Game theory study: Cooperative behavior meshes with evolutionary theory

April 6 2009, By Anne Trafton

Physics postdoctoral fellow Jeff Gore, left, and physics professor Alexander van Oudenaarden are harvesting yeast cells for experiments exploring the evolution of cooperation. Photo / Donna Coveney

(PhysOrg.com) -- One of the perplexing questions raised by evolutionary theory is how cooperative behavior, which benefits other members of a species at a cost to the individual, came to exist.

Cooperative behavior has puzzled biologists because if only the fittest survive, genes for a behavior that benefits everybody in a population should not last and cooperative behavior should die out, says Jeff Gore, a Pappalardo postdoctoral fellow in MIT's Department of Physics.

Gore is part of a team of MIT researchers that has used game theory to understand one solution yeast use to get around this problem. The team's findings, published in the April 6 online edition of *Nature*, indicate that if an individual can benefit even slightly by cooperating, it can survive even when surrounded by individuals that don't cooperate.

In short, the study offers a concrete example of how cooperative behaviors can be compatible with evolutionary theory.

Yeast may seem unlikely subjects for a study of cooperative behavior, but in fact they are perfectly suited to such studies, says Gore. Unlike humans, yeast have no emotions or thoughts that interfere with rational decision-making; their actions are solely driven by their genetic response to the environment.

"You can apply game theory to biological interactions and in some ways it's more broadly applicable than it is in humans," says Gore, the paper's lead author.

Game theory, traditionally employed by economists and military strategists, uses mathematics to predict individuals' behavior in certain situations.

Cooperators and cheaters

Working with MIT physics professor Alexander van Oudenaarden, also an author of the paper, Gore developed an experimental setup involving yeast sucrose metabolism. Sucrose is not yeast's preferred food source, but they will metabolize it if no glucose is available. To do so, they must secrete an enzyme called invertase, which breaks sucrose into smaller sugars that the yeast can absorb.

Much of that sugar diffuses away and is freely available to other yeast cells in the environment. In this scenario, yeast that secrete invertase are known as cooperators, while those that don't secrete invertase and instead consume the simple sugars produced by others are called cheaters.

If all of these simple sugars diffused away, with no preferential access to the yeast that produced it, then it would always be better to cheat, and the cooperators would die out.

The researchers observed that cooperating yeast have preferential access to approximately 1 percent of the sucrose they produce. That benefit outweighs the cost of helping others, allowing them to successfully compete against cheaters.

In addition, no matter the initial starting numbers of yeast in a given population, the microbes always come into an equilibrium state, with both cooperators and cheaters present. "It doesn't matter where you start. You always end up with equilibrium," says Gore.

This suggests that the yeast are playing what game theorists call a snowdrift game. The name of the game comes from a situation in which two drivers are trapped in cars behind a snowdrift. Each one can choose to get out and clear a path or stay put. If one driver does not shovel, the other must.

The best option is to "cheat" by staying in the car while the other driver shovels. However, the worst-case scenario occurs if both drivers cheat and no one gets home. Therefore, the best strategy is always the opposite of your opponent's strategy.

The same rules apply to the cheating and cooperating yeast: Like the driver who grudgingly gets out and shovels so that both she and her fellow motorist — snug inside his car — may continue on their journeys, the yeast who cooperate do so because there is a slight benefit for themselves. However, when most of the yeast are cooperating, it becomes advantageous for some individuals to cheat, and vice versa, which allows co-existence between cheaters and cooperators to arise.

Studies have shown that in the wild, yeast carry different numbers of copies of the invertase gene. This genetic diversity in the wild may be similar to the long-term coexistence of cooperators and cheaters observed in the laboratory, says Gore.

Provided by Massachusetts Institute of Technology (news : web)