Cheating favors extinction

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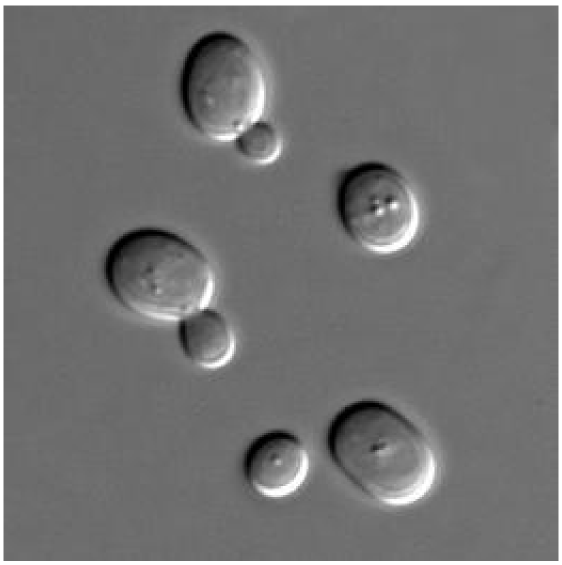

Sacharomyces cerevisiae cells in DIC microscopy. Credit: Wikipedia.

Cooperative behaviour is widely observed in nature, but there remains the possibility that so-called 'cheaters' can exploit the system, taking without giving, with uncertain consequences for the social unit as a whole. A new study has found that a yeast colony dominated by non-producers ('cheaters') is more likely to face extinction than one consisting entirely of producers ('co-operators'). The findings, published April 30 in the open access journal *PLOS Biology* by Alvaro Sanchez and Jeff Gore from the Massachusetts Institute of Technology, are the results of the first laboratory demonstration of a full evolutionary-ecological feedback loop in a social microbial population.

The researchers found that while a cooperative yeast colony that survives by breaking down sucrose into a communal supply of simple sugars can support a surprisingly high ratio of freeloaders—upwards of 90 per cent—a sudden shock to its environment is highly likely to result in catastrophe.

"One of the main things we were interested in was the idea that natural selection can have an effect on the ecology of a population, so that as a population is evolving, natural selection affects the ecological properties," said Dr Sanchez.

The researchers studied a cooperative species, Saccharomyces cerevisiae or 'baker's yeast', focusing on two strains: one which had the SUC2 gene that produces the enzyme invertase (the co-operators), and one lacking SUC2 (the cheaters) making it unable to produce this enzyme. Invertase breaks down sucrose in the environment to liberate glucose and fructose that can be used by all yeast cells in the colony.

"We were very surprised by the fact that the total population size for the mixed group (consisting of both co-operators and cheaters) was about the same at equilibrium as the total population size in the absence of cheaters (i.e. purely co-operators). We didn't expect that," Dr Sanchez explained. "If it weren't for the fact that the co-operators and cheaters were labelled with different colours, it would have been very hard to tell whether the population contained any cheaters or not".

This was the case when the environment was benign. But when those stable populations were suddenly exposed to a harsh environment, all of the pure co-operator populations survived, while just one of six mixed populations adapted to the fast deterioration in conditions, the researchers found.

Benjamin Allen, Assistant Professor of Mathematics at Emmanuel

College and Martin A. Nowak, director of the Program for Evolutionary Dynamics at Harvard University, co-authored an accompanying Primer in *PLOS Biology*, "Cooperation and the Fate of Microbial Societies".

"The experiments of Sanchez and Gore beautifully illustrate the central dilemma in the evolution of cooperation. The yeast society depends on cooperation, but if cooperation is plentiful, 'cheaters' can exploit the generosity of others. This leads to cycles of cooperation and exploitation," said Dr Allen.

The researchers found that an eco-evolutionary feedback loop links changes in population size, and their effects, with changes in the frequency of specific genetic types in the population. During the competition for survival between co-operators and cheaters, they showed that if the population starts off with sufficient co-operators then the social properties of the yeast spiral towards a final equilibrium position that comprises a stable mixture of co-operators and cheaters. However, if the initial population density, or the initial proportion of co-operators, is too low, then not enough simple sugars are produced, and the colony dies out.

More information: Sanchez A, Gore J (2013) Feedback between Population and Evolutionary Dynamics Determines the Fate of Social Microbial Populations. PLoS Biol 11(4): e1001547. doi:10.1371/journal.pbio.1001547

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