THE SHREWD MARKET TRADERS IN THE SOIL

April 2014 – If you think that humans are bizarre with the careful manipulation of their complex financial economies, you may need to think again. Fungi can be just as calculating in trading their phosphorus resources to plant roots offering sugar commodities. Now that evolutionary biologist Toby Kiers has uncovered how this ancient, underground marketplace functions, she wants to manipulate the plant-fungal market to support sustainable agriculture. Ultimately her aim is to understand the social lives of microbes, testing how they form alliances and barter deals.

By Rianne Lindhout

It was an incredible discovery. Evolutionary Biologist Toby Kiers (1976) revealed the refined ways in which fungi and plant roots in the soil apply the laws of supply and demand. "Fungi provide supplies of phosphorous and release them only to plants that offer the most sugar in return. It actually looks very much like a market economy. If we can get to the bottom of this, we will be able to create altruistic fungi that are more willing to help plants. Ideally it could reduce our dependence on artificial fertilizers."
If you think of evolution, the first thing that comes to mind is the competition between species: the survival of the fittest. But all around us organisms are engaged in intimate dances of cooperation and trading. From the billions of intestinal bacteria that power our guts to the birds and bees that pollinate our crops, we actually understand very little of how cooperative relationships evolve in nature.
In the last two decades, scientists have asked how cooperation can emerge through natural selection processes. The Kiers group is especially interested in how cooperative relationships between different species are stabilized over evolutionary time, despite the presence of individuals that try to "cheat" the system. In studying cooperative trade between plants and their root fungi, the group is systematically manipulating all of the conditions in which underground trade takes place. Their goal is to force partners to cheat and watch how the other responds. Can partners detect when they are getting a bad deal? How do they react? The Kiers group is studying plant and fungal trade strategies from the gene level up, asking how changes in the environment, such as artificial fertilizer, drive the evolution of trade approaches.

EVOLUTION & AGRICULTURE: A COMPLICATED POLITICAL INTERFACE

An aspect of her professional field that complicates matters is the fact that she straddles the worlds of evolution and agriculture. These two worlds are not an easy match, explains Kiers. "Farmers are sceptical: with all our evolutionary theories and models, they find us too theoretical. Evolutionary biologists are just as sceptical, they want to study pure systems to understand evolutionary dynamics. They do not yet see agriculture as an interesting and elegant object of study. But we believe that agronomic systems can be a perfect setting in which to see and study, and even manipulate evolution." Her paper on Darwinian agriculture in 2003 marked a tipping point, and the importance of an evolutionary perspective in agricultural development is gaining in popularity. Working at the interface between different disciplines suits Kiers perfectly. Collaborating with people who have different perspectives forces her to think creatively and see things in a new light. "I'm often asked to give presentations at all kinds of conferences, ranging from economics, microbiology and evolution to policy meeting with the United Nations. From all these disciplines, I collect as much information as I can and it helps guide my research. My aim is to always remain connected, refreshed and involved."

> 'It was quite impossible not to become a scientist'

To be able to collaborate with such diverse audiences, she needs an effective means of illustrating ideas. A good example was the alliance with animation artist Niels Hoebers for the project Public Science at VU University Amsterdam. "We made an animation film about how the market in the soil works. We were working on the storyboard and it was not easy. Hoebers asked a lot of very practical questions: how do the plants do this, how do the fungi do that? Perhaps it works like this? And I thought: that's a good idea, maybe it does work like that, let's look into it!" Incidentally, the two-minute film is definitely worth watching.
The appearance as part of the VU Public Science event was inspirational for Kiers for another reason. "My work on the evolution of cooperation in microbes was combined with the way in which you can apply microbes in design. Yet another new perspective! The many designers in the room gave me a great deal of feedback that I would never have received from scientists. Communicating with a non-scientific audience is a vastly underrated skill."

RISKY INVESTMENT WITH THE CHANCE OF SUPER RETURNS

What Kiers is doing with her research is actually a high-risk investment but also one that has a chance of an enormous return: a major step forward in sustainable agriculture. "It is gratifying that my appointment to a University Research Chair gives me the opportunity to continue with this groundbreaking research on the cusp of different disciplines. It may take another twenty years, but it will eventually pay for itself. Then we will be able to inoculate our agricultural land with useful fungi rather than with damaging artificial fertilizer for which the raw materials are running out."

> 'Each of us is in fact our own little community'

Kiers finds it frustrating when scientists are not given enough room to be creative. It was something she first noticed at the age of 19. As a Bachelor student of Biology in the US (Bowdoin College, Maine), she found research had a cook-book approach. Everything had a beginning and an end, everything was planned, with too little room for discovery. "My mentor saw that I wanted greater things and said: 'Leave the classroom and become a scientist!'" She headed off to spend a year at a small research station in the rain forest island in the middle of the Panama Canal: the Smithsonian Tropical Research Institute. "The world's most celebrated evolutionary biologists and ecologists were there. Everyone took me under their wing: they all wanted me to fall in love with the system they were researching. We dined together, talked and argued. I was exposed to a lot of ideas. It was quite impossible not to become a scientist there. Ultimately, it was the research into microbes and fungi that I found most inspiring."

NO ANTS WITHOUT ELEPHANTS

Now she is working at VU University Amsterdam, she spends less time in the rainforest. "I do less research myself each year, but I try to find new systems where we can study the evolution of cooperative dynamics. Last year, I spent three weeks in Kenya, where an incredible long-term project is running to model the effects of extinction of large herbivores like elephants and giraffes. Massive fences had been erected to create plots that they cannot reach. We see how delicate the balance of cooperative relations can be in nature. Rather than the trees benefiting from less herbivory, they actually suffer when elephants and giraffes are gone. Important ant partners that normally protect the trees from being eaten abandon the trees. And when the ants leave, the beetles attack. A Phd student is now analysing root samples to test how these knock down effects drive changes in below ground communities. We are guessing that the snowball effect will be huge, even for microbial communities."
Kiers believes we need a paradigm shift on how we think about microbes. When you consider that for every one of our human cells, there are roughly ten bacteria cells in and on our bodies, it makes you wonder what a human actually is. Kiers has asked this question in a publication aiming to understand the boundaries (or lack thereof) of orgamismality. Kiers: "We don't really understand it yet. Each of us is in fact our own little community. Exactly the same applies for plants and fungi. They dependent on each other and influence each other." If our intestinal bacteria do not feel well, we suffer as a result. It may cause us to choose a different type of food. Similarly, work on insects has found that our gut microbes even influence the mate we choose. "The question is the extent to which an organism's decisions are influenced by other organisms in the community. We as humans may feel we are making independent decisions, but this is naïve."
The issue is one that occupies Kiers at all times. "My work is such an important part of my life that I find it difficult to switch off. That can sometimes be quite exhausting. I have two children. They are constantly reminding me that you need to play to discover." When she looks at her successes, working with students and seeing how a whole new generation of scientists has become enthralled, she realizes science is driven by playful inspiration.

TWO CHAIRS CONNECTED BY ART

The loss of a single species can destroy a whole network. The idea of "too big to fail" is a concept we are also familiar with from the world of banking. Artist Annabel Howland combines science, finances and art and, in her multi-media project Producers-Parasites-Hosts also brings together two VU URC professors: Toby Kiers and Albert Menkveld.

The film Underground Market *by Niels Hoebers, starring the roots and the sugars, perfectly illustrates what happens in the soil between the plants roots and the fungal hyphae.*

CV TOBY KIERS

Born in 1976 in New York, New York | 1998 Research Fellow Smithsonian Tropical Research Institute | 2004 Japanese Society for the Promotion of Science Fellow, Kyoto, Japan | 2000- 2005 Phd in Ecology & Evolution, University of California, Davis | 2005 Darwin Fellow, Univ. of Massachusetts, Amherst | 2006 NWO Veni Fellow, VU University Amsterdam | 2011 NWO Vidi Fellow, VU University Amsterdam | 2013 European Research Council (ERC) Fellow | 2014 URC Professor of Mutualistic Interactions