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Complex Systems and Evolutionary Perspectives on Organisations

The Application of Complexity Theory to Organisations

Eve Mitleton-Kelly

Pergamon

COMPLEX SYSTEMS AND EVOLUTIONARY PERSPECTIVES ON ORGANISATIONS

THE APPLICATION OF COMPLEXITY THEORY TO ORGANISATIONS

ADVANCED SERIES IN MANAGEMENT

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London School of Economics, London, UK

2003

Pergamon
An Imprint of Elsevier Science

Amsterdam – Boston – Heidelberg – London – New York – Oxford
Paris – San Diego – San Francisco – Singapore – Sydney – Tokyo

ELSEVIER SCIENCE Ltd
The Boulevard, Langford Lane
Kidlington, Oxford OX5 1GB, UK

First edition 2003

Library of Congress Cataloging in Publication Data
A catalog record from the Library of Congress has been applied for.

British Library Cataloguing in Publication Data
A catalogue record from the British Library has been applied for.

ISBN: 0-08-043957-8

♾ The paper used in this publication meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).
Printed in The Netherlands.

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Foreword

In January 1995, the first Complexity Seminar was held at the London School of Economics, in the U.K. This was quite a momentous occasion as it proved to be the turning point for the series of seminars, which had started in December 1992 as the Strategy Seminar, focusing on the relationship between Information Systems and business strategies. That seminar, and those that followed it, had a profound effect on the research interests of Eve Mitleton-Kelly, the initiator and organiser of the series and thus laid the foundation for what became the LSE Complexity Research Programme, which proceeded to win several research awards for collaborative projects with companies. But the series also provided the material for this book. Earlier versions of the papers selected for this volume were first given at the LSE Complexity Seminar series.

The seminars focussed primarily on the application of the theories of complexity to organisations — an area of study quite new to U.K. businesses and academics and slowly helped to disseminate these ideas to the business and academic communities. Many academics started to apply a complexity perspective to their own discipline and research, after being introduced to the ideas at the LSE seminars and today, there is a proliferation of networks and seminar series throughout the U.K. on complexity.

Invited speakers both from academia and business led the seminars, which lasted a whole afternoon. There were usually two presentations during the three-hour session under a common theme, and a distinctive feature of the seminars was the emphasis on discussion in depth — not just short question and answer sessions following the presentations. Most seminars, including the discussions, were written-up and reports can be found on *http://www.lse.ac.uk/complexity* The website, which was originally set up to provide a common platform for researchers in organisational complexity, also provided one of the first network links in organisational complexity and is still accessed daily throughout the world.

Another key factor was that a core of regular participants had built up, who began to use the language and the concepts with ease and erudition — so newcomers did not feel that this was an odd event with only the speaker being familiar with this new peculiar language. When the formal seminar ended at 5.30 p.m. most participants stayed, and continued the discussion over wine and sandwiches until late. We often had to leave them at 7.30 or 8.00 p.m. with the last of the wine, still deep in conversation!

It was this building of a community of interest which sustained the seminar series for a whole decade. In January 2003 there was another change in direction. The European Commission, under the FET (Future Emerging Technologies) has funded a 3-year

Network of Excellence in Complex Systems, known as *Exystence* (*http://www.complexityscience.org*) There are 21 founding academic institutions throughout Europe that together set up the Network. From these are drawn the members of the Steering Committee and the Coordinators of the various Work-Packages. Eve Mitleton-Kelly is the Coordinator of Links with Industry and Government and thus a member of the Steering Committee, and is responsible for organising 3–4 seminars p.a. on behalf of *Exystence*. The first four *Exystence* seminars were held at the LSE between January and May 2003.

Eve Mitleton-Kelly
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July 2003

Author Biographies

Pierpaolo Andriani is a physicist and has been Project Manager for various Research and Development European projects with several years experience in the laser industry and laser research. In 1997 he decided to shift from coherent laser light to incoherent life and moved from Florence, Italy, into academia at the University of Durham Business School, where he currently teaches in innovation and management of technology. Current research focuses on the application of complexity theory to industrial clusters and on knowledge management.

Max Boisot is Professor of Strategic Management at the Univesitat Oberta de Catalunya in Barcelona, Associate Fellow at Templeton College at the University of Oxford, and Senior Research Fellow at the Sol Snider Centre for Entrepreneurial Research, The Wharton School, University of Pennsylvania. He was Dean and Director of the China-EC Management Programme (1984–1989), the first MBA programme to be run in the People's Republic of China. Has set up the Euro-Arab Management School in Granada, Spain, for the EU Commission and has taught in Japan, the U.S., Hong Kong, the Middle East, Russia and France. Max Boisot has published in *Adminstrative Science Quarterly*, *Organization Science*, *Research Policy*, and other major academic Journals. His latest book, *Knowledge Assets: securing competitive advantage in the information economy* (OUP 1998) won the Igor Ansoff Strategic Management Award 2000. His current research, being conducted at Wharton, consists of building an agent-based simulation model that can be applied in the field of knowledge management.

Petruska Clarkson, D. Litt. et Phil, Ph.D., FBPS, FBACP, C. Psychol. is a Consultant Philosopher, Chartered Management Consultant (CIMC) and Chartered Organisational Psychologist (BPS), Registered Group Psychotherapist and Supervisor with some 30 years international experience, who has more than 200 professional publications (23 languages) in these fields. She has extensive experience of researching and implementing Organisational Consulting for Change, Creativity and Leadership (amongst other themes) at all levels, particularly in applying the concepts of complexity and autopoiesis. Auto-poesis (or physis) and the application of the Clarkson Seven Level Model was the subject of her third Ph.D. She leads a Transdisciplinary Professional Doctorate Programme and other Consultancies, Executive Coaching and Trainings from PHYSIS, 58 Harley Street, London. e-mail: *petruska.c@dial.pipex.com*. *www.physis.co.uk*. She is a founder of the Applied Philosophy for Business International Association with Dr. Katerina Nicolopoulou

Raul Espejo is Managing Director of Syncho Ltd. and Visiting Professor at University College Worcester, U.K. He has published extensively in books and journals; is the author of over 50 academic papers, co-author of the books *Organization for Programme Management* (Wiley, 1979) and *Organizational Transformation and Learning: A Cybernetic Approach to Management* (Wiley, 1996) and co-editor of the books *The Viable System Model* (Wiley, 1989), *Organizational Fitness: Corporate Effectiveness Through Management Cybernetic* (Campus Verlag, 1993) and *To be and not to be, that is the System* (Auer Verlag, 1997). He has lectured and run seminars worldwide. In 1985 he created Syncho Ltd., a management consultancy in the field of organisational cybernetics, in the Science Park of Aston University and has been consultant of organisations like Hoechst AG in Germany, Hydro Aluminium in Norway, 3M in Europe, EdF in France and the Nuclear Inspectorate in Sweden and the National Audit Office and the Ministry of Education in Colombia. His current research is focused on the information society, organisational learning and transparency in decision-making. In particular he has been working in transparency issues related to the management of nuclear waste, initially in the context of the Swedish Nuclear Waste Programme and more recently in the contexts of the French and U.K. programmes.

Jane Gillies is a Research Fellow at Cranfield School of Management and Project Co-ordinator of NEXSUS, an ESRC funded Priority Network concerned with sustainable complex systems. This project involves six different projects of research across five universities, with the aim of developing inter-disciplinary models and definitions and increasing understanding of dynamic network processes. Her research interests focus on networks and organisational structures within industrial, business and public sector contexts. Specifically these relate to issues of network formation and growth, especially relationship building, collective behaviour and knowledge and learning processes. Key drivers and problems addressed are concerned with resilience, reliability, adaptability and co-evolution.

Lucas D. Introna is a Reader in Organisation, Technology and Ethics in the *Centre for the Study of Technology and Organisation* at Lancaster University. His research interest is the social dimensions of information technology and its consequences for society. In particular he is concerned with the way information technology transforms and mediates social interaction with specific reference to the moral dimension. He was associate editor of *Information Technology & People* (1996–2000) and is co-editor *Ethics and Information Technology.* He is a founding member of the International Society for Ethics and Information Technology (INSEIT) and an active member of IFIP WG 8.2, The Society for Philosophy in Contemporary World (SPCW), and a number of other academic and professional societies. His most recent work includes a book *Management, Information and Power* published by Macmillan, and various academic papers in leading journals and conference proceedings on a variety of topics such as: theories of information, privacy, surveillance, information technology and post-modern ethics, autopoiesis and self organisation in social systems, and virtual organisations. He holds degrees in Management, Information Systems and Philosophy.

Roger Lewin Ph.D. is a prize-winning author of 17 science books, including the acclaimed *Complexity: life at the edge of chaos*, which was named as one of the 100 most important science books of the twentieth century; he was the recipient of the inaugural Lewis Thomas Award for excellence in the communication of life sciences, in 1989; and the 1992 Annual award for contribution to issues in conservation, by the Society of Conservation Biology. Between 1990 and 1993 he was a visiting professor in biology at Wayne State University, and an Associate of the Peabody Museum, Harvard University from 1993 to 1998. He is a member of the Complexity Research Group at the London School of Economics, and speaks frequently at national conferences on complexity science and business. In 1998, Lewin and his partner Birute Regine, founded Harvest Associates, a business consultancy that brings the principles of complexity science to businesses that are struggling with transformation and change. In January 2000 Lewin and Regine published *The Soul at Work: embracing complexity science for business success*. which focuses on complexity in the human domain.

Robert MacIntosh received his Ph.D. in engineering from the University of Strathclyde and is currently a senior lecturer in operations management at the University of Glasgow. His research interests lie in the area of organisational transformation and this has led to extensive work on business process re-engineering as well as managerial applications of complexity theory. Working with concepts from complexity theory has also resulted in a parallel stream of work on management research methods which treat the knowledge production process as a complex adaptive system.

Donald MacLean received his Ph.D. from the University of Cambridge and spent several years working in the opto-electronics industry. He is a senior lecturer in strategic management at the University of Glasgow and his research interests lie in the development of alternative conceptions of the process and purpose of management. This research has involved the development of managerial applications of complexity theory. Together with Robert MacIntosh, he co-founded the Scottish Centre for Organisational Transformation (SCOT) which works in collaboration with a network of public and private sector organisations.

Ian McCarthy is an Associate Professor of Management of Technology in the Faculty of Business Administration at Simon Fraser University. His research focuses on understanding and designing competitive and sustainable organisational forms using systems methods, classification tools and evolutionary concepts. He is a qualified chartered engineer, a college member of the U.K. Engineering Physical Sciences Research Council and a director of the Complexity Society. Previously he was on faculty at the University of Warwick and the University of Sheffield; and held management positions at Philips Electronics, British Alcan and Footprint Tools.

Bill McKelvey received his Ph.D. from the Sloan School of Management at MIT in 1967 and is currently Professor of Strategic Organizing at UCLA's Anderson Graduate

School of Management. Early articles focus on organisation and socio-technical systems design. His book, *Organizational Systematics* (1982) remains the definitive treatment of organisational taxonomy and evolutionary theory. He chaired the building committee that produced the $110,000,000 Anderson Complex at UCLA—opened in 1994. He has directed over 170 field study teams on 6-month projects concerned with strategic and organisational improvements to client firms. In 1997 he became Director of the Center for Rescuing Strategy and Organization Science (SOS). From this Center he initiated activities leading to the founding of UCLA's Center for Computational Social Science. Recently McKelvey co-edited *Variations in Organization Science* (with Joel Baum 1999) and a special issue of the journal, *Emergence* (55 reviews of 34 books applying complexity theory to management) (with Steve Maguire 1999). Current publications focus on: philosophy of science; complexity science; self-organisation vs. selectionist order-creation; coevolutionary theory; human and social capital aspects of competitive strategy; distributed intelligence; organisation design; organisational dynamics; knowledge-flow dynamics; and bottom-up science via agent-based, adaptive-learning, computational models.

Eve Mitleton-Kelly is Director and initiator of the *Complexity Research Programme* at the London School of Economics, U.K.; Visiting Professor at the Open University; Coordinator of Links with Industry & Government in the *European Network of Excellence on Complex Systems*, *Exystence*; Director and Executive Co-ordinator of *SOL-UK (London)*, which is the London group of the global network *Society for Organisational Learning*. The focus of her research has been the strategy process in the business and information systems domains, with over 90 companies in the U.K. and USA. Her recent work has concentrated on the implications of the theories of complexity for IT legacy systems, organisational learning and the emergence of organisational 'forms' and has developed a methodology for identifying conditions that enable and constrain those processes, using the principles of complexity.

Katerina Nicolopoulou is a Research Fellow at INSEAD Business School, France as well as a Lecturer in the University of Westminster. She attained her doctorate (Ph.D.) at the London School of Economics (LSE), on the phenomenology of organizational learning and the use of new technologies in large scale organizations. Her previous work assignments include consultancies at the World Bank (Leadership Development Group), UNESCO (Division of Cultural Policies) as well as the private sector. She is a certified phenomenlogist, certified organizational and research supervisor and focus group facilitator. Her research interests include post-modern epistemology in thinking and practice and the implications for management realities in changing organizational, technological and socio-economic conditions. She is a co-founder with Professor Petruska Clarkson of the Applied Philosophy for Business International Association and co-Director of the European Institute for Interdisciplinary Research in Paris.

Birute Regine is a Harvard-educated developmental psychologist and therapist, who specialises in the dynamics and development of relationships. She collaborated with Carol Gilligan, author of a *Different Voice* on a naturalistic study of relationships in crisis at the Harvard Project on the Development of Girls and the Psychology of Women. She was also a teaching fellow for Erik Erikson and trained in gestalt therapy with Michael Miller. In 1996 and 1997 she was a visiting scholar at the Center for Research on Women and affiliated with the Stone Center at Wellesley College, Massachusetts, where she developed a narrative approach to organisational change. A prize-winning writer, she also speaks frequently at national conferences on complexity science, soul and business. She is currently a member of the Complexity Research Group, at the London School of Economics.

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Part I

Introduction

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Chapter 1

Introduction

Eve Mitleton-Kelly

Complexity is a relatively new discipline with immense power to change our way of thinking and seeing the world. This, in turn, can change the way we 'manage', design and structure organisations and create new ways of working and relating.

The book has brought together a set of selected papers by European and American academics from a variety of disciplines, that look at both the development of a new theory of *complex social systems* and its possible application to organisations. The specific authors were invited to contribute, because their work makes a significant contribution to the unfolding and understanding of these new and exciting concepts. They do not all agree with each other, but since diversity and variety is at the heart of complexity they each provide a strand of an intertwined whole, which will enrich and deepen our understanding. In an environment of increasing uncertainty and ambiguity it is necessary to learn how to hold, in tension, disparate or even contradictory views, without undue stress. The world is not a simple dyadic black or white entity, but a rich multi-coloured and many-hued ensemble, each strand or perspective contributing to an intricate and inter-related n-dimensional whole.

This therefore is not a 'text book' on complexity with a uniform perspective. The authors offer different perspectives and views on complexity. For example Mitleton-Kelly (Chapter 2) concentrates on '*objective*' complexity while Boisot (Chapter 9) focuses on *subjectively experienced* complexity and Espejo (Chapter 3) introduces the notion of *individual* complexity. Some authors (Mitleton-Kelly Chapter 2, Introna Chapter 10, and McKelvey Chapter 5) make a strong point about not using complexity exclusively as a metaphor while others are happy to do so. These different approaches explore different ontological and epistemological domains — ways of being and knowing — and consequently use different domains of discourse. Clarkson and Nicolopoulou (Chapter 11) provide one possible framework for the different perspectives by distinguishing seven domains of discourse based on epistemological preferences. What the chapters have in common, however, is that they are the result of long-standing research using the principles of complexity. They are the result of passion and commitment to the development of new ideas and to the exploration of the space of possibilities.

Complex Systems and Evolutionary Perspectives on Organisations

ISBN: 0-08-043957-8

The eleven chapters have been grouped into five Parts. Part I introduces each chapter and provides an overview. In some cases it also offers a simpler version of the argument that may help those not familiar with the concepts. It also highlights the unique contribution that each chapter makes to our understanding of organisations using a complexity perspective.

Part II sets the context by outlining the essentials of Complexity Theory for organisation studies, in terms of ten principles. It uses the 'logic' implicit in those principles to argue for a different way of organising, using an 'enabling infrastructure' of social, cultural and technical conditions to create an organisational environment that may facilitate organisational renewal, co-evolution and sustainability.

Part III offers four different perspectives on organisational processes. Raul Espejo (Chapter 3) uses the perspective and discourse of autopoiesis to make an insightful contribution to the study of complex social systems. McCarthy and Gillies (Chapter 4) introduce cladistics as a method of classification and help us to see the evolution of a whole industry as a complex adaptive system. Bill McKelvey (Chapter 5) addresses one of the key issues in complexity, the creation of new order and explains clearly and elegantly some difficult concepts in complexity science, such as entanglement, which may have some practical management applications. Pierpaolo Andriani (Chapter 6) re-interprets the industrial cluster from a complexity perspective with some surprising findings.

Part IV focuses on the implications of complexity theory for management processes. All three chapters use specific practical examples and discuss the implications in different contexts. The Lewin and Regine chapter (Chapter 8) is based on a study of a dozen companies in the USA and U.K. with detailed analysis of three cases: a Medical Centre in the USA, an advertising agency (St. Luke's) in the U.K. and a chemical process plant (DuPont). Two of the findings are of particular interest. In all three cases those involved were prepared to 'experiment' with new ways of working and to explore the space of possibilities. An enabling environment had also been created in all cases, which facilitated the emergence of new structures. These findings link directly with the discussion in Chapter 2 of an enabling infrastructure. MacLean and MacIntosh (Chapter 7) also discuss a specific case, but they trace the problems found by the application of a theoretical model in practice. This is an extremely valuable study as a contribution to the current debate on 'simple rules' and offers a good example of inappropriate application. Max Boisot (Chapter 9) takes his established work on the I-Space (Information Space) and develops it further by introducing Kauffman's NK network to show phase transitions in the I-Space that reflect ordered, complex and chaotic social processes. He then links strategic choice to the theory.

Part V deals with the philosophical issues in applying complexity theory to organisations. Lucas Introna (Chapter 10) claims that the nature of mathematical and physical systems is fundamentally and qualitatively different from social (human) systems. Introna also offers a convincing argument that complexity used only as a metaphor or analogy is limiting and often inappropriate. Clarkson and Nicolopoulou (Chapter 11) offer a framework, which differentiates between 7 different domains of discourse and explain some of the problems we encounter when we confuse or conflate the domains. Although this is the last chapter in the book (which is a linear devise) it fits well into a complexity context as it starts the next iteration by inviting the reader to go back to earlier chapters and re-read them using the 7 Domain framework.

The ten chapters that follow make a unique contribution to our understanding of complexity in an organisational context. Each chapter provides a different perspective of a complex organisational world and builds understanding by providing different pieces of a multi-dimensional jigsaw puzzle.

Part II: Essentials of Complexity Theory for Organisation Studies

Chapter 2 sets the theme, defines terms and explores ten 'generic' characteristics of complex adaptive systems. It explains how complexity arises through interactions of individual elements; it provides some of the scientific background to the development of this new theory and introduces the following generic characteristics of complex adaptive systems: self-organisation, emergence, connectivity and interdependence, feedback, far-from-equilibrium, exploration-of-the-space-of-possibilities, co-evolution, historicity, path dependence and the creation of new order. Its major contribution, however, is the attempt to begin a journey of exploration in developing a theory of *complex social systems* and in applying the theory to organisations. Chapter 2 explains that all organisations are complex social systems and that understanding them as such, provides executives with a powerful tool to create the conditions that will help organisations to co-evolve with a constantly changing economic and market environment.

Although the chapter discusses the scientific background to the principles or characteristics of complex systems it avoids a direct mapping from physical, biological, mathematical and other complex systems, onto social (human) systems. Introna (Chapter 10) eloquently explains the difference between physical and mathematical (and to this could be added chemical and biological) systems and social systems.

Chapter 2 critically assesses whether and how each generic characteristic is relevant and appropriate to a human complex system. It takes a strong stand in not adopting the widespread practice of using complexity as a metaphor or analogy but of trying to understand the *nature* of complex social systems and thus begins the development of a new *social complexity theory.* Introna (Chapter 10) explains why both metaphor and analogy are inadequate. He also argues for extensive scholarship, for the development of a new vocabulary and for detailed empirical work. All these requirements will take time, but a beginning has been made in both introducing a new vocabulary within an organisational context and on empirical work as illustrated by the other nine chapters.

A key characteristic of complex systems is their ability to create new order; that is to create something innovative and new. McKelvey (Chapter 5) explores the creation of emergent order in firms, in depth and provides a scholarly argument, based firmly on the physics, biology and organisational science.

It is recommended that readers read Chapter 2 first, to familiarise themselves with concepts and language of complexity.

Part III: Complexity Perspectives on Organisational Processes

Espejo in Chapter 3 takes quite a different standpoint and focuses on what he calls individual and social complexity. He introduces the term '*bodyhood*', which is defined as 'the embodied knowledge or complexity of an organisation, which is constituted by its resources (human and others) and their relations'. This is associated with variety or the number of the possible states of a situation, which could be extraordinarily large. However, the number of actual states we are aware of is much smaller and is dependent on our history and situation — Espejo therefore calls this *situational complexity.* "My *complexity in this situation* is likely to evolve from the distinctions I can make. They relate to the *actions* required from me in that situation over time". An individual's history is the series of selected distinctions and decisions made over time, from the many possibilities open in time and space, to that individual. They thus become the repertoire of incorporated practices, which make up that individual's bodyhood. Espejo then relates language, which becomes the articulation of the actions throughout one's history, to the space of possibilities.

The importance of bodyhood or the incorporated distinctions and practices, which define personal complexity, becomes clear when it is linked with learning. Because learning takes place when we embody new distinctions and practices.

Espejo distinguishes a social system from an institution and defines a social system as one that emerges from the *interaction* of individual roles, not from the individuals themselves. What he is trying to establish is that when individuals come together in a rich network of interactions, they may create the social system. While if they happen to be brought together through contingency (e.g. living in the same area or country) or through outside agency (they are employed by a specific organisation) they may not create the cohesion necessary for the creation of a social system.

Espejo's discourse is grounded in autopoiesis (the theory of self-production) and the terms and ideas he uses come both from the founders of biological autopoiesis (Maturana and Varela) and from social autopoiesis, developed by Luhman. According to Maturana, conversations are interactions in which people braid language and emotions. For example, a family creates cohesion and becomes a social system in conversation, and the "languaging[1] of their interactions is likely to be modulated by emotions like love and solidarity". If that cohesion is not sustained over time they are no longer a social system, only a collective. Furthermore learning takes place in a shared context.

Putting all this together we get self-constructed social systems, whose meanings are created by them. In this sense they are purposeful human activities, while for institutions, the generation of purpose often comes from outside, i.e. others create the meanings for them. They are purposive rather than purposeful. The implication is that

[1] **Languaging**' is the capacity we have to bring forth the world as we make distinctions in language (Maturana & Varela 1992: 234). Another term used in a special way is '**organisation**'; when used in the singular it means "a closed network of people in interaction creating, regulating and implementing its social meanings". When used in the plural, it is used in the normal sense of the word to mean a number of organisations.

the creation of meaning and the doing are separated and there is no direct communication of those creating the meaning with the environment. Thus, their learning is less effective. This is one of the main conclusions of the chapter — that a social system creates the capacity for learning and change and that not all institutions are necessarily social systems, only collectives. It follows from this that certain institutions are dysfunctional and the question raised is 'how can desirable social systems be produced?' The chapter explores a possible answer — it is based on learning, on reflection and an effective organisation structure.

Furthermore, it is the alignment of purpose in the information domain with identity in the operational domain that is critical in the emergence of an effective organisation, with the coherence of a social system. The process of meaning-creation is therefore critical and Espejo makes the strong claim that "failure, tension and unfairness in many systems are the result of poor understanding of meaning-creation-processes and of unreasonable external impositions".

The internal processes of meaning creation are predicated on closing the gap between individuals' meanings and the meaning they generate through the total organisation produced by their interactions, which may be achieved by enabling effective self-organising processes and through reflexivity and recursive leaning. A system's meaning is produced through the interaction of autonomous units, within autonomous systems, within autonomous systems and so forth. This unfolding is at the core of the *recursive organisation* of social systems (Beer 1979, 1985) and Espejo argues that the embodiment of organisational complexity requires this recursiveness. The challenge facing us is creating new desirable social systems and autonomy is the 'engine' identified for social development.

McCarthy and Gillies in Chapter 4 address organisational diversity, configurations (i.e. the form and defining characteristics of an organisation) and evolution through the framework known as cladistics. This is an evolutionary classification technique used within linguistics and the biological sciences. Chapter 4 introduces and defines organisations as complex adaptive systems that have a decision-making capacity capable of influencing current and future configurations. The Chapter discusses the value of classification and the different approaches that are used to produce organisational classifications. It summarises the various benefits and disadvantages of each approach, and provides guidelines for producing a classification of organisations. In accordance with these guidelines, McCarthy and Gillies propose the use of cladistics, and discuss the philosophic, theoretic and pragmatic issues associated with this method of classification.

The authors claim that complex systems theory is relevant to the study of organisational configurations, because of the following characteristics:

- The interacting components (technology, people, information, etc) within an organisation *self-organise* to create order i.e. a configuration.
- Understanding the *emergence* of new configurations helps organisations to identify new opportunities.
- Organisational configurations are considered to be complex adaptive systems that demonstrate goal directed *adaptation*.

A point to note is that McCarthy and Gillies advocate the use of metaphors and tools, which are able to capture characteristics such as self-organisation, emergence, innovation, learning and adaptation. They therefore open the debate in the book, on the use of metaphor and of tools, which have their origin in the biological sciences.

They also raise some very interesting and currently relevant questions, on the value and application of cladistics, in terms of: (a) Benchmarking — what is our current competitive position and how do we compare? (b) Diversity and configurations — where do we want to be? (c) Change, parsimony and strategy — how do we get there? (d) Population Ecology — what promotes an increase in a certain type of configuration?

Chapter 4 is a learned journey through the different terms of classification and clarifies the difference between, for example, typologies and taxonomies. Organisational classifications do not yet have a governing body for approving a standard classification system and the Chapter suggests some guidelines for a classification framework. McCarthy and Gillies take into account all the guidelines and propose cladistics as a method of classification. Cladistics studies the evolutionary relationships between entities with reference to the common ancestry of the group and the method is used by the authors as a way of classifying entities according to how they have self-organised, adapted and emerged over time. The result is a cladogram, which represents the known and emerging configurations as a series of bifurcations with resulting patterns and relationships. The example given is a cladogram of the automotive industry showing a common ancestry of Ancient Craft Systems. Bifurcations are shown over time and according to a set of cladistic characters, which position, for example the Toyota Production System as a bifurcation from Flexible Manufacturing Systems, which in turn have Just In Time Systems as their immediate ancestor.

Such classifications, the authors claim, provide insights into organisational diversity, such as observing the patterns and events, which accompany organisational change, and observing the most parsimonious route between different configurations. Furthermore, since the cladogram is a hierarchical system of information and relationships, it enables the addition of new configurations as time progresses and stimulates enquiry, observations and theory formulation.

McKelvey in Chapter 5 asks the fundamental question: "What causes order?" This is a multidisciplinary concern, which applies to matter, life, brains, artificial intelligence and social systems. He argues that ideas arising from quantum mechanics and its later development introduce concepts and words such as *entanglement, correlated histories, decoherence* and *coarse-graining* that can help organisation scientists in understanding the creation of new order in firms. 'Order' is taken to mean both the emergence of different *entities* or 'kinds' (organisms or social entities) and new *connections* between them. Furthermore, connections become ordered only in the context of environmental constraints.

Although he explores the history and application of these terms through the natural sciences, he does focus on social systems and draws out two key elements that seem relevant to organisations: (1) the notion of *entanglement* or *correlated histories* between pairs of agents; and (2) the *Bénard* process as the main engine of order-creation that applies across all phenomena from matter to social systems. Both are needed if *efficacious* and not maladaptive emergence is to occur — that is emergent structure fostering adaptation that enhances survival.

Entanglement can be seen as the interdependence of two entities (electrons or agents) such that neither can behave nor be understood independently; each entity has a *history* of effects from all the other entities it has come in contact with and cannot be isolated from its interactions with these entities. Entanglement occurs when a pair of entities has *correlated histories*. The negation of the entanglement effect is *decohence.* The first part of the argument is that firms need to create and re-create entanglement pools by introducing and maintaining *variety* and by discouraging the retention of obsolete structures based on strong cliques, advance specialisations, narrow functional boundaries, etc. Decohence or de-ordering of the old structures needs to take place, to 'uncorrupt' the entanglement pool if it has become corrupted by legacy structures.

The second part of the argument is based on the Bénard process and what McKelvey calls *adaptive tension*. The Bénard process is explained in Chapter 2, briefly, it is based on two horizontal plates with a thin layer of liquid between them. At rest the temperature of the plates and the liquid is uniform; however, when heat is applied to the bottom plate, a temperature difference is created between the bottom and top plate and conduction followed by convection set up a motion in the liquid. After a certain critical value the molecules in the liquid order themselves into right and left-handed cells. The ordering is emergent in that we cannot know in advance the direction of the cells, which cell will be left-handed and which right-handed, although we do know that after the first critical value the cells will appear. The difference in temperature between the bottom and top plates creates what McKelvey calls *adaptive tension*.

The two parts of the argument go thus: firms need to encourage both variety and networking at the *micro* level while *at the same time* creating adaptive tension that will produce efficacious emergent structures at the *macro* level. Creating the conditions that facilitate variety and/or emergent macrostructures, McKelvey argues, cannot be done in sequential alternation focusing on variety and then on emergent structures and back to variety, etc. Both activities have to exist at the same time. The other point McKelvey makes is that these activities cannot be expected to have an effect in the short term and that CEOs need to consider yearlong horizons.

In considering what fosters entanglement pools McKelvey introduces the idea of *entanglement ties*. He suggests that the entanglement pool is analogous to Granovetter's "strength of weak ties" finding, with the proviso that the ties encompass a broad set of correlated substantive interests across agents within a firm. He adds that the pool of weak ties also satisfies Ashby's "requisite variety" required for efficacious emergence to occur. Reviewing the literature that followed Granovetter's finding, McKelvey lists the different types of ties and introduces *entanglement ties*, defined as "direct weak ties that are not so weak as to not have some kind of recognised correlated 'history' of interaction nor so strong as to have established a collective 'pair-wise' bias against or predisposition toward specific organisational change possibilities".

Some suggestions on how to foster entanglement ties, while satisfying the requisite variety law, are to: (a) create a denser network of ties; (b) bring in employees with diverse backgrounds (histories) and interests; (c) create a diversity of meeting possibilities to 'connect' their histories; (d) create "imposed field effects based on incoming stimuli" that focus on creating entanglement ties rather than on emergent structure. 'Fields' are described as culture, specific organisational and power structures (e.g. command and control), markets, technology, etc.; and (e) to destroy or de-order obsolete structures, so as to recreate viable entanglement pools. What McKelvey is trying to identify are the conditions that will facilitate the regeneration of the right kind of entanglement pool and points out that producing entanglement at the micro level is independent of producing emergent macrostructure. He also acknowledges that activities aiming to create entanglement and efficacious emergence could work at cross-purposes. Nevertheless the two tasks of regenerating the entanglement pool and of creating adaptive tension are necessary and sufficient for the creation of efficacious emergent macrostructures.

The chapter goes into some depth to explain the background to entanglement including the difference between fine and coarse graining. Briefly, according the Gell-Mann the quantum world is the fine-grained structure, whereas the world of classical physics is the coarse-grained structure — one way of thinking about the difference is between the micro and macro levels of individual agent interaction and emergent macrostructures and the question McKelvey raises is "how does coarse-grained structure emerge from fine-grained — entangled — structure?" Those who need a good review of the literature and deeper understanding of these concepts will find the chapter of immense value. While those readers looking for a sound theoretical base for regenerating organisations and creating new order (new organisational structures or different ways of working and relating) will find the effort of going through the theoretical section of the chapter well worthwhile to provide the context for the more practical suggestions.

In addition, the chapter clarifies what complexity science is about — *it is fundamentally aimed at explaining order creation*. Since physicists have developed a language for talking about how order emerges from disorder at the quantum level, McKelvey suggests that this language helps organisation and complexity scientists understand how order emerges in firms. He does not use the language as a loose metaphor but to offer additional insights. He furthermore asserts that: "*Complexity theory applications to firms rest on environmental constraints in the form of Bénard energy-differentials as the engines of order-creation — defined as the emergence of both entities and connections constrained by context*. The latter, when applied to firms, are best thought of as 'adaptive tension' parameters". He adds that there are some valuable lessons from the natural sciences in understanding complexity and making it applicable to the management of firms, such as the shift from assumptions of homogeneous agents and statistical mechanics to heterogeneous agents and agent-based modelling; as well as recognition of the importance of an uncorrupted entanglement field as a precursor to efficacious emergence together with the Bénard process. Furthermore to be useful complexity theory has to offer a positive. It is not enough that managers are convinced that their firm is *not* a machine, they also need practical guidance and advice about what to do; and complexity science based on an understanding of the physical and biological applications of complexity theory does add value to organisational applications.

Andriani in Chapter 6 presents twelve rules for complexity, which include some of the principles or generic characteristics of complex systems, discussed in Chapter 2. He uses complexity and economic geography to develop an evolutionary model of the dynamics of industrial clusters, using the Italian town of Prato as a paradigmatic form of an industrial cluster, but also citing research on Hollywood and Silicon Valley. The literature on clusters uses economics and sociology and focuses on the network form of organisation. Andriani uses complexity to reinterpret the cluster phenomenology and reaches the following conclusions:

- A cluster is an emergent property arising from the interaction of a network of organisations within a geographic locality;
- It is defined by a particular type of environment, which features particular technologies and production methods; a distributed system of knowledge and a community;
- The social transactions set up an internal dynamic, which sustains the cluster;
- Continuous innovation and adaptability to extreme fluctuations in the market characterise the cluster;
- Knowledge in a cluster is highly distributed, tacit and dynamic. Individual agents act on local knowledge on the basis of micro motives; yet their constant interaction creates the macro behaviour of the cluster and its collective knowledge.

Taking the above conclusions into consideration, Andriani suggests that the industrial cluster, seen from a complexity perspective, breaks the axiom of asymmetry, which states that a large company can do everything that a small firm can do, but not vice versa. The cluster provides the small business with the conditions only available to a large organisation. In particular the cluster is able to achieve economies of scale through cluster coordination and to exploit the advantages of internal variety through diversification and constant innovation. Furthermore, the cluster form helps individual firms overcome the lack of information, which hampers small but isolated firms. The social cohesiveness of the cluster facilitates the rich exchange of information distributed within it, in a form idiosyncratic to the cluster.

Part IV: Implications of Complexity Theory for Management Processes

MacLean and MacIntosh describe a fruitful and instructive journey in Chapter 7. They start with three key insights from complexity theory: (a) that the structures, processes and procedures of an organisation can be generated by a *simple set of rules*; (b) that *positive feedback* can drive an organisation from one state to another; and (c) that for an organisation to become open enough to its environment to trigger a change in its order generating rules, it must experience *far-from-equilibrium* conditions. On the basis of these insights they developed a model called Conditioned Emergence and tried to apply the model to a real organisation. What happened in the next 2–3 years changed both their theoretical stance and the model itself.

One of the authors is a scientist and his Ph.D. work at Cambridge focused on non-linear and complex effects in optoelectronic switches and the other has been involved in research into business process re-engineering. Between them therefore they cover academically both the science and business studies domains. This shows in the clear way in which they describe the complexity principles that they use, such as dissipative structures. On the other hand this background may also have contributed to a rather direct application of principles from the natural sciences to human systems. In a very honest and disarming account of their intellectual journey, and after trying to apply their model in practice they came to the conclusion that "complexity theory must be developed further to embrace many of the idiosyncrasies of social systems and human elements . . . such as reflexivity, intentionality, emotion and intuition . . ."

Being aware of the criticisms against 'simple rules', they nevertheless persevered with the assumptions that identification of existing rules and new order generating rules, would help the organisation achieve a "rapid switch from one organisational archetype to another". They achieved the first part of the approach, which was to identify the existing rules. The problem came when the new rules were to be applied. The organisation refused to have such rules imposed from the top. This is a very important finding as it indicates that such 'rules' tend to emerge rather than be designed. It also indicates that the organisation as a whole, in its manifold interactions, creates its way of working and relating and the 'rules' then emerge from those interactions and new ways of working.

Another important finding was that the company developed its own variant of the Conditioned Emergence model influenced partly by the knowledge of complexity theory gained by the Managing Director and partly by the circumstances and experience of the senior team. That is, both theory and situated practice influenced the development of the model. It is interesting to note that only knowledge of complexity by the MD is mentioned. This is not an uncommon feature and has been observed in several other organisations, that only the top executive and sometimes his closest colleagues gain an understanding of the theory.

The benefits of the exercise were other than anticipated. MacLean and McIntosh introduced complexity and the Conditioned Emergence model to an undergraduate course on the management of transformation. They involved a set of students in the project and started a dialogue with the company through the MD. The dialogue set up between the academics, practitioners and students helped to reinterpret the model — and to see the primary task of management as the *facilitation* of emergence by *managing the interconnectedness*. In other words the emphasis has shifted to relationships and more specifically to the "*knowledge-creating network of relationships*". It is the creation of new knowledge and its sharing through learning that may ultimately make a difference.

Another important finding was that "intuition and emotion play a role in the recognition of an emergent property". The authors conclude from that finding that emergent properties are "somewhat in the eye of the beholder" which may be taken to mean, purely subjective. There is however an alternative reading, and that is that we need to learn to 'see' new patterns or properties as they emerge. If this could be achieved it would provide a significant advantage in a changing and competitive environment.

Finally, the authors conclude that learning, research and development are co-emergent properties of networks of relationships, and that this finding has implications for policy. The suggestion is that policy (of the funding Research Councils?) should promote the tri-partite relationship — but not in order to abstract, generalise and diffuse (which are the usual requirements of funded research), as this can only be of limited application; instead they should establish, nurture and recycle a plethora of transient, knowledge-producing micro-systems. This conclusion arises from the experience that each human system is quite unique, with its own history, culture and set of relationships. It therefore appears to be very difficult to generalise findings across different unique organisations. Perhaps what may be required are some general frameworks, which would then need to be specifically tailored to each organisation.

The debate on the use of 'simple rules' (i.e. whether organisations operate on the basis of a set of simple rules) in academia, consultancy and business would benefit from the lessons so clearly and honestly described by MacLean and MacIntosh. One of the key findings was that 'rules' emerge and cannot be designed and imposed top-down. Another was that understanding complexity theory did help the MD of the company and was instrumental in facilitating the creation and sharing of new knowledge.

Intuition and emotion also feature in the Lewin and Regine chapter (Chapter 8), which is based on a study of a dozen companies in the USA and U.K. ranging in size from 35 to 22,000 people. Lewin is the well-known author of '*Complexity: life at the edge of chaos*' and Regine is a developmental psychologist who specialises in the dynamics of relationships. The joint background of the authors comes through clearly in the chapter, with a clear understanding of complexity and an emphasis on relationships as one of the key findings from the study. They do not use complexity as a metaphor but believe that "by understanding the characteristics of complex adaptive systems in general, we can find a way to understand and work with the deep nature of organisations".

The chapter uses material and direct quotations from named individuals in several of the companies they studied. The collective force of these reported views shows the beginning of a change in thinking in CEOs. Not all started by knowing about complexity — most used intuition to help them change their organisations. However, what all had in common was that they were using the principles of complexity in an intuitive way. What they lacked was a theory to back up their 'hunches'. The two authors and this book, suggest that Complexity provides that theoretical underpinning which explains why the practices the various CEOs adopted were usually successful.

The chapter focuses on what they call '*paradoxical leadership*', which is the kind of leadership they found was common in the organisations they studied. One paradox is the paradox of allowing — which is providing direction without directing, or freedom with guidance. Another is the paradox of accessibility in that leaders are mutual but not equal — mutual in respect and ability to affect and be affected by others and also not equal in power.

The organisations they chose to study were organisationally flat, encouraged rich communication and valued diversity. They also explored new ways of working and relating. Most did not know whether the new approach they were adopting would work. In most cases it did. For the majority of the leaders it also involved a personal transformation and a change of mind set — they had to learn that they could not control their organisations but only influence where the company was going and how it evolved. Many described paying attention to people as individuals not as 'workers' or 'employees' and one manager described it as: ". . . without seeing who the person is, wanting them to be something for you rather than recognising who they are, is an act of imposition, not engagement. To be blunt, it's dehumanising. And people will resist when they're not included in the process and have things imposed on them".

The study found three common behaviours between these new leaders: they *allowed* new processes to emerge rather than be imposed; they were genuinely *accessible*; and they were *attuned* to their organisations, both at the macro level of the whole system, and at the micro level of interaction between individuals.

The process of *allowing*, means that they encouraged experimentation, and created the conditions whereby mistakes, contradictions, uncertainty and paradox were accepted, so that the organisation could learn and evolve. Being *accessible* and being *attuned* are linked, as both require an ability to listen to what individuals, teams and the organisation as a whole are saying. To this I would add, that a good leader is also attuned to the subtle changes in the external environment — to what the market is saying and what their customers need.

In one case study, the vice president of Patient Care at a USA Medical Centre, Linda Rusch, describes the *ripple* effect of small changes, which could propagate through the organisation building a critical mass for change. Those small introductions of change have been named '*trojan mice*' by Peter Fryer, the ex-Managing Director of the Humberside Training and Enterprise Council, in the U.K. He borrows and adapts the powerful and descriptive idea of the Trojan horse, infiltrating the organisation with small ideas or practices, which could have a significant effect. At the medical centre, Rusch introduced a question to her nurses: "how do the Medical Centre nurses care about their community?" From this small innocuous-seeming question sprouted many community projects, initiated by the nurses, and run voluntarily in their own time. The outcome was many small changes in the hospital's relationship with the community, which built a critical mass for some fundamental changes to take place. This is a key finding, as change often takes place at a micro level of individual interactions; which may then propagate through the organisation in an exponential manner, helping to create some major changes at a macro level. This also makes an organisation more responsive to changes in the environment and helps it co-evolve, which may reduce the need for externally imposed restructuring.

The main case study described is St. Luke's advertising agency in London, U.K. St. Luke's was set up from the beginning as a non-traditional business with the following elements: (a) the company's equity was distributed equally among all staff; (b) no one has a personal office, but they do have a 'chill-out space' which combines café, games room and library, and various 'brand rooms' which are rooms set aside for each client, decorated according to the pitch being developed; (c) the traditional linear model of creating advertisements, whereby the work passes from one person to the next, was transformed into a non-linear process, where everyone met at the same time in the brand room and resolved problems as they arose.

St. Luke's became so successful that they had to stop taking new accounts to reduce the stress on their staff, despite the fact that it had more than trebled in size. Some key characteristics, which contributed to this success were: (a) the emphasis placed on rich internal interactions of everyone in the organisation; and (b) the collaborative approach they adopted with their clients. The clients became involved from the very beginning with the St. Luke's team, and together they co-created the advertising campaign. This act of co-creation and direct involvement is again a common element in organisations using complexity thinking. In a totally different environment, in a DuPont chemical process plant, the operators and mechanics directly affected were involved in the re-design of a new control system, instead of the usual practice of bringing in outside engineers. The operators, mechanics and engineers worked together to co-create the new system that was up and running in "half the time and half the cost that it normally takes".

In all the cases cited a common element was trust. Individuals were trusted to get on with the job. Another element was the language used to describe these changes — they variously called it 'an experiment' or 'to experiment' or 'experiment in progress' or 'grand experiment' — and in each case the leader created an environment, which encouraged exploration of the new and cultivated conditions where people could self-organise and could create new structures. The emphasis throughout is on relationships. As the authors point out, human-relations management is not new, what is new is that complexity provides insights into *why* such practices are usually successful.

In Chapter 9, Boisot asks whether complexity can be reduced or whether it must be absorbed and raises the issue of objective and subjectively experienced complexity. Boisot is known for his work on the Information Space or I-Space in relation to different cultures. His early work on cultures was based on Cultural Theory, developed by the anthropologist Mary Douglas. In Chapter 9 he develops his original work on the Information Space and four institutional cultures, to quite a significant degree in an attempt to show what implications his analysis holds for the firm's strategy process.

The I-Space Conceptual Framework is based on the argument that data processing has two dimensions: codification and abstraction. Codification is briefly the creation of categories, while abstraction establishes the minimum number of categories required to make the assignment of phenomena to these categories, meaningful. Codification and abstraction are cognitive strategies that reduce data processing costs and help to make sense of the world by giving it a meaningful structure. The third dimension of the framework deals with the sharing of data and describes data diffusion processes. Boisot demonstrates how the sharing and the structuring of data are related by using a conceptual I-space cube and contrasting the two extremes of the highly personal and hard to articulate, concrete and undiffused knowledge of the Zen Buddhist with the highly codified and abstracted into prices and quantities knowledge of the bond trader. Between these extremes are many possibilities for structuring and sharing data and the differences in the possibilities can create distinctive cultural practices and institutional arrangements. The next conceptual development is to show four possible institutions in the I-Space: Bureaucracies, Markets, Fiefs and Clans, each with its distinctive culture and information sharing characteristics. It is important to note that the four institutional structures can work individually or in combination and that each firm may contain more than one institutional culture within it, which may need to be integrated. If any one culture predominates, dysfunctional behaviours may appear. This insight contradicts the popular assumption of strong mono-cultures and explains why the imposition of a single culture in an organisation is often counterproductive. The multiple micro-cultures in a complex organisational environment need to co-exist, to complement and to enrich each other.

Boisot shows the notion of multiple cultures both at a micro level, depicting functions within a firm, and at a macro level showing different industry structures (monopolistic, competitive, emergent and oligopolistic), each with its distinct culture. But this is not new work or strictly speaking related to complexity. It is the next step in the development of the framework that brings it into the complexity arena, by introducing Kauffman's NK network to explore the diffusion dimension. In the I-Space framework, N represents the number of agents and thus corresponds to the length of the diffusion dimension; K represents the degree of agent interconnectedness; while the tuning parameter P is used as a rough measure of data-processing complexity. By varying K and N and appropriately tuning P, phase transitions are created in the I-Space that reflect ordered, complex and chaotic social processes.

The term culture has many definitions, but nearly all of them involve the structuring and sharing of data within or across groups. How effectively it is done, asserts Boisot, is a function of the volume of data, the size of the group(s) and the density of social interaction within and between the groups. Using these three variables he locates the four institutional cultures in the ordered, complex and chaotic regimes. The outcome is that Bureaucracies are in the ordered regime, while markets and fiefs are in the complex phase, and clans sit on the 'edge of chaos'. One feature that distinguishes Bureaucracies from the other three institutional forms is the degree of coupling between agents. It is tight in Bureaucracies, which are bound into rigid hierarchical structures by well-structured roles and routines and a well-defined set of unitary goals. In fiefs, connectivity is dependent on personal loyalty. In markets coupling is well structured but highly transient and episodic; and in clans it is achieved through mutual trust. The last three forms function with varying degrees of loose coupling which is more difficult to manage than tight coupling. But loose coupling, by increasing requisite variety, allows the firm to manage (i.e. absorb) irreducible complexity over a wider range of states than tight coupling.

The implications of the analysis for a firm's strategy, is that in an increasingly complex business environment firms will need to shift the emphasis from the complexity reducing strategies to complexity absorbing ones. Although this conclusion has been picked up by the management literature, it is without the underpinning theory giving it explanatory power. Complexity provides that explanation and Boisot makes the link between strategic choice and theory.

Part V: Philosophical Issues in Applying Complexity Theory to Organisations

Introna in Chapter 10 argues that physical and mathematical systems are ontologically incommensurable to social systems. What this means is that the nature of the physical and mathematical phenomena have no common base or characteristic, which can be shared with social (human) systems. Ontological incommensurability claims that the phenomena or systems, which belong to these categories or domains, are *fundamentally* *and qualitatively different*. Therefore, there can be no direct mapping between these domains of reality. To support and substantiate this argument he asserts that social systems are situated *socially constructed* and *historically emerging phenomena*, and uses two notions central to our understanding of the social, *historicity* and *reflexivity*, to explain the distinctive difference of social phenomena.

Introna calls ‘complexity theory’ a general term, which includes chaos theory, dissipative structures and autopoiesis. Chapter 2 includes all these and some additional theories under the umbrella term. Espejo in Chapter 3 uses autopoiesis extensively to develop his argument for ‘desirable social systems’.

Furthermore, Chapter 10 is very outspoken and critical of the popular and common practice of using complexity as metaphor or analogy. Introna explicates both ‘analogy’ and ‘metaphor’, and helps clarify what these two devices mean and why they are limiting and often inappropriate. The conclusion is that we need to develop a new vocabulary of concepts and a new *social complexity theory*, which draws on what is commensurate, but recognises that which is incommensurate. This could lead to innovative developments in our understanding of social systems and ultimately to appropriate ways to intervene in organisational development. But such developments require extensive scholarship and detailed empirical work. There are no short cuts and this will take time.

Many complexity scholars, including some of the authors in this book, will disagree with Introna’s position, however these arguments need to be taken into account if we are to develop a valid and robust *social complexity theory*, which helps us to understand the nature and essential essence of complex social phenomena.

Clarkson and Nicolopoulou in Chapter 11, differentiate between seven domains of discourse, based on a model developed by Professor Petruska Clarkson. For example, the model places the discourse using metaphor and story in one domain (level 3), that of developing theory in another (level 6) and the discourse based on factual, scientific repeatable evidence in a third (level 5); the model also distinguishes between knowledge gained through the senses (level 1) and that based on feelings and emotions (level 2). As described in Chapter 2 and illustrated by all the other chapters in this volume, “there is no single approach to discussing complexity, but a variety of co-existing — and often competing — discourses”. (Clarkson and Nicolopoulou) By distinguishing and clarifying the different ontological and epistemological domains, the authors make a significant contribution to explaining how and why the different domains of discourse do and can co-exist with each other. The distinction is not only of academic interest, but has significant practical application in organisations and the authors claim that awareness of the distinctions improves organisational learning and enhances effective systemic interventions.

Furthermore, if we ignore or confuse the different domains we make epistemological category errors with several serious consequences. For example **domain confusion** occurs when a statement that expresses a group norm is taken to be fact or when something which is regarded as a fact is translated and applied as a value. Another consequence of category error is the creation of **conflict** when one or more domains of discourse are in opposition; such as applying one type of measurement (like financial profit, which is appropriate in one domain) to other domains where such a measurement may be inappropriate and/or irrelevant. A third epistemological error is **cross-level displacement**, when a condition cannot be expressed satisfactorily at its own level and tries to manifest itself on another level in symbolic form. The confusion between describing complexity using a factual/scientific discourse and expressing it using hypothetical/theoretical discourse is an example of cross-level displacement. The authors point out that there are different kinds of realities requiring different kinds of knowing, which need different criteria and different modes of discourse to express them. The denial of different kinds of co-existing realities leads to **domain conflation** and to the simplistic monistic error of “one-truth must be true for everybody all the time”.

The authors propose that we consider at least a heptuality (seven-sidedness) of co-existing epistemological discourses appropriate to the following seven domains of human experience:

Level 1: The **physiological/perceptual** epistemological domain is the realm of sensory experience. The sources of knowledge are the senses, including observation through the eyes.

Level 2: The **affective/emotional** epistemological domain, deals with emotions as subjective feelings, which arise in response to stimulus events. These are individual subjective experiences, which include fear, pain, joy, anger, etc.

Level 3: The **nominative/metaphorical** epistemological domain involves naming and the division into classes and categories. It is the area of objective nominalism, in that phenomena are grouped together on the basis of certain resemblances. Assigning names and sharing images or metaphors implies reflective common experience and the sharing of a vocabulary or lexicon.

Level 4: The **normative** epistemological domain is when the individual encounters the norms and values of the group, family, organisation, culture, etc. This level of discourse deals with knowledge of attributes and practices of people as ‘cultural beings’ and includes values, norms, collective belief systems and societal or organisational expectations. These ethical preferences and cultural constructions are not subject to logical tests of truth or statistical rationality (level 5).

Level 5: The **rational, logical** epistemological domain is the world of science, logic, statistical probabilities and provable facts, where causal relations can be clearly established. Facts in this domain exist as rational conclusions derived in a repeatable form from a body of well established empirical data and does not include subjective feelings (level 2).

Level 6: The **theoretical/narrative** epistemological domain uses hypotheses, theories, narratives and stories to explain natural phenomena and human behaviour and to make sense of the world. When verified or negated they pass from theory to the factual domain of level 5. Theory that is not underpinned by the rational observations of facts of domain 5 tends to rely on the belief structures of domain 4.

Level 7: The **transpersonal or currently inexplicable** epistemological domain is the realm of human experience, which is beyond clearly understood facts and theories and needs to be left open for the development of future discourse.

The seven domains of discourse illustrate the interwoven multiplicity of complexity in terms of different realities, or different aspects of the same reality or different interpretations of phenomena and cultural constructions. By distinguishing the domains of discourse it brings a much-needed conceptual clarity to this new emerging discipline.

EMK 8 January 2003

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Part II

Essentials of Complexity Theory for Organisation Studies

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Chapter 2

Ten Principles of Complexity and Enabling Infrastructures

Eve Mitleton-Kelly

Introduction

If organisations are seen as complex evolving systems, co-evolving within a social ‘ecosystem’, then our thinking about strategy and management changes. With the changed perspective comes a different way of acting and relating which could lead to a different way of working. In turn, the new types of relationship and approaches to work could well provide the conditions for the emergence of new organisational forms.

This chapter will offer an *introduction to complexity* by exploring ten *generic principles of complex evolving systems* (CES) and will show how they relate to social systems and organisations. These are not the only principles of CES, but gaining an understanding of these ten principles and how they relate to each other, could provide a useful starting point for working with them and applying them to the management of firms. An example of how a department of an international bank, in one geographic location, changed its way of working from the different dominant culture, will be given at the end to illustrate the proposition that providing the appropriate socio-cultural and technical conditions could facilitate the emergence of new ways of working and relating.

There is no single unified Theory of Complexity, but several theories arising from various natural sciences studying complex systems, such as biology, chemistry, computer simulation, evolution, mathematics, and physics. This includes the work undertaken over the past four decades by scientists associated with the Santa Fe Institute (SFI) in New Mexico, USA, and particularly that of Stuart Kauffman (Kauffman 1993, 1995, 2000), John Holland (Holland 1995, 1998), Chris Langton (Waldrop 1992), and Murray Gell-Mann (1994) on *complex adaptive systems* (CAS), as well as the work of scientists based in Europe such as Peter Allen (1997) and Brian Goodwin (Goodwin 1995; Webster & Goodwin 1996); Axelrod on cooperation (Axelrod 1990, 1997; Axelrod & Cohen 2000); Casti (1997), Bonabeau *et al*. (1999), Epstein & Axtel (1996) and Ferber (1999) on *modelling* and *computer simulation*; work by Ilya Prigogine

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ISBN: 0-08-043957-8

(Prigogine & Stengers 1985; Nicolis & Prigogine 1989; Prigogine 1990), Isabelle Stengers (Prigogine & Stengers 1985), Gregoire Nicolis (Nicolis & Prigogine 1989; Nicolis 1994) on *dissipative structures*; work by Humberto Maturana, Francisco Varela (Varela & Maturana 1992) and Niklaus Luhman (1990) on *autopoiesis* (Mingers 1995); as well as the work on *chaos theory* (Gleick 1987) and that on economics and *increasing returns* by Brian Arthur (1990, 1995, 2002).

The above can be summarised as five main areas of research on: (a) complex adaptive systems at SFI and Europe; (b) dissipative structures by Ilya Prigogine and his co-authors; (c) autopoiesis based on the work of Maturana in biology and its application to social systems by Luhman; (d) chaos theory; and (e) increasing returns and path dependence by Brian Arthur and other economists (e.g. Hodgson 1993, 2001). Figure 1 shows the five main areas or research that form the background to this chapter and the ten generic principles of complexity that will be discussed. Since the ten principles incorporate more than the work on complex adaptive systems (CAS), the term *complex evolving systems* (CES) will be used (Allen) as more appropriate to this discussion.

By comparison with the natural sciences there was relatively little work on developing a *theory* of complex *social* systems despite the influx of books on complexity and its application to management in the past 6–7 years (an extensive review of such publications is given by Maguire & McKelvey 1999). The notable exceptions are the work of Luhman on autopoiesis, Arthur in economics and the work on strategy by Lane & Maxfield (1997), Parker & Stacey (1994) and Stacey (1995, 1996, 2000, 2001). A theory in this context is interpreted as an *explanatory framework that helps us understand the behaviour of a complex social (human) system*. (The focus of the author's work and hence the focus of this chapter is on human organisations. Other researchers have concentrated on non-human social systems, such as bees, ants, wasps,

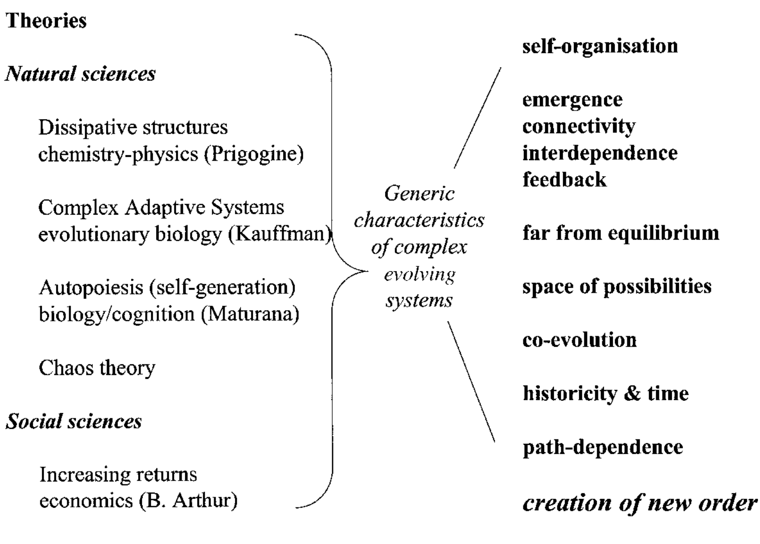

Figure 1.

etc.) Such a theory may provide a different way of thinking about organisations, and could change strategic thinking and our approach to the creation of new organisational forms — that is, the structure, culture, and technology infrastructure of an organisation. It may also facilitate, in a more modest way, the emergence of different *ways of organising* within a limited context such as a single department within a firm. The case study at the end of this chapter describes how a different way of organising emerged in the Information Technology Department in the London office of an international bank.

The chapter will discuss each principle in turn, providing some of the scientific background and describing in what way each principle may be *relevant* and *appropriate* to a human system. Regarding the five areas of research listed on the left hand side of Figure 1, dissipative structures are discussed at length as part of the 'far-from-equilibrium' and 'historicity' principles; complex adaptive systems research underlies most of the other principles and the work of Kauffman is referred to extensively; autopoiesis is not discussed in this chapter but it has played an important role in the thinking underlying the current work (for the implications and applications of autopoiesis see Mingers 1995); chaos theory is given a separate section, but the discussion is not extensive; and Arthur's work on increasing returns is discussed under the 'path-dependence' principle.

The four principles grouped together in Figure 1, of emergence, connectivity, interdependence, and feedback are familiar from systems theory. Complexity builds on, and enriches systems theory by articulating additional characteristics of complex systems and by emphasising their inter-relationship and interdependence. It is not enough to isolate one principle or characteristic such as self-organisation or emergence and concentrate on it in exclusion of the others. The approach taken by this chapter argues for a deeper understanding of complex systems by looking at several characteristics and by building a rich inter-related picture of a complex social system. It is this deeper insight that will allow strategists to develop better strategies and organisational designers to facilitate the creation of organisational forms that will be sustainable in a constantly changing environment.

The discussion is based on *generic principles*, in the sense that these principles or characteristics are common to all natural complex systems. One way of looking at complex human systems is to examine the generic characteristics of natural complex systems and to consider whether they are *relevant or appropriate to social systems*. But there is one limitation in that approach, which is to understand that such an examination is merely a starting point and not a mapping, and that social systems need to be studied in their own right.

This limitation is emphasised for two reasons: (a) although it is desirable that explanation in one domain is consistent with explanation in another and that these explanations honour the *Principle of Consistency* (Hodgson 2001: 90), characteristics and behaviour cannot be mapped directly from one domain to another, without a rigorous process of testing for appropriateness and relevance. Not only may the unit of analysis be quite different, but scientific and social domains may also have certain fundamental differences that may invalidate direct mapping. For example humans have the capacity to reflect and to make deliberate choices and decisions among alternative paths of actions. This capacity may well distinguish human behaviour from that of biological, physical or chemical entities; (b) a number of researchers consider the principles of complexity only as metaphors or analogies when applied to human systems. But metaphors and analogies are both limiting and limited and do not help us understand the fundamental nature of a system under study. This does not mean that neither metaphor nor analogy may be used. We use them as 'transitional objects' all the time in the sense that they help the transition in our thinking when faced with new or difficult ideas or concepts. The point being emphasised, is that using metaphor and analogy is not the *only* avenue available to us in understanding complexity in an organisational or broader social context. Since organisations are, by their very nature, complex evolving systems, they need to be considered as complex systems in their own right.

Another way of looking at complexity is that suggested by Nicolis & Prigogine (1989: 8) "It is more natural, or at least less ambiguous, to speak of *complex behaviour* rather than complex systems. The study of such behaviour will reveal certain common characteristics among different classes of systems and will allow us to arrive at a proper understanding of complexity". This approach both honours the Principle of Consistency and avoids the metaphor debate. It may however upset some sociologists who do not find 'arguments from science' convincing. But this is to miss Nicolis's and Prigogine's point, when they put the emphasis on the behaviour or characteristics of *all* complex systems. Nicolis and Prigogine are not behaviourists; they study the behaviour of complex systems in order to understand their deeper, essential nature.

This provides us with the underlying reason for studying complexity. *It explains and thus helps us to understand the nature of the world — and the organisations — we live in.*

The term '*complexity*' will be used to refer to the *theories of complexity* (in the literature the plural 'theories' is reduced to the singular for ease of reference and this practice will be used here) and '*complex behaviour*' to the behaviour that arises from the interplay of the characteristics or principles of complex systems.

Complexity is not a methodology or a set of tools (although it does provide both). It certainly is not a 'management fad'. The **theories of complexity** provide a conceptual framework, **a way of thinking**, and **a way of seeing the world**.

1. Connectivity and Interdependence

Complex behaviour arises from the inter-relationship, interaction, and inter-connectivity of elements within a system and between a system and its environment. Murray Gell-Mann (1995/1996) traces the meaning to the root of the word. *Plexus* means braided or entwined, from which is derived *complexus* meaning braided together, and the English word "complex" is derived from the Latin. Complex behaviour therefore arises from the *intricate inter-twining or inter-connectivity of elements within a system and between a system and its environment.*

In a human system, connectivity and interdependence means that a decision or action by any individual (group, organisation, institution, or human system) may affect related individuals and systems. That affect will not have equal or uniform impact, and will vary with the 'state' of each related individual and system, at the time. The 'state' of an individual or a system will include its history and its constitution, which in turn will include its organisation and structure. Connectivity applies to the inter-relatedness of individuals *within* a system, as well as to the relatedness *between* human social systems, which include systems of artefacts such as information technology (IT) systems and intellectual systems of ideas.

Complexity theory, however, does not argue for ever-increasing inter-connectivity, for high connectivity implies a high degree of interdependence. This means that the greater the interdependence between related systems or entities the wider the 'ripples' of perturbation or disturbance of a move or action by any one entity on all the other related entities. Such high degree of dependence may not always have beneficial effects throughout the ecosystem. When one entity tries to improve its fitness or position, this may result in a worsening condition for others. Each 'improvement' in one entity therefore may impose associated 'costs' on other entities, either within the same system or on other related systems.

Connectivity and *interdependence* is one aspect of how complex behaviour arises. Another important and closely related aspect is that complex systems are *multi-dimensional*, and all the dimensions interact and influence each other. In a human context the social, cultural, technical, economic and global dimensions may impinge upon and influence each other. The case study at the end of the chapter, illustrates how what on the surface appeared to be a technical problem involving the integration of information systems across Europe, was partially resolved by paying attention to some social and cultural issues.

But the distinguishing characteristic of a CES is that it is able to *adapt* and *evolve* and thus create *new order and coherence*. This creation of new order and coherence is one of the key defining features of complexity. Individuals acting 'at random' or with their own agendas nevertheless can work effectively as a group or an entire organisation — and may create coherence in the absence of any grand design. They can also create new ways of working, new structures, and different relationships, where hierarchies may be reversed or ignored, as in integrated project teams[1] where a senior executive outside the team may not hold a leadership role within the team, while a more junior employee becomes team-leader because he/she has the correct qualifications for leading that particular integrated project team.

Other features include the possibility of entities in a CES to *change their rules of interaction*; to *act on limited local knowledge*, without knowing what the system as a whole is doing; and to be *self-repairing* and *self-maintaining*. Reference to entities as individuals or collections (systems) is deliberately ambiguous, to emphasise the point that complex characteristics tend to be *scale-invariant* and could apply at all scales from an individual to a whole system as well as to systems at different scales (e.g. team, organisation, industry, economy, etc.).

[1] Integrated project/product teams (IPTs) are often used in the Aerospace and other industries to bring together representatives from different organisations or functions with the knowledge and skills necessary to design a new project or product.

1.1. Degrees of Connectivity

Propagation of influence through an ecosystem depends on the *degree* of connectivity and interdependence. Biological "ecosystems are not totally connected. Typically each species interacts with a subset of the total number of other species, hence the system has some extended web structure" (Kauffman 1993: 255). In human social ecosystems the same is true. There are networks of relationships with different degrees of connectivity. *Degree of connectivity* means strength of coupling and the dependencies known as *epistatic interactions* — i.e. the extent to which the fitness contribution made by one individual depends on related individuals. In biological co-evolutionary processes, the fitness of one organism or species depends upon the characteristics of the other organisms or species with which it interacts, while all simultaneously adapt and change (Kauffman 1993: 33). In other words a single entity (allele, gene, organism or species) does not contribute to overall fitness independently of all other like entities. The fitness contribution of an individual may depend on all the other individuals in that context. This is a contextual measure of dependency, of direct or indirect influence that each entity has on those it is coupled with.

In a social context, each individual belongs to many groups and different contexts and his/her contribution in each context depends partly on the other individuals within that group and the way they relate to the individual in question. An example is when a new member joins a team. The contribution that individual will be *allowed* to make to that team may depend on the other members of the team and on the space they provide for such a contribution, as much as to the skills, knowledge, expertise, etc brought by the new member.

In human systems, connectivity between individuals or groups is not a constant or uniform relationship, but varies over time, and with the diversity, density, intensity, and quality of interactions between human agents. Connectivity may also be formal or informal, designed or undesigned, implicit with tacit connections or explicit. Furthermore, it is the degree of connectivity, which determines the network of relationships and the transfer of information and knowledge and is an essential element in feedback processes.

2. Co-evolution

Connectivity applies not only to elements within a system but also to related systems within an ecosystem. An **ecosystem** in biology means, "each kind of organism has, as parts of its environment, other organisms of the same and of different kinds . . . adaptation by one kind of organism alters both the fitness and the fitness landscape[2] of the other organisms" (Kauffman 1993: 242). The way each element influences and is in

[2] Kauffman (1993: 33) borrows the hill-climbing framework with minor modifications, directly from Wright (1931, 1932) who introduced the concept of a space of possible genotypes. Each genotype has a 'fitness', and the distribution of fitness values over the space of genotypes constitutes a *fitness landscape*. Depending upon the distribution of the fitness values, the fitness landscape can be more or less mountainous.

turn influenced by all other related elements in an ecosystem is part of the process of co-evolution which Kauffman describes as "a process of coupled, deforming landscapes where the adaptive moves of each entity alter the landscapes of its neighbours" (Kauffman & Macready 1995).

Another way of describing co-evolution is that *the evolution of one domain or entity is partially dependent on the evolution of other related domains or entities* (Ehrlich & Raven 1964; Pianka 1994; Kauffman 1993, 1995; McKelvey 1999a, 1999b; Koza & Lewin 1998); or *that one domain or entity changes in the context of the other(s).* The notion of co-evolution places the emphasis on the *evolution of interactions* and on *reciprocal evolution* (Futuyama 1979). In human systems, co-evolution in the sense of the *evolution of interactions* places emphasis on the relationship between the co-evolving entities.

A point emphasised by Kauffman is that **co-evolution takes place within an ecosystem**, and cannot happen in isolation. In a human context a social ecosystem includes the social, cultural, technical, geographic and economic dimensions and co-evolution may affect both the form of *institutions* and the *relationships* and interactions between the co-evolving entities (the term *entity* is used as a generic term which can apply to individuals, teams, organisations, industries, economies, etc.).

A distinction may also be made between *co-evolution* ***with*** and *adaptation* ***to*** a changing environment. When the emphasis is placed on co-evolution with, it tends to change the perspective and the assumptions that underlie much traditional management and systems theories.

Although we make a conceptual distinction between a 'system' and its 'environment' it is important to note that there is no dichotomy or hard boundary between the two as in Figure 2, in the sense that a system is separate from and always *adapts to* a changing

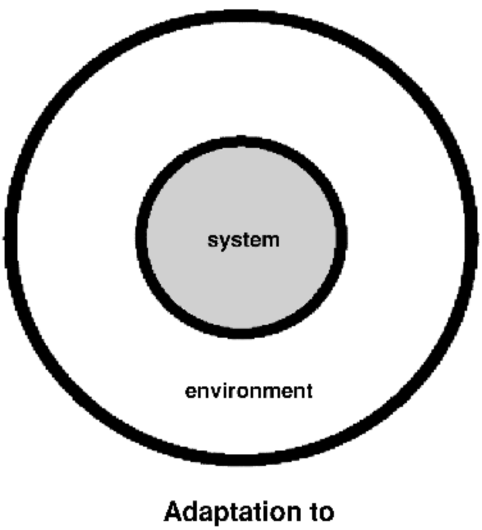

Figure 2.

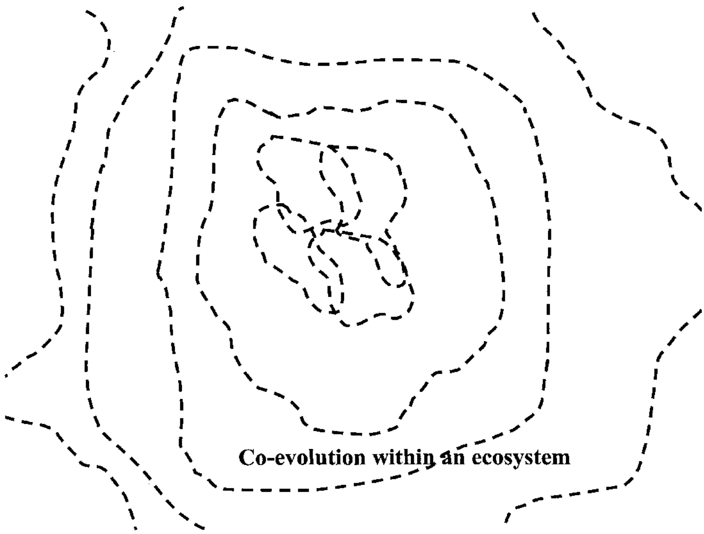

Figure 3.

environment. The notion to be explored is rather that of a system *closely linked with* all other related systems within an ecosystem, illustrated by Figure 3. Within such a context change needs to be seen in terms of *co-evolution with* all other related systems, rather than as *adaptation to* a separate and distinct environment. This perspective changes the way strategy may be viewed.

In a social co-evolving ecosystem, each organisation *is a fully participating agent which both influences and is influenced by* the social ecosystem made up of all related businesses, consumers, and suppliers, as well as economic, cultural, and legal institutions. Strategies consequently cannot to be seen simply as a *response to* a changing environment, which is separate from the organisation, but as adaptive moves, which will affect both the initiator of the action and all others influenced by it. The notion of co-evolution is thus one of empowerment, as it suggests that all actions and decisions affect the social ecosystem. No individual or organisation is powerless — as each entity's actions reverberate through the intricate web of inter-relationships and affects the social ecosystem. But co-evolution also invites notions of responsibility, as once the ecosystem is influenced and affected it will in turn affect the entities (individuals, organisations, and institutions) within it. This notion is not the same as pro-active or re-active response. It is a subtler 'sensitivity' and awareness of both changes in the environment and the possible consequences of actions. It argues for a deeper understanding of reciprocal change and the way it affects the totality.

Seen from one perspective, co-evolution takes place when related entities change *at the same time*. But in most observable examples it is more a matter of short-term adaptation and long-term co-evolution. Two examples will be used to illustrate this. The first example was given by Maturana at an Open University workshop (Maturana 1997). When I buy a pair of shoes, both the new shoes and my feet will change to accommodate each other. They co-evolve. What I observe at a macro-level after wearing the shoes several times and suffering from sore feet, may be co-evolution happening at the same time, as both my feet and shoes change to accommodate each other. But at a micro short-term level of minute-to-minute walking, there could well have been short-term adaptation of the one to the other. This reciprocal movement is illustrated more clearly by the second example given by a senior Marks & Spencer executive at an LSE Seminar. Weavers and knitters have influenced each other and produced new materials, which are knitted but look woven, and materials that are woven but look knitted. They have co-evolved over time, with short-term adaptation to each other and the market. Through the process of co-evolution they have produced something new, a new order or coherence; which is, as has been pointed out earlier, the key distinguishing feature of CES.

Co-evolution also happens between entities *within* a system, and the *rate of their co-evolution* (McKelvey 1999b) is worth considering. For example, how can the rate of co-evolution within and between teams be facilitated and improved? Co-evolution in this context is associated with learning and the transfer of information and knowledge. If one individual or one team learns to operate better, how can that knowledge or ability be transferred to other teams to help them evolve? Since co-evolution can only take place within an ecosystem, the notion of social 'ecosystem' also needs to be addressed. An ecosystem is defined by the interdependence of all entities within it. It provides sustenance and support for life. A community is a social ecosystem, if it provides mutual support and sustenance. When firms and institutions cease to function like a community or social ecosystem, they may break down. Some of the most successful organisations nurture their community or social ecosystem (Lewin & Regine 1999). The debate on organisational culture is attempting to address that issue. How can the organisation create the kind of culture that will help it to survive and thrive? Or what are the conditions that will help it co-create a sustainable social ecosystem?

Co-evolution therefore affects both individuals and systems and is operational at different levels, scales, or domains. Co-evolution is taking place at all levels and scales and can be thought of as *endogenous co-evolution* when it applies to individuals and groups *within* the organisation and as *exogenous co-evolution* when the organisation is interacting with the *broader ecosystem.* This however is a simplification — as the endogenous and exogenous processes are necessarily interlinked and the boundaries between the organisation and its 'environment' may not be clear-cut and stable. Furthermore the notion of 'ecosystem' applies both within the organisation and to the broader environment, which *includes* the organisation under study. Hence the notion of a complex co-evolving ecosystem is one of intricate and multiple intertwined interactions and relationships, and of multi-directional influences and links, both direct and many-removed. Connectivity and interdependence propagates the effects of actions, decisions and behaviours throughout the ecosystem, but that propagation or influence is not uniform as it depends on the *degree of connectivity.*

3. Dissipative Structures, Far-from-Equilibrium and History

Another key concept in complexity is dissipative structures, which are ways in which open systems exchange energy, matter, or information with their environment and which when pushed 'far-from-equilibrium' create new structures and order.

The Bénard cell is an example of a physico-chemical dissipative structure. It is made up of two parallel plates and a horizontal liquid layer, such as water. The dimensions of the plates are much larger than the width of the layer of water. When the temperature of the liquid is the same as that of the environment, the cell is at equilibrium and the fluid will tend to a homogeneous state in which all its parts are identical (Nicolis & Prigogine 1989; Prigogine & Stengers 1985). If heat is applied to the bottom plate, and the temperature of the water is greater at the bottom than at the upper surface, at a threshold temperature the fluid becomes unstable. "By applying an *external constraint* we do not permit the system to remain at equilibrium" (Nicolis & Prigogine 1989: 10). If we remove the system farther and farther from equilibrium by increasing the temperature differential, suddenly at a critical temperature the liquid performs a bulk movement which is far from random: the fluid is structured in a series of small convection 'cells' known as Bénard cells.

Several things have happened in this process: (a) the water molecules have spontaneously organised themselves into right-handed and left-handed cells. This kind of spontaneous movement is called *self-organisation* and is one of the key characteristics of complex systems; (b) from molecular chaos the system has emerged as a higher-level system with *order* and *structure*; (c) the system was pushed far-from-equilibrium by an *external constraint or perturbation*; (d) although we know that the cells will appear, "the direction of rotation of the cells is unpredictable and uncontrollable. Only chance in the form of the particular perturbation that may have prevailed at the moment of the experiment, will decide whether a given cell is right- or left-handed" (Nicolis & Prigogine 1989: 14); (e) when a constraint is sufficiently strong, the system can adjust to its environment in several different ways, that is *several solutions* are possible for the *same parameter values*; (f) the fact that only one among many possibilities occurred gives the system "a *historical dimension*, some sort of "memory" of a past event that took place at a critical moment and which will affect its further evolution" (Nicolis & Prigogine 1989: 14); (g) the homogeneity of the molecules at equilibrium was disturbed and their *symmetry was broken*;[3] (h) the particles behaved in a *coherent* manner, despite the random thermal motion of each of them. This coherence at a macro level characterises *emergent* behaviour, which arises from micro-level interactions of individual elements.

In the Bénard cell heat transfer has *created new order*. It is this property of complex systems to create new order and coherence that is their distinctive feature. The Bénard cell process in thermal convection is the basis of several important phenomena, such as the circulation of the atmosphere and oceans that determines weather changes (Nicolis & Prigogine 1989: 8).

[3] "The emergence of the concept of space in a system in which space could not previously be perceived in an intrinsic manner is called *symmetry breaking*" (Nicolis & Prigogine 1989: 12).

Ilya Prigogine was awarded the 1977 Nobel Prize for chemistry for his work on dissipative structures and his contributions to nonequilibrium thermodynamics. Prigogine has reinterpreted the Second Law of Thermodynamics. Dissolution into entropy is not an absolute condition, but “under certain conditions, entropy itself becomes the progenitor of order”. To be more specific, “. . . under non-equilibrium conditions, at least, entropy may produce, rather than degrade, order (and) organisation . . . If this is so, then entropy, too, loses its either/or character. While certain systems run down, other systems simultaneously evolve and grow more coherent” (Prigogine & Stengers 1985: xxi).

Symmetry breaking in complexity means that the homogeneity of a current order is broken and new patterns emerge. Symmetry breaking may be understood as a generator of information, in the sense that when a pattern of homogeneous data is broken by differentiated patterns, the new patterns can be read as ‘information’. This phenomenon applies to and can be interpreted at different levels, from undifferentiated code

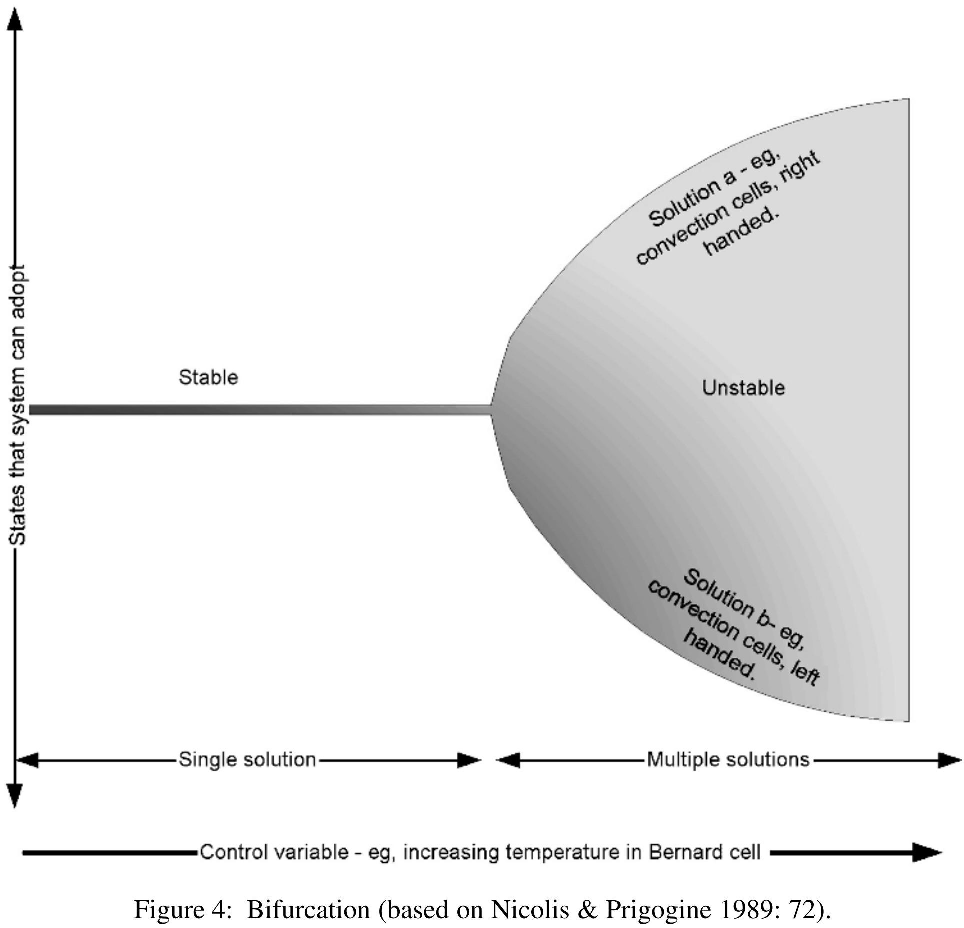

Figure 4: Bifurcation (based on Nicolis & Prigogine 1989: 72).

(homogeneous data) to exception reporting, when different or unexpected patterns appear to deviate from the expected norms.

In dissipative structures the tendency to split into alternative solutions is called *bifurcation*, but the term is misleading in that it means a separation into *two* paths, when there may be several possible solutions. However, as it is easier to explain the splitting of possibilities into two alternative paths, this simplified meaning will be used, with the proviso that multiple solutions are also possible. In the Bénard cell, a unique solution is present until the heat differential reaches a critical value. At that point the molecules self-organise themselves and become right- or left-handed cells. The two possibilities are present simultaneously. Figure 4 is borrowed from Nicolis & Prigogine (1989: 72) and illustrates bifurcation.

3.1. History

An observer could not predict which state will emerge; "only chance will decide, through the dynamics of fluctuations. The system will in effect scan the territory and will make a few attempts, perhaps unsuccessful at first, to stabilize. Then a particular fluctuation will take over. By stabilizing it the system becomes a *historical object* in the sense that its subsequent evolution depends on this critical choice" (Nicolis & Prigogine 1989: 72). At a totally different scale, the notions of chance and *history* are used by Kauffman to describe a view of evolutionary biology that sees ". . . organisms as ultimately accidental and evolution as an essentially historical science. In this view, the order in organisms results from selection sifting unexpected useful accidents and marshalling them into improbable forms. In this view, the great universals of biology — the genetic code, the structure of metabolism and others — are to be seen as frozen accidents, present in all organisms only by virtue of shared descent" (Kauffman 1993: xv).

In a social context, it is the series of critical decisions each individual takes from several possible alternatives that may determine a particular life path for that individual. The alternatives available, however, are constrained by the person's current state and the state of the landscape the person occupies. Thus the emergent behaviour of the person is not a matter of 'chance' but is the result of a person's selection among a finite set of perceived choices; as well as the past choices made (the history) that have shaped that person's life path. Once the decision is made, there is a historical dimension and subsequent evolution may depend on that critical choice; but *before* the decision is finalised, the alternatives are sources of *innovation* and *diversification*, since the opening up of possibilities endows the individual and the system with new solutions. When a social entity (individual, group, organisation, industry, economy, country, etc) is faced with a constraint, it finds new ways of operating, because away-from-equilibrium (established norms) systems are forced to experiment and explore their *space of possibilities*, and this exploration helps them discover and create new patterns of relationships and different structures.

Non-equilibrium may allow a system to avoid thermal disorder and to transform part of the energy communicated from the environment into an ordered behaviour of a new type, a new *dissipative structure* that is characterised by symmetry breaking and multiple choices. In chemistry, *autocatalysis* (the presence of a substance may increase the rate of its own production) shows similar behaviours, and the Belousov-Zhabotinski (BZ) reaction, under certain non-equilibrium conditions shows symmetry breaking, self-organisation, multiple possible solutions, and hysteresis (the specific path of states that can be followed depends on the system's past *history*) (Nicolis & Prigogine 1989; Kauffman 1993, 1995). Furthermore, *self-reproduction*, a fundamental property of biological life, is "the result of an autocatalytic cycle in which the genetic material is replicated by the intervention of specific proteins, themselves synthesized through the instructions contained in the genetic material" (Nicolis & Prigogine 1989: 18). In one sense, complexity is concerned with systems in which evolution — and hence history — plays or has played an important role, whether biological, physical, or chemical systems.

Similarly in a social context, when an organisation moves away from equilibrium (i.e. from established patterns of work and behaviour) new ways of working are created and new forms of organisation may emerge. These may be quite innovative if choice is allowed and the symmetry of established homogeneous patterns is broken. There is however a fundamental difference between natural and social human systems. The latter can deliberately create constraints and perturbations that consciously push a human institution far-from-equilibrium. In addition, humans can also provide help and support for a new order to be established. If the new order is 'designed' in detail, then the support needed will be greater, because those involved have their self-organising abilities curtailed, and may thus become dependent on the designers to provide a new framework to facilitate and support new relationships and connectivities. Although the intention of change management interventions is to create new ways of working, they may block or constrain emergent patterns of behaviour if they attempt to excessively design and control outcomes. However, if organisation re-design were to concentrate on the provision of *enabling infrastructures* (the socio-cultural and technical conditions that facilitate the emergence of new ways of organising), allowing the new patterns of relationships and ways of working to emerge, new forms of organisation may arise that would be unique and perhaps not susceptible to copying. These new organisational forms may be more robust and sustainable in competitive environments.

4. Exploration-of-the-Space-of-Possibilities

Complexity suggests that to survive and thrive an entity needs to explore its space of possibilities and to generate variety. Complexity also suggests that the search for a single 'optimum' strategy may neither be possible nor desirable. Any strategy can only be optimum under certain conditions, and when those conditions change, the strategy may no longer be optimal. To survive an organisation needs to be constantly scanning the landscape and trying different strategies. An organisation may need to have in place several micro-strategies that are allowed to evolve before major resources are committed to a single strategy. This reduces the risk of backing a single strategy too early, which may turn out not to be the best one, and supports sensitive co-evolution with a changing ecosystem. In essence, unstable environments and rapidly changing markets require flexible approaches based on requisite variety (Ashby 1969).

Flexible adaptation also requires new connections or new ways of *seeing* things. *Seeing* a novel function for a part of an existing entity is called '*exaptation*'.[4] A small example might help explain the concept. While on holiday, I was using my laptop computer in the garden. The computer was on a garden table, with a hole in the middle for an umbrella. The laptop was connected to a mobile telephone, which enabled me to send and receive emails and faxes. Both the computer and the mobile were attached to power leads, which were passed through a window into the house. The plethora of leads was both ugly and fragile, as people passing by could trip over them. They also took up a lot of space on the table. My son Daniel then used the hole in the middle of the table to keep the leads tidy and out of sight. The umbrella hole therefore gained a novel function, in keeping the leads tidy and safe. That simple solution was an example of an exaptation. Daniel 'saw' the different function for the umbrella hole, while no one else had even considered it.

When searching the space of possibilities, whether for a new product or a different way of doing things, it is not possible to explore all possibilities. It may, however, be possible to consider change one step away from what already exists. In this sense, exaptation may be considered an exploration of what is sometimes called the '*adjacent possible*' (Kauffman 2000). That is exploring one step away, using 'building blocks' already available, but put together in a novel way. According to Kauffman (2000: 22) the push into novelty in the molecular, morphological, behavioural, technological and organisational spheres, is persistent and happens through exploration of the adjacent possible. The *rate* of discovery or mutation, however, is restricted by selection to avoid possible catastrophes that could destroy a community. Bacteria and higher cells have a mutation rate well below the error-catastrophe, which is the phase transition that renders a population unsustainable. There seems to be a balance between discovery and what the ecosystem can effectively sustain. Both the biosphere and the econosphere seem to have "endogenous mechanisms that gate the exploration of the adjacent possible such that, on average, such explorations do successfully find new ways of making a living" (Kauffman 2000: 156). In the biosphere adaptations are selected by natural selection and in the econosphere by economic success or failure, at a *rate* that is sustainable. The current slowing down in the mobile telephone market, could well be an indicator of intolerance to the rate of innovation, which cannot be assimilated by the market.

Although the rate at which novelty can be introduced is restricted, the adjacent possible is indefinitely expandable (Kauffman 2000: 142). Once discoveries have been

[4] '*Exaptation*' is the term used by Stephen J.Gould and Stuart Kauffman. Darwin used the term '*preadaptation*'. "Darwin noted that in an appropriate environment a causal consequence of a part of an organism that had not been of selective significance might come to be of selective significance and hence be selected. Thereupon, that newly important causal consequence would be a new function available to the organism". Evolutionary adaptations "by such preadaptations, or exaptations, are not rare; they are the grist of adaptive evolution. Thus arose the lung, the ear, flight" (Kauffman 2000: 130).

realised in the current adjacent possible, a new adjacent possible, accessible from the enlarged actual that includes the novel discoveries from the former adjacent possible, becomes available. The constant opening up of niche markets in areas and products that only a few years earlier had not even been thought of, is an example of the ever expanding possibilities of the adjacent possible.

5. Feedback

Feedback is traditionally seen in terms of positive and negative feedback mechanisms, which are also described as "reinforcing (i.e. amplifying) and balancing" (Kahen & Lehman, http://www-dse.doc.ic.ac.uk/ ~ mml/). Putting it another way, positive (reinforcing) feedback drives change, and negative (balancing, moderating, or dampening) feedback maintains stability in a system. A familiar example of negative feedback is provided in a central heating system. A thermostat monitors the temperature in the room, and when the temperature drops below a specified level, an adjusting mechanism is set in motion, which turns the heating on until the desired temperature is attained. Similarly, when the temperature rises above a set norm, the heating is switched off until the temperature falls below the desired level. The gap between the desired and the actual temperature is thus closed. Positive feedback, on the other hand, would progressively widen the gap. Instead of reducing or cancelling out the deviation, positive feedback would amplify it.

One point needs to be made. First, feedback '*mechanisms*' are related to engineering and other machine-type systems, as indicated by the language used (e.g. 'adjustment mechanism'). When feedback is applied to human systems, the term feedback *process* will be used, in an attempt to avoid the machine metaphor and to distinguish human from other complex systems.

In far-from-equilibrium conditions, non-linear relationships prevail, and a system becomes "inordinately sensitive to external influences. Small inputs yield huge, startling effects" (Prigogine & Stengers 1985: xvi) that cause a whole system to reorganise itself. Part of that process is likely to be the result of *positive or reinforcing feedback*. "In far-from-equilibrium conditions we find that very small perturbations or fluctuations can become amplified into gigantic, structure-breaking waves" (Prigogine & Stengers 1985: xvii).

In human systems, far-from-equilibrium conditions operate when a system is perturbed well away from its established norms, or away from its usual ways of working and relating. When an organisation as a system is thus disturbed (e.g. after restructuring or a merger), it may reach a critical point and either degrade into disorder (loss of morale, loss of productivity, etc.) or create some new order and organisation — i.e. find new ways of working and relating — and thus create a new *coherence*. Positive or reinforcing feedback processes underlie such transformation and they provide a starting point for understanding the constant movement between change and stability in complex systems.

One reason for interventions that create far-from-equilibrium conditions may be that the current feedback processes no longer work. This may be the case when negative or balancing feedback processes that once were able to adjust or influence the behaviour of the organisation can no longer produce the desired outcome. When efforts to improve behaviour in order to improve performance and market position continually fail, and when incremental changes are no longer effective, then managers of organisations may resort to major interventions in an effort to produce radical change. These interventions may also fail, however, and an organisation may become locked in a constant cycle of ineffective restructuring. One reason for such failures is over-reliance on 'adjustment mechanisms' based on negative feedback loops that have worked in the past. But in a turbulent environment, the entire ecosystem may be changing, and we cannot always extrapolate successfully from past experience. New patterns of behaviour and new structures may need to emerge, and these may depend on or become established through new positive feedback processes.

In human systems, the degree of connectivity (dependency or epistatic interaction) often determines the strength of feedback. Feedback when applied to human interactions means influence that changes potential action and behaviour. Furthermore, in human interactions feedback is rarely a straightforward input-process-output procedure with perfectly predictable and determined outputs. Actions and behaviours may vary according to the degree of connectivity between different individuals, as well as with time and context.

Co-evolution may also depend on reciprocal feedback influences between entities. An important question is therefore, *how does degree of connectivity and feedback influence co-evolution?* A related question is, *how does the structure of an ecosystem affect co-evolution?* Kauffman makes the bold statement that "We have found evidence . . . that the structure of an ecosystem governs co-evolution" (Kauffman 1993: 279). This statement is based on computer simulations, but it is intuitively appealing and there is evidence that this finding may apply to social ecosystems (LSE Complexity Programme). Feedback processes may therefore have a bearing on degree of connectivity (at all levels), hence on ecosystem structure, and hence on co-evolution.

Furthermore, the two simple concepts of positive and negative feedback need to be elaborated in order to describe the multiple interacting feedback processes in complex systems, and we need to rethink the nature of feedback in this context to recognise multi-level, multi-process, non-linear influences.

5.1. Path Dependence and Increasing Returns

Brian Arthur argues that conventional economic theory is based on the implicit assumption of negative feedback loops in the economy, which lead to *diminishing returns*, which in turn lead to (predictable) equilibrium outcomes. Negative feedback has a stabilising effect, and implies a single equilibrium point, as "any major changes are offset by the very reactions they generate" (Brian Arthur 1990: 92). The example given by Arthur is the high oil prices of the 1970s, which encouraged energy conservation and increased oil exploration, precipitating a predictable increase in supply and resulting drop in prices by the early 1980s. But, Arthur argues, such stabilising forces do not always operate or dominate. "Instead positive feedback *magnifies* the effects of small economic shifts”, and *increasing returns* from *positive feedback makes for many possible equilibrium points*, depending on the negative feedback loops that may also operate in a system (Arthur 1990).

The possibility that a system may have more than one possible equilibrium point has also been described in section 3 under dissipative structures. In physico-chemical systems “two (or sometimes several) simultaneously stable states could coexist under the same boundary conditions”. Nicolis and Prigogine call this phenomenon **‘bistability’** and describe it as “the possibility to evolve, for given parameter values, to more than one stable state” (Nicolis & Prigogine 1989: 24). Furthermore, the specific paths that a system may follow depend on its past history. The point here is that past history affects future development, and there may be several possible paths or patterns that a system may follow. This explains why the *precise* behaviour of a complex system may be very difficult to predict, even while keeping the system within certain bounds.

The classic example illustrating Arthur’s argument of increasing returns (Arthur 1990, 1995) resulting from a virtuous circle of self-reinforcing growth is the videocassette recorder. “The VCR market started out with two competing formats selling at about the same price: VHS and Beta. Each format could realise increasing returns as its market share increased: large numbers of VHS recorders would encourage video outlets to stock more pre-recorded tapes in VHS format, thereby enhancing the value of owning a VHS recorder and leading more people to buy one. (The same would, of course, be true for Beta-format players.) In this way, a small gain in market share would improve the competitive position of one system and help it further increase its lead. . . . Increasing returns on early gains eventually tilted the competition toward VHS: it accumulated enough of an advantage to take virtually the entire VCR market” (Arthur 1990). This process is what Arthur calls ‘path dependence’ — the increasing pull of a new technology in attracting or enabling further developments. The more associated products (e.g. pre-recorded tapes) and support services (shops selling tapes in VHS format; selling VHS recorders; engineers becoming available to service the recorders, etc) proliferated, the stronger the position of the VHS format became, until it dominated the market.

Other technical standards or conventions established by positive feedback, increasing returns and path dependence, are the gauge of railway tracks, the English language becoming established as the standard language of air navigation and a particular screw thread, which often “cannot be changed even if alternative techniques or conventions may be better” (Mainzer 1996: 271).

The story however is not as simple as it may appear and the process leading to increasing returns and path dependence is not straightforward. Positive feedback is not the only process in operation in the examples given above. Apart from reinforcing feedback loops, there are negative feedback or stabilising loops also in operation. The two processes may be present simultaneously or they may follow each other as the market progresses through various economic cycles. Markets and economies are complex systems that co-evolve, are dissipative (in the sense that they are irreversible and have a history), show self-organisation and emergence, and explore their space of possibilities. As all these characteristics play out, the progression of any technology or market is not smooth.

Arthur in later studies (Arthur 2002) looks closely at the development of technology clusters (e.g. with electrification come dynamos, generators, transformers, switchgear, power distribution systems; with mass production and the automobile come production lines, modern assembly methods, 'scientific management' road systems, oil refineries, traffic control), which have defined "an era, an epoch, a revolution" (Arthur 2002). He shows how they eventually change the way business is done, and that they may even change the way society is conducted. The process starts with one or more technologies that 'enable' the new cluster (Perez 2002). The new technology cluster may at first attract little notice, but then starts to achieve successes in early demonstrations and small companies may be set up based on the new ideas. These compete intensely at this early turbulent phase and as successes increase, and Government regulation is mainly absent, the promise of large profits becomes apparent and the public may start to speculate. In certain cases this first exuberant phase is marked by a crash, and Arthur cites three examples, the railway industry crash in the U.K. in 1847; the Canal Mania of the 1790s with the shares crashing in 1793; and the recent Internet crash. In the past, the crash was followed by a sustained build-out or golden age of the technology, which influenced growth in the economy and the period was one of confidence and prosperity, like the period after 1850 in the U.K. when the railways became "the engine of the economy in Britain" (Arthur 2002). The last phase is one of maturity.

The point that Arthur is trying to make in this study is to show that if we take a historical perspective and compare the railways to the Internet then the real benefits are yet to come. While building his argument, however, he also shows the constant interplay between positive and negative feedback loops moving the markets between periods of expansion and stability. The story also illustrates co-evolution in the economy, exploration, the adjacent possible, and the emergence of new order.

6. Self-Organisation, Emergence and the Creation of New Order

Self-organisation, emergence and the creation of new order are three of the key characteristics of complex systems. Kauffman in the 'Origins of Order: Self-Organization and Selection' (1993) focuses on self-organisation and describes his argument in the title. He calls Darwinian natural selection a "single singular force" and argues that "It is this single-force view which I believe to be inadequate, for it fails to notice, fails to stress, fails to incorporate the possibility that simple and complex systems exhibit order spontaneously" (Kauffman 1993: xiii). That spontaneous order is *self-organisation;* he brings all three characteristics together when he refers to "the spontaneous emergence of order, the occurrence of self-organisation". He argues that natural selection is not the sole source of order in organisms and suggests that both natural selection and self-organisation are necessary for evolution; he then proceeds to expand evolutionary theory to incorporate both evolutionary forces.

Emergent properties, qualities, patterns, or structures, arise from the interaction of individual elements; they are greater than the sum of the parts and may be difficult to predict by studying the individual elements. Emergence is the *process* that creates new order together with self-organisation.

In systems theory, emergence is related to the concept of the 'whole' — i.e. that a system may need to be studied as a complete and *interacting whole* rather than as an assembly of distinct and separate elements. Checkland defines emergent properties as those exhibited by a human activity system "as a whole entity, which derives from its component activities and their structure, but cannot be reduced to them" (Checkland 1981: 314). The emphasis is on the *interacting whole* and the *non-reduction* of those properties to individual parts.

Francisco Varela (Varela & Maturana 1992; Varela 1995) in his study of the human brain sees emergence as the *transition* from *local* rules or principles of interaction between individual components or agents, to *global* principles or states encompassing the entire collection of agents. Varela sees the transition from local to global rules of interaction occurring as a result of explicit principles such as *coherence* and *resonance*, which provide the local and global levels of analysis (Varela 1995), but adds that to understand emergence fully, we also need to understand the *process that enables a transition*. The emergence of mental states for example, such as pattern recognition, feelings and thoughts may be explained by the evolution of (macroscopic) (Varela's *global* principles or states) "order parameters of cerebral assemblies which are caused by non-linear (microscopic") (Varela's *local* rules or principles) "interactions of neural cells in learning strategies far from thermal equilibrium" (Mainzer 1996: 7). Another area where the transition process is still not fully understood is that of human consciousness. There is an ongoing debate between neuroscientists and philosophers as to whether consciousness can be described as an emergent property of the neural activity of the brain.

The relationship between the micro-events and macro-structures is not always in one direction and there is *reciprocal influence* when *feedback* is in operation "One of the most important problems in evolutionary theory is the eventual feedback between *macroscopic structures* and *microscopic events*: macroscopic structures emerging from microscopic events would in turn lead to a modification of the microscopic mechanisms" (Prigogine & Stengers 1989). This is a *co-evolutionary* process whereby the individual entities and the macro-structures they create through their interaction, influence each other in an ongoing iterative process.

Modern thermodynamics describes the emergence of order by the mathematical concepts of statistical mechanics (Mainzer 1996: 4). Two kinds of phase transition (self-organisation) for order states are distinguished: conservative and dissipative. *Conservative* self-organisation means the phase transition of *reversible* structures in thermal equilibrium, such as the growth of snow crystals, which can revert to water or steam if the temperature is increased. *Dissipative* self-organisation is the phase transition of *irreversible* structures far from thermal equilibrium. Macroscopic patterns emerge from the complex non-linear cooperation of microscopic elements when the energetic interaction of the dissipative ('open') system with its environment reaches some critical value (Mainzer 1996: 4). Nicolis (1994) adds "non-linear dynamics and the presence of *constraints* maintaining the system far from equilibrium" are "the basic mechanisms involved in the emergence of . . . (self-organising) phenomena".

In an organisational context, self-organisation may be described as the spontaneous coming together of a group to perform a task (or for some other purpose); the group decides what to do, how and when to do it; and no one outside the group directs those activities. An example is what happened in an Integrated Project Team (IPT) in the Aerospace industry. The team was brought together to create a new project. The members of the team represented firms, which outside the IPT were competitors, but within the team had to cooperate and to create an environment of trust to ensure that sensitive information, necessary for the creation of the new product, could be freely exchanged. The team had to prepare a six-monthly report for its various stakeholders. This report was on hard copy and was usually several inches thick. Some members within the team decided that they would try an alternative presentation. They found that they had the requisite skills among them and they put in extra time to produce the next report on a CD. The coming together of the sub-team to create the new format for the report illustrates the principle of self-organisation. No one told them to do it or even suggested it. They decided what to do, how and when to do it.

Emergence in a human system tends to create irreversible structures or ideas, relationships and organisational forms, which become part of the history of individuals and institutions and in turn affect the evolution of those entities: e.g. the generation of knowledge and of innovative ideas when a team is working together could be described as an emergent property in the sense that it arises from the interaction of individuals and is not just the sum of existing ideas, but could well be something quite new and possibly unexpected. Once the ideas are articulated they form part of the history of each individual and part of the shared history of the team — the process is not reversible — and these new ideas and new knowledge can be built upon to generate further new ideas and knowledge. In the same way organisational learning is an emergent property — it is not just reification (giving objective existence to a concept) but a process based on the interaction of individuals creating new patterns of thought at the macro or organisational level. When learning leads to new behaviours, then the organisation can be said to have adapted and evolved. In that sense, learning is a prerequisite for organisational evolution. If that is the case, then firms need to facilitate learning and the generation of new knowledge — learning here does not mean just training or the acquisition of new skills, but the gaining of insight and understanding which leads to new knowledge.

Continuing with this line of argument, the new knowledge needs to be shared, to generate further new learning and knowledge. There are many reasons why this process is severely limited in most organisations; one of those reasons may be that learning is often seen exclusively as the provision of individual training and another is that the generation and sharing of knowledge is identified with the capturing of data and information in a database. This is not what the current argument is about. It is about understanding *connectivity, interdependence, emergence* and *self-organisation*. It is about how these characteristics of a human organisation, seen as a complex evolving system, work together to create new order and coherence, to sustain the organisation and to ensure its survival, particularly when its environment or social ecosystem is changing fast.

Furthermore, the logic of complexity suggests that learning and the generation and sharing of knowledge need to be facilitated by providing the appropriate socio-cultural and technical *conditions* to support connectivity and interdependence and to facilitate emergence and self-organisation. The latter two characteristics in particular are often blocked or restricted even in what are considered to be liberal organisational cultures by complicated authorisation procedures. It is not however the case that all emergent properties and all self-organisation are necessarily desirable or efficacious. McKelvey (Chapter 10, current volume) eloquently argues that under certain conditions emergence could be "compromised, biased, fragile, sterile or maladaptive". A negative side also applies to connectivity. Again complexity theory does not argue for ever-increasing connectivity, as there are limits to the viable connections that can be sustained and to the information that any individual can handle, that arises from these connections.

To summarise, the main points are: (a) if we see organisations as complex evolving systems and if we understand their characteristics as CES, we can work with those characteristics rather than block them; (b) those characteristics are closely related and we need to understand their interrelationship to gain maximum benefit from the application of the theory; for example, looking at emergence or self-organisation in isolation does not provide that deeper understanding; (c) to introduce the idea of *enabling environments* based on socio-cultural and technical conditions that facilitate rather than inhibit learning and the generation and sharing of knowledge; and (d) to sound a warning that connectivity cannot be increased indefinitely without breakdown and that emergence is not always efficacious but can also become maladaptive.

7. Chaos and Complexity

Chaos Theory (Gleick 1987) is concerned with those forms of complexity in which emergent order co-exists with disorder at the *edge of chaos*, a term coined by Chris Langton (Waldrop 1992, Penguin Books 1994: 230). When a system moves from a state of order toward increasing disorder, it may go through a transition phase in which new patterns of order emerge among the disorder, giving rise to the paradox of order co-existing with disorder.

But Chaos Theory is not identical with complexity, and the two concepts need to be distinguished in their application to social systems. Chaos theory describes non-linear dynamics based on the *iteration* either of a mathematical algorithm or a set of simple rules of interaction, both of which can give rise to extraordinarily intricate behaviour such as the intricate beauty of fractals or the turbulence of a river. Brian Goodwin (1997) describes such emergent patterns as the "emergent order (which) arises through cycles of iteration in which a pattern of activity, defined by rules or regularities, is repeated over and over again, giving rise to coherent order". Therein lies the key difference, because in chaos theory the iterated formula remains constant, while *complex systems may be capable of adapting and evolving*, of changing their 'rules' of interaction. Furthermore, "chaos by itself doesn't explain the structure, the coherence, the self-organizing cohesiveness of complex systems" (Waldrop 1992, Penguin Books 1994: 12). Applying chaos theory to human systems therefore may not always be appropriate, because human behaviour does not always mimic mathematical algorithms. Humans have cognitive faculties that may enable them to change their rules of interaction.

7.1. Self-Similarity

One of the features of complex systems is that similar characteristics may apply at different levels and scales. In an organisational context, the generic characteristics of complex systems may apply *within* a firm at different levels (individual, team, corporate), as well as *between* related businesses and institutions, including direct and indirect competitors, suppliers, and customers, as well as legal and economic systems. *Fractal* is the term often used to describe the repetition of *self-similar* patterns across levels or scale.

The concept of fractals is related to but distinct from the notion of '*hierarchy*' in systems theory. Hierarchy in the systems context does not refer to vertical relationships of organisational structure or power, but rather to the notion of *nested subsystems*. It is the interpretation of 'subsystem' that differs between the two theories. A fractal element reflects and represents the characteristics of the whole, in the sense that similar patterns of behaviour are found at different levels, while in systems theory, a subsystem is a *part* of the whole, as well as being a whole in its own right. It is "equivalent to system, but contained within a larger system" (Checkland 1981: 317). As Checkland (1981) notes, hierarchy is "the principle according to which entities meaningfully treated as wholes are built up of smaller entities which are themselves wholes . . . and so on. In a hierarchy, *emergent properties* denote the levels" (Checkland 1981: 314). In fractals, repeated properties denote the multiple levels of a system.

8. Managing Organisations as Complex Evolving Systems

If organisations were managed as complex evolving systems, co-evolving within a social ecosystem, emergence would be facilitated rather than inhibited, and self-organisation would be encouraged, as would exploration of the space of possibilities available to an organisation. Managers would understand that an organisation is an entity capable of creating new order, capable of re-creating itself. Management would focus on the creation of conditions that facilitate constant co-evolution within a changing environment, and would encourage the *co-creation* of new organisational form with those directly affected.

We next consider one case study that describes efforts to implement such complexity theory-based management approaches.

The Bank case study[5] The European operation of an international bank needed to upgrade all its European information systems to handle the common European currency by a rigid deadline that could not be changed. The project was completed successfully and on time. One of the main drivers was the pressure of legal and regulatory requirements that needed to be met before the bank was ready to convert to the common European currency. However, although the exogenous pressure was a necessary

[5] The Bank case study was written by Mitleton-Kelly and Papaefthimiou for the international workshop on Feedback and Evolution in Software and Business Processes (FEAST) London, July 10–12 2000 (Mitleton-Kelly & Papaefthimiou 2000, 2001).

condition, it was not sufficient for success. Many other conditions needed to be created internally to provide a *socio-technical enabling infrastructure*.

The project introduced new technologies, and because of its high profile imported an international team of technical experts. What facilitated technical success were certain social conditions initiated by the project manager in charge of the project. One of the most important aspects was creating a closer working relationship between business and information systems professionals than had been the norm in that particular organisation. Previously, the system developers, business managers, and operations personnel simply did not talk to each other unless absolutely necessary.

The project manager initiated a series of monthly meetings at which all three constituencies had to be present and had to discuss their part of the project in a language that was accessible to the others. The monthly meetings, supported by weekly information updates, enabled the three managers of technology, business, and operations to talk together regularly. Initially the meetings were not welcomed, but in time, the various stakeholders involved in the projects began to identify cross-dependencies in the business project relationships, which led to new insights and ideas for new ways of working. Once conditions for new forms of communication were provided, the individuals involved were able to self-organise, to make necessary decisions and take appropriate actions. Communication enabled micro-agent interaction that was neither managed nor controlled from the top. Once inhibitors were removed and enablers put in place, new behaviours and ways of working emerged, making the business fitter and more competitive.

Research identified some of the conditions that enabled the new way of working and relating, as well as some of the conditions that could have restrained it.

Some of the enabling conditions were:

(a) New procedures introducing regular monthly meetings, which supported *networking* and the building of *trust*, as well as a *common language* leading to mutual *understanding*;
(b) *Autonomy*: the project manager was empowered to introduce new procedures;
(c) A *senior manager* supported the changes, but did not interfere with the process;
(d) *Stability*: sufficient *continuity* was assured to see the project through, in an environment where constant change of personnel was a given;
(e) An *interpreter* mediated the dialogue between the domains of expertise represented at the meetings. This ensured understanding on both sides, but also helped to protect the technologists from constant minor changes in requirements.

The potential inhibitors were:

(a) Charging for system changes;
(b) Management discontinuity, resulting in projects not completed;
(c) Differing perceptions — e.g. improving legacy infrastructure could have been seen as a cost by business managers, without understanding its compensating benefits;
(d) Loss of system expertise during the project, through restructuring, downsizing, outsourcing, etc.;
(e) Lack of adequate documentation;
(f) Inaction when systems were seen as '*old but reliable*'.

Another important element in this project was the articulation of business requirements as an iterative process through regular face-to-face meetings. The business requirements meetings in the Bank were at a senior management level with: (a) a vice president who owned the product, was responsible for the P&L (profit & loss) and determined the business requirements; (b) a senior and experienced business project manager who was a seasoned banker, with a good knowledge of the bank; and (c) a senior technology project manager who defined the IS platform(s) and the technical development of the project. This constant dialogue created a willingness to communicate and a growing level of trust, both of which were essential enablers of co-evolution. These social processes can also be seen as positive *feedback or reinforcing processes*. For example, trust facilitates better communication, which in turn enables the building of IT systems that facilitate both better communication and the evolution of the business.

What was achieved in this case involved a project manager, supported by his senior manager, who created conditions that enabled dialogue, understanding, and a good articulation of requirements. He created the initial conditions that improved the relationships between the domains, but he could not exactly foresee how the process would work, or indeed whether it would work. As it happened, it did work, and substantial *network rapport* was established between the domains based on trust, a common language, and mutual understanding. They worked well together because the contextual conditions were right and they were prepared to *self organise* and work in a different way. The new relationships that emerged were not designed beforehand. They happened 'spontaneously' in the sense that they were enabled, but not stipulated.

The achievement in this case, however, could be a one-off event. Unless the new procedures and ways of working used in this project become embedded in the culture of the organisation, they may be forgotten over time. Once the project initiator moves on to another position or organisation, dissipation or reversion to the dominant mode of working may assert itself. In this case there has been some embedding to achieve continuity, but the process is fragile. Much of the embedding is the networking rapport that has been established, but the network rapport is implicit and informal, and is therefore under threat if there are too many and too frequent changes. The Bank's culture is one of constant change in management positions, and if the rate and degree of change is too great, then the networking and its ability to support emergent adaptations may be lost.

Summary and Conclusions

This chapter introduces some of the principles of complexity based on the generic characteristics of all complex systems. It uses the logic of complexity to argue for a different approach to managing organisations through the identification, development, and implementation of an *enabling infrastructure*, which includes the cultural, social, and technical conditions that facilitate the day-to-day running of an organisation or the creation of a new organisational form.

Enabling conditions are suggested using the principles of complexity. Complex systems are not 'designed' in great detail. They are made up of interacting agents, whose interactions create emergent properties, qualities, and patterns of behaviour. It is the actions of individual agents and the immense variety of those actions that constantly influence and create emergent macro patterns or structures. In turn the macro structure of a complex ecosystem influences individual entities, and the evolutionary process moves constantly between micro behaviours and emergent structures, each influencing and recreating the other.

The complexity approach to managing is one of fostering, of creating enabling conditions, of recognising that excessive control and intervention can be counter-productive. When enabling conditions permit an organisation to explore its space of possibilities, the organisation can take risks and try new ideas. Risk taking is meant to help find new solutions, alternative ways to do business, to keep evolving through established connectivities while establishing new ways of connecting (Mitleton-Kelly 2000).

This approach implies that all involved take responsibility for the decisions and actions they carry out on behalf of the organisation. They should not take unnecessary risks, nor are they blamed if the exploration of possibilities does not work. It is in the nature of exploration that some solutions will work and some will not.

Thus, another aspect of an enabling infrastructure is the provision of space, both in the metaphorical and actual senses. A good leader provides psychological space for others to learn, but also physical space and resources for that learning to take place. Individual and group learning is a prerequisite for adaptation, and the conditions for learning and for the sharing of knowledge need to be provided.

Complexity's great strength is that it crosses the boundaries of disciplines in both the natural and social sciences. It may one day provide us with a unified approach capable of linking those disciplines, because understanding the behaviour of complex systems in other subjects helps one gain deeper insights into phenomena in one's own field. Much work now being done on complexity in a variety of fields, from anthropology and psychology to economics and organisational science, will in due course change the way we see organisations, will help us understand their nature as complex systems, and ultimately will change the way that we manage organisations.

Acknowledgements

The chapter is based on research enabled through the support of the LSE Complexity Research Programme collaborators and by two EPSRC (Engineering and Physical Science Research Council) awards under the SEBPC Programme: IT & Computer Science Programme. The first one-year preliminary study (GR/42834) of the two-phase project and the second 3-year project (GR/MO2590) have been completed. The title for both projects was "*The Implications of the Theories of Complexity for the Co-evolution of the Business Process and Information Systems Development*". Both projects explore the findings from the sciences of complexity and examine the implications of generic characteristics of complex systems for organisations.

The EPSRC has also funded a third project, under the Innovative Manufacturing Initiative, on improving the concept definition process (GR/M 23175). This was a

collaborative project with Warwick University, Cranfield Ecotechnology Centre and the Aerospace Industry (Rolls-Royce, BAe Systems, GEC, Hunting Engineering, Smiths Industries, DERA, IMI Marston, Pilatus Britten, Lucas Aerospace).

A fourth major award, also by the EPSRC is funding a 3-year collaborative project under the Systems Integration Initiative entitled '*Enabling the Integration of Diverse Socio-cultural and Technical Systems within a Turbulent Social Ecosystem*' (GR/R37753). The industrial collaborators are British Telecommunications, Norwich Union Life, Rolls Royce Marine and Shell Internet Works. The project started on 1 September 2001.

The Complexity Programme industrial collaborators are both funding and research partners. They have included BT, Citibank (New York), GlaxoSmithKline, the Humberside TEC, Legal & General, Mondragon Cooperative Corporation (Basque Country), Norwich Union, Rolls-Royce Marine, Shell (International, Finance and Shell Internet Works), the World Bank (Washington, D.C.), AstraZeneca and several companies in the Aerospace industry including BAe Systems, DERA, GEC/Marconi, HS Marston, Hunting Engineering, Lucas, Rolls-Royce and Smith Industries.

The research has also been enhanced by the Strategy & Complexity Seminar series, the Study Groups on Complexity and Organisational Learning, the Complexity 'Game' and the Complexity Consortium at the London School of Economics.

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Part III

Complexity Perspectives on Organisational Processes

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Chapter 3

Social Systems and the Embodiment of Organisational Learning

Raul Espejo

1. Introduction

People's interactions may produce *social systems*, which, if and when they emerge, depend upon their *organisation* in order to learn. This paper relates the concepts of collective, social system and organisation. First, I introduce *complexity* as the concept underpinning our discussion of both effective organisation and learning. Second, I focus on social systems and their organisation. Social systems emerge from people's interactions, but these interactions may be the outcome of poorly or well structured organisational processes. An effective organisation increases flexibility and capacity for effective action. Third, having established at a general level the requirements for an organisation to build up its complexity, that is, its 'embodied knowledge',[1] I discuss the problem of producing desirable social systems. This requires social systems with organisations capable of learning. Learning is a generative mechanism for increasing and decreasing the complexity of social systems as they co-evolve within their medium. It is a mechanism for producing desirable functional capacity. Fourth, I discuss structural aspects of this generative mechanism. I will argue that the embodiment of organisational complexity requires having autonomous systems within autonomous systems within autonomous systems and so forth. This is the idea of *recursive organisations*. Finally, I use the idea of recursive organisation as a heuristic to approach the *social accounting* of organisational complexity. It is with reference to this accounting that I discuss some of the relations between institutions and social systems and offer reflections about strategies for complexity management, organisational learning and social change.

[1] The organisation's resources and their relations constitute 'Embodied knowledge', or complexity of an organisation. This is a concept equivalent to that of 'bodyhood' in Maturana's work (c.f. Maturana 1988).

Complex Systems and Evolutionary Perspectives on Organisations
Published by Elsevier Science Ltd.
ISBN: 0-08-043957-8

2. Complexity: Language, Conversations and Grounding

2.1. What is Complexity?

Something complex is not the same as something complicated. In a particular situation, understanding the total behaviour of many dynamically interrelated components may be very complicated, but dealing with the situation may not be necessarily complex. A good model of the situation may help the viewpoint to deal with it with only a relatively small number of alternative actions or responses. A Prime Minister dealing with a hugely important policy issue is likely to recognise only a limited number of options and have a very limited number of alternative actions. For *him/her* the situation is complicated but not complex.[2] On the other hand the situation is likely to be complex for those in the organisation implementing the policy. They have to deal with every detail of the policy; therefore a situation is complex if dealing with it requires making a very large number of distinctions and producing a very large number of responses, even if each situational state is very uncomplicated.

Complexity as detail rather than as complication can be related to Ashby's concept of variety (Ashby 1964). Variety is defined as the "number of *possible* states of a situation". It relates to the idea of possibilities. But, variety proliferates even for relatively simple situations. For instance, the number of possible patterns of interaction in time among seven people is 2^{42} (two to the power of 42), but naturally the number of actual patterns or distinctions seen by a viewpoint is much lower. We can say that this is the situational complexity for that viewpoint. Indeed, there is much more to complexity than the number of possible states, but as we will see below it is a powerful construct.

Furthermore, the number of interaction patterns that are likely to happen, based on the situational history, is much less than its variety. The number of interaction patterns I *can see* as different is likely to be only a handful, and not billions, as suggested by the number 2^{42}. My *complexity in this situation* is likely to evolve from the distinctions I can make. They relate to the *actions* required from me in that situation over time. More stringent action requirements will force more distinctions in order to behave competently. I will be creating a repertoire of responses and incorporating them as practices. The distinctions I make and the related actions or practices define my complexity in this situation. This history of selection of distinctions and creation of response capacity in multiple domains defines what I am. Of the many possibilities I've had throughout time and space, I have realised the ones precisely defining my current complexity. I'm the outcome of a myriad of contingent selections. In this process of selection, I was reconfiguring my complexity. But as implied by this argument at all moments, including of course the present one, I have been confronted with a number of *possible* futures. At each moment, this has been 'my current' situational *variety.* History — that is, my grounded experiences — restricts the realistic possibilities of action I have

[2] This is the reason he/she is able to deal with a large number of different policy issues or situations. The complexity for him/her is likely to be in this diversity, and not in each of the situations.

in any situation, and my languaging[3] limitation restricts the distinctions I can make at any point in time (i.e. there is a limited number of distinct futures I can language and create at any moment). While history relates to my incorporated practices — to my embodied knowledge — language (grounded in my history) relates to my space of possibilities. Indeed, my possibilities, however creative I might be, are restricted by the distinctions (i.e. states) I can invent, appreciate and act upon and not by the number of logically possible states, which are beyond me. Implicit in language is the possible interplay between deconstructing and reconstructing the meanings of my incorporated practices, hence the possibility of reconfiguring my complexity.

Therefore, *my incorporated distinctions and practices define my personal complexity* at a given moment in time. This is part of a learning process. As this happens some of my practices may become transparent to me, they are already part of my embodied knowledge. These distinctions and practices define my *detailed complexity* or my complexity in the *operational domain*. For instance, if I were a musician I would have started incorporating very simple distinctions and practices, like notes and scales. It is only after these distinctions and practices became transparent to me, that is, after I produced them without effort, that mastering more complicated scores would have became possible, and so forth. That is, this learning provides me with the platform for further learning.

On the other hand, the distinctions I make when experiencing breaks in the flow of my routine actions relate to variety or *complexity in my informational domain*. These distinctions open new possibilities as they create opportunities for the future. I use more or less formal models to create and produce meanings for these breaks. In any case, I need to language them in a given context (Espejo 1994). If as a result of this languaging, some old practices become irrelevant and new practices are incorporated then, learning is occurring, and I'm developing complexity in my operational domain (Figure 1). Complexity in the informational domain may help to produce new distinctions but if these are not supported by action, they are wasted distinctions.

Figure 1 illustrates the interplay of the informational and operational domains. The thick arrows represent complexity in my operational domain. They represent my moment-to moment flow of interactions as triggered by my tacit distinctions (this is the complexity based on my history). But, Figure 1 also illustrates breaks, that is my variety or complexity in my informational domain, as I develop awareness of the situation and perhaps make up new distinctions and develop new practices. The thin line in between the others and me represents this complexity.

Thus, my operational complexity is made effective in my moment to moment interactions in a given context. Our individual complexity co-evolves with the medium of our daily existence as we invent new distinctions and ground them in new practices. The engines for this learning are reconfiguring our complexity as well as creating new possibilities. Reconfiguring usually implies questioning the assumptions, values and norms that we take for granted. Creating new possibilities is usually the outcome of

[3] Languaging is the capacity we have to bring forth the world as we make distinctions in language (Maturana & Varela 1992: 234).

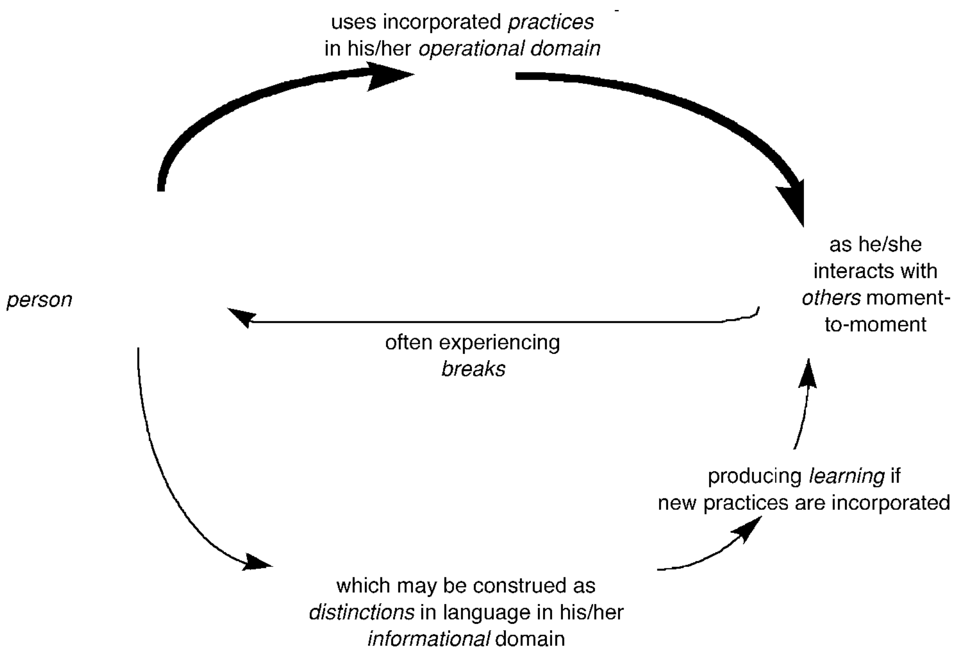

Figure 1: Individual complexity.

conversations about possibilities. This is the process by which we invent the world (Winograd & Flores 1986: 65; Espejo *et al.* 1996, Chapter 7).

In summary, learning takes place when we embody new distinctions and practices. As these practices become incorporated, our 'bodies' change; our complexities evolve. Once these distinctions and practices are grounded to the point where they become transparent, this complexity is part of our 'operational domain' and therefore 'unseen' to us. The process of grounding takes place in our 'informational domain'.

3. The Embodiment of Social Systems: Institutions and Organisation

3.1. Social Complexity

A social system emerges when relationships among individuals in a collective start to be conserved. These relationships are the forms of people's interactions. Particular linguistic structures, values, norms and so forth shape these forms. Identity is being established. This is what the collective conserves regardless of the disturbances it might experience. If their interactions fail to conserve their relationships, they cease being *that* social system (Maturana 1988).

Moment-to-moment interactions among people happen through conversations in shared interactive spaces or structural contexts. If these conversations and contexts produce stable linguistic structures, norms and values, a social system is emerging. The aspects conserved give form to their interactions, that is, to their relationships. We may say that a social system emerges from people's recurrent interactions, which constitutes these people as its *roles*, that is, as restricted human beings producing the interactions producing the system. Therefore, the social system emerges from people's interactions and not from the individuals themselves. The social system will exist for as long as the specific forms of their interactions are conserved. This kind of self-production, where the interacting roles are constituted by the social system emerging from their interactions, is a form of social autopoiesis[4] (Luhmann 1985). It is only when this recursion happens that we have an autonomous social system, otherwise it may be argued that there is only a collective of people.

It is apparent that without people constituted as roles, that is, without human resources, there is no social system. There is no energy producing the social system. These resources are necessary to produce the social system, though specific individuals are not essential to its emergence. The social system is produced by *roles* in interaction, and not by specific individuals. They can be any, as long as they conserve their forms of interaction. There is a process of reciprocal 'structuration'; people in interaction are responsible for structuring a social system, which in its turn is responsible for structuring their social roles. Therefore, it is apparent that a collective of people in interaction is not the same as a social system; however these people (as constituted roles) may embody one. It is this embodiment process that often is unnecessarily costly to people. As I will argue later, emerging social systems are often either dysfunctional or undesirable. This suggests the need to understand better how to enable desirable social systems. This is necessary research at the core of social transformation processes.

It is in conversations that we co-ordinate our actions with others (Maturana 1987). These conversations happen in a given cultural context, in which practices have already been encoded, that is, in contexts in which it appears we communicate effortlessly (almost) 'without the need for channel capacity'.[5] The stronger is this culture the less direct channel capacity we need for routine communications with others. (Espejo *et al.* 1996, Chapter 4).[6] Indeed, this is the complexity that has already been incorporated by relevant social systems.

[4] It is at the level of the interactions of roles that social systems can be seen as self-producing, that is, as autopoietic. This argument for social autopoiesis is based on Maturana and Varela's biological autopoiesis (Maturana & Varela 1980, 1992).

[5] Channel capacity relates first, to the channel between parts in interaction, which does not need to be physical since often these parts interact through their shared environment and second, to the capacity of this channel, that is, to its capacity to remove uncertainty in any transmission between a transmitter and a receiver (Ashby 1964: 179).

[6] Most of our interactions with others take place indirectly by the simple fact of sharing a common culture. In these indirect interactions we make distinctions and recognise new practices, thus we build up our operational complexity. This is a kind of "communications without channel capacity".

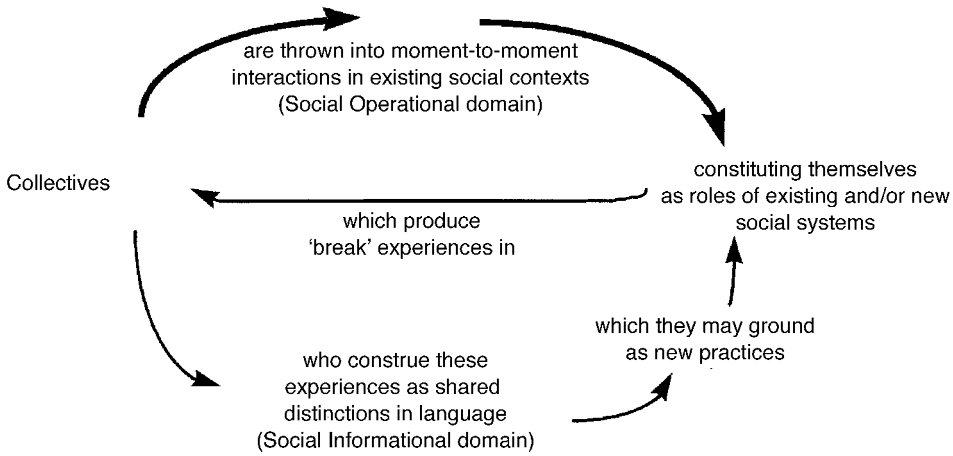

Figure 2: Complexity in social systems.

People in their moment-to-moment conversations, in existing social contexts, make possible the emergence of social systems.[7] Their tacit, culturally based, sharing of distinctions and practices, to the point where they co-ordinate their actions transparently, without apparent effort, enables their contribution to the emergence of a social system. From our perspective, we must realise that this effortless collective co-ordination of actions is the system's complexity. It is when people communicate (almost) without channel capacity that we know there is an incorporated operational domain, supported by a history of learning (Figure 2). However, as they experience breaks and create and share new linguistic structures and learn new practices, they may become, as they interact, the components of a new emergent social system. However, in this process they are operating in the informational domain of an existing social system. This is the mechanism for functional specialisation, opening possibilities for new organised collectives. Now they are experiencing the system's *variety*, that is, their ability to visualise possible future states for the system. It is when breaks happen that opportunities for different futures emerge. If that is what the social system wants to conserve, it bounds these opportunities; any linguistic structure perceived as threatening to their identity is likely to be rejected. They are locked in their history, that is, in their operational domain. However, break experiences will be construed in one form or another and through their conversations they are likely to ground these new distinctions

[7] According to Maturana, conversations are interactions in which people braid language and emotions. For example, when a family constitutes itself as a social system in conversation, the languaging of their interactions is likely to be modulated by emotions like love and solidarity. While the language they use is likely to be the outcome of a long-term social codification of distinctions, their conversations make apparent particular emotions. If they maintain cohesion over time, that is, if they conserve the forms of their interactions without loss of cohesion, they are enabling the emergence of a social system. Otherwise they are only a collective. In any case, the social codification of distinctions is the result of learning processes where people have learned to operate together in a shared context.

into new practices, thus developing the system's complexity. Of course, it may also happen, as they respond to breaks, that already learned practices are lost. Indeed, every year, several world languages disappear!

The trend in modern societies is towards increasing complexity. We are constantly witnessing an increased functional specialisation, which is creating more and more specialised conversations and related linguistic structures. This means that in modern societies we have an increased number of embedded social systems, each of them constituting roles from which particular social systems, with their own identities, emerge. This trend may be a strength but also, as we will see below, may be dangerous if these emerging systems are not aligned with people's primary concerns and purposes.

3.2. Social Systems, Institutions and Organisation

An institution, that is, a collective with a normative constitution, formally created for a purpose, may support the development of a social system. Institutions can provide embodiment to social systems. They may make possible functional differentiation. But, it is also possible that institutions may never produce desirable social systems, as their resources remain fragmented in spite of sharing a clear normative context. Institutions, in general, develop shared linguistic structures. These are valuable for social cohesion but they may become a hindrance if institutions lock themselves in them. This may slow down desirable social change.

Discussing the emergence and embodiment of *desirable* social systems requires one further distinction. This is organisation. A social system has in one form or another an organisation but it may be dysfunctional to its intended meanings. For instance illness rather than health may be the emergent meaning of a particular Health System. This would be the case of a system where its output is its main source of input.

An *organisation* is defined as a closed network of people in interaction *creating, regulating and implementing* its social meanings.[8] If a collective achieves this closure[9] it is producing a social system, regardless of whether it is a formal institution or not, or whether it is producing its intended meaning or not. But the challenge is achieving an organisation with the capacity to produce its intended meanings. Organisation may transform a collective into a social system. But, how difficult is for a collective to create, regulate and implement its intended meanings? Perhaps most collectives, in particular public institutions, run short of these requirements. Often social systems fail to produce their intended meanings. They lack an effective organisation. The most common situation is institutions lacking to different degrees the capacity to create, regulate and implement their own meanings. They may carry out some aspects, but not all of the three together. This increases the chances for social fragmentation. Public institutions

[8] These meanings are those emerging from the interactions of its components rather than those ascribed by people to the social system.

[9] Closure is a circular connectivity between the roles creating meanings for an organisation (e.g. policy makers) and the roles producing these meanings (e.g. workers). An organisation achieves closure when it creates and produces its own meanings.

are perhaps the clearest example of this; a ministry may wish to create a meaning for the sector it represents (e.g. Health) but often fails to produce an organisation out of its interactions with those other institutions responsible for its regulation and implementation. Other institutions, like for instance enterprises, may have themselves resources to create, regulate and implement their tasks, but still are unable to produce their intended social meanings. Their structure may be inadequate. The challenge is establishing the scope for designing *effective organisations* able to produce desirable social systems.

It is important to deal with the problem of meaning creation, that is, of purpose, avoiding the reification of social systems. As people make sense of their interactions and share meanings they create the platform for co-ordinating their actions. These are their purposes-in-use. People may also espouse purposes for their institutions. However, whether there is an explicit or tacit declaration of purposes, it is important to understand their generation. Social systems, in our context, are by definition self-constructed, that is, their meanings are created by themselves. In this sense they are purposeful human activities. On the other hand, in general, for institutions this generation of purpose comes from without, that is they do not create their own meanings. Others produce these meanings for them. They are purposive rather than purposeful. The implication is that the thinking of those creating meanings and the doing of those producing them is fragmented. They are not closing directly their communication loops with the environment; their learning is less effective. This is the relevance of effective organisation in the embodiment of social systems. It provides holistic capacity for learning and change, within the constraints of what people want to conserve.

An implication of this purposeful nature of social systems is the emergence of performance as a significant construct for them. It may become possible in the social system to assess performance and design/create the embodied knowledge to produce a desirable meaning. To facilitate this people need to appreciate the complexity of their own social system. Now people are conscious actors of their social construction; they are aware of their own organisation. Their conversations happen in shared communication spaces, in which linguistic structures have been grounded into shared practices.

Social actors as observers, experience and appreciate the social system's complexity as they develop awareness of the action domains implied by its ascribed purposes (that is, meanings).[10] These are the domains in which the social system's organisation needs incorporated practices in order to be recognised as an effective performer in its environment. It is in the actors' conversations in these action domains, when they experience breaks, that they construe new possibilities which they ground with new practices, actualising the system's variety. As these practices become transparent to the actors, that is, as learning takes place, the system's operational domain grows; its complexity is increased. The need for a system with a learning organisation emerges from the need to ground the distinctions made in conversations in its routines and practices.

[10] This point suggests the relevance of the processes creating meaning for the situation. Often this is done by a subset of the participants and it is not uncommon for external people to have an important influence. Often, the practicalities of participation frustrate these meaning creation processes, hence the relevance of methodological support for these purposes.

An issue to consider when awareness becomes significant is the alignment of the operational and informational domains. For a system without self-awareness this alignment may not be a problem, as its operational domain evolves naturally as its informational domain distinctions are grounded. But, for a self-aware system, there is the clear possibility that people's constructions in their information domain, as they ascribe and agree purpose (that is, meaning), are inconsistent with the system's embodied knowledge. As people ascribe consciously purpose they are implying a particular embodied knowledge, which is unlikely to be naturally in place. Organisational diagnosis and design may help to bridge these gaps.

4. Producing Desirable Systems

Learning is critical for the effective embodiment of social systems. This is the process underpinning the creation of organisational complexity. Learning is relatively easy when we have a clear focus for it, however it is not easy when this focus is hidden under multiple layers of contingency. Social systems are co-evolving in their media and therefore in need of learning to maintain stability and conserve their identity. Yet, it may not be clear what is that they are conserving, that is, what is that it is essential for them to conserve in order to maintain identity. When they are locked in particular linguistic structures, unable to learn, in spite of changes all around them, the cost of maintaining the social system is likely to be high. The system needs capacity to challenge its established values and norms in order to increase its flexibility in its medium. Social systems need to change in order to conserve the most essential aspects of their identity. This kind of learning — double loop learning (Argyris & Schon 1978) — is particularly difficult when the embodiment of the social system does not have capacity for self-reflection. This is an aspect to consider when setting up institutions.

Society institutions have the role of conserving aspects that society considers worth conserving. But, often institutions evolve without appreciating the meaning of their roles in the 'total system'. This makes it more difficult for them to develop consciousness of what is they must conserve and therefore what is the scope for desirable change. It is socially necessary 'to see and develop systems' going beyond thinking just in terms of institutions. Their organisation must have the capacity for creating, regulating and implementing their tasks. Once we put together this functional capacity as the embodiment of our social systems we have together in one body the generative mechanism for reflecting about identity and for making things happen. If effectively structured[11] this is a learning device of major social significance (Beer 1979, 1985).

There are major obstacles for double loop organisational learning (Argyris & Schon 1978; Kim 1993; Espejo *et al.* 1996). There are multiple reasons why social systems become locked into rigid linguistic structures and fail to adapt to their environments, adding to the cost of producing desirable social systems. In any case, we may expect

[11] The structure of an organisation is defined by the communication mechanisms that allow its resources (human and others) to operate together as a whole (Espejo *et al.* 1996).

that a weak capacity for learning will add to their inflexibility to produce desirable change.

Organisational learning relates to conversational processes in which people make sense of their actions, develop shared meanings and codes and ground practices in the form of frameworks, rules, routines, procedures and so forth. These practices enable their interactions as they build up the system's complexity. But, for all this to happen individuals need to create and develop distinctions and practices. Organisational learning relies on individual learning.

No doubt the cohesion of biological systems is far stronger than that of collectives, but social cohesion, if based on roles and systems of meanings rather than on particular individuals, can be indeed strong, as we witness when people defend their religious beliefs and values. As said above it is *roles*, and not specific individuals, that give cohesion to social systems. People may defect from systems if they so wish, but their roles may be constituted again and again. But, on the other hand, to the extent that their roles are not effectively constituted by these systems, their contributions will be *fragmented* and distant, limiting the scope of their contribution. In such situations the chances of achieving an effective organisation, and therefore learning, are reduced.

The challenge is to work out those aspects more likely to produce social cohesion. What does bring people together? Social systems as closed networks of interactions, assume roles that want to stay together and see a value in maintaining their interactions. They are tacitly recognising, in the interactions themselves, the value of producing a system. Whether a social system emerges from particular networks of interactions is an empirical matter, but we can anticipate some factors supporting this emergence. Often geography is offered as a source of cohesion, and indeed nations and communities with a great sense of cohesion and identity have emerged from people's interactions over time. However, when their essential diversity is not recognised, conflicts and wars also emerge from their interactions. *Empirically, it may be possible to work out when people's interactions produce observational closure, that is, a social system with the capacity to absorb variation* (de Zeeuw 1996). For instance in communities with social problems, it is more likely that 'observational closure' will emerge where people's interactions relate to 'survival networks', rather than to arbitrary geographic areas (Vahl 1997). In other words, in a modern society it is more likely that social cohesion will be produced by attempts to conserve social interests like sports, child care, employment and so forth, than by attempts to conserve a geographic neighbourhood. People's local presence for instance, is not enough for them to get involved in community work. Of course, social systems are realised by individuals, and they would not be possible if they were not there, but they are more likely to emerge as a result of people conserving rich linguistic structures, such as those for 'survival networks', than as a result of conserving local proximity. In a multicultural, diverse community, individuals are likely to feel they don't have much in common with others locally. In order to develop embodied knowledge it is critical that resources are related to 'aspects of conservation'; around which people see the point in co-operating. This identity is more likely to emerge if people's interactions are supported by an effective organisation. If we as observers distinguish an identity, we can be sure that there is already an organisation producing it, however weak and poorly structured it might be. Most commonly these organisations emerge from fragmented resources, however, wherever there is a stable linguistic structure there is some form of organisation behind it. We need to understand how to produce an effective alignment of resources with desirable social meanings, in order to enable the development of socially desirable systems. This is an important research programme for the future.

It is apparent that learning is necessary for this alignment to take place. First, individuals need to learn new distinctions and practices to interact effectively with those producing with them the social system. Second, institutions need to learn to align their resources with those of the system they are tacitly creating. And, third, social systems need to learn to align their own linguistic structures with those of the social systems they accept to belong to. These alignments and learning processes have profound social implications for individuals, institutions and social systems. The difficulty is in the possible mismatches between the values and norms emerging in people's interactions in their informational domain and the values and norms emerging in the operational domain of social institutions, based on the resources that society has allocated to sustain them. When resources are inadequate, institutional norms-in-use are unlikely to be consistent with people's expectations emerging from their interactions in their informational domain. This is where an *effective organisation structure* is critical. It allows achieving, at least cost, the social systems we want to have and maintain. We need to learn to overcome the many obstacles for individual and organisational learning. These are obstacles limiting the development of embodied knowledge, that is, limiting the structuring of the necessary organisation to realise desirable social systems.

5. Structural Aspects of Complexity: The Unfolding of Complexity

Accounting for individual and system complexities may help to bridge the gap between espoused theory and theory-in-use. This accounting is a means for anticipating problems and supporting necessary learning. We need awareness of the gap between the existing complexity and the required complexity to produce desirable change. Our lack of appreciation of complexity must be responsible for multiple interpersonal and institutional problems, adding to costs and unfairness in society. We must do much more in terms of designing effective organisations.

For individuals and systems this accounting is not only about how complicated their current tasks[12] are, but also about how much embodied knowledge (i.e. complexity) they have developed. Producing desirable meanings, under stringent performance criteria, depends on already incorporated distinctions and practices. Paradoxically, experiencing many breaks may suggest high variety (a large number of possible futures), but also low complexity (in the operational domain). These breaks might be a symptom that not

[12] As anticipated in another footnote, the idea of task I'm using is very much related to the idea of meaning creation. My assumption is that meaning implies some form of transformation and that making this transformation happen is the task. A related concept is that of performance. While I'm aware that these are very much managerial concepts, I think that they have a wider social relevance and that it is worth exploring this extension.

enough practices have been incorporated. Based on this idea, we can say that the multitude of moment-to-moment transactions already incorporated in a traditional bank's operational domain may make its complexity much larger than the complexity of a similar size high tech non traditional bank. The latter may be facing in relative terms more 'breaks' than the traditional bank (that is, may have a much larger variety), but also may have a much 'smaller' operational domain, of already incorporated practices. The same is the case for individual managers. Their 'large variety', as expressed by their on-going problem solving, does not imply that their complexities in the enterprise's action domains are large. On the contrary, it is likely to be very small as they rely on others to do whatever they do. Therefore, while the complexity of a chief executive's task (i.e. the total enterprise) is likely to be very high (because of the multiple already incorporated practices in the enterprise's action domain) his/her personal complexity in this domain is likely to be very low. He/she is not dealing directly with all the already incorporated, practices (like paying bills, sending orders to suppliers and the like). The executive's activities are more likely to be focused on the organisation's informational domain, where he/she will be dealing with a relatively large number of (complicated) distinctions and related responses, for which learning is necessary. His variety, in the informational domain, may be high, but his action options in each case are few.

5.1. Social Accounting of Individual Complexity

To account for our individual complexity we need to establish the action domains for this assessment. In order to be an effective performer I need to have requisite responses to perform with competence in those action domains. A musical critic assessing my operational complexity in that domain is doing this assessment in my informational domain. He/she must be able to detect breaks in my musical flow in order to establish the limits of my operational domain. Of course I could be my own critic. Since the assessment of complexity in the operational domain is always observer dependent it is fundamental to choose the right viewpoint to make it (Espejo 1987). This proposition puts firmly in observers the assessment of complexity.

To account for my individual variety (rather than complexity), that is, to account for my capacity to deal with breaks, I need to account for my learning capacity. I need to provide evidence that I have capacity to improve my current practices, unlearn old conceptual frameworks and learn new conceptual frameworks. For this purpose my action domains are those of continuous improvement and of reconfiguring my identity and not those, more obvious, of performing specific tasks. A proper viewpoint has to assess my capacity for improving and reconfiguring my current situation.

As managers we manage people contributing to the tasks we are accountable for. But often because of multiple reasons, including the unclear meaning of these tasks, the steering of people challenges us with far more variety than we can deal with directly. This makes it apparent the need we have to ground our variety in organisational practices, thus increasing the system's complexity and reducing our variety.

In practice, thrown into action, we manage some of this variety ourselves, the rest is simply left unattended. This argument suggests that there is scope for us to create

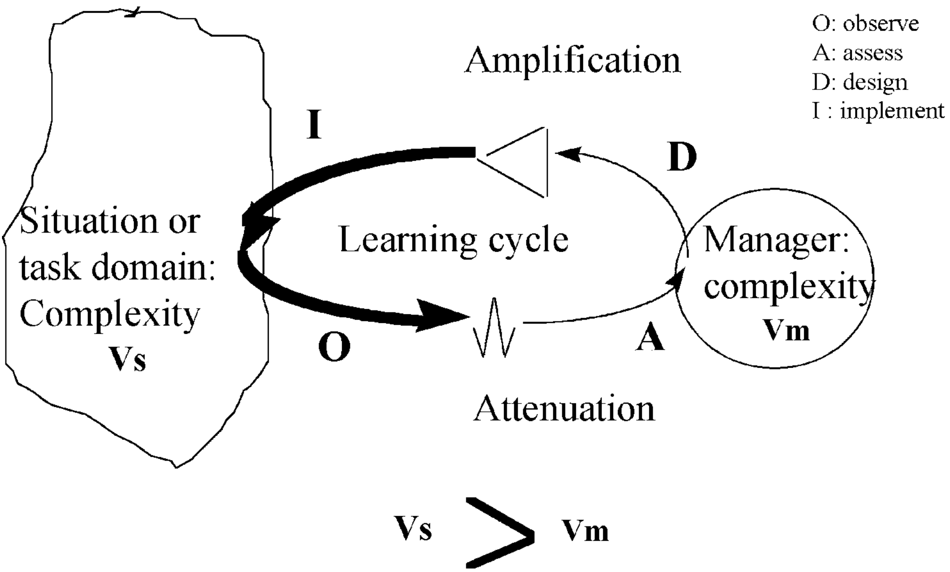

Figure 3: Management and complexity.

strategies to manage situational complexity more effectively (Figure 3). The most common strategy to attenuate situational complexity is ignorance, it is unavoidable and accepting it can be a blessing, however success in this strategy depends on our ability to delegate (a common amplifier of complexity), without losing cohesion, the *unmanaged relevant variety.* We must amplify our capacity to absorb precisely the relevant variety that we are leaving unattended, otherwise we are adding to cost and reducing effectiveness. The larger is this unattended variety, the lower is our performance in the task. To quote Ross Ashby "only variety absorbs variety" (Ashby 1964). In effect, managing variety beyond us requires to work through an organisation. It is through an organisation that we create meanings for our tasks and co-ordinate our actions with others. As managers it is not enough for us to develop our individual complexity, that is, to care for our personal learning, it is also essential to support organisational learning. This is a key strategy to manage *our personal variety* more effective.

In summary, to account for our individual complexity (in our operational domain) we need to establish which are our relevant action domains and rely on experts for this assessment. Of course, one of our action domains is managing a system's tasks. In order to account for this complexity (taking into account its operational domain) we have to support meaning creation processes (i.e. ascribing purposes) and know how to assess the organisation's performance in its environment. Operational complexity constitutes the worlds we live in, that is, our realities. However, the distinctions we make as observers belong to our informational domain. They may say more about us, as observers, than about the observed. Hence the importance of working out legitimate processes leading to this accounting. For this purpose we need to discuss further the social accounting of organisational complexity.

5.2. Social Accounting of a System's Complexity

The issue is that in order to manage social change it is necessary to account for the system's complexity in both the operational and informational domains and not only in the latter as often happens. Indeed it is a common experience for people to commit themselves to implement change without recognising the system's relevant complexity in its operational domain. At the personal level, if someone wants to do something physically demanding, where their lives may be at risk, they will account for their built up practices and see that they are adequate for the requisite stretching. Organisationally, this is less easy to account for and often we see that systems get involved in tasks for which they have not developed the requisite complexity. This is often referred to as the 'problem of implementation'. We fail accounting for organisational complexity.

When we ascribe purpose to a system the emphasis is on its relations with the environment. Is its organisation fit for the purpose?[13] Or, in other words, is the organisation effective? In this respect we are talking about its performance. Performance assessment, as said above, is in an observer's informational domain. But, if it is a social system, that is, if it is a system structurally coupled with its medium, it may have operational stability but it may not be fit to purpose. This implies that there is a system but not necessarily the one implied by the ascribed purposes. What people conserve, the system's identity, is likely to be much stronger than any purpose ascribed to it. If what people consciously conserve is a *relevant core competence* then the chances are that many purposes and related tasks will be possible (without threatening what they want to conserve). On the other hand, if they attempt to conserve a particular task (rather than a core competence) they may lock the system in an inflexible situation, that is, in social irrelevancy. Social systems need awareness of what is they are conserving.

An institution without identity is a heap of resources without cohesion and therefore it is not a social system. These resources are necessary to have a system, but they are not sufficient if there is no identity bonding them as a social system. But, an institution can be a social system with an ineffective organisation. That is, the institution may have an identity and the resources may be enough to create, regulate and implement the meanings it creates for itself, however it may not be aligned with the wider system it accepts or needs belonging to.[14] In the end it is the alignment of purpose with identity that is critical to have an effective organisation. This implies achieving a meaningful human activity with the coherence of a social system. Therefore, the process of meaning creation is critical. It can be argued that failure, tension and unfairness in many systems are the result of poor understanding of meaning creation processes and of unreasonable

[13] The problem of effective performance goes beyond this paper, however the overall discussion above makes it apparent that it should be possible to consider effectiveness also in the organisation's operational domain.

[14] In fact, it may be that the institution, in spite of its clear identity, should not become a system in this context, because its role should be supportive of a wider social purpose or good, and not justified by itself. Several public institutions fall in this category.

external impositions. Also, fragmentation of resources is responsible for an inadequate development of the organisation's embodied knowledge. In either case, empirically, we will not recognise observational closure, that is, a coherent whole with a large capacity to absorb variations.

These internal processes of meaning creation are hindered when there is a big gap between individuals and the total organisation. This is one of the problems with democratic processes in modern societies, where people often feel alienated and unable to contribute to the global processes for meaning creation, leaving them in the hands of a few politicians. Global purposes are likely to be seen as remote and far from an individual's concerns. People may feel alienated and unable to understand what is going on. It is necessary to bridge this mismatch. Bridging the gap between individuals and the global social system requires enabling effective self-organising processes. A system's meaning is produced by the interactions of its constituted autonomous units (i.e. its components). And, the meanings of these autonomous units are the outcome of the interactions of their own constituted (subsumed) autonomous units and so forth. This unfolding/constitution of complexity is at the core of the *recursive organisation* of social systems (Beer 1979, 1985). This has important implications for the accounting of complexity. A complex task is only possible if functional specialisation takes place. Whether this functional specialisation produces subsumed social systems is an open question and the concern of both diagnosis and design. Whether their interactions produce the system's ascribed purposes is also another open question. Often within institutions we see professional functional specialisation, for instance accountants and lawyers, in large manufacturing enterprises, working harder to conserve their professional functional specialisation than the enterprise's viability. While both types of professions are important in modern enterprises, it would appear that functional specialisation in a manufacturing organisation should happen along its core competencies and not along such professions. In other words, it makes no sense to restrict organisational change within a manufacturing enterprise in order to conserve, per se, the values and norms of the accountancy profession. Its structure will be experiencing the cancerous development of a dysfunctional resource. When this specialisation happens, the organisation suffers fragmentation hindering its capacity to learn and develop embodied knowledge in those aspects that are relevant to its purposes.[15] Hence, unfolding should be of *primary activities, that is, of subsumed systems producing through their interactions the system's intended meaning, and not of subsumed autonomous regulatory functions* (Espejo & Bowling 1998). The production of the products and services implied by the system's declared purposes should rely on autonomous units with their *own purposes* (for an effective development of embodied knowledge) producing the system's purposes. It is this reflexive and recursive aspect of purposes that may allow systems to develop a healthy organisation.

As stated earlier a system's complexity is built up over time as people language the breaks they experience and develop related practices. The codes and maps they create over time provide the context for their co-ordination of actions. This is the system's

[15] Therefore an embedded social system may support through its constituted interactions the embodiment of several social systems. This is an issue that requires further attention.

operational domain. However, experiencing breaks is the engine for their on-going learning. It is in this general framework that we need to think about accounting for complexity. To a significant degree the embodied operational domain for those 'seeing this system' is that of its subsumed systems (i.e. primary activities). The management of breaks in these subsumed systems, to a large extent, is transparent to those with the global view. The implication of this structural recursion is subsumed autonomous units, incorporating practices in their operational domains and experiencing breaks in their own informational domains. This is repeated as many times as necessary to absorb in full the complexity of their self-constructed tasks. This implies that the operational domain of a system is the outcome of *recursive learning processes*. The transparency experienced by people is the outcome of their structural position in the organisations, rather than the outcome of already fully grounded practices. The transparency they experience is built on top of the breaks of all those who are experiencing the variety of their realities at different levels of the structural recursion.

The above proposition suggests that accounting for a system's complexity is a recursive process demanding performance assessments for all primary activities. All autonomous (social) systems in a social system need to have capacity to create meanings for themselves and to regulate and implement the changes implied by these meanings. If this were not the case the subsumed units would not be systems and therefore they would lack the self-organising capabilities necessary for building up an effective embodied knowledge. In addition they must accept sharing the identity their interactions produce for the global social system.

6. Conclusion: Research and Social Change

In this paper, I have developed a particular approach to understand and account for complexity. Complexity relates to history, that is to the contingent selection of states for which practices have been incorporated over time. At each moment in time individuals and social systems, as they select options and develop new practices, create their futures. Therefore, complexity relates to history and variety to present possibilities shaping the future. Learning has been presented as a process of incorporation, which requires resources and organisation to take place.

Social systems emerge from people's interactions. It is collectives who provide the resources and energy for these systems to emerge. Often this emergence is the outcome of self-organising processes. However, in modern societies design may speed up the emergence of desirable social systems. This design is offered here as a research programme for the future. We need to account for a growing, but often inflexible, functional differentiation. Institutions of different kinds, because of their fragmented origins, may have locked social systems into inflexible arrangements reducing their capacity to learn. They may have succeeded in creating social systems with the capacity to produce themselves, but not in producing what is socially desirable over time.

This paper is an attempt to set up the agenda for this research. It wants to add to our understanding of how to contribute to social processes producing functional differentiation. It has emphasised the need to talk about social systems rather than institutions.

Social systems have been presented as closed networks of interrelated roles, purposefully creating meanings for their actions. I have proposed that social resources become social systems when they develop the capacity to create, regulate and implement their meanings. By this definition they self-construct their tasks, within the constraints of their own linguistic structures. We need to learn how to harness self-organisation processes in order to support the evolution of desirable social systems.

The challenge is creating new desirable social systems. Autonomy emerges as the engine for social development.

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Chapter 4

Organisational Diversity, Configurations and Evolution

Ian McCarthy and Jane Gillies

1. Introduction

despite the ease with which we may identify meaningful groupings of organisations, no commonly accepted classification scheme has been developed.
(Romanelli 1991: 80)

The term organisational configuration refers to the make up of an organisation, its form or defining characteristics. Miller (1987) and Mintzberg (1990) define configurations as commonly occurring clusters of characteristics that relate to an organisation's strategies, structures and processes. Different configurations exist because there are a number of forces that govern organisational variety and thus give rise to configurations. Miller (1987) refers to these forces as imperatives, because they influence the observed properties of the configuration. The desire to study and understand configurations and the accompanying imperatives is driven by the hope that true insight into an organisation's existence and behaviour will be acquired. This pursuit for organisational knowledge is almost devout, to the extent that terms such as: *organisational species* (Warriner 1984), (McCarthy *et al*. 1997); *organisational blueprint*, (Hannan & Freeman 1977) and *organisational gene pools* (McKelvey 1982) reflect the ambitions of the researchers concerned.

There have been numerous articles discussing organisational diversity in terms of processes (e.g. replication, mutation, recombination, learning, entrepreneurship, competition and natural selection); events (e.g. birth, death, transformation, speciation and extinction); characteristics (e.g. technological, structural, behavioural and strategic) and classifications (ad hoc, theoretical and empirical). This chapter is concerned with the role of classification in identifying, cataloguing and studying organisational

Complex Systems and Evolutionary Perspectives on Organisations
© 2003 Published by Elsevier Science Ltd.

ISBN: 0-08-043957-8

configurations and the associated knowledge on the processes, events and characteristics that both shape and define them.

Although classifying is often a simple and habitual process, it provides a valuable system for storing and communicating knowledge. It facilitates differentiation between the similar and dissimilar and has largely contributed to the advancement of knowledge in most academic disciplines. Cladistics, as with all classifications, is a method for systematically organising knowledge about a population of co-evolving entities. It is a process for studying diversity and attempting to identify and understand laws and relationships that will help explain the evolution and existence of the established and emerging configurations.

Despite the popularity and value of classification, many studies suffer from an inherent oversimplification (Baake 1959) and (Rich 1992). The problem is not the desire to classify entities of interest, but the multitude of classifications that have been constructed without any reference to, or application of, taxonomic methods and theories. To help avoid this problem the following sections view and discuss organisations as systems that seek to consciously evolve appropriate configurations for current and future survival. The different approaches used to produce organisational classifications are introduced and the various benefits and disadvantages reviewed and summarised as a list of taxonomic guidelines. In accordance with these guidelines, this chapter introduces the cladistic classification method as an appropriate method for understanding organisational diversity, configurations and evolution.

1.1. Complex Systems Theory, Configurations and Cladistic Classifications

In recent years the study of systems has developed with input from various disciplines to become known as *complex systems theory* (Anderson 1999; Morel & Ramanujam 1999), or, as some call it, *complexity theory* or *complexity science*. This branch of systems thinking has similar theoretical and applied motivations to that of other systems concepts such as soft systems methodology (Checkland 1981), systems dynamics (Forrester 1961) and general systems theory (Bertalanffy 1968), in that they all seek to model and understand the behaviour of systems. The distinctive stance taken by complex systems theory is that it is concerned with systems that exhibit: (i) a large number of elements comprising the system; (ii) significant interactions among these elements; and (iii) organisation in the system. This system anatomy generates three highly related characteristics of a complex system: *non-linearity*, *emergence*, and *self-organisation*. The consequence for managers is that complexity is a perceived systems attribute which increases as the number and variety of elements and relationships within the system becomes greater, and increases as the level of predictability and understanding of the system as a whole decreases. Thus, complex systems theory acknowledges that certain systems learn and evolve, and cannot be fully described by a single rule. It seeks to understand how the system elements and interactions self-organise to create new configurations.

Next, it is necessary to introduce the term *complex adaptive system*. These systems are complex systems, but the active parts that constitute the system are known as *agents*.

In organisations, agents are the decision-making entities (e.g. operators, control systems, managers, designers, etc.) that receive and process local information to create the events, outputs and internal dynamics of the system. The behaviour of agents is influenced by goal led operating rules known as *schemata*. For example, organisations develop schemata for issues such as; what products and services to provide; what technology to use; and how to manage the plant. Thus, unlike a biological system that blindly changes over time, a complex adaptive system has the ability to consciously alter its system configuration and influence its current and future survival. The implications and challenges for managers are that they should recognise that:

- Business and industrial problems are difficult to comprehend because of complex system behaviour i.e. the parts of a system produce collective behaviours in the system;
- Most (probably all) business and industrial systems are complex systems, exhibiting degrees of self-organisation, emergence, innovation, learning and adaptation;
- The study and modelling of such systems could benefit from metaphors and tools that are able to capture such characteristics and overcome the limitations of reductionist approaches.

To help address these issues, complex systems theory offers a set of metaphors and techniques (McCarthy *et al*. 2000) that place priority on the importance of relationships and patterns inside the system, and essentially the learning opportunity that the complexity mindset offers (Battram 1998). The relevance and utility of complex systems theory to organisational configurations is clear and revolves around the following:

- Organisations, their form and their defining characteristics are dynamic, non-linear systems that consist of interacting components (technology, people, information, etc.). The internal dynamic of these systems *self-organise* to create order i.e. a configuration. Self-organisation often emerges from the learning, adaptation and innovation processes that are key to business success and survival;
- The process of understanding the *emergence* of new configurations is an important characteristic of complex systems theory as it allows the identification of new opportunities. Literally, *emergence* means "to dive out" or "to come out of the depths". In the context of configurations and complex systems, emergence relates to the apparition of new system behaviour due to the collective behaviour of the parts, as opposed to the individual behaviour of each part, and the system's response to its environment;
- Organisational configurations are considered to be complex adaptive systems that demonstrate goal directed *adaptation* i.e. they seek to survive and satisfy markets by adapting themselves to meet the needs and expectations of the market. Adaptation refers to the conscious change process in the system and occurs because the system is open, has feedback mechanisms and has the ability to self-organise (Kauffman & MacReady 1995).

Finally, what is the role of cladistic classifications? It is a method that classifies entities according to how they have self-organised, adapted and emerged over time. The result is a classification system (a cladogram) that represents the known and emerging

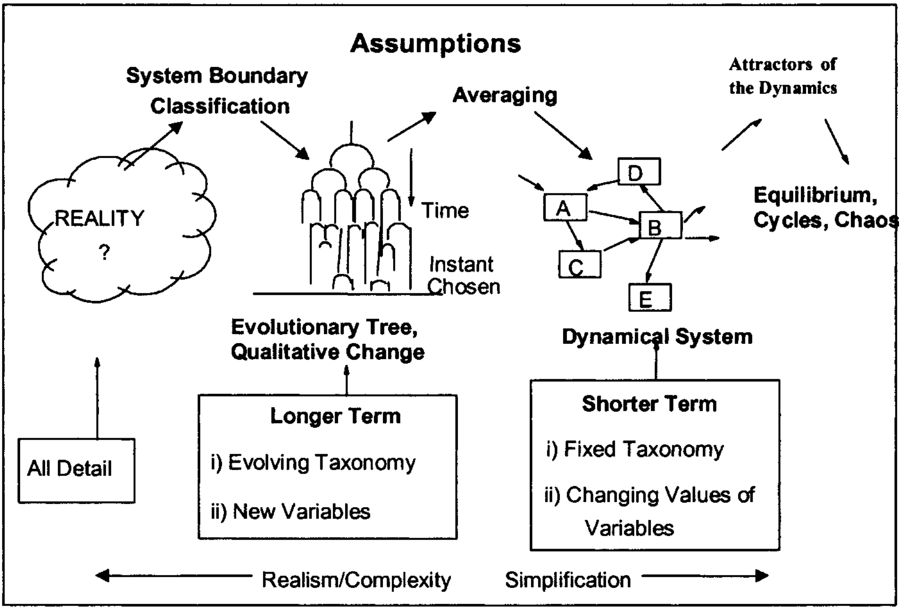

Figure 1.

configurations as a series of *bifurcations* with resulting patterns and relationships. Allen (1998) produced Figure 1 (*evolving taxonomies* vs. *fixed taxonomies)* to illustrate how an evolving classification should be used to understand and formulate rules and models about complex systems. For any configuration, there is a single past, but the possible futures are multiple and thus managers that are involved in developing and leading organisations will face the issues and questions below. These questions underpin the value and application of cladistics as discussed in section 5 of this chapter:

- *Benchmarking* — What is our current competitive position and how do we compare?
- *Diversity and Configurations* — Where do we want to be?
- *Change, Parsimony and Strategy* — How do we get there?
- *Population Ecology* — What promotes an increase in a certain type of configuration?

2. Systematics, Taxonomies and Classifications

The number and diversity of organisations is so vast, that classification provides a system for studying organisations, which have a high aggregate level of similarity. Classification enables researchers to order and compare organisations without losing sight of the underlying richness and diversity that exists within each group (Hambrick 1983). Carper & Snizek (1980) in their review of organisational classifications concluded that: "*the most important step in conducting any form of scientific enquiry involves the ordering, classification, or other grouping of the objects or phenomena under investigation*". This information management aspect of classification was emphasised by Cormack (1971) who in his lecture to the Royal Statistical Society summarised the benefits of a hierarchical classification, stating that: "*the information about the entities is represented in such a way that it will suggest fruitful hypotheses which cannot be true or false, probable or improbable, only profitable or unprofitable*".

Miller (1996) discussed configurations in terms of typologies and taxonomies. The subtle, but important difference between these two classification terms often causes confusion and limits communication. Thus, to aid understanding, a short discussion on key classification terms is provided.

Systematics is the label given to the "science of diversity" (Simpson 1961). Its application concerns the study of systems and the principles of classification and nomenclature. *Taxonomy* is the theory and practice of delimiting and classifying different kinds of entities (Mayr 1982) and (McKelvey 1982). Thus, constructing a classification is a taxonomic process and by the definition of *taxonomy*, groups (*taxa*) are formed and are then allocated a name (*nomy* = naming).

The primary difference between an empirical taxonomy and a theoretical taxonomy (typology) is the stage at which a theory of differences is proposed and the evidence then sought to support that theory. *Theoretical taxonomies* begin by developing a theory of configurations using *a priori* knowledge. Thus, the organisational groups are identified before they are arranged into a formal classification using organisational data. *Empirical taxonomies* gather data on the entities understudy and process this evidence using numerical tools. The configurations identified and the resulting theories are formed primarily from this statistical process. Hence, the data employed is used to construct the empirical taxonomy, instead of supporting the classification, as is the case with theoretical taxonomies.

The term *classification* refers to the development of a system or scheme for arranging entities into *taxa* (hierarchical groups), based on the characteristics or theory identified from the taxonomic process (Mayr 1982) and (McKelvey 1994). It is the visual representation of the identified groups, using methods such as a table, a simple list, or a hierarchical structure. A *classification scheme* represents only one category of taxa, whereas a *classification system* represents two or more categories of taxa (Chrisman *et al*. 1988). Thus, the noun "classification" refers to the arrangement that orders the diversity, regardless of whether a theoretical or empirical approach is used.

2.1. Review of Organisational Classifications

Existing classifications which embrace the subject of organisations include: organisational strategies (Chrisman *et al*. 1988); voluntary associations (Gordon & Babchuk 1958); canning firms and farmers unions (Emery & Trist 1965); general organisational classifications (Burns & Stalker 1961), (Miles & Snow 1978), (Mintzberg 1979), (Thompson 1967), (Perrow 1970) and (Van Ripper 1966) and classifications of manufacturing organisations and their operational and technological systems: (Constable & New 1976), (Wild 1971), (Johnson & Montgomery 1974), (Schmitt *et al*. 1985), (Barber 1986), (Barber & Hollier 1986) and (Woodward 1980).

The above instances are stand-alone classifications. That is, none of them are an extension or progression of another; they are not formally linked together. The fact that the classifications stand in isolation is compounded by the way that they are represented. Output representations include three-dimensional cubes; simple lists and two-by-two tables that bifurcate topical variables and make simplistic distinctions that have few implications.

To help maintain a classification system of real value would require some form of governing body that would approve organisational classifications and the names that are allocated to the identified groups. Chemistry, biology, botany and zoology all have recognised committees that formally approve the existence of newly identified types, the position of this type within the classification and the label given to this newly discovered type. Organisational classifications have not reached a level whereby such a governing body can effectively operate and exist. The result is that despite the prominence of a few well-known classifications, their collective contribution to the study of organisational diversity is limited. In addition, numerous classifications of organisations are so informal that they fail simple tests of logic and stability and are little more than tautologies (Carper & Snizek 1980).

2.1.1. Theoretical taxonomies A limitation of the theoretical approach is that the data used has been collected primarily in support of the developed taxonomy. This means that when applying the classification, researchers may inadvertently seek and collect data that supports their theory. Many believe that the numerous theoretical taxonomies do not have a proper defining theory and the result is not a true theoretical taxonomy, but rather an ad hoc arrangement of configurations (Bacharach 1980) and (Scott 1981). To help determine whether a theoretical taxonomy really has an accompanying theory Doty & Glick (1994) provide three guidelines for assessing the authenticity of a theory. These state that a theory should consist of constructs, have the ability to predict relationships among the constructs and that the predictions should be falsifiable. To test this last point the taxonomy should be empirically evaluated using quantitative data. This would help avoid the problem of logical closure that exists with theoretical taxonomies, where the taxonomy neglects the fit between theory and reality.

2.1.2. Empirical taxonomies With empirical taxonomies, the identification of groups should have no predefined agenda. That means that the sample of characters used to produce the classification determines the nature of the classification arrived at. This occurs because the classification is not driven by theory. The empirical taxonomist's solution is to aggregate all the characteristics into one grand measure of similarity, and the more characteristics that are measured, the more likely that any bias will be averaged out, resulting in an objective classification. This statistical emphasis leads to many studies where the primary value of the classification is the discussion of the statistical processes that underpin the classification, rather than the classification itself (McKelvey 1975) and (Samuel & Mannheim 1970).

Empirically constructed classifications tend to be problem specific and thus lack broader applicability to other settings and organisations (Samuel & Mannheim 1970). They tend to create a *special classification*, rather than a *general classification*, which is multidimensional and considers the organisation as a whole (Jeffrey 1977). The special classification approach contradicts the argument that true configurations will only be discovered by studying the organisation as whole, and yet special classifications still dominate in terms of number (Ulrich & Mckelvey 1990). The development of a general classification of organisations enables researchers to identify organisational characteristics that define groups, which lead to studies capable of describing, predicting and explaining the behaviour of the members of that group (McKelvey 1982).

2.1.3. Guidelines To both summarise the status of organisational classifications and to suggest a framework, which addresses the criticisms, this section compares the classification guidelines proposed by several key texts (Refer to Table 1).

McKelvey (1975) was not overly concerned with whether the approach was empirical or theoretical. His guidelines for creating organisational classifications focused on the need to achieve methodological consistency. The guidelines he proposed advocate the use of numerical tools, but emphasise the importance of selecting the population of characters and organisations. This paper was one of the first to acknowledge that organisational classifications did not refer to, or apply knowledge and techniques from the science of taxonomy.

McKelvey (1978) also discussed the need for a theoretical basis for classification. He argued that the formulation of a classification is a necessary prerequisite for the maturation of organisation science and that if a formal and scientific classification existed, there would be no need for contingency theory. Integrating both the method and the theory, Ulrich & McKelvey (1990) provided three general guidelines that suggested that a population perspective should be linked to a parsimonious theory of organisational differences and validated using statistical techniques.

Rich (1992) provided a comprehensive discussion on the merits and deficiencies of organisational classifications. He endorsed the need for a hierarchical classification created by a defined methodology. The first four guidelines govern the objectives and theory of the classification and advocate the need for a general classification, rather than a special classification. The classification should be considered a hierarchical system that could include all types of organisation and configurations. The final guideline stipulates that organisational classifications should be assessed on their utility and their ability to replicate reality.

Ridley (1993) reviewed the two main principles (phenetic and phylogenetic) and three schools (phenetic, cladistic and evolutionary) of biological classifications. The schools differ in how they represent evolution in classification. To judge the merits of each school of classification, Ridley uses the criterion of *objectivity* vs. *subjectivity* and

Table 1: Classification guidelines.

McKelvey (1975)	Ulrich & McKelvey (1990)	Rich (1992)	Ridley (1993)	Doty & Glick (1994)	Miller (1996)
Broadest Population. Define widest possible population of organisations.	*Theory*. Define or select a theory of organisational differences.	*Breadth*. Define the classification as either empirical or theoretical.	*Objective*. Represents an unambiguous property relevant to the entity's existence.	*Define Grand Theory*. Define theory to clarify the intended purpose of the classification.	*Organisational Wholes*. Classifications should be based on the driving forces of the organisation as a whole.
Sampling Organisations. Use a probability sampling plan without stratification for selecting the sample.	*Parsimony*. Define or select a parsimonious method for identifying organisational differences.	*Meaning*. Philosophical foundations should provide the basis for classification.	*Natural*. The classification conforms to non-defining characters as well as the defining characters.	*Define Set of Ideal Configurations*. Avoid confusion between what is a hybrid and what is an ideal configuration.	*Dynamic*. A classification is simply a snap shot, which changes as new forms emerge.
Exhaustive Characters. Include as many inclusive characters as possible.	*Statistical Evaluation*. Use numerical taxonomy to validate the classification.	*Depth*. The classification should be multivariable.		*Describe Ideal Configurations*. Using consistent dimensions describe each configuration fully and relate to the theory.	*Theoretical*. An underlying theory should integrate the identified form with the first two guidelines.

Table 1: Continued.

McKelvey (1975)	Ulrich & McKelvey (1990)	Rich (1992)	Ridley (1993)	Doty & Glick (1994)	Miller (1996)
Sampling Characters. Use a probability sampling plan for selecting the sample.		*Theory.* Either before or after the creation of the classification, develop a theory which encompasses both the breadth and depth.		*State Assumptions*. Explicitly state the assumptions about the theoretical importance of each construct used to describe the ideal configurations.	*Replicable*. The stability of the classification is such that different studies will enhance it rather than demolish it.
Broad Observers. Define a broad inclusive population characteristic observers.		*Quantitative*. Evaluate the classification using empirical evidence and numerical procedures.		*Testing*. The theories must be tested with conceptual and analytical models.	
Appropriate Analysis. The multivariate analysis must be able to process the full sample of characters.		*Completeness & Logic*. The system should be exhaustive, detailed and extendible.			

Table 1: Continued.

McKelvey (1975)	Ulrich & McKelvey (1990)	Rich (1992)	Ridley (1993)	Doty & Glick (1994)	Miller (1996)
Character Independence. Character must be individually measured and have an equal weighting.		*Recognisablity.* The classification should mirror the real world.			
Statistical Consistency. Statistical decisions should be described and applied consistently.					
Parsimony. Groups should optimise parsimony and homogeneity.					

natural vs. *artificial*. Ridley concluded that a cladistic classification is both natural and objective.

Doty & Glick (1994) described fully developed typologies as complex theories of organisational diversity that can be subjected to empirical testing. The five guidelines they proposed are to ensure that typologies with a real theory are created, rather than simple ad hoc arrangements. Thus, each guideline deals with the defining theory and the identification, definition and testing of the ideal configurations emerging from that theory.

Finally, Miller (1996) describes the shortcomings of existing empirical and theoretical taxonomies. He concluded that even the best theoretical taxonomies are simply products of inspired synthesis and a strong sense of aesthetics, while the weaker classifications are thin and arbitrary, because they cannot demonstrate any relationship between the diversity of configurations and their defining characteristics. Empirical taxonomies tend to lack theoretical significance and thus, the ability of the classification to generate insight or to advance a predictive task is very low. Miller advises that configurations should consider the organisation as a whole and not just individual imperatives of an organisation such as strategy or technology. The classification should be timeless, that is not to say that once a classification has been produced it is actual, valid and will not change. It is the taxonomic process that is timeless; it is capable of enabling the systematic examination of both past and future configurations. A classification is a snapshot of diversity, as time progresses the diversity might increase or decrease. Classifications should not be considered to be static; they emerge along with the entities they are grouping.

These six key texts have in common the following guidelines:

- The need for objectivity driven by a theory of differences;
- To study the entity as natural whole. Thus, classifications of organisations should consider and define the boundary of the organisational entities under study. Classifications of organisational dimensions are both valid and valuable, but you cannot naturally extend conclusions and findings to the whole organisation;
- The objectives and theory should reflect the timeless and dynamic aspects of organisational diversity;
- The system of representing the classification should be hierarchical to permit long-term exhaustivity and to maximise information management benefits;
- Validate the classification using empirical techniques that attempt to align theory with reality;
- Strive for a classification that is parsimonious according to the objectives and theory.

The following section introduces the cladistic approach to classification. This method has a basic philosophy that any set of configurations can have only one true phylogeny (evolutionary development), assuming that the configurations are derived from a common ancestral configuration. This assumption combined with its fifty-year track record in the biological sciences; make it well placed to address the above guidelines.

3. Cladistics: A Natural and Objective Classification

The cladistic school of classification involves studying the evolutionary relationships between entities with reference to the common ancestry of the group. This is referred to as *phylogeny*. Evolution provides the classification with an external reference point, because lineages do not change with a researcher's interest in a particular aspect of an organisation. Thus, cladistics attempts to reveal a change-induced structure, and the similarity represented is a *similarity of change*. This process of identifying ancestral relationships provides a focus through which researchers make can assumptions about organisational configurations and their defining characteristics. The following discussion on the cladistic classification method is an adapted summary of the work by (McCarthy *et al*. 2000) and (McCarthy & Ridgway 2000).

The application of cladistics to organisational configurations implies certain assumptions about organisational forms, their existence and diversity. Cladistic classifications are produced according to three basic assumptions: (i) any group of organisations are related by descent from a common ancestor; (ii) there is a bifurcating pattern of evolutionary change; and (iii) the change in organisational characteristics can be represented on the bifurcating lineages over time. Thus, two configurations that share a recent and common ancestor would be placed in the same group and two configurations sharing a more distant common ancestor would be placed in different groups, but they would be in the same family. As the common ancestor of two configurations becomes increasingly distant, they are grouped further apart in the classification. Supporting this type of evolutionary approach is Miller (1996) who suggests that insights about the emergence of configurations could be gained by studying the Darwinistic selection processes and the self-organising behaviour that govern organisations.

3.1. The Cladogram

A cladogram is the representation of a cladistic classification. It is a tree structure that illustrates the evolutionary history of a group of configurations and the relationships between the different configurations. To demonstrate how a cladogram is produced, the cladogram in Figure 2 and characteristics in Table 2 are referred to. The numbers shown on the branches of Figure 2 represent organisational characteristics that define the configuration. For instance, character "*1*" (standardisation of parts) has a specific location that indicates that *Ancient Craft Systems* do not possess character "*1*", but all subsequent configurations: *Standardised Craft Systems, Modern Craft Systems, Neocraft Systems, etc*. do possess character "*1*". Thus, *Ancient Craft Systems* are the ancestor of a new generation of manufacturing configuration that is based on the acquisition of character "*1*". Similarly, *Modern Craft Systems* are a descendant of *Standardised Craft Systems* as it later acquired character "*2*" (production time standards) and character "*47*" (division of labour). The characters "*13*", "*48*" and "*50*" resulted in the formation of *Neocraft Systems*, whilst the characters "*3*", "*16*" and "*32*" result in the emergence of *Skilled Large Scale Producers*.

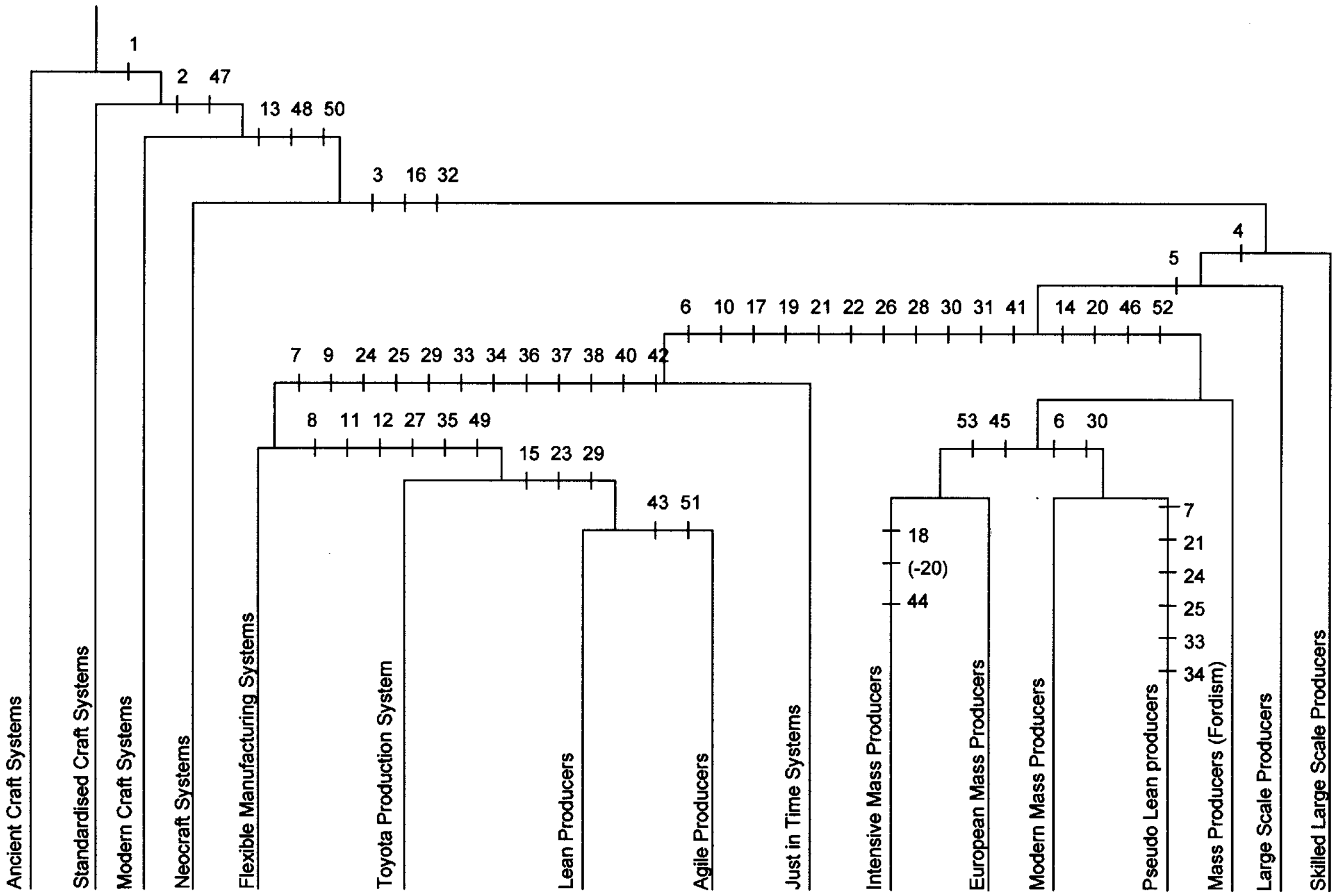

Figure 2: Automotive cladogram.

Table 2: Automotive cladistic characters.

1	Standardisation of parts	28	100% inspection/sampling
2	Assembly time standards	29	U-shape layout
3	Assembly line layout	30	Preventive maintenance
4	Reduction of craft skills	31	Individual error correction. Products are not re-routed to a special fixing station
5	Automation (Machine paced shops)	32	Sequential dependency of workers
6	Pull production system	33	Line balancing
7	Reduction of lot size	34	Team policy (team motivation, pay and autonomy)
8	Pull procurement planning	35	Toyota Verification of Assembly Line (TVAL)
9	Operator based machine maintenance	36	Groups vs. Teams
10	Quality circles	37	Job enrichment
11	Employee innovation prizes	38	Manufacturing cells
12	Job Rotation	39	Concurrent engineering
13	Large volume production	40	ABC costing
14	Suppliers selected primarily by price	41	Excess capacity
15	Exchange of workers with suppliers	42	Flexible automation for product versions
16	Socialisation training (master/apprentice learning)	43	Agile automation for different products
17	Proactive training programs	44	Insourcing
18	Product range reduction	45	Immigrant workforce
19	Automation	46	Dedicated automation
20	Multiple sub-contracting	47	Division of labour
21	Quality Systems (procedures, tools, ISO 9000)	48	Employees are system tools and simply operate m/c's
22	Quality Philosophy (culture, way of working, TQM)	49	Employees are system developers. If motivated and managed they can solve problems and create value
23	Open book policy with suppliers. Sharing of cost data and profits	50	Product focus
24	Flexible, multi-functional workforce	51	Parallel processing (in equipment)
25	Set-up time reduction	52	Dependence on written rules. Unwillingness to challenge rules such as the economic order quantity
26	Kaizen change management	53	Further intensification of labour. Employees are consider part of the machine and will be replaced by a machine if possible
27	TQM sourcing. Suppliers selected on the basis of quality		

Seven stages have been identified for constructing a cladistic classification of organisational configurations. These are shown in Figure 3 and are based on classic biological approaches to cladism (Jeffrey 1977), (Forey *et al.* 1992), (Minelli 1994) and (Sneath & Sokal 1973).

3.1.1. Define problem and select the organisational clade The starting point is to define the clade i.e. the boundaries of the study and what to classify. To help do this, organisational configurations are considered problem posing and problem solving entities that co-evolve, and new organisational configurations emerge as organisations adopt new imperatives. With this assumption it is reasonable to identify a clade differentiated on the basis of the industry into which it was born to survive and provide industrial solutions, e.g. the automotive industry, electronic component manufacturers, cutting tool manufacturers, etc. The example shown in Figure 2 is based on the automobile assembly industry. This sector exists as a population of manufacturing organisations that make and sell a closely related set of well-defined products. It has also been extensively documented making any investigation into its evolutionary development and different configurations relatively simple.

3.1.2. Character search and selection The above process of deciding what to classify, reveals a number of different organisational configurations that could constitute the clade. At this stage the complete membership of the clade is not yet known and thus, a primary objective of the classification process is to examine the evolutionary development of the configurations and to identify the members of the clade and the corresponding characters. Figure 4 illustrates the difference between a *polytomy* and a fully resolved *phylogeny.* A *polytomy* is a group whose ancestral descent (i.e. phylogeny) is unknown. It is believed that all the configurations in the group share a common ancestor, but how these configurations are related to one another is not known. On the other hand, the *phylogeny* exhibits how each configuration is related to one another and how they have evolved from the ancestor. The starting point for many classifications is nearer to a polytomy than to a phylogeny, as the researcher is likely to have some knowledge, but not a complete picture of the phylogenetic relationships.

The cladistic approach to classification has rules concerning what an acceptable taxonomic character is. For instance, a taxonomic character should point to a certain type of grouping between two configurations. This grouping is known as a *shared derived homology* (or a monophyletic group) where the defining characteristic of the group is *shared* by the configurations and has a *derived* (also known as *advanced*) state. Whereas the grouping is known as a shared derived homology, the defining characteristic that is central to this grouping is known as a *synapomorphy.* This relationship is shown in Figure 5, along with other groupings (Ridley 1993). To determine how many characters should be in a classification, there are a number of guidelines including:

- The number of characters should not be less than the number of branching points (i.e. number of configurations), assuming that each character specifies a branching point. Otherwise, polytomies would exist in the clade.

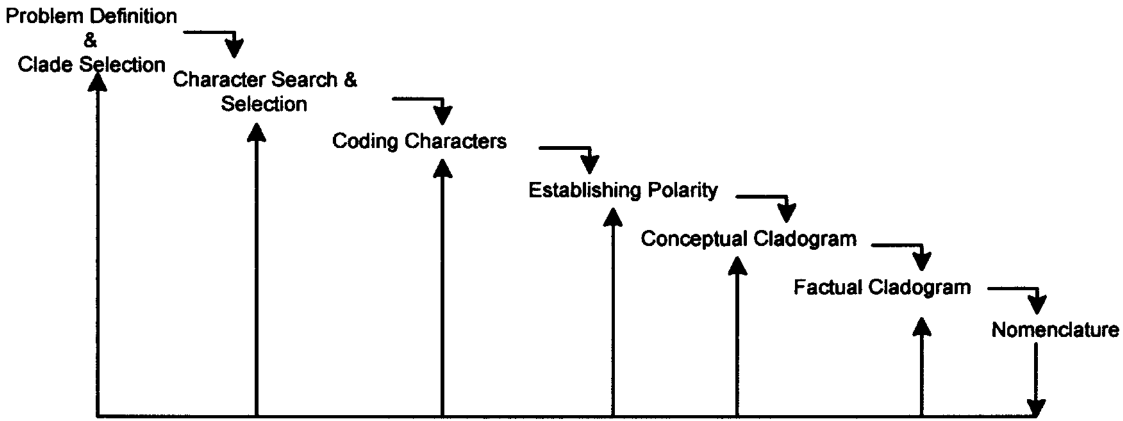

Figure 3: Seven stage waterfall model for building a cladogram.

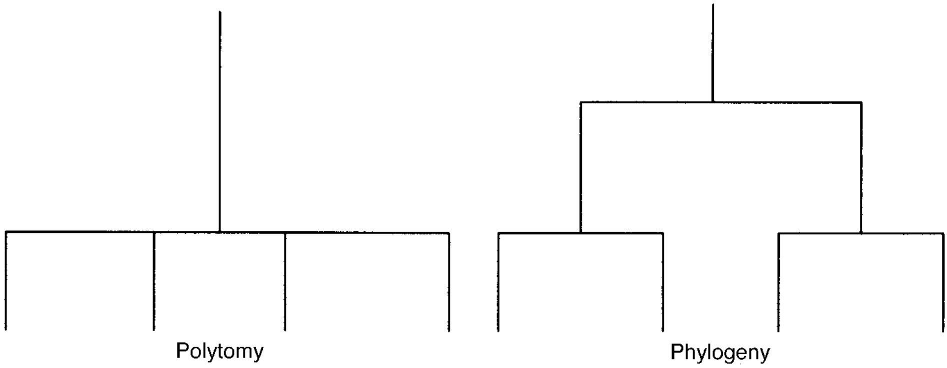

Figure 4: Polytomy and phylogeny.

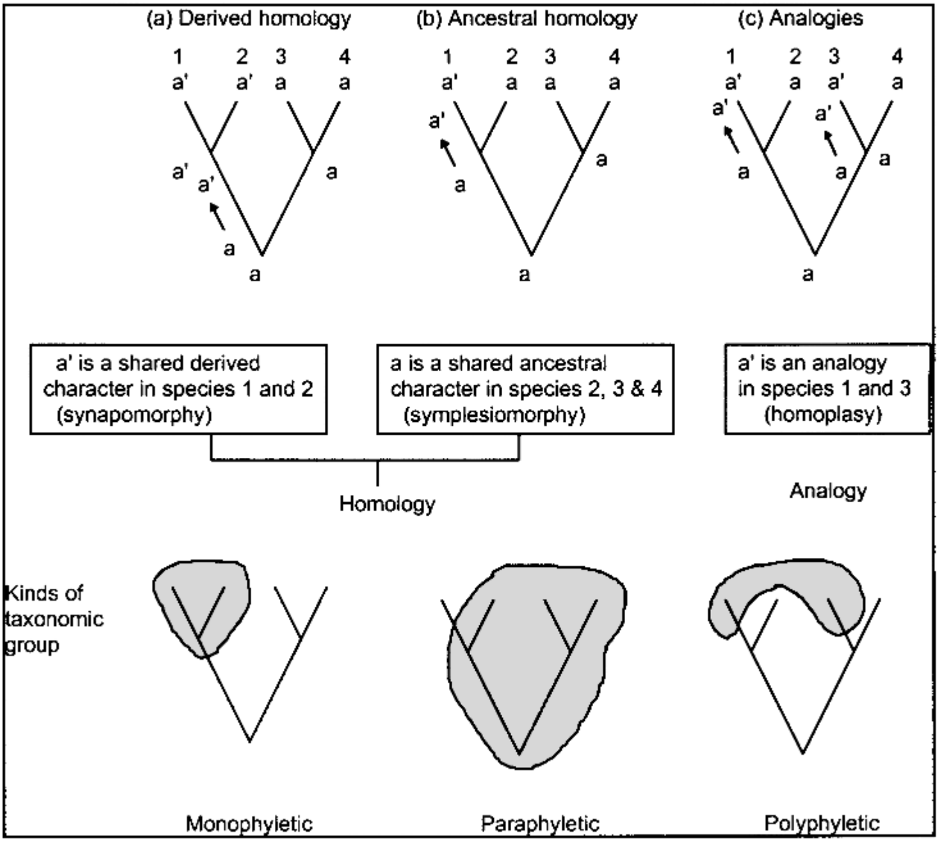

Figure 5: Homologies and analogies.

- To achieve confidence in a given phylogeny, there should be at least three characters per branching point (Felsenstein 1985).
- There is no theoretical maximum of characters in cladistics. The more congruent characters, the higher the confidence in the model.

In summary, Figure 6 represents the process of selecting characters. The first step is to search for characters that can potentially explain the similarities and differences between each configuration. The use of categories and lists of characters can aid character search, but the problem is still to decide whether these characters should be used, i.e. whether these characters form homologies or analogies. To select the characters, taxonomists can apply direct tests of homology, which do not require any hypothesis of phylogeny. When a character passes these tests, it becomes a primary

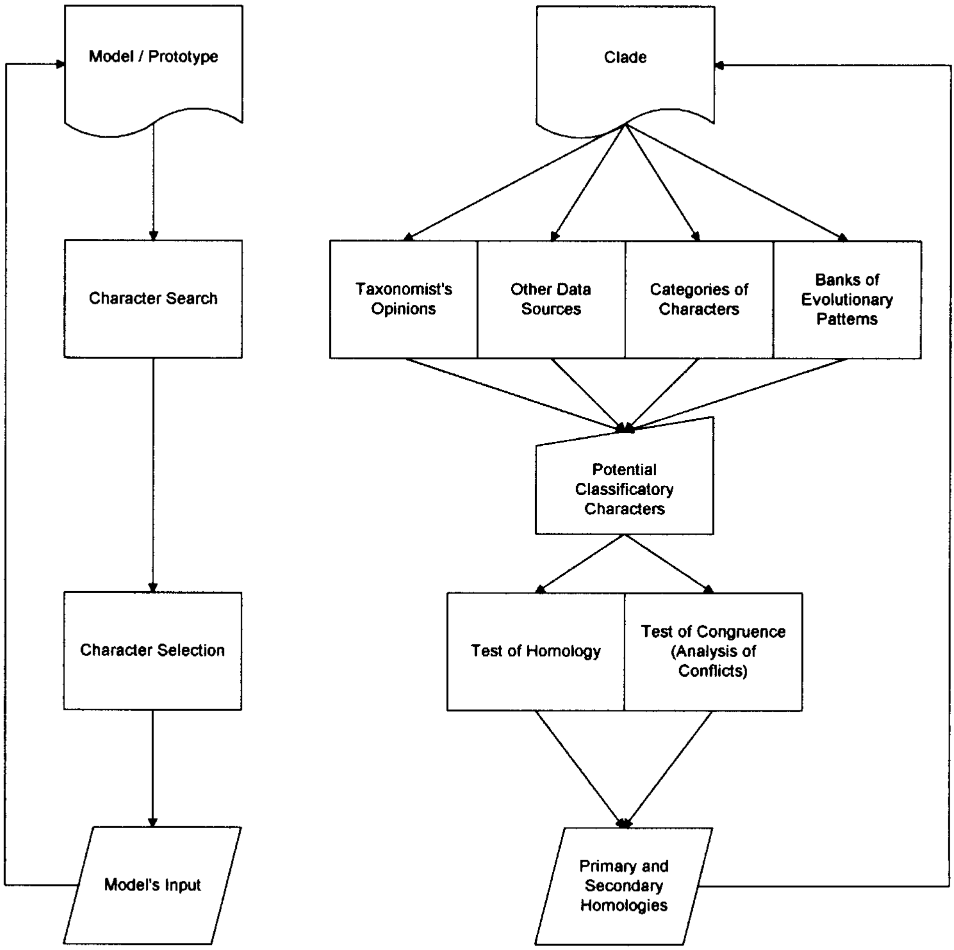

Figure 6: The process of searching and selecting characters.

homology, i.e. a hypothesis of homology. If a phylogeny is already known, the analysis of any potential character conflicts confirms whether any primary homologies were correct assumptions. If not they become secondary homologies (i.e. validated homologies). This process is iterated with several prototypes until the phylogeny is entirely resolved with secondary homologies.

3.1.3. Code characters To understand the relationship between configurations and characteristics, it is necessary to code the characters and thus translate the information into a form that will enable a researcher to determine phylogeny. This is possible because a cladistic character has three properties: *direction*, *order* and *polarity* (Swofford & Maddison 1987). See Figure 7.

The top transformation series has a *linear order*, whereas the bottom one has a *branched order*. The arrows indicate that there is an order between the various character states. For instance, in the top series, state 1 cannot be changed back to state 0. State 2 can eventually transform into state 4 if it goes through state 3. However, in the bottom transformation series, state 2 can never transform into state 4. If the transformation of character states can occur in only one *direction* (i.e. forward only), the character is said to be directed. If transformation in both directions is possible, it is undirected. When the actual direction of transformation for a character has been determined it is said to have a "polarised" state.

3.1.4. Establish character polarity In the Character Search and Selection Section above, similarity was defined as a synapomorphy between two configurations. It is important to note that this definition of similarity revolves around the notion of polarity. Character states can be *primitive*, (also known as *ancestral*), which means that they were inherited from the ancestor of a configuration. On the other hand, *derived* or *advanced* character states are the result of an evolutionary step. Derived characters are not possessed by an ancestor, but are possessed by the descendants. It is only the common possession of derived (or advanced) states that form cladistic similarity. This means that cladists need to specify which states are primitive and which ones are derived if they want to discover synapomorphies.

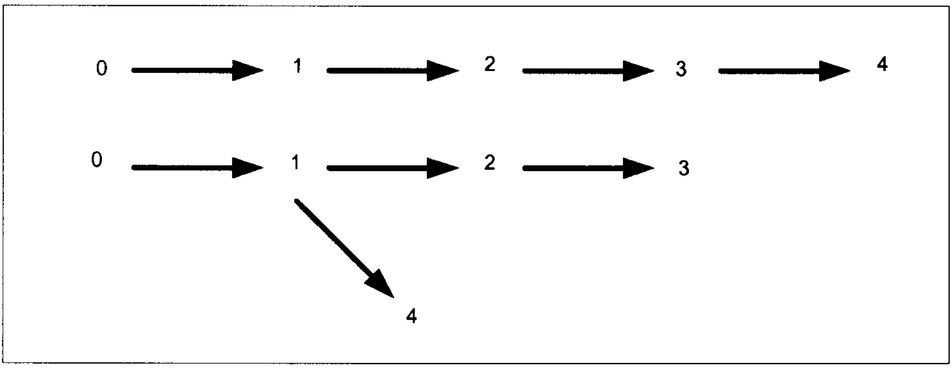

Figure 7: Transformation series.

There are a number of techniques that exist to determine polarity, but the method used to produce the cladogram in Figure 2 was the *outgroup method*. This method is popular in biological cladistics, although the debate over the direct and the indirect method is strongly contested. A comprehensive discussion on the method can be found in (Wiley *et al*. 1991) and (Maddison *et al*. 1984).

3.1.5. Construct conceptual cladogram Using tools such as the software MacClade™ (Madison & Maddison 1992), a cladogram can be constructed according to some simple rules: parsimony, homology and congruence, see (Felsenstein 1983), (Maddison *et al*. 1984) and (Wiley *et al*. 1991). Once a cladogram has been produced, the first step is to map the character changes onto the tree to create a systemic view of the proposed phylogeny. It is common practice to shape test the cladogram by adding additional organisations and characters. MacClade™ allows the user to manipulate cladogram structures and character data and to visualise the characters on each branch. Finally, MacClade™ provides tools for moving branches, re-rooting clades and automatically searching for the most parsimonious tree.

Parsimony is a supplemental concept used to extract the most likely phylogeny from a data table, when the numbers of conflicts is such that this task cannot be done manually. The changes from one character state to another correspond to the number of evolutionary steps that may be counted in a tree structure. The total number of steps in a cladogram is called the tree length, and the principle of parsimony states that the phylogenetic structure with the minimum tree length should be selected.

3.1.6. Construct factual cladogram This stage involves collecting empirical information on existing organisations and their defining configurations. This typically consists of plant inspections, discussions with employees, assessment of planning and control procedures and assessment of documentation (annual reports, business plans and surveys, etc.). The study aims to validate the existence of the characteristics identified during the previous stages. It will test the validity of any proposed tree structure by ensuring that the characteristic data matrix is complete (i.e. no important historical events which relate to characteristic have been omitted) and that the assigned polarity is correct. This stage is to an extent, validation by dissemination, because the factual data will be used to verify the conceptual data. Allocating existing organisations a position on the cladogram will also test the validity of any proposed tree structure.

3.1.7. Taxa nomenclature As with any classification, the identified configurations would be allocated names or labels that reflect the “essence” or defining nature of the configuration. The name given to a taxa of configurations is more than a word that simply acts as a means of reference. It should act as a vehicle for communication, be unambiguous, universal and indicate its position within the classification hierarchy.

4. The Utility of Cladistics

The value of the cladogram shown Figure 2 is derived from the structure of information displayed. It arranges the information into a phylogeny that could be considered a set of synchronic observations. However, to have application value, cladograms need to be associated with diachronic rules (e.g. historical development and forecasts). This is why the usefulness of cladistics is the same notion as its value, since both concepts are two particular ways to evaluate the relevance of a structure. This point is important to make, because it distinguishes the validity of the model (i.e. of the phylogenetic hypothesis) from the validity of the diachronic rules. The following sections review the possible application of cladistics to the study of organisations.

4.1. Benchmarking

Although benchmarking has been successful, it lacks a framework to co-ordinate all studies. Because benchmarking is solely concerned with comparing practice and performance between organisations, one would expect benchmarking to be a classification-intensive discipline. Yet this is not the case, since classifications are seldom used, with a few exceptions, see (Dale 1996). Classifications were dismissed early on by the pioneers of benchmarking as "prescriptive traps" (Camp 1989) and if a classification is not properly built, it is clear that the diachronic rules attached to it will be flawed. Thus, the recommendations and predictions that are attached to the classifications are indeed prescriptive traps.

Yet, if a benchmarking study were to use a classification that conformed to the guidelines listed in section 2.1.3, then it would be better placed to identify all appropriate working practices (i.e. the cladistic characters). The classification provides a system for detecting such practices, because they are an essential part of the viability of a configuration and the resulting cladogram. If a key character is overlooked, the structure and information content of the cladogram helps to reveal and explain this failure.

4.2. Organisational Change, Parsimony and Strategy

Since cladistics is a classification method that ties its definition of similarity to naturally occurring change processes, the result is that the information contained within a cladogram is potentially useful for identifying standard change sequences.

Most organisational change initiatives attempt to break away from the routines and procedures that have become ingrained in an organisation over the years and often restrict change into alternative competitive configurations. Thus, organisational change is strongly linked to the notion of path dependency and the constraints an organisation's history can exert on its current behaviour. Path dependence is the result of two distinct effects: (i) variation and randomness; and (ii) positive feedback (Sastry & Coen 1996). In other words, a variety of small events, some the result of chance, some the result of conscious design, aggregate together to form a larger system effect that becomes, through time, a configuration, reinforced consistently by a positive feedback process.

In addition, as a cladogram is constructed according to the rules of parsimony, the physical and financial cost of any identified change route would be minimised i.e. the route between any two configurations on a cladogram involves the minimum amount of character changes and bifurcation points. Thus, a cladogram could be compared to a map, which provides organisations with an unambiguous and precise definition of the starting and end points of the change journey.

4.3. Organisational Diversity and Configurations

Despite the need for knowledge on the evolution of new organisational forms, no theoretical consensus exists for organising and supporting the vast number of empirical studies that examine industrial and organisational diversity. Research into configurations is also criticised for its lack of a comparative framework, because the research does not seem to go beyond the building of typologies and of taxonomies (Miller 1996). Using a systematic and comparative method such as cladistics, permits an assessment of the generality of the attributes of complex systems that could play a significant role in explaining the processes by which the routines and structures of organisations and configurations persist and exist over time. Since diversity is a prime variable of an ecosystem's wealth and sustainability, it is not only legitimate, but also important to study it and to describe it through classifications.

4.4. Population Ecology

One of the themes of population ecology, as initially formulated by Hannan & Freeman (1989) is to study the growth of different populations of organisations. This involves selecting a specific population and then studying the evolution of certain organisational configurations. Simple population growth models derived from biology are used to determine ecological parameters and to demonstrate that the chosen population has followed a normal growth pattern under selective pressures, or that a population disappeared because it was not fit.

Hannan & Freeman (1989) stress that a key problem with this approach is selecting the unit of analysis. This issue is regularly raised in biology, where there is debate about the unit of selection: genes, individuals, or populations (i.e. species). Hannan and Freeman recommend using populations of organisations to study selection, but defining a population or an organisational boundary is an ever present problem in organisational science and is to a large extent an objective of the classification process. Baum (1994) and Singh (1994) discussed this problem and recommended using organisational systematics to determine the unit of selection. In other words, the classification of organisations defines the configurations and the members (specimens) of these configurations form the population that should be studied in population ecology.

By definition, cladistic species are monophyletic groups that have been created by non-random laws of change. It has never been specified that these forces include a selection process, or that selection is the only force at work. However, if indeed a selection process operates on organisations, then its signature could be present in the configurations.

5. Summary

Organisations are evolving systems that have a decision-making capacity capable of influencing the self-organisation, adaptation and emergence processes that create new configurations. To identify and understand existing and emerging configurations is a classification issue, and therefore to fully capture and represent the information, relationships and patterns that exist between different configurations, requires a classification that also acknowledges the evolutionary and complex adaptive behaviour of such systems. By using such an approach to understand configurations it is possible to influence managerial action on how to shape future organisational evolution.

Cladistics uses evolutionary relationships to identify and form groups, because evolution is the process that accompanies the changes that materialise to produce different configurations. The resulting classification and the knowledge contained within, provide insights into organisational diversity. These insights include: observing the patterns and events that accompany organisational change and identifying the most parsimonious route between different configurations.

To understand the cladistic method, a seven-stage waterfall model was presented (Figure 3) and although this has the advantage of being easy to follow, it fails to properly represent the real process of building an organisational cladogram. The problem is that cladistics in practice, is not a step-by-step process of knowledge extraction; there is significant overlap between the steps and concurrent activities. Cladistics attempts to extract knowledge by improving interactively the definition of the key-elements of a classification: the problem definition, the clade definition, the character search and selection and the inference of a phylogeny. This point is represented by Figure 8, which illustrates that a clade can only be identified if the phylogeny is known and the characters can only be selected if the clade is known. In other words, there is no logical starting point for such a problem, as the discovery of one variable is only possible when all other variables are known. Researchers have to start somewhere, with a hypothetical

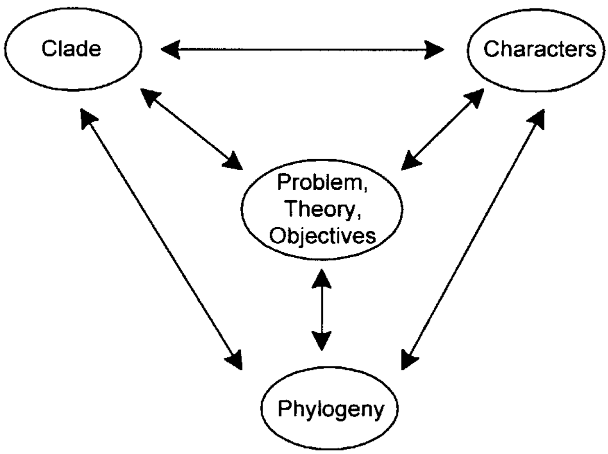

Figure 8: The lost 180 degrees problem in cladistics.

clade, and with a hypothetical set of characters. The test of congruence is the external criterion that is used to refine this initial guess into a knowledge-rich classification.

The clade selection process and the assumption that members of the clade are descendants of a common ancestor govern the classification objectivity and theory of differences (relationships of phylogeny). This is akin to tracking the evolution of configurations. As per the guidelines listed in section 2.1.3, cladistics advocates studying the entity in its entirety, whether that is the complete organisational system or a sub-system within the organisation. Thus, when attempting a cladistic classification of organisations, the process of constructing the classification will help define the boundaries, but will not focus on individual dimensions of the organisation. The focus is evolutionary descent, regardless of whether the characteristics are structural, technological, behavioural or social. A classification based on evolutionary lineages seeks to be natural, timeless and dynamic. A cladogram is a hierarchical system of information and relationships that enable the addition of new configurations as time progresses and stimulates enquiry, observations and theory formulation. A cladistic classification is first constructed using the theory of differences (phylogenetic relationships, the identification of synapomorphies and parsimony) and at each stage of the seven-stage framework; the falsifiability of the classification is tested. Falsifiability, through the test of congruence, is what guides researchers to improve their classifications. The conceptual cladogram is a theoretical taxonomy, which tempts the researcher with a multitude of relationships and possible hypotheses. This cladogram and the hypotheses it contains are validated using field research and empirical techniques that attempt to align theory with reality. Finally, a cladistic classification aims to be parsimonious, as the cladogram construction phase creates a tree that has the least number of evolutionary steps, without losing any identified monophyletic groups. This theory of parsimony is aligned with the theory of differences and can be tested by searching for different tree lengths.

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Chapter 5

Emergent Order in Firms: Complexity Science vs. the Entanglement Trap

Bill McKelvey

1. Introduction

Complexity science mostly asks: What causes order? (Mainzer 1997). Entanglement is about what exists before order emerges in the physical world. The Darwin/Wallace theory of natural selection (Darwin 1859) explains order (speciation) in the biological world, that is, why are there different *kinds* of organisms. Durkheim (1893) and Spencer (1898) also defined order as the emergence of *kinds*, specifically, social entities. Half a century later, however, Sommerhoff (1950), Ashby (1956, 1962), and Rothstein (1958) defined order not in terms of entities but rather in terms of the *connections* among them. In fact, order does not exist without both.

Quantum entanglement, as the precursor to emergent order, is much discussed in physics (Gell-Mann 1994; Omnès 1999). And the spontaneous origin of life is much discussed in biology (Kauffman 1993). Long ago, Ashby made two observations particularly relevant to the biological and social worlds. *Order* (organisation), he said, exists between two entities, *A* and *B*, only if this relation is "conditioned" by a third entity, *C* (1962: 255). If *C* is viewed as the "environment" which is external to the relation between *A* and *B*, it follows that connections become ordered only in the context of environmental constraints (Ashby 1956) — and disordered if the environment changes. This, then, gave rise to his "*law of requisite variety*" (1956). It holds that for a biological or social entity to be efficaciously adaptive, the variety of its internal order must match the variety of the environmental constraints.[1] Interestingly, he also observed that order does not emerge when the environmental constraints are chaotic (1956: 131–132).

[1] Allen (2001) amends Ashby's law to the "law of excess diversity" to compensate for the probability that some portion of the potentially adaptively relevant routines a firm might have will prove irrelevant.

Complex Systems and Evolutionary Perspectives on Organisations

ISBN: 0-08-043957-8

Complexity science's emergent-order explanations play out differently in the physical, biological, and social worlds. Natural selection is one way of explaining how order appears out of the primordial soup — the *selectionist* explanation. An additional explanation of order-from-entanglement — completely nonselectionist — emerges from quantum theory — the *decoherence* explanation. Preliminarily, think of *entanglement* as the interdependence of two particles or entities such that neither one can behave nor be understood independently, and decoherence as the negation of the entanglement effect. Gell-Mann (1994), focusing on coarse-graining, reviews how physical structures decohere from entangled electrons and/or wave packets. Though selectionist theories pervade economics (Friedman 1953; Alchian 1950; Nelson & Winter 1982) and organisation science (Kaufman 1975; Aldrich 1979, 1999; Weick 1979; McKelvey 1982; Baum & Singh 1994), decoherence theory is totally missing.

My discussion of entanglement, decoherence, and coarse-graining begins with a review of how order from coarse-graining emerges from the fine-grained structure of entanglement pools of quantum phenomena — all for the purpose of understanding the concept of *correlated histories over time* between pairs of electrons and how these affect emergence of higher-level structures. Specifically, I detail the process by which emergence arises from entanglement in the complexity region. This occurs in the so-called region at "the edge of chaos" — between the 1st and 2nd critical values of an imposed field created by energy-differentials in the natural world — what I have termed elsewhere "*adaptive tension*" in firms (McKelvey 2001, 2003b). Clearly the adaptive efficacy of emergent structure in firms depends on the purity of the entanglement field(s) existing within a firm in addition to the law of requisite variety. Given this, I then focus on: (1) the joint importance of entanglement *and* adaptive tension as co-producers of effective emergent structure; (2) an elaboration of adaptive tension control parameters; and (3) the interaction of selection and decoherence as causes of order-creation. The concept of "entanglement ties" is introduced to fill an operational hole in the sociological network literature. I conclude by discussing difficulties executives face in trying simultaneously to produce adaptively efficacious emergent structure and untarnished entanglement pools.

2. Defining Entanglement

In the classic "two-slit" experiment, a light source shoots photons at the panel holding the slits. What shows up on the viewing screen is a pattern of dark and light bands indicating that the photons travel as waves because, after passing through the two slits, they interfere with each other — doubling their strength in the light bands and cancelling each other out in the dark bands. But, if a detector is located at one of the slits, what hits the screen no longer appears as interfering waves but rather as particles. Further, if the detector is placed at only one slit — and thus apparently causing the wave to collapse into a particle, this same behaviour occurs at the other slit, even though there is no detector. In response to this effect, during the course of his classic debate with Niels Bohr, Albert Einstein uttered three memorable phrases: "God does not play the dice". "Is the moon there when nobody looks?" [slightly paraphrased] and "I cannot seriously believe in . . . spooky actions at a distance" (Mermin 1991: 501–502). Over the past 65 years the Bohr-Einstein debate and the classic two-slit experiment have been the subject of many philosophical discussions (Bohm 1951; Petersen 1968; Jammer 1974; Fine 1986; Cushing & McMullin 1989; D'Espagnat 1989; Healey 1989; Hughes 1989; Cohen *et al*. 1996) and many increasingly complicated experiments (Gribbin 1984, 1995; Bell 1987; Mills 1994; Omnès 1999). In recent years a complexity science perspective has been added (Mainzer 1997). Key points in the "history" of quantum theory are:

(1) Around the middle of the 19th century Hamilton introduced what is now known as the *Hamiltonian function H*, where total energy is a function of kinetic and potential energy. Taking a pendulum, for example, at any point in its swing, one can reduce its force, if it were to hit something, to $F = H(q, p)$ where q is a position coordinate and p is a momentum coordinate — at any given position, q, the pendulum has a momentum, p;

(2) In 1900 Planck discovered that electromagnetic oscillations only occur in discreet lumps, known as *quanta*. Introducing his *uncertainty principle*, Heisenberg observed that, since any attempt to measure an electron's q would alter its p (or vice versa), an electron's Hamiltonian function would forever remain an uncertainty;

(3) This led quantum physicists to replace the Hamiltonian qs and ps with the so-called *Hamiltonian operator*, such that $E = H(q, p)$ becomes $E = H(x)$, where x is the operator reflecting the unseparable values of q and p. From this emerged Schrödinger's wave function;

(4) Schrödinger's wave formulation includes wave *superposition*.[2] When waves appear superimposed, their individual states cannot be separated or located — they are *entangled* in a single wave packet. The process of detection — in the double slit experiment, for example — causes a wave packet to collapse and, therefore, the quanta, as particles, become visible — both after passing through the slit where the detector is and *also after passing through a "distant" slit having no detector.*

In the traditional interpretation of quantum phenomena, the visible world is somehow the result of the collapse of the countless billions of wave packets into particles of matter. The double-slit experiments show that, if an instrument is used to detect the passage of an electron through a slit, the wave packet is collapsed into a particle. Numerous theories have emerged to explain the "spooky action at a distance" and, further, what has caused all the wave packets in the visible universe to collapse into observable matter (Gribbin 1984; Fine 1986; Shimony 1978; Mermin 1991; Mills 1994; Cohen *et al*. 1996).

In a book written for popular consumption, Murray Gell-Mann (1994, Chapter 11) uses a few simple terms to explain the "Modern Interpretation" of how the world of

[2] When two waves of the same frequency and amplitude are "superimposed" their effect is: (1) magnified if their peaks and troughs coincide, as in a laser; or (2) if the peak of one wave occurs at the same time as the trough of the other wave, they cancel each other out, as illustrated in the double-slit experiment.

objects and deterministic natural laws coexists with the probabilistic world of quanta.[3] Electrons interact with one another such that the quantum state of the one is affected by the other. Thus, over a series of time intervals, their quantum states are correlated. The correlation of each quanta with all the others is referred to as *entanglement*. The quantum state of a given electron at a given time is, thus, a function of its entanglement with all the other electrons it is correlated with, possibly a virtually infinite number. Presumably, correlations with nearer electrons dominate correlations with electrons, say on the other side of the galaxy but, still, correlations from the farther electrons presumably filter through intervening neighbours to affect the neighbourhood of the nearer electrons.

At any given time, in a sequence of time intervals, each electron has a *history* of effects from all the other electrons it has come in contact with. Because of the countless correlations, and the differing quantum states of all the other electrons, each individual history is likely unique. Consequently quantum theorists cannot attach a probability of occurrence to each individual electron's history — its history is confounded by its interaction with all the other electrons' histories. Instead, they use a quantity, *D*(A, B) to record the relation between the quantum histories of two correlated electrons over time — thus *D* is always assigned to *pairs* of individual electron histories, A and B. *Entanglement* occurs when the *correlated histories* of pairs of electrons are greater than zero. If the two individual histories of a pair of electrons happen to be the same (unlikely) or are combined, *D* becomes a probability, between 0 and 1. If the individual histories are correlated, they are said to *interfere* with each other. Since most histories are correlated with other histories, *D* is seldom a probability and so, Gell-Mann says, "since the best that quantum mechanics can do in any situation is to predict a probability, it can do nothing in the case of histories that interfere with each other" (1994: 143). If histories almost always interfere, and thus *D* is almost never a probability, how can physicists predict with probability, let alone with what seems to most of us, virtual certainty? Gell-Mann refers to classical Newtonian, deterministic physics as "quasiclassical" physics" (p. 150) to recognise that even though natural physical laws seem deterministic and predictive, as more details are introduced, seemingly deterministic laws become probabilistic — *the more exact the measure, the more probabilistic the law*!

Gell-Mann refers to the world of interference-prone histories as "*fine-grained*" structure. Thus, the quantum world is the fine-grained structure whereas he labels the world of quasiclassical physics as the *coarse-grained* structure. The question then arises, How does coarse-grained structure emerge from fine-grained — entangled — structure? He uses the metaphor of a race-track. As you get to your seat at the race track and consider the odds on your favourite horse to win, you eventually ignore all of the

[3] I have double checked everything Gell-Mann says with the recent "modern interpretation" by Omnès (1999), whom Gell-Mann cites with approval. The Omnès treatment is more technical and treats in book-length what Gell-Mann covers in one chapter. Their views are consistent, but, for example, they do view the collapse of the collective wave packet(s) that is Mars, for example, in somewhat different ways. In addition, Omnès holds that decoherence in the universe is so pervasive and instantaneous that decoherence has happened long before any "observer" happens upon the scene — thus an observer such as the "watcher" (Mills 1994) is superfluous.

other factors that could affect the race — quality of horse, feed, and vets, the state of the track, sunlight, temperature, wind, swirling dust, flies, nature of the other people betting, track owners, mental state and health of the jockeys, and a hundred other factors that conceivably could affect the outcome of a race. All other times and the history of everything else in the universe is ignored. Everything about the horse loses importance except for when the tip of its nose crosses the finish line. The coarse-grained history of the race dominates all the other fine-grained histories of all the other possibly correlated factors. In his view, it is important to realise that this happens whether you are actually at the track or see the race or not.

How do the race probabilities emerge from the interference of the fine-grained structure? Gell-Mann says that when we "*sum over*" all of the detailed factors left out — that are not the tips of the noses of the few horses in, say, the fourth race — the interference effects average out at approximately zero — hence all the effects of the myriad tiny correlations among the details have no effect. The *context* of our interest in the winning horse causes us to sum-over all the other fine-grained correlations. The race-relevant correlations among all the fine-structure effects are focused on — to become the coarse-grained structure — whereas all the other detail correlations are summed-over and their "interference" made irrelevant. When this happens, there are three effects: (1) most of the history quantities, *D*, are ignored, that is, summed over; (2) the few correlated histories that become important do so because of the particular time and place — the context — meaning that the histories are similar and conjoined or the horses wouldn't be in the same race at the same place at the same time. This is to say that we now have D(A, A) or D(B, B) or D(A & B, B & A) in Gell-Mann's terms, that is, similar histories; and (3) since the interferences among these few correlated histories disappear, they become truly probabilistic and, thus, we can talk reasonably of the probability that one horse will nose out another. In other words, a coarse-grained history is a class made up of equivalent fine-grained histories.

Gell-Mann says: "A coarse-grained history may be regarded as a class of alternative fine-grained histories, all of which agree on a particular account of what is followed, but vary over all possible behaviours of what is not followed, what is summed over" (p. 144). Empirical researchers play this game every time they assume that the various effects not specifically hypothesised, or designed into their study as control variables, are randomised, that is, neutralise each other and are, thus, summed over. The emergent coarse-graining process overcomes the interference-term effect by translating entanglement into probability, what Gell-Mann speaks of as "*decoherence*" (p. 146).[4] Recall that the *interference terms* are the myriad correlations between pairs of particles in the fine-grained structure. Coarse-graining results in the selecting out from the myriad correlated histories of the same kind and the same level of relationship. Gell-Mann says coarse-graining "*washes out*" the interferences among histories in the fine-grained structure (pp. 145–146).

[4] Omnès (1999, p. 75) defines decoherence as "the absence of macroscopic interferences."

3. Coarse-graining and Complexity Science

It is clear from Gell-Mann's race track metaphor that coarse-graining is a function of context. If a law enforcement authority went to the track looking for dishonest bookmakers, then his or her emergent coarse-graining would be quite different. Coarse-graining is the result of external control parameters. This question returns to Ashby's idea of order created in the context of environmental constraints. "Control parameters", as Mainzer (1997) uses the term, refers to external forces causing the emergence of dissipative structures in the region of complexity. He begins with a review of Lorenz's (1963) discovery of a deterministic model of turbulence in weather systems. A discussion of research focusing on Benárd (1901) cells follows. Here we discover that "*critical values*" in the energy (temperature) differential, ΔT — the control parameter — between warmer and cooler plates of the cell affect the velocity, R (the so-called Reynolds number[5]), of the air flow, which correlates with ΔT. Suppose the plates of the cell represent the hot surface of the earth and the cold upper atmosphere. The critical values divide the velocity of air flow in the "cell" into three kinds: (1) Below the 1st critical value, heat transfer occurs via conduction — gas molecules transfer energy by vibrating more vigorously against each other while remaining essentially in the same place; (2) Between the 1st and 2nd, heat transfer occurs via a bulk movement of air in which the gas molecules move between the surfaces in a circulatory pattern. We encounter these in aircraft as up- and down-drafts; and (3) Above the 2nd critical value, a transition to chaotically moving gas molecules occurs.

What is of primary interest to chaos theorists is the discovery of what Lorenz calls the "*strange attractor*". Lorenz describes the system using three differential equations with three rate-of-change variables: x = circulatory flow velocity, y = temperature difference between ascending and descending air flows, and z = deviation of the temperature differential from its equilibrium value. What Lorenz finds is that the state of the system does not settle at some equilibrium but instead oscillates between paths sometimes within the x, z plane and sometimes within the y, z plane. The state of the system is also very sensitive to initial conditions. As Cramer (1993), Kaye (1993), and Mainzer (1997) show, this basic discovery has been replicated across many kinds of phenomena.

What is of primary interest to complexity theorists, however, is what happens in the region between the critical values, the region of emergent complexity where Prigogine's emergent dissipative structures form (Prigogine 1955; Nicolis & Prigogine 1989). Cramer (1993) observes that the three regions defined by the critical values define three kinds of complexity:

$$subcritical \rightarrow \mid 1st \mid \rightarrow critical \rightarrow \mid 2nd \mid \rightarrow fundamental.$$

His definitions appear in Table 1. The algorithmic compressibility characterising all the laws of classical Newtonian science appears mostly in the subcritical region but also in

[5] Mainzer (1997: 58), as does Haken (1983: 254) incorrectly terms R the Rayleigh number. R, is really the Reynolds number — a measure of the rate of fluid flow, in our case it is a direct function of the energy difference, T. In fluid dynamics, at a specific level of R, fluid flow becomes turbulent. This "critical value" of R is termed the Rayleigh number, R_c (Lagerstrom 1996).

Table 1: Definitions of kinds of complexity by Cramer (1993).

- '***Subcritical complexity***' exists when the amount of information necessary to describe the system is less complex than the system itself. Thus a rule, such as $F = ma = md^2s/dt^2$ is much simpler in information terms than trying to describe the myriad states, velocities, and acceleration rates pursuant to understanding the force of a falling object. "Systems exhibiting subcritical complexity are strictly deterministic and allow for exact prediction" (1993: 213) They are also "reversible" (allowing retrodiction as well as prediction thus making the 'arrow of time' irrelevant (Eddington 1930; Prigogine & Stengers 1984).
- At the opposite extreme is '***fundamental complexity***' where the description of a system is as complex as the system itself — the minimum number of information bits necessary to describe the states is equal to the complexity of the system. Cramer lumps chaotic and fundamental systems into this category, although deterministic chaos is recognised as fundamentally different from fundamental complexity (Morrison 1991; Gell-Mann 1994), since the former is 'simple rule' driven, and fundamental systems are random, though varying in their stochasticity. Thus, three kinds of fundamental complexity are recognised: purely random, probabilistic, and deterministic chaos. For this essay I narrow fundamental complexity to deterministic chaos, at the risk of oversimplification.
- In between Cramer puts '***critical complexity***'. The defining aspect of this category is the possibility of emergent simple deterministic structures fitting subcritical complexity criteria, even though the underlying phenomena remain in the fundamentally complex category. It is here that natural forces ease the investigator's problem by offering intervening objects as 'simplicity targets' the behaviour of which lends itself to simple-rule explanation. Cramer (1993: 215–217) has a long table categorising all kinds of phenomena according to his scheme.

the fundamental region of deterministic chaos. Mainzer (1997: 63) says, "mathematically, symmetry is defined by the invariance of certain laws with respect to several transformations between the corresponding reference systems of an observer". Thus, symmetry dominates the subcritical region and to some extent also applies to the fundamental region. Furthermore, the invariant laws are reversible (Prigogine & Stengers 1984). But, as a control parameter causes the R number to position between the critical values, the consequence is symmetry breaking because the laws of classical physics do not remain invariant.

As Prigogine observes, emergent dissipative structures, "far from equilibrium", in the region of emergent complexity are created as a result of importing energy into the system (at some rate) as negentropy (1955, Nicolis & Prigogine 1989).[6] Though this process is nonlinear and not subject to symmetry, Cramer (1993) observes that once

[6] Schrödinger (1944) coined negentropy to refer to energy importation.

created, dissipative structures become subject to the symmetry and invariant laws of classical physics. The final state of dissipation, that is, of perfect entropy, is describable by a master equation from statistical mechanics; the probable positions of millions of particles subject to Brownian motion can be reduced to minimal degrees of freedom. In reverse, the creation of emergent dissipative structures is in fact a creation of degrees of freedom. As Mainzer puts it, ". . . complexity means that a system has a huge number of degrees of freedom" (p. 65).

In the following three paragraphs, which I quote, Mainzer (1997: 66–68) takes us through the phase transition at the 1st critical value:

> We start with an old [existing] structure, for instance a homogeneous fluid or randomly emitting laser. The instability of the old structure is caused by a change of external [control] parameters, leading eventually to a new macroscopic spatio-temporal structure. Close to the instability point we may distinguish between stable and unstable collective motions or waves (modes) [energy/vector forces]. The unstable modes start to influence and determine the stable modes which therefore can be eliminated. Hermann Haken calls this process very suggestively a 'slaving principle'. Actually, the stable modes are 'enslaved' by the unstable modes at a certain threshold.
>
> Mathematically, this procedure is well known as the so-called 'adiabatic elimination' of fast relaxing variables, for instance, from the master equation describing the change of probabilistic distribution in the corresponding system. Obviously, this elimination procedure enables an enormous reduction of the degrees of freedom. The emergence of a new [dissipative] structure results from the fact that the *remaining* unstable modes serve as order parameters determining the macroscopic behaviour of the system. . . . (my italics)
>
> In general, to summarise, a dissipative structure may become unstable at a certain threshold and break down, enabling the emergence of a new structure. As the introduction of corresponding order parameters results from the elimination of a huge number of degrees of freedom, the emergence of dissipative order is combined with a drastic reduction of complexity. . . . Obviously, irreversibility violates the time-invariance symmetry which characterises the classical (Hamiltonian) world of Newton and Einstein. But the classical view will turn out to be a special case in a steadily changing world.

In the following, I trace out the order that Mainzer is describing and match his steps with Gell-Mann's coarse-graining process:

(1) Start with an existing dissipative structure behaving according to a Newtonian Hamiltonian — a coarse-grained structure in Gell-Mann's terms;
(2) Just before the 1st critical value is reached (from below), unstable vectors (wave packets, modes, energy, forces, motions) appear along with the stable vectors;

(3) As the unstable vectors multiply they begin to enslave the stable vectors, thus eliminating the latter. Degrees of freedom are thereby reduced, as is complexity. Decoherence is crumbling, resulting in interference and entanglement. Consequently, coarse-graining is reduced;
(4) The unstable vectors and their degrees of freedom disappear into a stochastic pool of Brownian motion. This leads to a vast reduction in degrees of freedom. Decoherence has nearly disappeared;
(5) The last few unstable vectors remaining become *order parameters* acting to create the emergent dissipative structures as the system tips over the 1st critical value into the region of emergent complexity — meaning that the order parameters surviving across the complete phase transition are totally the result of a stochastic process;
(6) At this juncture, order, complexity, and increased degrees of freedom emerge. The result is decoherence and emergent coarse-graining;
(7) The region of emergent complexity persists until the energy-differential is reduced by virtue of the continuing emergence of dissipative structures. That is, coarse-graining continues until the energy-differential is reduced. Of course, if the energy-differential is continuously renewed equal to, or even faster than the existing dissipative structures can reduce it, more dissipative structures will continue to emerge. Unless of course the energy-differential rises over the 2nd critical value. Then chaotic processes take over.

Mainzer teases out the fine-grained process events just before and after the phase transition at the 1st critical value. Recalling Omnès's (1999) argument, that in all but visible photons and superconduction, the decoherence processes occur more rapidly than can ever be measured, we realise that a physical system passes through the several states outlined in the bullets above very rapidly — too rapidly to measure, in fact. Nevertheless, we see that emergent structure is stochastically driven by the tail end of the disappearing unstable vectors. By this process, at the phase transition, most of the vectors simply disappear into entanglement. But the trace number at the end collapses the vectors (wave packets) thereby creating the order parameters governing the emergence of dissipative structures. This amounts to an explanation of emergent quantum chaos and the vanishingly small initial order parameters that, like the butterfly effect, eventually influence the forms of emergent dissipative structures of quasiclassical physics.

4. Entanglement in Firms

What causes order in firms? If order is caused, what in firms might cause it to emerge one way and not another? The first calls for complexity science to be applied to firms. The second suggests that language developed in quantum theory about how coarse-graining emerges from entanglement could also be useful. But how could anything coming out of quantum mechanics have relevance to the study of firms? I begin by defining order in firms. Then I touch on the relevance of entanglement and quantum theory for organisation science. Then I discuss entanglement dynamics as they might apply to managing firms.

4.1. Explaining Order in Firms

Three kinds of order exist in organisations: rational, natural, and open systems (Scott 1998). Rational systems result from prepensive conscious intentionalities, usually those of managers. Natural systems, such as informal groups, typically emerge as employees attempt to achieve personal goals in the context of a command-and-control bureaucracy. Open systems are in various ways defined by external forces. That all three exist goes unquestioned. What remains vague, however, are explanations about how they emerge, co-evolve, come to dominate one another, and collectively impact organisational performance. Specifically, how do these three forces combine to produce the order we see in firms, where "order" is defined in terms of formal structure and process and other patterns of behaviour within and by a firm?

McKelvey (1997) defines organisations as quasi-natural phenomena, caused by both the *conscious intentionality* of those holding formal office (rational systems behaviour) and *naturally occurring* structure and process emerging as a result of coevolving individual employee behaviours in a selectionist context (natural and open systems behaviour). Along this line, to date, two general order-causing effects in firms have already been identified: (1) selectionist microcoevolution (McKelvey 1997, 2001, 2003b) coupled with complexity catastrophe (Kauffman 1993; McKelvey 1999a, 1999c); and (2) more broadly, according to thick description researchers (Geertz 1973) and relativists or postmodernists (Burrell & Morgan 1979; Lincoln 1985; Reed & Hughes 1992; Hassard & Parker 1993; Weick 1995; Chia 1996), naturally occurring order in firms emerges from the conflation of the inherent stochastic idiosyncrasies of individuals' aspirations, capabilities, and behaviours — *the social scientists' analog of entanglement*.[7]

The question now is, What is the "engine" that sets these two (secondary) processes in motion? Increasingly, complexity science is seen as a promising place for developing a theory of "natural" order-creation in firms.[8] Management writers mostly emphasise chaos and complexity theories as a means of better understanding the behaviour of firms facing uncertain, nonlinear, rapidly changing environments (Maguire & McKelvey 1999b). This view is somewhat off the track (McKelvey 1999b). Going back to the roots of complexity science in Prigogine's work, we see more accurately that complexity science is fundamentally aimed at explaining order-creation (Cohen & Stewart 1993; Mainzer 1997). Much of normal science focuses on equating energy translations from one form of order to another — working under the 1st law of thermodynamics. This is all in the context of existing order. The 2nd law of thermodynamics focuses on the inevitable disintegration of existing order. Complexity science aims to explain the emergence of order — it is really *order-creation science* focusing on the 0th law of

[7] See McKelvey (2003a, c) and Henrickson & McKelvey (2002) for further discussion of the "marriage" of postmodernist ontology and normal science epistemology.

[8] Sociologists have studied the process of emergent social order since Durkheim (1893) and Spencer (1898). For recent examples, see Ridgeway & Berger (1986, 1988), Berger *et al.* (1998) and Mark (1998). Ridgeway and Berger focus on power legitimation. For them, differentiation follows from the influence of forces external to the social system. Mark focuses on information effects. For him, however, differentiation can emerge in totally undifferentiated systems without the effect of external forces.

thermodynamics (McKelvey 2003d). Complexity science applications have now spread to the physical, life, social, and management sciences (Nicolis & Prigogine 1989; Cowan *et al*. 1994; Belew & Mitchell 1996: Arthur *et al*. 1997; Mainzer 1997; McKelvey 1997; 2001, 2003b; Byrne 1998; Cilliers 1998; Anderson 1999; Maguire & McKelvey 1999a, 1999b).

4.2. A Language to Describe Emergent Order

Physicists have developed a language for talking about how order emerges from disorder at the quantum level. I think this language helps organisation and complexity scientists consider more clearly how natural order emerges in firms.

First, many authors of books applying complexity theory to management (reviewed in Maguire & McKelvey 1999b), use complexity theory in a loose metaphorical fashion in an attempt to help firms cope with an increasingly nonlinear, chaotic, rapidly changing competitive context, often by making a connection between the notion of "*empowerment*" stemming from the Organisation Development literature (Maguire & McKelvey 1999a) and the "*emergence*" or "*self-organising*" process central to complexity theory. McKelvey (1999b) and Maguire & McKelvey (1999a), and many reviewers in Maguire & McKelvey (1999b), question the fruitfulness of this approach, arguing that it rests on misinterpretations of complexity theory. Still, entanglement and decoherence might offer additional insights even within this metaphorical discussion.

Second, quantum theorists have developed terms that, still in a metaphorical way, offer organisation scientists a language with which to better pursue discourse about how order-creation emerges from stochastically idiosyncratic individual behaviours. Perhaps a little less metaphorically, entanglement and decoherence offer an alternative source of order in firms that stands independently of emergent order based on Darwinian selectionist processes (McKelvey 2003d). Given that order in firms is now thought of mostly as resulting from the visible hand of top managers or the invisible hand of selectionist processes (McKelvey 1997), introducing a theory of order based on entanglement and decoherence could give organisation scientists a significant new theoretical tool to use in explaining naturally emergent order in firms.

Third, physicists have learned to talk about, and deal with, particles lacking individuality because they are identical and, thus, interchangeable yet *also* existing in an infinite variety of stochastically idiosyncratic quantum states. Physicists and economists seem to have it both ways. On the one hand, they assume microentities — electrons, photons, rational actors — are all identical and interchangeable. On the other hand, each is different — particles have an infinite number of quantum states and actors have an infinite variety of utility functions. Organisation scientists can have it both ways as well: (1) Use homogeneity assumptions and mathematics when searching for generalisable propositions within existing order regimes; and (2) Use stochastic assumptions and agent-based models when studying order-creation — approaches I discuss elsewhere (McKelvey 1999a, 2000, 2002; Henrickson & McKelvey 2002).

Fourth, physicists describe how the large, tangible objects and elements of the physical world around us emerge from, and coexist with, the entangled world of quantum states. Furthermore, this language also serves to describe how the seemingly precise and deterministically predictive natural laws explaining the behaviour of these objects and elements can coexist on top of the entangled quantum world — remember, physicists are avowed reductionists (Gell-Mann 1994; Weinberg 1994). Again, physicists seem to have it both ways. On the one hand, they have become the hallmark science of both philosophers and the public because they have such accurate predictive success with their natural laws — which seem invariant. On the other hand, from Max Planck's earliest papers/experiments on quantum theory, through Schrödinger's work on the wave function, and onto Gell-Mann and others' development of modern quantum theory (Hoddeson *et al.* 1997), they have wrestled with the problem of how the seemingly rock solid reductionist natural laws could work, given that ultimately they reduce down to the probabilistic quantum world.

Finally, organisation science is torn between approaches to inquiry resting *either* on thick, qualitatively rich descriptions of individuals and organisations (Geertz 1973) and related anti-normal science views held by Kuhnian relativists (Kuhn 1970; Feyerabend 1975) and postmodernists of varying kinds (Burrell & Morgan 1979; Reed & Hughes 1992; Hassard & Parker 1993; Chia 1996); *or* on methods of normal science stemming from the natural sciences. Three things are important. First, at the beginning of the 21st century most sciences now rest on the observation that all generalisations are probabilistic and rest on phenomena that, at the lowest level of analysis, are stochastically idiosyncratic (Schwartz & Ogilvy 1979; Nicolis & Prigogine 1989; Kaye 1993; Gell-Mann 1994; Mainzer 1997; McKelvey 1997). Second, we need to thank postmodernists, geneticists, and quantum physicists for reminding us that the root phenomena, whether human, biological, or physical, are probabilistic and only problematically reducible to deterministic natural laws. Third, we need to remember, however, that the very process of qualitative "thick description" research, for many adherents, is tinged with an anti-science attitude (Gross & Levitt 1998; Koertge 1998; Sokal & Bricmont 1998). Why? Because the focus on the entangled histories of individuals, in whatever setting, absent attempts to explain the emergence and impact of higher-level structure and process has no generalisable or lasting value from the scientific and pragmatic perspectives of discovering truthful theories about how organisations work that might be of some use to managers and other employees. Science only works if, to use Gell-Mann's term, there is coarse-graining — *and* propositions or laws explaining the origin and/or functioning of the macro structures.

4.3. Decoherence and Emergence in Firms

Using complexity science, I have outlined the idea that quantum wave packets are collapsed by external forces and particularly by imposed energy-differentials, following the Modern Interpretation. Not to have done this would have left entanglement — and the decoherence of it via the human observer, or Mill's "watcher" of the universe — solidly in the hands of relativists and postmodernists who decry normal science because everything that is ostensibly and "objectively" detected by science is interpreted "subjectively" by the human observers — what we see is nothing more than the result of wave packets collapsed by subjective human observers. This would encourage the subjective, loose, metaphorical treatment of the term, entanglement, as it is applied to social systems. I have also developed a language that organisation scientists can use to explain naturally emergent order in firms — again in an attempt to get past loose thinking about emergence at "the edge of chaos" and "far from equilibrium".

I can now remind organisation scientists that the most fundamental message of complexity science: *Complexity theory applications to firms rest on environmental constraints in the form of Bénard energy-differentials as the engines of order-creation — defined as the emergence of both entities and connections constrained by context*. The latter, when applied to firms, are best thought of as "*adaptive tension*" parameters (McKelvey 2001, 2003b). Going back to the Bénard cell — the "hot" plate represents a firm's current position; the "cold" plate represents where the firm should be positioned for improved success. The difference is adaptive tension. This "tension" motivates the importation of negentropy and the emergence of adaptation fostering dissipative structures — assuming the tension lies between the 1st and 2nd critical values.

My review of entanglement, decoherence, and coarse-graining, modified by reference to complexity science, uncovers the second fundamental problem in applying complexity science to firms — so far totally unrecognised. Before considering the existence of quantum chaos or the effect of external energy-differentials, natural scientists have long since stopped questioning the existence and reality of quantum entanglements — defined as correlated quantum histories. Here is the problem: *Organisation scientists and managers about to apply complexity science to firms cannot willy-nilly assume that entanglement exists uncorrupted in a given firm. Absent entanglement, altering adaptive tension parameters could produce maladaptive results*.

The nature of the initial pool of entangled particles appears essential to the coarse-graining process. In Gell-Mann's view, coarse-grained structure emerges from entangled fine-grained structure as a result of external influences. Remove the external influence and macro structure disappears in the Bénard cell and coarse-grained quanta disappear back into wave packets. If energy-differentials are viewed as causes of coarse-graining, four critical differences appear:

(1) Given an initially "pure", uncorrupted, or untampered-with pool of entanglements, the first coarse-graining resulting from an imposed energy-differential could alter entanglement in an irrevocable fashion — whether in physical, biological, or social entanglement pools;

(2) Whereas in the Newtonian physical world (Cramer's (1993) subcritical complexity) of quanta and molecules the energy-differential effect is time-reversible, in the biological and social worlds, as Prigogine would say (Prigogine & Stengers 1984), it is a time-irreversible process. Omnès includes the physical world as well;

(3) As a consequence, especially in biological and social entanglements, any subsequent coarse-graining starts with some vestige of the prior coarse-graining effects remaining in the entanglement pool. This means that complexity science in the biological and social worlds is fundamentally different than in the physical world;

(4) In the social world — and particularly in the world of firms — there is the possibility, if not actual advantage or necessity, of constantly managing to preserve or recreate one or more pools of fine-grained entanglements as primordial bases from which subsequent energy-differential caused coarse-grained structures emerge.

To summarise, the logic sequence — in agent[9] terms — is as follows:

(1) There is some level of correlation between the histories of all possible pairs of agents in the fine-grained structure;
(2) Because each agent interferes with all the others, probabilities of how one agent affects another cannot be assigned — their destinies, thus, are entangled;
(3) Coarse-graining washes out interference terms in the fine-grained structure, which is to say, coarse-graining washes out entanglement and results in probabilities — and probabilistic natural laws — rather than interferences;
(4) Energy-differentials — adaptive tension — impinging on agents can, therefore, cause coarse-graining and the creation of probable outcomes emerging from the pool of entangled agents;
(5) In addition to causing coarse-graining, the likelihood that the energy-differential field effect will disrupt the entanglement pool so as to corrupt the "purity" of entanglement, so to speak, increases, going from physical to biological to social worlds;
(6) Because of the feedback effect, the interrelation of entanglement and adaptive tension in social systems sets them apart from physical and to some extent biological systems — though I would not rule out the effect in physical systems. For example, in a Bénard cell, if one removes the energy differential the molecules revert to the conductivity state and it is as if there had been no emergent structure. With organisations, however, successive emergent orders leave an accumulated legacy that usually does not disappear if the adaptive tension is removed — though it could easily deteriorate into a somewhat different coarse-graining.

4.4. The Entanglement Prerequisite

For complexity science to work, the entanglement pool must not only contain a rich set of fine-grained entanglements, but there also must be enough more highly correlated histories that coarse-graining produces structures that emerge as probabilities relative to the fine-grained interference terms (correlated histories) among agents. Organisation scientists should be quick to realise that the entanglement pool is somewhat analogous to Granovetter's (1973) "strength of weak ties" finding, with the proviso that the ties encompass a broad set of correlated substantive interests across agents within a firm.

[9] In agent-based computational models, an "agent" can represent any microentity, such as electrons, atoms, molecules, cells, organisms, species, language/process/conversation elements, individuals, groups, divisions, firms, etc. I use it in this "catch-all" sense here.

Weak ties parallel quantum entanglements in a couple of ways: (1) The weak ties an agent has with many other agents can "interfere" with the level of effort he or she puts into a particular tie and whether the particular tie will grow into a probability of meaningful action; and (2) Coarse-graining will not occur if: (a) there are not enough weak ties of randomly varying substantive contents to allow summing over to reduce the effects of the fine-grain structure to zero — that is, get rid of the interferences; and (b) if there are not enough weak ties having similar substantive contents for coarse-graining to cause the entanglement to decohere into coarse grained-structure. Further, the pool of weak ties, as entanglements, then satisfies Ashby's (1956) "*requisite variety*" required for efficacious emergence to occur, presuming that the energy-differentials become imposed on the agent system either naturally or intentionally. I emphasise "efficacious" because we are not interested in just any old emergence, but rather in emergent structure fostering adaptation that enhances survival. In the case of competitive strategy (Porter 1980, 1985, 1996; McKelvey 2003b) we are interested in emergence leading to economic rents.

Since Granovetter's initial focus on weak ties, sociologists have reconfirmed, but also complicated his simple differentiation of weak vs. strong ties. Various studies showing confirmation are reported in Granovetter's (1982) review of weak tie research. Burt (1992) argues that what is important here are the "gaps" — what he terms "structural holes" — between social cliques and not necessarily the nature of the ties that bridge them. Thus, Burt's theory of social competition and emergent strategy is based on the holes rather than the nature of the tie-bridges across them, though he admits that bridges are almost never composed of strong ties. Podolny & Baron (1997) develop a four-cell typology of kinds of ties based on two distinctions: (1) whether ties are person-to-person or (formal) position-to-position; and (2) whether the content transferred over the tie is about resources/information or about determinants of social identity. Emerging from this literature are the following kinds of network ties in organisations:

(1) **Face-to-face ties**: Strong ties based on frequent face-to-face meetings where "the entire bandwidth" of human interaction is captured (Nohria & Eccles 1992: 293);
(2) ***Philos* ties**: Friendship ties based on social interaction and discussion of personal issues (Krackhardt 1992);
(3) ***Simmelian* ties**: Occurs when two people are strongly and reciprocally tied to each other and both have similar ties to at least one other person in common (Krackhardt 1999); similar to Luce & Perry's (1949) definition of a clique;
(4) **Strong ties**: Frequent repeated ties (Granovetter 1973);
(5) **Bridges across social gaps**: Any kind of tie — strong, weak, redundant, nonredundant — is a bridge between two social clusters and is capable of carrying information (Burt 1992);
(6) **Weak tie bridges**: Defined as ties between clusters that are used, say, more than once a year but less than twice a week (Granovetter 1973; Burt 1992);
(7) **Direct (weak) ties**: Infrequent ties that, nevertheless, occur directly between two individuals, whether or not they bridge between social clusters and whether or not virtual ties exist (Granovetter 1973);

(8) **Indirect (weak) ties**: Ties someone has with all members of a social cluster by virtue of having access to all members via a chain of strong ties (Burt 1992).

None of the foregoing ties are "in motion" over time. Most sociological network research is static (Wasserman & Faust 1994; McKelvey 1999a). Missing is the entanglement notion of correlated histories built up over time. Further, Uzzi (1999) shows that, best advantage comes from an optimal mixing of weak and strong ties. But instead of having an optimal mix of clearly strong and clearly weak ties, consider one kind of tie that has some elements of both strong and weak. In other words, instead of mixing black and white elements to produce gray, let's simply try to work with elements that are already gray. Thus:

Entanglement ties: Defined as direct weak ties that are not so weak as to not have some kind of recognised, correlated "history" of interaction nor so strong as to have established a collective "pair-wise" bias against or predisposition toward specific organisational change possibilities.

It is possible to have entanglement present with direct weak ties occurring as little as once a year, as long as there is some evidence of correlated histories developed over time. "Histories", here, means that the weak tie pair shows evidence metaphorically equivalent to agents influencing each other in some fashion. It is to ask: What is the probability one can predict B's behaviour given knowledge of A's? A once-a-year attendance at a gathering where the CEO gives a speech does not qualify. But, if a listener follows the meeting with some email interchanges with the CEO evidencing mutual influence, then a "correlated history" is established. Entanglement may also be present with strong ties as long as the history is not so strong that it is beyond interference from other entanglement ties the pair partners might have. Thus, as soon as a tie becomes strong enough to show evidence of bias, predisposition, or "groupness", then it is too strong to be counted as entanglement. From the literature, Friedkin's operationalisation of both weak and strong ties illustrates entanglement: "Two scientists were said to have a weak tie if one reported talking with the other about his or her current work, but the other made no such report. Where both made this statement about one another the tie was defined as 'strong'" (1980: 120). Here the weak tie would not be entanglement because there is no correlated history. The strong tie is beginning to show correlated history, and thus entanglement, but it is not "strong" in my sense because there is no evidence of bias or predisposition.

4.5. Fostering Entanglement Ties by Weak-Tie Flooding

It follows from the foregoing discussion that the creation of efficacious emergent complexity in firms requires the requisite variety of entangled ties just as much as it requires an imposed adaptive tension. Given a population of agents in a firm, How to foster one or more entanglement pools? If entanglement-tie correlations do not have the necessary requisite variety, coarse-graining will not emerge, even if adaptive tension is imposed. If entanglement-tie pools are dominated by strong ties, emergent structure might be faulty with respect to efficacious adaptation. How to produce fine-grained entanglement ties among pairs of agent-histories that are in “all”, or at least many, substantive directions, i.e. satisfying the requisite variety law? Some weak-tie flooding alternatives are:

- Build up entanglement by creating denser networks of ties in the fine-grained structure;
- Bring in employees with diverse backgrounds (histories) and interests;
- Create diverse task and liaison groups, other meetings and social mixings — work related or not — where employees, more or less randomly, come together to share notes, ideas, perspectives and “connect” their individual histories and begin to build correlated histories;
- Create imposed field effects based on incoming stimuli that, opposite to adaptive tension, serve to create entanglement ties rather than emergent structure;
- Use field effect stimuli and other actions to destroy obsolete coarse-grained structures so as to recreate viable entanglement pools. They do not talk about it in terms of rejuvenating entanglement, but Baden-Fuller & Stopford (1994) do offer an approach toward decomplexification, that is, de-ordering.

Fostering entanglement pools is not easy because there are well known impediments. In general, anything that disrupts rebuilding the entanglement pools by retaining existing coarse-graining — that is, by retaining existing biased strong ties, or no bridge ties among biased, predispositioned cliques — is counterproductive. Strong egos, advanced specialisations, and narrow functional perspectives all work against entanglement-tie formation, mostly by devaluing any kinds of more broadly defined ties. Perspectives and activities that work to create strong clique, group, or departmental boundaries — which are coarse-grained structures — also work against entanglement-tie formation (Ashkenas *et al*. 1995). Prejudices of any kind, physical distances, and poor communication skills or attitudes prevent entanglement ties. Strong existing *fields* that serve to maintain coarse-graining at the expense of fine-graining are important, the most obvious being strong cultures, whether imposed by upper management intentionalities, technological demands, or shared values (Martin & Frost 1996: 602), or by neurotic founding entrepreneurs (Kets de Vries & Miller 1984). A rash of recent books applying complexity theory to management (reviewed by Maguire & McKelvey 1999a, 1999b) argue that strong command-and-control, that is, bureaucratic structures, impose “official” communication channels, sanctions, boundaries, and so forth, that warp entanglement pools. Strong path dependencies — whether leading to effective or ineffective behaviours — that serve to preserve some correlated histories at the expense of efforts otherwise going into creating broader and more random sets of entanglement ties disrupt entanglement. The dominance in a firm of a particular kind of technological or market orientation can also work against entanglement. The existence of a particularly competent person in a firm can, by simply solving problems by him- or herself, can undermine any need for correlated histories, as Johnson’s (1998) research indicates. From this, we can see that, in general, valuable human capital held by a few employees can undermine the need for emergent social capital, whether of the weak tie, entanglement tie or strong tie variety.

4.6. Entanglement and Adaptive Tension Sequencing

In Gell-Mann's (1994) treatment, focusing as it does on coarse-graining by external photon streams, mutual causality is not a problem — the photon-stream's coarse-graining does not feed back to corrupt the underlying entanglement pool of correlated quantum histories. Coarse-graining from adaptive tension field effects can, however, feedback to alter social entanglement pools. McKelvey (2001, 2003b) develops an approach in which CEOs can draw on ideas from complexity theory to create adaptive tension fields in firms so as to foster regions of complexity "at the edge of chaos" in which emergent structures aimed at solving the adaptive tension problems will occur. But, from the foregoing discussion it should also be clear that "fields" (such as culture, command and control structure, markets, technology, neurotic founders, etc.) also can work to create or disrupt social entanglement pools, potentially undermining the use of adaptive tension fields to foster efficacious emergence. Most importantly, it is possible that activities aiming to create entanglement and efficacious emergence work at cross purposes.

The basic principle is that uncorrupted social entanglement pools must be in place before identifying and setting up adaptive tension field effects and before efficacious emergence can take place. If coarse-graining emerges from fine-grain structure, and if fine-grain entanglement doesn't exist, then efficacious emergence cannot occur. Thus, entanglement ties must be in place before adaptive tension energy-differentials are imposed to foster coarse-graining. If agent properties and localities dominate over correlated histories, interrelations, and entanglement, then efficacious emergence is unlikely, or at best will be compromised, biased, fragile, sterile, or maladaptive.

In firms, however, CEOs would want (or have) to progress, or evolve, from one set of adaptive tension field effects to others over time. Is it realistic for CEOs to stop in between each adaptive tension field imposition aiming at altering coarse-graining to more or less reconstruct the fine-grained structure? How much effort should go into the interim re-creation of entanglement pools? Can this be accomplished quickly, if at all, given the impediments noted previously? The idea is *not* to inadvertently corrupt the creation of entanglement ties via the adaptive tension effects, otherwise the hoped-for outcome of the latter — emergent structures — are likely to be faulty adaptations. In addition, the time periods necessary to accomplish fine-graining or coarse-graining could vary widely. The level of energy-differential or adaptive tension displacement required is uncertain, again causing timing problems. The time necessary to undo previous coarse-grained structures is uncertain, and difficult, as the resistance to change and strong culture literature suggests. In short, even though CEOs might be attempting a sequenced approach, the likelihood is that fields working to recreate entanglement and foster emergence don't just stop and start their effects with "on-off" clarity. The odds are that they could be in effect at the same time — working at cross-purposes. Given all this, the sequential alternating approach seems dubious.

If alternating field effects is difficult, can fine- and coarse-graining, instead, take place simultaneously? Is it possible to impose fields simultaneously in firms, that aim to recreate both fine-grained and coarse-grained structures? I think the answer is yes. On the one hand, adaptive tension effects are, by definition, aimed at moving a firm toward a more adaptively improved state relative to competitors and other forces and constraints in its competitive environment. As detailed in McKelvey (2003b), adaptive tension fields are created by promulgating information that says, in effect, "Our productivity, our product quality, our product portfolio is *this* . . . but it needs to be *that* . . .". In contrast, the five bullets listed previously, about how to produce entanglement, have nothing intrinsically to do with adaptive tension — *producing fine-grained entanglement is independent of producing coarse-grained emergent structure*. Though not necessarily easy, there is nothing really to prevent an employee, for example, from constantly trying to meet and talk to additional *other* "unentangled" employees, mitigate clique barriers, or bridge Burt's (1992) structural holes (a dissipative structure), while *at the same time* working on a team of like-minded — that is, having coherent correlated histories — employees working to solve an adaptive tension problem. "At the same time" is the key, however. Given 8 hours a day, trade-offs have to be made between fine-grained and coarse-grained activities. Writ large, entanglement and adaptive tension can be worked on at the same time. Writ small, given 8-hour days, developing entanglement could take time away from dealing with adaptive tension. But, using year-long intervals, both activities could be pursued simultaneously.

4.7. Social Entanglement Propositions?

Summing up, neither entanglement nor adaptive tension separately are necessary and sufficient to foster efficacious coarse-grained emergent structure. Consider the following, seemingly broadly generalisable propositions:

(1) Two underlying generative processes, entanglement and adaptive tension (energy-differential) — within the critical value range — are both required to co-produce efficacious emergence.

They are "*co-producers*" of efficacious coarse-graining because they are both jointly necessary and sufficient (Churchman & Ackoff 1950). Absent adaptive tension, nothing happens. Absent uncorrupted entanglement and the emergence, if produced, will likely be faulty and not adaptively efficacious. Though not said, the emergence is "at the edge of chaos" due to the need for the adaptive tension to lie within the critical values — the 2nd of which separates the region of emergence from the region of chaos. In some instances, however, a quickly identified human capital solution will arrest the emergent structure (Johnson 1998). And, more likely, in the real world, entanglement is never totally absent or pervasive.

(2) The size and/or quality of the entanglement pool should match in requisite variety the complexity and multiplicity of the various tensions or energy-differentials imposed upon a firm.[10]

[10] As noted earlier (Note 1), Allen (2001) argues that Ashby's law of requisite variety should really be the "law of excess diversity" not all of the potentially adaptively relevant routines a firm might have will actually be relevant.

It is clear from discussions by Rothstein (1958), Ashby (1956), and Buckley (1967) that entanglement in a firm is in a "requisite variety" relationship to its over all adaptive tension. The higher the tension and the more different dimensions of adaptive tension, the more critical and the larger and more different kinds of correlated histories — entanglement ties — are required in the entanglement pool(s).

(3) Social entanglement ties are inherently unstable and deteriorate toward weak or strong ties over time because emergent structures disrupt unbiased correlated histories, strengthen bias and predisposition, are self-perpetuating, and are self-reinforcing. Often they leave a residue of corrupted entanglement even after adaptive tension parameters have dropped below the 1st critical value.
(4) Absent explicit attention to counteracting entanglement corruption, naturally occurring order in social systems is increasingly maladaptive over time — because of deteriorating entanglement and shifting context.[11]

While entanglement in quantum physics may tend toward equilibrium, social entanglement is inherently unstable because of feedback from prior emergent coarse-graining. Thus, over time, with sequentially occurring adaptive tension fields, the number of entanglement ties in a social system will decrease, being replaced by weak ties (pairs of agents stop having correlated histories) or biased strong ties (ties grow in strength to the point where they include bias and/or predisposition). Assuming that anti-corruption measures are ignored and that, therefore, entanglement slowly deteriorates, naturally occurring order is likely to be maladaptive. Further, over time, initially small emergent order formations will be self-reinforcing (Mark 1998), further disrupting the entanglement pool and leading to increased maladaptation.

(5) Given naturally occurring entanglement deterioration, emergent complexity thwarts efficacious adaptation, absent imposition of field effects aimed at "purifying" entanglement.

Kauffman (1993) argues that complexity, under conditions of complexity catastrophe, is an alternative source of order to that produced via natural selection forces. His theory rests on the idea that the adaptive landscape is turned into a "*rugged landscape*" by increasing complexity in ways that minimise the effects of natural selection.[12] A rugged landscape consists of an increased number of lowered adaptive peaks, thereby resulting in the increased probability that adaptive searches will end on suboptimal peaks. Thus, Kauffman's logic chain is:

• Complexity → rugged landscape → complexity catastrophe → order based on complexity by default rather than natural selection.

[11] This effect could very well underlie Salthe's (1993) biological and/or social system senescence and Meyer & Zucker's (1989) permanently failing organisations.
[12] How Kauffman's rugged landscape and complexity catastrophe ideas apply to firms is detailed in McKelvey (1999a).

An entanglement-based logic chain suggests that:

- Complexity → corrupted entanglement ties → maladaptive emergent structure → self-reinforcing entanglement deterioration cycles → order based on complexity-driven maladaptation in addition to the neutralisation of natural selection effects.

5. Conclusion

The classic double-slit experiments raise two fundamental questions in quantum mechanics: (1) Why does detecting collapse wave packets into particles? and (2) How does it accomplish this at the second slit where there is no detector? This discovery, replicated many times with photons and electrons, prompted Einstein's famous remarks: "God does not play dice"; Is the moon there when nobody looks?" and "I cannot seriously believe in. . . spooky actions at a distance". In producing their "Modern Interpretation" Gell-Mann (1994) and Omnès (1999) conclude that wave collapse is caused by forces external to the experiment, principally photons from the Sun and other more adjacent sources. In the course of developing this argument, they use key terms I introduce into this paper: *entanglement*, *correlated histories*, *decoherence*, and *coarse-graining*.

The root question in quantum theory expands, in complexity science, into a multidisciplinary concern about the engine that causes order-creation in matter, life, brains, artificial intelligence, and social systems (Mainzer 1997). And, needless to ask: Is there one primary engine working up and down the hierarchy of phenomena — from matter to social systems — or are there several and do they differ across disciplines — (discussed in McKelvey 2003d)? From all of this, I draw out two key elements that seem particularly relevant in the application of complexity theory to organisations: (1) the notion of correlated histories between pairs of agents, that is entanglement; and (2) the Bénard process as the main engine of order-creation so far discovered that applies across the hierarchy of phenomena — in addition to the Darwinian selectionist process, and human rationality, of course.

I conclude that it does not make sense to talk about emergence in organisations without worrying about: Emergence from what? In pursuing this argument, I introduce the concept of *entanglement ties* to separate the dynamics of quantum and complexity theories from the static (graph-theoretic-based) analyses of most sociological network analyses. My argument boils down to two aspects: (1) Without the Bénard process in operation, there is no reason to expect emergent structures; and (2) Without uncorrupted entanglement fields in organisations, there is little prospect for expecting adaptively efficacious emergent structures to appear. Corrupted entanglement fields in social systems are virtually guaranteed to appear, given the accumulated legacy of successive prior emergent macrostructures. The almost certainty of this eventuality separates order-creation studies in social systems from those in the biological world to some extent, and to a much greater extent from those in the physical world.

This conclusion raises the issue of how managers might best create the conditions of efficaciously emergent macrostructures in organisations. There are two tasks: (1) Making sure that entanglement pools are constantly being renewed so that corruptions (strong-tie cliques and the like) from prior emergent structures are eradicated or minimised; and (2) Creating the adaptive tension levels positioned within the critical values of the Bénard process. I consider the relative merits of trying to accomplish these tasks by sequential alternation as opposed to in-parallel. With a somewhat longer time perspective in mind, it seems more expeditious to think of trying to do both within the same time frame — recognising that activities that seem in-parallel in a one-year time span may in fact appear to be alternating give a day-to-day perspective.

There is talk in some circles that complexity theory applications in social/ organisation science would be better off if ties back to the natural sciences were eradicated. There is talk that complexity theory is *loose rhetoric* that, no matter what the diverse meanings of the terms are — terms such as emergence, chaos, complexity, point and strange attractors, nonlinear, and so forth — complexity theory is useful simply because it gets managers to abandon deterministic machine-based views of organisations. I think both of these views rest on faulty logic.

As this paper demonstrates, and as I argue elsewhere (McKelvey 1997, 2003b), lessons from natural science applications pertaining to:

(1) shifts from instrumentally convenient homogeneous agent assumptions and statistical mechanics;
(2) assumptions in favour of dynamics, heterogeneous agents, and agent-based modelling;
(3) recognition of the inescapable importance of an uncorrupted entanglement field as a precursor to efficacious emergence; and
(4) Bénard process driven efficacious emergence,

all are inescapable and offer considerable leverage to correct and make practically useful applications of complexity science to the management of firms. While loose rhetoric may be useful in getting managers to stop thinking of their firms as behaving like machines, stopping a "negative" is not the same as offering a "positive". A manager might reasonably ask, "Okay, so my firm isn't a machine! Now what do I do?"

I believe a careful review of physical and biological applications of complexity theory does add value to organisational applications, as I try to demonstrate in this chapter. True, some natural-world elements fall short of useful application in social systems, and some terms have to be carefully translated from natural science relevance to social science relevance. This does not mean loose rhetoric is the only recourse. Not at all! To avoid well known developments from the natural sciences is to risk putting energy into process reinvention, creating a confusion of unnecessary new terms, misapplying ideas already worked out, missing obviously advantageous approaches, and falling prey to the anti-science rhetoric of the postmodernists (Gross & Levitt 1998; Koertge 1998; Sokal & Bricmont 1998).

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Chapter 6

Evolutionary Dynamics of Industrial Clusters

Pierpaolo Andriani

> so widely decentralised and so spatially concentrated
>
> Powell, W. W. (1990: 310)

Introduction

Prato, a medium size Italian town is often regarded as a paradigmatic form of an industrial cluster. Few simple data illustrate the situation. In 1981 there were 10,695 firms in Prato with a total employment of approximately 61,000 people (Becattini 1997: 535; Lorenzoni & Ornati: 1988). Although most of these companies were classified as textile, none of them controlled more than 1 or 2 of the numerous production phases of the textile value chain. However, the production cycle requires the vertical and horizontal co-ordination of a number of firms, in the absence of a hierarchical or bureaucratic system of control and direction. How is this achieved?

This paper suggests that models based on complexity theory can help answer the above questions first, by framing the phenomena regarding clusters in the context of complex systems and second, by providing a tentative definition of clusters.

1. Twelve Rules for Complexity

A complex system may be defined as a system composed of many interconnected parts, interacting in a (mostly) non-linear fashion, and able to exhibit the properties of self-organisation and emergence. A good example of a complex system is offered by a colony of ants:

> Individual ants are remarkably automatic (reflex driven). Most of their behaviour can be described in terms of the invocation of one or more of about a dozen rules of the form "grasp object with mandibles", "follow a pheromone trail in the direction of an increasing (decreasing) gradient", . . . This repertoire, though small, is continually invoked as the ant moves

Complex Systems and Evolutionary Perspectives on Organisations

ISBN: 0-08-043957-8

> through its changing environment. The individual ant is at high risk whenever it encounters situations not covered by the rules. Most ants, worker ants in particular, survive at most a few weeks before succumbing to some situation not covered by the rules.
>
> The activity of an ant colony is totally defined by the activities and interactions of its constituent ants. Yet the colony exhibits a flexibility that goes far beyond the capabilities of its individual constituents. It is aware of and reacts to food, enemies, floods, and many other phenomena, over a large area; it reaches out over long distances to modify its surroundings in ways that benefit the colony; and it has a life-span orders of magnitude longer than that of its constituents. . . . To understand the ant, we must understand how this persistent, adaptive organisation emerges from the interactions of its numerous constituents" (Hofstadter 1979).

The following parts characterise the basic nature of a complex system (after Cilliers 1998):

(1) **Agents**: complex systems are formed by a large number of agents;
(2) **Interconnections**: agents are interconnected by a web of linkages;
(3) **Connectedness**: interactions among agents define three types of regimes: full connectivity takes place when the agents are all interconnected; sparsely connected networks are characterised by few channels of interactions; systems that are neither fully nor sparsely connected, but somewhere in between, are described as being on the "edge of chaos" (Waldrop 1995) or in a state of self-criticality (Bak & Chen 1991);
(4) **Non-linearity**: interactions are (in general) non-linear. There are two aspects to non- linearity: a) cause-effect relationship: there is no direct proportionality between input and output and b) superposition principle: the behaviours of the single parts of the systems can not be summed up to produce the final state. Non linearity has many implications. Long ago Aristotle understood that the whole is more than the sum of its parts. This principle has an important methodological consequence. Bak & Chen (1991: 26) summarise in the following extract: "*traditionally, investigators have analysed large interactive systems in the same way as they have small, orderly systems . . . They believed they could predict the behaviour of a large interactive system* ***by studying its elements separately*** *and by analysing its microscopic mechanisms individually. For lack of a better theory they assumed that the response of a large interactive system was proportional to the disturbance*";
(5) **Feedback loops**: even in a sparsely connected network interactions feed back creating a loop. The effect of a loop can be mutual reinforcement between cause and effect (positive feedback) as in a chain reaction, and therefore destabilising, or mutual attenuation (negative feedback) and therefore stabilising. In dynamic terms, a negative feedback corresponds to a position of stable equilibrium, as in the case of a small ball resting at the bottom of a cup. A disturbance that tries to bring the system out of equilibrium is faced by a counter force, which increases with the

distance. In contrast, as in the case of a pencil standing on its top, any small disturbance will dramatically alter the state of the system;

(6) Complex systems are **dissipative** systems: they need a constant flow of energy from their environment in order to sustain their internal degree of complexity. Prigogine (Nicolis & Prigogine 1989) distinguishes between near equilibrium and far from equilibrium dissipative systems: the former approximates a closed system in stable equilibrium and can be described by a linear and 'reductionist' approach, whereas the latter is open and energy (or information) hungry;

(7) Complex systems are **evolutionary**, they have a history. There are no general laws that apply independently from the system's specific evolution and idiosyncratic evolutionary circumstances. This means that luck or chance (or in Prigogine's language fluctuations) often plays a relevant role. The agents of a truly evolutionary complex system can not be averaged out: their micro-diversity (Allen 1997) is a necessary condition for their evolution;

(8) **Locality**: the agents obey the principle of locality, that is, they react to local information and are ignorant of the macro-picture (social agents can to a certain extent go beyond the principle of locality and internalise some of the complexity of their network. Reflexivity (Storper 1997: 36) refers to the "*deliberate and strategic shaping of their environment by taking a critical perspective on them*";

(9) **Self-organisation**: complex systems show a tendency to self-structure their collective patterns of behaviours. It is well known that a flock of birds flying in an arrow shape does not follow a leader or a (genetic or cultural) set of pre-defined commands. Instead the final shape is a macrobehaviour resulting out of micromotives. Self-organisation indicates the capability of a system to "*develop or change internal structure spontaneously and adaptively in order to cope with, or manipulate, their environment*" (Cilliers 1998: 90). Self-organisation is not the result of a deliberate strategy or a genetic necessity, but simply the result of the level of coherence that takes place between the individual actors in pursuing their local goals;

(10) **Coevolution**: because of the fundamental role of the system's internal connectivity, any action within the system is inherently circular in nature. Actions do not happen in isolation but they have the potential to trigger a series of cascading effects on the nodes (agents) with which the node is interconnected. The resulting effect is the virtual impossibility of isolated change, the transformation of any part without a simultaneous process of adaptation taking place in the rest of the system. Interdependence generates co-evolution, that is described by Kauffman (1995) as though the evolutionary process was happening on a rubber landscape where each step taken by any agent modifies the environment of the others;

(11) **Emergence**: when atoms organise into molecules or molecules into macro-organic molecules (the bricks of life), self-organisation generates a hierarchically organised world of nested, partially decoupled, complex systems. The emergence of one system (let's say a nation from a group of independent territories and towns) from another requires an increase of order at the spatio-temporal level of the new system. This process requires energy because it inverts the tendency of systems to increase their internal disorder, as measured by the thermodynamic concept of

entropy. This approach bears radical consequences: first, if emergence requires order and a negative flow of entropy to support that order, then systems in equilibrium are dead systems and active systems must be dissipative (rule 6); second, where Newtonian based disciplines study systems in equilibrium as synonymous of optimised and stable systems, complexity based sciences search for the laws of dynamically self-organising dissipative systems; third, being Newtonian systems deterministic, a defined trajectory will link the evolution of the system from a set of initial conditions to the final equilibrium state, whereas, according to complexity, multiple far from equilibrium states can correspond to the same set of initial conditions;

(12) **Self-catalytic reactions**: a mechanism that could explain the emergence of hierarchical ordered levels is introduced by Kauffman (1995) by suggesting that a set of chemical reactions becomes self-catalytic in the presence of a sufficient variety of molecules. If the variety is sufficiently large then there is a high probability that some molecules will play the double role of input/reagent and product of reaction, leading to a further increase in the variety and acceleration of the reaction. The autocatalysis generates a positive feedback mechanism that, on the one hand, by generating new molecules, increases the system's internal variety and, on the other hand, by connecting the existing molecules in a web of multiple reactions, reinforces the auto-catalytic process. Critical mass models are useful here (Shelling 1978). When a critical point of some control variables is reached then the system may become unstable and a branching set of solutions emerges. This represents a bifurcation point (Nicolis & Prigogine 1989), where local conditions (Allen 1988) force the system onto one of the branches of the bifurcation.

2. Industrial Clusters

The current descriptions of geographic clusters focus on the properties of co-location or proximity, vertical disintegration leading to flexible specialisation, peculiar governance forms based on cooperation-competition mixture, presence of collective learning and diffused tacit knowledge, and economies of agglomeration (different models based on an idiosyncratic mixture of all or some of the above features include: the neo-Marshallian or Italianate model (Piore & Sabel 1984), such as the textile cluster in Prato, high tech or 'hot spot' clusters (Pouder 1996) such as Silicon Valley (Saxenian 1995) or the Formula One cluster in Oxfordshire (Henry & Pinch 1997). Some authors extend the definition of cluster to embrace the 'hub & spoke' model (Gray *et al*. 1996), locally concentrated supply chain, the satellite industrial platform and the state centred districts (Markusen 1996).

The different forms of spatial aggregations reported above present few commonalties:

- aggregation over a geographically delimited territory;
- specialisation around a set of crucial designs, technologies and production techniques;

- presence of multiple forms of traded and untraded interdependencies;
- 'stickiness' (Markusen 1996) or 'embeddedness' (Granovetter 1985): the way in which practises of trade, production and provision of services are embedded in social systems and history;
- higher productivity: (Porter 1990, 1998; Becattini 1998) compared to traditional companies operating in the same sector (Saxenian 1995);
- "*neither market nor hierarchy*" governance form (Powell 1990).

3. Definition

This paper advances the proposition that clusters are complex systems propelled by an internal dynamic of self-sustaining cycles of social transactions. Clusters' dynamics are based on *positive self sustaining feedback mechanisms* and on the capability of highly interconnected web of relationships of generating a specific type of environment defined by the emergence of a macro-aggregate form of organisation and by a specific bundle of inter-related technological trajectories. Feedback mechanisms and webs of relationships are the source of a 'complexification' of the cluster, resulting from an increase in density and frequency of social transactions amongst agents (Boisot 1998).

This definition shifts the attention from the variables (attribute variables, see Scott 1991: 3) operating at the agents' and cluster's level to the variable focus on the dynamical properties of a web of autonomous and interdependent actors.

4. Phase Transition

An initial observation concerns the emergence of a network of interactive agents. Repeated transactions amongst agents generate a pattern of relations that defines the connectivity of the network. The transactions can take place either vertically along the value chain or horizontally between competitors, unrelated companies or agents and can take the form of traded or untraded interdependencies.

In a generic network, such as a Boolean network, defined by one type of node and one type of link, when the number of links becomes comparable to the number of nodes a giant network emerges (Kauffman 1995). The dynamics of the system becomes dominated by the effects generated by the multiple interdependencies amongst nodes. Under this condition the behaviour of the system experiences a phase transition from linearity to non-linearity (rule 4) and from evolution to co-evolution (rule 10). The behaviour of the system can not be derived from the sum of its single parts, but has to take into account first cooperative phenomena which arise from the multiple feedback loops and second the distinction between hierarchical, scale dependent properties.

4.1. Agents

Agents are the basic units of a complex system. If agents are defined as any actor able to perform a social transaction, then people are the first type of agents, but not the only one. Aggregation of people such as firms and institutions are also able to transact. What is important to notice is that the stress on legal agents (agents whose aggregative structure has a legal recognition, firms and institutions) misses two facts: first, that most of the transactions between legal agents take place outside the formal channels of transactions established by the legal agents, between communities that extend beyond the boundaries of the legal agents, and, second, that some of the most important transactions, such as those related to creation either of knowledge (innovation) or of new entrepreneurial activities (start-ups, spin-offs, etc.) are performed by individuals or communities that, though influenced by, may or may not be part of the legal structures. Excellent examples of these are provided by the informal communities described by Stacey (1995) and Brown & Duguit (1991). Stacey describes the role that informal communities, (spontaneous, self-organising groupings of employees within the legal community) plays in radical innovation, claiming that the chaotic nature of radical innovation requires ad hoc communities, more in tune with the complexity of the innovation. A similar observation is advanced by Brown and Duguit. They observed in a famous study on the professional groups of service photocopier technicians the self-organising of the technicians around '*communities of practice*'. These communities, which were not, at the time, recognised by the organisation, structured themselves around a specific language — story-telling, based on the communication of personal tacit knowledge, generalisation, taxonomies, routines, etc. — which was necessary to make sense of the idiosyncratic aspect of the photocopier service work.

Another example which sits outside the boundaries of legal organisations is represented by the Figure of the '*Impannatore*', typical of the textile industrial cluster of Prato, Italy (Becattini 1997; Malone & Laubacher 1998). The "impannatori" are business architects. Their role is to scan the environment, identify new markets, devise a new product (fashion collection) and organise, around that, an appropriate limited life consortium (Hall 1999) of selected suppliers. It is purely a co-ordinating role.

4.2. Links, Cooperation and Social Transactions

A link in a socio-economic environment takes the form of a social transaction. Two relevant questions concerning social transactions and phase transition are:

(a) under what conditions is a network of social transactions established?
(b) what are the mechanisms that favour an increase in transaction intensiveness?

The literature on industrial clusters points out that "*flexible economies rely on high-trust relations which they reinforce through their operations but cannot generate themselves*" (Sabel 1989: 46). But, according to Axelrod (1984) and game theory, the pre-existence of trust is not a precondition for the onset of cooperative behaviour; instead, cooperation can thrive in a world of "egoists" if transactions are likely to be iterated. The condition for iteration is provided in a geographic cluster by the proximity factor. In fact:

- If agents know that transactions are likely to be repeated ('*window of the future*'), then eventual opportunistic behaviours are likely to be reciprocated; and,

- If the identity of agents is known, then defection is less likely to represent a successful strategy; "*defectors thrive in anonymous crowds, whereas mutual cooperation may be frequent between neighbours*" (Sigmund 1992).

Therefore the higher the degree of correlation (density and frequency of social transactions), the higher the probability that cooperative behaviour will emerge. The emergence of cooperation causes the appearance of a system of internal feedback within the network, whereby the action of a single agent affects directly or indirectly the fitness of the other agents, thus determining the formation of a community of agents, obeying common rules and using common sets of values and beliefs. In other words, the locking of the network into a lasting pattern of interdependencies generates the emergence of shared rules of behaviour and mindsets. An example of this dynamics can be seen in the Hollywood cluster: according to Faulkner & Anderson (1987: 907) in the movie industry in Hollywood "*distinct networks crystallise out of persistent patterns of contracting when particular buyers of expertise and talent (film producers), with given schedules of resources and alternatives, settle into self-reproducing business transactions with distinct (and small) sets of sellers (directors, cinematographers, and fashionable actors and actresses*"). Likewise the above-mentioned Boolean network also our social network becomes dominated by the nonlinearities generated by the multiple interdependencies amongst agents. When this occurs, the network becomes characterised by a higher order structure (likewise the organisation of neurones into a brain, rule 11) and capable of collective reaction and anticipative behaviour.

4.3. Transaction Intensiveness

Transaction intensiveness is the key to the emergence of that web of relations that defines the specificity of an industrial cluster: the capability of the cluster's socio-economic agents to coordinate their micro activities into a macro coherent pattern. Transaction intensiveness is also key for the emergence of non linearities in the system: if the production of a good or service requires a complex set of transactions not subject to external control, then coordination must be ensured by the multiple feedback loops that link the agents into a giant network.

The increase in transaction intensiveness as a phenomenon taking place over a geographic delimited territory can be read as an effect of agglomeration. As Fujita & Krugman (1999: 2) points out:

> . . . the basic problem with doing theory in economic geography has always been the observation that any sensible story about regional and urban development must hinge crucially on the role of increasing returns, . . . the spectacular concentration of particular industries in Silicon Valleys and Hollywoods is surely the result not of inherent differences between locations but of some set of cumulative processes, necessarily involving some form of increasing returns, whereby geographic concentration can be self-reinforcing.

Increasing returns and transaction intensiveness are strikingly similar to the concept of self-catalytical reaction presented in rule 12. This is an important point, as it shows that some form of critical mass value is needed to describe the onset of the self-sustaining spiral of increasing returns or self-catalytic reaction. It is well known that when the behaviour of economic actors becomes interdependent with what other agents do, critical mass models become relevant (Mokyr 1990; Shelling 1978). The concepts of critical mass, agglomeration as a manifestation of increasing returns and self-catalytical dynamics suggest that the evolution of a network of economic agents can generate a cluster of increasing returns when the transaction intensiveness within the cluster reaches a critical value.

A network of organisations that undergoes a phase transition becomes characterised by the following properties:

(a) shift of the value creation activities outside the nodes of the network;
(b) emergence of a spiral between the forces of variety and the effects of recycling and multiplier;
(c) emergence of a complex place;
(d) emergence of a distributed system of knowledge.

4.4. Transfer of Value Creation Activities

The value created by a group of companies loosely interacting with one another (network) is simply the sum of the values generated at each individual node (linear dynamics). In the case of clustered companies, the total value is more than the sum of the values generated at each node (non-linear dynamics), because a relevant share of the value creating process takes place at the interface level. Due to the effect of the spiral represented on the left hand side of Figure 1, the social transaction environment that used to be mostly internal to the firm has been substituted by the system of relations between the specialised agents of the cluster. Stated another way, a cluster represents a governance form in which the value creating process is partially transferred from the company (node) into the cluster (system of relations).

According to this view the assumption that the firm represents the unit of analysis of economic and organisational studies becomes questionable (Arthur & Rousseau 1996). The unit of analysis becomes the system of relations between organisations (which need not be identified with firms) and the economic process becomes a process of conversation and co-ordination between agents. For example, Sabel (1989: 27) reports that in Prato the manufacturing/innovation units are the 400 sub-groupings around which the organisations in Prato self-organise.

4.5. Variety Spiral

This paper advances the proposition that at the phase transition when the transaction intensiveness of a cluster reaches a critical value, economies of variety, multiplier and

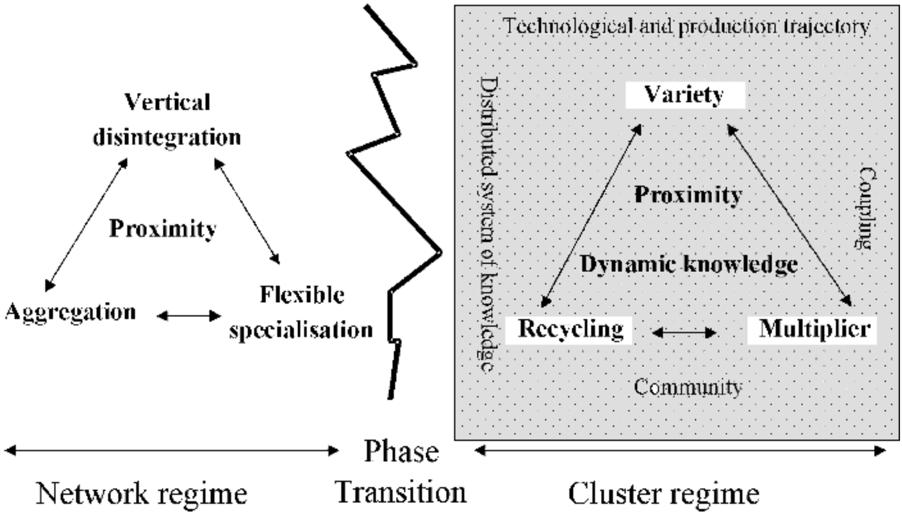

Figure 1: The dynamic of phase transition.

recycling effects form a self sustaining spiral of increasing returns (Figure 1). The components of the spiral are:

- *Variety.* "*Diversity probably begets diversity; hence diversity may help beget growth* (Kauffman 1995: 292). The fragmentation, brought by the processes of vertical disintegration and flexible specialisation, coupled with the internal differentiation generated by the internalisation of supply and demand within the boundary of the cluster (Economist 1999; Porter 1998), causes the internal variety of the agents to increase. The number (and complexity) of market niches within the cluster is consequently increased and the ownership of the final products is shifted from the nodes to the groupings within the cluster.
- *Multiplier.* Variety triggers a multiplier effect phenomenon: it is well known in economics that a transaction can have a cascading effect on successive transactions. Multiplier effect plays a more important role than in traditional hierarchical or market type of organisation because of the cluster's higher spatial density and frequency of social transactions. To explain the effect of the multiplier mechanism we draw from Fujita *et al.* (1999). If X represent the income derived from an export activity produced in a cluster (exogenous driver), then let's suppose that a fraction of it, let's say, αX is spent locally. This may lead to a second wave of transaction $\alpha^2 X$. The process is likely to be iterated, with the final result that the aggregate income Y (generated by the sum of the transactions within the cluster initiated by the initial export transaction) is:

$$\mathrm{Y} = \frac{1}{1-\alpha} * X$$

This is a linear equation which tells us that the higher α, the bigger the cluster's income. Key to the ability of α to deliver its benefit is the concentration of activities behind the final export to be concentrated into a geographic area. This observation leads immediately to a non linear relationship between α and Y and consequently to a self-sustaining growth mechanism. In fact, the positive correlation between the value of α and the concentration of economic activities within the cluster area indicates that the more the cluster internalises the socio-economic activities that are related to the initial export transaction X and the more the cluster can diversify within those activities, the higher will be α and the final income X. The multiplier formula captures the fact that as the size of the cluster economy grows, it becomes more convenient to produce a wider distribution of products and services within the cluster, giving rise to increasing returns dynamics.

- Recycling: the same resource, either tangible or intangible, is re-used in a cluster much more intensively than in the case of an isolated company. As John Holland (1995) puts it: "*that recycling can increase output is not particularly surprising, but the overall effect in a network with many cycles can be striking. A tropical rain forest illustrates the point. The soil there is extremely poor . . .; yet the forest itself is rich in both species and numbers of individuals. This state of affairs depends almost entirely on the forest's ability to capture and recycle critical resources*".

4.6. Variety and Competition

On the supply side the process of growth in a cluster takes place either via cost reduction or incremental and radical innovation. In the former case competition is described as perfect market competition and in biological terms is regulated by the Darwinian law of selection. This is a process that does not affect (and does not depend upon) the degree of variety of the system. In the latter case competition is driven by the creation of new market/technology niches and is defined as Shumpeterian competition. This process is akin to the process of speciation in ecology and is a variety generating process, because species belonging to different niches will not compete directly with one another.

The balance between the two effects (perfect market vs. shumpeterian or selective pressure vs. speciation) depends on the system's variety and on the rate of change of variety. The higher the degree of system's variety and the faster its rate of change, the more dominant shumpeterian competition will be (it has been observed by Gibbons & Metcalfe (1986) that the rate of innovation within a particular industry is directly proportional to its degree of economic variety). The terrain of competition will move from prey/predator type of interaction with its characteristic death/replacement process to the niche separation process based on webs of complementarities and innovation. The balance between the two mechanisms of competition depends (McKelvey 1999) on the rate of co-evolution, which becomes dominant at the phase transition, where a critical value of social transactions is achieved and a variety spiral mechanism comes into play. The distinction between the relative importance of the shumpeterian vs. perfect market competition can help in drawing another element of distinction between clusters and networks.

5. Emergence of Complex Place

We have seen in previous sections that when an aggregate of organisations becomes locked into a self sustaining web of interdependent transactions, the system may undergo a phase transition, whereby the appearance of systemic properties does represent the tangible sign of the emergence of a higher level of organisation. From the standpoint of the single agent, the emergence of the higher level of organisation constitutes an environmental change. The complexification brought by the variety generating mechanisms and made possible by proximity, introduces a new environmental layer (Marshall intuitively understood this when he pointed out that: "*The mysteries of the trade become no mysteries, but are as it were in the air*"), with the differentiation between the cluster's internal environment (external to the organisation but internal to the cluster) and external (external to both organisations and cluster). The two are different in terms of type of dynamics and value creation process.

This paper advances the proposition that complex systems can be differentiated from non complex ones by their ability to generate their own place (Figure 1), that is to nest, within the external environment a specific type of place, made by an unique blend of territorial culture, technology and organisational forms. This place is defined, first, by a high degree of coupling between place and agents, second, by a community of knowledge and practices and third, by an envelope of technological trajectories (Dosi & Orsenigo 1985) and production systems within the general technological environment.

5.1. Coupling

Unlike a traditional environment, where the agents act against a static background (from the standpoint of agents), there is a strong co-evolutionary coupling between agents and cluster. This close environment is a result of the agents connectivity and therefore sensitive to the agents' actions. "Porterian" or "strategic planning" type of strategies, that thrive in a static environment with low (or null) degree of coupling between agents and environment, are an example of Darwinian or evolutionary strategy. Instead, co-evolutionary strategies are necessary when significant coupling is present, and they need to take into account non-linear network effects (Arthur 1996).

5.2. Community

The place created by the complex interaction of agents is coincident with a Lamarckian community defined by a peculiar territorially bounded mix of competitive/cooperative behaviour.

The unit of socio-economic analysis changes from the organisation to what defines the socio-economic actor of the community. In Silicon Valley, this is the loosely coupled engineering team, which coalesces around a new technology/product/project and disappears to reappear somewhere else around a different innovation.

In Prato this is the team of microcompanies organised by an "impannatore" around the production and marketing of a new short life and seasonal line of fashion products. In the Hollywood movie industry a similar pattern of self-organisation emerges around a new film project (Storper 1989).

The community is also based on a set of local values and a specific approach to learning and information sharing, that is in large part unconscious and unnoticed: "*When the manufacturer of textile machinery and its client exchange information, criticisms and requests for customised variations, each is consciously convinced of pursuing its own interest. In doing so both contribute to raise the district productivity*" (Becattini 1998; Translation by the author). Similar forms of information exchange take place also outside the cluster's community, but without the same ethics of free communication exchange and cooperative practices and not on the same scale. The attitude towards exchanging information with competitors is the real acid test: "*This is a culture in which people talk to their competitors. If I had a problem in a certain area, I felt no hesitation to call another CEO and ask him about the problem — even if I didn't know him. It was overwhelmingly likely that he'd answer*" (Saxenian 1995: 33). This type of behaviour is less surprising if one thinks that in a cluster it would be difficult to hide a particular piece of information. It may be convenient to trade it for a future return. Also extreme mobility changes continuously the boundaries of competition and collaboration, so that previous competitors become allies and vice versa.

5.3. Technological Trajectories

The third element of the new place is technical: a cluster is formed by a set of related industrial sectors joined by relationships based on complementarities, proximity and history.

This dense and intensive web of complementarities between users and producers of technology within and across the different sectors defines a technological place that becomes with time endogenised. The boundaries of this endogenous place are defined by the bundle of inter related technological trajectories (Dosi & Orsenigo 1985) which emerge via the spontaneous and self-organising trial and error process of focussing around a set of crucial designs and production techniques. This place marks a distinctive difference from the network (supply chain) or independent type of organisation, in which, due to the centralised process of co-ordination, the technological choices tend to be restricted around a single technology or technological trajectory. The crisis of the semiconductor industry in the U.S. in the eighties, that caused the decline of industrial regions such as Route 128, home to company such as Digital Equipment Corporation, highlighted the weakness of a model of development based on integration and independence. "*The experience of the Route 128 minicomputer companies during the 1970s and 1980s illustrates the danger of betting on a product in an era of rapid technological and market change. Strategies and structures dedicated to incremental refinements within a single, established trajectory undermined the ability of these companies to respond rapidly to product and process innovations*" (Saxenian 1995: 103).

6. Clusters as a Distributed System of Knowledge

We have claimed that a cluster exists, as a meta-organisational form, because its elements can self-organise and generate a new organisational level that is defined by a proper place and a specific set of values and practices. This organisational level must be autonomously able, in order to perceive its internal changes and interact with external environment, to: (a) gather data; (b) organise them in informational patterns; (c) distil an operational representation (knowledge); and (d) store that information for future use. In short it must have antennae, capability of representation and memory.

How can purely decentralised systems process information in an organic way?

The problem of representation (sense making) in a cluster can be partially explained by the representation mechanisms of a neural network:

> a neural network consists of large numbers of simple neurones that are richly interconnected. The weights associated with the connections between neurones determines the characteristics of the network. During a training period, the network adjusts the values of the interconnecting weights. The value of any specific weight has no significance; it is the patterns of weights values in the whole system that bear information. Since these patterns are complex, and are generated by the network itself, there is no abstract procedure available to describe the process used by the network to solve the problem (Cilliers 1998: 28).

As in a neural network information is transformed into knowledge and then into action without the pre-requisite of a semantic system of rules. There is no need of a centralised system that stores information and dictates the rules of behaviour. The traditional pyramidal view of companies as an organised hierarchy that collects and transmits data and information in a bottom up fashion, codify knowledge at the top and create a syntax that is then percolated down the organisation does not hold in a cluster.

Memory is simply stored in the patterns of connections between agents spread across intra and inter organisational links. Knowledge creation involves a change in the pattern of connections, a reorganisation of the geography and typology of links. The crucial point is that this reorganisation is not based on a deliberate strategy (that would require an understanding of the cluster as a whole) but, on the contrary, is an involuntary by-product of the agents' attempts to maximise their fitness by means of local interactions and local information.

The problem of representation is different in the two types of organisations: monolithic organisations have to reduce data and information to theory and patterns compatible with a centralised scheme and logic. In a cluster the problem of representation remains tacit. Therefore multiple, subjective or node-dependent representations are possible — provided they are roughly in line with the deep structures of the cluster (Abrahamson & Fombrun 1994).

Because of its distributed system of representation, clusters cope naturally with large amounts of data and confused signals from the environment. This makes clusters more able to accommodate contradictory information and work out the consequent conflicts generated by that contradictory information. There are several reasons for this: first, as in a neural network, conflicts are worked out locally changing the weights of some connections and therefore adapting in a bottom up fashion to the new conditions; second, adaptivity is based on the local optimisation of conflicting constraints, which, as Kauffman (1995) shows (the number of conflicting constraints grows exponentially with the number of nodes) is easier to achieve than overall optimisation (according to this logic, clusters are better able than traditional organisations to change the size and dimension of the manufacturing/innovation unit therefore altering the density of conflicting constraints — "Patches optimisation"); third, the cluster is characterised by an embedded level of redundancy much higher than in the streamlined and efficient centralised organisations.

If clusters can process information and build knowledge altering the pattern of connections linking its agents, this implies that at the level of single agents there is only a limited understanding of the cluster's identity and dynamics. Though networks of relationships can be stable and long-lasting, most observers and participants fail to see them, observing instead a scattered set of dyadic relationships, favours and contacts (Peterson & White 1981).

This lack of understanding becomes particularly evident in times of crises. Prato experienced the emergence of the cluster form through the classical process of vertical disintegration of the traditional textile industry. During the periods (1945–1960) in which the two industrial circuits co-existed (the cluster and the traditional integrated textile firms), although there was a perception that a major change was under way, the general opinion was that the original organisational form developed in Prato represented an anomaly that would have been reabsorbed in the traditionally integrated industry (Becattini 1997: 539). In Silicon Valley things were no different:

> paradoxically, however, while the region's engineers saw themselves as different from the rest of American business, they failed to recognise the importance of the networks they had created. Silicon Valley's entrepreneurs failed to recognise the connection between the institutions they had built and their commercial success. They saw themselves as the world did, as a new breed of technological pioneers, and they viewed their success as independent of the region and its relationships (Saxenian 1996: 56).

In both cases the two communities (and the scholars studying them) failed to see the butterfly (the cluster form) hidden behind the caterpillar of the traditional organisational forms not only during the metamorphosis period but even after the butterfly had left its cocoon. This failure is less surprising when one considers that a multi-scale type of approach was needed.

7. Conclusions

The literature about clusters has made use of a variety of frameworks, all centred on the concept of the economics and sociology of the network form of organisation. I suggest that the use of complexity theory can contribute to this discussion reinterpreting the cluster phenomenology in the light of a dynamic and relational theory based on the power on non-linear relationships between agents. Furthermore building on the concept of emergence and self-organisation and on the result of the research on clusters, this paper introduces the following ideas:

- The organisational form defined as a cluster is an emergent property of the recurrent pattern of social transactions taking place in a network of interacting organisations over a geographic territory.
- The cluster is defined by the creation of a specific type of environment based on: (a) bundle of technological and production trajectories; (b) distributed system of knowledge; and (c) community. The cluster internalises fundamental socio-economic relationships, such as users-producers by means of territorial coincidence of supply and demand, and reduces uncertainty to a manageable level via the above mentioned internalisation and the exploration of a set of interrelated technological trajectories.
- Clusters are propelled by an internal dynamic of self-sustaining positive feedback loops of social transactions. Cycles of social transaction become self-sustaining when a critical density of social transactions is achieved. Under this condition a phase transition (see Figure 1) determines the evolution of a network into a cluster.
- The cluster depends for its survival on continuous innovation and represents an adaptive form to extreme market fluctuations (supply side — technology — and demand side — volatility in demand). Standardisation of techniques and ubiquitification of knowledge are incompatible with clusters.
- The knowledge of a cluster is highly distributed, tacit and dynamic. The packets of knowledge are elaborated by a system of self-organising distributed intelligence, similar to a neural network, but provided with local processing capability. Therefore, the cluster can be compared to a distributed system of knowledge, whereby the micromotives of the agents (and the local information upon which their strategy are based) aggregate to form a macrobehaviour and a collective knowledge.

Some of the previous points are summarised in Appendix, Table 1, which shows a comparison between the independent organisation and the cluster type of organisation.

The so-called axiom of asymmetry (Heindl 1945) states that, a large company can do everything that a small firm can do, but not vice versa. In fact, a small firm, taken in isolation, suffers from a chronic lack of information (Kirat & Lung 1999) and cannot achieve the same economies of scale and efficiency typical of the larger firms. But, economies of scale and efficiency depend on a learning process (learning curve, see Abernathy 1974), that, in its turn, demands a temporal window of environmental stability, in order to allow the optimisation of design parameters, production processes and fine tuning with the markets.

However, in a turbulent environment, characterised by a high rate of radical innovation and volatile market demand, investment in monolithic and inflexible organisations may not represent a good strategy. Flexibility and adaptivity become the keys for survival in the presence of high environmental uncertainty (uncertainty in the analysis of Knight (1921) is different from risk, as it is associated with unpredictability). In order to be flexible and adaptive a system has to do two things: first, tune itself towards a state of high sensitivity to external conditions ("*edge of chaos*"), and second, re-organise itself to match the complexity of the external environment (this second point is known as Ashby's principle of requisite variety).

The emergence of the cluster form breaks the axiom of asymmetry and generates the conditions for competition between the cluster and the monolithic company form in an uncertain environment: "*anything that can be done in the vertical way can be done more cheaply by collections of specialist companies organised horizontally*" (Grove 1993).

Why is this? Because a cluster can at the same time achieve economies of scale thanks to emergent internal co-ordination and exploit economies of variety (Stirling 1998) thanks to internal diversification and constant experimentation of product, process and organisational innovation. Clustered small firms do not suffer from the chronic lack of information of traditional small firms for two reasons: first, at the level of agents, the social transaction intensiveness generates an information wealth that remedies the traditional isolation of small businesses; second, at the cluster level, the emergence of a distributed system of knowledge determines an automatic and tacit processing of information in forms that are idiosyncratic to the cluster.

Clusters also serve another purpose, that allows us to extend the comparison between a large company and the cluster form of organisation:

> If individuals must specialise in knowledge acquisition and if producing goods and services requires the application of many types of knowledge, production must be organised so as to assemble these many types of knowledge while preserving specialisation by individuals. The firm is an institution which exists to resolve this dilemma: it permits individuals to specialise in developing specialised expertise, while establishing mechanisms through which individuals coordinate to integrate their different knowledge bases in the transformation of inputs into outputs (Grant 1997: 451)

The firm is not the only place where coordination of specialist knowledge types is achieved. In a cluster the role of Grant's individuals is taken by individual organisations, which complement one another and whose coordination becomes dependent upon the non linear properties of a web of agents. Coordination for free is an automatic and emergent property of a web of nonlinear social transactions that have evolved through a phase transition and achieves exactly the same purpose as in a firm. The mechanism that allows coordination to spontaneously emerge in a network context is the autocatalysis described in rule 12.

The capability of complexity in dealing with nested levels of emergent organisations offers a powerful interpretative framework that puts into place situations previously deemed to be contradictory. For example the sentences by Saxenian (p. 164) that, "*although Silicon Valley's success has been based on collaborative practices, the region has long been dominated by the language of individual achievement. For the first time, that language is being replaced by a vocabulary that recognises community as well as competition*" and by Tom Hayes, founder of Joint Venture, that: "*our aim is to build a comparative advantage for Silicon Valley by building a collaborative advantage . . . to transform Silicon Valley from a valley of entrepreneurs into an entrepreneurial valley*", miss the point that the emergence of a complex place does not require an intentional approach by the agents to do so. There is no contradiction between the emergence of a complex place based on co-operation/competition and a language of individual achievement, if one considers that the two aspects refer to different hierarchical levels: the former to the systemic property of the cluster and the latter to the local behaviour of the agents. A complex reading of Silicon Valley (or of any cluster that happens to be in a valley) as a cluster would reveal at the same time the presence of the valley of entrepreneurs and the entrepreneurial valley as co-existing and originating one from the other without any contradiction.

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Appendix

Table 1: Comparison between independent (monolithic network) organisation and cluster (distributed network).

Subject	**Independent company (monolithic network)**	**Cluster (distributed network)**
Strategy	Largely imposed	Emergent
Coordination of activities	Imposed	Emergent
Type of competition	Perfect market/ Schumpeterian	Mainly Schumpeterian
Increasing returns dynamics	Mainly diminishing returns	Dominant
Regime	Tending to the ordered regime typical of a low connectivity network	Coevolutionary Dissipative
Variety	Low/medium	High
Uncertainty	Controlled by the external environment	High for single agent; Manageable for cluster
Knowledge	Largely codified	Largely tacit
Localisation of knowledge	Relatively centralised	Dispersed but highly interconnected (neural network type)
Capability for recombining knowledge	Low	High
Capability for experimentation	Low/medium	High
Locus of value creation	Internal	External to organisations but internal to cluster
Importance of non economic drivers	Low-medium	Very high
Motivation of agents	Low	High (typical of small business)

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Part IV

Implications of Complexity Theory for Management Processes

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Chapter 7

Complex Adaptive Social Systems: Towards a Theory for Practice

Donald MacLean and Robert MacIntosh

1. Introduction

This paper presents an approach which has been developed to facilitate organisational transformation. The approach, called Conditioned Emergence, has been developed by drawing on insights from the emerging field of complexity theory.

The paper describes the development of the method, presents an example of the method's application and highlights some of the theoretical questions that have been generated through its practical application. In doing so, the paper raises a number of issues relating to research process. It also raises a number of issues which will have to be dealt with if we are to develop a theory of complex adaptive social systems (as opposed to unquestioningly transferring aspects of complexity theory from its original home in the natural sciences).

2. Complexity Theory and Strategic Change

Our own research into change in organisations led us to question the high failure rates encountered when implementing many of the approaches to managing change recommended in the literature. Here we introduce complexity theory as a new source of insights to the familiar area of managing change.

The development of complexity theory, as it has been popularly titled, is regarded by some as signalling the arrival of a new scientific paradigm in the Kuhnian sense (Kuhn 1962). Classical science describes a universe where events are determined by a combination of initial conditions and mechanistic laws which are played out as the cogs of a huge machine roll forward. The focus is on systems establishing equilibrium, with every action met by an equal and opposite reaction. The second law of thermodynamics adds a further twist to this image stating that, over time, mechanisms run down, losing

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ISBN: 0-08-043957-8

both energy and internal organisation. Life however, seems to contradict this classical view. Evolution points to a world where the level of order seems inexorably to increase. Nobel-prize winner Ilya Prigogine and colleagues, in the field of non-equilibrium thermodynamics and phase transitions, began to provide explanations for the generation and development of order in the world (Prigogine & Stengers 1984). Essentially, their work indicates that change, development and transformation take place in open systems, which exist in far from equilibrium conditions.

According to the theory of dissipative structures, systems behave in a stable manner until they reach a critical threshold, often termed a bifurcation point. As this bifurcation point is approached, the system's mechanisms become stressed, making it unstable. This drives the system from equilibrium into far-from-equilibrium conditions and opens up the possibility of radical, qualitative change. As the system experiences far-from-equilibrium conditions, it becomes open to its environment — importing energy and exporting entropy (which is a measure of disorder). In this highly unstable state, the system becomes susceptible to tiny signals and random perturbations which would have had little impact were it still at equilibrium. Positive feedback can turn these tiny changes into "gigantic structure breaking waves". (Prigogine & Stengers 1984: xvii)

Prigoigine's work provides a useful reference point from which to explain complexity theory — which can be more accurately thought of as an umbrella term, covering Prigogine's work along with that of many others. This work has been conducted in many fields, including mathematics (Lorenz 1963; Thom 1975; Mandlebrot 1977), biology and zoology (Goodwin & Saunders 1992; Kauffman 1993) artificial intelligence and artificial life (Langton 1986), laser physics (Haken 1983) and economics (Arthur 1989). Coveney & Highfield (1996) provide a good historical account of much of this work.

Complexity theory, in its broad sense, is perhaps best described as being organised around a number of central concepts. A primary concern is *with the emergence of order* in so called *complex adaptive systems* which exist *far from equilibrium* in an *irreversible medium*. Such order manifests itself through *emergent self-organisation*; this occurs as a limited number of simple *order-generating rules* or *linkages* operate across a *densely interconnected* network of interacting elements to selectively amplify certain random events via *positive feedback*. This propels the system away from its current state toward a new, ordered state in a way which is largely unpredictable. Whilst the detailed form of such emergent structures cannot be predicted, the range of broad possibilities is, to some extent, determined by the simple rules, or the connections which were applied to generate the new order.

3. Conditioned Emergence

Our own work focuses on transformation in organisations. This we classify as a rapid switch from one organisational archetype to another. For some authors archetypes denote subscription to a belief that the relationship between structure and process is manifest in a finite number of possible types or configurations with distinctive behavioural implications (e.g. Miles & Snow 1978; Mintzberg 1983; Miller & Friesen 1984). Greenwood & Hinings (1998, 1993) add the concept of "interpretative schemes" to emphasise the cognitive dimension of archetypal behaviour. We are primarily concerned with change, which is radical, all-encompassing and rapid.

The concept of switching from one archetype to another (Greenwood & Hinings 1988) is a useful way of capturing the essence of this transformation process which has been described in different ways by a variety of authors (see Miller 1982; Abernathy & Clarke 1985; Pettigrew 1985; Nadler & Tushman 1989). We have chosen to work with the concept of archetypes rather than the more familiar notion of culture (e.g. Schein 1985) or paradigm (Kuhn 1962; Pascale 1990) because our framework describes transitions between discrete and distinct organisational forms as opposed to movement along a continuum. Also, Greenwood and Hinings' definition of an archetype as a "set of structures and systems that reflects a single interpretative scheme" suggests a level of detail which is consistent with our prescribed sequence of interventions i.e. the elements of their definition represent the focal points of our model.

Three key insights from complexity theory have informed our work on organisational transformation. First is the notion that the structures, processes and procedures of an organisation can be thought of as being generated by a simple set of order generating rules. There are parallels here with other work of on routines (see Tranfield & Smith 1998) and we have also drawn heavily on Argyris's notion of defensive routines (Argyris & Schon 1978). The second insight is that positive feedback[1] applied to behaviour which is consistent with changes in these rules can drive an organisation from one state to another. Here we were struck by the organisational dominance of negative feedback mechanisms (e.g. budgets, forecasts, progress reports, corrective action plans, etc) and the comparative lack of any formal positive feedback mechanisms. The third insight is that in order for an organisation to become open enough to its environment to trigger a change in its order generating rules, it must experience far-from-equilibrium conditions. Again this is closely linked to Lewin's notion of unfreezing (Lewin 1947) but here there is a very specific emphasis on changing the order generating rules during this unfreezing process.

The Conditioned Emergence model developed from these insights and is presented as a three phase approach to dealing with rules, disequilibrium and feedback processes.

3.1. Conditioning

Prior to changing, the organisation must identify and reframe the rules which underpin its current form. By the end of this stage, the revised rules (around which the new organisational form will emerge) are agreed by the organisation.

3.2. Creating Far-From-Equilibrium Conditions

Having done the conditioning work, the organisation must move to far-from-equilibrium conditions in order to create space needed for the new structure to take hold. The onset

[1]Positive feedback here is used to denote any feedback which amplifies the change causing it. In contrast, negative feedback, which is a restoring feedback, suppresses the change causing it.

of a crisis, either real or precipitated, is required. This often takes the form of restructuring or changes to roles and responsibilities. While the organisation resides in such unfamiliar territory, it typically becomes more open — often developing a capacity to import energy and export entropy; i.e. in Prigoginian terms, it behaves as a dissipative structure. During this period, the new order based on the new rules developed in stage 1 will seek to impose itself.

3.3. Managing the Feedback Processes

As the new organisation begins to emerge from the change process, positive and negative feedback must be applied as appropriate. Traces of the old organisation will inevitably remain and there will be pressure to revert to tried and tested methods. The key managerial task is to resist this pressure while looking for small signals consistent with the rules structure agreed in stage 1. Anything which reinforces the new rules is encouraged in order that the effects may be amplified helping the new organisational form to take hold. The organisation will be somewhat unstable at this point as the old and new forms compete with each other. This will be particularly true at the outset since a return to previous methods would probably produce improved performance, in the short term, if the organisation were to push the old systems harder.

We were (and are) conscious of potential criticism of Conditioned Emergence as being reductionist, over-simplistic, or too mechanistic in its stance — and also to related connectionist arguments (such as those put forward by Cilliers (1998)) which dispute the existence of order-generating rules. Nevertheless, we felt that in pursuit of a theory complexity which addressed the concerns of management and systems comprising human beings, the approach offered an opportunity to tackle issues surrounding the role of human agency and system dynamics in a direct and theoretically consistent fashion. We attempt to provide some justification for this view in the following section.

4. Method

The management literature is currently in the throes of a debate on research process. Gibbons *et al*. (1994) describe two different modes of knowledge production which has been picked up by the management research community. Mode 1 research is portrayed as being driven by the academic community, theory is developed then applications of this new knowledge are considered, often with limited interaction with potential end users. In contrast, mode 2 research is "*characterised by a constant flow back and forth between . . . the theoretical and the practical . . . discovery occurs in contexts where knowledge is developed for, and put to use, while results which would have been traditionally characterised as applied — fuel further theoretical advances*". (1994: 9).

Pettigrew supports the adoption of mode 2 research in the field of management, while pointing out that management research faces a *double hurdle* in that it must be embedded in both the social sciences and the worlds of policy and practice (Pettigrew

1997). The British Academy of Management have now entered this debate by issuing a form of policy statement (Tranfield & Starkey 1998). This advocates that management research must engage with both theory and practice in a problem-solving way, and is sympathetic to much of the message about mode 2 research from Gibbons *et al*.

In an article which was specifically aimed at the field of Production and Operations Management, Westbrook advocated that we should embrace action research, pointing to the method's "theory building potential" (Westbrook 1994: 9). We believe that this message applies equally to all areas of management research. Action research has a long history, traceable back to the work of Lewin (1946), but it is often regarded as an inferior research method. Eden & Huxham (1996) characterise action research as research resulting from involvement with an organisation over a matter of genuine concern, where there is the intention to take action on the basis of the intervention.

This is an accurate description of the research approach which we initially adopted for the work presented here. We felt that using action research as a starting point would allow us to gain meaningful access to the unfolding dynamic of a social systems in a way that was necessary if we were to gain appreciation of the subtleties and nuances which might be important to our understanding and theory-building. Concerns about the extent to which our objectivity might be compromised by such a high-engagement form of research were allayed as we developed a richer understanding of the concept of *emergent properties*.

5. Emergent Properties

Emergent properties appear as macroscopic patterns in collections of elements amongst which non-linear interactions take place. The non-linearity means that such patterns cannot be understood in terms of simple sums or differences of interactions between the elements but arise out of the interconnectivity of the system in a way which makes cause and effect relationships difficult to characterise or predict. In essence, emergent properties exist at the level of the system, not at the level of the elements; they express a unity at the systems level which transcends differences amongst the elements, displaying them as features of an integrated whole.

The above is perhaps best illustrated by familiar examples, quoted here from the contemporary philosopher Roger Scruton (1997):

> When a painter applies paint to a canvas, he creates a physical object, by purely physical means. This object is composed of areas and lines and paint arranged on a two-dimensional surface. When we look at the painting, we see those areas and lines of paint and also the surface which contains them. But that is not all we see. We also see a face that looks out at us with smiling eyes.

This example conveys not only the idea of emergent properties, but also highlights some of the salient issues for social as opposed to physiochemical or microbiological systems where much of the contemporary work on such phenomena originated.

It suggests, for example, that whilst there is clearly a relationship between the configuration of elements and the quality of the emergent property, such relationships are at present poorly understood. We know that altering the shape of the mouth, or the mutual proximity of each eye will alter not only the local geometry of these features, but will alter the general impression created by the face, but we do not really know how, until we see the effect.

For some, partial knowledge can be gained via the concept of order-generating rules, archetypes or deep-structure which might give insight into the general form of emergents (MacIntosh & MacLean 1999), but many reject the notion of "rules-based" order (Cilliers 1998) favouring the assertion that the form of emergent properties is wholly unpredictable and determined entirely by the configuration of the elements in a way that can only be known through observation; they are thus said to be ostensive in nature (Goldstein 1999).

This also raises the question of the relationship between subject and object — the extent to which the face is a creation of observation, relying on the observer for the particular form of its existence. This of course introduces the possibility of emergent properties as causative phenomena in their own right. If for example, the emerging appearance of a face influences the artist's behaviour in real time, shaping both the appearance of the face and artist's technique and practice, then in a very real sense, both the face and the artist are developed out of the process of interaction — each is both created by and creator of the other.

The same argument could also apply, albeit in a less tangible though perhaps more subtle sense, to the act of observation itself; the image as observed emerging out of an initially vague awareness, with uncertainty and ambiguity being progressively exported as noise whilst self-reinforcing observations successively build up in a form of dissipative structure (Leifer 1989).

We thus have the possibility that in social systems, the non-linear relationships (or so-called positive feedback loops) extend back and forth between the cognitive and physical domains, observation in one giving rise to action in the other which reinforces the observation and vice versa.

Combining the threads of this discussion so far, leads one to two inter-related implications. On the one hand, emergent properties are (at best) only partly predictable in the ways in which they unfold and, on the other, the detailed expression of emergent phenomena is fashioned through the interaction of the so-called observer and the observed, or creator and the created.

Such assertions bear some similarity to the increasing familiar pronouncements of Heisenberg's uncertainty principle and observation dependent phenomena in post-Newtonian quantum mechanics (Wheatley 1999). The biologist and complexity theorist Brian Goodwin has recently called for the development of a "science of qualities" in response to growing awareness of such issues (1999). He advocates balancing our quantitative, reductionist science with an approach which is sensitive to the qualities of emergent phenomena.

Such a science would require open recognition of the principle of participation in understanding emergent phenomena, and as part of participative enquiry, make explicit use in the process of phenomena such as intuition and feeling. This seems to be consistent with the dissipative structures model of observation which we proposed earlier in this section; intuition and emotion are likely to play a role in the recognition of an emergent property, particularly in the early stages where the image is vague and ambiguous.

It is perhaps fitting to finish this section by pointing out that the concept of emergent properties, whilst central to complexity theory, is not new. The notion of wholes and unities is as old as the subject of philosophy itself, but the term emergence gained some popularity in the latter parts of the previous century (see Goldstein 1999) for a review of the development of the concept). However, we would argue that it has been refined and given renewed impetus under the umbrella of complexity theory. Incorporation of related ideas found in modern complexity theory has given it a more practically accessible form.

The case study in this paper summarises a research process where we were directly involved in the process of managing change within an organisation. During this process we collected primary and secondary data, attended management meetings, conducted interviews and held workshops on and off-site with staff from the organisation. However, the concept of emergent properties took on new meaning for us as the research described below unfolded.

6. Applying the Conditioned Emergence Model

In 1997, we began a project to apply the Conditioned Emergence model to a manufacturing company. Eventually, as we will describe, this project involved what we then saw as three separate sets of activities — management research (for the academics), business development (for the company) and management education (for some of our undergraduate students who became involved in the project).

Taking each of these perspectives in turn it may be helpful to frame the distinctive expectations of the three key stakeholder groups — academics, company staff and students. In addition to having a stake in the project, each stakeholder group also broadly shared a view of complexity theory which would underpin management of the process of their engagement, namely managing processes at the level of order generating rules, far from equilibrium conditions and positive feedback. We aim to illustrate this in the account which follows. It is somewhat selective, focusing as it does on issues which are central to its illustrative purpose.

In the Autumn of 1997, the authors and the senior management team of the company spent an extended weekend in the highlands of Scotland. The primary tasks of the weekend were that of introducing the various members of the project team to each other more fully, introducing key concepts for the early part of the project, and helping to define and refine a shared view of the project's scope and process.

In particular, the weekend sought to identify and create a shared understanding of the deep rules which may have been responsible for the current order in the company. As a means to this, the concept of routines was introduced, including that of defensive routines (Argyris & Schon 1978). It was felt that, as a conservative organisation in a predominantly defensive situation of late, working with the concept of defensive routines may help to create awareness of routine behaviour demonstrated by the company. Having identified such routines, the task was then to frame each routine in terms of a generative rule.

So for example, a routine price-cutting response to competitive pressures may have been underpinned by a rule such as "in competitive situations, reduce price to a level necessary to secure the sale".

Also, the concept of generative rules was used to create and articulate the basic form of organisation towards which the company (or its senior team at least) might realistically aspire. Such new rules would constitute the company's generative grammar, deep structure or archetypal source as described earlier (MacIntosh & MacLean 1999).

An important aspect of the weekend was the use of a range of experiences to promote awareness and understanding of concepts. For example, the nature and evolution of rules, routines and their consequences was demonstrated via an outdoor exercise during which participants learned a new skill then, through the passage of time and repetitive practice, habituated their new-found capability. Later on in the same day in a more stressful and somewhat similar exercise, participants involuntarily resorted to earlier successful practices even though they understood that the subtle differences in context and the nature of the current task rendered such practices useless and even counter-productive. This personal and highly visible experience eased the way for identification of work-related instances of similar phenomena i.e. work-based defensive routines and their corresponding generative rule.

The concept of far-from-equilibrium conditions was also discussed during the weekend; the response was that the company was sympathetic to the argument which said that the organisation had behaved like a dissipative structure, but that there was no need to manufacture far from equilibrium conditions as the company had just changed managing director, had recently relocated to a new site and had undergone an internal reorganisation from a functional orientation into a network of related business units.

The weekend was deemed by the company's senior team to have been highly successful. Participants felt that they had each got to know one another better, but more significantly, had developed and articulated a set of generative rules or principles to govern their mutual interaction henceforth. They felt this to be important in view of the uncertainty and upheaval, which they felt they faced in the months ahead. At the corporate level, they felt that they had reached a new degree of understanding of why the organisation was the way it was and how it might be changed. Specifically, they felt that they had succeeded in identifying a set of old rules and defensive routines which they sought to disarm, and had generated a replacement set which would underpin a new, more innovative, learning type of organisation.

Rather than lay out the entire sets of old and new rules here, we have selected one pair which will both illustrate the approach and provide a reference point later in the account. One of the rules underpinning defensive behaviour and a failure to develop new products was framed as "only innovate if it reduces costs". There was general agreement that this precluded the possibility of investment required to effect significant improvements and that this had in turn influenced the evolution of the company's portfolio of products and processes. In its place a rule which promoted lead-time reduction, maintained or improved quality and, if possible, reduced cost. This triad was promoted under the new rule "our advantage will stem from responsiveness leadership".

From a research perspective, the initial event signalled a departure from our earlier work in several important ways. First, there was a clear view that disequilibrium did not have to be introduced (since in this case it was already there). Second, the company seemed less clear about the extent to which, and how, the new rules would be managed into currency beyond the senior team. Third, there was no explicit desire to extend the scope of the researchers' interaction, who would operate through the senior team for the time being.

After the weekend, dialogue was maintained (particularly with the managing director) via regular e-mails, telephone conversations, meetings and trips to the company's site. As the change process gathered momentum in the company there was one departure from and two additions to the senior team and more open communication processes were introduced. Moreover, business results were improving — see Table 1.

At a second weekend event one year later, the company appeared to be developing its own variant of the Conditioned Emergence model, influenced partly by the knowledge of complexity theory gained by the managing director and partly by the circumstances and experience of the senior team. Specifically, there appeared to be reluctance to embark on what may have been viewed as a top-down indoctrination of the new rules into the company proper. Nor did there appear to be enthusiasm for attempts to surface and create old and new rules through some widespread form of intervention. The senior team appeared to be working with the rules which governed the interaction amongst members, but attempts at managing the company-level old and new rules had been limited to a presentation in which the version agreed by the senior team had featured.

There did however, appear to be a view that senior management had an important role to play in providing interconnects and managing feedback on the one hand, and in sustaining disequilibrium on the other. It was also stated that the process of transformation was beginning to slow down and that the middle management layer was probably the bottleneck. The response was to reconfigure that layer, and hand over responsibility for driving transformation to a selected group from within it. The only detailed briefing given to the so called "change-team" was that changes would accord

Table 1: Performance indicators.

	Turnover	Profits	Typical Lead-Times	On-Time Delivery
1996 (before project)	£22.0 m	–£950 k	12/13 months	c. 85%
1997	£17.5 m	£250 k	10/11 months	>90%
1998	£25.0 m	£1 m	9/10 months	>90%
1999	£29.0 m	£1.4 m	7/8 months	>90%

with the responsiveness leadership rule and that business process methodologies should play some role.

By now, an undergraduate course on the management of transformation was underway. Students on this course had gained a reasonable introductory knowledge of complexity theory in relation to management and were familiar with the Conditioned Emergence model. They had decided to approach the project "in the spirit of complexity theory", so that they could critically reflect upon themselves as members of a complex adaptive system and thus gain further insights into management of and in such entities. They organised themselves into two teams of seven or eight members, each of which developed a set of shared generative principles in preparation for the far-from-equilibrium conditions of the project.

As part of the process of briefing students about the company for their project, the managing director made a presentation to them. During this, he invited the students to contact him whenever they had questions to put to the company. A workshop followed where the students agreed that they would compile a series of questions which would be fed to the company in writing, distributed to the relevant internal groups, and written answers fed back. The students would then get an opportunity to explore these answers further with the lecturing staff and the managing director of the company.

In practice, what emerged was a three-way conversation between the students, the senior management team of the company and the authors. This conversation commenced as a number of questions framed by the students attempting simultaneously to evaluate both the transformation process and complexity theory as a conceptual aid. It soon, however, took on a life of its own and became primarily concerned with a single but important issue — the extent to which the company had actually changed. Specifically, the students suggested that some of the new rules articulated by the managing director were simply the old rules in a new form.

In particular, the responsiveness leadership strategy had given rise to a rule which was known as "better, faster cheaper" — namely innovations should deliver improvements in specification, lead-times and cost. The students and academics formed a view that the implicit "and" as opposed to "or" term in the rule meant that the rule was in fact reduced to the old rule "only innovate if it leads to cost reduction".

Views in the company's senior team were split, but the majority felt that the academic view was simply wrong, stating that the spirit and practice of the new rule was entirely different. The differences of opinion persisted, though there was general agreement within the senior team that the students were probably correct in the observation that the senior team had clearly transformed, but that the radical and widespread transformation of the company had yet to take place.

It occurred to the authors that a possible explanation for the above was that, unlike the case study where the Conditioned Emergence had been developed, the company appeared to have made little sustained effort to manage the new rules into currency beyond the boundaries of the senior team. Instead, they had adopted a view that the process of change should be orchestrated by the change team drawn from the middle management layer as we have already described. Where the senior team appeared to be focusing effort was on trying to "run the business" whilst maintaining far-from-equilibrium conditions, partly through internal changes and sustained efforts to communicate the uncertainty which lay ahead of the company.

Towards the end of the students' course, the authors were invited to hold seminars on "complexity and management" through the LSE Complexity Seminars (February 1999) and the EPSRC Complexity and Manufacturing Network. At both of these, presentations were made jointly between the academics and the practitioners and, out of dialogues, which were brought to a focus during these events, which are ongoing, a clear variation of the original Conditioned Emergence model is emerging. The primary difference is that the company held the view that the order generating rules will gradually emerge out of the flux of disequilibrium. The primary task of management is to facilitate this emergence by managing interconnectedness and promoting far-from-equilibrium conditions. This is an intriguing and plausible reinterpretation of Conditioned Emergence which itself appears to have emerged from the experimental dialogue set up between academics, practitioners and students.

7. Emergent Properties and the Project

Perhaps the first thing to note from the account presented above is that each party derived valuable outcomes from their involvement.

As researchers, we have deepened our understanding of some of the questions we had. Whilst we have no conclusive answers, we have, for example, seen the company treat order-generating rules as an emergent phenomena and continue to gain insights from our involvement in this approach. The students have, according to comments fed back as part of the QA process, gained a level of practical and theoretical understanding by making a contribution to a live experimental dialogue along with researchers and practitioners. Also, the company has effected significant improvements to its business situation and prospects, which despite the lack of definitive empirical evidence, the senior management team attribute to the project.

However, whilst the above paragraph conveys the mutual benefits at one level, it fails to effectively capture the nature of connectivity or mutuality in the project. In reality, each stakeholder group was not simply involved in their own activity, rather each in their own way took research, management and educational outcomes from their involvement in the process.

For example, the students engaged in the research process as part of their learning and each team developed its managerial capability as the initiative unfolded. Likewise, the company simultaneously improved its business, developed the management knowledge of its senior team and produced research output (in the form of presentations and publications) via the project. The authors also developed on the research dimension, enhanced their ability to manage projects such as this and developed the business of their research unit in terms of funding, publications, etc. We have attempted to depict this in terms of outcomes in Table 2.

Even Table 2 does not do full justice to the exchanges which took place. For example the students research process actually influenced business practice at the company, the unfolding business situation affected the research process of the academics, and so on.

Table 2: Stakeholders and outcomes.

	Education Outcomes	**Research Outcomes**	**Development Outcomes**
Students	Successful completion of the MOT course as part of a degree programme	Direct involvement in an action research project, contribution to theory development	Experience of project management, team work
Academics	Experience in new course development, skills in new learning methods	Development of complexity theory for social systems	Funding, track-record Contacts etc.
Practitioners	Input to academic courses and process, internal management knowledge	Development of in-house research skills engagement in co-research	Corporate transformation Publicity, Competence development

In attempting to describe the project in this fashion, we are impeded by our inability to articulate the true complexity of the project. We would argue that this may be due to our having misconceived its nature. Instead of viewing the project as an arena in which we might cross-fertilise three groups' approaches to three types of activity, the situation is simplified considerably if we conceptualise the project as a single system of knowledge production (Gibbons *et al*. 1994).

If we accept Maturana's position that humans are the elements of such systems (Maturana 1998), then we have a simple system with three primary categories of elements — students, academics and practitioners. In accordance with complexity theory, some combination of the interconnects set up amongst these elements or the rules which they share, together with disequilibrium and positive feedback, will give rise to the spontaneous development of order or the generation of emergent properties. We would argue that the research, education and development described above are just such emergent properties.

We will now consider this concept in more theoretical detail before moving on to some implications and conclusions.

8. Discussion and Implications

We return first to the empirical account to assess the extent to which the concept of an emergent is helpful in relation to it. We will do this by attempting to illustrate key sentences or phrases from the discussion of emergent properties.

> . . . they express a unity at the systems level which transcends differences amongst the elements, displaying them as features of an integrated whole.

In the account we identified outcomes in three domains expressed across the system. i.e. the managers, the students and academics all expressed research, educational and development outcomes. In a broad sense these outcomes are similar within each domain (e.g. they all relate to complexity theory or transformation) and have arisen out of a single network of interactions across the system. This in turns leads to the erasure of demarcation lines relating to practice, education and research. As opposed to discrete systems of knowledge creation, dissemination and application, we have a single distributed system of knowledge production (Gibbons *et al*. 1994; Pettigrew 1997) aspects of which might be variously interpreted as engaging members in genuine co-research, co-education and co-development.[2]

> . . . emergent properties are (at best) only partly predictable in the ways in which they unfold . . .

The project was formed around some basic agreed principles; to some extent the nature of the outcomes accords with these — there was three way dialogue, complexity theory itself was used as a theoretical reference, a project would be used, etc.; however, the detailed form of outcomes took shape as the interactions unfolded — for example the company's variation of the Conditioned Emergence model and the design of the student-company interaction arose out of the dynamic of the dialogue which had been established. There was no formulaic or clear pre-existing design, and it's doubtful whether the process or outcomes could have been designed or anticipated. In general terms, this means that knowledge production is both relationship-dependent and context specific. This turns the focus towards the production of knowledge which is applied in the context of its production — and a stronger case for activities such as action research and problem-centred learning.

> the detailed expression of emergent phenomenon is fashioned through the interaction of the so-called observer and the observed, or creator and the created.

In the project account above, we have tried to convey the importance of dialogue in shaping both the perception and unfolding dynamic of the project. There is no place for the frozen, unobtrusive witness; the very act of observation contributes to the formation of the observed and to subsequent observations. Given complexity theory's emphasis on sensitivity to initial conditions, the smallest of perturbations, and the impact of non-linear feedback, one is left with no escape from the consequential nature of one's interventions. The degree or level of involvement may be optional, but the consequences

[2]It is interesting to note that at a detailed level, differences exist between the outcomes e.g. the business development outcomes are not identical to those of the students or the academics; individual students experience different outcomes, etc. This raises interesting questions of system definition, levels and subsystems. Answers to such questions might lie in the fact that the individuals concerned are also members of other different systems.

are in no way guaranteed to be proportional. We would suggest that this should shift the emphasis of research intervention away from "damage limitation" and more towards fulfilling its creative potential in real-time.

The ostensive nature of emergent properties also reminds us that as they are recognised and partly created through observation, and are thus somewhat in the eye of the beholder. The source is that of a knowledge-creating network of relationships, and it is the relationships as much as the observations that should be managed.

> intuition and emotion are likely to play a role in the recognition of an emergent property

In the description of the project, we do not explicitly deal with this issue; however, emotion was implicit in the account of the students' contention concerning old and new rules and was evident in both written and verbal exchanges on the matter. Indeed, given the highly participative and creative nature of the project, it is difficult to justify excluding intuition and emotion from any part of the process. Nevertheless, they are (at best) treated with suspicion in accounts of research and, except in studies dedicated to them as phenomena in their own right, they are ignored or skirted over. We would join with Brian Goodwin (1999) in pressing for the more explicit consideration of their role in participative science.

In summary, we feel that there is a sufficient case for treating research, education and development as co-emergent properties of knowledge-producing systems. We believe that this has implications for policy in that learning, research and development are co-emergent properties of networks of relationships. As such they are dynamic and transitory. Policy should therefore promote high-involvement, boundary-spanning relationships in which knowledge is both produced and consumed. Indeed production and consumption are cross-catalytic processes. The ability to simultaneously co-create and co-apply is more important than the ability to abstract, generalise and diffuse. Consequently, policy should promote initiatives, which simultaneously generate learning, development and research outcomes but recognise that the detailed appearance of these outcomes will have limited use outside the context of their generation. In general, the move should be away from a policy of long-term collaboration between three macro-systems (education, research and development) towards a policy of establishing, nurturing and recycling a plethora of transient, knowledge-producing micro-systems.

9. Conclusions

Our aims here have been to highlight the practical benefits of employing complexity theory in the study of social systems and show how such applications might lead one to question some of our basic assumptions about the relationships between research, teaching and business practice. The project detailed here led us to re-affirm an old idea, namely the integration of research, teaching and fruitful application in practice. Our intention has been to show that perhaps our efforts at integration are something of a humpty-dumpty phenomenon. Rather than driving collaboration across boundaries, we should be facilitating the emergence of a natural unity, which both transcends and undermines the boundaries themselves. This natural unity springs from a common purpose, addressed through a single process of knowledge production.

In many ways, our claims echo those of a growing band expressing frustration. The issue of relevance is a perennial feature of management conferences, funding bodies, students and practitioners alike. The frustration is vented on a system, which appears to favour a strictly positivistic, normal-science approach with the emphasis on objectivity, rationality and data.

As described earlier, the management literature is currently in the throes of a debate on research process with many advocating a move towards “mode 2” knowledge production (Gibbons *et al.* 1994). We have arrived at much the same view of research process using the concept of emergent properties to develop and justify our claims. This perhaps leads to a final point of distinction, our insistence that research, education and development are properties of transient systems of knowledge production.

According to the theory of autopoiesis (Maturana & Valera 1987), such systems are structurally open, but organisationally closed. That is to say that they import energy from their environment but, whilst changes may be triggered by such imports, their form is generated from within. The issue of relevance thus takes on a new shape since educational, research and practical outcomes, can only relate to each other if they arise out of the same system. It may thus be time that we stopped treating them as though they are separate whilst appealing to them to behave as though they are one.

Through the project described here, and others, we have begun to develop a research process which is theoretically consistent with the subject of its investigation. Complexity theory appears to offer much in the way of new insights into how organisations as knowledge producing systems might be managed as complex adaptive social systems. We believe however, that complexity theory must be developed further to embrace many of the idiosyncrasies of social systems (as opposed to physical or chemical systems) and human elements. Only when we explicitly factor in human phenomena such as reflexivity, intentionality, emotion and intuition, will we move towards an understanding of what is actually meant by management in complex adaptive social systems.

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Chapter 8

The Core of Adaptive Organisations

Roger Lewin and Birute Regine

A World in the Throes of Change

The business world is in the throes of revolutionary change, a time when business leaders are preoccupied with change itself. Modern management theory borders on being obsessed with change of one sort or other — how to generate it, how to respond to it, how to avoid being overcome by it. At the onset of the twenty-first century, we are experiencing structural shifts in our economy brought about by the revolutions in computation and communication technologies. But, as Intel's Andy Grove indicates, change is not exactly a welcome guest in business: "With all the rhetoric about change, the fact is that we managers hate change, especially when it involves us" (Grove 1996).

The change is not only real, but it is also accelerating, driven by rapid technological innovation, the globalisation of business, and, not the least of it, the arrival of the Internet and the burgeoning domain of Internet commerce. In this new business environment, managers are finding many of their background assumptions and time-honoured business models inadequate to help them understand what is going on, let alone how to deal with it. Where managers once operated with a machine model of their world, which was predicated on linear thinking, control, and predictability, they now find themselves struggling with something more organic and non-linear, where limited control and a restricted ability to predict are the norm. As Colin Crook, a former senior executive with Citicorp, states in an article in *American Programmer*: "We must abandon the formal, static, linear planning process. . . . In the new non-linear world, no predictions remain valid for too long" (Crook 1996).

Managers, consultants, entrepreneurs, executives, and other business professionals — indeed, anyone who works — can take some comfort in the fact that they are not alone in riding a wave of great change that demands a different understanding of the world. Science, too, is in the midst of an important intellectual shift, a true Kuhnian (Kuhn 1996) paradigm shift that parallels what is happening in business, or, more accurately, is the vanguard of that change. Where once the natural world was viewed as linear and mechanistic, where simple cause-and-effect solutions were expected to explain the

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ISBN: 0-08-043957-8

complex phenomena of nature, scientists now realise that much of their world is non-linear and organic, characterised by uncertainty and unpredictability (Gallagher & Appenzeller 1999). As in science, managers are discovering that their world is not linear but rather predominantly non-linear, not mechanistic but rather organic and complex. The linear model for understanding the world, both in science and in business, has yielded impressive results. But in the new economy, the limitations of the mechanistic model are becoming starkly apparent. "The challenge lies in our ability to make sense of the rapidly changing context in which we are doing business", comments John Seely Brown, director of Xerox Corporation's Palo Alto Research Centre. "We need to find new ways of doing things. . . . To do things differently, we must learn to see things differently; . . . it is a matter of survival in the new world of business" (Seeley Brown 1997).

The realisation that most natural systems in the world are non-linear has given birth to the new science of complexity, whose midwife was the power of modern computation, which for the first time allows complex processes to be studied in some depth (Kauffman 1995; Holland 1998). The science is still in its infancy, and is multifaceted, reflecting different avenues of study. The avenue most relevant to understanding organisational dynamics within companies and the web of economic activity among them is the study of complex adaptive systems. Simply defined, complex adaptive systems are composed of a diversity of agents that interact with each other, mutually affect each other, and in so doing generate novel behaviour for the system as a whole, such as in evolution, ecosystems, and the human mind. But the pattern of behaviour we see in these systems is not constant, because when a system's environment changes, so does the behaviour of its agents, and, as a result, so does the behaviour of the system as a whole. In other words, the system is constantly *adapting* to the conditions around it. Over time, the system *evolves* through ceaseless adaptation.

We argue that business organisations are also complex adaptive systems. This means that what complexity scientists are learning about natural systems has the potential to illuminate the fundamental dynamics of business organisations, too. Companies in a fast-changing business environment need to be able to produce constant innovation, need to be constantly adapting, and be in a state of continual evolution, if they are to survive.

If complexity scientists are right in arguing that if complex adaptive systems of all kinds-in the natural world and the world of business-share fundamental properties and processes, then the science offers something that most management theories do not. The argument here is that most management theories are not really theories at all, but merely techniques for managing in a certain way (Lewin & Regine 2000). Complexity science is still nascent as a theory but it has determined certain fundamental processes and characteristics of complex adaptive systems. In other words, when we speak of businesses as complex adaptive systems we are not speaking of a metaphor or a technique; rather, we are saying that by understanding the characteristics of complex adaptive systems in general, we can find a way to understand and work with the deep nature of organisations.

This new science, we found in our work, leads to a new theory of business that places people and relationships-how people interact with each other, the kinds of relationships they form-at the core of management practice. In a linear world, things may exist independently of each other, and when they interact, they do so in simple, predictable ways. In a non-linear, dynamic world, everything exists only in relationship to everything else, and the interactions among agents in the system lead to complex, unpredictable outcomes. In this world, interactions, or relationships, among its agents are the organising principle.

Complexity science in the business realm, therefore, focuses on relationships: relationships between individuals and among teams; relationships to other companies in their business environment, or economic web; and, ultimately, relationship to the natural environment. And because the dynamics of complex adaptive systems are complex and largely unpredictable, accepting businesses as being such systems requires a different mind set: managers and executives cannot *control* their organisations to the degree that the mechanistic perspective implies; but they can *influence* where their company is going, and how it evolves.

Between January 1997 and January 1999 we conducted in-depth interviews with (usually) a cross section of people in a dozen companies in the U.S. and the U.K. that were structured according to the principles of complexity science: namely, they were organisationally flat, encouraged rich communication, and valued diversity. They ranged in size from 35 people to 22,000, and in economic activity from a family-owned retail paint and decorating store to a global biotechnology company, and from a chemical concern to a hospital. Our aim was to see if there were patterns in terms of management practice and emergent culture. If there were patterns that were common in such a diversity of organisations, then we would be able to propose that such patterns reflect something fundamental about complexity-guided management.

We knew from complexity science that interactions among agents of a system are the source of novelty, creativity, and adaptability. We can restate this in the language of complexity science as follows: in complex adaptive systems, agents interact, and when they have a mutual effect on one another something novel emerges. Anything that enhances these interactions will enhance the creativity and adaptability of the system. In human organisations this translates into agents as *people*, and interactions with mutual effect as being *relationships*. We recognised that it was possible that this dynamic could have been one of mechanistic efficiency. But what we found, universally, was that the relationships were grounded in a sense of mutuality: people share a mutual respect, and have a mutual influence and impact on each other. From this emerged genuine care. Care is not a thing but an action — to be care-full-to care about your work, to care for fellow workers, to care for the organisation, to care about the community. We saw that genuine care enhanced the relationships in these companies, with CEOs engendering trust and loyalty in their people, and the people being more willing to contribute to the needs of the company. In the context of complexity science, care, which enhances relationships, in turn enhances companies' creativity and adaptability.

We can see, therefore, that management practice guided by complexity science leads us to a very human orientation. Of course, there have been many human-centred approaches in management before, amongst the more notable being political scientist Mary Parker Follett's work done in the 1920s and 1930s in the United States, (Graham 1995) in which there has been a recent resurgence of interest. For more than half a century, there has been a constant battle between human-oriented management and scientific or mechanistic management, with the latter prevailing. But it is only now, and for the first time, that there is a science behind a human-centred way of thinking that gives a legitimacy to this realm of management.

"Business is about people" has been bandied around for some time, and yet rarely addressed with any human depth. Consequently, the feeling of not being valued is pervasive in the business world, and a few writers recognise the fact. "Too many people feel insecure, threatened, and unappreciated in their jobs", writes Tom Morris, a philosopher and business consultant (Morris 1997a). "Overall job satisfaction and corporate morale in most places may be at an all time low" (Morris 1997b). Peter Senge, director of the Centre for Organisational Learning at MIT's Sloan School of Management and author of *The Fifth Discipline*, notes that the prevailing mechanistic model of business encourages managers to see people as machines, not as people. "We deeply resent being made machinelike, in order to fit into the machine", he says (Senge 1997a). Henry Ford once said, "How come when I want a pair of hands, I get a human being as well?" A manager in today's knowledge-based economy might paraphrase this: "How come when I want a mind, I get a heart as well?"

Some managers recognise the lack of humanity in their organisations, and are frustrated with the perceived impossibility of doing anything about it, anything *genuine* that is. Alan Briskin, author and business consultant, quotes a manager in a large conglomerate as follows: "We're so busy moving people around, trying to meet our deadlines, trying to influence people to believe in what we're doing, that we just don't want to really look into anybody's eyes and see they have souls. We should start with the premise that we have souls. But souls are difficult to manage. And even if we talked about people having souls, it would probably be from a corporate viewpoint" (Briskin 1998). The manager's last point is that making "soul" into some kind of company slogan would be worse than not recognising the existence of workers' souls in the first place. But more to the point, trying to influence people to believe in what they are doing, without seeing who the person is, wanting them to be something for you rather than recognising them for who they are, is an act of imposition, not engagement. To be blunt, it's dehumanising. And people will resist when they're not included in the process and have things imposed on them.

Even Michael Hammer, one of the developers of reengineering, eventually came to realise that management is not just about organisational structures or process teams. In an interview in *The Wall Street Journal*, he admitted that in his enthusiasm to make companies more efficient and profitable he forgot about people. "I wasn't smart enough about that", he conceded. "I was reflecting my engineering background and was insufficiently appreciative of the human dimension. I've learned that's critical" (White 1996). Trust is critical if organisations are to excel, as the European business consultant Charles Handy argues forcefully in his recent book *The Hungry Spirit*. And trust was one of the major casualties in the rush to downsize in the name of reengineering. More than 70% of U.S. companies are struggling with low morale and lack of trust, principally as a result of the trauma of downsizing, according to a 1997 Wharton School survey (Koretz 1997). The same is true in Europe.

"In the living company, the essence of the underlying contract is mutual trust", says Arie de Geus, a former senior executive of Royal Dutch/Shell. "Before they will give more, people need to know that the community is interested in them as individuals" (de Geus 1997a). An important reason why some companies fail, he says, is that "managers focus exclusively on producing goods and services and forget that the organisation is a community of human beings that is in business-any business-to stay alive" (de Geus 1997b). It is common sense that if people are treated as machines, not as people, they are unlikely to give loyalty and trust-they will not give of their best. And yet, unfortunately, to use Voltaire's phrase, "common sense is not so common".

Many companies that are anything but human-oriented in their management practices survive and even thrive, of course — for a time. "If you've drained the tank of human goodwill and motivation, you can continue to coast downhill for a while, even at a pretty rapid clip", observes Tom Morris, "but heaven help you if you encounter any big bumps in the road or the competition forces you into an uphill struggle" (Morris 1997c). Senge is even more emphatic about the matter. "As we enter the twenty-first century, it is timely, perhaps even critical, that we recall what human beings have understood for a very long time", he says: "that working together can indeed be a deep source of life meaning. Anything less is just a job" (Senge 1997b). A complexity-guided approach to management not only leads to successful, adaptive organisations; it also makes work more than just a job.

Paradoxical Leadership

The leaders we spoke to shared a common trait — paradoxes. The fundamental paradox in this leadership style is leading by not leading. Since processes unfold in complex systems in unpredictable ways, leading organisational change cannot come about by simply adhering to a conventional command and control approach, which is essentially linear. To accept non-linear outcomes, uncontrollable processes, and uncertainty demanded nothing less than a personal transformation of the leader. We'll talk about this transformation in terms of an *organic* approach to the organisation and as a different way of *being* a leader.

An Organic Approach: Work is Relationship

Although all the organisations we spoke to underwent a unique process defined by their environment, their history, their objectives, they all shared similar underlying patterns in how these leaders facilitated change. In order to work with their organisations as complex systems, these leaders had to learn to let go of control. As Tony Morgan, CEO of the Industrial Society, a consulting organisation in England of 300 people, said, "By nature I'm a command and control type person, very much so, but at that time I was getting a feeling that the command and control and linear thinking had a very limited life globally. So I approached the Society from a completely different angle. I was looking at how to change people from a structured organisation to a non-structured one and I didn't do this by design, but by intuition. I found that relationships are the most important thing for engaging non-linear processes. If you don't have this, none of it will work. What happens is you become more aware of behaviours in relationships that lead to positive rather than negative outcomes.

"I can't conceive of myself as a leader without the burden of responsibility to create positive and powerful relationships with everyone I interface with. And I mean relationships, where you can speak to me openly all the time. And that's really difficult because you have to be interactive and keep working at it. Coming from a command and control existence, it was quite an adventure for me, but if you don't think that I didn't wake up in the middle of the night and say 'this feels very uncontrolled,' you're greatly mistaken. I spent most nights thinking that. This is why this job has been more demanding than any other, because if you work within boxes, it's easy, because that's not about people, and that's much harder".

In other words, when relationships become the means for guiding non-linear processes, leaders had to see the limits of their control, which was not an easy task. Instead they focused on the power of the interconnected world of relationships and the feedback loops they foster and feed. This makes sense from a complexity perspective because it is through interactions, that is relationships, that something novel emerges; and how people interact, whether they have a mutual affect on each other — that is respect and impact — influences what emerges, negatively and positively. By focusing on relationships, these leaders began to see their organisation as an interconnected human web, a living organism that unfolds, fluctuates, and emerges — a more organic view of their organisation. On this new ground, the workplace had become an *experiment in progress*.

To engage in this experiment, they had to change the existing structures based on a mechanical model which meant pushing the system into chaos. They did this by challenging the existing relationships, both emotionally and functionally. When Morgan took over the leadership of the Industrial Society it was in financial crisis and was heading for bankruptcy. This is why he felt a radically different style of management was needed, one that was based in his knowledge of complexity science.

"From the start", Morgan told us, "I said we're going to live in chaos. This is daunting for people who've lived in a world of a certain way to behave, certain boxes to live in. The question was whether we *could* live in chaos. What I set out to do was to actually get rid of the negativity that existed in relationships, especially in senior management, and lead them toward a consciousness of another way of working. We started tearing down the structure by allowing people to speak up and talk honestly. I started this process by speaking very directly in ways that were totally unexpected to them. Once I took the lid off, they all did it. It's creating a safe space for people which sounds simple, but it's painful for them and scary for me". Within three years the society had gone from fiscal deficit to healthy surplus.

At Monsanto, CEO Bob Shapiro led change in his organisation of 22,000 people by challenging the functional relationships. "The challenge was how to create radical change in a very proud, successful institution? I decided that the only way to make that happen in a successful organisation was to make it unsuccessful. Not financially unsuccessful, but simply making the old ways of working no longer possible. I wanted to break the organisation down internally, break old habits and old ways of doing things by giving people challenges that they couldn't handle. The problem with making changes in a big complicated organisation is that all the parts fit together. They may fit in a dysfunctional way, but they do fit. So you can't take any single part out, redesign it and plug it back into the system. You have to redesign all the parts at once. You have to get everyone working on it.

"The way we pushed the organisation into this grand experiment was by overloading it, by demanding much more of the system than its linkages as they were structured, which was very rigid and vertical, could handle. We pushed the organisation into chaos as a way of 'finding' new, more adaptable, creative ways of operating in the new environment. I just felt intuitively it was the way to go.

"I did know it would be hard. I used to get people lining up outside my door, saying, 'Bob, you've got to tell me; I've got five different things I have to do here. What's your priority?' I knew that the minute I would prioritise it, we'd be back into the old model, of the boss having the answers and telling people what to do. The astonishing thing about the whole process was how fast it went — just a couple of years. Very soon people were self-organising, posting proposals for a project they cared about, inviting others to join. The reason this works is because it's what people *really* want". The impetus for change was to find a way of transforming what traditionally had been a hybrid company — which had chemical, agricultural, biotechnology, and pharmaceutical operations — into a life sciences company, whose business environment demanded more agility than was previously necessary.

Like Shapiro, all the leaders in our study were not invested in establishing themselves as the ultimate authority, but rather they worked to extricate themselves instead of fostering dependence on their expertise. Rather than directing people, they cultivated conditions where people could self-organise and restructure around the existing issues, which meant *being* a different kind of leader.

A Different Way Of Being A Leader

There were three behaviours, ways of *being*, that were common to these leaders. They *allowed* new processes to emerge rather than be imposed; they were *accessible* to people by being authentic and caring; they were *attuned* to their organisations, both at the macro level of the whole system, and at the micro level of interaction between people.

Allowing

Paradoxical leaders allow — experimentation, mistakes, contradictions, uncertainty, and paradox — so that the organisation can evolve. At DuPont's Belle plant in West Virginia, plant manager Dick Knowles talked about this aspect of paradoxical leadership in terms of a bowl. "I developed this image of a bowl, a safe container, that gives people freedom to experiment, to create improvements. Paradoxically, the bowl gives you order and freedom at the same time. It's the leader's job to create the bowl through our conversations about our vision, our mission, our principles, our standards, our expectations. The leader creates conditions that make it okay for the people to grow, and an enormous energy gets released. People discover that they can make a difference, meaning begins to flow, you get a discretionary energy flow. That's the difference in energy between doing just what you have to, to keep from being fired, and being fired up and doing the max. Most people know what to do, if they have a good sense of the bowl".

When Knowles took over as plant manager, the facility had a terrible safety record, emissions were high, and productivity was low. Head office was planning to close down the plant, if there was no improvement. The following figures speak to the efficacy of Knowles's new management approach, which were achieved after three years:

- Injury rates were down by 95%;
- Environmental emissions were reduced by more than 87%;
- Up-time of the plant increased from an average of 65% to 90 to 95%;
- Productivity increased by 45%;
- Earnings per employee tripled.

The paradox of allowing is direction without directives, freedom with guidance.

Accessible: Authenticity and Care

In order to create rich connections within a system, the leaders we worked with placed value on authenticity and care, which made them accessible as human beings and set a standard of behaviour for the organisation.

Authenticity makes for a cleaner connection because you know where people really stand. "Trying to look good and be something else for someone is an efficiency as well as a mental health issue; it's tiring and a waste of time and energy when you try to be something you're not", Shapiro told us. All the leaders recognised the power of their example, and strove to embody these behaviours. As Morgan said, "It's about being observant of yourself when you're being inauthentic".

All these leaders cared about their people and took seriously the task of making work meaningful and the workplace as a fulfilling place to be. As Shapiro said, "We're not trying to extort more work out of people. We're giving them an opportunity to grow and do things they care about. If you do enough work that is worth caring about, it taps into a whole different level of involvement, commitment, creativity, and achievement".

And it starts with the leader in a very personal way. Hatim Tyabji, CEO of VeriFone, a global high tech company of 3000 people, put it this way: "The *being* is the cause; everything else is a manifestation of that being. That being is caring. And it starts with you. As a leader, you've got to care. It's got to come from within you. Some say that's common sense. The issue is practicing it. The most profound truths in the world are the simplest. Except they don't get practiced". As Shapiro succinctly stated, "If we get authenticity and if we get caring — then we've got it; the rest will fall into place".

The paradox of accessibility is that leaders are mutual but not equal — mutual in respect and ability to affect and be affected by others and also not equal in power.

Attuned

These leaders relied heavily on their intuition and ability to listen as a way of being attuned to their organisation. To be attuned at a micro level, Morgan put it this way, "The best thing you can do is shut up and listen". At a macro level, Shapiro described how he attuned himself to Monsanto. "It's at a very abstract systems level that it seems to me I have to operate. I have to influence the systems to keep them open. I have to identify places where there are constrictions or blindnesses, where there are denials, and try to help that out. My specialisation is generalisation".

Also, as Shapiro points out, attunement to the organisation is an evolving phenomenon. "The first year I was CEO, I really thought I ran the place. I was trying to change something, and I felt I was there pretty much by myself, with a few people who understood what we needed to do. We were pushing against this enormous system. By midway into my second year, I realised I wasn't running it, that we had the right people, at least in a lot of places, and that they were doing it. I understood what they were doing, where we were going, what we were trying to accomplish and I liked it. By my third year, a lot of the time I didn't even understand it. And it felt wonderful. As is perfectly appropriate, it felt as if the place was outgrowing me".

The paradox of being attuned is knowing and not knowing; knowing intuitively while not knowing all the facts.

A Culture of Care and Connection

People in these organisations told us that in this context, where they felt they belonged and were contributing to a larger purpose, they were more able to be flexible and more willing to change. People's capacity to adapt in turn made the organisation more adaptable and financially successful. And as Lao Tzu put it, they felt "we did it ourselves". But they also knew they were led to it.

Leader as Cultivator, Building a Critical Mass

Linda Rusch, vice president of Patient Care at Hunterdon Medical Centre in Flemington, New Jersey, sees her leadership role as that of a cultivator of her people. The thinking behind this for Rusch, who is a big proponent of the principles of complexity science and their relevance to a new way of working, is to encourage people to make changes in places that they feel they can make changes, recognising the power of small changes in complex systems. Small changes have two pathways in a system. One is like a drop of rain falling on a still pond — a small change can create a ripple effect; that is, it replicates and spreads throughout the system. Qualitatively, the newly introduced behaviour is the same, but it is now to be found throughout the organisation. The second is like the grain of sand that falls on a sand pile, which sometimes causes large avalanches. That small change initiated the emergence of something qualitatively different, and much bigger than the original change, as pent up energy in the system gets released: something old collapses, and something new emerges.

In the first case, the rippling of a new change throughout the organisation leads toward the building of a critical mass, leads towards the system being poised at the edge of chaos, the edge of great change. The second case represents the release of energy simmering in the critical mass, leading to large change. The two combined represent the pathway to creative adaptation for an organisation. Rusch's skill is in building a critical mass in the organisation, the essential first step to eventual, though often unpredictable, change. The importance of small changes in Rusch's thinking is immediately evident on her office door where a quote of Ghandi's is taped saying, "What ever you do may seem insignificant, but it is most important that you do it".

Rusch's philosophy of her work and her organisation's mission goes beyond traditional financial bottom line. "When you think about it, we make money off people being sick. When you look at the hospital census and the beds are filled, you think, we're making money. Now, that gets stuck in my throat; we can't think that way anymore. We need to make money, of course, but I wonder if there are different ways of doing that. If people are sick, you certainly want them to come to your hospital, but the essence for me is, wouldn't it be wonderful if we could survive as a medical centre by keeping our community healthy? Not just physically, but emotionally and psychologically as well.

"That's what I'm striving toward: how do we embrace this community of ours and give them services that they want, so that they have a higher level of functioning? That's why, seven years ago, when I came on board, we started with these questions: 'How do the Medical Centre nurses care about their community? What would it look like? How would we behave?' We then made a banner that we took to all our community programs that said, 'HMC nurses care about their community.' "

The result of Rusch's question and challenge to her nurses — 'How do the Medical Centre nurses care about their community?' — was a sprouting of many community projects, all initiated by the nurses, many small changes in the hospital's relationship with the community. A critical mass of reaching outward into the community was building energy. As Rusch puts it, "The hospital is like the hub with spokes going out into the community in different strategic areas". One of the most noteworthy aspects of these ongoing, evolving projects is not just that they are outcomes of nurses seeing something that needed to be done and then doing it, but that they are on a completely volunteer basis. The time spent is *their* time; the money spent is *their* money. As Rusch says, "We're not making anyone do community work. You can't *make* people do that, saying it's a condition of your employment". The nurses do this not because they *have* to but because they *want* to. This volunteerism, when translated into monetary community benefit, has been on the rise since 1995. In that year, the volunteer dollar was $112,570. In 1998, it was $424,034.

What these nurses have *wanted* to do is participate in many health fairs, which started with the local Shad Festival and now includes the Lanape Health Fair. At the Shad Festival, which takes place over two days each year, volunteer nurses, wearing blue t-shirts saying 'Hunterdon Medical Centre nurses care about our Community,' provide free blood pressure tests, and educational material, such as on Lyme disease. At the

Lanape Fair, every nursing unit sends a representative to educate the community, on concerns such as managing stress, identifying depression, preventing falls.

Several nurses wanted to volunteer for training in March of Dimes, and are now going out on engagements, speaking about maternal/child health topics. One nursing unit adopted a homeless family during Christmas, and all the nurses personally donated money. A group of operating room (OR) nurses created a community forum for people to become familiar with laparoscopic and orthopedic instruments, and to meet "Aesop" the robot who holds these instruments in OR. In this way community people could become familiar with surgical procedures, and would be less frightened should they one day undergo these procedures. Children are brought to the OR before their surgery for the same purpose — to familiarise them with the area and to ease anxiety about surgery. The maternity ward set up an infant car seat program in collaboration with police and car dealerships in order to teach people how to put a car seat in properly.

When health care is in crisis, and most nursing staff are disgruntled, anxious, stressed, and morale is generally low, how is it that Hunterdon nurses are doing such incredible things above and beyond their job? This might be thought to be related to the fact that Hunterdon is economically in the black. Should there be layoffs, one might speculate, people might be less interested in volunteering. Even so, not all hospitals that are economically sound get such a burst of creative giving and such a commitment to improving health and wellness in the community. In fact, Hunterdon's CEO, Bob Wise, believes there is a correlation between the hospital's success and its nurses' efforts at participation in the community:

"I can't avoid seeing the relationship between the hospital and the community as a reason for our financial success. We extend ourselves beyond the walls of the hospital and into the community, and community responds to that. The people see the commitment and the nursing care in the community, and then they want to go to our hospital for care because they know they will get good care. It's a positive feedback loop that's driven by the nurses' care and their commitment to the community. It's not just their professional skills, but the relationships they create and the philosophy they live by, which is to extend yourself beyond your job and make a difference in the community".

When leaders are able to embrace the paradoxes of a complexity-guided management practice, and cultivate small changes throughout their organisations, which propagate in an exponential manner, the organisations become highly adaptive and are able to evolve in a continually changing business environment.

Operational Structure

St. Luke's advertising agency, in London England, was formed in 1995 by thirty-five people who had constituted the U.K. office of the New York-based giant, Chiat/Day. They didn't want to be swallowed up in an impending merger with another industry giant, TBWA. The breakaway move was initiated by Andy Law, head of Chiat/Day's U.K. office, and now Chairman of St.Luke's. David Abraham, co-founder and chief operating officer of St. Luke's, described their motivation as follows: "We wanted to unlock the human potential trapped in conventional business environments in order to enhance creativity and competitiveness".

Within three years the agency's staff had more than tripled in size, and (in January 1998) had been voted The Agency of the Year, a much-coveted accolade in the business, by *Campaign*, the industry's trade magazine. The agency was also strongly successful in traditional financial bottom-line terms, and was turning away multi-million-dollar accounts because its people were fully stretched.

Three elements went into the establishment of St. Luke's as a non-traditional business organisation, the second and third of which were key to engaging non-linear dynamics of the organisation. First, from the beginning the company's equity was distributed equally among all staff, from Andy Law as chairman to Rose Hamilton the housekeeper. "That way you get rid of the ego and greed problem that is so rampant in this industry", says Law. "It also generates deep, genuine commitment to the organisation".

Second, no one has a personal office. Everyone has a place they can go to each day, of course, but no one has a desk that is exclusively his or her own. When they come to work in the morning, people pick up a cell phone and go to wherever is most appropriate place for the day's activities, and this might include what is known as the chill-out space, which is reminiscent of a cafeteria, games room, and library combined.

Third, the traditionally linear mode of creating advertisements was transformed into a non-linear process.

Some elements of the latter two had been present at Chiat/Day, but not to the extent that Law and Abraham developed them at St. Luke's. Law and Abraham were not guided by complexity science principles when they sought a new kind of design for the agency: they didn't know about them at the time. Rather, Law and Abraham's intuition was that rich and fluid interaction in a context of little hierarchy would unleash greater creativity in their people as individuals and in the organisation as a whole. This is very much what complexity science posits when considering organisations as complex adaptive systems.

Although the experiment ultimately was successful, it took about 14 months before St. Luke's people collectively figured out how to operate. And the learning period was extremely difficult, for everyone. In effect, the company was in the chaotic throes of breaking an old way of working and seeking a new one, a novel way that no one had a clue what it would look like, still less whether it would succeed. In the ensuing uncertainty, people were grumpy and bewildered, and there was a lot of backbiting. "I remember that time as being full of extreme agony, frustration, and despair, for everyone", recalled Law. "People were pleading, 'Where are we *going*?' 'What are we *doing*?' '*Why* can't we have our own desks?' I said, 'I just know that having offices is wrong. This is an experiment, and I don't know if it will succeed.'" Law deliberately stepped out of the organisation, in the sense of not trying to make it go in one way or another, just seeing what might unfold.

Law's conviction about the benefits of disposing of personal desks was that it would encourage more casual interactions among people, breaking a static office into a free-flowing environment in which serendipitous encounters would be centres of unexpected creativity. "I sat opposite someone for two years in my previous agency", explained Sue McGraw, an account manager. "I got to know him very well, and we became good friends. But I now know that it was at the expense of interacting with a lot of other people in the agency". Mark Lewis, an account director, insists that the benefits are huge. "It's fundamental to the process of creativity here", he said. "It may be hard and irritating in some ways, but it keeps us in contact with one another".

The structural focus of St. Luke's is what is called Brand Rooms, which are the only physical offices in the place. A room is set-aside for each client, and is then decorated according to the pitch that is being developed. For instance, the Brand Room for Boot's the Chemist looks like a teenage girl's bedroom, because the pitch is for a line of cosmetics for girls. All meetings relating to a particular client take place in the appropriate Brand Room, and everyone involved in the account — including the client — gathers there together. The aim is to create an environment that promotes a non-linear development of the pitch.

The traditional way of operating in the industry is rather linear. The account director assesses the client's needs, and then communicates these to the creative director. The creative director in turn communicates these needs to the creative team, who then work up a possible pitch. The team gives the account manager the proposed pitch, and he/she then makes a presentation to the client. Lewis explained that "Usually, the client will say, 'That's pretty good, but it's not quite what we had in mind.' And the whole linear progression begins again. It's a slow, iterative process, full of air locks, people aggressively defending their territories".

At St. Luke's the client is involved throughout the whole process, so there are never any surprises, never any 'it's not quite what we had in mind,' because the client is part of the process of creativity. One consequence of the client's constant involvement, Lewis told us, is that the client is usually much more willing to go with what he describes as "more dangerous work, more cutting edge work", because the client has seen the ideas unfold, has been part of the process of unfolding, and is not simply confronted with a wild idea out of the blue after months of silence.

As important as the client's involvement, however, is that the brand room provides a mutual space for all the people involved. Each brings his or her own expertise, but not a territory to be defensive over. "Everyone sits around — the account handlers, planners, creative people — and those meetings go crazy", Lewis said. "They're real brainstorming sessions, and we get to solutions really quick, because we're not pushing against each other, everyone comes together and it explodes. The planning is happening, the creative work is happening, and then, instead of saying, 'Okay, we've got the brief, let's think about strategy,' we start writing ads immediately and we start working out whether the strategy is right or not. Everything just goes crazy really, really early on".

McGraw compared the experience with that in her former agency. "You spend less time talking to a thousand different people about the same thing", she explained. "The team process is important because, rather than everyone having their own little jobs that they do and then write a piece of paper about it and pass it on to the next person, everyone sits together in the same room and talks. Differences get resolved on the spot, rather than passing a piece of paper to someone and waiting three days to get a response. Here, that takes half an hour". The whole non-linear process is much more dynamic and less controlled than the traditional mode of working, because a greater diversity of people is interacting at any one time.

The linear progression mode of working encourages ego, we were told, because each person feels a need to defend their contribution, which is done in isolation from everyone else's. In the non-linear team process, where each person can contribute ideas in any sector of the process, not just in their area of expertise, ego is much less of a problem, because it is a collective, emergent process. This is not to say that there are no big egos at St. Luke's. There are, of course. But the non-linear process serves to minimise the "I" and enhance the "we".

Growth is always a big issue with small, successful companies, particularly when the creativity depends on rich interactions among people who know and trust each other. Beyond a certain size, a group is simply too big for everyone to know everyone in this way. At St. Luke's, this problem is addressed by what Law calls the "magic number rule", which simply means that when a group exceeds thirty-five people, it splits. "With larger groups, it's not possible for people to care enough, for people to know what's going on, "Law explained. Coincidentally, anthropologists talk about magic numbers in hunter-gatherer societies, with the foraging band being about thirty-five people.

St. Luke's began life with thirty-five people, and is now more than a hundred, divided among five groups. The pressure to grow has been great, particularly as the agency's notoriety burgeoned. During 1997, for instance, when the staff doubled from fifty to a hundred and new accounts were coming easily, pressure started to mount, and, said Law, "it started to get tense, with people fighting with one another, everyone working too hard, we were getting overheated". The creative work was still good, he told us, but people were suffering. "So in the early summer, we said, Enough. We stopped taking pitches. We wanted time to cool down". It was out of this that the decision to split from two groups into five was made.

But even though the magic number rule may preserve the social and creative milieu within groups, the reality of size remains. "When you split into groups, to retain the spirit within each group, you still have people from other groups you might not talk to as much anymore", said George Porteous, an account manager who's been at the agency since its birth. "Wandering around the building these days, there's a sense of anonymity, an absence of the spirit where everyone knew everyone else when there were just thirty-five of us. But don't get me wrong. We do need to grow, as an example of how business can change". An important aspect of this sentiment is how growth and financial success is viewed. "To me, profits are like breathing", Law said. "You need it to live, but it's not what you live *for*".

Not every organisation can be as free-wheeling in terms of structure as the one at St. Luke's, of course; nor did we see it in the organisations we worked with. Nevertheless, each sought to operate in a more non-linear manner than they previously had been, in order to be more adaptive.

For Dick Knowles the change was difficult, for several reasons. For one thing, when Knowles became the manager of the Belle Plant in 1987, there was a long history of distance and suspicion between managers and workers, the physical plant was run down, and there was a strong animosity between the plant and the community where it was located. And for Knowles, it required a personal transformation from a long-practiced command and control style of leadership to accepting that front-line people had much more to contribute than had been allowed. He described how a new control system was designed and installed, by involving workers from the beginning rather than imposing it, thus changing the traditional structure.

"One of our first change efforts was replacing the outdated pneumatic instrumentation for controlling one of the chemical processes with an electronic system, which improves operability, gives higher product quality, and lower emissions", Knowles said. "Traditionally, this kind of switch-over is done by an outside group of engineers, and involves building a parallel process for use during the early stages of start up. That's usually necessary to get you through the teething troubles as the operators overcome their resistance and slowly get used to the new system. This takes time, and a lot of angst before the new system is running smoothly. We said we wouldn't do it that way. We'd let our own people be involved in and do the whole thing. The operators and mechanics worked with the engineers the whole time, so they knew what was going on, and could have their input. We didn't build a parallel system, because we were confident that we wouldn't need it. We didn't. We did the shift over in half the time and half the cost that it normally takes, setting a new standard for the company as a whole. And because the operators and mechanics had been so involved in the design process, and had become so committed to making it work, the new electronic control system started up quickly, and was fully operational in a few days. It is a wonderful example of the effectiveness and efficiency you can achieve by involving front line people in change that affects them".

The chefs at the River Café in London thrust themselves into the non-linear realm by devising two menus each day, depending on what food was in the kitchen, and what was available in the market that day. They credit the process with promoting creativity, but acknowledge that it is not always easy. "The strengths of what we do are also our weakness", Garry, one of the chefs, explained. "So, yes, the chaos of it all makes you very creative, but it can be very anxiety-making. Some restaurants do the same dishes week after week. You get very good at it, of course, but it loses inspiration". There's more freedom, but less control with the River Café way of doing things, and there are often last minute scares, when dishes don't work out as envisaged, they told us. "There are lots of chefs who can't live with this kind of uncertainty. We've had people come to work here and they are shocked by what we do. 'What the hell is going on here?' they ask. I know I wasn't sure that the lack of hierarchy and lack of discipline was a good thing, having been in a very hierarchical, aggressive kitchen previously. But then I began to see the creativity of it, and I now love it. And if you don't, then you leave. That has happened".

At Barclays Home Finance Division in Leeds, CEO Mike Ockenden eschewed the usual leader's corner office and instead occupied a small desk and computer terminal just like everyone else in the organisation. "It's a message of mutuality", he explained. "Not equality, of course, because I am the CEO. But it is a message of 'I'm with you and I'm accessible to you.' And you have to be genuinely available, not just pretend to be".

When Ockenden became CEO, there was a tradition of the managers being aloof from the workers, which hindered their effectiveness. "They would distribute memos around the floors, and then disappear back to their offices", he said. "They just weren't available to help people with problems. I told them that their job was to be a coach, a friend, and teacher, and that their team should be able to look to them as the inspiration for improving themselves". As a way of removing the physical distance between managers and workers, Ockenden had the managers move their desks onto the floor, to be among their people. "Nothing changed, because the managers just stayed at their desks. So one weekend I had their desks taken away. So when they came to work the following morning they couldn't sit down. And they said 'What are we supposed to do now?' And I said, 'Now you've got to walk around, haven't you. And you've got to go and be with your people.' Sure enough, things started to change and conversations started pretty fast, and new relationships started to build. It had a tremendous impact on the culture and the effectiveness of the organisation".

Like all the organisations we worked with, Barclays Home Finance Division pulled themselves back from the brink of financial hardship and became successful in traditional bottom line terms. Every leader stressed that this complexity-guided, human-oriented management practice was not a luxury that an already successful organisation can *indulge* in; rather it was the *means* for becoming successful.

Conclusion

Management guided by principles of complexity science leads to a human-oriented style of working, in which relationships become the new bottom line of business, and the organisation becomes highly adaptive. Human-relations management is not new, of course, and many of the individual behaviours we saw collectively in these companies have been posited in other management theories. Much of what Peter Drucker talks about in terms of the workplace being a community would be included in this, for instance (Drucker 1999). What is new is that complexity science provides insight into why such practices are usually successful: a human-oriented management practice is not simply "being nice"; rather it is a way of engaging the dynamics of a complex adaptive system — that is, enhancing interactions and allowing mutual effect — that leads to the emergence of a creative and adaptable organisation, just as happens in other complex adaptive systems, natural and artificial. There are many organisational development data that show a positive correlation between human centred management and business success (Pfeffer 1998). Viewing organisations as complex adaptive systems explains why this should be so (Lewin & Regine 2000).

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Chapter 9

Is There a Complexity Beyond the Reach of Strategy?

Max Boisot

1. Introduction

A quick overview of the development of strategy over the past three decades, suggests that it has been getting steadily more complex (Stacey 1993; Garratt 1987). This is both a subjective and an objective phenomenon. Objectively speaking, casual empiricism points to a world that is increasingly interconnected and in which the pace of technological change has been accelerating. The arrival of the internet is evidence of increasing connectivity — some managers find upward of 200 e-mails waiting for them each morning when they arrive at the office. The persistence and replication of Moore's Law is evidence of accelerating technical change. The spirit of Moore's Law — which stated that the speed of computer chips would double every eighteen months and that their costs would halve in the same period — has now spread out beyond the microprocessors and memory chips to which it was first applied (Gilder 1989) and has started to invade a growing number of industries (Kelly 1998). As a result, corporate and business strategists are today expected to deal with ever more variables and ever more elusive, non-linear interaction between the variables. What is worse, in a regime of 'time-based competition', they are expected to do it faster than ever before. This often amounts to a formidable increase in the objective complexity of a firm's strategic agenda.

Complexity as a subjectively experienced phenomenon has also been on the increase among senior managers responsible for strategy. While in many industralised countries lower level employees are working shorter hours, senior managers are working longer hours. Having to deal with a larger and more varied number of players, they travel more, they meet each other for breakfast, for lunch, and for dinner. And in New York, busy managers now balkanise their lunch, with the first course being devoted to one meeting in one restaurant, the second course being reserved for a second meeting in a second restaurant, and so on. They come out of their meals with more things to think about and with less time to think about them in. Can such growing complexity be tamed by some

Complex Systems and Evolutionary Perspectives on Organisations
Published by Elsevier Science Ltd.
Originally published in *Emergence*, Volume 2, Issue 1.
ISBN: 0-08-043957-8

intelligible ordering principle of the firm's own devising — i.e. is it what mathematicians refer to as "algorithmically compressible"? (Chaitin 1974; Kolgomorov 1965). Or does it simply have to be endured and dealt with on its own terms? In other words, can complexity be *reduced* or must it be *absorbed*? Adapting a certain number of simple concepts drawn from both computational and complexity theory, and applying them within a conceptual framework that deals with information flows (Boisot 1995, 1998) this is the issue addressed in this article.

The claims of neoclassical economic theory to the contrary notwithstanding, we have come to realise that human economic agents are boundedly rational creatures. There is a limit to the complexity that they can handle over a given time period (Simon 1957). Organisations are devices for economising on bounded rationality. They create routines for the purpose of reducing the volume of data processing activities that they have to deal with (March & Simon 1958). Routines, in a sense, embody working hypotheses concerning both the way that selected portions of the world function as well as how they can be mastered. Routines, therefore, carry a strong cognitive component that reflects individual or collective sensemaking and understanding (Weick 1995).

Nelson and Winter, writing in an evolutionary vein, see such routines as units of selection (Nelson & Winter 1982). Firms that fail to evolve new and adapted routines in response to changing circumstances, sooner or later get selected out — they are penalised if they fail to revise their working hypotheses in a timely manner in the face of discomfirming evidence. Obviously, timeliness is a relative concept, and some environments will be more munificent with respect to the availability of time than others. Yet it is equally obvious that the faster and the more extensively circumstances change, the less time will be available for adaptation to take place and the more likely it is that any given firm will be selected out, to be replaced by new, better adapted competitors. In such a case, a failure of learning and adaptation at the level of the individual firm is compensated for by learning at the level of a population of firms.

But are cognitive strategies that aim at sensemaking and the creation of new routines the only option open to firms for coping with the boundedness of rationality when confronted with complexity and change? Is understanding a prerequisite for effective adaptation? In answering these questions, it is worth recalling the relationship that has been posited between task or task environment and organisation (Woodward 1965; Lawrence & Lorsch 1967). Simply put, the evidence is that task shapes organisation structure. The relationship had originally been established at the level of individual organisation units within a firm, but it is in effect a fractal one — that is to say, self-similar at different levels of analysis (Mandelbrot 1982). It operates wherever we find agency, action, and structure working together. Narrowly construed and embedded deep within the firm, tasks are operational — i.e. assembling a vehicle, writing a marketing report, etc. At the broadest and highest level, however, tasks become strategic so that strategy shapes structure (Chandler 1962) and aims either to align the firm as a whole with the requirements of its environment or to shape the environment so as to render it hospitable to the firm and its possibilities (Weick 1979).

We can now phrase the issue before us as follows: do increases in the complexity of a firm's strategic task of themselves call for changes in the way that the strategy process is organised within the firm? And should these changes be primarily cognitive — i.e.

should they aim to accelerate and facilitate the sensemaking process among senior managers so that these can initiate the creation of new and better adapted routines?

The fit between task and organisation turns out to be one variant of Ross Ashby's (1954) Law of Requisite Variety (LRV). Adaptive learning requires that the range and variety of stimuli that impinge upon a system from its environment be in some way reflected in the range and variety of the system's repertoire of responses. For variety read complexity — or at least one variant of it (see below). Thus, another way of stating Ross Ashby's law is to say that the complexity of a system must be adaquate to the complexity of the environment that it finds itself in.

Note that we do not necessarily require an exact match between the complexity of the environment and the complexity of the system. After all, the complexity of the environment might turn out to be either irrelevant to the survival of the system or amenable to important simplifications. Here, the distinction between complexity as subjectively experienced and complexity as objectively given is useful. For it is only where complexity is in fact refractory to cognitive efforts at interpretation and structuring that it will resist simplification and have to be dealt with on its own terms. In short, only where complexity and variety cannot be meaningfully *reduced* do they have to be *absorbed*.

So an interesting way of reformulating the issue that we shall be dealing with in this article is to ask whether the increase in complexity that confronts firms today has not, in effect, become irreducible or "algorithmically incompressible"? And if it has, what are the implications for the way that firms strategise?

In tackling these two questions, we shall take strategic thinking to be a socially distributed data processing activity involving a limited number of agents within a population of agents that make up a firm. Strategic thinking involves the sharing of diverse, yet partially overlapping, representations between agents with a firm's strategy being an emergent outcome of the way that such representations are shared (Eden & Ackerman 1998). The structuring and sharing of knowledge between agents lies at the heart of the approach that we propose to adopt.

2. A Conceptual Framework: The I-Space

Organisations are data processing and data sharing entities. They are made up of agents who successfully coordinate their actions by structuring and sharing information both with insiders — i.e. in hierarchies — and with outsiders — i.e. in markets (Williamson 1975). Because agents are often subject to information overload, however, they are generally concerned to minimise both the amount of data that they need to process and the amount that they need to transmit in any time period (March & Simon 1958; Boisot 1998). For this reason organisational agents, when acting purposefully and under some constraint of time and resources, exhibit a general preference for data that already has a high degree of structure and that is therefore easy to transmit.

But how does data get processed into meaningful structures in the first place? We argue that data processing has two dimensions: codification and abstraction. Codification can be thought of as the creation of categories to which phenomena can be assigned together with rules of assignment. Well codified categories are clear categories and well codified assignment rules are clear rules. Thus, the less the amount of data processing required to assign a phenomenon to a category, the faster and the less problematic the assignment will be. We then say that both the phenomenon and the category to which it is assigned are well codified. Uncodified categories and rules of assignment, by contrast, are characterised by fuzziness and ambiguity. Assigning phenomena to categories will then be slow and costly in terms of data processing. Where no assignment can be made at all, the amount of data processing required to perform an act of categorisation may then well go to infinity.

If codification is about minimising the amount of data-processing required to assign phenomena to categories, abstraction establishes the minimum number categories required to make such assignments meaningful. Where few categories are required, the more abstract our treatment of the phenomenon can be and the larger become the data processing economies on offer. By contrast, the larger the number of categories required to perform a meaningful assignment, the closer we are to the concrete realities of the natural world. At the extreme, when no abstraction is possible, the number of potential categories available to us runs to infinity and we find ourselves dealing with concrete data in its full complexity.

Codification and abstraction are cognitive strategies that any intelligent agent deploys in order to economise on data processing costs. The two strategies mutually reinforce each other and help the agent to make sense of its world by giving it a meaningful structure. They form two of the three dimensions of our conceptual framework. The sharing of data between agents is captured by a third dimension in our framework that describes data diffusion processes. We can think of diffusion as the percentage of data processing agents within a given population of these that can be reached by an item of data per unit of time. Agents may, but need not be human. A population of firms, for example, could be located along the diffusion dimension in which case one might well be dealing with an industry. Or, more fancifully perhaps, the population of agents could be neurons. All that is required for the purposes of I-Space analysis is that agents be capable of receiving, processing, and transmitting data. The agents that are to be located on the diffusion scale, however, have to chosen with care to avoid mixing apples with oranges. Firms, for example, cannot jostle with individuals on the scale without undermining the analysis. A second issue is that agents have to be placed there for a reason. That is, they must share some interest with respect to the data that flows in the I-Space.

The structuring and sharing of data are related. The more one can codify and abstract the data of experience, the more rapidly and extensively it can be transmitted to a given population of agents. The relationship is indicated by the curve of Figure 1. At point A on the curve one is in the world of Zen Buddhism, a world in which knowledge is highly personal and hard to articulate. It must be transmitted by example rather than by prescription. But examples are often ambiguous and open to different interpretations. Zen knowledge, therefore, can only be effectively shared on a face-to-face basis with trusted disciples over extended periods of time (Suzuki 1956).

Point A’ on the curve, by contrast, describes the world of bond traders. It is a world where all knowledge relevant to trading has been codified and abstracted into prices and

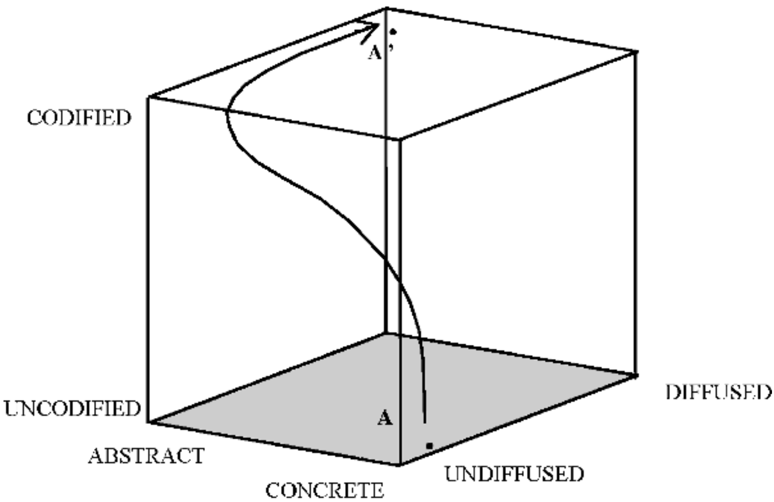

Figure 1: The diffusion curve in the I-space.

quantities. This knowledge, in contrast to that held by Zen masters, can diffuse from screen to screen instantaneously and on a global scale. Face-to-face relationships and interpersonal trust are not necessary. Only the technical and legal systems that support transactions need to be trusted, not transacting agents themselves.

Our Zen Buddhists and bond traders are, of course, caricatures. In the real world some Zen masters trade in bonds and some bond traders practice Zen meditation. What our example is intended to highlight is how different the information environments that confront agents can be, as these go about their business. The fact that certain agents will be exposed to a greater variety of information environments than others does not fundamentally alter the picture.

3. Transactional Strategies in the I-Space

The possibilities available to agents for structuring and sharing data, then, create different information environments. Two of them, those of Zen Buddhists and those of bond traders, were described above. Others are possible. Think, for example, of what happens when information is readily structured — and hence diffusible — but its actual diffusion is under some kind of central control. It is then often only made available to agents on a 'need-to-know' basis. In such an information environment, the possession of well structured knowledge will be treated as a source of organisational power over others and thus carefully hoarded. At the other extreme, we can think of situations in which knowledge is freely available to agents but in fact only diffuses in a limited way — and this, by interpersonal means — on account of being relatively uncodified and concrete. Knowledge will then become the property of small groups of agents whose size is limited by the possibilities of entertaining trust-based face-to-face relationships.

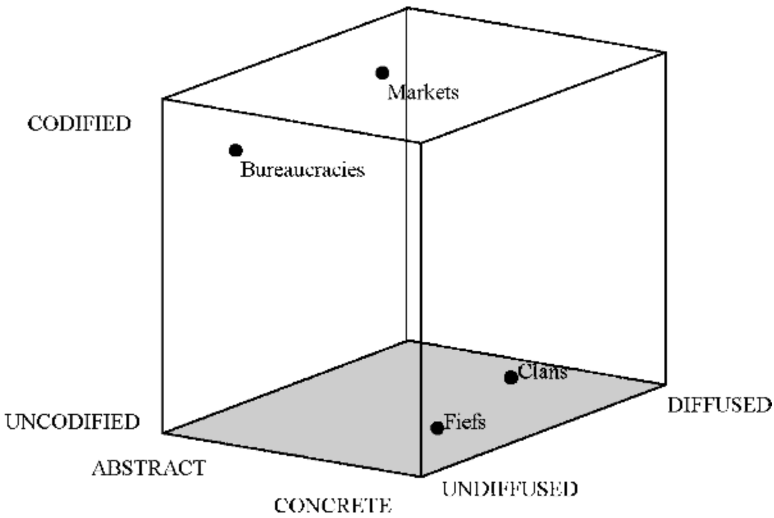

Figure 2: Institutions in the I-space.

Differences in the possibilities for structuring and sharing data can bring forth distinctive cultural practices and institutional arrangements. We identify four of these in the I-Space (Figure 2) and outline their essential characteristics in Table 1. The features which distinguish such institutional arrangements from each other are:

- the extent to which exchange relationships need to be personalised and the degree of interpersonal trust that they require;
- the extent to which data is asymmetrically held and hence constitutes a source of either personal or formal power;
- the degree to which specific types of exchange are recurrent and hence allow for emergent processes to operate.

Trust requires some ability by agents to get on to the same wavelength and implies some sharing of values. Power relationships require acquiescence. In this way, and drawing on Giddens's Structuration Theory (Giddens 1984) we move beyond purely cognitive issues of signification to address problems of legitimation and dominance (Bisot 1995).

The institutional structures located in the different regions of the I-Space lower the costs of processing and sharing data and hence of transacting in those regions. They can be thought of as a set of emergent Nash equilibria in iterated games between varying numbers of agents, equilibria that are partly shaped by the characteristics of the information environment in which the games take place. In effect, then, agents face two options when seeking data processing and transmission economies:

- Where data is amenable to codification and abstraction, move out along the codification and abstraction dimensions;

- Where it is not, foster the emergence of institutional structures appropriate to the information environment in which they find themselves.

These structures, as Nash equilibria, then act as what mathematicians call attractors in the I-Space, pulling in and shaping any transactions located in their neighbourhood or "basin of attraction".

The institutional structures depicted in Figure 2 can work individually or in combination. And as we have already indicated, they can also be adapted to the needs of different types of data processing agents. Figure 3, for example, locates a population of organisational employees along the diffusion dimension of the I-Space — i.e. it represents a firm. The diagram also assigns some of the key functions of the firm respectively to those regions of the I-Space that best describe their information environments. Where such an assignment is valid — and whether it is or not is ultimately an empirical matter that will depend on firm and industry characteristics — we would expect such functions to exhibit the cultural traits predicted respectively for

Table 1: Institutions in the I-space.

<table>
<tr><td>Codified Information</td><td>2. Bureaucracies
• Information diffusion limited and under central control
• Relationships impersonal and hierarchical
• Submission to superordinate goals
• Hierarchical coordination
• No necessity to share values and beliefs</td><td>3. Markets
• Information widely diffused, no control
• Relationships impersonal and competitive
• No superordinate goals — each one for himself
• Horizontal coordination through self-regulation
• No necessity to share values and beliefs</td></tr>
<tr><td>Uncodified Information</td><td>1. Fiefs
• Information diffusion limited by lack of codification to face-to-face relationship
• Relabonships personal and hierarchical (feudal/ charismatic)
• Submission to superordinate goals
• Hierarchical coordination
• Necessity to share values and beliefs</td><td>4. Clans
• Information is diffused but still limited by lack of codification to face-to-face relationships
• Relationships personal but non-hierarchical
• Goals are shared through a process of negotiation
• Necessity to share values and beliefs</td></tr>
<tr><td></td><td>Undiffused Information</td><td>Diffused Information</td></tr>
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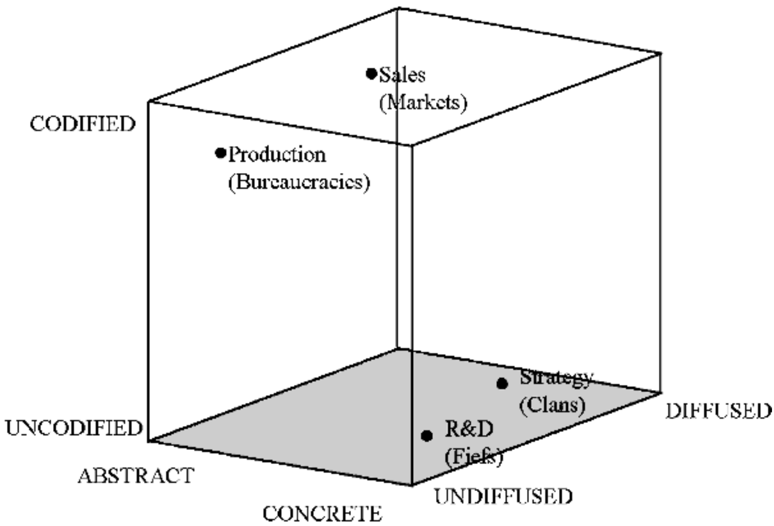

Figure 3: Some firm-level functions in the I-space.

each of these regions. The firm itself, therefore, would accommodate a variety of institutional cultures which then need to be integrated. Where one of these cultures predominates — i.e. acts as a strong attractor — at the expense of the others, dysfunctional behaviours are likely to appear. Thus, for example, a strong sales department driven by well defined customer needs in a competitive environment operates within a time frame that could undermine the more long term and 'blue skies' approach of an R&D department, should this be unable to defend its organisational interests.

Figure 4 treats the firm itself as a data processing agent in its own right and depicts a population of firms in an industry. Here, the I-Space allows us to explore industry-level structures and cultures. We see from the diagram that monopolistic and oligopolistic industries may have quite distinct cultures, and that these, in turn, are likely to differ significantly from industries characterised as either competitive or emergent.

4. Complexity in the I-Space

The issue that we are addressing is whether the growing complexity that the firm confronts remains accessible to strategic processes. We therefore now ask the question: do any of the concepts coming out of the new sciences of complexity have anything to contribute to strategic thinking, and do they lend themselves to treatment in the I-Space?

The first point to note is that some of the measures of complexity that have been put forward, find echoes in our codification and abstraction dimensions. Gregory Chaitin (1974) and Andrei Kolgomorov (1965), for example, have each separately developed the

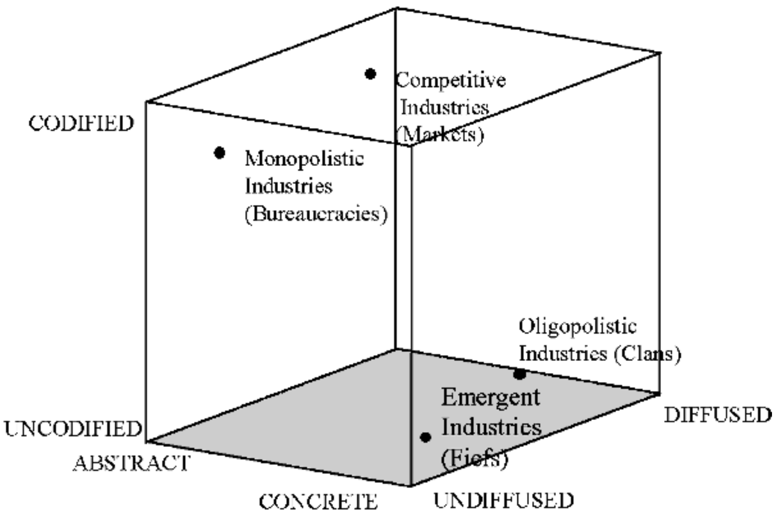

Figure 4: Industry structures in the I-space.

concept of Algorithmic Information Content (AIC). AIC is measured by the shortest programme that will describe a phenomenon such that it can be faithfully reproduced — our own definition of codification is the minimum number of bits of information that will allow us to adequately describe a phenomenon. Murray Gell-Man has pointed out, however, that such ‘crude’ complexity, as defined by AIC, is indistinguishable from randomness (Gell-Man 1994). He proposes a measure of what he terms ‘effective complexity’ to complement AIC and which he defines as the shortest programme that will describe the *regularities* that characterise a phenomenon — our own definition of abstraction is the minimum number of categories that will allow us to adequately capture a phenomenon. Clearly, if we adopt and adapt the definition offered by Chaitin, Kolmogorov, and Gell-Man, what we mean by information structuring can now be interpreted as an instance of algorithmic compressibility, a reduction in data-processing complexity. Equally clearly, the carrying out of such a reduction is a cognitive process.

To deal with the diffusion dimension of the I-Space, we must turn to the work of Stuart Kauffman (Kauffman 1993, 1995). Kauffman has been investigating the process of self-organisation from a theoretical biologist’s perspective. His random Boolean networks — he calls them NK networks — consist of nodes and linkages that switch on and off in a binary fashion, where N stands for the number of nodes in the network and K measures the density of connections between the nodes. Again, with some adaptation, NK networks allow us to examine the emergence of complex interactions in a population of agents. All that we require is that the nodes exhibit some minimal data-processing capacity and that the linkages be treated as communication channels between nodes. Treating each node as an agent, we can then establish measures of data processing complexity for each one. With increasing data-processing complexity, Kauffman’s model comes to look increasingly either like a neural net — where nodes can extend their communicative reach beyond their immediate neighbours (Aleksander & Morton 1993) — or like a cellular automaton — where they cannot (Wolfram 1994).

Following Kauffman, we shall let N represent the number of agents in our target population — N thus corresponds to the length of our diffusion dimension — and K represents the degree of agent interconnectedness. Thus an agent with a high K enjoys extensive interactions with other agents whereas one with a low K may be feeling pretty lonely. Kauffman then offers us a tuning parameter P — developed by two of his colleagues, Bernard Derrida and Gerard Weisbuch of the Ecole Normale Supérieure in Paris — to represent any switching bias present in the network, that is, the probability that the link between any two nodes will be activated. Where P has the value of 0.5, for example, no switching bias is present. Linkages between nodes are equally likely to be activated and to stay dormant so that the network behaves chaotically. As P approaches the value of 1, however, the network behaves in an increasingly orderly fashion until at 1 it reaches a frozen or steady state — either fully "on" or fully "off".

Kauffman's P bears a striking resemblance to Shannon's H, his measure of entropy or information in a channel (Shannon & Weaver 1949). In Shannon's scheme, H reached its maximum value when symbols in a sequence were equally likely to follow each other. Where the symbol sequence exhibited bias, this could be exploited by a suitable coding scheme to reduce the length of the sequence — i.e. it could be structured and its complexity reduced. We shall use P as a rough measure of data-processing complexity, with a low value of P (at or close to 0.5) corresponding to low levels of codification and abstraction, and a high value of P (at or close to 1) corresponding to high levels of codification and abstraction. Clearly, in our interpretation of P, we are once more combining Gell-Mann's crude and effective complexity in a single measure. The I-Space itself however, like Gell-Man, keeps the two concepts distinct.

By varying K and N and appropriately tuning P, Kauffman establishes phase transitions between ordered, complex, and chaotic regimes in random Boolean networks. In a similar fashion, by tuning P and varying K for a given N — in our own analysis, to keep things simple, we shall hold the number of agents located along the diffusion dimension constant even though in real life, agents are constantly coming and going along it — we can create phase transitions in the I-Space that reflect ordered, complex and chaotic social processes. Thus, for example, where the value of P is high — i.e. close to the value 1 — and the value of K is low — i.e. the density of interaction among agents is low — we are in an ordered regime where things are stable and predictable. Where, by contrast the value of P is close to 0.5 and the value of K is high we find ourselves in a chaotic regime where nothing is stable and valid predictions are hard to come by. In between these values for P and K we operate in a complex regime exhibiting varying degrees of stability and hence, predictability.

What are we in fact doing? Nothing more than varying either the amount of data processing that agents are required to carry out or the density of social interaction that they are expected to engage in. Although we are not yet in a position to present empirical results for this exercise — a research project is just getting under way at the Wharton School to test out the idea — we can offer an indication of what kinds of hypotheses might be tested by it.

5. Complexity Reduction (Analysis) vs. Complexity Absorption (Emergence)

The term culture has been defined in many ways (Kroeber & Kluckhohn 1952), but nearly all of them involve the structuring and sharing of data within or across groups. How effectively it is done is a function of the volume of data that is to be shared, the size of the group or groups that it has to be shared with, and the density of social interaction within or between such groups. Figure 2 locates institutional structures in the I-Space as a function of these three variables, and the way in turn that such structures combine in the real world impart to a given culture a unique configuration or "signature" in the Space. In effect, the location and nature of institutional structures in the I-Space reflect both the complexity of the data processing environment they find themselves in as well as that of the social interactions that they give rise to. Data processing activities and social interaction thus place these structures in a phase space as indicated in Figure 5 and according to the criteria outlined in Table 2. As we can see from the Figure, Bureaucracies clearly sit in the ordered regime whereas Markets and Fiefs, occupy the complex regime. Note, however that the complexity of markets is due to the number of agents that need to be coordinated whereas that of fiefs is attributable to the fuzziness of the information environment. Thus, whereas Markets operate with a P value closer to 1 — i.e. with prices that codify and diffuse all the relevant information — Fiefs, we would hypothesise, operate with a P value closer to 0.5. How close is an empirical question that cannot be addressed here. Clans, although also characterised by complexity, seem to be located close to the chaotic regime — with low values for P and medium values for K, they sit on the 'edge of chaos' (Langton 1992).

Over time, cultural and organisational evolution moves us from one set of institutional arrangements to another (North 1990). As we move, we shall sometimes

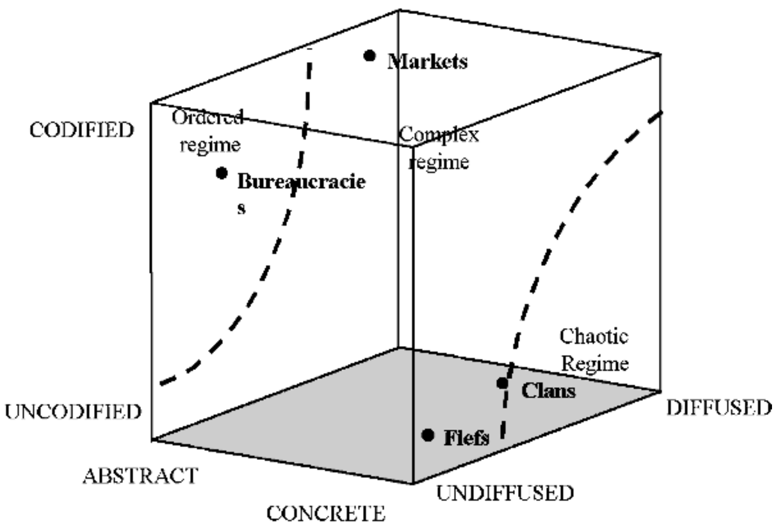

Figure 5: Institutions in phase spaces.

Table 2: The complexity of Transactional Structures.

	Relational complexity	Cognitive complexity	Overall Transactional Complexity
Markets	High (High K)	Low (High P)	Medium
Bureaucracies	Low (Low K)	Low (High P)	Low
Fiefs	Low (Low K)	High (Low P)	Medium
Clans	Medium (Medium K)	High (Low P)	High

experience phase transitions reflecting the extra expenditures of cognitive and social energy required both to overcome the attractive forces of a given institutional arrangement acting as a Nash equilibrium and to adapt to a new institutional regime. Whether it is worth moving or not depends on how far the benefits of doing so counterbalance the costs incurred in doing so. The benefits are measured in savings on energy expenditures — i.e. economies achieved either in the processing of data or in the coordination of agent interaction. The costs are the converse of the benefits: energy expended in learning how to process data in a new region of the I-Space and to coordinate new kinds of interactions between agents. We find ourselves, in effect, confronting the same kind of choices as those identified in the literature on transaction cost economics (Coase 1937; Willimason 1975, 1985; Eggertsson 1990), except that, given our broader treatment of data processing and cognitive issues, our options extend beyond those of markets and hierarchies *tout court* (Boisot 1986).

This is just as well. For we still have to cope with the effects of entropy in the I-Space, the tendency for data-processing activities and interactions between agents to lose their structure and become increasingly discorded over time. As might be imagined, the rate of entropy production is at its minimum in the ordered regime and at its maximum in the chaotic regime. We know from the second law of thermodynamics that in a closed system, entropy can never decrease. In the I-Space, we can effectively attempt to "close" the system by holding N, the number of agents, constant. That is to say, we can try to limit the entry and exit of agents into the I-Space by controlling access to the diffusion scale. If we succeed, entropy will then increase in the system in two distinct ways. Firstly, data, is always undergoing diffusion in the Space and hence tending to move transactions towards the right — towards the complexity of markets in the upper regions of the Space, and towards the chaos that lies beyond clans in its lower regions. Secondly, data that has been highly structured by moves along the codification and abstraction dimensions, becomes subject to the action of time — i.e. to institutional forgetting. Although with structured data the loss of institutional memory will operate more slowly than in the case of unstructured data, over time, unless maintained by further expenditures of energy, the structures created to preserve data gradually erode, thus pulling data processing activities back into the lower regions of the I-Space, where they become uncodified and concrete.

We can think of our institutional structures as emergent mechanisms that have the effect of minimising the rate of entropy production in the type of information environment they find themselves in. They capture and stabilise transactions, temporarily blocking — or at least slowing down — their movement either downwards or towards the right in the I-Space. In the absence of such structures, all transactions sooner or later drift into the chaotic regime and, unless they are 'open' to new inputs of energy and information — usually provided by new agents entering the I-Space — organisations disintegrate in a Hobbesian 'war of all against all'.

Generally speaking, wherever they can do so, we see entropy-minimising firms seeking out the ordered regime, one in which the value of P is high and the value of K is low. Firms prefer stability to instability and will simplify and routinise wherever they can. When is that? Whenever they have enough understanding of the tasks they face to reduce their data processing load as well as enough power to manage directly the coordination of agent interactions. Firms, then, *pace* Tom Peters (Peters 1992), do not thrive on chaos if they can possibly help it. Some degree of chaos may be a precondition for creativity and renewal, but chaos is also destructive of identity (Scumpeter 1934) and firms, like most of us, typically prefer what already exists (us) over what could exist (others). Under most circumstances, therefore, they shun the chaotic regime in the I-Space — one which is unsustainably high in energy expenditures — and, more often than not, they also seek to escape from the complex regime into the stability and security of the ordered regime, of simple and predictable routines, and of uncomplicated, hierachical relationships. In short, wherever possible, firms will economise on transaction costs by opting for bureaucracies in the I-Space — an institutional form that offers stability and order to firms experiencing their first significant growth (Boisot & Child 1988, 1996).

Yet what happens when the cognitive understanding required to move up the I-Space into bureaucracies is absent? Or when the power to coordinate agent interaction — a move to the left in the I-Space — is lacking? Is a gradual drift into the chaotic region of the Space the only option?

We argue that a firm has available two quite distinctive strategies for countering the action of entropy in the I-space. Assuming that it is not yet in the chaotic regime and hence disintegrating as an organised entity, it can either seek to *reduce* whatever complexity it confronts through cognitive and relational strategies that will move it towards the ordered regime — i.e. by increasing the value of P and either decreasing the value of K or of N or both. Or, it can seek to *absorb* such complexity by first allowing some drift towards the right and the settling down in a location that stops short of the chaotic regime, a strategy that requires the firm to invest in institutional and cultural arrangements appropriate to that location. Given that they lie outside the ordered regime, Markets, Fiefs, and Clans must be considered as much complexity absorbing institutions as they are complexity reducing ones. What do we mean by this?

We can approach this question by examining more closely the differences between Bureaucracies on the one hand and Fiefs, Markets and Clans on the other. One feature that distinguishes Bureaucracies from these other institutional forms is the tight degree of coupling between agents. Fiefs, Markets, and Clans are all characterised by varying degrees of loose coupling between agents. Bureaucracies are bound into rigid hierarchical structures by well structured roles and routines and a well defined and accepted set of unitary goals. Fiefs also exhibit hierarchy but the cement that binds agents together is much weaker: personal loyalty — and to transient agents, not to institutionalised roles. Markets bring agents together in well structured and legally enforceable transactions, but typically, when we are dealing with markets that are 'efficient' (Roberts 1987), these are 'spot' exchanges or at least time-limited ones. Only labour-market relationships are more durable, but then, once contracted, these take the transacting parties out of the Market and often place them in Bureaucracies. Outside the employment relationship, market players remain atomised, each free to pursue his or her own interests through a sequence of spot market transactions. Coupling is thus well structured but highly transient and episodic. Finally, clans are flexible structures that work through personal negotiation and mutual adjustment. Participants in clan transactions share the gain and share the pain. Here the binding of agents to each other is achieved through mutual trust. Personal trust is necessary precisely because the nature of the coupling is so uncertain and contigent and because, in contrast to markets, legal enforcement mechanisms are so weak. The looser the coupling between agents the larger the degrees of freedom they enjoy in what they think and how they behave. Also, the greater the variety that they can draw upon when dealing with increasingly complex tasks. Loose coupling between agents is more difficult to manage than tight coupling. But loose coupling, by increasing requisite variety, allows the firm to manage (i.e. absorb) ireducible complexity over a wider range of states than tight coupling.

The decision by a firm to absorb rather than reduce complexity can be interpreted as a decision to develop a cultural and institutional capacity in the Fief, Market, and Clan regions of the I-Space. The firm can then either develop that capacity internally — in which case it faces the challenge of managing the resulting complexity within its own corporate boundaries by fostering a corporate culture appropriate to the operational needs of Fiefs, markets, or Clans taken singly or in combination — or it can develop it through a judicious choice of the kinds of organisations that it collaborates with. It must then manage the complexity taking place at the interorganisational interface through transactional arrangements appropriate to the institutional needs of Fiefs, Markets, and Clans. Sometimes, the major challenge facing firms pursuing complexity absorption strategies, is to manage the tensions that result when they find themselves in an institutional environment that requires the location of interface management arrangements in one part of the I-Space while their corporate culture is located in another. Such tensions often surface in strategic alliances, joint ventures, or operations in foreign countries whose cultural and institutional structures differ radically from those found at home (Boisot & Child 1999).

6. Implications for Strategic Processes

What implications does our analysis hold for the firm's strategy processes? How does it help us to address the question we started out with?

Chandler — whose work on the relationship between strategy and structure was briefly refered to at the beginning of the article — has traced the evolution of the giant

U.S. corporations in the last decades of the nineteenth century (Chandler 1977) and showed how the adoption of well articulated functional structures allowed them to manage their growth. He also studied how, following continued growth, such firms were later led to decentralise their operations by creating divisional structures in the first decades of the twentieth century (Chandler 1962). Both the moves to the functional structure and then to the divisional structure were a response to the pressures of information overload. In the I-Space the moves corresponded to a trajectory first up the Space towards Bureaucracies, where tasks could be structured and assigned to functions, and then horizontally along the Space towards Markets, where tasks could be decentralised towards divisions that were made to compete with each other for critical resources such as capital, labour, and managerial talent. The strategy, then, was first to reduce complexity through the creation of articulate structures and secondly, as it kept on growing, to absorb it through a process of decentralisation that reduced the intensity and extent of organisational coupling required between players. Both moves, taken together, however, amounted to a cultural commitment to the upper regions of the I-Space.

The strategy remained serviceable until the 1980s. Firms grew, and also grew richer. But with the globalisation of markets and the acceleration of technological competition, the complexity that firms had to deal with kept on increasing. Today, we may be reaching the limit of what the upper regions of the I-space have to offer in terms of either complexity reduction or absorption. Both the culture of command and control that characterises bureaucracies and that of market-driven SBUs held to well structured short term performance objectives, entail a long term loss of entrepreneurship and a consequent inability to handle fuziness and uncertainty. Many firms have sensed this intuitively and have started experimenting with clan-like organisational forms such as networks (Nohria & Eccles 1992). They have therefore started building cultural and institutional capactity once more in the lower regions of the I-space. In those regions, they encounter regimes that go from the moderately complex (Fiefs) to the complex (Clans) to the chaotic (no institutionalisation possible). A fief culture is typically that of the small firm, the family business or the start-up. Loyalty to an idea or to an individual predominate. As numbers grow, however, and interactions between agents become more extensive — with the rapid growth of the internet, for example, N and K have both been getting bigger — either the personal power that characterises this culture needs to be formalised in a move up the I-Space towards Bureaucracies, or a decentralisation towards clan forms of governance needs to take place.We have characterised clans as an edge-of-chaos phenomenon. If, as we have argued, firms cannot thrive on chaos, might they still do so on the edge of chaos?

Mintzberg and Waters have distinguished between deliberate and emergent strategies. They suggested that strategy walks on two legs (Mintzberg & Waters 1985), one which is oriented towards analysis and plans, the other towards intuition and responsiveness to the unexpected. If they are right, then strategy has a need for a variety of distinct cultures inside the firm, some to handle the predictable and the routinisable — the deliberate — others to handle the uncertain and the complex — the emergent. In short, if one accepts the Mintzberg and Waters model of the strategy process, then, in an extension of the Chandlerian thesis that structure follows strategy, the appropriate cultures must also be developed to manage the structure as it grows in diversity and complexity. Take, for example, managing in Clans — on the edge of chaos. It requires an ability to handle much higher levels of uncertainty and anxiety than analytically trained executives are used to. Clans are typically volatile and unstable forms of social organisation (Macinnes 1996). They tend to generate more social entropy than do well structured bureaucracies. In an unforgiving selection environment, the extra organisational energy that they burn up has to be compensated for by higher levels of creativity and innovation. Yet it is the very need for greater entrepreneurship and innovation — brought about by hypercompetion (D'Aveni 1995), by globalisation, and by accelerating technical change — that is dragging many firms into the lower regions of the I-space in the first place. Unfortunately, they often bring with them an adminstrative heritage (Bartlett & Goshal 1989) that is ill-suited to the challenge that they face, namely, to foster a culture capable of absorbing complexity as well as reducing it.

Thus, insofar as the business environment is becoming more complex, firms will need to shift from the complexity reducing strategies that secured their success from the end of the nineteenth until the end of the twentieth century and place more stress on complexity absorbing ones — a shift away from Bureaucracies and towards Fiefs, Markets, and clans in the I-Space. Much of the popular management literature has picked this up. It stresses internal competition (Markets), the need for the large firm to behave like a small one (Fiefs), and the importance of interpersonal networking (clans). Yet without an appropriate theoretetical perspective on what is happening to firms, the insights emanating from this literature will remain underpowered. As we have indicated in this article, the burgeoning sciences of complexity can help to put this right.

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Part V

Philosophical Issues in Applying Complexity Theory to Organisations

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Chapter 10

Complexity Theory and Organisational Intervention? Dealing with (in)commensurability

Lucas D. Introna

Introduction

It would not be an understatement to say that complexity theory[1] has presented us with the apparently impossible possibility: to make sense of the seemingly "random" phenomena in nature and society. Through complexity theory, "randomness" becomes ordered as a new sophisticated type of order — namely, chaos (Jantsch 1980). Not only this, complexity theory tells us that first level order (equilibrium) can be a death trap, that it is in conditions of "far from equilibrium" that systems evolve new structures and adapt in creative ways (Prigogine & Stengers 1985). Even if popular discussions of complexity theory are stripped of their rhetoric, cut down to size, as it were, the promise of complexity theory is still significant.

There is no doubt that complexity theory has produced significant and interesting results in the mathematical domain. Furthermore, it seems that complexity theory provides an interesting and convincing account of certain natural phenomena such as turbulence, chemical transformations, the evolution of biological structures, and so forth. The obvious next step is to apply this theory to social systems. The notion "social systems" here refers to phenomena such as interpersonal relations, group functioning — such as cooperation or conflict — and the constitution of human institutions and organisations. If complexity theory can provide sophisticated answers to randomness and instability in mathematical and physical systems, then perhaps it can do so for social systems as well. Thus, we have seen a flood of authors attempting to do just this in

[1] The term "complexity theory" is used as a general term to include chaos theory, fractal theory, dissipative structures, and so forth. I would also want to include, somewhat controversially, autopoiesis in the broad family of complexity theory.

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ISBN: 0-08-043957-8

management theory (Stacey 1992, 1996), organisation studies (Gemmill & Smith 1985), psychology (Kahn & Hobson 1993), sociology (Smith & Gemmill 1991), and geography (Portugali *et al.* 1994), to name but a few.

On an intuitive level it seems that there must be something of value in complexity theory for the social sciences and in particular organisational theory. However, the uncritical use of complexity theory as a new "meta theory" that surpasses or even nullifies all previous thinking, is unwarranted and naive. Especially in an age when other meta or "grand" theories have started to lose their compelling appeal and legitimacy (Lyotard 1986), it seems highly unlikely that any single theory or even a set of theories would suddenly produce clarity and solutions for the social problems of human organisation — problems that have eluded systematic theory for millennia.

One of the reasons for these doubts is the inability of a previous "meta" theory, namely *general systems theory (GST)*, to live up to high expectations of providing useful answers to the complexity of human organisation — in spite of its success in fields such as engineering, simulation, and dynamic modelling. In the late 1960s and early 1970s there was an expectation that GST could be the "set theory" for understanding the fundamental constitutive and organising processes of social systems — in the way that set theory provides a basis for explaining the most fundamental operations of mathematics. However, the enormous enthusiasm with which system theory — in particular cybernetic theory — was adopted by the social sciences in the 1960s to early 1980s was followed by caution and eventually disappointment. It became evident that the notion of a "system", like the notion of a "set", is highly dependent on the notion of a "boundary". Critical social studies — using ethnography and phenomenology — showed that social boundaries can be fragile, diffused, and open to continuous dispute and renegotiation. Even the most obvious boundary between the "self" and "others", when carefully scrutinised, eludes systemic definition and analysis — except at a very basic and general level. If it were not for the development of complexity theory, there is a distinct possibility that the "systems movement" in the social sciences would have died out. Many of the exciting possibilities suggested by systems theory as a systematic and systemic "mathematical grammar" for social systems — for example, feedback loops — turned out to "breakdown" or become entangled in the politics of everyday social engagement when applied. The neat order assumed in systems models simply was not manifested in muddled and fragmented everyday organisational practices. Such models seemed useful to order our interpretations and descriptions, but did not by themselves provide the fundamental and comprehensive understanding some of their proponents expected.

It is the contention of this chapter that the "failure" of general systems theory in the domain of the social, as well as the current high expectations of complexity theory as a new social theory, are both predicated on a fundamentally incorrect assumption. Both of these theoretical movements are based on the assumption that there is no *essential* difference between the *mathematical and physical reality*[2] where these theories emerged

[2] "Mathematical reality" refers to mathematical operations and the artefacts produced through these operations such as the Mandelbrot set. "Physical reality" refers to physical transformations and the artefacts produced through these transformations such as dissipative structures.

and the *social reality*[3] where they are subsequently being applied. This chapter argues that the *ontological incommensurability* of the mathematical and physical domains, on the one side, and the social domain, on the other, will not allow us to make simple conceptual shifts between these domains of reality. Furthermore, this chapter argues that there is no easy way to finesse this problem.

Ontological Incommensurability

The thesis of this discussion is that physical and mathematical systems are ontologically incommensurable with social systems. What is meant by this phrase? First, the issue of ontology: *ontology* refers to the assumptions and beliefs that we hold about the very nature or essence of phenomena (their *is*-ness as it were). What it means to be A and *not* B — a human being and not a machine, for example. In other words, ontology is our view of the essential "stuff" which makes something belong to a certain category, class, or group, and not to another. Ontology is important since it provides the basis for the way we go about investigating and understanding phenomena (our epistemology) — and eventually the way we intervene in these phenomena. For example, we investigate an atom differently from a human organisation because we believe they are constituted in a fundamentally different way. Our ontological view will then influence us as to which methods of investigation are likely to yield results and which theoretical frameworks or ways of thinking would be most appropriate. When we construct theories we *always* operate within a particular ontology. The ontology may be implicit as an attitude about "the way the world is", or it may be explicitly formulated, as a belief about the nature of the world.

Second, *incommensurability* means having no common factor, base, or essential characteristic that if shared would warrant grouping one entity or phenomenon with some other. If something is incommensurable with something else, then there is no basis for comparing them. The language — terms, concepts, categories, notions — we may use to describe the one would not adequately capture the essence of the other. The example of a game is often used. We can never use the term "run" in cricket to describe football. Although the term "run" may be used in two kinds of games, the meaning of the term and the rules that determine when and how a "run" is a "run" would differ in ways that would make any comparison meaningless. Thus, if we raise a claim of ontological incommensurability, we are claiming that two or more phenomena or systems differ in their very essence — constitutive elements, processes, and logic — to such an extent that they are fundamentally and qualitatively different. What we know about the one cannot help us to understand the other. The only commonality that they might share is on such an abstract level that has very little to do with the pragmatics of each in its particular way of being — such as comparing the complex environments of

[3] "Social reality" refers to social interaction and the social phenomena produced through these interactions such as language, culture and meaning.

a particle in a stream of turbulence and a manager trying to cope with unpredictable changes in the market.

On the Ontology of Mathematical and Physical Systems

As ontology has to do with assumptions and beliefs, we would expect to find a number of ontologies for mathematical and physical systems. Nevertheless, there is a dominant ontology for mathematical and physical systems that is generally accepted as valid for these phenomena. This ontology holds that mathematical and physical systems consist of elementary parts whose constitution into complex structures is determined by more or less discernible laws[4] of logic or laws of nature. These laws of logic or nature operate independently of us and our investigations of them. The level of agreement about the degree to which these laws exist and operate may vary from scientist to scientist. Nevertheless in its ideal form this ontological view believes that the constitution of these phenomena is always the result of some underlying logic, a set of discernible causes and effects, that can be determined in principle.

For example, if we look at a human being as a physical system — in the way a physician does — we expect to be able to study the body and find the causes for a particular ailment. We expect that we can study the respiratory system or the cardiovascular system and unravel the system of connections — causes and effects — that operate there so as to determine its operation or logic. We expect that we could use this logic to treat other patients, since these systems operate with an "already there" logic, independent of our investigation of them. We then see our inability to treat a particular patient as a lack of understanding (clarity) about this underlying logic. A perceived lack of clarity suggests the need for further study to enable us to become more familiar with the interconnections and logic of its operation.

Sometimes the behaviour of a system may seem "random". However, complexity theory tells us that "randomness" on one level of analysis can be understood (made clear) as complex order (chaos) at another level of analysis. The more we understand of the system — at all levels of analysis — the more we will have access to its logic and the more we will be able to make *determinable and effective interventions* in the system — effectively treating the patient for example. It is important that we see the centrality in this ontology of the assumption of an *a priori (already there) logic or set of operations that fundamentally constitute the system*, independently of us, and that only needs to be unravelled in order to enable effective intervention in the system. It is important to take particular note of the ontological assumption that, for a given type of mathematical or physical system — the human body in our example — the logic and set of operations are *essentially the same, every time, and in every context.*

[4] When using the notion of a law here I am referring to the idea that there are, operating in the domain of investigation, a finite set of causes and effects, which can be unravelled in such a way that when we observe a particular cause(s) we will *always*, to a determinable level of certainty, be able to say what the resulting effect(s) will be. Usually this notion is used to varying degrees of strictness. However, this does not detract from the basic belief in such an ontology.

On the Ontology of Social Systems

Let us now turn to the ontology of social systems. Are social systems fundamentally different, in their very nature, from mathematical and physical systems? It was claimed above that in mathematical and physical systems we are dealing with an *a priori* empirical reality that, to the best of our current understanding, exists independent of us, is not constituted by us, or is not contingent on us, but is constituted by a set of *a priori* laws of logic or nature. Is this true for social systems? I propose that the answer is, "No", that social reality is fundamentally different.[5] The dominant ontology for social systems is that social systems are *socially constructed and historically emerging* phenomena. To understand what we mean by this, we need to take a closer look at two notions central to our understanding of all social phenomenon — namely, *historicity* and *reflexivity.*

Social systems are historical. They are what they are in the "now" as a culmination of what they were "yesterday" and what they anticipate to be "tomorrow". They have no zero-state or original position they can simply go back to. Once they come into existence, there can never again be a clean slate. In some way, every past event directly or indirectly limits or enables the "here and now", and constrains or makes possible what becomes viewed as a possible "future". For example, a group of managers who have operated under severe resource constraints for an extended period of time would tend to thematise and articulate their work in these terms. They become used to saying, "We can not do this or that because it would be to costly". If, however, they suddenly have resource abundance, they would tend to continue to articulate the possibilities open to them in these terms — thereby missing the new possibilities. It would take time and actual experience for them to start to think and *act* in a different way. This historical nature of social systems provides a measure of stability and continuity to their behaviour.

However, what makes the historical nature of social systems more profoundly problematic is the fact that social phenomena such as values, beliefs, predispositions, traditions, language, and collaborative practices evolve as an *implicit by-product* of the system's interactions. Often, these by-products are not directly perceived by its members as such. We are normally not that "transparent" to ourselves. Many influences on our behaviour are not readily accessible to us through our rational cognitive faculties. The members of a social system, collectively, are not likely to be capable of rationally "choosing" to change their values, beliefs, predispositions, language, and collaborative practices. Obviously, they can talk about them, and they can express a desire to change them. However, it is only through actual utilisation and realisation in action that such attributes of a social system are changed.

For example, we often tell ourselves that we want to eat healthier or exercise more. Yet, when we buy our food, we tend to buy the food we know or that we can prepare, and so we tend to end up eating the same food. It takes time and experience of new

[5] For an older and slightly different argument about the incommensurability of the social sciences with the natural sciences refer to the classic work by Peter Winch (1958) *The Idea of a Social Science and its Relation to Philosophy.*

practices to change our shopping, cooking, and eating habits. Sometimes this time is relatively short and sometimes it takes longer. Nevertheless, it always takes time, as it is a matter of enacting new patterns in actual practice.

Values, beliefs, predispositions, traditions, and language are only constituted in practice. Changing these patterns of interaction is even more difficult in a group where the pattern is dispersed and distributed amongst a number of members — often not in obvious or conscious ways. Furthermore, every system's history is a unique manifestation of the patterns of historical interactions specific to that system. In a basic sense, every social system is incommensurable in some respects with every other, and generalisations often lead us to theories that breakdown in some respect in this or that particular situation. Thus, we may end up needing to reinterpret a theory in every situation.[6]

Social systems are not only historical, they are also *reflexive*. This means that to a greater or lesser extent they are aware of their own historical being — they are self-conscious. They are observers of themselves and their surroundings. In as much as they are observers of themselves, they tend to take a stand on aspects of their history. In taking a stand, they tend to intervene in their histories. They may say, "We don't like what is happening to us and we want to change this". Or they may say, "We want a future that is different from the one we now expect". In "taking a stand", members of social systems become active and intentional authors of their own histories. However, they can only move from where they are towards what may be possible given where they already are. Their history provides structural constraints on the possibilities open to them. It is precisely the interplay between structure (values, beliefs, predispositions, traditions, language, and existing collaborative practices) and agency (reflexive awareness and interventions) that constitutes and reconstitutes social systems. As Giddens (1984: 25) observed:

> The constitution of agents and [social] structures are not two independently given sets of phenomena, a dualism, but represent a duality. According to the notion of the duality of structure, the structural properties of social systems *are both medium and outcome* of the practices they recursively organise [emphasis added].

The dialectical interplay between "structure"[7] and intentional action constitutes and reconstitutes the social world. Social agents reflexively participate in the co-creation of social reality. Of course there are structures that mediate choice (values, beliefs, predispositions, traditions, language, relations of power, and existing collaborative practices). Nevertheless, these structures can, in principle, at any time *become a stake*

[6] Some natural scientists may object and say that it is not just social systems that are historical but also natural systems — this is the whole point of evolutionary theory. However, the issue of history should be taken together with the issue of reflexivity, as discussed next.

[7] It is important to note that the term "structure" does not refer to something that has an *independent* existence separate from its material manifestation. For example, we do not "have" values as such. We value when we act in certain ways and not in others. When we run into a burning house to save a trapped victim, then an observer could posit that we "value" the life of others. However, it is not possible to say whether we did it because we value life. All we can say is that in the situation we did what *then* made sense to do.

in the game — in effect, they can come up for revision. Likewise there is always choice, though not unlimited choice. Our choice is always to some degree bounded by existing structures. We are free, but always to a greater or lesser degree entangled in our situated histories. However, our entanglement is never complete in the way that the laws of nature, or the laws of logic, weigh upon their subjects. There are always possibilities (room for manoeuvre), even in the most repressive regimes, to use our actions to convert structures into a stake in the game — to make structures both medium and outcome.

We should take careful note of this phrase "both medium and outcome". This means that social systems are historically situated, recursively emerging realities — i.e. they are continually redefining or reconstituting themselves as an integral and implicit part of their ongoing "operation". A mathematician might point out that this is exactly the nature of complex mathematical systems. It is through recursion that they generate complex structures such as fractals. This is correct. However, there is an essential difference. Social recursion, which is achieved through reflexivity, is contingent. We have no way of knowing in advance what the participating individuals in the system will include or exclude in their reflection. Even more fundamentally, they themselves may not consciously "know" — if by "know" we mean being conscious of the boundaries and scope of their reflection and being capable of articulating it if requested to do so. This is because members of a social system often are not conscious of the values, beliefs, and presuppositions they bring to bear in a particular reflection or judgement *while performing the actual reflection or judgement*. Through this historically situated recursion, social systems continually construct and reconstruct themselves.

To make this discussion more concrete, let us consider the example of a social phenomenon such as a conversation. A conversation is a socially constructed sharing of meaning in a situated context. When we start a conversation we could in principle speak about anything — yet we do not. The reason for this is that a conversation is already situated in some way. If we are at work and we meet a colleague, we tend to start with reference to some previous conversation — the project we are working on, or the football match we watched together. Likewise we could use any words with which we are familiar, but we do not. We tend to start with some words whose meanings we already share as the result of our previous encounters. We already share a language because we share a situated history — Wittgenstein (1956) refers to this as our "form of life".

Wittgenstein (1956) argues that words do not have meanings in the same way that a person, or a city, has a name. That is to say, when we utter a name it is equivalent to pointing to the object, person, or city — a view that is often referred to as the *representational view* of language (and meaning). In this view the meaning of the word is the object, action, and so forth that it refers to. In opposition to this, Wittgenstein argues that words become meaningful not through being associated with a specific object, action, or event, but through having a "rule-governed" and situated use. We do not understand the word "chair" because of its spelling or its pronunciation but because of the way it is used in a particular situated context. We can use the analogy of chess here. We understand the knight as a "knight" rather than a "queen", not merely because of its form — this we can obviously vary — but because we know and execute legitimate "knight" moves as part of the game of chess. Thus, we understand what a knight means because we use knights to make appropriate "knight" moves. So Wittgenstein contends: "Every sign [word] by itself is dead. What gives it Life? In use it is alive" (Wittgenstein 1956: 432). Also: "A meaning of a word is a kind of employment of it. For it [the "rules" for employment] is what we learn when the word is incorporated into our language" (Wittgenstein 1969: 61).

Someone may object that clearly the word "chair" means or refers to a chair-like object of a particular type or description, and of course this may be true. However, there are many situations in which this is not true. Take for example the situation where you enter somebody's office and your host points to an empty chair and utters the word "Chair?" In this situation the meaning of "chair" may be said to be "here is a chair if you would like to sit down". If one insists on the notion that the meaning of the word is the object it points to, then the appropriate response in such a situation would be, "I know that is a chair!" which would clearly be impolite and inappropriate in that situation. In that situated context, the word "chair" has a substantially different, socially constructed, meaning.

With this in mind, we can imagine what would happen if we tried to enumerate all the possible situations in which "chair" is not used merely to refer to an object. We could end up with an extremely long list. Not only that, but we may in many cases have to resort to quite elaborate descriptions (explanations) of particular situations and subtle conditions in which a particular use of the word "chair" would be appropriate in that specific situation or way of doing something. Furthermore, many of these descriptions could vary quite dramatically from one culture to another or from one organisation to another, or from one social group to another. As Wittgenstein (1956), Searle (1969), and others would argue, language is not only a way of communicating (pointing) but first and foremostly a way of doing things together. As people do things together, through language they innovate in applying or using words in different and novel ways to express local distinctions of import for their particular interaction. These local rules or ways of using words introduce potentially infinitely rich and subtle variations of situational use that may have a very specific and local understanding associated with it.

It is these local and situated modifications that allow us to tune our language to the infinite complexity of everyday life (of work, play, aesthetics, friendship, parenting, and so forth). In this way we generate the emergence of many diverse situated languages such as government-speak, nurse-speak, student-speak, consultant-speak, lovers-speak, and many more. These subtle local languages emerge as an *implicit by-product* of conversing in a particular situated context of doing things together. This is why Wittgenstein also said that meanings are not agreements of opinions, but agreements "in form of life" (Wittgenstein 1956: 241). Now clearly when we want to interact with another — whatever the purpose of the interaction — we do not at first sit down and agree to all the possible definitions or ways of using words. This would be impractical and probably largely impossible, since we will mostly only discover that we use a given word differently when we use it in a particular situation. Thus, it is important to note that the emergence of a local language is mostly an implicit process since the focus of our interaction is *not to frame a new language as such*, but rather to accomplish whatever it is we want to accomplish through our interaction. A particular way of speaking is thus both medium and outcome of ongoing interaction and conversation, which is itself situated in a context of some larger context of activity. Language, as shared social meanings, is a historically situated, socially constructed phenomenon that emerges as an implicit by-product of ongoing social interaction.

The shared social meanings of situated conversations in social systems do not have discernible *a priori* structure, logic, or laws that are independent of context or temporality. We cannot simply respond to a stranger's question in the street and say "refer your question to the chair" if there is not a situated reason for such an utterance, if that person does not have a history of involvement in meetings where such a phrase was appropriately used, and if the situated context does not make it clear to what particular meeting — and therefore to what particular person — this statement refers. This argument made about shared social meanings and their operation in everyday conversations can also be made for other social phenomena, such as values, beliefs, presuppositions, traditions, and collaborative practices. From this perspective, social systems can be seen as situated, socially constructed, and historically emerging phenomena.

The Ontological Incommensurability of Mathematical/Physical Systems and Social Systems

We can now summarise the ontological incommensurability between mathematical/physical systems and social systems as follows:

- In mathematical and physical systems the next state of the system is *determined* by, and only by, the structural properties of the system. These structural properties are assumed to exist independently of our interpretation of them. A structurally identical system will produce the same behaviour (sequence of states) irrespective of context or situatedness.
- In social systems the next state of the system is *constrained*, but not determined, by the structural properties present in that particular situated context. In every particular "next state", the structural properties themselves may or may not become renegotiated — not always as an explicit project, but often as an implicit by-product of the interaction itself. Differently stated, every "next state" may at any point be otherwise than expected though not completely so. As social systems are historical they will tend *not to be structurally identical*. What is true for one may or may not be true for another — and we cannot predict which it may be *a priori*.

From this perspective there would be those who say that the divide between the mathematical/physical and the social is a radical one.[8] They hold a *strong* view of

[8] The early work of Maturana is an example of this view.

ontological incommensurability. They would argue that it is useless to compare an *a priori* world of mathematics and physics with a *reflexively constructed* social world, since the very logic of the socially constructed world is subject to revision at every moment. In addition, since the process of reflexive intervention and participation by each agent is implicit, continuous, and ongoing, every manifestation of the social quickly develops a local logic of its own that is unlikely to be comparable to any other. For the holders of this strong view of incommensurability, to apply complexity theory to social science is a complete waste of time and resources — like comparing "run" in cricket to "run" in football. At the other extreme, there are those that argue that natural and social systems essentially belong to the same ontological category, and they deny ontological incommensurability altogether. They would argue that it is precisely our lack of full understanding of social reality that makes them appear to be fundamentally different from — incommensurable with — other systems. They may argue that is exactly the task of complexity theory to provide this unifying set of laws or principles, they may propose that complexity theory may be a meta-theory that can give an account of both. It seems that a large number of researchers in the complexity theory community belong to this group, many of them in an implicit rather than an explicit way.

Let us *assume* that the strong view of incommensurability is not entirely convincing, since there are at least some reasonable bases for doubting this position. For example, one could argue that there is some structural stability in social systems — the power of habit, routine, tradition, etc., would tend to discourage actors from becoming continuously reflexively engaged in the revision of these structural properties. Thus, although members of a social system could continuously work at revising it structurally, they tend not to do so. Furthermore, let's also *assume* that it is not reasonable to deny the claim of ontological incommensurability altogether, for to deny it altogether would mean that we could use the results of natural science "as is" in the social sciences. Clearly there would be many compelling reasons not to take this position. I would therefore hope that thoughtful researchers in the complexity field would agree that there is at least some level of apparent ontological incommensurability present that needs to be addressed before complexity theory can be accepted as a useful social theory. In the next section, I address the possibilities for such a reconciliation or accommodation.

Is Reconciliation or Accommodation Possible?

If one seriously accepts the issue of ontological incommensurability raised above, then one is faced with some challenges, such as developing new concepts, theories, and vocabulary that draw on that which is commensurate, but recognises that which is incommensurate. The challenge derives from the fact that this distinction is not obvious or trivial in any sense of the word. Given this serious reservation, how can we make complexity theory useful for our understanding of social systems? Three common approaches will now be suggested, their limitations discussed, and then an alternative approach will be presented.

Metaphor

One approach to using complexity theory in social science is to posit that complexity — including its terms, concepts, and theories — can be used as a *metaphor* for understanding certain aspects of social reality. What is important in this approach is the notion of metaphor. There are many ways in which this term is used. For example, Aristotle in his *Poetics* defined metaphor as "giving a thing a name that belongs to something else" (Sontag 1988: 5). For him, and for many strong positive scientists today, we create ambiguity when we give something a name that properly belongs to something else. We may only confuse things by doing so. However, let us rather consider a more positive view of metaphor proposed by Lakoff & Johnson (1980) and Klaus Krippendorff (1993), who suggest that we can use metaphor in a positive way if we carefully take note of the following:

(a) Metaphors may carry explanatory structures *from a familiar domain* of experiences *into another domain* in need of understanding or restructuring to do their "work";
(b) Metaphors require identifying some *structural similarities between these two domains*, however far fetched these may be;
(c) Metaphors have further *entailments for the target domain* that they thereby *organise* that go beyond any initial structural similarity (Lakoff and Johnson 1980);
(d) Metaphors *organise their users' perceptions and*, when acted upon, *can create the realities* experienced.

Let us consider these provisions carefully. How familiar are we with complexity theory, and how well understood is it? In the natural sciences — its "home ground" as it were — it is still seriously contested. What are the structural similarities between the natural and social science domains? Clearly there may be similarities on the common-sense, informal, everyday level. However, we have argued above that historical, situated, social recursion leads to structural plurality that makes it highly unlikely that we will encounter detailed structural similarity. Even if there is commensurability at some level, as we argued above, how can we separate the commensurable from the incommensurable? Complexity theorists often concentrate on the similar and tend to stay silent about the dissimilar, but how significant is that which is dissimilar? We have yet to see authors who use complexity theory as a metaphor write about what the complexity metaphor *cannot* explain or account for.

More importantly, metaphors may have entailments far beyond initial structural similarities. Thus we "stretch" the metaphor in ways that lead us to conclusions that cannot be supported by the purely structural similarity. This is an issue where we need to become much more critical of the metaphorical use of complexity theory. Especially since metaphors tend to organise their users' perceptions in such ways that, when acted upon, can create the realities experienced. Here there is clearly an ethical issue. Can we really tell organisations to "seek out the edges of chaos" or to actively seek conditions "far from equilibrium", purely because we sense some basic structural similarity between natural and social phenomena? What if the "dissipative structure" does not happen, and the organisation experiences death rather than a burst of creativity? Is it wise to let stories of apparent chaos and complexity in organisations lead us to brush aside concerns about ontological incommensurably as incidental or trivial?

Analogy

A second approach is to use complexity theory as an *analogy*. This position requires a stronger perception of ontological commensurability than the metaphor position. Rosenhead (1998) summarised the requirements for using complexity as an analogy, as follows:

(a) The natural scientific domain of complexity theory is better understood than that of the social domain it is applied to;
(b) There are concepts in the domain of complexity that can be put in clear one-to-one correspondence with precise equivalents in the second domain;
(c) Connections (especially causal ones) between groups of concepts in the first domain are implicitly preserved between their equivalents in the second domain.

Rosenhead (1998) has argued that it is not reasonable at present to use complexity theory as an analogy for theory development in the social sciences. It is especially in the fulfilment of requirements (b) and (c) that the use of analogy in applying complexity theory becomes questionable. If we agree that agents are in fact recursively involved in the (re)construction of social structures, then we may have a problem with condition (b) and most certainly with (c). For example, take the concept of systems "far from equilibrium" in complexity theory. What does this concept mean in social systems? What equilibrium is it referring to in a social system — power equilibrium, equilibrium of meaning, equilibrium of values or beliefs? All of these, or just some of them, and if some, which ones in particular? Unless we can give specific answers to these questions, it is not possible to fulfil conditions (b) and (c). For these reasons, we need to start asking what is incommensurate, rather than just focusing on what is commensurate.

Pragmatics

Another approach is to take a purely pragmatic view: "If it works, it is valid and can be used". This approach often bypasses theoretical debate in favour of going "out there" and "getting the job done". Proponents of this approach argue that complexity theory provides heuristics that can be used in a practical context to get some job done. In this approach, theory is regarded as merely a tool for getting a job done. Will this approach fulfil the promise of "bringing law to the lawless", or will it just lead to a proliferation of more concepts, ideas, and techniques in an already crowded "marketplace of ideas?" This approach could only further scatter an already fragmented understanding of the social world, and merely add to the confusion.

Where To From Here?

If the arguments made above touch on real issues of incommensurability in applying complexity theory in the social sciences, then we need to somehow resolve them. I suggest that there is only one realistic alternative, which is to develop a completely new domain of understanding which borrows from both domains, but which avoids any attempt to establish a direct mapping between them. The new domain would neither be complexity theory augmented by social theory, nor social theory augmented by complexity theory. Rather it would be a new *social complexity theory* in its own right. The process of developing the new theory would start with borrowing insights that exist in both domains. However, it should develop its own terms, concepts, and theories, and should not borrow anything from the original domains without critically interpreting and reformulating it. This process would be akin to developing a new game of sport using some key ideas and rules from both football and cricket — maybe something like hockey?

There is an example of such theory development in the work of Nicklas Luhmann (1990, 1992, 1995). Luhmann took some notions of autopoiesis developed by Maturana & Varela (1987) in biology and reinterpreted them in a social context. He also took some notions from social theory such as the work of Parsons and radically reinterpreted them (for example, challenging subjectivity and action as the basis for the social). With these insights Luhmann developed a highly original and innovative theory of social autopoiesis that transcends both the work of Varela and Maturana and the social theorists he draws upon. In Luhmann's work we have a new theoretical domain that no longer tries to map the two domains (biology and sociology) directly onto each other, but rather attempts to provide a wholly new window on the social domain as well as on autopoiesis. In Luhmann's work the terminology of autopoiesis gave way to his own terminology, yet certain key autopoietic elements remained, and likewise with the social theory. It is, however, clear from the many writings of Luhmann that his conceptual leap took many years of study as well as extensive scholarship. It was definitely not an easy, short cut, to a "new" theory, a haphazard mapping of the one onto the other.

Some Concluding Thoughts

In Luhmann's approach mentioned above, the result is a radically new social theory that suggests profoundly new ways of understanding the social domain. Many of the concepts in the theory challenge the existing orthodoxy in social theory. It also actively engages the historical traditions of social theory by giving detailed accounts of how it is *both similar to and different from* those traditions. It is this sort of work that suggests the possibility of opening up a new field of *social complexity theory*. From such an approach we may begin to understand the ways in which complexity theory can inform meaningful organisational intervention. However, if we continue simply to map complexity ideas onto the social domain, we will continue to see insignificant, unpredictable results and disappointments.

To conclude, it may be useful to summarise the argument made in this chapter as follows:

- There are reasons to believe that there is significant ontological incommensurability between mathematical/physical systems and social systems.

- This ontological incommensurability suggests that it would not be helpful nor ultimately feasible to merely map one domain onto the other. Such an exercise may be interesting, but it will not provide significant results.
- A more sensible route is the development of a radically new theoretical domain. Such development could begin with some of the original insights in the parent domains, but should not accept these uncritically. It should reinterpret and redevelop the insights it borrows to be consistent ontologically with the demands and constraints of the new theoretical domain under development.
- Such an approach to connecting complexity theory and social theory could lead to innovative understanding of social systems and ultimately to effective ways to intervene in organisational development.
- However, such developments would require extensive study and empirical work. There are simply no short cuts available.
- From this analysis I conclude that one cannot expect significant results from the mere "application" of pre-existing complexity theory — developed in the mathematical/physical domain — into the social domain, as is often currently being done.

There is also an important ethical issue at stake here. As management researchers, can we ethically suggest that organisations embark on radical programmes of transformation based on notions from complexity theory that may or may not correctly represent social and organisational phenomena? Obviously, one can understand the seductive power of applying these new "scientific" ideas to deal with the increasingly complex organisational environment of today. But it would be just as foolish to suggest that because the heart is "really just a pump", an engineer would therefore be qualified to treat patients with heart disease. There is certainly a sense in which a heart *is like* a pump, and engineering concepts may be useful to understand the way it functions as a pump. However, there are also very important ways in which a heart is different from a pump. It is these differences that are critical when intervening to treat a heart patient. It is the differences, rather than the similarities, that fundamentally limit our interventions. This chapter is an attempt to draw attention to such differences, and to encourage us to be more critical about what is being proffered as radically new ways of understanding and intervening in organisations.

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Chapter 11

Developing Epistemological Consciousness about Complexity: Seven Domains of Discourse

Petruska Clarkson and Katerina Nicolopoulou

Introduction

> All around us are facts that are related to one another. Of course, they can be regarded as separate entities and learned that way. But what a difference it makes when we see them as part of a pattern! Many facts then become more than just items to be memorised — their relationships permit us to use a compressed description, a kind of theory, a schema, to apprehend and remember them. They begin to make some sense. The world becomes a more comprehensible place. Pattern recognition comes naturally to us humans. . . . we are, after all, complex adaptive systems ourselves (Gell-Mann 1997: 89).

This chapter introduces a philosophically grounded conceptual tool for diagnosing and intervening in organisations through the categorisation of seven different phenomenographic domains of discourse (talk and text). It is a taxonomy of ontological and epistemological domains.

The seven-level model has been empirically field tested over some decades in organisational consultancy as well as in a research thesis (Nicolopoulou 2001). Experience in using the model suggests that epistemological clarification of different, but co-existing, universes of discourse is a potent method for dealing with complexity in organisations, facilitating diagnoses, improving organisational learning, and enhancing effective systemic interventions at all levels.

Complex Systems and Evolutionary Perspectives on Organisations

ISBN: 0-08-043957-8

The Problem

Complexity arises from the inter-relationship, inter-action, and inter-connectivity of elements within a system and between a system and its environment (Mitleton-Kelly, Chapter 2). There is no single approach to discussing complexity, but a variety of co-existing — and often competing — discourses. There is, therefore, the need for a Lexicon of complexity within which different terms in use can be defined in ways that can span across disciplinary boundaries. However helpful this may prove, the philosophical problem is more complex than that.

According to Brown & Duguid (2000: 205):

> . . . different scientific practices produce quite distinct epistemic cultures, and hence the sort of knowledge that might flow readily within one culture will not flow uninhibitedly between two. The distinctive practices that internally bind the epistemic cultures of microbiologists and the physicists externally divide them from one another simultaneously. The two together do not form an epistemically homogeneous "scientific community" any more, than . . . . technicians and senior management within an organisation from a single culture[1]

Brown & Duguid (2001) extend this argument by linking it to similar ones, such as Giddens (1990), who uses the concept of "disembedding" and "embedding" knowledge through the capacity of technology to move information quickly. The knowledge contained in transported information is "disembedded" from where it was epistemologically located before it was transferred. As a consequence, "embedding" it in a new situation might be problematic, since the new conditions are not necessarily similar to the old ones.

As Easterby Smith *et al*. (1998) explain:

> How you categorise and measure something depends on how you look at it and what you are differentiating it from. Since there are many different ontologies of organisational learning, the more one sets out to measure precisely its nature and extent, the more one is likely to fall into what Ryle (1949) calls a "category mistake". This occurs when measures appropriate to one kind of object are applied to another kind of object.

The *sine qua non* for all disciplined thinking is the avoidance of logical fallacies (Copi 1961), spurious conclusions (Aristotle) and category errors (Ryle 1966). According to Wolman (1965: 11): "The business of scientific inquiry is not to ascribe rationality to men but to study in a rational way the irrational ways of mankind".

A major reason for the confusion in the application of complexity science to organisational life is the ubiquity of category errors in this field. The Oxford philosopher

[1] The term "epistemic culture" is taken from the ethnographist Knorr Cetina (1999), who explores the extensive flow of knowledge across such communities that create and warrant knowledge (Brown & Duguid 2001).

Ryle (1966: 10) actually defined philosophy itself as "the replacement of category-habits by category disciplines". The need to address category errors is not new. Heraclitus, as we shall see later, already grappled with this 2,500 years ago. Human experience and therefore, human knowing, can be read along more than one domain of discourse. Confusion between domains, for lack of definition and delineation, leads to miscommunication.

Cook & Brown (1999: 381) comment that:

> Current work on organisations is limited . . . by the scant attention given to knowing in its own right . . . knowledge and knowing (should be) seen as mutually enabling (not competing) . . . knowledge is a tool of knowing, knowing is an aspect of our interaction with the social and physical world, and the interplay of knowledge and knowing can generate new knowledge and new ways of knowing. . . . This generative dance between knowledge and knowing is a powerful source of organizational innovation.

Another way of saying this is that different workers in this field are often operating from different universes of discourse. Their "text and talk" are from different worlds of meaning and too often one is assumed to exclude the others.

Background to the Seven-Level Model (or Seven Domains of Discourse)[2]

The conceptual schema of what was originally called "the seven-level model" was developed by Petruska Clarkson (1975) in order to help students who were grappling with information overload in the discipline of psychology. By assisting them in epistemologically ordering different domains of knowledge, their world became "more comprehensible".

Ontological domains of discourse reflect our experience of "being" (physis), our experience of ourselves. In natural everyday talk it is commonplace to say: "at one level this, at another level that". So perhaps it's true that overall I'm sort of "fine". This might for example mean that I am not physically ill but I am physically somewhat under par. I am also extremely worried about the threat of being made redundant in a forthcoming organisational merger. At one level I am pre-occupied about what a colleague really meant when they recently jokingly referred to my working class accent; I am at the same time confused about what to do about my guilt feelings for needing to take time off work to be with my sick child. At another level I am also excited about learning how useful understanding complexity science can be in my organisational learning and advancement. I am furthermore concerned about the ultimate meaning of my life now that I am

[2] The original Clarkson model (1975) was called 'seven levels of discourse'; later (1998), Maturana (personal communication) suggested the term 'domain' in order to avoid implications of linearity and hierarchy of the seven domains; also, because the tool serves for both epistemological as well as ontological clarification purposes.

facing ageing and retirement; at yet another level I am truly fine — I have moments of inexpressible peace in my garden.

Our experience of our own being-ness is often multi-vocal, having many voices "inside" our self — or selves. Only rarely does a human being feel "all of a piece" — "fine" all the way through at all levels. Whatever we do and whatever we choose to call these different voices or self-experiences, their continuing co-existence seems to be a fact — an existential given of human experience. The seven-level model has proved to be an invaluable tool for sorting these ontological experiences into epistemologically manageable categories, while preserving a perspective on the whole.

The Clarkson seven-level model is an archetype that provides a single epistemological container relating to what may appear to be mutually contradictory descriptions. The model is not intended to express any values in itself nor to set hierarchies of value. The model simply offers *a nominative category sorting tool* for thinking through the implications and ramifications of each level or domain and for clarifying and preventing the kind of logical fallacies that Ryle (1966) has identified as *category errors*.

Field Testing — One Example

In practice, the seven-level model has been used in a consultancy/training period in a large international financial institution. A matrix framework was developed using the seven domains of discourse in order to provide language and an epistemological framework for communicating concepts about complexity, leadership, and knowledge management (Nicolopoulou 1999 and see Appendix B for example). Participants in management development programmes using the seven-level model were sensitised to the different epistemological domains and came to appreciate the epistemological multiplicity of the concept of "complexity". Participants were able to classify experiences scripted as organisational stories in the appropriate epistemological domain to which they belong.

The model is phenomenographic (Marton 1981) in the sense that it describes differentiated domains of discourse. It is a way of conceptualising talk. In thinking and talking about complexity, we are faced with the challenge of perceiving and communicating about the different domains of discourse that must be used to capture and circumscribe the field holistically.

In this vein, this chapter will offer examples of the categorisation of complexity concepts in the different epistemological domains. This will be done by giving specific examples occurring in organisational settings. The model provides a classificatory tool for identifying and separating out: (a) different layers of knowledge; (b) different epistemological areas; and (c) the various realms of discourse and the methodology for establishing truth values in each. Each cognitive domain is equally coherent and internally consistent, and to a large extent we can choose between them according to our preference (Mingers 1995).

This model is not intended to be normative in any way. Its application should be judged solely by its usefulness for developing better epistemological consciousness and improving effective organisational actions. Any notion that one domain is "higher" or

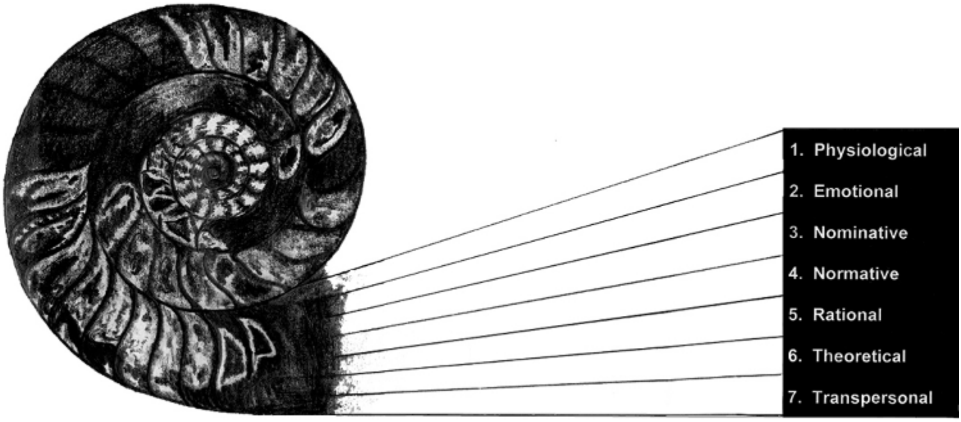

Figure 1.

"better" than another would constitute a misunderstanding of a relational model grounded in simultaneous wholeness (cf. Goldstein 1995). We like to use the million-year old (or more) ammonite as a natural image of the wholeness of the model.

The ammonite fossil concretely encapsulates many of the characteristics of the seven-level model — iteration across scale, simultaneous wholeness, a spiral which unfolds the different chambers (which are all present right from the smallest beginning to the point where nature or death interrupted it), distinct "chambers" infinitely repeating, creating unity from diversity and diversity in unity. Yet the ammonite *is* capable of being analysed one segment at a time.

The seven-level model can be imagined as showing a similar kind of ordering principle. Unfolding each domain of epistemology is like peeling off a layer of the ammonite to show how all seven compartments co-exist. However, given the limitations of human attention we usually focus on one layer for a particular purpose.

The seven-level model is aimed here at creating a way of thinking about what various complexity terms mean and how we are using them in different ways in different settings. In particular the model can help to clarify the "truth values" appropriate to each epistemological domain — thus preventing category errors, improper conflations, unnecessary confusions, and avoidable miscommunications.

There are different logical criteria — different kinds of "truth values" — for each domain (see Copi 1961). This means that different kinds of knowledge are evaluated by different means. Gellman (1997: 108) phrases this most crucial question in epistemology like this: "Was he [Comte or whomever] right? And in what sense?"

Application to Complexity: The Seven Domains of Discourse

In the section below, a description of the talk or text appropriate to each domain is presented for each of the seven domains of discourse and illustrated with examples from complexity in organisations. We also consider the appropriate criteria for establishing which kind of "truth" each domain concerns and its epistemological criteria.

Level 1: The Physiological/perceptual Epistemological Domain

This is the realm of *sensory* experience, the part of our experienced world which functions in time before language manifests. The sources of knowledge on this level are the objects and events perceived through our senses and also the proprioceptive experience of phenomena within our bodies. It concerns body processes such as sleep, arousal, psychophysiology, natural sleep rhythms, physical conditions of disease, the physical manifestation of anxiety, and general sensory awareness. It concerns observation through our eyes, but also "knowing" through all our senses, and evaluating by such means the effects of our actions on complex adaptive systems.

Example

Complexity theory is an attempt to capture and appreciate the changes in our ways of thinking and the ways organisations are consequently affected. People working in organisations are constantly being influenced by the unpredictable and rapidly changing world conditions around them. The environment around organisations has become complex beyond our previous experience and, in response to that, the various management initiatives that are employed in an attempt to make organisations more efficient in the face of changes, have all been influencing how people experience themselves and others and how they act on this sensory-physiological information inside organisations.

Epistemological Truth Value/Methodology

Physiological processes can be "measured" in some instances such as brain wave patterns on an EEG, but — as philosophers over centuries have been at pains to show — it is probably impossible to ever know whether another person's sensation of the colour red is similar or different from one's own. Perception, as pain, is irretrievably subjective and embodied. Yet we experience this kind of reality and act upon it with our bodies.

Level 2: The Affective/Emotional Epistemological Domain

This level comprises the *feelings* that we have in common with infants and animals-fear, pain, joy, anger etc. Emotions and subjective feelings pervade our existence, and even the smallest possible segments of our perceptions carry an emotional colour. Emotions are the subjective feelings which arise as response to one or another stimulus events. It's what we emotionally recoil from — or in response to which we exclaim enthusiastically, "Ah!"

This domain involves an affective area of experience and activity. It concerns those psychophysiological states or electro-chemical muscular changes in our bodies which we talk about as feelings, affect and/or emotion in psychology.

What one person experiences as distress in the vertiginous post-modern condition, another may experience as pleasurable excitement at the unfolding of creative potentials of chaos. It has been convincingly demonstrated and argued that there is always an emotional layer or sub-text to any communication — even if it is solely the acknowledgement of the other person's existence.

Example

The complex conditions inside the organisation, which respond to the increased complexity from the environment outside, create increased levels of demand for performance on behalf of the employees; people are required to perform more profitably, to different tasks and across different domains at the same time (see e.g. Hall & Moss 1998).

There is a great amount of pressure put on people to perform and this competition creates fear of failing when people are asked to perform tasks that they are not really very knowledgeable about. This creates what De Geus (personal communication 1994) has called a sense of fear and terror "in the boardroom", sometimes resembling what has been termed the Achilles Syndrome (Clarkson 1994).

Epistemological Truth Value/Methodology

Emotions are essentially subjective, experiential, and felt states; our knowledge about them seems to be existential, phenomenological, and unique. Many organisational cultures lack useful and efficient ways of processing the emotional levels of their relationships, their cultures, and their communications. Yet there are many psychological tools, techniques, and approaches which can identify and facilitate the emotional layers of the organisations.

Level 3: The Nominative/Metaphorical Epistemological Domain

This level comprises *naming* through words or metaphors — a process which rests on division of entities and events into classes and categories. This is the area of objective nominalism — phenomena are placed together on the basis of certain resemblances.

Linguistic identity is established through the repetition of a unique sound or illustrative image. Name giving and shared images or metaphors implies reflective common experience — the basis of any human culture — a shared vocabulary or lexicon.

Example

In terms of complexity, there are implications associated with the naming of the different concepts and ideas to be found in the field. For example, people might be confusing the notions of "complex" and "complicated" when they are thinking about complexity. Battram (1998) distinguishes between the two by using the metaphor of a television, a very complicated system, but not a complex system, in that the vast number of parts out of which the television set is comprised are connected in simple, predetermined ways that produce predictable operations.

Similarly, we need all the time to define and redefine concepts such as self-organised criticality, complex adaptive systems, emergence, autopoiesis. The LSE project on developing a lexicon for complexity reflects exactly the need for finding and articulating some kind of nominative agreement (about the words we use and what they mean) which reflects common understandings within this community of practice. The request to provide this paper is another.

Epistemological Truth Value/Methodology

In this realm of discourse there can be both agreement and disagreement within or between groups — i.e. within dialect or language or disciplinary groups — about "what things are called" or what metaphors are considered "fitting" about certain kinds of words that are taken to stand for certain kinds of objects or phenomena.

Without clarity of definition (or discourse about such definitions) words such as "autopoeisis" or "emergence" or "love" are often used idiosyncratically, whimsically or arbitrarily. Teubner (Colloquium on Autopoiesis at the London School Economics 1998) gave an example of a contract which was concluded on the basis of an agreement between two parties in terms of so many thousands of francs. However, the one party was using Belgian francs and the other French francs. The dispute was eventually resolved by reference to the laws of country in which the agreement was made — which was in fact Switzerland. Teubner's example demonstrates the differences between the nominative domain from the socio-legal epistemological domain.

As Gell-Man (1997: 33) writes: "The descriptive language must be previously agreed upon and not include special terms made up for the purpose. Of course, many kinds of arbitrariness and subjectivity will still remain".

Level 4: The Normative Epistemological Domain

The normative level comprises the various *ethical* aspects of the individual encountering the norms and values of the group, the tribe, the family, the organisation, the culture, the church, the political party, etc. This level of discourse tends to deal with knowledge of attributes and practices regarding people as "cultural beings" — whether in families, organisations, or national groupings. It deals with values, norms, collective belief systems, stereotypes of gender or race, and societal or organisational expectations.

Example

As philosophers since the earliest times to the ethicists of today have pointed out, everything that we say (or do not say) implicates issues of value and ethical preference — explicit or imbedded cultural constructions which privilege certain discourses or certain voices. “By asking only what is good for human beings [in terms of ‘objective’ cost-benefit analyses], they [i.e. cost-benefit analysts] are being presumptuous and arrogant” (Arthur in Waldrop 1992: 332).

Since Hiroshima and Nagasaki, few scientists still claim that science is “value free” or neutral to society’s concerns (Ziman 1967). For example, the founder of the Santa Fe Institute (Cowan in Waldrop 1992: 57) expressed his regret about the years of working on nuclear weapons: “his sense that the scientific community collectively abdicated responsibility for what it had done”. Of course, not all of them did; witness the celebrated case of Robert Oppenheimer.

Epistemological Truth Value/Methodology

The very fact that we are engaging in the study of complexity means that there are other areas of enquiry which we are choosing, consciously or not, to ignore or neglect. In any organisation the implicit values and norms — the so-called “organisational culture” — are both difficult to identify but also a major target for consultancy interventions in “culture change”.

Values, morals, and ethics are not subject to logical tests of truth or statistical rationality — it is a different realm of questioning and knowing. Norms provide containment and limitation, security and meaning, a sense of belonging or exclusion. “An organised belief system, complete with myths, may motivate compliance with codes of conduct and cement the bonds uniting the members of a society” (Gell-Mann 1997: 278) — often against others with competing beliefs.

Level 5: The Rational, Logical Epistemological Domain

This is the level of “*facts*”, the logical rational dimension of testable statements, where causal relations can be positivistically established. The rational domain permits clear principles of verification and falsification, and it operates with that which can be objectively identified, defined, and proved — at least for that time and that culture.[3]

Facts in this realm exist not as subjective feelings, mere words, or shared beliefs, but as rational conclusions derived in a repeatable form from a body of well established empirical data. This layer of knowledge and activity includes thinking, making sense of

[3] Gell-Man (1997: 285) reports how “almost all the distinguished geology faculty at Caltech were still contemptuously rejecting the idea of continental drift . . . They disbelieved [normative level 4] in continental drift despite mounting [level 5 factual] evidence in its favor. They had been taught that it was nonsense mainly because the geological community hadn’t thought of a plausible mechanism for it. But a phenomenon may perfectly well be genuine even though no plausible explanation [theoretical level 6] has yet turned up.

things, examination of cause and effect, working with facts and information of the time and place. It is vital to remember that all knowledge is always corrigible. It covers science, logic, statistical probabilities, provable facts, verifiability according to the positivist approach of Popper, established "truth" statements, and consensually observable phenomena.

Example

There is little factual consensus at this time about complexity. It is an evolving concept that researchers and practitioners alike are still untangling and explaining. All the activity which leads to quantifiable outcomes experimenting with complexity ideas, such as computer simulation, the experiments at the Santa Fe institute, and the Complexity Game at the London School of Economics, belong in this domain.

Epistemological Truth Value/Methodology

It is characteristic of all level five discourse that it is possible to establish truth values by consensual practices of that time and that culture. That is, it is the only realm of discourse where dispute can be settled by reference to observation or external tests resembling what is commonly understood as the modern positivistic scientific method. If there is disagreement about a "fact" within a particular knowledge community, it is a misnomer to call it a "fact" and it does not belong within this realm of discourse. It might be a theory, an explanatory hypothesis, or something belonging to another realm, but if there is dispute about it, it is not logically a fact. According to Gell-Mann (1997: 57) it is also important to "straighten out" the discrepancy between observation (level 5) and theory (level 6): "What takes place in the real world is the confrontation between theory and observation".

Level 6: The Theoretical/Narrative Epistemological Domain

The theoretical level attends to *explanations, metaphors, and stories* that are told to show how things have come about. They are the statements we use to make sense of the world. They do not establish the "Truth", but remain some of the possible versions that, when verified or negated, can pass from theory to the factual domain (level 5).

Within the sixth domain there are the hypotheses, explanations, narratives, and stories that humans have created in order to explain why things are they way they are and why humans behave the way they do. Theory that is not underpinned by the rational observations of facts of domain 5 tends to rely on the belief structures of domain 4 as in the example of Caltech geologists above.

Example

Almost all complexity "stories", "narratives", and "theories" fall into this category. In this domain, there has been an attempt to create multiple "narratives" of complexity so as to accommodate its diversity (the Mitleton-Kelly chapter in this volume that examines three different approaches to the theory of complexity is an example of work at this level). As Gell-Mann (1997: 78) noted:

> There are, in general, competing theories, each of which. . . may then be tested by further observation, often made in the course of experiments. How well each theory does, in competition with the others, at predicting the results of those observation helps to determine whether it survives. Theories in serious disagreement with the outcome of careful and well-designed experiments, especially experiments that have been repeated with consistent results, tend to be displaced by better ones, while theories that successfully predict and explain observations tend to be accepted and used as a basis for further theorizing (that is, as long as they are not themselves challenged by later observations).

Epistemological Truth Value/Methodology

When a theory, narrative, or hypothesis is "proved" true, it logically moves to the domain (5) of facts and logical or statistical probabilities. Until this becomes the case, such notions belong to the narrative or theoretical ontological and epistemological domain. However, there are criteria for judging whether a particular theory is better or worse. Such criteria help us to choose or prefer some theories or explanations or hypotheses over others. The criteria for evaluating such theories usually include dimensions such as validity, reliability, coherence, lack of internal contradictions, elegance, utility, economy of explanation (e.g. Occam's razor), "fit" with related theories, and already proven facts as explained above.

Level 7: The Transpersonal or Currently Inexplicable Epistemological Domain

This domain comprises the "alleged phenomena that challenge the known laws of science" (Gell-Mann 1997: 288). The *transpersonal* level also encompasses unexplained areas of human relationship and experience. This domain of epistemological discourse is the realm of human experience which is beyond clearly understood facts and theories and concerns the paradoxical, the unpredictable, and the inexplicable. It is a region that has to be left open for the development of future discourse and reference for currently unknown conditions. (For examples of the practical application of such ideas in organisational life see Chapters 10 and 12 of Clarkson 1995.)

This domain of discourse arises within an inner locus of evaluation and experience and is distinct from the outer locus of evaluation, which is group norm (level 4) related. This epistemological discourse includes notions like Jungian archetypes, synchronicity (e.g. Jaworkski 1998), people as spiritual beings, or — for those who want to use another nomination — the soul. Currently inexplicable experiences of intuition and the workings of creativity belong in this domain. In this transpersonal epistemological domain, we could represent complexity as those aspects of autopoiesis which are still mysterious, the "physis" or creative life-force (see Heraclitus in Kahn 1981 and Heidegger 1987), which is a name for describing how systems and organisms emerge and self-develop out of unpredictable circumstances — autopoietic emergence itself. Mingers (1995: 1) for example, makes a very explicit connection between autopoiesis and physis. He postulates that Heidegger practically invented the word autopoiesis in the following quote: "Physis also, the arising of something from out of itself, is a bringing forth, poiesis. Physis is indeed poiesis in the highest sense".

Example

There are many ways one can develop a discourse about such concepts, although one does not have to accept any of these given terms for talking about the "unexplained" or the currently inexplicable. These words of Gell-Mann (1997: 279) could suffice: "part of the grand search for pattern, for creative association that includes artistic work and that enriches human life".

Most human beings have experienced awe or wonder or synchronistic encounters, sudden flashes of intuition or creativity which are not circumscribed by the other realms of discourse discussed so far. This is the realm of discourse for these notions — at least until we can begin to sensibly speak about them in other levels of discourse.

It is often a characteristic of the seventh domain that we lack vocabulary which can truly represent what we know (or sense) at this level. "The thrill of knowing that one's prediction has actually been verified and that the underlying new scheme is basically correct is difficult to convey, but it is overwhelming" (Gell-Mann 1997: 78). In the oriental tradition it is said that the Tao which can be described is not the Tao.

Epistemological Truth Value/Methodology

It is characteristic of this domain that people are convinced by "direct experience" which feels impossible to articulate or effectively communicate to others who have not shared similar direct experience. It is the knowledge of the mystic, the "peak experience" of the quantum physicist who marvels silently at the beauty of our universe:

> Scientists of the second type [contrasted with Aristotelians], however, see the world as a process of flow and change, with the same material constantly going around and around in endless combinations. Lewontin called these scientists "Heraclitians", after the Ionian philosopher who passionately and poetically argued that the world is in a constant state of flux. "When I read what Lewontin said [about Heraclitus], it was a moment of revelation. That's when it finally became clear to me what was going on" (Waldrop 1992: 335).

For Heraclitus self-knowledge led to the knowledge of what is "shared by all" — a universal principle of wholeness. There is no part of the whole that does not remain in relationship with every other part. In the Heraclitean epistemology, questions of cognition are inseparable from questions of action and intention, questions of life and death (Kahn 1981: 100).

It is also very clear in Heraclitus' thinking that he shares Ryle's criteria for thinking errors due to category confusion — when one class of domain or kind of discourse is assigned a truth value which is logically inappropriate to that domain. An example of Heraclitus spelling this out: "Most men do not think (*phroneousi*) things in the way they encounter them, nor do they recognise what they experience, but believe their own opinions" (Fragment IV). *Phronesis* is translated by the word *thinking*, with the meaning of intelligence, understanding; and *phroneousi* as *think* in the sense of understand, think straight, act with intelligence. Heraclitus here in fragment IV is distinguishing two separate universes of discourse — the way people encounter things from the way in which they *recognise* (*ginoskousi*, know, be acquainted with) what they experience. He is pointing out a logical category error — believing one's own opinions, taking one's own preferences as fact. Opinions (beliefs) are in a different universe of discourse (the normative level four) than that which is true at an "objective" level of consensual reality at a particular time in a particular culture (the rational level five).

Some Consequences of Epistemological Category Errors

Domain confusion

> If we, as humans, try to take action in our favour without knowing how the overall system will adapt — like chopping down the rain forest — we set in motion a train of events that will likely come back and form a different pattern for us to adjust to, like global climate change. "So once you drop the duality", [Brian Arthur says], "then the questions change. You can't then talk about optimisation, because it becomes meaningless" (Waldrop 1992: 333).

A form of category confusion indicating a wrong identification of domains occurs in text and talk when a statement that expresses a group norm is taken to be fact. An example of a domain confusion would be a commonly heard phrase like: "It is the organisational values that have to change so as to accommodate change in organisational environments".

At one level, say the rationally governed domain five and its understandings of causality, something may be regarded as true "in fact". Within the normative domain, however, beliefs about the world may not match with the other domains of "objective" facts.

Another frequently occurring category error is the naturalistic fallacy, i.e. because something is regarded as a fact, some value is assumed necessarily to follow. For example, because money is proven to be a significant human motivator, paying staff more is assumed necessarily to lead to greater productivity.

Conflict

> If you really want to get deeply into an environmental issue, I told them, you have to ask these questions of who has what at stake, what alliances are likely to form, and basically understand the situation. Then you might find certain points at which intervention may be possible (Waldrop 1992: 332–3).

Conflict in epistemological domains exists when one or more levels are in opposition, which they often are. For example, some forms of measurement (like financial profit) are not appropriate or adequate for representing other organisationally significant dimensions of human experience.

Cross-Level Displacement

An example of cross-level displacement is environmental cost-benefit analysis in which, for example, "the benefit of having spotted owls is defined in terms of how many people visit the forest, how many will see a spotted owl, and what it's worth to them to see a spotted owl, et cetera" (Waldrop 1992: 332). In essence, cross-level displacement occurs when a condition pertaining to one level cannot find satisfactory expression on that level and tries to manifest itself on another level in symbolic form (perhaps as a symptom of an inability to articulate at the appropriate level of discourse).

The reality of a person's feelings is no less real than the reality of the fact that a glass will fall if dropped, and no less real than the fact that a chair upon which I may be sitting is a whirlpool of molecules in motion. Yet these are different kinds of realities — and are to be judged or evaluated by different means and measures. It is epistemologically appropriate — and often essential — to use different criteria for different kinds of knowing.

Domain Conflation

Brian Arthur uses as an example of domain conflation situations in which people speak about "a duality between man and nature, and [imply] that there's a natural equilibrium between them that's optimal for man. And if you believe this view, then you *can* talk about 'the optimisation' of policy decisions concerning environmental recourses" (Waldrop 1992: 333). [However, Arthur makes his disrespect for this kind of sloppy talk very clear.]

Epistemological domain conflation may be the most common form of logical category error in discourse, and involves the denial of different kinds of co-existing realities or discourses. It frequently takes the form of trying to fit the complexities of our experience of being and our talk about our world in a simplistic monistic "one-truth must be true for everybody all the time". Other forms of domain conflation involve setting up Platonic dualities or Hegelian triplicities — as if these can encompass complexity.

Conclusion

We have proposed that we should consider at least a *heptuality* (seven-sidedness) of co-existing human experiences and epistemological discourses appropriate to each of the seven domains of human experience. The seven domains of knowing and their modes of discourse are necessary to represent the complexity of human beingness and human knowing as an everchanging whole. The seven domains framework can be therefore applied as a conceptual tool for clarification of co-existing but distinct universes of discourse in organisational analysis.

We have also proposed that more effective and cost efficient organisational interventions could potentially be built upon clarification of the epistemological domains in which organisational "pathologies" can occur and be diagnosed. Clarifying the co-existing complexities of organisational realities as experienced by organisational members can provide a framework for understanding the different versions of what can change or what can go wrong in organisations.

Notes

(1) As with the illustration of the ammonite there is no intention of hierarchy. All these levels of experience and domains of discourse can be seen to co-exist at least from the beginning of time.

(2) Different domains of discourse or experience of "knowing" may co-exist. For example, one can believe that lying is morally wrong yet engage in intentional deception as a means of opposing a wrong like Nazi oppression.

(3) Certain domains may be prominent at any one moment and others may be in the background. Although people may sometimes believe that they can concentrate on several things at once, this is not true. They might quickly oscillate between different items, but at any one moment one level will be dominant, and the others less compelling.

(4) It is important to notice from the start that different epistemological levels (levels of knowing) may or may not contradict each other (e.g. the CEO may be both loved in some respects and disliked in other respects).

(5) It is possible to differentiate between the different domains when we differentiate the criteria for evaluating what kind of "knowledge" or logical "truth value" can be assigned to the different domains.

(6) People can write or talk with different degrees of clarity about the different domains — whether they have ever come across a given domain by name or not. However, it is actually uncommon for people who are not philosophically informed to carefully avoid category errors in their text and talk about complexity science and its uses in organisations.

(7) The seven-domains model is both ontological in that it is concerned with existence or being as well as epistemological in that it is concerned with knowledge, what and how we can know and the methodologies we use in distinguishing varieties of truth values between different domains.

> The objects that the observer brings forth in his or her operations of distinction arise endowed with the properties that realize the operational coherences of the domain of praxis, of living in which they are constituted. [This path entails] the recognition that it is the criterion of acceptability that the observer applies . . . that determines the reformulations of the praxis of living that constitute explanations in it. . . . Each configuration of operations of distinctions that the observer performs specifies a domain of reality (Maturana 1988: 30).

Acknowlegement

Thanks to Eve Mitleton-Kelly of the Complexity Project at the LSE for several opportunities to field test these ideas.

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Appendix A

THE SEVEN-LEVEL MODEL*

LEVEL 1 **The Physiological** concerns the person as a "body" with biological, physical, visceral, and sensational experience, temperament, body type, and predispositions. It concerns body processes, psychophysiology, natural sleep rhythms, food, physical symptoms of disease, the physical manifestation of anxiety, and general sensory awareness, proprioception, and "first nature". Physiological processes may be "measured" in some instances — such as brain wave patterns on an EEG — but it may be impossible to ever know at a physiological level whether another person's sensation of the colour red is similar to or different from one's own.

LEVEL 2 **The Emotional** concerns the person as "mammal". It is essentially a preverbal area of experience and activity. It concerns those psychophysiological states or electro-chemical muscular changes in our bodies we talk about as feelings, affect, and/or emotion in psychology. Emotions are essentially subjective, experiential, and felt states. Our knowledge concerning emotions seems to be essentially existential, phenomenological, and unique.

LEVEL 3 **The Nominative** concerns the person as "primate". Under this heading are included the awareness and labelling of experiences and the validation of experience through naming. It represents the verbal part of communication. Since at least the earliest biblical times, people have known that the "giving of names" develops "dominion", ownership and the feeling of mastery over the existential world and the transformation of human experience. There can be some agreement or disagreement within groups, within dialect or language or disciplinary groups, for example, about "what things are called". Within any common set of language rules the fact that certain kinds of words are known to stand for certain kinds of objects can be agreed, debated, or disputed.

LEVEL 4 **The Normative** concerns the person as social animal. It refers to norms, values, collective belief systems, and societal expectations. This level tends to deal with facts, knowledge of attributes, and practices regarding people as "cultural beings" — the tribe, the group, the community, the church, the political party, and organisations. The values, morals, and ethics of collective belief systems are not always subject to logical tests of truth or statistical rationality — they constitute a different realm of questioning or knowing.

LEVEL 5 **The Rational** concerns "Homo Sapiens" — the person as thinker. This layer of knowledge and activity includes thinking, making sense of things, examination of cause and effect, frames of reference, working with facts and information about time and place. It covers science, logic, statistical probabilities, provable facts, established "truth" statements, and consensually observable phenomena. It is characteristic of level 5 discourse that it is possible to establish truth values.

LEVEL 6 **The Theoretical** throws into relief the person as "storyteller" — as a meaning-maker, making sense of human experience through symbolism, story, and metaphor. This is based on the notion of theoretical plurality and relativity. Theories can be seen as "narratives" — stories that people tell themselves — interesting, exciting, depressing, controlling, useful, and relative, but no one forever true. "Theories" are in a different logical category from that of facts. In this category are the hypotheses, explanations, metaphors, and stories that humans have created in order to explain or test why things are as they are and why people behave as they do. Theories can be more or less elegant, economical, valid, reliable, explanatory, or practical. If a theory becomes widely accepted as "fact", it becomes relocated into the non-disputable level 5 area.

LEVEL 7 **The Transpersonal** refers to the epistemological area or universe of discourse concerned with people as "spiritual beings" or with the world of the soul. Beyond rationality, facts, and even theories, this domain includes the prescient regions of dreams, "direct knowing", altered states of ecstatic consciousness, the spiritual, the metaphysical, "quantum chaos", the mystical, the essentially paradoxical, the unpredictable, and the inexplicable.

Version of table taken from Clarkson (1995), *The Therapeutic Relationship*, London: Whurr.

Appendix B

	Complex adaptive system	Emergence/self organisation	Co-evolution/ interactions	Space of (adjacent) possibilities	Edge of chaos	Creativity/ Shadow system	Leadership = the emergent infrastructure
Physiological (physical and sensory)	Any organisation as a unit of complex activity	The favourite ‘spot’ in the office (the water fountain)	People connect through email, but still like to meet in person	Dispersed workplaces	The prominent work-laden office space	Organisational layouts and physical environments hinder creativity	Conference forums (away from the office)
Emotional (dealing with emotions)	Contentment in co-operation	Anxiety is an observed psychological phenomenon	Positive and negative feelings are critical for interacting	Stress due to change in organisations	Uncertainty causes insecurity when not contained	People feel the need to connect and share their everyday realities	Psychological leaders who can contain anxiety
Nominative (naming things)	The names ‘flexible’, ‘dynamic’, ‘adaptive’	Calling some phenomenon ‘trend’ or ‘pattern’	Naming behaviours ‘competitive’ or ‘co-operative’	People opening up the space of possibility in organisations by talking about complexity	‘chaos’ has often negative connotations	Institutionalising informal networks kills them off	He/she who is called ‘leader’ is not the only leader
Normative (social and group norms)	Participative and co-operative learning environment	Removing the control factor, Work could organise in Repeating patterns	Fostering relationship building in organisations through OD techniques	Creating a service for a niche market through observation of social behaviours	Creativity takes place out of the zone of stability	Informal networks exist/form all the time	Facilitating leadership in the team depends on the person’s abilities
Rational (testing with numbers)	Modelling, simulations	Scaling up and Down through metrics	Modelling	Simulations modelling	Metrics and evaluations	Measuring with staff surveys/ creativity creates dialogue	Creating indicators of leadership
Theoretical (based on theories and narrative)	Explanations/ Stories on flow diagrams	Issues of causality and trends	Fitness landscapes	Strategic planning	Psychodynamics of creativity	Innovation theories that are product and industry driven and HR theory	Creating theoretical frameworks for leadership
Transpersonal (beyond words, rationality, facts, theories)	The ideal of the ‘Learning Organisation’	The vision of the ‘amoeba’ organisation	The vision of the ‘matrix’ organisation	Archetypes of ‘network’ or ‘matrix’ organisation	Organisation seen as a ‘caring mother’ to contain creativity	HR practice putting in place playful activity; working towards a more ‘holistic’/ humane’ organisation	The vision of the ‘Guru’ leader, sensei, Lao Tsu