Session: Tools & modelling

Mathematical modelling of biofilms: what have we learnt?

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Mathematical modelling of biofilms goes back almost 50 years now so one might wonder what have we learnt from modelling that we wouldn't have learnt without? Or worse, were we mislead by models? To better understand the question it is worth remembering that the purpose of models is to simplify reality and tell us what biofilms would be like if a certain set of assumptions (inevitably simplistic given the complexity of biofilms) were true. Thus we can learn the effects of various mechanistic assumptions, physiochemical and biological processes on biofilm dynamics and structures.

Since a comprehensive answer is impossible in half an hour, I'll instead sketch some examples of key insights: **(1)** Recognizing the inevitability and importance of substrate concentrations gradients forming in biofilms, which in turn cause gradients in specific growth rate and other aspects of cellular physiology. **(2)** Recognizing how mass transfer limitations drive biofilm structure culminating in the elucidation of the 'fingering instability'.

These two entirely physicochemical explanations, not requiring any specific biological mechanisms, were hard for biologists to accept, but there was more to come: **(3)** Recognizing the importance of mechanics – inevitable mechanical interactions of neighbouring cells with each other or mediated by the extracellular matrix – on aligning and spreading of cells and the ensuing development of biofilm structure. In fact, the early phase of biofilm structure development can be explained solely by mechanics, a subject that probably most of us found boring at school. **(3a)** A related realization was that growth coupled with mechanical interactions would affect the (lack of) mixing between species in biofilms, causing a lack of diversity on a small scale.

(4) Recognizing that growth yield is more important for fitness in biofilms than specific growth rate. As this little point is probably my most important contribution to science to date, I will explain the reasons for this and show some evidence from natural systems that confirm the modelling results.

(5) Recognizing how metabolic interactions affect the development of spatial structure and how the spatial structure in turn affects metabolic interactions, leading to the self-organization of particular spatial structures from particular interactions.

Remember this is not an exhaustive list. If hope to have enough time to finish with some thoughts on mathematical models versus laboratory models versus 'natural' systems.