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Feedback Between Mechanical Stress and Physiology in Bacterial Cell Shape Determination

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Abstract:

Bacterial cells come in a wide variety of shapes and sizes, with the peptidoglycan cell wall as the primary stress-bearing structure that dictates cell shape. In recent years, cell shape has been shown to play a critical role in regulating many important biological functions including attachment, dispersal, motility, polar differentiation, predation, and cellular differentiation. Though many molecular details of the composition and assembly of the cell wall components are known, how the peptidoglycan network organizes to give the cell shape during normal growth, and how it reorganizes in response to damage or environmental forces have been relatively unexplored. We introduce a quantitative mechanical model of the bacterial cell wall that predicts the response of cell shape to peptidoglycan damage in the rod-shaped Gram-negative bacterium Escherichia coli. To test these predictions, we use time-lapse imaging experiments to show that damage often manifests as a bulge on the sidewall, coupled to large-scale bending of the cylindrical cell wall around the bulge. The direction of bending confirms the hypothesis of a longitudinal orientation of peptides and a circumferential orientation of glycan strands in the peptidogylcan layer. Our simulations based on our physical model also suggest a surprising robustness of cell shape to damage, allowing cells to grow and maintain their shape even under conditions that limit crosslinking. Finally, we show that many common bacterial cell shapes can be realized within the model via simple spatial patterning of peptidoglycan defects, suggesting that subtle patterning changes could underlie the great diversity of shapes observed in the bacterial kingdom.

About the Speaker:

KC Huang was an undergraduate Physics and Mathematics major at Caltech, and spent a year as a Churchill Scholar at Cambridge University working with Dr. Guna Rajagopal on Quantum Monte Carlo simulations of water cluster formation. He received his PhD from MIT working with Prof. John Joannopoulos on electromagnetic flux localization in polaritonic photonic crystals and the control of melting at semiconductor surfaces using nanoscale coatings. During a short summer internship at NEC Research Labs, he acquired an interest in self-organization in biological systems, and moved on to a postdoc with Prof. Ned Wingreen in the Department of Molecular Biology at Princeton working on the relationships among cell shape detection, determination, and maintenance in bacteria. His current interests include cell division, membrane organization, cell wall synthesis, and membrane-mediated protein interactions.