Mutually helpful species become competitors in benign environments

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Nature abounds with examples of mutualistic relationships. Think of bees pollinating flowers whose nectar nourishes the bees, or clownfish that fight off predators of anemones that in turn provide habitats for the clownfish. Each species benefits the other, and together their chances of survival are better than if they lived apart.

Now scientists at MIT have found that such mutualistic relationships aren't always set in stone. Depending on environmental conditions, once-simpatico species can become competitors, and in extreme cases, one species can even drive the other to complete extinction.

Studying two similar strains of yeast, the researchers found that this deterioration in relations is marked by multiple transitions in the species' degree of codependence. What's more, such mutualistic relations tend to break down in more "benign" environments, such as nutrient-rich conditions, in which each species isn't required to rely solely on the other to survive.

The researchers have published their results today in the journal *PLOS Biology*. The team is led by Jeff Gore, the Latham Family Career Development Associate Professor of Physics at MIT, and includes Tim Hoek, who performed most of the experiments as a research intern in MIT's Physics of Living Systems group; Eugene Yurtsev, Tommaso Biancalani, and Jinghui Liu of the same group; and Kevin Axelrod of Harvard University.

Breaking down relations

In laboratory experiments, Gore and his colleagues studied the interactions between normally mutualistic strains of yeast that cross-feed, each producing a needed amino acid for the other.

The researchers supplied gradually increasing amounts of nutrients to the yeast and observed population changes in strains grown both together and apart. They found that in nutrient-poor conditions, both strains did better together than they did alone, forming more mutualistic relationships in which each strain depended heavily on the other. The opposite was true in conditions with more plentiful nutrients: The strains seemed to do worse together, with one dominating strain that grew in size while the other dwindled and eventually collapsed.

Interestingly, as the amount of nutrients gradually increased, the relationship between the strains, originally mutualistic, transitioned through multiple phases before devolving into competition, and even extinction of one partner. With just a small amount of extra added nutrients, the strains established an "obligate mutualism," in which they were obliged to co-exist in order to survive. With more nutrients, a "facultative mutualism" took hold, in which the two strains could survive on their own but did better together. With even more nutrients, this relationship gave way to "parasitism," in which one strain thrived while the other's population plummeted.

Finally, when the researchers added the highest concentration of nutrients to the strains, they observed that the yeast's previously mutualistic relationship completely broke down: The strains were both worse off growing together, with one strain outcompeting the other for nutrients, eventually driving the weaker strain to extinction.

"What's amazing is, often when we talk about these interactions between species, we say, 'Oh, a clownfish and an anemone is mutualism, whereas a lion and an antelope is predator-prey.' We talk about these species having fixed interactions," Gore says. "Whereas here we see these strains go through all these different regimes, just by changing one knob."

A "niche overlap"

From their experiments, the researchers developed a simple model to predict the type of mutualistic relationship that would develop between the two strains, given how their populations changed over time.

"In mutualism, we see that first, the abundances of each species become equal, 50-50, and then the overall size of the populations reach equilibrium, whereas in the competitive regime it's the other way around," Gore explains. "So we can determine which regime of interaction the species are in, based on the dynamics of the species."

However, there may be a limit to the extent to which a mutualistic relationship can break down. The researchers note that the two strains of yeast they studied were genetically very similar, and had very similar resource requirements, feeding off similar nutrients to stay alive. This "niche overlap" may predispose a genetically close pair of species to completely break from each other in benign, nutrient-rich conditions, and instead compete for the same resources.

Mutualistic pairs such as clownfish and anemones, or, similarly, ants and acacia trees, may be sufficiently different in their nutritional requirements that they would likely not end up in complete collapse.

"We think the degree of niche overlap will influence how far along the mutualism-parasitism spectrum you would go, when the environment becomes benign," Gore says.

Ultimately, the group's results may help scientists better understand the ways in which interactions in nature can change with a changing environment.

"There's a general idea that more challenging environments favor mutualistic type interactions," Gore says. "These experiments provide further support for the idea that mutualisms will often break down or become more competitive in more benign environments. Which is something that people have seen some evidence for in natural populations, but this is a nice context in which we can see it happening in a very direct way."

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