Motility Enhancement through Surface Modification is Sufficient for Emergent Behaviors during Phototaxis

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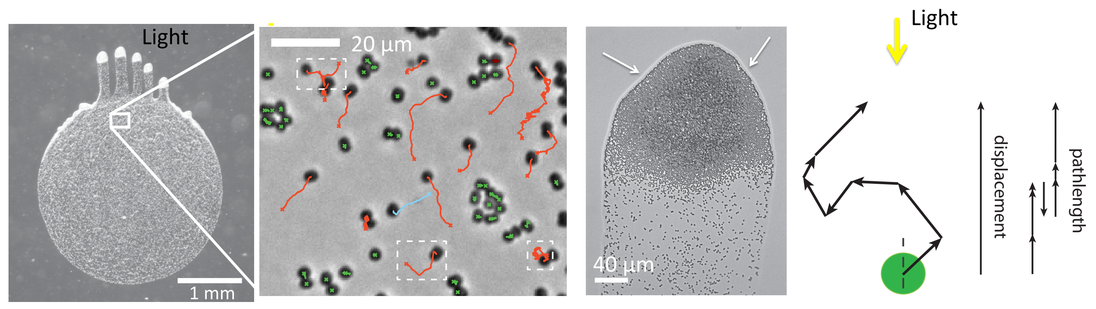
Introduction

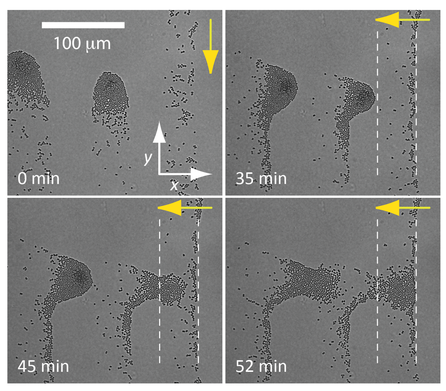
- The emergent behaviors of communities of genotypically identical cells cannot be easily predicted from behaviors of individual cells.
- In the cyanobacterium *Synechocystis*, we show that extracellular polymeric substances (EPS) play a major role in motility enhancement and community formation during phototaxis.

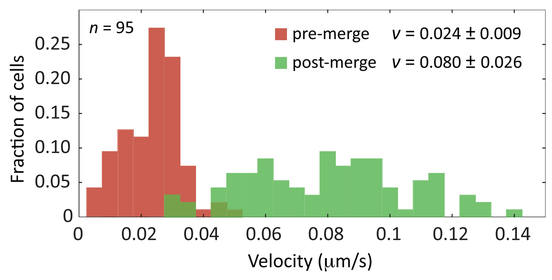


Phototaxis occurs on both single-cell and community levels. Cells exhibit biased random walk and secrete EPS. We quantify phototactic movment by measuring the cells' movement bias (= (displacement along axis) / pathlength.

EPS enhances single cell motility

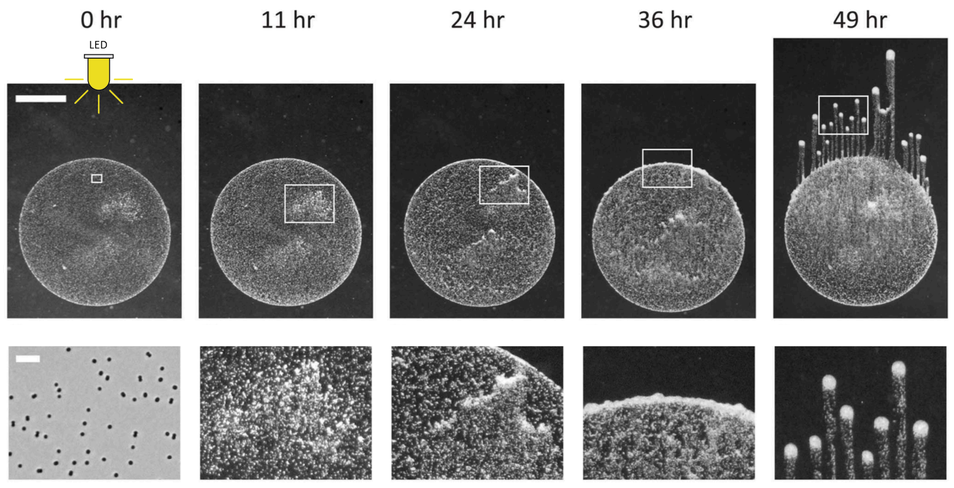
- Upon encountering a region of high EPS concentration (an adjacent finger), single cell velocities increased ~three-fold.





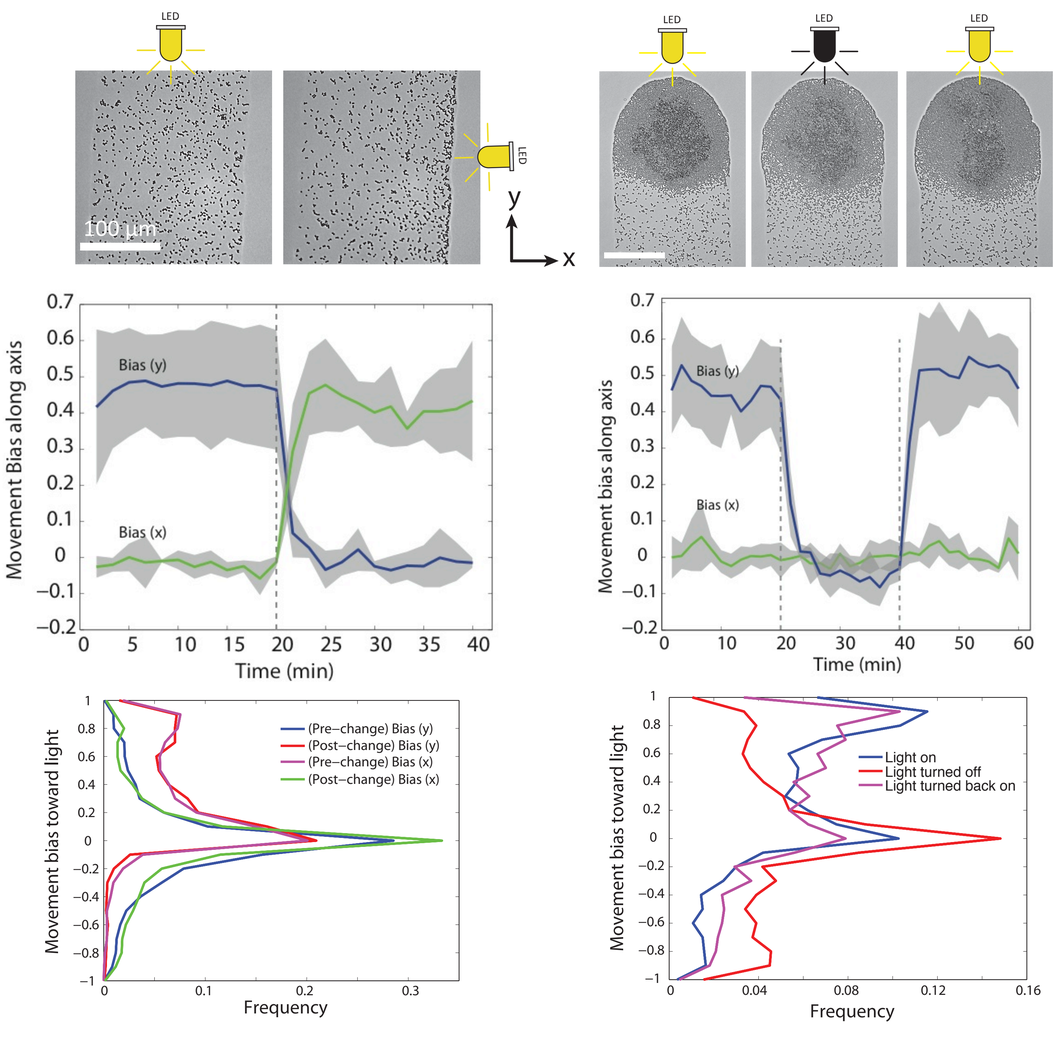
Higher cell density enhances phototaxis

- Heterogeneity in the cell distribution within an inoculation show a more pronounced phototactic response in more dense regions.



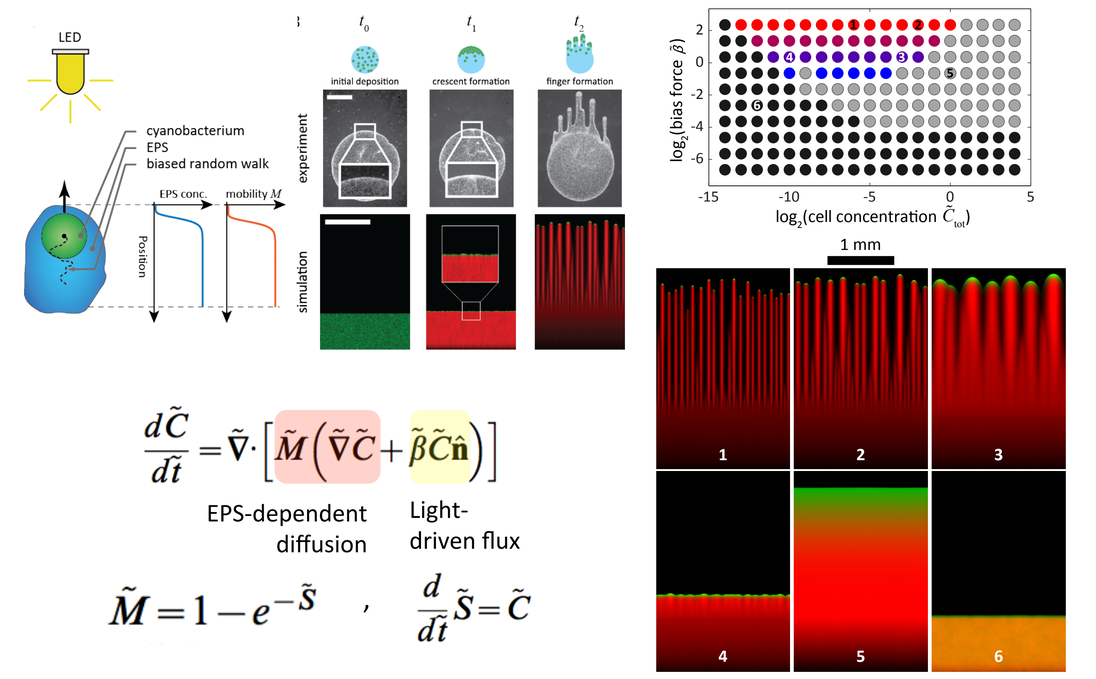
EPS does not confer information about directionality

- Upon a change in the light condition, cells rapidly change their motility behavior, with no persistence in their previous behavior.



Indirect, surface-based communication is sufficient to produce phototactic subcommunities

- We have developed a simple reaction diffusion model that assumes a biased random walk dependent solely on light direction and local EPS concentrations.
- Our model successfully reproduces the experimentally observed morphologies and timescales, while revealing simple relationships between cell concentration, light bias and community morphology.



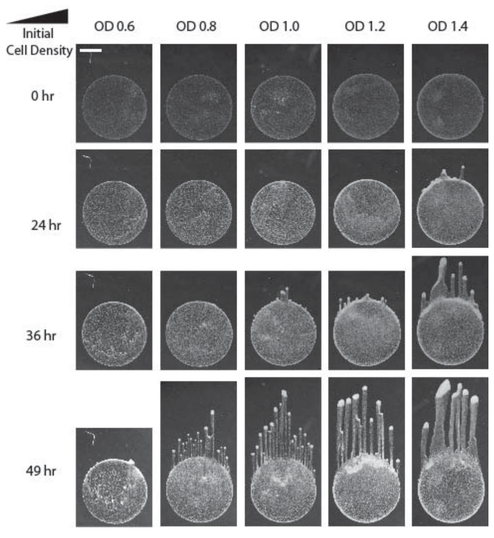
$$\frac{d\tilde{C}}{d\tilde{t}} = \tilde{\nabla}\cdot\left[\tilde{M}\left(\tilde{\nabla}\tilde{C} + \tilde{\beta}\tilde{C}\hat{\mathbf{n}}\right)\right]$$

EPS-dependent diffusion — Light-driven flux

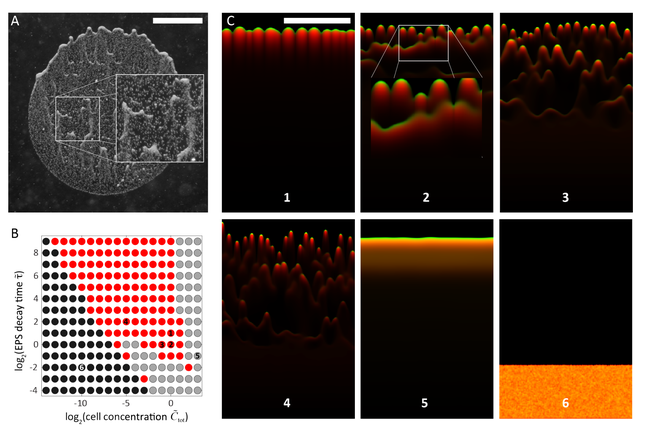
$$\tilde{M} = 1 - e^{-\tilde{S}} \quad , \quad \frac{d}{d\tilde{t}}\tilde{S} = \tilde{C}$$

Model successfully predicts effects of increased cell concentrations and EPS decay

- Experiments demonstrated the effects of cell concentration on finger development time and morphology.
- Addition of EPS decay created internal fingers inside the drop.

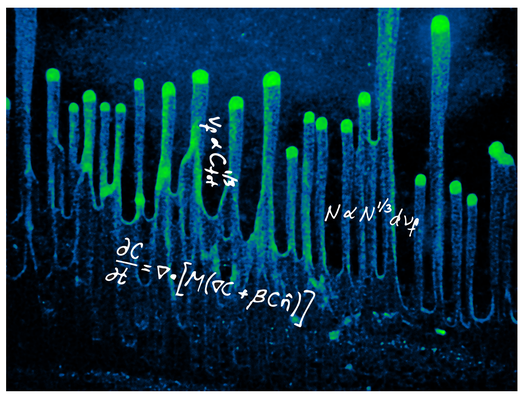


$$\frac{d}{d\tilde{t}}\tilde{S} = \tilde{C} - \frac{\tilde{S}}{\tilde{\tau}}$$



Conclusions

- The indirect, surface-based communication via EPS is sufficient, excluding direct cellular interactions or changes in single-cell behavior, for the emergence of complex community behavior.
- Such forms of surface-based communication can provide insight into the behavior of a wide array of biological communities.



Part of this work was published in PLOS Comp. Biol., Sept. 2013.
This work is funded by NSF/NIGMS #0758374, The Carnegie Institution of Science, the National Academies Keck Future Initiatives seed grant program, and the Stanford University Bio-X Interdisciplinary Initiatives Program.