Bacterial range expansion and the Fisher speed: a discrepancy in nutrient-rich media

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Introduction

- Bacteria can move into new regions by dividing (growth) and moving (motility). How this large-scale expansion relates to microscopic behavior remains poorly understood.

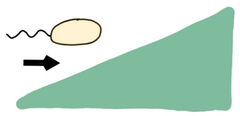

Figure 1: Bacterial chemotaxis

- Some bacteria exhibit chemotaxis and adjust their movement according to chemical gradients: towards a nutrient source, for example.

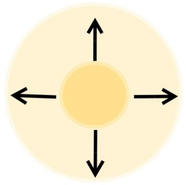

Figure 2: Large-scale range expansion of bacterial colonies

- The Fisher speed predicts range expansion rates from observed growth rate and diffusion (bacterial motility) but has not been rigorously tested in nutrient-rich media.

Research Question

Does the predicted Fisher range expansion speed match the observed range expansion speed in nutrient-rich conditions?

Results

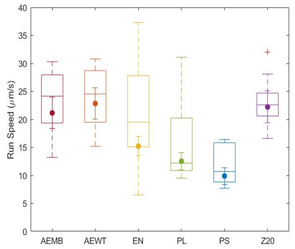

Figure 5: Average bacterial trajectory run speeds in μm/s. Solid points are weighted averages.

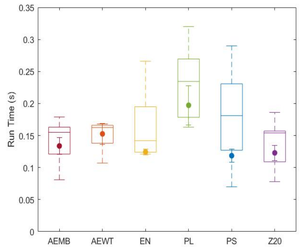

Figure 6: Average bacterial trajectory run times in s. Solid points are weighted averages.

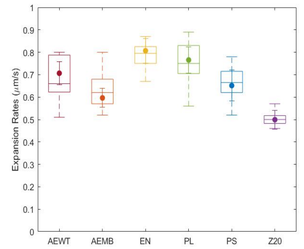

Figure 7: Average bacterial colony expansion rates in μm/s. Solid points are weighted averages.

- Data collected from observed trajectories (run speed and run time) was used to determine the theoretical Fisher speed.
- The Fisher speed was found to be much lower than the observed expansion rate, indicating some mechanism that is promoting range expansion in nutrient-rich conditions.

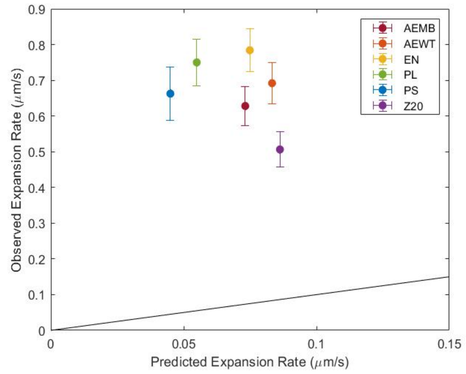

Figure 8: Comparison of observed and predicted (Fisher) expansion rates in μm/s. The black line represents the ideal correlation between observed and predicted expansion rates.

Methods

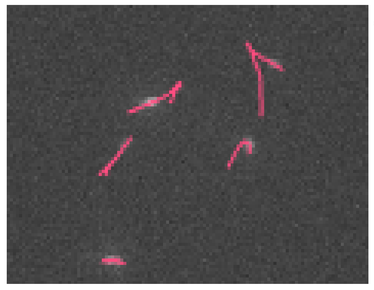

Figure 3: Aeromonas *tracks in swim plate media*

- Light sheet fluorescence microscopy was used to obtain bacterial trajectories in 0.2% agar at 30°C.

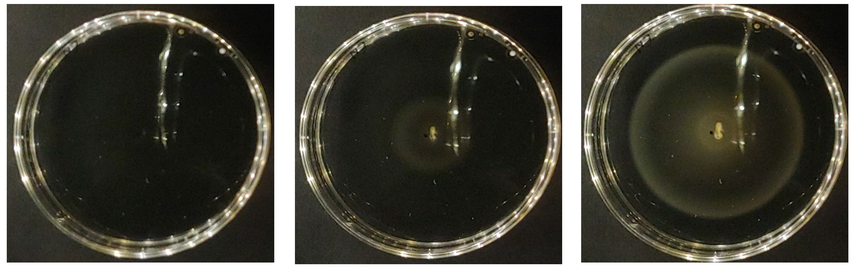

Figure 4: From left to right: Enterobacter *swim plates at 0hr, 5hr, and 7hr post-inoculation*

- 0.2% agar swim plates were inoculated with six strains of bacteria and left to grow at 30°C for 20hr intervals.

Conclusions

- The Fisher speed dramatically underpredicts bacterial range expansion in nutrient-rich media for the six strains examined.
- Similar findings (Cremer et al. 2019) for *E. coli* further support this discrepancy, attributing it to chemotactic behavior in nutrient-rich conditions.

Future Directions

- Examine how cellular motility drives colonization of the vertebrate gut.
  - Does higher motility expression indicate better colonization?
  - Can we "tune" colonization times by taking advantage of these diffusion behaviors?
- Examine how the proximity of zebrafish affects native gut microflora chemotaxis.
  - Do bacteria migrate towards zebrafish to colonize?

References

1. Lovely PS, Dahlquist FW. Statistical measures of bacterial motility and chemotaxis. Journal of Theoretical Biology, 1975.
2. Berg, Howard C. Random Walks in Biology. Princeton University Press, 1993.
3. Cremer J, et al. Chemotaxis as a navigation strategy to boost range expansion. Nature, 2019.

Acknowledgments

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