Tides of tolerance

Karl Sigmund and Martin A. Nowak

Humans, and many other species, have a tendency to cooperate and help each other. But how does such behaviour evolve? Some new computer simulations provide a plausible answer.

When Charles Darwin published his theory of evolution in 1859, he knew that cooperation and altruistic behaviour present something of a problem for a concept that is based on competition and the struggle for existence. He did, however, anticipate a solution: that provided with William Hamilton’s more than a century later, cooperation can emerge as a result of ‘kin selection’ in cases where interacting individuals are genetically related. On page 441 of this issue, Riolo and colleagues discuss a new model for the evolution of cooperation, in which individuals help others that are, in someway, like themselves.

This is not the first time that the idea of ‘like helping like’ has been suggested as a route to the evolution of cooperation. Twenty-five years ago, Dawkins introduced the ‘green beard effect’ as a thought experiment in sociobiology. Consider a gene that confers on its bearer not only a green beard (or any other visible effect) as a thought experiment in sociobiology. Considering a gene that confers on its bearer not only a green beard (or any other visible effect), such as an accent in a foreign language, could be a reliable tag that is hard to fake; hiding one’s accent in a foreign language is nearly impossible.

The basic outcome of the computer simulations is that a substantial degree of cooperation is established. Essentially, a ‘dominant cluster’ emerges, consisting of players sufficiently similar to help each other. This occurs even in the absence of repeated interactions and reputation effects — that is, without direct or indirect reciprocation. All that is needed is some recognition of what is ‘similar’, an ability that is widespread among animals (odours or visual cues can provide the required information). So, the mechanism that leads to cooperation is a form of kin selection — either classical (if traits are inherited genetically) or social (if they are inherited culturally, like a dress code).

One attractive feature of the new simulations is the evolution of tolerance — the recognition mechanism that discriminates ‘us’ from ‘them’. This tolerance does not freeze at some fixed value. Cyclically, it slowly increases over time, and then sharply declines. This drop occurs when the dominant cluster is dissolved from within as a result of mutation, by new individuals whose traits lie in the range of the dominant cluster but whose tolerance is considerably reduced. These newcomers are helped by all the residents of the established cluster but themselves help just a few, so they bear fewer costs than the established residents. A wave of intolerance then sweeps through the population, and in its wake a reduction in overall cooperation. But once a new dominant cluster is established, cooperation resumes at its former level and tolerance starts spreading again. The slow upward drift of tolerance seems to be due to a combination of mutation pressure and kin selection. It will be important in the future to explore the robustness of this phenomenon.

These oscillations of tolerance levels are striking, and bring to mind many historical instances. We are witnessing a wave of social and religious intolerance right now. It would be foolish, of course, to reduce the complexities of political life to the vagaries of a virtual population. Yet these computer simulations do capture the imagination, and may well lead to a cottage industry of follow-up investigations, just like Axelrod’s famous computer tournaments based on the ‘prisoners’ dilemma’ game.

The new scenario applies to both genetic and cultural tags. Part of its appeal is its obvious link to reality — school ties, club memberships, tribal customs or religious creeds are all tags that induce cooperation. Some of these tags are easy to fake and might invite exploitation. Language, on the other hand, could be a reliable tag that is hard to fake: hiding one’s accent in a foreign language is nearly impossible.

Furthermore, tags can help to encourage the usual suspects behind cooperation among unrelated individuals: direct and indirect reciprocation (whereby recipients
of help return the help, either to the donor or to a third party. In other words, tags bolster the emergence of cooperation in repeated interactions, and might even promote long-term pairings based on similarity. Indeed, to find out how much one has in common is one of the first delights of falling in love and contemplating a lifelong partnership.

But tags can also present major obstacles in overcoming segregation. Although the simulations by Riolo et al. do not produce dominant clusters that split into rival tribes, any territorial distribution would favour such ‘speciation’. Tags would then act as self-enforcing stereotypes, making it hard for tolerance to cross the divide. We know that discrimination is needed to sustain cooperation in the face of exploiters. But tag-based intolerance could turn discrimination away from the ‘bad guys’ and raise senseless antagonism.

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Figure 1 Surface chemistry in action. The formation of carbon dioxide ($CO_2$) by catalytic oxidation of carbon monoxide ($CO$) on a metal surface is an important reaction in air purification, emission control and chemical sensing. In their experiment, Hahn and Ho show that CO and oxygen atoms ($O$) adsorbed on a silver surface can be transformed into $CO_2$ with the help of an STM tip, which transfers electrons from or to the tip that can start a chemical reaction, or make atoms or molecules move on the surface. Pushing or pulling an individual atom or molecule with the tip can also make it move.

Hahn and Ho use the STM to dissociate the oxygen molecules ($O_2$) and to move individual CO molecules close to the oxygen atoms on the surface, and to induce the final reaction and desorption of the product ($CO_2$). Along the way, they image the intermediates on the surface — they observe, for instance, a complex consisting of two oxygen atoms close to each other and to a CO molecule. They also used the STM in its ‘inelastic electron tunnelling spectroscopy’ mode to monitor the vibrational behaviour of CO as it is nudged closer and closer to the two oxygen atoms. The formation of the $O-C-O$ complex is confirmed by observing a change in the vibrational frequency of the CO. Measuring the spatial distribution of the vibrational intensity of CO within the complex provides information about the structure of the reactants. In a separate set of experiments they induced the reaction by first transferring the CO molecule to the tip (by using a voltage pulse), moving the tip into position over an adsorbed oxygen atom, and applying a new voltage pulse with the opposite sign to transfer the molecule back to the target surface and to kick start the reaction.

These experiments provide atomic-scale details of a chemical reaction occurring at a surface. Intermediates that would not have a measurable lifetime at higher temperatures, and so cannot be observed during a thermal reaction, can be viewed directly. The clever part is to work at temperatures low enough for the intermediates to be frozen in time and to use electron injection rather than thermal excitation to make the reaction proceed.

The work of Hahn and Ho shows that it is possible to induce reactions that won’t proceed thermally by using tunnelling electrons to activate the reaction. Using an STM tip to induce chemical reactions at a catalytic surface is not an efficient way of producing large amounts of chemicals, but it is analogous to the way natural catalysts (enzymes) manage...