

Predicting Maximal Growth Rates From Genomes and Metagenomes for “Prokaryotes”, Eukaryotes, and Microbial Communities

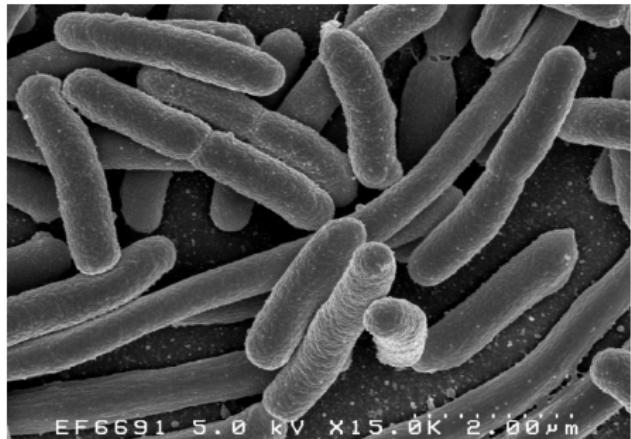
J.L. Weissman (*they/she*)

University of Southern California

May 28, 2022

Diversity of Maximal Growth Rates

Doubling times range from under 10 minutes to many days



Elapied at French Wikipedia, Public domain,

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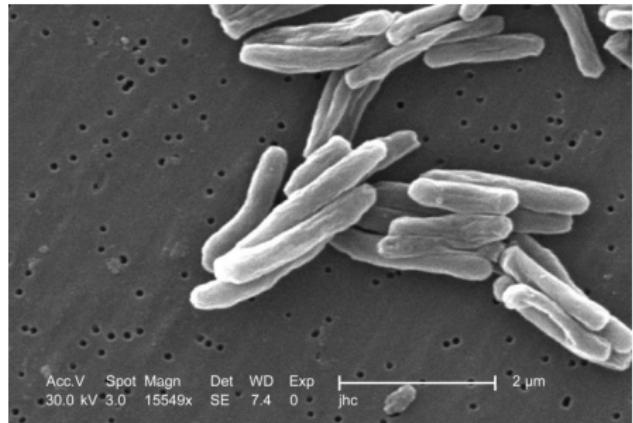
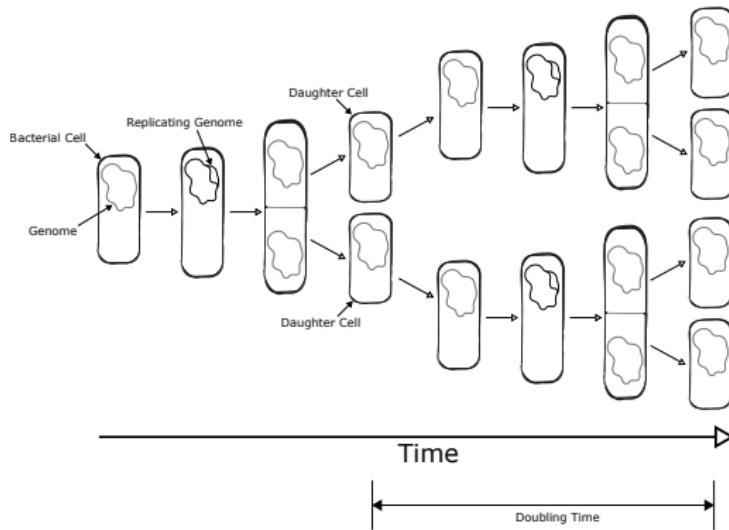


Photo Credit: Janice CarrContent

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Maximal Growth Rate

A Basic Parameter of Microbial Lifestyle



$$\text{Max. Growth Rate} = \frac{\ln 2}{\text{Min. Doubling Time}}$$

Diversity of Maximal Growth Rates

- a The diversity of growth potential across “prokaryotes”**
- b The diversity of growth potential across microbial eukaryotes
- c The growth potential of microbial communities

A Survey of Microbial Growth Potential

Not so easy...

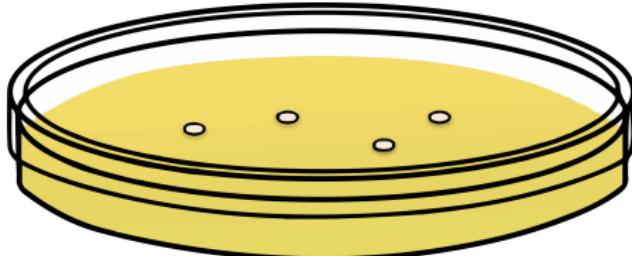
The Problem

We can't assay growth in many (especially slow-growing) organisms that we don't have in culture

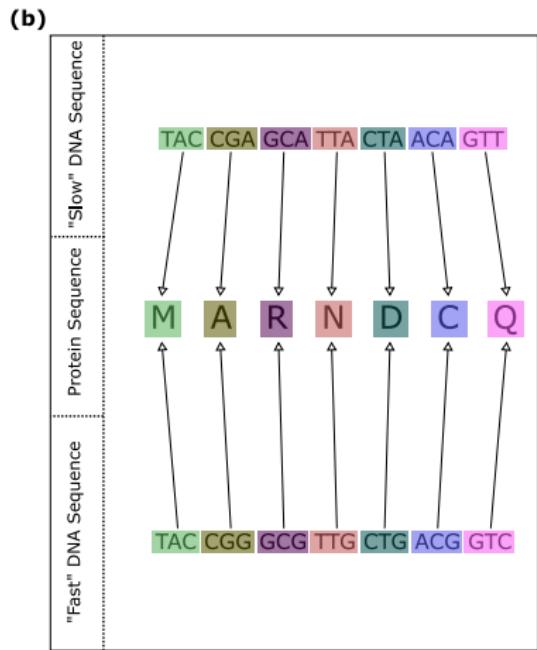
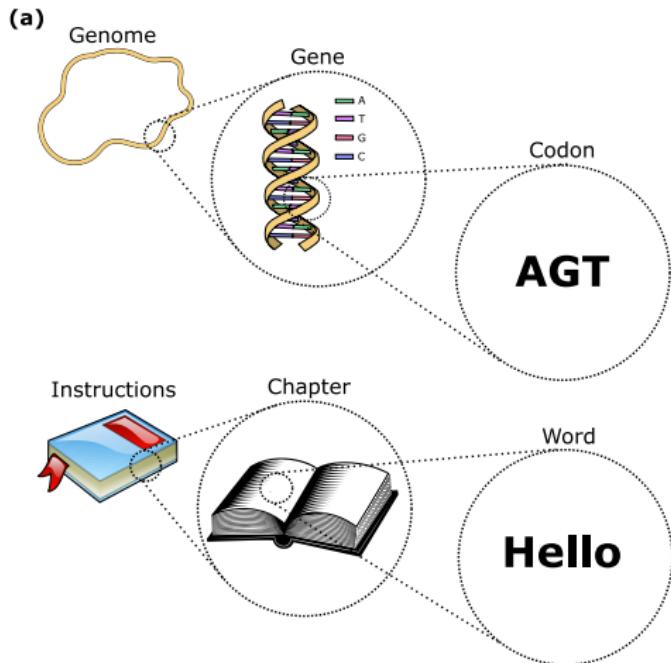
The Solution

We have genomes for many of these uncultured organisms...

Can we predict their maximal growth rates from their genomes?



Codon Usage Tells Us About Growth Potential



Our Approach

Measure Various Aspects of Codon Usage

- ① Average codon usage bias (CUB) of highly-expressed genes
 - How much are some codons favored over others?

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 - Do all highly expressed genes favor the same sets of codons?

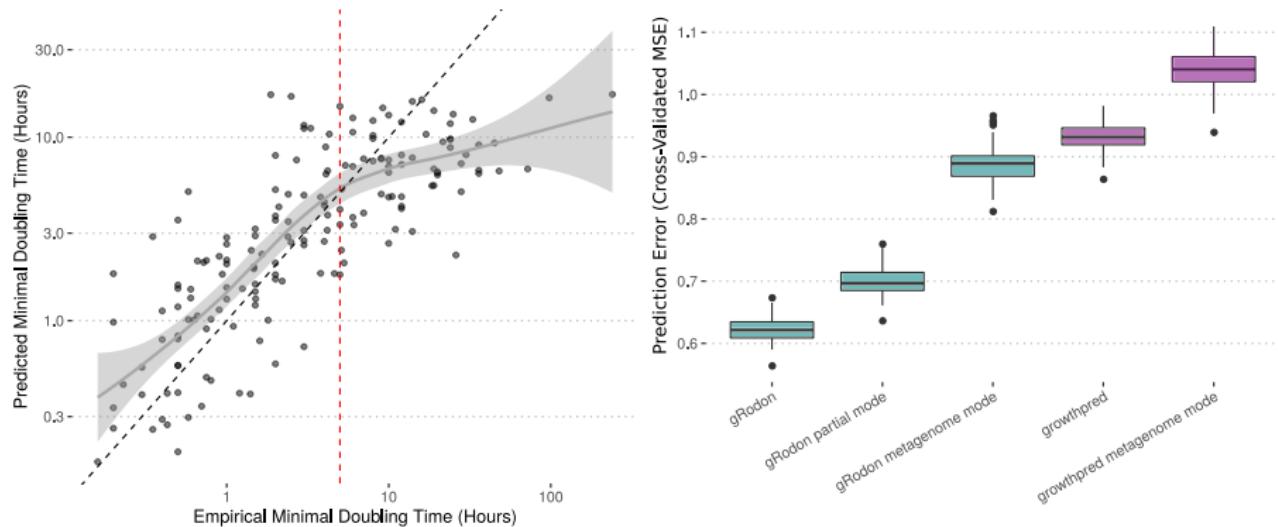
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- ③ Codon-pair bias
 - Are some codons more likely to show up adjacent to one another?

gRodon

Predictor considering multiple aspects of codon usage outperforms other predictors

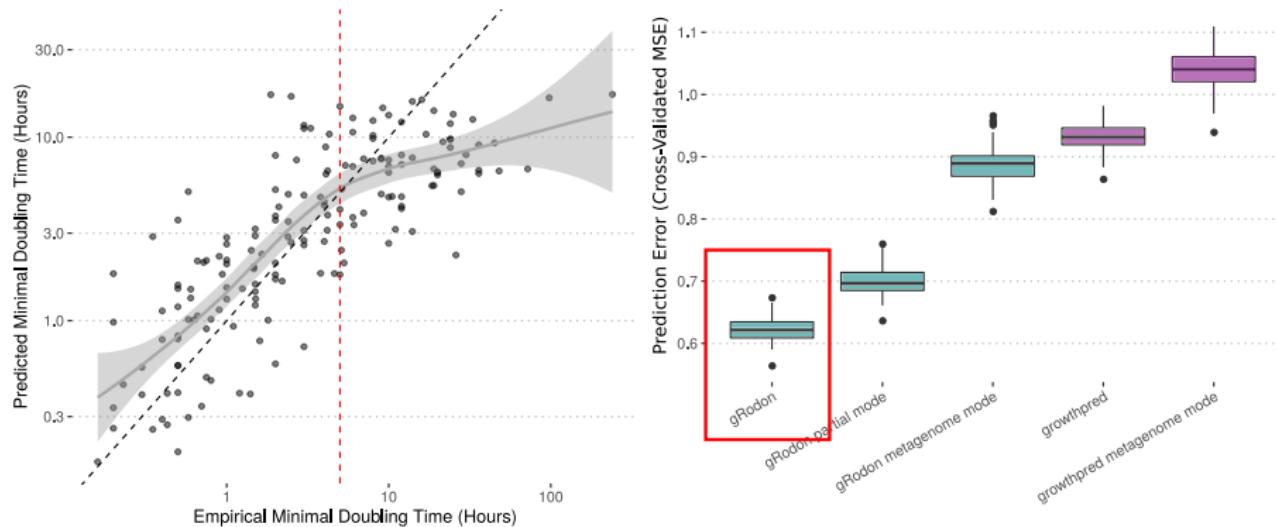


Easy-to-use R package

<https://github.com/jlw-ecoenv/gRodon2>

gRodon

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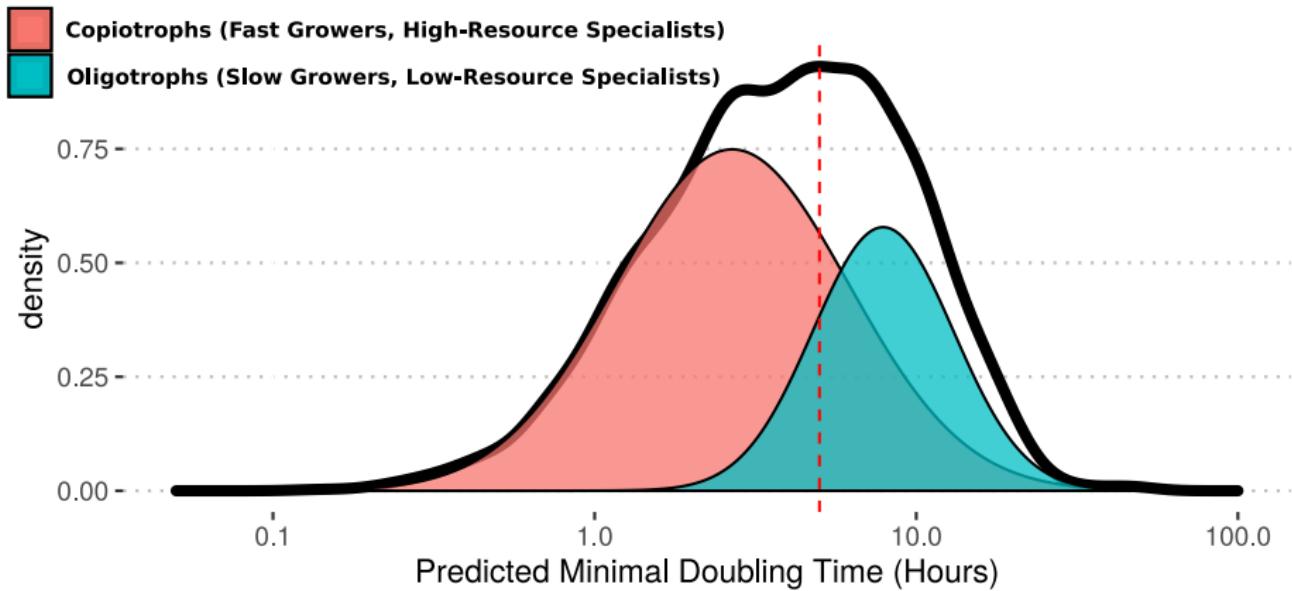


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Maximal Growth Rates Across 200k+ Organisms

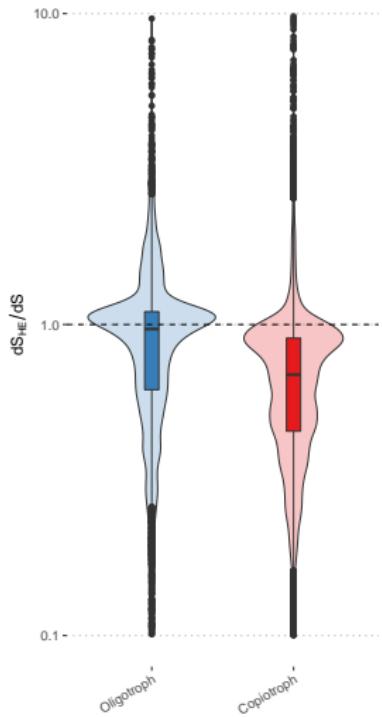
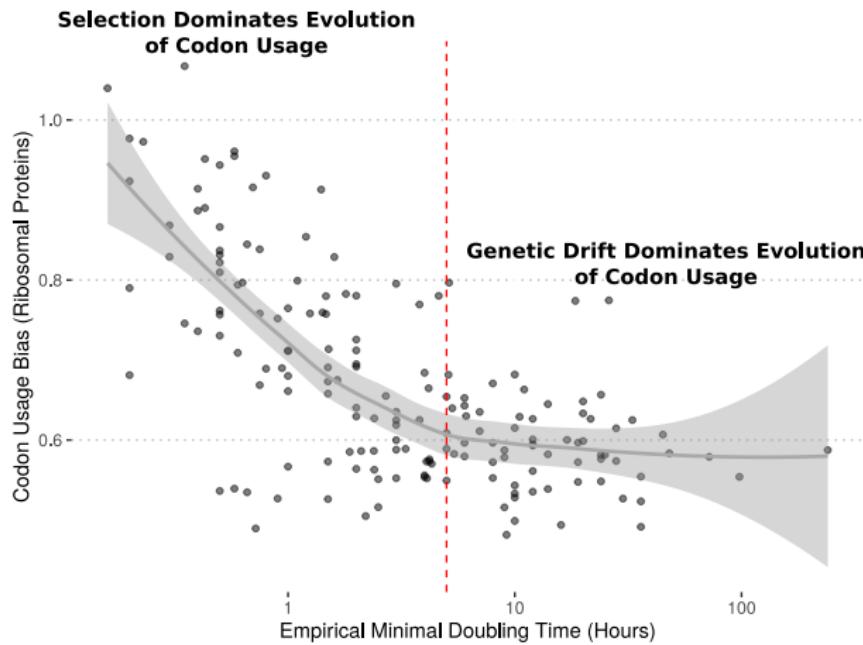
A Natural Cutoff for Oligotrophy



Two clusters of organisms based on growth rate (Gaussian mixture model)

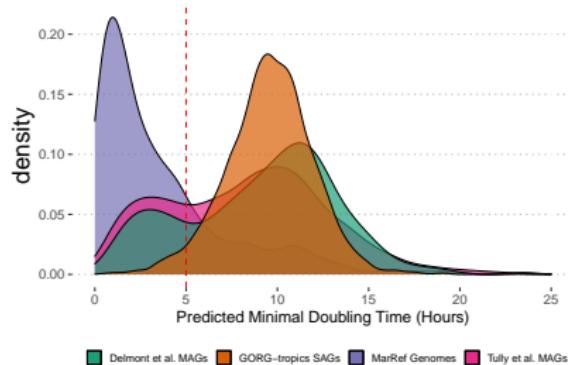
Selection Does Not Optimize Codon Usage In Oligotrophs

An evolutionary definition of copiotrophy and oligotrophy



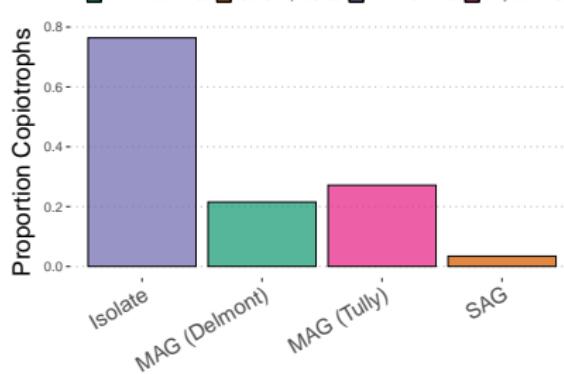
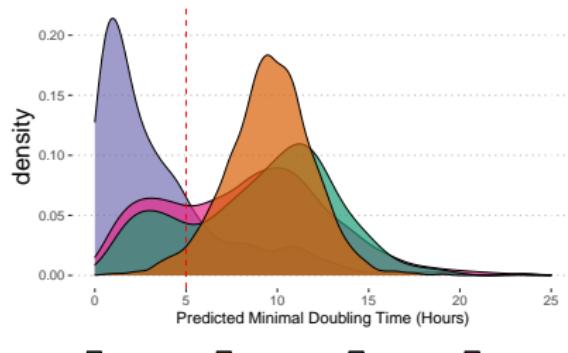
Oligotrophs Underrepresented Among Sequenced Isolates

Particularly apparent among marine organisms



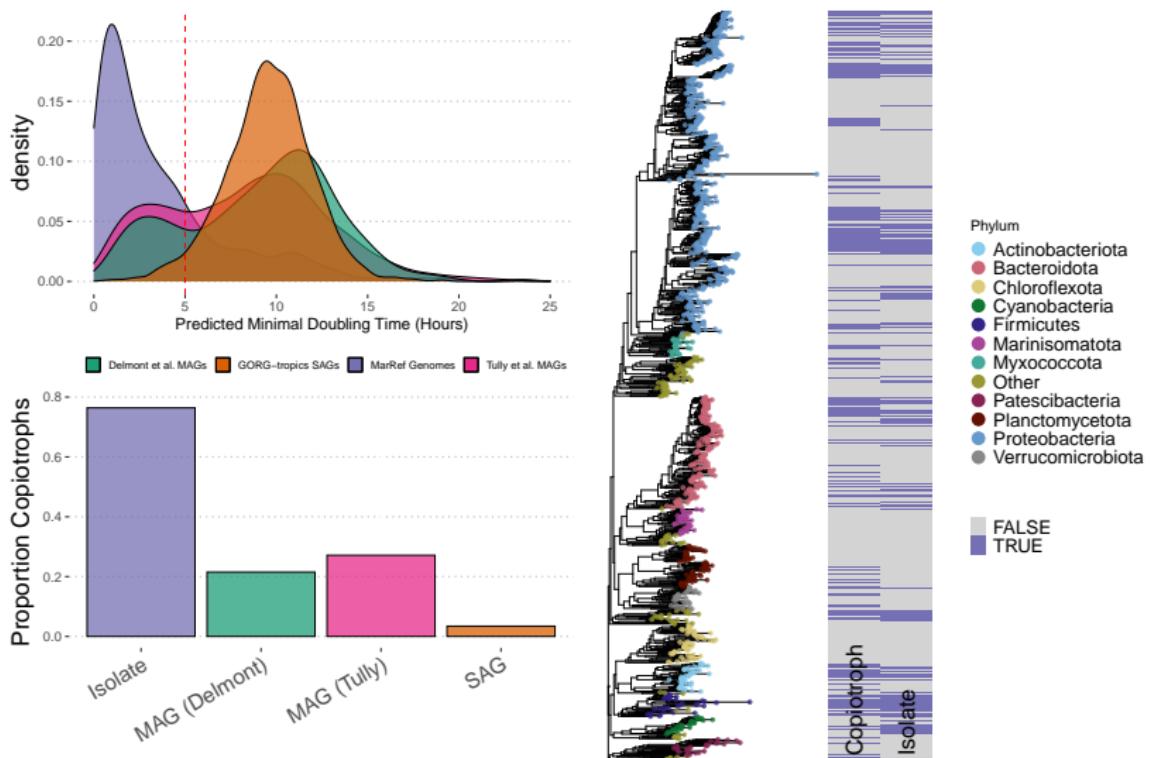
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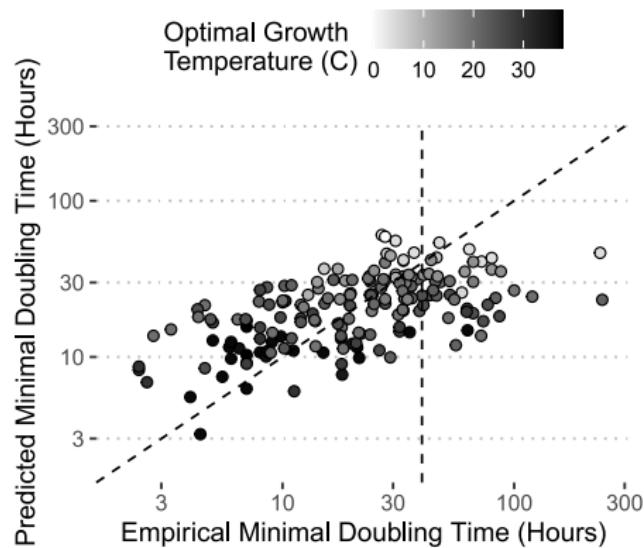


Diversity of Maximal Growth Rates

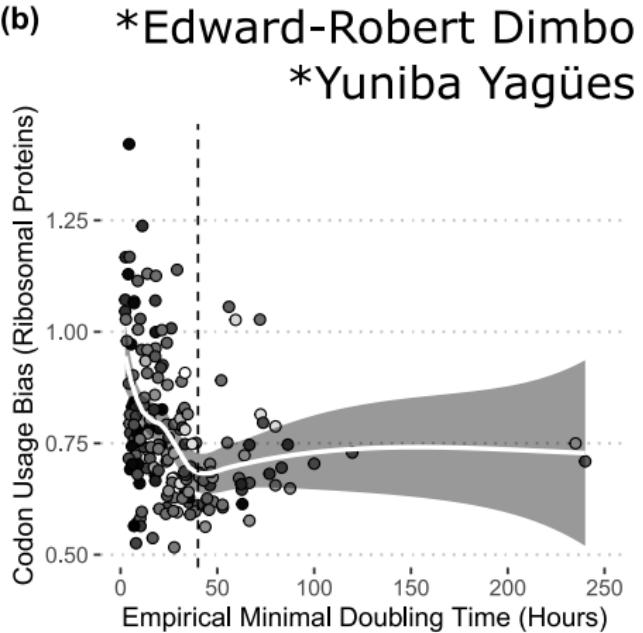
- ⓐ The diversity of growth potential across “prokaryotes”
- ⓑ **The diversity of growth potential across microbial eukaryotes**
- ⓒ The growth potential of microbial communities

Growth Rates of Microbial Eukaryotes

(a)

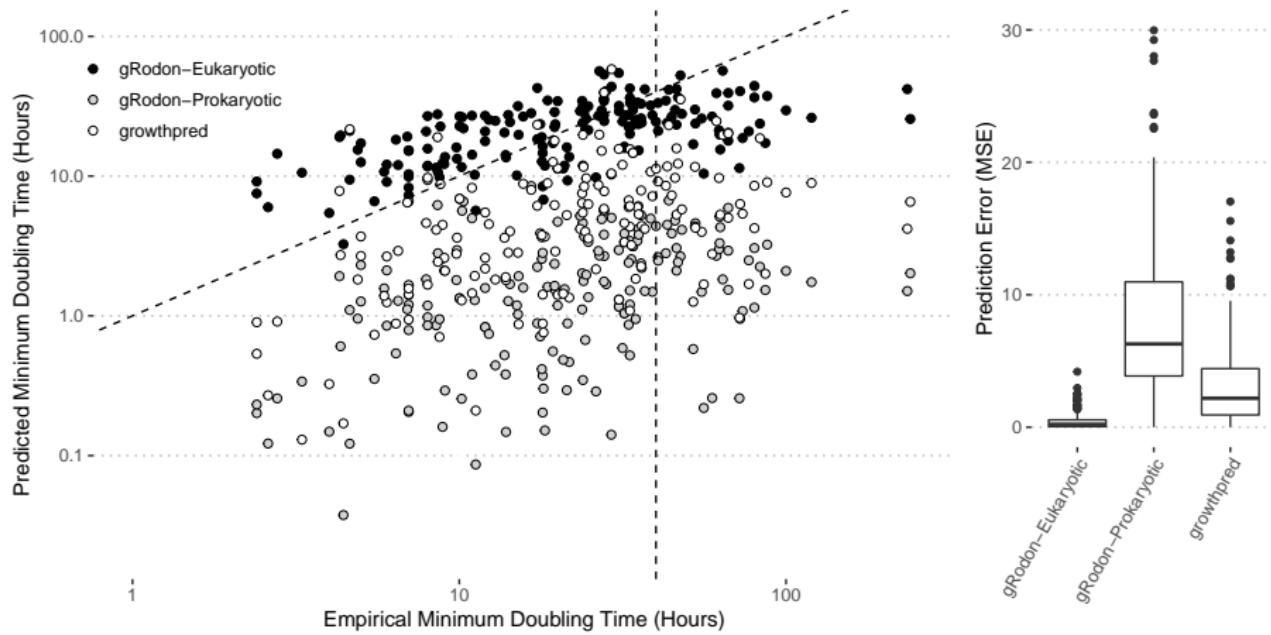


(b)

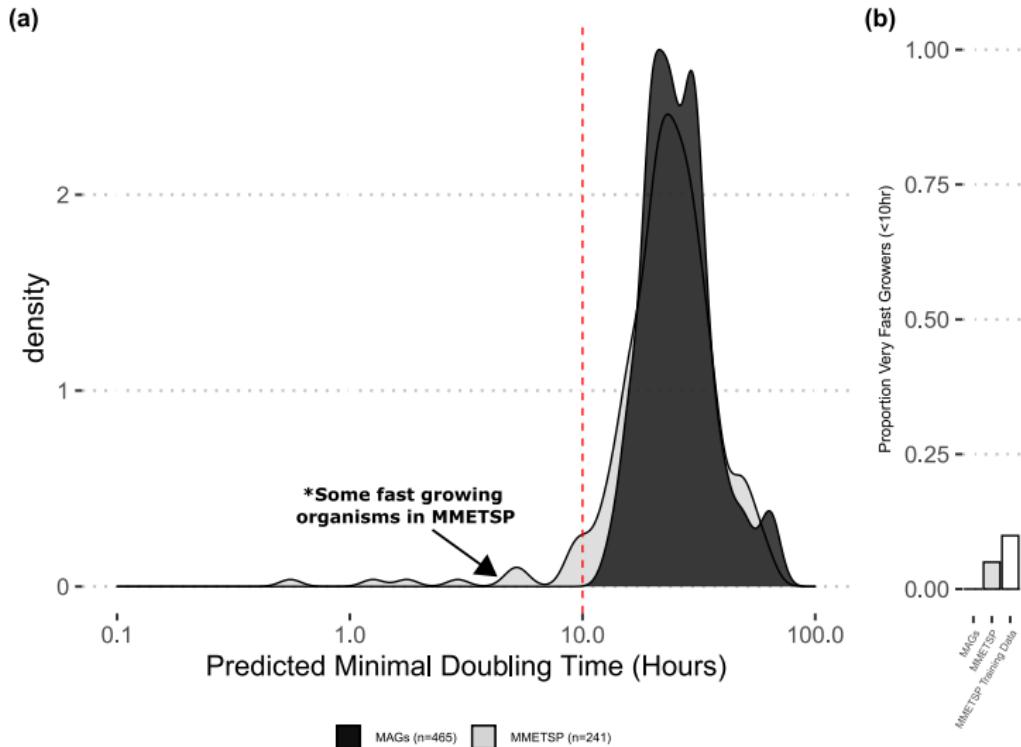


*Edward-Robert Dimbo
*Yuniba Yagües

Growth Rates of Microbial Eukaryotes



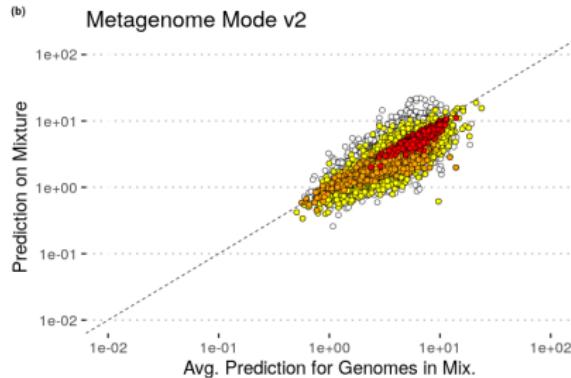
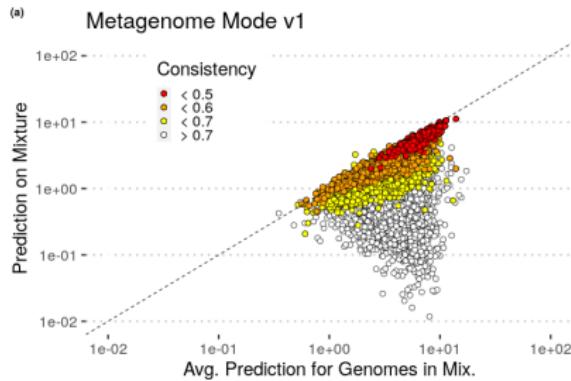
Collections of Sequenced Isolates Apparently Unbiased?*



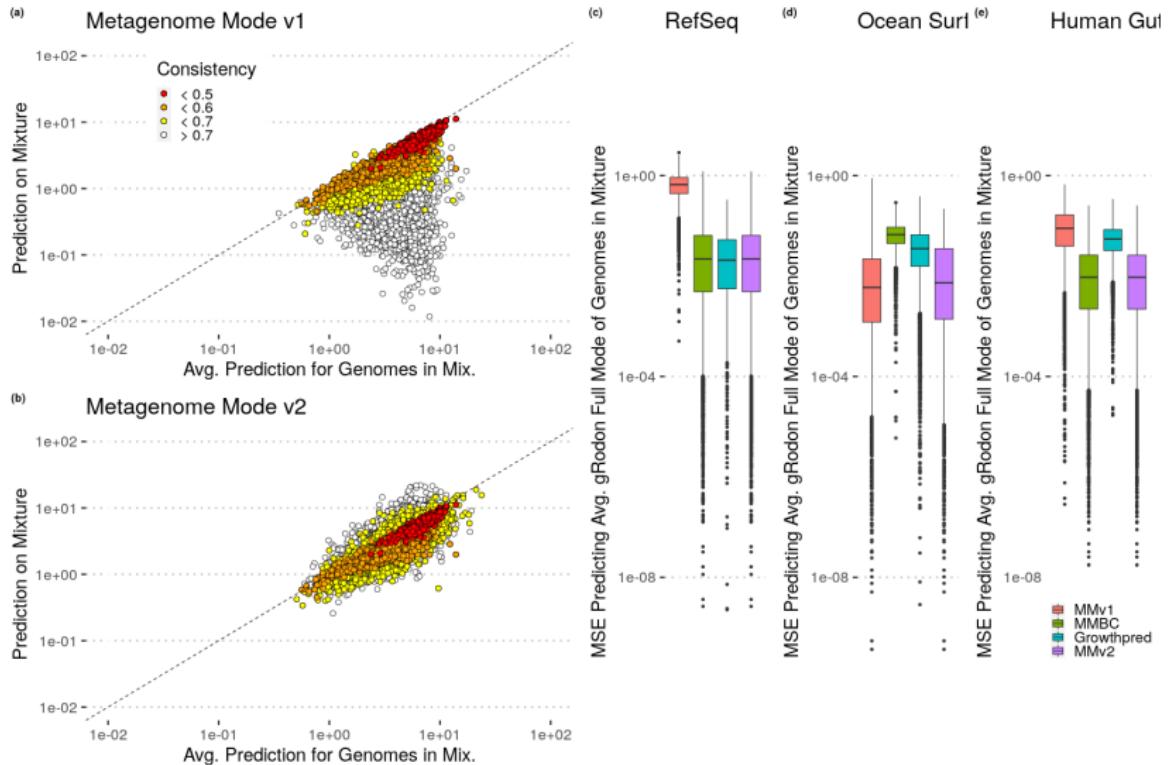
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Benchmarking Community-Wide Average Max. Growth Rate Predictions

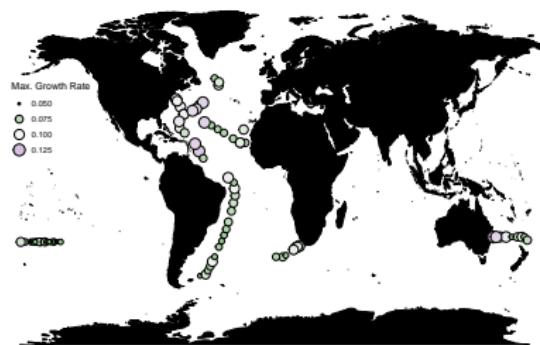


Benchmarking Community-Wide Average Max. Growth Rate Predictions

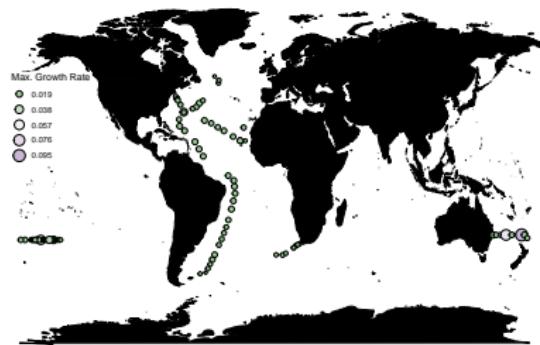


Shifts in Community-Wide Growth Potential

(a) Prokaryotes

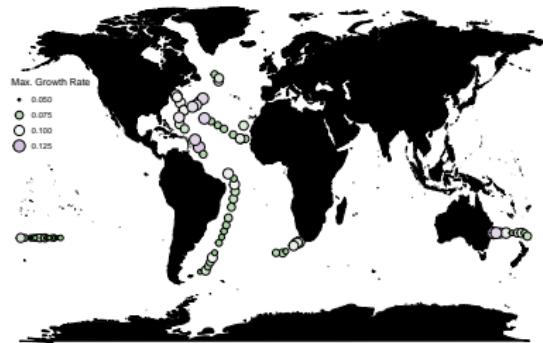


(b) Eukaryotes

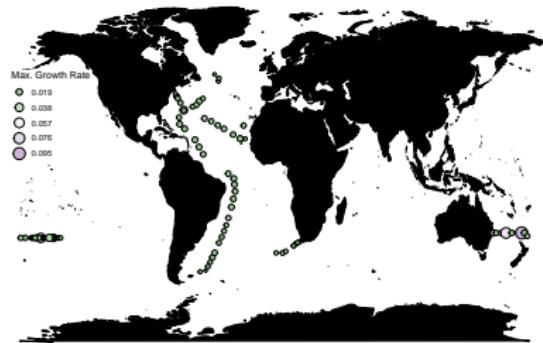


Shifts in Community-Wide Growth Potential

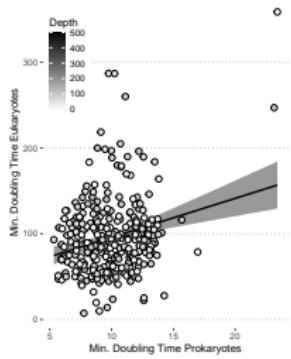
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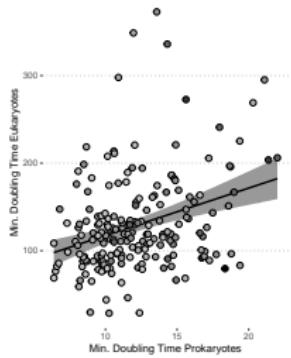
(b) Eukaryotes



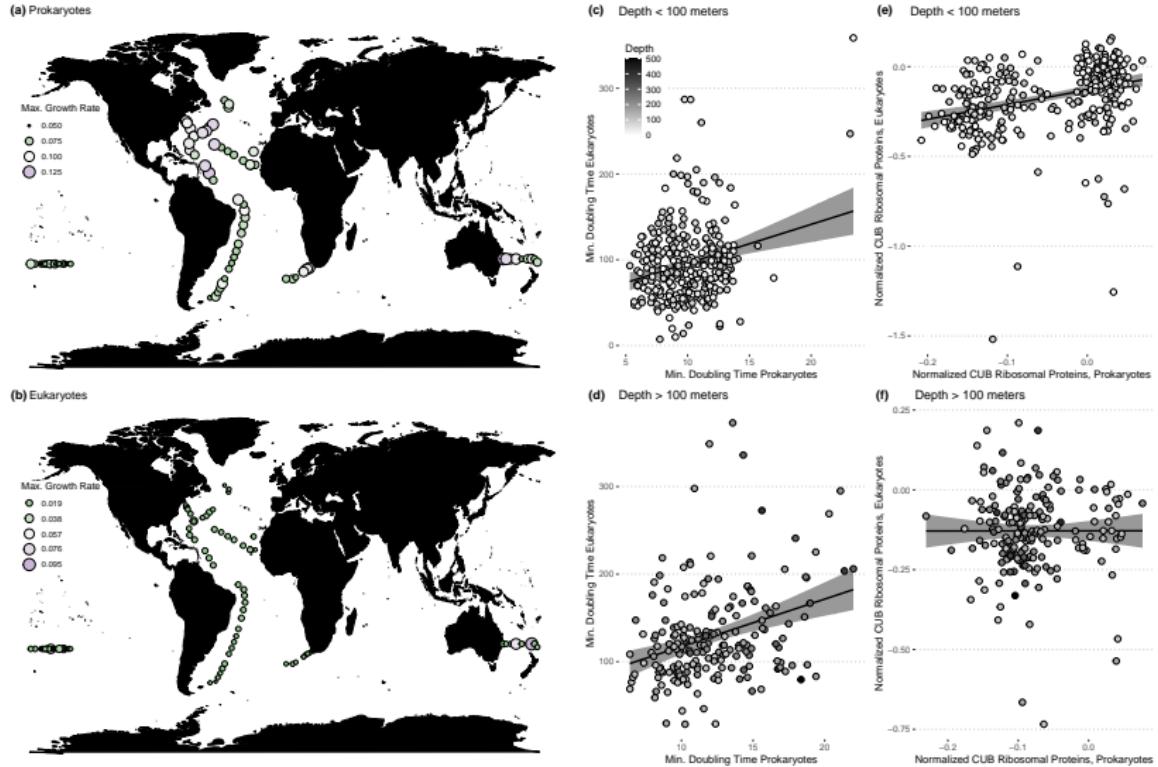
(c) Depth < 100 meters



(d) Depth > 100 meters



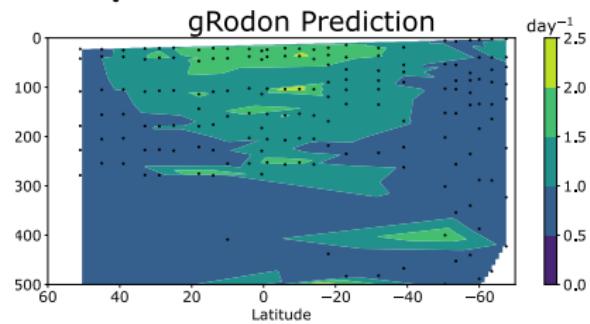
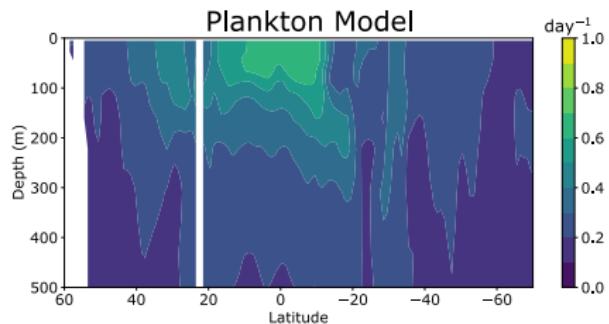
Shifts in Community-Wide Growth Potential



Moving Forward: Mapping Microbial Growth on Global and Local Scales

Comparisons with predictions from global plankton models in the works

Marine heterotrophs:



**Emily Zakem
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James Rosas, Oscar Escobedo

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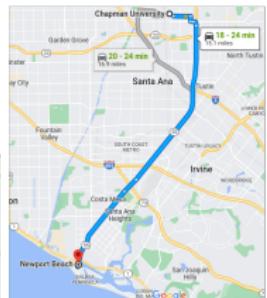
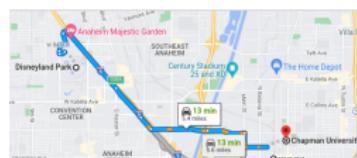
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Recruiting Postdoc(s) Summer 2023

Lots of ideas for gRodon v3 (and more). Let's build it together!

- Undergrad focused environment, lots of opportunities to mentor undergrad and masters students
- Very flexible - money not tied to a specific grant, we can tailor projects to your interests
- Mentor (me) invested in helping you achieve the goals that you set/develop the skills you want (e.g., developing skills desirable in industry, government, PUIs)



***Fully-funded masters in computational and data science also available**