ONE

THE GYRE

Rethinking Systems in World Politics

The North Pacific Gyre offers an odd yet important lesson for scholars of world politics. Consisting of four ocean currents, the gyre swirls clockwise in the North Pacific Ocean, touching the United States in the east, Japan in the west, the equator to the south, and the Aleutian Islands of Alaska to the north, while sheltering Hawaii in its central "convergence zone." While much of the gyre's approximately twenty million square kilometers are geographically remote from humans, it nevertheless harbors one of humanity's largest unintended creations: the Great Pacific Garbage Patch, "an area of widely dispersed trash that doubles in size every decade that is now believed to be roughly twice the size of Texas."[1] Others estimate the size of the patch as one-and-one-half times the size of the United States, extending to a depth of one hundred feet below the surface of the Pacific.[2] A "plastic soup" that includes degraded small particles of waste plastics, massive driftnets, and other refuse, the patch includes enough plastic to outweigh the zooplankton in the gyre by a factor of six to one, according to some estimates.[3] Because marine wildlife mistakes fine plastic particles for food, researchers have found increasing amounts of toxic chemicals in birds and fish. One concern is that these toxins will travel up the food chain with possible health consequences for the 20 percent of humanity that relies on fish for protein. This ecological nightmare arguably is a product of the global organization of production and consumption:

> [T]oday plastics have invaded the most distant places, from the Bering Sea to the South Pole. Indeed, when I was exploring a remote beach past the South Point of Hawaii, I found pill bottles from India and mashed pieces of various products—oil containers, detergent jugs, plastic cups—with Russian, Korean, and Chinese writing on them. It's hard to get your brain around these connections.[4]

The Great Pacific Garbage Patch clearly fits Hardin's definition of a tragedy of the commons.[5] The world's oceans are common property, untouched by state regulation and subject to overuse by self-interested actors who spread the costs of their overconsumption across vast distances. Yet the patch also is a *system* that exhibits coherence but is not static: It grows and evolves with the currents and winds. It is, furthermore, a "system of systems," a product of the interaction of social systems with a biophysical system. The interdependent, uncoordinated decisions of billions of human beings produce unintended consequences and create positive feedbacks that make state-based regulation increasingly difficult. The patch, in other words, is self-organizing. Governments did not create it, consumers did not intend it, yet consumption choices interact with wind, water, and rain to produce a thick plastic soup covering one-quarter of the Pacific Ocean.

This book is about such self-organized systems in global politics. It examines how individuals, civil society groups, firms, nation-states, and others organize to solve—or equally importantly, fail to solve—collective action problems characterized by "complexity." Although researchers have yet to agree on a definition of complexity,[6] they appear to share a sense that complexity suggests nonlinear and/or recursive relationships between causes and effects, and consequently "limits [to] the ability of individuals to identify the full set of possible outcomes or assign probabilities to particular outcomes of specific actions."[7] How do individuals, groups, and governments make decisions when faced with an inability to assess the likelihood of the outcomes of their actions? Answers to this question may shed light on some of the most vexing problems of world politics, in which the patterns of interactions among actors are as important to solutions as are the nature of the problems themselves. Such interactions characterize the simplest of social choice problems—how do groups make decisions when choosing among three or more options?—to the far-reaching global systems that touch everyone on the planet: the climate, finance, and public health, among others.

Complexity and self-organization are defining features of world politics today. This book makes three claims of interest to observers of world politics. First, self-organization is an important but nevertheless largely ignored reality of world politics. Although several scholars in the 1990s suggested complexity theory promised to make contributions to the study of world politics, the recent scholarship has failed to build on the foundation of these works.[8] Second, the interactions that create complexity and self-organization are not random. Rather, the networked structure of interactions crucially shapes the success or failure of collective action. To illustrate the ubiquity of these networks of interaction, the book explores broadly similar patterns and dynamics across economic, ecological, and political domains of world affairs. Finally, the book illustrates that computational methods—specifically the synthesis of agent-based models, social network analysis, and genetic algorithms—are invaluable tools for studying self-organization and complexity in world politics. The emerging field of computational social science seeks to investigate complex social phenomena. By definition, complex systems have a high degree of interaction effects; instability in cause-effect relationships over time and across scales, particularly due to feedback effects; and infrequent but sudden and theoretically and politically important changes. All of these attributes make it difficult for researchers to study complexity with empirical and statistical methods. For many important events, from state failure and secession to ecological catastrophes, researchers face additional difficulties gathering relevant data.[9] Computational methods have matured rapidly in the last decade, providing most researchers with an accessible if underutilized tool for understanding self-organization and complexity in world affairs.

The imagery of world politics as a complex gyre is not new. "Things fall apart; the centre cannot hold," William Butler Yeats wrote in his famous 1920 poem *The Second Coming*. The "widening gyre" that concerned him was the apocalypse, a metaphor for the destruction and political conflict Europe suffered during and immediately after World War I.[10] Yeats wrote about an event that has profoundly influenced theories of international conflict. Scholars argue that World War I occurred because of statesmen who possessed a cult-like faith in the superiority of offensive military doctrines;[11] inflexible bureaucratic routines that spread the conflict from the Balkans to the rest of Europe;[12] and the mismanagement by statesmen of the July crisis.[13] The war was inadvertent as events in obscure places and seemingly innocuous decisions contributed to a spiral of events over which statesmen quickly lost control. In this respect, the spiral theory of inadvertent war provides one of the most compelling arguments about emergent phenomena in world politics: microdecisions produced macrobehaviors that none of the political actors desired. One cannot simply reduce the war to the preferences of the tsar, kaiser, emperor, or king. Thirty-seven million people died.

The gyre also offers a useful metaphor for the seemingly uncontrollable and unpredictable nature of world politics today. Whether it is the sudden crisis in global finance capitalism, the civil conflict in Ukraine, or climate change, like Yeats's gyre global politics seem structured and coherent and yet, in the details, are unpredictable. Rosenau has characterized contemporary world politics as "the turbulence puzzle": "It consists of complex pieces that do not fit readily together and thus serves as an endless provocation to the intellect, to our capacity to grasp those individual, organizational, and international dynamics in which actions are negations of values and outcomes are discrepant from intentions."[14] Whichever metaphor one prefers—turbulence, spirals, or the gyre—together they suggest a conceptual focus on dynamics in world politics, and on the divergence between actors, preferences, and interests at one level and structures and outcomes at another.

World politics today feature many self-organized actors that one might characterize as "complex global social systems." One may generally define a complex global social system as a massively parallel organization of social actors who transcend the constraints imposed by sovereign boundaries and physical geography. Some of these systems help nation-states and others may oppose governments. Like the Occupy Movement, skilled individuals everywhere organize themselves into coordinated groups that produce collective goods on a local, transnational, and global scale. They do so often without the direction or involvement of governments, yet these social systems have profound consequences for what might be called traditional international politics, that is, among sovereign nation-states. These systems share some common features. Social actors organize themselves. They use information technology to coordinate their efforts. By using a massively parallel architecture, they not only multiply their scarce resources but also incentivize others to join the system. These complex global social systems may reflect national allegiances, as in the case of so-called patriotic hackers, but in all cases their efforts transcend territorial constraints and national borders. Their efforts have profound consequences for states, in some cases empowering them to improve social services while in others undermining their security and legitimacy.

The study of world politics is poorly equipped to conceptualize and theorize about such complex social systems. One example is "e-medicine." In South Africa, Project Masiluleke uses text messaging to direct people to HIV clinics outside their immediate communities, helping them avoid the stigma of the disease. A similar program in Uganda has helped authorities increase testing for the disease by about 40 percent. These efforts all take advantage of the power of networks to multiply modest efforts of individuals. The two-way communication of text messaging "forces you to take a moment to think and maybe act" in a way that passive media such as newsprint, leaflets, or billboards do not.[15] Even small efforts—such as providing people a map to the nearest clinic—can quickly mobilize large numbers.[16] Text messaging reminds tuberculosis patients in Thailand to take their medicines, improving their compliance with doctor-ordered care. Similar use of cell phones allows public health officials to provide basic care to remote villages in Mexico. The use of cell phones thus allows public health authorities to partner with private providers and extend scarce resources in places lacking adequate public health infrastructure.[17]

"Rumor registries" and crisis maps are other forms of self-organized social action. The Ushaihidi project empowered Kenyans to use cell phones to report postelection violence in 2007 and plotted these reports on an online map for others to read and to which to contribute new reports. Similar self-organized maps allowed humanitarian organizations to prioritize their efforts after the Haitian (2010) and Japanese earthquakes (2011) and the Pakistani floods of 2010. Such tools are not merely for societies lacking resources and infrastructure. The *Washington Post* used an online user-generated crisis map to monitor snow removal efforts during the "snowpocalypse" storm of February 2010 that dumped twenty inches on Washington.[18] Remarkably, these efforts become more valuable and effective as more individuals participate—a self-organizing virtuous circle of positive feedback—all without centralized direction or a hierarchy of authority. The *New York Times*, for one, suggests this may be the future of humanitarian relief: "The new paradigm is many-to-many-to-many: victims supply on-the-ground data; a self-organized mob of global volunteers translates text messages and helps to orchestrate relief; journalists and aid workers use the data to target the response."[19]

Complex global social systems may produce social ills as well as social benefits. The global interrelationship among banks holding credit default swaps helps explain how the failure of a relatively small portion of the American financial services industry reverberated in credit markets around the world: "What happens deep inside one national financial system can wreck another halfway around the world."[20] While presumably banks did not intend to cause harm, other social systems may have explicitly political agendas that seek to affect others adversely. Consider the phenomenon of patriotic hackers, or self-organized communities of like-minded individuals with computer skills. Russian nationalists staged a distributed denial-of-service attack on Georgian government agency Web sites during the August 2008 Russian-Georgian war. A similar cyberattack occurred on Estonian government information systems in 2007.[21] Other patriotic hackers seek to spy rather than disrupt. Chinese hackers have infiltrated the Pentagon, White House, and even the 2008 presidential campaigns of Barack Obama and John McCain.[22] During the protests following the contested 2009 election in Iran, an Iranian group of patriotic hackers attacked Twitter. Democracy advocates following the protests—indeed, any Twitter user—found their feeds redirected to an English-language page stating "This page has been hacked by the Iranian cyberarmy."[23] Responding to a request from the Dalai Lama to check his offices' information systems for malware, a team at the University of Toronto uncovered a vast cyberspy network they labeled "GhostNet." The researchers identified more than 1,200 computers in 103 countries that GhostNet had infiltrated, including computers at the Indian Embassy in Washington and at a NATO facility.[24] One advantage of patriotic hacking is that it blurs the relationship between governments and the hackers themselves; in none of the above cases could investigators prove conclusively that governments supported the patriotic hackers. This "attribution problem" protects hackers and governments alike from retribution; in general, anonymity may afford actors opportunities to pursue their interests unfettered from the state's ability to enforce the law. Interestingly, the hackers themselves appear to recognize the power of complex global social systems to amplify their modest efforts: in one instance, hackers broke into the information systems that control the United States' power grid and reportedly installed software that could disable the grid.[25] Some commentators suggest the United States is vulnerable to a "digital Pearl Harbor," in which a social network of patriotic hackers uses access to the computers that govern transportation and utility networks to wreak havoc on the American economy.[26]

Epidemics and pandemics also illustrate how interactions between social networks and individual behavior challenge the ability of states to govern effectively. One need only look at the public discussion a few years ago about the H1N1 virus, or "swine flu." A *Washington Post*-ABC News poll in 2009 found that more than 60 percent of Americans were unconcerned with the virus, suggesting that public health officials had yet to persuade people to get a vaccine shot.[27] Epstein reports an interesting counterexample from 1994, when citizens of Surat, India, fled the city to escape an outbreak of pneumonic plague even though the World Health Organization found no cases of the disease there.[28] This interaction between social networks and behavior makes it difficult to model the prevalence and speed of propagation of a disease. Classic epidemiological models "are ill-suited to capture complex social networks and the direct contacts between individuals, who adapt their behavior—perhaps irrationally—based on disease prevalence."[29] Indeed, similar interactions of networks and behaviors explain how computer viruses such as self-replicating "worms" propagate over computer networks: because computer users do not perceive the presence of such a computer virus, they unwittingly take risks by sharing disks and memory sticks or e-mailing attachments that infect other computers. Researchers tend to miss these interactions when focusing only on network structure on the one hand or behavioral modeling on the other. Scholars of world politics need to understand these interactions between patterns of communication and behavioral factors that they previously took for granted.

One reason for this is that the study of world politics suffers from a levels-of-analysis problem. The economic, technological, demographic, communications and ideational processes of "globalization" have fundamentally reconfigured the nature of social space, such that relations among individuals, organizations, and states increasingly assume forms that transcend territorial limitations, occur across the spaces of the planet, and defy the conventional hierarchy of the individual, the state, and the interstate system.[30] Scholars of globalization and civil society have made considerable progress in recognizing and explaining a domain of world politics outside of relations among sovereign states, but these efforts so far have failed to identify some common organizational features and processes of this "polycentric" world.[31] Rather than proffering an alternative theory of world politics, however, this book argues that such grand theory is unnecessary. Nor does the book argue for (or against) midrange theories. What our scholarship needs instead is a break with the orthodoxy of levels of analysis, which is a legacy of a specific subfield of political science (international relations) that is poorly suited to the ecumenical field of world politics. The traditional typology of the individual, state, and the system is both hierarchical and incomplete. Instead, to understand world politics today we need an analytical framework that emphasizes units of analysis, their interrelations, and the processes of self-organization these units produce either intentionally or by accident. In other words, we need to complement Waltz's classic formulation of *Man, The State, and War* with relational methods of analysis.[32] Fortunately, such a shift in our thinking about world politics requires very little methodological innovation. As the book shows, three separate traditions loosely united under the umbrella of "computational social science" provide scholars with the means to formalize the relational study of global politics. In the following chapters, the book discusses complex systems theory, evolutionary game theory, and social network analysis as useful tools for formalizing our thinking about how skilled individuals in world politics organize themselves outside the domain of interstate relations; how they adapt and learn; and how they produce the collective goods—whether socially beneficial or not—that are an enduring feature of world politics today.

WHAT ARE COMPLEX GLOBAL SOCIAL SYSTEMS?

A complex system is one "in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information processing, and adaptation via learning or evolution."[33] A complex *social* system is a complex system in which the components are social actors. A complex *global* social system is one in which the actors organize their interactions across the sovereign boundaries of two or more nation-states. As such, the networked topography of complex global social systems transcends the spatial topography of many forms of social behavior. Foremost, we think of people as the actors in complex global social systems, but a system may also consist of human-directed organizations: nation-states, multinational corporations, banks, and insurgent groups, to name just a few. Jervis offers a useful two-part definition of a "system" that helps us understand how we may conceive of relations among social actors as a complex social system. First, a system is a set of units that have some form of interdependency—that is, "changes in some elements of their relations produce changes in other parts of the system."[34] These interdependencies give rise to a second feature of a system, what some theorists call "emergent behavior" of the system, or simply "emergence": the system as a whole "exhibits properties or behaviors that are different from those of the parts."[35] Emergence is an important concept because it highlights the fallacy of composition in thinking about systems: one cannot infer properties or behaviors of a system simply by studying the units. Conversely, we cannot infer the behaviors or—importantly for social scientists—the preferences of units simply by observing the system.[36] This is the ecological fallacy. To avoid these inferential errors, we must study patterns of interactions as well as actors, interests, and structures. Social systems are "complex" not only because they produce emergent behavior, but also because this behavior allows the system to evolve, learn, adapt, and change over time even if actors in the system do not learn. Such change and adaptation in the system may emerge suddenly and chaotically—that is, complex social systems exhibit nonlinear change, in which small perturbations among social actors may produce large changes in the behavior of the system. Cause-effect relationships in complex adaptive social systems may break down, furthermore, across scales of aggregation or over time. Because social relations by definition involve social actors creating interdependencies, Miller and Page argue that "the innate features of many social systems tend to produce complexity."[37] To study complex social systems, then, one must study not only the social actors in the system but must also understand the nature and patterns of interdependencies among actors and the rules that govern their interactions over time. As a unit of analysis, then, the complex social system is fundamentally an aggregate, relational, and process-oriented unit.

One useful way to think about a complex global social system is as a network. As the next chapter explores, the metaphor of a network has broad appeal among scholars of world politics. Beyond the metaphor, however, social network analysis and its related field of graph theory offer a set of tools for formalizing the representation of relations among social actors, and for studying properties of social systems. Network analysis represents each unit as a "node" (which the literature sometimes calls a "vertex") and interdependent relations among actors as "links" (or "edges"). The distinction between nodes and links does not imply, however, that the nodes or links themselves are units of analysis. Rather, network theory finds that the pattern of interdependencies—that is, the structure of the network—has greater influence on the behavior of nodes than do individual-level attributes.[38] For this reason, network theorists formally map and measure the interdependencies among units; one cannot simply assert some general but unspecified relations among units and call it a "network." The mathematical field of graph theory is devoted to the representation of relations among nodes and the measurement of network properties, both at the macro level (for example, how "connected" is the network as a percentage of the total possible number of connections) and at the level of individual nodes (if one were to remove a particular node from a network, how would it affect the overall structure of the network?). With the tools of network theory and graph theory, one can represent almost any system characterized by discrete units with defined relations. *Social* network analysis is concerned, of course, with networks of social actors. Typically, social network analysis focuses on people as nodes; an epidemiologist might use social network analysis to study the spread of sexually transmitted diseases in a community, for example, by mapping relations among sexual partners.[39] But social network analysis also can also treat collectivities as nodes. For example, Davis et al. map ties among corporations by measuring the number of shared directors.[40] Similar studies have examined how networks of financial institutions affect market entry;[41] how innovator networks consisting of researchers, firms, and public laboratories formed in Jena, Germany;[42] and how network relations among nongovernmental organizations affected flood relief efforts in Mozambique in 2000.[43] Benson uses methods of social network analysis to estimate the effect of trading and security relationships on the incidence of interstate disputes.[44] In each of these studies, a "node" in the network represents a social group rather than an individual: a corporation, a bank, a laboratory, an NGO, or a nation-state.

Of course, one can use the methods of network analysis to study physical networks that facilitate global exchanges of goods, money, people, images, and ideas. Transportation grids (roads, rail, ports, and hub airports) are extraordinarily large networks. Likewise, utility networks consist of defined nodes (water treatment plants or power generation facilities) and links (pipes or transmission lines). While information systems such as cell phone networks or the Internet also have physical characteristics—fixed cell towers and servers, for example—they begin to blur the distinction between physical networks and social networks. While the power lines to my home are always connected, I am not always on the phone or always checking my e-mail. Thus, information networks exhibit some of the dynamism that characterizes social networks. This anticipates two important differences between social networks and physical networks. Systems such as transportation grids and utility networks change their structures in the long run, but with high degrees of asset specificity and high fixed costs they are not nearly as dynamic as social networks. Social networks by contrast "are continually changing through interactions among their constituent people, groups, or organizations."[45] The second important distinction is that actors in social networks learn and adapt. Social actors perceive their relations with others, they are endowed with beliefs, and they can act strategically. Importantly, social networks can affect the information that social actors receive, and hence shape their perceptions, knowledge, and behavior. In physical networks, nodes may have some limited capacity for adaptation—power stations can help equilibrate supply and demand for electricity across the grid, for example. Social actors are, however, much more adaptive and more idiosyncratic. While "networks help to create interests and shared identities and . . . promote shared norms and values,"[46] they may also provide nodes with resources to change the network. As the chapters that follow illustrate, communication among social actors has surprising effects on collective action: too much information in certain network structures can actually harm a group's social welfare. To understand complex social systems in world politics, then, we must study the organization or pattern of their interdependencies, whether we call these patterns "networks" or "systems."

An added layer of self-organized complexity in world politics arises from the interaction of social and physical systems. Actors as varied as terrorists, nongovernmental organizations, transnational advocacy groups, corporations, and others use physical networks, from communications to transportation, to provide collective goods. They do so without the hierarchical organization that characterizes both nation-states and traditional Fordist modes of production, and without recourse to the state's power to coerce. Admittedly, this is somewhat of a strong claim: traditional collective action theory asserts that smaller groups, and those with powerful actors willing to bear the costs of provision, are more likely to succeed in producing collective goods.[47] Yet numerous scholars of globalization and global civil society have noted that nonstate actors today are quite adept at producing collective goods both for their own organizations and for society as a whole.[48] So how do such massively parallel, loosely organized systems succeed, often in the face of opposition from nation-states? Traditional levels of analysis do not help us answer this question. Networks of action do not reside at the individual level, the state level, or the systemic level as traditionally conceived. Much of the literature on transnational activism, civil society, and nonstate actors offers some insights, but by and large this literature tends to ignore the specific patterns of interrelationships among actors. That is, while it posits "networks of knowledge and action"[49] and "transnational advocacy networks,"[50] the literature uses the word *network* metaphorically rather than formally. To formalize our thinking about these relationships, this book proposes that we focus on how specific systematized interdependencies help actors learn, adapt, and produce collective emergent behavior that is greater than the sum of their intentions.

From this discussion of the properties of a complex social system, one can see that the Great Pacific Garbage Patch is not a complex global social system. Its constituent parts are pieces of garbage, not social actors. It may be that, thanks to the ecology of Pacific Ocean currents, these pieces of garbage do indeed have some interdependencies that would allow us to characterize the patch as a *system*. But it is not a social system. Rather, it is the emergent property of a set of complex social systems involving production and consumption choices of individuals (that is, the global market) and their interactions with the ecosystem. To begin to understand social emergence on such a geographically vast scale, one must first consider the processes through which complex social systems evolve and adapt. Three such processes are integral to all complex social systems: conservation, selection, and innovation.

Conservation of Information and Strategies

All complex social systems conserve information in two ways. Today, networks may physically store information, a fact that allows rumor registries such as the Ushaihidi project or online traffic maps to inform the decisions of individuals, leaders, and organizations. The Program for the Monitoring of Emerging Diseases, or ProMED, allows physicians from around the world to e-mail reports of outbreaks of infectious diseases and toxins. A similar organization is the Computer Emergency Response Team, or CERT. This organization based at Carnegie Mellon University receives reports of computer viruses and Internet security vulnerabilities, reports them, and distributes recommendations and solutions. Each of these social systems takes advantage of the Internet's ability to receive, store, and distribute information with little or no centralized control. Yet complex social systems have existed since before the rise of digital media, and have used other, simpler ways to store information that do not require a physical repository. Indeed, an important feature of complex social systems is what one might call "collective memory," an idea that is somewhat counterintuitive but nevertheless is important. Collective memory persists in systems because actors pass along knowledge to their neighbors in the system. This phenomenon is well known in biology. Researchers have demonstrated that slime mold bacteria—primitive organisms with no brains—pass along information to nearby bacteria using pheromones. Such "pheromone tagging" allows the mold to communicate about the location of resources such as food. Using this mechanism, researchers were able to train a colony of slime mold to "solve" a maze; because they resided along the shortest path between two food sources, the bacteria more efficiently shared information and food than organisms off the shortest path.[51] Consider also the curious case of red deer residing in Germany and the Czech Republic which, two decades after the fall of the Berlin Wall, still do not cross the former East-West frontier: the "deer have traditional trails, passed on through the generations, with a collective memory that their grounds end at the erstwhile barrier."[52] Researchers have observed that deer that are only two years old will never venture across what once were dangerous grounds, clear evidence that deer pass knowledge of their trails to future generations. Just as in biological systems, complex social systems develop collective memory when actors learn from others, imitate successful actors, follow habitual routines, and combine all these behaviors over time.[53] There is some emerging evidence, furthermore, that social behaviors may in fact be "heritable," or passed genetically from parents to children.[54] Because complex social systems have many thousands, millions, or even billions of actors, furthermore, any given actor's departure from the network is unlikely to lead to the loss of knowledge that, in effect, resides in the collectivity as well as in individuals.

Selection of the Best Strategies

Complex social systems not only preserve information but also have mechanisms to identify or select the "best" performers. In ecosystems, natural selection identifies species and animals that are fittest through a couple of mechanisms. Herbert Spencer's oft-cited phrase "survival of the fittest" captures Darwin's idea of competition among species for scarce resources arising from environmental constraints. Thus, although antibiotics kill most bacteria, the population of bacteria has sufficient variation in resistance that the microbes that survive are highly resistant to antibiotics. This competition explains why tuberculosis has reoccurred in drug-resistant forms in New York City, for example.[55] Another mechanism of natural selection is sexual selection, or competition among individuals for mates. Interestingly, ecological competition and sexual selection may work at cross purposes: the peacock's feathers may give him a reproductive advantage, but he is notably conspicuous to predators. Complex social systems may exhibit some analogies to ecological competition and sexual selection. Clearly, in microeconomics, competition among firms for scarce customers is one form of selection; Jensen's study of commercial banks entering the investment banking market illustrates that the banks' ties to each other can facilitate advantageous access to consumers.[56] Likewise, sexual selection may play a role in the spread of sexually transmitted diseases.[57] Complex social systems may also create, however, selection mechanisms that are not found in complex biological systems. One example is the process of community enforcement. Though a very old example, the commercial laws of medieval Champagne fairs depended upon community enforcement to punish merchants who cheated. This allowed trade to flourish even though merchants in these traveling markets had strong incentives to cheat customers.[58] Information technologies today greatly facilitate community-based mechanisms of selection. Just as the World Wide Web empowers patriotic hackers to launch disruptions of government information systems, so too does it empower groups that monitor such abuses of the internet. After U.S. authorities arrested Colleen R. LaRose, known as "JihadJane" for her alleged involvement in a terrorist plot, her neighbors apparently were unaware of her political views. Yet My Pet Jawa and YouTube Smackdown Corps—both online communities of "anti-Jihadi Internet activists"—reported they each had tracked Ms. Rose's online postings for several years.[59] Wikipedia uses a similar form of community enforcement. Because anyone can create entries and edit the online encyclopedia, some have questioned its accuracy in the absence of editorial control. In one notable incident, someone edited the Wikipedia biographical entry of veteran journalist John Siegenthaler, accusing him of involvement in the assassinations of John F. and Robert F. Kennedy. "For four months, Wikipedia depicted me as a suspected assassin before [Wikipedia founder Jimmy] Wales erased it from his website's history. . . . The falsehoods remained on Answers.com and Reference.com for three more weeks."[60] Yet the Siegenthaler entry appears to be the exception. With millions of readers, Wikipedia's community of users is quick to correct errors—the accuracy of its entries today is comparable to that of *Encyclopedia Britannica*.[61] Wikipedia's community model has additional advantages over traditional print encyclopedias, furthermore. Not only does it have far more entries—more than four million English-language articles alone, compared to *Britannica*'s 65,000 articles—but the community corrects errors more quickly than any print encyclopedia possibly can.[62] Indeed, John Siegenthaler's biographical entry on Wikipedia now includes a link to another entry dedicated to the controversy over his biography.[63] These examples illustrate how selection processes such as community enforcement help complex social systems learn and adapt.

Innovation, Learning, and Adaptation

While competition and selection in complex social systems empower actors, these systems also encourage learning and innovation. Complex social systems are surprisingly adept at solving some challenging problems, in part because they recruit new ideas through one form of self-organized positive feedback: the more these systems attract knowledgeable and skillful individuals, the more useful they become to future users who may bring new ideas to the system. This is one form of "preferential attachment"—that is, the probability of an individual joining a system grows as other individuals join. Social systems also reward those individuals or organizations that learn the quickest or outperform others. One simple example is the Netflix Prize, established by the eponymous company that streams films online to subscribers. In 2006, the company offered a $1 million reward to anyone who could devise a way to improve by 10 percent the service's movie recommendations. Three years later, a team of seven mathematicians, computer scientists, and engineers from the United States, Canada, Israel, and Austria known as Pragmatic Chaos won the prize. In the intervening three years, Netflix received submissions from more than one hundred countries. Pragmatic Chaos itself emerged during the competition when three separate teams joined their efforts. Remarkably, another team of thirty volunteers had achieved an identical 10 percent improvement in Netflix's recommendations but submitted their solution twenty minutes after Pragmatic Chaos. Had Netflix tried to engineer a solution using traditional software research and development methods, it would have been much more costly. "The company would have had to shell out more than $3 million for just one year of the top performers' time, and that's assuming it could've sussed out who the top performers were going to be."[64] Yet the prize not only encouraged unlikely individuals to coordinate their efforts—it turns out Pragmatic Chaos's members worked for firms that are competitors—but it also encouraged innovation and a process of self-selection in which the community of competitors themselves identified the top performers. It saved the company both money and time.

Clearly, mechanisms of innovation work closely with those of conservation and selection. The rise of e-medicine shows how social systems can use technology to spread not only information but also innovations. Information networks may "allow the most promising ideas to spread easily, quickly and widely. 'If the internet is humanity's planetary nervous system, we are now building our planetary immune system,'" argued Nathan Wolfe of the Global Viral Forecasting Initiative.[65] Complex social systems have remarkable abilities to adapt, learn, and even predict political events with an accuracy even the most expert observers could only hope to achieve. For example, researchers have used search engine query data from Google to predict influenza outbreaks. If I am concerned that I have the flu, I may conduct a Google search to learn about the symptoms, treatment options, medicines, and perhaps nearby doctors. Even if I am well but know someone who has the flu, I may wish to get inoculated and ask Google to direct me to the nearest public clinic. Through my search engine queries, I have unwittingly identified myself as a susceptible individual. In this way, those in whom public officials are most interested identify themselves, an important form of self-organizing complex social systems. By using records of such searches on Google, researchers found they can identify outbreaks with a time lag of about one day, compared to the Centers for Disease Control and Prevention's reporting lag of one to two weeks.[66] Just as mechanisms of conservation, selection, and innovation help civil society solve problems, however, criminals may also use these mechanisms to achieve their objectives. After discovering GhostNet, one set of researchers noted problems of cyberespionage are likely to worsen: "What Chinese spooks did in 2008, Russian crooks will do in 2010 and even low-budget criminals from less developed countries will follow in due course."[67]

Similarly, prediction markets use mechanisms of competition and selection to learn about and predict social and political trends. In a prediction market, individuals buy and sell contracts for a particular future event such as whether a candidate wins an election. If the event occurs, holders of the contract receive payment, but if the event fails to occur the holder receives nothing. Because participants can trade contracts continuously, the current price of a contract reflects the trading community's estimation of the probability of the event occurring. In this respect, prediction markets institutionalize selection mechanisms: those who routinely guess poorly lose money, go broke, and exit the market, while those whose guesses tend to be more accurate will make money and continue to play. Speculators may play iteratively and continuously as long as they have money to purchase contracts. Without any centralized direction or leadership, then, prediction markets draw forth the latent expertise of the most knowledgeable members of a social group. In other words, prediction markets are one mechanism for aggregating social beliefs. They are surprisingly good at predicting social and political events. In one well-known example similar to the Google influenza prediction, a prediction market in Iowa identified flu epidemics two to four weeks before the state's public health reporting system identified them.[68] Another online prediction market, Intrade.com, allowed trading in contracts on the 2004, 2008, and 2012 presidential elections in the United States. Rather than polling a random sample of the electorate, Intrade's market allows anyone who is willing to risk money to buy future contracts. While one might expect problems with sample bias—perhaps only the wealthy and compulsive gamblers participate in the prediction market—in fact, the participants have strong incentives to make accurate predictions. Rather than asking themselves, "Whom am I going to vote for?" traders instead ask (1) whom is everyone else going to vote for? And (2) are other traders over- or underestimating the likelihood of a given outcome, because I can make money by buying and selling contracts before market movements? Those who answer these questions most accurately make money, while those who are less knowledgeable drop out of the market. Thus, Intrade's selection mechanism (the market) attracts and identifies expertise. In all three elections, the markets not only accurately predicted the eventual winner but also outperformed predictions based on traditional opinion polls. The 2008 presidential election in particular showed the prescience of the prediction market. Although most pollsters predicted Obama's victory in the weeks before the November 2008 election, none provided a prediction as accurate as Intrade's markets did. On November 3, 2008—the night before Barack Obama was elected president—the *Washington Post*'s online election map, based on data from Real Clear Politics, predicted Obama would win 338 electoral votes to John McCain's 200 electoral votes.[69] National Public Radio's pollster Kenneth Rudin predicted a 291-247 split in Obama's favor.[70] The *New York Times*, *Wall Street Journal*, Fox News, *Los Angeles Times*, and others identified several states as too close to call.[71] By contrast, Intrade.com's markets correctly identified the winners in forty-eight of the fifty states and predicted the exact ultimate electoral split of 365-173.[72] Intrade's markets also correctly predicted all fifty state contests in the 2004 presidential election.[73] What is more, Intrade forecast an electoral split that was larger than most pollsters had predicted, yet its outlier proved to be the actual Electoral College split. Although recent scholarship has identified deficiencies with "big data" analysis,[74] these examples illustrate how complex social systems use conservation, selection, and innovation to harness "the wisdom of crowds"[75] to solve difficult problems and provide collective goods, from encouraging citizens to seek health care to monitoring the spread of computer viruses.

SELF-ORGANIZATION AND ADAPTATION IN COMPLEX GLOBAL SOCIAL SYSTEMS

How do complex global social systems unleash the processes of conservation, selection, and innovation? Four features in particular explain the surprising ability of complex social systems to survive, adapt, and thrive in world politics: the skill revolution, massive parallelism, nonlinearity, and creative errors.

The Skill Revolution

Rosenau, for one, has argued that individuals have become increasingly skillful players in world politics.[76] Individuals have the knowledge to use information technology to inform their leaders, international organizations, and other states of human rights injustices, humanitarian crises, and other issues that concern them. Yet Rosenau argues that of greater importance is the ability of political actors to recognize how distant events affect their daily lives, and conversely how their local actions can affect distant happenings.[77] That is, actors today better understand "micro-macro" linkages between individuals on the one hand and national, transnational and global processes and structures on the other. This is an important difference between social systems and physical ones: in the former, "nodes" not only receive information from the network but try to change both the network itself and the behavior of distant nodes. For example, Iranian protestors during the summer of 2009 used a Persian-language social networking site based in the United States to mobilize both protestors residing in Iran and those Iranians living overseas.[78] Recognizing that social media empowered the protestors, the U.S. State Department quietly asked Twitter to delay routine maintenance that would have denied protestors an important source of information.[79] Similarly, patriotic hackers employ their skills in the service of their shared goals. Social systems not only help skillful individuals collaborate, they also empower actors to directly influence governments.

Massive Parallelism

Crisis maps, e-medicine, and community enforcement all are massive social systems characterized not by hierarchy but instead by parallelism. This "many-to-many-to-many" network structure helps social networks conserve information; avoid detection and circumvent state power; quickly identify and solve problems; and innovate.[80] Massively parallel systems conserve information; as noted above, even if someone leaves the social network, that person's departure is unlikely to cause a loss of information or expertise in the system. Such systems also protect members in a web of anonymity. This is one reason states find "cyberwar" so difficult to combat. The best that computer experts can do is identify the location of the servers from which cyberattacks originate, but they cannot identify the individuals who orchestrated the attacks:

> Leaving the attacks to informal cybergangs (the extent of the Russian state's involvement remains unclear), rather than trying to organize a formal cyberarmy, is cheaper, for one thing. The most talented attackers, with the best tools, might not want to work for the state directly. Best of all, from the state's point of view, is that it can deny responsibility for the attacks.[81]

Conversely, massive parallelism facilitates community problem solving. With so many participants in a social system, members can weed out bad information (as in Wikipedia) and identify those who violate social norms (as occurred with JihadJane). Open-sourced software takes advantage of a large community of volunteer programmers to identify problems and security vulnerabilities, and to engineer solutions. The popular Web browser Firefox illustrates an interesting paradox of massively parallel system. Firefox typically has more security vulnerabilities than other Web browsers: one report identified 169 vulnerabilities in Firefox compared to ninety-four in Apple's Safari browser and forty-five in Microsoft's Internet Explorer, both of which are proprietary or "closed-source" software. But Firefox has one of the smallest "windows of vulnerability," or time between when a security fault is identified and developer Mozilla pushes out a security patch. Indeed, Firefox had the smallest window of vulnerability of any browser in 2008, bested Safari in vulnerability times in 2009, and had a quicker time to patching vulnerabilities than Internet Explorer in 2011.[82] Along with Wikipedia, this example illustrates that although massively parallel systems may have more errors, they also may solve those errors and adapt more quickly than hierarchical systems. Finally, the sheer number of people in massively parallel social systems allows innovation to percolate from unlikely sources. The Netflix prize succeeded precisely because the company could not affordably and reliably identify engineers who could solve their business problem; the prize merely incentivized individuals to join into problem-solving networks. One researcher has suggested that individuals participating in massively parallel online role-playing games, or MMORPGs, would provide the U.S. armed forces with more realistic counterinsurgency experience than conventional training does.[83] A neuropsychologist who contributes to Wikipedia noted that the online encyclopedia's process of resolving disagreements about entries can encourage innovation. "Even people who are a pain in the arse can stimulate new thinking."[84]

Nonlinearity

Complex social systems exhibit increasing returns—that is, the system's output grows by a factor greater than one for each unit of input.[85] Increasing returns thus facilitate both growth and self-organization in complex social systems. Network effects are an important source of increasing returns. The idea of network effects is simple: to take a dated example, the first fax machine was useless because it fundamentally derives its utility from the fact that others use the technology as well. But with each additional purchase of a fax machine, the technology became more valuable. Systems with such network effects are characterized by *s*-shaped growth—that is, an initial period of slow growth followed by explosively rapid growth and then tailing off as the system is saturated. This explains why complex global social systems self-organize suddenly and surprisingly. These systems exhibit similar patterns of growth as they become more valuable both to their users and to those outside the system. While a crisis map with two users might be marginally useful, for example, each additional user makes the crisis map more informative, attracting new users who then contribute new information, and so on. Walt, for one, notes that as transnational connectivity grows, the likelihood of such "political contagion," or the spread of political ideas and methods, rapidly increases.[86] One consequence of such nonlinear growth is that complex systems are not decomposable—one cannot simply explain the properties of the system by examining the behavior of the components. Few recent episodes illustrate the nonlinearity of complex social systems and the fallacy of composition better than the financial crisis meltdown that began in 2007 but accelerated in October 2008. Interbank lending assured that the failure of a small portion of the U.S. credit market—subprime mortgages—quickly spread not only to the broader U.S. credit market but to overseas credit markets as well. In retrospect, national banking regulators were guilty of assuming the composability of finance: "The assumption was that if each institution was safe, then the system as a whole would be too."[87] Regulators today still struggle with the interdependent relationships among financial institutions. Although President Obama announced in January 2010 that "[n]ever again will the American taxpayer be held hostage to a bank that is too big to fail," one assessment noted that if implemented, this would require splitting the United States' four largest banks into forty-eight separate companies.[88] Such proposals ignored, furthermore, the systematic quality of finance:

> The proposals also betray a desire to ring-fence deposit-taking firms and let everything else fry. However understandable, the reality is that investment banks, credit-card operators, insurers and even carmakers' finance arms had to be bailed out. The system was too interconnected.[89]

While the liberalization of finance unleashed the power of positive returns in banking, it simultaneously created risks of cascading failures.

To capture the dynamism and nonlinearity of complex global social systems today, a number of scholars have offered neologisms. Two portmanteaus seem particularly insightful. Dee Hock, the founder of the Visa credit card company, proposed describing these social systems as "chaordic," or organizations that simultaneously exhibit properties of chaos and order.[90] Similarly, Rosenau suggests "fragmegration," or the "simultaneity and interaction of the fragmenting and integrating dynamics" that characterize new actors in world politics.[91] Such nonlinear dynamics in complex systems help explain their rapid constitution, evolution, and dissolution. So-called flash mobs take advantage of these multiplying effects to organize quickly, protest, and disperse before state authorities can react. The first presidential campaign of Barack Obama in 2008 provides another piquant example: it released an app for Apple's popular and then-revolutionary iPhone. Not only did the free app deliver to the user's phone information about the campaign's position on a range of issues, but it also included "a great volunteering tool that lets you make a difference any time you want by talking to people you already know. Your contacts are prioritized by key battleground states, and you can make calls and organize results all in one place."[92] Given the nature of iPhones—at once status symbols for elites and costly devices—the campaign tapped into the social networks of well-educated, motivated, and wealthy voters who in turn contact their well-educated, wealthy and motivated friends.[93] In effect, the phone does the campaigning for the candidate. These examples illustrate how skillful political actors can use network effects to multiply their efforts, communicate with others, and rapidly organize and mobilize supporters for their cause.

Creative Errors

Schumpeter's observation that "gales of creative destruction" characterize innovation in capitalist economies anticipates an important feature of contemporary complex global social systems.[94] They may be sloppy, inefficient, noisy, and error-prone, but such slack in complex global social systems serves three important purposes. First, it helps such systems escape what a game theorist might call suboptima. People can manage known errors but not unknown ones; deliberate errors and inefficiencies actually can help solve problems. Before seafarers had solved the navigational challenge of determining their longitude, they often would deliberately sail to either the east or west of their destination. Once they had reached the proper latitude, they would then know which direction to turn toward their destination. Such "off-course navigation" featured prominently in early aviation as navigators learned to find small islands in the Pacific Ocean. Ernest K. Gann, an aviator and author, memorably recalled the dangers of attempting to navigate precisely toward one's destination as he recounted flying across the rainforests of the Amazon to Corumbá, Brazil, in the 1940s. To find this city near the border with Bolivia, he and his captain sought a river to guide them:

> It is an axiom of flying that he who starts wandering around when in doubt never discovers his true whereabouts until it is too late. . . . Somehow, because of the unknown winds or the inaccuracies of the chart, we had come upon the wrong section of the river. Which way, then was Corumbá? To the north or to