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Guest editorial

Space, place, and complexity science

'Complexity' has been among the stronger currents in scientific thought during the last two or three decades. More so than many previous shifts in scientific thinking, the turn towards complexity has been promoted in media beyond the academy. There is a considerable history of titles equally at home on academic bookshelves or accompanying an overpriced coffee in the corner bookshop, among them *Chaos* (Gleick, 1987), *Complexity* (Waldrop, 1992), *Emergence* (Holland, 1998), and, more recently, *Six Degrees* (Watts, 2003). Even the inglorious end of complexity has been alleged in the popular science literature (Horgan, 1995). Such widespread coverage rightly engenders scepticism about the usefulness of 'complexity' and any shift in thinking substantial enough to be frequently accompanied by the word 'paradigm' deserves to be critically examined. In that spirit this issue of *Environment and Planning A* interrogates complexity science from the perspective of the spatial sciences.

Thrift, describing the geographic diffusion of complexity ideas, suggests that distinct, but interconnected networks of science, business, and 'New Age' philosophy (among others) have been important in promoting complexity as a way of framing a diverse range of problems (Thrift, 1999). Thrift also suggests a second meaning to the 'geography of complexity' insofar as it "is a body of theory that is preternaturally spatial" (page 32). He also notes that "links between geography and complexity *were* made in the 1970s" (page 32) but that the turn to Marxian and other approaches in geography around that time contributed to the general discrediting of the quantitative approaches that were the context for links between complexity and geography. This accident of timing reduced the impact of those links, confining research to a small group of scholars primarily concerned with issues in modelling. Modelling remains a central activity at the intersection of complexity science and spatial science (O'Sullivan, 2004), but it is clear that its relevance is now much wider given the resurgence of quantitative research in geography and allied growth in fields including sociology, political science, and anthropology. We are hopeful that this theme issue, along with a 'sister' theme issue of *Environment and Planning B: Planning and Design* (volume 32, issue 6) can reestablish those early links for a wider audience.

We wholeheartedly endorse the notion that complexity constitutes a body of thought that is inherently spatial. Before expanding on that view, the more immediate origins of this project should be made clear. These theme issues arose out of successful sessions on "Geographical Perspectives on Complexity Theory and Complex Systems" at consecutive annual meetings of the Association of American Geographers in Los Angeles (2002) and New Orleans (2003). The latter sessions were split between detailed expositions of complex dynamic models of spatial phenomena and more theoretically oriented presentations on the deep links between complexity and geography. While the more modelling-oriented presentations suggested a theme issue of *Environment and Planning B*, we felt that it was also important to explore the broader, theoretical linkages more thoroughly than had been possible in the conference presentations. Accordingly, papers exploring epistemological and ontological aspects of complexity with respect to space and place were invited, both from session participants and from others working on related complexity issues. The five papers presented here resulted from that invitation.

Before considering the spatiality of complexity and the individual contributions in more detail, it is appropriate that we define complexity at least provisionally before reflecting further on its inherent spatiality. It is not easy to define 'complexity' or 'complexity science' given its long gestation and continuing growth and maturation. Rather than add to the confusion, we settle here for a useable definition, based on widely accepted existing definitions.

Thus, complexity science is "the study of the behaviour of macroscopic collections of [many basic but interacting] units that are endowed with the potential to evolve in time" (Coveney and Highfield, 1995, page 7). Or again, in a complex system "the interaction among constituents of the system, and the interaction between the system and its environment, are of such a nature that the system as a whole cannot be fully understood simply by analysing its components" (Cilliers, 1998, page viii). Put another way, complex systems are irreducible and therefore not necessarily amenable to the reductionist methods characteristic of much of science. The irreducibility of complex phenomena arises because interactions among their constituent elements are nonlinear and their properties nonadditive, so that understanding how interactions 'scale up' from local to global behaviour is not straightforward. In complexity science 'the whole is more than the sum of the parts', or put yet another way, "more is different" (Anderson, 1972).

Understanding the constituent elements of an irreducibly complex whole does not guarantee an understanding of the whole system, although it may assist in understanding how those elements interact to produce the behaviour of the whole system. A language has developed in complexity science for describing the characteristics of complex systems. In particular, systems are *self-organised*, exhibiting structure that *emerges* from the interactions of the constituent elements. The evolution of systems over time is *path dependent* so that the next stage in the development of a system is not trivially predictable from its current state, but is instead a product of its whole history. More extended considerations of complexity and complexity science and their implications are presented by Manson (2001) and O'Sullivan (2004).

The inherent spatiality of complexity

We now expand on Thrift's claim that complexity is "preternaturally spatial" (1999, page 32). The emphasis on interactions among constituent elements of a system is critical. Because elements have some spatial configuration and interactions are not global but local, the spatial configuration of a system may be key to understanding and anticipating its behaviour. The proper approach to space implied by this perspective involves close study of the local situational characteristics of physical locations, of interactions among neighbouring locations, and of the flows along interaction networks. Interactions among system elements are spatially structured in ways that contribute to the evolution of the spatial structure in which they play out. The interplay between spatial configuration or pattern and process is similarly a central concern of the spatial sciences. The importance of spatial configuration in complexity science should lead to a recognition that not only is system evolution path dependent, but it is place dependent. This is a well-worn theme for the spatial sciences. Massey also makes this point, referring to a personal communication from Martin: "the notion of 'path-dependence'... is itself place-dependent" (Massey, 1999, page 273).

The inherent spatiality of complexity comes into sharper focus in light of comments by Hanson (2004) in her contribution to a plenary session at the 100th Annual Meeting of the Association of American Geographers. Hanson suggests that there is a distinct 'geographic advantage'[1] when tackling a host of questions. A key strength is that

> "the (great diversity of the) specific questions we ask ... can be a decided strength as it allows us to show the relevance of geography to a variety of problem areas (access to clean water, responses to climate change, sustaining biodiversity), in a range of settings and scales (urban neighbourhoods, smallholder farms, national parks), and to an array of audiences (community groups, NGOs, government agencies)."

The diversity of perspectives and approaches presented and discussed in the present theme issue exemplifies how this strength carries over to complexity-oriented spatial science and also reflects the interdisciplinary nature of much complexity research.

Hanson goes on to identify key aspects of the 'geographic advantage', particularly the distinctive framing of questions in space-based and place-based research through a focus on relationships between people and the environment, a focus on spatial variability, a focus on processes at multiple and interlocking geographic scales, and a focus on integrating spatial and temporal analysis. Considering each of these themes in turn (see below), a close alliance between space-based and place-based research and complexity is evident, to the extent that each element of the 'geographical advantage' can readily be seen as a key theme for complexity-oriented spatial science.

Focusing on *relationships between people and the environment* is a specific instance of the focus in complexity science on the relationship between the constituent elements of a system acting to produce emergent system behaviour that in turn acts back on the constituent elements altering or reinforcing their behaviour. A canonical example is Kauffman's (1993) notion of 'fitness landscapes' in evolutionary theory, in which the relative fitness of different species is not measurable in absolute terms but only relative to the other species present. Taken together, a given mix of species creates an environment that collectively determines the fitness of each within that mix. The constituent elements of the system collectively create an environment that acts back on the species, potentially leading to extremely complicated endogenously generated population dynamics.

Current interest in the use of agent-based models of land-use change is another area in which research on human–environment relationships is developed in ways that gel with complexity science approaches (Parker et al, 2003). Strong ties are also evident in research that treats the resilience and vulnerability of ecosystems as manifestations of complex systems (Holling, 2001). These examples highlight how complexity drives, and is driven by the broad-based interdisciplinary research needed to examine coupled human–environment systems. Complexity concepts and modelling approaches are ideally suited to advancing knowledge of these kinds of systems, especially with respect to their spatial variability and scalar and spatiotemporal dynamics. At the same time, human–environment research pushes complexity research beyond its usual focus on stylized, 'toy-like' models towards the messy reality of human decisionmaking in the context of social and natural complex systems.

[1] We are grateful to Susan Hanson for supplying an early draft of the paper arising from this plenary session. She notes that the 'geographic advantage' draws on ideas discussed at a meeting held at the Geography and Regional Science Program of the US National Science Foundation, 24–25 October, 2003. Also present were Ron Abler, Richard Aspinall, Tom Baerwald, Bernie Bauer, Gregory Chu, Roger Downs, Pat Gober, J W Harrington, David Hodge, Brian Holly, Nina Lam, Vicky Lawson, and Tom Leinbach. Although Susan Hanson speaks to, and of, geographers, her comments seem to us to apply equally well to researchers from the many allied disciplines who publish in this journal.

Spatial variability is, as has been noted, central to complexity science. *Where* elements are located in a system relative to other elements is critical to their behaviour. Complex systems are characterized by internally differentiated structure, not homogeneity, and their evolution is driven by the ongoing creation and propagation of this internal differentiation. This is a strongly spatial understanding of the world, consistent with space-based and place-based studies that accentuate the dialectic of space and spacelessness. As Sheppard (2002) notes, there is a tendency in scholarship on global networks (for example, of information or capital) to suggest that network flows are beyond place or space because they move rapidly, at times instantaneously, around the globe with little regard to what is on the ground. He argues, however, for the continued importance of "positionality", or position in relational space and time, as "both shaping and shaped by the trajectories of globalization and as influencing the conditions of possibility of places in a globalizing world" (page 307). Positionality mirrors an essential component of complexity, namely how continual change and evolution instantiate, change, or destroy system elements, depending on their relationships with other elements and the system as a whole. The explosive growth of a monopolistic region such as Silicon Valley first depends on geographical attractiveness, but then historical accident, positive feedback among firms, and path (*and* place) dependence guide the emergence of a high-tech agglomeration.

This leads naturally to the importance of focusing on *processes at multiple and interlocking geographic scales*, which has two effects on the scale of analysis. First, in complexity science, there is a presumption that at least two scales are relevant in any context: that of the individual elements, and that of the whole system. In many cases, scale is not explicitly examined beyond this simple 'local – global' dichotomy. However, an understanding of how the world is structured, embodied in complexity science is consistent with one that sees elements articulated into emergent aggregates that are themselves articulated into still larger aggregates, and so on. Although this view is consistent with earlier accounts of science, the novelty of complexity lies in a sustained attempt to grapple with the 'bottom-up' emergence of aggregate behaviour on the one hand, and the 'top-down' impact of emergent structures on the behaviour of constituent elements on the other. Although the relationships between only two scales remain the primary focus of most research, the importance of engaging in research across a range of scales is clear.

Second, there is recognition that appropriate scales of analysis are not fixed when dealing with a system marked by constant change and emergence. A complex system has no a priori scale levels because it does not result from superposition (that is, additive effects of system components), but from interactions among components dynamically giving rise to higher level structures. These structures, which define scale levels and thus appropriate scales for analysis, can be difficult to identify except by iteratively assessing relationships between lower level elements and higher emergent levels. Further complicating identification of scale levels is the potential for the system to shift scale levels or to create new emergent structures through complex processes of self-organization and bifurcation. The complex nature of 'the global', for example, forces us to question long-accepted conceptual constructs (such as the nation-state), and instead to examine the multitude of emergent actors and subsystems that comprise the global scale. The global moves from being a scale of analysis contrasted with local or regional formations, towards a phenomenon in and of itself that hosts shifting emergent phenomena such as migrations, currency crises, and environmental hazards (see Urry, 2003).

Finally, complexity science is concerned with simultaneous *spatial and temporal analysis* of systems. Much has been written about the general privileging of temporal change over spatial variability both in the natural and in the social sciences

(Prigogine and Stengers, 1984; Soja, 1989). Complexity remains focused on time because it defines—and is defined by—various kinds of change: learning, evolution, emergence, bifurcation, dissipation, chaos, and self-organisation. It is hard to imagine a completely static system that would be of interest to complexity research. Increasingly, however, complexity science is embracing spatial analysis to the potential benefit both of complexity researchers and of those in space-based and place-based disciplines. The combination of an 'environment' (in which system elements interact) and 'relationships' (interactions among elements) defines much complexity research, particularly in connectionist approaches such as cellular automata, agent-based modelling, and artificial neural networks. The environment–relationship pairing roughly mirrors conceptions of absolute and relative space in spatial sciences. However, disciplines with a strong spatial focus have made much greater strides in refining absolute, relative, and relational notions of space, and, importantly for complexity research, in using these notions to represent reality computationally.

In this issue

This journal, and its sister journal *Environment and Planning B*, have been at centre stage in developing approaches to environmental, planning, and geographical applications grounded in complexity. Contributors to this theme issue have played an important role in this development. In this issue we have encouraged authors to reflect critically on the broad implications of complexity science for space-based and place-based research. What lessons can we learn from developments in complexity science in other fields? What lessons can the wider complexity science community learn from us?

Malanson, Zeng, and Walsh present the most immediate example of how existing concepts and ideas in complexity science can inform analytical approaches in spatial landscape analysis. Their paper uses methods of pattern analysis that have one foot in traditional spatial analysis, and the other in the vast emerging literature on power-law distributions as hallmarks of complex systems. This paper foregrounds the search for spatial patterns as signatures of particular process dynamics, a persistent theme common to geography and complexity science more widely. In doing this the authors demonstrate both the power and also some of the ongoing challenges in using this technique. The potential is strong here for identifying characteristic scales at which underlying processes operate.

Wilson presents a wide-ranging review of some deep connections between more established ideas in geography and regional science's spatial analysis tradition, and 'new' ones in complexity science, adding to the argument that there are long-standing antecedents of complexity. Although this paper is couched in what will be formidable mathematics for some, its underlying message is clear. Equivalence between contemporary spatial models of ecosystems and models of urban systems indicate the potential for useful exchange between the two fields. This recalls Wilson's own importation to geography of approaches from statistical mechanics (Wilson, 1974), an intervention, which, ironically—in retrospect—Thrift holds partially responsible for the slow uptake of complexity ideas in geography, in spite of their evident relevance (1999, pages 32–33). However, it seems pertinent that in this instance the mapping between the fields in question—ecology and urban systems—is more immediately satisfying. Many of the same issues of competition over limited resources, with interactions strongly spatially structured, arise in both domains. This piece emphasises the strong pandisciplinary nature of complexity research.

Portugali's contribution speaks more directly to social scientists. Portugali has consistently worked to draw out deep connections between different methodological approaches to urban questions, which, as he argues here, are a direct result of the complex nature of cities. It is the very nature of the subject matter that forces such methodological diversity on us, and emphatically not confusion over the most appropriate or 'correct' way to approach the subject. In this paper Portugali identifies deep connections between methodological developments in complexity science and human geography, pointing to the former as perhaps providing a basis for formalising 'critical' strands in the latter. Whether or not critical geography needs to be formalised may be a matter of pragmatics (how best to reach diverse audiences), or simply a matter of taste. Regardless of the motivation, this surely represents progress beyond the prevailing often tense stand-off between quantitative and nonquantitative studies. Although the far-reaching importance of work that bridges this divide is emphasised by reference to Snow's 'two cultures', this paper is also part of a continuing, at times uneasy engagement between human geography and 'science', prompted in this case by complexity science (see also Massey, 1999; O'Sullivan, 2004; Sheppard, 2001).

This tone continues in the paper by Uprichard and Byrne, who demonstrate how complexity can provide a new interpretative frame for qualitative methods. Given that the usual 'scientific' response to contexts not immediately amenable to current quantitative methods is the development of yet more complicated methods, this is an interesting development. Here, realising the complexity of the phenomenon at hand leads not to a dense forest of equations and multiplying variables but instead to the recognition that the human beings at the heart of the complex system under study may be best placed to tell its story. There is a tricky balancing act to perform here if the accusation that this is simply an old approach dressed up in the latest fashionable clothes is to be successfully refuted. Two points can be made, the first rather cheeky, the other more substantial. If this were merely fashionable representation of old ideas, then much more contemporary garb would surely have been chosen (actor-network theory, perhaps?[2]). More seriously, we see here again how the complex nature of the phenomena at hand forces us to embrace methodological diversity in our investigations. The multiple scales and levels of interaction in a complex system make it imperative that we remain open minded about the appropriate analytical approach.

The need to embrace such methodological diversity is one of the strongest conclusions to emerge from Manson and O'Sullivan's consideration of some key questions for those (as here) working at the intersection of space-based and place-based research and complexity science. This paper also reemphasises points that are central to other papers in this collection, particularly the pivotal role of pattern–process relations and difficult questions about the relative importance of each. Questions as to the breadth of applicability of underlying models are also raised, and the issue of how models can be used most appropriately is brought to the fore. Although few clear-cut (simple?) answers are provided by the discussion, the challenge and promise of complexity science for space-based and place-based research is apparent throughout.

Concluding thoughts

It is our hope that these papers will provide further stimulus to critical thought across and between the diverse disciplines represented in *Environment and Planning A*. The very diversity of this journal (and its siblings *Planning and Design*, *Government and Policy*, and *Society and Space*) encourages us in the view that this is the perfect venue for opening the issues raised here to further discussion. Complexity is a moving target, and—even supposing it were to stay still long enough—it is doubtful that five papers could provide a sharply focused portrait of its overall shape and direction. We are

[2] Note that the intention here is to recognise that, although there are (many) contexts in which actor-network theory is an appropriate frame, this is probably not one of them, its current popularity in geography notwithstanding.

confident, however, that the inherent spatiality of complexity science comes across clearly in all of the contributions, and even more clearly in the collection taken together (the whole as 'more than the sum of its parts', perhaps?) The importance of engaging with complexity science for space-based and place-based researchers is apparent. It is equally apparent that researchers who are applying ideas from complexity science in their work, and often grappling with issues of space and scale for the first time, have much to learn from the long experience of geographers and others. We are hopeful that these papers point to what will become a growing discussion, in the pages of this journal and elsewhere, of ideas, questions, and issues raised by the encounter between space, place, and complexity.

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References

Anderson P W, 1972, "More is different: broken symmetry and the nature of the hierarchical structure of science" *Science* **177** 393 – 396
Cilliers P, 1998 *Complexity and Postmodernism: Understanding Complex Systems* (Routledge, London)
Coveney P, Highfield R, 1995 *Frontiers of Complexity: The Search for Order in a Complex World* (Balantine Books, New York)
Gleick J, 1987 *Chaos: Making a New Science* (Viking Penguin, New York)
Hanson S, 2004, "Who are 'we'? An important question for geography's future" *Annals of the Association of American Geographers* **94** 715 – 722
Holland J H, 1998 *Emergence: From Chaos to Order* (Perseus, Cambridge, MA)
Holling C S, 2001, "Understanding the complexity of economic, ecological and social systems" *Ecosystems* **4** 390 – 405
Horgan J, 1995, "From complexity to perplexity: can science achieve a unified theory of complex systems? *Scientific American* **284** 104 – 109
Kauffman S A, 1993 *The Origins of Order: Self-organization and Selection in Evolution* (Oxford University Press, New York)
Manson S M, 2001, "Simplifying complexity: a review of complexity theory" *Geoforum* **32** 405 – 414
Massey D, 1999, "Space – time, 'science' and the relationship between physical geography and human geography" *Transactions of the Institute of British Geographers, New Series* **24** 261 – 276
O'Sullivan D, 2004, "Complexity science and human geography" *Transactions of the Institute of British Geographers, New Series* **29** 282 – 295
Parker D C, Manson S M, Janssen M A, Hoffmann M J, Deadman P, 2003, "Multi-agent systems for the simulation of land-use and land-cover change: a review" *Annals of the Association of American Geographers* **93** 314 – 337
Prigogine I, Stengers I, 1984 *Order Out of Chaos: Man's New Dialogue with Nature* (Bantam Books, Toronto)
Sheppard E, 2001, "Quantitative geography: representations, practices, and possibilities" *Environment and Planning D: Society and Space* **19** 535 – 554
Sheppard E, 2002, "The spaces and times of globalization place, scale, networks, and positionality" *Economic Geography* **78** 307 – 330
Soja E W, 1989 *Postmodern Geographies: The Reassertion of Space in Critical Social Theory* (Verso, London)
Thrift N, 1999, "The place of complexity" *Theory, Culture and Society* **16** 31 – 69
Urry J, 2003 *Global Complexity* (Polity, Cambridge)
Waldrop M, 1992 *Complexity* (Simon and Schuster, New York)
Watts D J, 2003 *Six Degrees: The Science of a Connected Age* (W W Norton, New York)
Wilson A G, 1974 *Urban and Regional Models in Geography and Planning* (John Wiley, Chichester, Sussex)