Physics of Fluids

Division by fluid incision: Biofilm patch development in porous media

William M. Durham, Olivier Tranzer, Alberto Leombruni, and Roman Stocker

Citation: Phys. Fluids **24**, 091107 (2012); doi: 10.1063/1.4747154
View online: http://dx.doi.org/10.1063/1.4747154
View Table of Contents: http://pof.aip.org/resource/1/PHFLE6/v24/i9
Published by the American Institute of Physics.

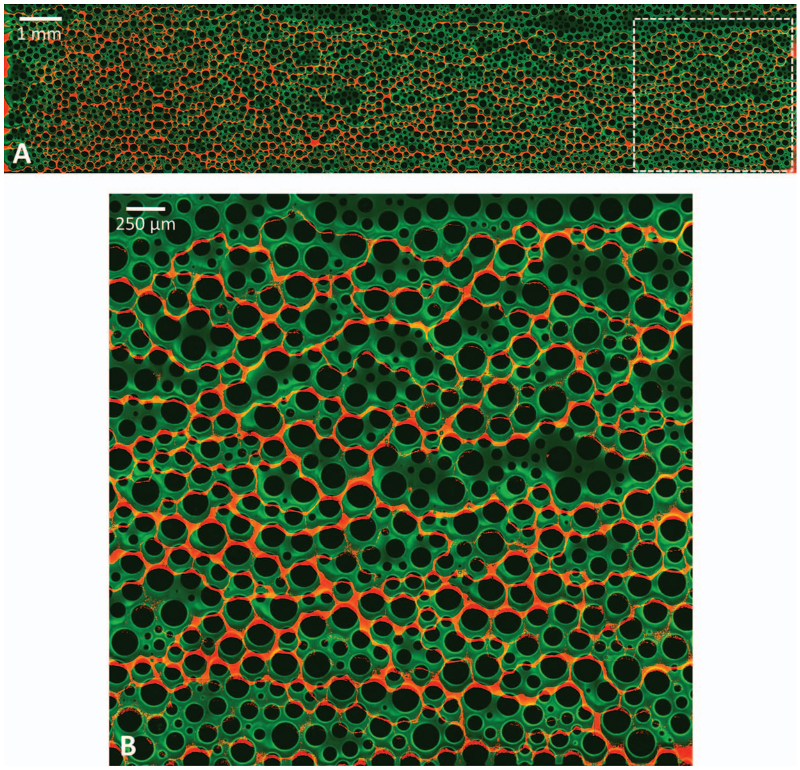

FIG. 1. The interaction of biology and physics generates emergent patterns of preferential flow in porous media. (A) A microfluidic device modeling a porous soil environment was seeded with *Escherichia coli* bacteria. Subsequent injection of a nutrient-containing media stimulates the growth of biofilm patches (bacterial auto-fluorescence shown in green) divided by channels of fluid flow (shown in red, shifted slightly to the right to reveal the underlying biofilm structure). (B) An enlargement of the region within the dotted square in panel A shows that auto-fluorescence is enhanced along the edges of biofilm patches.

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William M. Durham,[1,2,a)] Olivier Tranzer,[1,3] Alberto Leombruni,[1,4,5] and Roman Stocker[1,a)]
[1]*Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA*
[2]*Department of Zoology, University of Oxford, Oxford, OX1 3PS, UK*
[3]*École Polytechnique, 91128 Palaiseau, France*
[4]*DIIAR - SEZIONE C.I.M.I., Politecnico di Milano, 20133 Milano, Italy*
[5]*Regenesis Ltd, Bath BA1 5BB, UK*

(Received 3 August 2012; published online 17 September 2012)
[http://dx.doi.org/10.1063/1.4747154]

Biofilms form when bacteria attach to a surface and secrete a sticky polymeric matrix that cements neighboring cells together. These bacterial assemblages are found in diverse environments

a)Authors to whom correspondence should be addressed. Electronic addresses: william.durham@zoo.ox.ac.uk and romans@mit.edu

and have enormous importance in nature, industry, and medicine. While nearly all of our knowledge about these communities has been gleaned from biofilms developing on flat surfaces, biofilms often grow in porous, topologically complex environment where the potential exists for large nutrient-poor regions not irrigated by flow.

To obtain a mechanistic understanding of the processes that structure biofilm development within porous environments, we developed a microfluidic system that models the interstitial spaces within soil. Individual soil particles are simulated using a two-dimensional array of silicone cylinders. The transparent setup permits biofilm growth patterns and flow within pores to be imaged by epifluorescent and phase contrast video-microscopy, respectively. We find that in some flow regimes the transport of nutrients through the matrix of cells and posts triggers the formation of striking preferential flow channels, which convey fluid around biofilm patches (Fig. 1(A)). The edges of biofilm patches in contact with flow channels emit a stronger fluorescent signal than interior regions, suggesting that proximity to flow results in increased respiration rates (Fig. 1(B)). These results suggest that the interaction between flow and growth shape the dynamics of biofilm development within porous systems and may have important consequences on processes as diverse as biochemical cycling, antibiotic resistance, and water filtration.

We acknowledge the support of the Human Frontier Science Program (to W.M.D.), the National Science Foundation (Grant Nos. OCE-0744641-CAREER and CBET-1066566 (to R.S.)), and the Progetto Rocca at MIT.