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Immersed boundary approach to biofilm spread on surfaces

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We propose a computational model to study the growth and spread of bacterial biofilms on surfaces [1, 3]. Bacterial membranes are represented by boundaries immersed in a fluid matrix and subject to interaction forces. Growth, division and death of bacterial cells follow dynamic energy budget rules, in response to variations in environmental concentrations of nutrients, substances released by the cells and toxicants. In this way, we create, enlarge and destroy boundaries, either spherical or rod-shaped [7]. Appropriate forces represent details of the interaction between cells, and the interaction with the environment. Numerical simulations illustrate the evolution of small biofilm seeds. We are able reproduce experimentally observed features such as a tendency of rod-shaped bacteria to align [2] and the formation of inner gaps (due the cell death and reabsorption) which fill with fluid [5, 6]. We calibrated the death parameters to reach a certain aggregate size in the absence of antibiotics [4], as a result of a balance between dead and newborn cells (as it happens in many tissues). When we add antibiotics small necrotic regions appear at the edges. Resorting to antibiotic cocktails targeting both active cells in the outer regions and dormant cells in the inner core we succeeded in eradicating the biofilm as observed in experiments.

References

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