RTD Project MicroScapesX

Focussing on microorganisms

Microorganisms are usually invisible to the naked eye, yet they are omnipresent. Scientists involved in the MicroScapesX project are studying how the complex communities in which they live function. Their results could contribute to the improvement of treatments without the use of antibiotics for patients with burns.

Jan van der Meer checks the proliferation of the bacteria in the shake flask.

Microorganisms are found in soil and water, in the air, in other living organisms and on all surfaces. Whether they are useful or harmful primarily depends on which species live together. “They usually build useful communities”, says Jan van der Meer, a microbiology professor at the University of Lausanne, and the project leader of the RTD Project MicroScapesX. Yet for many reasons, it would be of interest to be able to selectively influence the microorganism mix, for instance in the human intestine. “Until now, this has been done by trial and error”, explains van der Meer, mentioning by way of example readily available probiotics, used to enrich the intestinal flora.

At the present time, the basic knowledge required for targeted interventions in the composition of such populations is missing. Little is known about which microorganisms occur together, how they colonize new habitats, and how their communities change in time and space. “Within the scope of MicroScapesX, we hope particularly to figure out what happens when additional species are introduced into an established ecosystem”, explains the project leader.

Considering microbial communities as a whole

Microorganism associations are often highly complex. “In the soil, for example, thousands of different species live together”, says van der Meer. The MicroScapesX scientists chose a systems biology approach to investigate the interactions between these tiny organisms more closely. The interdisciplinary team, consisting of microbiologists, modeling specialists and physicians, considers microbial communities as a whole and examines this system from different angles. Their approach is experimental but also involves computer models developed in-house. In this manner, they are able to accumulate many new insights regarding the coexistence of microorganisms. The models developed by scientists working under Dani Or at the ETH Zurich and Vassily Hatzimanikatis at the EPF Lausanne should in future make it possible to precisely predict the behavior and development of microbial communities.

Using microorganisms to clean soils

However, models can only be developed if they are supplied with data and tested. Van der Meer and his group are therefore investigating a soil system and its resident bacteria. Microorganisms have already been experimentally introduced into soil, in order to eliminate chemical contaminants such as oil. “Yet what the microorganisms actually do in the soil is not completely understood”, says van der Meer. Through their experiments, the researchers hope to determine what happens when they introduce new species into the system to eliminate pollutants. For example, they hope to learn how the preexisting microbes react, and whether they adapt once the composition of the community changes. The scientists are also interested in finding which particular species have a positive effect. In the long run, the plan is to introduce complete communities into contaminated soils to act as cleaning crews under controlled conditions, and to steer them in a targeted manner.

Colonization and coexistence

Before the scientists can implement such ambitious goals, they must identify the factors that promote the thriving of these beneficial communities. These could include the existence of nutrients, the availability of oxygen, or the way in which different species get along with each other.

Maja Schaffner

The experiments performed in the groups of Dani Or and David Johnson at the ETH Zurich should elucidate this last point and provide data for the development of models. The researchers are currently studying the interactions of different bacteria in artificial communities (see illustration). They are observing whether the microbes cooperate or compete with each other, and how these relationships influence their spatial distribution.

Fighting infections in burn wounds

Not only the interactions between various microorganisms, but also the microbes' colonization of new habitats is a subject of great interest to the scientists. Instead of restricting themselves to lab experiments, Yok-Ai Que and his team at the Lausanne University Hospital will also investigate this process by studying patients' burn wounds.

"Immediately after a burn has occurred, the destroyed areas of skin are nearly aseptic, but are then rapidly colonized by pathogenic microorganisms", explains van der Meer. These infections are dangerous and, in serious cases, lead to septic shock and even death. In addition, an invasion by harmful microbes is difficult to stop with antibiotics, as the pathogens very rapidly become resistant to the drugs during treatment.

The physicians at the Lausanne University Hospital are therefore investigating how the colonization of such a wound happens. They are particularly interested in determining which bacteria appear at which moment and whether they were already present on the skin prior to the burn. They also hope to find out if and how it is possible to stop the pathogen invasion without antibiotics. Nowadays, burnt areas of skin are, where possible, covered with skin from the patient's own body, washed regularly and treated with antibiotics to counter infection. "It might be possible to improve treatment by colonizing the wound with harmless microbes. These would occupy the territory and thus prevent the pathogens from spreading", explains van der Meer.

The scientists stain different bacteria with different colors in order to reveal their growth patterns within the community.
Illustration: Felix Goldschmidt, Eawag

Fruitful interdisciplinary collaboration

Van der Meer is obviously excited to be able to study life at the microscopic level, from a number of very different angles in such an interdisciplinary team. The partners meet regularly to discuss their progress. According to the project leader, it is very helpful that all the participants are knowledgeable in microbiology, even though they come from very diverse fields.

The project is still in the start-up phase and the scientists are not yet able to fully answer their numerous questions, however van der Meer already finds the collaboration between the five partners highly inspiring. "We learn so much from each other, for instance new techniques and approaches, or we exchange bacterial strains", the project leader happily reports. "In this way, we also come up with new ideas and starting points that bring us closer to our objective, which is to gain extensive knowledge of microbial communities."

MicroScapesX at a glance

Principle investigator: Prof. Jan Roelof van der Meer

Research groups:

- Prof. Jan Roelof van der Meer, Department of Fundamental Microbiology, University of Lausanne – Soil microbes and diversity analysis
- Dr. David Johnson, Institute of Biogeochemistry and Pollutant Dynamics, Department of Environmental Systems Science, ETH Zurich – Synthetic communities
- Prof. Dani Or, Institute of Terrestrial Ecosystems, Department of Environmental Systems Science, ETH Zurich – Agent-based spatial modeling of microbial communities
- Dr. med. Yok-Ai Que, Service of Intensive Care Medicine, Department of Adult Critical Care Medicine, Lausanne University Hospital – Burn wound treatments
- Prof. Vassily Hatzimanikatis, Laboratory of Computational Systems Biotechnology, Department of Chemistry and Chemical Engineering, EPF Lausanne and SIB Swiss Institute of Bioinformatics – Modeling of metabolic interactions

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Project type: Research, Technology and Development (RTD) Project

MicroScapesX
Design and Systems Biology of Functional Microbial Landscapes