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FREE BOUNDARY INSTABILITIES IN GROWING BACTERIAL COLONIES

Chiara Giverso [*1,2], Marco Verani[1], Pasquale Ciarletta[2,3]

[1]Politecnico di Milano - MOX, P.za Leonardo da Vinci, 32, 20133 Milano, Italy - chiara.giverso@polimi.it

[2] European Centre for Nanomedicine - CEN , Piazza Leonardo da Vinci, 32, 20133 Milan, Italy

[3] CNRS and Institut Jean le Rond d'Alembert, UMR 7190, Université Paris 6, 4 place Jussieu, case 162, 75005 Paris, France

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Recent experiments [1, 2, 3] have reported that an initially homogeneous bacterial monolayer might expand in a non-uniform manner, developing finger-like shapes and highly irregular contours. In this work we study the emergence of such front instabilities from a theoretical viewpoint, focusing on a bacterial colony plated on a Petri dish cover with agar and a thin layer of an inviscid fluid, in which bacteria can move.

The growth of the biological material along with the diffusion and consumption of nutrients provided by the agar are modeled at the continuum scale, by extending the morphogenetic theory presented in [4]. The mathematical model encapsulates: i) the diffusion equation for nutrients/morphogens, ii) the mass balance and iii) the force balances for the bacterial colony, coupled with proper boundary conditions at the free moving interface. In describing the process of mass accretion of the colony, we consider either a source term, being produced at each point by the set of living organisms, or a mass flux across the free boundary of the living material. Both the volumetric mass supply term and the surface mass flux are coupled with the local concentration of the diffusing nutrient.

The contour stability of the growing material is studied analytically for an initially circular colony, defining the dispersion relation in the linear stability analysis. In order to study the nonlinear effects driving the interfacial pattern, we finally perform finite element simulations of the growth process. The analytical and numerical analysis demonstrate that the free boundary is always unstable, pointing out that even if both the surface tension and the boundary velocity are stabilizing effects, undulated structures develop at the free boundary with typical length that depends on few characteristic parameters of the problem.

REFERENCES

[1] E. Ben-Jacob, I. Cohen, D. L. Gutnick. *Cooperative organization of bacterial colonies: from genotype to morphotype.* Annu. Rev. Microbiol. 52: 779–806, 1998.

[2] E. Ben-Jacob and H. Levine. *Self-engineering capabilities of bacteria.* J. R. Soc. Interface 3, 197–214, 2006.

[3] H. Fujikawa and M. Matsushita *Fractal Growth of Bacillus subtilis on Agar Plates.* J. Phys. Soc. Jap., 58 (11): 3875–3878, 1989.

[4] P. Ciarletta. *Free boundary morphogenesis in living matter.* Eur. Biophys. J., 41: 681–686, 2012.