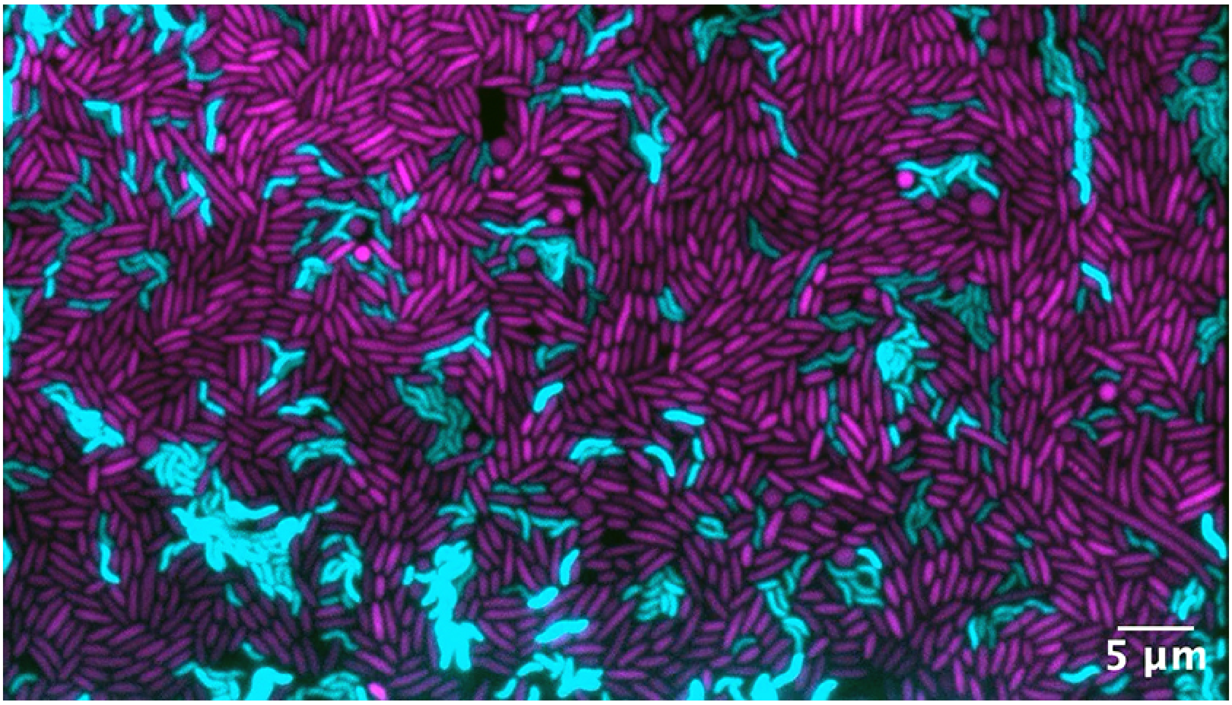

Bacteria eat bacteria

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Many bacteria produce a protein complex to inject poison in their neighbouring cells. This was previously thought to eliminate their competitors. But now researchers at Eawag and ETH Zurich have shown: The killer bacteria can act as biological predators that feed on their prey.

Even tiny organisms can be brutal – and not only eliminate potential food competitors, but also use their dead neighbours as a food source. This is the conclusion reached by the research group led by Olga Schubert and Martin Ackermann at the aquatic research institute Eawag. The researchers collaborated with Cara Magnabosco's team at ETH Zurich and other research groups and have just published their findings in the journal Science (*).

Spear with a poison-laden tip

The researchers became aware of this nefarious bacterial behaviour when they observed two different species of rod-shaped bacteria living in the sea in tiny growth chambers under the microscope. “We noticed that cells of one species began to disintegrate when they came into contact with cells of the other species,” says Astrid Stubbusch, first author of the study.

Both species belong to the same genus of so-called Vibrio bacteria. They differ in that only one species produces a complex of 14 different proteins. In technical terms, this complex is known as the “type 6 secretion system”, or T6SS for short. The technical name indicates that bacteria have several such systems. However, it does not reveal at all that these systems are highly complex weapons in a war that bacteria are fighting among themselves.

Martin Ackermann visualises the T6SS as a spear with a poison-laden tip. The predatory bacteria shoot the spear. It penetrates the neighbouring cell, however without inflicting fatal injuries. “Only the toxin that the spear brings into the neighbouring cell kills the cell," says Ackermann. This is because: "The killer cells themselves are immune to the toxin. If you grow them, they keep shooting at their neighbours without killing each other."

First round as a ball, then gone

The prey cells, on the other hand, belong to bacterial species that can produce neither a spear nor the proteins needed to detoxify the poison. When they are attacked, they die. Under the microscope, the researchers observed that the prey cells did not burst, but first became round as a ball – and then slowly dissolved.

The prey cells (pink) first become round and then dissolve (Video: Glen Dsouza).

The time it took for them to dissolve depended on which liquid the researchers pumped through the tiny growth chambers. One liquid contained alginate: this is a common carbon compound in the ocean. However, it can only be broken down by the prey cells and not by the killer cells. The other fluid contained a compound that can be metabolised by – and thus serve as food for – both species.

In the liquid with the food for killer and prey cells, the spherical cells were gone after just under 20 minutes, in the liquid with alginate only after around 86 minutes. Using model calculations, the researchers estimated that "the approximate total nutrient gain of T6SS cells through slow lysis is 2-fold to 50-fold greater than that through fast lysis," the researchers write in their article.

Like fox and hare

"The difference in the time it takes the cells to dissolve could mean that the killer cells load their spears with different toxins," says Glen D'Souza, the last author of the study. If the killer cells find dissolved food in their environment, they quickly kill the prey cells. This ensures that the prey cells do not eat away at the food contained in the environment.

However, if the killer cells cannot eat anything else, they have a great interest in not missing out on the organic molecules contained in the cell sap of the prey cells. "So they make sure that the prey cell in the neighbourhood empties itself slowly so that they can absorb as many nutrients as possible," says D'Souza.

The killer cells cannot grow on their own in the liquid with alginate; they are dependent on the prey cells. Once again, Ackermann has a catchy image at hand: he compares the alginate to grass in a meadow, the prey cells to a hare and the predatory cells to a fox. "The fox isn't afraid that the hare will eat away the grass, the fox can't eat it anyway," says Ackermann. "The fox simply hunts its prey."

The T6SS complex has been known to experts for some time. Until now, it was assumed that it mediates competition. "We have shown that this is not its only function," says Ackermann. "The predatory cells also use it to kill and eat their prey."

Genetically tuned for predatory life

In order to find out how widespread this newly discovered bacterial behaviour is and what ecological relevance it could have, the team combed through huge databases containing the DNA sequences of tiny creatures that have been caught by scientists sampling a wide variety of habitats.

At the end of these analyses, two things were clear. Firstly, the bacterial species that possess the T6SS genes often lack genes for the metabolisation of complex substances (such as alginate). In other words, many killer cells are genetically tuned for predatory life. In the course of evolution, they have specialised in eating neighbouring cells.

Secondly, the researchers' genetic analyses showed that “T6SS can be found practically everywhere”, says Ackermann. The researchers found the largest proportion of T6SS-positive bacteria – almost 40 per cent – in the so-called rhizosphere, i.e. the space around the plant roots in the soil, where very close cell contacts between many different microbes are the norm.

Possible effects on the carbon pump in the sea

Killer cells only make up around 4 to 7 per cent of all bacterial species in the oceans. However, the researchers suspect that they may play a role in the so-called carbon pump in the sea and thus could even influence the global climate

The carbon pump is based on the fact that the majority of marine life takes place in the uppermost water layers. On the surface, microscopic algae capture the sunlight. They grow and reproduce – and in the process extract carbon dioxide (CO2) from the atmosphere. They need the carbon to build up their biomass.

The algae are the food of the so-called zooplankton. These are many different, tiny creatures that swim around in the uppermost layers of water as long as they are alive. Then, as carcasses, they sink – mixed with dead algae and the excrements of the zooplankton still living above them – slowly and gently to the deeper layers of the oceans as flakes of so-called marine snow.

Most of the flakes are broken down by bacteria on this journey into the depths. This brings the carbon back to the surface. However, some flakes sink to the bottom of the oceans, where they remain for thousands of years. In total, the carbon pump deposits more than ten gigatonnes of carbon dioxide every year, which corresponds to around a quarter of global annual emissions.

How the killer cells influence the carbon pump with their predatory behaviour is still unclear. In the conversation, the researchers list several possible mechanisms that accelerate or, on the contrary, slow down the pump. “In any case, it is fascinating that relationships between microscopic bacterial cells could have an impact on the global carbon cycle,” says Schubert.

Cover picture: Glen Dsouza

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