Soil bacteria adapt to tolerate heavy metal stress in their local soil environment

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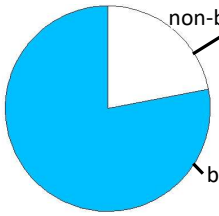
Introduction



The Pie of Life[1]: relative number of species by domain

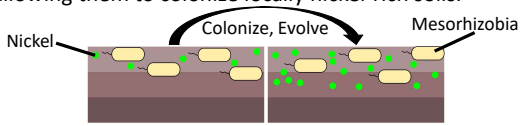
Bacteria are immensely diverse, but why is that? Our current model has two parts:

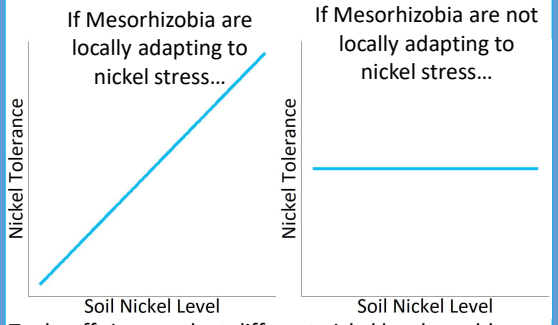
(1) Diversity is generated when bacterial populations adapt to their local environment[2].

(2) Trade-offs in survival between environments then maintain diversity[3].

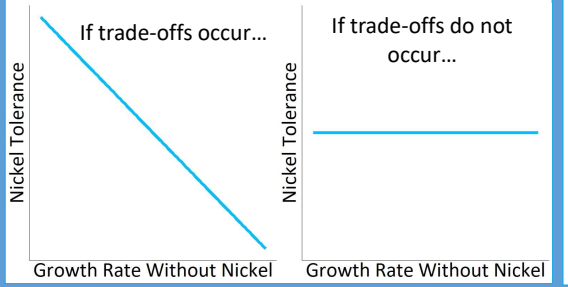
The mechanisms of local adaptation and trade-offs are often unknown in wild bacteria. We examined these mechanisms among wild Mesorhizobia bacteria.

Some Mesorhizobia have evolved tolerance to nickel, allowing them to colonize locally nickel-rich soils.





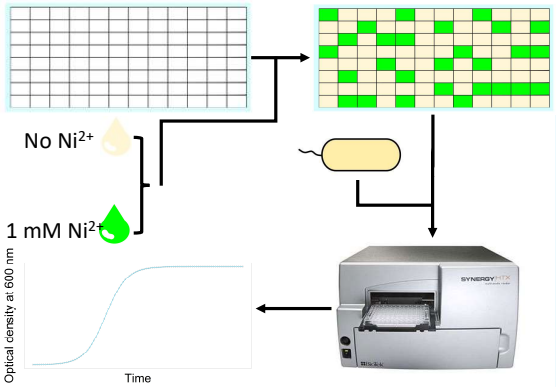
Trade-offs in growth at different nickel levels could maintain bacterial diversity in this system.



Questions

- Are bacteria from more nickel-rich soils more nickel tolerant than bacteria from nickel-poor soils?
- Does nickel tolerance trade-off with growth in nickel-free environments?

Methods



1. Grow 232 strains of bacteria from a variety of soils for 6 days in the presence and absence of nickel (n = 3 for each strain).

2. Estimate nickel tolerance as:

$$Nickel\ Tolerance = \frac{N_{nickel} - N_{no\ nickel}}{N_{no\ nickel}}$$

Where N_{nickel} and $N_{no\ nickel}$ is abundance in presence and absence of nickel, respectively, after 72 hours of growth.

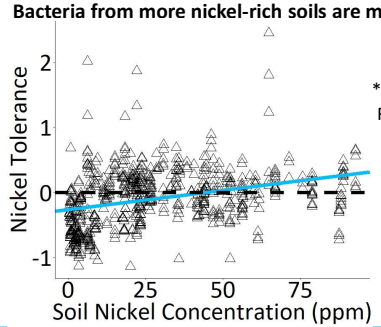
If Nickel Tolerance > 0, strain grows well in nickel.
If Nickel Tolerance < 0, strain does not grow well in nickel.

3. Estimate growth rate without nickel using an Easy Linear model[4].

4. Apply linear mixed models and test if slopes are non-zero.
Tolerance ~ SoilNickelLevel + (1|Soil) + (1|Strain), Gaussian error
Tolerance ~ GrowthRate + (1|Experiment) + (1|Strain), Gaussian error

Results

Bacteria from more nickel-rich soils are more nickel tolerant

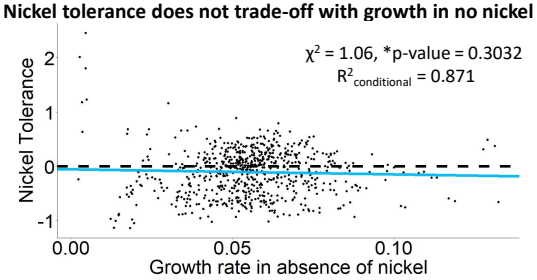


χ^2 = 18.248
*p-value = 1.939e-05
$R^2_{conditional}$ = 0.853

*p-values are from a likelihood ratio test for a non-zero slope

Results Continued

Nickel tolerance does not trade-off with growth in no nickel



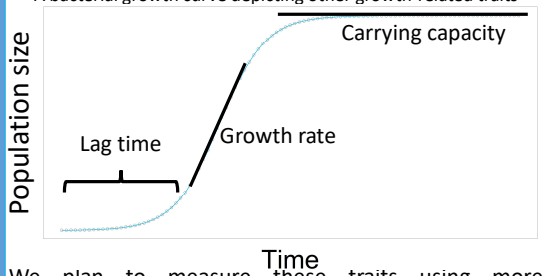
Conclusions

- Mesorhizobia adapt to the heavy metal stress of their local soil environment.
- This local adaptation does not trade-off with growth rate in nickel-free environments.
- Another mechanism or trade-offs between other traits may instead maintain diversity in this system.

Continued Research

Do trade-offs between nickel tolerance and other traits like lag time and carrying capacity maintain diversity?

A bacterial growth curve depicting other growth-related traits



We plan to measure these traits using more complicated growth models, like the Gompertz model[5].

Examining these traits will help complete the picture of how local adaptation and trade-offs create diversity.

Acknowledgments & References

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References:

1. Larsen, B.B., Miller, E.C., Rhodes, M.K. & Wiens, J.J. (2017). *Q. Rev. Biol.*, 92, 229–265.
2. Belotte, D., Curien, J.-B., Maclean, R.C. & Bell, G. (2003). *Evol. Int. J. Org. Evol.*, 57, 27–36.
3. Ferenci, T. (2016). *Trends Microbiol.*, 24, 209–223.
4. Hall, B.G., Acar, H., Nandipati, A. & Barlow, M. (2014). *Mol. Biol. Evol.*, 31, 232–238.
5. Zwietering, M.H., Jongenburger, I., Rombouts, F.M. & van 't Riet, K. (1990). *Appl. Environ. Microbiol.*, 56, 1875–1881.