UNDERSTANDING COMPLEX SYSTEMS

Springer: COMPLEXITY

Brian Castellani
Frederic Hafferty

Sociology and Complexity Science

A New Field of Inquiry

Springer

Springer Complexity

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Understanding Complex Systems

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UCS will publish monographs, lecture notes and selected edited contributions aimed at communicating new findings to a large multidisciplinary audience.

Brian Castellani · Frederic William Hafferty

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Dr. Brian Castellani
Department of Sociology
Kent State University
3300 Lake Road West
Ashtabula, OH 44004
USA
&
Department of Psychiatry
Northeastern Ohio Universities
College of Medicine (NEOUCOM)
Rootstown, OH 44272
USA
bcastel3@kent.edu

Dr. Frederic William Hafferty
Department of Behavioral Sciences
University of Minnesota Medical
School - Duluth
1035 University Drive
Duluth, MN 55812-2487
USA
phaffert@charter.net

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From Castellani: To my wife, Maggie, and my daughter, Ruby

From Hafferty: To my sons, Philip and David

Preface

By now, most academics have heard something about the new science of complexity. In a manner reminiscent of Einstein and the last hundred years of physics, complexity science has captured the public imagination. One can go to Amazon.com® and purchase books on complexification (Casti 1994), emergence (Holland 1998), small worlds (Barabási 2003), the web of life (Capra 1996), fuzzy thinking (Kosko 1993), global complexity (Urry 2003) and the business of long-tails (Anderson 2006). Even television has incorporated the topics of complexity science. Crime shows such as 24® or CSI® typically feature investigators using the latest advances in computational modeling to "simulate scenarios" or "data mine" all possible suspects—all of which is done before the crime takes place. The *World Wide Web* is another example. A simple search on Google.Com® using the phrase "complexity science" gets close to a million hits! Complexity science is ubiquitous. What most scholars do not realize, however, is the remarkable role sociologists are playing in this new science. Consider the following examples.

0.1 Sociologists in Complexity Science

The first example comes from the new science of networks (Barabási 2003). By now, most readers are familiar with the phenomena known as six-degrees of separation—the idea that, because most large networks are comprised of a significant number of non-random weak-ties, the nodes (e.g., people, companies, etc.) in these networks are generally separated by six or fewer links (e.g., Buchanan 2002, Watts 2004). Readers also may know, from the popular science literature, that the new science of networks is being used to explore a long list of cutting-edge topics, from the global spread of disease to terrorist cells to the human genome project to consumer purchasing behaviors (Buchanan 2002; Newman, Barabási, and Watts 2006). What is noteworthy, however, is that the leading researcher in this field, Duncan Watts, is a professor of sociology at Columbia University (USA). Equally noteworthy, the new science of networks is based, in large measure, on the past twenty years of research in the sociological field of social network analysis (Freeman 2004).

The second example comes from computer simulation, also known as computational modeling (Casti 1999). Over the last decade, computational modeling (the backbone of complexity science method) has made major inroads into science and the market place. From Mathematica® and MATLAB® to RePast® and SWARM,® various software platforms are now used on a regular basis to simulate living cells, state-level policies, disaster scenarios, chemical reactions, water treatment facilities, the collision of black holes, traffic patterns and the dynamics of the stock market (Gilbert and Troitzsch 2005). The list of pioneering scholars in this field includes John Holland, Robert Axelrod, Stephan Wolfram and Joshua Epstein, to name a few. It also includes, right up there at the top, the British sociologist, Nigel Gilbert, editor of the international periodical, *Journal of Artificial Societies and Social Simulation* (e.g., Gilbert and Abbott 2005; Gilbert and Troitzsch 2005).

The third example comes from the classical era of sociology. Many of the scholars regularly associated with the cannon of sociology—Emile Durkheim, Herbert Spencer and Vilfredo Pareto—were also instrumental in the creation and development of systems thinking. In fact, a variety of cutting-edge ideas in complexity science come from these canonical scholars. The best example is Pareto's 80/20 rule, which is crucial to understanding the structure of large, complex networks (Buchanan 2002). Another is Durkheim's concepts of system differentiation, which ties directly to the concepts of system bifurcation and strange attractors (Luhmann 1995).

The fourth example comes from the *complexity turn* in sociology. As Urry explains, in the last decade, a number of highly influential sociologists have begun to integrate the tools of complexity science into their work. These sociologists include Immanuel Wallerstein (2005), Andrew Abbott (2001), Niklas Luhmann (1995) and Manuel Castells (2000a). Wallerstein, for example, has integrated the work of Prigogine into his world systems theory (2005); Abbott has applied fractals, self-similarity and chaos to the structure and dynamics of the social sciences (2001); Luhmann has constructed a theory of modern society based on the concept of social autopoiesis (1995); and Castells has developed a theory of globalization using the concept of network. These sociologists are joined by a growing network of sociologists and likeminded scholars, including Duncan Watts, Mark Newman, Albert-László Barabási, Kenneth Bailey, Walter Buckley, Felix Geyer, Phillip Bonacich, David Byrne, Jürgen Klüver, and Christopher Goldspink. What is so exciting about this growing network of scholars is that they are involved in the creation of a new, international, post-disciplinary, highly mobile, intellectual community devoted to the study of *sociology and complexity science*, or, what we call, *SACS* for short.

In terms of main street sociology, the value of SACS, among other things, is the incredible new toolkit of theories, concepts, methods and techniques it offers sociologists. Here are some examples:

- In terms of method, SACS offers the following:
  - Agent-based modeling; otherwise known as generative computer simulation.
  - Cellular automata.
  - Neural networking; otherwise known as distributed artificial intelligence, specifically the self-organizing map.
  - Genetic algorithms.
  - Data mining.
  - The new science of networks.
  - Dynamical systems theory; otherwise known as chaos theory.
  - Fractal geometry.
  - New ways to use statistics, such as the Pareto distribution, power laws, regression, and cluster analysis.
  - Nonlinear, dynamic, mathematical modeling.
  - Discrete mathematics.

The strength of these methodological tools—which we discuss more extensively in Chaps. 2, 3 and 5—is their ability to handle the growing complexity of sociological work, such as the massive, electronic databases now regularly studied by sociologists. They also are very helpful in generating theory, testing policy, and conducting social experiments.

- In terms of theory, SACS offers the following:
  - Luhmann's new social systems theory.
  - Buckley's theory of society as a complex adaptive system.
  - Byrne's critical realism.
  - Geyer's radical constructionism.
  - Watt's concept of the small-world.
  - Barabási's concept of scale-free networks.
  - Bak's concept of self-organizing criticality.
  - Holland's theory of emergence.
  - Newman's complex networks.
  - And, the concept of the *complex social system*.

The last concept listed is, theoretically speaking, the most important tool SACS offers sociologists and likeminded thinkers. By drawing upon the theoretical advancements of complexity science, SACS offers a fresh and innovative approach to *sociological systems thinking* and its leading concept, the *social system*. In so doing, SACS not only reinvents the systems tradition in sociology, it provides an empirical, methodological and theoretical yield that is rather astonishing. To learn more about this astonishing yield, we need to turn to the purpose of our book.

0.2 Purpose of Book

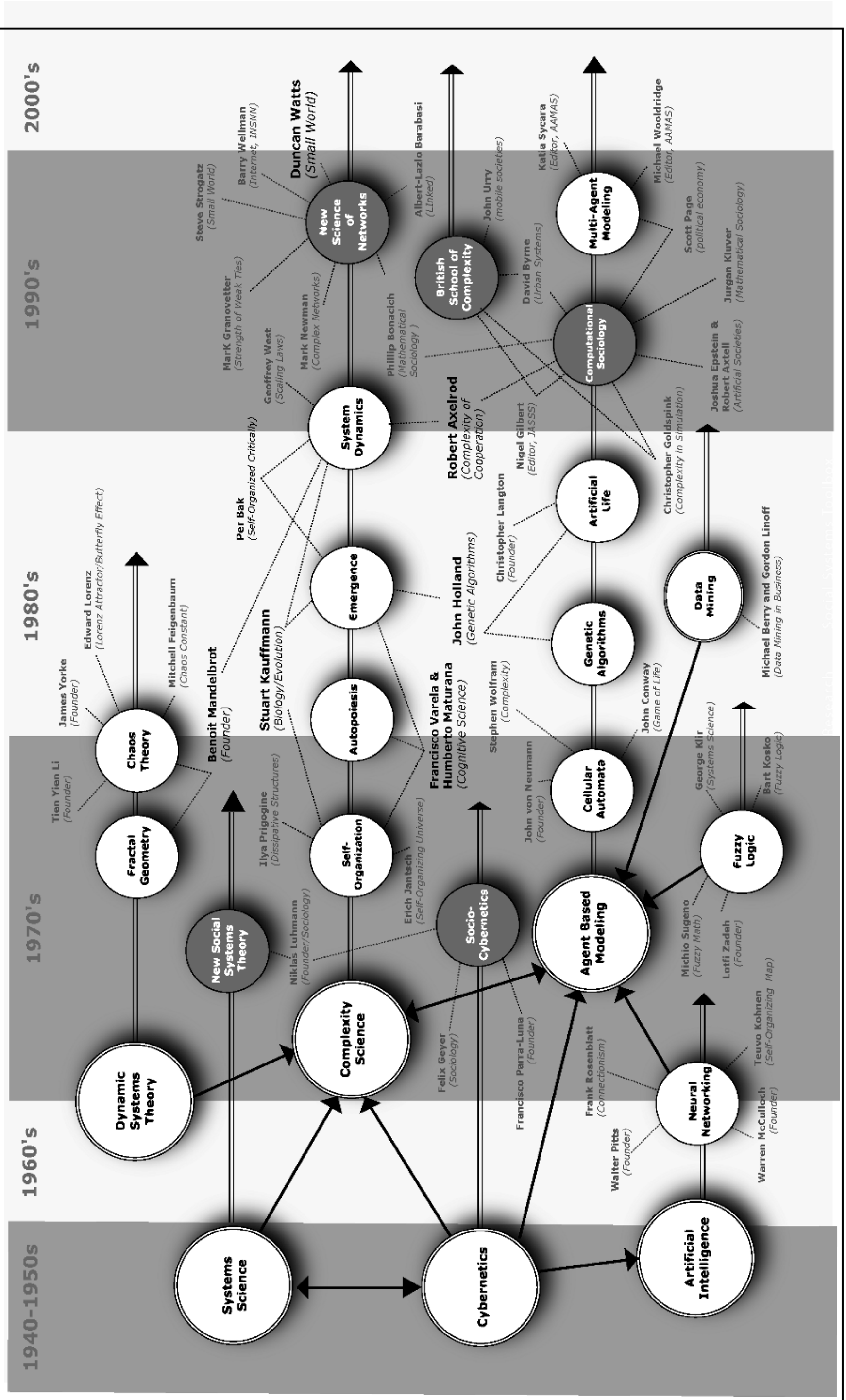
Given all that SACS has to offer, we wrote this book to introduce sociologists to, and provide a thoroughgoing review of, this new intellectual community.

Our book is the first complete overview of the SACS community, including its history, its connection to complexity science, and its five major areas of research: computational sociology, the British-based School of Complexity (BBC), complex social network analysis (CSNA), sociocybernetics and the Luhmann School of Complexity (LSC). As shown in Map 1 (See Chap. 10 for details about reading this map), these five areas represent the latest advance in sociological systems thinking, offering sociologists a powerful conceptual and methodological toolbox for addressing the growing complexity of their work.

To date, several excellent histories have been written on the larger field of complexity science (e.g., Capra 1996; Cilliers 1998; Waldrop 1992). There is also a growing list of articles and a few books that address the major areas of research in the SACS (e.g., Freeman 2004; Geyer and Zouwen 2001; Gilbert and Troitzsch 2005; Macy and Willer 2002; Rasch and Wolfe 2000). There is even a developing literature, primarily emerging out of the British-based School of Complexity (BBC), that critically examines the theoretical and methodological import of complexity science for sociological inquiry (e.g., Byrne 1998; 2001, 2002; Geyer and Zouwen 2001; Richardson and Cilliers, 2001).

Furthermore, two excellent books have been written about complexity science for a sociological audience. There is Eve, Horsfall and Lee's edited *Chaos, Complexity and Sociology: Myths, Models, and Theories* (1997) and Byrne's *Complexity Theory and the Social Sciences* (1998). Along with being over a decade old, these books focus on the history of complexity science and its implications for sociology. The current book, in contrast, focuses on the last decade of research integrating complexity science with sociology—something that the above two books, in many ways, helped to initiate and develop. Byrne's work, in particular, played a significant role in the development of the BBC.

Map 1: The New Science of Complexity



As such, to date, while a significant amount of work has been done to develop, assess and review the new science of complexity and its implications for sociology, the community of SACS as a whole has yet to be empirically identified, defined or reviewed, let alone treated as a formal scientific system for study. Providing such an overview, however, is not the only reason we wrote this book.

0.3 SACS Toolkit

In addition to reviewing the community of SACS, our book has a second purpose. We want to introduce readers to our new toolkit for modeling social systems, which we call, appropriately enough, the *SACS Toolkit*. Toolkits are designed to accomplish a task. They come with blueprints, guidelines, supplies, tools, techniques, information overviews, maps, figures, case studies, and so forth. The SACS Toolkit is designed for modeling social systems. The SACS Toolkit is comprised of the following:

- It has a theoretical framework, called *social complexity theory,* which provides researchers a set of working concepts and a practical framework for organizing their empirical inquiries into the structure and dynamics of most social systems. Related, the SACS Toolkit can be used with (rather than against) existing concepts and theories in sociology.

- It has a procedural algorithm, which we call *assemblage*, that provides researchers a step-by-step method for building from the "ground-up" a working model of a social system.

- It has a recommended list of methods and techniques best suited for studying social systems. While the SACS Toolkit can be used with just about any sociological method or technique, researchers will find the following toolset somewhat indispensable: cluster analysis, neural networking (specifically, the self-organizing map), social network analysis, grounded theory method, Foucault's genealogical method, fractal geometry, chaos theory, computational modeling, and data mining.

- An accompanying website comprised of additional reviews, case studies, graphics and so forth to help researchers learn about complexity science, SACS and the Toolkit. See www.personal.kent.edu/~bcastel3.

Chapters 2 and 3 provide a detailed overview of the SACS Toolkit. They also explain why we applied this toolkit to the study of SACS. Our study of SACS is a combination of historical and quantitative data. It also includes our usage of a variety of methodological techniques, such as historiography, grounded theory, statistics, social network analysis and the new science of networks. To handle the complexity of our data and related techniques, we turned to the SACS Toolkit. The strength of the SACS Toolkit is its ability to handle such a wide variety of data and techniques, all in the effort to model a complex social system.

Our application of the SACS Toolkit to the study of SACS resulted in the third reason we wrote this book.

0.4 Applying the Toolkit to SACS

The third purpose of our book is to demonstrate the utility of complexity science for sociological inquiry by applying the SACS Toolkit to our review of the SACS community. As the old adage goes, there is no learning like doing. The structure and dynamics of the SACS community are (no pun intended) rather complex. We therefore decided that the best way to handle this complexity was to employ the SACS Toolkit. Our book is therefore as much a handbook in SACS method as it is an introduction to SACS. In addition to Chaps. 2 and 3, throughout the book we provide the reader a number of methodological pauses, which address various issues related to the particular analysis in which we are engaging. To follow these pauses, the index has two major headings: *SACS Toolkit* and *Methodological Issues in Book.*

0.5 Outline of Book

Our book follows the traditional academic format: introduction (Chap. 1), method (Chaps. 2 and 3), summary of results (Chap. 4), detailed overview of results (Chaps. 5 through 8), and conclusion (Chap. 9).

Chapter 1 provides an overview of the systems tradition in sociology, focusing on its three major eras: the *classical era* of Marx, Spencer, Pareto and Durkheim; the *functional era* of Parsons, Merton and the new fields of cybernetics and systems science; and the *complexity turn era*, which includes the new scholars of SACS.

Chapters 2 and 3 introduce readers to the SACS Toolkit, including why we chose to use it to study the SACS community.

Chapter 4 summarizes the results our study. In fact, upon completion of this chapter, the reader has a basic working knowledge of SACS.

The next four chapters explore the SACS community in further detail. *Chapter 5* discusses the major environmental forces impacting SACS, including the growing complexity of sociological work and the emergence of complexity science. Chapter 5 (along with Map 1) also provides a formal (albeit brief) review of the new science of complexity, including its major traditions, key areas of study and methods, and leading figures. Chapter 5 therefore constitutes the *fourth* reason we wrote this book. It helps readers new to complexity science gain a basic sense of the field, along with directions for future research.

Chapter 6 provides a detailed overview of the five areas of research in SACS such that a given reader could begin to pursue research in any one of them.

Chapter 7 goes back to the late 1990s to see if there is some formal tipping point after which SACS emerges as a legitimate area of inquiry. From there, the last decade of development in SACS is explored.

Chapter 8 focuses on the structure and dynamics of SACS today, including its major hubs, authorities, gatekeepers and household names. This chapter also explores the fractal dynamics of SACS and its major intellectual trajectories.

Chapter 9 is our conclusions chapter. In addition to summarizing, in non-technical terms, the findings of our study, this last chapter examines the impact the SACS community is having on sociology today.

Chapter 10: Mapping Complexity. This final chapter constitutes the fifth reason we wrote our book: to provide readers a visual tour of complexity science and the new community of SACS. The SACS Toolkit is a highly visual method for modeling social systems. As such, our book relies upon, rather extensively, a series of images—maps, figures and graphs. Given our repeated usage of these images, we created Chap. 10.

Chapter 10 provides the reader a full-scale version of each image in the book, along with a basic introduction on how to read it, as well as directions about where in the book the image is first used and explained. This way, as the reader moves through the chapters, the images we repeatedly use, can be easily found.

Nevertheless, we do still provide a thumbprint of our images in the text. During the course of reading the book, the first time an image is used, it will be included in the text.

As a final note, all of the images in Chap. 10 are available, in color, at our website, for easy download. Maps 1 and 2 are also available electronically, with links to the internet so that teachers and readers can use the web to explore further the major scholars, topics, or fields of study in SACS and complexity science (See www.personal.kent.edu/~bcastel3/).

0.6 Ways to Read Book

We used the traditional format so that readers with different purposes and backgrounds could make effective use our book. This book can be read four different ways:

The Quick Read: For readers looking to gain a quick overview of the book, we recommend reading the conclusion (Chap. 9) first and then Chaps. 4 and 1, which provide a more detailed review of the SACS community and its connection to the history and current challenges of organized sociology and the sociological systems tradition.

The How-To Read: For those primarily interested in an in-depth understanding of the SACS Toolkit we recommend reading our method chapters first (Chaps. 2 and 3), followed by Chap. 4, which summarizes how we employed the SACS Toolkit to study the SACS community. From here, the reader can explore Chaps. 6 through 8 to see detailed examples of how we used the SACS Toolkit, along with Chap. 10, our visual tour.

The Sociological Read: For those interested in the sociological side of complexity science, we recommend reading Chaps. 1 through 4, followed by Chap. 9. This approach provides a good review of the systems tradition in sociology and the community of SACS, as well as our new toolkit for modeling social systems as applied to SACS.

The Full-Read: For those interested in a full review of the SACS community, complexity science and the SACS Toolkit, we recommend the following reading. Read the Chaps. 1, 2 and 3, then the conclusion, following by Chap. 4. From here, proceed to read Chaps. 5 through 8.

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Contents

1 Introduction

The complexity of sociology

1.0 Telling the Story of Sociology's Complexity

Deciding how to tell the story of western sociology and its complexity is not easy (Baehr 2002; Collins 1994; Coser 1977; Lepenies 1988; Merton 1968, 1996; Ritzer and Goodman 2004). One problem concerns the "nostalgia trap" of sociology—the tendency to conflate Merton's distinction between the *history* and *systematics* of sociology (1968). History has to do with hermeneutics: "recovering" the meaning of the historical texts of sociology by reading them as they were intended, including the audience for which they were created and the social and material contexts in which they were situated (Merton 1968). Equally important, history concerns historiography: the method of getting the "history" of sociological texts correct, including the exact influence they had upon whom and why and to what extent (Jones 1983). In contrast, systematics has to do with exegesis: making use of historical texts by applying them to the present; that is, creatively reading and interpreting "texts" from the past in terms of the concerns and intentions of today. Systematics involves "creating" new links between the present and the past (Jones 1983, p. 447). Said another way, the "history" of sociology has to do with reading the past for its own sake, while systematics has to do with constructing a "history of the present" (See Foucault 1991, Chap. 1).

The nostalgic trap is the process of conflating exegesis with hermeneutics and historiography. In so doing, history falsely becomes the confused with creative links contemporary sociologists make with the past; not history as it actually happened.

Moving forward from Merton, the new historians of sociology (circa 1980s) refer to the nostalgic trap as *presentist* history, in contrast to their own approach, which they call *historicist* history. For the new historians, while historicists keep history and systematics separate, presentists fall into the nostalgic trap, treating exegesis as history (Jones 1983; Seidman 1985).

For the new historians, the nostalgic trap is a problem, in part, because it ignores the political, economic, cultural, disciplinary and academic (i.e., historical) realities in which the discipline of sociology emerged and developed; and because it gives a false impression of the role different scholars and scholarly traditions have played in the progress of the discipline (See Connell 1997 and Jones 1983 for a review of this debate). For example, while Karl Marx is not a sociologist, his tremendous and continued influence on many sociologists renders his work, from a systematics perspective, "classic" and therefore part of the "cannon" of the discipline. From a historical perspective, however, Marx was not involved in the creation or development of sociology. Furthermore, most scholars writing under the disciplinary auspices or academic letters of "sociology" during the late 1800s and early 1900s did not treat Marx as a sociologist or his work a "classic." Neither did many of them—particularly in the United States, where the discipline of sociology would primarily take shape—treat Weber or Durkheim with much admiration or awe (Jones 1983). In fact, as Connell explains:

> Turn-of-the-century sociologists had no list of classics in the modern sense. Writers expounding the new science would commonly refer to Comte as the inventor of the term, to Charles Darwin as the key figure in the theory of evolution, and then to any of a wide range of figures in the intellectual landscape of evolutionary speculation (1997, p. 1513).

The other reason the nostalgic trap is a problem for historicists (and for Merton) is because it is so pervasive. As Jones (1983) and Connell (1997) explain, from Durkheim to Parsons to Giddens, the name of the historical game seems to be exegesis-as-history; or, as Merton states, "retrieving" past sociological texts for their use in the present (1968). Given the fame of the numerous presentists in sociology, their view has become—particularly since the 1920s—the standard account of the discipline. For example, as Connell points out, the majority of contemporary undergraduate and graduate textbooks in "English speaking" sociology consistently treat systematics as history (1997, pp. 1512–1515).

Because the nostalgic trap is an important issue in the historiography of sociology, we will keep the following five points in mind while telling our story of sociology's complexity.

- First, we will remember that the term "sociology" refers to a somewhat heterogeneous and often times conflicting and discontinuous network of scholars, theories, concepts, methods, intellectual traditions, schools of thought and substantive topics generally associated with the study of society.

- Second, we will remember that different scholars gather, organize, center, marginalize and ignore aspects of this "sociology" in distinctive ways, each telling a somewhat unique "story" about the discipline based on the particular "history of the present" they seek to construct—think Michel Foucault (1977, 1980, 1987).
- Third, we will remember that the storyline of sociology is not necessarily linear, seamless, progressive, or continuous. In fact, in many ways it is filled with intellectual cul-de-sacs, "dead-ends," breaks, retrogressions, tangents and, in some cases, unrecognized work. One example would be the continued marginalization of the works of W.E.B. Dubois and Jane Adams (Ritzer and Goodman 2004).
- Fourth, we will remember that there is no single sociology; instead, there are many. As Collins, for example, has made clear, the story of sociology in France is not the story of sociology in England; and the story of European conflict sociology is not the story of pragmatic sociology in the United States (Collins 1994).
- Finally, we will remember that, despite the nonlinear trajectory of sociology, and despite the different ways its stories can be told, there is a natural history to sociology and its various traditions, lineages, and so forth.

Reminding ourselves of these five points, however, will not keep us from exegesis. As Collins explains, while the new historians of sociology are correct to remedy the conflation of history and systematics, their remedy does not force one to avoid exegesis or its *integration* with hermeneutics. Even Merton makes this point. The history of sociology does not do away with exegesis. It makes exegesis better (1968, p. 33). In fact, despite the importance of hermeneutics and historiography (i.e., getting the past "right"), exegesis (i.e., reacquainting one's self with the classics, See Merton 1968, p. 33) moves ideas forward. One looks to the past (even if it is the immediate past) to create a new storyline of the present—think Foucault (1977) and Randall Collins (1994).

Given these important points, we will use the genealogical methods of Foucault and Collins to tell our story of sociology's complexity. While different in focus, both scholars combine hermeneutics, historiography and exegesis. First, Foucault, by placing great emphasis on the historical conditions of classic texts—that is, the relevant social practices in which they are situated, from the cultural to the institutional to the scientific—seeks to understand the past in terms of the concerns of the present (1977, 1987). Foucault is not interested in history for its own sake. Instead, he seeks to illuminate our current condition by searching out its breaks with and discontinuities from, as well as its connections to and links with the past

(Foucault 1991). Foucault's genealogies connect the present to the past by going back to the future. The genealogies of Randall Collins are somewhat opposite: they connect the past to the present. Through a firm footing in the historical conditions of the ideas he explores, Collins searches out and articulates, with great facility, the continuities of sociology; what one might call a sort of ongoing "historical exegesis" that focuses on the disciplines' major traditions, family resemblances, common challenges and comparable mistakes (1981, 1994, 1998). The value of both methods is their success at integrating the history and systematics of sociology.

By relying on these twin genealogical approaches, our story about sociology's complexity will move in dual directions, from the present to the past and the past to the present. Our story seeks out breaks and continuities, differences and similarities and it immerses itself in the history of sociology while taking at face value previous exegesis. With all of these points in mind, we turn to our story of sociology's complexity.

1.1 The Story of Sociology's Complexity

Our basic thesis—that is, the genealogy we wish to construct—is that western sociology (including its various smaller, national sociologies) has been and continues to be a profession of complexity, although not always of the same type. Industrialism, for example, is not postindustrialism, and European modernity is not American modernity. Nevertheless, since its formal emergence in the middle 1800s and, more specifically, since its establishment within the modern universities of Europe and North America at the turn of the previous century, the major challenge of sociology has been complexity (Baehr 2002; Collins 1994; Coser 1977; Heilbron 1995; Lepenies 1988; Merton 1968, 1996).

The primary basis for this challenge is western society. To study society is, by definition, to study complexity (Buckley 1998; Luhmann 1995; Urry 2003, 2005b). Starting with the industrial and "industrious" revolutions of the middle 1700s to early 1900s (Ashton 1964), western society transitioned—teleology not implied—into a type of complexity that, in many ways, did not previously exist (Toynbee 1884/2004). Urban centers and cities emerged, massive waves of emigration and immigration took place throughout Europe and North America; multiple ethnicities were forced to interact with one another; major innovations in technology, science and philosophy took place; democratic governments of various forms emerged, as did new forms of economic, political and cultural inequality, domination, oppression, conflict, and struggle—not to mention the impact all of this had on traditional ideas of family, marriage, gender, religion, the meaning of life, and one's private sense of self (Hunt, Martin, Rosenwein, et al. 2004; McKay, Hill and Buckler 2003; Wiesner, Ruff and Wheeler 2003).

Furthermore, as industrialization evolved into its later stages (i.e., Taylorism, Fordism, post-Fordism, etc), the complexity of western society evolved as well (Gilbert 1997; Howard and Louis 2006). This advance in complexity was further facilitated by the increasing division of labor, growth of the middle-class, expansion of the professions, civil rights, continued developments in technology and medicine, the rise of counterculture, increases in the lifespan of the general population and, finally, continued reform in the welfare state and social welfare (Diner 1998; Hofstadter 1955). It is within this material and ideological milieu of profound and rapid societal change that the first scholars of sociology made their mark (Baehr 2002; Collins 1981, 1994; Lepenies 1988; Ritzer and Goodman 2004).

1.2 Sociology's Complexity: The Early Years

Given our discussion about historiography we will assume that there is no definitive list of "classical" western sociologists. Instead, there are various "lists." We will therefore be specific about the canonical scholars in which we are interested. Of the numerous scholars writing during the middle 1800s to early 1900s, we focus on the following: Auguste Comte, Herbert Spencer, Karl Marx, Max Weber, Emile Durkheim and Vilfredo Pareto. We did not choose these scholars because of their status as "classical" thinkers. We chose them because they all participated in the formation of what, by the 1920s, would become known as the systems tradition in sociology. We call these scholars *systems thinkers* for three reasons:

1.2.1 Embracing the Complexity of Western Society

First, while working under different academic letters, governments, professional titles, political positions, cultural contexts and institutional arrangements (or the lack thereof), and while working at varying distances from the creation and development of the profession of sociology, these scholars conceptualized their work as a direct response to the increasing complexity of western society.

The idea that much of sociology or sociological thinking was created to address the major changes taking place in western society is a familiar and, in many ways, accurate story that students learn in undergraduate and graduate school (Baehr 2002; Collins 1981, 1994; Heilbron 1995; Lepenies 1988; Ritzer and Goodman 2004). Class conflict, industrialism, the rural/urban shift, social alienation, the challenges of laissez-faire government, cultural diversity, ethnic conflict, political revolution, the growth of the welfare state, religious fervor and collapse, church/state conflict, the encroachment of bureaucracy, capitalism, inequality, imperialism—this provided the core fodder for our canonical sociologists. All of this "fodder," including its associated social problems, was a direct outcome of society's growing complexity.

The concept that most aptly captures this focus during the classical era of thinking is *evolutionism*. Whether Darwinian or Hegelian, our short list of scholars adopted some form of evolutionism. In fact, the adoption of an evolutionary perspective goes well beyond our short list to include many early sociologists and sociologically minded thinkers now forgotten or marginalized through the annals of time (Baehr 2002; Collins 1981, 1994; Heilbron 1995; Lepenies 1988).

Evolutionism is the view that societies develop along a timeline moving from simpler to more complex forms of existence—think, for example, of Toennies' Gemeinschaft and Gessellschaft or Durkheim's mechanical solidarity and organic solidarity. This evolution can be conceptualized in organic terms (as in the case of Durkheim and Spencer), or in stages (as in the case of Comte and Marx). It can rely on Darwinian evolutionism (as in the case of Spencer) or Hegelian idealism (as in the case of Marx). Its can be observed through a single lens (as in the case of Marx) or multiple lenses (as in the case of Durkheim). Furthermore, it can be optimistically conceptualized in terms of progress, development, advancement and growth (as in the case of Spencer), or it can be somewhat pessimistically conceptualized in terms of exploitation, imperialism, regression, and decline (as in the case of Marx and Weber). It can even be viewed as some combination of both progression and regression (as in the case of Durkheim). Whatever the view—and whatever the political, economic, cultural or moral agenda of the scholar writing it—the common theme in all these approaches is that, starting in the 1700s and culminating in the 1900s, western society went through a period of increasing complexity. The goal of sociological inquiry for these scholars was to understand this qualitative change in complexity.

1.2.2 Embracing a Systems Perspective

The second reason we call these scholars systems thinkers is because they conceptualized the changes taking place in western society in systems terms; that is, they treated western society (and its various substantive issues) as a system. A system is a general concept that refers to a set of things and the relationships amongst them (Klir 2001). Systems come in all shapes and sizes: from airplanes and library catalogues to chemicals and biological cells to biospheres and the universe. They also vary in their degree of complexity. A system for counting numbers, for example, is rather straightforward, while a tropical rainstorm is rather complex. Given the wide range of possible systems, researchers catalogue them according to type (Klir 2001). One particular type is the set of all human social systems. Human social systems are distinguished in two important ways: the "things" of which they are comprised, which is some set of human social agents (individuals, groups, formal organizations, etc.), and the relationships amongst these social agents, which constitutes some form of social interaction (Byrne 1998; Holland 1995, 1998; Klir 2001; Luhmann 1995).

Conceptualizing western society as a system was very appealing to many sociologically minded scholars writing during the middle to late 1800s (Collins 1988, 1994). This is understandable given the wide-angle view they were trying to achieve. They were struggling to make sense of the incredible shifts taking place in western society and they needed immediate, concrete ways to treat society on its own terms—something that could be studied without "reducing it away" to the micro-level behavior of individual agents. Even Weber, for all his musings on interpretive method, nevertheless focused on primarily aggregate-level social behavior. The concept of "system" gave these scholars the conceptual weight and rigor they needed. With its strong macro-level or biological overtones, the concept of social system carried with it the semiotic sense of being a solid, tangible object for scientific study.

Examples: Marx studied the economic systems of Europe and, later with Engels, the class structure these economic systems produced. Durkheim focused on cultural systems and the functional role that solidarity and ritual played in holding together modern society. Comte examined the evolutionary stages through which society, as a social system, passed. Weber compared the evolving economic and cultural systems of western and eastern societies, along with the role bureaucracy plays in organizing an increasingly complex western society. Spencer studied the role that struggle and competition and, alternatively, negotiation and cooperation play in the formation, evolution and maintenance of society. And, Pareto studied how similar modern societies (as social systems) tend to reproduce similar structures of inequality. In fact, the idea of society as a system appealed so directly to the times that most of the scholars on our short list reified it, treating society and its various subsystems as real objects.

The tendency to treat a social system as a real, tangible object is known as *organicism.* For scholars such as Spencer, Pareto, and Durkheim, society is not just a system. It is every bit as real as a human being. Like the human body, western society is emergent, self-constituted, bounded, environmentally responsive and functionally differentiated. It is comprised of its own internal network of communication, which allows its various subsystems (economic, political, cultural, legal, etc) to coordinate with one another. Furthermore, it is constantly evolving, growing, changing and developing, all the while seeking balance, order, homeostasis and cohesion. Most important, following Haeckel's recapitulation theory of 1866, social systems like western society follow a phylogenic order: as they evolve, they move from simpler to more complex forms of existence.

The complexity of a human social system can be understood in two basic ways. It can be understood as a particular phase-state that emerges and develops over time, which we just mentioned, or it can be understood as an inherent characteristic.

Without being overly simplistic, the later view represents the celebrated insight of complexity science: all social systems, by definition, are complex (Klir 2001; Luhmann 1995).

The phase-state view, in contrast, represents that of many early sociological thinkers such as Spencer, Pareto and Durkheim. The concept of complexity as a phase-shift in the life of a social system like society (or any of its subsystems) is linked to our earlier concept of evolutionism. As societies increase in their internal differentiation (i.e., growth in industry or urban centers), they grow in complexity (i.e., growth in the division of labor or bureaucratic institutions).

Again, not all early sociologists based their systems perspective entirely on evolutionism. Nevertheless, despite their variances in approach, our short list of scholars treated the complexity of western society from an evolving systems perspective.

1.2.3 Learning from the Past

A third reason for identifying our short list of canonical scholars as systems thinkers is that their successes and failures can teach current sociologists and like-minded scholars how best to think about the complexity of western society from a systems perspective.

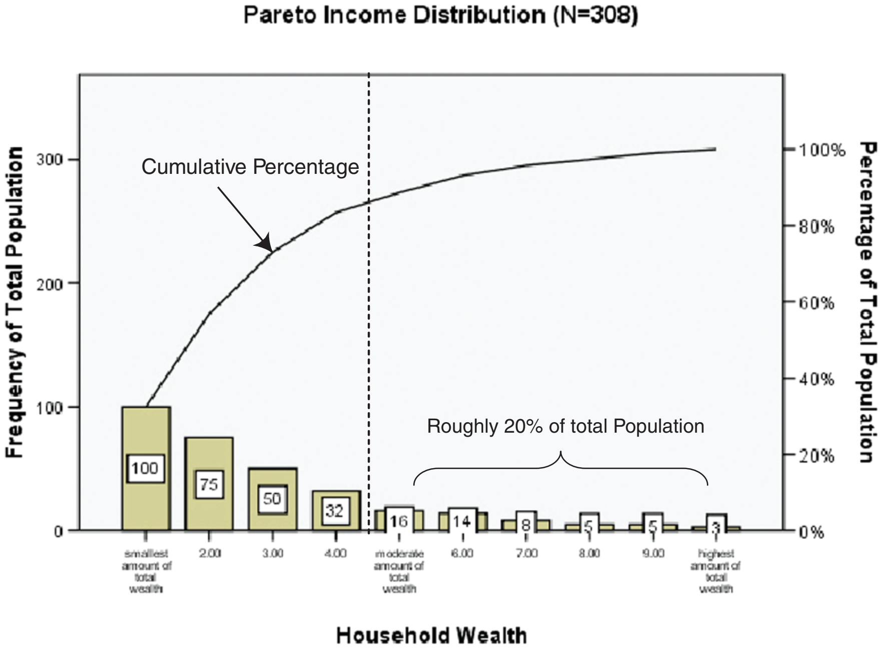
In terms of their failures, for example, these systems thinkers have demonstrated the limited utility and, often times, futility of treating social systems in strictly natural science terms. Evolutionism, equilibrium, homeostasis, organicism and Darwinian functionalism are concepts either to avoid or, at the very least, critically redefine.

In terms of their successes, many of the ideas our short list of scholars formulated actually predate or have been developed into key ideas in complexity science. An excellent example is the 80/20 Rule of Pareto.

1.2.3.1 Pareto is a Complexity Scientist?

Pareto (1848–1923) was an Italian economist, sociologist, engineer and political activist who wrote widely on the topic of western society during the industrial revolution. Strongly influenced by the systems thinking of both Marx and Spencer, including their views on inequality, Pareto set out to study the distribution of wealth in various European countries (Coser 1977). During his studies of the Italian economy, in particular, Pareto discovered that 80% of the land was owned by 20% of the population. His studies of other national economies revealed a similar pattern. Roughly 80% of the wealth of these countries ended up in the bank accounts of less than 20% of their citizens (Barabási 2003).

To demonstrate this fact, Pareto graphed his results, which he plotted as a basic mathematical curve—See Graph 1 as an example. (As a side note, remember that all of the maps, graphs, and figures for this book also are found in Chap. 10.) On Graph 1, the X-axis represents the relative wealth of a population (defined as percentage of total wealth owned) and the Y-axis represents the population in both frequency and proportion (expressed as a percentage of total population).



Using a graph similar to Graph 1, Pareto was able to determine how many people, at any particular point along the curve, had an income greater than a given x value. What he found was that as x increased at a particular rate—the exponential constant in the formula—the proportion of people with an income greater than x (shown on the Y-axis) decreased rapidly, always ending somewhere in the range of 20% of the population owning 80% of the total wealth (Adamic 2007; Buchanan 2002).

While numerous subsequent studies have found this distribution to be generally consistent, some have found the distribution to vary as much as 90–10, 95–20, or even 90–20 (e.g., Adamic 2007; Bak 1999). In terms of mathematical modeling, these types of variations are, however, expected and therefore not important. What is important is that the rule works! In fact, it works so well that it has been applied to numerous fields of inquiry, most notably mathematics, economics, physics and biology (Adamic 2007; Anderson 2006; Bak 1999; Barabási 2003; Buchanan 2002; West, Brown and Enquist 1997). Furthermore, the past hundred years of applying Pareto's insight have turned it into a scientific principle, which scholars now refer to as the 80–20 rule or, more generally, a power law (Adamic 2007; Bak 1999; West, Brown and Enquist 1997).

A power law is a polynomial relationship of the following type ($Y = X^{\alpha}$) where some quantity Y is a function of the exponential increase (α) in another quantity X. In this formula, Y is typically the dependent variable, which is related to changes in X, the independent variable, and its exponent α (Adamic 2007; Gunduz 2000, 2002). Readers may recognize the similarity between this equation and the binomial regression equation ($Y = bX + a$), where "a" is the intercept and "b" is the constant for changes in Y as a function of changes in X. In fact, when transformed into a log-log plot, the power law becomes linear, allowing for it to be treated as a basic binomial correlation, including the test for significance (Adamic 2007; West, Brown and Enquist 1997).

Three characteristics distinguish a power law such as the 80–20 rule from other binomial relationships. First, as shown in Graph 1, the relationship is not bell shaped. While a significant number of phenomena in mathematics and the social and natural sciences tend to take a bell shaped (Gaussian) distribution, the phenomena explained by power laws do not. They are curvilinear. Second, they are curvilinear because, while smaller events take place at a much higher frequency than the larger events on the graph, the larger events dominate. As Barabási states, "Power laws formulate in mathematical terms the notion that a few large events carry most of the action" (2003, p. 72). In the case of the 80–20 rule, for example, there are more poor people than rich people, but rich people, "collectively speaking," have most of the money. Third, some degree of scale invariance exists (West, Brown and Enquist 1997). At smaller or larger levels of scale (up to a point) the same basic relationship between Y and X is found. In the case of the 80–20 rule, for example, as one moves from the national to the state to the community level, one typically finds that the distribution of a population's wealth remains roughly similar, with most of the wealth at each level of analysis being in the hands of a few (Adamic 2007; Bak 1999; Mandelbrot 1997; West, Brown and Enquist 1997).

It is the muscle of the power law that eventually led to its usage in complexity science. From biological cells to social groups to ecosystems, the power law is reflected in the structure and dynamics of many complex systems (Bak 1999; Gunduz 2000, 2002; Mandelbrot 1997; West, Brown and Enquist 1997). To demonstrate this amazing insight, we will take a quick look at the research on structure.

In the new science of networks, a major area of study is the structure of very large, and highly complex systems (Barabási 2003; Buchanan 2002; Watts 2004). The small-world hypothesis, six-degrees of separation and scale-free networks are some of the more profound insights that sociologists, physicists, and mathematicians have made in the study of large, complex systems. These insights have to do with the fact that, while stochastic, complex systems are not entirely random or chaotic. In fact, while most complex systems cannot be fully determined, they do possess a tremendous level of order. Specifically, they tend to self-organize. Phrased in network terms, only a few nodes (called hubs) tend to be densely connected. On the internet, for example, less than 20% of all websites generally receive over 80% of all traffic; in the business world, 80% of a company's profits come from 20% of its products; and in the world of management, 80% of an organization's work is usually done by less than 20% of its employees (Buchanan 2002; Watts 2004). The same general phenomenon has been found in the study of cities, large friendship networks, international business networks, ecosystems and epidemiology (Buchanan 2002; Gunduz 2000, 2002; Mandelbrot and Hudson 2004; Newman, Barabási and Watts 2006). Most important (at least with respect to the focus of this chapter), this amazing phenomenon traces its intellectual lineage, in part, to the work of a sociologist, Vilfredo Pareto. Oddly enough, the 80–20 rule is not part of the sociological cannon. The reason why takes us to Parsons. But, first a concluding point.

1.2.4 Intellectual Dead End

Despite its initial widespread popularity, the systems tradition started by our short list of canonical scholars was, in large measure, dead by the first half of the 20th century. This is not to say, obviously, that these thinkers no longer had an impact on sociology. Certainly the work of Marx, Weber and Durkheim, for example, went on to have a profound impact on their separate national traditions in sociology—they are, after all, considered the classics—with influence in the formation and development of other disciplines such as economics, political science and anthropology. Still, despite the profound influence our canonical scholars had on the discipline of sociology, it was for the most part an impact devoid of any "systems" perspective. In fact, scholars such as Spencer, in whom the separation of sociology and systems thinking was impossible, were simply discarded. So was the terminology of systems thinking. Evolutionism, organicism, system differentiation—they were all thrown into the intellectual garbage bin of useless sociological ideas; that is, until the arrival of Talcott Parsons.

1.2.5 The Case of Parsons

Our story about sociology's complexity makes an exegetical break with the 1800s and Europe, crossing the Atlantic in search of the emerging discipline of sociology in the United States. Our destination is not, however, the University of Chicago and the work of Robert Park, Jane Addams, W. I. Thomas, or George Herbert Mead. Nor is our destination the work of W.E.B. Du Bois. We also do not visit Charles Horton Cooley at the University of Michigan. We even ignore the nomadic Thorstein Veblen. While all of these scholars are profoundly important to the development of western sociology, particularly in the United States, they contribute to sociological traditions other than the one in which we are interested.

As we stated at the beginning of this chapter, we are constructing a genealogy of the systems tradition. As such, we purposely ignore the above list of scholars and their work, turning instead to the Department of Social Relations at Harvard University, circa 1950s. Our destination is Talcott Parsons. Our reason is straightforward enough. Of the various attempts within sociology to address the growing complexity of western society from a systems perspective, including our short list of canonical scholars, the work of Talcott Parsons is the most important.

Most know the story of Talcott Parsons: his creation of structural functionalism, his triumphant rise to academic power and his eventual dominance of American sociology. Most also know about his presidency of the American Sociological Association in 1949, his work to develop the Department of Social Relations at Harvard University, and his significant influence on several generations of graduate students (Gerhardt 2002). Most also know about the crushing criticisms that were leveled at Parson's theoretical diamond, structural functionalism, during the 1960s and 1970s. These criticisms included such important issues as: (1) structural functionalism is not a theory; (2) it lacks explanatory power; (3) it explains away conflict and social change in the name of solidarity and order; (4) it is highly conservative and overly normative; (5) it misinterprets the ideas of many European sociologists; (6) it blatantly ignores the work of Karl Marx; (7) it is exceedingly abstract with almost no empirical grounding or application; (8) it makes the same evolutionist errors as Spencer and Durkheim; and (9) it falls into the trap of treating society as a biological organism (Collins 1988, 1994; Gerhardt 2002; Ritzer and Goodman 2004; Trevino 2001).

Given such criticisms, this usually is where the story of structural functionalism (at least as told in most textbooks), comes to an end (Collins 1988, 1994; Ritzer and Goodman 2004). While certain key concepts such as the *sick role* remain important, structural functionalism is another "dead-end" in the genealogy of the systems tradition in sociology. Or, at least, that is what most sociologists think. Unfortunately, this is not a "historically" correct story.

At present, the Parsons story is shaping up to be one of profound irony. It turns out that at the very moment that Parsons and "all things systems" were being discarded by most sociologists, several key advances in the newly emerging field of complexity science were taking place. And here lies the irony: these advances came from the same toolbox and interdisciplinary attitude Parsons had attempted, but failed, to foster in sociology (Capra 1996, 2002). The collapse of structural functionalism therefore does not appear to be the victory everyone had anticipated. Instead, our collective need to "do away" with Parsons and all things systems looks grossly shortsighted, particularly in light of the current challenges of complexity facing sociology today—which we will discuss in moment. For now, let us defend our provocation.

1.2.5.1 The Other Leg of Parsons

While Parsons' grand theory was grounded in the systems tradition of European sociology, his foundation had another leg, grounded in the emerging fields of cybernetics and systems science (Collins 1988, 1994; Gerhardt 2002; Ritzer and Goodman 2004; Trevino 2001).

As we explain in detail in Chap. 5, cybernetics and systems science are the first two "sciences" explicitly and specifically devoted to the study of systems; and, at the time of Parsons, represented the cutting-edge of science (Capra 1996; Hammond 2003). In fact, these twin sciences turned out to be two of the most important areas of scientific inquiry in the 20th century, leading to the development of artificial intelligence, game theory, communications, the computer, the internet, informatics, systems biology, computational modeling, machine intelligence, and a significant number of advances in modern mathematics, such as computational/discrete mathematics.

More important for Parsons and our study, they also turned out to be the intellectual forbearers of complexity science. In fact, just about every major accomplishment in complexity science can be linked to work that was done in these two sciences between the 1940s to the 1970s (Capra 1996, 2002; Casti 1994; Lewin 1992; Waldrop 1992). As shown in Map 1, in terms of complexity science method, there is the lineage that runs from cybernetics to distributed artificial intelligence to agent-based modeling and its key methods such as neural networking, genetic algorithms, artificial life and multi-agent modeling. This lineage also includes the historical links that cybernetics and systems science have with cellular automata and the development of fractal geometry and chaos theory. In terms of theory, this lineage includes the links that runs from systems science and second-order cybernetics to the creation and development of such key topics in complexity science as emergence, self-organization, autopoiesis, system dynamics and networks—all shown on Map 1.

But that is not the end of it. Not only did Parsons partially ground his theoretical dreams in cybernetics and systems science, he grounded his organizational and cultural hopes in them as well. From their historical beginnings, cybernetics and systems science have been resolutely interdisciplinary, seeking out empirical and theoretical insights relevant to the conduct of science in general (Bailey 1994; Hammond 2003). This interdisciplinary mentality is well demonstrated in their organizational arrangements. One example of such an interdisciplinary infusion is the Massachusetts Institute for Technology (MIT), home to most of the leading scholars in cybernetics and systems science.

Parsons took this mentality to heart by creating the *Department of Social Relations*, a few short miles from MIT up Massachusetts Avenue (Gerhardt 2002; Trevino 2001). For Parsons, the purpose of the Department of Social Relations at Harvard was to promote the interdisciplinary culture of the Arts & Sciences by creating a place where scholars could come together to work. The list of thinkers involved in Parsons' department, as either student or staff, is beyond impressive, including such important scholars as George Homans, Richard Solomon, Gordon Allport, Jerome Bruner, Harold Garfinkel, Robert Merton, Neil Smelser, Harrison White, Mark Granovetter, Barry Wellman and Stanley Milgram, to name a few (Collins 1988, 1994; Gerhardt 2002; Ritzer and Goodman 2004; Trevino 2001). For those fluent in complexity science, Harrison White is a pivotal figure in both computational sociology and social network analysis (Gilbert and Troitzsch 2005); Granovetter and Milgram's work is central to the small-world phenomenon and the study of complex networks (Watts 2004); and Homan's exchange theory is pivotal to Robert Axelrod's iterative game theory and the complexity of cooperation (Axelrod 1984, 1997). Thus, while the theory of Parsons may have failed, and while his department eventually was discontinued, his impact on the genealogy of systems thinking remains alive in complexity science—just not in sociology.

1.2.5.2 Sociology's Infinite Regress

In many respects, Parsons should be applauded for his incredibly prescient efforts to ground his theoretical and organizational efforts in cybernetics and systems science. This applause, however, does not lessen the crushing and altogether correct criticisms made of his work. In fact, cybernetics and systems science were criticized for many of the same issues as Parsons (Capra 1996; Klir 2001).

There is, however, a difference in the way sociologists (versus natural scientists) employed these criticisms. While sociologists used their criticisms of Parsons to "do away" with all things systems, including the rejection of cybernetics and systems science, scholars working in mathematics and the natural and computational sciences did not engage in such a whole-sale rejection (Capra 1996; Klir 2001). While these scholars were equally concerned with the ways in which cybernetics and systems science were "incorrectly applied" within their disciplines, and while they stuck to their critiques, they nevertheless sought to overcome the problems of these fields by "staying with them" so to speak. They developed the ideas; fixed them; moved them into the future and made new exegetical histories of the present. As a result, the natural sciences are at the forefront of complexity science (Casti 1999; Cilliers 1998). Sociology is not.

One of the well-documented problems of sociology is its tendency to use a theory's errors as an excuse to replace it with something else (Abbott 2000, 2001). For example, because Parsons and Spencer made the mistake of functionalism or evolutionism, respectively, the practice in sociology is to discard everything they said, condemn their work, and redeposit intellectual favor somewhere else. In the case of social systems, this means to refrain from talking about systems or progress or anything of that sort, even if these concepts have some value. In short, sociologists have a bad habit of "throwing out the baby with the bathwater." A related problem, given our apparent eagerness to discount things, is that we have the easy ability to work alongside other theoretical perspectives, all the while completely ignoring their critical utility to our work. As Abbot explains (2001), this ability has a lot to do with the boundary permeability of our discipline, which makes it is rather easy for sociologists to dismiss an idea, relevant or not.

While our discipline's characteristic approach to "dismissing knowledge" often has the advantage of immediate gain (we get away from bad ideas fast), it comes at a price. In terms of the increasing complexity of sociological work, the cost is being in the conceptual backwaters rather than at the forefront of the systems tradition and its latest manifestation, complexity science.

To illustrate this point, we will create a short laundry list of the things most sociologists lack or cannot do. Most sociologists:

- Have little to no training in agent-based modeling.
- Are not able to engage in or converse about neural networking.
- Lack the skills necessary to employ the tools of data mining.

- Cannot converse in computational or discrete mathematics, let alone make use of such techniques as cellular automata.
- Do not know how to employ the tools of dynamical systems theory, either in the form of fractal geometry or chaos theory.
- Cannot converse in the rich vocabulary and language of complexity science.
- Do not know how to use or critique the new science of networks.
- Are on the margins of the major journals, conference and funding streams devoted to the study of formal organizations as complex systems.
- And, finally, do not have the necessary techniques for studying the large, multidimensional, electronic databases that are now readily available on the internet for study.

Given these limitations, sociology now must "look in" on complexity science as something strange and wonderful that might benefit its work, rather than looking at it from "within" as something sociology helped to create. So, in many ways, sociology ends up back where it started prior to Parsons or, even worse, prior to our short list of canonical scholars: trying to understand the changing complexity of western society, but still basically unprepared to do so. Another genealogical dead-end.

1.2.6 The Rise of Complexity Science

Given the second collapse of systems thinking in sociology (first, the canonical scholars, second Parsons), our story makes another exegetical break. This time we leave sociology altogether. Our destination is mathematics and the natural sciences, specifically physics and biology during the 1970s and 1980s. Our focus is a small but growing network of scholars, including some of the most important scientists of the 20th century: Cowan, Gell-Mann, Prigogine, E. O. Wilson. There are two reasons for turning to this network. First, this network immersed itself within and helped to critically develop the systems tradition at about the same time that most sociologists were discarding this tradition. Second, this network stumbled onto an accomplishment that could have been, at least partially, sociology's. By drawing upon the latest developments in mathematics and computational modeling, this network advanced the tools of cybernetics and systems science to study, among other things, western society as a complex system. The name of this network of scholars, as we now know it, is *complexity science* (Capra 1996; Lewin 1992; Waldrop 1992).

As we discussed in the preface to this book, complexity science has captured the public imagination with discussions of emergence, swarming behavior, self-organization, computer simulations, and so forth. There is, however, a downside to this ubiquity. Complexity science has been confused with or mistaken for a variety of things. This is a real issue and something we hope we can "clear up."

First of all, complexity science is not a quasi-spiritual embrace of the great web of life—the idea that everything is interconnected with everything else, forming a seamless tapestry of existence (Capra 1996). While some scholars, such as James Lovelock and Lynn Margulis have put forth once controversial theories such as the Gaia hypothesis (which explains how the outer layer of the earth functions as a living, complex system), and while such ideas have inspired awe, they nevertheless are empirical propositions, meant to be "fought out" scientifically. To dismiss or conflate these ideas as metaphysics is to miss the point. The same is true of the brilliant work of Francisco Varela and colleagues, who spent decades examining the intersection of cognitive science and Zen Buddhism (Varela, Thompson and Rosch 1991). While their work creates a dialogue between complexity science and Buddhist philosophy, it does not treat the two as equivalent.

Second, complexity science is not beholden to any particular moral or political agenda (Hammond 2003; Klir 2001). Over the last half century, complexity science has served a variety of purposes, from the development of missile guidance systems and global corporations to smart-shopper cards and self-regulating washing machines to biotechnology and ecosystems research (Capra 1996). Given its numerous usages, complexity science will no more "save" or "destroy" the world than any other scientific discourse (Capra 1996; Hammond 2003). Complexity science is a very specific approach to empirical inquiry that has very specific features. While loosely associated with a variety of moral and political perspectives, these wobbly associations do not define the science. It is a science that can serve a variety of purposes.

Third, complexity science is not chaos theory or fractal geometry. In the popular science literature it is typical for authors to discuss bifurcation points (chaos theory), the nonlinear pattern of fjords (fractal geometry) and the network structure of global diseases (complexity science) as if they were the same science (Cilliers 1998). They are not. Most fractal structures are not complex systems. Total chaos is not a general trait of the universe and many complex systems are only marginally chaotic or fractal.

Furthermore, while complexity science is a general field of inquiry, chaos theory and fractal geometry are mathematical branches of dynamical systems theory; which, in turn, traces its roots back to Newton and the Calculus (Capra 1996). Despite these differences, chaos theory and fractal geometry do inform complexity science. In fact, they have proven amazingly powerful in the study of complex systems, helping researchers understand such various phenomena as stock markets, weather patterns, earthquakes and collective behavior (Bak 1999; Mandelbrot and Hudson 2004). Still, while these two areas of study are part of the mathematics of complexity, they are not complexity science.

Fourth, complexity science it is not postmodernism (Eve, Horsfall and Lee 1997). In the postmodern literature much has been made about the limits of modern science; how science is only one type of knowledge amongst many; how science has no authority over other forms of knowledge, and how empirical inquiry is basically writing (Best and Kellner 1991). To make their case, postmodernists have turned to a variety of sources. The main ones have been chaos theory and, to a lesser extent, fractal geometry, along with catastrophe theory and, most important for our discussion, the early work of complexity science.

In the thirteenth section of his now famous report, *The Postmodern Condition* (1984), Jean-François Lyotard makes the argument that chaos theory and its ilk (catastrophe theory, complexity science, etc) are creating a paradigm shift in academia, one that goes from the modern to the postmodern. His argument, which revolves around the concept of system, is as follows: (1) new research in the fields of chaos theory, fractal geometry, catastrophe theory and other related areas demonstrates that complex systems are not stable, controllable or knowable; (2) instead, they are unstable, uncontrollable and largely unknowable; (3) this realization about the nature of complex systems has forced these researchers to break with the reductionistic, quantitative and mechanistic methods of modern science; (4) this realization has required researchers to let go of the Newtonian, Enlightenment paradigm and its belief in a directly observable and knowable universe; (5) in place of modern science, these researchers have constructed a new, post-modern science, one that is based on the search for instabilities, irregularities, differences, dynamics, local knowledge, fractals, chaos, and so forth.

Two things are amazing about Lyotard's report, along with the postmodern literature that followed. First, Lyotard and his colleagues pretty much get the "science of complexity" wrong. Often not even close. This would be permissible if the purpose of their work was strictly playful or metaphorical, in the way that Derrida, for example, engages scientific ideas. Unfortunately, many of these writers are rather serious. They truly believe that modern science is nothing more than writing, politics and power, and that the latest advances in complexity science support this point. To demonstrate the lack of rigor and reason in such mischaracterizations of science, the physicist John Sokal decided to perpetrate his famous hoax (See Sokal and Bricmont 1999). In 1996 he published a paper in the journal *Social Text* that was, in his own words, a pastiche of fashionable nonsense—impossible mathematical statements and pseudo-scientific claims made by postmodernists, which he assembled together to create the simulacra of an argument. Remarkably, it was published. Sokal perpetrated his now-famous hoax to make an important point. When it comes to the usage of science on behalf of postmodern critique, standards of rigor and reason are required. Science is more than discourse and more than "just" politics and power. Science is real.

Still, for all the hoopla, Sokal never argued that all of postmodernism lacks rigor or reason; and here is where we return to the second amazing thing about Lyotard's report. Despite Lyotard's gross misrepresentation of the technical details of ideas such as dynamical systems theory, he correctly realized that the study of complex systems constitutes a new way of doing science. Even those critical of postmodernism, such as Sokal (Sokal and Bricmont 1999) and others (e.g., Cilliers 1998) concede this point. Lyotard also is correct that many of the major criticisms that postmodernists make of modern, western science are likewise made by complexity scientists. For example, postmodernism and complexity science share a similar concern with the limitations of modern science, particularly its reductionistic, linear, hierarchical and mechanistic thinking. It also is true that both take a subjectivist approach to knowledge and share a common interest in complexity, local knowledge and difference. Furthermore, both recognize the limits of quantitative science and take a more qualitative approach to their work.

However, it is not true that complexity theory has any intention whatsoever, as Lyotard states, of "producing the unknown," or in "theorizing its own evolution" as "discontinuous, catastrophic, non-rectifiable, and paradoxical" (1984, p. 60). It also is not the case that complexity theory is necessarily "anti-modern." Here is where complexity science and the postmodernists part ways, and here is why we make the point that complexity science is not postmodernism.

Complexity science can be called postmodern only insomuch as it is "beyond" modernism (Cilliers 1998). In other words, in an effort to understand the nonlinear, dynamic, evolving, emergent, negotiated, conflicted, highly interdependent, distributed, far-from-equilibrium, self-organizing properties of complex systems, complexity science has had to develop new ways of doing science, including new epistemologies, methods, concepts and theories. This change in the ways of "doing science" also has required complexity scientists to ask questions likewise posed by the postmodernists (Cilliers, 1998; Klir 2001). However, in contrast to the postmodernists, complexity scientists still believe in mathematics, albeit in a new computational, qualitative, highly nonlinear, form (Capra 1996). They still believe in science, albeit in a non-reductionistic, non-mechanistic, dynamic form. They still believe in rigorous empirical study—although they know that complete description of anything is impossible, both because of the limits of the knower and the methods used. They still believe in theory, albeit in a more meta-theoretical manner. They still believe that science solves problems by providing workable solutions, even if only temporary and partial. And, finally, they still believe in something that postmodernists cannot: synthesis. Contra postmodernists, complexity scientists believe that difference, local knowledge, and complexity are systems phenomena.

Now that we have clarified some of what complexity science is not, we can turn to what complexity science is. The basic viewpoint of complexity scientists can be articulated through a series of tenets, which begin from two different starting points. The first is similar to the theme we have put forth in this chapter: (1) in the last two decades, the complexity of western society has reached a tipping point, (2) this tipping point has resulted in a major phase shift in the organization of western society, including its involvement in the larger global society of which it is an active part; (3) this phase shift is, in large measure, a function of the computer revolution, post-industrialization and globalization; (4) the consequences of this phase shift (e.g., environmental collapse, global economics, cultural and political conflict, etc) cannot be adequately addressed by the normal tools of science; (5) new tools are needed, grounded in a systems perspective and the latest advances in computational modeling and mathematics; (6) complexity science is therefore the future of science (Byrne 1998; Luhmann 1995; Urry 2003).

The second argument emerges from the "cul-de-sac" view of modern science, the idea that scientific inquiry has reached a dead-end (Casti 1994; Capra 1996; Kauffman 1993, 1995; Klir 2001). The basic argument is that: (1) despite its tremendous successes, reductionistic science has "run its course;" (2) likewise, the quantitative program, specifically statistics and traditional mathematical modeling, has reached its limits; (3) new ways of doing science are necessary to move inquiry forward; (4) the best way to do this is by adopting a "complex systems" view of the world; (5) this view is characterized by the idea that life is holistic, self-organizing, emergent, highly relational, dynamic, interconnected, nonlinear, and evolving; and finally, (6) the latest advances in mathematics, networks, informatics and computational modeling give scholars the tools to employ a "complex systems" approach to scientific inquiry (Kauffman 1995, 2000; Wilson 2003; Wolfram 2002).

Despite starting from different points of departure, these two viewpoints arrive at the same place. First, while normal science (characterized as reductionistic and statistical) has achieved a great deal, it is insufficient for addressing the current challenges most researchers face. Second, to address these new challenges, two things are needed: a vocabulary grounded in the study of complex systems and a methodological toolkit created from the latest advances in computational modeling, data mining, qualitative method and mathematics. This is, for the most part, the purpose of complexity science. Everything it does methodologically, theoretically, substantively and organizationally follows.

So, why should sociologists care about complexity science? One good reason is that complexity science is making better usage of the systems tradition than we are, despite the fact that we helped to create this tradition. More important, complexity science offers us ways to effectively address the growing complexity of sociological work.

1.2.7 The New Challenge of Complexity

As in its early days, sociology is once again faced with the challenge to make sense of its complexity. Overnight, it seems, western society has gone through a major transformation in technology, economics, politics, and culture (Castells 2000a, 2000b; Urry 2003). As the 1970s progressed into the 1990s, many western societies began to transform from an industrial-based technology (and economy) to a post-industrial technology (Bell 1974/1999). The computer and related technologies underscoring the informatics revolution changed everything; global capitalism, politics, and culture merged at a new level (Castells and Cardoso 2006). Everything, including science, became more complex and faster (Gleick 2000).

In a manner similar to its formal emergence a century ago, sociology once again has the opportunity to recognize itself as a discipline of complexity. Once again, the growing complexity of western (and now global) society challenges organized sociology: (1) in the epistemological assumptions sociologist hold (Luhmann 1995); (2) the topics they study (Watts 2004); (3) the vocabularies they speak (Geyer and Zouwen 2001); (4) the data they collect (Castellani and Castellani 2003) and the methods they use (Gilbert and Troitzsch 2005); and, adding something new to the list, (5) the changing forms of institutional organization in which they are situated (Abbott 2000, 2001). Let us review these five challenges in greater detail.

First an extended caveat. At this point, the reader may get the impression that our storyline of sociology's complexity makes the same evolutionist error of previous systems thinking, primarily because we assume that the introduction of industrialized modernity and, later, postmodernity (post-industrialism, network society, globalization, etc.) constitute increased levels of complexity in western society. This impression is incorrect. As we explained earlier, evolutionism sees societies on a timeline moving from primitive to sophisticated, simplistic to complex, with some sort of teleology implied. That is, as things progress they get better, hence the affiliated terms: evolutionism and progressivism (Hofstadter 1955). We make no such progressive assumptions. We do, however, consider the data in our favor when we argue that pre-industrial, agrarian, western society is not as complex as modern and, later, postmodern society. By complex, we mean western society and its various parts have become more interdependent and inter-reliant, much faster and chaotic, more interconnected and informed (think information technology), much more quickly impacted globally by localized change, and, most important, more difficult to manage as a system—think international economics, global warming, etc. There also is no particular direction (trajectory) toward which all of this is going. No progress is implied. By "more complex" we also mean that, in moving from industrialized modernity to post-industrial post-modernity, the scientific study of western society has become more challenging, primarily in terms of the amount of information available, the speed at which this information develops and changes, the interdependence of different academic and disciplinary domains of investigation involved in managing and studying this information, and the increasing complexity of the methods needed to study it.

The growing complexity of scientific work brings us back to the five challenges of complexity facing sociology today, which we will review now. First, in terms of the epistemological perspectives of most sociologists, the challenge of complexity comes in the way that the philosophical assumptions of modern scientific practice have been shown to be limited in their ability to conceptualize and model it. Here we are thinking of the past fifty years of critiques made by social constructionism, the sociology of knowledge, the philosophy of science, feminism, postmodernism, neopragmatism, and post-structuralism (Best and Kellner 1991; Foucault

1980; Fuchs 1992; Haraway 1990; Rorty 1991a, 1991b; 1998). We are also thinking of the more recent critiques, as we discussed above, made by complexity science (Axelrod 1997; Capra 1996; Castellani, Castellani and Spray 2003; Casti 1999; Cilliers 1998; Gilbert and Troitzsch 2005; Holland 1995; Klir 2001; Klüver 2000; Macy and Willer 2002; Ragin 2000). For most sociologists, the limitations highlighted by these critiques come through a series of well-worn issues, each having to do with the difficulties of studying the dynamics of aggregate social behavior (Bonacich 2004a, 2004b; Ragin 2000; Watts 2004). These issues include the limitations of reductionism and nomothetic explanation, the troubles of deductive reasoning, the restrictions of the linear model of statistics, the difficulties of conceptualizing social reality in terms of variables and independent observations, and the problems of self-reference and representation (Byrne 2001, 2002; Eve, Horsfall and Lee 1997; Geyer and Zouwen 2001; Gilbert 1999, 2000; Luhmann 1989, 1995).

Second, in terms of what sociologists study, one of the best examples of the challenge of complexity is the confounding factor of globalization—which has made just about everything more complex—from managing and controlling businesses as complex organizations (Capra 2002; Richardson and Cilliers 2001) to analyzing and correcting stock markets and economic trends (Mandelbrot 1983, 1997; Mandelbrot and Hudson 2004; Urry 2003) to improving various ecosystems and environmental issues via their relationships with human socio-ecological systems (Capra 2002; Wilson 2003) to addressing the epidemiological dynamics of global information and health networks (Barabási 2003; Watts 2003, 2004). Polity, economics, culture, health care, inequality, work, family, identity; all have become more complex due to the rapid advance of globalization (Capra 2002; Castells 2000a, 2000b; Luhmann 1995; Urry 2003). Globalization also has also led to an increasing interdependence amongst many of the above issues. The way that ecological systems and their problems overlap with economic and political systems is one example. Another is the way in which cultural systems overlap with technological systems (Capra 2002; Castells 2000a, 2000b; Urry 2003).

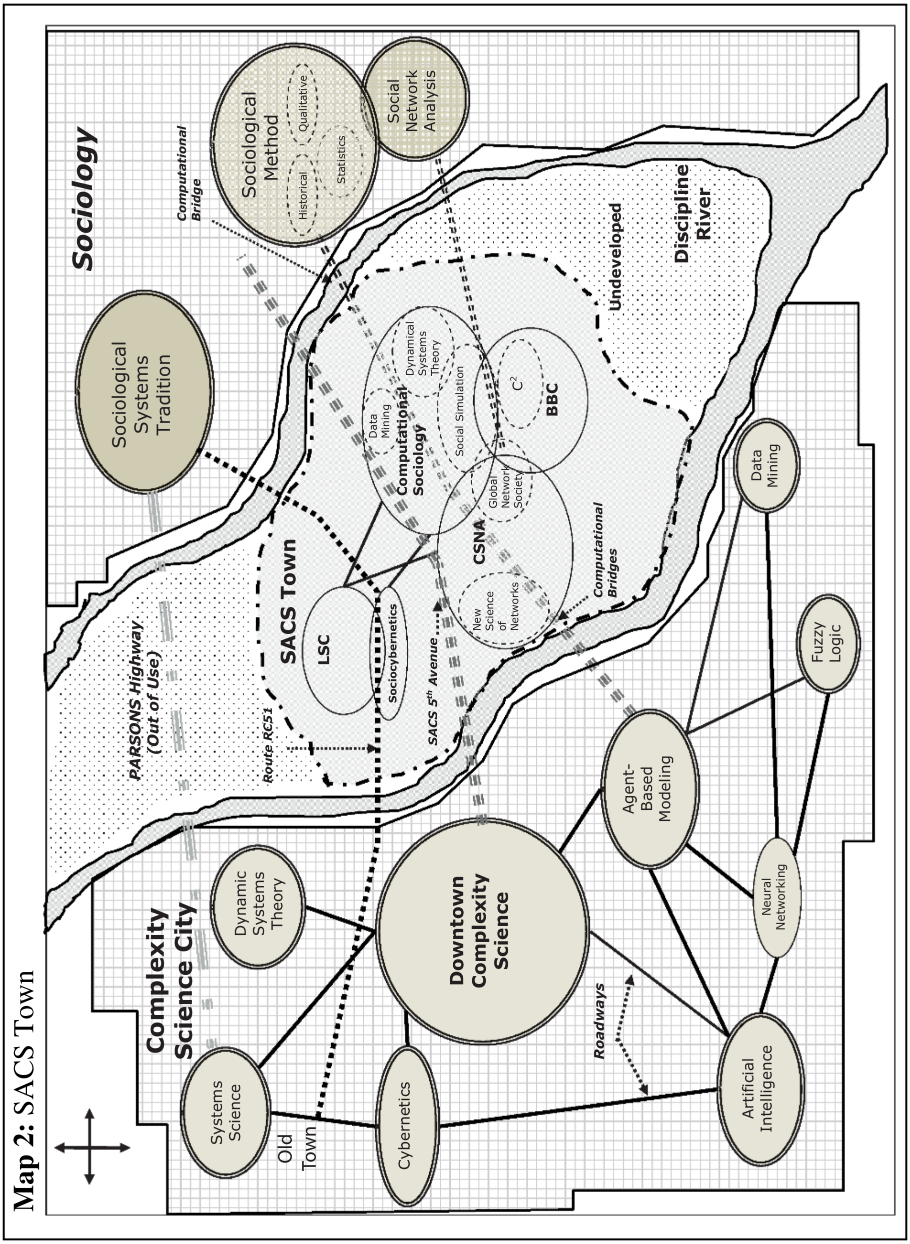
Third, in terms of the language and vocabulary (e.g., concepts and theories) spoken by sociologists, there are numerous examples of complexity's new challenge. Four quick examples illustrate this point. There is the failure of sociology—in the aftermath of Parsons—to arrive at any sort of formal or explicit theory of social complexity or social systems (See Castells 2000a, 2000b). Then there is the inability of sociologists to capitalize on early systems thinkers like Pareto and Spencer. Sociology also finds itself outside the complexity science loop in utilizing concepts such as autopoiesis, emergence, self-organization, along with the grants and funding associated with the analysis of these concepts. Finally, sociology has yet to recognize the value of treating such concepts as social class, formal organizations, inequality, social movements, or collective behavior in systems terms.

Fourth, similar challenges exist in terms of the increasing complexity of method and data. One example (which we have mentioned several times) is the increasingly complex and high-dimensional databases that are emerging through the informatics revolution. While powerful, statistics and qualitative method alone cannot handle these databases; sociologists need other methods. Another example is policy and evaluation research. At present, sociologists lack effective tools for modeling the consequences of small and large-scale policies or programs before they are implemented. Without such techniques as computer simulation, there is no good way to determine, ahead of time, what types of social change various policies or programs might produce. This is particularly problematic given the speed and range of impact that policies and programs have in the smaller, more global worlds in which we now live—think global disease transmission, international economy, bioterrorism, etc.

Fifth, there is the issue of the organization of sociology. As suggested above, the increasing extent to which the topics of science, writ large, no longer can be separated is challenging the disciplinary boundaries of sociology and the tendency for sociologists to become immured within smaller and smaller intellectual cul-de-sacs (e.g., Abbott 2000; Cole 2001). These challenges have led some sociologists to call for some type of transdisciplinary or post-disciplinary sociology or for new fields of study such as a *social physics* (e.g., Urry 2004).

Given the above five challenges, one can argue, in the spirit of C. Wright Mills that complexity has become the theme that unites the intellectual struggles and sociological imagination of many sociologists.

This is not, however, where our story about the systems tradition in sociology ends, with complexity scientists doing a better job addressing this theme than us. We have one last break to make. This time, however, it is a break filled with hope and promise—the hope and promise of new ways to effectively address the growing complexity of sociological work. We go to the late 1990s. Our destination is a small but growing intellectual community being built on the disciplinary edge of western sociology, a place we call *Sociology and Complexity Science*; or *SACS* for short (See Map 2).



Map 2: SACS Town

1.3 The Emergence of SACS

Sociology and Complexity Science (SACS) is an interstitial community taking root on the "outer banks" of sociology. As shown in Map 2 (See also Chap. 10), SACS resides at a fork in the intellectual river separating sociology from the natural sciences.

This fork (which goes around the eastern, right-hand side of SACS) did not always exist. In fact, it was intentionally created by main street sociologists during the 1970s, in an explicit and concerted effort to literally *wall off* systems thinking and its naturalistic views (think cybernetics, systems science, evolutionism, organcism, etc.) from mainland sociology. The consequence of this effort was that systems thinking (at least in sociology) became an island of intellectual inquiry. In time, the highways and bridges connecting sociology to the natural sciences, and, more specifically, the traditions of cybernetics and systems science (such as the Old Parsons Highway), fell into disarray.

It is on this island that the scholars of SACS took up residence. Why? Just on the other side of this island, as one crosses the intellectual river separating sociology from the natural sciences, is the new city of *Complexity Science*.

The community of SACS is part of what John Urry (2005b) calls the *complexity turn* in the social sciences. As Urry explains, most of the work being done within the SACS community got its start in the late 1990s, around the same time that complexity science was finally gaining international recognition; thanks, in large measure, to the growing prestige of the Santa Fe Institute (Santa Fe, New Mexico, USA), the birthplace of complexity science (Lewin 1992; Waldrop 1992). The scholars of SACS, however, lacked both a name and (as we have already pointed out) a mutual, collective awareness. In fact, they were spread out across Western Europe and North America, working (for the most part) in intellectual and geographical isolation from one another, pursuing diverse areas of study that, at the time, seemed hardly related.

In the late 1990s, these areas included: (1) *computational sociology* (e.g., Gilbert and Troitzsch 2005); (2) *complex social network analysis* (CSNA) (e.g., Watts 2004); (3) *sociocybernetics* (e.g., Geyer and Zouwen 2001); (4) the *Luhmann School of Complexity* (LSC) (e.g., Luhmann 1995); and, (5) the reconstruction of a post-disciplinary sociology grounded in complexity science, which we call the *British-based School of Complexity* (BBC) (e.g., Byrne 1998; Urry 2003).

Interestingly enough, despite this diversity, the agenda of these "sociologically minded" scholars was remarkably similar. The agenda basically was an exegetical restoration of the twin goals of Talcott Parsons. While it is historically accurate to say that Parsons was dead to the majority of western sociologists during the late 1990s, he was historically and exegetically alive within the growing network of SACS scholars. As shown in Map 2, this is why, in terms of its intellectual longitude and latitude, SACS lies just south of old Parsons Highway, which constitutes the first major intellectual thoroughfare connecting sociology to systems science and cybernetics, the original intellectual "downtown" of Complexity Science City, some fifty years ago.

1.3.1 Reinventing Parsons

By the late 1990s, the scholars of SACS were similar to Parsons in two important ways.

First, the scholars of SACS have sought to somehow integrate sociology with the latest advances in cybernetics and systems science. The reader may be wondering why we are talking about cybernetics and systems science instead of complexity science. There are three reasons. First, as mentioned earlier, complexity science is the intellectual outgrowth and, in many ways, the continuation of cybernetics and systems science. In fact, many of the leading scholars in complexity science, such as Stuart Kauffman, John Holland and W. Ross Ashby, are stars in cybernetics and systems thinking. Second, while complexity science gained international fame in the late 1990s, it still lacked an agreed upon name, going by such various titles as the study of complexity, complex systems research and systems thinking. In fact, the most widely acclaimed and definitive review of complexity science published at the time, *The Web of Life* (1996) written by Fritjof Capra, generally refers to this "new" science as systems thinking. Even Lewin (1992) and Waldrop (1992), both of whom wrote the first biographies of the Santa Fe Institute, concede this point, referring to it as the science of complexity, which they define as a cross-disciplinary grab-bag of scholars and viewpoints, all attempting to coalesce into some agreed-upon approach to addressing the growing complexity of scientific work. Third, and most important, many of the early scholars in SACS began their work as far back as the early 1980s, when complexity science was still cybernetics and systems thinking.

For example, during the late 1980s and early 1990s, the noted German sociologist, Niklas Luhmann (1995), was busy at work, integrating sociology with the research of cognitive scientists and leading Cyberneticians, Humberto Maturana and Francisco Varela (1998). Both Maturana and Varela were becoming leading thinkers in complexity science (Capra 1996), particularly in the areas of autopoiesis (a term they coined), emergence, and self-organization (See Map 1). Luhmann's work would lead to the development of new social systems theory, which led to the *Luhmann School of Complexity* (LSC).

Working in close intellectual proximity to Luhmann, various other systems thinkers from the same "post-Parsonian" generation, such as Walter Buckley and Felix Geyer, were busy keeping the sociological systems tradition going, albeit in a very different way. They sought to integrate sociology with second-order cybernetics. Their work resulted in the creation of *sociocybernetics* (e.g., Geyer and Zouwen 2001).

Still other scholars, working primarily in the area of method, would turn to the recent advances in complexity science. For example, during the 1990s, the British sociologist, Nigel Gilbert, worked to integrate mathematical sociology and computer-based simulation with the new area known as agent-based modeling—which is the intellectual outgrowth of cybernetics, second-order cybernetics, distributed artificial intelligence and systems science (See Map 1). The result was the new field called *computational sociology* (See Maps 1, 2, 3 and 8).

In an entirely different field of study (physics) and working with an entirely different set of tools (agent-based modeling, social network analysis and modern mathematics), physicists Duncan Watts and Steven Strogatz sought to solve a major problem in sociology: how people are connected to one another across very large networks (Watts 2003). Their research, known as the small-world hypothesis, led to the emergence of an entirely new field of study, called *the new science of networks*. By the early 2000s, this field would eventually become more sociological, turning into a broader area of inquiry, which we refer to as *complex social network analysis* (CSNA).

And finally, there was a small group of British sociologists, in particular John Urry (2003) and David Byrne (1998), who sought to integrate sociology with complexity science, but in a very different manner. Like all of the above examples, they drew on the same set of theories and methods. Unlike the above examples, however, this new *British-based school of complexity* (BBC) took an entirely different approach to their practice of sociology. Working with the theories of Michel Foucault, Anthony Giddens and Manuel Castells, these scholars integrated complexity science with a post-society, post-disciplinary, mobile-society sociology, and in the process created a very powerful model for doing global sociology from a systems perspective (Urry 2000a).

The second way that the early scholars of SACS are like Parsons is that despite differences, they all thought about sociology's complexity and its five major challenges in systems terms. Luhmann, for example, called his work *new systems theory*. Sociocybernetics is almost entirely comprised of European systems thinkers. Computational sociology was trying to simulate complexity as an agent-based system. CSNA was conceptualizing the structure of complexity in network/systems terms. The BBC was attempting to employ the network/systems perspectives of John Urry and Manuel Castells in order to treat various global topics (e.g., societal mobility, tourism, urban sprawl, etc) as complex social systems (Byrne 1998; Urry 2000a).

Nonetheless, this did not mean that these scholars embraced Parsons or much of the canonical work in sociological systems thinking. For example, while Luhmann not only drew upon the work of Weber, Marx and Parsons, including a brief time spent studying with the latter (Luhmann 1995), others, such as Duncan Watts (trained as a physicist) or Phillip Bonacich (trained as a social network researcher and mathematical sociologist) had no interest in Parsons or any of the canonical scholars whatsoever. Being mathematically trained, both Watts and Bonacich, however, would eventually express an interest in Pareto and the power law, as would Nigel Gilbert and other leading sociologists in SACS, such as Jürgen Klüver (2000).

But we are getting ahead of ourselves. Before we can continue our review of SACS, we need to get our study in order. First, we need to outline the questions upon which our review of SACS is based. Second, we need to discuss the method we used to conduct our review.

1.3.2 Questions for Our Study

During the course of our investigations, we were guided by three sets of questions, which we outline here.

- The first had to do with the composition of SACS. Basically, we wanted to know what SACS looks like today, circa 2008. For example, what do we know about its major areas of research? Which areas are most important? Who are the field's key scholars? Are there any identifiable subfields of study? How are the areas of research positioned in relation to one another? Do any of the areas overlap? What are the dominant trajectories within the field? Is the field stable? Will it differentiate into even newer areas of research? Finally, what environmental forces have had the biggest impact on the field and its major areas of research?
- The second set of questions had to do with the legitimacy of SACS. We basically wanted to know if it is an area of research, field of inquiry, subdiscipline, etc? Also, if it is a legitimate area of inquiry, is there a starting date for its formal emergence? And, if so, what did SACS look

like before and then after this date? Also, in terms of the current composition of SACS, does it meet the structural and intellectual criteria usually associated with an area of sociological study? For example, are its major areas of research well organized? Does it have a publication record comparable to other fields at similar stages of development? Do the scholars and areas of research in SACS have a common identity and a shared knowledge base? Are the scholars and areas of research in SACS connected to one another to the extent one would expect for a field in its first ten years of existence? Does the field have a sense of its boundaries and the environmental forces impinging upon it?

- The third set of questions had to with SACS' position within and impact upon organized sociology. For example, is SACS an extension of the systems tradition in sociology, or is it something else, perhaps something new? Also, what is SACS's role in the development of sociology? Are sociologists finding the work of SACS useful?

1.3.3 Method for Our Study

Our review of SACS is an *historical inquiry* into the emergence of a new field of study. It follows standard methods of demonstration, including "proof by means of historical documentation, quoting other texts, referral to authoritative comments, the relationship between ideas and facts, the proposal of explanatory patterns, etc" (Foucault 1991, p. 33). In this way, our overview of SACS, including our identification of the leading scholars, major areas of research, and the historical unfolding of this field, can be "verified or refuted as in any other history book" (Foucault 1991, p. 33). The data for our study is also standard: published reports, articles, books, websites, biographies, autobiographies, etc.

The quantitative component of our study is equally verifiable and normative. While most of our study draws upon historical archives, our study has a strong quantitative component. Chaps. 7 and 8, which examine SACS as a system, including its evolution over the last decade, draw extensively from a *Web of Science Citation Index* database we built of the Top 25 Scholars in SACS. With this database, we built a citation network, which we analyzed with *Pajek*, a freeware program for analyzing complex social networks (Nooy, Mrvar and Batagelj 2005).

However, while the data and basic techniques we use are normative, our approach to modeling SACS as a social system is new. During the course of our investigations, it became clear that the new community of SACS was best conceptualized as a social system—a formal intellectual system with identifiable boundaries, weak-ties drawing the various (clustered) areas of research together, pioneering scholars, leading institutions, periodicals, and so forth. Given this realization, we decided to employ the SACS Toolkit for our study, given it was created to model social systems. In other words, our book uses the tools of complexity science and the SACS community to study this community as a social system.

We believe that our usage of the SACS Toolkit is advantageous to the reader in two important ways. First, it allows the reader to gain a better understanding of the tools of complexity science and (more specifically) SACS by seeing them in action. Second, it allows our book to function, in part, as a handbook. Upon completion of this book, and along with the information and case studies at our website, readers should be able to use the SACS Toolkit in their own work. We therefore turn to our review of the SACS Toolkit—Chaps. 2 and 3.

2 SACS Toolkit—Theoretical Framework

2.0 Overview of the SACs Toolkit

The *SACS Toolkit* is a new approach to modeling social systems. It is comprised of three basic parts: a set of working concepts, a ready-to-go procedural outline for modeling social systems, and a short list of recommended techniques and methods currently used in sociology and complexity science.

- The set of working concepts is designed specifically to give researchers a practical framework for organizing their empirical inquiries into the structure and dynamics of most social systems. We call this framework *social complexity theory*.
- The procedural outline is the algorithm we created for assembling, from the "ground up," a working model of a social system. We call this method *assemblage*. Assemblage is a step-by-step set of guidelines that works hand-in-hand with the conceptual framework of social complexity theory.
- The recommended toolset of techniques and methods come from sociology and complexity science. As we discuss later, one of the main strengths of the assemblage algorithm is that it can be used with just about any methodological technique. Still, despite this flexibility, some techniques are better than others—or, at least we think—when it comes to modeling the complexities of social systems. The SACS Toolkit therefore has a short list of relatively indispensable techniques. In terms of the new techniques in complexity science, this list includes agent-based modeling (Gilbert and Troitzsch 2005), data mining, specifically the self-organizing map (Bigus 1996; Han and Kamber 2001), fractal geometry (Mandelbrot 1983) and the new science of networks (Newman, Barabási and Watts 2006). In terms of sociology, it includes cluster analysis, social network analysis, hierarchical regression, grounded theory (Glaser and Strauss 1967) and Foucault's archeological genealogy (1977).

2.1 Overview of Chapters 2 and 3

In the next two chapters we introduce readers to the SACS Toolkit. In Chap. 2 we review *social complexity theory*, our theoretical framework. In Chap. 3 we review *assemblage* and our recommended toolset, which, together, constitute the methodological component of the SACS Toolkit. Chap. 10 includes several figures we will use in this chapter, including two flowcharts, a Venn diagram, and a couple of maps and graphs.

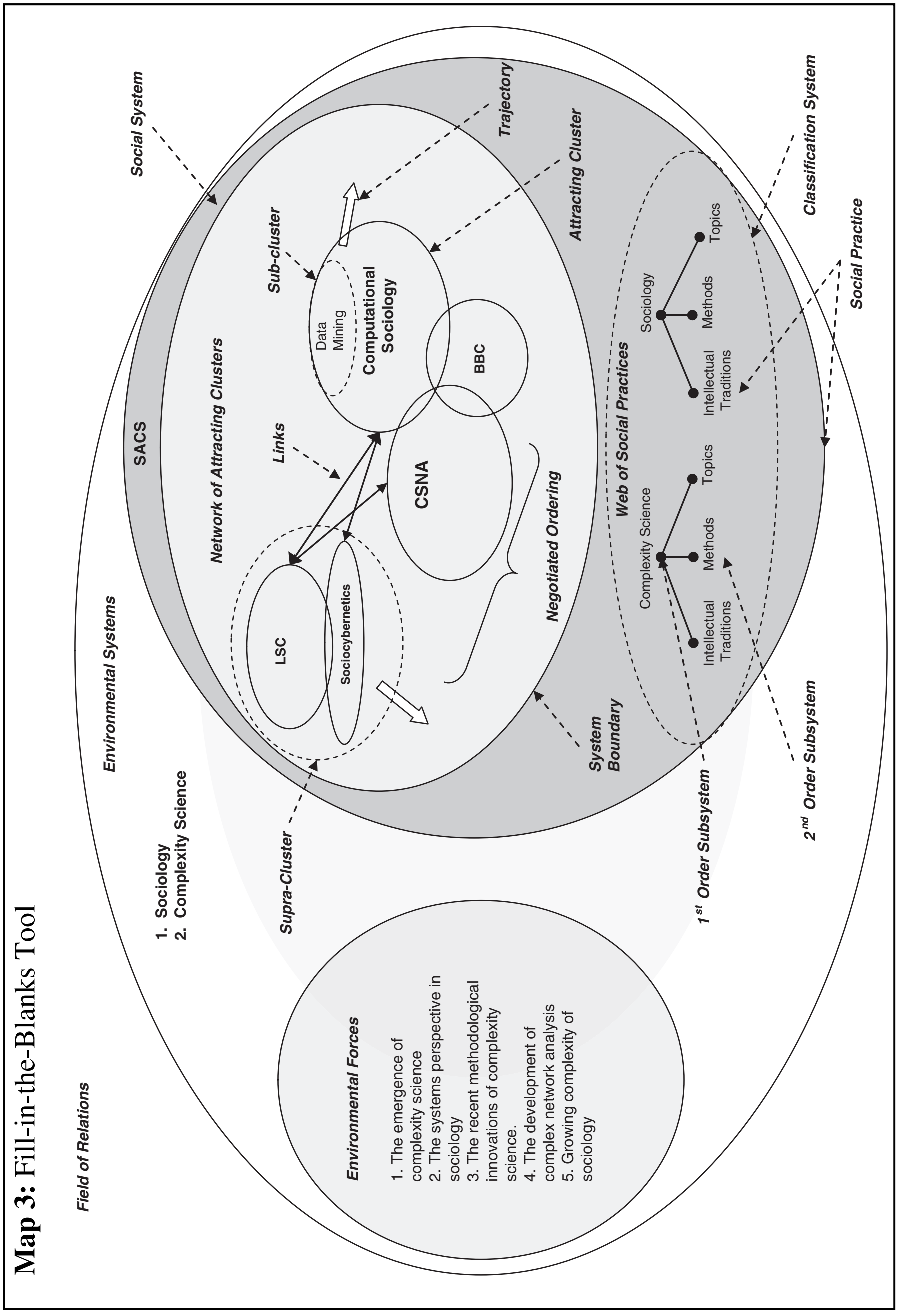
2.2 Social Complexity Theory

Social complexity theory is more a conceptual framework than a traditional theory. Traditional theories, particularly scientific ones, try to explain things. They provide concepts and causal connections (particularly when mathematical) that offer insight into some social phenomena. When one thinks of sociological theories, for example, one thinks of Max Weber's work on rationalization and bureaucracy (1946, 1968); Karl Marx's work on capitalism and class conflict (1970); Erving Goffman's work on social interaction and impression management (1959, 1967); or Anthony Gidden's theory of structuration (1984). These theories are held in high esteem because they explain the world to us, helping us see things a little bit better.

Scientific frameworks, in contrast, are less interested in explanation. They provide researchers effective ways to organize the world; logical structures to arrange their topics of study; scaffolds to assemble the models they construct. When using a scientific framework, "theoretical explanation" is something the researcher creates, not the other way around. An excellent example of such a "framework," is Anselm Strauss's general theory of social interaction, as outlined in *Continual Permutations of Action* (1993). Unlike his grounded theoretical work with Barney Glaser, which gives specific "accounts" (explanations) of such social processes as grieving or chronic illness, Strauss's general theory is an "all-purpose" toolkit designed to help researchers explore a variety of sociological topics.

Similar to Strauss, social complexity theory is a scientific framework. It is an all-purpose scaffolding designed to help researchers (1) organize and arrange, (2) categorize and sort, (3) classify and label and (4) manage and control their empirical inquiries into the structure and dynamics of various social systems. Social complexity theory does this by providing researchers a theoretical filing system and an associated vocabulary that they can use to create their own model of a social system.

As shown in Map 3 (SACS Toolkit Map), the filing system of social complexity theory consists of five organizational folders: (1) field of



Map 3: Fill-in-the-Blanks Tool
Field of Relations
Environmental Forces
1. The emergence of complexity science
2. The systems perspective in sociology
3. The recent methodological innovations of complexity science.
4. The development of complex network analysis
5. Growing complexity of sociology
1. Sociology
2. Complexity Science
Environmental Systems
Supra-Cluster
Social System
SACS
Network of Attracting Clusters
LSC
Sociocybernetics
Links
Sub-cluster
Data Mining
Computational Sociology
Trajectory
Attracting Cluster
BBC
CSNA
Negotiated Ordering
System Boundary
Web of Social Practices
Complexity Science
Intellectual Traditions
Methods
Topics
Sociology
Intellectual Traditions
Methods
Topics
1st Order Subsystem
2nd Order Subsystem
Classification System
Social Practice

relations, (2) web of subsystems, (3) network of attracting clusters, (4) environment, and (5) system dynamics. In turn, each folder contains its own subfolders. The environment folder, for example, is subdivided into two major headings: (a) environmental systems and (b) environmental forces, both of which are further subdivided according to: (i) type, (ii) relevance and (iii) impact. Using this filing system, researchers can empirically investigate the structure and dynamics of a social system, confident that they have an effective way to manage their study.

The researcher's confidence is further secured through the vocabulary of social complexity theory, which consists of a concise list of terms for thinking, talking and writing about the structure and dynamics of a social system. Some of these terms, such as attractor points, phase transitions or environmental forces are borrowed from complexity science (Capra 1996). Others, such as negotiated ordering, trajectory or differentiation are modifications of recognizable sociological terms (Strauss 1993). Still others, such as the web of social practices, network of attracting clusters or multi-singularity are new. Of the various terms relevant to social complexity theory, one of the most important is social practice. Before discussing our filing system, we therefore need to explicate this term.

2.2.1 Social Practice

In the fields of sociology, anthropology, and continental philosophy, a new branch of social theorizing has emerged called *practice theory* (Ahearn 2001; Castellani 1999; Dreyfus and Rabinow 1983; Jenkins 1992; King 2004; Reckwitz 2002; Stueber 2006). The most well known theorists in this branch are Anthony Giddens (1984), Pierre Bourdieu (1990) and Michel Foucault (1980). Despite the numerous differences amongst these scholars, they are united by a common concern and strategy.

In terms of concern, they seek to avoid what Dreyfus and Rabinow, in their review of Michel Foucault call "the Scylla of hermeneutics" and "the Charybdis of structuralism" (1983). The Scylla of hermeneutics has to do with the tendency to treat the human subject as the ontological basis for social reality, as typically is done in cognitive science, psychology, and humanistic philosophy (Giddens 1984). In contrast, the Charybdis of structuralism has to do with the tendency to treat social reality (e.g., society) as independent of human agency, as is typically done in European sociology, functionalism, structural anthropology, and systems thinking (Dreyfus and Rabinow 1983). Another way to express this dual concern is that practice theorists seek to overcome the structure/agency dualism. That is, they seek to avoid turning social reality into either the study of structure or of agency (For a more in-depth review, see Giddens, 1984, Chap. 1).

As a common strategy, practice theorists approach the structure/agency dualism in three important ways. First, they conceptualize social reality as social practice. Bourdieu, for example, has his concepts of practice and field (1990); Giddens his duality of structure (1984); and Foucault his concepts of organizing practice and dispositif (1980). Second, they define social practice as some combination of structure and agency (Ahearn 2001; Jenkins 1992; Reckwitz 2002; Stueber 2006). Foucault, for example, has his theory of knowledge and power (1980); Bourdieu his theory of habitus (1990); and Giddens his theory of structuration (1984). Third, they treat sociological inquiry as the study of social practice. As Giddens notes, "The basic domain of study of the social sciences, according to the theory of structuration, is neither the experience of the individual actor, nor the existence of any form of societal totality, but social practices ordered across space and time" (1984, p. 2). As this statement suggests, theorists such as Giddens, Bourdieu and Foucault consider basic rituals such as brushing one's teeth or saying "hello" as types of social practice. So too are major topics like health care, economics, or politics. In fact, the entire sociological landscape—dispositif (Foucault 1980)—is made of social practice. Social practices can vary in length of time, from a quick cell phone conversation to the long-term life of a religion. They can vary in size, from the micro-politics of caring for oneself to the macro-dynamics of global society. They can vary in level of stability, from the spontaneous emergence of a crowd to the more entrenched patterns of family and government. And they can vary in complexity (a point we will come back to later), from such simple phenomena as using a pencil or pronouncing a word to more complex practices such as creating SACS and its five major areas of research.

Given its conceptual utility, Foucault, Giddens and Bourdieu all treat social practice as their critical concept. We follow suit. For us, sociology is the study of social practice. We do, however, have our own take on social practice.

While Foucault, Giddens and Bourdieu do an excellent job articulating three very useful (although somewhat different) definitions of social practice, none were to be the basis for a theory of social systems. During the course of our investigations we therefore found it necessary to construct our own definition.

First, we use Foucault's definition as our base. In comparison to Bourdieu and Giddens, it does a much better job clarifying how agency and structure couple to create social practice. Furthermore, Foucault's approach is the most "systems" oriented of the three. In fact, we find in Foucault a wealth of ideas useful for building a theory of social systems, specifically his concept field of relations (one of our theory's primary terms) and his theory of interaction (Foucault 1983). Foucault's concept of social practice, however, is slightly biased toward the structuralist side of the agency/structure dualism. To counteract this bias, we infuse Foucault's definition with symbolic interactionism, specifically the work of Herbert Blumer (1969) and Anselm Strauss (1993). This infusion not only emphasizes the role agency plays in social practice, but opens the door for such important concepts as negotiation, resistance, and difference—all of which, as we explain later in this chapter, are central to our theory of social systems. (For a more detailed discussion of our integration of Foucault and symbolic interactionism and the advantages of this infusion see Castellani 1999.) Finally, we integrate this infusion with several key thinkers in complexity science, particularly Maturana and Varela (1998) and their concepts of knowing and coupling. This last modification helps us connect social practice with some of the major epistemological advances complexity scientists have made, particularly in linking the natural and social sciences (Ehrlich 2000).

Based on these modifications, we define social practice as follows: Social practice is any pattern of social organization that emerges out of, and allows for, the intersection of symbolic interaction and social agency. In addition, we note the dual dimensions of "allows for" and "emerges out of" in this definition. Social practice is both the cause and the consequence of symbolic interaction and social agency. In fact, they cannot exist without each other. Symbolic interaction provides social practice its structure, while social agency provides social practice its dynamics. In turn, social practice provides symbolic interaction and social agency an organizing framework. As stated above, social practice is any "pattern of organization" that allows for the intersection of symbolic interaction and social agency. By "allowing" we mean that social practice, as an emergent phenomenon, is a conduit. It defines, constrains, limits, controls, regulates, disciplines, obligates, enables, facilitates, permits, creates and makes possible the intersection of symbolic interaction and social agency (Castellani 1999).

2.2.2 The Five Components of Social Practice

Our definition of social practice is comprised of five basic components: (1) inter-action, (2) social agents, (3) communication, (4) social knowing and (5) coupling. While these five components move beyond the confines of the structure/agency dualism, they align themselves with the terms of this dualism as follows: social agents and inter-action are subsumed under the general heading of social agency; communication and social knowing are subsumed under symbolic interaction; and, coupling becomes our technical term for the intersection of symbolic interaction and social agency.

We will now review each component, focusing on how it helps us understand more fully the structure and dynamics of social practice, as well as how it helps us navigate a course between the Scylla of hermeneutics and the Charybdis of structuralism.

1. Social practice is comprised of interaction. Interaction refers to the movements, behaviors, processes and interdependent actions of social practice, along with the actions of the agents and communication strategies of which a social practice is comprised. Interaction also refers to the various types of relationships that can exist through social practice—for example, relations of power—as well as the various forms and expressions these relationships can take, such as conflict, negotiation, domination, and contract (Castellani 1999). The entire package of interactions involved in a social practice is referred to as its *dynamics*. Borrowing this term from physics, we use it to refer to interaction in the plural sense: dynamics as a web of "inter-actions" of which a social system is comprised, and the course of actions a social system takes.

2. Social practice is comprised of social agents. We use this term to overcome the structuralist leanings of Foucault. Social practice is not just the enactment of macro-level social structure (Foucault 1977). Social practice includes all types of social agents, from small groups to businesses to educational institutions to nation-states and so forth. As a side note, a social agent also can be a social practice.

3. Social practice is comprised of communication. Social practice cannot exist without the sharing and exchange of information. Language, in turn, is an instrument of communication. There are formal languages, scientific languages, biochemical languages, paralanguages, etc. There also are discourses, codes, rules, formulas, etc. The smallest unit of communication is a *communication strategy*. A communication strategy can be a single letter, word, facial gesture or machine code, or it can be something more extensive, such as a monograph, handbook, etc. The main criterion of a communication strategy is that it constitutes a single act of symbolic exchange, one that cannot be broken down into something simpler or more basic without losing the intention of the strategy itself.

Our definition of communication is distinctive because it moves us away from the hermeneutical leanings of most sociological theories of symbolic interaction. Our definition does this in two important ways. First, we are able to explicitly separate symbolic exchange from interaction. This is helpful because, in so doing, we can make inter-action a more comprehensive process. Interaction is not just the behavior of humans in relation to themselves, others, and the world. It also is the interaction of discourses, codes, social institutions, cultures, nation-states and so forth (See Castellani 1999). Second, we are able to replace the term symbolic with the term communication. We do this for three reasons. First, we want to accent the fact that symbolic interaction is far more inclusive than just verbal and nonverbal language. It involves the entire spectrum of symbolic exchange, including machine and biological communication. Second, we want to highlight the relational property of symbolic interaction. Communication is specifically defined as the exchange of information. Finally, we want to emphasize the fact that communication is not limited to human actors. In the information age, governments communicate with each other; websites communicate with each other; traffic patterns communicate with each other, and so forth, with little to no human involvement.

4. Social practice is comprised of social knowing. Social knowing is the human element of social practice. Social knowing can be facilitated by artificial intelligence and by various forms of machine communication—one example is the phone or computer, another is assistive technology for people with disability. Still, social knowing is something living organisms do. The most advanced form of social knowing is human social knowing (at least on planet earth).

Social knowing involves aligning social practices with the worlds in which humans live. Said another way, in order for a social practice to do its job, it has to "line up" with the world. That is, it has to work for the needs, desires, interests, concerns, or wants of humans; otherwise it is useless and discarded. The job of social knowing—defined as social mind in action—is to make sure that each and every social practice, from a pragmatist perspective, works.

The idea that social practices have to "work" comes from the pragmatist tradition, which extends from William James, Charles Sanders Pierce and John Dewey to the Chicago School of Sociology and symbolic interactionism, to recent neo-pragmatists such as Richard Rorty and Cornel West (Denzin 1992, 1996; Rorty 1999; West 1989). As these scholars argue, a social practice has to be useful to remain part of the human repertoire. Social practice has to help us get along in the world. It has to help us get the things we want done, such as staying alive, overcoming illness, finding a job, managing or controlling our enemies, having fun, creating new technologies, satisfying our excesses and addictions, explaining to us the purpose of our lives, or just passing the time. In other words, the purpose of social practice is to help humans manage their socio-biophysical lives.

It is important to point out that our definition of social knowing does not conceptualize the utility of social practice in terms of moral or ethical obligation. Neither does it worry about a social practice's "truth" in the abstract. Truth is an adjective assigned to social practices that work. Furthermore, there are no Spencerian overtones of the "survival of the fittest" in this approach to social practice. Utility can be more than a matter of might or right. From a pragmatist perspective, "useful" simply means "works." If a social practice helps some person or group accomplish their goal, it continues to exist, even if it is deemed by "others" to be deviant, immoral, untrue, anti-social, unhealthy, destructive, irrational or dumb—unless these others (and here is where "might" and "right" step in) have the power to stop or eliminate the social practice. The public health campaign in the United States against smoking is a good example.

The process of creating, learning, adapting, adjusting, developing, improvising, combining, discarding or replacing social practices so that they "line up" with the world is the job of social knowing. The concept of social knowing, at least as we employ it here, comes from the work of Maturana and Varela (1980, 1998) and, to a lesser extent, Chomsky (2000), Fodor (2000) and Ehrlich (2000). Of the various mental processes connected to the brain-based knowing of humans, there is a set of modules (see Fodor's use of "module" in his computational theory of mind) that help us navigate our existence as social animals. These modules consist of processes such as self, language, cognition, the "I," emotional intelligence, and so forth. Together, these modules constitute the social mind. Social mind is distinct from other forms of human knowing, particularly those ways of knowing that are not brain-based, such as the immune system, nervous systems, cardiovascular system, and so forth (Maturana and Varela 1998; Varela, Thompson and Rosch 1991).

The literature in social psychology and cognitive science have empirically identified and demonstrated the existence of a modular social mind in two important ways. First, without social interaction these modules do not emerge. The best example is feral children, where many of the modules associated with social mind are not developed (such as language) or are severely impoverished (such as a sense of self). Second, when the modules of social mind do not work appropriately, they result in social incompetence. Social incompetence is the behavioral manifestation of a failure of effective social knowing. Examples of modular impairment leading to social incompetence include cognitive or mental disorders such as autism, schizophrenia, anxiety, or Alzheimer's disease (Sacks 1995). The social practices of daily life—communicating with people, getting to work on time, paying the bills, managing one's emotions, etc—are extremely difficult for the people who suffer these modular disorders, creating the possibility for stigma and the label of incompetence (Goffman 1959).

As the above empirical demonstrations suggest, social mind is a brain-based process, an extension of our biological existence, that emerges through our interactions with other humans and the various environments in which we are situated (Maturana and Varela 1980, 1998). That is why social mind is given its name. It is that part of our brain-based knowing that seems to have emerged and developed to capitalize upon and manage our relatively unique existence as complex social animals. Moreover, in the absence of social interaction, social mind has no reason to exist (Ehrlich 2000; Mithen 1996).

What our two empirical demonstrations do not make clear, however, is that mind is an action. Given the structure of the English language, social mind, although written and spoken in sentences as a noun, is not a thing (a noun or an object). Instead, it is a verb (a process or a dynamic system). That is why, to highlight the active, dynamic and relational character of social mind, we use the term *social knowing*. Social knowing is social mind in action. It is the activity of living social minds, as they interact with themselves, the world, and other forms of human-based knowing. More important, social knowing is the activity of social minds in interaction with other social minds and, let us not forget, the social practices these interactions need and create. We must remember that social mind and its social knowing have no reason to exist, and cannot fully develop, without social practice. In this way, social mind and social practice are sui generis. One cannot exist without the other. Without a social mind and its social knowing, there is no need for social practice. Without social practice, social minds cannot emerge, act, develop or interact.

Finally, social knowing is fundamentally interpretive because it is the unique product of human, brain-based knowing. Here we once again draw from the work of Maturana and Varela (1980, 1998) and, to a lesser extent, Chomsky (2000), Fodor (2000) and Ehrlich (2000). We also lean heavily on the traditions of symbolic interactionism, ethnography, cultural anthropology, culture studies and, most importantly, pragmatism. Empirically speaking, the activity of "making social practices work" by "lining them up with the world" is not the same thing as "creating social practices that accurately represent the world as it truly is." Language, for example, does not have to accurately represent the world "as-it-is" to work. It need only allow us to interact with the world in a successful way—which still is a rather amazing accomplishment. Said another way, if we were to trace our evolutionary tree backwards, it does not seem, empirically speaking, that there ever has been a need for our social mind to achieve a strict understanding of the world "as-it-is" (Ehrlich 2000). Nor has there been a need to obtain what the naïve realists refer to as a "one-to-one" correspondence with objective reality in everything we do. A case in point: our knowledge of the world, like our minds, is constantly changing, constantly evolving. It never ends because the world, in all its complexity, cannot be contained in any one "conceptual net" of understanding. Furthermore, as the theoretical biologists and complexity scientists, Maturana and Varela point out, our knowing in many ways is species specific (1998). Human knowing—

or, to be more exact, human social knowing, as expressed by our social mind through its dialogue with the world via social practice—is only one type of knowing. Other forms of knowing include insect, plant, machine, and so on. Understanding the structure and dynamics of social practice and, more specifically, social systems depends on this empirical point. The term "interpretation" highlights the fact that human social knowing is a human project grounded in our particular unique socio-biophysical arrangements and makeup.

5. Social practice involves coupling. This term refers to the plasticity of social practice. Social practices are good at connecting, linking, attaching, merging, joining and uniting with other social practices. So are their components. The interactions, social agents, communication patterns and social knowing of one social practice are easily coupled—that is, shared, glued, fastened, exchanged or combined—with those of another. Social practices also are good at coupling with the biophysical worlds in which they take place, including the human bodies that enact them and the various environmental systems in which they are situated. Social practice is not divorced from the biophysical world. It is simply another level of emergent biophysical organization. In fact, one might even say that the study of social practice (and therefore sociology) is a branch of biology. Reframed in this way, sociology is the branch of biology that studies (1) the emergence and development of social mind and social practice; (2) the interactions between social minds and social practices (symbolic interactions, impression management, exchange theory, game theory, etc); (3) the aggregate byproducts of social minds and social practices (societies, economies, cultures, personalities, oeuvres, historiographies, etc); and (4) the interactions amongst these various areas of socio-biophysical existence.

6. We have one last point. Social practices are good at creating other forms of social practice. In other words, a social practice can emerge out of the union and intersection of other smaller (and sometime larger) social practices. An intellectual community like SACS, for example, is made up of a long list of smaller social practices, such as colleges and schools, department and units, work teams and project groups, occupational statuses and work roles, areas of research, scholarly methods, etc. Like molecules, social practices are constantly colliding and combining to form other social practices.

2.2.3 Social Systems as Social Practice

As stated earlier, we will use social practice as the critical concept in our theory of social systems. We therefore turn to a discussion of how social practice forms the basis of our theoretical framework.

Social complexity theory begins with the assumption that a social system is a type of social practice. For us, the term "social system" is really an adjective, a way of organizing our understanding of certain types of social practices that are best described as system-like. Based on current research, social systems are said to have the following properties. They are emergent, self-organizing, bounded, functionally autonomous, thematically centered, differentiated, agent-based, rule-following and complex (that is, they are comprised of a dense number of connections and interactions and often a large number of variables). They are also dynamic, evolve across time-space, and are situated within and impacted by a variety of environmental systems and forces. For a more thorough overview of this definition, see Byrne (1998), Cilliers (1998), Luhmann (1995) and Urry (2003).

The town of SACS, for example, as a type of social practice, meets the criteria for the category of a social system. First, SACS is emergent; the whole of the field is more than the sum of its parts, including its scholars, areas of study, educational institutions, websites, journals, etc. Second, SACS is self-organizing; it has coalesced into a field of study with little to no external guidance or control on the part of some specific conference, committee, department or school. Third, SACS resides in bounded form on the "outer bank" of sociology and just outside the city of complexity science. Unlike medicine, law, or clinical psychology, however, one does not need a specific credential, degree or disciplinary permission to do work in this field. Instead, SACS's boundary is informal, relaxed and unincorporated. Fourth, SACS is functionally autonomous (although not independent): while SACS has obvious connections to sociology and complexity science, it nevertheless is its own area of study, with its own journals, conferences, departments etc. Fifth, the scholars of SACS have a common set of concerns around which their work revolves, including: (a) addressing one or more of the six challenges of complexity, (b) figuring out how to integrate the intellectual traditions, theories and methods of sociology and complexity science to enhance sociological inquiry; and, (c) treating social complexity in systems terms. Sixth, and related, SACS is differentiated into a network of attracting clusters, each representing one of the various ways its dominant theme is practiced. These are: (1) sociocybernetics, (2) Luhmann School of Complexity (LSC), (3) computational sociology, (4) the British-based School of Complexity (BBC), and (5) complex social network analysis (CSNA). Seventh, SACS is agent-based with dense, local connections within the major research communities and with semi-developed connections amongst them. Eighth, SACS has a past, present and future trajectory within the systems tradition in sociology. As we will argue throughout the rest of the book, SACS is the latest stage in the systems tradition within sociology. And, finally the trajectory of SACS has emerged and evolved within the larger environmental systems of sociology, complexity science, western society and (more recently) global society. Given these characteristics, SACS is a social system.

2.2.4 Overcoming the Agency/Structure Dualism

The second assumption with which social complexity theory begins is that social practices are the building blocks of a social system. As we explained in our review of coupling, many types of social practice, particularly those that are more complex, tend to emerge out of the coupling of some set of smaller (but sometimes larger) social practices. The social practice of writing, for example, emerges out of the coupling of such various practices as typing, working a computer, reading the current literature, conversing with colleagues, using language, forming sentences and paragraphs, etc.

There are several advantages that come from the idea that social systems emerge out of the coupling of two or more social practices. One of the most important (and the one we will discuss here) is our ability to avoid a major flaw found within both the systems tradition and complexity science: the perpetuation of the structure/agency dualism. Systems theorists are faced with the Charybdis of structure (that is, conceptualizing social systems from the top-down, as already existing emergent structures) while complexity scientists have their Scylla of hermeneutics (that is, conceptualizing social systems from the bottom-up, as the product of micro-level interactions alone).

The Charybdis of structuralism within the systems tradition extends back to our short list of canonical scholars reviewed in our introductory chapter. For example, this bias can be found in the organicism of Spencer and Durkheim, and in Marx's dialectical materialism. We also see it in Weber. Despite all Weber's emphasis on verstehen, his analyses primarily were conducted from a top-down, macro-level perspective. Fifty years later, Parsons made the same structuralist mistake. Furthermore, and for all of his criticisms of Parsons, the contemporary sociologist and complexity scientist, Niklas Luhmann (See Sect. 6.3) fell into the same structuralist trap. In fact, reading Luhmann (1995) one wonders if humans even exist.

Complexity science reflects an opposite bias. Here, scholars drift toward treating social agents as the ontological basis of social systems (the

Scylla of hermeneutics). The major thesis underlying most complexity science is that social systems emerge out of the micro-level interactions of a network of rule-following agents (Axelrod 1997; Holland 1998; Wolfram 2002). In fact, complexity scientists are so adamant about this point that they call their approach *agent-based*, and they talk about building social systems from the ground-up (as opposed to the top-down)—all in an effort to distinguish their work from the structural biases of older systems thinking (Cilliers 1998; Gilbert and Troitzsch 2005; Holland 1998). In so doing, however, complexity scientists fall prey to treating social systems as little more than the aggregate product of symbolic interaction.

While we strongly endorse an agent-based view, and while we consider it a major advance over previous systems thinking, we nevertheless think that, at least when it comes to the study of such complex systems as human organizations, health care systems, professions, global economies, and so forth, greater empirical yield comes from thinking about social systems as practice-based; that is, from thinking of social practice as the fundamental building blocks of a social system, rather than rule following agents. In many ways, the remainder of this chapter and this book is an attempt to defend this point.

Consider, for example, SACS. One could easily construct a map of the network of actors in this social system. The system, however, does not emerge out of these actors. Instead, it emerges out of the two dominant social practices that are coupling to create this new field of study, namely sociology and complexity science—we will have much to say about these two social practices in Sect. 2.2.6 of this Chapter. From this perspective (e.g., social practices as the building blocks of social systems) each scholar—such as Nigel Gilbert or Duncan Watts or Niklas Luhmann—is more than just a social agent. Each scholar constitutes one of the numerous ways the social practices of sociology and complexity science couple to create the new field of SACS. In other words, the names of particular scholars in the system of SACS do not just represent individuals (social agents); they represent specific expressions of social practice, including interaction, communication, social knowing and coupling—as enacted by these scholars. In other words, while different agents make different social practices unique, it is only because they already are part of these social practices. Said another way, social systems are more than just agents following rules. They are agents involved in the coupling of social practice.

To make our theory of "social systems as social practice" clearer, let us turn to an overview of the major filing system of social complexity theory. We begin with the *field of relations*.

2.2.5 Field of Relations

As shown in Map 3 (SACS Toolkit Map) and Fig. 1 (Venn diagram), social systems are situated in a field of relations. The field of relations is defined as the intellectual arrangement and bracketing of all information necessary to construct a model of a social system. We borrow the term from Michel Foucault, the practice theorist we discussed earlier (See Dreyfus and Rabinow 1983). For us, this term has three functions: conceptual, organizational and methodological.

1. Conceptually, the field of relations functions as the grid of analysis—something Foucault calls a dispositif (See Dreyfus and Rabinow, 1983, pp. 118–125). Its purpose is to articulate the space in which all the elements a social system of study— along with their relationships—can be located and coaxed into coming together. In this respect, the field of relations simultaneously is an artificial product of the researcher and something externally real, which the researcher legitimately studies.

Our metaphor of SACS as an intellectual community is a good example of this duality. While SACS is not literally a town, the term "SACS" illustrates or captures the intellectual space in which the intersection of complexity science and sociology currently is taking place. This analogy of an intellectual town also is a useful way to treat the connections SACS has to the intellectual tradition of systems science. Examples being our discussion of the Old Parsons Highway or our situation of Luhmann's new social system theory near the intellectual remains of Harvard's Department of Social Relations.

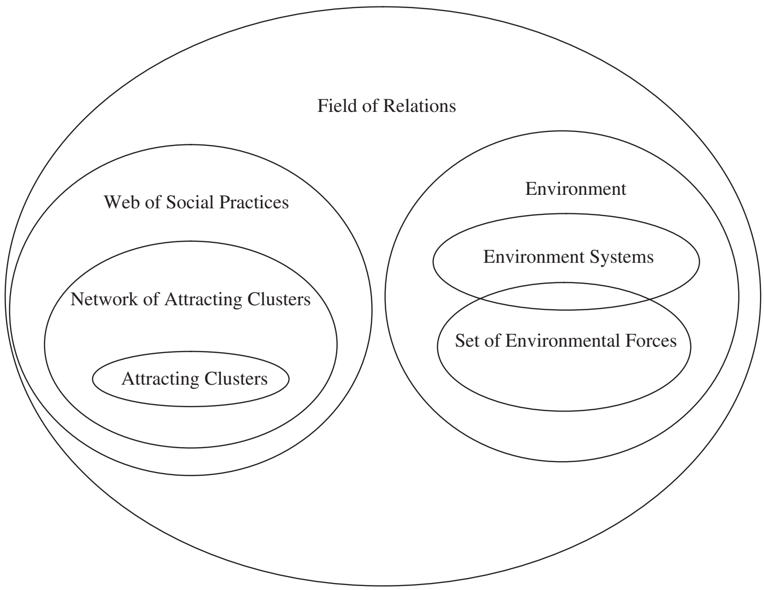


Figure 1: Venn Diagram of SACS Folder

2. The second purpose of the field of relations is organizational. As we explained above, social complexity theory is a rigorous framework of organization. Social complexity theory provides a way for researchers to make sense of the chaos of modeling social systems, which is does by giving the researcher a set of conceptual folders, sub-folders, a filing system, and so forth for organizing everything in a set of predetermined format. The assemblage algorithm, in turn, provides the researcher a set of procedures for collecting and analyzing these files, sub-files, etc.

Perhaps one of the best filing systems available to modern science is set theory. Set theory is the study of the proper ways to think about, organize and discuss the collection of objects (sets) and the relationships these object (as sets) have with themselves and one another (Clapham and Nicholson 2005). The field of relations, therefore, operates as the universal set for any social system of study such that:

$$F = \{x_1, x_2, x_3 \ldots x_n | x_n \text{ is relevant to some social system of study}\} \tag{2.1}$$

In this equation, *F* stands for the field of relations and x_n stands for any piece of information relevant to the study of a social system. Any collection of x_n taken from *F* to model a social system constitutes a subset of *F*. In fact, the web of subsystems folder, network of attracting clusters folder, and environment folder are culled out of *F*. In short, these folders are subsets of *F*.

The formal arrangement of *F* and its subsets is shown in Venn diagram (Fig. 1). Beginning with *F*, each subsequent folder used to model a social system is visualized as a subset to the Nth order. For example, the environment and web of subsystems folders are 1st order subsets of *F*. In turn, the network of attracting clusters is a subset of the web of subsystems, and as we discussed earlier, environmental systems and environmental forces are subsets of the environment folder.

Map 3 provides an example of how we use the field of relations to organize our study of SACS. The field of relations constitutes the entire map, which we define as all things relevant to constructing a model of SACS. Within this general field are several key subsets: (1) there is the subset called sociology, which is one of the two environmental systems (the other being complexity science) in which SACS is situated; (2) there is the subset of environmental forces (the growing complexity of sociological work) that defines the external forces impacting the formation and development of SACS; (3) there is the web of social practices, which contains the building blocks of SACS; (4) and, finally, there is the network of attracting clusters—a subset of the web of social practices—in which we identify five subsets, one for each of the five major areas of research in SACS.

3. The third purpose of the field of relations is methodological. The strength of using the field of relations is that it can be directly applied to the organization and management of one's database, as well as the collection and analysis of empirical data. This is of particular importance when collecting, organizing and analyzing quantitative data, primarily because there is no theoretical slippage moving from theorization to quantitative data collection and analysis—a major bonus strength of the SACS Toolkit. In fact the field of relations, when coupled with set theory and matrix algebra, is the organizational equivalent of the database formats used in such software packages as SPSS® and MATLAB®, both of which are used by the SACS Toolkit when studying quantitative data.

As a side note, to help organize the model building process, assemblage (the methodological component of the SACS Toolkit) uses the folder systems of social complexity theory to organize the field of relations database. Here, again, we turn to the data mining literature and the idea of active data management. Active data management is one where the database is constantly updated, developed and revised based on the changing needs and concerns of the researcher. Passive is the traditional approach, wherein once a database is created, it is not significantly changed in any way.

Taking an "active" approach to data management, the subsets of the field of relations become their own databases—each, of which, is also a major folder in social complexity theory: environmental systems, environmental forces, web of subsystems, network of attracting clusters and system dynamics.

In the case of SACS, for example, database #1 contains the five environmental forces impacting SACS—see Map 3 for a list. Database #2 contains the two environmental systems in which SACS is situated, sociology and complexity science. The third database contains all the information necessary to build a model of SACS. The third database, in turn, is comprised of two smaller databases: the data for the web of social practices and the data for the network of attracting clusters. The web of social practices database contains the twin practices out of which SACS emerges, sociology and complexity science. Both of these social practice databases are further divided into three major sections: intellectual traditions, methods and topics—See Map 3.

The network of attracting clusters database is comprised of the five dominant ways that the social practices of SACS couple together. These "couplings" corresponds to the five areas of research in SACS: complex network analysis (CNSA), the Luhmann School of Complexity (LSC), sociocybernetics, computational sociology and the British-based School of

Complexity (BBC)—See Maps 3 and Figure 2 for a visual rendering of this database.

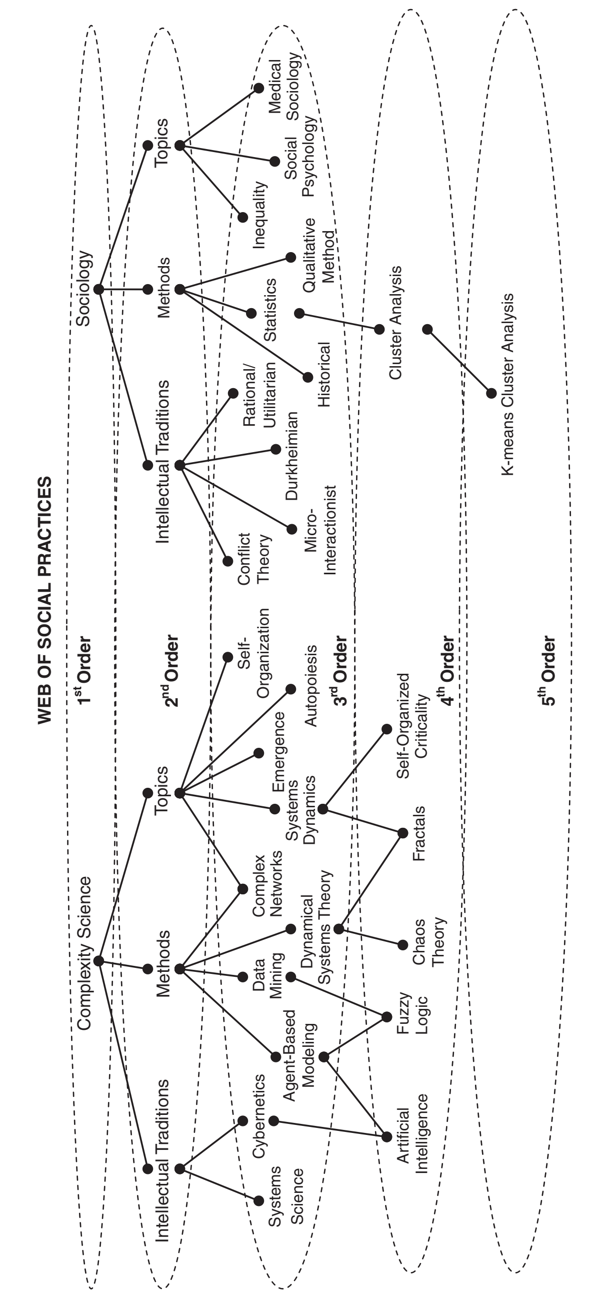
Before proceeding further, we need to introduce the dimension of time-space. Social systems rarely are studied at a single moment in time-space. Instead, the usual goal is to model a social system as it evolves across time-space. One of the distinguishing features of complexity science is the significant emphasis it places on dynamics: how things change across time-space (Holland 1998; Wolfram 2002). In fact, as we discuss in detail in Chap. 5, this emphasis is what makes complexity science such a powerful methodology (Axelrod 1997; Casti 1999). For complexity scientists, it is one thing to outline structure, but quite another to understand how this structure actually unfolds. The SACS Toolkit has the same orientation. It ultimately is interested in the dynamics of social systems; how they emerge, self-organize, and evolve. The same is true of SACS. The reader will note that, even in our introductory chapter we emphasized the evolving tradition of systems thinking in sociology and the place of SACS in that tradition. Our databases also reflect this bias toward dynamics. Each database contains information at several key points in time, starting in the late 1990s and ending with the present, 2008.

2.2.6 Web of Social Practices

The web of social practices is the folder used to manage one's empirical inquiries into the set of practices that couple together to form a social system of study. We use the term "web" in this concept to highlight the interdependent, relational nature of social practice.

As we previously discussed, social practices are the building blocks of a social system. As building blocks, they come in all shapes and sizes, varying in type, length of time, level of stability, number of agents, type of agents, forms of communication, ways of knowing and complexity. A system's social practices can themselves be treated as systems; something we refer to as a subsystem; or, systems within a system of study. These subsystems however, are not necessarily a smaller unit of social reality than the system of study. As shown in Map 3, for example, SACS is comprised of two major social practices—sociology and complexity science—both of which are social systems. These systems are much larger and more widely practiced than SACS. Nonetheless, they are part of the building blocks of SACS and are therefore treated by social complexity theory as part of its web of social practices. (They are also, as a side note, treated as environmental systems, which is a point we will clarify in Sect. 2.2.8.)

Figure 2: Web of Social Practices for SACS



Although the web of social practices can take a variety of visual forms, we have found that the organizational chart or tree diagram is the most useful representation—see Fig. 2. In such a diagram, the system's social practices are ranked according to their relative importance and position, with each additional ordering of practices subsumed under the previous order (remember our discussion of set theory). The subsystems of sociology and complexity science, for example, are divided into their own subsystems and social practices—See Fig. 2. We refer to these successive subdivisions as the Nth order of subsystems and sub-practices. Theoretically speaking, the ordering of subsystems and sub-practices can continue ad infinitum. In SACS, for example—see Fig. 2—one can "tool down" (to use a data mining term) into the subsystem of sociology, going on to method (2nd order subsystem), then statistics (3rd order subsystem), then cluster analysis (4th order social practice) and then, finally, k-means cluster analysis (5th order social practice). One could imagine going even further (although our diagram does not) to a 6th order social practice that specifies different usages of the k-means cluster analysis, such as our own integration of this technique with neural networking (Castellani, Castellani and Spray 2003).

While a structural diagram of the web of social practices is organizationally efficient and productive, it does not in-and-of-itself make a social system. Dynamics also are needed. At this point, however, the web of social practices is purposely devoid of dynamics. It avoids dynamics at this point so the researcher can focus on getting everything in order. Let us explain.

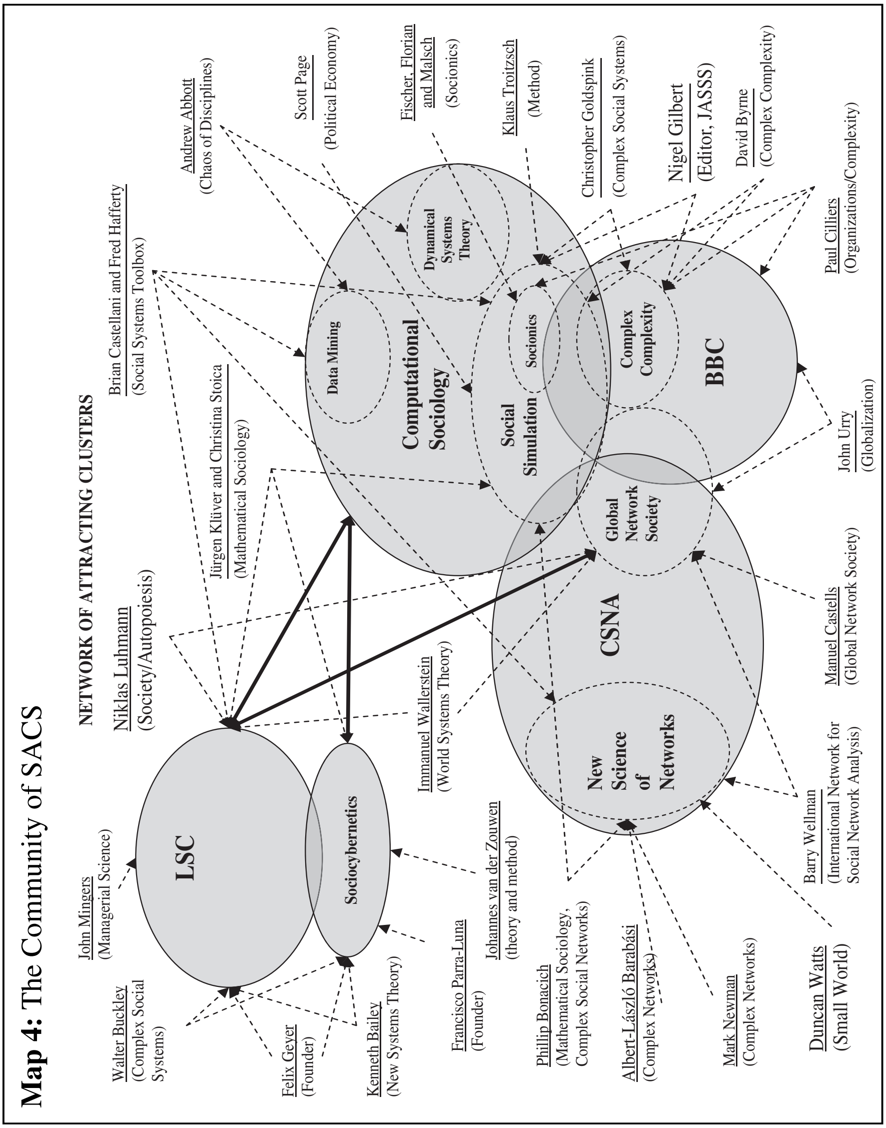
As an analogy, one can think of building the web of social practices as akin to opening a board game and first having to arrange all of its pieces before ensuing play. A more socially nuanced analogy would be hosting a party. Behind every successful party (even the most casual) is a host of preparations and checklists. Once the game or party starts, however, it is all about dynamics and interaction. You do not want to exit the game or party because you forgot something, or worse, you do not want everything to stop because a key element is missing. The same is true when studying social systems. One wants to have everything in order before turning to a study of the coupling process and its consequent dynamics. The job of getting all the relevant social practices into place, including the key social agents, interactions, communications and social knowing relevant to these social practices is the purpose of the web of social practices. At this point, the only thing missing is the coupling of these social practices. This brings us to our next major folder, the network of attracting clusters, which is all about dynamics.

2.2.7 Network of Attracting Clusters

As shown in our Venn diagram (Fig. 1), the network of attracting clusters is a subset of the web of social practices. As a subset, it provides a list of the different ways the web of social practices tends to couple. In turn, each "coupling" constitutes one of the numerous ways a social system is practiced. As we explain later, the goal of assemblage (our method) is to reduce our list of couplings to the most salient (i.e., outstanding, prominent, significant, leading, major) ways a social system is practiced at any given moment in time-space. Drawing upon the language of fractal geometry, chaos theory, and the new science of networks, each of these major couplings/practices is defined as an attractor point in the social system, a hub around which a variety of similar couplings tend to cluster. When assembled together, these major couplings/practices form a network, hence the name of this folder, the network of attracting clusters.

Map 4 depicts the network of attracting clusters for SACS. Each oval on this map represents one of the major ways that SACS is practiced; that is, one of the major ways that the intellectual traditions, methods, and topics of sociology and complexity science tend to couple. Together, these ovals represent the five major research communities in SACS at a particular moment in time-space; specifically SACS in Europe and North America, circa 2008. In the language of fractal geometry, each oval in our map is an attractor point around which a more exhaustive list of minor couplings (in this case, scholars and subfields of research) gathers. In fact, these minor couplings represent the scholars hovering around these five communities. Remember our point about social practice being the building blocks of a social system? Based on this idea, the scholars in SACS are empirical expressions of the numerous "couplings" taking place within and between the five research communities of SACS. In other words, the scholars of SACS (at least for the purposes of social complexity theory) are not just people; they are expressions of the coupling of social practice.

To understand more fully the network of attracting clusters, we need to spend time discussing the concepts of coupling, attractor points, difference, and system boundaries. We therefore turn to a brief overview of these concepts.



Map 4: The Community of SACS

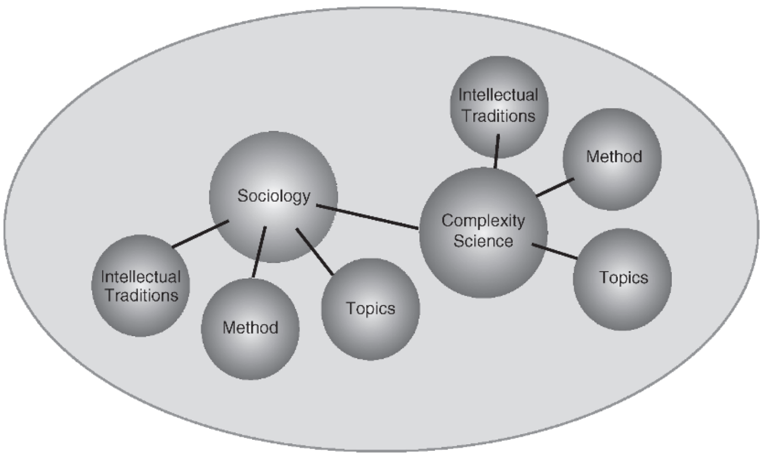
2.2.7.1 Coupling

As we explained earlier, coupling refers to the plasticity of social practice and its characteristic habit of connecting, linking, attaching, merging, joining and uniting with other social practices. Like a form of sociological DNA, social practices can be combined to form just about every possible "manifestation" of social reality, including social systems.

Think, for example, of those "tinker toy" models of various molecules students build in grade school. Social complexity theory views systems in a similar way. One might imagine—being fantastical for a moment—a computer program containing a list of every type of social practice in its toolbar for modeling SACS. In this computer program, one could click-and-drag these various social practices onto a three-dimensional grid where they could be merged, positioned and linked to one another until some basic "molecular" model of their configuration emerged. The result would be a system's web of social practices. Such a molecular model might look like Fig. 3. Furthermore, in constructing this model, the researcher could show how the different couplings of these various social practices "express" the system in different ways. This is an important statement and the crux of what we need to discuss now.

So far in our review of social complexity theory, we have established the following: (1) social systems are situated within a field of relations; (2) social systems are a type of social practice; (3) social practices are the building blocks of a social system; (4) social systems are comprised of a web of social practices; and (5) social systems emerge out of the coupling of two or more social practices. While each of these five theoretical

Figure 3: Web of Social Practices as Molecule



points is unique in the complexity science literature, and while all five go a long way toward establishing the utility of social complexity theory, they are a theoretical prelude/introduction for the next two points: (6) at any given moment in time-pace, a social system is multiply expressed and (7) this multiplicity of expression comes from the different ways that a system's social practices couple together. Let us explain.

2.2.7.2 Attractor Points

As an isolated point, the idea that social systems are multiply expressed is not new. Even the most basic of social practices, such as saying "hello," can be expressed in a variety of ways. The same is true of macro-level practices such as corporations or governments. None of these large-scale systems can easily be determined ahead of time, primarily because they possess the ability for multiple forms of expression.

What complexity science has added to this idea is that a social system's multiple forms of expression emerge out of the collective behavior of micro-level interactions. (Remember, however, that we disagree with a strict agent-based approach.) A network of adaptive social agents, following a simple set of rules, can create all sorts of complex outcomes, many of which cannot be predicted or repeated with certainty.

An excellent example is the work on agent-based modeling by Craig Reynolds. At his website (http://www.red3d.com/cwr/boids/), Reynolds provides several dozen examples of how a set of primitive agents (he calls them boids), following a simple set of rules (avoid the red boids, slow down at the wall, etc), can create endless variations of basic social practices such as following the leader, queuing at a doorway, or forming a line. While predictable within a certain set of parameters, the dynamics of Reynolds's boids are never the same. They are multiply expressed.

At the macro-level, an excellent example is the work on agent-based modeling by Joshua Epstein and Robert Axtell (Epstein and Axtell 1996). On a computer-simulated planet called *Sugarscape*, Epstein and Axtell have created a colony of social agents. The world of these agents revolves around a basic resource, sugar. Agents eat sugar, trade sugar, fight over sugar, migrate to find more sugar, split off into separate colonies over sugar, and even consume too much sugar and die. The population of Sugarscape ebbs and flows like an epidemiological study of predator-prey models. Similar to Craig Reynolds' boids, the dynamics of Sugarscape is confined to a rigid set of parameters. Still, and despite this containment, the expressions of this system are never the same. New things are always happening. And it is absolutely fascinating to watch.

In complexity science, a social system's tendency toward multiple forms of expression is captured by the concept of attractor point. This concept comes from physics and a branch of mathematics known as dynamical systems theory, something that extends back to calculus and Newton's study of the movement of objects in time-space, such as planets orbiting the sun. Currently, the two most popular areas in dynamical systems theory are chaos theory and fractal geometry, both heavily involved in the study of attractor points and nonlinear dynamical systems; that is, complex systems that operate in a position far from equilibrium. (As a side note, social systems are a type of nonlinear, dynamical system.)

Nonlinear, dynamical systems are categorically distinct because they are multiply expressed. In mathematical verbiage, this means they do not "settle" into a single solution. Instead, they self-stabilize (self-organize) into multiple solutions called attractor points. In nonlinear dynamical systems, attractor points can have a fractal appearance. They also often act in a manner that is, mathematically speaking, strange. Unlike the attractor points of simple systems (a pendulum, for example), strange attractors are neither exact nor permanent solutions. Instead, they are temporary "solutions" toward which a nonlinear dynamical system is drawn. One can see this process take place, for example, when a simulated system is iterated by computer in time-space (Érdi 2007).

As a side note, the life of a system's multiple solutions (its set of attractor points) is a function of the system's relative stability as it evolves across time-space. Highly chaotic systems, like storms or hurricanes, lack the stability one would find in a city's daily traffic patterns; which, in turn, lack the stability one would find in the changing political or economic control of most western governments.

Furthermore, there also tends to be more than one attractor in a nonlinear dynamical system. This is another reason why nonlinear dynamical systems are strange and the main reason why they are important for complexity science. In a nonlinear dynamical system—otherwise known as a complex system—each attractor point represents one of the myriad of possible ways the system can be solved/expressed.

This is the crux of our sixth point. Following the insights of complexity science and fractal geometry, we recognize that, at any given moment in time-space, a social system is being multiply expressed. What we take issue with, however, is the idea that this multiplicity is grounded in aggregate patterns created by a network of rule-following social agents. Instead—and this is our seventh point—this multiplicity comes from the various ways a social system's web of social practices couple.

2.2.7.3 Difference

As Klir explains, the term “system” can be applied to any set of things and the relationships amongst them—from card catalogues to airplanes to economies (2001). As long as the focus is on a set of things and the relationships amongst them, one is focusing on a system. Given such broad application (we touched on this point in our introductory chapter) a primary task of systems scientists is to identify and catalogue the different types of systems that exist or can be created.

In the field of systems science, the term “social system” refers to a particular type of system, namely those comprised of humans, their various aggregate creations (groups, formal organizations, economies, social institutions, etc), and the relationships amongst them. A modern society for example—think of the work of Durkheim or Parsons—is a system of differentiated social institutions (economy, government, health care, education, family, work, etc.) and the relationships amongst them. In turn, a formal organization is a collection of social roles and social groups and the network of formal and informal relationships, all created and designed for some specific purpose, such as educating students or making cars. In this classic sense of the term, “social system” refers to any human activity where the whole is more than the sum of its parts; that is, where the relationships amongst a set of humans and their various aggregate creations result in something more than the sum total of their interactions.

While we embrace this line of inquiry, we want to move in a different direction. For us, this traditional definition, while necessary, is insufficient. What is missing is the network of attracting clusters. Said another way, the traditional definition of a social system does not take us beyond the web of social practices.

If one were to frame the traditional definition of a social system (a la Durkheim, Parsons or more recently Luhmann) in the language of social complexity theory, we would say that systems emerge out of the collective interactions of a set of social practices. For these scholars, however, any concerns with the multiplicity of expression within a given system, or to issues of difference, would be confined to the manner in which this emergent social system changes across time-space. These scholars have no interest in the coupling process and the simultaneous differences this coupling produces at any given moment in time-space. It is here, therefore, that we part ways with traditional systems theorists.

For us, social systems ultimately emerge out of the coupling of social practice and the differences this coupling produces. From this perspective, the “things” of which a social system is comprised are not its social practices per se, but their couplings. Moreover, the system’s “relationships” are not just the interactions between these social practices, but (more important) the interactions between their various couplings. Said another way, a social system emerges out of the complex interactions in the different ways it is practiced. It emerges out of the network of attracting clusters.

Consider SACS. While the common theme in SACS is "integrating sociology and complexity science for the purposes of enhancing sociological inquiry," there is no one way to do this. As shown in Fig. 2, SACS emerges out of the coupling of two major social practices: sociology and complexity science. More specifically, SACS emerges out of the coupling of their respective intellectual traditions, methods and topics. The coupling of these two social practices does not, however, result in only one type of research—a singularity. Instead, it produces a wide variety of research agendas—a multiplicity. In the vernacular of complexity science, each of these research agendas constitutes one of the major attractor points in SACS. In turn, the numerous research agendas cluster around each attractor point. Map 4 visualizes this perfectly. On this map are the five main areas of research, including the smaller subfields located within, across, or between them. Also, orbiting around these five areas are the smaller research agendas of the key scholars in SACS.

The concept of *difference* is critical to our definitional approach to social systems. A social system is not a singularly. Instead—and this is our eighth point—it is a *multi-singularity*. A system, as a whole, is grounded in the interactions amongst its different forms of expression. While the researcher ultimately is studying a system (a singularity), the focus is always on the complex ways that this system's multiple forms of expression (coupling) interact—and thus create the system. Hence, a social system is a multi-singularity.

This does not, however, end our discussion of the network of attracting clusters. The possibility for multiple outcomes does not mean "anything goes." While, theoretically speaking, sociology and complexity science could be coupled ad infinitum; in practice this never happens. In the past ten years, for example, only five major areas of research have emerged in SACS, and of these five, only two are widely embraced: computational sociology and complex social network analysis. In this respect, while social systems are multiply expressed, over time they tend to constrain themselves. Why this is the case has yet to be empirically detailed. Nevertheless, as shown in the work of Luhmann (1995), Abbott (2000), Gunduz (2000, 2002) and others, social systems tend to place limits on themselves. These limitations tend to emerge in the form of dominant attractor points around which the majority of minor expressions cluster.

This "limitation in expression" is another defining feature of a social system, and also represents our ninth major point. While social practices can couple to form a potentially limitless number of solutions, these different ways of “practicing” a social system tend to constantly organize and settle down into a smaller network of attractor points (solutions). In terms of specifics, social systems couple to create, at minimum, two internal attractor points—this is our tenth point. The maximum number of attractor points, however, is a matter of empirical inquiry and utility, a point we will address in our review of our method, assemblage.

2.2.7.4 Boundaries

The last term we need to address in our review of the network of attracting clusters is *system boundary*. Just as a system emerges out of the coupling process, the system’s boundaries are determined within the process of coupling.

We have, however, a challenge. While the concept of boundary is a problematic term for sociologists (and something we will discuss in a moment), it is absolutely essential to the study of social systems. Only when boundaries are established can everything else about a social system be determined with any degree of certainty. This includes: (1) identifying the system/topic of study; (2) determining how it is positioned in time-space; (3) examining what lies inside and outside the system; (4) reviewing the larger environmental systems at play; (5) identifying the impact of these environmental forces; (6) assessing how the system responds to these environmental forces; and (7) studying the nature of the system’s internal dynamics, including its evolution over time; that is, its past, current and future trajectory. As such, articulating the definition of system boundary is a delicate task. We turn to this task now.

The concept of system boundary is heavily influenced by its usage in the natural sciences, particularly biology. Within this context, only physical systems have boundaries. Planets, molecules, cells, bodily organs, brains and animals all have definable insides and outsides that one can physically study. Social systems appear different. A system’s network of attracting clusters does not result in the creation of a physical boundary in the same way that a body or tree has a boundary. Or does it?

For us, social systems have empirically definable, legitimately real boundaries. The problem is that they do not emerge at the perimeter of a social system. They emerge at its center. Thus, our eleventh major point: the boundaries of a social system are defined as and emerge out of the limits of its coupling process. As such, a social system’s boundaries come from its center, not its edge.

Consider SACS, for example. This intellectual town emerges out of the coupling of complexity science and sociology. Where, however, does this coupling end? Theoretically—never. There always is the possibility for one more expression of the system; one more way of coupling its social practices. In another respect, however, the coupling does end. It ends through the emergence of the dominant attractor points around which a system's minor variations in practice cluster. In other words, it ends with the network of attracting clusters for a given moment in time-space.

In this way, the social system of SACS does have an empirical boundary—albeit a temporary one. While there always is the theoretical possibility for one more coupling, the empirical reality (as noted above) is that, at any given moment in time-space, the network of attracting clusters for SACS tends to settle into an identifiable system with (remember our biological definition of a boundary) definable insides and outsides that one can study. Change, add to, or replace SACS's web of social practices and the network of attracting clusters will change. It may even morph into an entirely different system of study.

For example, if the social practices of SACS evolved to include the complex organizations and management studies—two disciplines similar to but different from sociology—its coupling process would change, thus impacting the major attractor points in the system. This, in turn, would not only create a new and different network of attracting clusters, but also, in turn, new and different boundaries for SACS, or something other than SACS.

As this example illustrates, in order to identify the boundaries of a social system, one begins with the web of social practices, attempts to construct the network of attracting clusters and consequently map them. Once mapped, the boundaries for the system are defined at a particular moment in time-space. As shown in Maps 4 and 8, we even can visualize these boundaries by creating a map of the network of attracting clusters. The level of detail one wants in such a visualization of a system's boundaries depends upon the detail one achieves (or needs) in the network of attracting clusters. In SACS, for example, we defined the boundaries according to the most widely practiced areas of research, along with their major research subsets and the scholars orbiting these five areas. One could, however, push this further, and examine any one area of research (for example, computational sociology) to create an even more detailed map, including each and every scholar and their numerous programs of research. It all depends upon the information needed. Whatever the detail, the constitution of the boundary for a given system would follow the same process. With this final point, we turn to our next folder.

2.2.8 Environment

The fourth folder in social complexity theory concerns the environment within which a social system functions. Social systems are situated in a larger set of environmental systems and interact with and adapt to those forces.

1. *Environmental systems* can be larger, smaller or similar in size to the social system of study. An environmental system can also be an internal dimension of a social system, which is momentarily treated as external or "outside" the system of study. Take, for example, SACS. While sociology and complexity science are the twin social practices from which this town emerges, they are also the twin social systems within which SACS is situated. In this way—and we follow Luhmann (1989)—sociology and complexity science are both internal and external to the boundary line of SACS. When coupled together, by SACS scholars, these two social practices produce a unique social system called SACS. When practiced on their own, they form their own systems, called sociology and complexity science.

2. *Environmental forces* are any factors treated as externally relevant to the coupling and internal dynamics of some social system of study. Although not entirely accurate, one can think of these "external forces" as independent variables. What one is trying to understand, in this case, is the impact these independent (environmental) variables have on some social system of study, which is our dependent variable. The only limitation in this analogy is that external forces do not so much impact a social system as much as they interact with it.

In the case of SACS, for example, there are five major environmental forces: (1) the emergence of complexity science as a field of study; (2) the evolution of the systems perspective in sociology; (3) the recent methodological innovations of complexity science; (4) the sudden popularity outside SACS and complexity science of network analysis; and (5) the growing complexity of sociological work. Our study of SACS primarily is interested in how its network of attracting clusters has responded to these forces and how these interactions have shaped SACS's past, current and future trajectory, particularly within the larger social systems of sociology and complexity science.

2.2.9 System Dynamics

The final folder in our theoretical framework is dynamics: the relationships, forces and motions that characterize the "play" in a social system—all of which occur, at least for social complexity theory, within and amongst its network of attracting clusters.

Reiterating a previous mantra, the analysis of a social system is not limited to identifying its network of attracting clusters. It requires, for example, one to understand; (1) how the attracting clusters in a network interact with themselves and each other; (2) how these interactions impact the social system of which they are a part; (3) how these interactions change over time; and (4) the influence and impact environmental forces and systems have on the network of attracting clusters. Without such an analysis of a system's dynamics, one has only a partially useful model: a discrete, cross-sectional snapshot of the system at a particular moment in time-space. To build a full model, one must assemble numerous discrete moments (cross-sectional snapshots of the system in time-space) to form a moving picture, a systems-movie. As we will explain shortly, the purpose of assemblage is to help the researcher create this "moving" model.

In our study of SACS, for example, we did not feel it sufficient to identify the five major research communities currently in existence, circa 2008. We also were interested in the point at which SACS emerged as a legitimate field of study, the areas of research that existed at that time, the environmental forces that contributed to this emergence, and the changes that took place in SACS between its formal emergence and today. We needed more than a dynamics folder, however, to answer our questions. We also needed a list of dynamic terms.

2.2.9.1 Dynamic Terms

Social complexity theory employs a variety of terms to discuss the dynamics of a system. The most important are (1) trajectory, (2) negotiated ordering, (3) differentiation, and (4) self-organized criticality. Given the constraints of space and time, we will provide only the briefest definitions. For more information, see our website.

1. The concept of *trajectory* is taken from the work of Anselm Strauss and colleagues (See Strauss 1993). We developed this term to refer to the course, movement and evolution of a social system within time-space and within any environmental system(s) in which it is situated or with which it is co-evolving. For us, this term also refers to the interactions and individual trajectories contained within the network of attracting clusters, including the trajectories of a social system's subclusters and supra-clusters. For example, one can analyze the trajectory of SACS within the systems tradition in sociology or complexity science. One could also examine the trajectory of computational sociology within the community of SACS—see Map 3, for an example.

2. *Negotiated ordering* comes from our development of a key concept in the theoretical repertoire of Anselm Strauss: negotiated order (Strauss 1993). We use Strauss' term as follows.

First, we turn the term into a verb, changing it from negotiated order to negotiated ordering. Second, we define negotiated ordering as the sum total of arrangements amongst a network of attracting clusters, including the various negotiations responsible for this order. By arrangements, we mean: (1) the conceptual and spatial layout of the major and, if deemed important, minor attracting clusters in a social system; (2) the patterns of relationship that form amongst these attracting clusters; (3) the evolving trajectory of these various clusters and their patterns of relationships (interactions, ties, links, etc.) across time-space; and (4) the impact all of these patterned relationships and their conceptual and spatial layout have on the social system of study, including its trajectory within some larger environmental system. For example, as explained in Chap. 10, all of the maps used in the current book are pictures of the negotiated ordering of SACS. Each map provides some insight into how SACS is ordered within time-space.

3. The concept of *differentiation* combines the work of Niklas Luhmann (1995) and fractal geometry. It also draws upon Abbott's (2000) creative usage of the concept fractal cycle. For us, differentiation refers to the method social systems use to handle their increasing complexity; and to the processes by which the attracting clusters in a social system subdivide, disappear, or emerge in response to various internal and environmental challenges that the system faces as it evolves through time-space.

For example, prior to 1998, SACS was not a formal community or field of study. Instead, it was an informal, intellectual system revolving around the intersection of two key clusters: sociocybernetics and the Luhmann School of Complexity (LSC). In fact, one could argue (as we did in the introductory chapter) that this was what the systems tradition looked like in sociology during the 1980s. Computational sociology is off to the side, not yet formally developed, sort of floating on its own. All of a sudden, circa 1998, the systems tradition differentiated into a whole new topography that created the network of attracting clusters we identify with SACS today: the new systems tradition in sociology.

4. The last concept is *self-organizing criticality*. Social systems are not static. Instead, they operate in a position best characterized as far-from-equilibrium (Bak 1999; Capra 1996; Cilliers 1998). One of the major advances made by complexity science—contra Parsons and the early systems thinkers—is the empirical realization that complex systems do not seek a state of equilibrium or stasis (Bak 1999; Holland 1998; Luhmann 1995). Neither, however, do they collapse into chaos (Cilliers 1998). Instead, they seek a position somewhere between these two states. Complex sys-

tems achieve stability by settling into a particular phase state that allows them to manage their relative entropy, chaos and stasis. Ilya Prigogine—one of the leading thinkers in complexity science—received the Nobel Prize in chemistry in 1977, in part, for his theory of dissipative structures, which—condensed—explains how complex systems (particularly chemical and biological) achieve their self-organizing order through their chaos (Prigogine and Stengers 1984).

A similarly successful (albeit more highly contested) theory on system stability is that of Per Bak and colleagues (See Bak 1999). This theory asserts that many complex systems manage their internal dynamics by achieving a critical state, which they call self-organized criticality.

Self-organized criticality is important because it allows complex systems to "weather" small-scale and large-scale change without falling apart or collapsing into chaos. This is not to say that complex systems do not vary in their degree of stability or that they cannot fall apart, because in some cases they do go through radical change or pass some tipping point beyond which they can never return. In fact, one of the main undertakings of complexity scientists such as Geoffrey West, president of the *Santa Fe Institute* (www.santafe.edu), is to catalogue how biological organisms, at varying levels of scale, maintain their respective functional and structural designs in the face of so much internal and external dynamics. For example, why do human cells stay a certain size? Does stability in size allow cells to preserve what they are? How about social systems? Is there a limit to how large a government or society can become before it falls apart? In the words of Luhmann (1995), how much complexity can a social system handle before it needs to differentiate into another form?

Drawing on the work of Per Bak and colleagues (See Bak 1999), we use self-organized criticality to refer to the tendency of the network of attracting clusters in a social system to arrive at and maintain (without external guidance or an overseer) a state of relative stability. More important, as we explain in Chap. 8, we also use this term (in combination with the power law—remember our discussion of Pareto and the power law in our introductory chapter) as a measure of a social system's relative stability and robustness as it evolves through time-space, particularly as it goes through important phase transitions.

In the case of SACS, for example, we use this concept to ask: What events caused this field suddenly to differentiate and emerge in 1998? Furthermore, and in the aftermath of this tipping point, how stable has SACS become? Is SACS relatively well defined?

It is with these final questions that we come to the end of our discussion of social complexity theory. We now turn to a discussion of our algorithm for modeling social systems, *assemblage*.

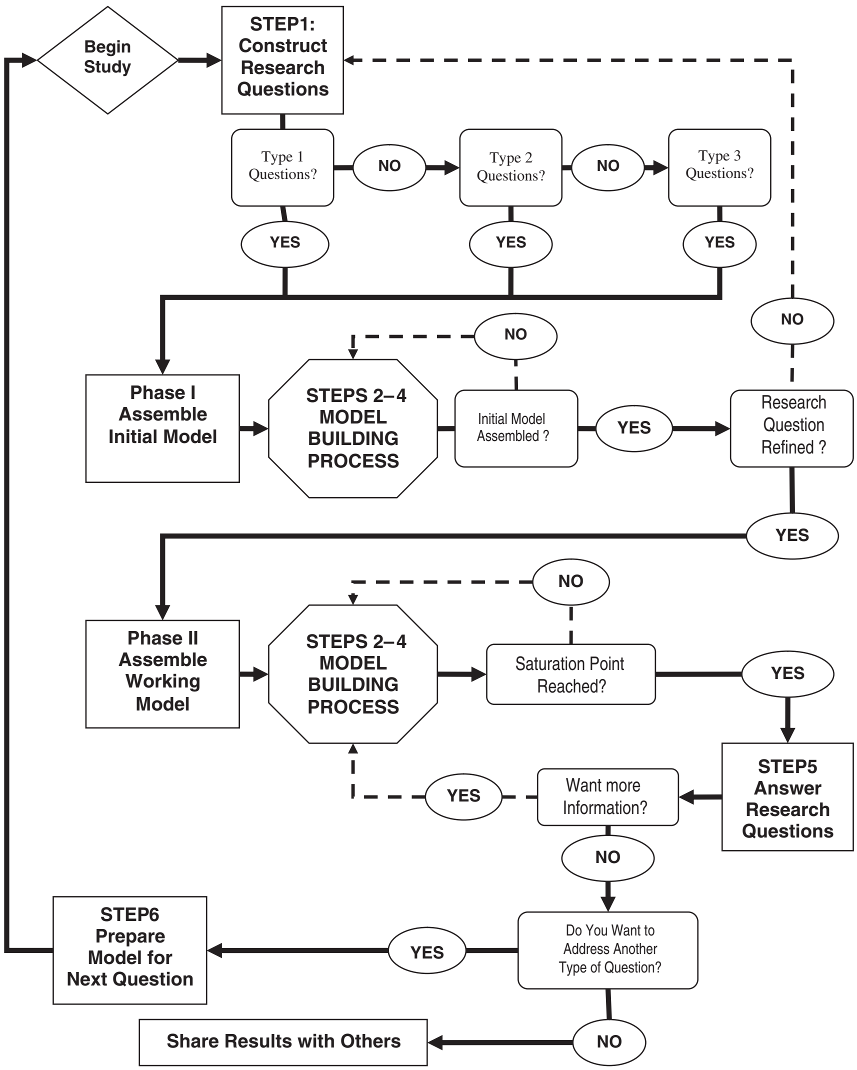
3 SACS Toolkit—Assemblage

3.0 Introducing Assemblage

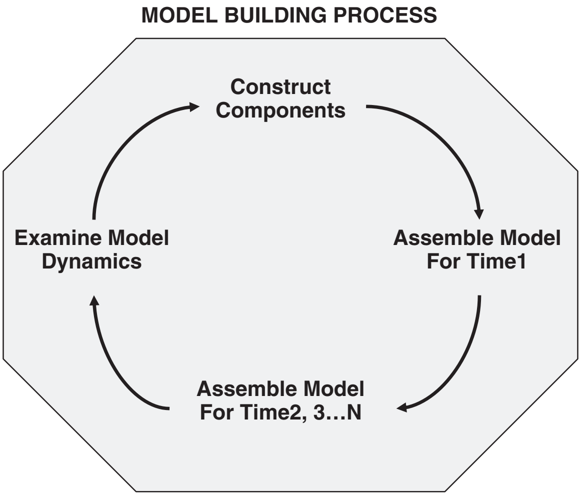
Assemblage is a case-based, system-clustering algorithm for modeling social systems. It is built on the organizational framework of social complexity theory and represents the procedural component of the SACS Toolkit.

As shown in Flowcharts 1 and 2 (See also Chap. 10), the goal of assemblage is to move researchers through a six-step algorithm for constructing a model of some social system of study. This algorithm roughly proceeds as follows: (1) help the researcher define a set of research questions in systems terms; (2) establish the social system's field of relations and determine the web of social practices out of which it emerges; (3) use this information to catalogue the numerous ways the system is coupled/expressed at a particular moment in time-space; (4) condense/cluster this catalogue into a smaller grid of the system's most important practices to create the network of attracting clusters; (5) examine the internal dynamics of this network for a particular moment in time-space, including its interactions with key environmental forces and its trajectory within key environmental systems; and, finally (6) assemble these discrete, cross-sectional snapshots of the system into a moving model, concluding with some overall sense of the system as a whole. Once done, researchers can "data mine" this model to answer the initial study questions or to generate new questions or models.

Flowchart 1: The Assemblage Algorithm



Flowchart 2: The Core Steps



3.1 The Key Features of Assemblage

As a set of procedures, assemblage has seven key features which, when combined, make it unlike any other complexity science method available today. This is not to say that some of the features of assemblage (such as its case-based approach to analysis) are not found in other methods and techniques. But, it is to say that no other complexity science method has all seven features.

1. Assemblage is specifically designed for modeling social systems. One of the hallmarks of complexity science is the realization that all complex system, be they biological, sociological or ecological, share a similar set of characteristics. For example, all complex systems are emergent, self-organizing, dynamic, and evolving (Cilliers 1998; Klir 2001). Not all complex systems, however, are the same. The complexity of human agents and their communication abilities, for example, present researchers with a unique set of theoretical and methodological challenges (Byrne 2001; Cilliers 1998; Klir 2001; Luhmann 1995). We created assemblage because of these challenges. Assemblage is designed for modeling social systems; nothing else.

2. Assemblage is theoretically grounded. As shown in Flowcharts 1 and 2, the purpose of assemblage's six-step algorithm is to operationalize the folder system of social complexity theory.

3. Assemblage has no data preference. Unlike the majority of complexity science methods, assemblage works equally well with numerical, qualitative, and historical data. Despite frequent references to being multidisciplinary or

even trans-disciplinary, complexity science method is strongly biased toward the analysis of numerical data (Bar-Yam 1997). In fact, one could count on two hands the number of qualitative or historical studies done in complexity science. Assemblage has no such bias.

One of the powerful contributions sociologists make to the study of complex systems is the awareness that statistical and computational methods are (at best) limited and (at worse) powerless for modeling certain dimensions or types of social systems. For example, if you want to understand a social agent's subjective experience of living within a particular social system (say, a poor, urban community), you will find the tools of statistics and computational modeling rather limited. You gain a much richer understanding of these experiences, for example, through the techniques of ethnography and qualitative interviewing.

Assemblage recognizes this sociological point. Assemblage also recognizes that different types of social systems, such as the dynamics of governments, cultural fads, or professions are often best handled when non-numerical forms of inquiry are included in the model build process. As such, assemblage is designed to work with all types of modeling processes: qualitative, historical, statistical, computational, and their various combinations. In our study of SACS, for example, the data ranges from archival and historical to personal communication to quantitative data culled from the *Web of Science Citation Index*.

4. Assemblage can be used with a variety of methodological techniques. From mathematical modeling and hierarchical regression to cluster analysis and causal modeling to ethnography and historical method, assemblage works well with and makes use of just about any qualitative, historical, statistical or computational tool or toolset available in sociology and complexity science. Researchers can use, add, remove or augment the tools they use to build their models, based on the type of social system being studied, the data collected, or the model being constructed.

The reason assemblage can be used with such a wide variety of tools and toolsets is because these tools do not drive the model building process. Instead, the six-step algorithm of assemblage, along with the theoretical framework upon which it is grounded, drives model building. Any tool can be used as long as the researcher uses it in service of modeling a social system.

5. Assemblage is unique in that it takes a case-based approach to modeling complex social systems. As we explained earlier, there is no one way the social practices in a social system couple. Neither is there any one social practice that explains how a social system works. Instead, a social system emerges out of the complex relationships amongst a set of social practices.

We have found that the most methodologically useful way to handle this level of complexity is to use a case-based approach. A case-based approach treats a social system as a set of cases, each of which represents one of the multiple ways that a web of social practices couples to express some social system of study.

At this point in our review, the connection between cases and coupling should make sense. From the perspective of social complexity theory, a case is a synonym for the coupling of social practice. A case represents one example, expression, instance or illustration of a social system of study. Said another way, if we define a social system as a network of attracting clusters, a "case-based" approach is useful because it allow us to build a social system from the ground (cases) up.

In the case of SACS, for example, each scholar or group of scholars is a case—one example of how the social practices in SACS couple. As one clusters these cases into similar groups, one begins to create the network of attracting clusters.

The trick, however, is figuring out how to identify, collect, and describe the right set of cases. Sometimes, as when analyzing a social system qualitatively or historically, the trick is to look first for the most widely practiced cases. In other instances, as when analyzing a social system statistically or computationally, the trick is to analyze hundreds or thousands of cases at a time.

Regardless of the number of cases considered or the particular technique used, the procedure of assemblage is basically the same: you consider and use representative cases as a method to profile and catalogue the various ways that a web of social practices is expressed. You continue doing this until the best set of cases and the necessary number of social practices is determined. Once this process is complete, you are ready to move to the next major step in the assemblage process, which also happens to be the final way in which assemblage is unique in the world of complexity science method.

6. Assemblage is a data-compressing, system-clustering method. As we have said several times and in different ways, the ultimate goal of assemblage is to help the researcher create a social system's network of attracting clusters and to model the dynamics of this network across time-space, particularly as this system is situated within some set of environmental systems. To accomplish this task, the researcher has to cluster the social system into its key attractor points. Using a case-based approach to modeling, each case not only is an expression of coupling, it also is an attractor point in the social system, insomuch as it represents (as just discussed) one possible way the web of social practices is coupled, expressed, etc.

The goal of assemblage, however, is not to map each and every attractor point. While multiple cases need to be considered, mapping all or most of them usually is not necessary, and sometimes contraindicated. There are several reasons why. First, as discussed in the data mining literature—which assemblage draws upon rather extensively—mapping a larger number of cases is too time consuming or expensive (Han and Kamber 2001). Furthermore, as discussed in the complex network analysis literature, a large number of cases tend to create an overly busy map which makes interpretation cumbersome if not impossible (Nooy, Mrvar and Batagelj 2005).

Most important, however, an overly dense map seldom yields additional empirical insight. Generally, a network that contains the most dominant, important, or widely practiced clusters is sufficient. Occam's razor (the principle of parsimony) applies: all things being equal, the simplest solution is the best. In this way—and here we draw directly from Kohonen (2001) and his self-organizing map technique—assemblage is a *data reduction technique*. It tries to reduce and compress the complexity of a social system into a simpler and more understandable form. The product is a network of the key attracting clusters, including: (1) an internal profile and thick description of each cluster; (2) an overview of the distribution of the various cases within each cluster; (3) a map of any additional sub- or supra- clusters; and (4) an overview of the interactions, relationships, and conceptual distances of the clusters in relation to one another and the system as a whole.

Once this network of attracting clusters has been created, it is then reconstructed over a series of discrete moments in time-space and put together to create (as we discussed earlier) a moving picture of the system's dynamics, along with its trajectories within various environmental systems. If greater detail is needed, this can be done post hoc. Or, if one wants a more complete picture, one can "drill down" (to use a data mining term) into a particular cluster to construct a more refined and focused map of a particular section of some social system of study.

7. Finally, assemblage provides a novel approach to visualizing social systems. We specifically designed the SACS Toolkit to provide a sophisticated series of visual aids to help the reader grasp the structure and dynamics of any given social system of study. The most important visual aid is the map. For more information on the map and the visual orientation of the SACS Toolkit, see Chap. 10.

3.2 The Six Steps of Assemblage

Now that we have a basic understanding of what make assemblage unique, we quickly will review its main steps—see Flowcharts 1 and 2 (For a more detailed overview of these steps, see our website). We also will address these steps in varying degree of detail throughout the rest of the book.

In fact, subsequent chapters are ordered around the six-step assemblage algorithm. Chapter 4 provides an overview of our results; Chap. 5 addresses environmental systems and environmental forces; Chap. 6 uses the web of social practices to create the network of attracting clusters for SACS; Chap. 7 creates a moving picture of SACS between 1998 and 2008; Chap. 8 uses the new science of networks to examine SACS as a system; Chap. 9 summarizes our study, situating SACS within the larger environmental systems of complexity science and sociology; and Chap. 10 contains all of the visual aids upon which our study relied.

3.2.1 Step 1: The Research Question

The assemblage process begins with the researcher constructing the empirical questions that will guide the study. These questions can be organized into one of three types.

1. Can I learn something from modeling my topic as a social system? The first type of question is the one most scholars will probably use assemblage to answer. In this case, a scholar wants to address some sociological topic of interest in complex systems terms and is therefore interested in modeling the topic as a social system.

Our study of SACS is an example of this first type of question. During the course of our investigations, we realized scholars were integrating the theories, methods and topics of sociology and complexity science in multiple ways to create a rather diverse set of research programs. While differences existed, we also could tell that the interactions amongst these research areas were self-organizing into some type of larger field of study. The questions however were how, why, where, and to what extent? We also knew there were external factors impacting the formation of this new field, but we were unsure how and in what ways. We were also aware that this new field drew from, and yet was situated within, the larger fields of sociology and complexity science. The question for us was how best to represent all of this complex information? The answer was to treat SACS as a social system. Once we did, our study began to coalesce.

2. Is the social system I am studying unique? While social systems are isomorphically similar, their structure and dynamics often are quite different.

For example, while academic fields like SACS and medical sociology share similarities, they are different from other types of social systems such as cities or governments or cultural movements. The second type of question focuses on the similarities and differences amongst different types of systems.

For example, in seeking to generalize our findings about SACS, one might want to examine the dynamics of academic fields in general. Questions one might ask are: Is there a limit to the number of competing research areas an academic system can manage before the field (or at least parts of it) differentiates into a new field of study? Also, why has so much of science gone the direction of increasing specialization? Correspondingly, why is it that even a science like complexity mimics the same type of specialized behavior, with fields like SACS emerging, even though the work done in these fields is resolutely interdisciplinary?

3. Does my social system of study tell me anything about social systems in general? The third type of questions is a general version of the second. Here the focus is on the structure and dynamics of a social system. For example, what do we know about the general process of emergence or self-organization within social systems? Or, how do social systems evolve? A variant of this third question is discerning how social systems are similar to or different from other types of complex systems.

These, then, are the three major types of questions the researcher can ask. They are by no means mutually exclusive and, in some cases, the researcher may want to address all three at once. Common to all three types of questions, however, is the need to think about some topic in systems terms.

3.2.2 The Core: Steps 2 through 4

As depicted in Flowchart 1, once the researcher has defined the study's questions, it is time to construct the model. The model building process is comprised of two major phases; (1) the initial model and (2) the final model. As shown in Flowchart 1, the researcher moves through Steps 2 through 4 to create the initial model and then repeats these steps until a final model is achieved.

3.2.2.0 Phase 1: Constructing the Initial Model

Assemblage is unique in that it requires the researcher to begin with (as best as possible) a holistic, working knowledge of the system of study, even if this knowledge is very basic and rough. Without some initial understanding of the model, researchers run the risk of getting lost or (worse) finding themselves unable to see the "forest for the trees." Studying a social system is, after all, complex. It therefore is important to begin the study with some global understanding of the topic and one's model of it. This is why building the initial model requires the researcher to do a basic run through Steps 2 through 4.

Consider, for example, our study of SACS. Below is a section of a paper we wrote for a 2004 conference, which provides a sense of how we originally conceived of our model. In the paper we identified and named our new field of study and outlined its major areas of research; that is, its network of attracting clusters:

> There is a new field of study that has emerged in sociology. It is best named the sociology of complexity. It is comprised of seven major areas of research: (A) socionics, which integrates sociology and social simulation; (B) new sociological systems theory, which draws from systems theory and second-order cybernetics; (C) socio-cybernetics, which integrates social systems theory, second-order cybernetics and complexity theory; (D) artificial societies and social simulation, which focuses on the theory and method of social simulation; (E) sociology of complexity theory both mathematical and theoretical; (F) sociology of complexity method, which integrates sociology with artificial intelligence and mathematical sociology and includes, for example, fuzzy method, neural networking, fractals and power laws; and finally (G) sociology of organizational complexity, which studies formal organizations as complex systems.

While our initial overview was wrong, we were close. Research areas A, D and F all became computational sociology and G was discarded because it was not sociological enough—90% of the research done in this area is by scholars in organizational and management science, not sociology (Capra 2002). Still, we had something to work with and this initial conception was very useful as we refined our inquiry in the second phase of research. By 2006 we had arrived at the following:

> A new field of inquiry has emerged, which we call the sociology of complexity. At present, the sociology of complexity is comprised of four major areas of research: complex social networks, new social systems theory, sociocybernetics, and computational sociology.

This model was a major improvement, but it still needed work. And so we proceeded. Finally, by 2008, we settled on the specific network of attracting clusters we use in this book.

One research area, however, that took considerable time to define was the British-based School of Complexity (BBC). We had gone back and forth about some type of BBC. At one point we even considered a more general cluster, which we tentatively called the "European-based school of complexity." Then we came across McLennan's 2003 article about "Sociology's Complexity" and he confirmed our suspicions. His discussion outlined what ostensibly is the "BBC," which includes researchers in other parts of Europe and Australia, but nevertheless, is centralized in England.

We also decided to rename new social systems theory as the Luhmann School of Complexity (LSC). Two reasons: there is a long list of systems theories in sociology and complexity science, and they are rather different from one another; second, since Luhmann's death, his ideas have been developed further by a growing list of scholars in the social sciences and the humanities, turning his work into a new school of thinking, the LSC. With these two revisions done, our picture of the network of attracting clusters was complete.

Finally, we decided by the spring of 2008 that our new field was not the sociology *of* complexity (SOC) as it was the intersection of sociology *and* complexity science (SACS). This last insight, in particular, illustrates well the importance of developing an initial, working model. Although our initial inclination was to adopt some "sociology of" label, our network of attracting clusters kept reminding us otherwise, pushing us toward a more inclusive and dynamic sociology "and" complexity.

From here we were able to move to our final model. But we are getting ahead of ourselves. We need to review Steps 2 through 4 to explain how we achieved the model we had by spring 2008.

3.2.2.1 The Core: Steps 2 through 4

As shown in Flowchart 2, Steps 2 through 4 are the core of the model building process: (a) constructing the basic components of the model (which includes the field of relations, the web of social practices and the network of attracting clusters), (b) assembling the model at each discrete moment in time/space, and (c) organizing these discrete moments in time (these snapshots of the system) into a comprehensive "moving" picture of the system's dynamics across time-space, including the system's relationship with the environmental systems in which it is situated. Let us review each step in more detail.

3.2.2.2 Assembling the Components

Referring once again to Flowcharts 1 and 2, to build a model of a social system, one must proceed through a somewhat extensive series of steps, even in the initial stages of modeling building. This process follows the filing and folder system of social complexity theory.

It begins by our developing a field of relations. Here our concern is with standard methodological issues. What data will we collect? How will it be stored? How will we organize (update etc.) our database? What will be our study design, including how many discrete moments in time will we analyzed and why? What analytic techniques will be used—qualitative analysis, historical method, agent-based modeling? And, what types of maps are going to be constructed to develop the visual depiction of the model?

It is important to point out that all these types of "methodological" questions go hand-in-hand with the initial construction of the model's web of social practices, network of attracting clusters, key environmental forces and environmental systems. Assemblage is more like engineering and architecture than it is theoretical science. When building a model, one's list of supplies and the various tools and techniques one needs evolve as the project unfolds. In other words, the database and initial model are developed simultaneously; each informing the development of the other. In the case of SACS, our database continually changed over time as we identified, dropped, and added new clusters and as we redefined, catalogued and prioritized our web of social practices. We also revised our list of environmental forces several times as we struggled to determine which aspects of sociology and complexity science SACS drew upon, as well as how the researchers in SACS simultaneously treated these two fields, particularly mainstream sociology, as outside to their work.

The iterative nature of assemblage makes the case-based approach something the researcher employs from the beginning. Here we draw upon an important lesson from the field of data mining. While data mining often is associated with a particular toolset (neural networking, decision tree analysis, cluster analysis), it really is a strategy for data management and analysis (Han and Kamber 2001). The goal of data mining is to use various computational algorithms to create and develop a database that researchers can use to generate sequential and timely information about an ongoing area of inquiry. This is why data mining is so useful to the modeling of social systems. By building the database and model at the same time, the researcher allows them to become "smarter" about each other. The cases chosen for analysis help to make important decisions about what to analyze next and also how.

3.2.2.3 Assembling the Model at Time_1 through Time_N

Once the basic folders (components) have been constructed, the next step is to assemble the folders (components) for a discrete moment in time-space. We generally designate this first discrete moment as Time 1. For Time 1, the goal is to use the case-based system clustering techniques of assemblage to construct the network of attracting clusters for the model, including a thick description of: (1) each cluster, subcluster and supra clusters; (2) the network of attracting clusters, including the interactions, relationships and conceptual distances amongst its clusters; (3) the relationships the network of attracting clusters has with key environmental forces; and (4) the impact these relationships have on the system of study. Once these pieces of information are complete, the researcher then turns to a full description of the social system for the first time period of study. The researcher's description of the entire system is globally and holistically oriented, including its relative level of stability, its trajectory within the various larger systems of concern and so forth.

If additional time periods are being studied, the above steps are repeated, including beginning with the construction of the web of social practices and environmental forces. In our study of SACS, for example, we not only were interested in the system circa 2008, but also its formal emergence in the late 1990s, which is when the major *complexity turn* took place in the social sciences (Urry 2005b). We therefore constructed our model at two major time periods: the late 1990s and 2008. Once we had a holistic picture of these time periods we integrated them to gain an overall view of SACS. This holistic view was than situated in the larger timeframe of the systems tradition within sociology, making the formal emergence and development of SACS the latest stage of a systems trajectory within sociology.

3.2.2.4 Examining the Model's Dynamics

Once the discrete time periods in which the researcher is interested have been approximated, the next step is to put them together to examine the model's internal and external dynamics; that is, the relationships, forces and motions that characterize a social system as it moves through the researcher's predefined period of time-space. The study of dynamics focuses on two major areas: (1) the network of attracting clusters and its interaction with key environmental forces (those external factors impacting a system of study) and (2) the system as a whole and its movement within various environmental systems (the larger settings in which a system of study is situated).

In the case of SACS, we were very interested in this community's internal dynamics. Specifically, we wanted to know which areas of research were the most dominant and why. Furthermore, we wanted to know what impact their dominance was having on the current and future trajectory of SACS. In terms of the impact of certain environmental forces on SACS, we primarily wanted to know how the current vogue of complexity science is helping the momentum within SACS; that is, how is the widespread adoption of complexity science helping to legitimate the work being done in SACS by sociologists and likeminded scholars? Finally, in terms of environmental systems, we wanted to know the impact SACS is having on sociology today and, more specifically, the systems tradition within sociology. Before we could answer any of these questions, however, we had to do a validity check.

3.2.2.5 Validity Check

An important part of assemblage is stopping to perform a validity check. Despite all the hard work one might put into the initial model, the researcher still needs to periodically stop and ask the basic question "Is my topic of study best studied and modeled as a social system?"

To answer this question, we turn to the methodological work of Glaser and Strauss (1967), particularly Glaser's later work on the topic of emergence versus forcing (1992). Drawing on Glaser (1992), one must ask: "Have I forced my topic to fit the framework and procedures of the SACS Toolkit or does the model of my topic naturally emerge?"

To answer the above question, we need to examine various aspects of our model. For example, do the identified attracting clusters that I identified actually interact with one another to form a social system, or are they disparate areas of inquiry I am forcing into a network of my own making? Or, does the web of social practices I have created make sense? Does the model "hold together" relatively well or does it keep falling apart? Can I really use such terms as self-organization, emergence, tipping point, attracting clusters and so forth to describe my topic, or am I forcing these terms on my data? Finally, am I just saying the same thing about my topic as everyone else, albeit with the fancy new tools of complexity science?"

As shown in Flowchart 1, if the answer to any one of these questions is "no" then the researcher needs to revisit the study questions, revise the initial model, or switch to a different methodological toolkit. If one can answer "yes" to all of these questions, then one can proceed to the final model.

In the case of SACS, for example, it took us a while to say "yes" to all of our questions. One barrier (which we mentioned earlier in this chapter) that kept us nervous about the utility of our toolkit to study SACS, was our name for this new community. For the first two years of our study, we kept calling SACS the sociology of complexity, which was inaccurate and misleading. The problem was that too many scholars from other fields were involved in SACS. Also, many of the sociologists involved in this town sought to be free of the disciplinary confines of sociology and were therefore uninterested in creating yet another "sociology of" something. Once we stopped forcing our model, however, the idea of calling this community sociology *and* complexity science introduced itself and things emerged more exactly. With these types of issues resolved, we were able to finish our model.

3.2.2.6 Iterative Looping Disorder

When it comes to modeling complex systems, there is an important counterpoint to the validity check. We call this counterpoint Iterative Looping Disorder (ILP). The symptoms of ILP include an obsessive need to "get it right," particularly during Phase I; an inability to trust the process and allow things to change, including one's initial research question(s); a fear that if one does not understand everything upfront then one is "data fishing" or making things up as one goes along; a failure to maintain a global picture of the problem; a strong tendency to be overwhelmed by the complexity of it all; and, most dangerous, a false belief that one's model will or must address everything.

The threats of ILP thus require that assemblage once again make use of the tools of data mining and grounded theory. Active data management, staying grounded, and allowing the model to self-organize at its own pace are all important practices if one is to effectively model some social system of study. Without such an "active" approach to model building, everything can easily fall apart. Like any algorithm, assemblage has its normal pace. Moving out of Phase I takes place only when the researcher has (1) a good sense of the questions being asked and (2) a basic sense of the model, primarily as a function of the initial cases considered, the web of social practices created, the environmental forces identified, and the initial network of attracting clusters constructed. With one's initial model assembled, the researcher is ready to move on and repeat the whole process again in Phase II.

In the case of SACS, we had to let go of the idea that our model would be perfect. We had to admit that others may organize this new field in different ways, according to a different set of social practices, and so on. Our model was an introduction. It was something others would have to confirm or deny in varying degrees, as it was studied over time. Once we acknowledged this point, we were able to move a lot quicker.

3.2.3 Step 5: The Working Model

With the initial model developed, the goal of Phase II is to arrive at a refined model of one's topic of study. To achieve this model, the researcher returns (multiple times if necessary) to Steps 2 through 4 until a point of saturation is reached. Saturation is defined as the point at which any additional information obtained in Stages 2 through 4 does not result in any significant new insights to the study.

In the case of SACS, for example, we realized we were done when no new additions to the network of attracting clusters were achieved. We could have kept changing names or moving scholars around, but such moves did not yield any new insights. At this point, we were able to refine our set of environmental forces and work on our understanding of SACS as an extension of the sociological systems tradition.

3.2.4 Step 6: Conclusion

As shown in Flowchart 1, the final two steps in the assemblage process are to share one's results with others and, if necessary, prepare the model for another set of questions. Often times, these two processes happen simultaneously.

One challenge of the SACS Toolkit is determining how to share one's results with others. To repeat an earlier point, the study of social systems is complex. During the course of even the most routine model building, a tremendous amount of data is amassed. There are lots of questions to answer, even in the simplest model construction. This is why, as we mentioned above, the SACS toolkit, like many complexity science theories and methods, places so much emphasis on visual representation. Drawing on the adage that "a picture is worth a thousand words," we strongly recommend that researchers use the extensive visualization techniques we used in the current book, many of which we borrowed from social network analysis, neural networking, qualitative method, cluster analysis and visual sociology, to name a few. We also highly recommend using the internet to augment published studies—as we have done with the companion website for this book. The advantage of the internet, for example, is that one can provide movies and simulations of one's data, as well as house the entire model and its database for others to use. Finally, we recommend extensive usage of visual aids. As stated earlier, see Chap. 10 for a review of the visual component of assemblage and the SACS Tolkit.

With this said, we have reached the end of our introduction of SACS Toolkit. We hope this introduction is sufficient to allow you, the reader, to following our review of SACS. If you need more information, please see our website or contact us. We now turn to our study.

4 Overview of SACS

Sociology and Complexity Science (SACS) is an interstitial town being built on the outer banks of sociology. In fact (See Map 2, Chap. 10), it resides at a fork in the intellectual river separating sociology from the natural sciences. Just across the river from SACS is the newly built city of *Complexity Science*. In terms of its intellectual longitude and latitude, SACS is just south of old Parsons Highway which once ran from sociology to the natural sciences and, more specifically, the older city of Systems Science and Cybernetics, the original intellectual downtown of Complexity Science City some fifty years ago.

Given the traditional format of our book, in this chapter we provide a quick overview of SACS. Chapters 4 through 8 provide the details of this overview.

Because our review of SACS is also a case study in the application of the SACS Toolkit, two caveats are necessary before we begin:

1. During the course of this chapter we will address each of the major folders and subfolders of social complexity theory. The order of their presentation will not, however, follow Chap. 2. Instead, it will follow the storyline we chose to introduce SACS to readers.

2. Next, the assemblage algorithm will recede into the background—as does any method once the researcher begins reporting results. In Chap. 4 (and throughout the rest of the book) whenever an issue of method is addressed, it will be treated as a pause: a chance to explain to the reader how we arrived at certain results; and, more importantly, what data or methodological techniques we used to achieve those results.

Having made points 1 and 2, this chapter is organized as follows: We begin with a review of the web of social practices for SACS, followed by a discussion of SACS's network of attracting clusters. From here we move to a discussion of the internal dynamics of SACS, focusing on (1) the negotiated ordering of this community, (2) this community's overall connectedness, (3) its key hubs, authorities, gatekeepers and household names, and (4) its major, internal trajectories. Next, we outline the major environmental forces impacting SACS. We follow this with a discussion of the legitimacy of SACS as an intellectual community. We end by situating SACS within complexity science and sociology to determine the impact that SACS is having within these larger environmental systems.

4.0 Web of Social Practices

As we discussed in detail in Chap. 2, SACS is comprised of two dominant social practices: sociology and complexity science. These two social practices can be further organized according to their respective intellectual traditions, methods and topics of study.

Within sociology, the dominant intellectual traditions are systems thinking, structuralism (leading, eventually, to post-structuralism), exchange theory, rational-choice theory, symbolic interactionism and, to a small extent, conflict theory. The dominant methodological traditions are mathematical sociology and social network analysis, followed by historiography. The dominant topics are society (particularly post-modern global society and societies), cities, formal organizations, and various types of social networks.

In terms of complexity science, the dominant intellectual traditions are cybernetics and systems science. The dominant methods are agent-based modeling, in particular computer simulation and data mining. The dominant topics are emergence and network dynamics, and to a lesser extent self-organization and autopoiesis.

4.1 The Network of Attracting Clusters

As shown in Maps 4 and 6 (See Chap. 10), this town is currently comprised of five major attracting clusters. Each of these clusters appears to constitute a somewhat autonomous area of research. We labeled these five areas as follows: complex social network analysis (CSNA), computational sociology, the Luhmann School of Complexity (LSC), sociocybernetics and the British-based School of Complexity (BBC).

Before we proceed, however, a quick methodological pause on terminology is necessary. In this book, the reader will note that we often shift terminology—moving back and forth between the technical terms of our theory and the descriptive terms we use to review SACS. A case in point is our usage of such terms as *attracting cluster* versus *area of research*. In terms of SACS, they refer to the same thing: the main attracting clusters in SACS constitute this system's major areas of research. The same is true of *sub-cluster* and *sub-cluster of research*: they are synonyms for the minor areas of research in SACS. Another is *community* and *town*. We use *town* as our technical definition of the type of intellectual space SACS constitutes. We use the term *community* to get around the monotony of using town over and over and over again. Plus, community adds something to our concept of town—it gives it some life and agency. We also sometimes use the term *research community* as yet another way of talking about an area of research—again, we switch terms to bring life and agency to the latter concept. *Trajectory* and *direction* are also synonyms mixed to overcome literary monotony. With this caveat made, we return to our discussion of the five areas of research in SACS.

The goal of *complex social network analysis* (CSNA) is to study the dynamics of large, complex networks such as the internet, global diseases, and corporate interactions (Watts 2004). Through the usage of key concepts and methods in social network analysis, agent-based modeling, theoretical physics, and modern mathematics (particularly graph theory and fractal geometry), this field of inquiry has made some astonishing insights into the dynamics and structure of social systems (i.e., small-world phenomena, scale-free networks, etc.). This area of research is comprised of two subclusters: *the new science of networks* and *global network society*. As shown in Map 4, the former primarily emerges out of the work of Duncan Watts and colleagues, while the latter (which overlaps with the BBC) primarily emerges out of the work of John Urry and the sociological study of globalization. The latter also comes from the work of Manuel Castells (Castells and Cardoso 2006) and the later work of Immanuel Wallerstein which, since 1998, increasingly makes use of complexity science, particularly the work of Ilya Prigogine (Wallerstein 2001, 2004, 2005).

The second area is *computational sociology*. This field is basically a microcosm of complexity science method, both in terms of the larger fields of research upon which it draws and the methods its uses (Gilbert 2000; Gilbert and Abbott 2005; Macy and Willer 2002). The focus of researchers in this field, who are also leaders in complexity science method, amount to two: social simulation and data-mining, both of which are subclusters within computational sociology. Social simulation uses the computer to create an artificial laboratory for the study of complex social systems (Gilbert and Troitzsch 2005) and data-mining uses machine intelligence to search for non-trivial patterns of relations in large, complex, real-world databases (Castellani and Castellani 2003).

The third field, and the one most different from the first two in terms of epistemology and method, is the *Luhmann School of Complexity* (LSC). Based primarily upon the work of Niklas Luhmann (1995), the goal of this perspective is to reinvigorate the study of society as a complex social system. In this way, this perspective can be read as an attempt to succeed where Parsons failed, primarily by relying upon the latest advances in systems science and cybernetics, which are the same two fields Parsons drew upon to do his work (Luhmann 1995).

The fourth major area of research is *sociocybernetics* (Geyer and Zouwen, 2001). The main goal of this field is to integrate sociology with second-order cybernetics and Niklas Luhmann, along with the latest advances in complexity science. In terms of scholarly work, the focus of sociocybernetics has been primarily conceptual and only slightly methodological or empirical.

The final area of research is what we label the *British-based School of Complexity* or BBC for short. While the substantive foci of this growing network of sociologists is quite varied—ranging from urban growth (Byrne 2001) to globalization (Urry 2003), with the largest focus being on computational sociology (Gilbert and Troitzsch 2005; Klüver, Stoica and Schmidt 2003)—their common agenda is to advance the sociological understanding and usage of complexity science. In so doing, these sociologists are at the forefront of many of the epistemological (Byrne 2001, 2002), methodological (Gilbert 2000) and organizational (Urry 2000a) issues confronting the study of social systems (Urry 2003). The BBC is also distinct in that it has instituted a number of important organizational arrangements in support of this goal, including the development of interdisciplinary centers, departments, conferences and associations devoted to the study of social complexity. In these ways, because of the BBC, British sociology is much further ahead in the study of social complexity than Canadian, American or most Western European sociology.

4.2 Internal Dynamics of SACS

4.2.1 Negotiated Ordering

We borrow Anselm Strauss's concept of negotiated ordering to describe the complex set of relations (dynamics) that exist amongst SACS's five areas of research.

As shown in Map 4, our review of the historical data suggests that the three most dominant areas of study in SACS are, in order, CSNA, computational sociology and the LSC. In terms of impact, the most important scholars are the German sociologist and creator of new social systems theory, Niklas Luhmann; the British sociologist and Editor of *Journal of Artificial Societies and Social Simulation* (JASSS), Nigel Gilbert, who is also a key figure in the BBC; and, the physicist and co-originator (with Steven Strogatz) of the small-world phenomenon and international figure in the study of complex social networks, Duncan Watts, who is also Professor of Sociology at Columbia University, New York City, USA. The area of study with the smallest impact on SACS is sociocybernetics, which is a formal Research Committee (RC51) in the *International Sociological Association*.

As shown in Map 4, in terms of their relationships with one another, there is a significant conceptual overlap amongst computational sociology, CSNA and the BBC (see Chap. 10 for an explanation on how to read Map 4). All three areas also share a number of the leading SACS scholars. Interestingly enough, none of the leading scholars in these three clusters of research are linked to all three. In contrast to these three clusters are LSC and sociocybernetics, which share considerable conceptual overlap with each other. Although distant, they are not conceptually detached from the other three areas of research, as demonstrated by the bold-faced arrows linking the five areas of research. For example, as we explain later, the LSC plays a small but important role in computational sociology; and sociocybernetics has a lot to say about the epistemological issues associated with studying complex social systems that others in SACS have used (Klüver 2002).

4.2.2 Internal Trajectories

According to our review of the historical data (See Chap. 8), SACS appears to be going in two different directions. These differences in trajectory have a lot to do with the epistemological differences amongst the five clusters of research. As we explain in detail later, much of the differentiation within SACS over the last ten years has been fractal. Borrowing from Abbott's *Chaos of Disciplines* (2001), as SACS developed over the last ten years, many of its key areas of research have emerged and settled into some degree of self-organizing order. This process not only has led to the creation of new areas of study, but it also has tended to replicate many of the longstanding epistemological and methodological differences found in sociology. One example is Snow's famous cultural division between the humanities and natural sciences. For example, scholars involved in the LSC and sociocybernetics tend toward a more constructionist epistemology, use historical and qualitative methods, and lean more in the direction of the humanities and philosophy of science. These two areas of study also historically precede the other three clusters of study in SACS—see Map 1. Because of their general orientation, one can collapse sociocybernetics and the LSC into a supra-cluster, which we call *old-school* systems thinking.

In contrast to this old-school supra-cluster are the scholars involved in the other three clusters, which tend toward a more critical-realist epistemology, use computational and statistical methods and lean more in the direction of the natural sciences. Because all three of these clusters are newer and more strongly influenced by the latest trends in complexity science, we refer to this supra-clustering as *new-school* systems thinking.

Based on our analysis of these two supra-clusters, SACS appears to be going in somewhat different directions: one going towards the humanities camp within sociology and the other toward the natural science camp within complexity science.

These two trajectories are not, however, the end of the story. Within the old-school and new-school supra-clusters, one can "tool down" to find both tendencies (old-school and new-school trajectories) present, albeit on a more subtle scale. For example, in the new-school trajectory one can find scholars who lean more toward the humanities, versus those who lean more toward the natural sciences. The scholars leaning more toward the humanities are those involved in the study of globalization, use historical method and dynamical systems theory and are the key advocates for a post-disciplinary sociology. Key examples of this humanities perspective are Andrew Abbott and John Urry. Those leaning more toward a new-school perspective are involved in the study of complex social networks, use data mining and social simulation, and advocate for a more interdisciplinary sociology. Key examples of this perspective are David Byrne, Duncan Watts, and Nigel Gilbert. As such, one can construct a series of micro trajectories within the two dominant trajectories of SACS. This "multiplicity" of trajectories has created somewhat of a balancing act in SACS, keeping the town from tipping too far in either the new-school or old-school direction. However, despite this negotiated ordering, SACS seems to be leaning in favor of the new-school trajectory, albeit with a significant humanities influence.

4.3 Environmental Forces

The epistemological and methodological differences amongst the five clusters are not the only reason why the old-school and new-school supra-clusters (trajectories) are going in different epistemological directions. The directional division between these two supra-clusters also has to do with the impact certain environmental forces are having on SACS.

There are five main environmental forces impacting SACS (See Map 3). Before we proceed, a quick caveat is necessary. As we discussed in our method chapter, an environmental force is any factor treated, perceived, reacted to, experienced or seen as externally relevant to the coupling and internal dynamics of some social system of study. For example, in the case of SACS, while the scholars of this community are significantly involved in the development of complexity science, the new science of networks, and the systems tradition in sociology, these forces have an external quality to them insomuch as this community sees its work in response to these "external" forces. An excellent example is the work of the prominent sociologist, Philip Bonacich. While a pioneer in social network analysis and mathematical sociology, he has written about the new science of networks and agent-based modeling as external forces impacting his work, to which he and his colleagues (despite being pioneers in the development of these forces) must respond. In short, when it comes to a social system, an external force is a matter of perception and communication.

Having made this caveat, the first two forces are (1) the emergence of complexity science and its initial topics of inquiry, specifically the study of autopoiesis and self-organization (Capra 1996), and (2) the continued, albeit marginal presence of a "systems" perspective in sociology, particularly in Europe (Collins 1998; Ritzer and Goodman 2004; Turner 2001). These two environmental forces are important because they instigated much of the earliest research in SACS. The early impact of these environmental forces led to the development of two of the oldest and interrelated areas of research in SACS: the LSC (Luhmann 1995) and sociocybernetics, which includes such key thinkers as Walter Buckley, Kenneth Bailey and Felix Geyer (Geyer and Zouwen 2001). On Map 1, one can see that these two areas of research are historically located near the beginning of complexity science and its intellectual traditions, namely systems science, cybernetics and artificial intelligence, and that they precede the development of the contemporary methods of complexity science, specifically agent-based modeling.

The third environmental force is the more recent development of complexity science, particularly its methodological innovations of the last twenty years. This force is important because it is responsible for the recent and rapid growth of computational sociology, the third area of research in SACS (Gilbert and Troitzsch 2005). Because of its methodological focus, computational sociology is located on Map 1 within the intellectual trajectory of agent-based modeling.

The final two and most recent environmental forces are: (4) the five challenges of complexity facing sociology today, and (5) the sudden and extremely popular academic interest in social networks by scholars working in the natural sciences, mathematics, economics, epidemiology, and medicine (Buchanan 2002). Both of these forces began to impact SACS in the late 1990s.

The latter force (the rise of social network analysis) is specifically responsible for the emergence of the fourth area of research in sociology and complexity science, complex social network analysis. While social network analysis has been a major topic of research in sociology over the last two decades (Freeman 2004), it is the newest topic in complexity science and SACS (Freeman 2004; Watts 2004). This is almost directly due to the academically popular work of Duncan Watts (small-world phenomena), Albert-László Barabási (scale-free networks) and Mark Newman (structure and dynamics of social networks).

The five challenges of complexity—environmental force 4—also have had an impact on the study of complex social networks, primarily through the growing interest of social network scholars in such topics as cyber-society and the emerging, global network society in which most of the world now lives (Castells 2000a, 2000b; Urry 2003).

The most important environmental forces shaping the BBC (the fifth area of research) are complexity science and the five challenges of complexity. As Urry has argued, the growing complexity of social life, particularly in the aftermath of globalization, requires a major overhaul of sociological theory and method; in fact, it may even require going beyond sociology to some sort of post-disciplinary form of social science (Urry 2000a, 2003). For him, the best place to find the intellectual tools and structural framework needed for this overhaul is complexity science. In a more refined and focused way, Urry's view is also the argument of other leading scholars in the BBC, including David Byrne (1998, 2001) and Nigel Gilbert (1999).

Environmental forces are also impacting the current trajectory of SACS. The slight tipping of SACS toward the new-school trajectory has a lot to do with the vogue and direction of complexity science, which is almost entirely tilted in the natural science direction. For example, while the LSC is a major field of research in SACS, it is not part of the current complexity science culture. (One would be hard-pressed, for example, to find any current leader in complexity science using anything written by Luhmann.) In stark contrast are computational sociology and the new science of networks, which are having a strong reciprocal relationship with the larger field of complexity science. For example, as shown in Maps 1 and 4, Duncan Watts is a leading figure in complexity science and SACS; as is Nigel Gilbert. Furthermore, because the majority of complexity scientists lean in the epistemological and methodological direction of the natural sciences, this gives credence to the new-school orientations of complex social network analysis, computational sociology and the BBC—pulling SACS in this direction. In turn, because of the influence of environmental forces, CSNA and computational sociology currently have the biggest impact on SACS.

4.4 The Legitimacy of SACS

Based on our research, we are reasonably confident that, as of 2008, SACS is a legitimate area of inquiry—just not in the typical academic way one would think. Consistent with most of the cross-disciplinary work taking place in the social sciences today, SACS does not fit the more familiar categories of discipline, subdiscipline, school of thought or field of study (Urry 2000a, 2000b, 2005a, 2005b). Instead, it constitutes a category of its own.

Based on our analysis of the historical data, SACS is best described as an interstitial town being built on the "outer banks" of sociology. There are six reasons for this conclusion: (1) the type of intellectual space SACS provides its citizens; (2) the diversity of its major research areas; (3) the form of government SACS enacts; (4) the type of community it supports; (5) its common concerns; and (6) its interstitial, cosmopolitan culture. We will now discuss each of these reasons.

4.4.1 SACS as Enclosed Intellectual Space

True to the common/familiar definition of a physical town, SACS functions as an enclosed place, space or clearing within or upon which a network of clusters or residencies—in this case, scholarly residencies—are built. Being an intellectual town, these residencies range from schools of thought to fields of study.

When we use the term "clearing" to describe SACS, we are drawing from the work of Foucault (and Heidegger, for that matter) and the idea that creating human knowledge is the act of clearing out a space; that is, moving established concepts to the side, pushing older methods and theories out of the way, building and arranging new ideas, creating alternative spaces for different types of work to be done, different types of intellectual tools to be used, and different types of truth games to be practiced (Dreyfus and Rabinow 1983; Foucault 1977, 1979, 1980). Clearing a space also involves drawing boundary lines or articulating brackets—think phenomenology—around a space to help scholars determine what is to be studied, who or what has the authority to speak, and the theories, concepts, and methods by which the investigation of a particular subject may take place (Castellani 1999; Dreyfus and Rabinow, 1983; Foucault 1972, 1980).

While an intellectual space can constitute a variety of forms, a town is a particular type. While a town provides some form of enclosure (boundary lines or brackets) and is therefore more intellectually developed than an area of research, it is by no means as developed as an interdisciplinary field of study such as complexity science (which we refer to in Map 2 as a city), or a discipline like sociology (which we refer to in Map 2 as an intellectual state).

Even more important, a town is generally less developed than the areas within it. SACS, for example, is much younger than the areas out of which it emerges. In fact, while the tipping point for the coalescence of the five areas in SACS is roughly 1998 (See Sect. 4.5 below for more info), the town has only become more organized in the last couple of years.

4.4.2 The Five Research Areas of SACS

While a town like SACS does not fit the more familiar categories of discipline, field of study, etc., its five areas of research do. The first area is complex social network analysis (CSNA). Located just across the bridge from Complexity Science City, it is the most well known by academics outside SACS, thanks in large measure to the popularized work of several brilliant physicists: Steven Strogatz, Duncan Watts, Mark Newman and Albert-László Barabási (Buchanan 2002).

In terms of its organization and development, CSNA is an interdisciplinary field of study. An interdisciplinary field of study is an area of study with a defined and widely recognized domain of inquiry. There also is a shared understanding of the topics of study, methods and vocabulary, along with a common identity and label. Such a field is not, however, located within the intellectual or organization confines of a single discipline. For example, one of the most well known scholars in CSNA is Duncan Watts—famous for his work with Strogatz on the "six degrees of separation" problem (Watts and Strogatz, 1998). Interestingly enough, while trained as a mathematical physicist, his primary academic affiliation is with the Department of Sociology at Columbia University where he is a professor. Also, while he has written articles for such sociological journals as *Annual Review of Sociology* (2004) and *American Journal of Sociology* (1999), he primarily publishes in top-tiered, natural science journals such as *Nature* (1998) and *Science* (2003).

The same type of interdisciplinary "grounding" done by Watts in CSNA is routine in SACS's second field of study, sociocybernetics. Known in Europe as Research Committee 51 (RC-51), the organizational structure for sociocybernetics comes from the *International Sociological Association* (www.unizar.es/sociocybernetics). As stated on the RC-51 website, "Sociocybernetics can be defined as systems science in sociology and other social sciences."

While sociocybernetics employs the latest advances in cybernetics and systems science—including such concepts as autopoiesis—and while it is highly critical of the work of Parsons, it nevertheless remains part of the systems tradition in sociology (Geyer and Zouwen 2001; Ritzer and Goodman 2004). In fact, sociocybernetics is home for most of the sociologists who carried on the systems tradition in the aftermath of the collapse of structural-functionalism, including Walter Buckley, Francisco Parra-Luna and Felix Geyer (see www.unizar.es/ sociocybernetics, accessed 18 April 2007). It is important to note, however, that while these sociologists are systems thinkers, they are not structural-functionalists and therefore are not part of the "American" neo-functionalist camp (Ritzer and Goodman 2004). In fact, it is because of their different and more "European" orientation to systems thinking, that these scholars built Route RC51—see Map 2. While RC51 connects the systems thinking tradition in sociology with the older intellectual downtown of Complexity Science City, it has nothing to do with the Parsons highway. (As a side note, it is because of the strong "overlapping" connection sociocybernetics has with the LSC that Route RC51 runs through the intersection of these two areas.)

The third major area in SACS is computational sociology. Originally the brain-child of British sociologist, Nigel Gilbert (1999), computational sociology has expanded over the last ten years to become the methodological centre of SACS. It is also, after complex social network analysis, the most widely recognized area (sub-cluster) outside of SACS. Its "outside" recognition has to do with the two, cross-town bridges its scholars are constructing, called Computational Bridges (See Map 2). Computational Bridges carry scholars from sociological method to computational sociology to agent-based modeling. While neither of the two Computational Bridges is by any means finished, significant work has been accomplished.

It is the extensive interdisciplinary, bridge-building activity of computational sociology that makes it less of a subdiscipline or field of study and more a "branch" of sociology: a divergent line of thought, a particular course of intellectual activity that extends outward across the discipline into new territories (www.wikipedia.org, accessed on 18 April 2007). As a disciplinary branch, computational sociology is supported by a small network of organizational (in particular, educational) structures, including professional associations, academic departments with degree programs at the undergraduate and graduate level, established funding streams, associated journals etc—all of which reside in SACS. It also has several smaller offshoots, each of which is concerned with a particular methodological issue regarding the integration of complexity science and sociological method. These smaller offshoots range from fractal geometry (Abbott 2001) and data mining (Castellani and Castellani 2003) to fuzzy logic (Ragin 2000) and qualitative method (Castellani, Castellani and Spray 2003).

The next major area in SACS is the Luhmann School of Complexity (LSC). In contrast to a field of study or disciplinary branch, a school of thought is an internally and externally defined way of doing scholarly work, based on the teachings or instruction of a particular teacher or group of teachers. Poststructuralism and pragmatism are two examples. While the scholars in a school of thought often have a shared identity, common vocabulary, similar methodology and related topics of study, their common identity lacks the widespread organizational and institutional support of a field of study or discipline.

As a school of thought, the LSC primarily revolves around the work of one man: the German sociologist, Niklas Luhmann. Working for years in almost complete anonymity—Luhmann came to sociology later in life—his work has become (contra Habermas) one of the most important schools of thought in Germany (Knodt 1995). Luhmann's work is also a major influence within the five areas of SACS, in particular sociocybernetics (Geyer and Zouwen 2001) and computational sociology (Klüver 2000; Klüver, Stoica and Schmidt 2003).

As the oldest area in SACS, LSC resides along the northern edge of town near the ruins of structural-functionalism. In fact, part of the LSC's foundation comes from the old *Department of Social Relations* at *Harvard*—Luhmann used his 1960-1961 sabbatical to study with Parsons (Knodt 1995). The LSC, however, is not the only school of thought in town. It is because of its age and prestige that the LSC is the largest school of thought in SACS.

The final area in SACS is the British-based school of complexity (BBC). While the BBC is a much smaller school of thought than the LSC, it is equally as powerful, due in large measure to it being more contemporary (Urry 2003). Not only does it make use of the latest advances in computational sociology and complex social network analysis, it also has almost nothing to do with the intellectual traditions of systems science or evolutionism and systems thinking (McLennan 2003). Instead, its theoretical and conceptual references points are contemporary: Gidden's structuration theory, Foucault's post-structuralism, sociological and political feminism, urban studies and globalization theory, particularly the "network society" work of Castells (2000a, 2000b) and the "mobile society" work of Urry (2003). The BBC also is resolutely post-disciplinary (Urry 2003). Unlike much of European and North American sociology, which remains entrenched in the formal intellectual boundaries of doctoral-granting institutions, the BBC has broken with its formal disciplinary ties, attempting to forge a new sort of "trans-disciplinary" science of sociology—we will come back to this point later.

4.4.3 The Non-Corporate Government of SACS

The third reason SACS is an intellectual town is because of its unique form of government. At present, SACS is most similar to an unincorporated town. While comprised of a network of research areas, this network does not constitute a formal intellectual system. Instead, it is best seen as an informal system with weak academic boundaries. SACS is therefore primarily an intellectual designation; somewhere for scholars with likeminded concerns about the intersection of complexity science and sociology to reside intellectually. Also, as an unincorporated town, SACS lacks a charter, legal name, central government, formal boundaries, etc. Any form of organization, regulation or economic support comes from the larger entities in which it is situated (namely sociology or complexity science) or the smaller areas of which it is comprised; that is, CSNA, sociocybernetics, computational sociology, LSC, and the BBC. If SACS were to incorporate, its network of five areas would need to self-organize into a more formal intellectual system with stronger academic boundaries—something the citizens of SACS currently do not appear interested in doing.

4.4.4 The SACS Community

As noted earlier, we use the term "community" to bring life and agency to our concept of town. In social network analysis and the new science of networks, given their focus on agency, scholars like to talk about scientific networks in community terms (Newman 2001a, 2001b, 2003). For example, when discussing the cohesiveness of a scientific network, they will talk about how well the scholars in this network are connected. Who are the hubs in this community? Who are the authorities and so forth?

For example, we can talk about the five major areas of research in SACS as separate scientific communities. We can also discuss how well connected these five communities are. Case in point, while all five areas of research in SACS are well connected locally—with most of the scholars knowing and working with one another—the connections amongst these five communities are significantly less developed and generally weak. Following the work of Newman (the leading authority on the structure of scientific communities, 2001a, 2001b, 2003), SACS appears to be a typical scientific community, with connected areas of research bound together by a series of weak ties—see Maps 6 and 7.

4.4.5 Common Concerns

While SACS is an informal, intellectual system with relaxed academic boundaries and weak, informal scholarly connections amongst its five areas of research, it has a common set of implicit and (increasingly) explicit concerns, questions, and ways of doing work.

4.4.5.1 The Challenges of Complexity

Despite differences in theoretical and methodological background or substantive and disciplinary focus, the scholars in SACS are creating or employing new tools to address one or more of the challenges of complexity facing sociology today. (If the reader recalls, in our introductory chapter we discussed these challenges, which range from epistemology and methods to substantive topics and data collection.)

In the case of epistemology, for example, Byrne has written a series of essays on the impact computers have on our "understanding" of social reality (2002), the utility of critical realism for complexity science (1998, 2001) and the widening distinction between "reductionistic complexity science" and "complex complexity science" (2005). Other epistemological examples include the work of Cilliers (1998), Richardson and Cilliers (2001) and Frank and Troitzsch (2005).

In terms of the complexity of electronic data, Castellani and colleagues have written several essays on the challenges of managing and analyzing large, electronic databases. Their work specifically focuses on merging neural networking, data mining and grounded theory to study complex databases (Castellani and Castellani 2003; Castellani, Castellani and Spray 2003). Other examples addressing the management of complex data include Newman, Barabási and Watts (2006), Ragin (2000) and Abbott (2000).

In the case of analyzing social complexity, Charles Ragin has written a series of articles and monographs on the utility of fuzzy set theory and comparative, case-based analysis for studying social systems (2000, 2008). Philip Bonacich has written on the utility of computational modeling for studying social networks (2002), and Nigel Gilbert has worked (almost single-handedly at the start) to develop the field of computational sociology and, in particular, computer-based simulation, including the creation of the well-respected, international periodical, *Journal of Artificial Societies and Social Simulation* (http://jasss.soc.surrey.ac.uk/JASSS.html).

In terms of the increasing complexity of sociological topics, scholars in the BBC, for example, working primarily under the intellectual direction of John Urry, have taken on the twin issues of globalization and global society (2000, 2003). They are joined in their research—and in its implications for identity, work, politics and so forth—by the scholars in the LSC, primarily through the intellectual framework of Niklas Luhmann (1995). Other examples of complex topics studied by the SACS community include medical professionalism (Castellani and Hafferty 2006), social communication (Klüver and Klüver 2007), urban environments (Byrne 2005, 2004, 1998), human organizations (Capra 2002) and the social sciences (Abbott 2001) to name a few.

In terms of developing a new language to discuss the complexities of social life, Watts has widened the vocabulary of social network analysis (a sociological field of study) to address the structure and dynamics of large, global networks (2004). Luhmann has created a comprehensive theory of global society (1995), Buckley has created a theory of society as a complex, adaptive system (1998), and Geyer and Zouwen (2001) and Eve, Horsfall and Lee (1997) have each published an edited monograph on the utility of complexity science concepts for sociological inquiry. Other examples of developing a vocabulary for the study of social complexity include Cederman (2005) and Mclennan (2003).

Finally, in terms of the increasing complexity of academic life, scholars in SACS have developed a diverse number of creative institutions. Examples include the *Centre for Research in Social Simulation* (cress.soc.surrey.ac.uk/), the *University of California Los Angeles (UCLA) Degree in Human Complex Systems* (hcs.ucla.edu/ home.htm); the *Center for the Study of Complex Systems* (cscs.umich.edu); and *Computer Based Analysis of Social Complexity* (www.cobasc.de/softcomputing).

4.4.5.2 Connecting Sociology and Complexity Science

While the scholars residing in SACS may go by different names, and while they employ different theoretical and methodological tools, there is one question central to their work: how can we integrate the intellectual traditions, theories and methods of sociology and complexity science to enhance sociological inquiry?

Whether discussing method, substantive topic or theory, the researchers in SACS are in strong agreement that their work is more than the enthusiastic but non-critical application of “all things complexity science” to sociology. While such a non-critical and overly enthusiastic literature does exist—particularly in the managerial sciences (e.g., Wheatley 1994)—and while scholars in SACS have been accused of being somewhat overzealous in the importance they attach to their work (McLennan 2003), the majority of scholars in SACS are involved in the accepted scientific (and painstaking) practice of methodically linking up two domains of formal thought—in this case, sociology and complexity science.

4.4.5.3 Social Complexity as a System

As we hinted at in our review of our canonical scholars, one of the most important theoretical insights of complexity science is that complexity is not a thing in-and-of-itself. Instead, as Luhmann explains, complexity is a "self-conditioning state of affairs" (Luhmann 1995, p. 24). It is a type of self-order that happens to act like a system. In this way, complexity is a descriptor for a type of system: one that is characterized as highly relational, interdependent, emergent, self-organizing, dynamic, evolving, adaptive, and open-ended (Capra 1996, 2002; Cilliers 1998). The same is true of social complexity: while it differs in isomorphic structure from other types of complexity—as found, for example, in physics, biology and chemistry—it shares many of the same features, the most important being that it is a type of system (Axelrod 1997; Cilliers 1998; Goldspink 2002, 2003; Holland 1998; Klir 2001).

The insight that social complexity is a type of organization that acts like a system, and is therefore best viewed in "complex systems terms" is the theoretical foundation for the scholars of SACS. Whether it is Goldspink's *Modeling Social Systems as Complex* (2000), Klüver's *Dynamics and Evolution of Social Systems* (2000) or Urry's *New Global Systems Theory* (2003), the basic argument is the same: social complexity is best understood as a system and therefore best studied in complex systems terms.

4.4.6 Interstitial Character of SACS

The final important characteristic of SACS is its culture: while small, this town has developed an interstitial culture—one that celebrates the in-between of things. In SACS, scholars have acquired an intellectual passport to travel across, within and between disciplines, subdisciplines, fields of study, research areas, substantive topics, theoretical traditions, conceptual frameworks, methodological techniques, organizational arrangements, and so forth, all in an effort to create the growing list of intellectual tools and techniques that SACS now offers researchers to connect, combine, merge, unite and join the theories, concepts and methods of sociology and complexity science (Byrne 1998; Cilliers 1998; Holland 1998; Klir 2001; Luhmann 1995; McLennan 2003; Urry 2000; Watts 2004; Wilson 1998).

An excellent example of the interstitial and cosmopolitan culture of SACS is the work of Duncan Watts and colleagues, which (in his own words) is devoted to developing "new models of large, complex networks that capture the general features of networked social systems, and a coherent set of metrics for characterizing them" (www.sociology. columbia.edu/fac-bios/watts/faculty.html, accessed on 14 April 2007). As Watts explains on his website, a "thorough treatment" of the numerous methodological and theoretical challenges associated with such an ambitious research project requires "expertise from a broad range of disciplines." It is for this reason that the scientific community Watts is building in SACS "brings to bear on the study of complex networks" a broad range of interdisciplinary ideas from "computer science, statistical physics, nonlinear dynamics, econometrics and social network theory, as well as substantial empirical and historical knowledge of the phenomena to be examined" (www.sociology. columbia.edu/fac-bios/watts/faculty.html, accessed on 14 April 2007). In short, Watts promotes an interstitial culture.

4.4.7 Why Not Call SACS the Sociology of Complexity?

It is because of its resolutely interstitial and mobile, cosmopolitan culture that SACS is not called the Sociology of Complexity. SACS is not another sociology *of* something; instead, it is sociology *and* something—specifically, *sociology and complexity science*.

In sociology, it has become standard practice (and in most cases rightly so) to codify a new domain of inquiry by placing the words *the sociology of* in front of it. The sociology of medicine, sociology of mental health, and sociology of knowledge are just three examples of this practice. While useful, this practice tends to limit a topic to single ownership—the term "of" signifies possession and origination. The sociology of medicine, for example, is used to distinguish it from, say, biology, medical economics or the psychology of medicine, often times with little overlap of topics or work.

The problem with SACS is that, while such a descriptor might be to the town's advantage—securing for it a place in the oddly baroque politics and economics of contemporary academia—it is not empirically or philosophically correct. Philosophically speaking, SACS is a town of "and, and, and…." And, empirically speaking, it is a town of unions, connections, intersections, and interdisciplinary interactions. In fact, some SACS scholars such as Urry (2003) think their work is even post-disciplinary or perhaps trans-disciplinary, and there are some such as Capra (2002) and Watts (2004) who see their work as an altogether new form of science.

While it remains to be seen if the pronouncements of these scholars are justified, the term SACS seems to describe well the intellectual town in which they live.

It is for all the above reasons that SACS (and we will argue this point in detail later) is the latest genealogical development in the systems tradition in sociology—a new way of doing science that promises to not only extend one of the oldest traditions in our discipline, but also effectively to branch out into science in general to address the growing complexity of sociological inquiry.

4.5 The Formal Emergence of SACS

So, when did SACS emerge as an interstitial town? To answer this question, we need to discuss in greater detail the concept of *tipping point*.

In the academic literature there are several variations of the term "tipping point." For us, a tipping point is a type of relatively sudden social change strongly associated with the phenomena of emergence and critical phase transitions. A tipping point is the particular moment when a set of immediate events leading up to some type of global social change suddenly coalesce to create something larger than itself—a gestalt, if you will. In terms of time-space, this moment of coalescence is appreciably small relative to the set of events leading up to it, hence the concept's name, tipping point: the cumulative effect of a rather small set of immediate events/changes suddenly results in rather large-scale, global change/consequences. This does not mean that the events prior to this more immediate set of events are not relevant. It only means that social change suddenly takes place because of these immediate events; that is, because of them a social system suddenly emerges or quickly tips from one state or form to another. Examples of the former include riots, revolutions, the collapse of economies, and the emergence of new fields of study. Examples of the latter include paradigm shifts in science, the western transition to modern forms of psychiatry and criminal justice (think Foucault) and the sudden (punctuated equilibrium) shifts in governmental control from one political party to the next.

For the current study we sought the tipping point for the formal emergence of SACS. To find this point, we had to go backward in time. Starting in 2008 we ran our model in reverse, stopping at discrete moments in time (usually every couple of years) in order to observe changes in the negotiated ordering of the network of attracting clusters—specifically, we kept looking to see if this field's five areas of research still existed—to arrive at the point at which the model deflated into some form of pre-field existence.

The date we arrived at was 1998 ± 2 years. This date was chosen for three reasons. First, as Urry (2003) explains, it is the historical point in time during which many scholars in the social sciences made the *complexity turn*; which he defines as the attempt to address the growing complexity of sociological work through a critical usage and integration of the tools of complexity science and social science.

Second, it is the point at which SACS transitions from a loosely defined two-cluster network comprised of the LSC and sociocybernetics to the five-cluster network of which the field is currently comprised.

Third, 1998 is comprised of a significant set of small events that produced tremendous global change in the field; one might say, even led to the formal emergence of SACS. Here is a list of some of these key events (See Chap. 7, Sect. *7.2.1.2 The Tipping Point of 1998* for an exhaustive list.) In 1998, Watts and Strogatz published their famous article on the small-world phenomenon in *Nature*, which started the new science of networks. Nigel Gilbert started *Journal of Artificial Societies and Social Simulation*, the key journal for computational sociology. Sociocybernetics was formally recognized as a *Research Committee* (RC51) at the 1998 *World Congress of Sociology* in Montreal. Niklas Luhmann, the pioneering creator of new social systems theory died, causing a major reconsideration and re-evaluation of his oeuvre. And, finally, David Byrne, a leading scholar in the BBC, published one of the first reviews of complexity for sociologists, titled *Complexity Theory and the Social Sciences*.

4.6 Situating SACS

The last issue we need to address is the position of SACS within complexity science and sociology. The conclusions we arrived at, which we have already in some degree discussed, are as follows.

Because of the interstitial quality of SACS, this field is unique in that it simultaneously resides within both complexity science and sociology. Within complexity science, however, SACS tends to appear fragmented, looking less like either a field of study or a complex social system. As show in Map 1, when situated within complexity science, SACS appears to fall apart, spreading out into five somewhat disparate areas of study, each with its own intellectual trajectory. However, in many ways this is a matter of focus. Looking at Map 1, if one engages in the Gestalt technique of keeping SACS in the foreground and allowing the other areas on Map 1 to recede, the network of attracting clusters in Map 4 appears. In other words, one finds the same negotiated, conceptual ordering. Even the conceptual gap shown in Map 4 that exists between the old-school and new-school supra-clusters is seen in Map 1.

Within sociology, the position of SACS is very much different. Here, SACS is the latest manifestation of the oldest, still standing tradition in sociology: the systems perspective.

As we discussed in our introductory chapter, the trajectory of the systems tradition within sociology can be broken down into three major phases. The first phase can be called *classical systems thinking*. This phase begins with the work of Comte, Marx and Spencer and ends with the work of Pareto, Durkheim and Weber. The second phase can be called *functionalist systems thinking*. This phase begins and ends with the work of Talcott Parsons and his colleagues. The third phase is the emergence of SACS or what might be called the *complexity turn* in systems thinking.

This third phase begins with the work of Niklas Luhmann and Walter Buckley, both of whom focused on integrating sociology with the newly emerging field of complexity science, specifically the concepts of self-organization, emergence and autopoiesis. This third perspective is then further transformed through the combined work of CSNA, computational sociology and the BBC.

During these three phases, the systems perspective also significantly changes in its relative size, position and importance within the discipline of sociology. During the classical phase, the systems perspective held a position of relative dominance and was widely practiced. This dominance reached its zenith during the functional phase, only to collapse by the end of this second phase. During the current phase (the complexity turn), the systems tradition seems to be once again emerging from the margins (that is, the outer-banks) of sociology.

How far SACS will move into the center of sociology, however, is another question. As Abbott explains in *Chaos of Disciplines* (2003), one of the great strengths and weakness of sociology (and this is true of SACS as well) is the permeability of its disciplinary boundaries. The strength of sociology's permeability is that the discipline is rather open to new ideas, even if not always accepting of them—one can think here of the postmodernism debates and the unfortunate schisms it created, some of which still exist. The weakness of this permeability, however, is that sociology lacks the cohesion and consensus common to the natural sciences. As such, sociology tends to lack a center, which makes it hard for any new idea to "capture" the imagination of most sociologists in any significant way, let alone to emerge as a dominant tradition that holds the focus of the discipline for any great length of time.

As such, rather than producing any sort of paradigm shift within sociology, the future trajectory of SACS will probably evolve as follows: (1) it will make its initial splash, transforming the tradition of systems thinking into a more sophisticated and useful attractor point in sociology; (2) as this attractor point becomes stronger, an increasing number of scholars and early advocates such as ourselves will cluster around it; (3) this growing interest will allow SACS to move from its current somewhat marginal position to a position closer to the center; (4) this movement will be aided by the current importance that complexity science and the increasing complexity of sociological work have on the daily lives of sociologists; (5) but, at least for now, that is as far as it will go. The possibility for SACS to take center stage in sociology or for SACS to cause some type of post-disciplinary or trans-disciplinary paradigm shift in sociology, as called for in the work of John Urry (BBC) is highly unlikely. Sociology is just too permeable and decentralized. Sociology is also substantively driven.

The major divisions within sociology are not just epistemological, theoretical and methodological, they are also substantive. In fact, the substantive divisions within sociology are the main reason why SACS is invisible to most sociologists. This is particularly true in the United States. The problem is that most sociologists do not read outside their cul-de-sac of study. Innovations taking place in other fields—such as the application of SACS to some area of study—remain hidden to those outside the domain of inquiry. As a result, it becomes difficult for any type of culture of innovation to take place across the field.

There is some hope, however, that SACS can demonstrate its utility to the field as a whole. As Bonacich (2004b) and Morris (2004) have pointed out regarding CSNA, and as Gilbert and Troitzsch (2005) have pointed out regarding computational sociology, a major shift will only take place when:

- The methods of complexity science make their way into graduate and undergraduate courses in statistics and research method;
- The concepts and ideas of complexity science—as Niklas Luhmann (1995) and David Byrne have argued (1998)—make their way into undergraduate and graduate sociological theory courses;
- The role of globalization and complexity—as Urry argues (2003)—are explicitly addressed by the discipline of sociology.
- Sociology becomes more friendly toward the natural sciences

Until then, the trajectory and impact of SACS within sociology will remain important but small. This, then, is a basic overview of our model and findings. With this general overview complete, we now turn to a more detailed review of the major points we made in this chapter.

5 Environmental Forces

To understand fully the dynamics of SACS, including the unique goals and concerns of its community of scholars, one needs a working knowledge of complexity science, as well as a general understanding of the current debate surrounding sociology's complexity. Because most sociologists do not possess this working knowledge, we begin our detailed examination of SACS by reviewing the five environmental forces impacting SACS.

Sociology's Complexity: The first environmental force has to do with the increasing substantive, theoretical, methodological and organizational complexity that confronts sociologists today. While sociology was born a profession of complexity, the discipline needs a theoretical and methodological overhaul—or, at least, that is the communicated viewpoint of scholars working within SACS and therefore one of the primary motivators for the work being done in this town.

Systems Thinking: The second force is linked to an important intellectual lineage in both complexity science and sociology, namely systems thinking. In terms of complexity science, systems thinking comes from the intellectual traditions of systems science and cybernetics (See Map 1). In terms of sociology (as we discussed in our introductory chapter) systems thinking comes from many of the scholars associated with the cannon of sociology—Spencer, Comte, Weber, Marx, Durkheim—as well as more recent sociological figures as Talcott Parsons.

Complexity Science: The final three environmental forces have to do with the historical emergence of complexity science over the past thirty or so years. Our third environmental force is the initial development of complexity science and its earliest topics of inquiry, specifically the study of autopoiesis and self-organization (Capra 1996). Our forth environmental force is the more recent development of complexity science, particularly the last twenty years of methodological innovations in agent-based modeling, dynamical systems theory, fuzzy logic, and data mining (Gilbert and Troitzsch 2005). The final environmental force is the popularization and academy-wide interest in the new science of networks (Buchanan 2002).

To help readers gain a working knowledge of complexity science and sociology's complexity, we will provide a brief overview of each environmental force, including its major themes, scholars, literature, etc. Then, with this working knowledge, we will explore how that force has impacted one or more of the five areas of research in SACS. Later, in chapters six through eight, we will examine the impact these forces have had on

SACS's previous, current and (where relevant) future trajectory. We begin with sociology's complexity.

5.0 Sociology's Complexity

Our discussion of sociology's complexity takes us to two important points in time-space. The first is the *Gulbenkian Commission on the Restructuring of the Social Sciences*, which met in three different places (Lisbon Portugal, Binghamton New York, and Paris France) from 1994 to 1995. The members of this committee included (1) Immanuel Wallerstein (Chair), (2) Calestous Juma, (3) Eveln Fox Keller, (4) Jürgen Kocka, (5) Dominique Lecourt, (6) Valentin Y. Mudimbe, (7) Kinhide Muschakoji, (8) Ilya Prigogine, (9) Peter J. Taylor and (10) Michel-Rolph Trouillot. Their goal: "to write a book-length programmatic analysis" of where the social sciences "should be heading in the next 50 years" (www.binghamton.edu/fbc/gulb.htm#gulbdesc). The result was *Open the Social Sciences: Report of the Gulbenkian Commission on the Restructuring of the Social Sciences*, published in 1996.

The second point in time-space is several turn-of-the century editorials on the future of 21st century sociology, published in such well-known periodicals as *British Journal of Sociology*, *Contemporary Sociology*, *Current Sociology* and *American Sociological Review*.

These two points in time-space are important to sociology's complexity for two reasons. First, they represent some of the most recent and exhaustive attempts to surmise the current state of sociology and the social sciences in general, including the complex challenges they face and the best ways to address them. One could add other works to this list, such as the culture studies and postmodern literature, which have over the last twenty years engaged in an extensive critique of the intellectual and structural conditions of organized sociology, the social sciences, and the academy in general (Best and Kellner 1991). Another important literature would be Continental philosophy and its companion, the philosophy of scientific knowledge (Rorty 1991a, 1991b). None of these literatures, however, is explicitly involved in SACS or the new science of complexity.

The second reason these two points in time-space are important is because many of the key sociologists involved in their creation are also, by no coincidence, leading scholars in SACS. In terms of the *Gulbenkian Commission*, the main SACS scholar is Immanuel Wallerstein, a world-renown sociologist and world system theorist who, in the aftermath of the

1996 Gulbenkian Report increasingly has incorporated complexity science into his work (2001, 2004, 2005). A second key Gulbenkian member is Ilya Prigogine, the Nobel Laureate, physicist and leading complexity scientist, who has had an impact on SACS, primarily through his influence on Wallerstein and through his concepts of dissipative structures, emergence and self-organization (Prigogine and Stengers 1984). In terms of the millennial ponderings of sociology, the main SACS scholars are Andrew Abbott (Editor of *American Journal of Sociology* and author of *Chaos of Disciplines*), Manuel Castells (renown for this trilogy on the emerging global network society), John Urry (leading scholar in the British-based school of complexity and author of *Global Complexity*) and (once again) Immanuel Wallerstein.

It is rather interesting that the scholars of SACS are extensively involved in national and international debates about the future of sociology. It seems that integrating sociology and complexity science correlates strongly with a concern about sociology's future. In fact, while we cannot review the arguments of each and every SACS scholar, most of them, in one way or another, have addressed the issue of sociology's complexity in their writing. This common fact does not mean that SACS is the only or best way to address the growing complexity of sociological work. For example, Wearne (1998) provides a thoughtful and useful critique of the Gulbenkian Commission's *Open the Social Sciences* (1998) pointing out the dangers of blurring disciplinary boundaries and the simplicity of assuming that the common theme of complexity will fix things. McLennan (2003) provides an excellent critique of sociology's millennial ponderings, in particular the British-based school of complexity (BBC), pointing out that some of these ideas lack rigor or are just plain ridiculous.

Criticisms aside, our main point here is that there is good evidence to suggest that the work of SACS has emerged, in very significant ways, to deal with the challenges of complexity facing sociological work today. Our goal in the remainder of this section is to use the *Gulbenkian Report* and sociology's millennial ponderings to show how the scholars of SACS conceptualize sociology's current future as one of complexity.

5.0.1 Wallerstein's Gulbenkian Commission

As we discussed in the introduction to this book, like the earliest days of the discipline, sociology once again is faced with the challenge of complexity. This challenge confronts sociology in: (1) the epistemological assumptions sociologist hold (Luhmann 1995); (2) the topics they study

(Watts 2004); (3) the vocabularies they speak (Geyer and Zouwen 2001); (4) the data they collect (Castellani and Castellani 2003) and the methods they use (Gilbert and Troitzsch 2005); and, adding something new to the list, (5) the changing forms of institutional organization in which they are situated (Abbott 2000, 2001).

The *Gulbenkian Commission*, headed by Immanuel Wallerstein, drew these five issues together by focusing on the last: how sociology and the social sciences are organized and how recent challenges to this organizational structure (grounded in post-WWII America and Europe) require new solutions.

To discuss the organization of the modern Academy, the Commission's report (Open the Social Sciences 1996) takes the reader on a glossing and breakneck (although factually accurate) tour of the historical construction of the social sciences—32 pages to be exact—ending in 1945, just before the ascendancy (albeit brief) of the American model of higher education. From this point, the reader is thrown into a 37-page historical overview of the three major environmental forces that have profoundly changed the utility of the modern university model for at least the near future. These three forces are: (1) the change in world political structure, particularly the rise of American dominance; (2) the massive, world-wide expansion of the human population and its productivity; and (3) the concurrent world-wide (albeit uneven) growth of the modern university.

As a result of these three forces, a trilogy of issues has emerged for the social sciences. The first concerns the validity of the social science's disciplinary distinctions. In a world of increasing complexity, where intellectual traditions, theories, methods and topics of study are shared (sociologists studying economy; psychologists studying group behavior, etc), and in a world where there is an increasing demand to graduate students with market-driven degrees (corrections, social work, management, etc.), the hyper-specialization and multiplication of disciplinary divisions has become a major problem.

The second issue concerns the social science's parochial "Eurocentric" heritage. How can the western social sciences claim universalism, when most of its "universal" ideas come from specific cultural, political, and scientific traditions? Since the late 1940s, this question has been raised repeatedly by activists and social critics, as well as scholars working in such areas as feminism, cultural studies, philosophy of knowledge, and philosophy of science.

The third issue—and the one we are most concerned about in terms of our review of SACS—concerns the validity of C. P Snow's famous distinction between the two cultures: the natural sciences versus the humanities. The Commission's basic argument is that a common theme has emerged amongst the natural sciences, the humanities and their interstitial relative, the social sciences. This theme is complexity and, more specifically, the complex system. According to the Commission, this theme makes the "two cultures" distinction, and the social science's interstitial role within it, moot.

For this last conclusion, the Commission relies heavily on Prigogine and his understanding of complexity science. The Commission makes the case that modern physics has spent the last hundred years dismantling the Newtonian-Cartesian model of science, the very model upon which much of the two-cultures distinction is based. In turn, a significant segment of modern physics has opted for a science much closer to that practiced by sociology and the social sciences in general. Why? To help them handle the "arrow of time;" that is, the dynamics and growing complexity of their work. Put simply, and we mean simply, physics (and this goes for the rest of the natural sciences as well) has been creating and embracing new ways of thinking (as well as modifying and redressing older ways of solving problems) to handle the new topics it studies, including areas one would never think a physicist or biologist would tackle, such as the study of human cities, social networks, economics, and the human mind (Capra 2002; Newman, Barabási, and Watts 2006). The evolution of new ways of doing natural science begs the question: If a significant percentage of physics and a growing segment of the natural science community employ a model of science unlike that discussed in Snow's two cultures, and if a growing network of these researchers (qua complexity science) are venturing into the social sciences and even, in some instances, the humanities (e.g., Wilson 1998), where do the cultural boundaries lines of the Academy exist? Equally important, what does it mean to practice sociology when the boundaries of physics and many of the natural sciences have exploded outward into traditional domains of sociology, and where humanistic epistemologies such as Zen-Buddhism, constructivism and multiculturalism are being embraced by physicists, chemists and ecologists? In such a new and exciting academic world, the "two cultures" distinction seems less useful and, perhaps, even historical incorrect. What, then, should the social sciences do? According to the Gulbenkian Report, the social sciences should unify under the common topic of complexity and the shared theories, concepts and methods complexity scientists use to study it. If there is any idea unanimously supported by the residents of SACS, it is this one.

5.0.2 SACS's Millennial Musings

In addition to the Gulbenkian Report, sociology's complexity has been addressed in the special editions of several prominent British, North American and international sociology journals. Using the millennium as a somewhat arbitrary excuse to reflect on the "future of sociology in the 21st century," journals such as *Contemporary Sociology* (American Sociological Association), *Current Sociology* (International Sociological Association) and *British Journal of Sociology* (British Sociological Association) invited top sociologists to ponder two issues: what the major challenges are for contemporary sociology and, if given a sort of magic wand, how would they address these challenges?

This list of scholars was dominated by residents of SACS, including, once again, Immanuel Wallerstein, as well as Andrew Abbott, Manuel Castells and John Urry. Similar to the Gulbenkian Report, these scholars focused, at least in part, on the historical conditions of the social sciences. Unlike the Gulbenkian Report, however, they were primarily concerned with the challenges of sociology's complexity.

In his excellent manuscript, titled appropriately enough, *Sociology's Complexity* (2003), the British sociologist, Gregor McLennan (2003) identifies three themes embedded in the millennial articles of the scholars of SACS. The first has to do with the disciplinary status of sociology. Given its emergent complexity, is sociology entering an interdisciplinary phase or can it maintain its boundaries? Can sociology stand strong against the encroachment of complexity science, culture studies, gender studies, and the turning of many sociological topics into vocational studies, physics or some other disciplinary perspective? Or, should sociology adopt a "post" or "trans" disciplinary posture? In other words, should sociologists become even more sophisticated generalists and transdisciplinary scholars, or should they remain more narrowly focused on their traditional definitions of work?

The second theme has to do with method. As argued by Urry (2000b), Byrne (2002) and others (Abbott 2000), does sociology need a major methodological revamping? Are current methods out-of-date or just plain useless in the face of the informatics revolution and the explosion of electronic data? Does sociology need a new set of rules for inquiry?"

The third theme has to do with the need for—contra postmodernism—large-scale (albeit not grand theory) explanations for all things sociological. This theme is a function of universalism and globalization. Can any local knowledge be understood without simultaneously understanding its connection to global, universal knowledge? Can the social sciences know everything about something?

An excellent example of how SACS scholars have responded to these three themes is Andrew Abbott's *Reflections on the Future of Sociology* (2000). While his ideas do not by any means represent the entire range of responses in these millennial special issues, they do give a sense of the general direction.

Basically, Abbott breaks the challenges of sociology into two basic types: structural and intellectual. Structural challenges have to do sociology's position within the university and academic system—McLennan's first theme. Abbott's argument is nuanced and, in many ways, contradictory to the Gulbenkian Report. While he supports the idea of a post-disciplinary sociology, he does not see this taking place, at least in terms of the structural organization of sociology.

When comparing the different university and disciplinary systems in which sociology departments are situated in various countries in the west—which is the focus of Abbott's reflections—he concludes that sociology in the United States is unlikely to become structurally inter- post- or trans-disciplinary. If anything, sociology faces a narrowed "structural" parochialism in light of the increasing encroachment of the humanities (i.e., culture studies, etc.) and the natural (social physicists, complex network analysis, etc.), social (communications, women's studies, etc.) and vocational sciences (social work, minority relations, etc.). Europe, however, looks much different given its heavier reliance upon government and free-standing research institutes and centers and its ease with interdisciplinary arrangements that can employ, graduate and hire doctorates involved in transdisciplinary and generalist research. Even here, however, despite everything discussed in the Gulbenkian Report, Snow's "two cultures" still looms large, as does the ever-increasing demand, based on heavy market forces, to graduate students with "job-based" rather than "academic-based" degrees. As such, while the possibility for an intellectual, transdisciplinary perspective is strong, the structural conditions of sociology seem intact, at least for the moment.

Intellectual challenges have to do primarily with the knowledge revolution taking place in sociology as a function of the disparate and uneven, yet amazingly global transition of academia into the information age (Abbott 2000, p. 298). Addressing this morass of complexity, Abbott responds to McLennan's other two themes (2003).

First, he addresses the explosion in electronic communication, a revolution in database collection, connection, management, and, most important, analysis. As Abbott states, "The single most important challenge facing the empirical social sciences in the next 50 years is finding patterns in such monumentally detailed data. And the blunt fact is that sociology is woefully unprepared to deal with this problem" (p. 298).

To fix the problem, Abbott explains, will require an almost complete revamping of normative method and theory, forsaking the current variable-driven, reductionistic orientation to data analysis for "a world of iterative pattern-recognition, of simulation, of Monte Carlo optimization. It is a methodological world that will draw heavily on computer science, on an algorithmic and aleatory approach to knowledge" (Abbott 2000, p. 299).

The final theme is the radical transformation in history and time, which is impacting the very nature of the concepts, codes and categories we use to classify all things sociological. Abbott's best example is census categories such as race, ethnicity, occupation, education and religious affiliation. History, particularly its current compressed and sudden "global" jolt forward, has changed these concepts. Because so much of sociology is anachronistic, it lacks a theoretical framework that "grounds" these concepts in their appropriate socio-historical context. Ironically, sociology, the discipline most concerned with the arrow of time, lacks an adequate theory for the current compressed history in which we live.

Sociology's lack of historical grounding leads to Abbott's call for sociologists to "rebuild general social theory." "Sociology," he states, "needs a big new theoretical idea" (2000, p. 299). This new generalist theory, in addition to addressing the challenges of data and history, needs to address the concept of culture—particularly the most powerful meaning making institutions, media and politics—and the moral and political challenges of sociology's long tradition of trying to improve society, given the current global and historical complexities that any such attempts must encounter. And, what would be the name of this new, big idea? For the scholars of SACS, it would be complexity science.

5.1 Systems Thinking

While "systems thinking" is a major tradition in sociology, it has a separate but intersecting history within the natural sciences. This history runs through the twin traditions of systems science and cybernetics and their offshoots, namely artificial intelligence, second-order cybernetics, cognitive science, computer science and computational mathematics—to name just a few of the "big ones." In fact, as we explain below, systems science and cybernetics are so intertwined that they go by the general name of systems science (Klir 2001).

5.1.1 Systems Science: A Brief History

As Capra (1996) and others explain (Hammond 2003; Jantsch 1980; Klir 2001), while complexity science represents a possible paradigm shift in the natural sciences, it simultaneously is the intellectual outgrowth of the last forty years of work done in the interconnected fields of systems science and cybernetics (Hammond 2003; Klir 2001). In fact, many of the scholars who are now retrospectively associated with the creation of complexity science were actually trained in or associate themselves with one or more of these antecedent areas – see the following (www.asc-cybernetics.org/index.htm) or (http://isss.org/world/index.php).

The theoretical biologist, Humberto Maturana, for example, worked within the cybernetics and artificial intelligence traditions, collaborating with both Warren McCulloch (artificial intelligence) and Heinz von Foerster (second-order cybernetics) (Capra 1996, pp. 95–99). The evolutionary biologist and a former leading figure at the *Santa Fe Institute*, Stuart Kauffman, also worked within the artificial intelligence tradition and likewise collaborated with Warren McCulloch (Waldrop 1992, pp. 112–113). John Holland, the creator of genetic algorithms and leading figure at the *Center for the Study of Complex Systems* worked in and collaborated with many of the leaders in the artificial intelligence, including Arthur Samuel and John McCarthy (see below). Also, Fritjof Capra, the theoretical physicist, while writing some of the best "general audience" books on complexity science (Capra 1996; 2002), continues to situate himself within the systems science tradition, particularly ecological systems science (Capra 1996). Finally, Talcott Parsons, while grounded in the sociological approach to systems thinking, drew extensively from systems science and cybernetics (Hammond 2003).

5.1.2 Systems Science

As Debora Hammond explains in *The Science of Synthesis* (2003), systems science got its start during the 1940s and 1950s through the work of Ludwig von Bertalanffy. A biologist by training, Bertalanffy became unsatisfied with the techniques of reductionism, believing that biological organisms cannot be studied using the methods of physics. Instead, he believed a holistic, systems view was needed. Biological organisms, for example, are complex, dynamic systems wherein the relationships between the things of which they are comprised are more important than the things themselves. In addition, biological systems are self-organizing, open-ended systems which, as Darwin showed, seek higher orders of emergent complexity. If the existence of an organism is dependent upon its emergent level of organization, then it cannot be reduced to something less complex. It must be studied as a system. Otherwise, one commits the error of reductionism.

An excellent example of this reductionistic error comes from cognitive science and its approach to mind. While reductionists want to reduce mind to the brain, systems scientists, such as Noam Chomsky, Humberto Maturana, Francisco Varela, John Holland and Gregory Bateson treat mind as a level of analysis unto itself: while the mind is, in part, a form of brain-based cognition, it is a complex system unto itself and therefore more than brain (Capra 1996; Chomsky 2000). To treat the mind as anything less is to study the brain, not the mind.

As Bertalanffy developed his ideas he began to believe that a systems perspective probably is the best approach not just to biology but to science and society in general. He therefore developed his ideas into a formal theory for science, which he called general systems theory (GST). Like complexity science, GST takes a holistic, trans-disciplinary, meta-theoretical approach to science, searching for the general principles that govern all complex systems. Working with a number of colleagues, including the economist Kenneth Boulding, the biologist Ralph Gerard, the anthropologist Margaret Mead, and the mathematician Anatol Rapoport, Bertalanffy incorporated the perspective of GST into a set of bylaws, which in 1954 formed the basis for the *Society for General Systems Research* (SGSR), which exists today as the *International Society for the Systems Sciences* (www.isss.org). The bylaws are as follows:

> (1) to investigate the isomorphy of concepts, laws, and models from various fields, and to help in useful transfers from one field to another; (2) to encourage development of adequate theoretical models in fields which lack them; (3) to eliminate the duplication of theoretical efforts in different fields; and (4) to promote the unity of science through improving communication among specialists" (www.isss.org).

In many ways, the principals embedded in these bylaws are shared by many of the leading complexity scientists and centers for the study of complexity (Érdi 2007). In fact, if one replaced the term "systems" with "complex systems," one could locate these principals within the mission statements of such important complexity science institutions as the *Santa Fe Institute*, *European Complex Systems Society*, and *Center for the Study* *of Complex Systems*. In other words, the spirit of systems science remains important to the endeavors of complexity scientists.

5.1.3 Cybernetics

If systems science is the study of the general properties of systems, cybernetics is the study of control and communication within systems (Capra 1996). The study of machine systems is commonly referred to as "first-order cybernetics" while the study of animal and human systems is referred to as "second-order cybernetics" (Geyer and Zouwen 2001). Like systems science, cybernetics emerged during the 1940s and 1950s through an impressive cohort of scientists. In addition to the prodigious mathematician, Norbert Wiener, who created the field, other key thinkers include the mathematical genius John von Neumann—who, amongst other things, created the computational algorithm known as cellular automata—and Warren McCulloch, who worked with John Pitts to create one of the first artificial neural networks.

As Hammond explains (2003), although general systems theory and cybernetics emerged along separate trajectories, they became almost immediately intertwined. There were three reasons for this unification. First, both traditions focus on the general properties of systems, particularly complex systems. Second, they almost immediately began using each other's methods and concepts. Third, the numerous areas of study created by scholars in these respective sciences drew upon common traditions of thought. In fact, these sciences are so interrelated that the term *system science* often is sufficient to refer to both (Klir 2001).

As many sociologists know, the initial insights of cybernetics were so impressive (although doomed in their naïve grasp of how social systems work) that they even impacted the social sciences. Norbert Weiner, for example, wrote a popular book titled *The Human Use of Human Beings: Cybernetics and Society* (1950). Such ideas were taken up and integrated within sociology by such thinkers as Walter Buckley—who would later influence the emergence of sociocybernetics—and, of course, Talcott Parsons, the creator of structural functionalism. The incompleteness and partial failure of these ideas when applied to sociology and the social sciences led, in part, to efforts within SACS to rethink what a "systems" perspective could offer sociology. The most important scholar to address this issue is Niklas Luhmann and his new social systems theory, which takes us to the next section.

5.1.4 Systems Science and SACS

There are several reasons why the twin traditions of systems science and cybernetics are so important to SACS. First, several of the key scholars in SACS are also leading figures in these twin sciences. This list includes Niklas Luhmann as well as Felix Geyer, Francisco Parra-Luna, Kenneth Bailey, and Walter Buckley. In fact, Bailey was 2003 President of the *International Society for the Systems Sciences*.

Second, while part of the sociological tradition, sociocybernetics, as the name implies, is a direct descendant of cybernetics, in particular second-order cybernetics. We explain this link in great detail in the next chapter.

Third, new social systems theory, particularly as conceptualized by Niklas Luhmann, is thoroughly entrenched in the systems science tradition. Of particular importance to Luhmann's work is that of theoretical biologists and cognitive scientists, Humberto Maturana and Francisco Varela (1998), specifically their concept of autopoiesis, one of the more important ideas in the early years of complexity science. Again, we discuss this link in great detail in the next chapter.

The fourth and final way systems science impacts SACS is through its methodology, which takes us to a discussion of an important outgrowth of systems science: the field of artificial intelligence.

5.1.5 Artificial Intelligence

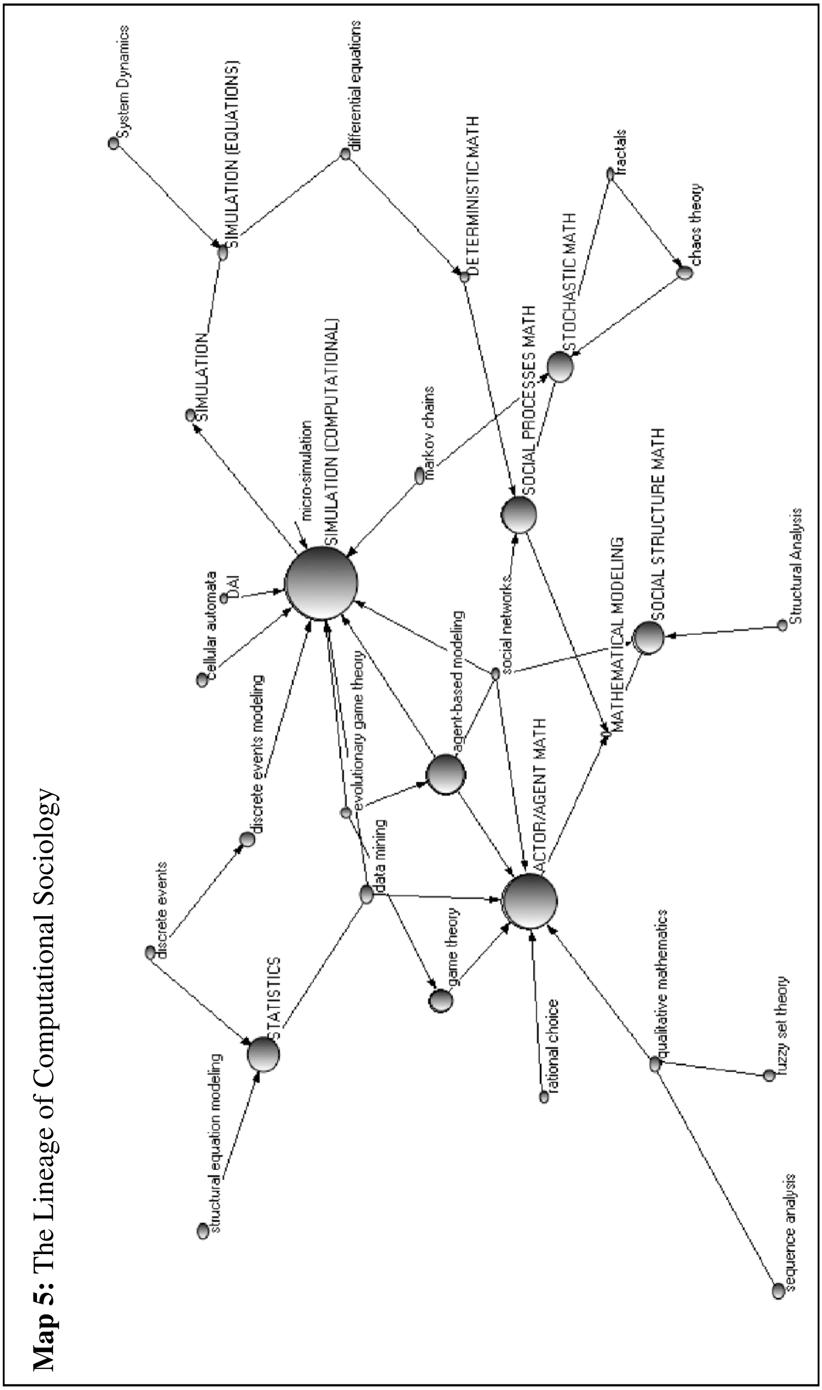
One of the most significant results in the merger between systems science and cybernetics is the field of artificial intelligence (also latter known as distributed artificial intelligence) which is defined as the attempt to use the computer to simulate the human mind (Holland 1998). While the founders of cybernetics, such as Warren McCulloch, John Pitts, and John von Neumann made important strides in the establishment and development of the field of artificial intelligence (AI), it was John McCarthy who coined the term and, in conjunction with Shannon (one of the leading cyberneticians), Marvin Minsky (founder of the MIT Artificial Intelligence Lab) and Rochester (neural networks), put together the first AI conference in 1956 at Dartmouth. Other well-known scholars include Alan Turing, who is considered by many to be one of the founding fathers of the computer and computer science, and Arthur Samuel, popularly known for his development of a checker-playing computer game (Holland 1998).

If systems science and cybernetics provide SACS with one of its primary theoretical and conceptual frameworks, artificial intelligence provides SACS with most of its method (Map 1). As Capra explains (1996, p. 79), complexity science is impossible without the computer. While Bertalanffy and other system scientists made important advances throughout the 1950s and 1960s, they were methodologically stymied (Érdi 2007). The techniques of the day (statistics, mathematical modeling) were unable to effectively model the complexity these scholars were trying to address (Capra 1996, p. 79). Once the computer revolution took place, everything changed. With each advance in computational power came the ability to do more sophisticated forms of computational mathematics.

Eventually, work in artificial intelligence exploded into the creation of a host of new areas of computational mathematics and science. Some of these new areas, such as distributed artificial intelligence, focus on the problems of modeling intelligence; others, such as cellular automata, branch outward to model the dynamics of mathematical equations and biological systems; and still others, such as fuzzy logic, set out to rethink the conceptual basis of modern mathematics.

It is important to note, however, that artificial intelligence is more than the advancement of computer hardware or software. While strongly linked to computer science, artificial intelligence and the techniques that grew out of it—agent-based modeling, data mining, dynamical systems theory, fuzzy logic, etc—are unique in that they represent a "systems" approach to computer modeling: the focus is on modeling the dynamics of ever-increasing complex systems, be these systems mathematical equations, phone lines, the internet, gaming software, medical diagnostic machinery, smart appliances, weather patterns, traffic, the electrical grid, or complex social systems such as the economy, politics, culture, etc.

It is because of its systems orientation coupled with its computational power that artificial intelligence eventually became the methodological backbone of complexity science and, later, SACS. In fact, as shown in Map 5, one can plot the development of the methods in SACS (in particular computational sociology) in concert with (and as a reaction to) the historical evolution of artificial intelligence and its development of distributed artificial intelligence, artificial neural networking, cellular automata, genetic algorithms, agent-based modeling and multi-agent modeling (Gilbert and Troitzsch 2005).



Map 5: The Lineage of Computational Sociology

5.2 Complexity Science

As we have stated (almost to the point of redundancy by now), and as argued by a growing list of preeminent scholars throughout the natural and social sciences, the major challenge of 21st century science is to think about the world in terms of systems and their complexity (Capra 1996; Cilliers 1998; Holland 1995; Gell-Mann 1995; Gleick 1987; Jantsch 1980; Kauffman 1995; Luhmann 1989; Maturana and Varela 1998; Prigogine and Stengers 1984; Urry 2003; Wilson 1998). In fact, this challenge is so profound that many scholars believe it is creating a Kuhnian paradigm shift in the natural sciences, resulting in a new way of doing science called, appropriately enough, complexity science (Capra 1996; Wolfram 2002).

5.2.1 The Making of Complexity Science

As Capra explains (1996), it was during the 1970s that a small but growing network of scholars, working in the traditions of systems science, cybernetics and artificial intelligence, began to expand and rethink the insights of these fields to create for themselves a new toolkit of theories, concepts and methods to better handle their primary topic of concern: the complex system. While working in disparate areas of study across the sciences, the common goal of these researchers was to find new ways to think about and study what they variously referred to as complex adaptive systems, self-referential systems, autopoietic systems, dynamical systems, systems near chaos, dissipative systems, non-equilibrium open systems, self-organizing systems, emergent systems, and living systems (Capra 1996, 2002; Jantsch 1980; Lewin 1992; Waldrop 1992). Eventually, these various terms would be collapsed into one term, the complex system. The name of this new area of inquiry would coalesce as well to become complexity science, or what we call Complexity Science City—see Map 2.

As shown in Map 1, this now canonized network of early scholars includes such pioneer thinkers as Robert Axelrod, Per Bak, George Cowan, John Holland, Stuart Kauffman, Christopher Langton, Niklas Luhmann, Humberto Maturana, Ilya Prigogine, and Francisco Varela (Capra 1996, 2002; Jantsch 1980; Lewin 1992; Waldrop 1992). This initial network of scholars is important because, through their joint efforts, they accomplished six important goals essential to the establishment of their new field of inquiry: (1) they popularized complexity through a series of mainstream, academic monographs; (2) they helped to create a set of leading institutes where likeminded scholars could interact; (3) they began many of the journals and conferences devoted to the study of complexity; (4) they created a new and empirically grounded vocabulary for the study of complex systems; (5) they developed many of the key areas of research in the field; and (6) they helped to develop the methods of complexity science, specifically, agent-based modeling and dynamical systems theory. We will review each of these accomplishments in greater detail.

5.2.2 Popularizing Complexity

As we detailed in our introductory chapter (See Sect. *1.2.6*), one of the important accomplishments of this field has been its ability to capture a popular audience within and outside the academy. This has worked to the advantage of this new field, helping it to develop at a much quicker pace than a field normally evolves (Capra 1996; Lewin 1992, Waldrop 1992).

A long list of the works that have "popularized" complexity science include (in chronological order) Erich Jantsch's *The Self-Organizing Universe* (1980), Ilya Prigogine and Isabelle Wiley's *Order out of Chaos* (1984), James Gleick's *Chaos* (1987), Humberto Maturana and Francisco Varela's *The Tree of Knowledge* (1992), Roger Lewin's *Complexity* (1992), John Casti's *Complexification* (1994), Murray Gell-Mann's *The Quark and the Jaguar* (1995), Stuart Kauffman's *At Home in the Universe* (1995), Fritjof Capra's *The Web of Life* (1996), John Holland's *Emergence* (1998), Edward O. Wilson's *Consilience* (1998), Duncan Watts's *Small Worlds* (2003), Per Bak's *How Nature Works* (1999), Albert-László Barabási's *Linked* (2003), Fritjof Capra's *The Hidden Connections* (2002) and Mark Buchanan's *Nexus* (2002).

The popularization of complexity science, however, has led to several conflations within and criticisms of the field. In our introductory chapter we dealt with some of these conflations, such as complexity science is not postmodernism or new age mysticism. Here we deal with some of the criticisms, which revolve around two themes.

The first is that complexity science became too popular too fast, and long before many of its pioneering claims could be empirically and theoretically evaluated, critiqued or developed (Lewin 1992; Waldrop 1992). An example here is the radical claim, primarily advanced by Stuart Kauffman (2000) that self-organization is the other half of the Darwinian equation, and that adaptation is only part of the story. While data has been offered to suggest a degree of validity in this claim, it requires a lot (and we mean a lot) more empirical study before evolutionary theory is rewritten. Another is Per Bak's self-organizing criticality. Bak's idea, which uses the power law and computational modeling to explain why certain systems like rice and sand piles maintain their order in the face of so many small and (less often) large “perturbations” is a brilliant insight. However, it does not always hold when tested empirically. Furthermore, it is hard to understand how a rice pile is a complex dynamic system or how rice is on par with an economy or biological cell. Again, this is not to dismiss Bak’s idea. In the end, it may prove entirely correct. Nevertheless, there is some concern that the popularity of complexity science causes ideas to become popular and therefore embraced before rigorously challenged and defended.

The second criticism is that many scholars, particularly those in the humanities and social sciences lack rigor or reason in their usage of the concepts and ideas of complexity science. One example is the field of management studies (Richardson and Cilliers 2001). At present, the field can be divided into two areas: managing complex organizations and understanding the dynamics of complex organizations. The former is the more popular of the two and can be found in such mainstream publications as Wheatley’s *Leadership and the New Science* (1994) and Capra’s *The Hidden Connections* (2002). The latter, which is more empirically driven, has three foci: (1) how complex organizations handle internal complexity and change; (2) how organizational culture, bureaucracies and hierarchies work together; and (3) how complex organizations adapt to the increasingly complex, global society in which we are now living (Mathews, White, and Long 1999; McKelvey 1999; Richardson and Cilliers 2001). The primary critique that the latter makes of the former is that the former is metaphorical and methodologically sloppy; and, in some instances, just plain wrong. For example, what does it mean to argue, as Wheatley does, that a business is autopoietic? If she is using this term as Maturana and Varela and other cognitive scientists and theoretical biologists do, then she is wrong. Maturana and Varela (1998) make it clear that the term is reserved for the study of biological organisms. If she is using this term as Niklas Luhmann does (1995), then she is strictly talking about communication networks and not business. Either way, she would need to demonstrate her claim empirically. One must show a business engaging in autopoiesis. (For a more in-depth overview of this debate see *Organization Science*, 1999, Volume 10, Issue 3)

Despite such criticisms, popularization has been an important component to the success of complexity science, and has helped a much wider audience not only appreciate but eventually move into the more rigorous literature of this new way of doing science.

Oddly enough, this popularity has not bled over into SACS yet. While the popularity of complexity science has been a major impetus for SACS scholars; they have, for the most part, worked in the backwaters of complexity science’s glamour. This seems to be due, in large measure, to the widespread malaise or (to be less critical) lack of awareness sociologists have of SACS and its relevance for their various empirical inquiries.

5.2.3 Material Conditions

Although not represented in Map 1, any review of complexity science has to begin with a brief overview of its most important organization: the Santa Fe Institute (Lewin 1992, Waldrop 1992). As sociologist Randall Collins explains, one of the most important material conditions necessary for the emergence of a formal field of knowledge is the various intellectual institutions we associate today with the academic mind, which range from colleges and universities, to research institutes and think-tanks, to conferences and journals (Collins 1994). Complexity science has followed this same algorithm. The field has worked hard to put together a growing network of conferences, educational institutions, think-tanks, and journals necessary for it to emerge, evolve, and thrive. These material accomplishments would not have taken place, however, had it not been for the Santa Fe Institute, which is, in many ways, the butterfly flapping its wings (initial conditions) that caused the world-wide intellectual storm called complexity science.

The Santa Fe Institute (See Lewin 1992; Waldrop 1992) is the brainchild of George Cowan (physical chemistry). It was established in 1984 with the explicit goal of becoming the leading center for the study of complexity. To this end, it has succeeded. This Institute has held many of the most important early conferences in the field (self-organization, artificial life); published some of the field's most important journals (*Complexity*). It also has provided residence for visiting scholars and postdoctoral fellows; functioned as an educational institute for younger scholars; acted as a clearing house for working papers, articles and books written by leading scholars in the field; created a growing interdisciplinary community of scholars working at other institutions throughout the world, and set the agenda for the leading areas of research in the field. Twenty-years later, there now are over fifty organizations devoted to the study of complexity, yet the Santa Fe Institute remains a hub in this intellectual network.

Other key institutions, many of which have direct ties to or are part of SACS, include: *The Center for the Study of Complex Systems* at University of Michigan (www.cscs.umich.edu); *The European Commission's Complex Systems Network of Excellence* (which has links to every major research group, institution and periodical involved in the study of complexity throughout the world) the *New England Complex Systems Institute*, which is, thanks to the vision of Yaneer Bar-Yam (1997), the host of the annual

International Conference of Complex Systems (www.necsi.org); and the *European Complex Systems Society* (www.cssociety.org). For a detailed overview of these institutions and their links on the internet, see our website (www.personal.kent.edu/~bcastel3).

5.2.4 A New Vocabulary

The fourth and more technical way that complexity science has become part of the intellectual imagination—and one of the primary ways it has influenced the community of SACS—is through the increasing scholarly usage of its powerful concepts, such as fractal scaling (Mandelbrot and Hudson 2004), autopoiesis (Maturana and Varela 1998), self-organization (Kauffman 2000), emergence (Holland 1998), and self-organized criticality (Bak 1999). The most important of these concepts, however, and the one around which they all revolve is the *complex system* (Capra 1996; Cilliers 1998).

The reason this term is so important is because, at least based on current research (Klir 2001), it appears that complexity is not a thing in-and-of-itself. Instead, it is a way of describing the type of system that emerges when certain things interact with one another in a particular way (Capra 1996; Cilliers 1998; Klir 2001). Said another way, complexity appears to be a form of organization (system) that emerges when certain "sets of things" interact in "certain ways" with one another. George Klir, the systems scientist and fuzzy logic scholar (2001), expresses the "system" formula as follows:

$$S = (T , R) . \tag{5.1}$$

In this formula, S = system, T = thinghood, and R = systemhood such that a complex system (S) can be catalogued according to the set of things of which it is comprised (T) and the types of relationships these things have with one another (R). While simple, the brilliance of this formula is that it can be developed to catalogue any and all types of systems, including those defined as complex (Klir 2001).

The problem, however, is that because the field of complexity science is so new (20+ years) and because the types of systems it studies are so varied—from complex mathematical equations to biological systems to human systems to ecological systems—there is no formally agreed upon definition of what is a complex system (Byrne 2001; Cilliers 1998; Klir 2001; Richardson and Cilliers 2001). Following Cilliers (1998), the best that can be offered is a list of characteristics which most complex systems are assumed to exhibit to varying degrees—be these systems mathematical, physical, biological, psychological, social, or ecological. Anything beyond this list, however, including variances in terminology, must be left to complexity scientists working in their respective fields of study.

Having said this, here is a basic list of the characteristics commonly associated with complex systems. First, complex systems are *dynamic*; that is, they are time dependent. Second, they are *agent-based*. Most complexity scientists agree that, while complex systems are emergent phenomenon, they are built from the ground up; that is, they are comprised of a large number of interacting agents (be they a set of numbers, genes, neurons, people, governments) which, through their interactions with one another, form the system of which they are comprised. Third, they are *rule following*: agents follow a set of guidelines (rules, codes, prescriptions, parameters, communication strategies) for their interactions with one another. Fourth, they are *self-organizing*. Without any external pressure or overriding guidance from an overseer or pre-defined set of *meta-rules*, agents in complex systems are able to self-organize into a system of their own making. Fifth, while relatively stable they operate in a position *far from equilibrium*—a position described as the midway point between chaos and complete order. Sixth, they are situated within a *larger environment* (web of systems). Seventh, to survive in their various environments, they *evolve*; that is, they are able to *adapt* to internal and external threats or changes through their own methods of self-communication or feedback. Eighth, they are *emergent*. While complex social systems are agent-based, they cannot be reduced to the rules or agents of which they are comprised. They are, in the words of Gestalt psychology, more than the sum of their parts (Capra 1996). This is why, as Holland explains (1998), complex systems have to be addressed holistically. Finally, as Klir (2001) and others point out, complex social systems are *intellectual constructs* (Cilliers 1998; Geyer and van der Zouwen 2001; Maturana and Varela 1998). Given the complexities of studying complexity, scholars in the field humbly acknowledge that defining a system as complex is both an act of the researcher and a property of the system itself. It is therefore standard practice in complexity science to adopt a constructivist epistemology of one sort or another, be it critical realism, constructivism, or post-structuralism (Cilliers 1998; Klir 2001; Maturana and Varela 1998).

5.2.5 Topics of Study

Because complexity science is so rigorously interdisciplinary—ranging from theoretical physics and biology to psychology and medicine to economics and business—any overview of the field faces an important decision. One can review all of the various substantive areas of research, or one can look for common themes across these areas of study. Because our focus is on the impact complexity science has had on SACS, and because our discussion of the research in SACS is substantively driven—that is, we are examining how complexity science is employed to do sociological inquiry—we will settle for the latter: a conceptual overview of complexity science.

As shown in Map1, complexity science is organized into five major themes: self-organization, autopoiesis, emergence, system dynamics and complex networks. (As a side note, an electronic version of Map 1, with links to each and every tradition, topic, and scholar can be found at our website.)

Methodological Note

Before we proceed, a note on method is needed. The empirical support for our conceptual organization of complexity science is based on four major sources of information.

1. The first source is our review of the website for the *Santa Fe Institute* (www.santafe.edu) which, historically speaking is the organizational focal point for the emergence of complexity science in the 1980s. Over the last twenty years the Santa Fe Institute has remained at the forefront of complexity science.
2. The second source is the popular reviews of complexity science, all of which offer their own overview of the field. These include Bak (1999), Barabási (2003), Buchanan (2002), Capra (1996, 2002), Gell-Mann (1994), Gleick (1987), Hammond (2003), Holland (1998), Jantsch (1980), Kauffman (1995), Lewin (1992), Maturana and Varela (1998) and Wilson (1998).
3. The third source comes from our review of a set of leading educational websites devoted to complexity science. The two most important are *CALSResCo* (www.calresco.org/index.htm) and *American Society for Cybernetics* (www.asc-cybernetics.org/index.htm).
4. The fourth source comes from our review of the empirical literature. We conducted a literature review to see if anyone had done a citation index analysis of the published research in complexity science. We found two research reports.

   a. The first report is located at *The Complex Systems Network of Excellent,* nicknamed Exystence (www.complexityscience.org/index.php). Exystence "is funded by the European Commission to develop collaboration among European researchers interested in Complex Systems" (See front page of website). On this website there is a link to a java-script, citation-based map of the topics in complexity science.

b. The second report is by Johanna Bergmann and John Casti, titled *Mapping Complexity Research: A Bibliometric Analysis*, which they presented to the *Exystence Steering Committee* at the Torino Meetings (11 November 2002). This report can be downloaded in PDF or PowerPoint Format. On the Exystence website, click on the *Focus Document* icon, which is located under the icon *Work Packages*. Bergmann and Casti examined roughly 1,000 papers posted on the Santa Fe website between 1989 and 2002. Their presentation subsequently was put into article form by Bergmann, Paier and Resetarits. The new title is *Towards a Roadmap of Complexity Research Using a Bibliometric Visualization Tool* (prepared for the EXYSTENCE Focus Document section of the website and posted April 2003). We focused on pages 6 through 15, which provide a visual map of complexity science—see Map 3.

Across these four major sources of information, we identified five major research themes. They are as follows:

Self-Organization: Self-organization is the idea that the structure of a complex system cannot be reduced to a set of external meta-rules or a smaller and more salient list of key variables because the structure of a system is the system itself. The structure of a complex system is located in and amongst the emergent patterns of novel relationships formed by the network of interacting agents that comprise the system (Capra 1996). The theme of self-organization can be found in the work of Cilliers (1998), Jantsch (1980), Kauffman (1993) Prigogine (see Prigogine and Stengers 1984), and Haken (1983)—to name a few (see Capra 1996).

Emergence: The thesis that a complex system is more than the sum of its parts leads to the second theme in complexity science: emergence. Emergence addresses one of the most important issues in complexity science: complex systems are, by definition, emergent phenomena and therefore must be studied as systems. To ignore or reduce the system-hood of a system to anything less is to do something other than complexity science. The leading thinkers in emergence are Holland (1998) and Maturana and Varela (1980, 1998). More recent work draws upon the concept of *swarming*: how groups, without any external orchestration, self-organize and emerge into existence, creating and maintaining a level of behavior greater than themselves (Miller and Page 2007). This includes traffic jams, the standing ovation problem, flocking behaviors, and crowd control (Miller and Page 2007).

Autopoiesis: While the idea of autopoiesis has been used rather loosely in writings in and about complexity science, it has a very specific meaning. As explained by Maturana and Varela (1980), they created the term to distinguish living from nonliving systems. Autopoiesis literally means "self-producing" and refers to the self-organizing processes by which certain complex systems such as the mind come to possess the characteristic of being *alive*. Maturana and Varela state: "Our proposition is that living beings are characterized in that, literally, they are continually self-producing. We indicate this process when we call the organization that defines them an *autopoietic organization*" (1998, p. 43). Given the bravado of their claim, Maturana and Varela's framing has produced considerable controversy, which has spilled over into the sociology of complexity. While Maturana is content to define cells, minds and bodies as living systems, he is less willing to define social systems as living (Maturana and Varela (1980). This has reintroduced a series of important questions for sociologists. Are social systems alive? If so, in what ways are they alive?

System Dynamics: The fourth major theme in complexity science examines how complex systems evolve and adapt to internal and external conflicts and change. System dynamics is the largest theme in complexity science in terms of the number of researchers involved in it. In fact, if one goes to the Santa Fe Institute's website and examines their major topics, most of them (as of 2008) have to do with dynamics, including the dynamics of large, complex networks. The current topics at the Santa Fe Institute (circa 2008) are: (1) emergence, organization and dynamics of living systems; (2) dynamics and quantitative studies of human behavior, history and social institutions; (3) information processing and computation in nature and society; (4) emergence, innovation and robustness in evolutionary systems; and (5) physics of complex systems—see (www.santafe.edu).

The main reason dynamics is such a major theme is because it is the most intractable. As Luhmann points out (1995), what makes a system complex is, in part, its unpredictability. A complex system has the potential to evolve and develop along more than one trajectory and to settle on more than one solution at any given time. In other words, as Prigogine and others have demonstrated (Bak 1999; Kauffman 2000; Maturana and Varela 1998), the network of interacting agents upon which a complex system is based constantly adapts to perturbations inside and outside of the system and therefore constantly evolves to maintain its relatively novel patterns of relationship. Given this state of constant disequilibrium, complex systems are best described as dynamic, nonlinear, adaptive and evolving. This fact of disequilibrium also has forced scientists to draw upon or created a wide variety of concepts to describe these dynamics. Some of the more important terms include dissipative structures (Prigogine and Stengers 1984), self-organized criticality (Bak 1999), structural coupling (Maturana and Varela 1998) and edge of chaos (Gleick 1987).

The New Science of Networks: The final theme in complexity science is networks. The formal entrance of complexity science into the field of *social network analysis* took place in 1998 with Watts and Strogatz now famous “Collective Dynamics of ‘Small-World’ Networks” published in *Nature*. While some of the insights of this paper have proven problematic for the study of social networks, such as its model’s dependence upon an underlying lattice structure to guarantee global connectivity (Watts 2004, p. 248), it demonstrated to physicists, mathematicians and other researchers in the natural and computer sciences that very large, complex networks can be effectively understood. While partially random and chaotic, social networks possess an order and pattern that can be analyzed using the tools of graph theory and agent-based modeling (Barabási 2003; Watts 2004).

The reaction across the sciences to Watts and Strogatz paper has been quite impressive. Of the areas currently studied by complexity scientists—with, perhaps, the exception of agent-based modeling—the study of complex networks is the most popular, focusing on such important topics as affiliation networks, scale-free networks, and the small-world phenomenon. For example, a 2008 “cited reference” search on the *Science and Social Citation Index* for Watts and Strogatz 1998 article gets 2,393 hits and counting.

There is, however, a rather important sidebar to this story. The new science of networks, while advancing at a breathtaking pace, has done so, at least initially, in almost complete ignorance of the sociological field of study known as social network analysis (Bonacich 2004b; Freeman 2004; Scott 2000; Watts 2004). As Bonacich explains (2004b), not only has this fact alienated some sociologists, but it has led to degrees of redundancy and error on the part of complexity scientists. An example of redundancy is the creating of new terms for existing concepts—links instead of ties. An example of error is using very simple mathematical models to explain very complex social phenomenon. (For a more in depth review of the redundancy and error of the new science of networks, see Bonacich 2004a, 2004b; Freeman 2004; Morris 2004; Watts 2004).

Nonetheless, and as Freeman points out (2004), while the initial failure of complexity scientists to engage the sociological literature did reflect and result in a schism between the new science of networks and social network analysis, there are now signs of merger and synthesis between the two (Urry 2003). This merger, as Watts explains, is helping to make; “substantial progress on a number of previously intractable problems, reformulating old ideas, introducing new techniques, and uncovering connections between what had seemed to be quite different problems” (2004, p. 243).

5.2.6 Method

The final way that complexity science has become part of the intellectual imagination—and has significantly influenced the work of scholars in SACS—is through the new list of methods upon which it draws.

We made a conscious effort when constructing Map 1 to draw a historical and conceptual distinction between complexity science and its methods. It is important for the reader to understand that, while agent-based modeling is used to simulate complex systems, and while many of the leading scholars in complexity science, such as John Holland (the creator of genetic algorithms), Christopher Langton (the developer of artificial life) and Stephan Wolfram (a leader in the study of cellular automata) have played an important role in the creation and development of this field, agent-based modeling is a field of study unto itself. In other words, not everyone who develops or uses the techniques of agent-based modeling consider themselves to be complexity scientists (Axelrod 1997; Cilliers 1998; Epstein and Axtell 1996; Holland 1998).

Methodological Note

As with our review of the topics of complexity science, we relied upon several sources to establish timelines of the major developments in computational modeling as well as conceptual overviews of the field: (1) *American Association of Artificial Intelligence* (www.aaai.org), (2) *American Society for Cybernetics* (www.asc-cybernetics.org/index.htm), (3) *Wikipedia* (www.wikipedia.org), (4) *Eric Weisstein's World of Science* (scienceworld.wolfram.com), (5) *Journal of Artificial Societies and Social Simulation* (jasss.soc.surrey.ac.uk/JASSS.html) and (6) the *Santa Fe Institute* (www.santafe.edu).

In addition, over a three-year period we conducted an in-depth overview of the mathematical and computational science literature by immersing ourselves in a re-education in mathematics, including an extensive review of many of the key research topics in modern mathematics and computer science: set theory, fuzzy set theory, the calculus, discrete mathematics, matrix algebra, linear algebra, statistics, graph theory, network analysis, dynamical systems theory, fractal geometry, chaos theory, neural networking, cluster analysis, cellular automata, power laws (probability density functions, log-log graphs), scaling behavior, genetic algorithms and multi-agent modeling. We also examined the mathematical and computational literature in mathematics, physics, biology, ecology and economics to understand how complexity science uses such key concepts as Brownian motion, stochastic processes (Markov chains), phase distributions, tipping points, self-organizing criticality, fitness landscapes, game theory, predator-prey models and artificial life.

In addition, the senior author of our book published two papers on data mining and its usage in the study of health, health care, and education (Castellani, Castellani and Spray 2003; Castellani and Castellani 2003).

Finally, we made use of an extensive list of monographs and articles published on the topic of complexity science method. The following is a list of some of the more important references we used: cellular automata (Wolfram 2002); chaos theory (Gleick 1987), neural networks (Garson 1998; Kohonen 2001); fuzzy logic (Kosko 1993), genetic algorithms (Holland 1995), fractal geometry (Capra 1996; Mandelbrot 1983), artificial life (Adami 1999; Langton 1990), complex network analysis (Watts 2004), multi-agent modeling (Miller and Page 2007).

Based on the above information, we arrived at the outline presented in Map 1. First, we identified the two major intellectual traditions of agent-based modeling: cybernetics and artificial intelligence. We then identified all of the smaller areas of research that are part of agent-based modeling. Finally, we identified other methods that do not easily fit under the heading of (but are associated with) agent-based modeling, namely dynamical systems theory, social network analysis, complex network analysis, fuzzy logic, and data mining.

5.2.6.1 Overview

While complexity science is generally hailed as a paradigm shift, a strong argument can be made that it is primarily a shift in method. This is not to take away from the concepts and theories that complexity scientists have developed. But, as we explained in our review of artificial intelligence, without the computer the field of complexity science would probably not have emerged (Capra 1996; Casti 1999; Cilliers 1998; Gilbert and Troitzsch 2005).

The same probably can be said of SACS—without the computer, this community would not exist. While the method of choice for some scholars working in the LSC (i.e., Luhmann 1995), the British-based school of complexity (i.e., Urry 2003) and sociocybernetics (i.e., Geyer and Zouwen 2001) is historical, and while there is a small but growing network of sociologists who are interested in creating a toolbox for doing qualitative complexity science (Castellani, Castellani and Spray 2003; Castellani and Hafferty 2006; Ragin 2000), the majority of research done in SACS is computational based. In fact, as we show in detail later, it is through their creation, critical usage and development of the computer and computational modeling that SACS scholars have had their biggest impact on the broader field of sociology (Gilbert and Abbott 2005).

The major areas in complexity science method upon which SACS scholars draw are (1) agent-based modeling (specifically computer simulation), (2) data mining, (3) artificial intelligence (specifically neural networking), (4) dynamical systems theory (specifically, fractal geometry and chaos theory), (5) fuzzy logic and (6) the new science of networks.

1. Agent-based modeling comes out of artificial intelligence and then widens. It is focused on using the computer as an artificial lab for modeling and studying complex systems, albeit at a reduced level of complexity.

2. Data-mining uses many of the same algorithms as agent-based modeling, except it is designed to find non-trivial and non-obvious patterns in large, high-dimensional real-world databases. These databases can be textual, visual, or quantitative.

3. As we discussed earlier, artificial intelligence (AI) has a long history in complexity science. The most important advances in AI that are used in complexity science and SACS come from distributed artificial intelligence. These advances include neural networking and genetic algorithms.

4. Dynamical systems theory comes out of calculus and the mathematical study of dynamic systems. It uses the computer to solve previously intractable (although often easily formulated) mathematical equations. The first major subfield is fractal geometry. The other major subfield is chaos theory.

5. Although not as major in its impact, the fifth methodology is fuzzy logic: the revamping of set theory through the logic of non-probabilistic, approximate reasoning. Its impact on complexity science is more indirect, primarily through its influence on the work done in agent-based modeling and data mining. Fuzzy logic's impact on SACS is slightly stronger, coming primarily through Charles Ragin and his *Fuzzy-Set Social Science* (2000). Nonetheless, it has yet to receive the full attention of SACS.

6. The final area is the new science of networks. While a topic of research, this area of study is also methodologically driven (Scott 2000). Relying on an integration of graph theory, discrete mathematics, data-mining, social network analysis, power laws, probability density functions and agent-based modeling, this methodology attempts to understand the structure and dynamics of large-scale, complex networks, be they physical (internet), biological (viruses), or social (global economy).

While all six methodologies listed above have their important differences, they are similar in three important ways. First, they all find traditional mathematical modeling and statistics limited in their ability to effectively model complex systems. Second, they are all, for the most part, computationally based. Third, they are qualitative in orientation.

Because we spend significant time in the next chapter reviewing the new science of networks, our review below focuses primarily on dynamical systems theory, agent-based modeling and data mining. Furthermore, because of their overlap, we will combine artificial intelligence with agent-based modeling. Finally, given the constraints of time, and because of its marginal role in complexity science, we also will not review fuzzy logic here. For an excellent "popular" review of the field see Kosko (1993). For an excellent technical account see Klir and Yuan (1995). For an excellent overview of the application of fuzzy logic to sociology, see Ragin (2000).

5.2.6.2 Dynamical Systems Theory

The reason dynamical systems theory is so important to complexity science is because it represents a mathematical breakthrough in the study of complex equations, also technically referred to as complex systems (Bar-Yam 1997). As Capra explains, complexity science is not the sudden awareness on the part of scientists that the world is complex. That the world is complex is an obvious fact. What made complexity science possible—and this is why we can argue that it is more a methodological, rather than theoretical revolution—is that scientists finally created a set of methods that could model this complexity. This is where dynamical systems theory comes in.

As Capra states: "To avoid confusion it is useful to keep in mind that dynamical systems theory is not a theory of physical phenomenon but a mathematical theory whose concepts and techniques are applied to a broad range of phenomena" (1996, p. 113). The genius of dynamical systems theory is that the scholars working in this field of mathematics found ways to more effectively model the complexity of life by making advances in their understanding and usage of complex, highly dynamic, mathematical equations, which they call dynamical systems (Weidlich 2000).

Dynamical systems theory and its programs of research—the most important of which are chaos theory and fractal geometry—is a new field of study that uses a variety of computational techniques to solve what have been, historically speaking, highly complex mathematical functions, that is, equations/formulas that cannot be easily solved or plotted (Capra 1996; Mathews, White and Long 1999). These computer-based solutions, however, are not based on traditional forms of proof. Instead, they are found algorithmically and iteratively, using the incredible processing power of computers (Capra 1996, p. 128).

For example, while the mathematical genius and creator of fractal geometry, Benoit Mandelbrot, arrived at many of his mathematical insights through his desire to more accurately model the natural world (coast lines, stock market fluctuations) and while scholars have used his ideas to make important advances in the study of chaotic and complex systems (fractal scaling, fractal self-similarity, strange attractors), his insights are first and foremost mathematical breakthroughs. In other words, he created/ advanced a new form of geometry that is better able to handle the dynamics of certain complex functions. Once realized, these insights were used to more effectively model certain types of real-world complex systems. The same is true of chaos theory. It is a breakthrough in our understanding of the real-world because it is a breakthrough in our understanding of chaotic mathematical equations and formulas (Cilliers 1998; Gleick 1987).

In terms of complexity science, the insights of fractal geometry and chaos theory are important in two ways. First, they have given scholars an important list of concepts—fractal scaling, self-similarity, deterministic chaos, self-affinity and strange attractors—to use in their study of complex systems. Second, they have helped to clarify the relevance that chaos and chaotic dynamics have in the study of complex systems: the basic consensus amongst complexity scientists is that, while chaos plays an important role in the emergence, self-organization and evolution of a complex system, complex systems are not entirely chaotic; instead, they function at the edge of chaos in a position referred to as *operating far from equilibrium* (Kauffman 2000). Examples of the application of this second insight include Bak's concept of self-organized criticality to stock markets (1999), Gunduz's application of scaled growth to ancient empires (2000, 2002), and Abbott's application of self-similarity to the dynamics of the social sciences (2001).

Still, for all these insights, dynamic systems theory and its usage of the computer to solve complex mathematical equations is, in and of itself, insufficient for the study of complexity (Cilliers 1998)—although a few, such as Weidlich (2000), might somewhat disagree. What complexity scientists also need is a set of computational tools that can break free of an equation-based approach to the study of dynamical systems, which dynamical systems theory still, in many ways, relies upon. It is for this reason that the field of agent-based modeling has become such an important methodological tool to scholars in SACS (Holland 1998; Waldrop 1992; Wolfram 2002).

5.2.6.3 Agent-Based Modeling

Agent-based modeling is the culmination of a long list of fields of study and programs of research. These include artificial intelligence (primarily distributed artificial intelligence), cybernetics, fuzzy logic, systems science and obviously, although not shown on Map 1, computer science (Axelrod 1997; Cilliers 1998; Epstein and Axtell 1996; Holland 1998). In addition to a growing list of simulation platforms and software programs—*Swarm* (www.swarm.org), *Sugarscape* (Epstein and Axtell 1996)—some of the more popular methodological techniques include cellular automata (Wolfram 2002), genetic algorithms (Holland 1998), artificial neural networks (Garson 1998; Kohonen 2001), artificial life (Adami 1999; Langton 1990) and multi-agent modeling (Epstein and Axtell 1996; Klüver, Stoica and Schmidt 2003). In terms of SACS, the major program of research in this methodological area is *computational sociology* (Gilbert and Troitzsch 2005).

Regardless of the computational technique used, the goal of agent-based modeling is to use the computer to simulate (as complex) some aspect of reality. Agent-based modeling does this by creating an artificial world on the computer that is a reasonably accurate, albeit more basic model of whatever the complexity scientist is interested in examining (Axelrod 1997; Casti 1999). Such models include, for example, the mind (which is why agent-based modeling emerged from the field of distributed artificial intelligence), genes, biological cells, evolutionary cycles, social networks, social organizations, the economy, and ecosystems (Capra 1996). The constant goal across all these models is to understand how complex systems work by simulating them on the computer and then studying the product (Axelrod 1997).

The usage of the computer to simulate complex systems, however, does not make agent-based modeling unique. Since the computer first emerged, system scientists and scholars in cybernetics have used a variety of computational techniques to simulate social complexity. One of the most well-known is *system dynamics*, created by the systems scientist, Jay Forrester. Readers may have encountered this model indirectly through the popular (but controversial) work of Donnella Meadows and colleagues, who were some of the first researchers to simulate the future environmental impact of globalization—see *The Limits to Growth* (1972) and *Beyond the Limits* (1992).

While complexity scientists recognize the utility of these older ways of using the computer to simulate complexity, they ultimately believe that, in order to simulate a complex system, a computational model needs to act like one—albeit, as Axelrod explains (1997), at a more abstract and simpler level. In other words, a computational model needs to be (to the best of the scientific community's abilities) agent-based, rule-following, self-organizing, emergent, dynamic, adaptive, evolving, operating in a position far from equilibrium, and open-ended.

One strategy scholars use to make their models agent-based, rule-following, self-organizing (and the rest of the above list) is by designing their models to emerge from the bottom-up. This is what makes agent-based modeling unique in the world of computational modeling—the belief that the global dynamics of complex systems are best understood by assembling them from the micro-level upward.

One avenue to understanding the *bottom-up* approach, is to begin with what it is not, namely a "top-down" approach—using traditional computational modeling, statistics, and most mathematical modeling. In the top-down approach, the model is defined in advance and viewed 'from above,' in the aggregate (Klüver, Stoica and Schmidt 2003). As in Foerester's *system dynamics* (a differential equation approach), the researcher decides ahead of time on a set of variables and, more important, on their relationships including the type, strength, and level of importance. All that is left to do is run the model. Scenarios can be changed, but only in advance by changing the variables and parameters within the system.

Agent-based modeling takes the opposite approach. Rather than begin with a set of variables and their predefined relationships, agent-based modeling begins with a set of predefined agents and the rules for their operation (Holland 1998). The rule of thumb here is that the emergent properties of a complex system result from a network of interdependent, interconnected and interactive agents carrying out a basic set of rules. Agents can be anything: a genetic code, neuron, biological cell, person, animal, social group, organization, ecosystem, country, etc. So can the rules. They can be simple, as in the case of John Conway's original *Game of Life*, or they can be more complex, as in the case of a game like *SimCity*®. Either way, the complex, global dynamics of an agent-based model result from its network of agents adaptively and locally performing a set of rules (algorithms) over a defined period of time (iterations/discrete cycles).

For these two reasons, agent-based models are sometimes referred to as "self-organizing." With little or no external pressure or over-riding guidance from a pre-defined set of meta-rules—although the researcher obviously monitors and, to an extent, controls the modeling process—the network of agents within an agent-based model settle into their own pattern of order (Goldspink 2000, 2002; Holland 1998). As such, and as Epstein explains (2007), agent-based modeling could be alternatively (and perhaps more accurately) called *constructive modeling*, *generative modeling* or *recursive modeling*. The complexity of a system is built working from the ground up.

Regardless of the name used, when this algorithm-based, discrete, iterative, self-organizing, agent-based model is set in motion, the researcher examines the type of adaptive, emergent system that is created and the self-organizing processes by which it evolves and is formed (Axelrod

1997; Bak 1999; Capra 1996; Cilliers 1998; Holland 1998; Kauffman 2000; Klüver, Stoica and Schmidt 2003).

At this point, a caveat is necessary. While neural networking, cellular automata, genetic algorithms, multi-agent modeling and the long list of computer platforms and software programs associated with agent-based modeling fit the general definition of a "bottom-up" approach to addressing issues of complex systems, this is about as far as any statement of communalities can go. To go beyond this and argue that all of the techniques listed above act alike or are equally useful in modeling complex systems simply is not true. Not only do these techniques differ greatly in the design and complexity of their architecture, they also differ in their purpose and generative power. That is, they differ in their ability to construct a complex system of some degree of validity or reliability, regardless how these terms are epistemologically defined (Epstein 2007; Frank and Troitzsch 2005).

For example, while the neural networking technique known as the Self-Organizing Map (SOM) is an excellent technique for preserving and projecting the complexity of high-dimensional data onto a low-dimensional visual display, and while it is excellent at allowing this data to self-organize into a meaningful set of visual clusters (Kohonen 2001), it is not very useful at simulating the type of self-replication and system construction (remember the alternative names of agent-based modeling listed above) achieved by cellular automata (Wolfram 2002). By extension, while cellular automata are excellent at mapping the emergence and evolution of a complex system, they are not truly agent-based (Gilbert and Troitzsch 2005). It is therefore important that one have a clear understanding of these different methods and their relative strengths and weakness. With this said, we turn to our final method, data mining.

5.2.6.4 Data Mining

While most reviews of complexity science focus on agent-based modeling and dynamical systems theory, they often forget the third major method in this field, data mining.

Like agent-based modeling, data mining is a highly interdisciplinary field of study, both in terms of the repertoire of techniques it draws upon and the various fields in which it is being applied. In terms of its repertoire of techniques, it is historically grounded in "statistics, machine learning, artificial intelligence and reasoning with uncertainty, databases, knowledge acquisition, pattern recognition, information retrieval, visualization, intelligent agents for distributed and multimedia environments, digital libraries, and management information systems" (Fayyad 1996, p. 23).

In our own work, for example, we used several techniques: k-means cluster analysis, discriminant analysis (particularly its canonical discriminant function), and neural networking, particularly the self-organizing map (SOM). In fact, we have even gone so far as to integrate the SOM (Kohonen 2001) with the qualitative technique known as grounded theory method (Castellani, Castellani and Spray 2003).

Still, regardless of the technique used, data mining is ultimately an exploratory process of knowledge discovery that uses machine intelligence (both supervised and unsupervised) to uncover non-trivial (meaningful) patterns of information in the types of high-dimensional, complex databases that otherwise strain the capacities of current method (Berry and Linoff 2000).

Data mining also is an entire way of thinking about the organization and analysis of data, with the emphasis on an active program of data management. Despite its complex historical lineage and areas of application, and despite variances in the techniques scholars use, there is a general consensus about the purpose of data mining. In contrast to agent-based modeling, which focuses on the simulation of complex systems, data mining focuses on the analysis of real-world empirical databases, particularly the large, complex, multidimensional databases common to our information-technology society. The goal is to use the algorithms of data mining to create and develop a database that researchers can use to generate important and timely information about an ongoing area of inquiry. This is why data mining is so appealing, for example, to the business community.

In grocery sales, for example, the more knowledgeable you are about your shoppers, the better able you are to maintain your inventory. To do this you need to develop an ongoing data warehouse of information, something you will "mine" continually to track changing customer preferences. That is one reason why grocery stores have a "preferred shopper card." These cards not only provide customers with discounts, but they also allow store managers to know what various types of customers might buy in the future based on current shopping preferences. Following the logic of data mining, and operating with very large and complex grocery store data warehouses (thousands of shoppers with long grocery lists), the goal is to find complex, qualitative patterns and rules within the data even though what shoppers buy or will purchase is not known ahead of time. For example, a store may find out there has been an increase in the purchase of organic bread by shoppers who buy peanut butter, This suggests that, if organic peanut butter (higher priced and with a larger profit margin) was shelved next to the organic bread, peanut butter people might purchase this type of peanut butter. This is intelligent data mining: as this database is developed by the researcher in terms of the factors and items included, removed or revised, it becomes "smarter" about the preferences and choices of shoppers, thereby making more accurate predictions about what shoppers might like in the future or how their preferences might change.

The utility of data mining to sociology should be obvious. As we mentioned earlier, one of the most difficult challenges facing sociologists today is figuring out how to analyze the incredibly large and complex databases readily available for them to study (Castellani, Castellani and Spray 2003; Gilbert and Abbott 2005). Like complexity science, however, data mining has not been fully realized in sociology. There is, however, a push to make better use of it, primarily through a flurry of recent publications, some of which we mentioned above (Castellani, Castellani and Spray 2003; Castellani and Castellani 2003). This, then, completes our review of the forces of complexity.

6 Five Areas of Research

Now that we have a working knowledge of the key environmental forces impacting SACS, we turn our attention to the inside of this community. As we noted repeatedly, and as shown in Map 4, there are five major areas of research in SACS: complex social network analysis (CSNA), computational sociology, the British-based School of Complexity (BBC), the Luhmann School of Complexity (LSC) and sociocybernetics.

Our goal in this chapter is to review these five areas. We organize our review around the *web of social practices profile* for each area.

As we discussed in Chaps. 2 and 3, the web of social practices profile for SACS is comprised of six sections: (1) *Complexity science lineage*, which explores how the area of research has been historically influenced by systems science, cybernetics and, in some cases, artificial intelligence; (2) *Sociological lineage,* which explores how the area of research has been historically influenced by the various traditions in sociology, particularly systems thinking; (3) *Complexity science method*, which explores how agent-based modeling writ large is used in the particular area of research; (4) *Sociological method*, which explores how the area of research makes use of the various methodologies and techniques currently available in sociology; (5) *Complexity science topics*, which explores how and to what extent the area of research is involved in one or more of the five major themes that dominant complexity science today and (6) *Sociological topics*, which explores the substantive topics, issues and concerns in sociology that are important to the particular area of research.

It is important to note, however, that while we address all six sections for each area of research, we do not address these sections in the same order or give all six sections equal billing in our review of each area of research. For example, while our review of complex social network analysis (CSNA) is broken down according to all six sections, it does not follow the order shown in the previous paragraph. Another example is our review of the British-based School of Complexity (BBC), which collapses complexity science topics and sociological topics into one section.

Finally, if an area of research is comprised of one or more sub-clusters of research, we end by reviewing those areas. For example, CSNA is comprised of two sub-clusters of research: global network society and the new science of networks.

6.0 Complex Social Network Analysis

The first and most popularized area of research in SACS is complex social network analysis (CSNA). It has the following *web of social practices* profile.

Complexity Science Lineage: The term "network" is probably not the first thing that comes to mind when thinking about systems science. Nevertheless, CSNA has a rather fascinating, although not initially obvious, connection with the twin traditions of systems science and cybernetics. As Capra (1996) and others note (Hammond 2003; Jantsch 1980), the term has played an important role in the development of these two traditions, as well as the advancement of complexity science. For example, in the cybernetic study of communications systems, the concept of networks is very important: information networks, telecommunications networks, computer networks, wiring diagrams, graphs, the internet, the World Wide Web, etc. It is also relevant to chemistry including the study of catalytic cycles, dissipative structures, bifurcation points and phase-structures, as well as systems biology and the study of cellular structures and ecosystems. Going even further along the disciplinary food-chain, the term *network* has been crucial to the development of artificial intelligence, starting with McCulloch and Pitts and their first mathematical model of an artificial neural network. The concept of network also is linked to the advances in distributed artificial intelligence and connectionism, and then (finally) to the more recent advances in neural nets, genetic algorithms and agent-based modeling (Garson 1998).

Given this web of influences, the ground-breaking work of CSNA did not just "suddenly emerge." It came from a rather rigorous and important intellectual lineage. The best example is Watts and Strogatz's famous 1998 article in *Nature*, title *Collective Dynamics of Small-World Networks* (1998). If one examines the 27 references cited in this paper, they read like an abridged history of the term *network* in systems and complexity science. There are, for example, references to chemistry, systems biology, artificial neural networks and ecology as well as systems science, cellular automata and dynamical systems theory. More specifically, there are references to Robert Axelrod and Stuart Kauffman: two of the most important pioneers in complexity science. Furthermore, Steven Strogatz, is a widely recognized figure in dynamical systems theory, specifically the study of chaos (Strogatz 1994).

Complexity Science Method: CSNA's connection to the methods of complexity science is more obvious. For example, as the citations in Watts and Strogatz's article demonstrate, CSNA makes extensive use of a variety of areas in complexity science, including graph theory, evolutionary game theory, artificial neural networks and discrete mathematics. It also makes use of agent-based modeling, including Boolean networks and, more specifically, cellular automata. For a thorough and updated review of the major developments in CSNA, go to (1) Albert-László Barabási's website (www.barabasilab.com/) and also (2) the *International Network for Social Network Analysis* (www.insna.org/)

Sociological Method: In terms of sociological method, the most important contribution comes from social network analysis (Scott 2000, 2002; Scott, Carrington and Wasserman 2005). For example, Watts and Strogatz's 1998 publication in *Nature* cites Kochen's (1989) edited volume on the small-world problem and Wasserman and Faust's *Social Network Analysis: Methods and Applications* (1994). Newman and Barabási likewise cite regularly the social network literature, as do many scholars involved in the new science of networks. Wallerstein, Castells and Urry also make regular use of social network analysis, albeit to study world systems, globalization, and the new global network society.

Complexity Science Topics: The most important topic in CSNA is the complex system. As we noted earlier, complexity scientists use the term network and system interchangeably. This is an important point to remember because, when reading the CSNA literature, particularly the new science of networks, one does not see the term system extensively used, although that is what they are often discussing (Capra 1996; Cilliers 1998; Hammond 2003). Capra makes this point, for example, in the study of living systems. He states, "The view of living systems as networks provides a novel perspective on the so-called hierarchies of nature. Since living systems at all levels are networks, we must visualize the web of life as living systems (networks) interacting in network fashion with other systems (networks)" (p. 35).

The etymological relationship between system and network has continued into CSNA. For example, while the LSC and sociocybernetics talk about social systems, scholars in CSNA talk about networks, extending from the *new science of networks* research of Barry Wellman and Phillip Bonacich to the *complex global network* research of Manuel Castells and John Urry. Nonetheless, everyone is talking about the same thing. The main difference is that the scholars in CSNA see the concept of network as the most valuable way to study social systems. In fact, one can define CSNA as the study of the structure and dynamics of large, complex systems, particularly human social systems, through the theories and methods of social network analysis.

Sociological Topics: In terms of sociological topics, the focus of CSNA is rather extensive, ranging from the study of internet communities, mobile societies and global social networks to epidemiology, health behaviors and the spread of disease to professional ties, interlocking directorates and poverty traps. In fact, the work of CSNA is so broad that it cannot be discussed intelligently in anything less than a book. For a good introduction to this far-reaching literature see Barabási (2003), Buchanan (2002), Freeman (2004), Scott (2000, 2002), Scott, Carrington and Wasserman (2005) and Watts (2003).

Here are, nevertheless, two examples. The first comes from the sociology of occupations and the sociology of organizations literature (Capra 2002). Here the focus is on the network structure and dynamics of formal organizations, businesses, and their various economic associations (Salganik, Dodds, and Watts 2006). Interestingly enough—and we do not have time to address this issue fully—scholars in CSNA have not developed the study of formal organizations to the extent one might imagine (Freeman 2004). In fact, if one wants to learn more about organizations as complex social networks, one has to go to another area within complexity science altogether: the computational economics, management sciences and business literature (Hammond 2003). Like CSNA, all three of these areas have a rich connection to systems science, cybernetics and the development of complexity science method, including associations with (1) the *Sloan School of Management* at the *Massachusetts Institute of Technology*; (2) the systems dynamics work of Jay Forrester (sysdyn.clexchange.org/ people/jay-forrester.html) and (3) the soft systems methodology of Peter Checkland (www.lums.lancs.ac.uk/profiles/peter-checkland/). As a side note, Checkland is a professor at *Lancaster University*, UK, where John Urry and many other leading scholars in the British-based school of complexity are employed or affiliated.

The second example comes from the globalization literature, which is housed, in part, in the British-based school of complexity. This literature draws extensively on the "global network theory" of Manuel Castells (2000a, 200b), the world systems theory of Wallerstein (2005), and the global complexity and mobile sociology literature of John Urry (2003). We will discuss this second example in greater detail below.

Sociological Lineage: Within sociology, CSNA draws upon a variety of micro-interactionist traditions, including exchange theory, game theory, rational-choice theory, and symbolic interactionism. All of them, in one way or another, are linked to the theoretical and conceptual work of social network analysis. As Freeman explains (2004), although social network analysis tends to be treated primarily as a method (Scott 2000), it is also a theory with significant connections to cultural anthropology (exchange theory), political economy (game theory, rational-choice theory) and agency-oriented theories such as symbolic interactionism. One can even go further and trace many of these micro-level theories to Emile Durkheim—who is on our short list of founding "sociological systems thinkers."

6.0.1 The Sub-Clusters of CSNA

While the above profile provides a general introduction to CSNA, its scholars can be divided into two major subclusters of study, each with its own unique take on the traditions, methods and topics of sociology and complexity science.

6.0.1.1 The New Science of Networks

The first subcluster of research in CSNA is the *new science of networks*. As shown in Maps 4 and 6, in addition to Duncan Watts, other key scholars in this field include Albert-László Barabási, Mark Newman, Philip Bonacich and Barry Wellman.

Albert-László Barabási is *Emil T. Hofman Professor of Physics* and Director of the *Center for Complex Networks* at the University of Notre Dame, USA. Like Watts, Barabási's focuses on the structure of complex networks. Barabási's focus, however, has taken him in an entirely different direction. Shortly after Watts's ground-breaking work on the small-world phenomena, Barabási and his team made several discoveries to do with the scale-free nature of large networks (www.nd.edu/%7Ealb/html/people.html). Put simply, Barabási found that the network connections in complex networks follow a power law, with the mostly densely connected nodes being the least frequent and the least connected nodes occurring the most, and he found this to be true at multiple levels. Like Watts, this insight gave researchers some confidence that complex networks, although overwhelming in their structure, are not entirely random. Instead, they adhere to one of the dominant principles of the universe: order exists amidst chaos. Barabási and his research team have recently turned their attention to the structure of economic and human-disease networks. For a detailed overview of their projects, along with some tremendous graphics, go to the *Center for Complex Network Research* (http://www.nd.edu/~networks/) or their *Product Space and Wealth of Nations* website (www.nd.edu/%7Enetworks/productspace/index.htm).

Mark Newman is *Professor of Physics and Complex Systems* at the University of Michigan, USA. He is also a faculty member in the *Center for the Study of Complex Systems* at University of Michigan—the brainchild of John Holland and home to Robert Axelrod—and he is an external faculty member of the Santa Fe Institute. As stated on his website, Newman is interested in three key aspects of networks: affiliation, collaboration and network flows (www.lsa.umich.edu/physics/peopleprofile/0,2708,,00.html?ID=802).

Affiliation has to do with "who knows who in a community, how contact networks form, and how structure affects the diffusion of information over networks…" (Ibid). Collaboration has to do with information exchange, as in the "networks of scientists and business-people…" (Ibid). Flows have to do with such phenomena as the spread of disease and infection through a network, as well as network epidemics.

Philip Bonacich is *Professor of Sociology* at the University of California, Los Angeles (UCLA) and Editor of *Journal of Mathematical Sociology*. He is an important figure in the history of social network analysis, and is known for such methodological innovations as his modification of the degree centrality approach, a measure of how connected and influential people are in a social network (Scott 2000; Scott, Carrington and Wasserman 2005). In fact, Bonacich's methodological innovations connect him to the new science of networks, where he is applying evolutionary game theory, cellular automata and simulation to the study of social networks. His reviews of key publications in the new science of networks have also helped to bridge the divide between sociologists and complexity scientists (2004a, 2004b). So have his involvements in the development of the *UCLA Center for Human Complex Systems*, one of the few undergraduate programs in the United States devoted to the study of complex networks (hcs.ucla.edu/home.htm).

Barry Wellman is, in the language of network analysis, an authority. Hubs, like Duncan Watts, are the most densely connected nodes in a network; authorities, like Wellman, facilitate linkages. One small example is the numerous academic titles Wellman holds. Here are just a few: (1) *S.D.* Clark Professor of Sociology, *University of Toronto*; (2) Research Associate, *Centre for Urban and Community Studies*, University of Toronto; (3) *NetLab* Director; and (4) International Coordinator, *International Network for Social Network Analysis* (INSNA). He also is a major historical figure in social network analysis, responsible for almost single-handedly creating INSNA (www.insna.org), which houses three of the field's top journals, *Social Networks*, *Journal of Social Structure* and *Connections*. Wellman's current research focuses on the structure and dynamics of network communities in cyberspace (Wellman and Haythornwaite 2002). Previous research, which connects him more directly to the second subcluster of research in CSNA (global network society) focuses on how people around the world develop and maintain local, personal networks in today's global society (Wellman 1999).

With the key scholars identified, we turn to a bit of history. The name for the new science of networks subcluster of research comes from a 2004 article that Duncan Watts wrote for the *Annual Review of Sociology*, titled, appropriately enough, *The "New" Science of Networks*. According to Watts, the new science of networks has the following profile:

- It builds "on a long tradition of network analysis in sociology and anthropology (Degenne and Forse 1994; Scott 2000; Wasserman and Faust 1994)" (p. 243).
- It builds on "an even longer history of graph theory in discrete mathematics (Ahuja et al. 1993; Bollobas 1998; West 1996)…" (p. 243).
- It is "spurred by the rapidly growing availability of cheap yet powerful computers and large-scale electronic datasets…" (p. 243).
- Its scholars come from a variety of disciplines, including "the mathematical, biological, and social sciences…" (p. 243).
- Its goal is to make "substantial progress on a number of previously intractable problems, reformulating old ideas, introducing new techniques, and uncovering connections between what had seemed to be quite different problems" (p. 243). Examples of intractable problems include the analysis of large-scale, complex networks, the study of the evolution and transformation of complex networks over time, and the study of how information, innovations, disease, cultural fads and so forth flow/move through complex networks (See Newman, Barabási and Watts 2006). Old ideas include affiliation networks, the small-world problem and community structure. New techniques include discrete mathematics, the power law, cellular automata and agent-based modeling. Cross-disciplinary connections include similarities in network structure at different levels of scale, from a protein to a human organization to an ecosystem.

The reader may recall, as we discussed in Chap. 5, the new science of networks typically is treated by popular reviewers as the latest and greatest topic in complexity science, with a slight nod to sociology (Buchanan 2002). It is because of this exegetical tendency that we placed the new science of networks on Map 1 at the far right-end of the complexity science trajectory.

The hermeneutical reality, however, is that the new science of networks is just as much a part of organized sociology as it is complexity science. Watts concedes this historical point in his 2004 article when he states that the label "new science of networks" may "strike many sociologists as misleading, given the familiarity (to social network analysts) of many of its central ideas" (p. 342). "Nevertheless," he argues, "the label does capture the sense of excitement surrounding what is unquestionably a fast developing field—new papers are appearing almost daily—and also the unprecedented degree of synthesis that this excitement has generated across the many disciplines in which network-related problems arise" (p. 243).

In fact, Watt's statement is so correct that we used it to add a sixth characteristic to the new science of networks profile: the scholars of the new science of networks are primarily interested in the structure and dynamics of networks; with only a secondary concern for substantive problems in social network analysis. If one looks, for example, at the 2,393 *Web of Science* publications that reference Watts and Strogatz's 1998 article, approximately 75% or more are in the subject areas of physics, mathematics, computer science, biology, and cognitive science. Many of these articles, in turn, use or apply their ideas to substantive topics in social network analysis. However, for the most part, their primary focus is the structure and dynamics of complex social networks in general—not sociology.

However, and once again, this empirical fact does not dismiss the importance of sociology to the new science of networks. While the study of complex social networks has become a major topic for complexity scientists (Buchanan 2002), and while these scientists (mostly physicists) have arrived at some incredible results through the usage of computational and mathematical modeling (Barabási 2003), these insights (all several thousand articles worth of them) do not trump or diminish the work that sociologists have been doing in social network analysis for the last thirty-five years (Bonacich 2002; 2004b; Freeman 2004; Morris 2004). For example, as Bonacich (2004b) and others have pointed out (e.g., Freeman 2004; Morris 2004), the complexity science literature repeats many of the insights of earlier social network research: small-worlds, short-cuts, weak links, centrality, clustering. Furthermore, the complexity science literature, while mathematically grounded, is theoretically lacking when it comes to understanding real-world networks. Again, Watts concedes this point: "Physicists may be marvelous technicians, but they are mediocre sociologists" (2004, p. 264).

Given these numerous shortcomings, why is the new science of networks part of SACS? Two reasons: First, as we already suggested, the new science of networks needs the substantive theories, concepts and real-world experiences of sociology. That is why so many of its scholars, from Watts to Newman to Barabási, have reached out to sociologists and their work. Second, whether mainstream sociology likes it or not, social network analysis needs the new science of networks. Despite all of the criticisms against complexity science, many sociologists realize the importance of integrating complexity science with social network analysis (Bonacich 2004a; Freeman 2004; Morris 2004). The new science of networks represents a much desired future for social network analysis and for addressing sociology's complexity: an interdisciplinary and international network of scientists, supported by a wide-ranging institutional structure, well-trained in applied mathematics and, more important, the computational techniques of agent-based modeling, thoroughly grounded in the theoretical and methodological traditions of sociology and social network analysis, epistemologically beyond the trappings of reductionism and the linear model of statistics, making use of very large databases, which they can employ for studying various aspects of our emerging global (network) society. As Bonacich states, "We are lucky that physical scientists and mathematicians have become interested in social networks. Of course we feel slighted; not all of our contributions will be noted. But this is the cost of moving onto a very much larger intellectual stage" (2004b, p. 4).

6.0.1.2 Global Network Society

If the new science of networks is distinct because of its secondary concern with topical application, the study of *global network society* is the exact opposite. It is almost entirely driven by its substantive concerns. Slightly modifying our original definition of CSNA, the goal of global network society is to study the structure and dynamics of global society through the theories and methods of network analysis.

It is because of this unique "network" approach that global network society not only holds a distinct position within CSNA and SACS, but also the globalization literature (Urry 2003). We can state this uniqueness as follows: While the new science of networks involves the realization that one can study very large, complex networks; global network society is the realization that global society is best viewed as a large, complex network, or, more accurately, a series of complex networks within networks within networks (Capra 2002). Let us explore this idea in greater detail.

To Globalize or Not to Globalize

The first and most difficult hurdle to jump in the globalization literature is not empirical but epistemological. Before one can ever consider the data, one must decide which view of globalization is correct. This sounds backwards, and it is.

Fact: the increasing interdependence of our global existence, including animal and plant, cannot be adequately contained within the confines of any one theory (Capra 2002). Globalization is too new, too fast and just too complex and overwhelming a force. Any theory, no matter how good, is underdetermined by the evidence. As such, no one theory holds sway. Instead, there are several competing views.

In his book, *Global Complexity*, Urry summarizes these views into one of several types—although none are mutually exclusive. First, there is *globalization as social networks* (Urry 2003, p. 4). All around the world, the social networks in which people participate are becoming less local and more global; and, in the process, these networks are transcending, undermining, overcoming and deflating traditional networks defined by one's nation, state, culture or economy. The most poignant example is the new trans-national world of business, with its corresponding world-wide network of banking, raw materials, and product distribution. As leaders in the business community, these individuals work all over the world; as parents they send their children to international baccalaureate programs; and as private citizens they secure their retirement in one country, buy their homes in another; and have friendship networks that span the globe.

The second is *globalization as information technology* (Urry 2003, pp. 4–5). Information technology—cells phones, computers, microchips, smart machines, faxes, the internet, the World Wide Web, satellites, televisions, etc—has radically altered the geography of modern life, undermining the modernist notions of time-space, including the creation of an electronic world community (Wikipedia, Myspace.com, YouTube, etc). Variants of this view include Freidman's (2007) the-world-is-flat perspective.

Perhaps the most optimistic view is the third: *globalization as neo-liberal ideology* (Urry 2003, pp. 5–6). Depending upon one's country of perspective, this view alternatively is labeled as neo-conservative (USA), neo-liberal (England) or western (South America). Whatever the label, the view is that globalization represents the gift of western society to the rest of the world, including its businesses, capitalism, democracy, and civil rights. Globalization is great because it "frees up" markets and economies so that capitalism, along with its economic, cultural and political benefits can be more globally fluid.

The fourth is *globalization as performance* (Urry 2003, pp. 6–7). This view focuses on cultural transformation, with the hope of bringing forth in people a global conscience and a global humanity. From this perspective, globalization is cultural praxis. It is a tool for changing how people act, including their behaviors toward oppressed and marginalized people, inequality, the environment, working conditions, and so forth. The *global warming* movement and the related work of Al Gore is an example of this type of globalization.

The final perspective is *globalization as a complex system* (Urry 2003, pp. 7–8). This is, generally speaking, the perspective of those working within the area of global network society. The most widely known scholars include Immanuel Wallerstein, Manuel Castells, John Urry and, to a lesser extent, Barry Wellman.

Is the Entire World a Complex Network?

The GSN literature is massive, both in its ambitions and in its verbiage. First, there are the ideas themselves, which includes the work of Immanuel

Wallerstein and his groundbreaking world systems theory. As we explained earlier in our discussion of the Gulbenkian Commission, Wallerstein's work did not begin in complexity science. Instead, it emerged out of the intersection of three major influences.

The first influence is the great French Historian, Fernand Braudel, from whom Wallerstein develops his idea of the longue durée (large historical cycles) and the extensive network structure of global capitalism.

The second influence is dependency theory, from which he creates his notions about the way dominant, hegemonic countries (particularly those in the west) exploit peripheral, agrarian-based societies, such as those in the south and the east. Here, Wallerstein claims that globalization is a euphemistic term for the global encroachment of western capitalism and the capitalistic machine. This view, which focuses entirely on the world economy, could equally be called an anti-globalization perspective.

The third influence is global Marxism. Traditional Marxists (particularly in sociology) focus on the structure and dynamics of social class as it takes place within particular nation-states such as England during the 1800s. Wallerstein focuses on the *fin de siècle* of capitalism: colonial-imperialist relations at the global level.

By interlacing all three influences, Wallerstein creates a stunning conceptual and visual map of the world and its countries, which he divided into three tiers: core, semi-peripheral and peripheral. The core has all the resources and power and the periphery has little to none; the semi-periphery is somewhere in the middle. Using this geographical lexicon, Wallerstein has, over the years, examined the structure and dynamics of this three-tier system, primarily along economic lines, with profound insights. Within the past decade, he has pulled into his theoretical framework concepts from complexity science, talking about the world system in terms of bifurcation points, perturbations, chaos and turbulence, networks, emergence and self-organization (2004, 2005).

With over seventeen books and numerous articles, essays, lectures, invited speeches and commentaries, Wallerstein is one of the most influential scholars in sociology and the globalization literature, only outdone by our second scholar, Manuel Castells. At present, Castells is one of the most widely cited scholars in sociology, with over 3,000 citations on *Social Science Citation Index*.

Castells is best known for his monumental trilogy, *The Information Age: Economy, Society and Culture*—originally published by Blackwell between 1996 and 1998 and revised and published as a second edition between 2000 and 2003. The premise of this trilogy (and subsequent works) is that a new form of social structure has emerged, which Castells calls *network society*.

There are three causal mechanisms responsible for network society, all of which took place during the last thirty years of the 20th century: (1) the counter-culture movements of the 1960s in North America and Western Europe; (2) the "socioeconomic restructuring of both capitalism and statism" (Castells 2000, p. 694); and (3) the computer and information revolution, which has increasingly spread to the east and the south. Of these three, the information revolution is the most important, hence the title of his trilogy, *The Information Age*.

Castells' emphasis on western society's shift to information technology parallels the thesis of Daniel Bell's *The Coming of Postindustrial Society* (1974/1999). This thesis is as follows: the computer and information revolutions have changed the world. Unlike Bell, however, Castells does not confine his inquiry to western society. Furthermore, Castells has the advantage of time. Bell published his work in 1974, with a slight revision in 1999. Castells published his trilogy in the late 1990s, just as the internet, World Wide Web, and so many other forms of information technology were gaining momentum. Finally, Castells does not argue that the information revolution caused network society; instead, network society capitalizes on the information revolution.

Network society is historically unique because it responds to and makes extensive use of information technology to create new forms of economic, political and cultural organization. Network society is also unique because these new forms of organization are creating a new global network and corresponding geography. The term "network" therefore explains two things for Castells.

First, it explains "how" people use information technology to transcend traditional notions of time-space to connect with others around the world. Here, one thinks of people who are good at "networking" with others, including power lunches, passing out business cards, winning friends and influencing people. At the global level, networking extends to the behaviors of businesses, formal organizations and so forth. These connections can be economic, as in the case of the global economy; they can be political, as in the form of new activist movements; or cultural, as in the form of internet communities and virtual reality. In all three instances, the traditional boundaries of nation, state, culture, and identity are transcended (at least partially) to create new forms of social organization. And, what do these new forms of organization look like when plotted? Here is the second thing networks explain. They look like complex, technology-based, dynamic, fragmented, chaotic, flowing, self-organizing, autopoietic, open-ended, emergent, global, social networks.

With these two aspects of network explained, we come to a major point for Castells. Globalization is not the process of the current world, as we know it, becoming a smaller place. Little in the data suggests this to be true. Traditional forms of society have not gone global. Instead, the opposite has happened. The traditional forms of society are beginning to disappear and are being replaced by network society. Stated another way, globalization represents the emergence of network society. It is network society that has gone global.

Here we come to another major point for Castells. As network society increases its global hold on the world, its new forms of economy, politics and culture are clashing with older, traditional notions. These clashes have major consequences for our globe, including (1) the slow collapse of the nation-state, (2) a reactionary rise in fundamentalism, (3) the backward-looking emergence of nationalist identities, (4) a growing divide between the information class and the rest of the world, (5) the partial breakdown of the welfare state, and (6) increasing difficulties in monitoring, controlling and regulating network society as it ebbs and flows between order and chaos, regularity and disaster.

Interestingly, Castells' solution for these global social problems, along with the information revolution that is fueling them, is more networks. According to Castells, network society has emerged because it provides people a level of flexibility and adaptability that the older forms of economics, politics and culture do not. Think, for example, of businesses outsourcing their work—or of international trade, global markets, internet-based communities or electronic trading—all powerful ways to handle or capitalize on the information revolution to get ahead in business. Likewise, we have activist groups around the world using the internet and telecommunications to momentarily cluster together for such things as Earth Day or the World Trade Organization meetings. Then there is the ability of people to use the internet to open-up and undermine the totalitarian states in which they live. Like the Ouroboros eating its own tail, network society feeds off itself. Network society is the best way to respond to and make use of the information revolution, which, in turn, accelerates the expansion of the information revolution, which leads to more network society, and so on. This, Castells argues, along with its conflict with the older forms of society, is the globalization phenomenon.

John Urry, our third major theorist, could not agree more. In fact, he is willing to take Castell's argument one step further. Not only is network society real, it has become a massive, world-wide, complex system: self-organizing, bifurcating, autopoietic, emergent, chaotic, unstable, operating far-from-equilibrium. In 2003, Urry published the first full articulation of his view in his book, *Global Complexity*. This was not, however, his first swing at the topic of globalization. Urry has been at the business of studying globalization for quite some time, including the publication of a long list of rather provocative books and papers, earning him over 500 citations. In his work, which runs from such topics as *The Tourist Gaze* (1990) and

Consuming Places (1995) to *Mobile Sociology* (2000a) and *Sociology Beyond Society* (2000b), Urry does not try to shock or impress readers with his usage of the latest theoretical trick or methodological gadget. As he explains in his opening statement to *Global Complexity* (2003), he draws upon new ideas in hopes of improving his sociological imagination. This is the hope that led him to complexity science and, from there, to the idea that globalization (or, more specifically, Castell's global network society) is best viewed as a complex system.

During the course of his research, Urry found himself struggling to make sense of the massive complexity associated with globalization. As a consequence, Urry began to read the complexity science literature. This led him to realize that while the current globalization literature has done a great job highlighting and developing our understanding of the world today, it ultimately is doomed to failure because it lacks a sufficient theory of global complexity. Fortunately, the field of complexity science, when effectively integrated with sociology, provides just such a theory. Urry had the beginnings of a new framework. In *Global Complexity* (2003) he explores this new framework.

At this point a caveat is necessary. Because Urry's ideas are in the initial stages of development, *Global Complexity* (2003) is more of a work-in-progress than a formal statement. It is not well defended empirically and it is not a systematic treatise. Instead, Urry's purpose is more focused. He wants to get the reader to consider the idea that global network society might be a complex system. If Urry is correct—which can only be established by rigorous empirical study—he will have provided a major breakthrough in our understanding of the new global world in which we live.

6.1 Computational Sociology

The main methodological cluster of SACS is computational sociology. It has the following *web of social practices* profile.

Complexity Science Lineage: The most fascinating aspect of computational sociology is the extent to which its historical trajectory parallels the development of complexity science method, including the intellectual traditions upon which it draws (Gilbert and Troitzsch 2005). In fact, computational sociology looks remarkably similar to the methodological trajectory we outlined in our review of complexity science method in Chap. 5. Because of this parallel, we refer to computational sociology as a microcosm of complexity science method.

As stated in Chap. 4, computational sociology is a *branch* of sociological inquiry: a formal sub-field extending outward across the discipline into new territories. Since the 1950s when it first emerged, computational sociology has mimicked the methodological developments of systems science and cybernetics, and still later complexity science (Gilbert and Troitzsch 2005). This includes drawing upon and (in some cases) developing key areas within modern mathematics, computer science and artificial intelligence such as graph theory, matrix algebra, structural modeling, distributed artificial intelligence, system dynamics, game theory, computational modeling, fuzzy logic, and agent-based modeling (Halpin 1999).

For example, the first article in computational sociology was published in 1957 by Guetzkow and Bowes "The Development of Organizations in a Laboratory" (See Halpin 1999, p. 1504). Five years later Guetzkow went on to publish an edited work titled *Simulation in Social Science: Readings* (1962), which included James Coleman's "Analysis of Social Structures and Simulation of Social Processes with Electronic Computers." For readers new to this area, Coleman is a major historical figure in SACS, including his pioneering work in mathematical sociology, rational choice theory, social network analysis and computational sociology. Of particular note is his 1964 classic, *Introduction to Mathematical Sociology.*

As Halpin points out (1999), these early works on computational sociology use or reference many of the development in computational methods at the time, including discrete events modeling and computer gaming. To create a context for the reader, during this same time period (late 1950s to early 1960s) Prigogine introduced his concept of dissipative structures, Wiener published *The Human Use of Human Beings* (1956), Ashby published *Introduction to Cybernetics* (1956), McCarthy and colleagues held the first artificial intelligence conference at Dartmouth (See Chap. 4) and Forrester created systems dynamics—the equation-based, simulation technique most sociologists and social scientists used during this time period (Gilbert and Troitzsch 2005).

For the next forty years, computational sociology would continue to mimic the intellectual lineage of complexity science method, including years of existing on the margins of mainstream social scientific inquiry (Macy and Willer 2002; Gilbert and Troitzsch 2005). As Halpin points out, "Computer simulation has played a significant, although secondary, role in sociology almost as long as sociologists have had access to computers.... However, simulation has waxed and waned in prominence and has always stood apart from the mainstream of sociology, which has not fully appreciated its contribution" (p. 1488). It is somewhat sad and discouraging that the very methods and techniques responsible for so many advances in the natural sciences, along with an important role in the development of the computer, computer science, the internet, the World Wide Web, and in many ways globalization, remained for so long on the margins of social scientific inquiry. But, that is another story. Fortunately, things are changing, thanks to the rising vogue of agent-based modeling. One example is the 2005 Special Edition of the *American Journal of Sociology*, entirely devoted to the history and usage of computational sociology and agent-based modeling.

Complexity Science Topics: There is little in complexity science that computational sociology does not explore (Miller and Page 2007). The only exception is the study of substantive areas such as physics, chemistry and biology. The main themes we discussed in Chap. 5, however, are all addressed: self-organization, autopoiesis, emergence, system dynamics and social networks. For example, of the 273 articles listed on the *Web of Science, Social Science Citation Index* (Accessed Feb 2008) for the *Journal of Artificial Societies and Social Simulation*, all of the major themes in complexity science are addressed, with the most popular being system dynamics (N=18) and networks (N=14).

Sociological Topics: As Miller and Page (2007) and others have acknowledged (e.g., Gilbert and Troitzsch 2005), substantively speaking, computational sociology is very diverse. Its work is all over the place. Not only is computational sociology heavily interlaced with the intellectual traditions and topics of systems science, cybernetics and complexity science, it also crosses a wide array of disciplinary boundaries in the social sciences, ranging from business, political science and public policy to epidemiology, economics and demography to small-group dynamics, ecology and organizations to social networks and environmental and urban planning (Gilbert and Troitzsch 2005; Halpin 1999; Macy and Willer 2002).

An example of this interdisciplinary impulse is Axelrod's review of the 2002 *Web of Science, Social Sciences Citation Index.* While Axelrod found a total of 77 publications for the keyword "simulation," they were published in 55 different journals. The establishment of the *Journal for Artificial Societies and Social Simulation* (as well as *Computational and Mathematical Organization Theory*, *Sociological Methods and Research* and *Behavioral Science*) has gone a long way toward consolidating the research of computational sociology, but the interdisciplinary impulse remains strong.

Another example of this interdisciplinary impulse is computational sociology's name. Depending upon the reviewer, computational sociology is: (1) a branch of sociology (e.g., Macy and Willer 2002); (2) part of some other social science discipline such as computational economics (Miller and Page 2007); or (3) part of the larger field of computational social science (Axelrod 1997; Gilbert and Troitzsch 2005; Halpin 1999).

As a final example, many of the leading scholars in computational sociology are simultaneously situated within different areas of study. Scott Page, for example, is a Professor of Political Science, Complex Systems and Economics at University of Michigan. He is also former director of the *Center for the Study of Complex Systems* at Michigan and an external faculty member of the Santa Fe Institute. Currently, he is one of the rising stars in complexity science and computational modeling (Miller and Page 2007; Page 2007). However, depending upon the reviewer, he is a computational economist, complexity scientist, or computational social scientist. The same conflation is true of Page's colleague at Michigan, Robert Axelrod. Like Page, Axelrod is heavily involved in political science, economics and complexity science, and is variously associated with computational modeling in general, computational social science, computational economics, and computational sociology. We can keep going. Another colleague at Michigan is John Holland, the creator of genetic algorithms and leading historical figure in complexity science. Again, depending upon how his work is approached, he has been situated in all the computational fields we have so far mentioned.

As these examples illustrate, the reason the boundary lines between computational sociology and the various other areas of computational analysis are so often blurred is because their intellectual traditions, topics of study, and areas of substantive research parallel each other to a profound extent. This parallel even continues into the intellectual traditions of sociology.

Sociology Lineage: Both computational sociology and complexity science method draw upon a long list of intellectual traditions within sociology, most of which are micro-level in their orientation: rational-choice theory, exchange theory, symbolic interaction, ethno-methodology, and (at a slightly more meso-level) the sociology of formal organizations. Much of this orientation toward micro-sociology comes from the heavy influence economists and political scientists such as Axelrod and (more recently) Page (2007) and Epstein (2007) have had on computational modeling, as well as the current intractability of modeling large-scale social systems (Axelrod 1997).

There is, however, an emerging meso/macro level literature in computational sociology and complexity science method, which is focused on developing a rather sophisticated sociological understanding of the scalability of large social systems (Fischer, Florian and Malsch 2005). This area goes by the name of *socionics*. As Fischer, Florian and Malsch explain (2005), socionics focuses on several important themes: (1) transforming sociological theories and concepts into computer models; (2) examining the link between the scalability (a.k.a. emergence) issue in computational modeling and the micro-macro link in sociology; and 3) using sociology to develop the tools of computer science (Klüver 2000, 2002). If one were to locate socionics on our network of attracting clusters (Map 4), it would be a 2^{nd} order sub-cluster within simulation, which is one of the three major sub-clusters of study in computational sociology.

Complexity Science and Sociological Method: While the above parallels between computational sociology and complexity science method are important, the most significant parallel is the methodological repertoire and lineage of these two areas. Both computational sociology and complexity science are a genealogical hybrid of mathematical modeling, statistics and simulation. In fact, every single area within computational modeling and complexity science method can be easily linked to one or more branches on this genealogical network. Consider, for example, the following.

1. Statistics: The first major genealogical branch in computational sociology is statistics. In addition to the traditional branches associated with this methodology (regression, factor analysis, analysis of variance, etc.) statistics includes a specific sub-set of techniques highly applicable to modeling social systems, including structural equations modeling, k-means clusters analysis and discrete events analysis. There also is computer simulation within statistics, as demonstrated in Monte Carlo studies. The most important area within this genealogical areas, however, is the development of neural networking, decision trees, and the new field of data mining (Castellani and Castellani 2003; Castellani, Castellani and Spray 2003). Data mining also is one of the rising subfields of study within computational sociology.

2. Mathematical Modeling: The second major genealogical branch is formal mathematical modeling, which is comprised of three additional arms. The first is the *mathematics of structure*, which leads to the development of structural analysis, social network analysis and eventually the new science of networks. Readers may not realize it, but social network analysis actually began (and in many ways remains) a field of formal mathematical modeling—graph theory, game theory, etc—created to model the structure of social groups (Scott 2000). That is why one of the leading journals in social network analysis is called *Journal of Social Structure* (www.insna.org/). In fact, it is because of its strong connection to structural mathematics that social network analysis "discovered" many of the insights later developed and made popular by scholars like Watts and Barabási.

In mathematical modeling, the second major branch is the *mathematics of processes*, which is further subdivided into deterministic and stochastic mathematics (Weidlich 2000). Genealogically speaking, deterministic processes leads to differential equations and difference equations—what complexity scientists refer to as a top-down, macro-level approach to modeling complex systems—as opposed to a bottom-up, agent-based perspective (See method section of Chap. 5).

In stark contrast to this deterministic approach is the genealogy involved in the study of stochastic processes, which leads to Markov chains, Brownian motion, dynamical systems theory and (more specifically) chaos theory and fractal geometry—all of which eventually tie into simulation and computational modeling and from there into agent-based modeling. This genealogical arm also leads to the second major subfield of study in computational sociology: dynamical systems theory, as in Gunduz's application of fractal scaling to the growth of the Ottoman and Roman empires (2000, 2002) and Abbott's fractal analysis of the chaotic, scale-free behavior of the social sciences (2001).

The third major genealogical branch in formal mathematical modeling is the *mathematics of actors and agents,* which leads to game theory, rational choice theory, data mining, evolutionary game theory, and (amazingly enough) the integration of mathematics with qualitative data analysis—examples of the latter include soft modeling, fuzzy-set social science, and the integration of neural networking with qualitative method (Castellani, Castellani and Spray 2003; Castellani and Castellani 2003).

3. Simulation: The final major genealogical branch is simulation, which can be broken down into two major arms: equation-based modeling and computational modeling. The first arm leads to system dynamics and the work of Forrester and is strongly connected with deterministic mathematical modeling, which takes us to calculus and, more recently, control theory. The second arm basically is a rehearsal of everything we discussed about the history of agent-based modeling in Chap. 4, including distributed artificial intelligence, cellular automata, etc. Genealogically speaking, this final area also leads to the third major sub-cluster of study in computational sociology: simulation.

4. Putting it all together: When all of these genealogical areas are brought together, you get Map 5 (See Chap. 10). To create this map, we did the following.

First, we read all of the major reviews on computational sociology and its related areas, including mathematical sociology and sociological game theory. These reviews included Axelrod (1997), Epstein (2007) Gilbert and Troitzsch (2005) Halpin (1999) and Macy and Willer (2002), Swedberg (2001) and Troitzsch (1997). Next, for each of these reviews we constructed a methodological genealogy, including all the major lineages, areas of study, key scholars and major and minor techniques identified. From here, we looked for similarities amongst the reviews and their respective genealogical trees. Fourth, we took the different genealogies and integrated them to create a final tree. We then entered this information into the social network software package *Pajek* (pajek.imfm.si/doku.php). From here we conducted a vector analysis, looking for the hubs and main authorities in our genealogical tree of computational methods. We then used Pajek to create a visual representation of our network. As shown in Map 5, the larger the node for a particular method or the closer it is to the center of the graph, the more important it is to computational sociology. We then compared Map 5 with our review of complexity science method to examine their similarities. One will note, for example, that on Map 5 the most important areas are computational modeling, agent-based modeling, actor/agent mathematics, the study of stochastic processes, structural mathematics (social network analysis) and statistics. This map captures quite well our review of the lineage of complexity science method. Based on our analyses, we concluded that: (1) computational sociology is a microcosm of complexity science method; and (2) the parallel between these two areas is a function of their shared lineages, theories, topics and methods.

6.1.1 What Makes Computational Sociology Unique

Now that we have a good sense of what makes computational sociology similar to complexity science method, we need to discuss what makes it unique. Despite its strong interdisciplinary impulse, and despite its parallels with complexity science method, the fact remains that scholars created computational sociology to study social systems. This substantive focus does not mean the insights of computational sociology do not transfer to the natural or computational sciences. Case in point: a specific goal of socionics is to transfer the theories and concepts of sociology to advance the field of computer science by exploring how, for example, humans can be of assistance to computers (Fischer, Florian and Malsch 2005). Still, despite all this transfer, the fact remains that human social systems are, to a certain extent, isomorphically unique.

It is this uniqueness that forms the basis for computational sociology's distinct approach to its work. Human social systems present two major challenges to those who would model them. The first is the unparalleled intelligence of human social agents and the second (which comes from the first) is the astonishing complexity of the systems human agents create.

One of the most complex biological systems on the planet is the human brain. Put 6 billion of these brains together, along with the global network they create, and the product is even more complex. Going further, if one proceeds to examine the myriad of social systems this network of human brains create, along with the unlimited ways these systems interact and impact one another, let alone the relationships these interacting systems have with the biological and physical world, and one has a major methodological challenge (Gilbert and Troitzsch 2005). It is this methodological challenge that defines the purpose of computational sociology.

6.1.2 Three Subfields of Study

Currently, computational sociologists have developed three major approaches to the study of social systems. The first and most widely practiced is social simulation, followed by data mining and then dynamical systems theory. Because we already surveyed these three methods in Chap. 5, our review here is more specific, focusing on key scholars, journals, conferences and unique research projects.

6.1.2.1 Social Simulation

As Halpin (1999) and others have explained, although the tools and techniques of social simulation have been around since the 1960s, it only is recently that social simulation has ascended from its marginal status within sociological method to a position of relative prominence (Cederman 2005; Gilbert 1999; Gilbert and Troitzsch 1997; Macy and Willer 2002).

The growing popularity of simulation is due, in part, to the development of agent-based modeling, high-powered personal computers, and new software platforms. It is also due to the hard work of a small list of scholars and the numerous world-wide conferences, journals and areas of study they have worked very hard to develop.

The most important periodical in social simulation is *Journal of Artificial Societies and Social Simulation* (JASSS). Since its inception in 1998, JASSS has had over 6 million successful hits (information accessed 26 January 2008), with an average daily hit rate of just over a thousand (jasss.soc.surrey.ac.uk/JASSS.html). On its website, one can also find a java-based diagram of every JASSS articles and its citation links with all other JASSS articles. There is also a "Top 20" list of the most viewed articles. The JASSS citation network and Top-20 list provided a useful window into current trends in simulation. For example, in terms of the "Top 20" list we examined (26 January 2008), half of them dealt with methodological and theoretical issues and the other half substantive topics. Specifically, five articles reviewed or discussed how to do simulation; three articles explored how to model highly complex social systems; two used simulation to advance sociological theory; and the other ten examined various empirical topics such as youth culture, pandemics, cooperation, kinship networks and human language. The JASSS articles most highly cited by other JASSS articles revealed a similar pattern. These highly cited articles focused on simulation techniques and the dynamics of complex systems, followed by various empirical topics such as simulating opinion polls and disease networks.

These two data patterns at JASSS also corroborate a major point we will develop in the next two chapters. Simulation, like much of the research in SACS, is in the early stages of development, with scholarly work significantly divided (almost equally) between developing the methods and theories researchers need to guide their inquiries and actually doing empirical research, including the usage of simulation to develop theory.

Of the numerous scholars in simulation, several are worth mentioning here. The first is Professor of Sociology at University of Surrey (UK), Nigel Gilbert. Not only is Gilbert the creator and Editor of JASSS, he also is Director of the *Centre for Research in Social Simulation*. (http://cress.soc.surrey.ac.uk/). Gilbert's work in simulation revolves around one dominant theme: tirelessly championing computational modeling as a legitimate method for sociological research. Like Barry Wellman, Gilbert is an authority. The list of accomplishments he has amassed in the pursuit of this connecting vision is impressive, including his involvement in just about every major European conference and world-wide association in the field of social simulation, as well as editing, writing or co-writing numerous articles, technical reports and handbooks on simulation (Gilbert 1999, 2000; Gilbert and Troitzsch 2005).

Another key scholar is Gilbert's co-editor and co-author, Klaus G. Troitzsch, University of Koblenz-Landau (Germany). Like Gilbert, Troitzsch is a pioneer in the development of computational sociology and is involved in just about every aspect of the field, from his work as Forum Editor of JASSS to his involvement in the massive *European Social Simulation Association* to his co-publications with Gilbert (Gilbert and Troitzsch 2005) to his development of various new techniques for simulation.

Other key scholars in social simulation include: (1) Jürgen Klüver (2000) and colleagues (e.g., Klüver, Stoica and Schmidt 2003) who are working on a mathematical, agent-based theory for the study of social complexity and communication; (2) Christopher Goldspink, who has been developing a metatheoretical framework for modeling complex social systems (2000, 2002); (3) Philip Bonacich, who (as we discussed earlier) is a key figure in network theory and mathematical sociology; (4) Joshua Epstein and Robert Axtell (1996), well-known for their concept of generative social science and their work on growing artificial societies; and (5) Joerg Strübing (1998) and colleagues (e.g., Fischer, Florian and Malsch 2005), who are part of a network of researchers interested in the interface between sociology and multi-agent systems research (MAS). The name for this emerging field, as we mentioned earlier, is *socionics* (Müller, Malsch and Schulz-Schaeffer 1998). Strübing is specifically interested in integrating multi-agent systems with the symbolic interactionist work of Anselm Strauss (1993).

6.1.2.2 Data Mining

As we explained in Chap. 3 of this section, data mining is a data-driven, exploratory process of knowledge discovery and database management that uses various methods in statistics, mathematical modeling and simulation to discover meaningful patterns of relationship in large electronic databases (Berry and Linoff, 2000; Castellani and Castellani 2003). The advantages of this method for sociologists are several: (1) it can qualitatively analyze quantitative data; (2) it can focus on social processes and relationships; (3) it can work well with existing qualitative techniques, such as grounded theory; and (4) it can handle nonlinearity, data noise and conceptual fuzziness.

Surprisingly, despite the overwhelmingly widespread application of data mining in the disciplines of business, economics, education, health care and computer science, it remains an underdeveloped area in computational sociology, SACS, and sociology in general. Given the increasing challenges sociologists face in managing and studying the massive electronic databases now available to them, it is amazing that these techniques remain on the margins, pointing once again to the need for a major overhaul in the methodological component of sociology departments. For more information on the utility of data mining, particularly its integration with qualitative method, please see Castellani, Castellani and Spray (2003) and Castellani and Castellani (2003).

6.1.2.3 Dynamical Systems Theory

Of the three areas, this is the least used. However, thanks to the work of Gunduz (2000), Abbott (2001), Ragin (2000) and Weidlich (2000), this subfield of computational sociology has achieved some impressive insights. For example, Gunduz (2000, 2002) and Abbott (2001) have explored how fractal scaling and self-organized criticality relate to sequencing and social change. The work of Charles Ragin (2000) focuses on the relationship between fuzzy logic and case-based research—a major impetus for our development of the SACS Toolkit and the case-based approach of assemblage. Finally, Wolfgang Weidlich (2000) makes significant strides in the usage of systems nonlinear dynamics (formal mathematical modeling) to model a variety of social processes—from political transitions and group interactions to urbanization and evolutionary economics.

For an excellent review of the potential of dynamical systems theory, specifically chaos theory, for modeling social systems, we recommend Eve, Horsfall and Lee's edited book, *Chaos, Complexity and Sociology: Myths, Models, and Theories* (1997). Although it was published over a decade ago, it outlines the value of chaos theory for sociological inquiry. From there, we recommend reading Weidlich's *Sociodynamics: A Systematic Approach to Mathematical Modeling in the Social Sciences* (2000). Although the latter is highly mathematical, it concretely demonstrates how chaos theory and, more generally, formal mathematical modeling, can be used to examine complex, chaotic social processes. Additional mathematical works to read include Bar-Yam (1997) and Boccara (2004).

6.2 British-based School of Complexity

While all five research areas in SACS endeavor to make significant advances in the normative work behaviors of mainstream sociology, none is more ambitious or radical than the British-based School of Complexity (BBC). The BBC is not just interested in revising or advancing the current practice of sociology. It seeks an entire reformulation of its theories, concepts, methods and organizational arrangements, based primarily on the latest advances in complexity science. It is because of this comprehensive reformulation from a particular perspective that we refer to the BBC as a school of thought: a defined way of doing work based on a particular scholar or group of scholarly ideas, which has a shared identity, common vocabulary, mutual methodology and similar topics of study. To make sense of the BBC's reformulation, we will review its *web of social practices* profile.

6.2.1 Complexity Science Lineage

The first major goal of the BBC is to create a post-disciplinary sociology. By post-disciplinary we mean the following. The word "post" refers to any type of sociology that goes beyond the discipline's current institutional arrangements and intellectual divisions. These "post" disciplinary arrangements can be inter-disciplinary (between or amongst disciplines), trans-disciplinary (above and beyond disciplines) or even anti-disciplinary (without disciplinary boundaries). By disciplines we mean "competing and autonomous groupings of researchers and teachers that are, in crucial respects, historically arbitrary" (Scott 2005, p. 136). Disciplines exist through their institutional backing, primarily in the form of financial support. Disciplines also exist because of their institutional control over the granting of degrees (in particular the doctorate) and the conferring of credentials. Disciplinary and institutional boundaries, particularly in the social sciences often bear little resemblance to their associated intellectual divisions. Intellectual divisions are clusters of shared themes, concerns, topics, methods and lineages, which often cross over or repeat themselves within various disciplines. Examples include the study of social psychology, gender and inequality in such disciplines as sociology, psychology, economics, education, business and medicine. At their most extreme, intellectual divisions (particularly when they are ignorant of one another) lead to hyper-specialization and the creation of scholarly cul-de-sacs.

The BBC's goal to overcome the disciplinary boundaries and institutional and intellectual divisions of contemporary sociology connects it to a long-standing tradition of post-disciplinary thinking in systems science, cybernetics and complexity science. To see the BBC's connection to this tradition, let us take a detour into a bit of this tradition's history.

The reader may recall from Chap. 5 that, going as far back as the 1940s, the goal of systems science has been to unite the natural and social sciences under the common banner of systems thinking. This goal is reflected in the variety of disciplines involved in systems science, from biology (Ludwig von Bertalanffy) and anthropology (Margaret Mead) to psychiatry (James G. Miller) and engineering (Claude Shannon) to mathematics (Walter Pitts) and economics (Kenneth Boulding). It is also reflected in the bylaws of systems science's major organization, the *International Society for the Systems Sciences*: "(1) to investigate the isomorphy of concepts, laws, and models from various fields, and to help in useful transfers from one field to another… (4) to promote the unity of science through improving communication among specialists" (isss.org/world/index.php). Finally, it is reflected in sociology through the intellectual and institutional goals of Parsons and the Department of Social Relations at *Harvard University*.

There is a good reason why systems science, cybernetics and complexity science have been so successful at creating a post-disciplinary science. It has to do with their approach.

The common-but-doomed method of fostering unity across the sciences has been to call for some type of disciplinary dissolution, such as no more academic departments, or for some type of hyphenated, bio-psycho-social institutional program. Systems science considers these moves moot. Instead, systems science focuses on the intellectual divisions of science. System science argues that, while hyper-specialization may be a necessary evil of empirical inquiry, it alone does not science make. At some point scientists need to address their common theme: the growing complexity of scientific work and the need for a systems perspective to address it. While the topics of science can be divided, broken down and reduced in an effort to grasp them initially, the real success of science will only come when these topics, in all of their complexity, are put back together and studied as systems. Science is ultimately the study of complex systems.

Slowly but steadily, the natural and computational sciences have begun to embrace this "complex systems" theme, which is currently spreading rather well across their various departments and schools. As a consequence, the disciplinary divisions of the natural and computational sciences are beginning to seem less important.

The same is not true of main street sociology—this point moves us closer to the post-disciplinary thinking of the BBC. Main street sociologists have ignored the systems tradition for so long that they do not seem to appreciate the paradigm shift to systems thinking taking place in the natural and computational sciences, ranging from physics and systems engineering to the human genome project and systems biology to environmental planning and systems ecology to computer science and the rapid development of multi-agent systems (Capra 2002; Érdi 2007; Hammond 2003; Klir 2001). Lacking a systems perspective, most sociologists also do not see or understand why disciplines like physics and biology are branching outward into sociology and other domains of social scientific inquiry. Instead, they see these post-disciplinary movements as an encroachment into their "sacred" domains of inquiry, which must be dismissed or defended against (Bonacich 2004a; Watts 2004). Most important, however, sociologists do not see the spread of systems thinking into their own discipline. As such, they do not see the purpose of the BBC's call for a post-disciplinary sociology. In fact, most sociologists probably see the BBC's claims as dreadfully unnecessary, fancifully absurd, or well-intended but doomed. Nothing, however, could be further from the truth.

Now, we are back finally to the BBC. Like systems science, cybernetics and complexity science (or the Department of Social Relations at Harvard some thirty years ago), the goal of the BBC is to create a post-disciplinary sociology grounded in the theme of complex systems. As we articulated in our introductory chapter, this theme goes as follows: (1) in the last two decades the complexity of western society has reached a tipping point; (2) this tipping point has resulted in a major phase shift in the organization of global society; (3) this phase shift is, in large measure, a function of the computer revolution, post-industrialization and globalization; (4) the consequences of this phase shift (environmental collapse, global economics, cultural and political conflict, etc) cannot be adequately addressed by the normal tools of sociology; (5) new tools are needed, grounded in a systems perspective and the latest advances in computational modeling and mathematics; (6) complexity science is therefore the future of sociology (Byrne 1998; Luhmann 1995; Urry 2003).

The most outspoken scholar advocating for a post-disciplinary sociology is John Urry (2000). As one of the leading sociologists in the BBC, Urry has been consistent in his argument for a new sociological imagination grounded in the tools of complexity science. His argument is a variant of the above theme we just stated, with emphasis on two key aspects of it: (1) the rise of global network society and (2) the growing complexity of sociological work (Urry 2000).

As we discussed earlier, following the work of Castells, Urry (2003) argues that network society has gone mobile, and is transforming itself into a massively complex global system. The only hope for studying this complex social system is to transform the tools of sociology by critically integrating them with the latest advances in complexity science. This transformation and critical integration require sociologists to move out of their intellectual comfort zones, to seek the margins of the discipline, and to explore new intellectual terrain, all in the hopes of collaborating with scholars and ideas from the rest of the sciences and the humanities (Urry 2000).

There is a caveat, however. Contrary to what one might expect, Urry's post-disciplinary sociology is not a call for the collapse of organized sociology. Far from it. While Urry agrees wholeheartedly with Wallerstein, Prigogine and the Gulbenkian Commission that sociologists need to unite with the rest of the sciences under the common banner of complexity and systems thinking, he does not think much of the idea of sociology becoming an interdisciplinary social science. Remember, systems science goes for intellectual not disciplinary change. Following this line of thinking, Urry is not seeking the demise of the sociological enterprise. Instead, he seeks mobility.

If society has gone mobile, so must sociology and more specifically sociologists. Citing the work of Dogan and Pahre's *Creative Marginality* as an example (1990), Urry explains that most innovations in the social sciences today take place at the margins (Urry 2000). That is why places like SACS and the BBC are built on the outer banks of sociology: the marginality of these intellectual towns and communities allow for tremendous cross-disciplinary movement and creative synergy. Unexpectedly enough, however, creative marginality needs a firm disciplinary foundation upon which to build its bridges of innovation—Urry takes this point from Dogan and Pahre (1990). SACS and the BBC, for example, can only be post-disciplinary because the outer banks of sociology (despite their permeability) are disciplinarily stable. In other words, the discipline of sociology does not need to go mobile; sociologists interested in addressing the complexity of their work need to go mobile.

While not a member of the BBC, another of our millennial scholars, Andrew Abbott, whom we discussed back in Chap. 5, agrees with Urry. If we recall his argument, Abbott sees very little evidence to suggest that organized sociology—that is, the academic departments and degree granting institutes associated with the discipline—has, will, or can go post-disciplinary based on institutional reform alone (2000, 2001). Furthermore, following systems science, there really is no need. People have to get bachelors and doctorates in something; besides, most of the push in the Academy (particularly in the United States) is toward market-based (not interdisciplinary) degrees anyway; and universities and college need a useful division of institutional labor to function.

Still, the European academy has been slightly more flexible in its institutional arrangements. As Abbott explains (2000), unlike the social science academy in the United States, where departmental boundaries are more rigid, the European academic system is better at structurally facilitating post-disciplinary arrangements through institutional reform within the social sciences, based primarily on some shared intellectual focus—such as the study of complex systems. This is due, in part, to a less entrenched disciplinary system, a more direct relationship between the social sciences and governmental agencies, a higher number of sociologists involved in free-standing institutes and centers, the development of international societies, and much stronger governmental funding, including growing support from the European Union (Abbott 2000, pp. 297–298). This difference in structural arrangements between the United States and Europe has been to the benefit of the BBC.

In terms of departments and centers, scholars in the BBC are creating, developing or participating in an incredibly successful network of programs, research groups, departments, all oriented and based upon a similar theme: complexity science. If one were to map this network of institutional arrangements and then overlay it on a map of the UK, one would have a topographical picture of the BBC. These institutional arrangements include the following:

- *The Innovations in Research Methodologies* group of the School of Applied Social Sciences at Durham University.
- *Center for Research in Social Simulation* (CRESS) Department of Sociology, University of Surrey, which is linked to a multitude of research projects, grants, business-academic liaisons, etc (cress.soc.surrey.ac.uk/)
- *The European Social Simulation Association* (www.essa.eu.org).
- *European Complex Systems Society* (www.cssociety.org).
- The European Commission's *Complex Systems Network of Excellence* (EXYSTENCE).
- *Centre for Mobilities Research* and *Centre for Science Studies*, Department of Sociology, Lancaster University (www.lancs.ac.uk/fass/sociology).

- *Lancaster Complexity Network*, Institute for Advances Studies, Lancaster University (www.lancs.ac.uk/ias/researchgroups/complexity/complexity.htm).
- *The Centre for Complexity Research*, University of Liverpool and Lancaster University.

6.2.2 Complexity Science and Sociological Methods

The second major goal of the BBC is methodological advancement. By now, the reader should know the following mantra well: from the topics it studies to the data it collects, the work of sociology has grown increasingly complex. Sociologists therefore need new methodological techniques and tools, primarily those coming from the science of complexity: agent-based modeling, data mining, computational statistics, dynamical systems theory, discrete mathematics, the new science of networks, and so forth. Without these methodological advances, organized sociology will become increasingly outdated or even obsolete.

Perhaps the most outspoken scholar in the BBC advocating for methodological overhaul is Nigel Gilbert, whom we discussed in our earlier review of computational sociology. He is not, however, the only one calling for reform. Another major scholar, who we have yet to discuss in much depth, is David Byrne.

Professor at the School of Applied Social Sciences, Durham University, Byrne is a leading sociologist in the UK and former editor of one of its flagstaff journals, *Sociology*. Byrne is also a methodologist, and a very thoughtful and creative one at that. His articles and books are well crafted, well written, intelligent and subtle. He does not make grand statements. He makes important provocations. One of his important provocations, written about in a series of articles with titles such as "Platonic Forehand versus Aristotelian Smash" (2002) and "Complexity, Configurations and Cases" (2005) is that, while complexity science is great, sociologists need to think carefully about how to employ, develop and even ignore its various techniques and tools. There are too many epistemological, conceptual and theoretical issues at stake. One example: the danger of losing the sophistication of sociological explanation to the simplicity of simulation.

As we discussed in our method chapter, complexity scientists tend to treat social systems as the outgrowth of simple processes (Byrne 2001, 2002; Cilliers 1998; Macy and Willer 2002). Byrne calls this perspective *simplistic complexity* (2005). Richardson and Cilliers (two important scholars affiliated with the BBC) refer to it as *reductionistic complexity* *science* (2001). The basic view of the simplistic/reductionistic perspective, which is practiced by such powerful and important thinkers as Holland (1998) and Wolfram (2002), is that a system's complexity (regardless of the system) emerges out of a very basic set of rules carried out by a large network of agents (mathematical numbers, biological cells, plants, ants, fish, etc) over a defined period of time. Amazingly enough—and Byrne (2005) as well as Richardson and Cilliers (2001) agree with this point—reductionistic complexity scientist has been quite successful at modeling various types of social systems, specifically those at a smaller (meso) scale. From the study of traffic patterns to the group-level transmission of cultural values to the competition of businesses, scholars using a reductionistic approach have demonstrated that social systems can be initially understood rather well through the agent-based iteration of a basic set of discrete rules (Axelrod 1997; Halpin 1999; Macy and Willer 2002; Watts 2004).

Still, as Byrne (2001) and others point out, this initial understanding is not the same as explanation (Gilbert and Troitzsch 2005; Goldspink 2000, 2002; Klüver, Müller, Malsch and Schulz-Schaeffer 1998; Strübing 1998). There is still a significant amount of theoretical and epistemological slippage that happens when moving from the articulation of a few rules upon which some social system is based to actually explaining how this social system emerges. Agar discusses this "slippage" in detail in *My Kingdom for a Function* (JASSS, 6, 3, 2003). While advocating the usage of computer simulation, Agar recognizes that the concepts he developed through this qualitative research did not transfer easily to the rule-oriented thinking of the computer. There was much slippage, begging Agar to ask, rhetorically, did I give up my empirical kingdom (his qualitative work) for a function (a set of computer algorithms)?

To remedy this problem, Byrne suggests that for sociology a new approach to complexity science methods needs be developed, one that he refers to as *complex complexity*, or what we will call C^2. We turn now to a review of this perspective.

6.2.3 C^2

The desire to embrace and yet develop the tools and techniques of complexity science through their rigorous integration with the methods and theories of sociology has resulted in the development of a major subcluster of research in BBC, which we call, after Byrne, *complex complexity* (C^2). The goal of C^2 is twofold: (1) use the critical lens of sociology (specifically the sociology of science) to examine the claims of complexity science method and (2) explore, critique and advance the epistemological, theoretical and methodological rigor of complexity science methods by integrating them with existing sociological theories, methods and techniques.

The reader may wonder how C^2 differs from computational sociology. The answer to this query is that C^2 is a subset of computational sociology, based on the particular epistemological, theoretical and methodological viewpoints of the BBC.

As a side note, not all of the scholars in BBC are British. Cilliers and Goldspink are Australian and Troitzsch is German. Goldspink, however, recently took a position at Gilbert's *Center for Research in Social Simulation* (CRESS), University of Surrey. Regardless of their academic affiliation, we refer to all of these scholars as part of BBC because they are involved in the creation and development of its common intellectual concerns and identity, including involvement in its publications, conferences, journals, centers, think tanks, and academic networks.

Getting back to the parallels between C^2 and computational sociology, one might also think of C^2 as the epistemological branch of computational sociology. While much of computational sociology focuses on developing and employing the tools of simulation, data mining, and so forth, C^2 takes a step back to consider the legitimacy of these methods for sociological inquiry. One example of this focus is the 2005 issue of JASSS (Volume 8, number 4) which was devoted to the epistemological status of simulation for social science inquiry. Organized by Frank and Troitzsch, this issue came from a series of papers delivered at a "workshop on 'Epistemological Perspectives on Simulation' in July 2004 at the University of Koblenz, in which some thirty colleagues participated" (See jasss.soc.surrey.ac.uk/8/4/7.html. Accessed 31 January 2008). The questions these scholars addressed ranged from "What kind of research questions can be addressed by simulation?" to "How does a simulation model relate to reality?" to "What kind of real world decisions can be supported by simulation?"

While the answers provided by these scholars are a discussion for another time, their combined insights are relevant to our current point. If sociologists are going to ultimately embrace and develop the tools of complexity science to the advantage of sociological inquiry—and, hence, society—the seriously hard and tedious work of carefully integrating them with sociological theories and methods will need to take place with the broader program of research in computational sociology.

6.2.4 Integrating Complexity Science and Sociological Topics

The third major goal of the BBC is to make the "complex system" its primary theoretical framework. Theory is a major goal of the BBC. To date, other than Luhmann, the BBC is the only area of sociology to offer a new and somewhat complete theory of social complexity. Examples include Byrne's *Complexity Theory and the Social Sciences* (1998) and Urry's *Mobilities* (2007) and *Global Complexity* (2003).

As a related goal, the BBC also seeks to use the complex systems framework as the basis for exploring any and all sociological topics. These topics range from globalization to urban planning to social mobility to gender and inequality.

Reviewing the sociological topics of BBC also is to review its current and developing network of scholars. While our review of the BBC here has focused on a small handful of scholars, with particular emphasis on the work of Byrne, Urry and Gilbert, there is a rather extensive network of scholars involved in the BBC. The work of these scholars is quite broad: economics, psychology, geography, medicine, political science. This work also has extensive links to complexity science, particularly its development in Europe.

As a side note, the European Union has invested heavily in the development of a complexity science perspective throughout the sciences, government and the business community. This investment, to our knowledge, is unparalleled. It also is incredibly successful. Several BBC scholars have been pivotal to this enterprise, the most noteworthy being Nigel Gilbert—see (cssociety.org/tiki-index.php).

Returning to our discussion of topics, the last agenda of the BBC is to use the vast repertoire of complexity science concepts (self-organized criticality, bifurcation points, fractal scaling, attractor points, etc) to rethink or enhance sociological inquiry. An excellent example is John Urry's Center for Mobilities Research (CeMoRe) at Lancaster University, which houses over 15 residential and visiting scholars (www.lancs.ac.uk/fass/sociology/cemore/). Common to the work of these scholars is the idea that sociology must move beyond traditional nomenclature, particularly the concept of society as linked to the concept of nation-state and embrace a view of society as highly mobile and global.

6.2.5 Sociology Intellectual Traditions

The final goal of the BBC is to develop systems thinking by updating it with the latest advances in sociological theory and continental philosophy.

While the methods of complexity science have significantly advanced systems thinking, complexity scientists are not very sophisticated when it comes to sociological theory or post-positivistic epistemology. Remember our quote earlier from Watts: "Physicists may be marvelous technicians, but they are mediocre sociologists" (2004, p. 264). Complexity science needs theoretical and epistemological advancement.

The fourth goal of the BBC is to help complexity science make this advancement. Examples of theories and epistemologies the BBC draws upon to advance complexity science include: (1) Urry's (2003) extensive use of Castells; (2) Walby's (2007) integration of complexity science, sociological systems theory and the literature on inequality; (3) Cillier's (1998) integration of complexity theory with post-structuralism, specifically the work of Derrida; and (4) Byrne's (1998) development of a complexity science grounded in critical realism.

Conclusion

In spite of its accomplishments, the BBC is not yet a complete and coherent school of thought. Everything is still in flux, but it is quickly shaping up. The number of new scholars, articles, conferences, intellectual networks, websites and international links emerging (almost monthly) within the BBC is impressive. There is definitely a sense one gets from studying the BBC that some type of critical point where it transitions into something larger is looming. What that something is remains unclear. Our best guess is the merger of the BBC into what one might refer to as a broader European School of Complexity, with several branches of thought. The Complex Systems Society just released a "Who's Who in Complexity Science" registry. It would be very interesting to do a network analysis of this registry to see if such a European School of Complexity is emerging (cssociety.org/tiki-index.php). Whatever this transition turns out to be, the BBC will play a primary and major role in its development.

6.3 The Luhmann School of Complexity

The other major school of thought in SCAS is new social systems theory, or what we will alternatively call the Luhmann School of Complexity (LSC). We use this alternative name for two reasons.

First, we use it to distinguish LSC from the variety of systems theories that exist within sociology, systems science and complexity science (See

Bailey 1994; Hammond 2003; Klir 2001). For example, there is systems science in general, which is comprised of a variety of frameworks: (1) Bertalanffy's general systems theory, (2) Forrester's system dynamics, (3) Capra's ecologically-based systems theory; (4) Miller's living systems theory; (5) engineering-based systems theory, specifically the work of George Klir; (6) biological and developmental systems theory; and (7) control systems theory. From here one can go to the variety of systems perspectives in sociology and the social sciences (which have links to systems science as well). These social science perspectives include the early systems thinking of Pareto, Spencer, Marx and Durkheim. They also include, more recently, structural-functionalism and the work of Parsons, as well as the development of neo-functionalism, specifically the work of Jonathan Turner. System thinking also extends to other disciplines including family systems theory (psychology), economic systems theory and political systems theory. Getting back to sociology, there are also the more recent systems theories of Wallerstein, Castells and Urry (which we have mentioned); the social systems theory of Walter F. Buckley (which is used as the theoretical basis to sociocybernetics); and the new systems theory of Kenneth Bailey—another key scholar in sociocybernetics who, by the way, is a professor of sociology at UCLA where he is a colleague of Bonacich, one of the leaders in the new science of networks. Finally (and our list is by no means complete), there are the systems theories of complexity science, some of which we have reviewed in detail in Chap. 5: Holland's emergent theory, Prigogine's dissipative structures theory, Maturana and Varela's autopoietic theory, Kauffman's evolutionary theory, and so forth.

While the Luhmann School of Complexity (LSC) borrows from and makes important contributions to these various systems traditions, it truly is a unique perspective and should be treated as such. Furthermore, as Hammond points out (2003) of the various systems perspectives within the social sciences (and specifically sociology), LSC is the most dominant. Its distinct character therefore needs to be highlighted (For an interesting network visualization of Luhmann and his links with systems theory, see www.systems-thinking.de/.)

The second reason we use the term LSC is because, since Luhmann's death his ideas have been developed further by a world-wide list of scholars in the social sciences and the humanities. This posthumous work—which would take a book to review—has turned Luhmann's ideas from one scholar's view of the social world into a new school of thinking. For example, an author search on the *Web of Science Social Science and Humanities Citation Index* gets almost 3,000 hits for "N. Luhmann." Some of the more well-known leading scholars involved in the LSC movement include (1) Hans-George Moeller (who has written one of the best English-speaking overviews of Luhmann's work); (2) Eva Knodt (one of

Luhmann's best German-to-English translators); (3) Stephan Fuchs (one of Luhmann's students and now a leading advocate); (4) Gunther Teubner (a major international figure in the Luhmann school of thought and Professor of Private Law and Legal Sociology, University of Frankfurt and Centennial Professor, London School of Economics); (5) Dirk Baecker (a more recent contributor to the LSC and a member of the Department for Communication and Cultural Management, Zeppelin University); and, finally, (6) Loet Leydesdorff (a major figure in the LSC and Senior Lecturer, Department of Communication Studies, University of Amsterdam). For a more complete overview of Luhmann's legacy, see Moeller's *Luhmann Explained: From Souls to Systems* (2006).

6.3.1 The Luhmann School of Complexity Profile

To gain a better understanding of the LSC, we will review its *web of social practices* profile. However, we will do so by way of a comparison to the BBC in hopes that this contrast will help to articulate what makes these two schools similar and yet unique.

Complexity Science Lineage: Like the BBC, the LSC is resolutely post-disciplinary, situating itself comfortably within the systems science tradition. Furthermore, like Urry, the goal is to go mobile, but not to dissolve the boundaries of sociology.

Consider, for example, Luhmann. Not only did Luhmann arrive late to the discipline of sociology, he never fully fit in. He was always more a systems science scholar than a sociologist; and his work always spilled over into other disciplines and areas of study. In fact, Luhmann is the embodiment of Urry's *creative marginality* because his work drew upon and added to such diverse areas as biology, philosophy, mathematics, history, historiography, literature, and law—the last being Luhmann's first academic background and professional life. As Arnoldi points out, Luhmann liked sociology because is did not "restrict" him academically (2001, p. 12). The fact that Luhmann is now seen as giving sociology a distinct character through his new social systems theory, "would probably please him" (Arnoldi, 2001, p. 12)

Another example is the academic diversity of the rest of the scholars involved in the LSC. Case in point: if one examines the 61 publications by Luhmann listed on the *Web of Science Social Sciences and Humanities Citation Index*, the following is revealed. Only 40% of those citing Luhmann are in sociology (N=224). The remaining (60%) come from disciplines as broad as literary studies, law, management, philosophy, geography and communications studies. The disciplinary diversity of scholars in the LSC is further corroborated by the tremendous variety of journals in which these 224 citations are published. Examples of the over hundred different journals include: *Zeitschrift Fur Padagogik*, *Cambridge Journal of Economics*, *and Journal of Law and Society*.

Sociological Lineage: Despite the intellectual diversity of the LSC, it is (ironically) the most traditionally sociological area in SACS. More specifically, it has the most direct ties to the systems tradition in sociology, including Luhmann's direct work with Parsons.

Sociological systems thinking is not, however, the only lineage within sociology upon which the LSC draws. The LSC is also very much grounded in German sociology, running from Marx and Weber to Habermas and the Frankfurt School to phenomology and the work of Schutz. In fact, part of Luhmann's fame comes from his notorious and often heated debates with Habermas over the utility of critique, reason, Enlightenment ideals, systems thinking and, most important, communication (Leydesdorff 1996). Luhmann's students and followers have continued this debate (e.g., Moeller 2006).

Complexity Science and Sociological Method: Unlike the BBC, the LSC has little to do with agent-based modeling. A basic search on JASSS, for example, gets a couple of hits where an author uses simulation to test some of Luhmann's ideas. The German sociologist and computational modeling expert, Klüver, for example, has made use of Luhmann (2000). There is even a nod to Luhmann in the work of socionics, which has a strong footing in German sociology (Fischer, Florian and Malsch 2005). Beyond this, however, the dominant methods used in the LSC are historical or literary. By literary we mean the methods of the humanities: argument, essay, textual analysis and the study of discourse.

Complexity Science and Sociology Topics: Two topics dominate Luhmann's work: autopoiesis and society. Society is the sociological topic he wants to elucidate and autopoiesis is the complexity science topic he uses to make this elucidation happen. To better understand these twin concepts and the role they play in his work, we need to review Luhmann's theory. While the LSC has been developing Luhmann's ideas for the past decade, including revision, critique and application, Luhmann's original work remains central to this school of thought. Furthermore, at least to our knowledge, no revised neo-Luhmann theory has been written. As such, to understand Luhmann is to understand the LSC. We therefore turn to a review of Luhmann.

6.3.2 Niklas Luhmann: A Basic Review

The most famous systems scientist in sociology is the creator of structural-functionalism, Talcott Parsons (1902–1979) (Bailey 1994; Luhmann 1989, 1995; Turner 2001). Not only did Parsons conceptualize society and its constituent parts as a system, but he did so using the terminology of 1950s cybernetics and systems science: adaptation, feedback, system evolution, goal attainment, and equilibrium (Collins 1988). As Parsons began to fall from theoretical favor during the 1970s and 1980s (replaced, in part by conflict theory and Marxism), so too did systems theory. Even the neo-functionalist Jeffrey Alexander concedes this point (Ritzer and Goodman 2004, p. 226). What most sociologists, particularly those in the English-speaking world, do not realize, however, is that while functionalism remains theoretically marginalized, sociological systems theory is alive and thriving (primarily in Europe) in large measure due to the work of Niklas Luhmann (1989, 1995).

Over the last thirty years of his life, Niklas Luhmann (1927–1998) developed one of the most extensive theories of modern society and its constituent parts. He called this theory *system theory* (1995). As Bailey (1994) and others explain (Arnoldi 2001; Turner 2001), system theory sits at the intersection of three fields of inquiry; complexity science, radical constructionism and sociology (specifically the work of Parsons). Drawing upon these three traditions, Luhmann argues that the purpose of sociology is to provide modern society with a way to communicate with itself. This is why, for example, Luhmann titled his magnum opus, *The Society of Society* (See Mingers 2002). For Luhmann, sociology is part of society. It is one of a variety of functionally differentiated subsystems within society—a discipline within the larger subsystem of academia and science that exists to provide society a discourse about itself. In this way, then, when sociology speaks, society is speaking (communicating) with itself.

For Luhmann, society is the most important topic in sociology because, without a fundamental theory of society sociology lacks a proper understanding of itself. This thesis is central to Luhmann's oeuvre. To understand it more fully we need to review his concept of autopoiesis.

6.3.2.1 Social Autopoiesis

Despite the breadth of his theoretical approach to the study of society, any review of Luhmann has to begin and end with his second most important concept, autopoiesis. Luhmann's usage of autopoiesis, which literally means self-producing, is taken from the work of Humberto Maturana and Francisco Varela (1980, 1998). Both theoretical biologists and complexity scientists, Maturana and Varela created the term to provide a *materialist* explanation for the difference between living and nonliving systems. What makes a living system unique for Maturana and Varela is not so much its composite parts and structure, but rather the organizational form it takes. In their own words, "Living beings are characterized by their autopoietic organization. They differ from each other in their structure, but they are alike in their organization" (1992, p. 47). Luhmann, in turn, transported the work of Maturana and Varela to the field of sociology, and created a new term, *social autopoiesis*, which he applies to the study of society.

Framed within the concept of social autopoiesis, Luhmann argues that society is best conceptualized as a self-producing, complex, emergent, self-organizing, self-steering, structurally open-ended, organizationally closed, dynamic, adaptive, evolving, autonomous system of communication. We will break this argument down into a series of points to make it clear.

1. Society is a complex system of communication. For Luhmann, what distinguishes society from all other systems—be they physical, technological, psychological—is that it is entirely symbolic (1989). Society is a complex network of discourses, which, through their interactions, self-organize to form an emergent system of communication.

2. Society, as a system of communication is not agent-based. Like the French structuralists (Claude Lévi-Strauss) and early post-structuralists (Michel Foucault), Luhmann is an anti-humanist (Moeller 2006). While humans are obviously connected to society, society does not ride on the backs of individual communication—otherwise known as symbolic interaction. Instead, society, as a system of communication, is an emergent phenomenon, taking place above and beyond the agents of which it is comprised. Once society emerges, its patterns of communication have nothing to do with humans. Society is like a dumb communication machine, with little need of human supervision or guidance. Said another way, and in stark contrast to the dominant view of complexity scientists, society is not created from the ground-up. Luhmann states it this way, "Whether the unity of an element should be explained as emergence 'from below' or as constitution 'from above' seems to be a matter of theoretical dispute. We opt decisively for the latter" (1995, p. 22). Society is comprised not of individuals but of communication relationships. From this vantage-point, society is a complex system of communication.

Luhmann's conceptualization of society as communication does not mean, however, that society and human beings are independent, or that society is not structurally reliant upon the communicative acts of humans. Society obviously is a human affair. It is just that (contra Habermas) once society emerges through the symbolic interactions of human beings, it is no longer *organizationally* dependent upon these human agents.

3. Still, while society is not organizationally dependent upon humans, people are not so lucky. According to Luhmann, humans are enveloped within society so fully that society constitutes their inescapable horizon of thought. Here Luhmann is drawing upon Heidegger, Hegel and phenomenology. Because communication is central to human knowing, all human thought is immured within a particular societal pattern of communication (Luhmann 1989, 1995). This is true of the academic construction of knowledge as well. From sociology to physics, all of the sciences are patterns of communication within the larger societal system of which they form a functional part. Every human form of knowing is part of society because everything human is a socially constructed from societal communication.

4. The idea that all knowledge is housed within the communication patterns of society leads to one of Luhmann's big insights: society cannot have perfect communication about itself or anything else because it cannot get outside its own communication, primarily because society constitutes the whole of human communication.

5. Because society is a system of communication, it is not geographically bounded (Bechmann and Stehr 2002). In direct contrast to the majority of sociological thinking, Luhmann does not believe that society is a physically situated aggregate of human interactions—such as a nation-state. Instead, it is a process, a perpetual system of communication. This does not mean, however, that society has no boundaries. But, what defines these boundaries is not geography. Instead, its boundaries have to do with communication, which leads to our next point

6. Society, as an autopoietic system, is bounded by its relations of communication. In other words, society is an organizationally closed system through its relations of communication, (Mingers 2002). Anything outside communication per se, or about which communication is engaged, is society's environment. It is for this reason that Luhmann describes society as being autonomous. Consider communication within a group of people. Whatever (or whomever) is not part that group's communication network is treated as someone on the outside. Even an individual member of this group, if she or he is ex-communicated (note the term communication within this act), becomes someone outside the group.

7. As an organizationally closed system, the goal of society is self-production (Luhmann 1995). Put simply, following Durkheim, Spencer, Parsons and the structural-functionalists, society exists to perpetuate itself.

8. While society is autopoietic, it is not alive (Luhmann 1989, 1995). For Luhmann, because society is a system of communication that is independent of human agency, it cannot be alive. Instead, it is more like a dumb machine.

9. One of the most important challenges to modern society is complexity (King and Thornhill 2003; Luhmann 1989). In concert with the majority of complexity scientists, and with scholars working in SACS and the field of globalization, Luhmann argues that society is becoming increasingly complex, as a global system of communication (Geyer and Zouwen 2001).

10. As an autopoietic system, society addresses its growing complexity by differentiating into a network of emergent subsystems (Luhmann 1982). Examples of these subsystems include the various social institutions associated with modern society: science, marriage, family, health care, education, economics, politics, law, culture, art, etc. (See Moeller 2006).

The autopoietic function of each subsystem is to communicate with society about a particular issue of complexity. In other words, when society finds itself unable to handle its internal or external complexity, often due to some type of challenge (be it an issue of health care, epidemic, ecological crisis, economic inequality or political conflict) a subsystem will emerge and do so by establishing for itself an open-ended boundary between itself (as a subsystem of communication) and the particular issue of complexity it was created to address. This issue of complexity, in turn, becomes this subsystem's environment. In other words, the complexity of a system, while internal to itself, often leads to the emergence of a subsystem which treats this internal complexity as its environment, about which it communicates to itself and others as external to itself. For example, the discipline of sociology is a subsystem of society, which treats society—the system in which sociology is situated—as the environment about which sociology communicates, as if society were external to the discipline, even through sociology is situated within society.

The key here, is that a subsystem's environment is not really separate from the system's communication about it (Luhmann 1989, 1995). In this way, the environment is not a thing. Neither is it an external object of subjective knowing. Instead, the environment is a series of "internal constructions" created through a subsystem's relations of communication. In other words, the environment is a linguistic (i.e. social) construction created internally by a subsystem to deal with (adapt to) some particular complexity of life—which finally brings us back to the reason why the concept of society is so important to Luhmann's sociology.

As we discussed at the beginning of this section, Luhmann believes that modern society is going through a period of major transformation. To address this transformation, as the early scholars of sociology once did, Luhmann argues that sociology needs to get back to its primary task: creating theories of society that help society communicate with itself. From this perspective, if Luhmann were alive he would embrace the mobile sociology of Urry, and Castell's global network society, because they are attempts to rethink society in terms of what society is communicating to sociology about itself. Put simply: sociology is the primary communicator to society about what society itself is communicating regarding its evolving challenges. Without such proper communication, sociology is useless—and society is partially silent.

6.3.3 The LSC Today

While Luhmann passed away in 1998, as we mentioned earlier, other scholars are advancing the work of the LSC. These scholars include Klüver (2000, 2002) Mingers (2002), Moeller (2006) and Turner (2001).

One key question for these LSC scholars is the extent to which society and its various subsystems, including complex human organizations, meet Luhmann's definition of social autopoiesis. As stated earlier, Maturana and Varela created their term to distinguish living from non-living systems. How, then, can a nonliving, relatively dumb system of communication, such as society, engage in the processes of self-production and self-preservation? These are issues that Luhmann's work, despite all of its brilliance, did not resolve.

A second question of great interest to LSC scholars is the extent to which society is truly free of human agency. Luhmann has been scathingly critiqued for his complete dismissal of human agency (Mingers 2002). After Parsons and the criticisms leveled against him for the absence of people in his work, along with the massive movement toward agency-based theories in sociology during the 1980s and 1990s, it is hard for scholars, even within the LSC, to grasp Luhmann's theoretical avoidance of agency. This issue is therefore of primary importance within the LSC, and for scholars outside this area of research.

Nevertheless, regardless of how one addresses the above two questions, one must recognize that the LSC constitutes a formidable theory of society which, agree with it or not, must be reckoned with. It is the power of Luhmann's work that makes the LSC a major player in SACS, complexity science, the tradition of systems thinking and sociology.

6.4 Sociocybernetics

The final research community is sociocybernetics. It has the following *web of social practices* profile.

6.4.1 Complexity Science Lineage

The connection of sociocybernetics to the cybernetics lineage is more pronounced and direct than any other area in SACS. For example, while the LSC is connected to cybernetics through the work of Maturana and Varela, and while CSNA, the BBC and computational sociology draw upon cybernetic methods, none can claim to be a branch of the cybernetics tree. Sociocybernetics can. In fact, it is a direct descendant and major branch of cybernetics—see Map 1. Furthermore, several key scholars in sociocybernetics are major figures in the cybernetics tradition, namely Walter Buckley, Kenneth Bailey, and Felix Geyer.

As Geyer and Zouwen explain (2001), sociocybernetics emerged out of the growing interest of system scientists in the application of cybernetic principles to the study of social systems. The classic example of this growing interest is Norbert Weiner's *The Human Use of Human Beings: Cybernetics and Society* (1950/1954). The reader may recall that earlier in this chapter we defined socionics, in part, as the study of how human systems are becoming more like computer systems through the human/computer interface. We also defined socionics as the control of computer systems through the study of how they act like human systems. These are the same goals of cybernetics, as envisioned by Wiener, with a major twist. To make sense of this twist, and how it led to the development of sociocybernetics, we take a brief historical detour into the work of Wiener.

6.4.1.1 The Development and Limitations of Cybernetics

It is important to remember that, when Wiener invented cybernetics, it was the early 1950s. In mathematics, this was the beginning of the computer age and, in the United States, it was the beginning of the cold war. A brave new world was emerging comprised of new communication systems, war games, missile guidance systems, computer databases, game theory. And (going into the 1960s) concerns with governmental control over society were a major intellectual and political issue. (As a side note, Wiener was a liberal and opposed to military usage of his ideas—see Hammond 2003.)

The 1950s was also the heyday of American sociology, including Talcott Parsons and the Department of Social Relations at Harvard; C. Wright Mills' *Power Elite* (1956); and David Riesman's *The Lonely Crowd* (1950), which sold over 1.3 million copies.

Most important for the current story, the 1950s was the beginning of the merger between computer science and social science (remember the methodological lineage of computational sociology we reviewed earlier), creating a new vision and understanding of how humans and their human societies worked. Wiener was one of the scholars at the forefront of this merger.

Wiener's argument in the *Human Use of Human Beings* is twofold. First, he believed that the human/computer interface was creating an entirely new world, for which science needed to help society prepare. The second argument, however, is what got Wiener into trouble. He believed, based on the first argument that the best way to gain control over contemporary human society was to understand how it acted like a computer system. More specifically, how society acted like a machine-based communication system. Of the various arguments made by cybernetics, this one pushed sociologists and social scientists away from this field (Capra 1996). It is one thing to claim that the computer/human interface is creating a new society (which we refer to today as post-industrial, postmodern, global network society). It is quite another, however, to argue that human society is best understood through the framework of communication networks.

Once again, we need to contextualize Wiener's argument. When cybernetics first emerged, it was a major hit in the natural sciences and engineering. Transferring the success of cybernetics to the social sciences made sense. If society is becoming a massive communication system, then understanding it through the framework of cybernetics seemed best. It was quite reasonable for Wiener, being a mathematical genius and innovator in the control of communication systems (feedback, control theory, chaos and noise in systems, Shannon's information theory, etc), to move his theory to the study of society. (As another aside, let us not forget that even Luhmann defines society as a communication system.) The computer was the perfect metaphor for understanding human systems.

Wiener, however, was wrong. He was wrong for two reasons. First, unlike machines, human systems are reflexive. They can react and adapt to the scientist's knowledge of them. Second, scientists do not exist outside the human systems they study.

These two realizations of the limits of cybernetics for studying society led Wiener and his colleagues to create a new version of cybernetics, which Heinz von Foerster called *second-order cybernetics*: the study of control and communication in human, particularly social systems.

6.4.1.2 Second-Order Cybernetics

Second-order cybernetics is important to the development of sociocybernetics for two reasons. The first is its emphasis on *self-observation within systems*. Second-order cybernetics recognizes that social systems are meaning making, communicating, self-reflexive, self-regulating and self-producing phenomena. This is why Foerster defines second-order cybernetics as the "cybernetics of observing systems" (See Capra 1996). Nonliving systems such as a computer, welding machine, internet, or cell phone are not self-observing. They do not possess—at least not yet—the capacity for self-reflection. At best, they are forms of artificial intelligence. Information comes in, it is processed, and a certain set of actions take place. Social systems, in contrast, are self-observing. They have the capacity to reflect on themselves and therefore change their behavior, both in relation to themselves and those observing them.

The second reason why second-order cybernetics is important to the development of sociocybernetics is because it addresses the problem of *observing self-observing systems*; or what is referred to in sociology as the "sociology of knowledge" problem. This problem, which most sociologists are well versed in, focuses on many of the arguments raised by the linguistic turn in philosophy, sociology, and the humanities (post-structuralism, postmodernism, feminism, multiculturalism, and neo-pragmatism). How are we able to understand society if we are situated within it? Can sociologists do naturalistic inquiry? Even more important, pace Luhmann, how does society come to know itself?

6.4.1.3 Sociocybernetics is 3rd Order Cybernetics

While the above two reasons were important to the development of sociocybernetics, they were insufficient. At the end of the day, even second-order cybernetics did not seem to the early scholars of sociocybernetics as sufficient for the study of social systems (Geyer and Zouwen 2001). The whole project of cybernetics needed to be pushed further.

Said another way, the scholars of sociocybernetics were not content with the one-way transfer of second-order cybernetics to the study of sociology. Instead, they believed a two-way relationship needed to be established where sociology and second-order cybernetics critically intersected to create a new approach to the study of social systems. Hence a new area of research within SACS emerged.

6.4.1.4 The Argument of Sociocybernetics

If the argument of sociocybernetics sounds familiar, it should. This is the same argument we have discussed in this book regarding complexity science and its integration with sociology. The only difference is that sociocybernetics made this argument over 40 years ago.

The first sociologist to make the argument of sociocybernetics was the American sociologist, Walter F. Buckley, professor of sociology at the University of New Hampshire and 1998 honorary chair of the sociocybernetics research committee (RC-51) of the International Sociological Association.

In a series of books and articles, most notably his 1967 publication *Sociology and Modern Systems Theory*, Buckley argued that the sociological theory of systems needs to be rewritten. The action-based, functionalist theories of Parsons, along with the equilibrium and evolutionary models of Durkheim and Spencer, needed to be thrown out and replaced with the latest advances taking place in second-order cybernetics. Equally important, second-order cybernetics needed to be integrated with the ideas of sociology.

The result, for Buckley, was the realization that social systems are complex, open-ended, dynamic, self-organizing emergent phenomena. Furthermore, social systems operate in a position between chaos and order, adapting to internal and external pressures through the twin forces of morphostasis and morphogenesis. The last two terms Buckley created to provide his own version of social autopoiesis: the dynamics by which a system reproduces itself while adapting to internal and external pressures to change.

6.4.1.5 Too Much Too Early

The sociological reception of Buckley's ideas is a story of too much and too early. While second-order cybernetics and systems science immediately got the point, sociology (in a manner reminiscent of its whole-scale rejection of all-things systems) seemed to miss the boat.

For example, the review of Buckley's 1967 book in the *American Sociological Review* was by the famous systems scientist, Anatol Rapoport, not a sociologist. Rapoport understood what sociologist did not: Buckley's ideas were far ahead of his time. The result was that Buckley's ideas were not significantly embraced. Even though he leveled a thoroughgoing critique against Parsons and created a new theory of social systems, the zeitgeist in sociology was moving away from systems thinking. Fortunately, his work did not go entirely unused. Likeminded sociologists in the 1970s and 1980s picked up his ideas to create what they saw as a new field of study, which they began to call sociocybernetics.

6.4.1.6 The Formal Emergence of Sociocybernetics

While Buckley was instrumental in pioneering the idea, sociocybernetics, as a legitimate area of research, was the brainchild of a small network of scholars working at the intersection of sociology and cybernetics. These scholars include Francisco Parra-Luna, Felix Geyer, Richard Henshel, Kenneth Bailey and Johannes van der Zouwen.

Parra-Luna was the primary originator of this area, working almost single-handedly to gain sociocybernetics status as a research group in the International Sociological Association in 1980. Over the next two decades, however, sociocybernetics had difficulty coalescing into a meaningful area of study. Finally, by 1999 sociocybernetics became a research committee (RC-51) in the *International Sociological Association*. During this time, it also established its own journal (*Journal of Sociocybernetics*), created a governing Board, developed its membership, began amassing a growing network of several hundred publications and put together a website (www.unizar.es/sociocybernetics/).

By the late 1980's, Parra-Luna was not alone in his efforts. He had much help. One of his most important helpers is Felix Geyer, Professor of Sociology, University of Amsterdam. While Geyer has not written a system theory of society nor created any major methodology, like Barry Wellman in complex social network analysis and like Nigel Gilbert in BBC and computational sociology, he is an authority. He has written most of the reviews on sociocybernetics, worked diligently to keep the RC-51 running, published book chapters and articles on various issues in sociocybernetics, founded the *Dutch Society for Systems Research*, co-edited with Zouwen the most updated book on the field (2001), and steadily sung the praises of this area of research to cybernetics and sociology. He has been recognized for these efforts. In addition to his status within the International Sociological Association, he is part of the "Who's Who" list of the American Society for Cybernetics and, equally important, the membership of RC-51 had swelled to over 240 scholars, boasting a network of scholars from across the social and natural sciences.

The eclectic nature of sociocybernetics's historical development is another feature it shares with the intellectual lineage of complexity science. Like complexity science, sociocybernetics is organizationally and intellectually post-disciplinary. In fact, sociocybernetics is so post-disciplinary that, if it were not for its status as a research committee in the *International Sociological Association*, one would be hard-pressed to even recognize the field. The reason, following the logic of creative marginality, is that most of its scholars claim primary identity in other areas, with their sociocybernetics affiliation being secondary. For example, just within SACS alone, members of sociocybernetics range from Jürgen Klüver (computational sociology) to John Mingers (LSC) to Immanuel Wallerstein (global network society). Despite the post-disciplinary nature of sociocybernetics, when it comes to the traditions of sociology, its focus is clear.

6.4.2 Sociology Lineage

Minor variations in theoretical usage aside, the sociological lineage to which sociocybernetics is linked is sociological systems thinking, including the ideas of the canonical scholars: Spencer, Marx, Weber, Pareto, and Durkheim. As we discussed earlier, however, sociocybernetics seriously sidesteps the structural-functionalist stage of systems thinking, avoiding altogether the work of Parsons. Instead, sociocybernetics turned its attention to Buckley and then Luhmann. These two scholars are the dominant theoretical frameworks in sociocybernetics (Geyer and Zouwen 2001).

6.4.3 Complexity Science and Sociology Method

It is important to remember that, like the LSC, sociocybernetics got its start way before the emergence of complexity science. As such, its methodological lineage reads somewhat like the history of computational sociology, starting with an early interest in equation-based modeling, artificial intelligence and control theory, turning to cellular automata and computational modeling, and eventually agent-based modeling. Unlike complexity science method, however, sociocybernetics is equally historical and qualitative in its methods, particularly when it comes to studying formal organizations and the various subsystems of society: economy, law, politics, etc (Geyer and Zouwen 2001).

6.4.4 Complexity Science and Sociological Topics

The last issue to address is the topics of sociocybernetics. Unlike the BBC or the LSC, which seek to revise key concepts in sociology such as society, the focus of sociocybernetics has consistently been on integrating sociology and second-order cybernetics. In fact, as Geyer and Zouwen have argued in a series of publications (1992, 2001), despite interest in a variety of empirical topics, the dominant topics in sociocybernetics all have to do with constructing a meticulous theory of social systems in light of second-order cybernetics and the challenge of studying social (self-observing) systems.

Here is a brief overview of these themes. Starting in the late 1970s and early 1980s, the theme was refuting Parsons and replacing his ideas with the latest advances in systems science and second-order cybernetics. The next major theme, appearing during the middle 1980s was examining the dynamics of social systems, conceptualized as systems in transition. The primary empirical focus for this work was developing countries, with a nod to world systems theory. In the late 1980s and early 1990s, the focus moved to the "paradoxes inherent in the observation, control and evolution of self-steering systems—specially the paradox important to policy-makers worldwide: how can one steer systems that are basically autopoietic and hence self-referential as well as self-steering" (Geyer and Zouwen 1992, p. 4)? By the late 1990s (and up to the present) the focus of sociocybernetics shifted to the newly emerging field of complexity science, focusing on the epistemological, methodological and theoretical challenges of studying complexity. In their 2001 edited book, *Sociocybernetics*, Geyer and Zouwen organized this theme into three subsections: growing societal complexity, autopoiesis, and observation of social systems.

Conclusion

While sociocybernetics might not enjoy the popularity of the new science of networks or computational sociology, and while it does not have the focus and following of the LSC or the BBC, it is an important area of research in SACS, primarily because its work is like therapy: while excited about the new ideas in cybernetics, systems science, agent-based modeling, artificial intelligence, complex networks and complexity science as a whole, the epistemological concerns sociocybernetics has with the difficulties of studying social systems reminds us to always proceed cautiously, making sure we are doing science and not the latest fad. With this said, we have completed our review of the areas of research in SACS.

7 The System of SACS

Now that we have a good understanding of the various parts of SACS, including its key environmental forces, major environmental systems, underlying social practices, primary areas of research and leading scholars, we want finally to assemble these parts to study SACS as a system. In broad brush strokes, the current chapter focuses on the evolution of SACS between 1998 and 2008. Chapter 8 focuses on the structure and dynamics of SACS today, circa 2008. Before we begin, however, a methodological pause is necessary.

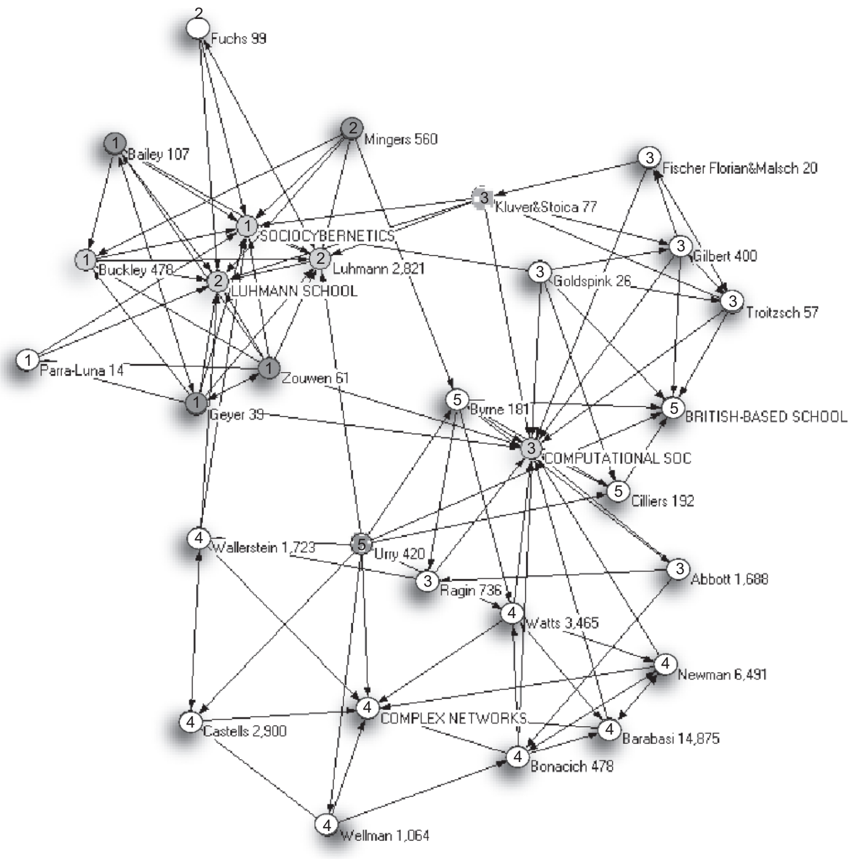
7.0 Why More Method?

As we explained in the preface (Sect. 0.3) and introductory chapter (Sect. 1.3.3), the bulk of this study—both in terms of data and method—has been historical in nature, relying upon such archival materials as websites, periodicals, books, articles, personal communication with key SACS scholars, reviews, biographies, autobiographies, and critical commentaries. Based on this historical archive, we wrote Chaps. 1 through 6 and created our maps of SACS, specifically Maps 2 and 4, which visualize the system of SACS and its network of attracting clusters. While this historical archive has proven immensely valuable, it is insufficient for the current chapter. Additional data, (specifically a citation database) and additional techniques (specifically social network analysis and the new science of networks) are needed. In this section we explain these additional resources and how we will go about using them.

7.0.1 More Data and Techniques

As we stated in Chap. 2, one of the strengths of the SACS Toolkit is its ability to work with a variety of data and data-analytic techniques. The data and techniques used in the current book are a case in point. To assemble a model of SACS that other researchers can likewise create, test, verify and develop for themselves, we needed to move beyond the historical database upon which the majority of our book has been based to include a repeatable quantitative study. We therefore decided that, in addition to the historical model we had constructed (as shown in Maps 2 and 4) we would create a current citation-based, social network model of SACS—see Map 6. Not only would such a model allow us to validate our historical findings, it would provide a level of detail we so far lacked, such as SACS's degree of interconnectedness, hubs, authorities, gatekeepers, household names, and powerbrokers. Furthermore, we could analyze this model using the latest techniques and concepts of social network analysis and the new science of networks, specifically the network software program *Pajek* (Nooy, Mrvar and Batagelj 2005). Before we proceed, a caveat is necessary about our new techniques and their corresponding terms.

Map 6: Social Network Model of SACS



7.0.2 Into the Swamp Again!

Excluding Chap. 4 (which provided a brief overview of our findings) this book has focused on what we call "a detailed study of the swamp." By this we mean that we have meticulously moved through several marshes of new terms and techniques; quite a few bogs of innovative scholars and new schools of thought; and even an everglade or two of new research areas (often times in lists of fives), all with little concern for the "big picture" of SACS. One would think, then, that having finally arrived at the end of our book we would be free of all quagmires in Chaps. 7 and 8. "No more new terms and techniques," we could finally exclaim! Unfortunately, no such freedom can yet be granted. A dry land or bird's eye view of SACS must wait for Chap. 9.

While Chap. 7 and 8 survey SACS as a complete system, they take us yet again into a swamp of new terms and techniques. These new terms (which we have yet to really define) include hubs, authorities, bridges, gatekeepers, internal impact, external impact, funneling, impact, weak-ties, strong-ties, the small-world phenomena, local links, global links, trajectories, fractal-scaling, 1^{st} and 2^{nd} and n^{th} degrees of separation, internal connectedness, and interlinking. The new techniques include: (1) the network software program called *Pajek*, (2) several of the distance measures used in the new science of networks, and (3) the last couple of steps in the assemblage algorithm.

Given this onslaught, readers may find some sections of Chaps. 7 and 8 rather tedious. To help, we will do the following. First, we have organized Chaps. 7 and 8 into a series of "bite size" sections, focusing on one or two points at a time. Second, we stop whenever we can to define or explain quickly what we are doing. These pauses will also prove useful to readers well-versed in these terms and techniques because, as we explain below, we use some of them in slightly unique ways on behalf of the SACS Toolkit. Third, we provide references for further reading at each step of the way. For those readers completely unfamiliar with the terms and techniques of social network analysis (specifically *Pajek*) or the vocabulary and methods of the new science of networks, we recommend the following resources while reading Chaps. 7 and 8: Barabási (2003), Buchanan (2002), Nooy, Mrvar and Batagelj (2005), Scott (2000) and Scott, Carrington and Wasserman (2005). With these caveats, we turn to a discussion of how we constructed our database and how we used *Pajek* to analyze it.

7.1 Data and Procedures

Our discussion of *Pajek* and our database is organized as follows. We begin by discussing how we used our historical database to arrive at our Top 25 scholars database. Next, we discuss how we collected the data for these Top 25 scholars, including: (1) a rough estimate of each scholar's total citations, (2) their links to the five areas of research in SACS, and (3) their links with the other Top 25 scholars. From here we turn to a review of procedure. We explain what *Pajek* is and the type of network we used it to create. Next, we review the terms we used for discussing the powerbrokers in our network: hubs, authorities, gatekeepers, household names. We end by explaining how to read the maps *Pajek* creates (See Map 6 and 7) and, most important in terms of empirical corroboration, their similarity to the historical maps we used in the preceding chapters of this book.

7.1.1 Is a Network a System?

As suggested in our "detailed study of the swamp" discussion above, during the course of the next two chapters, the reader will see a rather sudden shift to "all things" networks. This shift may leave some readers wondering why? If the reader recalls, in our chapters on the SACS Toolkit, we explained that, when discussing the overall structure and dynamics of a social system, the primary emphasis is on the network of attracting clusters and its evolution within time-space. In this way, the term *network of attracting clusters* is synonymous with the term *social system*. We will therefore use these two terms interchangeably.

7.1.2 Choosing the Top 25 Scholars

Throughout this book we have focused on the "movers and shakers" of SACS: the leading scholars in each of this town's five areas of research. Gilbert, Watts, Luhmann and Urry are all movers and shakers; so are Byrne, Geyer, Wallerstein and Bailey. As shown in Map 4, when you add these names together, your total is about N=25. Because the purpose of our citation network is to replicate (hopefully) and model the system of SACS, we confined our network model to this list of Top 25 scholars.

Before we proceed, however, we need to make two caveats. First, while we are confident that our Top 25 list well represents SACS, this confidence does not preclude other researchers creating a slightly different list.

Second, the reader should not mistake our Top 25 list for the larger community of SACS. While we have no exact figure on the total number of scholars working in SACS, it is certainly far greater than N=25; perhaps somewhere around three or four hundred. For example, the total registered members of RC-51 alone (the research committee for sociocybernetics) is N=95.

7.1.3 Database

To assemble SACS into a social network model we turned to the *ISI Web of Science Citation Index*. The *Web of Science* (owned by *Thompson Scientific*) is an online catalogue of over 8,700 journals in the sciences, social sciences and humanities (scientific.thomson.com/products/wos/). Researchers can use this catalogue to conduct a variety of searches, including scholar, subject, and cited reference searches. We used the *Web of Science* to create a cited reference search on SACS. We took the Top 25 scholars historically identified in Map 4 and collected three important pieces of information.

Total Citations: First, we collected the total number of citations (Σ) for each scholar. We treated this Σ as a measure of a scholar's intellectual impact. This Σ is, however, a crude measure because it includes all citations to a scholar, without distinction as to the type of article or book being cited. While most of what our Top 25 scholars have published relates to the topics of SACS, this is not always the case. We did not remove these non-SACS publications (or the citations of them) for two reasons: (1) their incidence seemed to be low; and (2) the task of removing them would have required us to carefully read over a thousand publications.

The Σ for each of our Top 25 scholars was arrived at using one of the following three methods.

- First, for those Top 25 scholars who primarily publish articles, we conducted an *Author Search*, which gave us the total number of articles the scholar published between 1980 and 2008—the timeframe covered by the *Web of Science*. From here we were able to create a citation report, which included: (1) a summation of the number of times the scholar is cited, (2) a list of the publications citing the scholar, and (3) a breakdown of the articles citing a scholar by subject area, document type, scholar and institution.
- Second, for those Top 25 scholars who primarily write books, we conducted a *Cited Reference Search*. This second type of citation search allowed us to determine the total number of times anything written by a

scholar has been cited since 1980 in the 8,700 different journals catalogued by the *Web of Science*. From this data we generated the same types of report as our author search.

- Third, for those Top 25 scholars who primarily write articles but have published an important book or two, we did a cited reference search for the book and an author search for the articles. We then combined these citation records for a grand total.

Areas of Research: in addition to ∑, we conducted a keyword search for each scholar to: (1) identify the areas of research in SACS the scholar is affiliated with; (2) corroborate if the historical part of our study (Chaps. 4 through 6) correctly identified the scholar's affiliation; and (3) determine if the scholar is involved in any additional areas of study within SACS. For example, while Barabási is primarily affiliated with complex social network analysis, he makes extensive usage of agent-based modeling and is associated with computational sociology.

Top 25 Citation Matrix: From our total citations list we created a database of who-cites-whom amongst our Top 25 scholars, as well as their scholarly links with their respective areas of research. It is this database that we used in *Pajek*. All of the ties (links, connections, relationships) shown in Map 6 are limited to the citations amongst the Top 25 scholars, as well as their respective areas of research. No additional links are considered. Wallerstein, for example, is linked to global network society, the LSC and sociocybernetics; he cites the work of Castells; and he is cited by Castells, Urry and Ragin.

7.1.4 Analytic Procedure

To create our social network model of SACS, we used the software package *Pajek*—which is Slovenian for spider. Created by Batagelj and Mrvar (See Nooy, Mrvar and Batagelj 2005), *Pajek* is designed for the visualization and analysis of large social networks and is freely available for noncommercial use (*Pajek*.imfm.si/doku.php).

Loading the Database: To begin, we uploaded our database into *Pajek*. The first section of our database contained a label for each of our 25 scholars, including their last name and their total number of citations. Barabási, for example, who has been cited almost 15,000 times, is listed as "Barabási 14,875." Next, we listed the other top scholars in SACS (including collaborations) who cite them. Barabási, for example, is cited by Watts, Newman and Bonacich. We next included a list of the areas of research in which each of our Top 25 scholars participates. Barabási, for example, participates in CSNA.

SACS as a One-Mode, Directed Network: With our database uploaded, we next ran *Pajek* to construct a one-mode, directed (edges) network. A one-mode network allows all of its nodes to be related to each other; a directed network allows the researcher to define the direction of each link. In a directed network, weak-ties refer to those links were the arrow goes in only one direction; strong-ties refer to those links with arrows going both ways.

SACS Partitioned: We partitioned our citation network according to the five areas of research in SACS, which we arrived at from our historical inquiries. In *Pajek*, partitioning is a useful technique because it allows the researcher to identify, cluster and map a set of nodes in a network based on a predefined characteristic.

We used partitioning because, based on our historical research, we had already identified, clustered and mapped our Top 25 scholars according to their primary area of research in SACS. In other words, we already knew what partitions they belonged to—See Map 4 and the scholarly links.

Database in hand, we wanted to see if *Pajek* would use our five partitions to generate a similar map. If *Pajek* generated a similar map, we could be confident that our model is reasonably valid: we could state that, on two different occasions and with two different databases the same basic negotiated ordering of SACS emerged.

Map 6 shows the partitioned network that *Pajek* created. As the reader can see, Map 6 is very similar to Map 4.

Vectors and Powerbrokers: The final step in our procedure was to generate a set of vectors maps we could use to examine the powerbrokers in SACS—that is, the key hubs, authorities, gatekeepers and household names in this intellectual town. Vector maps identify powerbrokers by assigning numerical values to the nodes in a network. Once these values are assigned, the nodes in a network can be analyzed statistically. For all their sophistication, the concepts of hubs, authorities, gatekeepers, and household names are really just statistical procedures applied to the nodes in a network.

In the case of SACS, for example, *hubs* are the nodes (scholars or areas of research) in the network that are most often cited by the other nodes (scholars) in the network; in particular, they are the nodes most often cited by the other popular nodes in our network—popular nodes are other hubs or authorities. As shown in Map 6, Luhmann is a major hub.

Authorities are the nodes (scholars) in our network that cite the highest number of nodes, particularly the popular nodes. As shown in Map 6, Bailey is an example of an authority.

Gatekeepers are those nodes comprised of one or more bridges that, if removed, disconnect different areas of research (attracting clusters) in our network from one another. An excellent example of a gatekeeper is the team of Klüver and Stoica. As shown in Maps 6 and 7, they are gatekeepers because, if you remove their links from our network, computational sociology becomes almost entirely disconnected from sociocybernetics and the LSC.

Household names are those scholars in Map 6 with the highest total citations. Barabási, for example, is the biggest household name in SACS, with an amazing 14,875 citations.

7.1.5 How to Read the Map 6

Maps 6 and 4 are the same basic map. Like Map 4, Map 6 is a two-dimensional representation of SACS. The closer a node is to the center of the map, the more of a powerbroker it is. For example, the most centrally located area of research in our citation network is computational sociology. Location, however, is not the only indicator of the powerbrokers in a network. Power-brokering extends beyond location to node type: hub, authority, gatekeeper, household name, etc. Urry, for example, is highly central to SACS, demonstrating a significant level of internal power-brokering—he is, in fact, a major gatekeeper. Bailey and Mingers, in contrast, are on the periphery of SACS. Both, however, have a significant level of impact on the LSC—both are also major authorities in SACS. Furthermore, while Watts and Newman are peripheral to our citation network, they are major household names due to their massive total citations.

7.1.6 Map 6 Versus Map 4

While the layout of Maps 6 and 4 are similar to each other, they share some intentional differences. Let us explain.

One of the benefits of using multiple data sources is the ability to triangulate one's research. In terms of the current study, for example, we have our thick descriptions from Chap. 6, as well as Maps 4 and 6, which, when combined, create our model of SACS. More specifically, Map 6 intentionally provides us a different picture of SACS than does Map 4.

Map 4 is designed to highlight the five attracting clusters in SACS, with secondary emphasis on their respective scholars. As such, scholars are placed in relation to the primary cluster of which they are a part, rather than their relationship to other scholars. The strength of Map 4 is that it gives us a good understanding of the general layout of SACS, along with a sense of which clusters are the most important. For example, while Map 6 suggests that sociocybernetics and the LSC are internally important, Map 4 gives a better picture of the overall impact (both internally and externally) of these areas, suggesting that sociocybernetics plays a much lesser role than shown in Map 6.

Map 6, in contrast, is a citation-based model of SACS, with primary emphasis on the Top 25 scholars and their relationships with each other and their respective areas of research. In these maps, scholars and their areas of research are positioned by *Pajek* based on the manner of and degree to which they are connected with one another. The strength of Map 6 is that it gives us a good understanding of the internal dynamics of the Top 25 scholars in SACS. For example, while we have spent significant time in this book discussing the tremendous impact that Watts, Barabási and the new science of networks have on science today, their influence on the Top 25 scholars of SACS is marginal. It appears that most of their influence in SACS is based on their impact on areas outside this intellectual town—specifically complexity science and the larger scientific community. This external influence is why, as we will discuss in Chap. 8, these scholars are referred to as household names: they are important to SACS because of their external impact. Now that we have a basic understanding of how our database and *Pajek* work, we will turn to the final assembly of our model.

7.2 The Emergence and Growth of SACS (1998–2008)

The remainder of this chapter is organized around two foci: (1) how SACS got started; and (2) how SACS developed over the past decade.

The first focus takes us back to the late 1990s where we search for SACS's formal tipping point. Here, we wanted to know whether there was a particular point in space-time where SACS suddenly began its journey to become the town we know today. Furthermore, if parts of this town existed prior to the late 1990s, due to the legacy of the systems tradition in sociology, what happened to these older parts? Conversely, why did the newer areas of SACS, such as the new science of networks, find SACS a worthwhile place to take up residence?

The second focus takes us on a quick ten-year tour of SACS's journey to become the town it is today. Our tour addresses three major aspects of SACS's journey: its evolution, differentiation, and interlinking (both local and global) between 1998 and 2008. Let us now turn to our review.

7.2.1 The Emergence of SACS

The town of SACS formally emerged in Europe and North America during the late 1990s, a period of time John Urry (2005b) refers to as the *complexity turn*. As we discussed in Chap. 4, the complexity turn signifies a rather sudden qualitative shift in attitude and interest within the social sciences (specifically economics, sociology and the managerial sciences) toward the topics of complexity and complexity science. While complexity science had been around since the early 1980s, it was not until the late 1990s that social scientists suddenly "discovered" this new science and its ideas. In fact, this sudden "discovery" on the part of the social sciences has all the characteristics of a social tipping point.

7.2.1.1 Tipping Point

In the academic literature there are several variations of the term "tipping point" (Buchanan 2002; Gladwell 2000). For us, a tipping point is a type of relatively sudden social change strongly associated with the phenomena of emergence and critical phase transitions. A tipping point is the particular moment when a set of immediate events leading up to some type of global social change suddenly coalesce to make that change happen—a gestalt, if you will. In terms of time-space, this moment of coalescence is appreciably small relative to the set of events leading up to it, hence the concept's name, *tipping point*: the cumulative effect of a rather small set of immediate events/changes suddenly results in rather large-scale, global change/consequences. This does not mean that the events prior to this more immediate set of events are irrelevant. It only means that social change suddenly takes place because of these immediate events; that is, because of these events a social system suddenly emerges or quickly tips from one state or form to another. Examples of the former include riots, revolutions, the collapse of economies, and the emergence of new fields of study such as SACS. Examples of the latter include paradigm shifts in science, medicine, psychiatry and criminal justice, such as those studied by Foucault (1972, 1979, 1988), or the sudden (punctuated equilibrium) shifts in governmental control from one political party to the next.

7.2.1.2 The Tipping Point of 1998

The tipping point for SACS is 1998 (± 2 years). There are two reasons. First, during this time period a series of immediate events took place that lead to the sudden emergence of SACS: In 1996, Wallerstein and the

Gulbenkian Commission published *Open the Social Sciences*; between 1996 and 1998 Castells published his trilogy, *The Information Age*; and, in 1998 the new science of networks burst onto the scene with the publication of Watts and Strogatz's small-world phenomenon. In terms of computational sociology, in 1998 Nigel Gilbert started the *Journal of Artificial Societies and Social Simulation*; and, in 1999 he and Troitzsch published *Simulation for the Social Scientist*, the first handbook to put computational sociology on the intellectual map. In terms of sociocybernetics, in 1998 Parra-Luna and colleagues established themselves as a Research Committee (RC-51) in the International Sociological Association. Sadly, 1998 also marks the year of Niklas Luhmann's death. However, his passing launched a major international evaluation of his oeuvre and the LSC. Finally, in terms of the BBC, in 1998 Byrne published his very important book *Complexity Theory and the Social Sciences*, which was the first formal introduction to complexity science written by and for a social scientist. In this book Byrne also introduced readers to the newly emerging "BBC" approach to complexity science, primarily through his discussion of such topics as critical realism and urban planning.

The second reason that 1998 (± 2 years) constitutes a tipping point is because, as a function of these immediate events, a qualitative shift took place in SACS. Three new attractor points emerged—computational sociology, CSNA and the BBC—expanding and transforming this town into a whole new community. Let us explore this expansion and transformation further.

7.2.1.3 Don't Forget the Systems Tradition

While the complexity turn and the events of 1998 (± 2 years) constitute a historical tipping point for SACS, these actions alone do not this new town make. Prior to 1998, SACS was comprised of two major attracting clusters of research, sociocybernetics and the LSC. What the tipping point of 1998 therefore constituted was the transformation and expansion of an existing town into something entirely new and different—not the sudden emergence of a whole new intellectual community. Let us do a bit of archaeological digging.

As shown in Map 2, SACS resides just south of the dilapidated Parsons Highway, the thoroughfare of the functionalist phase in the sociological systems tradition. This highway connected the long-standing systems tradition in sociology with systems science and cybernetics in the natural sciences. In other words, structural functionalism used to reside in roughly the same intellectual space as SACS now does, albeit slightly north, given its connections to the intellectual lineage of complexity science—namely cybernetics and systems science. As such, what Map 2 does not show is that, if unearthed, the upper west side of SACS (where sociocybernetics and the LSC reside) is built partially on the ruins of the old city of Structural-Functionalism.

As we discussed in Chap. 6, sociocybernetics has the longest history in SACS, going all the way back to the 1960s and the work of Buckley and, later, to the 1980s and the work of Geyer, Parra-Luna, Bailey, and Zouwen. Given the strong connection these scholars have with the systems tradition in sociology, it made sense for them to build their new community just south of structural-functionalism. Like Parsons, the scholars of sociocybernetics sought a place where they could easily move between sociology, cybernetics and systems science, as well as create their own forms of institutional freedom.

However, because the scholars of sociocybernetics are not structural-functionalists, it made sense for them to build on a fresh, new plot of land, rather than entirely set up shop within the confines of the structural-functionalist tradition. And so, during the late 1980s and early 1990s, the first community of SACS was built, including the development of a new intellectual highway, the RC-51, which replaced the old, collapsed Parsons Highway.

In spite of all this groundbreaking work, the scholars of sociocybernetics had barely set up shop when their intellectual focus shifted sharply from second-order cybernetics to complexity. Two reasons underscore this shift. The first is environmental, complexity science hit the scene. The second is internal to SACS, a new neighbor moved into town.

In the late 1980s, the LSC arrived and set up shop. Looking at Map 2, it makes sense why the LSC built a community at the natural science fork in sociology's disciplinary river. Like the scholars of sociocybernetics, the LSC sought easy access to cybernetics, systems science and the newly emerging complexity science. More specifically, it sought close proximity to second-order cybernetics and the work of Maturana and Varela and their concept of autopoiesis. As a consequence, and much like cybernetics and systems science some thirty years earlier, the LSC and sociocybernetics almost immediately joined forces to become a sort of twin science. Almost from the beginning, however, this relationship was biased in the direction of the LSC. While the scholars of the LSC did not make extensive use of sociocybernetics, in sociocybernetics the LSC (as we discussed in Chap. 6) is extremely important.

As the LSC and sociocybernetics merged during the late 1980s and early 1990s, the town of SACS took its first real shape. But then things changed. By the late 1990s, the scholars of sociocybernetics and the LSC were no longer the only communities in town. Other sociologists and likeminded scientists found themselves building communities in SACS as well.

7.2.1.4 The Sudden Arrival of Everyone Else

While the early arrival of sociocybernetics and the LSC to SACS is easily attributed to their strong connections to systems thinking and systems science, it may seem less evident why the BBC, CSNA, and computational sociology would do so as well. We need to remember, however, several important things.

First, as shown in Map 2, Complexity Science City (CSC) resides just west of SACS. In other words, SACS is the only real intellectual space in sociology (albeit along its current margins) where scholars interested in a complex systems perspective can simultaneously build an intellectual community, engage in the type of creative marginality they seek, and go mobile. In fact, during the 1990s most of the sociologists who set up shop in SACS did so to shorten their daily commute into intellectual territories of which they were already a part. Gilbert, for example, worked for many years in CSC, alone, developing the ideas of computational and agent-based modeling. To create, finally, an intellectual space that is recognized by the mainland of sociology, praised by complexity science methodologists, and yet far enough away from both sociology and complexity science sufficient for computational sociologists to remain mobile, is a real accomplishment.

The creative marginality of SACS also works in the other direction—not everyone in this new town makes the trek from sociology to complexity. Some travel the other way. Watts, Newman and Barabási, for example, are all physicists. SACS is useful to them because, like Gilbert, it provides a similar creative marginality. In SACS they are free of the restraints of traditional physics to explore areas within sociology. Watts even went so far to join the Department of Sociology at Columbia University. And so, with the sudden arrival of everyone else, SACS, as we know it today, came into existence.

7.2.2 A Decade of Growth (1998–2008)

While the late 1990s frame the formative emergence of SACS, the following decade (1998–2008) represents a phase of significant development. During this decade, SACS went through a rapid phase of evolution, differentiation and interlinking, all of which are still going on today.

7.2.2.1 Dominant Theme

As we progress through the following swamp of details regarding the evolution, differentiation and interlinking of SACS, the reader will notice two major themes. First, there is a major intellectual division within SACS, with sociocybernetics and the LSC on one side and the BBC, CSNA and computational sociology on the other. Second, this division resulted in a decade-worth of uneven growth in SACS, with the evolution and differentiation of sociocybernetics and the LSC being almost entirely overshadowed by the evolution and differentiation taking place throughout the rest of the town.

7.2.2.2 Evolution

As soon as the BBC, CSNA and computational sociology arrived in the late 1990s, they began changing the intellectual landscape of SACS. The BBC, for example, particularly between 2000 and 2003, quickly involved itself in almost every aspect of SACS, from its governance to its collective identity. Furthermore, the BBC brought a new perspective free of the theoretical trappings of traditional systems thinking. Other than the BBC's commitment to creating a post-disciplinary sociology grounded in the theme of complex systems, the BBC bears no resemblance whatsoever to sociocybernetics or the LSC, including almost no shared topics or themes of concern. The only common topic is globalization. But, even here, Urry's global network society bears little resemblance to that of Luhmann's.

The BBC's lack of connection with sociocybernetics and the LSC is captured in Map 6. Other than Urry's link with Luhmann (which only acknowledges the latter's work) and Goldspink's link to sociocybernetics (which comes from his 2003 *JASSS* review of Geyer and Zouwen's 2001 edited book on sociocybernetics), there are no directed links running from the BBC to sociocybernetics or the LSC.

Computational sociology and CSNA have similarly weak connection to the LSC and sociocybernetics. While computational sociology and CSNA have strong connections to the intellectual traditions of cybernetics and systems science, they have had little to do with the work of the LSC or sociocybernetics. For example, as shown in Map 6, there are no directed ties running from CSNA to sociocybernetics or the LSC, other than the fairly recent links (circa 2003) of Wallerstein and Urry. Also, there are no links whatsoever going from the new science of networks to either the LSC or sociocybernetics.

The weak or absent connections that the BBC, CSNA, and computational sociology have with sociocybernetics and the LSC resulted in a decade of uneven growth in SACS. Not only did the former three areas grow at a much faster pace; their growth had no positive impact on the other two areas. The consequence for SACS was that sociocybernetics and the LSC became somewhat overshadowed by the rising size and prominence of the other areas of research.

This overshadowing was fueled by three environmental forces impacting SACS during this time period (1998–2008): the increasing popularity of complexity science, the widespread adoption of agent-based modeling amongst the general scientific community; and the massive natural science literature created in the wake of the new science of networks. For example, as of 2008, Barabási alone has been cited almost 15,000 times, an absolutely incredible number that towers over the 700 citations for all the scholars in sociocybernetics combined. Part of this difference in total citations has to do with the way natural scientists do research: a problem emerges, such as the structure of complex networks, and a significant segment of the field collectively comes together to address it until some degree of accepted resolution is accomplished. In contrast, research in the social sciences tends to be done by much smaller groups—sometimes as small as 25–50 researchers. Given these differences, to have 700 citations in the social sciences is rather significant. Still, it does not compare to the citations of Barabási.

And so, throughout the late 1990s and the first eight years of the 21st century, while the three new areas evolved at a phenomenal pace, almost taking over SACS, the older two areas evolved at a significantly slower pace, becoming somewhat overshadowed by their new neighbors. Interestingly enough, this uneven pattern of evolution was mimicked in the internal differentiation of SACS.

7.2.2.3 Differentiation

Our usage of the term "differentiation" comes from the work of Luhmann (1982, 1995). For Luhmann, differentiation is the mechanism a social system uses to handle its internal complexity. As a social system becomes more complex, it divides into a series of attracting clusters, which can further subdivide into their own subclusters, all in an effort to create a more sophisticated division of labor. Academia, for example, has split into the natural sciences, social sciences and the humanities, each of which has split into a series of disciplines, which have likewise differentiated into a set of subdisciplines, fields of research and so on.

A significant level of differentiation took place in SACS, starting with the tipping point of 1998. First, to handle the growing complexity of its work—more scholars, more topics, more methods, more theories—three new attractor points emerged in SACS: the BBC, CSNA and computational sociology. As the decade proceeded, however, these three new attractor points were not enough, resulting in the secondary emergence of six additional subclusters (the new science of networks, global network society, simulation, data mining, dynamical systems theory and complex complexity) and one second-order subcluster, socionics. Let us explore further these subclusters.

In CSNA, for example, while scholars involved in the study of global network society and the new science of networks shared similarities in focus (including a common interest in globalization), their methodological and substantive foci required them to go in somewhat different directions. In terms of method, scholars involved in the study of global network society were more historical, while the scholars involved in the new science of networks were more computational. In terms of substantive concerns, the former was driven by its vision of creating a new sociology grounded in the concept of a global society, while the latter saw globalization as an interesting way to test its theory of large, complex networks. Global network society also emerged, in part, through the migration of BBC scholars (Urry, in particular) into CSNA. And so, a series of differentiations occurred within CSNA. In fact, one could argue that CSNA emerged out of the coalescence of its two sub-clusters and that the complexity of CSNA has kept these sub-clusters distinct areas of work.

Similar differentiations took place in the BBC and computational sociology. C^2 (complex complexity) emerged around 2003 as a key subcluster in the BBC. Meanwhile, computational sociology differentiated into simulation, data mining and dynamical systems theory. Simulation further divided into general simulation and socionics. General simulation emerged through its strong connection with Gilbert and the BBC. Socionics emerged through the work of Fischer, Florian and Malsch (2005), as well as a number of other key German sociologists, such as Klüver and Stoica.

No differentiation, however, took place in sociocybernetics or the LSC. While both areas of research employ a variety of methods and concepts and while both explore a variety of topics, none of this variety resulted in a significant internal differentiated within either cluster. With that said, we turn to the issue of interlinking.

7.2.2.4 Interlinking

In the new science of networks, the relational terms *links*, *connections*, and *ties* are often used as synonyms for the associations between a set of nodes. (Nodes, by the way, are also often called vertices and sometimes egos.) Of the three relational terms, "ties" is the most specific and is used to discuss the quality of a link or connection. The classic example of the technical usage of the term "ties" is Granovetter's research on strong-ties and weak-ties (1973). Characteristic of all three relational terms is their static nature. While relational, they are structural terms. They describe what is. Interlinking, in contrast, is a dynamic term.

Interlinking refers to the process by which a network of attracting clusters becomes more densely connected. We can think about interlinking at two levels: the local and the global. *Local interlinking* refer to the growing internal connections amongst scholars within a given research area—also called a partition, attracting cluster or attractor point surrounded by cases. *Global interlinking* refers to the growing connections amongst two or more research areas. In most scientific networks, global interlinking is less dense relative to local interlinking (e.g., Newman 2001a, 2001b).

Between 1998 and 2008 a significant level of interlinking took place within SACS. As with the evolution and differentiation of SACS, the major theme here is the lack of global interlinking between sociocybernetics and the LSC with the rest of SACS and, as a consequence, the uneven growth this lack of global interlinking produced.

Local Interlinking

A common technique used to examine the interlinking of a network is the *walk*. The walk is a tour through a set of nodes to determine how densely connected they are. Walks come in two types: semi and full. A semi-walk is the easiest. Starting with any node in a network or sub-network, a semi-walk is one where the researcher can go to any other node in the network or sub-network, without worrying about the direction of the links' arrows. Networks or sub-networks that allow a semi-walk are referred to as weakly connected or just connected. A full-walk is one where, starting at any node, the research can obey the arrows of each link and still move to every other node in a network or sub-network. Networks or sub-networks where a full-walk can be accomplished are called fully connected.

As shown in Map 6, after a decade of development, circa 2008, a semi-walk is possible throughout the entire network of SACS, which indicates that all five areas of research in this town are connected. The five areas of research within SACS are also internally connected.

- Sociocybernetics and the LSC are well linked, although only a semi-walk is possible within this sub-network of scholars. Part of the reason the connections amongst the scholars of sociocybernetics and the LSC are so well developed is because these links were present before the tipping point of 1998 and because, at least since the late 1980s, scholars in sociocybernetics have relied extensively on the work of Luhmann (Geyer and Zouwen 2001).

- A semi-walk is likewise possible for CSNA.
- There is even a trifecta within the new science of networks, allowing for a full-walk between Watts, Newman and Barabási.
- The rest of CSNA has also become connected rather well over the last decade, due in large measure to the prominence of the scholars involved in this area of research, namely, Wallerstein, Castells, and Urry.
- Computational sociology is also well interlinked. There are two reasons. The first has to do with the rapid and widespread popularity of agent-based modeling (Gilbert and Troitzsch 2005). The second has to do with the incredible networking of Nigel Gilbert. As we discussed in Chap. 6, Gilbert is an absolute powerhouse. A man of many talents, he has worked very hard to promote computational sociology, involving himself in just about every aspect of this new area, from steering committees, conferences and websites to research, think tanks and handbooks to business applications, editing the *JASSS* and creating curriculum. In fact, it would be interesting to create (based off the Erdös Number) a "Gilbert Number" for all of the researchers in computational modeling. Gilbert's tremendous interlinking has paid off. Computational sociology is a highly connected area.
- Finally, there is the BBC. These scholars rather quickly developed their research agendas into meaningful attractor points, primarily through their interdisciplinary institutional affiliations, their shared identity as British sociologists, their common concerns with the growing complexity of sociological work, and their need for new theories, methods and concepts grounded in complexity science. The ideas of the BBC has fast gathered a growing network of colleagues from across the sciences, as well as scholars outside the United Kingdom.

Global Interlinking

Global interlinking is important to a scientific network such as SACS for three reasons. First, it allows the network of attracting clusters to settle into a somewhat stable intellectual system. Second, its allows the intellectual system to form a common identity, develop a shared methodological repertoire, generate mutual topics of interest, and so forth—basically, everything we discussed in Chap. 4 regarding the characteristics of an intellectual town or community. Third, global interlinking allows the areas of research within an intellectual system to intersect for the purposes of differentiating or evolving into new areas of research or new sub-clusters.

As the global interlinking within an intellectual system develops, some of these connections will change from weak to strong, resulting in new avenues of study, some of which will turn into new attractor points of research. In SACS, for example, the strong ties between Gilbert and computational sociology resulted in the creation of general simulation, while the strong ties between Urry and CSNA resulted in the creation of global social networks.

The reader must remember, however, that SACS does not fit the traditional categories of field, sub-discipline, etc, which is why we call it an intellectual town. What makes SACS unique is that it is open-ended, non-incorporated, weakly governed, loosely affiliated and post-disciplinary. As such, it probably will never coalesce into the type of globally interlinked system one finds in the traditional sub-fields found in sociology or physics. Or perhaps SACS will? As we discuss in Chapter 8, for all its creative marginality, SACS appears to have the structure and dynamics of a typical academic community. But we will have to wait until later to explore this point. For now, we need to finish our review of the global interlinking that took place in SACS between 1998 and 2008.

Over the last decade, the links running from the LSC and sociocybernetics to the rest of SACS have remained rather weak or nonexistent. In fact, the LSC and sociocybernetics would be almost completely detached from the rest of SACS if it were not for the recent links developed by Urry, socionics, and the team of Klüver and Stoica.

As a side note, it is worth pointing out that Klüver and Stoica, as well as the key scholars in socionics are all German. As such, they are not only very familiar with the work of Luhmann; they see its relevance to simulation and computational sociology, which partially explains their links with the LSC and sociocybernetics, both of which are also strongly tied to German sociology. In fact, Klüver is a member of the RC-51. The global links between the LSC and the rest of SACS may therefore develop once English-speaking sociologists have translated texts that allow them to engage this literature.

Despite the weak, global ties between the west and east sides of SACS, other areas of this town are rather well-connected globally. For example, starting in 1998, and continuing onward to 2008, the BBC and computational sociology have remained strongly connected. This connection is due in large measure to Nigel Gilbert's heavy involvement in the creation and development of both areas of research. The BBC is also strongly connected to CSNA, primarily through the work of Urry. This connection, however, did not come about until the first decade of the 21st century when Urry began to ground his theory of mobile society in the work of Castells, complexity science, and the new science of networks. In turn, CSNA is strongly connected to computational sociology, primarily because computational sociology functions as the methodological toolbox of CSNA. This, then, gives us a sense of the development of SACS over the last decade. We turn now to a review of SACS today.

8 SACS Today

Now that we have a basic sense of when SACS emerged and how it developed over the past decade, it is time to examine its negotiated ordering, circa 2008. Our examination is organized into four major sections

Overall Connectedness: We begin with a general picture of SACS, focusing on the unique and combined information provided us by Maps 4, 6 and 7, with a focus on the degree to which SACS is internally connected. This discussion builds on our Chap. 7 review of how SACS evolved between 1998 and 2008. With this general picture, we then turn to a detailed review of the most important scholars and areas of research in SACS.

Powerbrokers: As we discussed in Chap. 6, the most important scholars and areas of research in SACS, which we call powerbrokers, are those nodes with the biggest impact on the structure and dynamics of this intellectual town. While these powerbrokers go by many names, we focus on four types: hubs, authorities, gatekeepers, and household names. We end this section summarizing this information to identify the top areas of research in SACS.

Internal Division: Next, we examine the dynamics and internal trajectories of SACS. While the focus here is on SACS, circa 2008, we continue to note the same two themes discussed in Chap. 7: the growing intellectual division within SACS between the west and the east side, and the dominating presence of the east side on the current trajectory of SACS. The question, however, is why? What is the cause of these opposing trajectories? The majority of this chapter will be spent answering this question.

The Near Future: Finally, we examine where SACS might be heading next. While the trajectory of the east side currently controls the direction of SACS, how long will this last? Alternatively, if the east side does not remain dominant, what might happen next? For example, are there any new scholarly stars on the rise? Or, are there any new areas of research that might significantly shift the current negotiated ordering of SACS?

8.0 Negotiated Ordering

8.0.1 Generating Map 6

We begin our review of SACS today (circa 2008) by discussing how we created the layout for Map 6. It was created using an energy command from *Pajek* (Nooy, Mrvar and Batagelj 2005). An energy command is a layout procedure that iteratively moves the nodes in a network to a set of locations in two or three dimensional space in order to "minimize" their overall variations in line (ties, links, etc) length. An energy command stops when the network settles into a state of relative equilibrium (Nooy, Mrvar and Batagelj 2005, p. 16). We created Map 6 with the Kamada-Kawai command because it is designed to produce stable results for smaller, connected networks (Nooy, Mrvar and Batagelj 2005, p. 17). With this in mind, we turn to a review of the general structure of SACS today.

8.0.2 General Structure of SACS

When looking at the layout of Map 6, the first thing that stands out is its tremendous similarity to the layout of Map 4—which is exactly what we had hoped for. Both maps, for example, situate sociocybernetics and the LSC next to each other in the upper western region of SACS; and, they both situate computational sociology and the BBC near each other on the east side of town, with CSNA positioned down near the bottom. Map 6 also highlights how the scholars associated with the new science of networks and global network society cluster into two different areas, albeit the inverse of their position in Map 4. Finally, all three maps place Wallerstein and the team of Klüver and Stoica between sociocybernetics and the LSC on the one side and computational sociology, CSNA and the BBC on the other.

The strong similarities in the spatial layout of Map 4 and 6 suggests that our historical and quantitative examinations of SACS have given us similar results and thus our general model of SACS is reasonably valid and reliable. It is valid because the overall layout of the scholars and areas of research in both maps are similar. It is reliable because two different sources of information—historical and archival on the one hand and quantitative and citation-based on the other—resulted in similar findings.

Still, despite these similarities, there are some interesting differences between our two maps. For example, while Map 4 places the BBC in the lower right corner, Map 6 places it to the right of computational sociology, in a more mid-eastern position. Furthermore, in Map 6 the top three scholars in the BBC (Byrne, Gilbert and Urry) are positioned at a distance from their primary areas of research—Urry is located all the way down near CSNA; Byrne is located close to computational sociology; and Gilbert is in the upper right-hand corner.

These results suggest that, somewhat contrary to Map 4, when the citations amongst the Top 25 scholars are considered, the BBC appears less intellectually integrated, with the respective subclusters of research to which Byrne (complex complexity), Urry (global network society) and Gilbert (simulation) belong pulling them away from one another. In other words, not only is the BBC somewhat marginal to the overall dynamics of SACS, it appears that the BBC is intellectually distributed, with its three top scholars extensively involved in their own particular subclusters of research.

How, then, do we explain our argument in previous chapters that the BBC is a major player in SACS? The answer comes from our Chap. 5 discussion of intellectual mobility: the BBC is a highly mobile area of research that is heavily invested in creative marginality. The strength of the BBC, therefore, is the extent to which it infuses itself into the other areas of SACS—specifically global network society, the new science of networks, computational sociology and general simulation. Said another way, the spatial arrangement of the BBC within SACS matches its intellectual profile. Rather than clustering inward like the scholars of the LSC and sociocybernetics, it extends outward to the other areas of research in SACS.

Computational sociology is similarly diffuse. While data mining, dynamical systems theory and simulation are the three main subclusters of computational sociology, they are somewhat distant from one another. Gilbert, for example, is located along the upper east side of Map 6, surrounded by all of the scholars involved in simulation, while Ragin and Abbott are positioned more toward the center and right side, respectively. Again, this diffusion does not suggest a lack of cohesion—all of the scholars are close to the computational sociology node. Instead, it suggests that the orientation of computational sociology is outward, with links to other areas of research in SACS, particularly those on the east side of town.

The same diffusion is found in CSNA, which takes up the entire bottom right to bottom center of Map 6. With the scholars of global network society on the left side of CSNA and the new science of networks on the right, CSNA reaches (links, connects) outward to the larger town of SACS.

In fact, one could make the case that *outward diffusion* is a major theme for the east side of SACS. For example, while the west side has only three directed links extending outward from sociocybernetics and the LSC to the rest of SACS, there are seven links running from CSNA, the BBC and computational sociology to the west side.

Still, despite these differences, as we will discuss next, the town of SACS as a whole is connected, constituting the typical structure of a scientific network. In other words, while the differences we are highlighting amongst the five areas of research in SACS are important, we do not wish to overstate them. Let us explain.

8.0.3 Degree of Connectedness

Taking into account the last decade of global and local interlinking within SACS—all of which we discussed in Chap. 7—this town (circa 2008) appears to be a typically connected scientific network. Here is why. Following the work of Newman (Newman 2001a, 2001b; Newman and Park 2003) on the structure of scientific networks:

- No one node is isolated from the rest, thereby allowing the researcher to go on a semi-walk from any one scholar or area of research in SACS to any other. (For a review of the term *semi-walk*, see Chap. 7, Sect. 7.2.2.4)
- The degree of separation amongst the scholars and areas of SACS is also reasonably small, with 5 being the maximum degrees of separation between any two nodes, and 2 to 3 being the average degrees of separation between any two nodes.
- Each of the five areas is connected internally; that is, the scholars for all five areas, despite their diffusion, are spatially located near rather than away from one another.
- The subclusters of research in SACS are spatially tight, with the scholars involved in global network society, the new science of networks and general simulation positioned close to their respective subcluster of research.
- The five areas of research, along with their subclusters, are connected to one another through a series of weak-ties—single directed arrows. (For a review of the term *weak ties*, see Chap. 7, Sect. 7.1.4)

Given that our citation network is comprised of only N=30 nodes (25 scholars and five areas of research), one may not think much of the above results. In fact, one might think a modest-sized network like SACS is going to constitute a *small world*, no big insight. This would be, however, a false assumption. While comprised of only N=30 nodes, the scholars and research areas of SACS are spread out across a wide number of disciplines, from sociology and physics to economics and managerial science to applied mathematics and computer science. Furthermore, the scholars of

SACS come from all over the world: Australia, England, Germany, United States, etc. In many ways SACS is a large network, with rather significant disciplinary and geographical distances. Nonetheless, and despite these distances, this network constitutes a *small world*: while clustered into non-random, local areas of research (and subclusters of research), the weak links amongst these clusters (also not random) ensure that this new intellectual town is well-connected, keeping the paths between any two scholars to less than 5-degrees of separation (For more on the definition of a small world, see Watts 2004).

The small world character of SACS is further supported by the average number of first-degree ties in this town (mean = 6.60; median = 6). First-degree ties connote the primary links amongst scholars, representing one-degree of separation. (As a side note, the more first-degree ties a network of attracting clusters has, the more densely connected it is.) The lowest first-degree score in SACS is 3, which goes to Fuchs. This means that Fuchs is directly connected to only three other nodes (two areas of research and one scholar). The highest first-degree score is 15, which goes to computational sociology.

Another observation is that the distribution of degree scores in our citation network follows a *power-law distribution*, with the lowest degree scores (3 and 4) being the most frequent (seven nodes) and the largest degree score (15) being the least common. (For a review of the power-law, see Chap. 1, Sect. 1.2.3.1) We do not, however, put much weight behind this observation because the total number of nodes in our model is N=30.

In terms of the dynamics of strong ties, there is a trifecta in SACS between Watts, Newman and Barabási; and another near trifecta between (1) Bonacich, Barabási and Newman and (2) Gilbert, Troitzsch and the scholars of socionics. These trifectas and near trifectas are the classic triangles or partial triangles, respectively, discussed in the "strength of weak ties" work of Granovetter (1973), who found that strong ties do not occur in isolation; instead, they tend to form triangles or partial triangles. Trifectas are also found in the work of Newman (2001a, 2001b, 2001c, 2004), who discovered that the collaborative ties amongst scientists tend to be triangular: if a scholar publishes with two different scientists on a regular basis, there is a high likelihood that the other two scientists will likewise collaborate, forming a triangle of first-degree collaboration.

Given Newman's work (2001a, 2001b, 2001c, 2004), it is worth pointing out that this town lacks the number of collaborative triangles one would expect. For example, one would think that there would be at least one collaborative triangle amongst the top scholars in each of the five research areas. This is not the case. For example, despite Urry's tremendous networking skills, he is not part of a collaborative triangle—at least not amongst the Top 25 scholars in SACS. Given the low number of collaborative triangles, it appears that while SACS is highly clustered, it is by no means done forming its internal connections.

Overall, however, SACS has evolved into a scientific community with local connections for each of its attracting clusters and subclusters of research, with typical weak ties running from one area of research to the next. Furthermore, these weak ties create a small world: despite being a geographically and intellectually diverse town, SACS is a connected community. Nonetheless, and in terms of these connections, SACS appears to be in its formative stages.

8.0.4 Powerbrokers

Our analysis of the hubs, authorities and gatekeepers of SACS, as well as our assessment of the top three areas of research in this new community, results in the same set of themes we discussed in Chap. 7:

1. The LSC and sociocybernetics have formed a sort of twin science, resulting in a rather dense network of local (inward) connections located on the upper west side of Map 6.
2. In contrast, the newer areas of SACS and their subclusters are congregated together on the east side of town, forming their own somewhat diffuse network of local (outward) connections.
3. An intellectual rift exists between the west and east sides of town.

8.0.4.1 Hubs

Using *Pajek*, we searched for the top hubs in Map 6. Because all 25 scholars are connected to their respective programs of study, we expected most of the hubs to be areas of research. This was the case. The three most important hubs were sociocybernetics, the LSC and computational sociology.

Given their high degree of internal (inward) connections, we expected that two of the largest hubs in SACS would be sociocybernetics and the LSC. They are directly connected to eleven of the Top 25 scholars in SACS; two-degrees of separation from the next nine, and only three-degrees of separation from the remaining five. They are also the two oldest areas in SACS. Given their "elder" status, they have had the time to collect a large number of internal connections. This turned out to be the case.

Sociocybernetics and the LSC also boast the top two scholarly hubs, Luhmann and Buckley. As the two oldest scholars in SACS, their work stretches back to the 1960s and 1970s. Their historical position in SACS seems to be to their advantage. They are the scholars most often cited by the other top 23 scholars in this town. Nonetheless, the majority of these citations mostly come from other scholars in sociocybernetics and the LSC, not the rest of SACS.

The importance of computational sociology points to a different story within SACS. While the LSC and sociocybernetics are hubs because of their historical importance to this town, computational sociology is a hub because of its methodological use. As the methodological hub of SACS, computational sociology has 15 first-degree ties and 9 second-degree ties.

8.0.4.2 Authorities

Our list of the top authorities in SACS reveals a different aspect of this town. As the reader may recall, in a scientific network an authority is a scholar who cites, reviews, comments on, or makes use of the greatest number of other scholars, particularly the major scholarly hubs. (In Map 6, these are the nodes with the greatest number of outward arrows, particularly to the hubs in the network.)

Given the historical status of the LSC and sociocybernetics within SACS, it was no surprise that the leading authorities were Geyer, Zouwen, Bailey and Mingers. While Luhmann and Buckley are scholarly hubs because their ideas are central to the work of the LSC and sociocybernetics, Geyer, Zouwen, Bailey and Mingers are authorities because they most often cite their sociocybernetics and LSC colleagues. The major problem, however, with the "internal" citing record of Geyer, Bailey and Zouwen is that this record does not translate into outward influence on the rest of SACS. Because the citations of the east side are mostly inward to their own cluster, the authorities located in this part of town have not had an impact on the rest of SACS. For example, other than the LSC and sociocybernetics, Bailey has no links to anything else in SACS: Geyer and Zouwen at least reach outward to computational sociology, but these links are not strong-ties.

The authority status of Mingers tells us a different story about SACS. While currently a minor player in this community, Mingers is an internationally recognized authority in managerial science and, more specifically, the application of complexity science to the study of complex human organizations. A professor in the Kent Business School, University of Kent (U.K.), Mingers (560 citations) represents a possible future for SACS—something Map 6 does not reveal. While the application of complexity science to the study and management of human organizations is one of the largest substantive foci of complexity science today (Capra 2002), it is an untapped area of research within SACS. Mingers, however, has not given up, taking up residence in SACS, albeit on the margins. The problem, however, is that the direction of his links currently extend outward to the other Top 25 scholars in the town—on Map 6, all of Mingers' links go away from him. If the direction of these links were to change, however, and other or new scholars in SACS began using Mingers' work, a new attractor point could very easily emerge with SACS. The name of this cluster might be something like *the sociology of complex organizations* or *complex managerial science*.

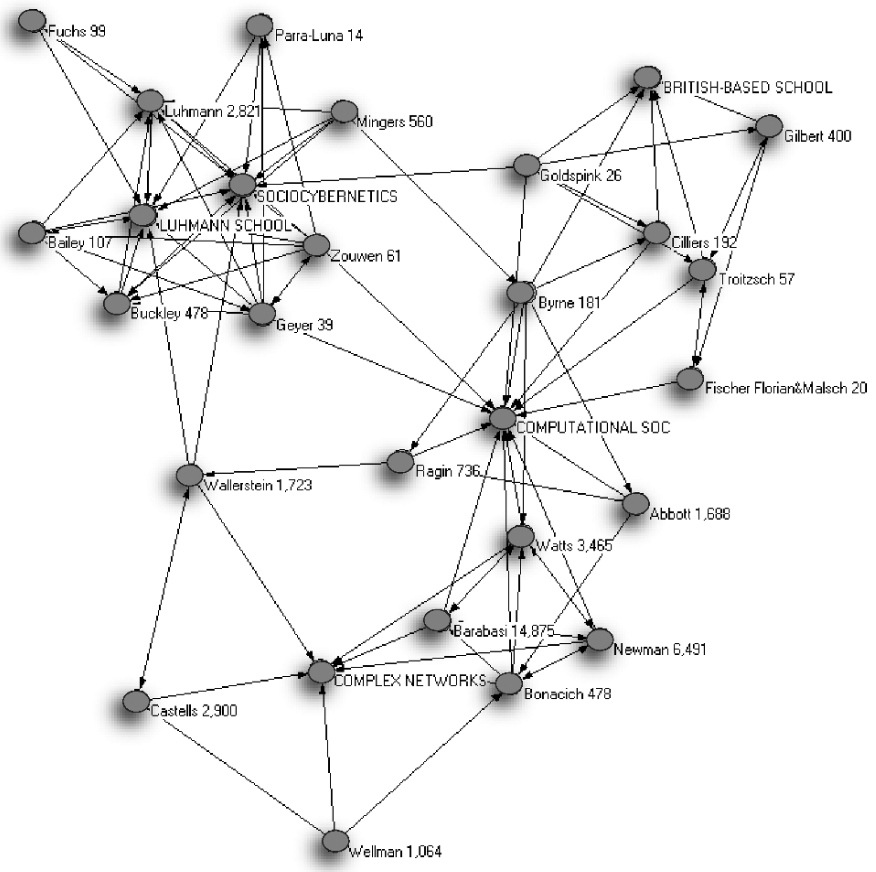
8.0.4.3 Gatekeepers

As we explained in Chap. 7, gatekeepers (a type of authority) hold a scientific network and its various areas of research (partitions, clusters, subclusters) together. While working within their own area of research, gatekeepers tend to draw upon or bring together scholars and areas of research outside their immediate focus, thereby making the important global connections (weak-ties) that sustain a scientific network's small world character. In fact, if the gatekeepers in a scientific network are removed, their absence increases the "degrees of separation" amongst the other nodes in the network, and most often also cuts off one area of research or subcluster of research in the network from the rest. It is therefore important to know who the gatekeepers in a network are.

The two major gatekeepers in SACS are Urry and the team of Klüver and Stoica. Urry is important because his links go outward to every major area in SACS; including: (1) Castells and global network society; (2) Watts and the new science of networks; (3) the BBC and its unique approach to complexity; (4) Byrne and computational sociology; (5) Luhmann and the LSC; and, (6) Wallerstein and sociocybernetics. As a gatekeeper, Urry is one of the most important scholars in SACS. Remove his weak-ties from the network of attracting clusters and SACS becomes a little less cohesive, a little less connected, and a little less of a town. Klüver and Stoica are important because they connect the northwest side of SACS to computational sociology.

To test further the gate-keeping abilities of Urry and Klüver and Stoica, we removed them and their links from our *Pajek* database to see how it would change the network. As shown in Map 7, if Urry and the team of Klüver and Stoica are removed, the mean degree score drops from 6.60 to 5.85 and the median degree score drops from 6 to 5. The highest first-degree score (computational sociology) also drops from 15 to 13. Furthermore, as shown in Map 7, the west and east sides of SACS pull further away from each other, with Luhmann being dramatically shifted to the upper west side and the BBC moving to the upper east side. This is perhaps the most interesting result here: removing Urry or Klüver and Stoica, while not fatal to SACS, does increase the divide between the east and west sides. Furthermore, while the loss of these gatekeepers does not drastically reduce the degree score for SACS, their loss does make this community less integrated.

Map 7: Social Network Map of SACS Minus Gatekeepers



8.0.4.4 Household Names

Household names are an important part of a scientific network (particularly one striving for legitimacy) because they bring important outside attention and recognition. In the case of complexity science, for example, much of its early success was based on the intellectual powerhouses who promoted its "crazy" ideas, including Murray Gell-Mann, Kenneth Arrow, George Cowan, and Philip Anderson (Lewin 1992; Waldrop 1992).

The household names in SACS have brought this town a similar level of success it might not otherwise have attained. At present, the three biggest household names in SACS belong to the new science of networks. With a combined total of almost 25,000 citations, Watts, Barabási, and Newman are three of the most important names in complexity science today. As we previously quoted Bonacich as stating, "We [sociologists] are lucky that physical scientists and mathematicians have become interested in social networks. Of course we feel slighted; not all of our contributions will be noted. But this is the cost of moving onto a very much larger intellectual stage" (2004b, p. 4).

8.0.4.5 Top Areas of Research

So, how do we summarize the above information to identify the top three areas of research in SACS? Given our analysis of the current *negotiated ordering* of SACS and its hubs, authorities, gatekeepers and household names, along with our knowledge of the last decade of development in this town, here are (in order) our top three areas of research: CSNA, computational sociology and the LSC.

There are six reasons why CSNA has evolved to become the top area of research in SACS. First, it is comprised of the two largest growing subclusters of research: the new science of network and global network society. Second, as a result of the growth in these two areas, CSNA has a massive citation base of 31,000 publications. Third, in terms of household names, this area boasts three of the most popular and highly cited scholars in complexity science today; namely, Barabási, Newman and Watts. CSNA also boasts two of the most important scholars in sociology and globalization studies, namely Castells and Wallerstein. Fourth, in terms of internal impact, CSNA has strong ties with computational sociology. Fifth, CSNA also has strong internal ties to the BBC, primarily through the work of Urry. Finally, in terms of environmental forces, the new science of networks is one of the most popular areas of study in complexity science today.

There are four major reasons why computational sociology has evolved to become the second most important area in SACS. First, while not the most highly cited area outside the SACS community, computational sociology is important because of its utility to complexity scientists. Just about everyone in SACS and complexity science use the methods of computational sociology. For example, if you examined all of the publications in SACS and complexity science based on the methods they use or the methodological issues they explicitly or implicitly address, computational sociology is the dominant methodological toolset of choice. As discussed earlier, the importance of computational sociology is further corroborated by the fact that, as we discussed earlier, this area of research has 15 first-degree ties and 9 second-degree ties to the top 25 scholars in SACS. Third, as we discussed in Chap. 6, computational sociology boasts one of the mostly highly connected and important scholars in agent-based modeling and complexity science method, namely Gilbert. Finally, in terms of internal importance, computational sociology is home to the gate-keeping team of Klüver and Stoica.

As one of the original areas of research in SACS, the LSC is the third most important area, primarily because of its fortitude. Little of the research or methods made "vogue" in complexity science today look like the work of the LSC. As we discussed in Chap. 5, for example, the LSC is historical and literary in focus, whereas complexity science is mathematical and computational. The LSC also is rigorously opposed to agent-based modeling, while complexity science is almost exclusively a bottom-up approach. Finally, the LSC is profoundly theoretical, whereas complexity science is more methodological and substantive. Despite these incredible differences, the LSC remains an important area of research in SACS, primarily because of its popularity in Germany and the growing international status of Luhmann.

This is not, however, where our summary of SACS ends. We have to address one last point: why a division exists between the east and west sides of this new intellectual community.

8.1 Internal Division

Following Newman's work on the structure and dynamics of intellectual networks (2001a, 2001b, 2004), SACS is a typical community insomuch as it is comprised of several localized areas of research which are, for the most part, spatially clustered. Furthermore, these areas of research are globally connected through a series of weak-ties. Some of these weak-ties, however, are weaker than others, particularly in terms of the east and west sides of this town.

The weak-ties between the east and west sides suggest this town has two opposing trajectories, each of which is pulling SACS in a different direction. Of the two, the east side trajectory seems to be the more powerful and, in fact, is currently pulling most of SACS in its direction. Our question, however, is why? To answer this question, we return to our Chap. 4 discussion of the interstitial character of SACS.

8.1.1 The Interstitial Character of SACS

SACS is a town that celebrates the "in-between" of things. Its scholars thrive on creative marginality and mobility. They seek new theories, ideas and methods, as well as new institutional designs and blueprints that allow them to address the growing complexity of contemporary life. Their search has not been in vain, as they have created a cutting-edge scientific community that is resolutely interstitial.

As we explained in Chap. 4, the interstitial character of SACS is manifested in six ways: (1) the type of intellectual space it provides its citizens, which, for the most part, does not exclude any particular area of study or form of inquiry; (2) the diversity of its major areas of research, which draw from all of the sciences; (3) the form of government its residents enact, which has little interest in policing its boundaries; (4) the type of community its supports, which is informally held together through a loose network of scholarly connections; (5) the common concerns of its residents, which go beyond their respective disciplines to embrace a "complex systems" perspective; and (6) the cosmopolitan culture it celebrates, which is highly interdisciplinary and international.

If one were to condense these six interstitial characteristics into one dominant quality, it would be stated as follows: the goal of SACS is to overcome, blur, or erase the interstitial boundaries between the sciences, sociology and the humanities in order to create a new framework for studying social systems.

The problem, however, is that while this effort has accomplished a great deal, it has not entirely succeed. At present, SACS seems to be moving along two different trajectories, which we believe is the result of a major epistemological division between its east and west sides. To make sense of this epistemological division, we turn to Abbott's book, *Chaos of Disciplines* (2001).

8.1.2 The Chaos of Sociology

Abbott's book is not about SACS. It is about sociology. More important, it is about sociology's interstitial character, its epistemological self-similarity, and its fractal, scale-free evolution as a discipline. Abbott's thesis, however, along with several of his key concepts can be employed to explain the epistemological differences in SACS. By epistemology, Abbott means the structured, academic *ways of knowing* scholars use to understand the world: traditions, theories, methods, concepts, etc.

Because sociology (like most of the social sciences) is an interstitial discipline, it is forever caught in an internal war. Not quite sure who the enemy is, sociology has never been completely scientific or humanistic; never quite rational or artistic, never entirely objective or political, never completely quantitative or qualitative, never really macro or micro, never fully structure or agency. Instead, as sociology has evolved over the last century, this discipline's numerous traditions have developed along the same lines of conflict.

What is interesting about these aforementioned conflicts is that they tend to have a dualistic character: consensus versus conflict, culture versus structure, applied sociology versus pure sociology. Even the traditions of sociology are regularly expressed in dualistic terms: micro-sociology versus macro-sociology, functionalism versus conflict theory; statistics versus qualitative method. These dualisms even emerge in sociology's philosophical wars: constructivism versus positivism, for example, or modernism versus postmodernism.

Dualisms aside, what is most fascinating about these lines of conflict is that, no matter what a new or winning area of research does to assuage or dissolve these conflicts, they do not go away. Over and over again, the battle lines in sociology are redrawn, opposing lines of conflict re-emerge, and new languages and methods are, in turn, re-created, all in an enduring effort to push these traditional conflicts to one side or the other: structure over agency, narrative versus analysis. In the end, however, now matter how innovative the "new" tradition or winning area of research, it invariably internalizes, recycles and recapitulates the very conflicts it sought to overcome. This, Abbott explains, is sociology's disciplinary chaos.

To say that sociology is chaotic, however, does not mean that the discipline lacks structure or order. Quite the opposite is true. The title of Abbott's book is therefore somewhat of a misnomer. Instead, the book highlights the fractal structure and order of sociology's disciplinary chaos. Let us explore this fractal chaos further.

Abbott employs a unique approach to the study of fractals. As we discussed in Chap. 5, fractals are geometrical shapes with the following characteristics. First, unlike the shapes of traditional geometry (e.g., squares, triangles, circles, etc.) they are not smooth. Instead they are rough and fragmented. Second, despite their irregularity, they have a distinct pattern and shape: at decreasing levels of scale, one finds that any magnified section of a fractal looks like a reduced version of the whole. A stem on a head of broccoli looks like the broccoli. A small section of a river looks like the river. Mathematicians refer to the process by which a fractal recapitulates itself at decreasing levels of scale as *scale-free behavior* (Mandelbrot 1983). Lastly, there is no one fractal object, either mathematically or naturalistically. The term “fractal” is a general heading for a rather extensive catalogue of objects and phenomena that are non-smooth and yet roughly self-similar at multiple levels of scale.

Scientists have applied the field of fractals to a wide range of phenomenon, from religious symbols and the complex rhythms of the heart to crowd behavior and the clustering of galaxies (Capra 1996; Mandelbrot and Hudson 2004). Even Mandelbrot (the founder of this field) has spent considerable time studying the “fractal nature” of the stock market (Mandelbrot 1997, Mandelbrot and Hudson 2004).

Abbott is therefore not the first scholar to apply fractals to the study of sociological phenomena. Neither is he the first to use the terms of this field in slightly creative ways. For example, even Mandelbrot’s application of fractals to economics can be conceptually difficult, forcing him to reconstruct or invent new terms, such as self-affinity (fractals found in two-dimensional economic charts and graphs) over self-similarity (fractals found in two or three dimensional Euclidian space) (See Mandelbrot 1997, Mandelbrot and Hudson 2004.)

Abbott engages in the same sort of conceptual innovation. While he holds to the general theme of fractal geometry, he retools several of its key concepts for the purposes of sociological analysis.

For Abbott (2001), the lines of conflict in sociology are essentially fractal. This means that these lines of conflict are self-similar and scale-free. It also means that these conflicts tend to be dualistic, even when they are grouped to form the major traditions of sociology. A classic example is qualitative versus quantitative research. As Abbott explains, these two traditions are really a collection of biases along several lines of conflict. Quantitative method tends to favor positivism, analysis, realism, social structure, transcendent knowledge and is cast at the individual level. Qualitative method, in contrast, tends to favor interpretation, narrative, constructionism, culture, situated knowledge and is cast at the emergent level (Abbott 2001, pp. 28–33)

By *self-similar*, Abbott means two things. First, one can examine any tradition or area of research within sociology and find that, upon analysis, its epistemological structure is a reduced version of the discipline, including sociology's traditional lines of conflict: macro versus micro, qualitative versus quantitative, etc. At all levels of scale, no matter how one takes sociology apart, one finds the same basic epistemological divisions repeated. In other words, the self-similarity of sociology is roughly scale-free. Abbott explains it this way: "[Whatever line of conflict one uses] to distinguish groups of social scientists, we will then find these groups internally divided by the same distinctions" (2001, p. 10).

By *self-similar* Abbott also means that, as sociology evolves across time-space, it tends to recycle (albeit in new forms) the same basic epistemological distinctions of the past. Abbott refers to this self-similar recycling process as a *fractal cycle*. Organized sociology has never done a good job policing its disciplinary borders. As a result, the discipline is constantly entertaining and embracing new ideas. For example, one can go to just about any annual meeting in sociology and find sessions ranging from mathematical modeling to auto-ethnography, rigorous empirical inquiry to thoroughgoing philosophy of language, epidemiology to literary theory, historiography to political activism. In fact, there is almost no end to what someone with the title of "sociologist" can study or do.

While this type of academic freedom is worthy of applause, it is not without problems. One particular problem, which concerns Abbott the most, is the failure of many of these ideas to break free of their epistemological past. Conceptually speaking, no matter how new or innovative a technique is, it generally recycles many of the same insights and ideas that sociologists have been generating for the past century. This "recycling of ideas" is particularly true at the epistemological level—positivism versus constructionism, fact versus value, science versus politics, and so forth.

As such, Abbott explains, one cannot "make" the history of sociology to read like the natural sciences' steady progress of knowledge. Sociology's history is far too messy. Instead, while some progress takes place (to be fair, Abbott does acknowledge that we have learned a thing or two over the last century) the history of sociology generally reads like the recycling of older ideas, albeit in the language of some new theory, method or epistemological perspective.

And how long is a cycle? According to Abbott, the recycling of sociological ideas takes about 20–25 years. He states: "There is good reason to expect a cycle of about this length. Twenty years is about the length of time it takes a group of academics to storm the ramparts, take the citadel, and settle down to the fruits of victory. There is a common pattern." (p. 24). During this 20-year time period the biases of the dominant position holds sway. Eventually, however, conflicts of the past creep in, causing the dominant position to differentiate along the same old epistemological lines, including the lines it originally opposed.

The question, however, is why? Why is sociology doomed to repeat the past? Why can't it break out of its fractal cycle? Why does almost every new or winning position internalize, differentiate and recapitulate the very lines of conflict it sought to overcome?

The basic answer—which we have already hinted at—is that sociology is too complex. It is no coincidence that sociology is an interstitial discipline. Its topics of study (from global network society to the nuances of organizational behavior to the dynamics of self) are so diverse that, to try to know it all is intellectually punishing. As such, no matter how empirically successful a tradition, philosophy, theory or method, it tends to be *under-determined* by the sociological evidence. Even SACS cannot net the whole of social reality.

Because no one perspective can explain everything, scholars are always searching for other ways to do their work. Ironically, this very search leads them back to the lines of conflict they sought to destroy. In the process, these scholars end up internalizing and, inevitably, recapitulating the very lines of conflict they sought to overcome.

But, we still have not answered our question. Why can't sociology break out of its fractal cycle? Well, sociology actually can and sometimes it does—but only to a certain degree. To accomplish new insights or ideas (particularly at the epistemological level), such a break requires something seldom done.

Before we explain what that "something seldom done" is, let us rehearse what Abbot has so far said. For Abbott, (1) sociology is an interstitial discipline; (2) because of its interstitial character, sociology is prone to internal conflict; (3) the lines of conflict within sociology tend to be dualistic, with opponents taking one side or the other; (4) regardless who wins, each side tends to internalize and recapitulate the lines of conflict they sought to overcome; (5) the fractal recycling of these lines of conflict is a function of the fundamental complexity of sociology (sociological phenomena cannot be fully explained by any one theory, method or epistemological framework); and, finally, (6) sociology generally does not escape this fractal dynamic.

So, what can sociologists do? One possibility is to change the epistemological lines of conflict along which they argue. If one can recombine, intersect or highlight the dualisms of the discipline in a novel way, one is "off and running" into an entirely new area. For example, instead of doing quantitative or qualitative work, combine these traditions to do something new. Given the fractal nature of sociology, it is inevitable that the traditional "quantitative versus qualitative" line of conflict will emerge within your new approach. No matter. While this line of conflict will repeat this longstanding dualism, it will do so along a new and different trajectory. Think intellectual mobility. Think creative marginality. Think fractal discovery.

8.1.3 The Fractal Dynamics of SACS

It is time, now, to employ Abbott's argument to explain the intellectual division between the east and west sides of SACS. Over the past decade, SACS has made several important breaks with sociology's epistemological past. These breaks have come in one of two ways: *combining* the opposing sides of several lines of conflicts in sociology or *highlighting* many of the marginalized lines of thought within sociology's systems tradition.

Combining Dualisms: Throughout this book we have we discussed most of the ways SACS has combined various dualisms to head into new intellectual (epistemological) territory. For example, scholars in SACS have: (1) combined theory and method to create simulation as a theoretical tool (Axelrod 1997); (2) blurred the boundaries between the social and natural sciences to generate the new science of networks (Urry 2004); (3) merged qualitative and quantitative method to develop computational modeling (Gilbert and Troitzsch 2005); and (4) overcome Snow's two-cultures war to generate new forms of postmodern epistemology (Byrne 1998). It is these combinations that make SACS a unique contribution to the systems tradition in sociology (and to complexity science). But, this is not where the uniqueness or contributions of SACS stop.

Highlighting Marginalized Ideas: In chapters one through seven, we also discussed the various marginalized ideas SACS highlights. In terms of method, for example, instead of taking a macro-level, top-down, structure oriented, static, variable-based approach to modeling systems, the scholars of SACS have taken a micro-level, bottom-up, agent-based, dynamic, social interactionist approach. And, in terms of theory, the scholars of SACS have inverted most of the theoretical stereotypes associated with Parsons. We reviewed these stereotypes in our introductory chapter: structural functionalism is not a theory; it lacks explanatory power; it explains away conflict and social change; it overplays solidarity and order; it is highly conservative and normative; it is exceedingly abstract, with almost no empirical grounding or application; it makes the same evolutionist errors as Spencer and Durkheim; and, it falls into the trap of treating society as a biological organism. By virtue of inverting these stereotypes, the theoretical orientation of SACS is significantly different. Its theories are highly explanatory; embrace conflict and change; emphasize instability and chaotic order; strive for creative marginality; focus on being descriptive rather than prescriptive; seek to be critical rather than normative; ground themselves in the data; focus on building models rather than constructing abstracted theory; and, finally, refrain from naïve evolutionism or the idea that social systems are just like biological systems.

These are the dualisms SACS has combined and the marginalized ideas it has highlighted to chart a course into new epistemological territory. Or, this is, at least, partially the case. Over the past decade, while the east side of SACS has been strongly committed to practicing the above dualistic combinations and highlighted marginalized ideas, the west side has not. In fact, the west side seems to support most of the dualisms the east side has tried to overcome. The west side also seems to contest the marginalized ideas the east side highlights.

It appears, therefore, that SACS has its own fractal line of conflict, with the east and west sides taking opposing positions. This line of conflict is also scale-free because it manifests itself at several levels, starting with the east and west side, going down to their respective areas of research and still further to their respective subclusters of research. There are, however, some important qualifications:

- While all five areas of research in SACS (along with their respective subclusters) recapitulate the east-west conflict, this recapitulation has not caused SACS to differentiate at these smaller levels of scale into opposing internal trajectories.
- At least for the moment, the east side's perspective seems dominant.
- The dominance of the east side is due, in large measure, to the environmental impact of complexity science. Complexity science is academically popular, powerful and persuasive. Given this popularity, it has a strong epistemological hold on SACS. In fact, it is so strong that, at present, the epistemological perspective of complexity science is, for the most part, the epistemological perspective of the east side.
- There is a possibility, however, that, despite the popularity of complexity science, the east side's epistemological dominance could change. But, that is a point for discussion at the end of this chapter. Our concern here is to articulate the fractal line of conflict within SACS. The line of conflict differentiating the east and west side of SACS comes from their respective differences on two major epistemological dualisms.

Our two themes for the intellectual (epistemological) divisions between the east and west sides, which we will discuss below, are as follows:

- Following C. P. Snow's famous *two-cultures* distinction, the east side's epistemological bias is toward the natural sciences, while the west side's bias is toward the humanities.
- The east side also supports a micro-level approach to modeling social systems, while the west side supports a macro-level approach.

8.1.3.1 Dualism 1: Snow's Two Cultures

In terms of C. P. Snow's two cultures, SACS is a *microcosm* of the battle within sociology (its parent discipline) over which approach to knowledge (fact or value) is superior.

As an interstitial discipline, sociology sits at the cross-fire of a larger cultural war: the battle over Snow's two cultures. Is sociology a science or is it politics and art? For Abbott (2001), sociologists can never resolve this question. The epistemological options available to them (or at least the ones they seem to repeatedly create), force them into the same two predictable corners of the philosophical map—fact or value. As such, and at all levels of its work, sociology reinstates the cultural war between the natural sciences and the humanities. Abbott puts it this way, "The interstitial quality of sociology recapitulates locally the relation of the social sciences in general to the natural sciences and humanities. The social sciences stand uneasily between these other modes of knowledge, the mode of facts and the mode of values" (Abbott 2001, pp. 6–7).

Consider, for example, a epistemological tree of knowledge for sociology. Moving from left to right along this disciplinary "tree of knowledge," the various epistemological positions and perspectives of sociology can be divided, grouped and catalogued into two major fractal-like branches. One branch grows in the direction of the humanities and the other in the direction of the natural sciences.

Following Abbott, what is fascinating about this tree of knowledge is that, at decreasing levels of scale—that is, smaller and smaller branches—the same initial division between the humanities and the sciences is recapitulated. For example, while postmodernism, multiculturalism, and post-structuralism have their differences, they all push sociology in the direction of the humanities. So do constructionism, constructivism, and pragmatism. Similarly, while differences exist between neo-Marxism, conflict theory and feminist sociology, they too lean sociology toward the humanities, albeit on the political end of the spectrum.

We can go on to find this type of self-similarity at even smaller levels of scale. Moving along the humanities branch, for example, one can tool down to post-structuralism, for example, to find one branch growing in the direction of Foucault's humanities-based perspective versus Bourdieu's scientific-based perspective. While both scholars lean strongly in the humanities direction, their work still internalizes Snow's cultural division.

We can find the same divisions at decreasing levels of scale along the scientific branch of sociology. On this side of sociology's epistemological tree there is, for example, realistic sociology, logical positivism, critical-realism, and neo-positivism. Nonetheless, even within these categories one finds, for example, that qualitative method leans more toward the humanities, while statistics leans more toward science. Going still further within qualitative method, for example, while ethnography and grounded theory bend toward science, auto-ethnography and constructivist grounded theory bend toward the humanities. Tooling down even further to the individual level, while Glaser and Strauss's grounded theory tends toward the humanities, Glaser tends toward science and Strauss tends toward the humanities. In fact, the epistemological differences between these two scholars led, in part, to their separation and subsequent creation of two different approaches to grounded theory method (See Glaser 1992).

And so we come to the end of Abbott's thesis. The fractal-like, scale-free epistemological battle over Snow's two cultures pervades the interstitial discipline of sociology. The resulting picture suggests that, at least on this dimension, sociology is a highly fractal discipline.

So, what does all of this have to do with SACS? It appears that, at least at the present time, despite all of its efforts to become mobile and creatively marginal, SACS has internalized and recapitulated Snow's two cultures war.

Returning to sociology's tree of knowledge, in terms of the divide between the humanities and the natural sciences, SACS is strongly aligned with the natural sciences. For example, all five areas of research in SACS are positioned close to the natural sciences and, more specifically, complexity science—see Map 2. The epistemological bias of the Top 25 scholars in SACS is also scientific, leaning more toward "fact" than "value" (Abbott 2001, p. 7). These scholars do, after all, turn to complexity science to solve their struggles with complexity.

Despite the prevailing tendency of both the east and west sides of SACS to lean in the epistemological direction of the natural sciences, both have differentiated along the traditional line of *fact versus value*. For example, sociocybernetics and the LSC rely almost exclusively upon humanistic forms of inquiry, namely historiography and philosophical method. Their view of the social system is more extensively influenced by continental philosophy (i.e., hermeneutics, phenomenology, etc.); and their epistemological orientation is toward radical constructionism and second-order cybernetics. In contrast, CSNA, computational sociology and the BBC all tend toward the natural sciences, relying almost exclusively upon mathematical modeling or computational inquiry of one type or another. Their view of the social system is more extensively influenced by the "naturalistic" epistemology of complexity science; and, as such, they are strongly biased toward critical realism and neo-positivism.

One can go further with this recapitulated division. While the LSC (with its connections to continental philosophy) tends strongly toward the humanities, sociocybernetics (with its direct link to second-order cybernetics) tends more toward science. Tooling down further within the LSC, while Luhmann (given his *philosophy of knowledge* orientation) leans strongly in the direction of the humanities, Mingers (given his business orientation) leans toward the sciences.

The same divisions at decreasing levels of scale exist on the east side. While computational sociology and CSNA lean toward the sciences, the BBC leans toward the humanities. Going still further within CSNA, while the new science of networks (with its litany of physicists) leans toward the sciences, global network society (with its politically driven sociologists) leans toward the humanities. Tooling down even further into global network society, while Castells and Wallerstein (with their eye on the data) tend toward the sciences, Urry (with his eye on ways of *knowing* the world) tends toward the humanities.

Still, while these scholars have recapitalized Snow's two-cultures at decreasing levels of scale within SACS, these smaller forms of cultural recapitulation have not perturbed this town into further differentiation. It appears that the epistemological sway of complexity science (as an environmental force) on the eastside is too strong to allow for such internal division. As we discuss at the end of this chapter, however, this sway may not remain the case for long. Still, at present, a division remains at the macro-level between the east and west sides of SACS.

8.1.3.2 Dualism 2: Micro Versus Macro Systems Thinking

The second dualism in SACS is methodological. While the east side takes a micro-level approach to modeling social systems, the west side upholds a more macro-level approach. To explain this difference, we turn to a brief history of the systems tradition in sociology.

In terms of the macro-micro conflict in sociology, the systems tradition has historically upheld the macro position. This "historical siding" means that, as a tradition, systems thinking has tended toward a systems-oriented, historical, macro-level, top-down, structural, emergent, linear, variable-based approach to modeling society. As such, it has generally opposed those traditions within sociology that favor a non-systems, micro-level, bottom-up, agent-based, nonlinear, dynamic, context-dependent, social interactionist approach.

Despite this general orientation, systems thinking has internally recapitulated the micro-macro conflict on at least three different occasions over the past century. In other words, the systems tradition has followed Abbott's fractal cycle.

Cycle 1: The first movement through this fractal cycle came during the classical era of systems thinking. While Marx, Durkheim and Pareto strongly favored a macro-level perspective, Weber and Spencer took a more micro-level systems approach. Marx had his dialectic and Durkheim has his social fact—both top-down perspectives. In contrast, Weber had his method of *verstehen* and Spencer had his competition amongst individuals, which propelled society to its highest ideals—both bottom-up views of how systems emerge and evolve.

Cycle 2: The second cycle came with Parsons and the structural functionalist movement. With his gargantuan theory of everything, Parsons obviously embraced a macro-level perspective. Not all structural functionalists, however, followed Parsons in his view. The best example is Parsons' protégé, Merton, whom we discussed in the introductory chapter of this book. Merton, seeking a more micro orientation, developed what he called his *theories of the middle range*.

Cycle 3: The third cycle begins with the emergence of SACS in 1998. As with the previous two fractal cycles, scholars would differentiate along the micro-macro split. However, while the west side would perpetuate the traditional, macro-level approach, the east side would do something new. It would break with tradition to practice the most radical *micro-level* approach yet constructed. Let us explain.

While the classical and functional cycles of the systems tradition recapitulated the micro-macro conflict, the micro side of this split was never dominant. Furthermore, the micro-level approach has never really been radically "micro." For all of Weber's emphasis on verstehen, his work is massively historical and macro. The same is true of Spencer. His work is historical, economic, naturalistic and philosophical. Even Merton, the micro-level representative of the functional era, opted for a more meso-level approach, which was consistent with his interests in survey research and bureaucratic analysis—hence his advancement of theories of a middle range. In other words, none of these scholars ever took seriously the idea that a set of micro-level agents, through their complex interactions with one another, could create the larger emergent system of which they are a part. As such, none of these scholars ever advocated a methodology based on a strictly micro-level, bottom-up, agent-based, nonlinear, dynamic, context-dependent, social interactionist approach to modeling society.

The east side of SACS, however, has seriously embraced a micro-level approach. As such, the methodology of the east side constitutes a major epistemological breakthrough in the systems tradition, branching out into new territory. The east side has satisfactorily recombined the traditional biases of the systems tradition to create the first "true" micro-level approach to modeling social systems.

In terms of historical credit, however, the east side has not been alone in the creation of this new fractal trajectory within epistemological space. Powerful environmental forces helped to procure this new approach, namely complexity science and (a force we have yet to discuss) the micro-level traditions in sociology.

The Impact of Complexity Science: The epistemological impact of complexity science on the east side of SACS is obvious and direct. If the epistemology of the east side constitutes a major break with sociological systems thinking—independent of complexity science—the epistemology of complexity science constitutes an even larger break with the systems tradition in general, both in the form of systems science and cybernetics. As shown in Map 1, like the east side of SACS, complexity science is the first micro-level approach to modeling complex systems. In fact, in many ways, Map 1 charts how complexity science broke with its macro-level traditions.

To make our point, let us go back to Chap. 5 and our discussion of the methods of complexity science. If the reader recalls, we explained that in many ways the revolution of complexity science is a breakthrough in method. The traditional macro-level approach to modeling complex systems (dominant from the 1940s to the 1970s) failed. In general, it proved too difficult to model complex systems using such top-down methods as statistics or differential equations alone. The digital computer revolution, however, created a whole new set of methodological procedures. All of them micro-level and systems-based in their approach: discrete mathematics, fractal geometry, chaos theory, dynamical systems theory, cellular automata, distributed artificial intelligence, computational modeling, social network analysis, data mining, genetic algorithms, the new science of networks. With complexity science, a whole new methodology was born, which we now call *agent-based modeling*. As we discussed in Chap. 7 (and, as visualized in Map 6) the impact of this new method on the east side of SACS is all encompassing.

The Impact of Micro-Sociology: While complexity science is very important, there is another environmental force worth mentioning, the micro-level traditions of sociology. To make our case, we turn again to the issue of complexity science method.

While the computer revolution provided the hardware necessary for a breakthrough in systems method, several micro-level traditions in sociology helped to provide the *software*. Said another way, the theoretical orientation of systems method (now called agent-based modeling) did not emerge in a vacuum. It came from scholars working in a variety of disciplines and fields of study across the social sciences. Of particular note were those scholars working in what Collins calls the rational/utilitarian tradition of sociology (1994, p. 122). Strongly affiliated with political science and micro-economics (in particular, game theory), these sociological traditions include exchange theory, rational choice theory and social network analysis.

Here is why these theories are so important to the development of complexity science method (and the east-side of SACS): while micro in orientation, they are primarily interested in how micro-level behaviors produce macro-level patterns. For example, how do the interactions amongst a set of nodes create the larger network of which they are a part, including its various patterns? How do weak-ties reduce the degrees of separation in a network? How do two prisoners, seeking their own advantage, work together for their individual good? And, how far will these prisoners take it? Also important, how does this "prisoner's dilemma" transfer to the negotiations amongst companies and nation-states? How does this dilemma result in patterns of stability in the market? And, what do these patterns look like?

As these types of questions emerged within the rational/utilitarian tradition, a fractal differentiation occurred. A macro-level camp emerged, which had, as its focus, the role micro-level behaviors play in increasingly complex systems. Out of this camp came such notable complexity scientists as Robert Axelrod, John Holland, Kenneth Arrow, and, more recently, Scott Page. Along with these scholars also came the new fields of computational economics, computational political science and, in terms of SACS, computational sociology and (in part) the new science of networks. In other words, the micro-level, agency-based epistemology of complexity science and, more specifically, the east side of SACS comes from, to a significant degree, the macro-level camp of the rational/utilitarian tradition.

The intellectual power, popularity and persuasiveness of the micro-level methodologies of complexity science, and the macro-level theoretical camp of the rational/utilitarian tradition upon which they are based, explains why the east side dominates the epistemological trajectory of SACS today. No matter how useful the west side's ideas might be, they are old-school. By old-school we mean that, while the west side breaks with the macro-level theories of Parsons, it has not fully embraced the methodologies of complexity science, and thereby continues to use what is perceived as an outdated, largely ineffective, macro-level approach to modeling social systems. In stark contrast is the new-school epistemology of the east side. Grounded in the methodologies of complexity science and the micro-traditions of sociology, the east side of SACS not only breaks with macro-level theorizing, it favors a completely micro-level approach to modeling social systems. And so we come to the end of our fractal inquiry.

8.2 The Near Future of SACS

Before ending this chapter, we have one last question to address. What might SACS differentiate into next? Overall, we see little evidence to suggest that the negotiated ordering of this town has settled or will remain stable as it evolves over the next decade. There are several reasons for this conclusion.

First, there is no reason to assume that the new-school trajectory of the east side, despite its support by complexity science, will continue to dominate SACS. For example, if the reader recalls from our Chap. 6 review of the BBC, as the spokesperson for complex complexity (C^2), much of Byrne's work is a thoroughgoing critique of the overly micro-level perspective of complexity science. As we discussed in Chap. 6, while Byrne applauds the new-school trajectory into new epistemological space, he ultimately wants to move past what he sees as its somewhat simplistic theoretical and methodological assumptions about how social systems and human beings, as social agents, work (e.g., Byrne 2001, 2002, 2005).

As we also discussed in Chap. 6, Byrne is not alone in this critique. His concern is echoed by some of the more recent debates in computational sociology over the challenges of simulating humans and their social systems (Goldspink 2000, 2002). It also is echoed in the work of Luhmann and the work of Urry, Wallerstein and Castells on global network society. And, it is a concern we have raised on several occasion in this book—specifically Chaps. 2 and 3, which outlines our theory of social practice and the methodological perspective of assemblage.

While the criticisms of Byrne and others have by no means reached a critical mass, we may find that, as SACS matures, these criticisms cause a fractal break within the micro-perspective of the east-side, resulting in a meso-level approach to modeling social systems. We will have to wait and see.

The second reason for instability in SACS is computational sociology. There is strong reason to believe that this research area is not done dividing. For example, scholars within SACS have yet to fully appreciate the value of data mining and dynamical systems theory for their work. Given the strong bias toward the new science of networks and agent-based modeling, it may be some time before these other methods take hold. Nevertheless, they do hold great promise.

The third reason for instability in SACS is qualitative method. Given the qualitative focus of Byrne (2005) and Ragin (2000), along with the work we are doing in terms of the integration of computational sociology and qualitative method (e.g., Castellani and Hafferty 2006; Castellani, Castellani and Spray 2003), a new area of research may emerge, separate from computational sociology, such as *qualitative complexity science*.

The fourth reason for instability in SACS is substantive. There are numerous substantive areas that could emerge or become dominant in SACS. One we mentioned earlier (via the work of Mingers) is the integration of complexity science and managerial science (Capra 2002). As a side note, we remain surprised that the application of complexity to human organizations has not captured the attention of sociologists. Just to make sure we were not missing something, we even poured through the conference proceedings for the last couple of American Sociological Association meetings and were unable to find any sessions or roundtables devoted to the study of formal organizations as complex systems. However, if sociologists were to embrace the work of Mingers and others, this could create a new area of research in SACS sufficient to alter its current negotiated ordering. We will see.

The final reason for instability in SACS is globalization. There is a strong potential for the study of global network society to significantly rise in position and importance within SACS. While *globalization studies* is a new area, it is an extremely popular and important topic with no signs of slowing down. How important complexity science will be to Globalization Studies remains to be seen (Urry 2003). At the very least, as globalization studies becomes more empirically grounded, the methodological tools of the new science of networks and computational sociology will be almost mandatory (Urry 2003). There is no other way to really study globalization substantively, as indicated by the work already done in this area by Castells, Wallerstein, Newman, Barabási, Watts and Urry.

And so, we come to the end of our review of SACS today. We turn now to our concluding chapter to examine the legitimacy of this new town and its current impact on sociology.

9 Conclusion

9.0 Overview

We come, finally, to our conclusions. As we stated in the preface, our purpose was to introduce sociologists to, and provide a thoroughgoing review of a new area of inquiry we call sociology and complexity science, or SACS for short.

SACS is a new intellectual town that has taken root on the outer banks of sociology. It is located at the fork in intellectual river separating sociology from the natural sciences. The scholars of SACS have taken up residence at this particular fork because of its close proximity to systems science, cybernetics, and, more specifically, the newly built city of complexity science.

In turn, complexity science, with its systems view of life, is touted as "the science of the 21st century." Murray Gell-Mann, Steven Hawking and E. O. Wilson, for example, have all made this claim. With its long list of innovative techniques and concepts, complexity science promises to unite the sciences under a common banner: exploring the increasing complexity of life and science through the common toolkit of complex systems thinking. The methodological innovations complexity scientists have made include the development of cellular automata, genetic algorithms, computational modeling, fuzzy set theory, distributed artificial intelligence, data mining, multi-agent modeling, complex network analysis, chaos theory, and fractal geometry. In addition to the complex system, other innovative concepts include emergence, self-organization, autopoiesis, self-organizing criticality, and the small-world phenomenon.

SACS, as we have demonstrated throughout this book, is part of the new science of complexity. As its own intellectual community, SACS is comprised of a small but growing network of scholars, devoted to integrating complexity science with sociology for the purpose of enhancing sociological inquiry. This community boasts an impressive list of top scholars in complexity science and sociology. Examples of the former include Duncan Watts, Mark Newman and Albert-László Barabási. Examples of the latter include Immanuel Wallerstein, Manuel Castells and Niklas Luhmann.

At present, SACS is comprised of five major areas of research: complex social network analysis (CSNA), the British-based School of Complexity (BBC), the Luhmann School of Complexity (LSC), sociocybernetics and computational sociology. Two of these areas have their own subclusters of research. Computational sociology is comprised of simulation, data mining and dynamical systems theory; while CSNA is comprised of global network society and the new science of networks.

9.1 Why Read This Book

All sociologists, regardless of their area of inquiry, should have a basic knowledge of the leading scholars and areas of research in SACS. As we outlined in our preface, SACS offers sociologists an impressive list of methods, techniques, concepts and theories for addressing the growing complexity of sociological work. In terms of method, this list includes agent-based modeling, cellular automata, neural networking, data mining, the new science of networks, dynamical systems theory; otherwise known as chaos theory and so forth. In terms of theory, this list includes Luhmann's new social systems theory; Watt's concept of the small-world; Barabási's concept of scale-free networks; Bak's concept of self-organizing criticality; and, most important, the *complex social system*.

And what is the cause for this increasing complexity in sociology, along with the need for the tools of SACS? The answer is the shift in western society to post-industrialism, along with the massive acceleration of globalization, to which science has been responding by embracing a complex systems perspective.

9.2 Expressing Old Ideas in New Ways

With our argument for reading this book made, we turned to a history of systems thinking in sociology. While many of the techniques and concepts of SACS are innovative and impressive, the ideas upon which they are based are not new. Starting in the middle 1800s, sociology was born and continues to be a discipline of complexity. From then until now, one or more of its leading scholars have rather consistently sought to address the growing complexity of the discipline's work from a systems perspective.

For example, one can go back to the list of scholars now part of the canon of sociology and note that a major purpose of their work was to address the growing, changing, evolving, shifting complexity of western society as it turned, moved, shifted into the industrial era. They also employed one type of systems perspective or another to study this new complexity—be it Darwinian or Hegelian. These scholars of the classical era of systems thinking included Karl Marx, Max Weber, Vilfredo Pareto, Herbert Spencer and Emile Durkheim.

Forty years later, the functionalist era of systems thinking (1940s–1970s) employed a similar approach. What made the functionalist era unique was that Parsons not only reached out to the classical era of systems thinking, he also reached out to the newly emerging fields of cybernetics and systems science to complete his theoretical vision. Both of these fields are the intellectual forerunners to complexity science. Just about everything we associate with complexity science today—from the study of complex systems and self-organization to the development of cellular automata and agent-based modeling—grew out of these two traditions and the scholars involved. In fact, many of the leading scholars in these two fields are seen as dominant historical figures in complexity science: John Von Neumann, Humberto Maturana, Francisco Varela, Stuart Kauffman, George Klir, and Warren McCulloch to name a few.

The mistake main street sociology made in the post-functionalist era was that, wanting to be free of systems thinking, they engaged in a wholesale dumping of everything and anything associated with functionalism, including cybernetics and systems science. Had sociology remained committed to and involved in these natural science fields, albeit critically developing them, the discipline would stand at the forefront of complexity science today. Instead, while a small group of sociologists are significant players in the field, the work of complexity science and SACS is marginal to main street sociology, particularly in the United States.

Given this historical record, a secondary purpose of our book was to help sociologists become, once again, involved in the systems tradition. By introducing sociologists to SACS, we hoped to introduce others to the current era of systems thinking in sociology, as well as to offer a thorough review of the new theories, concepts, methods and techniques being employed by some of the top sociologists and complexity scientists in the world today in order to address the growing complexity of sociological inquiry. Having made the intentions of our book clear, we turned to our review of SACS.

9.3 Reviewing SACS

We addressed three basic sets of questions in our review of SACS. The first had to do with the composition of SACS. When did it emerge? Why is SACS a town? What are its major areas of research? Who are its key scholars? What environmental forces have the biggest impact on SACS? And so forth. The second set of questions had to do with the legitimacy of SACS. For example, does SACS look like a typical intellectual community? Has it achieved a level of relative stability? Are its areas of research well organized? The third set of questions has to do with SACS's position within and impact upon sociology. For example, is SACS part of the systems tradition in sociology? Have any of the key scholars of areas of research in SACS made a major contribution to sociology? Before we could answer these questions, however, we needed to address the issue of method.

9.4 SACS Toolkit

Given the tremendous complexity of our topic, we realized (albeit slowly at the beginning of our work) that the best way to conduct our review of SACS was to use the tools of this new field and its parent, complexity science. In other words, we used our topic of study to study our topic—hence our two methods Chaps. 2 and 3. In these chapters we introduced readers to the new toolkit we have created for modeling social systems, which we call the SACS Toolkit.

The SACS Toolkit is comprised of three major components: a theoretical framework, an algorithm, and a recommended toolset. The theoretical framework, called *social complexity theory*, provides researchers scaffolding for arranging and organizing their study of a social system. The algorithm, called *assemblage*, provides an extensive list of procedures for building a social system from the ground-up. The recommended toolset—which includes, for example, neural networking, cluster analysis, agent-based modeling, grounded theory and social network analysis—is our list of the methods and techniques used in complexity science and sociology today best suited for modeling and analyzing social systems.

9.5 What We Learned About SACS

With the SACS Toolkit in hand, we proceeded to address our three major questions. Here are some of the highlights.

In terms of its composition, we learned that SACS is not a discipline, subdiscipline, field of inquiry or area of research. Instead, it is an intellectual town. Towns are highly interstitial places of intellectual residency situated on the outer banks of one or more disciplines. Scholars build towns so they can capitalize on the type of creative marginality and intellectual mobility these types of intellectual spaces allow.

We also learned that SACS is comprised of five major areas of research, all of which are relatively well defined. These five areas are: computational sociology, complex social network analysis (CSNA), the British-based School of Complexity (BBC), sociocybernetics, and the Luhmann School of Complexity (LSC).

SACS was founded in the late 1990s with the *complexity turn* in the social sciences—although the LSC and sociocybernetics had been around since the late 1980s, albeit in a very elementary form. As defined by Urry (2005b), this turn has to do with the realization by a wide range of sociologists that the increasing complexity of sociological work was best handled through an integration of sociology with the new field of complexity science.

In terms of its legitimacy, the network structure of SACS is that of a typical intellectual community. For example, the main scholars of SACS are clustered into localized areas of research, with weak ties running from one cluster to another; there are also hubs and authorities in SACS, along with major household names and key gatekeepers—all the various things complexity scientists look for when studying intellectual networks. In other words, the structure and dynamics of this town are consistent with the findings of current research (See Newman 2001a, 2001b, 2004).

There is only one major issue in terms of the internal cohesion in SACS. There appears to be a major intellectual rift between the east and west sides of this town. On the east side are the three newest areas of research: computational sociology, CSNA and the BBC. On the west side are the two oldest areas: sociocybernetics and the LSC.

The divide between the east and west side of SACS has to do with their different epistemologies. While all five areas of SACS lean heavily in the direction of the natural sciences, the west side of SACS favors an old-school perspective, characterized by a humanities based, macro-level, top-down, structure oriented, static, variable-based approach to modeling systems. In contrast, the scholars on the east side of SACS take a new-school perspective, which favors a natural-science, critical realist, micro-level, bottom-up, agent-based, dynamic, social interactionist approach to modeling social systems.

What the intellectual division between the east and west sides of SACS means for the future of this town is unclear. What is clear, however, is that the new-school approach to modeling systems dominates the current trajectory of SACS. This dominance is based, in large measure, on the current power and popularity of complexity science, which shares the same epistemological views of the new-school approach. It is also clear that, while complexity science falls outside the intellectual purview of most sociologists, SACS is making an important, albeit diffuse, impact on sociology. We turn to a brief review of this impact now.

9.5.1 The Impact of SACS

As Abbott explains in *The Chaos of Disciplines* (2001) it takes about 20–25 years for any new area of inquiry to make itself known in an interstitial, open-ended discipline like sociology. Abbott states, "There is good reason to expect a cycle of about this length. Twenty years is about the length of time it takes a group of academics to storm the ramparts, take the citadel, and settle down to the fruits of victory. There is a common pattern." (p. 24).

As a new town, SACS tipped into existence around 1998 and has been under development for a decade. If we take Abbott's quote at face value, SACS is about half-way through its cycle, with roughly ten years left. Using Abbott's timetable, we would say that SACS is presently "storming the ramparts" and, in some cases, "taking parts of the citadel" of sociology.

In terms of taking parts of the citadel, global network society and simulation have made the greatest inroads. Global network society has gone the furthest because it is a well recognized area of sociological thinking, due to the phenomenal work of Castells and Wallerstein and, more recently, Urry. Whether other scholars agree with these ideas is not of concern. The fact is, they are on the map. Simulation has advanced significantly as well. For example, the *Journal of Artificial Societies and Social Simulation* (JASSS) is recognized as a leading journal in computational modeling and sociology. The well-known social network theorist and mathematical sociologist, Bonacich, is the major figure in SACS. The leading scholar in computational sociology, Gilbert, has written a handbook for Sage on computational modeling. The *American Journal of Sociology* (AJS) had a special edition devoted to the topic of computational sociology. And, undergraduate and graduate departments are starting to teach computational sociology.

In terms of storming the ramparts, but not yet making it into the citadel, there is the new science of networks. Surprisingly enough, despite the phenomenal impact this area of research has had on the natural and computational sciences, it has not had the impact on sociology one would expect. Part of this has to do with the resistance sociologists have to this new work. For example, while Watts' famous article on the small-world phenomenon (published in *Nature*) has been cited over 2,000 times, his sociological version of this article, published in *American Journal of Sociology*, has been cited only 95 times. The other part of sociology's resistance has to do with lack of methodological training. As Morris points out (2004), undergraduate and graduate education needs to be revised significantly in order for sociologists to catch up with the latest advances in complexity science.

The BBC has had a significant impact on British sociology, where it has stormed the ramparts and taken parts of the Citadel. But, outside the UK it does not have a major presence.

The LSC has definitely taken the citadel in German speaking sociology, but elsewhere, like the BBC, it has a marginal presence at best. However, Luhmann is getting more play as his work is translated into English and French. Within the *International Sociological Association*, sociocybernetics (Research Committee 51) has stormed the ramparts and settle into its part of the citadel to enjoy some of the fruits of its victory.

Still, despite these inroads, the current success of SACS does not tell us if this town will ever become a major player in main street sociology. Then again, for such a highly mobile community of scholars who enjoy living in such a creatively marginal town, the type of parochial victory Abbott mentions may not hold much sway.

Instead, we like to think that the scholars of SACS see a greater victory in Anselm Strauss's one-third principle. Anselm Strauss was a brilliant sociological theorist, medical sociologist, symbolic interactionist, and methodologist who, along with Barney Glaser, co-created the qualitative method known as grounded theory (Glaser and Strauss 1967).

In an essay he wrote to honor Strauss, Glaser (1991) outlined the things his friend and colleague had taught him about collaboration and, more important, the intellectual life. One of these lessons Glaser calls Strauss' *one-third principle*. When we go to share our work with the world, Strauss explained to Glaser, "One third will read our work and love it. One-third will dislike it and criticize it according to their own canons. And one-third will simply ignore it. But one-third favorability among colleagues is ample for career and recognition and for attracting students and friends all over the world" (1991, p. 15). It is this dictum, we believe, that governs the scholars of SACS and the prospects for our current book.

10 Mapping Complexity

As we explained in our review of complexity science (Chap. 5), given the challenges of modeling complex systems, scholars in this new of field of study (particularly those working to advance agent-based modeling and the new science of networks) have developed a rather significant list of visual techniques. The purpose of these visual techniques is to help researchers and readers grasp what are otherwise difficult issues to explain verbally. Said another way, complexity scientists take the viewpoint that *a picture of a complex system is worth a thousand words*.

The SACS Toolkit adheres to the same viewpoint. As explained in Chaps. 2 and 3, the SACS Toolkit is highly visual, relying upon a rather extensive repertoire of techniques taken from social network analysis, the new science of networks, social simulation, fractal geometry, cluster analysis, grounded theory, and the self-organizing map literature.

Integrating these techniques, the SACS Toolkit provides a novel approach to visualizing social systems. In this chapter (and throughout the book) we provide readers a viewfinder into this novel approach. In addition, all of the maps, figures and graphs in our book can be examined and downloaded—in color—from our website. Our website also provides an electronic version of Maps 1 and 4—with links to the internet—so that readers can learn about the major scholars, topics, or fields of study in SACS and complexity science (See www.personal.kent.edu/~bcastel3/).

10.0 The Map

The most important visual technique in the SACS Toolkit is the *map*. Maps provide *global* snapshots of some aspect of a social system. They are not meant to visualize a social system in its entirety. Such a map would be, if not impossible, at least impractical. Maps are guides, not actual representations.

While global in focus, maps vary according to a list of dimensions—function, scale, detail, time-space, etc. For example, as the seven maps in this chapter demonstrate, while some maps (such as Map 1) provide a historical overview of a social system (in this case complexity science), others (such as Map 2) focus on a specific moment in time (i.e., the network of attracting clusters for SACS circa 2008).

One important difference we have noted in map function, which we wish to discuss here, is between maps created for the researcher versus maps created for the reader. All seven maps provided in this chapter were originally created to help us, as the researchers, model the structure and dynamics of SACS and to help us understand its position within the larger systems of sociology and complexity science. Only when we wrote the book did they turn into maps intended for the reader.

For example, we initially created Map 1 as a way to visualize the history of complexity science, as it has developed over the last sixty years, including its intellectual lineages, major topics of study, and key historical figures. Map 1 proved very useful during the early stages of the modeling building phase because it allowed us to: (1) grasp the new field of complexity science, at the global level; (2) distinguish SACS, as its own field of study, from complexity science; and (3) determine where the five major areas of research in SACS are situated within the intellectual traditions, methods and topics of complexity science.

Map 2 is another example of a working map. In the middle stages of our research we had a difficult time dealing with the interstitial character of SACS, as well as the issue of whether SACS constituted the *sociology of something*—in this case, the sociology *of* complexity. We decided to create a map of SACS as an intellectual town. As we developed our map we realized that SACS really was not the *sociology of complexity*. Instead, given its interstitial character, it was better characterized as *sociology and complexity science*. Map 2 also provided us a metaphorical language (that of geography and archeology) that we used to outline sociology's historical relations with cybernetics and systems science, starting with Parsons and ending with SACS—See Chap. 4, specifically, Sect. 4.4.

Map 3 is our final example. This map (along with Figs. 1–3 and Flowcharts 1 and 2) visualizes the theoretical filing system used by the SACS Toolkit, providing a graphic checklist of all the things one needs to address when building a model of a social system. In fact, we found ourselves turning to Map 3 even during the final editing phase of our book, making sure we had a proper grasp of our model and that everything had been adequately addressed.

In summary, in terms of the SACS Toolkit, maps (along with their related figures and graphs) are an effective tool for modeling social systems. Given their utility (as well as our constant reliance upon them throughout this book) we placed all of our maps, figures and graphs here, in one chapter. This way the reader can refer to them as needed. For each map, figure and graph, we provide a brief description of how to read it, along with directions for where to go in the book for further study. In fact, we hope that Chap. 10 is reasonably self-sufficient that it can be read as a visual tour of our book.

10.1 *Map 1: The New Science of Complexity*

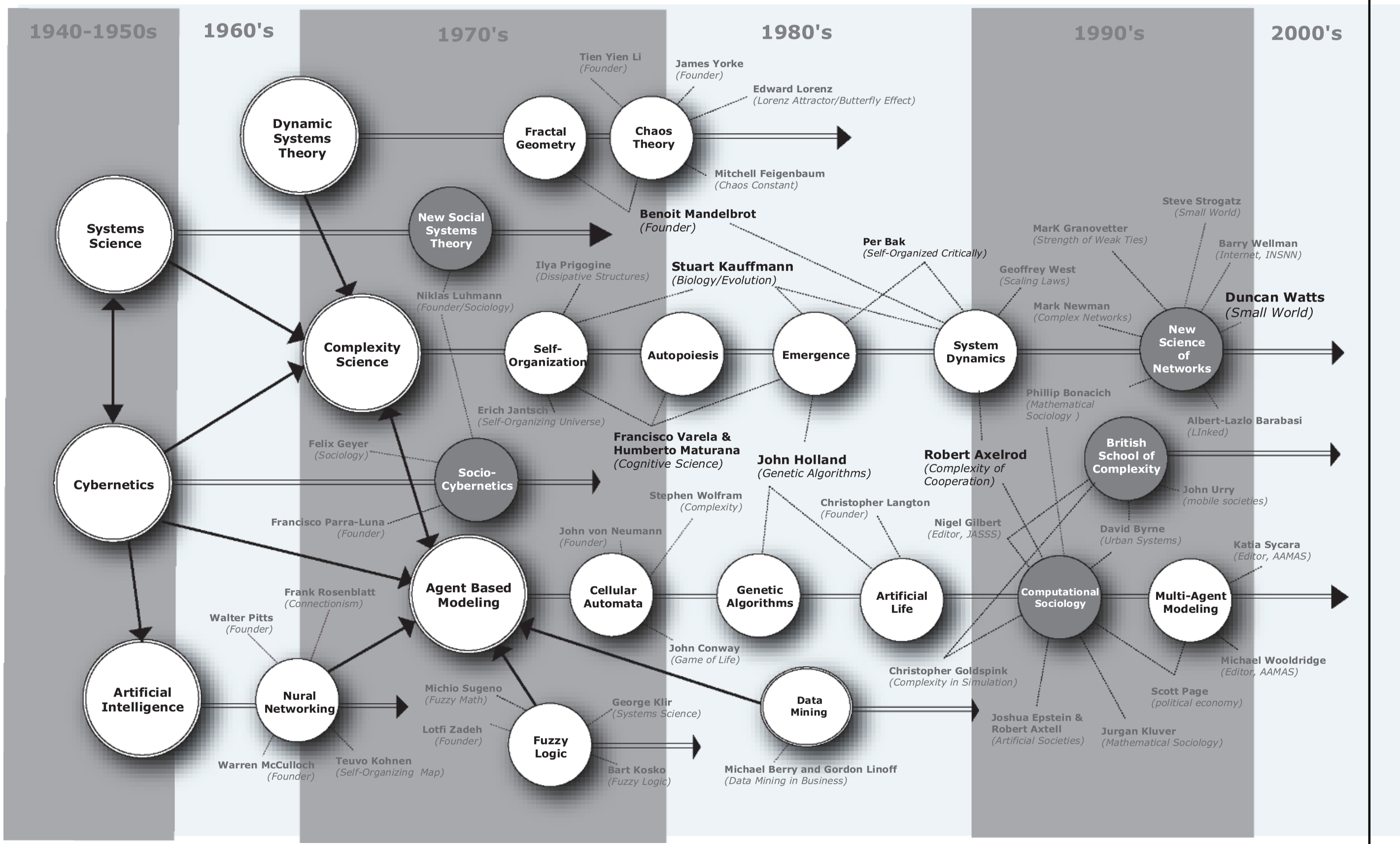
Map 1 is a conceptual representation of complexity science and the five areas of research in SACS: computational sociology, complex social network analysis (CSNA), the Luhmann School of Complexity (LSC), sociocybernetics, and the British-based School of Complexity (BBC). All five areas of SACS are in grey.

Map 1 is to be read as follows: First, it is roughly historical, working as a timeline that is divided into five major periods, going from left to right: (1) old-school systems thinking, (2) the perturbation of complexity, (3) the new science of complexity, (4) progress, and (5) recent developments.

Because of the diversity of research in complexity science, Map 1 focuses on the key topics in the field that unite various substantive inquiries. These key topics are self-organization, emergence, autopoiesis, system dynamics and networks. Each field of study is represented as a double-lined ellipse, with a double-lined arrow moving from left to the right. The relative size of these ellipses is strictly a function of the space needed to write the name of each field. Double-lined arrows represent the trajectory of each field of study. Space constraints required that the length of these arrows be limited; readers should therefore assume that all of them extend outward to 2009. The decision where to place the various fields of research respective to one another is also somewhat arbitrary. However, we did try to position similar areas near each other. Areas of research identified for each field of study are represented as single-lined circles. The size of these circles is strictly a function of the space needed to write the different names. The intellectual links amongst the fields of study and areas of research are represented with a bold, single-lined arrow. The head of these single-lined arrows indicates the direction of the relationship. In some cases, the relationship is mutual.

For each area of research, we also include a short list of the leading scholars. This list is not exhaustive; but it is representative, based on number of citations, general recognition, and importance in the historical development of the area of research. For each scholar we provide the following information: name, most widely known contribution, and links to key areas of research. The links amongst the scholars and their respective areas of research are represented by a dashed line. One will also note that the names of the scholars differ in font size. This was done to demonstrate their relative importance within complexity science and the sociology of complexity.

Map 1: The New Science of Complexity



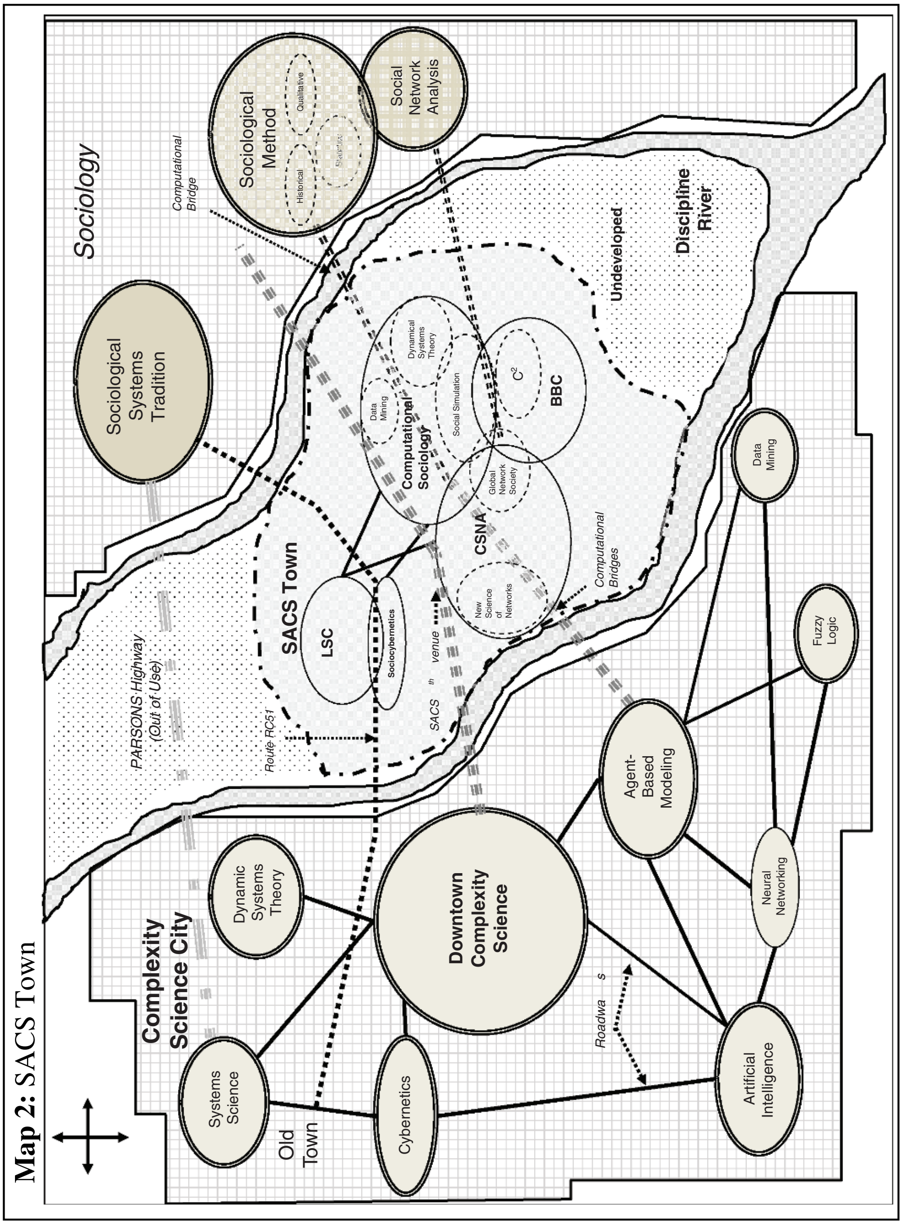
10.2 *Map 2: SACS Town*

Map 2 visualizes SACS in geographical and archeological terms. In terms of geography, our goal is to position SACS (metaphorically speaking) relative to the two largest intellectual systems of which it is a part, namely complexity science and sociology. In terms of archeology, our goal is to position SACS and its five areas of research relative to the functionalist phase of the systems tradition in sociology.

The Geography of SACS: Map 2 is to be read like a typical road map, wherein disciplines, fields of study and schools of thought are treated as states, cities, towns and communities; and wherein the positioning of these various municipalities are thought of in geographical (spatial) terms and the connections (links) between these various municipalities are thought of in terms of roads, highways and so forth. The division between these intellectual systems is also taken into account in the form of spatial dividers such as rivers, forks, and boundary lines.

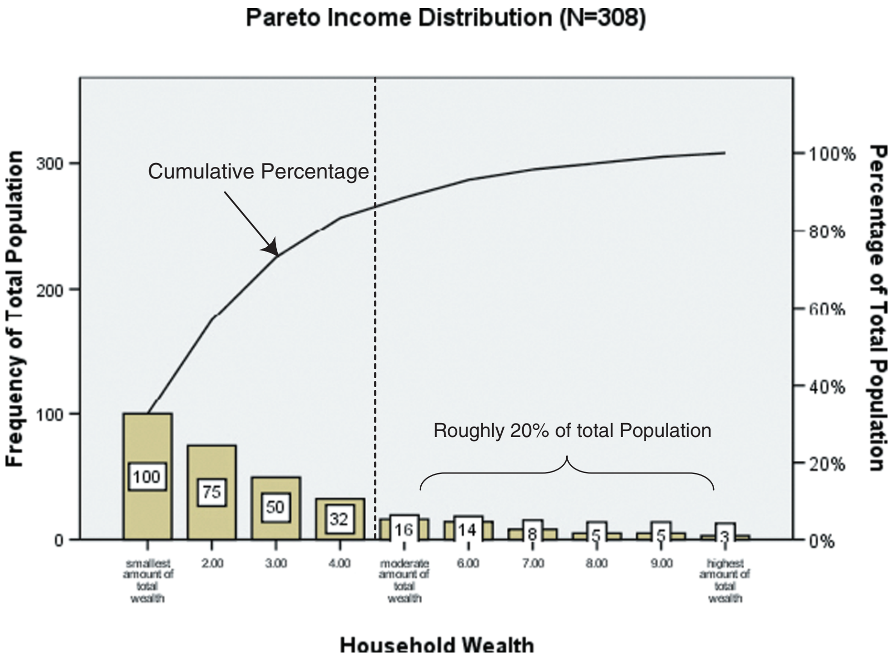
For example, sociology is treated as a state, while the natural sciences are conceptualized as a country. Complexity science is viewed as a city and SACS is treated as a town. For more information on the geography of Map 2, see Chap. 1, Sect. 1.3. See also Chap. 4, in particular 4.4. Like Map 1, circle size in Map 2 is strictly a function of the space needed to write the name of each field, with one noted exception. Because the sub-clusters of research are subsumed under their respective areas of research, they are purposely smaller in size. For example, Global Network Society is a sub-cluster of research within Complex Social Network Analysis (CSNA) and so it is smaller.

The Archeology of SACS: In Chap. 4 we spend time discussing the links between the functionalist phase of the systems tradition in sociology and its current complexity phase, which has to do with SACS. Map 2 provides a way to conceptualize this relationship by visualizing the archeological ruins of functionalism, including such things as old Parsons Highway. While metaphorical, we found Map 2 very helpful in our own model building process and in our explanations of the history of SACS. For more information, see Chaps. 4 and 7, in particular, Sect. 7.2.



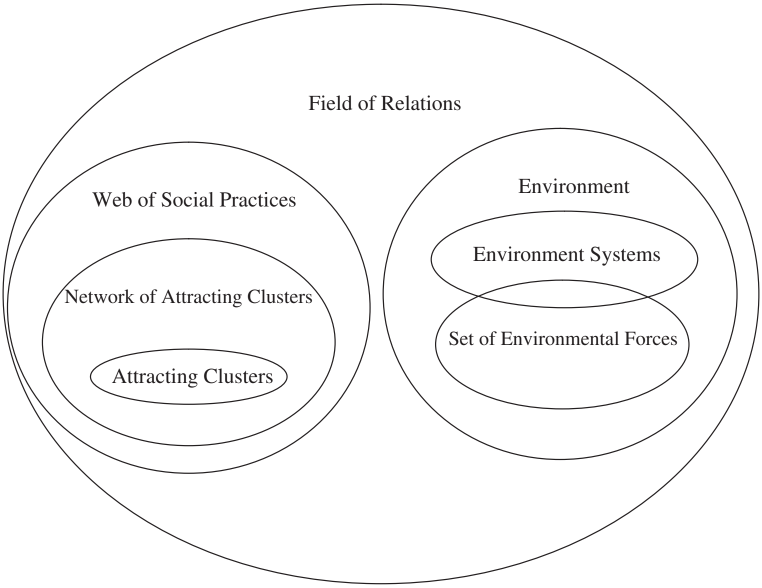
Map 2: SACS Town

10.3 *Graph 1: The Pareto Distribution*



This Graph is an example of the classic Pareto Distribution wherein the top 20% of households own roughly 80% of the total wealth in a given population. For more information on this graph, see Chap. 1, Sect. 1.2.3.1

10.4 *Figure 1: Venn Diagram of SACS Folders*



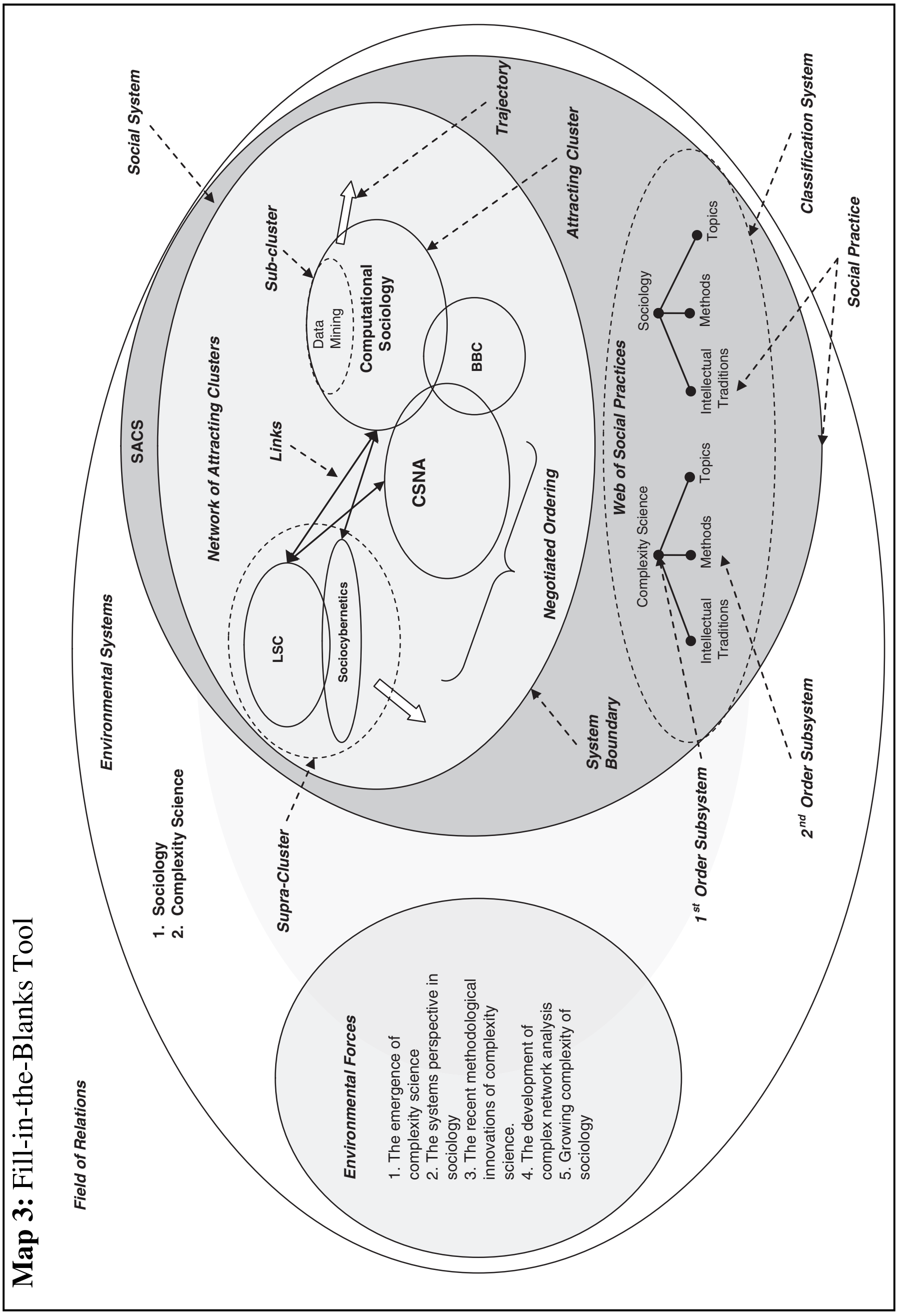
This Venn diagram visualizes the folders (as subsets) used by social complexity theory—the theoretical framework of the SACS Toolkit—to organize an investigation into a social system. For more information on this diagram, see Chap. 2, Sect. 2.2.5.

10.5 *Map 3: Fill-in-the-Blanks Tool*

Map 3 is a visual aide used by the researcher during the model building process. It works as a fill-in-the-blanks picture. As the model is built, the researcher fills in the various areas of the map. Each area corresponds to one of the conceptual folders from the SACS Toolkit—environmental systems, web of social practices, network of attracting clusters, etc. The researcher also uses the map to ensure that all of the major terms in the SACS Toolkit are used appropriately, such as negotiated ordering, trajectory, sub-cluster and so forth.

The particular model shown in Map 3 is SACS, circa 2008. In Map 3 are found the key environmental systems and forces impacting SACS, as well as a brief overview of the web of social practices and the network of attracting clusters for SACS. For a complete rendering of the web of social practices, see Fig. 2. For a complete picture of the network of attracting clusters, see Map 4. Also, for a visualization of the assemblage algorithm, which is used to create Map 3, see Flowcharts 1 and 2.

Once filled in, or during the process of creating Map 3, the researcher gains a quick overview of the model. The researcher can also use Map 3 to assist visually such questions as: Is my model working? Can I explain my model to a colleague or myself and it makes sense? Is my model holding together well? Am I arriving at some new insights? Do my attracting clusters make sense? Are they positioned correctly in relation to one another? Have I accounted for all of the necessary environmental forces? And so forth. For more information on Map 3, see Chap. 2.



Map 3: Fill-in-the-Blanks Tool

10.6 *Figure 2: Web of Social Practices for SACS*

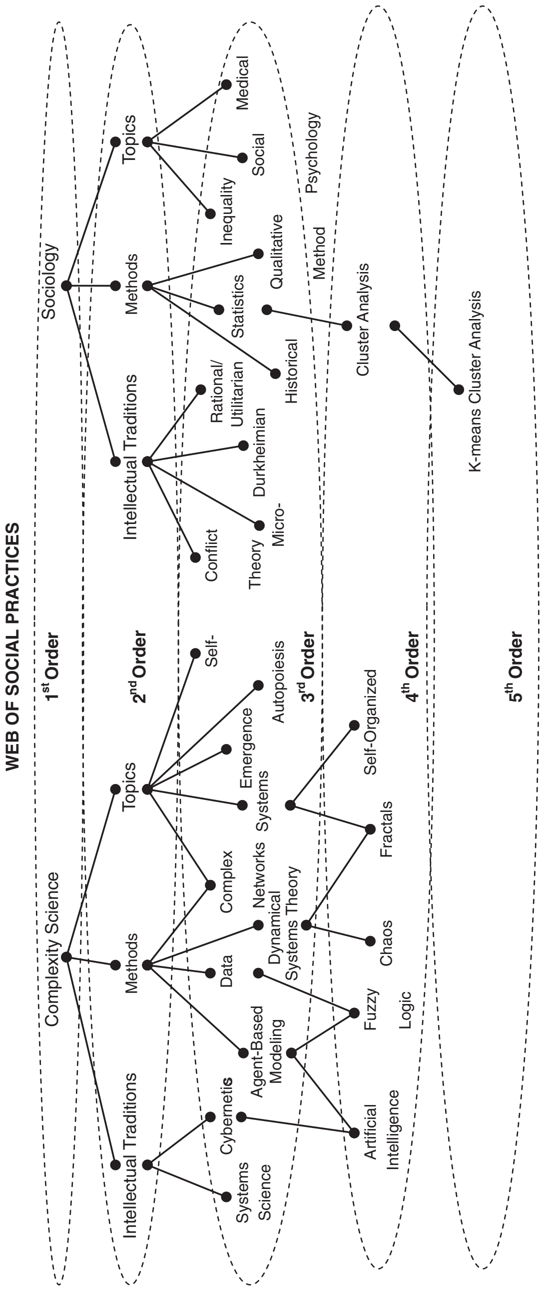


Figure 2 shows the web of social practices for SACS. Like a root structure, the web of social practices is organized into a series of successive (nth order) layers, each of which is subsumed under the social practices found in the preceding layer. For example, under the first-order social practice, sociology, are the second order sub-practices of intellectual traditions, methods and topics. Moving to the third-order, within methods, for example there are the sub-practices of historical, statistical and qualitative method. One can continue this layering ad infinitum, depending upon the level of detail needed for one's model. For more information on the web of social practices and its usage in our study of SACS, see Chap. 2, Sect. 2.2.6.

10.7 *Figure 3: Web of Social Practices as Molecule*

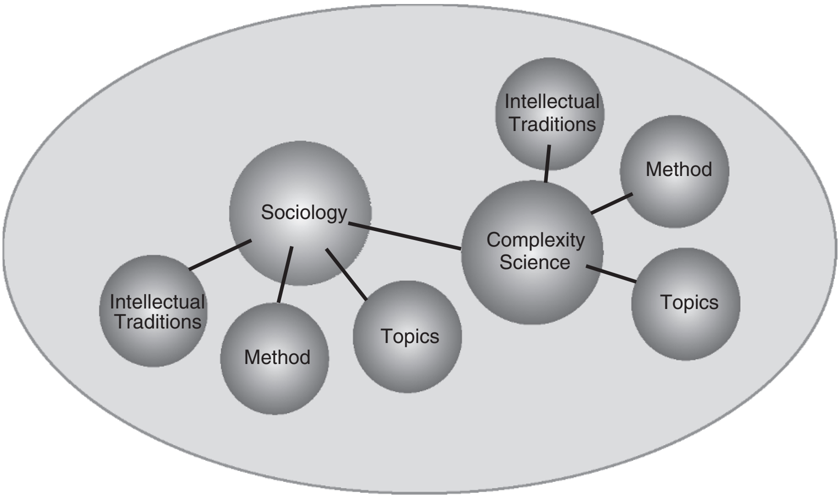


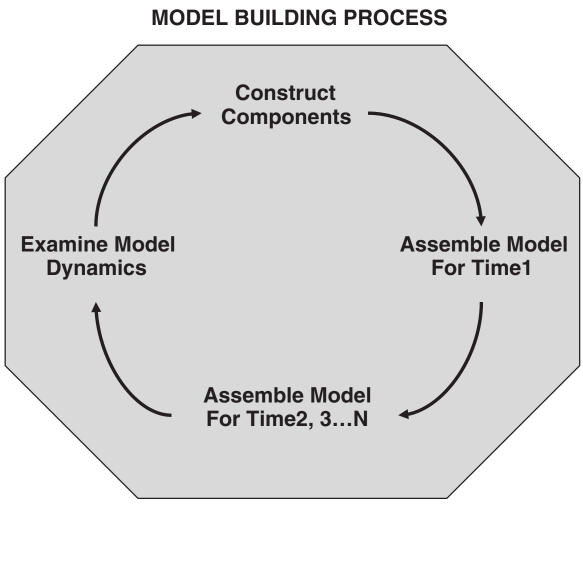
Figure 3 shows the web of social practices for SACS as a molecule. This figured is used to demonstrate our concept of coupling. For more information see Chap. 2, Sect. 2.2.7.1

10.8 *Flowcharts 1 and 2*

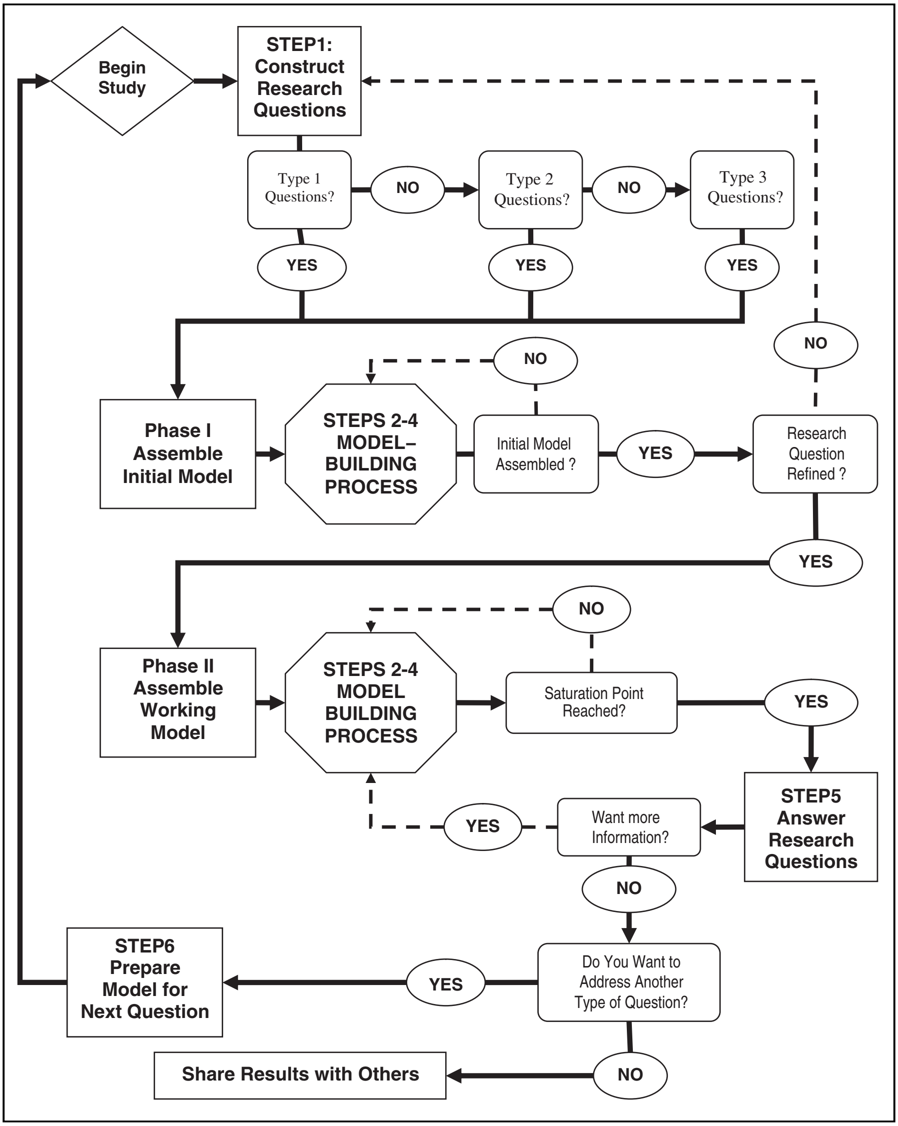
Flowcharts 1 and 2 visualize the assemblage algorithm used by the SACS Toolkit to construct a model of a social system from the ground-up. *Assemblage* is a case-based, system-clustering algorithm for modeling social systems. It is built on the organizational framework of social complexity theory and represents the procedural component of the SACS Toolkit.

As shown in flowchart 1, the goal of assemblage is to move researchers through a six-step algorithm for constructing a model of some social system of study. This algorithm roughly proceeds as follows: (1) help the researcher define a set of research questions in systems terms; (2) establish the social system's field of relations and determine the web of social practices out of which it emerges; (3) use this information to catalogue the numerous ways the system is coupled/expressed at a particular moment in time-space; (4) condense/cluster this catalogue into a smaller grid of the system's most important practices to create the network of attracting clusters; (5) examine the internal dynamics of this network for a particular moment in time-space, including its interactions with key environmental forces and its trajectory within key environmental systems; and, finally (6) assemble these discrete, cross-sectional snapshots of the system into a moving model, concluding this some overall sense of the system as a whole. Once done, researchers can "data mine" this model to answer the initial study questions or to generate new questions or models. Flowchart 2 provides a detailed overview of the core of the model building process—Steps 2 through 4.

Flowchart 2: The Core Steps, 2 Through 4



Flowchart 1: The Assemblage Algorithm



10.9 *Map 4: The Community of SACS*

Map 8 depicts the network of attracting clusters for SACS. It was created based on our historical study of SACS circa 2008.

Each oval on this map represents one of the major ways that SACS is practiced; that is, one of the major ways that the intellectual traditions, methods, and topics of sociology and complexity science tend to couple. Together, these ovals represent the five major research communities in SACS at a particular moment in time-space; specifically SACS in Europe and North America between 2006 and 2008—computational sociology, sociocybernetics, the Luhmann School of Complexity (LSC), complex social network analysis (CSNA), and the British-based School of Complexity (BBC).

In the language of fractal geometry, each oval in Map 4 is an attractor point around which a more exhaustive list of smaller couplings (in this case, scholars and subfields of research) gathers. Said another way, the scholars listed in Map 4 are empirical expressions of the numerous "couplings" taking place within and between the five research communities of SACS. In other words, the scholars listed on Map 4 are not just people; they are expressions of the coupling of social practice.

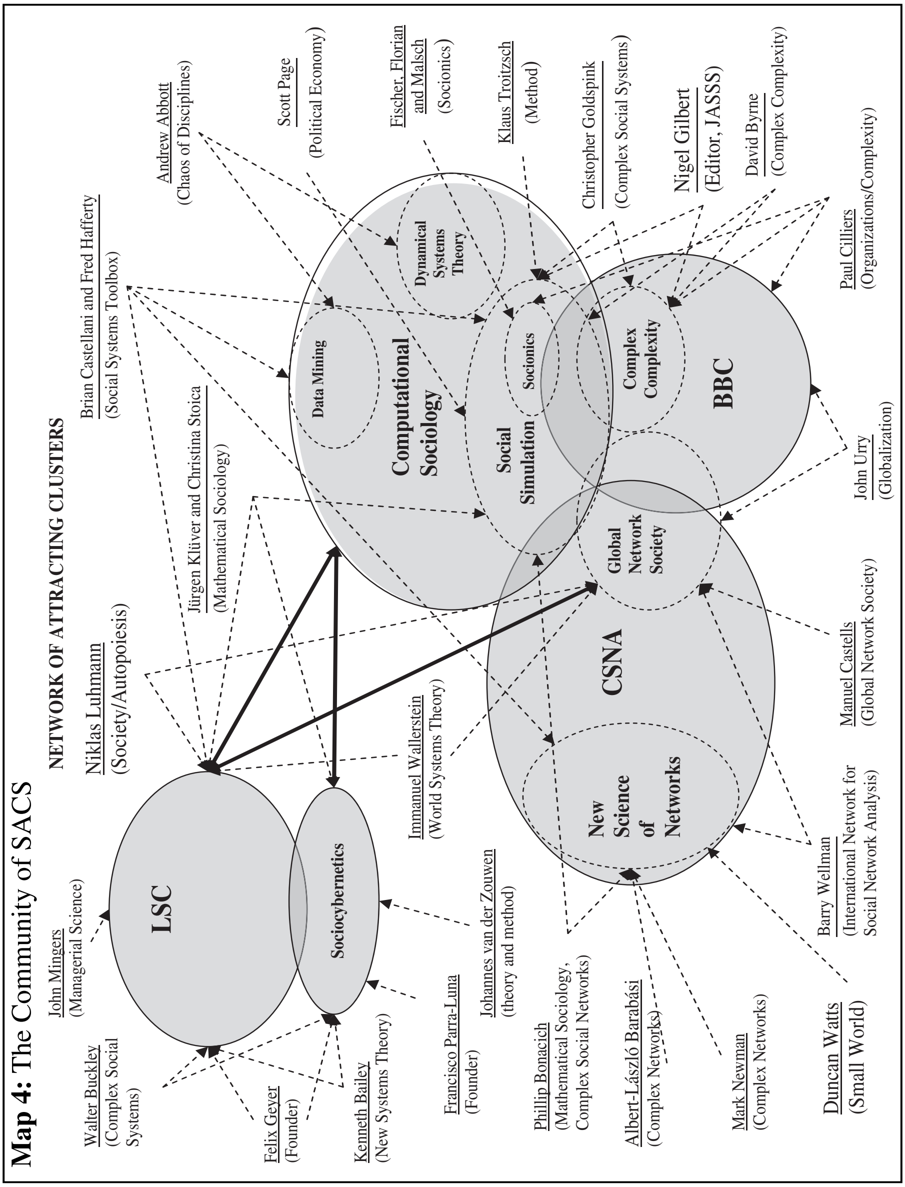
The dotted arrows show the primary areas of research to which the scholars on Map 4 are linked.

Below each scholar's name, in parentheses, is the area of work for which the scholar in most known. As in Map 1, the larger the font for a scholar, the more important the scholar is to SACS—see Chap. 7, Sect. 7.1.4 for our definition of scholarly importance, which has to do with hubs, authorities, gatekeepers and household names.

The dotted ovals within the five areas of research are the sub-clusters of study within SACS. Some of these sub-clusters overlap with more than one area of research, as in the case of global network society.

The solid arrows show which areas of research and sub-clusters in SACS have the strongest relationships with one another.

The closer an area of research is to the center of Map 4, or the larger an area of research is, the more important it is to the last decade of development in SACS (1998–2008). For our definition of importance, see Chap. 7.


Map 4: The Community of SACS
NETWORK OF ATTRACTING CLUSTERS
Niklas Luhmann
(Society/Autopoiesis)
Brian Castellani and Fred Hafferty
(Social Systems Toolbox)
Andrew Abbott
(Chaos of Disciplines)
Scott Page
(Political Economy)
Fischer, Florian
and Malsch
(Socionics)
Klaus Troitzsch
(Method)
Christopher Goldspink
(Complex Social Systems)
Nigel Gilbert
(Editor, JASSS)
David Byrne
(Complex Complexity)
Paul Cilliers
(Organizations/Complexity)
John Urry
(Globalization)
Manuel Castells
(Global Network Society)
Barry Wellman
(International Network for
Social Network Analysis)
Duncan Watts
(Small World)
Mark Newman
(Complex Networks)
Albert-László Barabási
(Complex Networks)
Phillip Bonacich
(Mathematical Sociology,
Complex Social Networks)
Johannes van der Zouwen
(theory and method)
Francisco Parra-Luna
(Founder)
Immanuel Wallerstein
(World Systems Theory)
Jürgen Klüver and Christina Stoica
(Mathematical Sociology)
John Mingers
(Managerial Science)
Walter Buckley
(Complex Social
Systems)
Felix Geyer
(Founder)
Kenneth Bailey
(New Systems Theory)
LSC
Sociocybernetics
Computational
Sociology
Data Mining
Dynamical
Systems
Theory
Social
Simulation
Socionics
Complex
Complexity
BBC
Global
Network
Society
CSNA
New
Science
of
Networks

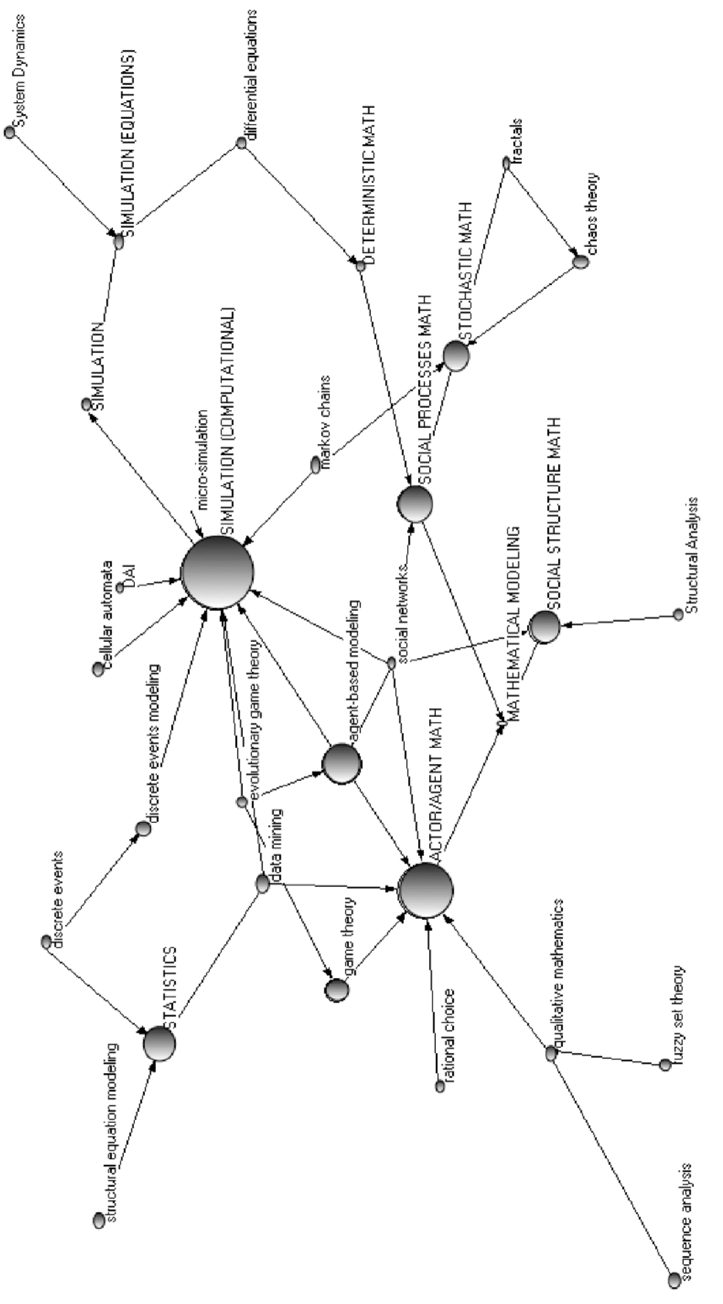
10.10 *Map 5: The Lineage of Computational Sociology*

Map 5 was created in the network software package called Pajek (Nooy, Mrvar and Batagelj 2005). It provides a genealogical tree of the impact the various areas in mathematics have on computational sociology, including statistics, computer simulation (specifically agent-based modeling) and formal mathematical modeling (specifically, discrete mathematics, stochastic processes and dynamical systems theory).

Map 5 was also created to visually demonstrate which areas of modern mathematics have had the biggest influence on computational sociology. The larger the circle (node) is in Map 5; the bigger its impact on the work being done in computational sociology today.

For a detailed review of how we created Map 5, including how we defined "impact," see Chap. 6, Sect. 6.1. *Complexity Science and Sociological Method.*

Map 5: The Lineage of Computational Sociology



10.11 *Map 6: Social Network Model of SACS*

Maps 6 and 7 wer created in the network software package called Pajek (Nooy, Mrvar and Batagelj 2005). Map 6 is a social network model of SACS based on the published links amongst the Top 25 Scholars in SACS. The database for this model came from the Web of Science Citation Index. See Map 6 Notes for details. See also Chap. 7, Sect. 7.1.5 and Sect. 7.1.6.

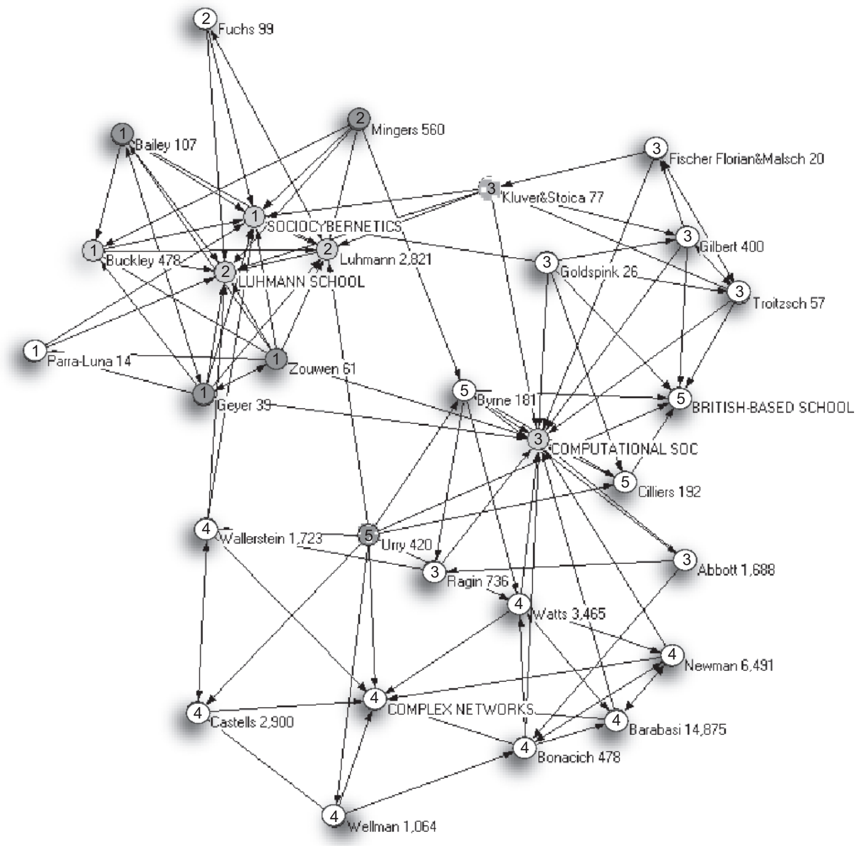
Reading Map 6

In terms of reading Map 6, the numbers in the circles represent the area of research to which the Top 25 Scholars belong. In Pajek, these areas of research are referred to as partitions: 1 = Sociocybernetics; 2 = Luhmann School (short for Luhmann School of Complexity); 3 = Computational Soc (short for computational sociology); 4 = Complex Networks (short for complex social network analysis); and 5 = British-based School (short for the British-based School of Complexity). The five areas of research are in UPPERCASE to distinguish them from the scholar nodes.

The color of the circles refers to the type of powerbroker the node is within the network of Top 25 Scholars: gatekeepers, authorities and hubs. Regular nodes are white; Gatekeepers are checkered; authorities are dark grey and hubs are light grey. Household names (the fourth type of powerbroker) are indicated by the total citations for a Top 25 Scholar—this is the number located next to the name of each Top 25 Scholar. Wallerstein, for example, has been cited 1,723 time; whereas Goldspink has been cited a total of 26 times.

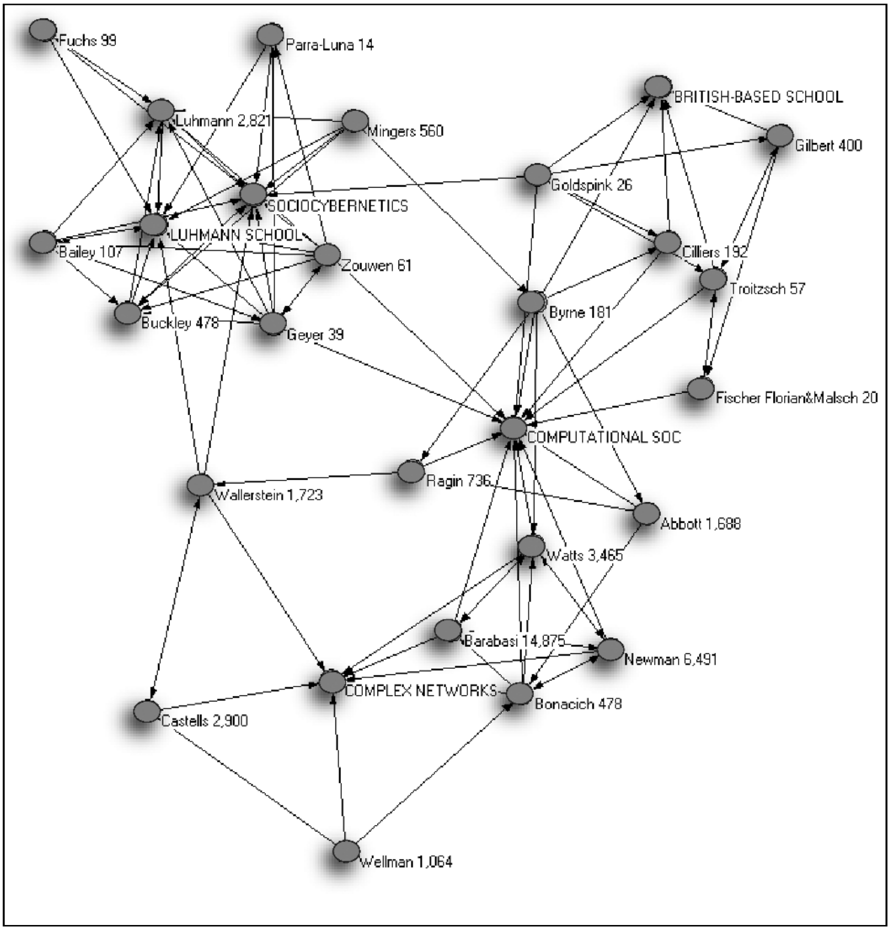
As a final note, the direction of the arrows run from the citing scholar to the scholar being cited. Wellman, for example, cites Bonacich. If the arrow runs both ways, each author cites the other. Newman and Watts, for example, cite each other.

Map 6: Social Network Model of SACS



10.12 *Map 7: Social Network Map of SACS Minus Gatekeepers*

Map 7 is the same model as Map 6 and is read exactly the same way. The only difference is that Map 7 does not highlight the hubs, authorities, household names or gatekeepers in SACS. Instead, it shows what the SACS community looks like if the two gatekeepers amongst its Top 25 Scholars were removed. For more information on Map 7 and the concept of gatekeeper, see Chap. 8, Sect. 8.0.4.3.



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