

The mathematics of being nice

Using mathematics to tackle some of biology's biggest questions, **Martin Nowak** has concluded that an ability to cooperate is the secret of humanity's success. He talks to **Michael Marshall** about drawing fire from Richard Dawkins, the perils of punishment, and devising the mathematical equivalent of the rules of religion

Why are you so fascinated by our ability to help each other out?

Cooperation is interesting because it essentially means that you help someone else, someone who is a potential competitor. You reduce your own success in order to increase the success of somebody else. Why should you do that? Why should natural selection favour such behaviour? To answer these questions I use evolutionary dynamics, evolutionary game theory and experimental tests of human behaviour.

You say there are five different ways in which we cooperate that give us an edge, in terms of natural selection. Tell me about them.

The first one is called direct reciprocity. This is when individuals have repeated interactions, so if I help you now, you may help me later. There is also indirect reciprocity, which takes place in groups. If I help you, somebody else might see our interaction and conclude that I'm a helpful person, and help me later. That's a reciprocal process relying on reputation.

The third mechanism is when neighbours help each other – cooperators survive in

clusters. This is called spatial selection, and it plays an important role, not only for people but for bacteria, animals and plants. Then there is group selection: it may be that our group of cooperators is better off than another group of defectors: here selection acts on two levels, because in our group there is more cooperation.

Group selection has had a tricky reputation, and has been attacked by evolutionary biologists. Do you think it has now been rehabilitated?

The introduction of the concept of group selection, some 40 years ago, was imprecise. But recent mathematical models explain very clearly when group selection can promote the evolution of cooperation. There must be competition between groups and migration rates should be low.

Unless I've lost count, there should be one mechanism left.

The last one is kin selection, which can occur when you help a close relative.

You published a paper on kin selection last year that caused a bit of controversy.

I have no problem with kin selection when it is properly formulated. My criticism is directed against the current use of inclusive fitness theory, which is the dominant mathematical approach used to study aspects of kin selection.

Can you explain?

Inclusive fitness theory assumes that the personal fitness of an individual can be



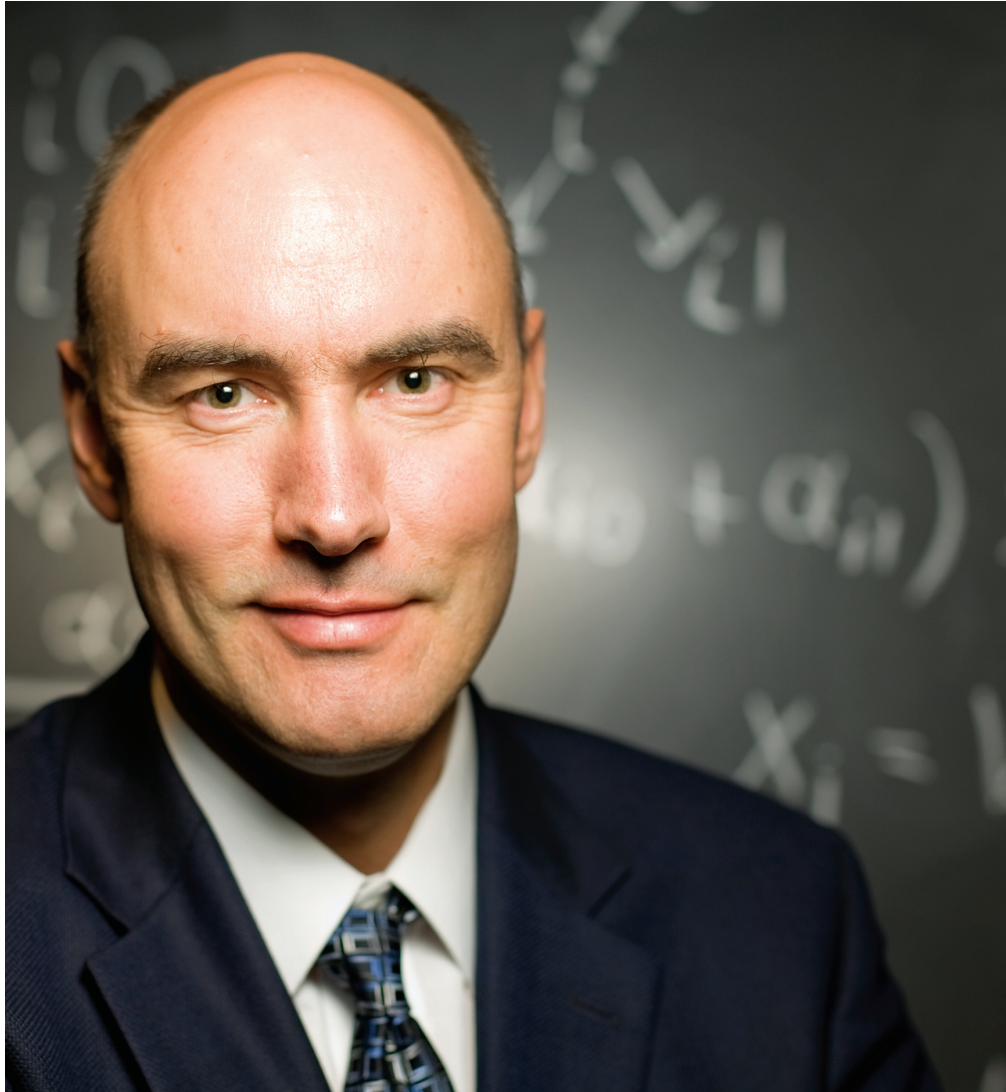
partitioned into components caused by individual actions. This restrictive assumption implies that inclusive fitness theory is a limited approach that cannot be used to describe typical situations that arise in social evolution. The standard theory of natural selection does not make such a limiting assumption. In that recent paper we showed that inclusive fitness theory is a subset of the standard theory.

Inclusive fitness is a key concept of evolutionary biology. No wonder that many biologists, including Richard Dawkins, reacted negatively when you attacked it (New Scientist, 2 October 2010, p 8). Do you think people are now coming around to it?

I feel that it is beginning to be appreciated. I would say the negative response rests on a

PROFILE

Martin Nowak is professor of mathematics and biology at Harvard University. He has a PhD from the University of Vienna, Austria, became professor of theoretical biology at the University of Oxford aged 32, then moved to Princeton University and later to Harvard. His book *SuperCooperators: Altruism, evolution, and why we need each other to succeed*, co-authored with Roger Highfield, *New Scientist's* editor, is out this month



position in the group. Punishment leads to retaliation and vendettas. It's very rare that punishment is used nobly.

Over the years you've applied mathematics to a lot of different areas of biology. Is it your aim to put the whole field on a mathematical footing?

Yes. It has happened in many disciplines of science. It's a kind of maturation process. Without a mathematical description, we can get a rough handle on a phenomenon but we can't fully understand it. In physics, that's completely clear. You don't just talk about gravity, you quantify your description of it. The beautiful thing about mathematics is that it can decide an argument. Some things are fiercely debated for years, but with mathematics the issues become clear.

Unlike most evolutionary biologists, you are religious. Do you think it is a problem for the public perception of evolution that it is seen as supporting atheism?

In my opinion, a purely scientific interpretation of evolution does not generate an argument in favour of atheism. Science does not disprove God or replace religion. Evolution is not an argument against God, any more than gravity is. Evolution explains the unfolding of life on Earth. The God of Christianity is "that without which there would be no evolution at all".

So how do you see religion?

I see the teachings of world religions as an analysis of human life and an attempt to help. They intend to promote unselfish behaviour, love and forgiveness. When you look at mathematical models for the evolution of cooperation you also find that winning strategies must be generous, hopeful and forgiving. In a sense, the world's religions hit on these ideas first, thousands of years ago.

Now, for the first time, we can see these ideas in terms of mathematics. Who would have thought that you could prove mathematically that, in a world where everybody is out for himself, the winning strategy is to be forgiving, and that those who cannot forgive can never win?

Do you feel isolated from other evolutionary biologists because of your religious beliefs?

No, I don't think it's an issue. I once had a great discussion with another biologist about science and religion. He was deeply religious. Two weeks later I read that he had been made head of the US National Institutes of Health. He is Francis Collins. ■

misinterpretation of the paper. People think that we are saying relatedness is unimportant, but this is not at all what we said.

People who are open-minded are beginning to realise that the results of our paper are beautiful: simple mathematical models based on standard natural selection are sufficient to explain the evolution of eusociality or other phenomena in social evolution. The strange mathematical contortions of inclusive fitness theory are unnecessary. In other words if you are interested in a mathematical description of evolution, a situation can never arise in which you would need an inclusive fitness approach.

You have also been involved in some other big debates. Can you tell me about your work on punishment?

Many people feel that punishment is a good thing, that it leads to human cooperation. So their idea is that unless you cooperate with me, I punish you. It might even cost me something to punish you, but I do it because I want to teach you a lesson. One cannot deny

"Evolution is not an argument against God, any more than gravity is"

that punishment is an important component of human behaviour, but I am sceptical about the idea that it's a positive component.

I have analysed the role of punishment using mathematics and experiments. I think that most uses of punishment are very much for selfish interests, such as defending your

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