1 Emergence, complexity, and social science

> How it is possible that institutions . . . can arise without a common will aiming at their creation [is] the significant, perhaps the most significant, problem of the social sciences.
>
> Carl Menger

Societies have often been compared to other complex systems. Inspired by the rise of science and technology, writers in the eighteenth century compared societies to complex artificial mechanisms like clocks; such metaphors are now broadly known as *mechanistic* (La Mettrie [1748] 1912). Inspired by Darwin's influential theory of evolution, nineteenth-century *organicists* compared the various institutions of society to the organs of the human body (Paul von Lilienfeld, Albert Schäffle, and Herbert Spencer). Just after World War II, Talcott Parsons' influential structural-functional theory was inspired by cybernetics, the study of "control and communication in the animal and the machine," the subtitle of a seminal book published by mathematician Norbert Wiener in 1948. Cybernetics was centrally concerned with developing models of the computational and communication technologies emerging in the post-war period, but many cyberneticians applied these models to biology, anthropology, and sociology. In the 1960s and 1970s, general systems theory continued in this interdisciplinary fashion; it was grounded in the premise that complex systems at all levels of analysis – from the smallest unicellular organisms up to modern industrial societies – could be understood using the same set of theories and methodologies (Bertalanffy 1968; J. Miller 1978).

Common to all of these approaches is the basic insight that societies are complex configurations of many people engaged in overlapping and interlocking patterns of relationship with one another. Some key questions raised by these society-as-system metaphors are, How do complex social systems originate, when they are not consciously designed by anyone? What do social relations and configurations look like? Which societies are the most effective, and which are stable and long-lasting? How could

a stable complex system ever change and evolve, as societies often do? What is the role of the individual in the system? These questions have long been central in sociology.

Beginning in the mid-1990s, several scientific developments converged to create a qualitatively more advanced approach to complex systems, and these developments have significant implications for social scientists. The general systems theories of previous decades were always more successful at explaining natural systems than social systems; in spite of the universalist ambitions of such theorists, social scientists generally ignored them. In contrast, the latest work in complex dynamical systems theory – which I refer to as a *third wave* of systems theory (Chapter 2) – is particularly well suited to sociological explanation. In this book, I argue that sociologists should bring these developments into the heart of their discipline; the third wave has the potential to contribute to resolutions of long-standing unresolved issues in sociology and provides methodologies that are of immediate practical use for sociologists (Chapters 8, 9, and 10).

Third-wave systems theory grew out of developments in computer technology. From the 1970s through the early 1990s, computer use in sociology was focused on systems dynamics simulations, in which changes in macrovariables of society – population, poverty rates, urban densities – were mathematically modeled (e.g., Forrester 1971). In the 1990s, however, computer power advanced to the point where societies could be simulated using a distinct computational agent for every individual in the society through a computational technique known as *multi-agent systems* (Chapters 8 and 9). A multi-agent system contains hundreds or thousands of agents, each engaged in communication with the others. The researcher can use these simulations to create *artificial societies* and to run "virtual experiments" – in which properties of agents and of the communication language are varied and the subsequent changes in the overall macrobehavior of the system are observed. Multi-agent systems have been used by complexity researchers to simulate a wide range of natural systems, including sand piles, industrial processes, and neuronal connections in the human brain; in the late 1990s, this methodology was increasingly used to simulate social systems.

This new methodology has led complexity theorists to become increasingly concerned with *emergence* – the processes whereby the global behavior of a system results from the actions and interactions of agents. Philosophers of science, who have been concerned with emergence for almost a century (Chapter 3), refer to properties of system components as being "lower-level properties" and to emergent properties of the entire system as "higher-level properties." In both psychology (Chapter 4) and

sociology (Chapter 5), the relation between lower-level and higher-level properties has often been theorized in terms of emergence. But these various treatments of emergence in the social sciences have been scattered and are often contradictory. In Chapters 3, 4, and 5, I critically review these various treatments and develop a foundational account of social emergence.

Like "emergence," the term "complexity" has also been used somewhat loosely in the last decade. In the most general sense, complex phenomena are those that reside between simplicity and randomness, at "the edge of chaos," in Kauffman's (1993a) terms. When the laws governing a system are relatively simple, the system's behavior is easy to understand, explain, and predict. At the other extreme, some systems seem to behave randomly. There may be laws governing the behavior of a system of this type, but the system is highly nonlinear – small variations in the state of the system at one time could result in very large changes to later states of the system. Such systems are often said to be *chaotic*. Complex systems are somewhere in between these two extremes. A complex system is not easy to explain, but it is not so chaotic that understanding is completely impossible (as argued by researchers associated with the Santa Fe Institute, including Murray Gell-Mann and Stuart Kauffman).

In complex systems so conceived, relatively simple higher-level order "emerges" from relatively complex lower-level processes. Canonical examples of emergence include traffic jams, the colonies of social insects, and bird flocks. For example, the V shape of the bird flock does not result from one bird being selected as the leader, and the other birds lining up behind the leader. Instead, each bird's behavior is based on its position relative to nearby birds. The V shape is not planned or centrally determined; it emerges out of simple pair-interaction rules. The bird flock demonstrates one of the most striking features of emergent phenomena: Higher-level regularities are often the result of simple rules and local interactions at the lower level.[1]

In the social sciences, a comparable example of an emergent phenomenon is language shift. Historians of language have documented that languages have changed frequently throughout history, with vocabulary and even grammar changing radically over the centuries. Yet until the rise of the modern nation state, such changes were not consciously selected by any official body, nor were they imposed by force on a population. Rather, language shift is an emergent phenomenon, arising out of uncountable everyday conversations in small groups scattered throughout the society

[1] A computer simulation of bird flock emergence has been developed by Reynolds (1987).

(Sawyer 2001a). In this social system, the "lower level" consists of the individual speakers, their interactions are the individual conversations, and the "higher level" is the collective social fact of language as a group property.

Common to both of these examples is that emerging at the global system level are patterns, structures, or properties that are difficult to explain in terms of the system's components and their interactions. Whether or not a global system property is emergent, and what this means both theoretically and methodologically, has been defined in many different ways, and one of the primary purposes of this book is to identify and clarify these many senses of the term in the social sciences. For example, in some accounts system properties are said to be emergent when they are *unpredictable* even given a complete knowledge of the lower-level description of the system – a complete knowledge of the state of each component and of the interactions of all the components. In other accounts, system properties are said to be emergent when they are *irreducible*, in any lawful and regular fashion, to properties of the system components. In yet other accounts, system properties are said to be emergent when they are *novel*, when they are not held by any of the components of the system (see Cilliers 1998 for an extensive list of the characteristics of complex systems). Philosophers of science have debated such properties since the burst of emergentist theory in the 1920s (Chapter 3); some philosophers emphasize one or another of these features, and others argue that there are no such properties in nature. Social scientists have applied widely different definitions of emergence, resulting in conceptual confusion (Chapter 5).

Nonetheless, there is a consensus that complex systems may have autonomous laws and properties at the global level that cannot be easily reduced to lower-level, more basic sciences. Thus the paradigm of complexity is often opposed to the paradigm of reductionism (Cederman 1997, Chap. 3; Gallagher and Appenzeller 1999). For example, philosophers of mind generally agree that mental properties may not be easily reduced to neurobiological properties, due to the complex dynamical nature of the brain. In an analogous fashion, I use complex dynamical systems theory to argue against methodological individualism, the attempt to explain groups in terms of individuals. In Chapters 5, 8, 9, and 10, I show why methodological individualism will have limited success as a potential explanation for many group phenomena.

Complexity theorists have discovered that emergence is more likely to be found in systems in which (1) many components interact in densely connected networks, (2) global system functions cannot be localized to any one subset of components but rather are distributed throughout the

entire system, (3) the overall system cannot be decomposed into subsystems and these into smaller sub-subsystems in any meaningful fashion, (4) and the components interact using a complex and sophisticated language (Chapter 5). Not all complex systems have all of these features; for example, interaction between birds in a flock involves very simple rules, but it manifests emergence because of the large number of birds. Conversely, the complex musical communication among the four musicians in a jazz group leads to emergent properties, even though there are only four participants (Sawyer 2003c). These properties of emergence were originally proposed to explain complexity in biological and physical systems; in this book, I argue that all four of these properties are found in social systems, perhaps to an even greater extent than in natural systems.

These properties are interrelated in most complex systems. For example, social systems with a densely connected network are less likely to be decomposable or localizable. In modern societies, network density has become progressively greater as communication and transportation technology has increased the number and frequency of network connections among people; some complexity theorists suggest that this results in *swarm intelligence* (Kennedy and Eberhart 2001). Swarm intelligence and network density were first explored by French sociologist Émile Durkheim, who referred to the phenomenon as *dynamic density* (cf. Durkheim [1895] 1964, 114–5), and in Chapter 6, I argue that Durkheim was the first social emergence theorist and that contemporary complexity theory sheds new light on several poorly understood aspects of Durkheim's writings.

The individual and the group

The social science disciplines that emerged in the nineteenth century were centrally concerned with the uniquely complex nature of human societies, and the relationship between the individual and the collective has always been one of the most fundamental issues in the social sciences. This relationship was a central element in the theorizing of the founders of sociology and economics, including Comte, Weber, Smith, Menger, Durkheim, Simmel, and Marx. The processes whereby aggregated individual actions lead to macroeconomic phenomena have been a central focus of neoclassical microeconomics. Contemporary organizational theory is deeply concerned with how organizational structure influences individual action and how individual behavior results in the emergence of global organizational properties (Carley and Gasser 1999; Cyert and March 1963; Marion 1999). In sociology, this relationship

is known as the *micro-macro link* (J. C. Alexander et al. 1987; Huber 1991; Knorr-Cetina and Cicourel 1981; Ritzer 2000). Theories of the micro-macro link are central, if implicit, to many twentieth-century sociological paradigms, including structural functionalism (Parsons [1937] 1949, 1951), exchange theory (Blau 1964; Homans 1958, 1961), and rational choice theory (Coleman 1990).

Drawing on both philosophical discourse and on systems theory, many sociological accounts of the micro-macro link use the term "emergence" to refer to collective phenomena that are collaboratively created by individuals, yet are not reducible to individual action (Archer 1995; Bhaskar 1979, 1982; Blau 1981; Edel 1959; Kontopoulos 1993; Mihata 1997; Parsons [1937] 1949; Porpora 1993; T. S. Smith 1997; Sztompka 1991; Whitmeyer 1994; Wisdom 1970). Emergence theories attempt to explain the nature of society as a complex system by accounting for how individuals and their relations give rise to global, macro social phenomena, such as markets, the educational system, cultural beliefs, and shared social practices (e.g., politeness and power dynamics). However, despite the broad appeal of the term "emergence," it has never been adequately theorized by social scientists, and as I show in Chapter 5, there is much confusion surrounding the term.

For example, microeconomists and some sociologists attempt to explain macro social properties by identifying the micro-to-macro process of emergence – how individual actions and dyadic interactions aggregate to result in macro social phenomena, such as institutions, social movements, norms, and role structures. Sociologists use the phrase "methodological individualism" to describe this bottom-up approach to modeling social phenomena. Sociologists who attack this approach argue that there are macro social phenomena so complex that they could never be successfully modeled in this way. Instead, they argue that sociology will always have irreducibly social terms and laws. In Chapters 5 through 7, I explore theories of emergence in sociology, show that these treatments have been inadequate and remain confused, and propose a clarifying framework that draws on philosophy of science and complexity theory.

In the latter decades of the twentieth century, a renegade group of psychologists known as *socioculturalists* have used "methodological individualism" to invoke a different enemy – the individualist focus of mainstream psychology. Sociocultural psychologists argue that traditional psychology must be redefined to incorporate social and cultural context. In their writings, "methodological individualism" refers to the experimental methods of research psychology, where the unit of analysis is a single randomly sampled individual and where the variables are all measured

properties of individuals. Socioculturalists emphasize the collective creativity of human collaborative action in small groups, such as in family settings, classrooms, and the workplace (e.g., Sawyer 2003c). In Chapters 4 and 7, I explore emergence in sociocultural studies of small groups because this work has recently begun to address long-standing sociological issues.

Although both sociologists and socioculturalists share a rejection of individualist reductionism, the forms of reductionism they explicitly oppose are somewhat different. The Austrian economists who first elaborated methodological individualism in the middle of the twentieth century – Hayek, Popper, and Mises – took pains to distinguish it from methodological psychologism, the true foil of the socioculturalists. These economists never thought that economics would reduce to psychology. My discussion speaks to both sociologists and socioculturalists and uses emergence theory to fruitfully explore these different anti-individualist approaches.

To date, complex systems conceptions of emergence have had almost no impact on these debates. In Chapters 8, 9, and 10, I draw on the study of complex dynamical systems to provide new perspectives on these important unresolved issues – the relations between individuals and groups, the emergence of unintended effects from collective action, and the relation between the disciplines of economics and sociology. In short, my conclusion is that whether or not a social system can be understood solely in terms of its component individuals and their interactions is an empirical question, to be resolved anew with respect to each social system. Theories of emergence from complexity science show why some social properties cannot be explained in terms of individuals. Thus, economics and psychology cannot assume that methodological individualism can exhaustively explain human behavior in social groups. However, not all social systems are irreducibly complex, and some social properties can be explained by identifying their processes of emergence from individuals in interaction. Complex systems theory can help to determine which approach will be most appropriate for which social property.

Studies of social groups must be fundamentally interdisciplinary because a focus on emergence requires a simultaneous consideration of multiple levels of analysis: individuals, their communication language, and the group. The explanation of any given social system cannot be provided by psychology, sociology, or economics alone; it will require interdisciplinary teams (and perhaps even a new type of graduate student training) of the sort that are currently being attempted in the computational modeling of social systems (Chapter 8).

Sociology and symbolic communication

A second goal of this book is to suggest a potential rapprochement between microsociology and macrosociology. Within both sociology and economics, theorists interested in emergence – in the relations between agent action and interaction at the lower level and the global properties of the society at the higher level – have not considered the role of symbolic communication. However, artificial societies show that when the agent communication language changes, the processes of emergence change, and the global properties that emerge often change as well. In Chapter 9, I combine two strands of current research to show that sociologists and economists must foundationally incorporate sophisticated theories of symbolic communication in their models of emergence. First, I discuss several artificial societies and show how changes in agent communication result in changes in emergence. Second, I discuss recent empirical studies of emergence in small social groups (Sawyer 2003c, 2003d); these empirical studies show that group properties emerge from rather complex and subtle differences in symbolic communication. To date, the role of communication in social emergence has been neglected.

The third-wave view of social systems as agents in interaction reveals the importance of complex communications among individuals. The complexity of human language distinguishes complex social systems from the complex systems studied in the natural sciences. As a result, social systems have unique properties that are not held by other complex systems in nature, and social systems require elaborations of the notions of emergence and complexity that were originally developed to explain complex systems in nature. The study of the unique properties of social systems can contribute to complex dynamical systems theory more generally, and this book will be of interest not only to social scientists but also to researchers in the interdisciplinary field of complexity science.

The complexity of social systems does not entail that methodological individualism will always fail. After all, emergence and complexity have been more fully embraced by economists than sociologists – for example, economists participate actively in interdisciplinary complexity groups such as the Santa Fe Institute and the University of Michigan Center for the Study of Complex Systems – and neoclassical microeconomics is foundationally based in methodological individualism. In Chapter 5, I show how social properties may be emergent from individual action and interaction, yet not reducible to explanation in terms of them, and I provide an account that clarifies which properties of social systems can be explained with methodological individualism and which

cannot. The theory of social emergence allows the distinctive perspectives of economists, sociologists, and psychologists to be considered and integrated.

The primary audience for this book will be sociologists, who will learn how these new developments in complexity science have the potential to transform sociological research. Psychologists and economists will learn how these transformations in sociology might affect their disciplines (particularly in Chapter 10). A secondary audience will be complexity researchers more broadly, who may gain insights into how they might extend their formalisms and models to adequately capture a broader range of complex dynamical systems – not only natural systems but also social systems.

2 The third wave of social systems theory

The first wave of social systems theory is Parsons's structural functionalism, the second wave is derived from the general systems theory of the 1960s through the 1980s, and the third wave is based on the complex dynamical systems theory developed in the 1990s. This book focuses on the third wave of systems thinking in sociology. Third-wave systems theory has more potential relevance to sociology than the first two waves, and it offers theoretical concepts and methodological tools that have the potential to speak to unresolved core sociological issues. Because the third wave has not yet had much impact on the social sciences, a primary goal of this book is to demonstrate that third-wave theory addresses weaknesses of the first and second waves and to show the practical and theoretical implications for the social sciences.

First- and second-wave systems theories often discussed social emergence, but these prior treatments were overly brief and insufficiently developed; foundational questions related to emergence were not addressed. For example, both individualists and collectivists often refer to themselves as emergentists, yet their positions are theoretically incompatible (Chapter 5). Collectivists argue that although only individuals exist, collectives possess emergent properties that are irreducibly complex and thus cannot be reduced to individual properties and relations. Yet emergence has also been invoked by methodological individualists in sociology and economics. Methodological individualists accept the existence of emergent social properties but claim that such properties can be explained in terms of individuals and their relationships.

Thus, contemporary uses of emergence in sociology and economics are contradictory and unstable; two opposed paradigms both invoke the concept of emergence and draw opposed conclusions, one consistent with methodological individualism and one inconsistent with it (also see Kontopoulos 1993). The problem arises in part because neither sociologists nor economists have developed an adequate account of emergence. Contemporary sociologists are not the first to be confused about