# Evolving bacteria through a game of rock-paper-scissors

By John Timmer | Published 2 months ago

"Imagine a nontransitive community in which, for convenience, we call the players Rock, Paper, and Scissors." It's a rather unusual line to find in a scientific paper, but the study it comes from is part of a special edition of *PNAS* on the evolution of social behavior. And rock-paper-scissors is not only a good way to settle an impasse; it provides a way of understanding a biological phenomenon that has been termed "survival of the weakest."

To understand this phenomenon, you have to understand what a non-transitive community is. The easiest way to understand this is to examine the three different types of bacteria used in the experiments described in the paper. One of them produces a protein, colicin, that's toxic to other cells; it also makes a set of proteins that allow it to survive the toxins it makes. Producing all these proteins exacts an energetic cost, so these bacteria can be outcompeted by cells that don't face the same burden.

A second strain has mutations that eliminate the proteins colicin binds to. This is a big help if the first strain is around, but these proteins perform helpful functions, so these cells can also be outcompeted by healthy, wild-type cells. And those healthy, wild-type cells are the final strain involved. The result of mixing all three is a rock-paper-scissors like situation, with each strain growing better when faced with competition from only one other. So, the resistant strain will outcompete the toxin-producer, which will kill the wild type cells, which will in turn outcompete the resistant one.

What happens when you throw them all together? That's where the survival of the weakest comes in. If one of the strains of bacterial successfully wipes out the one it grows better than, then it will be left with nothing but the third choice—which necessarily will grow better than it can. So, the selective pressure ends up favoring strains that don't effectively wipe out any competition they can; instead, it favors the evolution of restraint. As the authors phrase it:

> Next, imagine a less-restrained variant of Rock, called Rock*, that displaces Scissors at a faster rate. In a Rock*-Paper- Scissors community, the abundance of Scissors decreases because of the increased prowess of Rock*. As a consequence, Scissors' victim (Paper) is liberated, which can displace Rock*. In an ironic twist, the improved Rock* decreases in abundance because of the expansion of its victim's victim.

Survival of the weakest has been in the literature for at least a decade, and a variety of species have been identified that exhibit this sort of three-factor transitive relationship. But does it actually promote survival of the weakest? So far, experimental support has been lacking, and that's something the authors have set out to provide.

To run their tests, they set up bacteria in 96-well plates, so that each plate contained nearly 100 different ecological communities. Each community was allowed to grow for 12 hours, after which they were transplanted to new growing media. In a control test, each strain of bacteria was simply propagated on its own. In one experimental conditions, all three populations of bacteria were mixed during each transfer. In the final experiment, mixing occurred only among neighboring wells, which should reflect ecosystems where migration is physically constrained.

After dozens of transfers, no single strain came out on top. There was a consistent bias towards the resistant strain, and the toxin producers generally tended to do the worse, but the ecosystem seemed to stably maintain each of the tree strains. After the transfers were done, the authors obtained cells from the resistant strain and tested their growth. Cells grown on their own, with no competition, grew the fastest after the experiment was done. Those that had undergone transfer throughout the ecosystem grew a bit slower, and the ones that had been transferred locally grew more slowly still.

This is exactly what you'd predict from a survival of the weakest perspective. The cells that were transferred locally had evolved to adjust to their fellow players in the rock-paper-scissors game—to grow a bit more slowly so that they wouldn't crowd out their fellow strains. Those that were transferred globally might not be so finely attuned to their fellow players, and so grew at an intermediate rate. The authors performed a series of experiments to test whether other explanations might account for this slow growth, but all of them indicate that the bacteria must be grown in a competitive environment for this deceleration to evolve.

To an extent, the authors argue, the rock-paper-scissors ecology has forced a sort of altruism—delayed growth for the good of the community—for purely selfish reasons. They also note that the transitive competitions that have been described in the natural world take place in areas of behavior, like mating strategies, so it's possible that this sort of competition has driven the evolution of more complex social interactions. So it might be possible to expand the study to something even more complex than bacteria.

I also look forward to this work being expanded so that bacteria can model rock-paper-scissors-lizard-Spock.

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Image: University of Arkansas