COMPLEXITY THEORY, GLOBALISATION AND DIVERSITY

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ABSTRACT

The paper reviews and argues for the importance of insights from the trans-disciplinary 'complexity theory' for Sociology. Complexity theory addresses issues that lie at the heart of classic Sociological theory. These include: the tension between general theory and explanation of specific phenomena; emergence, that is, the relationship between micro- and macro-levels of analysis; and the concept of system. In particular, it is argued that Sociology has much to benefit from the new thinking about the concept of system that has taken place within complexity theory. In an era of globalisation, Sociology needs to develop its vocabulary of concepts in order to address large scale, systemic phenomena. Special attention is paid to the application of specific concepts from complexity theory to social phenomena, including: co-evolution of complex adaptive systems, fitness landscapes, and path dependency. The implications for Sociology of distinctions and differences within complexity theory, especially those between the Santa Fe and Prigogine approaches, are addressed. While the focus of the paper is on the theoretical issues, the example of globalisation is used to illuminate the analysis, especially in relation to the changing nature of polities and their interrelationships.

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Introduction

Complexity theory offers a new set of conceptual tools to help explain the diversity of and changes in contemporary modernities undergoing globalisation. It constitutes a challenge to more traditional forms of theorising in sociology and offers new ways of thinking about diverse inequalities and social change in a global era. Complexity theory offers new ways of thinking about some of the classic dilemmas in social science, in particular, engaging with the tension between the search for general theory and the desire for contextual and specific understandings (Calhoun 1998; Griffin 1993; Haydu 1998; Kiser 1996; Kiser and Hechter 1991), which lies at the heart of the tension between realist (Archer 1995; Bhaskar 1997; Byrne 1998; Sayer 1992; Somers 1998) and post modern (Cilliers 1998; DeLanda 2000; Lyotard 1978) approaches. Complexity theory confronts the postmodern challenge to modernist metanarratives to address issues of diversity and complexity more adequately and responds without giving up the quest for explanation and analysis of causation. Critical to these theoretical developments is the re-thinking of the concept of 'system', rejecting old assumptions about equilibrium in favour of the analysis of dynamic processes of systems far from equilibrium, and re-specifying the relationship of a system to its environment. It thus provides a new framing for empirical enquiries into diversity and social change.

The search for general theory in more traditional scientific thought in many disciplines has often involved a process of reducing complex phenomena to simpler ones. This may involve either a reduction downwards to ever smaller units of analysis as in the movement from organisms to cells to genes in modern biology (Rose 1997) or in the methodological individualism of rational choice theory (Coleman 1990; Goldthorpe 2000; Kiser and Hechter 1991), or it may involve a reduction upwards, as in much structuralist thought in the social sciences (Althusser 1971; Parsons 1951). By contrast other schools of sociology reject these ambitions for general explanation by means of reduction, sometimes by staying close to the meaning of human actors (Smith 1987), sometimes by privileging thick rich descriptions over the search for causal explanation. Complexity theory offers a way of surpassing this polarisation by the development of ontological depth that is not at the expense of explanatory power. In this respect, complexity theory has many parallels with the development of realism in sociological thought (Archer 1995; Bhaskar 1979, 1989, 1997; Sayer 1992). It shares a concern with processes of 'emergence' and of different levels and modes of abstraction. This facilitates the development of some of the concerns of classical sociology, such as combining an understanding of both individual and social structure, that does not deny the significance of the self-reflexivity of the human subject while yet theorising changes in the social totality.

Some conceptualisation of systematic relationships is indispensable for Sociology. In the context of the empirical analysis of the large-scale interconnections involved in the process of globalisation, this theoretical requirement becomes even more acutely obvious. Complexity theory offers new developments in the conceptualisation and theorisation of systems. Sociology has had something of a hiatus in the development of its thinking about large scale processes and especially about systems during the postmodern turn, while complexity theory within the natural and mathematical sciences has proceeded apace on these issues. Most classic theory in Sociology has addressed the social within a large framing, invoking some kind of concept of social system, whether this is understood at the level of capital, as in Marx (1954), either global (Wallerstein 1974) or national (Jessop 1990), a society, as in Durkheim (1966) and Parsons (1951), especially nation-states (Giddens 1984), or a world religion (Weber 1958). In the turn against the metanarrative (Lyotard, 1978), which has overtaken social theory over the last two decades most large scale theorising, from Marxist to Parsonian, has been marginalised. This has proceeded together with the privileging of issues of particularity, of difference (Felski 1997; Taylor 1994) and of agency (Emirbayer 1997; Giddens 1984) in social theory and analysis. Yet, the emergence of concern with global processes has led to a revival of interest in large scale processes, and of inequality alongside difference, in order to comprehend the meaning and implications of globalisation (Benhabib 1999; Castells 1996, 1997, 1998). In this new context, it is time to think again about the vocabulary of concepts available to social theory to address issues at a large scale, systemic and global level. It is in this context that an investigation of the relevance and usefulness of the concepts developed within complexity theory becomes especially relevant (Urry 2003). It is thus timely to investigate the advances that have occurred in complexity theory within other disciplines in order to see whether and if so how these might assist the development of thinking within sociology.

Complexity theory is not a single coherent body of thought but is constituted by a range of different traditions and approaches. One key divergence is over the extent to which a traditional scientific research programme can be utilised to deliver on the promise of complexity theory, as suggested within the Santa Fe school, or the extent to which the implications of non-linearity and of unknowability require a new epistemological framing of the scientific endeavour, as suggested by Prigogine. This divergence is paralleled in the different interpretations of complexity theory in sociology, between, on the one hand, Byrne (1998) who argues for the inherent compatibility of complexity theory and realism, and on the other, Cilliers (1998) who argues for the inherent compatibility of complexity theory and postmodernism. Alternatively, as argued here, complexity theory transcends such old polarities. Complexity theory has inspired two main ways of addressing the issue of change and diversity. The first involves the concept of the co-evolution of complex adaptive systems, where the concept of co-evolution replaces any simple notion of single directional impact. The second involves the notion of saltation, of sudden, critical turning points, in which small changes, in the context of complex systems, give rise to bifurcations and new paths of development that are self-sustaining. These may be understood either as competing accounts of change, reflecting the tensions between the different branches of complexity and chaos theory, the first associated with the Santa Fe school and the second with the Prigogine school, or, ultimately, as reconcilable.

Key issues that are part of this debate will be considered in this paper include: re-thinking the concept of system and their inter-relationships; and re-thinking concepts to analyse social change including co-evolution and path dependency.

Re-thinking the concept of system

A core feature of complexity theory is its anti-reductionist analytic strategy, which is inextricably connected to a fundamental re-thinking of the nature of systems, so as to better conceptualise the simultaneously dynamic and systematic inter-relationships between phenomena. The traditional concept of 'system' in sociology, mired in old notions of a self-balancing equilibrium, is rightly rejected in contemporary sociology. Yet some features of the concept of system, notably that of systematic and self-reproducing inter-relationships, remain indispensable to all kinds of sociology. Even when systemic conceptions are not explicitly included, they are often smuggled into the analysis. The new theorisations of system within complexity theory radically transform the concept making it applicable to the most dynamic and uneven of changing phenomena. Some of these changes are a result of quite simple re-conceptualisations, such as replacing the conception of parts and wholes with the notion that each system takes all other systems as its environment, while others are more complex conceptions of the relations between systems as well as dynamic conceptions of their uneven, non-linear, transformations.

The concept of system is central to recent developments in complexity theory. In the disciplines of biology, especially through the work of Maturana and Varela (1980), cybernetics, mathematics and computing, development of the concept of system has proceeded rapidly with a series of profound re-constructions of the notion. In contrast, in Sociology, the use of a concept of system has been but little developed in the last three decades (with rare exceptions such as Luhmann 1995), and its use is marginal and controversial in the contemporary discipline. While many of the old forms of systems thinking did have serious problems, new advances in complexity theory provide the tools with which these may be addressed. A re-working of the concept of system in social theory in the light of the new complexity theory is essential. A revised concept of system is indispensable for the sociological project, in general, and the analysis of globalisation, in particular. Nevertheless, there are important issues in the translation and application of the concept of system between different disciplines that need to be carefully addressed, rather than supposing that the application of the concept is the same in different contexts.

The concept of system is needed in sociological analysis for many reasons, including making better sense of connections between different levels of phenomena, for example, in relation to notions of emergence and path dependency. In particular, the analysis of globalisation requires that the question of systemness be addressed because events in one part of the globe affect those in another. In order to understand globalisation there needs to be some conception of actual or potential systematic interconnections at a global level.

In the complexity sciences there has been very extensive work on developing the concept of system, while in Sociology over the last three decades only a little work has been done developing the concept. This is at least partly as a result of the trenchant rejection of both Parsonian structural-functionalism and of Marxism, each of which had contributed systems-based thinking to Sociology. In the avalanche of criticism of 'meta-narratives' (Lyotard 1978), and the turn to a postmodernist frame of reference, there was little enthusiasm in the mainstream of the discipline for development of the concept of system. So, the development and refining of the concept, which had been taking place within both functionalism (Alexander 1984; Merton 1968; Smelser 1959, 1962) and Marxism (Althusser 1971; Poulantzas 1973), slowed significantly. However, there have been a few exceptions, such as the work of Luhmann (1995), the Marxist regulation school (Jessop, 2001, 2002; Amin 1994), world systems theory (Chase-Dunn 1989; Wallerstein 1974), and organisational theory (Mitleton-Kelly 2001; Wilke 1997).

A major strength of most classical sociology is its ontological depth in that it engaged analytically with both individuals and social institutions and often several further ontological levels within a single explanatory framework. This has not always been a continuing feature of sociological theory, which has tended to privilege just one ontological level, whether system, discourse or individual. Complexity theory enables us to invoke and develop this strength of classical sociology. In order to pursue the further development of the concept of system in Sociology it is useful to examine briefly its traditional use in classical Sociology. This enables the better positioning of innovations in the concept of system informed by complexity theory in relation to major schools of thought within Sociology.

Of the classic sociologists, Durkheim (1952, 1966, 1984, 1995) had the clearest concept of a unified social system, equating it with the concept of society. The social level was not to be reduced to that of individuals, but constituted a level in its own right. His analysis of social change was gradualist, with conceptions of social structure that changed during the process of modernisation, becoming increasingly differentiated. Drawing on Durkheim, Parsons (1949, 1951), developed this notion of system, producing an elaborated account of its constituent elements, its structures and sub-systems, a four-fold division of key functions (AGIL), a theory of social order based on the cohesive force of consensually held norms and a mechanism of change towards modernisation, that of internal differentiation. The concept of system is one of self-equilibration, that is, returning to balance after pressure to change. Attempts to deal with criticisms that this framework dealt insufficiently with conflict, power, lack of consensus and inequality were met by refinements (Merton 1968; Smelser 1959) intended to provide analyses of contested change, social inequality and the possibility of dysfunctions. However, despite these revisions, this functionalist school is widely regarded as discredited, though see Alexander (1982, 1984, 1998) and Luhmann (1985, 1990, 1995)[1]. From the perspective of complexity theory, some of the severe limitations of Durkheimian thought are a result of utilising an equilibrium conception of system, which Merton and Smelser did not revise. One consequence of this is the difficulty in addressing diversity and sudden change.

Marx saw capitalism as a system in a more complex way than the Durkheimian tradition, theorising both institutions and social relations, and processes of change that included both gradual evolution and processes of sudden transformation (Reed and Harvey 1992; Urry 2003). Unlike the Durkheimian and Parsonian tradition, Marx's (1954) conception of social system did not involve the assumption of equilibrium. Marx's (1963, 1967) theory of change included both long periods of gradualist development and modernisation of the forces of production which are interrupted by revolutionary upheavals led by self-conscious politically motivated and self-organised groups of people, during which the system changes abruptly into a new form. Marx's conception of social system is more consistent with complexity theory than that of Durkheim because it does not presume a self-balancing form of equilibrium, but rather allows that the social system may be far from equilibrium, generating sudden and violent change to the path of development. However, Marx's framework is restricted by the limited conceptual space for diverse inequalities beyond those of class and for the possibility of diverse paths of development.

While the systems theory derived from Parsonian functionalism has many problems, with its presumption of a return to equilibrium following perturbations or disturbances, yet some conceptualisation of systematic inter-relatedness and of self-reproduction of social patterns is needed by sociological theory. Several revisions to

[1] Luhmann (1995) synthesises functionalism and phenomenology with the insights of early complexity theory (Knodt 1995) and thereby challenges the simpler versions of this critique of functionalism. Luhmann attempts to integrate the concepts and insights of complexity theory into sociology, modifying these so as to be suitable for a social rather than natural system – Luhmann (1990, 1995). He especially developed those concepts concerned with systems and drew out their epistemological implications. Key to Luhmann's approach is the simplifying assumption at each system takes all others as its environment. It is this that enables him to move beyond the rigidities of conceptions of systems in terms of parts and wholes. Luhmann integrates insights from complexity theory with both Parsonian functionalism, especially notions of system and of function, and phenomenology, especially the interest in communication (Knodt 1995). The heritage of Marx is relatively absent, as is seen in Luhmann's lack of interest in analysing power, inequality and the economy, as is also that of Mead (1934), as seen in his dismissal of the subject as a significant analytic locus. Further, the work is highly abstract and, despite attempts at application to specific social systems, such as those of law (Luhmann 1985) and art (Luhmann (2000), remains devoid of content about changing forms of social inequality. Thus Luhmann's work, while a rare and important development of systems thinking in recent Sociology, is limited in its direct relevance to analyses of changes in social inequality. As it stands it is unable to adequately integrate, as matters of central rather than marginal concern, issues of conflict, inequality, materiality and agency.

the concept of system have been explored including using instead terms such as ‘web’ (Simmel), ‘network’ (Scott 2001; Castells 2001) or ‘regime’ (Krasner 1983), thereby reducing the degree of closure and the tightness of the connections implied by the term ‘system’. These developments have the advantage of recognising the significance of the incomplete saturation of the social space by the network (or other entity) under consideration and the softness of the causal connections as a consequence of inter-penetration by other networks. However, it has weaknesses precisely in its lack of theoretical precision. Indeed, it appears that terms such as regime are predominantly more specialised, softer, narrower, variants of the concept of system, rather than fundamental alternatives to it. They have been used not least because of the discomfort of social scientists with the deficiencies of old rigid equilibrium forms of system theory.

Complexity theory is a trans-disciplinary development (Capra 1997), so it is important to be careful as to the specific nature of the translation of concepts and theories from between different disciplines, especially between those based on mathematical abstractions and those that include the complications of empirical observations. While there have been attempts to develop a unified theory of complexity (Holland 1995), the significance of the relationship of a system with its environment, ambiance or context means that this is fraught with difficulties (Chu et al 2003). Sociology has often rejected the application of theoretical developments from the sciences on the grounds that they miss the particularity of what is human (Luhmann, 1995). Not only this, but outside of the sub-discipline of social studies of science (Haraway 1997; Law 1991; Latour 1987; Pickering 1995), which, while well developed, is rather segregated from much of social theory, the view as to what constitutes scientific method is often long behind these developments, indeed, even located in a view of science as positivist (Harding 1986). The argument here is that recent developments in science, such as those around complexity theory, have produced concepts that are more sophisticated than most sociology imagines. There is much to be gained from the examination of the concepts, methods and epistemology of complexity theory in order to see what insights they offer for sociology after a due process of re-specification to ensure an appropriate application. While systems share common features, they differ according to context, for example, whether this is biological, social, or physical, and this needs due consideration.

There are two key inter-related features of the new conceptions of systems that depart from older forms of systems theorising that are of particular importance: first, the nature of a system as self-organising together with the system/environment distinction; and secondly processes of change variously conceptualised as non-linear, as co-evolution of complex adaptive systems within changing fitness landscapes, path dependency and saltation, punctuated equilibria and waves.

System/environment distinction

That systems are self-reproducing is definitional of a system. Early work in complexity theory on the conceptualisation of systems as self-organising was inspired by the work of Maturana and Varela (1980). In this the process of self-reproduction a system is seen as self-organising and self-defining. The system has internal processes that internally connect and reproduce the system. These features are called autopoietic by Maturana and Varela (1980). Autopoiesis is a network of processes, in which each component participates in the production or transformation of other components in the network. In this way the entire network continually re-makes itself. The system is produced by its components and in turn produces those components. This includes the creation of a boundary that specifies the domain of the network's operations and thus defines the system as a unit (Maturana and Varela 1980). That a system is self-reproducing and self-organising is key to many of the more empirical based analytic developments associated with complexity theory from biology (Kaufmann 1993, 1995) to political science (Jervis (1997) to legal studies (Teubner 1997). For example, Teubner (1997) argues that there has been a proliferation of decentred law-making processes as a consequence of globalisation and that these forms of law-making are a result of acts of self-validation, not the actions of nation-states. These are acts of self-validation; of the self-organisation of legal professionals.

One of the important contributions of complexity theory to the re-theorisation of systems is the key distinction between the system and its environment. This distinction developed by Bertalanffy (1968) and Luhmann (1995), is common across complexity theory (Capra 1997). This disarmingly simple notion facilitates the more subtle and flexible theorisation by the new systems theory.

This distinction between a system and its environment together with the understanding of systems as self-organising and self-reproducing provide the basis of a new way of thinking about systems in sociology as well as other disciplines. In particular, it does not entail a presumption of hierarchy between inter-connected phenomena; rather hierarchy is a special case of differentiated systems. This makes for a more flexible conceptualisation, providing the conceptual possibility to avoid rigidities such as that of 'part and whole' (Parsons 1951) and of 'base-superstructure' (Marx 1967), as well as the ambiguities of 'relative autonomy' (Althusser 1971). These involve some kind of hierarchical relationship between nested sub-parts of a system. The sub-systems in Parsons' (1951) formulation are a particularly rigid example of this. Within Marxist systems theory there were two interpretations of the formulation. The simpler and more popular version was that of a base-superstructure model, in which the economic base determined the political and cultural superstructure. A more complex interpretation was that of Althusser's relative autonomy, that removed the simple hierarchy of these elements, making it a relative hierarchy. This in turn raised the question of the degree of autonomy entailed without unduly stretching the notion of the relative hierarchy of the elements.

The solution to this problem in complexity theory is to consider that each system has as its environment all other systems. This replaces the rigid notion of a hierarchy of sub-systems by a much more fluid conception of the mutual impact of systems. This means that the phenomena that many systems-based Sociologists have treated as subordinate elements within systems are here conceptualised as separate systems. This enables us both to keep the notion of system, and the notion of systematic inter-relatedness, while yet not pre-specifying, in a rigid way, the nature of these inter-connections.

Thus a key insight associated with the system/environment distinction is that it is possible to reject the necessity that systems are nested. In some circumstances they may be, but not in others. Sociological conceptions of systems have often over-stated the extent to which systems are nested. For example, the notion that a 'society' in the modern era can be understood as a nation-state that contains nested economic, political and cultural systems is widespread (Giddens 1990). However, this is theoretically and empirically erroneous. In at least the contemporary world, the spatial and temporal reach of economic, political and cultural systems often do not map onto each other. For example, the regulation of the economy in the UK is centred in the EU, while the governance of the welfare state is centred in the UK, and there is not one 'nation', but several, English, Welsh, Scottish, and Irish either wholly or partly located in the territory of the UK (Walby 2003). Complexity theory facilitates the better framing of these questions about the relations between economy, polity and culture in empirical research, as well as theory.

A key implication of the system/environment distinction for empirical research is that of the rejection of analysis in terms of the parts of a whole system. Rather than looking for and analysing the function of a part for the reproduction of the whole 'society', there is the absence of the assumption that there is such a nested set of systems. Rather the extent of the coherence, of the close coupling of systems, is a question for empirical research.

Co-evolution

Complexity theory can be used to re-frame accounts of social change. Some conventional accounts of social change use a simple notion of a social force impacting on another social entity. Within complexity theory, the concept of co-evolution replaces this notion of an entity having a simple impact on another entity. Since every system is understood to take all other systems as its environment, systems co-evolve as they complexly adapt to their environment (Kaufmann 1993, 1995). These are 'complex adaptive systems'. The concept of autopoiesis is important for understanding the way that systems are seen to co-evolve and adapt to each other, rather than one simply impacting on another (Maturana and Varela 1980). Since each system has an internal system, any initial impact will have complex effects upon the internal relations of the other system. Hence the response of the system is unlikely to be simple.

Systems interact with each other. They may do so in such a way, called coupling by Maturana and Varela, that they assist in the reproduction of each other. In this case the mutual modifications of the systems as they interact does not lead to the loss of the identity of each system. Of course some interactions with other systems may lead to the loss of identity of one or both systems, but this is not coupling. Coupling may lead to the generation of a new unity in a different domain from that in which the coupled entities maintain their identities. This new unity may itself be autopoietic, in the sense of self-reproducing. Thus there may be a network of autopoietic systems dependent upon each other for the maintenance of their identities. 'An autopoietic system whose autopoiesis entails the autopoiesis of the coupled autopoietic unities which realize it, is an autopoietic system of a higher order (Maturana and Varela 1980: 109).

In order to respond to its environment a system changes internally. Since its environment is composed of other systems, these other systems also change internally. Systems impact on each other in ways other than those of a simple hierarchy or of a simple impact on a stable environment. Rather, systems are co-evolving; they are complex adaptive systems (Holland 1995, 2000; Kaufmann 1993, 1995). This notion that a system changes as well as the systems with which it is interacting goes beyond the old conception that an entity simply acts on another entity. Rather there is mutual impact; they both change as a result of this interaction; they co-evolve.

Kaufmann (1993, 1995), drawing on challenges to traditional thinking about evolution such as those of Eldredge, moves beyond the field of biology to a more general account of complexity thinking. He develops an analysis of co-evolution, using a concept of 'fitness landscapes', while arguing against reductionism. He develops general accounts of the emergent properties of systems, and of their self-organisation, using material drawn from a range of scientific disciplines. He argues that self-organisation is intrinsic part of certain types of system, rather than something that is either random, or explicable only at the level of the component elements. Kaufmann (1993, 1995) addresses the complex nature of this co-evolution among and between multiple systems via the concept of 'fitness landscapes'. This concept is initially derived from analyses of the evolution of species, but may be regarded as a concept that is potentially transferable to other types of systems. The environment or landscape that each system faces is changed as a result of changes in the systems that constitute that landscape. So as one system evolves, it changes the landscape for others, changing their opportunities, and thereby their potential for success or weakness. The landscape can be adapted or deformed by systems as they co-evolve. This alters the opportunities faced by other systems, with complex consequences for their development.

The process of interaction between a system and its environment involves selection and temporality (Luhmann 1995). It involves selection, in that the system has to recognise which phenomena, out of a range, are to be responded to. It involves temporality, since a process of change takes time. Co-evolution is not instantaneous, but a process that takes place over time. Internal processes have to adjust to external changes. The temporal lag in the changes within systems as a result of their interaction is not merely inevitable, but is key to understanding the nature of social change.

The implications of the concept of the co-evolution of complex adaptive systems for empirical research include the imperative to look at the interaction between entities, and not to presume a one-way direction of causality. Further, it is likely that both (or several) of these entities will change during their interaction, thus requiring a complex appreciation of the objects under study.

An example of the usefulness of this new conceptualisation is that for grasping the relationship between globalisation and states. The conventional accounts have often described this as one in which globalisation impacts on nation-states, reducing their capacity for autonomous action especially in relation to the welfare of their citizens (e.g. Crouch and Streeck 1997; Martin and Schumann). But the notion of 'impact' leaves out of focus the process of dynamic adjustment of polities to each other in the context of globalisation. In the context of the response of European countries to globalisation such an approach has particular difficulty in grasping the changing nature of the European Union during this process. The use of the concepts of co-evolution of complex adaptive systems in a fitness landscape re-frames this process and enables a more adequate account. Rather than asking about the impact of globalisation on European States, it is more appropriate to ask about the co-evolution of globalisation, the European Union (which has grown in powers), and Member States (who despite giving up their powers to the EU are better able to complete their domestic agendas having done so) (Walby 1999). The Member States have transferred powers to regulate the economy from the domestic, country specific, arena to the European Union. But to treat this as a zero-sum game would be inadequate. Rather the domestic agendas of the governments of these relatively small European countries are better achieved by such a transfer of powers (Milward 1992). The concept of co-evolution captures this process better than that of impact. Further, globalisation does not simply act on the European Union, but this polity is itself part of a process of creating globalisation, for instance in its role in re-negotiating international trade regulations. The process of co-evolution involves the complex adaptation of systems of European countries, the European Union and the global. This co-evolution has resulted in a changed fitness landscape within which the Member States and European Union operate, with different implications for the powers of these entities. Within a changing global landscape, the European Union has increased its powers over the regulation of the economy, while the Member States have reduced theirs. 'Impact' is far too blunt a concept to capture these complex processes. Rather 'co-evolution', 'complex adaptive systems' and 'fitness landscapes' facilitate the improved understanding of the processes.

While the concept of co-evolution appears to bring with it assumptions about gradual rather than precipitate change, this captures only one type of social change. The second major contribution of complexity theory to analyses of social change is through the re-framing and development of the concept of path dependency.

Ontological depth and emergence

Complexity theory offers a re-framing of the debate about the significance of ontological depth and the importance of a non-reductive analytic strategy. Much traditional science, both natural and social, has had a preference for a single level of analysis, a tendency to search for connections that reach back to one fundamental level (Rose 1997). Much complexity theory by contrast has as a core assumption the importance of ontological depth, of levels that are linked, within a system, and that the relationships in one level are not reducible in any simple manner to those in another. However, some bottom up approaches, such as those of agent-based computational models (Epstein 1999), suggest that ultimately a well-specified model can generate macro-structures from micro-level specifications. The relationship between the levels is captured by the concept of emergence. This recognises that each level contains the objects that are present in the other levels, but that they can be analysed differently. It is not so much that the whole is greater than the parts as that it is different from the parts. Emergence may be studied from either the bottom up (Holland 1995) or the top down (Holland 2000). Examples from biology include that many cells together constitute a living organism; that many individual beasts together constitute a species; that several different species in the same habitat constitutes an ecological system (Capra 1997; Rose 1997). Within social science examples include: that individuals living together constitute a household; that individuals working together constitute an organisation; that many citizens constitute a nation.

For social theory, emergence is a key concept in linking different levels in a system, especially the levels of individual, structure and system. It enables the thinking of the simultaneous 'existence' of each level. It does not necessarily privilege one over the other, rather they are recognised as co-existing and linked. Each level has different patterns and can be subject to different kinds of theorisation. Patterns at 'higher' levels can emerge in ways that are hard to predict at the 'lower' levels. The challenge long-addressed in sociology is how such levels are to be linked. This question of the nature of 'emergence' has been framed in a variety of ways including those of 'macro-micro linkage', 'individual and society', the 'problem of order' (Alexander 1982), and 'structure, action and structuration' (Giddens 1984). There have been many who have sought to integrate a concern with individual social action with a concern with macro level social forms, from Habermas (1987, 1991) and his theory of both communicative action and steering systems, to Bourdieu (1984) and his concern with habitus as well as capital and field, to Giddens (1984) and his re-writing of structure-agency theory. These attempts to deal with the micro-macro relation are involved with the process of 'emergence', of patterning at the macro level despite enormous complexity at the level of individual actors. In social science, these analyses have been given practical application and expression in areas such as social movement theory, with its concern with the emergence of new forms of social values and social organisation, and in the theory of revolutions (Skocpol 1979), with its concern with critical turning points. The concerns of social science theory thus significantly overlap with those of complexity theory, even as the latter has developed a specialised vocabulary of concepts. The interweaving of the concerns of classic Sociological theory with that of complexity theory has the potential to move both bodies of theory forward.

The issue of ontological depth is raised in different ways in different disciplines. Whether or not one level is privileged within a particular discipline is subject to controversy. In Economics the main neoclassical tradition assumes that the key level is constituted by rationally choosing individuals, although heterodox economist traditions allow for multiple levels and institutions (e.g. North 1990). Most of the classical Sociological theorists assumed more than one level was needed, from Marx to Durkheim they took as core concerns those of the relationship of the individual to the social, the achievement of social order, and the nature of social structure. Although within Sociology some rational choice theorists have attempted to lay claim to the status of the most scientific approach (Coleman 1990; Kiser and Hechter 1991; Goldthorpe 2000), thereby contesting a multi-layered approach in Sociology, this is not the dominant approach. Rather, within Sociology the relationship between 'structure' and 'agency' (Giddens 1984) is a key part of the issue as to how to maintain both levels of analysis, with varying interpretations as to how these are appropriately balanced (Archer 1995; Mouzelis 1993, 1995). These entail the same notions as lie at the heart of the concept of emergence. That is, the terrain of 'emergence' is a key terrain of sociological analysis. Potentially, Sociology has much to contribute to complexity theory about the analysis of emergence. This is because it has long been at the heart of sociology, even as it is subject to much controversy. There is a multiplicity of attempts at engaging with this issue, including not only the debates on structure and agency, but also debates about micro-macro linkages, network theory, and social movement theory. A realist approach has often been important to these developments, either implicitly or explicitly.

Complexity theory runs parallel to approaches to social science that presume multiple levels linked together and shares the concept of emergence.

Path dependency

There are different approaches to the analysis of change in complexity theory. In addition to that of the gradualism implied by the concept of co-evolution of complex adaptive systems, change may be sudden and precipitous. These sudden changes may lead to different paths of development, that is, rather than there being one universal route of development, there may be several path dependent forms. Key to this analysis is the point at which paths of development diverge. This moment may be understood as a critical turning point, or bifurcation in the path of development. Complexity theory accounts of these critical changes reject previous conceptualisation of change as gradual and proportionate. Rather small changes may have large effects on unstable systems. Changes may be sudden, akin to processes of saltation, as a moment of crystallisation of a new structure and form. The smallness and perhaps contingency of the event that precipitates these large scale changes is inconsistent with many previous accounts of causality, and outside many simple forms of mathematical modelling based on linearity, being instead non-linear (Kaufmann 1993, 1995).

Eldredge (1985, 1986) challenges the traditional interpretation of evolution as one of steady development based on the gradual selection of individual organisms that is capable of being reduced to genes. Rather he demonstrated that the process of selection could be better understood if the level of the species became the focus rather than that of the organism. This was because evolution did not take place gradually, with individual organisms slowly changing, but rather as a process of 'punctuated equilibria' in which there were long periods of stability followed by periods of change in which many species became extinct and many new ones were generated. The most important aspect of the process of evolution was that of the relationship between species within an ecology. Species, rather than genes, were the key level of analysis. A reduction to the level of the organism, or indeed of genes, is less helpful to an explanation than the emergent level of species.

Complexity theory has emphasised the importance of non-linear changes, of small events leading to large scale changes in systems, and of the bifurcation of paths of development in both the natural and the social sciences. Within the natural sciences the example often cited (or imagined) is that of a small disturbance to the atmosphere in one location, perhaps as small as the flapping of a butterfly's wings, tipping the balance of other systems, leading ultimately to a storm on the other side of the globe (Capra 1997). The lack of a proportionate linear relationship between cause and effect is troublesome for conventional science and its associated mathematics.

Mathematical modelling has contributed much to the analysis of this phenomenon within complexity theory, especially through chaos theory, the analysis of the way that turbulent systems may suddenly bifurcate and resolve into two or more self-ordered entities. This entails non-linearity and lack of direct proportionality between cause and effect, since this is not a gradual process, but rather one that is sudden (Capra 1997). That is, modern mathematics provides a set of technical means by which to describe the concept of path dependency abstractly and analytically.

These developments in mathematical theory are paralleled in social science by Abbot (2001) who argues for the importance of sequence and narrative in his critique of ‘general linear reality’ in ‘variable sociology’ (although he does not explicitly cite complexity theory). Abbot criticises the methods used in mainstream quantitative Sociology and its assumption of ‘general linear reality’ that depend upon: fixed entities with attributes; monotonic causal flow that assumes a movement from large to small; univocal meaning; absence of sequence effects; casewise independence; and independence of context.

The concept of path dependency in the social sciences can be re-framed and re-developed in the context of complexity theory. Path dependency is a crucial process in understanding different modernities, different forms of social relations in different countries. Key to this is the role of social and political institutions that lock-in certain paths of development, through their shaping of power, opportunity and knowledge (Arthur 1989; David 1985; Mahoney 2000; North 1990; Nee and Cao 1989; Pierson 2000a, 200b, 2001).

Within economics, complexity theory has advanced the concept of path-dependent economic changes constituting it as a major challenge to conventional neoclassical assumptions about economic behaviour (David 1985). Within economics, a debate has raged over whether or not neoclassical assumptions, including the notion of decreasing returns, individuals acting rationally to maximise their preferences, and an equilibrium based model, should be abandoned or significantly modified as a result of theories of path development. The challenge comes from analyses of new technologies which, it is argued, were developed as a result of contingent events that led to the lock-in of advantage to other technologies even though the ones developed were less efficient than those not developed (Arthur 1989). A lead example is that of the use of the QWERTY keyboard, rather than the more efficient DVORAK alternative (David 1985). Further examples include the use of VHS rather than Beta for videotapes and the steel and petroleum car rather than steam or electric cars and other modes of transportation (Urry 2004; Waldrop 1992).

The phenomenon of ‘lock-in’ to divergent paths of development challenges neoclassical economic theory. At the broadest level it contradicts the universalism of this theory by its presumption that different paths of economic development can occur and be self-sustaining. More specifically, it challenges the assumption of equilibrium on which so much economic modelling is based.

One way in which lock-in may be understood is through the role of institutions, which affect the knowledge and opportunities of individuals (North 1990). A second way in which lock-in has been addressed within economics is the theory of increasing, rather than decreasing, returns to scale, in which those entrepreneurs with an initial advantage, even if for contingent reasons, are able to set the path of development around a new technology in an economic system which is not in equilibrium (Arthur 1989). Arthur argues for the significance of disequilibrium in explaining the dynamism of certain economies. This is a radical challenge to the neoclassical paradigm in that it posits the notion that there can be multiple rather than a singular equilibrium point, that is, that it is possible for systems to be in equilibrium in more than one position. He argues further that the events that precipitate a shift in the system may occur as if by chance, and that the earlier they occur in a series of events the more important they may be.

This concept of increasing returns to scale implies a positive rather than negative feedback loop within the system. Old types of system theory, based on the assumption of a tendency to return to a single equilibrium point, operated with a notion of negative feed back loops. A feedback loop is a circular arrangement of causally connected elements in which each element affects the next, until the last feeds back into the first element, thus completing the loop (Capra 1997). These are intrinsic to self-regulating systems (a standard assumption of neoclassical economics about economies). Negative feedback loops are those that are self-balancing, returning a system to equilibrium. One of Arthur's key contributions to complexity theory was to develop the understanding of the importance of positive, not just negative, feedback loops, in which increasing, rather than decreasing, returns to scale drove the system forward, rather than returning it to equilibrium.

However, there are questions about the precise nature of path dependency mechanisms (Mahoney 2000; Rihani 2001) and the extent of their sustainability over the long term (Crouch 2001; Nee and Cao 1999). In opposition to Arthur's position, Liebowitz and Margolis (1995) argue that the case for path dependency within economics has been much over-stated. They distinguish between three forms of the argument, which have different implications. First, the path followed may not be sub-optimal and thus not in contradiction of neoclassical assumptions. Second, that the path was unknowable at the time that the path was chosen whether or not it was sub-optimal, and thus again not in contradiction of neoclassical assumptions. Third, that while the path was sub-optimal, there was no movement to a more optimal path. They suggest that only the third constitutes a serious challenge to neoclassical economics, yet there is often elision between the three models, with a case based on one of the first two being represented falsely as if it were an example of the third. This, they argue, is illustrated by the frequent recourse to a very limited number of examples, examples which they think are anyway questionable, in that there were reasons by which the preferences could be accounted for within mainstream economic theory. While there may be exceptional circumstances as to why the most effective technology is not implemented at the outset, the institutions of the market will eventually lead to investment in the most effective technology, and an adjustment will occur. This leaves the issue as one that is open to empirical investigation. Do the mechanisms of economic markets eventually and in the long run prove dominant over initial choices, and, indeed, over political institutions?

This question of the extent to which distinct paths of development are sustainable in the long run, not just the short run, is a key issue in many debates about the nature of globalisation (Held et al 1999). Complexity theory re-frames these debates about globalisation in terms of the sustainability of path dependent forms over the long run. A central question is whether economic pressures that are increasing constituted at a global level will transform local political formations, or whether locally specific paths of development are and can be self-sustaining (Castells 1996, 1997, 1998; Crouch and Streeck 1997; Pierson 2001)? On the one hand it was argued that global economic forms would dominate, that is, universalist processes would overcome path dependent forms of nation-state economic and political regulations (Crouch and Streeck 1997; Ohmae 1990, 1995; Martin and Schumann). On the other hand, the continued existence of varieties of capitalism (Hall and Soskice 2001) and distinct welfare state regimes (Esping-Andersen 1990) depends upon the resilience of path dependent processes. Pierson (2001) argues that mature welfare states have self-reinforcing processes over extended periods of time, not least as a result of shifting the framework within which actors construct and understand their own interests. Swank (2002) demonstrates that those some types of polity are better able to sustain welfare expenditures than others, in particular, those of a more social democratic form sustain such state provision to a greater extent than polities of a more liberal form. The implication here is that some forms of lock-in of paths of development are more robust than others and that path dependent forms of development can themselves be revised. The issue of path dependency is then partly a question for empirical investigation.

Co-evolution of complex adaptive systems or sudden bifurcations in path dependent developments?

The mechanisms by which change and emergence take place are differently understood by different branches of complexity theory. First, are the notions of co-evolution and complex adaptive systems, associated with the Santa Fe Institute version of complexity theory. Second are the notions of change via 'saltation', that is, an abrupt or sudden transformation or more associated with the Prigogine influenced 'chaos' version of the theory (Harvey 2001), including the notion of 'punctuated equilibria' Eldredge (1985, 1986; Gould 1989), where there are periods of little change followed by periods of rapid sudden change. There are differences between the two schools as to whether the stimulus for such a change might lie in indigenous learning and internal development (Santa Fe Institute) or in the radical transformation of the environment (Chaos theory) (Harvey 2001).

In social science, this is a key question that requires empirical investigation to provide answers in specific contexts. For example, the extent to which there are self-sustaining paths of development, such as welfare state regimes or varieties of capitalism or gender regime, or more general or gradual processes either as result of economic development or globalisation, requires empirical investigation.

In practice, many sociological analyses using modern statistics have utilised rather simple equations, assuming a direct proportionality, a linear relationship, between the changes in the size of the phenomena under investigation (Abbot 2001). Complexity theory has challenged the easy assumption that direct proportionality, linearity, is the norm (Prigogine and Stengers 1984; Prigogine 1997). Rather, the relations between phenomena are not so simple and their statistical modelling demand equations of enormous, non-linear, complexity. This is especially the case in relation to attempts to model positive rather than negative feed back loops in systems far from equilibrium (Arthur 1989). In some cases the complexity of the equations means that they cannot be solved using the traditional analytic method, and only the power of modern computers can lead to their solution. In others, the equations are too complicated to be soluble by existing resources. This means that while the phenomena are still considered to be determined, they are unknowable using either contemporary or foreseeable techniques.

There are two schools of thought within complexity theory on this central paradox of the determined yet unknowable nature of the universe. One, following Prigogine, which is as often called chaos theory as complexity theory, embraces and emphasises the element of the unknowable, building a complex philosophy around this interpretation, with an approach to knowledge development more similar to that found in the humanities than that traditionally found in the natural sciences. A second, developed at the Santa Fe research institute, emphasises the element of determination, seeking and finding order in apparently chaotic systems, supporting a more conventional scientific approach.

Prigogine (1997) uses nuclear physics as an example of a scientific discipline that recognises that the act of scientific observation itself intervenes in and thereby alters the nature of the phenomenon under investigation. In the investigation of these sub-atomic particles there is no choice but to use observation methods that have this effect, since there are no others. This locating of the observer not merely in the middle of the phenomenon under investigation but changing it, unsettles the conventional scientific discipline that demands the clear separation of observer and observed, in order to maintain the purity of the phenomenon under investigation. The unknowability of the universe using conventional scientific techniques is one of his conclusions. This is an epistemological claim, not an ontological one (Medd and Haynes 1998). One of its implications is the search for more humanist methodologies, and the exploration of the power of metaphors.

The Santa Fe research centre by contrast has placed a high priority on finding order where others thought there was none. They searched for and found patterning in phenomena others saw as merely chaotic, indeed as random. A highly sophisticated mathematics harnessed to new computing power is the basis of their continuing faith in the potential of a merely reformed conventional scientific methodology to deliver improved knowledge of patterns in the universe.

This division into two schools of thought is echoed in the social scientific appreciation of complexity theory. On the one hand Cilliers (1998) and DeLanda (2000) emphasise the unknowability of the world, Cilliers taking complexity theory as a defence of the postmodern as opposed to modern perspective on the social world, and Delanda, full of suggestive metaphors loosely derived from complexity theory, emphasises the non-linear and lack of equilibrium in history. On the other hand Byrne (1998) uses complexity theory as a defence for realism, to support the modernist argument as to the deterministic nature of the world, arguing that complexity accounts are foundationalist.

However, while the differences between various interpretations of complexity theory may be significant (Medd 2001), the apparent divergence between the Santa Fe and Prigogine schools of complexity and chaos theory should perhaps not be overstated. If the former is seen as more concerned with mathematically modelling the inner structuration of systems, while the latter focuses on the external relations then their efforts may be considered more complementary than opposed (Harvey 2001). Any polarisation of view between realism and postmodernism is now misplaced. Rather, complexity theory allows us to transcend these old divisions. The world may be considered to be both determined and to some extent unknowable.

Conclusions

Complexity theory has developed powerful new ways of thinking about systematic relations, including the nature of systems and of change. These are of use to Sociology, especially as it grapples with the nature of the connections and changes involved in the process of globalisation. Complexity theory facilitates the development of general social theory as well as the explanation of specific contextual occurrences. It is a resource for Sociology, by offering concepts developed for analysis in parallel but not identical contexts, rather than a set of definitive constructs. Complexity theory is consistent with the classical Sociological heritage, though processes of interpretation are required in order to translate concepts into those relevant for Sociology.

Complexity theory facilitates the revision of the concept of system to grasp the unstable and dynamic processes of change. A key implication of the system/environment distinction for empirical research is that of the rejection of analysis in terms of the parts of a whole system. Systems may not be nested. This new flexibility in theorising systems facilitates the analysis of the different temporal and spatial reaches of economic, political and cultural systems, rather than assuming that they neatly overlap, as in conventional approaches to the analysis of the nation-states as society. Complexity theory addresses the nature of emergence and demonstrates the importance of non-reductionist explanations for science, including social science. The new way of thinking about systems is useful in conceptualising the nature of the connections and linkages involved in globalisation, a process that by its nature involves large-scale processes.

Complexity theory offers a new vocabulary to grasp issues of change, so that simple notions of uni-directional impact are replaced by that of mutual effect, the co-evolution of complex adaptive systems in a changing fitness landscape, as well as by concepts to capture sudden non-linear processes of rupture, saltation, and path dependency. This facilitates a more subtle understanding of the diverse processes of social change in an era of globalisation.

Bibliography

Abbot, Andrew (2001) *Time Matters: On Theory and Method*. (Chicago: Chicago University Press).
Alexander, Jeffrey C. (1982) *Theoretical Logic in Sociology: Volume 1: Positivism, Presuppositions and Current Controversies*. (London: Routledge and Kegan Paul).
Alexander, Jeffrey C. (1984) *Theoretical Logic in Sociology: Volume 4: The Modern Reconstruction of Classical Thought: Talcott Parsons*. (London: Routledge and Kegan Paul).
Alexander, Jeffrey C. (1998) *Neofunctionalism and After*. (Malden Mass: Blackwell).
Althusser, Louis (1971) *Lenin and Philosophy and Other Essays*. (London: New Left Books).
Amin, Ash (ed.) (1994) *Post-Fordism: A Reader*. (Oxford: Blackwell).
Archer, Margaret S. (1995) *Realist Social Theory: The Morphogenetic Approach*. (Cambridge: Cambridge University Press).
Arthur, W. Brian (1989) ‘Competing technologies, increasing returns, and lock-in by historical events’, *The Economic Journal*, 99, 116-131.
Arthur, W. Brian (1994) *Increasing Returns and Path Dependence in the Economy*. (University of Michigan Press).
Benhabib, Seyla (1999) ‘Sexual difference and collective identities: the new global constellation’, *Signs*, 24, 2, 335-361.
Bhaskar, Roy (1979) *The Possibility of Naturalism: A Philosophical Critique of the Contemporary Human Sciences.* London, Harvester.

Bhaskar, Roy (1989) *Reclaiming Reality*. New York, Verso.

Bhaskar, Roy (1997) *A Realist Theory of Science*. London, Verso.

Bourdieu, Pierre (1984) *Distinction: A Social Critique of the Judgement of Taste*. (London: Routledge and Kegan Paul).

Byrne, David (1998) *Complexity Theory and the Social Sciences: An Introduction*. (London: Routledge).

Calhoun, Craig (1998) 'Explanation in historical sociology: Narrative, general theory, and historically specific theory', *American Journal of Sociology*, 104, 3, 846-71.

Capra, Fritjof (1997) *The Web of Life: A New Synthesis of Mind and Matter*. (London: Flamingo).

Castells, Manuel (1996) *The Information Age: Economy, Society and Culture; Volume 1: The Rise of the Network Society*. (Oxford: Blackwell).

Castells, Manuel (1997) *The Information Age: Economy, Society and Culture; Volume II: The Power of Identity*. (Oxford: Blackwell).

Castells, Manuel (1998) *The Information Age: Economy, Society and Culture; Volume III: The End of Millennium*. (Oxford: Blackwell).

Chase-Dunn, Christopher (1989) *Global Formation: Structures of the World-Economy*. (Oxford: Blackwell).

Chu, Dominique, Roger Strand and Ragnar Fjelland (2003) 'Theories of complexity: Common denominators of complex systems', *Complexity*, 8, 3, 19-30.

Cilliers, Paul (1998) *Complexity and Postmodernism: Understanding Complex Systems*. (London: Routledge).

Coleman, James S (1990) *Foundations of Social Theory*. (Cambridge, Mass.: Belknap Press of Harvard University Press).

Crouch, Colin (2001) 'Welfare state regimes and industrial relations systems: The questionable role of path dependency', in Bernhard Ebbinghaus and Philip Manow (eds) *Comparing Welfare Capitalism: Social Policy and Political Economy in Europe, Japan and the USA*. (London: Routledge), pp. 105-124.

Crouch, Colin and Streeck, Wolfgang (eds) (1997) *Political Economy of Modern Capitalism: Mapping Convergence and Diversity*. (London: Sage).

David, Paul (1985) 'Clio and the economics of QWERTY', *American Economic Review* (Papers and Proceedings of the ninety-Seventh annual Meeting of the American Economic Association), 75, 2, 332-37.

DeLanda, Manuel (2000) *A Thousand Years of Nonlinear History*. (New York: Swerve Editions).

Durkheim, Emile (1952) *Suicide: A Study in Sociology*. (London: Routledge).

Durkheim, Emile (1966) *The Rules of Sociological Method*. (New York: Free Press).

Durkheim, Emile (1984) *The Division of Labour in Society*. (Basingstoke: Macmillan).

Durkheim, Emile (1995) *The Elementary Forms of Religious Life*. (New York: Free Press).

Eldredge, Niles (1985) *Unfinished Synthesis: Biological Hierarchies and Modern Evolutionary Thought*. (Oxford: Oxford University Press).

Eldredge, Niles (1986) *Time Frames: The Rethinking of Darwinian Evolution and the Theory of Punctuated Equilibria*. (London: Heinemann).

Emirbayer, Mustafa (1997) 'Manifesto for a relational sociology', *American Journal of Sociology*, 103, 2, 281-317.

Epstein, Joshua M. (1999) 'Agent-based computational models and generative social science', *Complexity*, 4, 5, 41-60.

Esping-Andersen, Gøsta (1990) *The Three Worlds of Welfare Capitalism*. (Cambridge: Polity).
Felski, Rita (1997) 'The doxa of difference' *Signs*, 23, 1, 1-22.
Giddens, Anthony (1984) *The Constitution of Society*. (Cambridge: Polity Press).
Giddens, Anthony (1990) *The Consequences of Modernity*. (Cambridge: Polity Press).
Goldstone, Jack A. (1998) 'Initial conditions, general laws, path dependence, and explanations in historical sociology', *American Journal of Sociology*, 104, 3, 829-45.
Goldthorpe, John H. (1969) *The Affluent Worker in the Class Sttructure*. (Cambridge: Cambridge University Press).
Goldthorpe, John H. (2000) *On Sociology: Numbers, Narratives, and the Integration of Research and Theory*. (Oxford: Oxford University Press).
Griffin, Larry J. (1993) 'Narrative, event-structure analysis, and casual interpretation in historical sociology', *American Journal of Sociology*, 98, 5, 1094-1133.
Gould, Stephen Jay (1989) *Wonderful Life: The Burgess Shale and the Nature of History*. (London: Norton).
Habermas, Jürgen. (1987) [1981] *The Theory of Communicative Action. Volume Two: The Critique of Functionalist Reason*. (Cambridge: Polity Press).
Habermas, Jürgen. (1991) [1981] *The Theory of Communicative Action. Volume One: Reason and the Rationalization of Society*. (Cambridge: Polity Press).
Hall, Peter A. and Soskice, David (eds) (2001) *Varieties of Capitalism: The Institutional Foundations of Comparative Advantage*. (Oxford: Oxford University Press).
Haraway, Donna (1997) *Modest_Witness@Second_Millennium.FemaleMan_Meets-Oncomouse: Feminism and Technoscience* New York, Routledge.
Harding, Sandra (1986) *The Science Question in Feminism*. Ithaca, Cornell University Press.
Harvey, David L. (2001) 'Chaos and complexity: Their bearing on social policy research', *Social Issues*, 1, 2.
Accessed at: http://www.whb.co.uk/socialissues/harvey.htm
Hausner, Jerzy, Bob Jessop and Klaus Nielsen (eds.)(1995) *Strategic Choice and Path-Dependency in Post-Socialism: Institutional Dynamics in the Transformation Process*. (Aldershot: Edward Elgar).
Haydu, Jeffrey (1998) 'Making use of the past: Time periods as cases to compare and as sequences of problem solving', *American Journal of Sociology*, 104, 2, 339-71.
Held, David, Anthony McGrew, David Goldblatt and Jonathan Perraton (1999) *Global Transformations: Politics, Economics and Culture*. (Cambridge: Polity Press).
Holland, John, H. (1995) *Hidden Order: How Adaptation Builds Complexity*. (Reading, Mass.: Addison-Wesley).
Holland, John, H. (2000) *Emergence: From Chaos to Order*. (Oxford: Oxford University Press).
Jervis, Robert (1997) *System Effects: Complexity in Political and Social Life*. (Princeton: Princeton University Press).
Jessop, Bob (1990) *State Theory: Putting the Capitalist State in its Place*. (Cambridge: Polity).
Jessop, Bob (ed.) (2001) *Regulation Theory and the Crisis of Capitalism: The Parisian Regulation School*. (Cheltenham: Edward Elgar).
Jessop, Bob (2002) *The Future of the Capitalist State*. (Cambridge: Polity Press).

Kauffman, Stuart A. (1993) *The Origins of Order: Self-Organization and Selection in Evolution*. (Oxford: Oxford University Press).
Kauffman, Stuart A. (1995) *At Home in the Universe: The Search for Laws of Self-Organization and Complexity*. (London: Viking).
Kiser, Edgar (1996) 'The revival of narrative in historical sociology: What rational choice theory can contribute', *Politics and Society*, 24, 3, 249-271.
Kiser, Edgar and Michael Hechter (1991) 'The role of general theory in comparative-historical sociology', *American Journal of Sociology*, 1, 1-30.
Knodt, Eva M. (1995) 'Foreword' to Niklas Luhmann, *Social Systems*. (Stanford: Stanford University Press).
Latour, Bruno (1987) *Science in Action: How to Follow Scientists and Engineers Through Society*. (Milton Keynes: Open University Press).
Law, John (ed.) (1991) *A Sociology of Monsters: Essays on Power, Technology and Domination*. (London: Routledge).
Liebowitz, S. J. and Stephen E. Margolis (1995) 'Path dependence, lock-in, and history', *The Journal of Law, Economics, and Organization*, 11, 1, 205-226.
López, José and John Scott (2000) *Social Structure*. (Buckingham: Open University Press).
Luhmann, Niklas (1985) *A Sociological Theory of Law*. (London: Routledge and Kegan Paul).
Luhmann, Niklas (1990) 'The autopoiesis of social systems' in Niklas Luhmann *Essays on Self-Reference*. (New York: Columbia University Press).
Luhmann, Niklas (1995) *Social Systems*. (Stanford: Stanford University Press).
Luhmann, Niklas (2000) *Art as a Social System*. (Stanford: Stanford University Press).
Lyotard, Jean-Francois (1978) *The Postmodern Condition: A Report on Knowledge*. (Minneapolis: University of Minneapolis Press).
Mahoney, James (2000) 'Path dependency in historical sociology', *Theory and Society*, 29, 507-548.
Marx, Karl (1954) *Capital*. Volumes, 1, 2, 3. (London: Lawrence and Wishart).
Marx, Karl (1963) *The Eighteenth Brumaire of Louis Bonaparte*. (New York: International Publishers).
Marx, Karl and Friedrich Engels (1967) *The Communist Manifesto*. (London: Penguin).
Maturana, Humberto R. and Francisco J. Varela (1980) *Autopoeisis and Cognition: The Realization of the Living*. (Dordrecht: Reidel).
Maturana Humberto R. and Francisco J. Varela (1987) *The Tree of Knowledge: The Biological Roots of Human Understanding*. (London: Shambhala).
Mead, George Herbert (1934) *Mind, Self and Society*. (Chicago: Chicago University Press).
Medd, Will (2001) 'Making (Dis)connections: Complexity and the policy process?', *Social Issues*, 1, 2. Accessed at: http://www.whb.co.uk/socialissues/wm.htm
Medd, Will and Paul Haynes (1998) 'Complexity and the social', accessed at: http://www.keele.ac.uk/depts/stt/cstt2/comp/medd.htm
Merton, Robert K. (1968) *Social Theory and Social Structure*. (New York: Free Press).
Milward, A.S. (1992) *The European Rescue of the Nation-State*. (New York: Routledge).
Mitleton-Kelly, Eve (2001) *Ten Principles of Complexity and Enabling*

Infrastructures
http://is.lse.ac.uk/complexity/PDFiles/publication/Ch2_Mitleton_Kelly.pdf
Mouzelis, Nicos (1993) *Back to Sociological Theory: The Construction of Social Orders*. (London: Macmillan).
Mouzelis, Nicos (1995) *Sociological Theory: What Went Wrong? Diagnosis and Remedies*. (London: Routledge).
Nee, Victor and Yang Cao (1999) 'Path dependent societal transformation: Stratification in hybrid mixed economies', *Theory and Society*, 28, 799-834.
Nicolis, Gregoire and Ilya Prigogine (1989) *Exploring Complexity: An Introduction*. (New York: W.H. Freeman).
North, Douglass C. (1990) *Institutions, Institutional Change and Economic Performance*. (Cambridge: Cambridge University Press).
Parsons, Talcott (1949) *The Structure of Social Action: A Study in Social Theory with special reference to a group of recent European writers*. 2nd edition. (Glencoe. Ill.: The Free Press).
Parsons, Talcott (1951) *The Social System*. (New York: The Free Press).
Pickering, Andrew (1995) *The Mangle of Practice: Time, Agency and Science*. (Chicago: Chicago University Press).
Pierson, Paul (2000a) 'Increasing returns, path dependence, and the study of politics', *American Political Science Review*, 94, 2, 251-268.
Pierson, Paul (2000b) 'Not just what, but *When*: Timing and sequence in political processes', *Studies in American Political Development*, 14, 72-92.
Pierson, Paul (ed.) (2001) *The New Politics of the Welfare State*. (Oxford: Oxford University Press).
Poulantzas, Nicos (1973) *Political Power and Social Classes*. (London: Verso Books).
Prigogine, Ilya (1997) *The End of Certainty: Time, Chaos, and the New Laws of Nature*. (New York: Free Press).
Prigogine, Ilya and Isabelle Stengers (1984) *Order Out of Chaos: Man's New Dialogue with Nature*. (London: Heinemann).
Reed, Michael and David L. Harvey (1992) 'The new science and the old: complexity and realism in the social sciences', *Journal for the Theory of Social Behaviour*, 22, 4, 353-380.
Rihani, Samir (2001) *Complex Systems Theory and Development Practice: Understanding Non-Linear Realities*. (New York: Zed Books).
Robinson, William I. (2001) 'Social theory and globalization: The rise of a transnational state', *Theory and Society*, 30, 157-200.
Rose, Steven (1997) *Lifelines: Biology, Freedom, Determinism*. (London: Allen Lane).
Rycroft, Robert W. and Don E. Kash (1999) *The Complexity Challenge: Technological Innovation for the 21st Century*. (London: Pinter).
Sayer, Andrew (1992) *Method in Social Science: A Realist Approach*. 2nd edition. (London: Routledge).
Scott, John (2001) *Social Network Analysis: A Handbook*. 2nd edition. (London: Sage).
Skocpol, Theda (1979) *States and Social Revolutions*. (Cambridge: Cambridge University Press).
Smelser, Neil J. (1959) *Social Change in the Industrial Revolution: An Application of Theory to the Lancashire Cotton Industry, 1770-1840*. (London: Routledge and Kegan Paul).

Smith, Dorothy (1987) *The Everyday World as Problematic: A Feminist Sociology*. (Boston: Northeastern University Press).
Somers, Margaret R. (1998) '"We're no angels": Realism, rational choice, and relationality in social science', *American Journal of Sociology*, 104, 3, 722-84.
Swank, Duane (2002) *Global Capital, Political Institutions, and Policy change in Developed Welfare States.* (Cambridge: Cambridge University Press).
Taylor, Charles et al (1994) *Multiculturalism: Examining the Politics of Recognition*. (Princeton: Princeton University Press).
Teubner, Gunther (ed.) (1997) *Global Law Without a State*. (Aldershot: Dartmouth).
Urry, John (2003) *Global Complexity*. (Cambridge: Polity Press).
Urry, John (2004 forthcoming) 'The "system" of automobility', *Theory, Culture and Society*.
Von Bertalanffy, L. (1968) *General Systems Theory: An Outline of a General Theory of Models*. (New York: George Brazillier).
Walby, Sylvia (1999) 'The new regulatory state: the social powers of the European Union', *British Journal of Sociology*, 50, 1, 118-140.
Walby, Sylvia (2001) 'Against epistemological chasms: the science question in feminism revisited' *Signs: A Journal of Women in Culture and Society*, 26, 2, 485-509.
Walby, Sylvia (2003) 'The myth of the nation-state: Theorising society and polities in a global era', *Sociology*, 37,3, 531-548.
Walby, Sylvia (2005 forthcoming) *Complex Modernities*. (London: Sage).
Waldrop, M. Mitchell (1992) *Complexity: The Emerging Science at the Edge of Order and Chaos*. (London: Penguin).
Wallerstein, Immanuel (1974) *The Modern World-System: Capitalist Agriculture and the Origins of the European World-Economy in the Sixteenth Century*. (New York: Academic Press).
Weber, Max (1948) *From Max Weber: Essays in Sociology*. Translated and edited by H.H. Gerth and C.W. Mills. (London: Routledge and Kegan Paul).
Weber, Max (1958) *The Religion of India: The Sociology of Hinduism and Buddhism* (Glencoe: Free Press).
Weber, Max (1968) *Economy and Society: An Outline of Interpretive Sociology*. Volumes 1, 2, 3. Edited by Guenther Roth and Claus Wittich. (New York: Bedminster Press).
Weber, Max (1994) *The Protestant Ethic and the Spirit of Capitalism*. (London: Routledge).
Wilke, Helmut (1997) 'Autopoeisis and organised complexity' accessed at http://bprc.warwick.ac.uk/lseeg3.html