

Bacterial Individualism: A Survival Strategy for Hard Times

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Topics: Pollutants

No two bacteria are identical – even when they are genetically the same. A new study reveals the conditions under which bacteria become individualists and how they help their colony grow when times get tough.

Whether you are a human or a bacterium, your environment determines how you can develop. In particular, there are two fundamental problems. First: what resources can you draw on to survive and grow? And second: how do you respond if your environment suddenly changes?

A group of researchers from Eawag, ETH Zurich, EPFL Lausanne, and the Max Planck Institute for Marine Microbiology in Bremen recently discovered that the number of individualists in a bacterial colony goes up when its food source is restricted. Their finding goes against the prevailing wisdom that bacterial populations merely respond, in hindsight, to the environmental conditions they experience. Individualists, the study finds, are able to prepare themselves for such changes well in advance.

Scarcity fosters diversity, diversity promotes flexibility

In a recent paper in the journal *Nature Microbiology*, researchers working with Frank Schreiber have shown that individual cells in bacterial colonies can differ widely in how they respond to a lack of nutrients. Although all of the cells in a group are genetically identical, the way they process nutrients from their surroundings can vary from one cell to another. For example, bacteria called *Klebsiella oxytoca* preferentially take up nitrogen from ammonium (NH_4^+), as this requires relatively little energy. When there isn't enough ammonium for the entire group, some of the bacteria start to take up nitrogen by fixing it from elementary nitrogen (N_2), even though this requires more energy. If the ammonium

suddenly runs out altogether, these cells at least are prepared. While some cells suffer, the group as a whole can continue to grow. "Although all of the bacteria in the group are genetically identical and exposed to the same environmental conditions, the individual cells differ among themselves," says Schreiber.

Detailed insights thanks to the latest technology

Schreiber and his colleagues were only able to reveal the astonishing differences between the bacteria by studying them very closely. "We had to measure nutrient uptake by individual bacterial cells – even though these are only 2 µm large," explains Schreiber. "Usually, microbiologists study the collective properties of millions or even billions of bacteria. It was only thanks to the close collaboration between the research groups, and by pooling our expertise and technical equipment, that we were able to study the bacteria in such detail."

Bacteria are individualists too

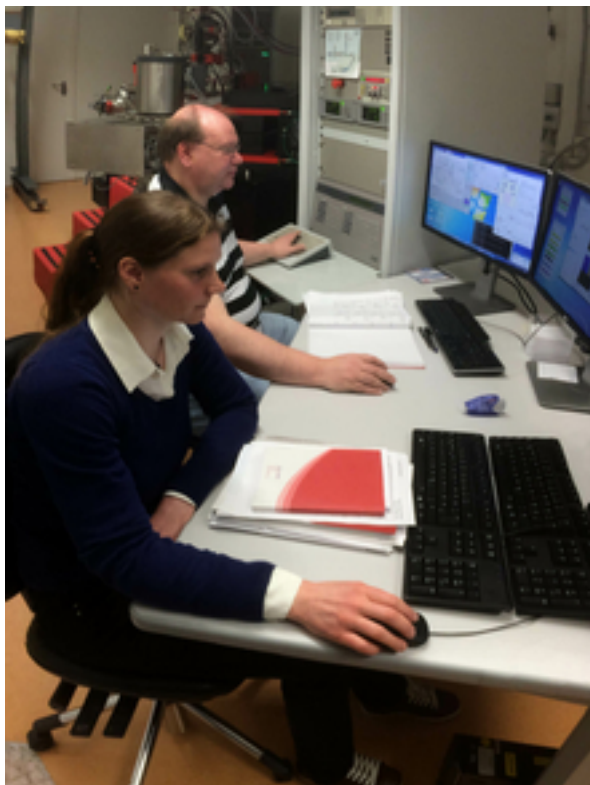
The present study shows to what extent individuality – in bacteria and in general – can be essential in a changing environment. Differences between individuals give the group new properties, enabling it to deal with tough environmental conditions. "This indicates that biological diversity does not only matter in terms of the diversity of plant and animal species but also at the level of individuals within a species," says Schreiber.

Next, Schreiber and his colleagues plan to study whether the individualistic behavior of specific individuals is of equal importance in natural environments.

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Using so-called chemostats, bacterial cultures of *Klebsiella oxytoca* are supplied with varying concentrations of ammonium and an excess of gaseous nitrogen (N₂).
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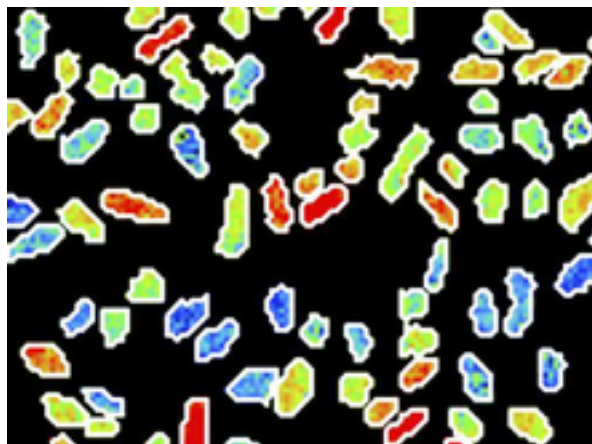


Technician Daniela Teinken and co-author Sten Littmann working on the NanoSIMS (Nanometer-scale Secondary Ion Mass Spectrometer) at the Max-Planck-Institute for Marine Microbiology. The NanoSIMS is one example of large research equipment that made this study possible. Using the NanoSIMS, researchers can measure nitrogen fixation in individual cells within a bacterial group.
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The NanoSIMS at EPFL Lausanne and the Center for Advanced Surface Analysis at the University of Lausanne, with (from the left) co-authors Stéphane Escrig and Anders Meibom, as well as Florent Plane.

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Single *K. oxytoca* cells. This images, generated using a NanoSIMS, shows the enrichment of the cells with heavy nitrogen (^{15}N) after being fed with it. The color differences between individual cells show that genetically identical cells within a population incorporate differing amounts of nitrogen into their cell mass (warmer colors represent more nitrogen incorporation).

(Copyright: Frank Schreiber)

Original publication

Phenotypic heterogeneity driven by nutrient limitation promotes growth in fluctuating environments

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Marcel Kuypers
Tel. +49 421 2028 602
mkuypers@mpi-bremen.de

Press service

Dr. Fanni Aspetsberger
Tel. +49 421 2028 947
presse@mpi-bremen.de

Andri Bryner
Tel. +41 58 765 51 04
andri.bryner@ewag.ch

Contact



Martin Ackermann
Director
Tel. +41 58 765 5122
martin.ackermann@eawag.ch

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