CHAPTER 1

Thinking About the World We Make

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Despite nearly a hundred years of theorizing, scholars and practitioners alike are constantly surprised by international and global political events. The abrupt end of the much-studied Cold War was widely unanticipated, as were the consequences of the collapse of communism in Europe. The defining characteristics of four decades of international politics were erased in a few short years, but the globalization of economic and social life has continued. The 1997 Asian finance crisis rattled the US and European stock markets, civic strife in Venezuela influences the price of oil, and the needs of AIDS patients in South Africa challenge international agreements on intellectual property. Out of the blue, terrorists attacked within the United States one sunny September morning. A year earlier, in the space of a few months the global economy lurched from rapid expansion to recession and flirted with deflation.

After so much ink has been spilt, we still know so little about international relations and world politics that events continue to surprise us. There is no agreement on the cause of this failure. Some believe that international theorists think too small and fail to synthesize relevant insights from a range of disciplines (Buzan and Little 2001); others criticize the emphasis on positivist methods (Smith, Booth, and Zalewski 1996); and postmodern scholars reject the ahistorical, rationalist foundations of most international theory (Der Derian and Shapiro 1989; George and Campbell 1990). This book takes a different tack. It argues that the reality of world politics is more complex than dreamt of in current theories.

Current theories of world politics assume that the social world is appropriately modeled as a simple system; this book proposes that it should instead be viewed as a complex system. In this book my colleagues and I describe, and demonstrate the benefits of, a paradigm of system emergence from complex

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agent interactions that we call "complexity". The study of complexity in systems is "complexity science" and descriptive, explanatory, or predictive theories—formal statements that generate empirically testable hypotheses—based in complexity ideas and concepts are "complex systems theories."[1]

Like realism, complexity is a thought pattern, set of beliefs, or ideological orientation about the essence of political reality that organizes theorizing about and empirically investigating events in world politics. Realism assumes that essential human characteristics drive political behavior within fixed structures; complexity views politics as emerging from interactions among interdependent but individual agents within evolving institutional formations. So world politics is a more or less self-organizing complex system in which macroproperties emerge from microinteractions. This and the next chapter outline a taxonomy of the central ideas and concepts of a complexity paradigm of world politics from which useful theories or models of complex world politics may be constructed.

This ontological shift from simple to complex systems opens new paths to knowledge and understanding yet incorporates much current knowledge; it validates novel research methods; and theories founded in this approach will generate radically different solutions to policy problems. In the next section, I compare basic concepts of simple and complex systems and thereby frame a complexity paradigm. Following that, I show how complexity concepts can be used in theories of world politics. In the final section of this chapter I outline the rest of the book.

FROM SIMPLE TO COMPLEX

A system is a portion of the universe within a defined boundary, outside of which lies an environment. An atom is a system, as is an animal or a country. Usually, the definition of the boundary is a convenience used to assist human analysis, as when scientists define for study an individual ecosystem. A pond is only arbitrarily separated from its shoreline, the air, and the Sun. Similarly, a definition of "country" may be in terms of its recognized sovereign territory, its terrain and ecosystems, its economy (where the distinction between gross national and gross domestic product is important), or its state or government.

A system is simple if the units and their relations are relatively fixed, permitting reasonable prediction of future system states. An automobile may be complicated, but it is a simple system. Each of the parts has a specific role in the system, and the actions of all the parts are centrally coordinated toward a collective outcome. The existence of workshop manuals further illustrates the simplicity of the system: they identify all potential problems and explain how to

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remedy them. They also illustrate problems and solutions, define the characteristics of each part, and the range of relations between them in exhaustive detail.

As table 1.1 shows, a living system is complex in many ways that an automobile is not. The two primary differences between complex and simple systems are diversity and decentralization. In an automobile there are many diverse parts constructed for very specialized roles, but there is centralized coordination of their operations through mechanical or electronic management systems. In living systems, not only are the units diverse but each has a range of freedom of choice denied to parts in a mechanical system. Because units in a complex system have discretion in their choice of behavior, they are commonly called "agents."

Decentralized decision-making increases complexity. One measure of complexity is the length of the shortest possible message that fully describes the system (Gell-Mann 1994, 30–38). Description of a jaguar in the jungle is longer than of a quark (a unit within an atom). If all the units of a system are identical, system description is shorter; only one unit need be described in detail. Thus, heterogeneity among the units increases description length.[2] But if the units also have behavioral discretion, system description requires description of the units (perhaps by class), of the range of their available choices, and of the rules of behavior that each will follow in making their individual choices.

Centralization of decision-making simplifies complicated systems. Modern automobiles have sophisticated management systems that use miniature

TABLE 1.1. CHARACTERISTICS OF SIMPLE AND COMPLEX SYSTEMS

Simple Systems	Complex Systems
Few agents	Many agents
Few interactions	Many interactions
Centralized decision-making	Decentralized decision-making
Decomposable	Irreducible
Closed system	Open system
Static	Dynamic
Tend to equilibrium	Dissipative
Few feedback loops	Many feedback loops
Predictable outcomes	Surprising outcomes
Examples:	Examples:
Pendulum	Immune systems
Bicycle	Genes
Engine	Molecules in air
Boyle's law	Ecosystems
Gravitational system	Markets

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computers to govern feedback cycles and responses to environmental changes. Although these systems respond almost instantaneously to multiple indicators, there is only a single programmed response to any change in system condition. These centralized management systems prohibit freedom of choice in the units.

In living systems, decision-making is decentralized, and units can choose their actions. Bacteria have fewer choices of behavior than ants, which are, in turn, more regimented and less "free" than animals. Mammal societies are more complex than anthills or bacterial infections. As the "degrees of freedom" of choice for individual members in a system increase, the range of individual behaviors increases, making the system more complex.

The common assumption, usually implicit, that a system is simple rather than complex simplifies analysis. If the system is simple, it can be decomposed into its parts. It is nothing more than its parts and their defined relationships. The automobile can be disassembled and reconstructed and work just as well as it did before. Disassembling a living system, or removing any part of it, can destroy the system or, at least, make it much less than it was previously. Only Victor Frankenstein has yet been able to deconstruct and reconstruct a human and breathe life into it.

The desire to simplify analysis also leads to the common assumption that the system under study is closed to other systems, does not exchange energy with them, and is not affected by them. The desire among social scientists for closed systems reflects their common admiration for the analytical control of the laboratory sciences. The laboratory is designed to close the system under study. Boyle's law that pressure and temperature are inversely related can be demonstrated to be true only within a closed cylinder within a controlled environment. Unfortunately, social systems are always open, and wishing them closed often makes assumption of closure unreasonable.

Simple systems usually are static and tend to equilibrium; complex systems are always dynamic and they are dissipative. This is most clearly illustrated by the "arrow of time" (Prigogine 1997). Without an input of energy, a simple system can remain largely unchanged for long periods. It declines only marginally by interaction with its environment (to that extent, it is an open system). The automobile is a static system that remains in equilibrium if no energy (for example, gasoline and human control) is added to the system. In contrast, a living system perpetually changes. Humans age and die, a dynamic process of constant change in the cells within our bodies and the relationships between them. And we are "dissipative structures" because we have to draw energy from our environment in the form of oxygen, food and water merely to stay alive (Prigogine and Stengers 1984).

Even in simple systems, effects can feedback on their causes. Negative feedback slows down processes, and positive feedback speeds them up. The thermostat is the classic example of a simple system with a negative feedback loop. As

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the air cools below the set-point temperature, an electrical circuit closes to turn on the furnace and blow hot air into the room. When the air is returned to its set point, the circuit opens and the furnace shuts down. The homeostatic behavior of animals reflects feedback from activity (hunger, hunt, satiation, sleep). Environmental selection operates on the individual agent as a form of feedback; behavior can change from punishment/reward contact with the environment.

Complex systems usually have multiple feedback loops. Positive feedback loops strengthen the cause and the subsequent effect in an ever increasing cycle that can lead to nonlinear transitions and system collapse. For example, atmospheric scientists hypothesize that positive feedback loops caused Venus's swirling toxic mists and 900-degree surface temperatures (Schneider 1989). Some scientists fear that climate change on Earth could also progress with a nonlinear shift in the system (Ocean Studies Board et al. 2001).

Complex systems are unpredictable. By its nature, nonlinearity is unpredictable and difficult to represent mathematically, and most complex systems are potentially nonlinear. In complex systems, prediction as a path-dependent extrapolation of historical processes runs the risk of nonlinear change. Beyond the very short term, the range of possible system paths for a complex system widens dramatically. Decentralized decision-making and diversity among agents permits a wide range of agent actions and openness to changes in environmental conditions (the state of another complex system), and the prevalence of positive feedback loops inject further uncertainty into the system under study.

Complex systems may not be predictable, but they may be simulated with interacting rules for agent behavior. These rules may be few and simple, yet the outcome of their interaction can simulate complex systems in which agent behavior appears random and system order seems accidental. For example, the flocking behavior of birds looks random and disorganized but can be modeled with three rules (Waldrop 1992, 241–43). The location of water temples in Bali can be simulated with a few rules of kinship and farming practice (Lansing, Kremer, and Smuts 1998). The collapse of the Anasazi civilization in the American Southwest has been explained by the interaction of social rules and environmental changes (Axtell et al. 2002). In comparison to an automobile, the game of checkers seems uncomplicated. Yet it "provides an almost inexhaustible variety of settings (board configurations)" (Holland 1998, 76). Because complexity emerges from the simple rules of checkers, we should expect that "complexity will be pervasive in the world around us" (76) both natural and social. But it also "gives hope that we can find simple rule-governed models of that complexity." That hope is partially fulfilled by simulations of social systems with agent-based models in which systems are modeled from the interactive behavior of essential agents, as described throughout this book.

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The characteristics summarized in table 1.1 and described in this section are most commonly associated with each genus of system, simple or complex. No single descriptor defines either simple or complex systems. For example, simple systems may have many and diverse parts and complex systems (e.g., of bacteria) may have homogeneous units; and complex systems can be, at least temporarily, in equilibrium, while some simple systems appear dynamic. However, the more descriptors of one system genus that can be attributed to a specific system, the greater is the probability that that system is of that genus. Thus, complexity is an accumulation of the characteristics of complex systems.

The next section shows how complexity concepts can be used to construct a complex systems taxonomy of world politics (that is further elaborated in chapter 2).

COMPLEX SYSTEMS IN WORLD POLITICS

Intuitively, the social world seems complex in the sense described here, but current theories of world politics model it as a simple system. As Ruggie (1993) comments, world politics theories are "reposed in deep Newtonian slumber."

Newton described a universe formed out of particles that were all made from the same material and whose movements in absolute space and time were governed by forces that followed unchanging and universal laws. These laws could be expressed exactly through mathematics (Capra 1982, 65–67; Ruggie 1993). For example, the properties of gases can be reduced to the mathematically describable motion of their atoms or molecules. Thus, the image is of a universe constructed like a perfect mechanical watch. Science, aided by mathematics, was the method for prizing open the watch case to see the workings inside (Hollis and Smith 1990, 47).

Locke and other early political and social theorists enthusiastically emulated Newton and attempted "to reduce the patterns observed in society to the behavior of its individuals" (Capra 1982, 69). A fixed human nature was presumed to determine human behavior, and "natural laws" governed spontaneous human society: "As the atoms in a gas would establish a balanced state, so human individuals would settle down in a society in a 'state of nature.'" Natural laws included freedom, equality, and property rights (Locke 1980, 123–27; Kymlicka 1990, 95–159).

The shadow of Newton's universe continues to obfuscate knowledge in the social sciences. For example, while neoclassical economics remains the dominant explanation of economic phenomena, it is "an economic science after the model

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of mechanics—in the words of W. Stanley Jevons—as '*the mechanics of utility and self-interest*'" (Georgescu-Roegen 1975, emphasis in the original). Economic actors are assumed to be rational in their pursuit of undefined, subjective self-interest. Their behavior is assumed to be an objectively rational response to external forces such as the level of supply and demand of goods and services. If supply exceeds demand and prices fall, economic actors will increase their purchases. In such a model, agency is limited to only economic interests and programmed responses to external stimuli.

Recent debates about agency and structure do not hide the similarly mechanistic paradigm that still drives orthodox theories of world politics. Essentially identical units—interests and identities are assumed to be exogenously formed—are driven by "natural laws" to behave predictably in response to exogenously determined conditions. A rational-choice approach, borrowed from neoclassical economics, is used in an attempt to generate ahistorical, universal explanations of relations between states. The result is several significant simplifications of reality. For example, concentrating on the state as the unit of analysis causes an analytically convenient but arbitrary separation of international and domestic politics, and the theoretical focus on "explaining constancies, not change" privileges structure over agency (Smith 2004).

Constructivist theories—the most recent incarnation of liberalism—posit that state interests and identities are intersubjectively malleable at the margin through interaction with other states. While it is now historically located within international society, as in rational-choice theories, the state remains the unit of analysis. Thus, I start with the state to better illustrate the primary concepts of a complexity taxonomy of world politics.

Emergence

A complex system is commonly described as more than the sum of its parts. That is, properties of the system are emergent, created by the interaction of the units. The basic unit of any social group is the individual. In biological terms, the human body is a system; socially, each human is an essential unit within several systems, and any social group, including the state, is an emergent system. Social and political institutions emerge from the interaction of individual humans and human groups. Groups may be local or national; they may be loose-knit coalitions or adhesive groups of fervent followers, and may be more or less centrally organized. Out of the interactions among this mélange of groups and individuals emerges the set of institutions, people, and practices that scholars call the "state."

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Open Systems

The state is not a closed system: it is open to other natural and social systems. For example, defined as a political system, it is open to technological, cultural, and economic systems that influence political choices and processes (Skolnikoff 1993; on political economy, Gilpin 1996 and Strange 1994, 1996 among many others).[3] The state also is open to other states and, as constructivism argues, is influenced by interactions with them.

Some social systems are both within and outside the state. For example, unions, major corporations, and nongovernmental organizations (NGOs) cross boundaries and operate in several jurisdictions simultaneously (Goddard, Passé-Smith, and Conklin 1996; Korten 1995; Keohane and Nye 1971).

Although the state is evidently an open system, theories of world politics conventionally assume that all systems are closed to their environment much as optimal natural science experiments are controlled and isolated from unwanted external influences. Despite occasional attempts to bring in domestic politics (Evans, Jacobson, and Putnam 1993; Putnam 1988), the state is usually modeled as a unit with exogenous identity and objective interests. This greatly reduces the range of possible causal explanations for any perceived social event, simplifying causal analysis and hypothesis generation and testing.

The assumption of closure thereby permits historical theorizing and supports the widespread belief among scholars that general laws can be found. This would be impossible if social systems were modeled as open, because "constant conjunctions (empirical regularities) in general only obtain under experimentally controlled conditions"—that is, under closure (Patomäki and Wight 2000). Open systems are "susceptible to external influences and internal, qualitative change and emergence" (232) and "outcomes might be the result of many different causes and the same cause might lead to different outcomes" (229). Small changes that can initiate a radical system shift may come from a change in environmental conditions, or from inside, from interactions among its constituent agents. The nonlinearity of open systems prevents the theorist from mapping specific causes to observed effects. Thus, open dynamic systems are inherently unpredictable (Doran 1999). But that is no reason to model them as closed systems.

Meta-agents

The state is both an emergent system and a unit within the international system of states. In Holland's (1995) terminology, they are "meta-agents" whose "internal models" (discussed below) emerge from the interaction of domestic agents. State behavior then results from the interaction of internal model and external

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reality, and feedback is available on whether internal system processes and state behavior "fit" within the environment, not unlike the concepts elaborated in Putnam's (1988) two-level game, though in a more fluid and dynamic relationship. The concept of meta-agents can be used in any issue area in which agents and actions at more than one level of aggregation are involved.

In contrast, orthodox international relations (IR) theory usually takes the state as the primary unit of interest, while recognizing in passing the potential influence of substate and nonstate actors. Constructivism and other cognitive theories treat states as subjects, but the state still is assumed to be a unitary actor whose identity and interests change primarily as a result of interaction with other states (Wendt 1994). The extent to which states also may self-consciously change their interests and identity is debated, but the potential for change as a result of domestic political discourse is usually disregarded (Hasenclever, Mayer, and Rittberger 1997, 186–92).

Internal Models

Each human agent, the essential unit of any social system, has an internal model of his or her desires and beliefs about how to achieve those desires in the world.[4] If their beliefs are out of synch with reality, they will act inappropriately, fail to achieve their goals, and may be punished. Agents who learn from such an experience, change their internal models and, thus, their behavior.

Individual agents' behaviors are responsive and purposeful but not objectively rational. According to Elster (1986, 16), an action is rational if it is the best way for an actor to satisfy his or her desire based on beliefs that are optimal given the available evidence and as much information as possible, given the desire. Beliefs and desires must be free of internal contradictions. Finally, actions must be the intended result of beliefs and desires. This is substantially the same description of rationality used by Green and Shapiro (1994, 6) to explain the foundations of rational-choice theory. However, by assuming diversity among agents, complexity does not make the simplifying jump to an assumption of objective rationality. Each agent can have unique desires and unique beliefs about how to achieve them. The alignment of behavior with desires and beliefs indicates agent rationality, but there is no assumption that the outcomes of an agent's choices will be individually or collectively rational or will match agent intent. This is not Simon's "substantive conception of rationality" quoted and approved by Keohane (1988): "'behavior that can be adjudged objectively to be optimally adapted to the situation." Because agents cannot predict the effects of their actions in complex systems, behaviors of individual agents are "optimally adapted" to their situation only accidentally. Rationality is subjective—within the agent—rather than objective.

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Constructivism broadens "the array of ideational factors that affect international outcomes" and introduces "logically prior constitutive rules alongside regulative rules" (Ruggie 1998). The concept of internal models potentially extends the ideational content of world politics theories, while at the same time making analysis of agent motives more difficult. However, simulation of agent behavior now is possible.

Internal models drive agent behavior, but those models may change when tested in a selective environment. Agents that consistently act in ways that are selected by their social environment as suboptimal face eradication. Because states are themselves systems, the process of matching internal model to external reality is one of trial and error. As Putnam (1988) has suggested, the state may be not be able to move its internal model—particularly in terms of its (causal) beliefs about what is possible—to accord with the reality of the international system. If all states are adaptive complex systems, then the international system emerges from coevolution. International norms influence behavior through the internal process of internal model formation, one component of which is the desire to participate in a society of nation-states. In chapter 5, Hoffmann investigates how states changed their beliefs during negotiations over regulation of ozone depleting substances and how the internal model of the United States adapted to these changes.

Dynamic Systems

Superficially, complexity appears to have some affinity with other world politics systems theories, like neorealism and world systems. As Waltz (1979, 91) describes the international system, it is "formed by the coaction of self-regarding units," and its structure is "formed by the coaction of their units" and "emerge[s] from the coexistence of states. . . . International-political systems, like economic markets, are individualist in origin, spontaneously generated, and unintended." However, the similarity is more perceived that real, as shown in more detail in chapter 2.

The distinction is in the details: in conventional systems theories, structure is a fixed or only slowly changing determinant of agent behavior. In complex systems, structure is dynamic but "organization" is fixed. The "organization of a living system is the set of relations among its components that characterize the system as belonging to a particular class (such as bacterium, a sunflower, a cat, or a human brain)" (Maturana and Varela 1980, 18). To describe the organization, it is only necessary to describe the relationships and not the components. For example, self-organization is "a general pattern of organization, common to all living systems, whichever the nature of their components." The *structure* of a complex system is the actual relations among actual physical components: "[I]n

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other words, the system's structure is the physical embodiments of its organization." While organization is static—a cat cannot become a dog—structure is dynamic. Thus, structure is not fixed but a fleeting embodiment—in social systems manifested by institutions—of the deep organization within apparent chaos. As the momentary embodiment of prior agent interactions, complex system structure changes dynamically.

In complex systems, structure has a social role but no purpose. In functional social theories like constructivism and neoliberalism, "history is path-dependent in the sense that the character of current institutions depends not only on current conditions but also on the historical path of institutional development" (March and Olsen 1998, 959). Because "rules, norms, identities, organizational forms, and institutions that exist are the inexorable products of an efficient history . . . surviving institutions are seen as uniquely fit to the environment, thus, predictable from that environment" (958). Complexity science makes no such assertions: it does not assume or judge the fitness or efficiency of emergent institutional arrangements. Institutions and rules are the consequence of history but may not fit agents' purposes.

The common (usually implicit) assumption that the international system is homeostatic is a stronger version of the orthodox presumption that events in different spatiotemporal locations may be compared. It is equally untenable. Simple dynamic systems find a point of equilibrium that is "sustained by micro-mechanisms operating in finely attuned and compensating ways" (Elster 1983, 31–32). Despite its "balance of power" bromide, classical realism is really about the processes of systemic change from dynamic forces. Realism presumes that just as the neoclassical market continually returns to an equilibrium between demand and supply, the international system returns to a balance between many forces.

Complex social systems are never homeostatic: in both markets and world politics the frequent and temporary equilibrium points are always distinct phenomena. Each state of balance, like a human standing still through tensions between opposing muscles, is a fleeting event within a specific set of conditions, a point on a path of change. The dynamic European system has found several momentary points of balance between myriad forces. Tudor England understood the need to change alliances to continually balance power in Europe. Though power was balanced in Europe before World War I and in the Cold War, the conditions were unique to each period.

Causation

The uncertainty of complex social systems calls into question conventional world politics assumptions about causation. Conventional world politics

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theories presume that causation is proximate and proportionate. Like most of social science, they have adopted Hume's rules for causal explanations (Hume 1975).[5] These rules require that the cause can be shown to precede the effect, that cause and effect are contiguous (there was no intermediate event), and that there is a "necessary connection" between events such that this cause can be shown to always precede this effect under consistent conditions. For at least four reasons, these rules are not appropriate causal explanations in complex social systems. First, they only apply in closed systems in which conditions can be controlled. But if social systems are open, it is unlikely that conditions will remain constant or be comparable between different states of affairs. In an open system, a cause may have different effects at different times due to changed conditions. Therefore, it is not surprising that no general laws of world politics have been found. Second, social systems are so complex that parsimonious theories that attempt to isolate single (or few) causes for observed effects may dangerously oversimplify models. In complex social systems, the events noted at the start of this chapter (among others) are surprising only when we expect to find a singular cause. Understood as the emergent consequence of multiple interacting prior events, such events are less astounding. The events of September 11, 2001, may be the result of *all* of the explanations commonly offered: failures of collection, coordination, and distribution of intelligence; a clash of cultures; hatred by fanatics; and so on. But each of these "causes" were themselves caused by multiple prior events. Osama Bin Laden is the product of his family, Islam, the Saudi culture, and personal experience defending Afghanistan against the Soviets. The clash of cultures (or civilizations: Huntington 1993) is as much a consequence of U.S. actions as of Muslim choices. Intelligence failures resulted, in part, from decisions that restricted human intelligence gathering, decisions made by successive US governments after several high-profile misadventures in the 1970s. Thus, September 11 could have emerged from a plethora of choices and events across the globe over decades, not as an inevitable consequence of any of them but as a path-dependent phenomenon. And if it was not path dependent, it was a symptom of a nonlinear system shift that cannot be predicted or explained. In neither case is conventional thinking about causation useful. Third, the immediate cause of an effect may, as part of a higher-order Markov chain, itself be the effect of an earlier, and possibly more important, cause. If an earlier cause is more important than later ones in the chain, this implies action at a distance in space/time that both Newton and Hume reject (Elster 1983, 26–30). Fourth, causation may be simultaneous as in open, emergent systems where the interaction of parts of the system constitute the system.

In addition to these limits to the normal rules of causal explanation, assumptions of the proportionality of cause and effect are often erroneous. As dis-

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cussed above, in open, emergent systems, small perturbations in the system may have very large effects, making identification of the connection between cause and effect nearly impossible and explanation problematic. Was the fact of Kaiser Wilhelm's withered arm or his relationship with his English nanny a sufficient cause of World War I (Röhl 1998)?

In a complex system, many factors symbiotically cause an effect. Theorists should look to the evolution of the system, not to individual events, for causes of observed effects. Patomäki and Wight (2000, 230) argue that "ontologically, the social world can only be understood as a processual flow that is intrinsically open and subject to multiple and at times contradictory causal processes." Unintentionally, this is a fair exposition of complex systems. Social phenomena only occur because agents act within an existing and real context that is "not reducible to the discourses and/or experiences of the agents," as constructivists argue. As Maturana and Varela (1980, 98) wrote: "[O]ur problem is the living organism and therefore our interest will not be in properties of components, but in processes and relations between processes realized through components." In social systems, processes are not as automatic as they are in insects and bacteria. Humans and social groups are conscious and self-aware entities (that is, their internal models are more elaborate and complex) who, therefore, may act strategically toward some goal within their perception of their environment.

PLAN OF THE BOOK

Most social sciences have begun to embrace complex systems concepts. Ideas from thermodynamics coupled with a concern for economic systems' environmental effects (Georgescu-Roegen 1975, 1971) led to the development of ecological economics that specifically models the economy as an open system (Barbier, Burgess, and Folke, 1994; Krishnan, Harris, and Goodwin 1995; Costanza 1991; Daly 1991). Brian Arthur and others have identified the presence and effect of feedback loops in economic systems (van Staveren, 1999; Arthur, Durlauf, and Lane 1997; Arthur 1990; Arthur 1989; Anderson, Arrow, and Pines 1988; Romer 1986). Complex systems approaches have attracted sociological interest (Luhmann 1998, 1990; Eve, Horsfall, and Lee 1997; Knapp 1999; Hanneman 1988; Collins, Hanneman and Mordt 1995) and touched public administration and organization studies (Griffin 2002; Stacey 2001; Marion 1999; Elliott and Kiel 1999). Even political science is not immune (Richards 2000; Axelrod 1997; Jervis 1997; Cilliers 1998; Cederman 1997; Cederman and Gleditsch 2004), though efforts are disparate and inchoate. This book is designed to drive forward the complexity research agenda as a viable alternative to orthodox theories of world politics by establishing the central concepts and ideas

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needed for the development and empirical assessment of complex systems theories of issue-areas in world politics.

The next nine chapters further develop the concepts outlined in this chapter and illustrate their application to several world politics issue areas. Chapter 2 begins to sketch out a taxonomy of complexity by comparing complex systems concepts to those developed more than three decades ago for a general systems taxonomy. Systems theories that were relatively popular in the early days of the Cold War have, in recent years, have fallen into disrepute as overly "grand" in purpose. Harrison, with Singer's aid, compares and contrasts conceptual descriptions between general systems and complex systems taxonomies. Several concepts are common to the two approaches, but this chapter also identifies the important differences between the two taxonomies. Complexity is not a warmed-over version of general systems theory but builds on its ideas to generate theories that better explain issue-areas in world politics.

As this is a new approach to understanding world politics/IR, this book does not attempt to illustrate its application to the whole range of possible issues. The next four chapters show how complexity can generate new insights and hypotheses when applied to selected issue areas. They are arranged from the least to most technical in their use and application of complexity concepts. Because this book is an introduction to complexity in IR that is intended to initiate research rather than to develop applications adapted to all issue-areas of international relations, these chapters are only exemplars of the application of the complexity paradigm. None formally models their case but they all describe how their hypotheses might be further elaborated or empirically tested.

In chapter 3, Dennis Sandole argues that complexity creates opportunities to integrate and synthesize apparently opposing worldviews. He reconsiders theories of identity-based conflict in the post-9/11 world and proposes a theoretical framework to demonstrate that traditionally competing *Realpolitik* and *Idealpolitik* (conflict resolution) approaches can coexist. Not only can they co exist, but more robust guides to identify conflict and formulate policy responses can be constructed by integrating both approaches into a single framework.

In chapter 4, Walt Clemens attacks a knotty puzzle that has emerged from the collapse of the Soviet empire: why have some ex-Soviet states fared far better than others? Natural resources, education, and ethnic homogeneity do not explain why the Baltic states and Slovenia are joining the European Union, while oil-rich and more-homogeneous states are embroiled in factional fighting or war, or have stagnated in neo-Stalinism. Using complexity concepts, Clemens proposes an innovative explanation of why some newly freed states appear to have failed while others are joining the EU.

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Drawing on complex adaptive systems theories (a version of complexity that uses more life science concepts), Clemens notes that some states were "fitter" than others and so better able to exploit opportunities that opened for them after the collapse of the Soviet empire. Seeking the sources of that fitness, he finds that long-standing, religiously inspired institutions in the Protestant countries developed internal models in the population that reduced ethnic tensions and increased acceptance of democratic virtues. He also shows that his marker for fitness correlates with measures of development and describes how to empirically test his hypothesis.

Matt Hoffmann looks at the coevolution of states' internal models in chapter 5. He considers two puzzles in the formation of the international regime designed to protect the stratospheric ozone layer: why did the norm governing participation change and why did the United States accept this new norm?

Hoffmann shows that rational explanations are deficient and that complex systems concepts can help us to unravel both puzzles. From a complexity perspective, evolution of the universality norm is a simple story of complex adaptation. As some Southern Hemisphere states' internal models changed to universal participation, the flux in the system eventually led other states to adapt to the new international norm. Hoffmann shows that when the United States reconsidered its internal model (with some pressure from domestic groups), it recognized it would have to accept the universality norm and negotiate in good faith with the South to achieve its goal of an effective treaty. He concludes with suggestions for theoretical, empirical, and methodological development of these ideas.

In recent years, genocide within a country has become an international issue. The stimulus to this international interest in domestic interracial relations was the terrifying genocidal violence in Rwanda in 1994 that killed possibly as many as eight hundred thousand people. In addition to the moral implications, since Rwanda it is now clear that genocide in one country has serious consequences for its neighbors, making it a legitimate concern for the international community ("The Road Out of Hell," *Economist*, March 27, 2004, 25–27). In chapter 6, Ravi Bhavnani shows how complexity concepts can help us to understand why the speed and magnitude of the killing was so much greater than in all previous ethnic attacks in that country.

Conventional explanations of the scale of the Rwandan violence are inadequate. Bhavnani shows how bottom-up simulations can generate new hypotheses about the spread of ethnic violence. Building on evidence from the field and reasonable assumptions about relationships between extreme and moderate Hutus, he describes a simulation of how the killing rampage took hold so quickly and led to murder even within families.

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The next three chapters explain the empirical validity of simulations, discuss potential problems with constructing complex systems theory, and show how multiple ABMs may be used to improve forecasting and decision-making. Chapter 7 is a reprint—used with permission—of part of Robert Axelrod's chapter entitled "Advancing the Art of Simulation in the Social Sciences," in *Simulating Social Phenomena*, edited by Rosario Conte, Rainer Hegselmann, and Pietro Terna (Berlin: Springer-Verlag, 1997), 21–40. Axelrod argues that simulation is best thought of as a new way of doing social science. Inductive methods are needed to find patterns in, for example, opinion surveys and macroeconomic data, and sometimes in international interactions. If social agents are assumed, as in conventional theories, to be objectively rational actors, deductive methodology suffices. Simulation is the third way—the only way, if agents are assumed to be adaptive. In the social sciences, the most common form of simulation is agent-based modeling (ABM), which builds systems from the bottom up rather than, as with deductive methods, from the top down. Like deduction, simulation starts with explicit assumptions, but it cannot prove theorems. Like induction, it looks for patterns, but it uses data generated from defined rules rather than the real world. Axelrod argues that, in social science simulations, simple is better: like thought experiments simulations can deepen understanding of fundamental processes.

David Earnest and Jim Rosenau in chapter 8 question whether political systems are complex systems, as commonly understood, and argue that simulation of political systems begs the questions it attempts to answer: who are the actors and who has authority? They reject complexity as a theory, because it fails the standard of theory in positivist epistemology and offers no alternate epistemology; and implicitly they reject more limited applications of complex systems theory. While Axelrod describes simulation as a third way, Earnest and Rosenau argue that it is no way: it lacks both the empirical appeal of induction and the disconfirmative value of deduction. For them, thought experiments are "much ado about nothing." They acknowledge that complexity is an attractive paradigm but argue that more development is required before it may generate viable theories of world politics.

Chapter 9 is an indirect response to Earnest and Rosenau's critiques. In Desmond Saunders-Newton's opinion, while there are epistemological problems with ABMs, these are neither insurmountable nor critical problems. As scholars debate the fine points of ontology and epistemology, complex systems thinking and ABMs already are being put to use in the service of policymakers to generate and assess multiple policy options.

Saunders-Newton argues that complex systems thinking and computational methods that emphasize agent-level phenomena are part of a new transdiscipline that allows analysts to rigorously consider increasingly complex

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phenomena in an interdisciplinary way. In addressing the epistemological issues surrounding computational methodologies, he argues that efficacy or usefulness is more important than the quality of model isomorphism and method. He then describes how several computational social science models (including ABMs), integrated with computer-assisted reasoning methods, are being used in the Pre-Conflict Management Tools Program being tested at the National Defense University for its ability to assess social vulnerability.

The concluding chapter draws some general lessons from the four cases and shows how they illustrate important complexity concepts. It then assesses the validity of simulations and computational models and the epistemological questions they raise. It also shows that, from complexity concepts and ideas, complex systems theories for issue-areas can be specified and models for specific problems generated. Yet, because political systems are complex—and becoming more complex—a new epistemology and new methods are needed to understand them. Finally, it shows that recognition of complexity in politics suggests radically new policies for addressing international problems and pursuing national interests.

NOTES

1. The terms "world politics" and "international relations" are used interchangeably throughout this book. I use "world politics" to better reflect the multilevel structure of the political world to which complex systems thinking is so well adapted. Patomäki and Wight (2000, 232–33) opine that the "key error" of much international theorizing is "to treat levels of the state and the international system as related as agents to structures" instead of as "layers" within world politics. The terms "complex system" and "complex adaptive system" are often used interchangeably; the concepts described here principally derive from the latter. I use the term "paradigm" in the sense of a set of assumptions, concepts, values, and practices that comprise a view of reality, and in that sense it is quite comparable to "worldview" (Hughes 2000).

2. Common knowledge also shortens description. "Bicycle" conveys to most people a clear image of the system. Imagine how much more complex would be a description to a Martian who is completely unfamiliar with a bicycle or any of the common parts used in its assembly.

3. Smith (2004) comments that world politics/IR theorists err in thinking of the state as solely political. Whether the state is modeled as political interacting with other subsystems of society or as a political unit of a social system among economic and cultural agents depends on the question being addressed.

4. In this book, the terms "internal model," "mental model," and "schema" are used interchangeably.

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5. As a skeptic, Hume also argued that causation is a human construct. All we ever see is the conjunction of events, and we impute a causal relationship. But without an explanatory force linking cause and effect, causation cannot be "real" (Patomäki and Wight 2000).

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