Nigel Franks

The Genesis of the (Super-)Organism in Evolution and Ontogeny

Born 1956 in Oldham, Lancashire. 1974-76 University of Leeds, Department of Pure and Applied Zoology, B.Sc.; 1978-80 Smithsonian Tropical Research Institute, Panama; PhD. Thesis: *The Evolutionary Ecology of the Army Ant* Eciton burchelli *on Barro Colorado Island, Panama.* 1980-82 Research Fellow, Harvard University. 1982-90 Lecturer, since 1990 Senior Lecturer, in Ecology, School of Biological Sciences, University of Bath. — Research interests in ecology (predator-prey interactions and community structure), behavioural ecology (kin selection, life history strategies, division of labour in social insects), evolution (self-organization and collective problem-solving in social insects). — Address: School of Biology and Biochemistry, University of Bath, Bath BA2 7AY, GB.

The central enigma of biology is that its awe-inspiring diversity and complexity (at all levels from bio-macromolecules to bio-diversity) has arisen from a process, evolution by natural selection, that involves, at least in part, randomness and chance. Self-organization theory begins to suggest how biological complexity can spring from the partly haphazard process of natural selection. Self-organization theory shows how complex and sophisticated patterns and processes can arise through large numbers of surprisingly simple interactions among the sub-components of a system. In other words, how relatively simple micro-processes can generate novel designs at the macroscopic level.

The greatest unsolved problems in the life sciences lie in the domain of developmental biology. Self-organization theory suggests an explanation of how a simple code (i.e. the genetic code) can give rise to the organism, in all its glory, be it *Eschericha coli* or *Elephas maximus*. This theory suggests how biological pattern (phenotypes) can arise without explicit encoding of all its details in the genome: it explains some of the emergent properties in biological organization. However, in science, theory alone does not suffice. Biology is both an empirical and a theoretical subject. One of the major problems in developmental biology is that not only is there, as yet,

no potentially adequate theory but that experimentation is also extremely difficult. It is all too easy to take organisms apart but very difficult to put them back together again. This is, in part, why I have chosen to investigate superorganisms rather than organisms. The supra-organismic ant colony, because it is assembled from individual organisms, can be quickly taken apart and put together again, without subjecting individual workers to invasive treatment. Furthermore, we can directly observe and quantify the critical interactions among its subcomponents: The worker in an ant colony is the functional equivalent of a cell in an organism. But unlike cells in an organism, we can directly observe the interactions among worker ants. For these reasons, social insects offer the possibility of unravelling the key enigma in biology, the genesis of the organism (and the superorganism) in evolution and ontogeny.

Ant colonies embody all of the most important aspects of biological organization. In simple terms, they are more than the sum of their parts and they are robust, flexible, fault-tolerant systems capable of self-repair. Our elucidation of these properties makes these studies of interest not only to the field of biology but also to both the academic and industrial computer-science communities.

My studies at the Wissenschaftskolleg have been dedicated to furthering our understanding of the combined role of self-organization and natural selection in biology. I have contributed to the focal project of my stay in Berlin, a book on "Building Biological Superstructures: Models of Self-Organization"*. In addition, I have completed a monograph on *Social Evolution in Ants* and written or completed a number of primary papers in this field. (These publications are listed below.)

I wish to take this opportunity to thank all the staff of the Wissenschaftskolleg zu Berlin for facilitating every aspect of my studies during the 1993/1994 academic year. I have never before encountered an institution entirely populated by such professional, helpful, cheerful and charming people. The Wissenschaftskolleg zu Berlin is indeed a superstructure which is more than the sum of its parts.

Books in Preparation:

Camazine, S., Deneubourg, J. L., Franks, N. R., Seeley, T. D. (1995) *Building Biological Superstructures: Models of Self-Organization*

* cf. pp. 255 ff. in this volume.

Bourke, A. F. G., and Franks, N. R. (1995) *Social Evolution in Ants.* Princeton University Press (in press)

Papers in Primary Journals:

Sendova-Franks, A. B., and Franks, N. R. (1994) "Social resilience in individual worker ants and its role in division of labour." *Proceedings of the Royal Society.* London (B) 256: 305 — 309

Stickland, T., Franks, N. R. (1994) "Computer image analysis provides new observations of ant behaviour patterns." *Proceedings of the Royal Society.* London (B)

Franks, N. R., and Tofts, C. (1994) "Foraging for work: how tasks allocate workers." *Animal Behaviour* 48: 470-472

(In addition, I have submitted 6 other papers to primary journals during my time in Berlin.)

Chapters in Edited Books:

Franks, N. R. and Partridge, L. W. (1994) "Lanchester's Theory of Combat, Self-Organization and the Evolution of Army Ants and Cellular Societies." In: *Behavioral Mechanisms in Evolutionary Ecology.* (ed. L. Real) Chicago University Press, pp. 390-408

Seminars:

1) "Self-Organization in Sociobiology", Wissenschaftskolleg zu Berlin, 16th November 1993

2) "The Mathematics of Warfare and the Evolution of Combat in Ants." Zoologisches Institut der Universität Zürich, 2nd December 1993

3) "Self-Organization and Collective Intelligence in Ants: Questions of Priority." Schwerpunkt "Emergence of pre-rational intelligence in biology: From sensorimotor intelligence to collective behavior", Zentrum für Interdisziplinäre Forschung Universität Bielefeld, 26th January 1994

4) "Social Organization and Self-Organization Mathematics and Biology", Joint Lecture Programme, Zoologisches Institut und Mathematisches Institut der Universität Würzburg, 11th February 1994