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> I think the next century will be the century of complexity. (Stephen Hawking, cited in Sanders and McCabe, 2003: 5)

> Where small-world ideas will lead us in five or ten years is anyone's guess, but they may reveal something about the way our ideas link up with one another, how discoveries in biology, computer science, sociology and physics can be so intimately connected. (Buchanan, 2002: 208)

> The protestors are winning. They are winning on the streets. Before too long they will be winning the arguments. Globalisation is fast becoming a cause without credible arguments. (*Financial Times*, 17 August 2001, cited in Aingers et al., 2003: 503)

Introducing Complexity

Various analysts at the beginning of the 21st century are developing and applying the physics of complexity to contemporary social science. This article is organized around this emergent literature and examines overlaps and interplays between analyses of physical and social worlds. This literature is seeking to found what we might term a 21st-century social physics. Physicists and mathematicians seeking to analyse especially the mathematics of networks are turning to the sociology of social networks (see physicist-turned-sociologist Watts, 1999, 2003; Barabási, 2002; Buchanan, 2002). While sociological and more general social science analyses of global processes increasingly deploy the physics and mathematics of complex, non-linear adaptive systems (see Capra, 2002, for an interesting crossover).

Various social analysts of modernity and globalization implicitly draw upon 'complexity' concepts and ideas even where these are not explicitly articulated. Giddens (1990) characterizes the modern world as being like a driverless out-of-control 'juggernaut' system that has set in motion irreversible processes stretching across the globe and generating various

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uncontrollable side-effects. Harvey (1989) describes the processes by which time and space are not given and absolute but are increasingly 'compressed' by various novel technologies of transportation and communications that subdue and unify space. More recently, Bauman (2000) describes the nature of a speeded-up 'liquid modernity', as it shifts from being heavy and solid to being light and liquid, and where speed of movement of people, money, images and information is paramount. Analogously, Hardt and Negri suggest that nation-state sovereignty has been replaced by a single system of mobile power, of 'empire'. This is a 'smooth world', de-territorialized and decentred, without a centre of power and with no fixed boundaries or barriers. All is movement (Hardt and Negri, 2000: 136).

Castells sees the strength of increasingly global networks as resulting from their self-organizing nature and not from centralized hierarchical direction as with older-style rational-legal bureaucracies. He shows the 'chaotically' subversive effects of the personal computer upon the state bureaucracy of the Soviet Union that historically controlled all information flows, including access to the photocopier (Castells, 1996: 36–7, 2001). With regard to science, Rifkin notes that contemporary 'science' no longer sees phenomena 'as static, fixed and given'; the observer is seen as changing that which is observed, apparent hard and fast entities always comprise movement, and there is no structure seen as separate from process (2000: 191–3). While Beck (Beck and Willms, 2003) describes various boomerang effects, how corporations and states generate consequences that return to haunt them since there are complex systems where everyone is simultaneously inside and outside. Each suffers the unintended consequences of the boomerang returning to slice off the head of its thrower. Elsewhere, Urry (2003) deploys the notion of 'global complexity' to examine the uneven, unpredictable and for a time irreversible processes of change sweeping across the contemporary landscape.

So notions of a new 'social physics' are in the air; there is an emergent complexity 'structure of feeling' (Kwa, 2002; Maasen and Weingart, 2000; Thrift, 1999). Indeed, a complexity manifesto is being developed in various works exploring the overlaps and parallels between the physical, biological and social worlds. Most notably, Capra has produced a 'unified conceptual framework for the understanding of material and social structures' (2002: xv, see also Capra, this volume). Many writers are analysing 'events, novelty and creativity', seeing these as organized in and through various non-linear dynamic systems possessing emergent or vitalist properties (see Fraser et al., 2004).

The US-based Gulbenkian Commission on the Restructuring of the Social Sciences, chaired by Wallerstein and including non-linear scientist Prigogine, reflected this emerging complexity turn. It advocated breaking down the division between 'natural' and 'social' science since both are to be seen as characterized by 'complexity' (Wallerstein, 1996). The Commission recommended how scientific analysis 'based on the dynamics of non-equilibria, with its emphasis on multiple futures, bifurcation and choice, historical dependence, and . . . intrinsic and inherent uncertainty' should be the model for the social sciences and this undermines, they argue, clear-cut divisions between social and natural science (Wallerstein, 1996: 61, 63).

While physicists Laughlin and Pines summarize how, while physics once studied fundamental laws to which everything could be reduced, it now studies multiple forms of organization: 'The central task . . . is no longer to write down the ultimate equations but rather to catalogue and understand emergent behaviour. . . . We are witnessing a transition from . . . reductionism, to the study of complex adaptive matter' (cited in Buchanan, 2002: 207). Self-assembly at the nanoscale is a current example within science and technology of new analyses of complex organization.

Complex Relationality

I am not seeking to characterize here the complexity sciences in general, but just to outline some characteristics of 'complex relationality' relevant to the subsequent analysis of global relationships. There are very many relevant contributions derived from the physical and social sciences (see Axelrod and Cohen, 1999; Byrne, 1998; Capra, this volume; Casti, 1994; Cilliers, 1998; Davies, 2001; De Landa, 1997; Eve et al., 1997; Hayles, 1991, 1999; Jervis, 1997; Kauffman, 1993; Kelly, 1995; Krugman, 1996; Maturana, 1981; Mingers, 1995; Prigogine, 1997; Prigogine and Stengers, 1984; Rasch and Wolfe, 2000; Rescher, 1998; Rycroft and Kash, 1999; Urry, 2003; Watts, 2003; White, 1992; Zohar and Marshall, 1994). What then are some characteristics of complex relationality? (see Cilliers, this volume.)

Overall, complexity science investigates systems that adapt and evolve as they self-organize through time (see Mitleton-Kelly, 2003). Such complex social interactions have been likened to walking through a maze whose walls rearrange themselves as one walks. New steps then have to be taken in order to adjust to the walls of the maze that adapt to one's movement through the maze (Gleick, 1988: 24). Complexity thus investigates emergent, dynamic and self-organizing systems that interact in ways that heavily influence the probabilities of later events (Prigogine, 1997: 35). Such intersecting systems are like a 'dynamical zoo' involving changes in patterns that are 'wildly unlike the smoothly additive changes of their simpler cousins' (Axelrod and Cohen, 1999: 14). This complex systems world is a world of avalanches, of founder effects, self-restoring patterns, apparently stable regimes that suddenly collapse, punctuated equilibria, 'butterfly effects' and thresholds as systems tip from one state to another.

Such dynamic, non-linear and complex properties of physical, biological and social systems stem from new ways of understanding 'movement'. In the 20th century, science saw the collapse of classical physics based upon absolute time and space, solid impenetrable matter made up of interacting 'billiard balls' and strictly determinant laws of motion. In its place there is 'the strange world of quantum physics, an indeterminate world whose almost eerie laws mock the boundaries of space, time and matter' (Zohar and Marshall, 1994: 33). Large-scale patterns or properties emerge from, but are not reducible to, the micro-dynamics of particular phenomena. Thus gases are not uniform entities but comprise a seething confusion of atoms with the interactions, obeying the laws of quantum mechanics, more important than the elements themselves. The laws governing gases derive not from the behaviour of each individual atom but from their statistical relational patterning; as Bohm put it, it is the dance not the dancers that are key.

As a consequence, according to Prigogine, there is the 'end of certainty' as the complexity sciences overcome the 'two alienating images of a deterministic world and an arbitrary world of pure chance' (1997: 189). Complexity science repudiates the dichotomies of determinism and chance, as well as stasis and change. Complex systems with very large numbers of elements do not simply sustain unchanging stability. Complexity elaborates how there is always order and disorder within physical and social phenomena, and especially in various hybrids. Order and chaos are often in a kind of balance where the components are neither fully locked into place but yet do not dissolve into anarchy. They are 'on the edge of chaos'.

Such systems are viewed as interacting dissipatively with their environment so constituting 'islands of order' within an increasingly turbulent sea of disorder (Prigogine, cited in Capra, 1996: 184). Processes are far-from-equilibrium, or, better, there are multiple equilibria. Interactions between elements are non-linear so that 'very small perturbations or fluctuations can become amplified into gigantic, structure-breaking waves' (Prigogine and Stengers, 1984: xvii). Elements at one location have significant time–space effects elsewhere through multiple connections and trajectories, such as individual local decisions to drive by car (rather than to use slower modes, take public transport or live closer to work or family) resulting in extensive emergent 'far-from-equilibrium' effects of an 'out-of-control' global car system (see Cilliers, 1998; Urry, 2004). These connections between agents' actions and emergent system effects occur through an irreversibility of time (as opposed to the reversible time of classical physics; see Coveney and Highfield, 1990).

Moreover, such non-linear phenomena dominate more of the inanimate world than was previously thought, being 'an essential aspect of the network pattern of living systems' (Capra, 1996: 122). With non-linearity there is no consistent relationship between causes and effects. The same 'cause' can in specific circumstances produce quite different kinds of effect. Minor changes in the past can produce potentially large effects in the present since small events are not 'forgotten' (Gleick, 1988). In a non-linear system: 'adding two elementary actions to one another can induce dramatic new effects reflecting the onset of cooperativity between the constituent elements. This can give rise to unexpected structures and events whose properties can be quite different from those of the underlying elementary laws' (Nicolis, 1995: 1–2).

Thus, over time, there are not only negative feedback mechanisms, that were the basis of earlier cybernetic systems theory. There are also positive feedback loops that drive change and set up 'self-reinforcing systems' through positive feedback (Hayles, 1991, 1999). There can be increasing returns and different patterns of path-dependent development (see Arthur, 1989, 1994). What is important in this analysis is the ordering of events or processes since 'history matters' and different paths could have been taken (Mahoney, 2000: 536; North, 1990: 100; Walby, 2002, on how history matters in gender regimes). The system of petroleum-based automobility stemmed from increasing returns from the end of the 19th century onwards. Once economies and societies were 'locked in' to the steel-and-petroleum car, then increasing returns resulted for those producing and selling the car and associated infrastructure (even though petrol was initially the least promising fuel system: see Arthur, 1989). From small causes, economies and societies were locked into a pattern that ensured the preconditions for automobility's self-expansion over the 'century of the car' (see Urry, 2004).

Such long-term emergent (or what others term vitalist) patterns emerge from co-evolution and mutual adaptation. A complex system is the result of a rich interaction of simple elements that 'only respond to the limited information each is presented with' (Cilliers, 1998: 5). Agents act in terms of the local environment, but each entity adapts to, or coevolves with, local circumstances within an environment in which other similar entities are also adapting (Gilbert, 1995: 148). Each co-evolves, demonstrating a 'capability to "orientate" to macro-level properties' so bringing into being emergent properties (Gilbert, 1995: 151).

In particular, the emergence of patterning within a given system over time results from the mathematics of 'attractors'. If a dynamic system does not move over time through all possible parts of a phase space but instead occupies a restricted part of it, then this is said to result from attractors (see Byrne, 1998: 168–9). The simplest attractor is a point, as with the unforced swinging of a pendulum. Everything reaches the single equilibrium point. A more complex example is a domestic central heating/air conditioning system, where the attractor consists, not of a single point, but of a specified range of temperatures. The relationship is not linear but involves a negative feedback mechanism that minimizes deviance (De Landa, 1997: 68). And in certain systems there are 'strange attractors', to which the trajectory of dynamical systems is attracted through billions of iterations and positive feedbacks. Such a space may be either indeterminate within the boundaries or there may be various sets of boundaries, as with the butterfly-shaped Lorenz attractor. Such attractors are immensely sensitive in the effects that they generate in response to slight variations in their initial conditions: And as iteration occurs time and time again, so an unstable but patterned disorder develops (Casti, 1994: 28–32). Much science has been concerned to characterize the topology of such strange attractors. Iterations in non-linear systems result in values that topologically produce a kind of repeated stretching and folding effect, often known as the 'baker transformation' (Capra, 1996: ch. 6).

Finally, points of bifurcation may be reached when the system branches as it moves through a fitness landscape. If a system passes a particular threshold with minor changes in the controlling variables, switches occur and emergent properties turn over. Thus a liquid may turn or tip into a gas, relatively warm weather suddenly transforms into an ice age, agricultural societies turn into industrial economies. The Bénard instability particularly shows such a patterning (Prigogine and Stengers, 1984: 212–18). As the temperature rises between two horizontal plates there is no specific pattern among the molecules. However, as a threshold gets crossed, organization occurs forming hexagonal cells. But if the temperature rises still further, molecules demonstrate chaotic behaviour. The Bénard cells maintain their self-organizing fluid pattern as long as the temperature remains within certain limits. If the temperature moves above or below the threshold then the self-organizing pattern breaks down.

Thus complex systems (as opposed to the many linear non-complex systems) are potentially unstable, nothing is fixed forever and there is: 'the possibility for a pattern of actions to occur to put the key in the lock and make a major turning point occur' (Abbott, 2001: 257). Systems move across turning or tipping points. As analysed by Gladwell, tipping points involve three notions: that events and phenomena are contagious; that little causes can have big effects; and that changes can happen dramatically at a moment when the system switches. Recent examples of this include the consumption of fax machines and of mobile phones, when at a given moment every office seems to need a fax machine or every mobile person needs a mobile phone, and the system dramatically flips over (Gladwell, 2000: 272–3).

Complexity and Marx

It may seem odd to turn here to Marx's analysis of capitalism, but, in some ways, his account from a century and a half ago of the unfolding 'contradictions' of the capitalist mode of production is the best example of complexity analysis within the social sciences (even though he did not possess the relevant language: see Byrne, 1998; Reed and Harvey, 1992). Such an assessment has also been articulated by biologist John Maynard Smith, who says of Marx and Engels: 'I think the reason why they were dialectical materialists was that they were trying to understand . . . complex systems in a world in which there was no mathematical language . . . that they could use to describe them' (1994: 688–9). Marx's writings are especially relevant to thinking through ways of analysing 'global complexity'.

The Manifesto of the Communist Party argues that the: 'need for a constantly changing market chases the bourgeoisie over the whole surface of the globe. It must settle everywhere, establish connexions everywhere' (Marx and Engels, 1952: 46–7; see also Elster, 1985; Harvey, 2000). This putative globalization results from how individual capitalist enterprises maximize profits and hence pay their workers as little as feasible or make them work as long as possible. This 'exploitation' continues unless the state, or collective action by trade unions, prevents it. The consequence of repeated local actions reproduces the capitalist system and its emergent properties of class relations. Substantial profits are generated, so offsetting what Marx hypothesized as the tendency of the rate of profit to fall. Such profits reproduce the emergent class relations of capital and wage-labour that are integral to the capitalist system. Out of those profits certain 'ideal collective interests' of capital are met through a 'capitalist state' that secures and sustains the legal form of private property, the availability of appropriate labour-power, the conditions of the circulation of capital and so on (see Jessop, 2002, on the nature of capitalist states).

However, sustaining order through each capitalist exploiting their local workforce simultaneously results in emergent contradictions. First, since it is in the interests of each enterprise (but not of all enterprises), to minimize the wages paid to their employees, the emergent level of demand for capitalist commodities is sub-optimal (Elster, 1985: 46–7). Hence, there is over-production, the under-employment of capitalist resources (especially labour-power) and periodic capitalist crises that call into question the system as a whole, although these are subsequently mitigated in the mid-20th-century 'West' through 'Keynesian' policies to increase 'effective demand' through public expenditure.

Further, capitalist competition produces a workforce that is relatively deprived and has the potential to be increasingly organized. Emergent from ordered capitalist relations is a working class that, through widespread class struggle, will generate social revolution – 'workers of the world unite' – and the establishment of a 'higher' emergent order of 'communism'. Capitalist relations over millions of iterative actions are seen as producing the opposite of what capitalists intend to reproduce through exploiting their particular workforce: an emergent working class that is increasingly internationalized.

And the geographical limitations of existing capitalist markets lead individual capitalist firms to seek alternative markets. *The Manifesto of the Communist Party* describes how the: 'need for a constantly changing market chases the bourgeoisie over the whole surface of the globe . . . the bourgeoisie has through its exploitation of the world market gives a cosmopolitan character to production and consumption in every country' (Marx and Engels, 1952: 46–7). This worldwide capitalist expansion will thus: 'smash down Chinese walls' and spread capitalist exploitation and hence the emergent proletarian class worldwide. Thus local capitalist exploitation results, Marx argues, in non-linear emergent effects of a revolutionary proletariat increasingly organized across the globe (Harvey, 2000; Marx and Engels, 1952), as well as a 'catastrophic' (in terms of the existing system) branching of capitalism into a new emergent order of world communism (Reed and Harvey, 1992). In seeking its own transcendence from wage-slavery the proletariat generates a new emergent order overcoming these various contradictions of the non-linear capitalist system.

We now know that this analysis was 'mistaken' in predicting worldwide social revolution that would start first in the most advanced capitalist political economies. However, complexity analysis may illuminate why this might have been so. Relatively small perturbations in the capitalist system produced a different branching from what Marx predicted a century-and-a-half ago. Only a relatively small set of causes would have been necessary to generate a radically different emergent outcome. Thus it may have been only rather minor 'causes' that produced a branching of capitalism towards a post-Fordist 'welfare' consumerism during mid-20th-century capitalism. It may not have been such a striking failure of Marx's analysis of capitalism that worldwide social revolution did not emerge out of the emergent contradictions of the capitalist system.

Generally, therefore, Marx's structure of argument illuminates 'complex relationality'. We have seen how such complex relationality explains the ways in which local forms of information and action can result in the emergence of far-from-equilibrium system effects. According to Marx, each capitalist firm operates under non-equilibrium conditions and responds to 'local' sources of information and opportunity. The emergent complex system results from a rich interaction of these simple elements that responds to the limited information each is presented with (Cilliers, 1998: 5). Capitalists and workers act in terms of the local environment but each adapts to, or co-evolves with, these local circumstances. But each only does so within an environment in which others are also adapting, so that changes in one will have consequences for the environment and thus for what others are able to do (Gilbert, 1995: 148). Emergent consequences result from adaptations and co-evolution through countless iterations at a 'local' level, but where through emergence consequences never remain local and systems (such as global capitalism) are not under 'control' (being like a juggernaut or with boomerang effects).

Finally, here Marx famously contributes to understanding the relationship between 'structures' and 'agents' through arguing that:

> Men [sic] make their own history, but they do not make it just as they please; they do not make it under circumstances chosen by themselves, but under circumstances directly found, given and transmitted from the past. The tradition of all the dead generations weighs like a nightmare on the brain of the living. (Marx and Engels, 1968: 96)

Many have attempted to interpret and develop this phrasing that captures how neither structures nor agents are dominant and in which 'history matters'. Within contemporary sociology this formulation has been elaborated within Giddens' conception of the 'duality of structure' (1984). He examines the temporal or recursive processes by which 'structures' are both drawn on to generate actions, and then are the unintended outcome of recursive actions by knowledgeable agents. So, as with Marx, there is not a dualism but a 'duality' in which structure and agency are bound together and co-evolve over time. This structurationist formulation breaks with linear notions since it sees the rules and resources of systems as drawn upon by knowledgeable agents and then feeding back through actions to reproduce system rules and resources. There are not fixed and separate entities of 'structure' and 'agents' that possess variable characteristics, a view powerfully critiqued by Abbott (2001).

However, turning a complexity lens on Giddens brings out how he insufficiently examines the complex, systemic character of these structure-agency processes. These are, I would argue, better understood through the concept of 'iteration' rather than 'recurrence'. Iteration means that the tiniest of 'local' changes can generate, over many repeated actions, unexpected, unpredictable and chaotic outcomes, sometimes the opposite of what agents thought they were intending. Events are not 'forgotten' within the analysis of such systems. Complex changes stem from how agents iteratively respond to local configurations. Agents may conduct what appear to be the same actions involving a constant imitation of, or response to, the local actions of others. But because of what can be tiny adaptations of other agents, iteration results in transformations in even large-scale structures. Iteration can produce through emergence, non-linear changes and the sudden branching of large structures. Change can occur without a determining 'agency'.

And, indeed, if we return once more to Marx, what he emphasized is that the relations of production are composed not just of relations of person to person, group to group, class to class. He characterizes systems composed of dynamic intersecting forces and relations of production, and in many of his substantive analyses there are detailed analyses of what I term 'material worlds'. Such worlds are never the outcome of social processes, since 'the notion that social ordering is, indeed simply social also disappears. . . . what we call the social is materially heterogeneous: talk, bodies, texts, machines, architectures, all of these and many more are implicated in and perform the social' in a way, as Marx tried to capture, without the advantage of the last 150 years of social science (Law, 1994: 2).

Rethinking the Global

So far I have examined some general characteristics and features of a complexity analysis of various systems. It has also been suggested that, in certain ways, Marx prefigured some elements of complexity analysis, although he struggled to characterize his argument without the terminology now available. He was a complexity-theorist *avant la lettre*. I now consider whether complexity helps understanding of the diverse material worlds implicated in the 'globalization' of economic, social, political, cultural and environmental relationships (for more detail, see Rosenau, 2003; Urry, 2003).

We can begin by noting that there are various systems formulations that take the unit of analysis to be 'society'. Famously, Talcott Parsons' cybernetically influenced writings view societies as autonomous and self-reproducing. 'Society', he says, is 'the type of social system characterized by the highest level of self-sufficiency relative to its environment, including other social systems' (Parsons, 1971: 8, see also Hayles, 1991, 1999; Parsons, 1960). Such a view stemmed from the apparent autonomy of American society, a characteristic universalized to all other societies without noticing the specificity of the 20th-century USA. Parsons presumes that there is within such autonomous societies a hierarchy of values and norms that works through society at all levels, a notion of social equilibrium, and strong negative feedback or steering mechanisms that can rapidly and effectively restore societal order (see Luhmann, 1990, 1995, for a related if more sophisticated analysis of systems as complexity-reducing).

We have seen that the notions of complex relationality suggest that there would not be such a clear and effective set of internal processes constituting a reinforcing or nested hierarchy. Moreover, processes to restore order almost always engender unforeseen consequences, taking the society further away from equilibrium. There are positive as well as negative feedback mechanisms. And even if societies were once bounded, which, given the empirical significance of empires, is unlikely, they are not any more. Indeed, over the past decade the social science of globalization has extensively described many of these relationships that transcend the societal. Criss-crossing 'societies' are many mobile, material systems in complex interconnections with their environments, having effects time–space distantiated from where they originate, and with positive as well as negative feedback mechanisms that mean that order and chaos are always intertwined. There are various self-organizing networks moving systems far from equilibrium, and there is no social order accounted for by 'purified' social processes.

However, this social science has mostly presumed an all-powerful global level or scale as integrated and homogeneous, transforming in linear fashion localities, regions, nation-states, environments and cultures. Globalization (or global capitalism) is the new 'structure', while nations, localities, regions and so on, comprise the new 'agent', to employ conventional social science distinctions but given a global twist. Globalization is often taken to be both the cause and the effect of contemporary processes (see Rosenberg's critique, 2000). The global is a new larger and more powerful 'region' that is able to bend localities, regions, nation-states, environments and cultures to its mighty will. Many different entities or scales are then reduced to globalization seen as a successful and dominant structure (see, for reductionist globalization, Albrow, 1996; Chase-Dunn et al., 2000; Fukuyama, 1992; Martin and Schumann, 1997; Ohmae, 1999).

But various iconic events of the new world disorder problematize such reductionist globalization. The events of 11 September 2001 showed the disorder, paradox, the unexpected and the revenge of the repressed (see Malpas and Wickham, 1995, on the necessity of system failures). The linear metaphor of scales, stretching from the local to the global, or from the micro level to the macro level, does not seem plausible and should be replaced by analyses of multiple systems of mobile connections. There is no top or bottom of the global, but many systems of connections or circulations that effect relationality at multiple and varied materialities and distances.

More generally, Latour maintains that: 'there is no zoom going from macro structure to micro interactions . . . [since] both micro and macro are local effects of hooking up to circulating entities' (1999: 19). Thus the social (and the global): 'possesses the bizarre property of not being made of agency or structure at all, but rather of being a circulating entity' (Latour, 1999: 17). There are many systems that are neither macro nor micro but circulate between each through what Dillon summarizes as: 'speed; velocity; waves; continuous flow; pulsing; fluidity and viscosity; rhythm; harmony; discordance; and turbulence' (2000: 12). Such systems are more or less intense, more or less social, more or less 'networked' and more or less 'at a distance' (Dicken et al., 2001: 102–4; see Rosenau, 2003, on 'fragmegration').

Overall, then, there is not so much a reductionist but a complex relationality (or global complexity). This involves a wide array of systems of networked or circulating relationships implicated within different overlapping and increasingly convergent mobile, material worlds or hybrids. The global, then, is comprised of various systems, operating at various levels or scales, and each constitutes the environment for each other. Thus, criss-crossing 'societies' are many other mobile, material systems in complex interconnection with their environments.

There are two main forms taken by these systems, what I call global networks and global fluids. The first provides a way of rethinking the analysis of McDonaldization through the lens of the analysis of actor-network theory (Law and Hassard, 1999; Ritzer, 1998). Very many phenomena across the world are organized through globally integrated networks such as that characterizing McDonalds. Such a network is tightly coupled with enduring and predictable connections between peoples, objects and technologies that stretch across multiple and distant spaces and times (Law, 1994: 24; Murdoch, 1995: 745). Relative distance is a function of the relations between the components comprising that network. The invariant outcome of a network (the same service) is delivered across space in ways that overcome regional boundaries through a network of technologies, skills, texts and brands (as Mol and Law, 1994, discuss in the case of scientific findings that can travel in such ways). These networks are globally integrated and ensure that the same 'service' or 'product' is delivered in more or less the same way across the network. There is 'normally' a lack of network failure.

Such services and products are predictable, calculable, routinized and standardized. Many 'global' enterprises organized through such globally integrated networked relations, such as McDonalds, American Express, Coca Cola, Microsoft, Sony, Greenpeace, Manchester United, and the other 44,000 or so multinational corporations (Klein, 2000; Ritzer, 1998). These are powerful networks, often located in many societies, but where the relations between the nodes of the network are critical.

Second, there are various systems that I refer to as global fluids, entities that are somehow not simply networked. Examples of powerful global fluids include world money (Eatwell and Taylor, 2000), automobility (Urry, 2004), social movements (Sheller, 2000), digitized information (Brand, 1999), the internet (Plant, 1997), the anti-globalization movement (Aingers et al., 2003), international terrorism (Gunaratna, 2002), smart mobs (Rheingold, 2002) and so on.

Global fluids travel along various routeways or scapes, but they may escape, rather like white blood corpuscles, through the 'wall' into surrounding matter and effect unpredictable consequences upon that matter. Fluids move according to novel shapes and temporalities as they break free from the linear, clock-time of existing socio-scapes. Such fluids result from people acting upon the basis of local information and relationships, but where these local actions are, through iteration, captured, moved, represented, marketed and generalized, often impacting upon hugely distant places and peoples. Such fluids demonstrate no clear point of departure, just self-organization and movement at certain speeds and at different levels of viscosity with no necessary end-state or purpose. Fluid systems create over time their own context for action rather than being 'caused' by such contexts. This self-organization can occur dramatically and overwhelmingly, like a flood or a torrent moving between or across borders or boundaries.

The iconic global fluid is the internet. This rather obscure technology, designed by the American defence intelligence in the 1970s and 1980s, unpredictably resulted in an astonishing worldwide system of many-to-many communications around the globe. The transformation of this distributed, horizontal military-based system into the hugely fluid global internet stemmed from various American scientific and research networks, and from counter-cultural efforts to produce a computer network that possessed horizontal public access. The internet did not originate within the business world, nor from within any single state bureaucracy (see Castells' history, 2001). In significant ways, its users are key producers of the very technology. The autopoietic, self-organizing character of the internet is described as follows:

> No central hub or command structure has constructed it. . . . It has installed none of the hardware on which it works, simply hitching a largely free ride on existing computers, networks, switching systems, telephone lines. This was one of the first systems to present itself as a multiplicitous, bottom-up, piecemeal, selforganizing network which . . . could be seen to be emerging without any centralized control. (Plant, 1997: 49)

The internet is the best example of how a technology invented for one purpose, military communication in the event of a nuclear attack, unpredictably and irreversibly evolved through iteration into purposes unintended and undreamt of by its early developers.

It has resulted in a massive worldwide activity, with 16 million users in 1995, 400 million users in early 2001, and a predicted 1 billion by 2005

(Castells, 2001: 3). Information on the internet is doubling every few months (Brand, 1999: 14, 87). An awesome pattern of path dependence has been laid down. The internet enables horizontal communication that cannot be effectively surveilled, controlled or censored by national societies. It possesses an elegant, non-hierarchical rhizomatic global structure and is based upon lateral, horizontal hypertext links that render the boundaries between objects within the archive endlessly fluid.

The internet can be seen as a metaphor for global fluids, involving thousands of networks, of people, machines, programmes, texts and images in which quasi-subjects and quasi-objects mix together in new hybrid post-human forms. Ever-new computer networks and links proliferate mostly in unplanned and mixed patterns. Such a fluid space is a world of mixtures. Messages 'find their way', rather like blood, through multiple capillaries. Fluids can get around absences. Such computer networks are not solid or stable and are contingent. Hypertext programmes and the internet comprise: 'webs of footnotes without central points, organizing principles, hierarchies' (Plant, 1997: 10).

Somewhat analogously, the anti-globalization movement can be described as a non-hierarchical rhizomatic global fluid:

> Like a virus, uncontrollable and untameable, this inspiration flowed from city to city, country to country, spreading at the same speed as the trillions of dollars involved in the reckless unsustainable money game of international capital. . . . Capital's dream of super fast networks . . . was turned on its head. (Aingers et al., 2003: 65)

And part of its critique of capitalism and science is to critique reductionist forms of thought, as opposed to new complexity formulations.

Central to the self-understanding of the anti-globalization movement is an implicit commitment to the sciences of complexity since they best explain complex webs of life that constitute the interconnected and hybridized character of global relationships. And complexity also seems to describe the networked, leaderless, distributed, fluid character of the movement itself. Like a flock of birds taking off, these movements demonstrate patterned emergence but without either anarchy or centralized hierarchy. They are self-organizing or autopoietic smart mobs or swarms (see Aingers et al., 2003: 70–3: Rheingold, 2002). Complexity analyses seem to capture the ways in which 'mobilization' involves flows of emotional or charged energy that occurs within social movements, flows involving non-linear switches in organization that can occur once a threshold is passed.

Thus swarming across the world are diverse systems, each constituting the environment within which the others adapt and co-evolve. These hybrid systems include many different global networks and global fluids, as well as societies, 'supra-national states', global religions or 'civilizations', international organizations, international meetings, NGOs and cross-border regions (Habermas, 2001: ch. 4). There are multiple 'islands of order' within a sea of increasing disorder.

States have characteristically sought to produce 'order', to effect governmentality. Once this involved governing a relatively fixed and clear-cut national population resident within each territory and constituting a clear and relatively unchanging 'community of fate' or nation-state (Lash and Urry, 1987, 1994). Now, though, the fluid and turbulent nature of global complexity means that states have to adapt and co-evolve in relation to enormously different sets of global networks and fluids that transform the space beyond each state. States thus co-evolve as the legal, economic and social regulators, or gamekeepers, of systems of networks and fluids generated through the often unpredictable consequences of many other systems. Thus: 'the role of the state is actually becoming more, rather than less, important in developing the productive powers of territory and in producing new spatial configurations', as with the US-led global coalition against terrorism (Swyngedouw, 1992: 431). There has been an enormous expansion of nation-state structures, bureaucracies, agenda, revenues and regulatory capacities, in order to adapt to the multiple and overlapping global networks and fluids moving across borders through time–space in dizzying, discrepant and transmutating form. States are not converging in a uniform direction but becoming more diverse, such as the US state, the EU and Afghanistan under the Taliban, as each adapts and co-evolves in relationship to the configuration of systems which each seeks to orchestrate (Weiss, 1998: ch. 7).

This, moreover, has significant implications for how we might think of the relations of power. Bauman usefully outlines a 'post-panoptical' conception of power (2000: 10–14). Power is not necessarily exercised through co-presence, as one agent gets another to do what they would otherwise not have done through interpersonal threat, force or persuasion. Power no longer necessarily involves the imagined co-presence of 'others' within a literal or simulated panopticon. The prime technique of power Bauman says is: 'escape, slippage, elision and avoidance', creating the 'end of the era of mutual engagement' (Bauman, 2000: 11). The new global elite, rules: 'without burdening itself with the chores of administration, management, welfare concerns' (2000: 13). Power is thus all about speed, lightness, distance, weightlessness. This is so both for elites and for those resisting elites, such as anti-globalization protesters or bio-terrorists. Power runs in, and especially jumps across, different global networks and fluids.

Power, we know from Foucault, is not a thing or a possession. Power flows or runs along and across various networks and fluids, increasingly detached from specific territory or space, and may be non-contiguous. Thus, new forms of power are both necessitated by, and made possible through, computer-based forms of information gathering, retrieval and dissemination (Power, 1994). Power is hybridized and technologized through vision machines, satellites, bugs, listening devices, microscopic cameras, CCTV, the internet, total information awareness, iris recognition and new computerized means of sharing information (see Lyon, 2001, on post-11

September 2001). Moreover, everyday life also increasingly involves speed, lightness and distance, with the capacity to move information, images and bodies relatively unnoticed through extensively surveilled societies (such as bodies transmutating from student to tourist to terrorist back to student and so on). Power is significantly mediated and this functions like an attractor. Within the range of possibilities, the trajectories of systems are drawn to 'attractors' that exert a gravity effect upon those relations that come within its ambit. The global media exert such a gravity effect, with almost the whole world both 'watching' and being seduced into being 'watched' (as with the videos of bin Laden). And because power is mobile, performed and unbounded, attempted ordering by the most powerful can result in complex unintended effects that take systems away from equilibrium. In such unpredictable and irreversible transformations, mobile power is like sand that may stay resolutely in place forming clear and bounded shapes with a distinct spatial topology (waiting, say, to be arrested or bombed) or it may turn into an avalanche and race away, sweeping much else in its wake. And, correspondingly, challenging that power is also hard since bombing certain nodes of power cannot destroy the 'lines of flight' that simply flow like 'packets' in email systems, following different routings and getting round destroyed nodes.

Conclusion

Gray describes the current state of the globe as 'an intractably disordered world' (2001). I have tried to show that 'complexity' provides some metaphors, concepts and theories essential for analysing such intractable disorderliness. Existing global analyses lack this kind of conceptualization necessary for examining these strangely ordered systems that are complex, rich and non-linear, involving multiple negative and positive feedback loops. Such global systems are characterized by unpredictability and irreversibility; they lack finalized 'equilibrium' or 'order'; there are, following Prigogine, pools of order that heighten overall disorder. Systems do not exhibit and sustain unchanging structural stability. Complexity elaborates how there is order and disorder within all physical and social systems. Following Gray, we can see how there is a complex world, unpredictable and irreversible, disorderly but not anarchic (see Malpas and Wickham, 1995, on sociology's obsession with systems as necessarily ordered).

One feature of this disorderliness can be seen through the prism of 'empire'. Hardt and Negri argue that the concept of 'empire' has replaced nation-state sovereignty or 'society'. By 'empire' they mean the emergence of a dynamic and flexible systemic structure articulated horizontally across the globe, 'governance without government' that sweeps together all actors within the order as a whole (Hardt and Negri, 2000: 13–14). Empire is the sovereign power, creating a 'smooth world', the single logic of rule that now governs the world. This new sovereignty is deterritorialized and decentred, with a merging and blending of a 'global rainbow' (Hardt and Negri, 2000: xiii).

However, a complexity analysis would suggest that the concept of 'empire' is too generalized. It is more consistent with complexity formulations to think of empire not as characterizing global relations as a whole. Empire is more a strange attractor. Thus societies are through iteration becoming more like 'empires'; over time they are being irreversibly drawn into the 'basin' of empire. There are various indicators of this iteration. Contemporary societies increasingly possess a visible imperial centre, with icons of power of buildings, landscapes and brands. While beyond the centre there is a spreading of effects outwards, with a relative weakness of some borders. And within such 'empires' there are emergent inequalities rather than, as in at least welfare societies, attempts to create citizenship rights common throughout the territory. In particular, societies are drawn onto, attracted to, the world-as-stage, showing off trophies, competing with each other for the best skyline, palaces, galleries, stadia, infrastructures, games, skilled workforce, universities and so on. And societies as empires seek to avoid scandal and risk. Societies are drawn into this attractor and this remakes certain of them as 'empires', the USA being the most powerful of such societal empires on the world-as-stage. The USA possesses a number of exceptional centres (New York, Los Angeles, Washington), icons of power (the Pentagon, Wall Street, Hollywood, Ivy League universities, Texan oil wells, Silicon Valley, MOMA), a porosity of certain borders, and huge 'imperial' economic and social inequalities. It is the paradigm case of 'society as empire', and is the exemplar for other societies, and other super-societies, to follow, to be drawn into the basin of empire.

And each society as empire produces its opposite, its co-evolving other, its rebellious multitude. Huge transformations are taking place in the production of 'empire-and-multitude' across the globe. Global markets generate 'wild zones' of the increasingly dispossessed, with significant parts of the former USSR, sub-Saharan Africa, the Balkans, central America and central Asia being places of absence, of gaps, of lack. Such zones possess weak states with limited infrastructures, no monopoly of the means of coercion, barely functioning economies often dependent upon commodifying illegal materials, an imploded social structure and relatively limited connections to the global order. The events of 11 September 2001 demonstrate the complexity of 'asymmetric threats', that 'wars' are increasingly fought between formally unequal powers, with the apparently weak able to inflict massive blows on the apparently powerful (as well as the reverse of course; see Gunaratna, 2002). It is almost the secular equivalent of 'The first shall be last, and the last shall be first.' More generally, through the various global fluids of money laundering, the drug trade, urban crime, asylum seeking, people smuggling, slave trading and urban terrorism, the spaces of the wild and the safe zones of multitude and empire are chaotically juxtaposed (the 'boomerang' effect of global markets). Such markets have brought the 'whole world' closer, and this is especially and paradoxically true of those bent on violent destruction and especially on destroying the 'American empire'.

Thus, in systems analyses, components are irreversibly drawn towards 'attractors'. Such components within any system operate under conditions far from equilibrium, partly because each responds to 'local' sources of information. But components at one location have substantial time–space effects elsewhere through multiple connections and awesome trajectories. Such systems possess an unpredictable history which then irreversibly evolves and where past events are not 'forgotten'. Points of bifurcation can be reached when the system branches; 'causes' and 'effects' can be disproportionate. There are non-linear relationships between them, with the consequence that systems may move dramatically from one state to another. Systems can reach 'tipping points', when what seem like long-term stabilities unpredictably flip over into their apparent opposite. Examples of such tipping and bifurcation include the overnight 'collapse' of the Soviet Empire, the astonishing growth of the internet from almost no users to 1 billion users worldwide, the spread of mobile phones so that new mobiles are now more common than landline phones, the overnight emergence of global terrorism/fear after 11 September 2001 and so on. This provides a rich and critical agenda for a complexity take on global dis/order.

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