Nature Reviews Microbiology | Published online 24 Apr 2017; doi:10.1038/nrmicro.2017.46

BIOFILMS

Communities in sync

> two distant biofilms could exhibit synchronized oscillations in growth rate and electrical signalling

Bacteria in a biofilm can communicate to direct system-level behaviours, such as coordinated growth dynamics. However, it is unclear whether communication within a bacterial community can extend to modulate the behaviour of distant populations. Writing in *Science*, Liu *et al*. now show that distant biofilms can coordinate their behaviour and switch from in-phase to anti-phase growth oscillations, depending on nutrient availability.

Growth oscillations in a biofilm are driven by a negative feedback loop; biofilm growth starves interior cells, which, in response, send electrical signals to slow growth and thereby increase their access to nutrients. These oscillations are driven by long-range electrical signalling, which the authors hypothesized could affect the growth of distant biofilms. To investigate this, two distant *Bacillus subtilis* biofilm communities were grown in a microfluidic chamber that had a steady flow of glycerol (a carbon source) and glutamate (a nitrogen source). The expansion rate of the biofilms was measured using time-lapse phase-contrast microscopy and the dynamics of electrical signalling were recorded using the fluorescent cationic dye thioflavin T. Remarkably, two distant biofilms could exhibit synchronized oscillations in growth rate and electrical signalling, which suggests that distant communities of bacteria can interact and synchronize their behaviour.

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Next, the authors derived a mathematical model that predicted that the synchronized behaviour between the two biofilms was a function of nutrient (glutamate) concentration and the ability of bacteria to communicate. This model predicted that higher glutamate concentrations would facilitate in-phase (synchronized) oscillations and that lower concentrations would promote anti-phase oscillations. In addition, the model predicted that lower communication levels between bacteria or higher competition for nutrients would require an increased concentration of glutamate (more than regular levels) before in-phase oscillations could be achieved.

To test the model, two oscillating biofilms were grown in the presence of a normal or reduced concentration of glutamate. Notably, synchronization was observed at regular glutamate concentrations and anti-phase oscillations were observed at lower concentrations. Furthermore, the Δ*trkA* mutant (which is reduced in its ability to communicate using electrical signalling), required a two-fold increase in glutamate to achieve in-phase oscillations between distant biofilms. Moreover, the Δ*gltA* mutant (which cannot synthesize glutamate) also required an increase in the availability of glutamate for synchronized behaviour between biofilms. These observations thus validate the predictive power of the model.

The authors suggest that time-sharing (that is, competing users vary their dynamics to take turns consuming resources) could explain why two biofilm populations may use anti-phase oscillations when exposed to a reduced supply of nutrients. Time-sharing could enable increased growth under nutrient-limiting conditions. In support of this, two biofilms grown at lower glutamate conditions had a faster growth rate than two biofilms grown under normal conditions.

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ORIGINAL ARTICLE Liu, J. *et al.* Coupling between distant biofilms and emergence of nutrient time-sharing. *Science* http://dx.doi.org/10.1126/science.aah4204 (2017)