

## Complexity theory as a link between space and place

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**Abstract.** Since the early 1970s, the notions of *space* and *place* have been located on the two sides of a barricade that divides what has been described as science's two great cultures. Space is located among the 'hard' sciences as a central term in the attempt of geography to transform the discipline from a descriptive into a quantitative, analytic, and thus scientific, enterprise. Place, on the other hand, is located among the 'soft' humanities and social philosophy oriented social sciences as an important notion in the post-1970 attempt to transform geography from a positivistic into a humanistic, structuralist, hermeneutic, critical science. More recently, the place-oriented geographies have adopted postmodern, poststructuralist, and deconstruction approaches, while the quantitative spatial geographies have been strongly influenced by theories of self-organization and complexity. In this paper I first point to, and then explore, structural similarities between complexity theories and theories oriented toward social philosophy. I then elaborate the thesis that, in consequence, complexity theories have the potential to bridge the geographies of space and place and, by implication, the two cultures of science. Finally, discuss in some detail conceptual and methodological implications.

### Two cultures

Snow's thesis is that the breakdown of communication between the 'two cultures'—that of the sciences and that of the arts and humanities, or 'literary intellectuals'—is a major hindrance to solving world problems. He originally delivered this thesis in 1959 in the Rede Lecture, and reformulated it a few years later in his book *The Two Cultures and a Second Look* (Snow, 1964). "It is hard to see", writes Yee in a review of a 1993 edition of the book "why quite such a fuss was made over Snow's lecture at the time; as he himself was the first to admit ... [that] nothing he said was particularly original" (Yee, 1993).

But there is something original, I think, in Snow's thesis: the interpretation and perception of scientific differences not in terms of differences of logic, method, or opinion, but in terms of cultural differences—a view that appears later, albeit implicitly, in studies about the history, philosophy, and sociology of science. For example, in *The Structure of Scientific Revolutions* Kuhn (1962) develops the notion of 'normal science'—a period during which scientists conform to the dominant paradigm, partly because they are convinced by it and partly because conservative tendencies make it much safer and convenient to conform.

Cultures come into existence by emphasizing the common values, norms, and material goods shared by their members, and by emphasizing and often exaggerating the differences between their common elements and those of other groups. Cultures survive by the process of cultural reproduction—the process that routinely and daily produces and reproduces the common (often exaggerated) elements that unite the group's members, as well as the differences between them and other groups (Giddens, 1997).

Snow's use of the term 'culture' to refer to a certain grouping among the scientific community implies that scientists are no exception in this respect—they are first and foremost human beings and, as such, tend to form cultural groups by emphasizing

and often exaggerating the common elements that unite them and those that separate them from other groups, by forming stereotypes both of themselves and of the others.

It is interesting to note in this connection that the very term 'sciences versus humanities' is culturally biased—it is typical of the English-speaking cultures. In Hebrew, for example, there is no parallel to the term 'humanities': instead we use the term *mada'ei ha'ruach*—which literally means the 'sciences of the human spirit'.

In the discipline of geography, the rise of structuralist, Marxist, and humanistic (SMH) approaches in the early 1970s saw the emergence of two distinct cultures—SMH versus positivist/quantitative geographies—with all the ingredients indicated by Snow and by cultures in general: a breakdown of communication, emphasis and exaggeration of differences between the cultures, stereotypic images of the other, and a process of cultural reproduction that reinforced and safeguarded the differences. This last was implemented in many ways, including: scientific journals which, because of their specialized nature, could easily exclude the views of the other—a process that was practically executed by an army of referees, 'guardians of the wall', which protected the minds of the groups' members from intruding ideas; general introduction textbooks which by their very nature, tend to stereotype complex relations; specialized conferences that naturally exclude the other; and endless numbers of lectures and university courses that followed and reproduced the two cultures.

### The bifurcation

The history of the space–place split in geography is well recorded. It started in the early 1970s when some of the leading figures of the quantitative/positivistic geography that had dominated the discipline in the 1960s started to question the scientific and social validity of their own project. The most prominent among these was Harvey who, in 1969, published *Explanation in Geography*—probably the most comprehensive statement of positivistic geography at the time, and who in 1973 with *Social Justice and the City*, produced the most influential critiques to date of positivistic geography, that is to say, of his own *Explanation*. Harvey's attack came from a Marxist–structuralist standpoint. Other geographers attacked positivistic geography from phenomenological and idealistic positions which later came under the title *humanistic geography*. A central tenet in this line of criticism was the tension between place and space. The notion of 'place', according to humanistic geographers such as Tuan (1977) in *Space and Place* and Relph (1976) in *Place and Placelessness*, refers to the intimate human relations between people and their homes, neighborhoods, cities, lands, and countries. The positivistic 'space', on the other hand, is an alienated, alienating, and dehumanizing abstract concept—a placelessness. Structuralist and humanistic geographers claimed that the notion of space as conceptualized by positivist geographers was part of an ideological false consciousness that tended to obscure people's view of their real conditions of existence.

This dichotomy between place and space marks the usage of these terms in the geographical discussions of the 1970s. Subsequent SMH, postmodernist, and poststructuralist geographers (see below) have further elaborated both notions (Hubbard et al, 2002, pages 16–18) and have exposed their multidimensionality: instead of the place–space dichotomy of the 1970s, they now portray the two notions in terms of a continuum at one end of which stands the humanistic geographical place of the 1970s and at the other, a socially produced space. Between these extremes is a multiplicity of places and spaces that form the continuum. The gap now is between this place–space continuum and 'space' as employed by positivist geographies. The title of this paper refers to this new conceptualization of space and place and to the possibility that complexity theory has the potential to bridge this gap.

The SMH attack caused a split within the discipline into two parallel streams: SMH geographies in one stream and positivistic geographies in the other. The positivistic geography included, as well as 'quantitative geography', 'regional analysis' with its orientation toward economic theory and system approaches, and 'behavioral geography' which has developed more as a branch of cognitive science than of human geography since the 1970s.

The abbreviation SMH does not indicate an identity between Marxism, structuralism, phenomenology, and idealism. The differences between these approaches are significant and in some cases (see below) are as great as the differences between each of them and positivism. SMH indicates, first, the wider geohistorical context: the days of the early 1970s were the aftermath of Vietnam and students' upheavals of the 1960s in Europe and the USA. Second, in the specific history of geography, SMH geographies emerged more or less at the same time—united by their common positivistic 'enemy'; by their self-image as the intellectual, anticapitalistic avant-garde of the discipline; and by social theory as their source of inspiration. In particular, they became influenced by the Frankfurt School interpretation of social theory and philosophy, with its emphasis on qualitative analysis and hermeneutics, and rejection of logical positivism and its quantitative analysis.

These uniting elements have obscured the differences between structuralism, Marxism, and the humanistic approaches and, more importantly, the similarities and potential links between them and various positivistic geographies. For example, mathematical methods can be, and have been, employed in order to criticize "neoclassical economic geography and to develop a Marxian political economic alternative", and "progressive human geography can take advantage of quantitative practices" (Sheppard, 2001, pages 535–536). Furthermore, as we shall see below, systems theory had and has strong links to structuralism and Marxism, and the positivistic cognitive geography shares many common areas of interest with humanistic and postmodern geographies.

More recently, SMH geographies have adopted postmodern, poststructuralist, and deconstruction (PPD) approaches, while several areas of quantitative spatial geography are now influenced by theories of self-organization and complexity.

### **Postmodern, poststructuralist, and deconstruction (PPD) geographies**

It is common to see the origin of postmodernism, deconstruction, and poststructuralism in the writing of personalities such as Foucault, Derrida, Lyotard, and Jameson, among others, and in precursors such as Nietzsche, Heidegger, Lacan, and Wittgenstein (Dear, 2000, page 31). What is common to PPD writers is that they have questioned and turned their backs on, various positions which, since the appearance of 'postmodernism' have been regarded as characteristics of 'modernism'. Among other things, they have exposed and criticized the obsession of modernism with history, time, and progress, and have questioned the belief in an Archimedean point from which one can derive moral as well as scientific truth. In his *Time's Arrow and Archimedes' Point*, Price (1996) writes that the attempt to find an Archimedean perspective on reality was one of the greatest efforts of modern science and philosophy. The belief in the possibility of defining such a point was common not only to physicists and philosophers (to whom Price refers), but also to modernist social theorists—be they Marxists, structuralists, humanists, or liberals.

The rejection of any fixed point of departure shows up in the reluctance of PPD writers to say what postmodernism *is* and to concentrate instead on what it *is not*: "I'll use the term *modern* to designate any science that legitimates itself with reference to a metadiscourse", writes Lyotard (1984, page xxiii) and then adds that postmodernism is the "incredulity towards metanarratives" (xxiv). "[I]t is hard to know

what postmodernism is", writes Dear (2000, page 25), and Cilliers (1998, page 113) argues: "The word 'postmodern' has acquired so many different meanings that it has become impossible to define it." The term 'postmodernity', says Luhmann (2000, page 40), "cannot say what it means, because this will lead to ... its deconstruction."

The doubts concerning the Archimedean point are related directly to the criticism of history and progress: if there is no Archimedean point, then there is no clear end and neither truth nor possible notions of progress and direction toward it. In such a world and reality one is thus left with coexisting entities (cultures, aims, ideals, truths, ...) with no hierarchy among them: that is to say, with a multiplicity of spaces and places. "The great obsession of the nineteenth century", wrote Foucault (1986, page 22), "was, as we know, history ... The present epoch will perhaps be above all the epoch of space." Thus, the subtitle of Soja's (1989) *Postmodern Geographies* reads: *The Reassertion of Space in Critical Social Theory*.

Proponents of PPD claim, with Lyotard (1984), that the rejection of any Archimedean point allows a highly dynamic and creative interpretation of society, culture, and science. Critics of postmodernism, for example, physicists Sokal and Bricmont (1998) in their *Fashionable Nonsense*, argued that such a rejection leads to the 'abuse of science'. Modernist social theorists have claimed that the rejection of such a point, be it an objective truth or alternatively a social consensus in Habermas's (1984; 1987) sense of 'communicative action', makes postmodernism unethical (Habermas, 1992). In a similar manner, Gellner (1992, page 49) argued that postmodernism is essentially a form of extreme modernist relativism which, in its turn "does entail nihilism". Postmodernists have responded by saying that PPD approaches are not nihilist in that they hold an ethical position that can be described as 'softer', context-dependent, forms of modernist ethical standpoints. Thus, in the concluding section to his book, Dear (2000, page 318) writes:

"I do not pretend to be a 'pure' postmodernist; my scholarly, personal and professional lives are too committed to social activism to be comfortable with extremes of relativism. But my ... commitments to ... Marxian epistemologies ... have been radically undermined."

On the other hand, deconstructivism in architecture (a notion that echoes and negates the Russian constructivism of the 1920s) goes hand in hand with the capitalist-liberalist ideologies that typify the current global economy: for example, the architecture of Eisenman, Gehry, Tsumi, or Hadid, and the work and writing of Koolhaas (1995).

There is no place here to elaborate further on the debate concerning the various PPD positions. [For a detailed discussion of the various views and their relation to geography and urban studies, see Dear (2000, in particular chapter 2)]. However, regardless of what one's position on the above is, it would be fair to say that the various notions of PPD authentically reflect the experiential sensation of life and society at the end of the 20th and the beginning of the 21st centuries: a somewhat chaotic and unstable *Network Society* (Castells, 1996), highly connected by complex channels of communication, constantly under a bombardment of information of all sorts, a fast-changing world, with shrinking distances, loss of direction, and all the rest. Postmodernists tend to interpret these phenomena as markers of a genuine postmodern reality (Lyotard, 1984), whereas others follow Harvey's (1989) view that these 'postmodern phenomena' are in effect modernism in disguise—markers of the latest stage of capitalism and by implication of modernism.

Strange as it may sound, a similar world-view has emerged from the hard sciences—with notions of chaos, instability, nonlinearity, bifurcation, and catastrophe—not in order to describe the human world within which we live but, rather, the properties of the material world. To be sure, the meaning of words such as 'chaos', 'catastrophe',

'instability', and the like in the context of the sciences is very different from their use in ordinary language: chaos theory is a formal mathematical theory regarding stochastic and deterministic behavior of the elements of certain systems in specific conditions, and similarly Thom's (1975) catastrophe theory deals with discontinuities, and so on. But the fact that these scientists have picked these terms and used them metaphorically as names for their respective processes is not without meaning.

### Theories of complex systems (TCS) and their relation to geography

Parallel to the process by which more and more SMH geographers adopted PPD views, quantitative geographers became more and more attracted by the ones of complex systems (TCS) and associated approaches. The germ for this move was already present in the various systems approaches that had become popular in geography and planning after the appearance of von Bertalanffy's (1968) *General System Theory* (Bennett and Chorley, 1978; Chadwick, 1971; McLoughlin, 1969). But the current geographical interest in TCS was specifically influenced by the appearance of Prigogine's theory of *dissipative structures* (Nicolis and Prigogine, 1977), Haken's (1983) *synergetic* theory of complex systems, and Mandelbrot's (1983) fractals.<sup>(1)</sup> In fact, the first links to geography were made not by geographers but by physicists such as Allen, who reformulated central place theory in terms of Prigogine's dissipative structures (Allen, 1981; Allen and Sanglier, 1981; Allen et al, 1985), and Weidlich (1987; 1994; 1999), who applied Haken's theory of synergetics to social and urban dynamics.

It was only at a later stage that geographers joined the lead of the aforementioned physicists. Examples of early adopters in geography are Wilson in his (1981) book on catastrophe theory, and Goodchild (1980), and Mark (1984) in their work on fractals. More recently, one can mention Dendrinis and Sonis (1990) on *Chaos and Socio-spatial Dynamics*, Sanders (1992) on *Systèmes de Villes et Synergétique*, Batty and Longley (1994) on *Fractal Cities*, and Portugali (1999) on *Self-organization and the City*. It must be emphasized, however, that the number of geographers' studies in which TCS is applied is rather small. The majority of geographers were attracted less by the theoretical and philosophical ideas enfolded in the TCS, or the mathematical formalisms that accompanied these theories, but more by some of the methodologies associated with the study of complex systems, namely cellular automata (CA) and agent-based (AB) simulation models.

Most human geographical studies are thus related to TCS through the use of CA and AB modeling and do not adhere to the deeper messages of TCS: that TCS have discovered properties in matter hitherto assigned to life, art, and society; that structure of explanation of TCS is similar to hermeneutics; that they have many similarities to PPD theories except that they do not refrain from searching for, and theorizing about, the way in which Archimedean points are created (and in this respect they are not nihilistic); and that they have the potential to bridge the two cultures of geography, between space and place and between Snow's two cultures. However, before elaborating these deeper messages and this thesis, it will be useful to say a few introductory words about TCS.

### Theories of complex systems

Common to theories of complex systems is that they refer to systems that are open and complex (in contrast to systems which are closed and simple). 'Open' in that they exchange matter, energy, and information with their environment, and 'complex' in at least one of the following two respects. First, the parts of such systems are so numerous

<sup>(1)</sup> At a later stage the Santa Fe School of complexity science became influential too.

that there is no way to establish causal relations among them. Second, the parts form a complex network with feedforward and feedback loops which make it hard or impossible to follow how such systems give rise to 'emergent' effects. The brain, with billions of neurons/parts, exemplifies both properties. Such systems exhibit nonlinearity, phase transition, self-organization, and the like. Particular theories differ both in the emphasis they assign to the different phenomena of complex systems, and in the domains in which they are empirically applied. This last point is significant as it affects the feedback from such applications. Thus Haken's synergetics tends to emphasize how local synergy between parts of a system gives rise to global structure, and the way in which global structure in turn enslaves the parts. Prigogine's theory of dissipative structures, on the other hand, puts special emphasis on the role of fluctuations and dissipations and the transfer of matter, energy, and information through the boundaries of the systems. These differences are not unrelated to the fact that Prigogine's theory was applied (beyond the domains of physics and chemistry) to socioeconomic-oriented domains, including urbanism, whereas Haken's synergetics was applied to a wider spectrum that also included aspects of brain dynamics and cognition.

As noted above, geographical applications follow the lead of the grand theories: Prigogine's was employed by Allen as a basis for his theory of the socioeconomic dynamics of cities as complex systems. In a similar manner Bak's self-organized criticality was applied to the socioeconomic urban domain (Batty and Xie, 1999); Mandelbrot's geometry of fractals was applied to the morphology of cities as complex systems (Batty and Longley, 1994; Benguigui et al, 2000); and Haken's synergetics served as a basis for Weidlich's sociological and urban theories—and his studies on cognition and behavior were extended to cognitive geography and a cognitive approach to urban dynamics (Haken and Portugali, 1996; Portugali, 2002; 2004). Kohonen's (1989) theory of *self-organizing maps* has also been applied to cognitive geography (Lloyd, 2000).

### **TCS—the deeper messages**

As noted above, the more influential TCS originated in physics and chemistry—where the study was of inanimate matter. This is significant for two reasons. First, physics has traditionally been regarded as a 'hard' science and a model for other disciplines. The attempt by geography, in the 1950s and 1960s, to become a science was directly associated with physics and with what Gregory (1994) termed 'physicalism'. Direct analogies, like the gravity–interaction model, as well as economically oriented location theory, provided the foundation for quantitative human geography.

Second, like the preceding two grand theories—relativity and quantum theory—TCS have found properties in matter hitherto assigned to the organic and human domains—including history, evolution, irreversibility, and nonlinearity (Portugali, 1985). As a consequence, several of the notions that originated in the study of complex systems can be related to similar notions that originated in the domain of social theory. Here are some brief examples:

(a) TCS and social theory are essentially systemic and even holistic. TCS reject atomism, and social theory refuses to conceptualize society in terms of essentially independent disciplines (economics, sociology, politics, etc).

(b) TCS and social theory prefer to conceptualize 'development' and 'evolution' in terms of abrupt changes rather than as a smooth progression. As a consequence, in both we find an emphasis on structural changes. In social theory the common terms for an abrupt change are social/political/cultural 'revolutions', whereas in the language of TCS one tends to speak about 'bifurcations' and 'phase transitions'. It is interesting to note that Gould and Eldredge (discussed by Gould, 1980) have suggested that

biological evolution too proceeds as a sequence of abrupt changes—a process they have termed *punctuated equilibrium*. The TCS notion of ‘steady state’ is similar to the notions of ‘epoch’, ‘period’, or ‘mode of production’ of social theory. This last is similar to the notion of synergetics ‘order parameter’. Furthermore, the synergetics notions of ‘enslavement’ and ‘circular causality’ are close to the social theory notions of ‘social reproduction’ and even more so to the notions of ‘socio-spatial reproduction’ as conceptualized by geographers and social theorists of space such as Lefebvre (1995) or Giddens (1984).

(c) The recent emphasis of PPD on viewing reality as ever-changing and transforming is close to the TCS notion of ‘a far from equilibrium condition’ which is the basic characteristic of complexity and is also the reason for the general popularity of notions such as ‘chaos’ and the ‘butterfly effect’.

(d) Conceptualizations of space in the sciences and in social theory and humanities have converged, as discussed in the next section.

### Space (and place)

In the Newtonian world-view, space was essentially perceived as an independent container (independent of time) within which independent bodies coexist in spatial causal relations of attraction and repulsion (Bohm, 1980). This view was adopted in the location theory that provided the foundation of positivist human geography. In the latter, complex reality is reduced to a large container in which the spatial interaction between such bodies/entities as settlements, central places, and demand is governed by spatial forces such as: mass measured by population; and distance measured by transportation cost (Portugali, 1985; 1993); etc.

After the advent of the theory of relativity and quantum theory, this mechanics world-view came to be seen as an abstraction from a subtler reality in which space is only relatively independent from time and the bodies in it (Bohm, 1980). This is also the case in TCS in which space is, on the one hand, a landscape full of forces, and, on the other, a product—an order parameter—that emerges out of the interactions that take place ‘on it’; once emerging and existing, this order parameter prescribes the behavior and interaction of the parts. This view is also implicit in cellular automata/agent-based urban simulation models in which the cells—the parts of the system—are only relatively independent as their properties are essentially some function of their relations to their neighbors. (On the spatiality of CA and AB models, see Couclelis, 1991; 1997; Takeyama, 1997; Takeyama and Couclelis, 1997).

Such a world-view comes close to the perception of space as it appears in social theory in the writing of Giddens (1984), Harvey (1996), Castells (1989; 1996), and Lefebvre (1995), among others. These writers speak about *The Production of Space* (the title of Lefebvre’s book) or, more precisely about ‘the *social* production of space’, in which they mean ‘social’ in the wider sense of the word that includes also the economic, political, cultural, and so on. Thus space is not a natural objective entity but an artifact—a product of the historically specific socio-spatial relations between humans. As a social product and an artifact, space feeds back to and participates in the process of socio-spatial reproduction (Soja, 1989).

Both in TCS and in social theory, space is thus a product. In social theory the emphasis is on space as a social product; in the domain of complex systems space might be seen as a social product, when one deals with complex artifacts such as a city, but it might also be seen as a natural product, when one deals with the space constructed in the organic world, for example. But the important contribution of TCS is in the view that space is not just a product—an end product—but also what in Haken’s synergetics is called an ‘order parameter’—a collective variable which emerges out of

the interaction of the parts, but which, once emerged, enslaves and prescribes the behavior of the parts by means of what I define below as 'information compression.'<sup>(2)</sup>

The discussion on space in social theory came associated with "a renewed and rising interest in place ... of ... authors who think independently of ... [Heidegger's] ... Being. Common to all these rediscoverers of ... place is a conviction that [contrary to Heidegger] place itself is not fixed thing ... . Instead, each tries to find place *at work*, ... of something ongoing and dynamic" (Casey, 1997, page 286, original emphasis). This view of place is even more prominent in the writing of scholars of place and space who go beyond the phenomenological perception of these terms. Thus, writing from the perspective of his 'space of flows', Castells describes place by reference to the physical and social dynamics of "the Parisian *quartier* Belleville" (1996, page 423). The majority of people, he emphasizes, "live in places" and their perception of space is "place-based". Similarly, for Massey (1991; 1995), Kilburn in London is a typical place; its dynamics is at once local and global: local with respect to the political, economic, and social interactions that bind its inhabitants into a community network, and global by virtue of their social, political, and economic relations that stretch out over the global space. A similar view of place is portrayed by Sheppard (2002), but with respect to 'geoeconomic places' in the context of the global space economy.

Unlike the notion of 'space', 'place' has not been intensively studied in the context of positivist quantitative and TCS geographies. The natural context for a discussion of place was cognitive geography (or 'behavioral geography' as it is often called), and indeed in its early days there were interesting discussions concerning sense of place (Lowenthal, 1961; 1985; Lynch, 1960; 1991; see also Hubbard et al, 2002). But the bifurcation of geography into two distinct cultures, as described above, put an end to these early beginnings. Cognitive behavioral geography joined the positivistic culture, concentrating on quantitative scientific notions such as 'space' and 'spatial behavior' (Golledge and Stimson, 1997; Kitchin and Blades, 2002), leaving the study of 'place' to the 'nonscientific' domains of SMH and PPD (see, for example, Casey, 1997; Hubbard et al, 2002, pages 16–18).

However, as elaborated below, from the conjunctive perspective of TCS and cognitive geography, space and place are interrelated in the sense that space is an abstraction from the very experiential reality within which people live and act, that is to say, an abstraction of places. I show below that, similarly to space, place is an artifact that comes into being in the process of self-organized information compression.

### The differences

The similarities between complexity and social theories noted above have not escaped the attention of writers from a variety of domains and, paralleling TCS, we see a steady stream of studies responding to these similarities from the perspective of the sciences (Capra, 1982; 1996; Peat, 2002), philosophy (Mainzer, 1994), media/cultural critics (Johnson, 2001), social theory, and the so called New Age (Thrift, 1999).

Several attempts have also been made to explore the possible links between PPD and TCS. Kellert (1993) closes his nonmathematical introduction to chaos theory with a chapter that points to several similarities between PPD, feminist theory, and chaos theory. He suggests that feminist theory provides an explanation of Prigogine and Stengers's observation that chaos theory was neglected for many years. Cilliers (1998) emphasizes the similarities between connectionist interpretations of complexity, Lyotard and, to a lesser degree, Derrida. The collection edited by Rasch and

<sup>(2)</sup> This view is close to Lefebvre's in *The Urban Revolution* (2003), which was strongly rejected by Castells (see Smith's introduction in Lefebvre, 2003).



Wolfe (2000), is centered mainly on Luhmann's systems-theory approach to society and postmodernity. In geography, see Thrift (1999) and Portugali (1985; 1993; 1999).

It is important not to be carried away by the similarities: TCS and social theory oriented SMH and PPD do differ from each other. First, although both refer to the chaotic nature of systems, they differ in the role which they assign to chaos: PPD tends to portray chaos as a state of reality, whereas TCS tend to describe it as the starting point for a process of self-organization that brings *Order Out of Chaos* (Prigogine and Stengers, 1984). Second, although both emphasize phase transitions/revolutions and processes of reproduction which maintain steady states, they differ in their view of how revolutions/phase transitions are created. Social theories are more deterministic in this respect: Marxism tends to emphasize materialism and historical determinism, while Hegelian idealism stresses determinism of the human spirit. According to TCS, the various forces acting on the system (materialist, idealist, or others) are in principle not deterministic, that is, they cannot determine the evolution or fate of the system. Rather, such forces are considered *control parameters*, and all they can do is to push the system into strong fluctuation and chaos. Once this happens, they lose control and the system organizes itself, that is to say, by means of its internal dynamics it gets into a new state of a 'far from equilibrium' steady state and order. A third difference concerns methodologies.

### Methodologies

Methodology is often considered *the* unbridgeable gap between Snow's two cultures and, by implication, between TCS and social theory oriented geographies. The gap seems clear and sharp: the methodological tools of the 'hard' sciences are reductionism, mathematical formalism, statistical analysis, and explanation, whereas those of the 'soft' humanities and social theory the exact opposite—antireductionism, understanding in place of explanation, and hermeneutics in place of analysis. The gap is specifically distinguished with respect to the natural versus the artificial domains, but also within the artificial domain, for example, with respect to the specialized social sciences versus social theory approaches in which fragmentation of the social whole into independent disciplinary domains is rejected.

The notion 'natural sciences' is founded on the (often implicit) assumption that one can clearly differentiate the natural from the artificial. Given this assumption, the aim of the natural sciences is to reveal the laws of nature which, by virtue of being natural, are universal and thus objective. In the sciences, therefore, "the term 'artificial' has a pejorative air about it" (Simon, 1999, page 3). One does not want artifacts in one's data or results. All this is in sharp contrast to research domains which deal with artifacts, which, by their very nature, are the products of human thought, labor, action, and imagination and as such are influenced by social norms, politics, culture, and social structure.

The apparent success of the natural sciences in revealing the properties of nature and in transforming theoretical knowledge into 'hard' technology has made them a model for a 'genuine science'. This, has resulted in a situation of permanent crisis, or at least tension, in the human and social disciplines which, by their very definition, deal with artifacts. Hence, on the one hand we find the view that in order to qualify as genuine sciences these disciplinary domains have to adopt the methodological approach of the sciences—the so-called 'scientific method'; on the other hand we find the view that the artificial domains are fundamentally different from the natural and hence should develop their own specific methods. The disintegration of the social domain into specialized 'social sciences' such as economics, sociology, linguistics, psychology, politics, human geography, and so on, follows the first view, whereas the

insistence of social theory on the treatment of society as a single whole that is not reducible to independent social science disciplines follows the second view. Marx, for example, considered his theory of historical materialism the social equivalent of Darwin's theory of evolution (Meek, 1971, page 193). In Marxist theory, Frankfurt School thinkers like Habermas and Marcuse were specifically active in fostering this second view. More recent examples include Giddens's (1984) structuration theory, and of course the work of PPD scholars.

This methodological debate is a permanent fixture in the artificial domains; not only as above, the social sciences versus social theory approaches, but also in disciplines that deal with planning and design (is planning or urban design a science or an art?) as well as within every social science. Geography is no exception. The 'quantitative revolution' in human geography followed the first line of thinking, seeking to transform geography from a descriptive to an analytical–scientific discipline, whereas the 'SMH revolution' and the subsequent postmodernist approaches followed the second.<sup>(3)</sup>

The question of how can, or should, our specific domain become science is thus common to all sciences of the artificial. An attempt to untangle this question was made by Simon in *The Sciences of the Artificial*, and who, in the 1999 edition, takes into consideration TCS.

### The ant hypothesis

Simon starts by noting that both the natural and the artificial domains are highly complex. The great achievement of natural science was twofold. First, to show, following Descartes, that every complex natural phenomenon can, and methodologically should, be comprehended by means of *analysis*, decomposing the phenomenon into its simple elementary parts and reconstructing the causal relations between these parts. Second, to show that a few purposeless and thus natural laws govern the interactions between the few elementary parts that generate the enormous complexity of nature.

Unlike natural entities, artifacts are the products of aims, intensions, plans, design, and engineering. Plans, design, and engineering, according to Simon (1999) are different forms of rational adaptation to the specific environment, social and otherwise, within which people live. Now, unlike the few and simple natural laws that are the cause of the observed complexity of the natural world, the causes of the artificial world as we observe them in reality are complex. That is, human behavior as we observe it in reality is complex. But this observed complexity should not deceive us, says Simon, because it is only the external appearance of an innately simple behaving system. As an illustration he suggests the two-part 'ant hypothesis':

"An ant, viewed as a behaving system, is quite simple. The apparent complexity of its behavior over time is largely a reflection of the complexity of the environment in which it finds itself" (1999, page 52).

"Human beings, viewed as behaving systems, are quite simple. The apparent complexity of our behavior over time is largely a reflection of the complexity of the environment in which we find ourselves" (page 53).

Most geographical applications of TCS, particularly in the domain of cities, implicitly follow Simon's ant. This is very convenient as most geographical applications have strong inclinations toward economic theory and Simon's ant behaves very much in line with the *homo economicus*—the one-dimensional, selfish, rational, profit-maximizing, imaginary person that is implicitly or explicitly assumed in most economic models,

<sup>(3)</sup> For a similar debate in the sciences see Feyerabend's *Against Method* (1975). See Oreskes (1998) with respect to modeling.

including location theory. The ant hypothesis also underlies most recent geographical applications of TCS, particularly the bottom-up agent-based and cellular-automata models prevalent in the last two decades. These typically start with agents which, like the ant, have one or a few simple aim(s) 'in mind'. These agents come to the city and enter into a local/simple interaction with a cell, its neighboring cells, and agents. The interaction between the simple ant-like agents gives rise to an urban system which in time becomes more and more complex. As the urban environment becomes more complex, so also does the observed behavior of the urban agents seem—but essentially it is not. The complexity is thus a property of the global system as a whole, but not of its individual parts.

This apparently makes perfect scientific sense and indeed might provide a basis for sciences of the artificial which obey the two traditional principles of scientific explanation: that simple causes give rise to a highly complex reality, and Occam's razor principle—that the simplest explanation is best.

But there is a 'little' problem in the above scientific scheme: several experiments with animals' behavior, on the one hand, and the inner rationale of TCS in the life and human domains, on the other, falsify Simon's hypothesis (Portugali, 2003). First, ethological experiments show that rats' exploratory behavior (Golani et al, 1999) is innately complex: rats perform the same complex exploratory behavior when put in a complex environment as they do in a simple environment. According to the pragmatist and ecological approaches currently dominant among students of behavior, the evolutionary rationale for this is that the innate behavior of rats, as well as of other animals, has been evolutionally shaped in the context of complex environments (Freeman, 1999; Gibson, 1979; Varela et al, 1994). Second, in my own research on *Self-organization and the City* (Portugali, 1999) I find that the city (similar to language) is a *dual* self-organizing system: both the city as a whole and each of its parts, that is, human agents, is a complex self-organizing system.

This duality of the city and of complex human systems in general entails a major methodological problem that concerns both the core of scientific explanation—causality and simplicity—and the very essence of complexity. The initial conditions of simple systems are simple: relatively few independent parts, within a system that is itself isolated from its environment. The initial conditions of complex systems are complex: a very large number of interacting parts, linked by a complex network of feedback and feedforward loops, within a system that is open to and, thus part of, its environment. As noted above, in social theory such initial conditions catalyzed the conclusion that the 'scientific method' is not applicable to such systems. The significant achievement of TCS is to show that even with such complex opening conditions a scientific approach is possible. The principle that allows a scientific treatment of complex systems is self-organization, which takes the forms of *information compression*.

### Information compression

'Information' is central to complex systems, by definition. Their openness and large number of interrelated parts from complicated networks, characterized by complex feedback and feedforward loops which allow intensive flows of information.

Information is also important in Shannon's theory (Shannon and Weaver, 1949), which played a seminal role in the development of system thinking and understanding. For Shannon, information is a pure quantity (usually measured by 'bits') devoid of any meaning. This makes sense only in closed systems where the number of possible states which the system can take is finite and known a priori; hence the link between information and entropy, which is a property of closed systems. For example, the information conveyed by throwing a die is 2.5 bits, that is, the logarithm

to the base of 2 of the 6 possible states the system can take. But complex systems are by definition *open*; so what is the meaning of information in complex systems?

Haken (2000) studied information in relation to complex systems. The key feature here is that complex systems 'self-organize', that is to say 'interpret', the information that comes from the environment. In other words, the meaning assigned to the message depends on the receiver (the receiving system), and not just on the message itself as in Shannon's theory. Haken thus distinguishes two forms of information: *semantic information* which is information *with* meaning; versus *Shannonian information* which is information with "meaning exorcised" (Haken, 2000, page 15).

Self-organization is a process of information compression: a large number of parts, each conveying its own specific message, enter into an interaction that gives rise to one or a few order parameters. On emerging, the order parameter(s) enslave the many parts of the system with their many messages. The *slaving principle* of synergetics can thus be seen as an 'information-compression principle': the many potential messages enfolded in the system are being compressed or enslaved into the message of the order parameter. Or, in other words, depending on the internal dynamics of the system, a given external message or set of messages, which can be interpreted and affect the system in a multiplicity of ways, is eventually compressed in a unique way.

In physical systems the transfer of information from sender to recipient depends on the state of the receiving system. Given a signal that transmits a certain message, its impact on a complex system is not causally predetermined: when governed by one attractor the message conveyed will affect the system ('will be interpreted') in one way, and when it is governed by other attractors, in other ways. Fluctuations are thus important to the process of self-organization: they can push the system from one state or attractor to another and thus cause it to respond differently (self-organize) to a given signal.

In biological systems a given signal or message can be interpreted differently depending on the animal's biology (DNA) and experiential memories (for example, conditioning). In the human domain we should add to this list the agent's character, including personal life experience, values, cultural affiliation, and social status.

The above applies to relatively simple cases in which a given single message that can be interpreted in a multiplicity of ways is self-organized and compressed in a unique way. It also applies to the really complex situation which concerns individuals under a bombardment of information, that is, under a multiplicity of messages from a multiplicity of sources and of all kinds. This is typical of the dynamic of cities: every agent operating in the city is continually subject to a multiplicity of messages in the form of views, noises, smells, etc. In order to behave and survive, the agent (person, company, etc) must make sense of all those signals and messages. In other words, the agent must interpret or compress the many messages to a form which is comprehensible by humans' cognitive capabilities and constraints. For example, by the magic number 7, plus or minus 2 which, according to Miller's (1956) classic, limits our capacity for processing information in short-term memory.

Haken and Portugali (2003) have studied information in the context of the city. They show that different elements of the city transmit different quantities of Shannonian information which can be measured in practice by means of information bits, for example. However, this becomes possible only after the city has become self-organized, that is to say, closed in a specific way: in other words, after information has been compressed in a specific way. Such information compression is done partly individually by reference to an individual's personal experience in the city, and partly collectively by reference to cultural and social entities shared by large groups in the city. This process of self-organized information compression is implemented in a variety of ways:

by 'grouping' a variety of elements into singular entities; and by abstraction, that is to say, by categorization. The thesis which I elaborate in the next section is that place and space are two forms of information compression.

### **Place and space as two forms of information compression**

From the point of view of TCS, place and space are two forms of information compression. As noted, information compression in general, and in cities, is implemented in two ways. The first entails grouping or compressing a large set of human activities, artifacts, emotions, and interactions into singular entities with unique identity, that is to say, places. Social theory oriented (SMH and PPD) geographers have elaborated and scrutinized in some detail the process of place creation and the shift "from space to place and back again" (Harvey, 1996, page 291). They portray a process that is at once emotional and functional, related on the one hand to the subjective identity of individuals, and on the other to their collective cultural, social, political, and economic life (Hubbard et al, 2002). There is no room here for a detailed survey of these studies, but I would like to add to the rich literature on this issue that the process of place creation is nicely captured by Giambattista Vico's notion of *poetic geography*:

"By the property of human nature that in describing unknown and distant things, in respect of which they either have not had the true idea themselves or wish to explain it to others who do not have it, men make use of semblances of things known or near at hand ... The ancient geographers agree on this truth ... they confirm that ancient nations, emigrating to strange and distant lands, gave their own native names to the cities, mountains, rivers, hills, straits, isles and promontories (Vico [1744] 1961, page 234).

Vico's process of poetic geography is in line with the pattern-recognition paradigm as described by Haken's (1991) synergetics and the aforementioned process of information compression by means of grouping. In all such processes, stored memories and sensations are used as means to solve an existing cognitive task: in the example described by Vico, to transform anonymous environmental spaces into unique familiar places.

Through this process each city acquires a name (Jerusalem, Paris, New York) which immediately makes it singular, connected to specific memories, history, geography, and mythologies. Each city is further subdivided into a hierarchy of unique singular places (Soho and Harlem in New York, Montparnasse and Quartier Latin in Paris), each with its own name, character, image, specific history or historical association, specific memory, and identity.

As we know, there are geocultural differences in this process: in Europe naming goes down to the level of streets, and only then does it become technical, that is, 'spatial', when each building gets a number. In Japanese cities it goes all the way down to the level of single buildings, whereas in the USA there is a superposition: below the level of cities, we find 1st Street, 2nd Street etc, but also a subdivision into neighborhoods (Soho, Harlem). Note that despite the originally planned 'placelessness' of the notions 1st, 2nd, ... Street, the experiential urban dynamics has transformed such anonymous numbers into meaningful places, so that 5th Avenue or 42nd Street in New York have become unique places which carry with them memories, symbols, images, and the like.

The fact that an identity like 'New Yorker' "can make sense to the polyglot millions who occupy that place", writes Harvey (1996, page 323), "testifies precisely to the political power than can be mobilized and exercised through activities of place construction in the mind as well as on the ground." This fact also testifies to the intimate link between place construction as a collective process and the way in which each individual constructs his or her own personal self-identity, which is among the most

subjective of human sensations. This link and play between the local and the global, the individual and the collective, forms the core of synergetic and other theories of complex systems.

The second form of information compression is the process of categorization. This was traditionally a central topic in philosophy and has recently attracted the attention of cognitive scientists and students of complex systems. In cognitive science, the work of Rosch et al (1976) was seminal in bringing categorization to the center of interest. Subsequent studies on the issue (for example, Johnson, 1987; Lakoff, 1987; Varela et al, 1994) played a central role in changing the view about the whole nature of cognition and mind: from classical cognitivism to embodied cognition.

Cognitive studies on categories and categorization have revealed several types of categories and several processes of categorization. *Classical* categories come into being when a set of instances share one or a few common properties which make them members of a category and differentiate them from nonmembers. *Family resemblance* categories, as originally introduced by Wittgenstein, entail a “complicated network of similarities overlapping and criss-crossing: sometimes overall similarities, sometimes similarities of detail” (1953, paragraph 66). Unlike in classical categories, the members need not share common defining properties. Some family-resemblance categories are characterized by what Rosch et al (1976) have termed *prototypicality*. Such categories are typified by a core–periphery structure (Johnson, 1987; Lakoff, 1987) in which some central instances of the category are more typical of the whole category than are other peripheral instances. These studies have suggested that the various processes of categorization are implemented by means of humans’ innate visual capabilities (for example, color categories), capabilities for poetic thinking (for example, categorization by means of metaphors, metonyms, and the like), and capabilities for analogies and abstraction.

Studying the cognitive process of categorization from the perspective of complex systems, Kohonen’s (1995) theory of *Self-organizing Maps* demonstrates that categorization evolves by means of self-organization in a typical complex system. In subsequent studies Kohonen’s approach has been employed in conjunction with the paradigm of pattern recognition of synergetics (Daffertshofer, 1998). Haken and Portugali (2003) show that, in the context of cities, the starting point for categorization might be one place or a set of unique singular places, each with its own name and identity, which, by means of the various processes of categorization, are given a single identity and name. Thus, Paris, Jerusalem, New York, etc become members of the category ‘city’, and inside cities places such as Harlem and Soho in New York become ‘neighborhoods’, and so forth. By means of this process of categorization places are being transformed into spaces.

Humanistic geographers have emphasized the emotional and experiential – phenomenological dimensions of place creation, very much in line with Heidegger’s notions of ‘being’ and ‘dwelling’. They have criticized the processes that create spaces as processes that create placelessnesses—nonhuman, alienated, and alienating places. SMH, and more recently PPD, geographers have further elaborated the notions of place and space, exposing their multidimensionality. In particular, they have emphasized that place and space are first and foremost social products—with the implication that their production is part of the overall process of sociospatial reproduction.

Quantitative geographers have tried to define human geography as a precise ‘hard’ spatial science by transforming places into spaces; SMH and PPD geographers have gone to the other extreme by criticizing the very attempt to quantify the spatiality and ‘platiality’ of human life and relations. TCS can integrate the two seemingly opposing views. As suggested above, with TCS place and space are portrayed as two forms and facets of a single process of information compression which complement each other.

A purely spatial placeless city, neighborhood, or even street, with no name, identity, history, or mythology is surely not humane. But at the same time, without transforming the humanly rich urban places into one-dimensional cities, neighborhoods, or streets there is no possibility of counting how many cities there are, or how many rich or poor neighborhoods; and without transforming multidimensional human beings into one-dimensional persons (a process strongly condemned by Marcuse, 1968), there will be no way to count the number of people living in a certain city.

Place and space are thus two forms of information compression. There are other forms of information compression which are, in fact, more prevalent in social theory. For example, the notion of 'mode of production' takes the complexity of social, economic, political, and cultural life and compresses them into a single ordering principle. The same can be said of other notions of social theory. The difference is that social theory has arrived at this way of looking at reality mainly by means of hermeneutics, discourse, and language, whereas TCS use mathematical formalism (plus hermeneutics, discourse, and language). I say 'mainly' because, as shown by Sheppard (2001), there is no logical contradiction between mathematical analysis and SMH/PPD views. Sheppard's view, however, is an exception that proves the prevalent view that quantitative and mathematical approaches and qualitative SMH and PPD approaches contradict one another.

Although the methodology differs—mathematical formalism versus hermeneutics—the deep structure of the two methodologies is identical: you start with a complex reality/system, identify its order parameters and modes of production, and show how the modes of production compress the complexity of reality while reproducing it, and so on in circular causality and sociospatial reproduction.

### **The two cultures once again**

The finding that Shannonian information in the city becomes possible only after information has been self-organized and compressed in a specific way (Haken and Portugali, 2003) is rather surprising. It shows that, contrary to what was assumed before, the qualitative–semantic and the quantitative–Shannonian forms of information are interrelated, and that the qualitative–semantic information preconditions the quantitative–Shannonian form. A similar outcome emerged from the preceding discussion: in order to produce abstract quantitative space, one needs qualitative experiential places. As shown by Haken and Portugali (2003), semantic information is created by means of humans' innate cognitive capabilities as well as by reference to politics, culture, and society. In a similar manner, places and spaces are created by reference both in innate cognitive capabilities (that is, grouping people according to their age, color, or gender) as well as by reference to politics, culture, and society.

From the perspective of complex systems the culture of place and the culture of space thus approach each other, like the two ends of an almost-closed circle: the line separating them is very long but the distance between them is short. TCS have the potential to bridge this gap, if geographers from each of the two cultures start taking the other side seriously.

A step in this direction was recently made in Thrift's (1999) examination of "The place of complexity". "First", he states, "I want to take ... complexity theory seriously. It *does* have ... important things to say." But then he retreats: "But second, I want to recognize that complexity theory is just another business opportunity. It is up for sale ... So, third, ... my account ... is tinged with irony and is more than a little ambivalent" (page 33, original emphasis).

Irony and ambivalence are certainly appropriate, specifically in light of the abuses of complexity theory which Thrift describes. But at the same time he also illustrates

the suspiciousness that currently marks the relations between the two cultures of geography. It remains to be seen whether geographers can overcome this suspiciousness and realize the bridging potential enfolded in TCS. At stake here is a gap between two cultures.

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