Beware of microbial traffic jams

May 13 2016, by Robert Sanders

Over a 12-hour period, multiplying yeast widen a crack in a gel by nearly a millimeter, showing they have the ability to alter their environment as they spread.

When tiny microbes jam up like fans exiting a baseball stadium, they can do some real damage.

University of California, Berkeley, physicists found this out the hard way when the baker's yeast cells (*Saccharomyces cerevisiae*) they were studying multiplied so prolifically that they burst the tiny chamber in which they were being raised.

When UC Berkeley postdoctoral fellow Morgan Delarue measured the force the growing mass of cells exerted as they pushed against one another, he calculated that it can be nearly five times higher than the pressure in a car tire—about 150 psi, or 10 times atmospheric pressure.

This is more than just a weird observation, said Oskar Hallatschek, a UC Berkeley assistant professor of physics and leader of the team. Budding yeast or other living cells, which split in two and grow exponentially in number, may well generate such mechanical forces to alter their environment, possibly in damaging ways. This may be even more important for cells like yeast that cannot move.

"Our results suggest that self-driven jamming and the build up of large pressures is a natural tendency of proliferating cells, and may be contributing to microbial pathogenesis and biofouling," he said. Biofouling is when bacteria or other organisms grow so prolifically as to interfere with the operation of machinery, such as happens in water pumps.

In fact, when graduate student Jörn Hartung grew yeast in a gel, he found that they split the gel, a possible example of how they could create cracks in rocks or soil particles.

"The mechanism that allows these populations of cells to generate such forces could be relevant to remodeling the microenvironment," Hallatschek said. "If you are constrained, maybe it's good to be able to break the material and change the pore's sizes in the environment."

Hallatschek, Delarue, Hartung and their colleagues at UC Berkeley and the Max Planck Institute for Dynamics and Self-Organization in Göttingen, Germany, reported their findings this week in the journal *Nature Physics*.

In a commentary in the same issue of the journal, physicists Shreyas Gokhale and Jeff Gore of the Massachusetts Institute of Technology wrote that the work may "prove to be the starting point for a new class of experiments at the interface of physics and biology."

Microbial avalanches

Hallatschek was exploring the consequences of space limitations on the biophysics of microbes, and developed a microfluidic bioreactor 30 microns across—about one ten thousandth of an inch—in which he could grow yeast cells and control the degree of confinement.

His experiments showed that when microbes grow in narrow channels, they tend to get stuck and unstuck like sand grains flowing down a hopper or candy from a gumball machine. The result is an intermittent flow characterized by stoppages and avalanches.

"People have looked at sand flowing down a hopper and observe a very jerky flow like we've observed here," he said. "This is due to the formation of force chains that form a bridge that holds back the sand flow for a while. When one of the bridges breaks, the sand flows again. So you get a series of stop-and-go avalanches."

As a consequence of this self-inflicted jamming, microbes can generate mechanical contact pressures of up to 1 megapascal: large enough to strain or even crack the confining cavity.

Hallatschek's team is currently simulating the yeast cell growth computationally, using flowing and "proliferating" sand as his model.

More information: Morgan Delarue et al, Self-driven jamming in growing microbial populations, *Nature Physics* (2016). DOI: 10.1038/nphys3741

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Provided by University of California - Berkeley

Citation: Beware of microbial traffic jams (2016, May 13) retrieved 27 April 2024 from https://phys.org/news/2016-05-beware-microbial-traffic.html

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