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The Good, the Bad, and the Ugly: How mathematics helped to explore the fantastical world of biofilms

Bacterial biofilms are microbial depositions on submerged interfaces. Bacteria attach to the surface and start producing a slimy substance that protects them. While many environmental engineering techniques are based on the good aspects of biofilms, they are harmful in medical and industrial contexts. The term “biofilm”, however, is a misnomer: Rather than as a homogeneous film, they often develop in complex spatially heterogeneous structures and morphologies. For a decade now, modeling how these structures arise has increasingly drawn mathematical attention (not to mention the numerous cellular automata models or individual based models that have been developed for an only slightly longer period by engineers and biologists). Bacterial biofilms can be understood both as spatially structured populations and as complex fluids. Taking, independently, either view as a starting point we can derive a biofilm model in the form of a quasilinear parabolic equation that simultaneously comprises two non-linear diffusion effects: a porous medium equation degeneracy as the dependent variable vanishes and a super-diffusion singularity as it approaches an a priori known upper bound. In this talk we will focus on the mathematical results for this type of equation and show some numerical simulations. Time permitting (i.e. likely not) we will also discuss an extension of the model to include quorum sensing as a means of bacterial communication.