Biofilm biomechanics : the physics of bacterial cooperation.

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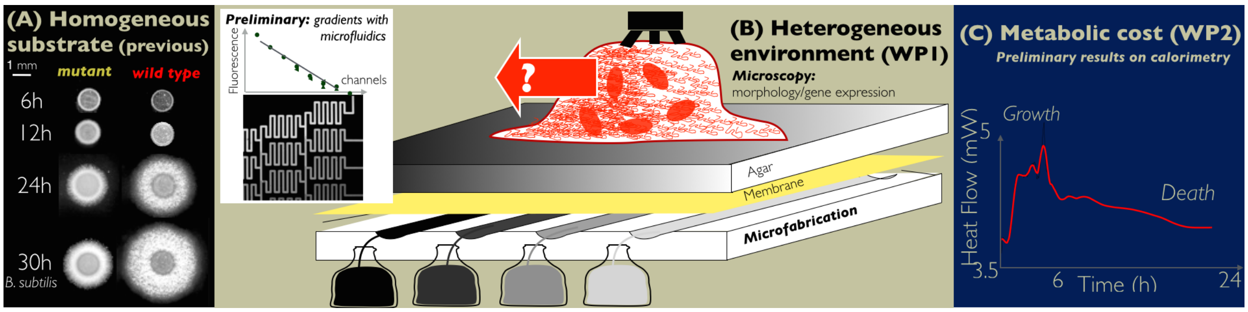

The evolution of living organisms is shaped by the physical environment where they live. Bacteria live in a world where viscous drag imposes severe constraints on motility. However, cooperation among bacteria allows to overcome these severe constraints. Cooperation starts as soon as free-living cells land on a surface that provides a little moisture and nutrients. Attached to this surface, they settle down and proliferate, giving rise to sedentary communities called biofilms. Living inside the biofilm, cells organize in a well-defined division of labor and display a remarkable resilience to antimicrobial agents. Biofilms cause millions of healthcare-associated infections every year and are thus attracting increasing attention in the scientific community. Many cells in the biofilm produce a combination of sugars and proteins that holds the community together as a protective glue. We recently showed that due to this polymeric substance, the biofilm behaves as a hydrogel, able to shrink and swell depending on the environment. The polymeric matrix thus help spreading of the colony (left panel of figure).

In this project we propose to use this analogy to explore the biomechanics of Bacillus subtilis biofilms and elucidate whether and how the physical behavior of a biofilm is under biological control.
1) we will build an experimental setup to expose biofilms to different external conditions (osmotic pressure, concentration of chemicals..). See panel B of the figure.
2) we will use time-lapse optical microscopy to monitor the three dimensional morphology of the biofilm growing in different conditions
3) we will use fluorescence reporters to probe whether biofilms respond genetically to changing physical environment.
4) we will monitor the costs of making the polymers, using calorimetry. See panel C figure.

We will perform theoretical and numerical work, based on the model we proposed in ref (1), to elucidate what are the relevant physical forces involved in biofilm growth and probe whether they are under biological control. Gene expression patterns will be analyzed in collaboration with M. Brenner (SEAS, Harvard). This framework will provide a quantitative concept of adaptation and optimality for biofilm growth and thus help the understanding and interpretation of the experimental data.

Refs:
(1) "Osmotic spreading of Bacillus Subtilis biofilms driven by an extracellular matrix"
A Seminara, TE Angelini, JN Wilking, H Vlamakis, S Ebrahim, DA Weitz and MP Brenner *PNAS*, **109**, 1116-1121 (2012).
(2) "Biofilms as complex fluids"
JN Wilking, TE Angelini, A Seminara, MP Brenner and DA Weitz, *MRS Bull*, **36**, 1 (2011).
(3) "Bacterial biofilm shows persistent resistance to liquid wetting and gas penetration"
A Epstein, B Pokroy, A Seminara, J Aizenberg, *PNAS*, **108**, 995 (2011).