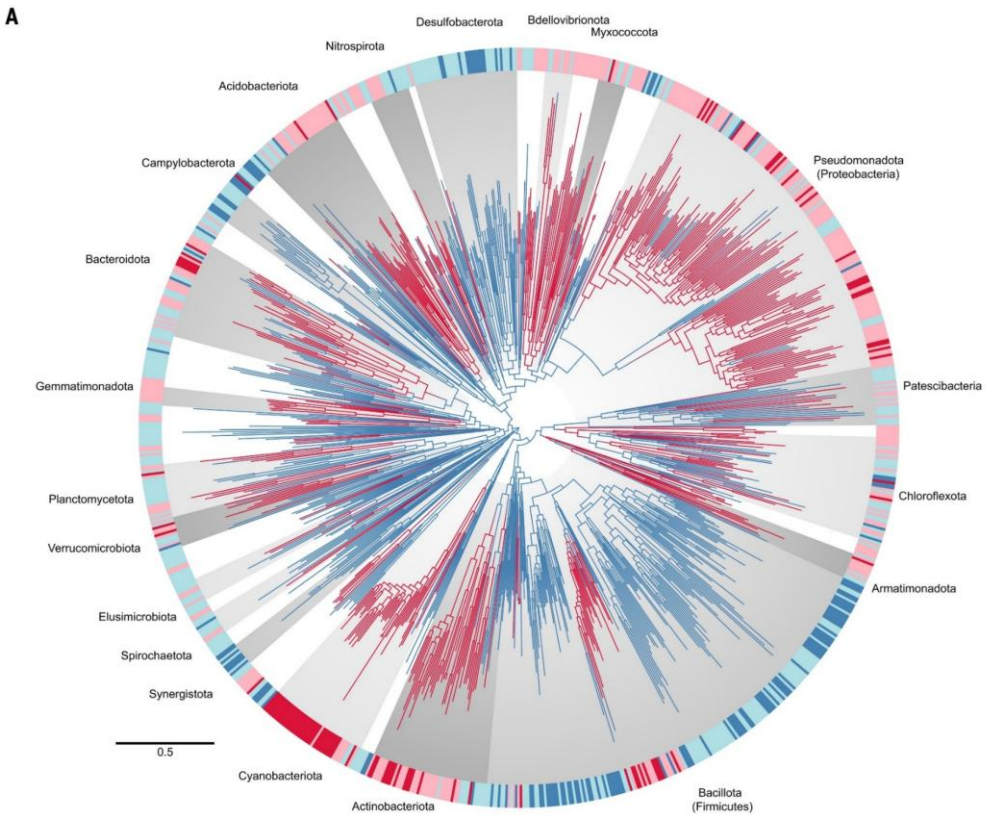
Negotiation between sequence fossil & GE=OE



Strong Sequence & Fossil evidence
+Add GOE soft maxima
=remains unchanged

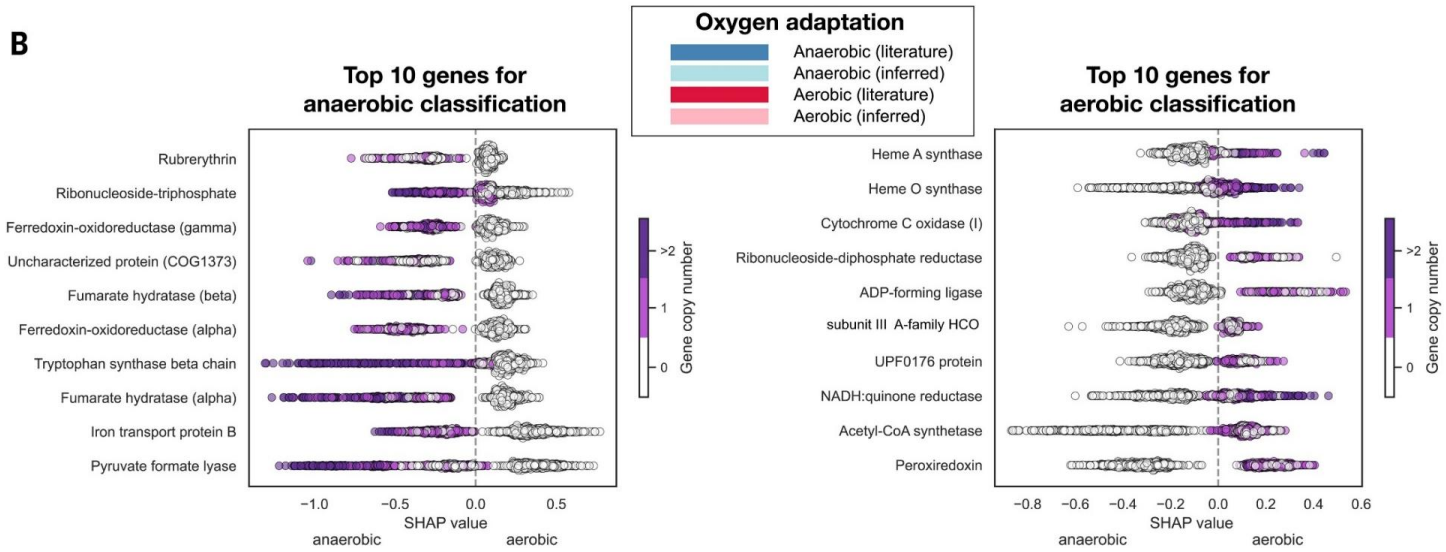
Ambiguous Sequence & Fossil evidence
+Add GOE soft maxima
=re-date the node after GOE

The evolution of oxygen adaptation in Bacteria

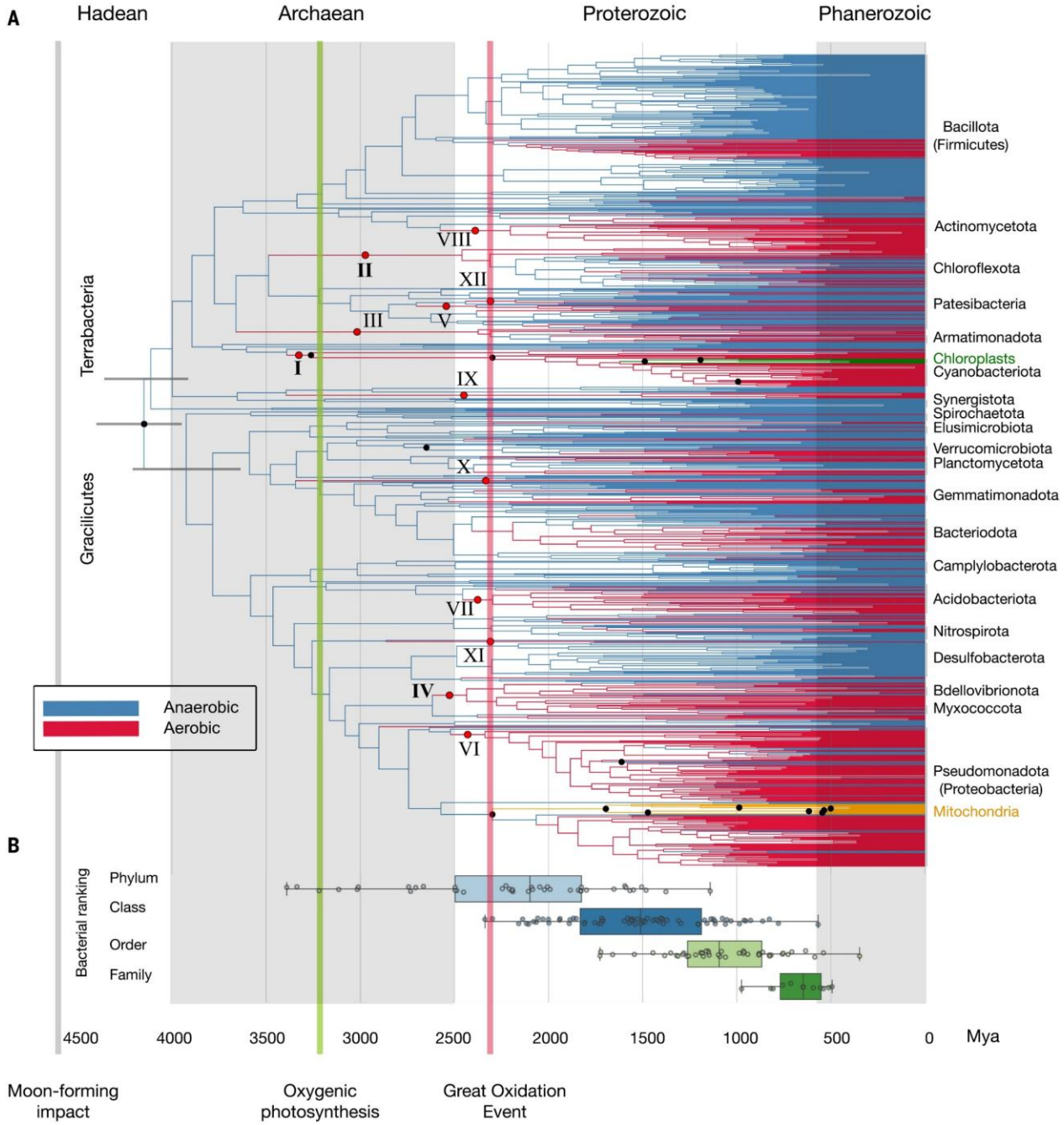


(A)A species tree of Bacteria (inferred using 65 marker genes from 1007 genomes using a custom site-heterogeneous substitution model), with branches colored according to predicted ability to grow in the presence of oxygen (red, aerobic; blue, anaerobic).

(B)Genes with the strongest contribution (SHAP values) to classification as aerobic or anaerobic according to the XGBoost. Each dot represents one node in the tree. On the left, genes with a higher copy number predict an anaerobic lifestyle; on the right, genes with a higher copy number predict an aerobic lifestyle.

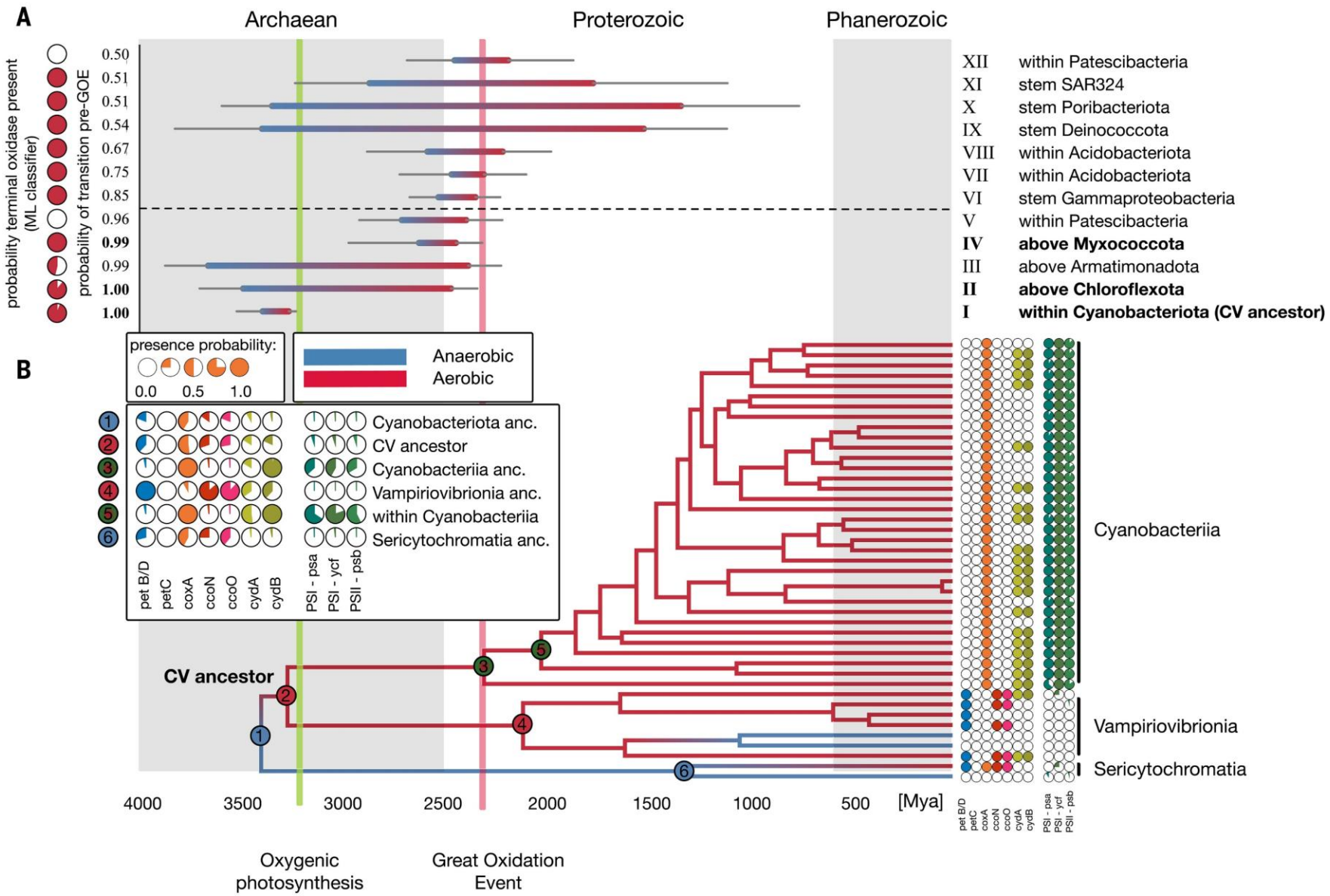


A GOE-dated phylogeny of Bacteria



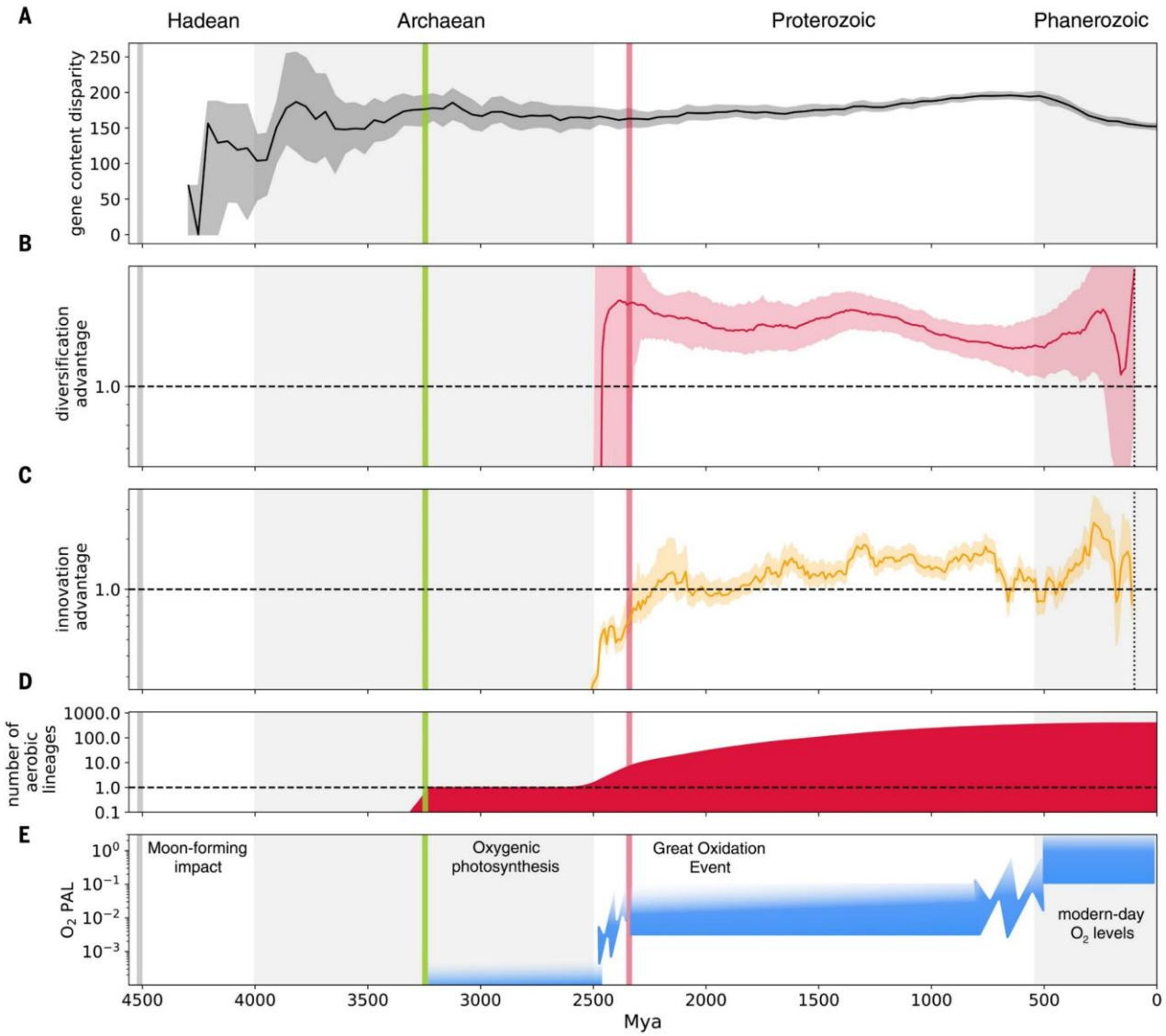
(A) Dated phylogenetic tree of Bacteria. Mitochondrial and chloroplast branches are colored in orange and green, respectively.
(B) Inferred ages of taxonomic ranks as defined in GTDB.

Aerobic metabolism predates GOE and likely enabled oxygenic photosynthesis



(A) Age ranges for inferred aerobic transitions that likely predate the GOE.
(B) Aerobic transitions and gene content evolution within Cyanobacteriota.

Bacterial evolution through geological time: aerobics hold more advantages



(A) gene content disparity.
(B) the relative diversification rate for aerobic and anaerobi lineages.
(C) the relative rate of anaerobic-to-aerobic versus aerobic-anaerobic transitions.
(D) Number of aerobic lineages.
(E) atmospheric oxygen levels through time.

Conclusion

1. GOE-based soft maxima provide a new calibration strategy for bacterial molecular dating.

2. The times of origin of the major bacterial taxonomic ranks (phylum, class, order, and family).

3. Most aerobic expansions occurred after the GOE, but some key aerobic transitions predated it, indicating that early oxygen adaptation—particularly in the cyanobacterial lineage—likely preceded and may have facilitated the evolution of oxygenic photosynthesis.

Thank you for your attention
Q&A