Microbiomes in light of traits: a phylogenetic perspective

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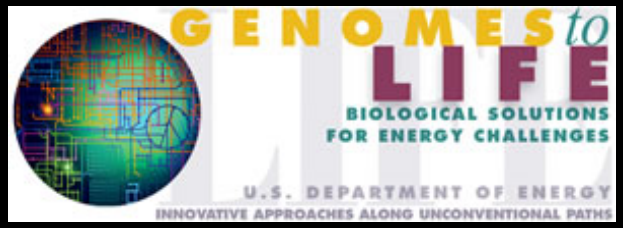


Is phylogeny predictive of traits?

- We are rapidly cataloguing the phylogenetic diversity of the oceans
  - Will this inform us of ocean functioning?

- Microbial diversity is immense
  - Can phylogenetic relationship be used for predicting traits?

Is phylogeny predictive of traits?

W. Ford Doolittle: NO!

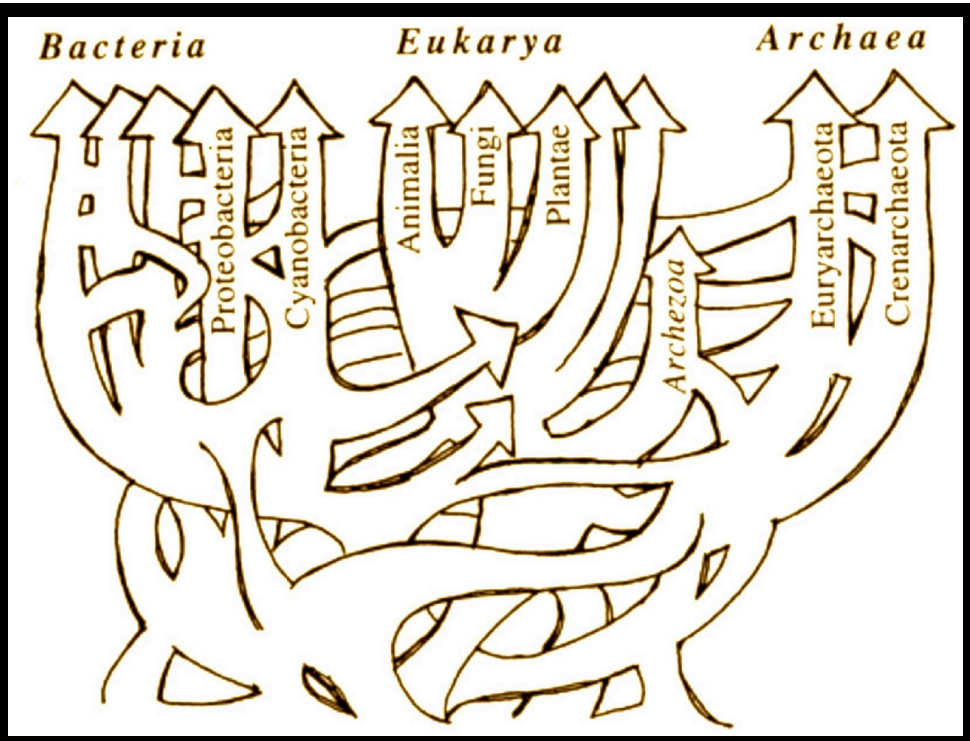
Is phylogeny predictive of trait?

W. Ford Doolittle: **NO!**

REVIEW

Phylogenetic Classification and the Universal Tree

W. Ford Doolittle



Many studies have shown lateral gene transfer

review article

Lateral gene transfer and the nature of bacterial innovation

Howard Ochi

* Department o
† Department o
‡ Howard Hugh

Research

Open Access

Unraveling the genomic mosaic of a ubiquitous genus of marine cyanobacteria

Alexis Dufresne[¤*†], Martin Ostrowski[¤‡], David J Scanlan[‡], Laurence Garczarek[*], Sophie Mazard[‡], Brian P Palenik[§], Ian T Paulsen[¶], Nicole Tandeau de Marsac[¥], Patrick Wincker[#], Carole Dossat[#], Steve Ferrie[**], Justin Johnson[**], Anton E Post[††], Wolfgang R Hess[‡‡] and Frédéric Pa

OPEN ACCESS Freely available online

PLoS GENETICS

Patterns and Implications of Gene Gain and Loss in the Evolution of *Prochlorococcus*

Gregory C. Kettler[1,2☯], Adam C. Martiny[2☯¤], Katherine Huang[2], Jeremy Zucker[3], Maureen L. Coleman[2], Sebastien Rodrigue[2], Feng Chen[4], Alla Lapidus[4], Steven Ferriera[5], Justin Johnson[5], Claudia Steglich[6], George M. Church[3], Paul Richardson[4], Sallie W. Chisholm[1,2*]

Is phylogeny predictive of traits?

Norm Pace: **YES!**

Is phylogeny predictive of function

Norm Pace: **YES!**

A Molecular View of Microbial Diversity and the Biosphere

Norman R. Pace

"The (16S rRNA) tree can be considered a rough map of the evolution of the genetic core of the cellular lineages that led to the modern organisms."

Many other studies have demonstrated that phylotypes are distributed or responding in predictable manners

Annually reoccurring bacterial communities are predictable from ocean conditions

Jed A. Fuhrman*†, Ian Hewson*‡, Michael S. Schwalbach*, Joshua A. Steele*, Mark V. Brown*§, and Shahid Naeem¶

Physiology and molecular phylogeny of coexisting *Prochlorococcus* ecotypes

Lisa R. Moore*†, Gabrielle Rocap*†‡§ & Sallie W. Chisholm†‡

Macroecological patterns of marine bacteria on a global scale

Anthony S. Amend[1,2]*, Tom A. Oliver[3], Linda A. Amaral-Zettler[4,5], Antje Boetius[6,7], Jed A. Fuhrman[8], M. Claire Horner-Devine[9], Susan M. Huse[4], David B. Mark Welch[4], Adam C. Martiny[1], Alban Ramette[6,7], Lucie Zinger[6], Mitchell L. Sogin[4] and Jennifer B. H. Martiny[1]

Resistance, resilience, and redundancy in microbial communities

Steven D. Allison*‡ and Jennifer B. H. Martiny†§

Departments of *Ecology and Evolutionary Biology and †Earth System Science, University of California, Irvine, CA 92697

Are functional traits linked to organismal phylogeny in microorganisms: **Yes or No!**

No:

Clear evidence of lateral gene transfer and other ways of convergent evolution in most (if not all) bacterial lineages

Yes:

Clear biogeography of most bacterial lineages

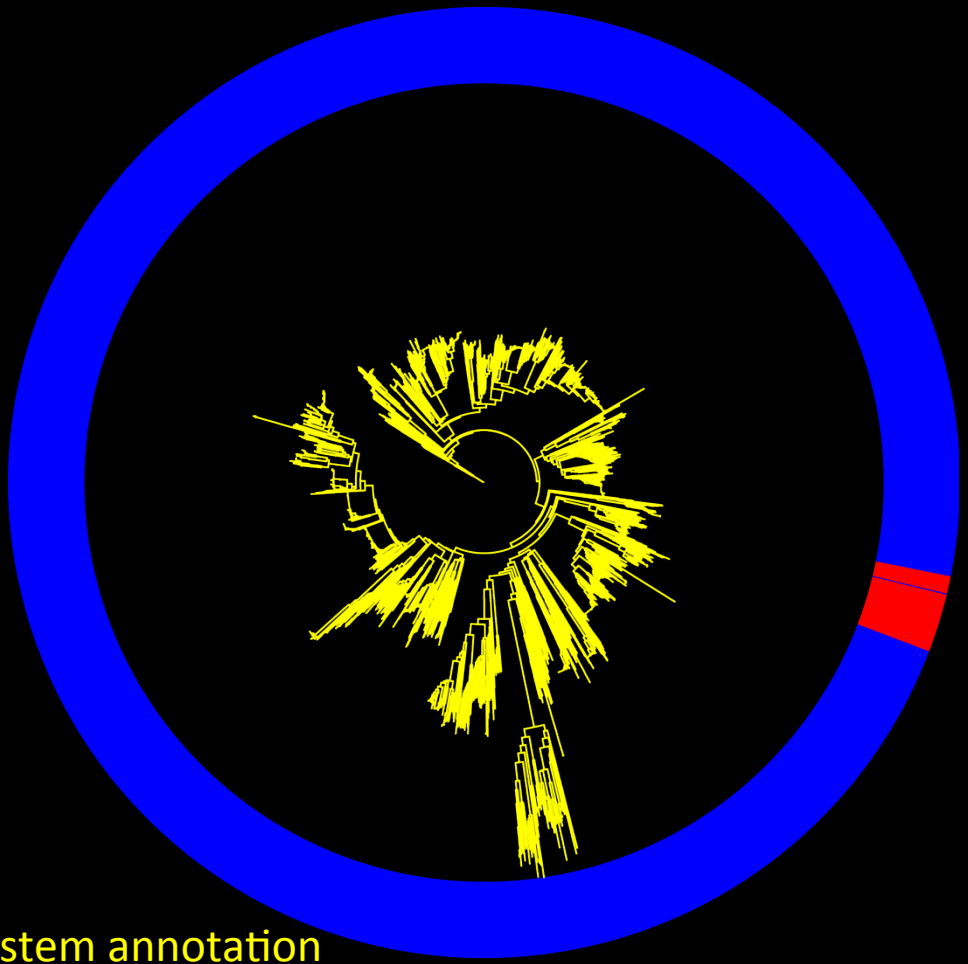
Community often changes when perturbed

Some metabolic basis for classification

What is the phylogenetic distribution of functional traits?

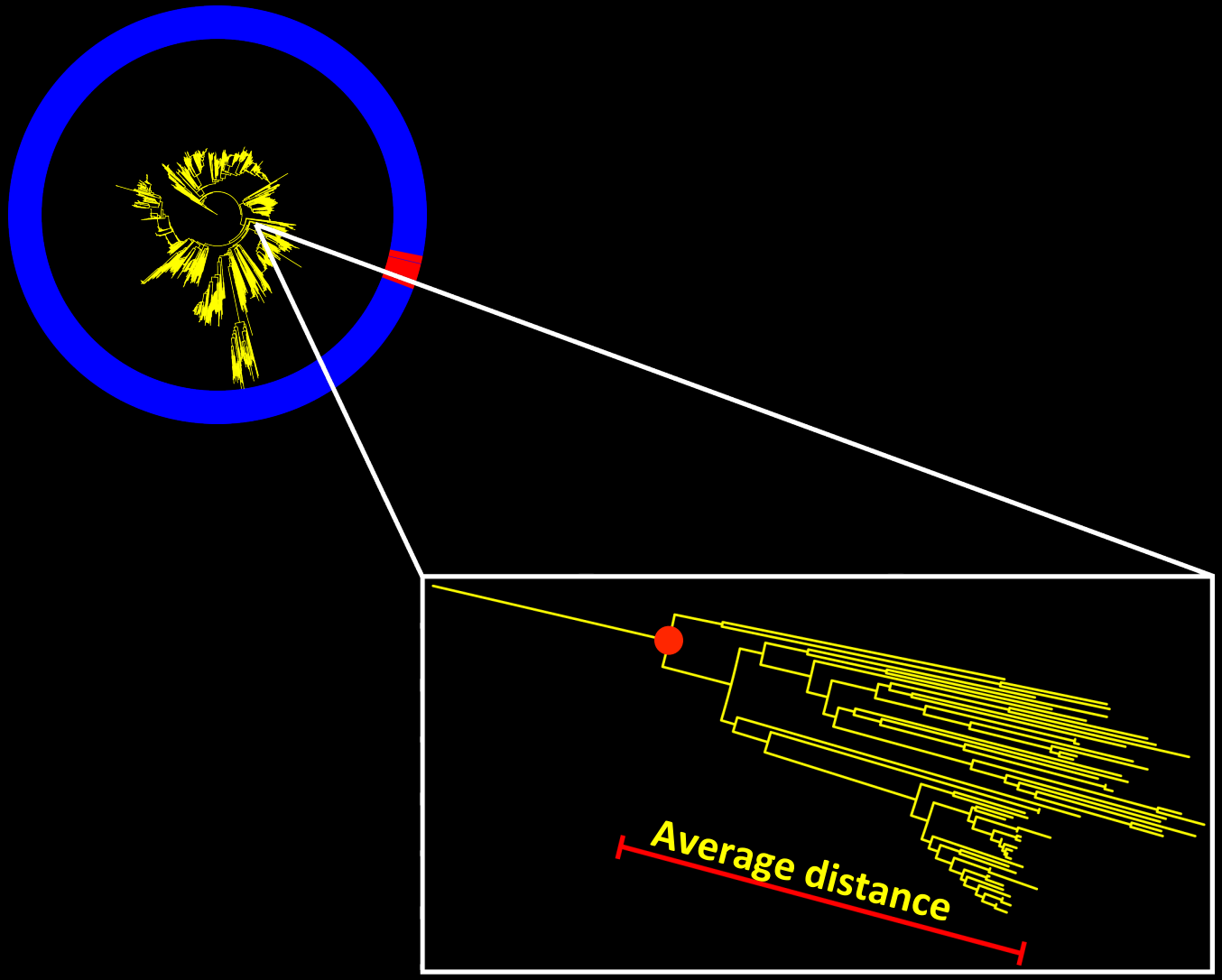
Martiny et al., *in press*, Martiny et al., *2013*

Oxygenic photosynthesis

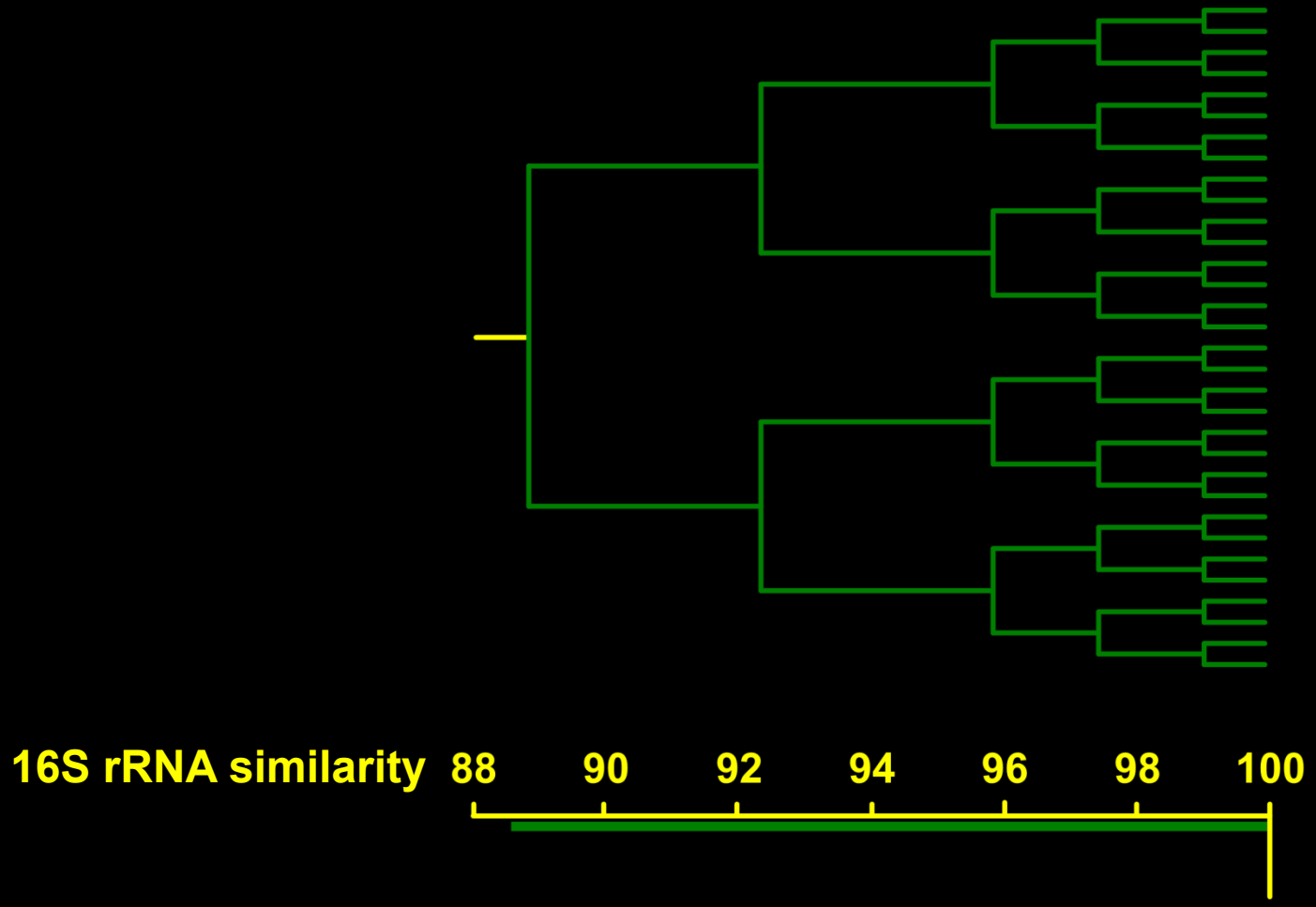


Based on SEED subsystem annotation
and 16S rRNA tree (Silva alignment)

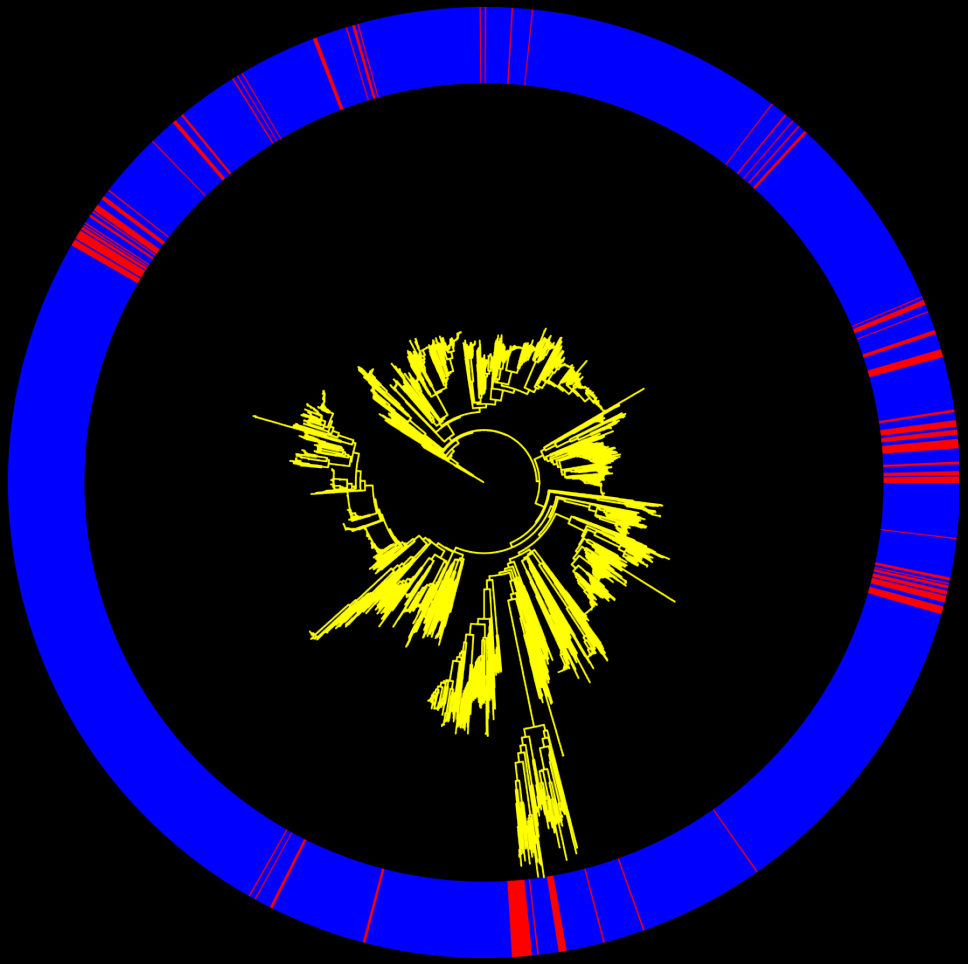
Oxygenic photosynthesis



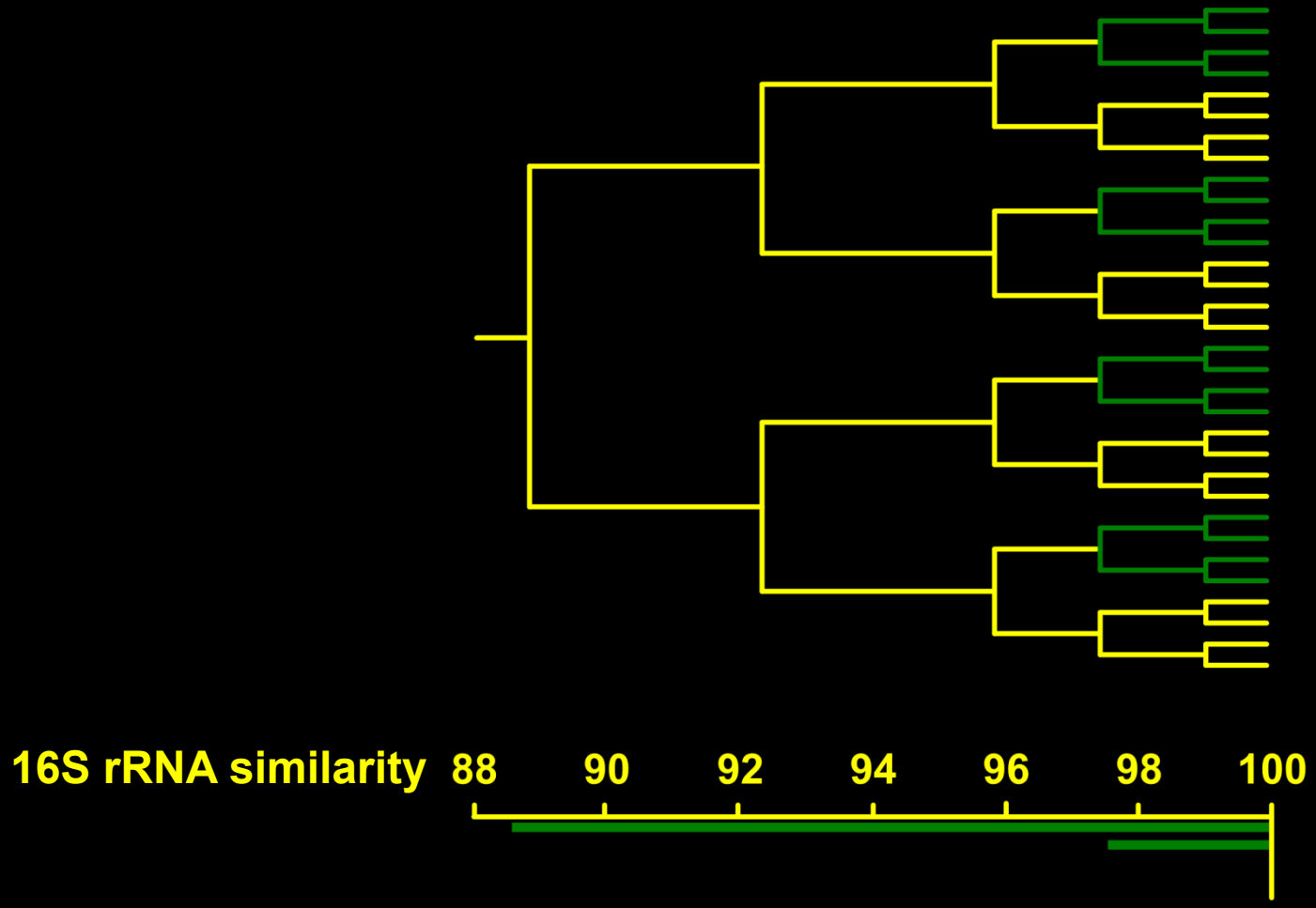
Oxygenic Photosynthesis



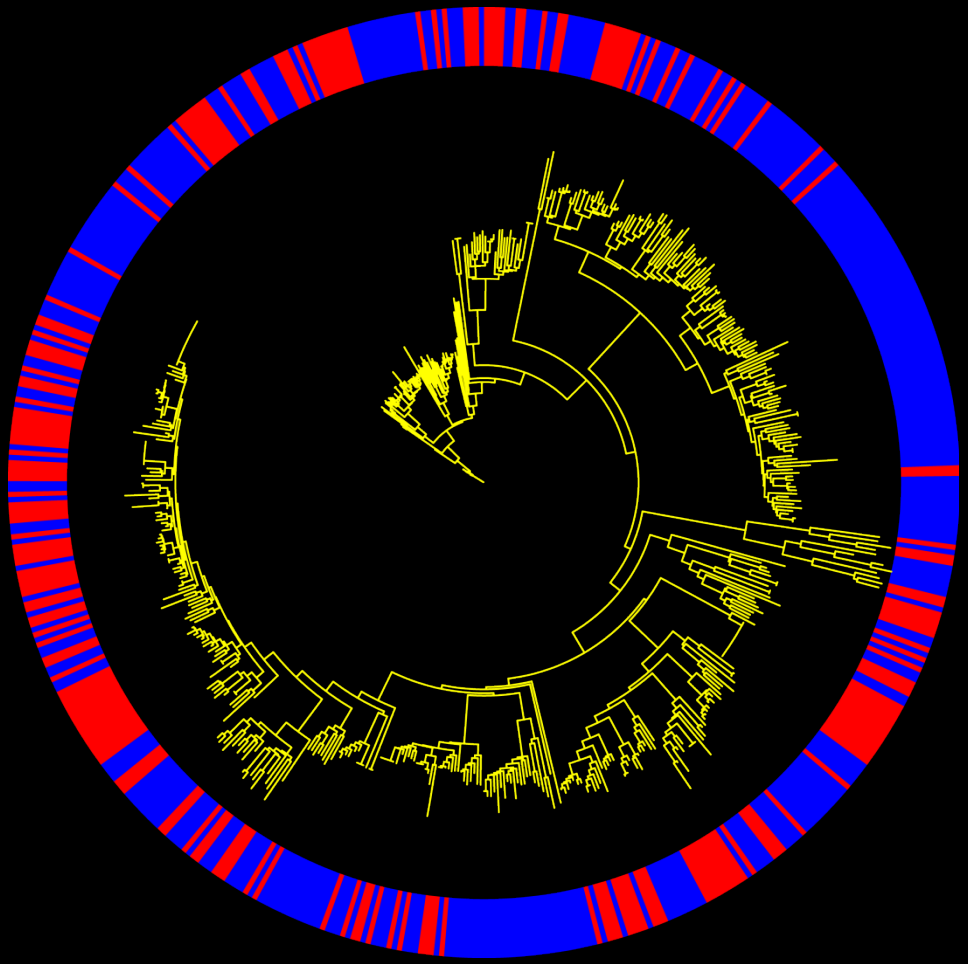
Nitrogen fixation



Nitrogen fixation

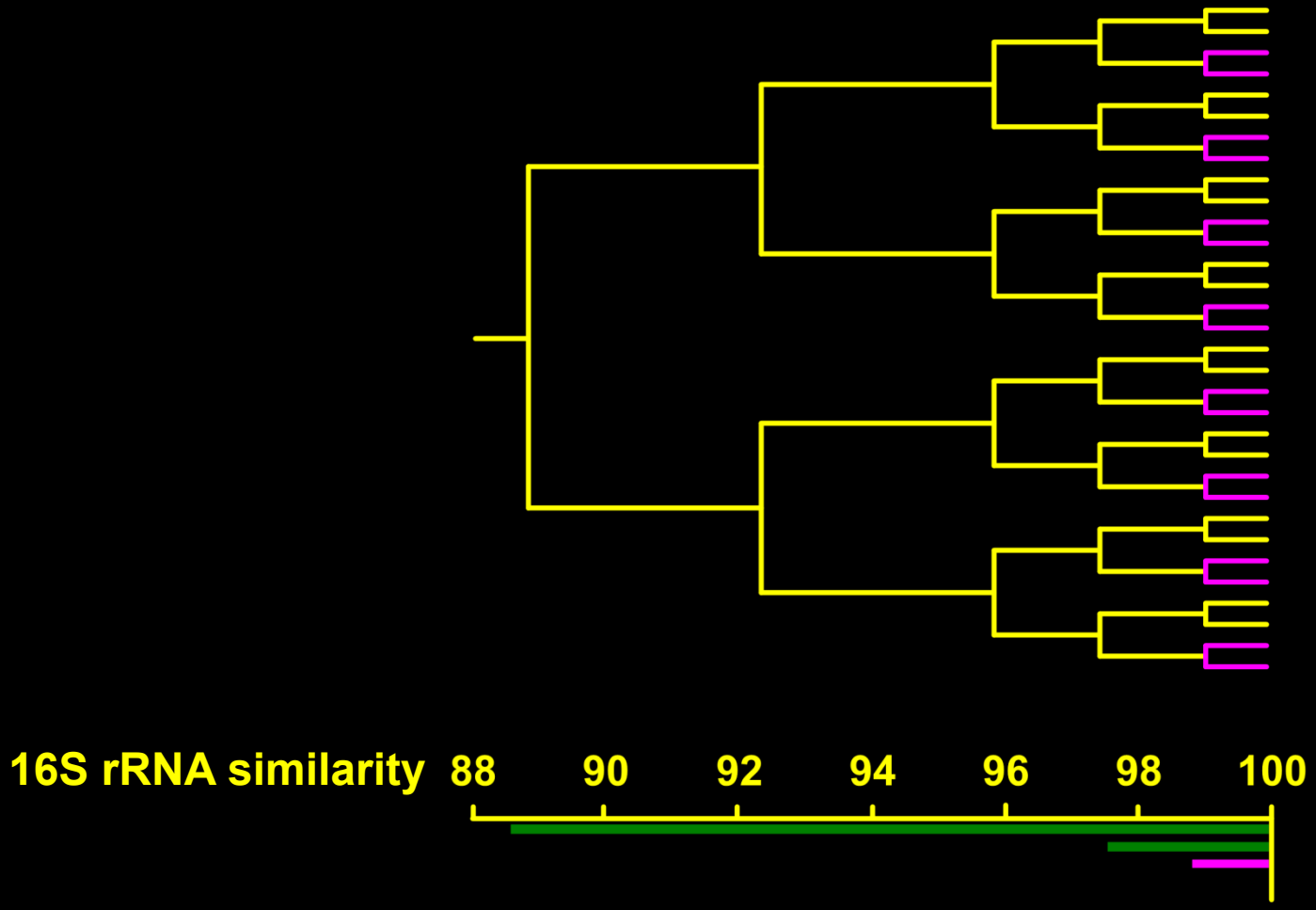


Carbon source

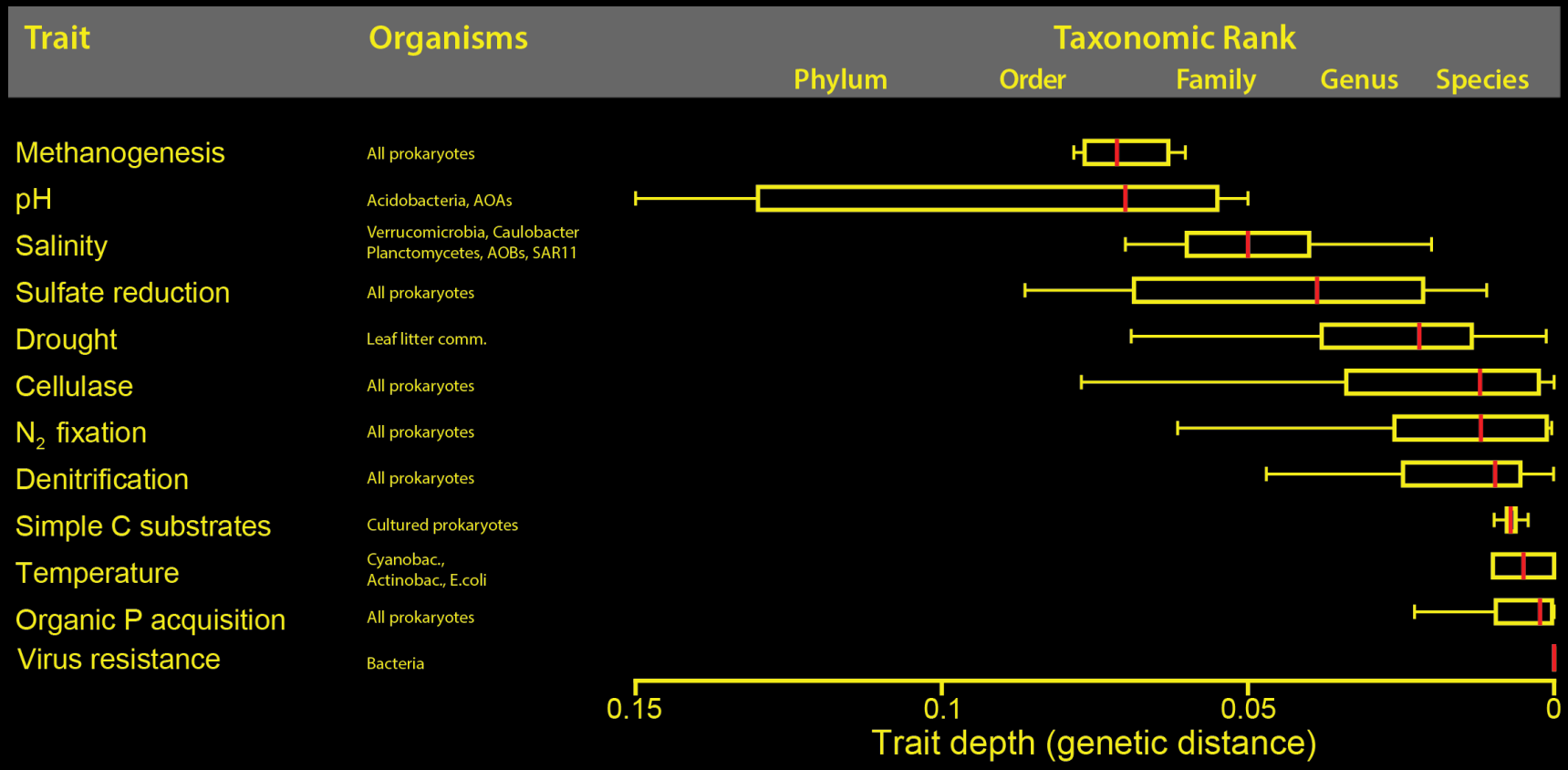


Based on growth in Biolog plates

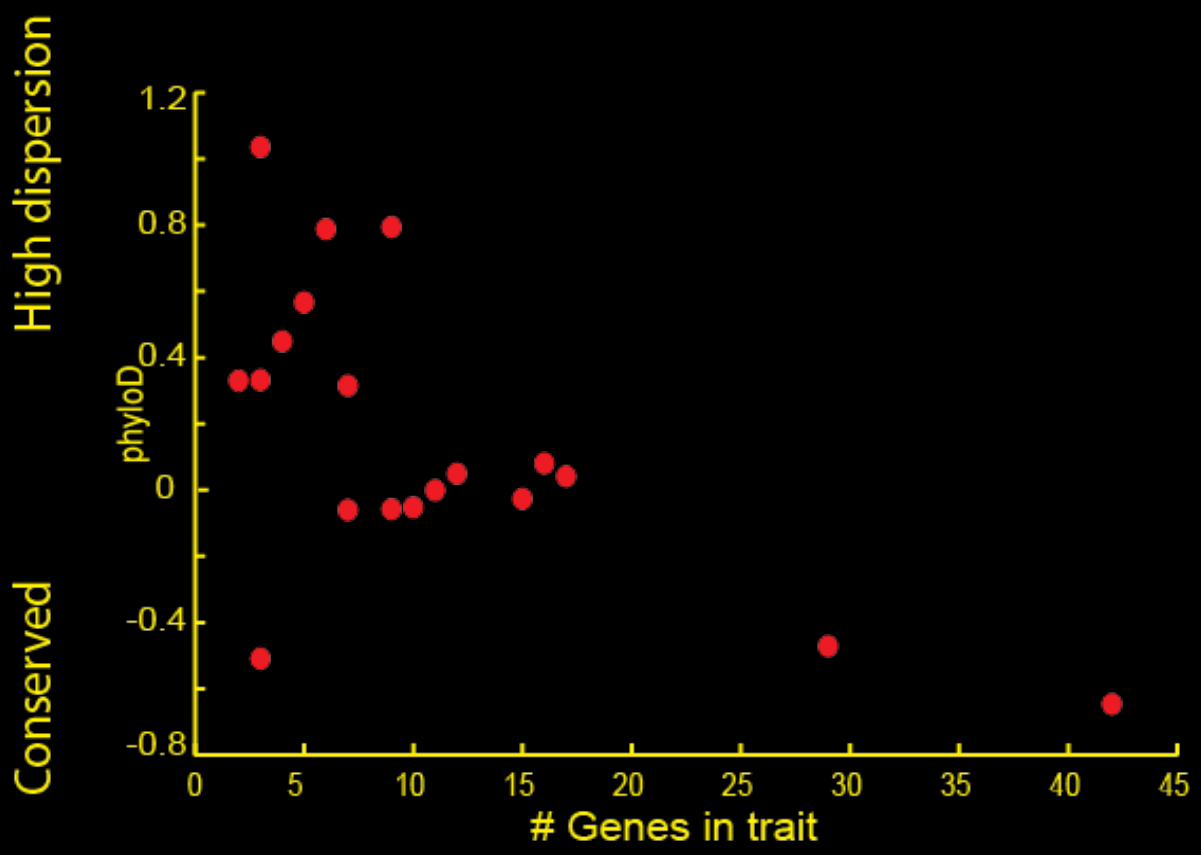
Carbon source



Hierarchy of trait depths



What controls this variation in phylogenetic dispersion?



$R^2 = 0.43$, $p < 1.1 \times 10^{-3}$

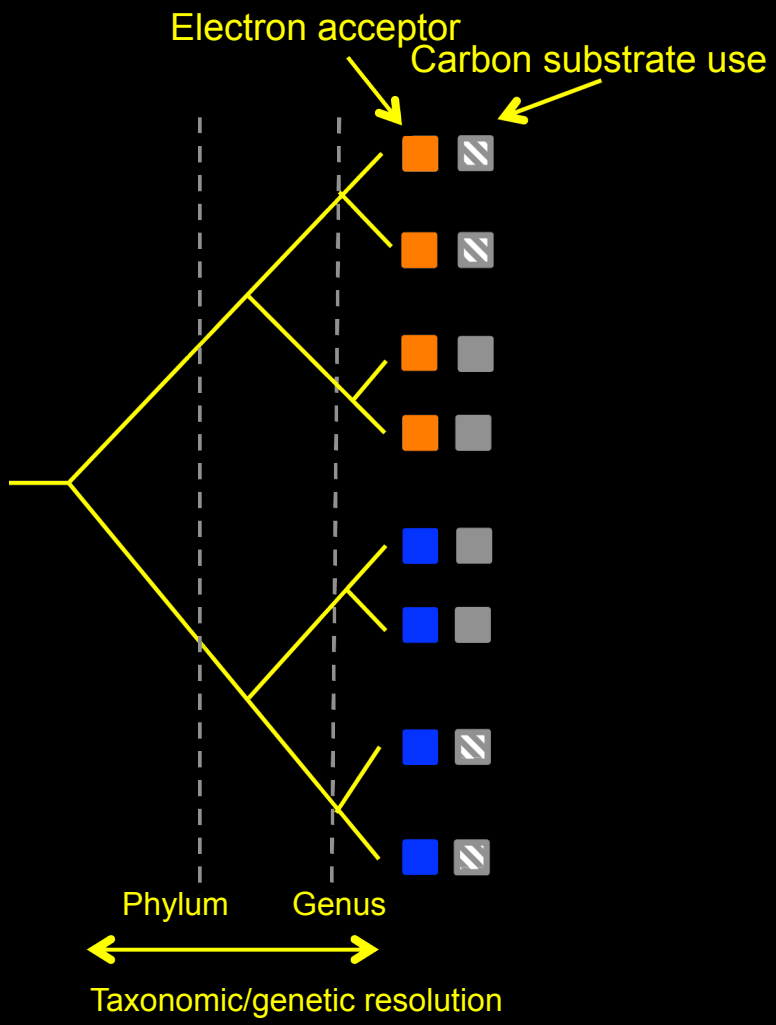
Prediction:

Complex traits are associated with deep clades

Simple traits are associated with tips of tree

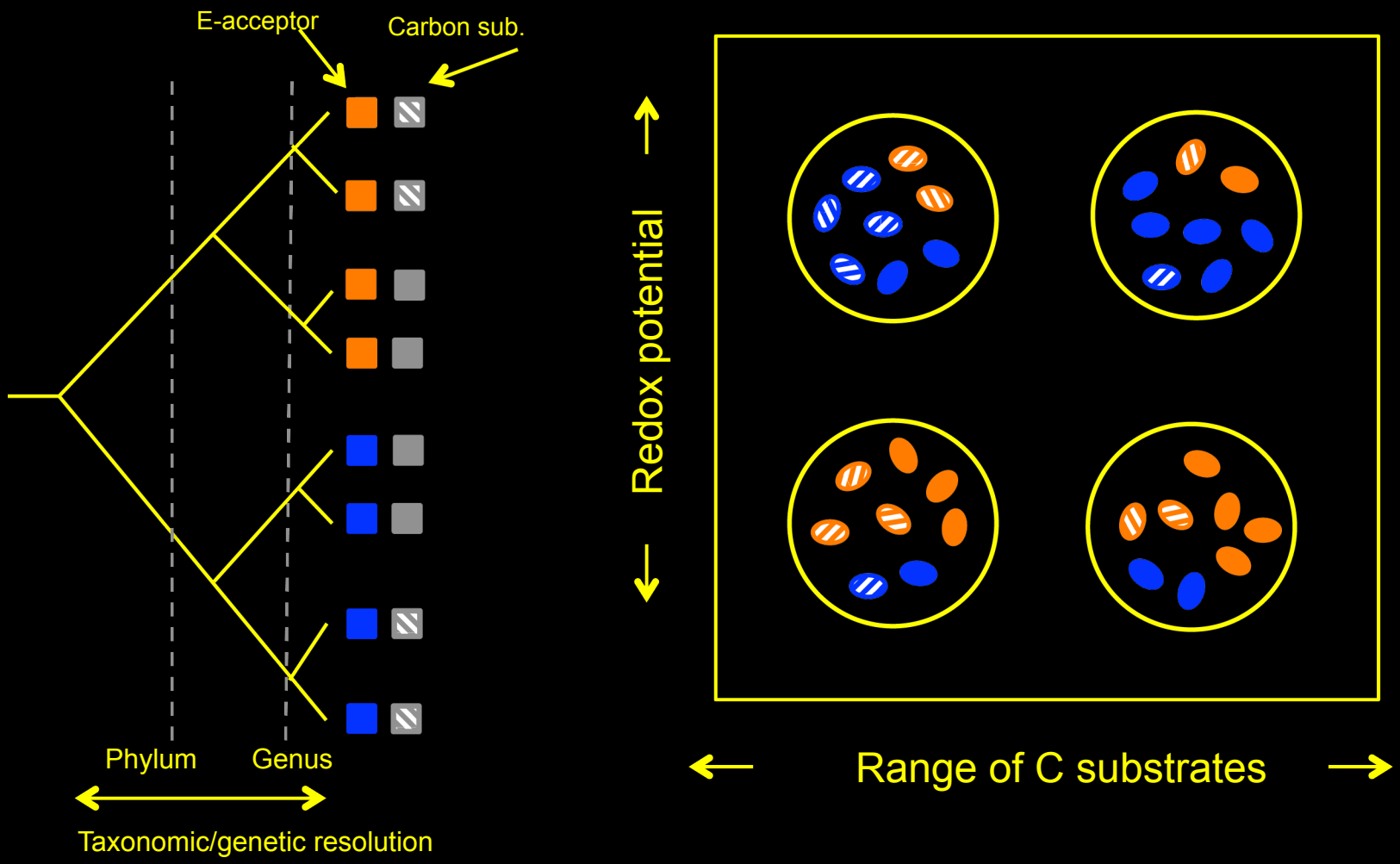
Implications for biogeography

Phylogeny of trait



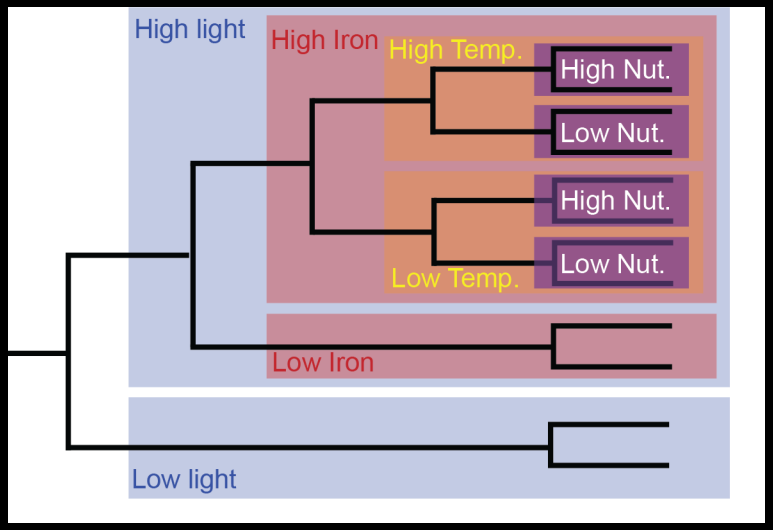
Implications for biogeography

Phylogeny of trait -> Community change



Case: *Prochlorococcus* biogeography

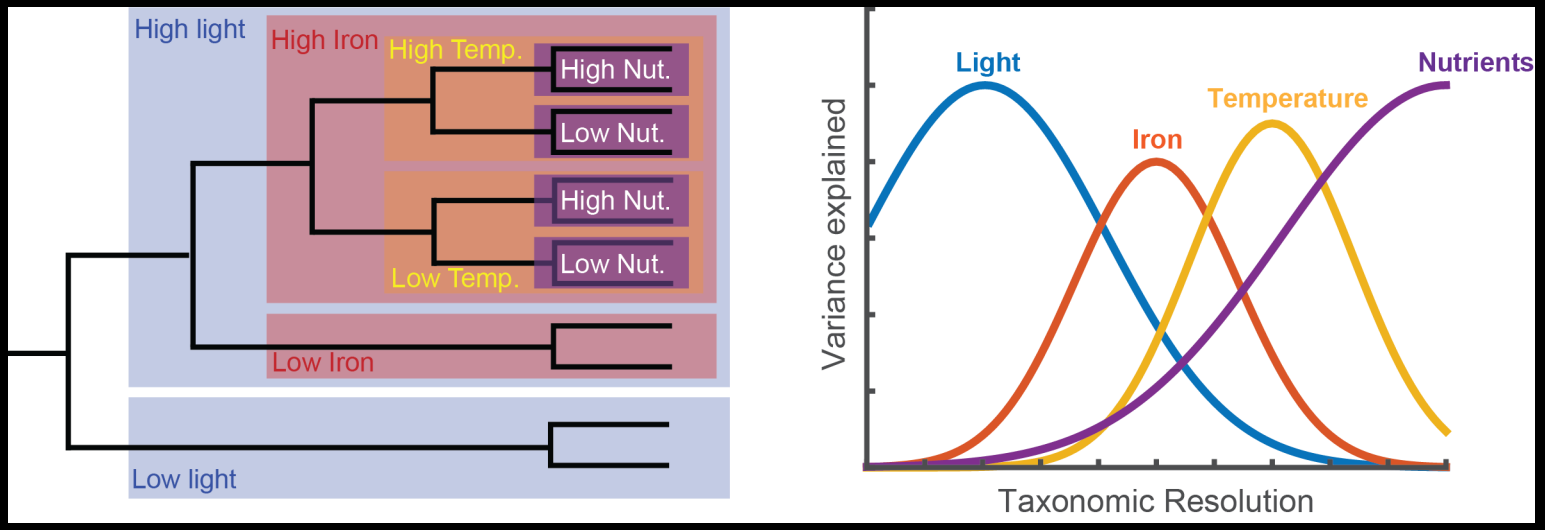
Phylogeny of traits



Martiny et al., 2009

Case: *Prochlorococcus* biogeography

Phylogeny of trait -> Community change



Martiny et al., 2009

This concept is important for understanding microbial biogeography

You say: “Light and temperature controls the distribution of microbial diversity in the ocean”

I say: “At the taxonomic definition you use, yes, but at other levels of phylogenetic divergence carbon substrate availability or nutrient supply ratios might be important”

Conclusion

- The Norm Paces and Ford Doolittles of this world are both right

- Traits in microbes are associated with a continuum of phylogenetic depths
- The dispersal and depth of clades that contain a trait are connected with the trait's complexity
- Phylogenetic dispersal of traits is important for biogeography (case of *Prochlorococcus*)

Thank You

Topic for discussion Tuesday afternoon (w. Jorn Bruggeman)