Under pressure: mechanosensitive regulation of the bacterial divisome

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***Short Abstract* — Bacterial cell division starts with the formation of the future septum by the polymerized FtsZ protein in the mid-cell plane (the so-called Z-ring). There is evidence, though, that *Escherichia coli* division process can be perturbed by mechanical pressure. Using time-lapse fluorescence microscopy and microfluidics, we show that when compressing growing *E. coli* cells up to a ~ 50% cell thickness reduction, cells develop into amorphous pancake-like shapes, and the FtsZ cutting scaffold is assembled into a point-like complex whose progression is not often confined to a plane. These results show a gap of knowledge in the interplay between cell geometry detection and FtsZ dynamics under mechanical perturbations.**

***Keywords* — Bacterial divisome, bacterial cell division, cytokinesis, Z-ring, cell size homeostasis.**

I. INTRODUCTION

CELL division is a critical process for cell viability that requires the assembly of the division machinery, the divisome, as well as a precise spacio-temporal coordination. In *Escherichia coli* the assembly of the divisome starts with the formation of the prospective septum by the polymerized FtsZ protein in the mid-cell position (the Z-ring). The mid-cell position detection is driven by the oscillating Min system (that captures cell's geometry [1]) and its interplay with FtsZ [2,3]. A recent study revealed that *E. coli* cells under low compression forces (15% cell thickness reduction) displayed a discontinuous Z-ring formation [4]. In a different study, *E. coli* cells were trapped in a chamber with 0.25μm-height elastic ceiling and the authors reported the incapacity of the Min system to track down the aberrant morphology. However, division accuracy (defined as equipartition of the mother's cell volume among its two daughter cells) was comparable to that of uncompressed wild-type cells [5].

Using time-lapse fluorescence microscopy and microfluidics, we show that when compressing growing *E. coli* cells up to a ~ 50% cell thickness reduction, FtsZ becomes a cutting-point scaffold that slashes the membrane as it moves, often following a path not even confined to a plane. These results are against the idea of an active constrictive role of the Z ring during cell division and support the hypothesis that the Z-ring acts during cytokinesis as a recruiting structure for the membrane and cell wall remodeling machinery.

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II. SUMMARY OF RESULTS

In order to elucidate the dynamics of the divisome cutting-edge complex under mechanical compression in single cells, we quantified different observables. First, we characterized the maintenance of cell size homeostasis by checking the validity of the incremental rule (that states that cells add a constant volume before dividing, with independence of cell size at birth). Strikingly, our data indicates that the incremental rule still holds, despite the apparent random trajectory of the divisome cutting-point.

Then, we compared global effects (cell geometry) versus local effects (effective membrane tension) in a quantitative manner. To that end, we used a custom program that estimates the symmetry axes of cells and the cell perimeter curvature. Specifically, we relate the localization of the divisome cutting scaffold with respect to the symmetry axes, to the most probable curvature in which the divisome scaffold first appears. Our analysis shows that whereas the distribution of the divisome distance to the shortest symmetry axis has a lot of variability, the divisome seems to assemble preferentially in regions of zero curvature, instead of regions with positive curvature (where the effective membrane tension is smaller).

III. CONCLUSION

Our results a) indicate that the localization of a Z-dot is controlled, preferentially, by local geometrical effects (curvature) rather than global geometrical traits, b) support the hypothesis that the Z-ring acts as a recruiter of the membrane-wall synthesis machinery, and c) indicate a robust control of cell-size homeostasis in bacterial cells.

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