Bioengineers fill holes in science of cellular self-organization

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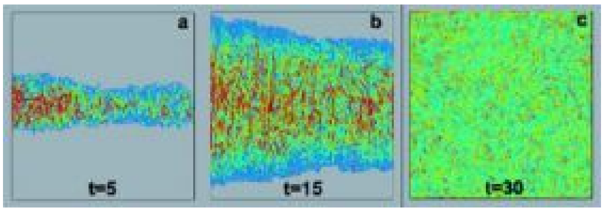

Results of MD simulations for the colony growth in a closed container. The growth is limited by four rigid walls. The size of the square domain is Lx=Lz=136.6d where d is the cell diameter. a-c: Initially the colony is prepared by placing randomly oriented cells of different length in the middle section. The panels show snapshots of the population taken at t=5.0, 15.0, 30.0. The cells are colorized according to the value of the contact stress.Credit: UCSD

The chemical and biological aspects of cellular self-organization are well-studied; less well understood is how cell populations order themselves biomechanically – how their behavior and communication are affected by high density and physical proximity. Bioengineers and physicists at the University of California San Diego, in a paper published in the current issue of the *Proceedings of the National Academy of Sciences,* have begun to address these fundamental questions.

The UC San Diego scientists focused their research on dense colonies of the rod-shaped bacteria Escherichia coli. By analyzing the spatial organization of the bacteria in a microfluidic chemostat – a kind of mini-circuit board for liquids rather than electrons – they found that growth and expansion of a dense colony of cells leads to a dynamic change from relative disorder to a remarkable re-orientation and alignment of the rod-like cells.

That finding, described in their paper "Biomechanical Ordering of Dense Cell Populations," allowed them to develop a model of collective cell dynamics, and to use this model to "elucidate the mechanism of cell ordering, and quantify the relationship between the dynamics of cell proliferation and the spatial structure of the population."

One of the authors, Lev S. Tsimring, at UC San Diego's Institute of Nonlinear Science, explained the bioengineers' use of bacteria to study the biomechanical ordering of cells.

"When environmental conditions are harsh, bacteria like to stick together. The most typical form of bacterial organization in nature is a biofilm: a dense quasi-two-dimensional colony of bacteria. Biofilms grow in and on living tissues, the surfaces of rocks and soils, and in aquatic environments," he said, "but they're also found in man-made systems and devices such as industrial piping and artificial implants. And bacteria are known to actively migrate toward surfaces and small cavities, where they form high-density colonies."

At low densities, he said, bacteria and other cells communicate "remotely" by sending chemical signals – "chemotaxis" – but, as they aggregate and form dense communities, direct biomechanical contacts play a bigger and bigger role in how they organize themselves.

"Although previous studies have explored the complex signaling mechanisms in the early stages of biofilm formation," Tsimring said, "the biomechanics of direct cellular contacts have received little attention. We focused, therefore, on the structure and dynamics of a growing two-dimensional colony of non-motile bacteria."

His fellow researcher, Jeff Hasty, at the Institute for Nonlinear Science and UC San Diego's Department of Bioengineering, said the team's work provides a multiscale description of cell colony growth.

"Our results reveal how cell growth and colony expansion trigger the formation of the orientational order in the population," Hasty said, "which, in turn, affects the mechanical and biochemical properties of the colony."

The details of their research, the authors say, helps scientists understand how the local interaction of elementary components leads to collective behavior and the formation of a highly organized system.

Source: University of California - San Diego

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