Evolutionary Perspectives on the Determination of Bacterial Cell Shape

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Short 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. We have introduced a quantitative mechanical model of the cell wall that predicts the response of cell shape to peptidoglycan damage in the rod-shaped Gram-negative bacterium *Escherichia coli*. Our work has shown that many common bacterial cell shapes can be realized within both our model and in experiments via simple spatial patterning of the cytoplasm and cell wall, suggesting that subtle patterning changes could underlie the great diversity of shapes observed in the bacterial kingdom.

***Keywords* — Bacterial morphology, intracellular organization, cytoskeleton, cell shape**

I. Purpose

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. How much control does a cell have over its shape, and can we tap into control mechanisms to synthetically engineer new morphologies? 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 have introduced 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. 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. Our current research focuses on identifying the molecular factors responsible for cell shape determination and characterizing their phylogenetic diversity. Our work has shown that many common bacterial cell shapes can be realized within both our model and in experiments via simple spatial patterning of the cytoplasm and cell wall, suggesting that subtle patterning changes could underlie the great diversity of shapes observed in the bacterial kingdom.

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