It pays to cooperate

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Many species exhibit cooperative survival strategies—for example, sharing food or alerting other individuals when a predator is nearby. However, there are almost always freeloaders in the population who will take advantage of cooperators. This can be seen even among microbes such as yeast, where "cheaters" consume food produced by their neighbors without contributing any of their own.

In light of this, evolutionary biologists have long wondered why cooperation remains a viable survival strategy, since there will always be others who cheat. Now, MIT physicists have found a possible answer to this question: Among yeast, cooperative members of the population actually have a better chance of survival than cheaters when a competing species is introduced into an environment.

This experimental setup, in which yeast must coexist with a bacterial competitor, more closely mimics natural environments, where species often have to compete with one another for scarce food and other resources.

"It's very difficult to study these things in the truly natural context," says Jeff Gore, an assistant professor of physics at MIT and senior author of the new study, which appears in the journal *Molecular* Systems Biology on Nov. 13. "These experiments can act as a bridge between single-species experiments and very complicated ecosystem dynamics that are out there."

Hasan Celiker, an MIT graduate student in electrical engineering and computer science, is the paper's lead author.

Cheaters do prosper, sometimes

Gore and Celiker studied a strain of yeast that relies on small sugars such as glucose and fructose for nourishment. When yeast cells are grown in a test tube containing sucrose, some secrete an enzyme that breaks the sucrose down into smaller sugars, most of which diffuse away and are available to any nearby yeast cell.

In 2009, Gore and colleagues published a study showing that in a stable population of these yeast, freeloaders dominate. Only 14 percent of the yeast cells cooperate by secreting metabolic enzymes, while the rest enjoy the bounty of others' work.

In the new study, the researchers wanted to bring their experimental system closer to the complexity of natural environments. "Our approach is to start with the most simple system you can," Gore says. "Then we'd like to try to understand these more complicated interactions between different species, so as a baby step in that direction, we added a bacterial competitor."

This bacterial competitor consumes much of the sugar produced by the cooperative yeast, and also competes for other resources, such as nutrients. After these bacteria were added, the percentage of cooperators in the yeast population increased to about 45 percent.

This isn't because the yeast "decide" to become more cooperative, as humans might when faced with an external threat, Gore says. It's determined purely by genetics. "That's the point of doing experiments with microbial populations: There should be a mechanism that we can understand," he says.

Extra competition

In this case, the researchers found two mechanisms at work. First, in the face of extra competition for sugars, the cooperators have a slight advantage over cheaters because they have slightly easier access to the sugar they produce themselves.

A related mechanism involves population density. When bacteria are present, the overall yeast population stays smaller and is forced to spread out more, making it harder for the freeloaders to find food.

"The cheater cells can really spread when there are a lot of other yeast, because there's a lot of sugar out there for them. If there aren't very many yeast, then it's challenging for cheaters to spread," Gore says.

Though the experiment does not precisely replicate natural conditions, it does show that it is important to try to get as close to those conditions as possible, Gore says.

"If you just study something in isolation, such as yeast in a test tube, you might conclude that cooperation is very unstable," he says. "But if you look at these populations in the wild, where their densities are limited and they have to interact with all these other species, you might come to very different conclusions for how difficult it is for the cooperative behavior to survive."

In future studies, Gore hopes to add further complexity to the experimental microbial ecosystems, including varying the size of the yeast habitat.

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