FROM BIOLOGY TO BUSINESS AND BEYOND

THE SECRETS TRADERS TELL

THE RISK, THE WHOLE RISK AND NOTHING BUT THE RISK

BUSINESS AT oxford

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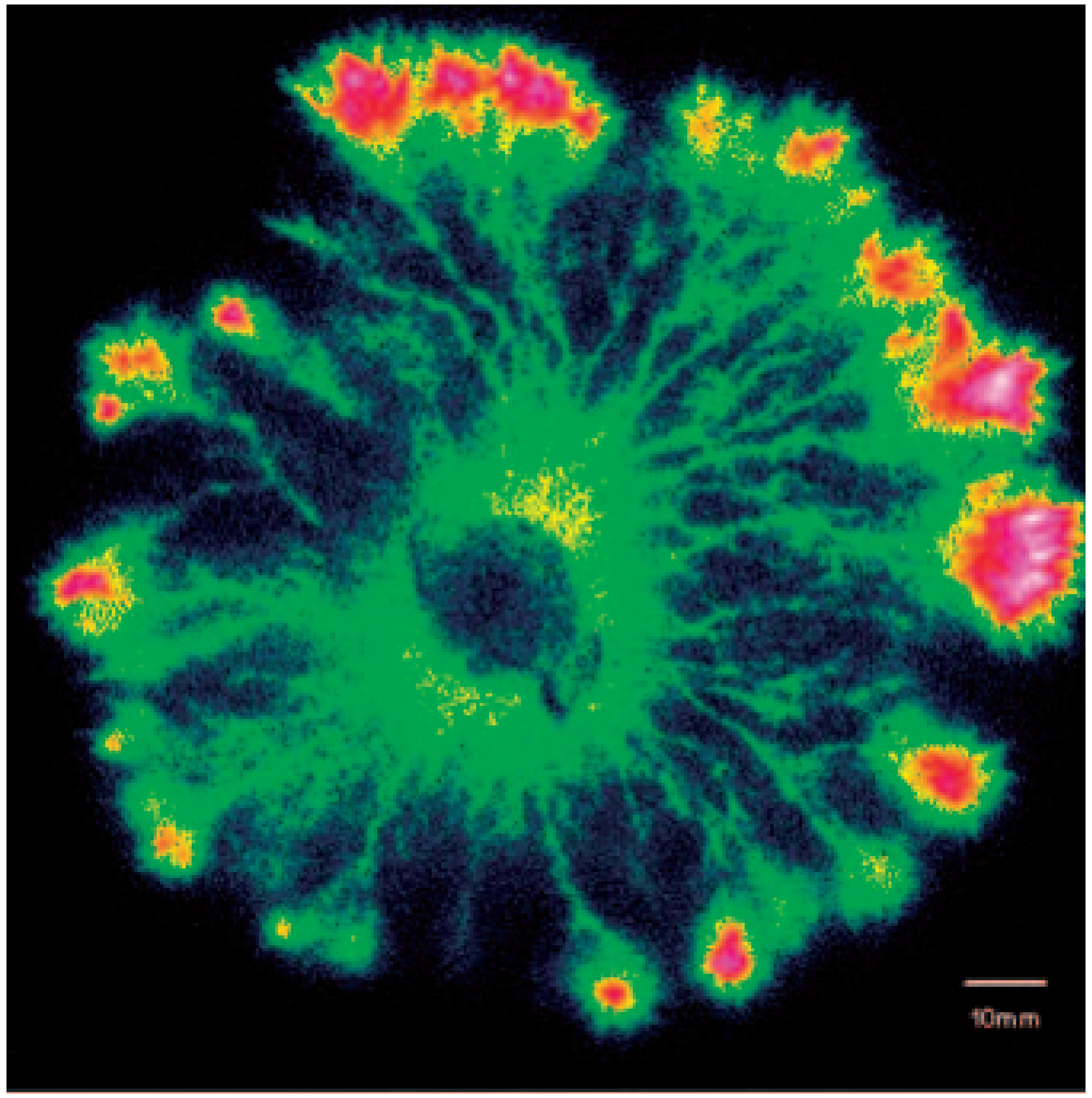
Image of nutrient transport in a fungus courtesy of M. Tlalka, S. C. Watkinson, P. R. Darrah and M. D. Fricker. Research supported by the BBSRC and NERC.



From biology to business and beyond

Felix Reed-Tsochas looks at the lessons to be learnt from woodland fungi.

Consider the following phenomena – the foraging trails generated by ant colonies seeking out food resources; the organisation and management of flexible supply chains in manufacturing and retail; the creation and transmission of innovative ideas and knowledge in high-tech industries; the pattern of e-mail and phone traffic within organizations; the transmission of infectious diseases via social contacts; the congestion caused by introducing shortcuts in transportation networks; the correlations between the movements of different currencies in foreign exchange markets; the patterns in space and time which characterise terrorist incidents and attacks by insurgents.

What do they all have in common? One answer is that all of them are currently being studied at Oxford. But perhaps more interestingly, it has also been discovered that all of them can be understood and modelled if we think of them as dynamically evolving network structures – that is to say, as distributed systems without any centralised control.

Of course, the constituents and the properties of these systems differ radically. No-one would suggest that they can all be accounted for by one master theory or universal model. However, in each case we can gain unique and novel insights into the behaviour of the system by modelling it in terms of so-called 'agents' which are linked to each other via a complex and evolving network structure.

The agents in our models may represent individual ants in a colony; traders in financial markets; inventors contributing to a technology domain through patents and other publications; organisations and firms which are connected to each other in a supply chain; or different units within terrorist or insurgent groups. Agents representing different entities will clearly need to be assigned different properties: whereas in some cases it may be appropriate to assume that agents follow fixed simple rules of thumb, in other cases we may wish to allow agents to engage in purposeful decision-making and give them the ability to learn from past mistakes.

However, following the approach adopted in most agent-based models of complex systems, it is important that we do not assume that the agents in our models are perfectly rational decision-makers or calculating machines with complete information about the system or network which they inhabit. Agents may be able to foresee some limited consequences of their own actions, but they cannot predict how the aggregate of their collective actions will affect the evolution of the overall system.

The emergent properties of such systems cannot be trivially reduced to the properties or behaviour of the constituent parts. The individual properties of all the constituent agents within a system are not sufficient on their own to characterise and model the system. Agents will interact with other agents through mechanisms such as the exchange of resources and information or by establishing a link of trust or reciprocity, and the local and global features of the resulting pattern of interactions often have a very significant impact on the overall system behaviour. If we envisage agents as sitting at the nodes of a large network structure, then the links between these nodes correspond to the flow of different types of resources and information, or represent some kind of established relationship.

As examples of such links, we can think of the flow of materials within a supplier network; the transmission of viruses between individuals; the flow of capital between venture capital firms and the firms they invest in; the joint membership of a company board; or the co-authorship of a patent. In modelling such systems, we must allow for the fact that agents may not only regulate the resources flowing through them, but can also break existing links and create new ones.

Clearly, models involving a heterogeneous population of agents linked through a complex and changing network structure are highly nonlinear, and are very difficult and challenging to analyse. But rapid advances in this field of study are currently being made, by bringing in different tools from statistical physics, mathematical biology, analytic sociology, and computer science. These ingredients, when mixed in the right way, may give us a powerful new lens through which to view and understand such systems.

In Oxford, the research on complex networks and agent-based models described above is being pursued within a recently founded interdisciplinary research cluster called CABDyN (Complex Agent-Based Dynamic Networks – see http://sbs-xnet.sbs.ox.ac.uk/complexity/). Because CABDyN aims to develop network models that can be applied across a wide range of disciplines and application domains, it is crucial that more than ten departments within Oxford are currently active participants. The Saïd Business School has played an important role from the start, hosting CABDyN's first international conference in October 2003 and many of CABDyN's research workshops and seminars.

The recently launched MMCOMNET Project (Measuring and Modelling Complex Systems across Domains), which is funded under the European Commission's New and Emerging Science and Technology Programme, is also led from the Saïd Business School. The project

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involves seven University Departments in Oxford and five other European partners in France, Germany, Switzerland, Poland, and Sweden.

The work of CABDyN has attracted considerable interest in the media, and recent pre-prints that have received wide press coverage range from a network model of voting behaviour in the Eurovision Song Contest to a model of the intensity of civilian casualties in the armed conflicts in Iraq and Colombia. In order to give a clearer picture of this kind of research, let me give one more detailed example of our ongoing research.

Mark Fricker and his colleagues at the Department of Plant Sciences have over a number of years conducted extensive laboratory experiments to collect data on the evolving network structure and the patterns of nutrient transport in foraging saprotrophic woodland fungi. These fungi cover large areas of the forest floor, and are known to scavenge efficiently for scarce resources in a varied and changeable environment, and to adjust their network architecture effectively to environmental cues such as damage or predation. Of course, the fungus is able to adapt its structure and to redistribute nutrients in a well-coordinated manner without the need for any centralised form of control or intelligence, and so the network structure reflects the outcome of a process of biological self-organisation which has been honed by evolution. Neil Johnson and his students in the Department of Physics are currently developing a range of agent-based models to try to account for the structural evolution of these fungal networks, in order to see whether the observed growth patterns can be replicated in computer simulations starting with very simple rules for agents in agent-based models. However, the larger research agenda goes well beyond the attempt to replicate the observed behaviour of a particular biological system in a computer model. We know that woodland fungi are highly adaptive and resilient, and represent a real-world compromise between fragile efficiency and costly robustness. If agent-based models enable us to understand the mechanisms and processes that allow such structures to grow and evolve, then we can perhaps abstract some more general principles for self-organised design and bring them to bear in very different application domains.

Might the lowly fungus give us some clues on how to make supply chains or transportation networks, for example, less vulnerable and more flexible and adaptable? ■