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LAW'S COMPLEXITY: A PRIMER

J.B. Ruhl*

INTRODUCTION

The legal system. It rolls easily off the tongues of lawyers like a single word—thelegalsystem—as if we all know what it means. But what *is* the legal system? How does it behave? What are its boundaries? What is its input and output? How will it look in one year? In ten years? How should we use it to make change in some other aspect of social life?

These are foundational questions; yet, of the tens of thousands of references to "the legal system" in legal literature,[1] few of the authors say anything about it *as a system*. To be sure, questions about the nature of law and legal systems have occupied jurisprudential investigations for centuries, but even in this subset of the literature little attention is given to the *system* half of "the legal system."[2] After centuries of building and thinking about our legal system, we still do not have ready answers for such questions of the first order.

One thing over which many authors seem to agree, however, is that there is something "complex" about the legal system, using the two terms in close proximity as if to impart some deeper understanding.[3] So, for example, one author suggests that "no complex legal system can provide clear textual answers to every issue or dispute that falls

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1. A January 9, 2008, search of Westlaw's TP-ALL library for *"legal system"* yielded 80,962 documents.

2. For a summary of some of the literature on law as a system see J.B. Ruhl, *The Fitness of Law: Using Complexity Theory to Describe the Evolution of Law and Society and its Practical Meaning for Democracy*, 49 VAND. L. REV. 1407 (1996).

3. A January 9, 2008, search of Westlaw's TP-ALL library for *"legal system" /s complex!* yielded 2,312 documents, and a search for *"complex legal system"* yielded 226 documents.

within its scope as time goes by,"[4] and another claims that intellectual property rights law "has radically evolved since the nineteenth century when there was no structure, to the present where there are complex legal systems and rules in place."[5] One author even goes so far as to refer to "*massively* complex legal systems," suggesting that they "require a great deal of constituting."[6] I have no doubt that these propositions are accurate. Beyond conjoining "complex" and "legal system," however, these works and many others like them venture no further into what makes the legal system *complex*.

Perhaps it is so obvious that the legal system (whatever it is) is complex (whatever that means) that one need say no more about its complexity—it's complex, so there you have it, and that means Proposition X is true. But when one claims that Proposition X follows from the fact that the legal system is complex, in that it will not always provide clear answers, or it requires a great deal of constituting, or it is more complex now than it was a few centuries ago, one necessarily must develop or adopt a theory of what complexity is, otherwise how can we conclude that it is *complexity* that leads to the truth of the proposition? It cannot suffice to respond simply that the legal system is complicated, or has a lot of parts, or is hard to predict, for those are merely observations—all true I would add—about the consequences of its complexity. What is it, exactly, that makes the legal system complicated, with many parts, and hard to predict? Would not knowing the answer to that question help us better understand the legal system and how to design and employ it for the general welfare of society?

To put it another way, would assembling a cogent, descriptively accurate theory of what makes the legal system complex help us to formulate more accurate and useful propositions about the legal

4. Andrew D. Mitchell, *The Legal Basis for Using Principles in WTO Disputes*, 10 J. INT'L ECON. L. 795, 795 (2007).

5. Christopher B. Conley, Comment, *Parallel Imports: The Tired Debate of the Exhaustion of Intellectual Property Rights and Why the WTO Should Harmonize the Haphazard Laws of the International Community*, 16 TUL. J. INT'L & COMP. L. 189, 210 (2007).

6. Ernest A. Young, *The Constitution Outside the Constitution*, 117 YALE L.J. 408, 417 (2007) (emphasis added).

system? I have to believe it would, and in my pursuit of such an explanation I have leaned heavily on the theory of complex adaptive systems—the study of systems comprised of a macroscopic, heterogeneous set of autonomous agents interacting and adapting in response to one another and to external environment inputs.[7] Emerging primarily from the physical sciences in the 1980s, complex adaptive systems theory has spread to economics,[8] ecology,[9] sociology,[10] and beyond. Along with a growing number of legal scholars,[11] I am working to import the theory into the study of legal systems.

When we talk of using complex adaptive systems theory to inform legal theory, we can think of it as applying on one or more of several levels of contextual depth. At the surface, one might recognize that there are complex adaptive system properties in the economy, poverty, war, terrorism, crime, the environment, and other realms we attempt to manage and regulate through law, and ask simply what that means for law. How should law be configured so as to best approach these complex social and physical systems? At a deeper level, one might ask whether law itself is a complex adaptive system. Why, for example, if the economy and other social systems exhibit

7. There is no universally applied definition for complex adaptive systems. A good working definition is "macroscopic collections of simple (and typically nonlinearly) interacting units that are endowed with the ability to evolve and adapt to a changing environment." European Commission, Complexity in Social Science Research Project, COSI - Glossary, http://www.irit.fr/COSI/glossary/fulllist.php?letter=C (last visited Mar. 6, 2008).

8. *See* ERIC D. BEINHOCKER, THE ORIGIN OF WEALTH: EVOLUTION, COMPLEXITY, AND THE RADICAL REMAKING OF ECONOMICS (2006); Robert M. May et al., *Ecology for Bankers*, 451 NATURE 893 (2008).

9. *See* SIMON LEVIN, FRAGILE DOMINION: COMPLEXITY AND THE COMMONS (1999).

10. *See* JOHN H. MILLER & SCOTT E. PAGE, COMPLEX ADAPTIVE SYSTEMS: AN INTRODUCTION TO COMPUTATIONAL MODELS OF SOCIAL LIFE (2007); R. KEITH SAWYER, SOCIAL EMERGENCE: SOCIETIES AS COMPLEX SYSTEMS (2005).

11. A January 9, 2008, search of Westlaw's TP-ALL library for *"complex adaptive system"* yielded 168 documents. Not all of the entries substantively discuss complex adaptive systems theory to inform legal theory or the design and application of law. The prize for mentioning "complex adaptive system" and "complex legal system" in the same document at the time of my search goes to just two authors. *See* Bernard Trujillo, *Patterns in a Complex System: An Empirical Study of Valuation in Business Bankruptcy Cases*, 53 UCLA L. REV. 357 (2005); Julian Webb, *Law, Ethics, and Complexity: Complexity Theory and the Normative Reconstruction of Law*, 52 CLEV. ST. L. REV. 227 (2005). Of course, after this publication there will be at least three.

complex adaptive system properties, the legal system would not? That does not seem plausible. To push further, if the economy and the legal system are both complex adaptive systems, then one would also expect the two systems to interact complexly with each other, as well as with all the other complex social and physical systems with which they are interconnected. And if law complexly affects the economy and other systems, and the economy and other systems complexly affect law, the distinct probability is that law affects itself complexly.

At its deepest level, therefore, complex adaptive systems theory as applied to the legal system presents a rich and dynamic field of study. It asks whether the targets of law are complex adaptive systems, and if so what that means for law's design. It asks whether law itself, however we define its boundaries, is also a complex adaptive system, and if so what that means for law's design. And it asks how law and its regulatory targets co-evolve and what that means for law's design.

This article orients those three questions within the context of complex adaptive systems theory. Part I provides a short primer on complex adaptive systems theory and suggests ways of usefully mapping it onto the legal system to expand our understanding of its behavior and properties. To make the case for the practical utility complex adaptive systems theory has for law, Part II explores a few of the major implications the theoretical foundation has for institutional and instrument design issues in law. I close by offering suggestions for next steps in the development of the theory of law's complexity.

There is a legal system, and it is complex and adaptive. We can leave it at that and intuit propositions that seem likely to follow, or we can dive headfirst into law's complexity to swim amidst its chaos, its feedback networks, its self-organization, its scales, its emergence, and its sheer dynamism. For those who have already taken that dive, I hope this work serves as a useful status check and blueprint for further work. For those who have not taken the dive, I hope this will persuade you to join us, or at least to dip your big toe into the whirlpool of law's complexity.

I. THINKING OF LAW AS A COMPLEX ADAPTIVE SYSTEM

There would be no point to exploring a model of law as a complex adaptive system if doing so would not open up windows to new understanding of law as a system. Complex adaptive systems theory studies how agents interact and the aggregate product of their interactions. But the study of law already abounds with such theories. Game theory, for example, focuses on actors in bilateral strategic interactions.[12] More generally, interaction models based on law and economics study market-level efficiencies by projecting interactions between multitudes of "rational actors" that represent the averaged-out behavioral traits of the infinite masses.[13] The problem, as Miller and Page point out, is that "most economic, political, and social interactions involve moderate numbers of people."[14] They elaborate:

> Most social science models require either very few (typically two) or very many (often an infinity) agents to be tractable. When an agent interacts with only a few other agents, we can usually trace all of the potential actions and reactions. When an agent faces an infinity of other agents, we can average out...the behavior of the masses and again find ourselves back in a world that can easily be traced. It is in between these two extremes—when an agent interacts with a moderate number of others—that our traditional analytic tools break down.[15]

Most actors in the legal system interact in this moderate numbers context in which there are too many interacting agents to fit neatly into bilateral models, but not enough agents to ignore idiosyncratic behavior by averaging-out to an infinite numbers "rational actor" model. Appellate lawyers, for example, know there is a limited pool

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12. *See* Martin Shubik, *Game Theory, Complexity, and Simplicity Part II: Problems and Applications*, 3(3) COMPLEXITY 36, 37 (1998) (describing game theory's impact in mathematics, science, philosophy, and policy advocacy).

13. *See* BEINHOCKER, *supra* note 8, at 3–71; MILLER & PAGE, *supra* note 10, at 4–5.

14. MILLER & PAGE, *supra* note 10, at 221.

15. *Id.*

of judges who might wind up on a panel, and that the judges have different judicial persona. No competent lawyer would draft an appellate brief to align with a particular panel composition without knowing those are in fact the judges on the panel, nor would the lawyer draft a brief based on a panel composed of "average judges" if the lawyer knew who the judges on the panel are. Throughout the legal system, agents interact in ways suggesting that the differences between agents matter, because they do. Complex adaptive systems theory is about building models for moderate number contexts in which agent heterogeneity can and usually does influence outcomes, and as such it is worth exploring how it might inform our understanding of the legal system.

A. What Is a Complex Adaptive System?

The term "complex adaptive system" implies two relatively unremarkable properties—adaptation and a system—and a third property that is at the heart of the theory—complexity. Starting with a single agent sitting inert all by itself, we move to a system where two or more agents interact, and they interact adaptively if they use "if/then" responses to chart their respective moves. Game theory's two-player prisoner's dilemma is such a system.[16] Although bilateral adaptive system models are rather simple, multi-agent adaptive systems can grow large in size, diverse in types of agents, and extensive in different "if/then" rules of adaptation, but that alone might not make them more than *complicated.* Complicatedness and complexity are not the same.

For example, few would dispute that the legal system is complicated—in the United States one must study law three years just to have the privilege of taking the bar exam! And law is only one of many social worlds in that respect. But the "very basic question we must consider is how complex, versus complicated, are social

16. *See generally* Shubik, *supra* note 12.

worlds."[17] The distinction goes to the essence of complex adaptive systems theory.

> In a complicated world, the various elements that make up the system maintain a degree of independence from one another. Thus, removing one such element (which reduces the level of complication) does not fundamentally alter the system's behavior apart from that which directly resulted from the piece that was removed. Complexity arises when the dependencies among the elements become important. In such a system, removing one such element destroys system behavior to an extent that goes well beyond what is embodied by the particular element that is removed.[18]

Complex adaptive systems theory studies these inter-agent dependencies and the system-wide effects they produce. While there is no universally agreed upon metric for determining what it takes to move an adaptive system to a complex adaptive system and for measuring the degree of complexity,[19] the theoretical model has come to rest on a collection of agent and system properties that are at the core of complexity. Ecosystems provide a useful medium for explication of these properties.

Preeminent biologist Simon Levin has described ecosystems as the "prototypical examples of complex adaptive systems."[20] John Holland, one of the leading figures in complex adaptive systems research, has explained why:

> Ecosystems are continually in flux and exhibit a wonderful panoply of interactions such as mutualism, parasitism, biological

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17. MILLER & PAGE, *supra* note 10, at 27.

18. *Id.* at 9. Thus "work is needed on distinguishing the complex ... from the just complicated in the presence of many possible explanatory models and imperfect data. Nicholas W. Watkins and Marvyn P. Freeman, *Natural Complexity*, 320 SCIENCE 323, 333 (2008).

19. *See* MILLER & PAGE, *supra* note 10, at 188–89.

20. Simon Levin, *Ecosystems and the Biosphere as Complex Adaptive Systems*, 1 ECOSYSTEMS 431, 431 (1998) (emphasis removed).

> arms races, and mimicry....Matter, energy, and information are shunted around in complex cycles . . . [and] the whole is more than the sum of its parts. Even when we have a catalogue of the activities of most of the participating species, we are far from understanding the effect of changes in the ecosystem.[21]

These broad agent and system behavior properties can be unpacked into several essentials. Starting with agent interactions, the foundation of an ecosystem is agent *heterogeneity*. Known as biodiversity in ecology, variety in the assembly of species is an important driver in how complexly the species interact.[22] Yet, although different assemblies would lead to different sets of interactions, underlying all species interactions are *deterministic rules* of chemistry, biology, and physics.[23] As in all complex adaptive systems, complex ecosystem behavior can arise from fairly simple rules of nature. What makes the interactions complex is how the rules, when set in motion among the diverse species and physical attributes of an ecosystem, produce *nonlinear relationships* between different agents and attributes. Some of the earliest work on nonlinearity in complex adaptive systems, for example, studied relationships between predator and prey, such as the lynx and the hare, which exhibit frequent explosions and crashes in populations.[24]

Of course, the lynx and the hare interact within the larger ecosystem, responding to far more than each other. The assembly of species and physical attributes builds *network connectivity* through which *flows* of energy and information link all the species to all

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21. JOHN HOLLAND, HIDDEN ORDER: HOW ADAPTATION BUILDS COMPLEXITY 3 (1995). A similar account explains that "ecological communities are among the most complex entities studied by scientists, as they are composed of thousands of species with many distinct lifestyles, interacting in a myriad of ways. Understanding the relationship between the complexity and diversity of ecological systems, and their stability and persistence, is the perennial challenge in ecology." Robert D. Holt, *Asymmetry and Stability*, 442 NATURE 252, 252 (2006).

22. *See* Levin, *supra* note 20, at 433 (discussing the importance of genetic, species, and ecosystem diversity).

23. *See id.* ("[A]ll ecosystems are complex adaptive systems, governed by similar thermodynamic principles and local selection.").

24. *See* HOLLAND, *supra* note 21, at 16–18 (explaining why there is no proportionate relationship between the numbers and trends of the interacting lynx and hare populations).

others in direct or indirect causal relationships.[25] Many of those ties may seem attenuated, but any of the ties could play a significant role in regulating ecosystem properties. For example, simply replacing "sit and wait" spiders with "active hunting" spiders in a grassland ecosystem can lead to dramatic changes in vegetation patterns.[26] Spiders, of course, do not eat plants, so how can the type of spider affect the pattern of vegetation? The answer involves grasshoppers, which do eat plants, but which also must adjust their survival behavior based on spider predator tactics. The chain of effects followed the network of connectivity between species: changing the spider predator tactic altered grasshopper feeding strategy, which in turn altered the vegetation pattern. The key move in this chain is the *feedback* grasshoppers receive when they test strategies for avoiding spiders while feeding on plants.[27] What worked in response to sit and wait spiders might be disastrous for avoiding active hunting spiders, and the grasshoppers better adjust accordingly. The architecture of the agent network causal connections thus lies at the core of what happens in an ecosystem. Change the network architecture, and you very likely have set in motion adaptive feedback changes throughout the ecosystem. The system is not just complex—it is complex and *adaptive.*

The spider-grasshopper-vegetation network is but one of a multitude of such causal chains in a grassland ecosystem. What we identify and study as the grassland ecosystem, is, in fact, the *emergence* of landscape scale phenomena from the aggregation and

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25. *See* Levin, *supra* note 20, at 433 ("[F]lows . . . provide the interconnections between parts, and transform the community from a random collection of species into an integrated whole, an ecosystem in which biotic and abiotic parts are interrelated."). The study of social system networks thus is a critical component of complex adaptive systems theory. *See* MILLER & PAGE, *supra* note 10, at 154–65. Although social network theory has been developing for decades, vastly improved statistical methods and computational power have made it possible to model extremely complex social networks based on complex adaptive systems theory. *See* Karen Heyman, *Making Connections*, 313 SCIENCE 604 (2006); D.R. White, *Networks and Complexity: Converging Streams of Research*, 8(1) COMPLEXITY 14 (2003).

26. *See* Oswald J. Schmitz, *Effects of Predator Hunting Mode on Grassland Ecosystem Function*, 319 SCIENCE 952 (2008).

27. *See* Levin, *supra* note 20, at 434 ("[T]ight linkages between . . . interacting species provide reliable and rapid feedbacks for individual behaviors.").

interaction of network causal chains operating in the field.[28] Put a collection of species on the landscape, give them time to adjust to their environment and each other, and what emerges is what we call an ecosystem. We call it an ecosystem because we need a word to capture the holistic set of landscape-level properties that the species assembly produces. The important aspect of emergence in complex adaptive systems is that it cannot be understood through reductionist methods—i.e., by examining the parts of the ecosystem underlying its operation one at a time.[29] If one were to study just spiders, just grasshoppers, or just plants, one would not likely make the connections made in the research that studied them interacting all together. So, although studying each part of an ecosystem is important work, at some point the only way to understand the ecosystem is to study it at the landscape scale.

It is when we make the move from studying agents to studying systems that the particular attributes of complex adaptive systems become prominent. As the spider-grasshopper-vegetation research illustrates, the particular assembly of species drives the ecosystem, and changing the assembly can steer it in a different direction. If active hunting spiders make it to an area first, their hunting tactics may send the area into a pattern that over time makes it difficult for sit and wait spiders to infiltrate, which "locks in" the pattern even more strongly. This *path dependence* property means that the future of the ecosystem depends on the past, and events of the past limit the

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28. Emergence has been defined as "complicated global patterns emerging from local or individual interaction rules between parts of a system." P. M. Binder, *Frustration in Complexity*, 320 SCIENCE 322, 322 (2008). Because emergent properties are the system-wide product of many such local interaction rules, it is not possible to describe emergent properties simply by describing the interaction rules. Emergence thus is "a process that leads to the appearance of structure not directly described by the defining constraints and instantaneous forces that control a system." James P. Crutchfied, *Is Anything Ever New? Considering Emergence*, *in* COMPLEXITY: METAPHORS, MODELS, AND REALITY 515, 516 (George A. Cowan et al. eds., 1994). For a sweeping discussion of emergence in social and natural systems, see Peter A. Corning, *The Reemergence of "Emergence": A Venerable Concept in Search of a Theory*, 7(6) COMPLEXITY 18 (2002).

29. *See* ROBERT G. BAILEY, ECOSYSTEM GEOGRAPHY 16 (1996) ("[W]e cannot understand ecosystems by only considering their separate components.").

range of possible events for the future.[30] Over time, network architecture builds along the path of the system, laying a foundation of *self-organized structure* that lends stability to the ecosystem within its environment of exogenous conditions.[31]

On the other hand, the diversity of species, their nonlinear relationships, and the network connectivity of feedback between them mean that change is constantly happening within the ecosystem. The active hunting spiders may be "locked in" for now, but if the sit and wait spiders are better able to withstand a severe winter, they may be able to take over the next spring, thus setting in motion a new regime. When we peer into the ecosystem, we see change like this constantly occurring, but on the landscape level, we still see a stable grassland ecosystem. This *critical state* of "stable disequilibrium" is a hallmark of complex adaptive systems.[32]

Change within an ecosystem is constant and built into the critical state of dynamic behavior, but it is not uniform in frequency or magnitude. Rather, most change in ecosystems is relatively minor, such as annual dry seasons, with only the occasional severe change, such as a drought of record. The distribution of change events in complex adaptive systems thus does not exhibit normal bell-shaped curve properties. Instead, we almost invariably find change occurring in *power law event distributions* in which vast numbers of small changes are punctuated by infrequent large changes.[33] Complex adaptive systems build *adaptive capacity* based on this kind of change regime, not based on a normal distribution. An ecosystem, for example, builds *resistance* capacity to withstand environmental

30. *See* MILLER & PAGE, *supra* note 10, at 216 ("[A]gents [in a complex adaptive system] find themselves in a path-dependent world, in which early choices determine future possibilities."). Path dependence is evident in the way species assemble in an ecosystem. *See* Levin, *supra* note 20, at 433.

31. *See* Levin, *supra* note 20, at 433 ("The ontogeny of an ecosystem represents a particular form of evolution . . . [in which] flows become modified, and the system assumes shape through a process of self-organization.").

32. Thus self-organized criticality is "a generic pattern of self-organized non-equilibrium behavior in which there are characteristic long-range temporal and spatial regularities." PETER COVENEY & ROGER HIGHFIELD, FRONTIERS OF COMPLEXITY: THE SEARCH FOR ORDER IN A CHAOTIC WORLD 432 (1995).

33. *See* MILLER & PAGE, *supra* note 10, at 165–77.

changes such as fire regimes, and builds *resilience* capacity to rebound from severe incidents.[34]

Notwithstanding the remarkable capacity of complex adaptive systems to maintain their properties over time, we must return to the cold, hard truth that all systems ultimately are built on deterministic rules that cannot be violated. There is a limit to the resistance and resilience of any complex adaptive system, and if pushed hard enough or persistently enough, a system might move into a *phase transition* through which a radically new network architecture is installed.[35] Moreover, just as nonlinear relationships define agent interaction, the system phase transition may occur as a sharp discontinuity "tipping point" and the new regime may "lock in" through path dependent effects. Many ecologists fear that climate change, for example, may be the agent of phase transitions in ecosystems around the globe, and that these transitions may be irreversible.[36]

B. Law's Complexity

I have used ecosystems to describe the building blocks of complex adaptive systems theory because the proposition that ecosystems are complex adaptive systems is entirely noncontroversial. Making the jump from physical and biological systems to social systems has seen controversy for the obvious reason that humans are the intentional

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34. *See* C.S. Holling & Lance H. Gunderson, *Resilience and Adaptive Cycles*, *in* PANARCHY: UNDERSTANDING TRANSFORMATION IN HUMAN AND NATURAL ECOSYSTEMS 25–62 (Lance H. Gunderson & C.S. Holling eds. 2002).

35. *See* Levin, *supra* note 20, at 433 (discussing "the potential for threshold behavior and qualitative shifts in system dynamics under changing environmental influences").

36. Consider, for example, the effect of rising temperatures in tundra regions, where permafrost conditions have been maintained for centuries, once methane gases trapped in the frozen soil stratum are released. *See* Katey M. Walter et al., *Methane Bubbling from Siberian Thaw Lakes as a Positive Feedback to Climate Warming*, 443 NATURE 71 (2006). The effect leads to a positive feedback loop: as the greenhouse gases are released, they contribute to warming that melts the tundra faster, which releases more greenhouse gases more rapidly, and so on. *See* Katey M. Walter et al., *Methane Bubbling from Northern Lakes: Present and Future Contributions to the Global Methane Budget*, 365 PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A 1657 (2007). Ecologists believe these and other transformations in the tundra "could be a one-way ticket." John Bohannon, *The Big Thaw Reaches Mongolia's Pristine North*, 319 SCIENCE 567, 568 (2008).

designers of social systems. Spiders and grasshoppers and plants are not conscious of their network or of the grassland ecosystem, and certainly do not purposefully try to alter them. Humans are a different story. Yet people have long appreciated that they are part of social *systems* and that remarkable system properties emerge from their collective interactions. Adam Smith's theory of the invisible hand of markets is a theory of emergent properties.[37] It seems implausible that there would not be many such invisible hands at work throughout social worlds. Complex adaptive systems theory is aimed at making the invisible hands of markets and other social systems visible.

One might accept the presence of invisible hands throughout social life and the value of using complex adaptive systems theory to understand them better, but nonetheless resist applying complex adaptive systems theory to *legal* systems on the ground that the law is where humans write the rules for other social systems. But this misses two fundamentals. First, the legal system, as a source of rules for regulating other social systems, should take into account how those systems operate. If one wishes to regulate a complex adaptive social system, one ought to think like a complex adaptive social system. Second, law, as in the collection of rules and regulations, is the product of the legal system, a collection of people and institutions. Law, in this sense, is simply an emergent property of the legal system the same way prices are an emergent property of markets.

It defies reason to believe that the legal system would be the one social world in which invisible hands are not at work. Rather, all of the ingredients and properties of complex adaptive systems are there at work in the legal system. As the following chart shows, the legal system exhibits all of the *agent* properties of complex adaptive systems.

37. *See* BEINHOCKER, *supra* note 8, at 26, 38; MILLER & PAGE, *supra* note 10, at 106.

Agent Property	CAS Theory Principles	Legal System Examples
heterogeneity	complex adaptive systems consist of a number of different classes of autonomous agents	• legislatures, courts, and agencies • lawyers and clients • federal, state, and local
deterministic rules	the agents interact with and adapt to each other according to deterministic rules	• courts interpret legislative acts • legislatures overrule courts • superior courts reverse or affirm lower courts • legislatures delegate to agencies • agencies implement statutes • courts review agency action • lawyers challenge all of the above
nonlinear relationships	the agent interaction rules do not produce behavior that is in continuous proportionate relationships over time; sharp tipping points and discontinuities frequently occur	• political leadership of legislatures changes • new statutes are enacted or old statutes are amended or repealed • new agency heads are appointed and change policy direction • courts overrule precedent unexpectedly, but infrequently
network connectivity of feedback	there is high connectivity, or feedback, between agents, parts, and scales of the system, creating a network of nodes and channels through which information (energy, money, food) flows	• systems of court appeals • agency hierarchical structure • legislative oversight of agencies through hearings and reports • judicial review of agencies • legislative response to judicial statutory interpretations • employees move within and between institutions

Similarly, as the following chart suggests, both the common law and public law systems exhibit complex adaptive *system* properties emerging from the agent interactions.

System Property	CAS Theory Principles	Legal System Examples
emergence and aggregation	as system scope grows, system behavior emerges from the aggregation of network causal chains which cannot be explained by examining any isolated part of the system	• the Endangered Species Act (ESA), enacted in 1973, has been amended several times, implemented through rules and policies of several administrations, and interpreted by courts in numerous cases[38] • the question "what is ESA law?" thus cannot be answered solely by consulting just the statute, or the cases, or the policies
path dependence	the next state of the system depends on the information that has flowed through the system in all prior states	• the ESA and most of today's environmental laws were originally enacted over 25 years ago, and many retain much of their original structure • judicial interpretations continuously build on prior cases[39] • agencies continuously refine rules through amendments and implement through policies
self-organized structure	as system scale grows, the system tends to organize around a set of deep structural rules that lend stability to system behavior	• the common law evolved deep doctrinal rules that lent stability to the system over time
critical states	notwithstanding deep stable structure traits, dynamic qualities of the system (nonlinear	• the common law also continuously changes as new knowledge and new circumstances enter the

38. For a thorough overview of the history and implementation of the Endangered Species Act, see STANFORD ENVTL. L. SOCIETY, THE ENDANGERED SPECIES ACT *passim* (2001) and MICHAEL J. BEAN & MELANIE J. ROWLAND, THE EVOLUTION OF NAT'L WILDLIFE LAW 193–276 (3d ed. 1997).

39. The classic treatment of path dependence in the law is, of course, found in Oliver Wendell Holmes, Jr., *The Path of the Law*, 10 HARV. L. REV. 457 (1897). For modern versions, see Oona A. Hathaway, *Path Dependence in the Law: The Course and Pattern of Change in the Legal System*, 86 IOWA L. REV. 601 (2001); Mark J. Roe, *Chaos and Evolution in Law and Economics*, 109 HARV. L. REV. 641 (1996).

System Property	CAS Theory Principles	Legal System Examples
	relationships, network feedback) lean toward change at the "surface" of the system, so that the system evolves under a "stable disequilibrium" set of behaviors, sometimes near or "on the edge of" the chaotic	system[40] • American property law, for example, changed significantly from British property law over time, responding to different conditions between the two societies and land domains[41]
power law event distribution	the distribution of the "size" of events in the system does not exhibit a binomial normal distribution, but rather takes on asymptotic properties with many "small" events and very few "large" events	• the Supreme Court very infrequently overrules precedent • a very small fraction (0.025 percent) of the 4 million judicial opinions reported in LexisNexis databases accounts for over 80 percent of all citations.[42]
adaptive resistance and resilience capacity	as a result of these internal behaviors, the system as a whole proves *resistant* to environmental perturbations and *resilient* at returning to or near its self-organized critical state following a perturbation	• congressional efforts to overhaul the ESA to protect "property rights" have failed miserably for 20 years • indeed, few environmental laws have received even congressional fine tuning since the Clean Air Act Amendments of 1990
phase transitions	if pushed too far from its self-organized critical state, however, either by a massive perturbation or by constant pressure from less severe perturbations, the CAS could "tip" in a	• to repel congressional reform efforts, Bruce Babbitt, as Secretary of the Interior in the 1990s, engaged in a series of administrative reforms, dramatically changing the way the ESA is implemented as well as its long-term

40. As Justice Scalia has famously observed, under the common law "changed circumstances or new knowledge may make what was previously permissible no longer so." Lucas v. S.C. Coastal Council, 505 U.S. 1003, 1031 (1992).

41. *See* John G. Sprankling, *The Antiwilderness Bias in American Property Law*, 63 U. CHI. L. REV. 519 (1996) (tracing the evolution of American property law with respect to wilderness areas, which responded to conditions much different from those in Britain that shaped early common law property doctrine).

42. Thomas A. Smith, *The Web of Law*, 44 SAN DIEGO L. REV. 309, 324–28 (2007).

System Property	CAS Theory Principles	Legal System Examples
	nonlinear and potentially irreversible move into a new set of behaviors	political status[43]

To be sure, showing that complex adaptive systems theory maps well onto the legal system does not, I confess, prove that the legal system is a complex adaptive system. But that is not the test to which the usefulness of complex adaptive systems theory should be put. Rather, it should suffice to show that the model of complex adaptive systems provides useful design lessons for the legal system—that if we think of the law as a complex adaptive system, we are better at designing law as a system. I turn to that question in the next section.

II. IMPLICATIONS FOR LEGAL SYSTEM DESIGN

By making the invisible hands of physical, biological and social worlds visible, even if only opaquely, complex adaptive systems theory has the potential for vastly improving our understanding of their inner workings and the effects of change on system futures. Change in social systems is often beyond human control, in which case how we respond to such external change events could be guided by complex adaptive systems theory. But in social systems, change very often is the specific intent of human intervention, in which case knowing how the system responds to change should be an important factor in the design of the instrument of change. The problem for both types of change is that by their very nature, complex adaptive systems make tinkering an undertaking plagued by uncertainty. Law is no exception.

43. I cover this series of reforms in detail in J.B. Ruhl, *Endangered Species Act Innovations in the Post-Babbittonian Era—Are There Any?*, 14 DUKE ENVTL. L. & POL'Y F. 419 (2004), and J.B. Ruhl, *Who Needs Congress? An Agenda for Administrative Reform of the Endangered Species Act*, 6 N.Y.U. ENVTL. L.J. 367 (1998).

A. The Challenges of Tinkering with Complex Adaptive Systems

Returning to the example of ecosystems, the story of the spiders and the grasshoppers speaks volumes about the challenges of tinkering with complex adaptive systems to produce specific intended outcomes. In ecosystems, something so small as changing the type of spider in the species assembly can alter something so large as the vegetative pattern. Complex adaptive systems generally display this *sensitivity to initial conditions*, whereby relatively small changes in the setup conditions can make a relatively large difference in the system dynamics.[44]

How change happens in response to different conditions depends largely on the feedback it sends to agents in the system. When the spiders were changed in the grassland ecosystem, the grasshopper responded using feedback to test new foraging strategies. There were, of course, a limited number of options available to the grasshoppers in terms of traits and behaviors to adjust, combinations of which formed its *fitness landscape,* showing how well each combination would fare over time.[45] But in testing combinations, the grasshopper faces *conflicting constraints* as changing one trait or behavior may on its own look promising, but may have adverse effects in other respects.[46] For example, staying perfectly still might be a good strategy for avoiding sit and wait spiders, but it also limits access to food sources.

Change in our grassland ecosystem does not end with the grasshopper's adaptive move. Say the grasshopper devises a strategy that balances conflicting constraints and achieves a relatively high "peak" on its fitness landscape. What will the spiders do then? Of course the spiders will test new strategies as well, faced with their own fitness landscape (which the grasshoppers' new strategy has

44. *See* Levin, *supra* note 20, at 433 ("[T]he potential for alternative development pathways [for ecosystems] is enormous.").

45. For an extensive and cogent description of fitness landscapes, see STUART KAUFFMAN, AT HOME IN THE UNIVERSE 26-27, 154-67 (1995).

46. *See id.* at 170 ("[T]he contribution to overall fitness of the organisms of one state of one trait may depend in very complex ways on the states of many other traits.").

adjusted) and set of conflicting constraints. And so the arms race of *co-evolutionary fitness landscapes* is in play—like Alice in the Red Queen's land, all species must run in the race just to stay in place.[47]

The co-evolution of fitness landscapes confounds efforts to design change in complex adaptive systems with specific intended results. Consider kudzu and the many other introductions of species humans have designed to "solve" a "problem" with an ecosystem, only to have the plan backfire wildly.[48] We repeatedly delude ourselves that we can isolate parts of ecosystems and adjust them without affecting anything else in the ecosystem, when in fact the *irreducibility of system behavior* requires us to take ecosystem-level properties into account whenever we touch any part of the system.[49]

Of course, given the complexity of ecosystems, we have no practical choice but to manage them through their parts as we perceive them. So we are bound to misfire on occasion and get it right on others. When we realize we have made a mistake (as we know we did with kudzu), we often find an *irreversibility of system states* forces us to live with the consequences.[50] Complex adaptive systems cannot be rewound and restored to prior states. On the other hand, when we find to our delight that we have achieved success, as the grasshoppers might eventually have found in their response to the new spider regime, we must be mindful of the *impermanently optimizable fitness* of complex adaptive systems.[51] The arms race of co-evolving fitness landscapes requires constant adjusting to the coevolving fitness landscapes. There is no rest for the agents in a complex adaptive system.

47. Thus Murray Gell-Mann has explained that "[a]n ecological community consists, then, of a great many species all evolving models of other species' habits and how to cope with them." MURRAY GELL-MANN, THE QUARK AND THE JAGUAR: ADVENTURES IN THE SIMPLE AND THE COMPLEX 237 (1994).

48. *See* Peter M. Vitousek et al., *Biological Invasions as Global Environmental Change*, 84 AM. SCIENTIST 468 (1996). For a series of articles covering the invasive species issue comprehensively, see *Special Section: Population Biology of Invasive Species*, 17 CONSERVATION BIOLOGY 24 (2003).

49. Thus the futility, even folly, of employing reductionist methods of study for complex adaptive systems. *See* MILLER & PAGE, *supra* note 10, at 41–42.

50. *See* KAUFFMAN, *supra* note 45, at 23.

51. As the late Per Bak put it, "[t]he self-organized critical state with all its fluctuations is not the best possible state, but it is the best state that is dynamically achievable." PER BAK, HOW NATURE WORKS 198 (1996).

Inherently, therefore, complex adaptive systems exhibit *unpredictable future states*.[52] A system may be stable and predictable over some relevant time frame and scale, but it is never entirely static, and small changes in one condition can lead over time to large changes in another condition. For example, ecologists know climate change will change ecosystems, but at present they have only rough and tentative predictions for how, when, and where.[53] The chance of accurately predicting all that will change in a particular ecosystem if global temperatures rise by 2° C is slim; the chance that we could tinker in that process and thereby ensure a designed outcome is even more remote.[54]

B. Designing Law as a Complex Adaptive System

Law is an enterprise in inducing change in social systems, and here again the design issues of complex adaptive systems map well onto the legal system, as shown in the following chart.

Design Issue	Effects on CAS Design	Legal System Examples
sensitivity to initial conditions	due to feedback, nonlinearity, and emergence, relatively small changes in starting conditions can lead to relatively large differences in system	• what if William the Conqueror had lost? • what if someone other than Bruce Babbitt had been Secretary of the Interior in the 1990s?

52. Norman L. Christensen et al., *The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management*, 6 ECOLOGICAL APPLICATIONS 665, 669 (1996) ("[W]ith complexity comes uncertainty," thus "we must recognize that there will always be limits to the precision of our predictions set by the complex nature of ecosystem interactions.").

53. *See* Douglas Fox, *Back to the No-Analog Future?*, 316 SCIENCE 823 (2007) ("[I]f the climate changes over the next 100 years as current models predict, surviving species . . . are likely to be reshuffled into novel ecosystems unknown today.").

54. *See* Stefan Rahmstorf et al., *Recent Climate Observations Compared to Projections*, 316 SCIENCE 709 (2007).

Design Issue	Effects on CAS Design	Legal System Examples
	dynamics	
conflicting constraints on the fitness landscape	changes in one system component to promote fitness may be limited by properties of other system components also designed to promote fitness	• stricter environmental regulation has costly economic effects[55] • market-based solutions risk hot-spots of pollution[56]
co-evolutionary fitness landscapes and "Red Queen" effects	improvements in system A's fitness prompt adaptive co-evolutionary moves in other systems that could reduce system A's fitness possibilities under its new configuration, prompting yet further adaptation in system A	• landowners race to develop when they anticipate new more restrictive regulations[57] to which local jurisdictions respond by enacting "permit moratoria"[58]
irreducibility of system behavior	because emergence is a system scope phenomenon, system behavior cannot be understood and designed by studying a single agent or group of agents	• one cannot understand the common law of torts by studying one case, or even all the cases representing one doctrine • one cannot pinpoint the provision of the Endangered Species Act (ESA) that accounts for all the

55. The capital expenditures on pollution abatement required under environmental laws were over $5 billion in 2005 alone, and the operating costs were over $20 billion. *See* U.S. CENSUS BUREAU, ECONOMICS AND STATISTICS ADMIN., U.S. DEP'T OF COMMERCE, POLLUTION ABATEMENT COSTS AND EXPENDITURES: 2005 (2008), *available at* http://www.census.gov/prod/2008pubs/ma200-05.pdf. *See generally* Cass R. Sunstein, *Paradoxes of the Regulatory State*, 57 U. CHI. L. REV. 407, 409-11 (1990) (describing the costs and benefits of Clean Air Act regulation).

56. The widely acknowledged potential for regulatory pollutant and habitat trading programs to produce "hot spots" of adverse impact is discussed in general in James Salzman & J.B. Ruhl, *Currencies and the Commodification of Environmental Law*, 53 STAN. L. REV. 607, 638–40 (2000), and more specifically in connection with climate change policy in Michael P. Vandenbergh, *Climate Change: The Equity Problem*, 26 VA. ENVTL. L.J. 55, 60–61 (2008). *See generally* Noga Morag-Levine, *The Problem of Pollution Hotspots: Pollution Markets, Coase, and Common Law*, 17 CORNELL J. L & PUB. POL'Y 161 (2007).

57. *See* David Dana, *Natural Preservation and the Race to Develop*, 143 U. PA. L. REV. 655, 677–95 (1995).

58. *See* Tahoe-Sierra Preservation Council, Inc. v. Tahoe Regional Planning Agency, 535 U.S. 302 (2002).

Design Issue	Effects on CAS Design	Legal System Examples
		program's impacts on property rights
irreversibility of system states	because the present system state is a product of all information that has flowed through the system to that point in all past states, the system dynamics cannot be reversed to past states, but only steered into new directions approximating where the past might have led had different decisions been made then	• repeal of a regulatory law, or overruling of a precedent, cannot rewind the world back to the state that existed just prior to when the law or prior ruling was promulgated
impermanently optimizable fitness	because of co-evolutionary fitness landscape effects, superior fitness cannot be "locked in" permanently and attempts to do so may prove counter-productive	• the ESA, as powerful as it is today, stands no chance at conserving all endangered species in the face of climate change • making the ESA "stronger" could make it even less effective as a practical matter over time if property rights issues flare up
unpredictable future states	taking all of the complex adaptive system properties into account, the future states and "big" events of a system are not predictable over relevant time horizons	• Although we knew a severe hurricane would eventually land near New Orleans, Hurricane Katrina revealed the lack of sufficient planning and policy structure for response • If climate change plays out as expected, what will law look like in 25 years, and not just environmental law, but the law of insurance, contracts, financing, and other fields affected by climate change?

What lessons come out of this exercise? Many are possible, but three implications seem to me to be most prominent in terms of designing legal systems and laws. First, we must bear in mind that our normative goals for law and the legal system are premised on us believing we have the ability to isolate the "good" from the "bad" in the social system we hope to manage, when in fact that is impossible. Complex adaptive systems are not normatively good or bad—we impute those subjective judgments on them—and there is no way to extract the "bad" parts from a system without affecting what remains *unpredictably.*

Given this, the second lesson is that feedback and conflicting constraints make unintended consequences[59] and trade-offs[60] an inevitable product of our attempts to do just that—to focus legal initiatives on parts of a social system. Often we do in fact solve the problem the targeted part was causing, but because that part was connected to other parts, some of which we valued as "good," we cannot cut off the feedback through the network that regulating the "bad" part is bound to prompt.

This leads to the third and most important lesson—that law should be designed around the complex adaptive systems model, whereas generally it is not. Much of environmental regulation, for example, is based on "front-end" decision making premised on the belief that we can predict and assess all the consequences of a decision and take measures to facilitate the positive effects and mitigate the negative

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59. Unintended consequences are so common in law that one author has suggested there is a "law" of unintended consequences in law. *See* A. A. Sommer, Jr., *Preempting Unintended Consequences*, 60 LAW & CONTEMP. PROBS. 231, 231 (1997). A classic example is evidence that the restrictions on land use the Endangered Species Act imposes to protect endangered species have actually prompted habitat destruction as landowners attempt to prevent species that might come under the statute's protection from residing on their property, which only exacerbates the need for protection. *See* Dean Lueck & Jeffrey A. Michael, *Preemptive Habitat Destruction Under the Endangered Species Act*, 46 J.L. & ECON. 27 (2003).

60. Trade-offs also are common in law and policy. *See* John D. Graham & Jonathan Baert Wiener, *Confronting Risk Tradeoffs*, *in* RISK VERSUS RISK: TRADEOFFS IN PROTECTING HEALTH AND THE ENVIRONMENT 1–42 (John D. Graham & Jonathan Baert Wiener eds., 1995).

effects.[61] As Miller and Page explain, law is not alone in that respect, as social sciences in general have depended on such simplified models.

> Using traditional tools, social scientists have often been constrained to model systems in odd ways. Thus, existing models focus on fairly static, homogeneous situations composed of either very few or infinitely many agents (each of whom is either extremely inept or remarkably prescient) that must confront a world in which time and space matter little. Of course, such simplicity in science is a virtue, as long as the simplifications are the right ones. Yet, it seems as though the world we wish to know lies somewhere in between these extremes.[62]

Similarly, regulatory structures throughout the administrative state depend too heavily on simplified front-end models at the expense of procedures and standards for "back-end" monitoring of and adaptation to change through time and space.[63] I include in that assertion not just change in the social worlds in which law is operating, but change induced by the law itself. Law, as a complex adaptive system, coevolves with the social systems it aims to regulate, and thereby induces changes on itself. Discounting this possibility by loading all assessment of change in pre-decisional stages of regulation invites a stream of unintended consequences. Complex adaptive systems theory reveals that, while these consequences may be unanticipated, they should not be unexpected. Above all else, therefore, the theory of law's complexity counsels us to design law to think like complex adaptive system.

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61. For a thorough review and critique of "front-end" regulatory models, see SIDNEY A. SHAPIRO & ROBERT L. GLICKSMAN, RISK REGULATION AT RISK: RESTORING A PRAGMATIC APPROACH (2003); Sidney A. Shapiro & Robert L. Glicksman, *The Missing Perspective*, 20(2) ENVTL. F. 42 (2003).

62. MILLER & PAGE, *supra* note 10, at 5.

63. For an overview of such "adaptive management" models of regulation, see J.B. Ruhl, *Regulation by Adaptive Management—Is It Possible?*, 7 MINN. J.L. SCI. & TECH. 21 (2005).

CONCLUSION

The goal of a theory of law's complexity is not to work around the complexity of the legal system, but to immerse lawyers and legal institutions in it by making the invisible hands of law visible. What questions must we ask to make those invisible hands more visible? Taking a cue from Simon Levin's list of questions for ecology,[64] I suggest legal scholars focus on the following lines of research as they sort through what makes legal systems complex and not just complicated:

- What patterns exist in the distribution and organization of legal systems?
- Are these patterns uniquely determined by local conditions or are they historically and spatially contingent?
- How do legal systems become assembled over social time?
- How does evolution shape legal system properties?
- What are the relationships between legal system structure and functioning?
- Does evolution of legal systems increase resiliency or lead to criticality. Does it lead to the edge of chaos?

The general model of law as a complex adaptive system outlined above draws on examples and anecdotes to begin to answer those questions by mapping complex adaptive systems theory onto the legal system. But much more work is needed to build a robust, durable theoretical framework to guide practical decisions about legal design across many social contexts. One thrust of theoretical work will be to dig deeper into applied legal fields to increase the resolution of the theory. I have devoted attention in that respect to environmental and administrative law,[65] as have others,[66] and

64. *See* Levin, *supra* note 20, at 435.

65. *See* J.B. Ruhl, *Thinking of Environmental Law as a Complex Adaptive System: How to Clean Up the Environment by Making a Mess of Environmental Law*, 34 HOUS. L. REV. 933 (1997).

scholars from other fields have begun to apply complex adaptive systems theory to a wide range of contexts including administrative law,[67] mediation and alternative dispute resolution,[68] bankruptcy,[69] health law,[70] international law,[71] land use regulation,[72] intellectual property,[73] regulation of the internet,[74] and telecommunications.[75] The other necessary thrust of research will be empirical, with particular focus on the networks of legal systems[76] and identification of power law event distributions in the legal system.[77]

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66. *See* Gerald Andrews Emison, *The Potential for Unconventional Progress: Complex Adaptive Systems and Environmental Quality Policy*, 7 DUKE ENVTL. L. & POL'Y F. 167 (1996).

67. *See* Donald T. Hornstein, *Complexity Theory, Adaptation, and Administrative Law*, 54 DUKE L.J. 913 (2005).

68. *See* Robert A. Creo, *Mediation 2004: The Art and the Artist*, 108 PENN. ST. L. REV. 1017 (2004); Arthur B. Pearlstein, *The Justice Bazaar: Dispute Resolution through Emergent Private Ordering as a Superior Alternative to Authoritarian Court Bureaucracy*, 22 OHIO ST. J. ON DISP. RESOL. 739 (2007).

69. *See* Trujillo, *supra* note 11; Bernard Trujillo, *Self-Organizing Legal Systems: Precedent and Variation in Bankruptcy*, 2004 UTAH L. REV. 483 (2004).

70. *See* Debra Gerardi, *The Culture of Health Care: How Professional and Organizational Cultures Impact Conflict Management*, 21 GA. ST. U. L. REV. 857 (2005).

71. *See* Mark D. Belcher & James W. Newton, *International Legal Development: A Complex Problem Deserving of a "Complex" Solution and Implications for the CAFTA Region*, 12 SW. J. L. & TRADE AM. 189 (2006).

72. *See* John Mixon & Kathleen McGlynn, *A New Zoning and Planning Metaphor: Chaos and Complexity Theory*, 42 HOUS. L. REV. 1221 (2006); John R. Nolon, *Champions of Change: Reinventing Democracy Through Land Law Reform*, 30 HARV. ENVTL. L. REV. 1 (2006).

73. *See* Andrea M. Matwyshyn, *Organizational Code: A Complexity Theory Perspective on Technology and Intellectual Property Regulation*, 11 J. TECH. L. & POL'Y xiii (2006); Deborah Tussey, *Music at the Edge of Chaos: A Complex Systems Perspective on File Sharing*, 37 LOY. U. CHI. L.J. 147 (2005).

74. *See* Susan Crawford, *Shortness of Vision: Regulatory Ambition in the Digital Age*, 74 FORDHAM L. REV. 695 (2005).

75. *See* Barbara A. Cherry, *The Telecommunications Economy and Regulation as Coevolving Complex Adaptive Systems: Implications for Federalism*, 59 FED. COMM. L.J. 369 (2007).

76. Theodore Y. Blumoff, *On the Nature of the Action-Omission Network*, 24 GA. ST. U. L. REV. 1001 (2008); Barbara A. Cherry, *Maintaining Critical Rules to Enable Sustainable Communications Infrastructures*, 24 GA. ST. U. L. REV. 945 (2008); Gregory Todd Jones, Douglas H. Yarn, Reidar Hagtvedt, & Travis Lloyd, *Homogeneity of Degree in Complex Social Networks as a Collective Good*, 24 GA. ST. U. L. REV. 929 (2008); Daniel M. Katz, Derek K. Stafford, & Eric Provins, *Social Architecture, Judicial Peer Effects and the "Evolution" of the Law: Toward a Positive Theory of Judicial Social Structure*, 24 GA. ST. U. L. REV. 975 (2008); Bernard Trujillo, *Randomness and Complexity in Social Explanation: Evidence from Finance and Bankruptcy Law*, 24 GA. ST. U. L. REV. 911 (2008).

77. *See* Thomas Bak, *Power Law Distributions and the Federal Judiciary*, 46 JURIMETRICS J. 139 (2006) (filings per district follow a power law); Daniel A. Farber, *When the Court Has a Party, How Many "Friends" Show Up? A Note on the Statistical Distributions of Amicus Brief Filings*, 24 CONST. COMMENT. 19 (2007) (amicus brief numbers do not follow a power law); Daniel A. Farber, *Earthquakes and Tremors in Statutory Interpretation: An Empirical Study of the Dynamics of Interpretation*, 89

Revealing the unpredictable qualities of legal systems through this kind of research should lead not to a sense of futility for law, but rather to an understanding of law as a rich and dynamic system that demands our active participation. Thinking of law as a complex adaptive system reveals the importance of laws and lawyers as integral parts of law's fitness landscape, but just as surely reveals the importance of humility. We will never get the legal system "just right," at least not for long, but if we are mindful of its properties and the need for continuous work at living within its stable disequilibrium, we can hope to keep it fit indefinitely.

MINN. L. REV. 848 (2005); David G. Post and Michael B. Eisen, *How Long is the Coastline of the Law? Thoughts on the Fractal Nature of Legal Systems*, 29 J. LEGAL STUD. 545 (2000); Smith, *supra* note 42.