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# The Arrow of the Law in Modern Administrative States: Using Complexity Theory to Reveal the Diminishing Returns and Increasing Risks the Burgeoning of Law Poses to Society

J.B. Ruhl

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# The Arrow of the Law In Modern Administrative States: Using Complexity Theory to Reveal the Diminishing Returns and Increasing Risks the Burgeoning of Law Poses to Society

*J.B. Ruhl* \*  
*Harold J. Ruhl, Jr.*\*\*

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\* Assistant Professor of Law, Southern Illinois University School of Law. I am thankful to Arnold Reitze and Pat Kelley for their helpful comments on early drafts of this Article, and to Southern Illinois University for the research support that made my contributions possible. Please direct comments to [jbruhl@siu.edu](mailto:jbruhl@siu.edu).

\*\* Professional Engineer, Durham, Connecticut. Please direct comments to [hjr@connix.com](mailto:hjr@connix.com).

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## INTRODUCTION

Was the Constitution an exercise in building a social system or a social structure? To some that question may pose a distinction without a difference, but emerging theories regarding the evolution of adaptive systems suggest important differences between the behavioral qualities that define society as a dynamical operating system versus the characteristics of society as a finished structure. One can scour the Constitution and find no indication of how society is supposed to look in the end or at any particular point along its path. By contrast, today's society seems fixated not on the sociolegal *system*, but on the TV-screen picture of what society should look like at any moment. Our heavily-governed society appears willing at every turn to subvert our constitutional system by twisting, jiggling, bending, and adjusting the picture of the moment to its liking. Alas, every time society thinks it has tuned the picture into focus, when it sits down to enjoy the program, the static and distortion have returned. The distinction between the mechanisms that move society along its path and the vision of how society should look at any instant goes to the very core of legal theory.

This Article uses tools from the emerging field of complexity theory to explore the role law plays in the evolution of the sociolegal system and the way in which the use of law to "tune" the picture of modern society has contributed to the increasing fragility of that system. Adaptive systems, which by their nature are generally nonlinear, dynamical, and complex in their behavior,<sup>1</sup> are the subject matter of complexity theory.<sup>2</sup> We contend

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<sup>1</sup> A system exists whenever two or more agents interact. The system is described as linear when the relationship of the agents' interactions can be described in strictly proportional terms (e.g.,  $y = 2x + 3z$ ), meaning that "we can get a value for the whole by adding up the value of its parts." JOHN HOLLAND, *HIDDEN ORDER* 15 (1995). For example, the fuel consumption of a plane might depend on the plane's velocity, altitude, size, and other variables operating in a linear relationship. See P.G. DRAZIN, *NONLINEAR SYSTEMS* 1 (1992). Many systems, however, are nonlinear in that the relationships of the agents represent "a feedback loop in which the output of an element is not proportional to its input." *Id.* at 1-2. Such a nonlinear system is considered dynamical if the agents' relationships evolve with time or with some variable like time. See *id.* at 1. The classic example of a nonlinear system is the relationship between a predator population and its prey. See HOLLAND, *supra*, at 16-18. The population of either over time depends on the population of the other over time. See *id.* Moreover, the system relationships may progress through different transient states and ultimately into an enduring, steady-state relationship over time. See *id.* The sociolegal

that the sociolegal system exhibits the qualities of adaptive systems, and that our understanding of its evolutionary process and direction can be improved through application of complexity theory.

We begin Part I of this Article by using examples from environmental law to describe how the basic complexity theory model of dynamical systems can explain the behavior and evolution of the sociolegal system.<sup>3</sup> This leads inevitably to exploration of

system, given its tremendous number of components and constantly changing environmental conditions, will likely never escape the transient state, but this observation does not prevent using complexity theory to describe where the sociolegal system is headed.

<sup>2</sup> Complexity theory refers to the body of literature and research devoted to studying and understanding the transient and steady-state behavior of some nonlinear dynamical systems. Complexity theory thus has been described as "the study of the behavior of macroscopic collections of [interacting] units that are endowed with the potential to evolve in time." PETER COVENEY & ROGER HIGHFIELD, *FRONTIERS OF COMPLEXITY* 7 (1995). Complexity theory embraces the more popularized branches of chaos theory and catastrophe theory, and as such is an overarching field of mathematical analysis of the behavior of nonlinear dynamical systems. The study of such systems can be quite technical in substance. *See, e.g.*, HOLLAND, *supra* note 1 (explaining nonlinearity of predator-prey relationship). However, many of the recent and most influential works in the field focus on applications of the technical theory to real world phenomena, such as biological evolution. *See, e.g.*, JOHN L. CASTI, *COMPLEXIFICATION* 94, 210-11, 252-53 (1994) (applying technical systems theory to insect population dynamics, technological disasters, and water flow); JACK COHEN & IAN STEWART, *THE COLLAPSE OF CHAOS* (1994) (applying technical systems to biological, intellectual, and cultural evolution); *COMPLEXITY: METAPHORS, MODELS, AND REALITY* 185, 245, 287 (George Cowan et al. eds., 1994) (applying technical systems theory to immunology, brain circuits, and molecular biology); MURRAY GELL-MANN, *THE QUARK AND THE JAGUAR* 69-70, 246-48, 252 (1994) (applying technical systems theory to biological evolution, reproduction, and diversity of ecological communities); BRIAN GOODWIN, *HOW THE LEOPARD CHANGED ITS SPOTS* 187-95 (1994) (applying technical systems theory to origin of life, ant colonies, and play-like behavior); STUART KAUFFMAN, *AT HOME IN THE UNIVERSE* 58-61, 74-80, 245-71 (1995) (applying technical systems theory to organizational development, reaction networks, and homeostasis); KEVIN KELLY, *OUT OF CONTROL* 86-90 (1994) (applying technical systems theory to co-evolutionary games).

<sup>3</sup> We have developed in other articles the basic model of how the sociolegal system can be portrayed as a complex adaptive system and how the findings of complexity theory can contribute to an understanding of the mechanics of how that system behaves and evolves. *See generally* J.B. Ruhl, *Complexity Theory as a Paradigm for the Dynamical Law-and-Society System: A Wake-Up Call for Legal Reductionism and the Modern Administrative State*, 45 *DUKE L.J.* 849 (1996) [hereinafter Ruhl, *Complexity Theory as a Paradigm*] (setting forth general behavioral model); J.B. Ruhl, *The Fitness of Law: Using Complexity Theory to Describe the Evolution of Law and Society and its Practical Implications for Democracy*, 49 *VAND. L. REV.* 1407 (1996) [hereinafter Ruhl, *The Fitness of Law*] (setting forth general evolutionary model); Harold J. Ruhl, *Brief Discussions of: Truth, Axiomatic Systems, the Science of Complexity, Non-Linear Dynamic Systems, a New Understanding of Entropy, and a New Look at Time's Arrow, as Applied to Understanding the Structure and Behavior of Our World, Particularly the Origins of Life, and Other Manifestations of Far from Equilibrium Systems Including the Origins and Risks of Sustained*

the “arrow” of sociolegal evolution in our current medium of American politics — the administrative state.<sup>4</sup> All complex

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*Positive Economic Growth, and the Origins of Organizational Error in and the Consequent Collapse of Politics* (last modified Jan. 23, 1997) <<http://www.connix.com/~hjr/model01.htm>> [hereinafter Ruhl, *Brief Discussions*] (providing internet world wide web page with detailed technical explanations of complexity theory and its potential applications to various social issues).

The subject of this Article is the direction in which those behavioral and evolutionary mechanics are leading the sociolegal system given its current transient state. Other authors have described how complexity theory or branches of it help explain how law behaves and evolves generally. See generally Vincent Di Lorenzo, *Legislative Chaos: An Exploratory Study*, 12 YALE L. & POL'Y REV. 425, 432-35 (1994) (developing model for legislative decision-making based on chaos theory); Thomas Earl Geu, *The Tao of Jurisprudence: Chaos, Brain Science, Synchronicity, and the Law*, 61 TENN. L. REV. 933, 942-75 (1994) (discussing potential significance of chaos and emergence to legal theory); Andrew Hayes, *An Introduction to Chaos and the Law*, 60 UMKC L. REV. 751, 764-72 (1992) (discussing chaos theory and its application to judicial decision making); Mark J. Roe, *Chaos and Evolution in Law and Economics*, 109 HARV. L. REV. 641 (1996) (modifying classical legal evolutionary model to accommodate concepts from chaos theory, path dependence and modern evolutionary theory); Robert E. Scott, *Chaos Theory and the Justice Paradox*, 35 WM. & MARY L. REV. 329 (1993) (applying chaos theory to legal dilemma between “present justice” and “future justice”). Several other works discuss nonlinear dynamical systems analysis, sometimes very briefly, in specific legal settings. See Lawrence A. Cunningham, *Capital Market Theory, Mandatory Disclosure, and Price Discovery*, 51 WASH. & LEE L. REV. 843, 854-71 (1994) (applying chaos theory to capital market regulation); Lawrence A. Cunningham, *From Random Walks to Chaotic Crashes: The Linear Genealogy of the Efficient Capital Market Hypothesis*, 62 GEO. WASH. L. REV. 546, 571-608 (1994) (applying chaos theory to capital market regulation); Michael J. Gerhardt, *The Role of Precedent in Constitutional Decisionmaking and Theory*, 60 GEO. WASH. L. REV. 68, 114 (1991) (explaining Supreme Court constitutional jurisprudence using, among other mediums, discussion of chaos theory); Glenn Harlan Reynolds, *Chaos and the Court*, 91 COLUM. L. REV. 110, 113-14 (1991) (explaining Supreme Court constitutional jurisprudence using chaos theory); William H. Rodgers, Jr., *Where Environmental Law and Biology Meet: Of Pandas' Thumbs, Statutory Sleepers, and Effective Law*, 65 U. COLO. L. REV. 25, 56-74 (1993) (discussing chaos theory surfacing in evolutionary biology commentary as metaphor for evolution of environmental law).

<sup>4</sup> The term “administrative state” connotes that two conditions exist in the political structure of the society. First, the political structure is based on a state model rather than a clan or tribal system. In states, there are more established and legitimated features of territorial organization, differentiation by class and occupation rather than by kinship, monopoly of force, authority to mobilize resources and personnel, and legal jurisdiction. See JOSEPH A. TAINTER, *THE COLLAPSE OF COMPLEX SOCIETIES* 26-28 (1988). The second condition is that these features of the state have become highly articulated through a bureaucratic, rather than feudal, model of organization and distribution of power. See ROGER D. MASTERS, *THE NATURE OF POLITICS* 187-203 (1989) (describing development and function of bureaucracy). Through the rule of law, highly centralized and developed bureaucracies facilitate the coercion and coordination of behavior needed to support very large societies, but they also exact a resource cost on the society. The subject of this Article is what happens when this administrative state — in particular, the legal structure within which it is embedded — becomes so large that the costs associated with its further growth exceed the benefits conferred on the society.

dynamical systems have an arrow of irreversibility; their evolutionary processes cannot be put into reverse so as to re-create the past. Law shares this property. It unfolds as part of a sociolegal system that could no more return to a prior point on its path than could the weather be reversed. Hence the weather and other complex dynamical systems, such as ecosystems, economies, brains, and, we posit, the law, all have their directional arrows. The challenge is determining the directions in which the arrows point.

To learn more about the arrow of law, we then delve more deeply into the findings emerging from applications of the complexity theory model in two diverse but converging fields. First, we examine the archaeological research dealing with the collapse of organized, governed, hierarchical, centralized, productive societies — societies operating through highly developed social structures. Work in this field, particularly that of Joseph Tainter,<sup>5</sup> has revealed how societies increase their structural complexity to confront internal and external sources of stress. As any one component of society (e.g., the economy) becomes more structured, other components (e.g., communications) may also have to become more structured simply to coexist with the first component. In this way, the relationships between components of this complex social structure begin to display the complex behavior generally associated with nonlinear dynamical systems.

At a point along the curve of investment in more social structure, a society's further investment leads to decreasing marginal benefits in terms of promoting adaptive social behavior. The historical record evidences that when this point is reached, the social system usually experiences rapid deconstruction. We extend Tainter's theories explaining why this collapse of social structure occurs to include law as a factor that contributes to increasing social structure and its decreasing benefits. The administrative state's mistaken premise has been that increasing the complexity of sociolegal *structure* leads inexorably to an increase in the adaptability with which the sociolegal system operates and evolves.<sup>6</sup> We argue that the opposite is true.

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<sup>5</sup> See TAINTER, *supra* note 4, at 127-92 (explaining relationship between complexity and collapse).

<sup>6</sup> Unfortunately, "complex" is the best term to use to describe both the structure and

Second, we discuss theories of technology, in particular those of Stuart Kauffman<sup>7</sup> and Edward Tenner.<sup>8</sup> These theories demonstrate the nonlinearity of technological advancement and the potential for social vulnerability that accompanies increasingly advanced and interrelated technology systems. The technological apparatus of modern developed nations, though a source of great problem-solving power, is also a source of social fragility as ever smaller “bugs” in the technology can lead to ever larger dislocations in society. Eventually, no disruption is less than critical to the system. Analogizing from those findings to the legal system and the ever-expanding volume, intricacy, and inter-relatedness of laws, we explore the potential for failure of the adaptiveness of legal institutions.

The discussion of complexity theory and its use in the fields of archaeology and technology reveals three overarching themes. First, evolving dynamical social systems tend towards increasing use of complex structures to solve problems posed both from within the system and from the outside environment. Second, although complex structures initially enhance complex, adaptive behavior in society, with increasing investment in structural complexity, a system eventually begins to experience diminishing returns in terms of that investment’s contribution to long-term sustainability of the system behavior. Third, at the point where the cost of investing further in complex structures exceeds the problem-solving benefits, the system becomes vulnerable to collapsing into a simpler mode of behavior. This collapse may be its sole remaining survival response to stress. Without some limiting force on the tendency of a dynamical social system to increase its structural complexity as its principal response to

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the behavior of many nonlinear dynamical systems. When referring to structure, complexity generally means many system components, complicated organizations, intricate details, and so on. When referring to behavior, complexity generally is associated with adaptive and robust sustainability of the system. The distinction is crucial for, as we show herein, a simply structured system could behave complexly, and a complexly structured system could behave simply. *See generally infra* text accompanying notes 23-42 (discussing complexity of systems and behavior). Hence we are left with no choice but to distinguish carefully in our two uses of the term “complex” throughout this Article and to ask the reader to keep the distinction in mind.

<sup>7</sup> See KAUFFMAN, *supra* note 2.

<sup>8</sup> See EDWARD TENNER, *WHY THINGS BITE BACK* (1996).



system stress, the system will become increasingly susceptible to behavioral failure.

In Part II of the Article, we meld this lesson from complexity theory into a model of the “arrow of law” in the complexly structured administrative state. As the archaeological record demonstrates, states did not emerge as a form of social structure until about six thousand years ago. Administrative forms of state structure are even more recent — about three thousand years old. Administrative states as heavily endowed with centralized bureaucracy, regulation, litigation, and management as are many modern societies are a phenomenon of only the past few centuries. The highly structured form of the modern administrative state is thus an unprecedented development in history and the pinnacle of the burgeoning of law and its institutions.<sup>9</sup>

Is the modern administrative state immune to the features of dynamical systems revealed by complexity theory? We believe not. Rather, we posit that the administrative state, in the absence of some limiting force, may reach a point after which it enters a cycle leading towards diminishing returns on investment in law and increasing vulnerability to behavioral collapse of the sociolegal system. That cycle has five steps: (1) society’s effort to create predictable, stable, picture-perfect sociolegal outcomes leads it to rely increasingly on new and more interrelated laws to fine tune its picture at the moment; (2) which leads to increasing stratification of subgroups in society as each new law produces its unique sets of “winners” and “losers” in terms of economic and social impact of those laws; (3) which leads to increasing numbers of subgroups and decreasing cross-membership between subgroups as members of society increasingly define themselves according to highly personal sets of outcomes under the vast array of laws; (4) which leads to increasing inequality in society as the spectrum of possible outcomes broadens and people are distributed widely across that spectrum; (5) which, of course, is inconsistent with society’s idealized picture

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<sup>9</sup> The evolutionary arrow of this form of political organization is unmistakable. All form and manner of the management and resolution of social issues is channeled through the administrative state, leading to an ever-increasing complexity of sociolegal structure. The rule of law, in other words, only increases in complexity and in the resources it demands of society for its support.

of how it should be structured and thus leads the administrative state to produce more new laws, restarting the cycle. Ironically, new and supposedly improved laws, the fundamental weapon the administrative state uses to weed out inequality and other social maladaptations, fuel yet more inequalities and maladaptations.

Once the sociolegal system enters this cycle, the arrow of law does not point in a promising direction. The legal system eventually becomes part of the overall problem of diminishing returns on investment in sociolegal structure, thereby contributing fundamentally to society's increasing vulnerability to sociolegal instability. Left to its own devices, the administrative state has not demonstrated a propensity to correct the behavior that is the root of the problem. Rather, it doles out new and increasingly complicated laws, and creates ever more legal institutions to combat the social defects it spawned from the previous generation of laws. With each generation of increased legal structure, the administrative state becomes more insular, less subject to change, and thus even more committed to the direction indicated by the arrow of law. At some point the complexly structured administrative state ceases to be a problem-solving mechanism and becomes the problem.

In Part III of the Article, we offer two maxims that may be able to break the sociolegal system out of this cycle before behavioral collapse is inevitable. The first maxim is obvious — make less law. Its goal is simply to place a check on the tendency of society to increase legal structure. Among the various social institutions that can be used to address perceived problems, law should be used only when it offers the solution with the least potential to increase social complexity. To fulfill that goal, we explore several examples of how the modern administrative state's law-making approach and philosophy could be reconfigured to suppress the tendency to increase the legal structure's complexity, unless doing so is absolutely necessary.

The second maxim is more subtle — for any new laws that pass the necessity test of the first maxim, design them to minimize the number of and disparity between winners and losers. For example, we show how proposals for increased attention to cost-benefit analysis in law might run afoul of this maxim if not properly designed. The goal here is to decrease the social inequality and heterogeneity caused by legal institutions.

To be sure, these two requirements for new laws — one a gateway test and the other a design standard — may be just the beginning of how the system, rather than the picture, must be redesigned to ensure lasting sociolegal adaptiveness. We are not the first to propose measures on this scale.<sup>10</sup> But we believe we offer a new theoretical and practical basis for demonstrating that, unless the administrative state takes these steps, it may someday find itself as fodder for a future complexity theory study of how the arrow of law can be aimed foolishly towards the point of no return.

### I. WHY LAW'S PATH HAS AN ARROW — DESCRIBING LAW AS A COMPLEX ADAPTIVE SYSTEM

Oliver Wendell Holmes described change in law as following a “path” rather than some utterly random process.<sup>11</sup> His aim was to develop a theoretical understanding of law that would allow legal change to take place “with conscious articulate reference to the end in view.”<sup>12</sup> Holmes recognized, however, that as a practical matter the path of the future was dictated largely by traditions and incremental historical development along the path of the past.<sup>13</sup> Many scholars today have expanded Holmes's

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<sup>10</sup> One of the more influential commentaries to emerge in recent years regarding the direction of the modern administrative state is Philip K. Howard's somewhat rambling, largely anecdotally-based manifesto. Howard's work focuses on the symptoms of centralized, rationalized, bureaucratized government in the United States. See PHILIP K. HOWARD, *THE DEATH OF COMMON SENSE* (1994) (arguing for minimal role of government and for more flexible, streamlined administrative law process). Although we point out in this Article when we share in some of Howard's diagnoses, his analysis does not purport to offer a model for evaluating underlying systemic conditions or proposed remedies. His book, however, is invaluable for its collection of human interest stories of the manifestations of the phenomena we discuss herein. See *infra* Part II.A-B (discussing complexity problem in modern administrative state). Howard also demonstrates that one does not really need to use complexity theory, or any other fancy model of law and society, to sense that something is wrong with the system. See HOWARD, *supra*, at 22-29 (illustrating crushing complexity of legal bureaucracy).

<sup>11</sup> See O.W. Holmes, *The Path of the Law*, 10 HARV. L. REV. 457, 457-58 (1897) (arguing that development of law is not random but occurs as logical outgrowth of previously formulated legal principles).

<sup>12</sup> *Id.* at 469.

<sup>13</sup> See *id.* at 468-69. We would credit Holmes for forging the idea that where law is depends on all the prior points where law has been. However, we show herein why Holmes's effort to construct a legal theory based on some vision of an end point of law was misguided. See *infra* text accompanying notes 15-18 (suggesting that law moves along path

depiction of the path of law. They describe changes in law as being “path dependent” in that, at any moment, law’s position along its path of change is the result of many prior choices of direction at forks along the way.<sup>14</sup> When society chooses one of several possible branches at each decision node — for example, ban guns or don’t ban guns — the possibility of evolving along the other branches is necessarily foregone. Path dependence theory thus adds to Holmes’s path metaphor the variable of human selection of alternate paths and a deeper understanding of the consequences of that choice.

But path models of change in law fail to convey an essential characteristic of the process — law can only move in one direction along its path of change. The footsteps law leaves behind as it moves along its path do not simply rest unchanged, waiting for society to retrace its steps if it decides not to venture further down the chosen path.<sup>15</sup> Surely this is obvious to anyone who thinks about the problem. Consider, for example, the era of Prohibition ushered in with the Eighteenth Amendment<sup>16</sup> and ended by the Twenty-First Amendment.<sup>17</sup> This is the classic example of American society choosing one branch of the path of law and later, regretting the decision, trying to reverse direction and choose an alternate branch. Society’s progress between those two decision points had transformed the path of law forever. Society could not simply return to the first decision node,

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that can never be retraced).

<sup>14</sup> For example, in his discussion of path dependence theory, Professor Mark Roe examines how decisions made in the past commit a system to certain paths, thus limiting other options, perhaps even irreversibly. *See* Roe, *supra* note 3, at 643-44 (analogizing path dependency to winding, present-day road that tracks fur trader’s trail from past). As Roe explains,

[t]oday’s road, dependent on the path taken by the trader decades ago, is not the one that the authorities would lay down if they were choosing their road today. But society, having invested in the path itself and in the resources alongside the path, is better off keeping the winding road on its current path than paying to build another.

*Id.* at 643.

<sup>15</sup> Hence, despite the analogy path dependence theory offers for decisions about the future, we show herein why society cannot “consciously re-engineer our . . . system . . . by . . . returning to a branch node and going down another path.” *Id.* at 665.

<sup>16</sup> *See* U.S. CONST. amend. XVIII (repealed 1933).

<sup>17</sup> *See* U.S. CONST. amend. XXI.

pick a different branch of the path, and skip merrily along the new way as if nothing had happened.<sup>18</sup> When society wants to change the direction of law, it can make a sharp turn towards the path that might have been, but it can not retrace its steps. The path of the law is a one-way street; it has an arrow.

To create a coherent model of law's process of change, we turn to complexity theory and its study of adaptive systems. All such systems move along a path of change in a manner that is inherently dissipative in nature.<sup>19</sup> The weather, for example, unfolds continuously without ever repeating itself exactly. When the sun comes out after a storm, it does not replicate a prior sunny day. There is no reverse switch on such adaptive systems. We posit that law can be usefully modeled as a complex adaptive system. Further, the general model of change offered by complexity theory and insights emerging in specific applications of that model in other disciplines can greatly enhance our understanding of the arrow embedded in law.

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<sup>18</sup> If anything, Prohibition solidified organized crime in the United States and spread the culture and consumption of alcohol more widely through the population, two effects which could not easily be undone simply by repealing the Eighteenth Amendment. See generally SEAN DENNIS CASHMAN, *PROHIBITION: THE LIE OF THE LAND* (1981) (chronicling history and social consequences of Prohibition).

<sup>19</sup> The Nobel laureate Ilya Prigogine defined a dissipative system as one for which the driving force is the nonequilibrium flux of matter and energy through the system that increases order and sustainability in the system. See KAUFFMAN, *supra* note 2, at 21. Because these systems experience nonequilibrium in terms of input, they necessarily cannot be "reversed" so as to replicate the conditions of the system at a prior point in time. See *id.* An important focus of complexity theory research is whether dissipative systems can overcome the commonly posited drive towards disorder that many theorists believed to be associated with maximum entropy in systems that are in final thermodynamic equilibrium. In other words, can disorder on the input side lead to order on the output side, and if so, how? See *id.* 20-21 (explaining organization of nonequilibrium structures); *infra* note 65 (discussing complexity theory approaches to equilibrium question). Consistent with Prigogine's theorem, we conceive of order in the sociolegal system as being the system's computable component (structure) made possible by the axiomatic system we call law. We are concerned in this Article largely with the relationships in the sociolegal system between the quantity of this structure, the associated directed use of energy, and the system's consequential behavioral responses. We encourage the reader to explore further the underlying model suggested by Prigogine's theorem and its possible applications to various sociolegal issues at an internet world wide web page that contains an article written by Harold J. Ruhl. See Ruhl, *Brief Discussions*, *supra* note 3 (providing work in progress which uses formal axiomatic systems model to understand entropy, and thus system evolution, in new way).

### A. The General Model of Law as a Complex Adaptive System

Complexity theory is about the study of change in systems. While complexity theory is not the first model for examining the process of change in systems, it is the first fundamentally new way of approaching the question of change to emerge in decades.<sup>20</sup> Moreover, it has the unique quality of incorporating significant themes of other major theories of change, such as Newtonian physics and Darwinian biology, and applying the unified themes to systems as diverse as the weather and a dripping faucet.<sup>21</sup> Legal theory has been fascinated with the implications of those prior theories of change to law.<sup>22</sup> Similarly, the

<sup>20</sup> Several authors have detailed the histories of the development of complexity theory, which has been brought about largely through the efforts of the Santa Fe Institute. See generally JAMES GLEICK, *CHAOS* (1987) (discussing developments in chaos theory during 1970s); ROGER LEWIN, *COMPLEXITY: LIFE AT THE EDGE OF CHAOS* (1992) (recounting developments in complexity theory during 1970s); M. MICHAEL WALDROP, *COMPLEXITY: THE EMERGING SCIENCE AT THE EDGE OF ORDER AND CHAOS* (1992) (discussing development of complexity theory at Santa Fe Institute). Current information about the field is best obtained from the journal *COMPLEXITY* and from the internet world wide web pages of the Santa Fe Institute, *Studies in the Sciences of Complexity* (visited January 21, 1997) <<http://sfi.santafe.edu/sfi/publications/addison-wesley.html>>, and the Los Alamos Nonlinear Science Information Center, *Nonlinear Science e-Print Archive* (visited January 21, 1997) <<http://xyz.lanl.gov>>.

<sup>21</sup> Complexity theory's underlying premise is that "similar patterns of activity can arise in systems that differ greatly from one another in their composition and in the nature of their parts. . . . They all show similar types of dynamic activity — rhythms, waves that propagate in concentric circles or spirals that annihilate when they collide, and chaotic behavior." GOODWIN, *supra* note 2, at 77.

<sup>22</sup> For example, a number of late-nineteenth- and twentieth-century American legal theorists have expressly used Darwinian and other evolutionary models to explain the development of legal rules. See, e.g., E. Donald Elliott, *The Evolutionary Tradition in Jurisprudence*, 85 *COLUM. L. REV.* 38 (1985) (tracing evolution as common underpinning for different theories of law); Donald L. Horowitz, *The Qur'an and the Common Law: Islamic Law Reform and the Theory of Legal Change*, 42 *AM. J. COMP. L.* 233 (1994) (focusing on Islamic law reform and comparing to other legal systems); Herbert Hovenkamp, *Evolutionary Models of Jurisprudence*, 64 *TEX. L. REV.* 645 (1985) (examining theory of evolution and its role in jurisprudence); M.B.W. Sinclair, *The Use of Evolution Theory in Law*, 64 *U. DET. L. REV.* 451 (1987) (examining theory of evolution and its applicability to law). For an overview of the use of classical Newtonian scientific method in American legal theory, see Nancy Levit, *Listening to Tribal Legends: An Essay on Law and the Scientific Method*, 58 *FORDHAM L. REV.* 263 (1989). For an application of what lies beyond classical scientific theory, providing an exploration of how twentieth-century post-Newtonian physics might serve as a metaphorical background for new legal theories, see Laurence H. Tribe, *The Curvature of Constitutional Space: What Lawyers Can Learn from Modern Physics*, 103 *HARV. L. REV.* 1 (1993). For a discussion of how advanced principles of mathematics can apply to legal theory, see Mark R. Brown & Andrew C. Greenburg, *On Formally Undecidable Propositions of Law: Legal*

development of this new theory of change calls for our examination of what complexity theory has to say for law.

One of complexity theory's most striking developments has been identifying properties of change that are common to many forms of dynamical systems. These properties can be grouped under several broad headings: (1) description of the behavior of the system according to the community of its components; (2) description of the mechanics of evolution in the system and the coevolution of that process with change taking place in surrounding, interconnected systems; and (3) description of the direction of change in terms of overall system behavior and success — the system's arrow. In this section we use these three broad headings to summarize the major concepts in complexity theory and demonstrate how they can be built into a model of the process and direction of change in law.

### 1. Community — Prediction Is a Futile Exercise

Assuming we could gather all relevant information about a dynamical system, that system could be described by the  $n$  variables that influence its behavior — such as mass, speed, size, temperature, . . .  $n$ .<sup>23</sup> Assuming we could find a big enough computer, this community of variables could be plotted in an  $n$ -dimensional space<sup>24</sup> within which we could track the path, or trajectory, of the system's evolution.<sup>25</sup> Generally, if a system has more than a few variables, its trajectory is found to be nonlinear in behavior. Nonlinear systems behave according to properties that can be defined only through examination of the collection

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*Indeterminacy and the Implications of Metamathematics*, 43 HASTINGS L.J. 1439 (1992), and John M. Rogers & Robert E. Molzon, *Some Lessons About the Law from Self-Referential Problems In Mathematics*, 90 MICH. L. REV. 992 (1992).

<sup>23</sup> The discussion in this section of the Article is derived principally from KAUFFMAN, *supra* note 2, at 75, 187, which explains the structure of large Boolean numbers, and CASTI, *supra* note 2, at 33-37, 40-42, which explains the structure of dynamic systems. For a more detailed exposition on how complexity theory offers a model for the dynamical behavior of the sociolegal system, see Ruhl, *Complexity Theory as a Paradigm*, *supra* note 3, at 916-26.

<sup>24</sup> The system's phase space is "[a]n abstract space in which a single point completely defines the instantaneous state of a dynamical system. . . . The dimension of the space depends on the number of variables needed to define the system." PETER COVENEY & ROGER HIGHFIELD, *THE ARROW OF TIME* 364 (1990).

<sup>25</sup> Thus, "[a]s the system evolves in time it maps out a trajectory in the phase space." *Id.*

of the system components, not through reductionist study of any one system component. For example, snow acts in ways not readily apparent from the study of a single snowflake. This property, known as emergence, is a special function of the power of the type, number, and the level of interdependence of the system's components.<sup>26</sup> When trajectories of such systems are plotted, researchers find that most systems eventually settle into one or more of three general behaviors based on what are referred to as the system's "attractors."<sup>27</sup>

One type of behavior would be represented by a trajectory moving towards a fixed point in the plotting space. This is known as a fixed point attractor system exhibiting stable steady state behavior in which all of its variables stop changing (stasis) once it is on the attractor. In a more complicated type of behavior, the system, once on the attractor, exhibits a cyclical,

<sup>26</sup> A definition of emergence would be "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. Crutchfield, *Is Anything Ever New?: Considering Emergence, in COMPLEXITY: METAPHORS, MODELS, AND REALITY*, *supra* note 2, at 515, 516. Cohen explains that the key to understanding why emergence occurs lies in the number of system components and their interaction — with increasing numbers of system components, eventually the sum effect of the interactions between the components becomes a dominating characteristic of the system. See COHEN & STEWART, *supra* note 2, at 182 (explaining effect of increasing components on system interaction). For example, a system consisting of 10 components has 45 possible one-to-one pair combinations; a system of 1000 components has almost 5,000,000 such combinations; and a system of 1 million components has almost 5 billion such pairings. See *id.* In large systems, therefore, "if the effect of any particular interaction is tiny, we may not be able to work out what it is. We can't study it on its own, in a reductionist manner, because it's too small; but we can't study it as part of the overall system, because we can't separate it from all the other interactions." *Id.*

<sup>27</sup> To suggest that there are only three kinds of attractors is a gross simplification, as there are many subclasses and variations, but most texts lump the discussion into the three broad categories we use in this Article. See CASTI, *supra* note 2, at 28-42 (explaining fixed point, limit cycle, and strange attractors); COVENEY & HIGHFIELD, *supra* note 24, at 157-58, 201-03.

An attractor is simply a model representation of the potential long term behavior of the system, a useful concept for exploring different kinds of long-term behavior. See *id.* at 360. The attractor is not a force of attraction or a goal-oriented presence in the system, but simply depicts where the system is headed based on the rules of motion in the system. See COHEN & STEWART, *supra* note 2, at 206-07 (stating that chaotic activity defines where attractor lies and where it will go). A lake draining a watershed illustrates this distinction. The rainfall landing in the watershed moves according to forces of attraction such as gravity; the lake is the result of the collective interactions of rain with gravity, geography, and so on, but is not itself a force of attraction for the rainfall. See KAUFFMAN, *supra* note 2, at 78 (explaining concept of attractors in large Boolean networks).



trajectory repeatedly visiting some fixed set of points. This is known as a limit cycle attractor system exhibiting stable periodic behavior. In the third type of behavior, the system's trajectory would be plotted as a tangled web buzzing around the surface of its attractor in a never-repeating, never-crossing, aperiodic trajectory. This is known as a strange attractor system exhibiting chaotic behavior. Strange attractors are a core subject matter of complexity theory.

Strange attractors are important because systems that are in trajectories on them exhibit several forms of behavior in addition to emergence that lead to unpredictability of their trajectories. First, although strange attractor systems behave according to deterministic rules, they display apparently random output — for example, the same physical and chemical laws form all snowflakes, but no two are alike. This property is known as deterministic randomness or chaos behavior.<sup>28</sup> Second, a system exhibiting such chaotic behavior is extremely sensitive to its initial and temporal environmental conditions. This property, known as sensitivity, means that two similar systems that at one time are located at very close points can later be found to have diverged from one another wildly.<sup>29</sup>

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<sup>28</sup> Chaos behavior thus has been described as "order *masquerading* as randomness." GLEICK, *supra* note 20, at 22. Classic examples of chaos in physical systems run by deterministic rules are the erratic dripping patterns from water faucets and the motion of a pinball. See Tom Mullin, *Turbulent Times for Fluids*, in *EXPLORING CHAOS* 59, 60-61 (Nina Hall ed., 1991) (analyzing flow of water from tap and explaining mathematical complexity of modeling turbulent systems); Ian Percival, *Chaos: A Science for the Real World*, in *EXPLORING CHAOS*, *supra*, at 11, 14-15 (analogizing motion of pinball to chaos in complex system). Although the rules determining the presence of chaos in such systems may be simple and rigid, the randomness of the system's behavior prevents easy discovery of all the rules merely by observation of the behavior. Thus, chaotic behavior "only looks complicated because you don't know what the rule is." COHEN & STEWART, *supra* note 2, at 197. More to the point, even if you did know what the rule is, making the system computable, you could not predict what will happen very far into the future.

<sup>29</sup> A useful mental image that illustrates the difficulty of predicting the behavior of systems experiencing sensitivity to initial and temporal conditions is the story of German theoretical chemist Otto Rossler, who observed a saltwater taffy-pulling machine in operation. The story, as told by Casti, is that Rossler observed that the contraption stretched and folded a batch of raisin taffy according to the same mechanical procedure over and over again. However, the raisins in the taffy appeared to change relative positions with no *apparent* order. He contemplated the question of what would be the long-term fate of two raisins initially placed very close together, surmising that over time they might separate in position quite dramatically. Indeed, although we know that the machine applies the same procedure ad infinitum to the taffy, it would be very difficult to predict where the raisins will be

Together, emergence, chaos, and sensitivity behaviors join to give strange attractor systems a propensity to experience an arbitrarily large divergence in trajectory based on arbitrarily small changes in system variables. Sometimes, moreover, the effect of a variable change, even one arbitrarily small in magnitude, is so pronounced that the system is thrown into the basin of an altogether new attractor. The effect is like an avalanche that occurs without warning after the temperature of a snow mass rises just above a certain point. This is known as catastrophe behavior.<sup>30</sup> Given that a nonlinear system can display any or all of these properties, predicting the complete system trajectory for any substantial time period is so difficult that it is impossible in the true sense of the word.<sup>31</sup>

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in relation to each other, say, one month into the process. See CASTI, *supra* note 2, at 91-92 (illustrating repetitive stretching motion as chaotic process).

<sup>30</sup> See *id.* at 43-85 (explaining how small, gradual changes in causes can give rise to catastrophic effects); COHEN & STEWART, *supra* note 2, at 209-12 (using climate change to illustrate catastrophe theory). The unpredictability of catastrophe stems from the fact that "it may take only the tiniest of changes to trigger the switch." *Id.* at 212. The result of such an arbitrarily small perturbation of the system, however, can be an arbitrarily large, and irreversible, shift in the system's rules of motion, known technically as the vector field. This can produce a radical change in the system's behavior. See CASTI, *supra* note 2, at 26, 89-90 (defining vector field and illustrating effect small changes may have on system's rule of motion).

<sup>31</sup> Beginning with Kurt Gödel's work in the 1930s and culminating more recently with Gregory Chaitin's research, mathematicians have demonstrated that no form of proof chain can prove all the truth that is meaningful to a formal axiomatic system. Provable truths, it turns out, are infinitely less in number than truths which cannot be proved using the axiomatic system. The latter are nonetheless true since they exist as possible outcomes of the universe the formal axiomatic system is attempting to describe. Some truths, however, are provable but so complex in behavior that they are not capable of prediction. Calculating them is on the same order of difficulty as simply waiting for them to be observed, and hence they appear random. Strange attractors are personified by this type of truth — deterministic (provable) randomness (unpredictable). See JOHN L. CASTI, *SEARCHING FOR CERTAINTY* 75-76 (1990) (asserting that chaotic processes defy accurate computational prediction); John L. Casti, *Confronting Science's Logical Limits*, *SCI. AM.*, Oct. 1996, at 102, 103-05 (discussing similarity in unanswerability between mathematics and nature); Gregory Chaitin, *A Random Walk in Arithmetic*, in *EXPLORING CHAOS*, *supra* note 28, at 196, 201-02 [hereinafter Chaitin, *A Random Walk*] (arguing randomness and unpredictability as unifying principles); Gregory J. Chaitin, *Randomness in Arithmetic and the Decline and Fall of Reductionism in Pure Mathematics*, in *COOPERATION AND CONFLICT IN GENERAL EVOLUTIONARY PROCESSES* 89, 93-112 (John L. Casti & Anders Karlqvist eds., 1995) (describing potential for new approach to mathematics due to computer technology). Chaitin's work in this field is also available on the Internet. See *G.J. Chaitin Home Page* (visited Mar. 3, 1996) <<http://www.research.ibm.com/people/c/chaitin>> (connecting user to Chaitin's home page). In summary, this highly technical branch of mathematics proves that "[f]or every

Despite their unpredictability, we should not think of strange attractors as being all for the worse. To the contrary, because they are not limited by rigid properties, as are fixed point and limit cycle attractors, strange attractors can adapt to perturbations in the system's environment.<sup>32</sup> Consider when a bacterium capable of evolving through wildly variable mutations (strange attractor sensitivity) meets an antibiotic that applies an unchanging strategy of attack (fixed point attractor stability). Eventually, the bacterium may evolve into a form that avoids the antibiotic's method of attack, and the antibiotic will be powerless to counter adapt. In a harsh world, adaptation means survival.

To be sure, a system consisting of nothing but strange attractors may spin wildly out of control at the drop of a pin without adapting in any beneficial way. The consistency and order that comes with the fixed point and limit cycle attractors provide their own benefits. This is why researchers have found that the most robust systems manage to stay balanced between order and chaos through a delicate mix of fixed and periodic (ordered) and strange (chaotic) attractors.<sup>33</sup> In a sense, because

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consistent formalization of arithmetic, there exist arithmetic truths unprovable within that formal system," and hence "[t]here exist numbers having complexity greater than any theory of mathematics can prove." CASTI, *supra* note 2, at 139, 146. Translated into broader complexity theory principles, this means that "we'll never get at all the truths by following rules; there's always something out there in the real world that resists being fenced in by a deductive argument." *Id.* at 150. To the extent, therefore, that society conceives of law as its formal axiomatic system for describing sociolegal behavior and conditions, there is no predictivist legal theory that can be accurate all of the time. Society will experience sociolegal outcomes that could never have been predicted using the available laws, regardless of how many laws we add to the pot to attempt to improve prediction. See Ruhl, *Complexity Theory as a Paradigm*, *supra* note 3, at 893-906 (critiquing modern American legal system from complexity theory perspective); Rogers & Molzon, *supra* note 22, at 997-1002 (analogizing legal systems to axiomatic systems). We demonstrate later why this gap between prediction and reality leads to stress in the sociolegal system that increases with the addition of new laws to the system. See *infra* text accompanying notes 149-50 (theorizing that increased investment in legal structure leads to decreasing returns).

<sup>32</sup> Adaptation is associated with the feedback and feed forward loops made possible by multiple paths of interactions between system components. See *infra* notes 50-54 and accompanying text (describing coevolution of systems resulting from feedback responses). Thus, adaptation "is an emergent property which spontaneously arises through the interaction of simple components." GLEICK, *supra* note 20, at 339 n.314. Adaptation allows "the system to restructure, or at least modify, the interaction pattern." CASTI, *supra* note 2, at 271.

<sup>33</sup> Thus, "complex systems constructed such that they are poised on the boundary between order and chaos are the ones best able to adapt by mutation and selection. Such poised systems appear to be best able to coordinate complex, flexible behavior and best

the presence of ordered behavior is holding them back from the edge, these systems can draw as much as possible from the adaptive qualities of emergence, chaos, sensitivity, and catastrophe properties without falling all the way into disaster. A system poised in this manner "at the edge of chaos" is likely to be adaptive and successful — a complex adaptive system.<sup>34</sup>

These concepts provide an apt analogy for law.<sup>35</sup> The evolution of law can be described by identifying the attractors that define the underlying basic norms that legitimize the sociolegal outcome for a particular set of issues. Law has no fixed set of attractors. Instead, it has a variable spectrum of first-order principles that we point to as the foundations and justifications for legal rules designed to resolve social issues. At any given time, therefore, a rule of law exhibiting the behavior of some underlying attractor or basic norm of legal order may govern a particular social issue. For example, the doctrine of regulatory takings of property, which the Supreme Court has attempted on many occasions to divine from the Fifth Amendment,<sup>36</sup> can be portrayed as a tussle between three attractors of the sociolegal system — freedoms, rights, and regulations. That is, one's freedom to use property as one wishes can be restricted by rights vested

able to respond to changes in their environment." Stuart A. Kauffman, *Whispers from Carnot: The Origins of Order and Principles of Adaptation in Complex Nonequilibrium Systems*, in *COMPLEXITY: METAPHORS, MODELS, AND REALITY*, *supra* note 2, at 83. Complexity theory refers to these systems as Complex Adaptive Systems or CAS. See HOLLAND, *supra* note 1, at 4 (comparing disparate subjects exhibiting unique complicating dynamics but which nevertheless demonstrate trait of coherence under change, and are thus collectively referred to as CAS).

<sup>34</sup> Theorists call the complex behavior region the "sweet spot" or the "edge of chaos." See Kauffman, *supra* note 33, at 84.

<sup>35</sup> For a detailed description of the strength of the analogy, see Ruhl, *Complexity Theory as a Paradigm*, *supra* note 3, at 866-75, 880-92, which traces seemingly unpredictable tidal shifts of sociolegal structure to the underlying logic or attractor that threads through and binds to the process of legal evolution.

<sup>36</sup> "[N]or shall private property be taken for public use, without just compensation." U.S. CONST. amend. V. The Court's earlier jurisprudence had established the "regulatory takings" doctrine, that is, "if [governmental] regulation goes too far it will be recognized as

in others, through such means as the law of nuisance, and government regulation, such as land use controls.<sup>37</sup>

As legal systems traverse near their attractors, moreover, we find repeated examples of behavior resembling the surprises that emanate from emergence, chaos, sensitivity, and catastrophe. Often a law designed to address a problem identified in society has effects never anticipated at the time of enactment. An example is the federal Superfund law, which was designed to remediate contaminated lands through, among other mechanisms, stringent liability rules. Those rules led completely unexpectedly to the widespread "brownfields" problem, in which abandoned urban industrial sites in communities sorely in need of economic investment lie idle because of potential developers'

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a taking." *Pennsylvania Coal Co. v. Mahon*, 260 U.S. 393, 415 (1922). Although its jurisprudence developed little in the way of guidelines for applying that principle, the Court's decisions evolved towards the general doctrine that land use regulation constitutes a taking when it "does not substantially advance legitimate state interests or denies an owner economically viable use of his land." *Agins v. City of Tiburon*, 447 U.S. 255, 260 (1980) (citations omitted). For an extremely comprehensive history of the regulatory takings doctrine and the legal commentary thereon, see William Michael Treanor, *The Original Understanding of the Takings Clause and the Political Process*, 95 COLUM. L. REV. 782 (1995).

<sup>37</sup> Only when government regulation restricts freedom of property use in ways that exceed that which could be enforced by rights of nuisance action does the government have to determine whether the property has been taken within the meaning of the Constitution. The Supreme Court explained that

confiscatory regulations, *i.e.*, regulations that prohibit all economically beneficial use of land . . . cannot be newly legislated or decreed (without compensation), but must inhere in the title itself, in the restrictions that background principles of the State's law of property and nuisance already place upon land ownership. A law or decree with such an effect must, in other words, do no more than duplicate the result that could have been achieved in the courts — by adjacent landowners (or other uniquely affected persons) under the State's law of private nuisance, or by the State under its complementary power to abate nuisances that affect the public generally, or otherwise.

*Lucas v. South Carolina Coastal Council*, 505 U.S. 1003, 1029 (1992).

fear of liability under Superfund.<sup>58</sup> Other examples abound in the different walks of law.<sup>59</sup>

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<sup>58</sup> Professor William Rodgers has written extensively about what he calls statutory "sleepers (provisions with consequences not anticipated at the time of enactment)," which, he asserts, "have played an important role in the history of environmental law." WILLIAM H. RODGERS, JR., ENVIRONMENTAL LAW § 1.3, at 43 (2d ed. 1994). The brownfields phenomenon is a classic example. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. §§ 9601-75 (1994), generally imposes strict liability on the present owner of a contaminated property regardless of the owner's lack of involvement in causing the risk to human health or the environment. See ALFRED R. LIGHT, CERCLA LAW AND PROCEDURE § 4.5.1 (1991) (noting obfuscation and confusion in legislative history concerning any causation or nexus standard for liability under statute); see generally Mehron Azarmehr, *Status of Joint and Several Liability Under CERCLA After Bell Petroleum*, 24 ENVTL. L. REP. 10250 (1994) (examining legislative and case law history prior to and after *In re Bell Petroleum*, which found that joint and several liability was not mandatory in CERCLA cases). The Environmental Protection Agency's regulations implementing CERCLA, see 40 C.F.R. pt. 300 (1995), involve a complicated and lengthy process of site investigation, remedy selection, and negotiation between the government and responsible parties. See LIGHT, *supra*, at §§ 3.2.5-3.3.6 (detailing CERCLA's remedial investigation, feasibility study, selection of remedy, remedial design, and enforcement procedures). The average cost of completing an investigation and remedy selection at a CERCLA site is \$1.3 million, and the average cost of implementing the remedy is around \$30 million. See Jerry L. Anderson, *The Hazardous Waste Land*, 13 VA. ENVTL. L.J. 1, 10-11 (1993) (exploring ways to recoup expenses from potentially responsible parties). These factors create the conditions under which "financiers are frequently not supportive of industrial redevelopment projects. The fear of becoming involved with these properties has left historical industrial and commercial centers — often associated with industrial and port areas — with a decreasing number of sites in which new businesses can flourish, and an eroding tax base." Bernard A. Weintraub & Sy Garza, *The Redevelopment of Brownsites*, NAT. RESOURCES & ENV'T, Spring 1995, at 57; see, e.g., E. Lynn Grayson & Stephen A. K. Palmer, *The Brownsites Phenomenon: An Analysis of Environmental, Economic, and Community Concerns*, 25 ENVTL. L. REP. 10,337, 10,337-38 (1995) (explaining issues surrounding redevelopment of abandoned urban hazardous waste sites); Julia A. Solo, *Urban Decay and the Role of Superfund: Legal Barriers to Redevelopment and Prospects for Change*, 43 BUFF. L. REV. 285, 285 (1995) (arguing that Superfund has detrimental effect on renewal and should be amended); R. Michael Sweeney, *Brownfields Restoration and Voluntary Cleanup Legislation*, 2 ENVTL. L. 101, 101 (1995) (discussing voluntary cleanup initiatives and suggestions for reuse and redevelopment of industrial sites). Another example, though more comical in nature, involved the vegetable oil industry. It realized that the broad definition of "oil" found in the Oil Pollution Act of 1990 would subject tanker vessel transportation of vegetable oils to the same level of regulation as is applied to petroleum oils. The oil industry successfully lobbied regulatory agencies to enact the Edible Oil Regulatory Reform Act, requiring the agencies charged with implementing the Oil Pollution Act to differentiate between the types of oils. Nonetheless, the industry remains disappointed with the severity of the regulations the agencies ultimately promulgated. See Jeanne Grasso, *OPA 90 — How Good Intentions Can Lead to Unintended Results*, ENVTL. L. AT MD., Fall 1996, at 15, 17 (criticizing regulation as imposing significant costs without providing additional cleanup or damages fund).

<sup>59</sup> See, e.g., *Air Bags Cut Fatalities, But Increase the Risk for Elderly, Children*, WALL ST. J., Oct. 4, 1996, at A2 (reporting that federal study shows air bags, mandatory in certain vehi-

Probably no one is surprised that law often exhibits these unexpected outcomes, not any more than we are surprised by changes in the weather. However, complexity theory helps us understand the underlying sources of those seemingly random occurrences and formulate strategies for managing their causes and effects. In particular, complexity theory demonstrates that reductionist approaches to analyzing the causes and effects of dynamical system behavior, which approaches have been the signature of classical science and legal theory, will unwittingly lead society to decisions that only exacerbate the surprise phenomenon.<sup>40</sup>

Complexity theory thus can prompt new ways of looking at sociolegal behavior. If law and society interact as a dynamical system, how can we approach law in ways that promote a

cles after specified dates, pose increased risks to certain subpopulations); Marci A. Hamilton, *Next, Congress Will Protect Your Right to Sunny Weather*, WALL ST. J., Sept. 18, 1996, at A19 (describing unintended applications of Religious Freedom Restoration Act); Doug Levy, *Doctors Study Fitness of Spouse-Abuse Laws*, USA TODAY, Sept. 9, 1996, at D1 (noting that physicians are concerned that laws requiring them to report cases of spouse abuse will deter victims from seeking care).

Not wishing to take full blame for these results, some Congress members contend that judicial and administrative interpretations of the laws often defeat or at least depart from the legislative intent. These members suggest that Congress periodically convene a "corrections day" to clean up such problems by corrective legislative action. See John Copeland Nagle, *Corrections Day*, 43 UCLA L. REV. 1267, 1268 (1996). Nagle posits that these "mistakes" are generally perceived as errors by Congress, courts interpreting the statute, or agencies implementing the statute. In fact, Nagle argues, all such mistakes are attributable to Congress being sloppy, unthinking, neglectful, or wrong. See *id.* at 1273-80. He admits of one exception in this regard: when "the consequences of a statute were unforeseeable — not just unforeseen — when Congress enacted the statute, then Congress cannot be blamed for a problem it could not have anticipated." *Id.* at 1280 n.44. This exception is, in our view, an enormous one, perhaps suggesting that it is not fruitful to think of any unintended consequences as being the result of anybody's "mistake." Indeed, although we do not condone sloppy, unthinking, or neglectful legislative behavior, we suggest that the harder Congress tries to predict the outcome of its enactments and anticipate misfirings, the more "mistakes" it will commit.

<sup>40</sup> See Ruhl, *Complexity Theory as a Paradigm*, *supra* note 3, at 893-916. By "reductionist" we mean the belief that an observable, complex phenomenon can be studied and fully understood by first reducing it to its simplest, indivisible components in operation during the phenomenon. The process then requires studying each of those components until a complete understanding of its nature is obtained. Finally, one must reassemble all the components, understanding each as part of the whole, the premise being that the rules of operation of the whole are now fully understood. That form of analysis has predominated as an organizing principle for classical scientific inquiry for centuries. See COHEN & STEWART, *supra* note 2, at 33-34 (reviewing philosophy of reductionism).

complex adaptive system capable of withstanding stress from within and without? We must, at the very least, be attuned to the balance between ordered and chaotic forces that is essential to maintain adaptive qualities. But these forces also lead inevitably to unpredictable qualities in law.<sup>41</sup> When legal institutions are premised on the objective of producing centralized, predictable, lasting, stable output, therefore, should we not consider whether the cost of that reductionist approach is adaptability of the sociolegal system?<sup>42</sup>

## 2. Evolution and Coevolution — There Is No Absolute End Point Structure

The  $n$ -variable model of the community of components in a system also serves as the foundation of complexity theory's model of evolutionary mechanics.<sup>43</sup> Consider what happens when any one variable in a system is altered, say for the purpose of improving fitness. For example, the weight of a predator species might be increased. That change might increase the animal's strength, but also slow it down. At some point the increase in weight might slow the animal down so much that the increase in strength is irrelevant, perhaps because its former prey is too fast for it. When variables both within and between systems<sup>44</sup> are coupled or interrelated in this manner, the system may experience conflicting constraints between variables. Adding too

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<sup>41</sup> For example, even bastions of classical economics are resigned to the fact that "[t]wo hundred years of economic 'science' have done nothing to improve the ability of forecasters to predict recessions." See Alan Murray, *The Outlook: A Recession Awaits the Next President*, WALL ST. J., Aug. 26, 1996, at A1.

<sup>42</sup> For a discussion of how other commentators have addressed that question, without the benefit of complexity theory but leading to the same conclusions we believe are reached under a complexity theory based analysis, see Ruhl, *Complexity Theory as a Paradigm*, *supra* note 3, at 906-26.

<sup>43</sup> The discussion in this section of the Article is derived principally from KAUFFMAN, *supra* note 2, at 31. For a more detailed exposition on how complexity theory offers a model for the evolution of the sociolegal system, see Ruhl, *The Fitness of Law*, *supra* note 3, at 1407.

<sup>44</sup> Until now the discussion has focused on the behavioral mechanics of a single system. As this section of the Article demonstrates, however, evolution of any single system involves the interaction of that system within nested multi-levels of related systems.



much of one variable to improve one aspect of system behavior could trigger responses in another variable that work against the system.<sup>45</sup>

If the level of system success expected at each of the combinations of system variables could be plotted, the result would be a “map” of the relative fitness of the combinations — a fitness landscape displaying “peaks” of high fitness combinations and “valleys” of low fitness combinations.<sup>46</sup> The objective of adaptive change in the system, of course, is to stay on the high parts of this landscape in the face of outside disturbances. The mechanics of moving over the landscape, therefore, are of great interest to the system. The system might “walk” across the landscape through gradual, incremental testing of altered variable combinations, hoping to find a higher spot.<sup>47</sup> But that mode of travel is slow and prevents the system from quickly testing faraway

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<sup>45</sup> As Kauffman explains:

Here is the problem: in a fixed environment, the contribution of one trait — say, short versus long nose — to the organism’s fitness might depend on other traits — for example, bowed versus straight legs. Perhaps having a short nose is very useful if one is also bowlegged, but a short nose is harmful if one is straight legged. . . . In short, the contribution to overall fitness of the organism of one state of one trait may depend in very complex ways on the states of many other traits.

KAUFFMAN, *supra* note 2, at 170.

<sup>46</sup> Kauffman describes “variations toward ‘peaks’ of high fitness on a fitness landscape. And natural selection is thought of as ‘pulling’ an adapting population towards such peaks. We can imagine a mountain range on which populations of organisms . . . are feeling their way to the summit.” *Id.* at 154; see also COVENEY & HIGHFIELD, *supra* note 2, at 108 (suggesting fitness landscape is “[a] mountainous terrain showing the locations of the global maximum (highest peak) and global minimum (lowest valley) [and] [t]he height of a feature is a measure of its fitness”). The image of a fitness landscape has been used since the biologist Sewall Wright first proposed it in the 1930s as a way of discussing gene combinations. Since then, with the advantage of high-speed computers, complexity theory researchers have made tremendous strides in exploring the quantities and processes upon which the landscape is imposed in a variety of applications. See, e.g., Catherine A. Macken & Peter F. Stadler, *Evolution on Fitness Landscapes*, in 1993 LECTURES IN COMPLEX SYSTEMS 43, 45-46 (Lynn Nadel & Daniel L. Stein eds., 1995) (reviewing Wright’s landscape model as adapted by Maynard Smith to protein evolution, by Spiegelman to in vitro evolution, and by Kauffman to affinity maturation in immune response).

<sup>47</sup> The rules of the “adaptive walk” are simple: starting from wherever the species is on its fitness landscape, consider the fitness level that results when a randomly chosen gene is altered. If it is a fitter level, go there; if it is not a fitter level, try again. See KAUFFMAN, *supra* note 2, at 166 (demonstrating random fitness landscape populated by randomly assigned fitness levels to 16 genes, wherein natural selection and self-organization are observed).

points to find peaks significantly higher than those nearby. Therefore, the system might find a way to “jump” greater distances across the landscape, as risky as that might be. Indeed, by tapping into the emergent, chaotic, sensitive, and catastrophic system forces, which can trigger large shifts in system trajectory based on small changes in system variables, a very long jump may be possible, though its destination will be unpredictable.<sup>48</sup>

The metaphor of fitness landscapes carries complexity theory far in describing evolution in a host of different systems, particularly in biology. For example, sex — the exchange of genes between two species members on their relative fitness peaks through sexual reproduction — offers a way of moving much further across fitness landscapes than is available to species who reproduce without gene exchange.<sup>49</sup> To be sure, not all sexual reproduction significantly improves the species. But sex enhances the possibility of significant advances because the power to move far across the fitness landscape is presented. Complexity theory offers an explanation of why sex developed as an evolutionary strategy and how it works.

The fitness landscape metaphor, moreover, also reveals the mechanics of coevolution of systems.<sup>50</sup> As one species moves

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<sup>48</sup> Such events in nature are often known as accidents. The power of accident — of the chaos, emergence, sensitivity, and catastrophe that small accidents can unleash — should not be underestimated. Starting at the small level and working up, it seems clear that

the space of possible molecules is vaster than the number of atoms in the universe. Once this is true, it is evident that the actual molecules in the biosphere are a tiny fraction of the space of the possible. Almost certainly, then, the molecules we see are to some extent the results of historical accidents in the history of life.

*Id.* at 186.

<sup>49</sup> Many evolutionary biologists believe that “sex has evolved . . . to permit genetic recombination. And recombination provides a kind of approximation to a God’s-eye view of . . . large-scale features of fitness landscapes.” *Id.* at 180. Indeed, sex is counterintuitive, in that it requires two parents and involves each parent’s sacrifice of gene structures that allowed it to live long enough to reproduce; whereas a haploid organism can simply pass its genes intact along to its offspring, and they to theirs, with only the possibility of mutation to upset (or improve) the design. *See id.* (detailing numerous advantages resulting from genetic recombination compared to reproduction as result of division); *see also* GELL-MANN, *supra* note 2, at 253 (asking rhetorically, “What are males really good for?”). There must be some benefit, therefore, to genetic recombination that outweighs the benefit of genetic stasis. That benefit, according to complexity theory, is the ability it offers species to jump across landscapes.

<sup>50</sup> As Kauffman explains,

across its landscape, the conflicting constraints presented to other systems at the same or different levels of the hierarchy of systems may change, altering their respective fitness landscapes. A swifter prey, for example, changes the fitness landscape of its predator. Perhaps the predator will also evolve into a swifter form, possibly at the expense of strength, and wind up finding another prey species; or perhaps the predator species will fail to evolve and lose all its fitness (become extinct). In any event, when any two systems are coupled in this manner, evolution in one system alters the fitness landscape of the other. Any evolutionary response in the latter is then felt in the fitness landscape of the former, and so on. Coevolution between interrelated systems is like an endless exercise in game theory.<sup>51</sup>

Research has indicated that the coevolutionary process between systems, like the behavior of the community of variables in any single system, may exhibit orderly or chaotic behavior depending on how tightly coupled are the systems involved in the coevolutionary interplay. There is a level of variables that defines how each system influences and is influenced by others in its environment. The more tightly connected those influences are, the more chaotic the systems' coevolution will be. A balance point in that spectrum — the point of transition from order to chaos — thus exists at which system dynamics are optimized.<sup>52</sup> Moreover, the more broadly the coevolutionary connections are spread into separate "patches" of evolutionary dynamics, the

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[t]he idealization we have used [thus far] that fitness landscapes are fixed and unchanging is false. Fitness landscapes change because the environment changes. And the fitness landscape of one species changes because the other species that form its niche themselves adapt on their own fitness landscapes. Bat and frog, predator [sic] and prey, coevolve. Each adaptive move by the bats deforms the landscape of the frogs.

KAUFFMAN, *supra* note 2, at 208.

<sup>51</sup> See *id.* at 217-21 (analogizing between coevolution and famous "Prisoners' Dilemma"). Kauffman notes that in a single game of the Prisoners' Dilemma, the rational strategy of the two independent agents is defect-defect, but that in a repeated game different strategies emerge as the independent agents come to understand the coordinated nature of their choices. This effect, posits Kauffman, provides an analogy to the coevolution of fitness landscapes, though coevolution in biological organisms takes place without conscious predecision. See *id.*

<sup>52</sup> See *id.* at 230 (explaining that "[t]he highest average fitness occurs precisely at the transition from order to chaos").

more adaptive the coevolutionary process will be at any level of coupling.<sup>53</sup> A “patchy” system has more problem-solving units in operation and is more able to absorb a “hit” from outside. A corn field, for example, is less adaptive to external stress than is a diverse forest ecosystem.

Having laid down these basic models, complexity theory focuses on testing what happens in systems that are tightly coupled versus those which are loosely coupled, how many patches are needed to foster adaptive problem solving, the impact of the size of the system, how much change in one system is needed to prompt change in another, and so on.<sup>54</sup> These are questions that can be posed with respect to law as well.

The fitness landscape analogy may provide new insights into the evolution of law. Laws certainly face conflicting constraints.<sup>55</sup> For example, a prominent theme in environmental law is whether land use regulation has bumped up against the protection of private property under the regulatory takings doctrine.<sup>56</sup> The fitness of a land use regulation law — its success in

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<sup>53</sup> Kauffman explains:

The basic idea of patch procedure is simple: take a hard, conflict-laden task in which many parts interact, and divide it into a quilt of nonoverlapping patches. Try to optimize within each patch. As this occurs, the couplings between parts in two patches across patch boundaries will mean that finding a “good” solution in one patch will change the problem to be solved by the parts in adjacent patches. Since changes in each patch will alter the problems confronted by the neighboring patches, and the adaptive moves by those patches in turn will alter the problem faced by yet other patches, the system is just like our model coevolving ecosystems.

*Id.* at 252-53.

<sup>54</sup> See, e.g., *id.* at 171-206 (discussing limits to selection, self-organization, rugged landscapes, and coevolution). Kauffman’s work suggests that the coupling effect and the questions flowing from it have universal application to any complex adaptive system. Commentators in the field of organizational behavior have also focused on these questions, particularly the level of coupling. See, e.g., Frank W. Lutz, *Tightening Up Loose Coupling in Organizations of Higher Education*, 27 ADMIN. SCI. Q. 653 (1982) (concluding that universities’ success hinges on becoming more tightly coupled). Other legal commentators have pointed to their work as having significance to legal systems. See, e.g., M.B.W. Sinclair, *Plugs, Holes, Filters, and Goals: An Analysis of Legislative Attitudes*, 41 N.Y.L. SCH. L. REV. 237, 264-68 (using coupling theory to analyze legislative attitudes toward statutory control).

<sup>55</sup> One of the major conclusions Peter Yeager reached after his years-long study of the Environmental Protection Agency was that there are “systemically embedded constraints in our political economy” and that “the operation of [such] constraints . . . is a dynamic process.” See PETER C. YEAGER, *THE LIMITS OF LAW* 30 (1991).

<sup>56</sup> For example, we believe most observers would agree that the enforcement of the

meeting its goals — thus may depend on whether it can avoid that conflicting constraint. And whether the regulation avoids that constraint in the long run may depend on how the regulatory takings doctrine itself changes, as it has appeared to do recently.<sup>57</sup>

Law's evolution may make long jumps across the fitness landscape to survive in this coevolving world. For example, nuisance law was once the core of environmental law.<sup>58</sup> Over time, the

Endangered Species Act has bumped up against a significant conflicting constraint in the form of increased concerns about the effect of species protection regulation on the use and value of private property. See J.B. Ruhl, *Biodiversity Conservation and the Ever-Expanding Web of Federal Laws Regulating Nonfederal Lands: Time for Something Completely Different?*, 66 U. COLO. L. REV. 555, 582-601, 632-42 (1995) (discussing property rights motivated backlash against Endangered Species Act); J.B. Ruhl, *Section 7(a)(1) of the "New" Endangered Species Act: Rediscovering and Redefining Federal Agencies' Duty to Conserve Species*, 25 ENVTL. L. 1107, 1137-43 (1995) (discussing shift in attitude from species protection to protection of property rights). This type of regulation relying on increased and more coercive command-and-control forms of species protection on private lands poses no realistic chance of being held a regulatory taking. See Glenn P. Sugameli, *Takings Issues in Light of Lucas v. South Carolina Coastal Council: A Decision Full of Sound and Fury Signifying Nothing*, 12 VA. ENVTL. L.J. 439, 504 (1993) (concluding that post-*Lucas* judicial developments show that *Lucas* has limited practical effect on real property regulation). Today's political reality, however, makes such a law highly unlikely to be a "fitter" legal structure in the long run than the present structure or a structure relying on alternative methods of regulation. Indeed, many legislative initiatives at the federal and state level are overt efforts to retract environmental regulation, especially species protection laws, where it is perceived as having "gone too far" with respect to private property rights. See generally David Coursen, *Property Rights Legislation: A Survey of Federal and State Assessment and Compensation Measures*, 26 ENVTL. L. REP. 10,239 (1996) (surveying current federal proposals and state laws designed to safeguard private property rights). That movement in turn has spurred legal commentators to examine the early foundations of property law to determine whether private property rights have always carried with them the extensive freedoms they are often portrayed as having always had. See, e.g., Fred P. Bosselman, *Limitations Inherent in the Title to Wetlands at Common Law*, 15 STAN. ENVTL. L.J. 248 (1996) (arguing that courts should apply English Common Law to wetlands regulation cases); Myrl L. Duncan, *Property as a Public Conversation, Not a Lockean Soliloquy: A Role of Intellectual Legal History in Takings Analysis*, 26 ENVTL. L. 1095 (1996) (discussing how dynamic tension between private and public rights in American property law shapes environmental policy); James M. McElfish, Jr. et al., *Property: Past, Present, Future*, ENVTL. F., Sept.-Oct. 1996, at 20 (arguing that environmental regulation is necessary to preserve individual property rights).

<sup>57</sup> See *supra* notes 36-37 and accompanying text (explaining regulatory takings doctrine and its development).

<sup>58</sup> A nonrespassory nuisance is the invasion of another's interest in the private use and enjoyment of land. See RESTATEMENT (SECOND) OF TORTS § 821D (1979). It is no exaggeration to say that

[t]here is no common law doctrine that approaches nuisance in comprehensiveness or detail as a regulator of land use and technological abuse. Nuisance

rapid increase in pollution outstripped the effectiveness of nuisance law. Therefore, in the 1970s, the system made a long jump to what was then a much fitter form of regulation — command-and-control statutes.<sup>59</sup> The rest of society has not stood motionless since the 1970s, however. Rather, it has evolved in response to that statutory response and today poses very real challenges to the fitness of the command-and-control approach.<sup>60</sup>

Society is thus on the brink of addressing system-level questions regarding environmental law that are similar to those addressed by any other set of coevolving systems. These questions include the appropriate balance of federal and state powers (a question of patch size) and the degree to which regulatory, market, or privatized forces will become the primary policy making tool (a question of coupling).<sup>61</sup> Therefore, change in law

actions reach pollution of all physical media — air, water, land, groundwater — by a wide variety of means. Nuisance actions have challenged virtually every major industrial and municipal activity that today is the subject of comprehensive environmental regulation. . . . Nuisance theory and case law is the common law backbone of modern environmental and energy law.

RODGERS, *supra* note 38, § 2.1, at 112. Through the nuisance doctrine, courts have shut down several polluting operations. *See, e.g.,* City of Harrisonville v. W.S. Dickey Clay Mfg. Co., 289 U.S. 334, 339-40 (1933) (awarding damages caused by municipal pollution of stream); Steiffer v. City of Kansas City, 267 P.2d 474, 479 (Kan. 1954) (enjoining operation of municipal landfill because of fires and odors); Whalen v. Union Bag & Paper Co., 101 N.E. 805, 806 (N.Y. 1913) (enjoining operation of industry found to cause pollution of agricultural land); Costas v. City of Fond Du Lac, 129 N.W.2d 217, 222 (Wis. 1964) (enjoining operation of municipal sewage disposal plant because of its emission of noxious odors).

<sup>59</sup> From 1970 through 1976, in quick order Congress enacted or substantially amended 10 major environmental regulation statutes covering air, water, and land pollution, project planning, workplace safety, manufacturing, species protection, and public drinking water. *See* J. William Futrell, *The History of Environmental Law*, in ENVIRONMENTAL LAW: FROM RESOURCES TO RECOVERY, § 1.2(I)(1), at 35 (1993) (compiling congressional statutes regulating environment). That record was nearly duplicated during the same period in the field of natural resources protection. *See id.* § 1.2(I)(4), at 39 (collecting statutes protecting natural resources).

<sup>60</sup> For example, the recent literature is replete with commentary addressing the inadequate degree of sensitivity of the present environmental law regulatory system to matters of economic efficiency, risk allocation, and private property rights. For a current and comprehensive overview of the thrust of reform proposals on these fronts, see Robert L. Glicksman & Stephen B. Chapman, *Regulatory Reform and (Breach of) the Contract with America*, 5 KAN. J.L. & PUB. POL'Y, Winter 1996, at 9 (1996).

<sup>61</sup> For a discussion of how other commentators have addressed those questions, without the benefit of complexity theory but leading to conclusions which we believe a complexity theory based analysis supports, see Ruhl, *The Fitness of Law*, *supra* note 3, at 1408-37.

appears to follow processes which can be described using the tools of analysis that the complexity theory model has assembled. As complexity theory develops deeper understandings of the mechanics of fitness landscapes and system coevolution, perhaps the dynamics of legal evolution will be better understood as well.<sup>62</sup>

### 3. The Arrow — Decisions Are Not Revocable

The image of coevolving fitness landscapes illustrates the point made in the beginning of this section — the path of the law is a one-way street. When a system steps across its metaphorical fitness landscape, the coevolutionary impact with other coupled systems' landscapes transforms the former's reality. The peak left behind may be there no more. This means that a system can not turn back along its trajectory to a point in the past. It may only make forward turns and curves.

At any point in time, the best guide for which direction to choose is the fitness landscape. One challenge, however, is that every step up a hill or peak on the landscape (a decision) presents several dilemmas, even if it is the best decision of the moment. First, at least at that point in time, the peak has a finite height, and the system risks getting stuck there.<sup>63</sup> Of course,

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<sup>62</sup> Another important and strongly parallel field of study in this regard is known as law and biology, whose adherents examine the relationship between the biological evolution of human behavior and legal rules and institutions. See, e.g., MARGARET GRUTER, *LAW AND THE MIND* (1991) (examining link between human development and creation of law); *THE SENSE OF JUSTICE* (Roger D. Masters & Margaret Gruter eds., 1991) (analyzing link between human development and sense of justice); Owen D. Jones, *Evolutionary Analysis in Law: An Introduction and Application to Child Abuse*, 75 N.C. L. REV. (forthcoming Apr. 1997) (describing model for analyzing evolutionary behavioral traits for use in developing legal policy regarding child abuse); Owen D. Jones, *Law of Evolutionary Biology: Obstacles and Opportunities*, 10 J. CONTEMP. HEALTH L. & POL'Y 265 (1994) (examining relationship between evolutionary biology and law); William H. Rodgers, Jr., *Deception, Self-Deception, and Mythology: The Law of the Salmon in the Pacific Northwest*, 26 PAC. L.J. 821 (1995) (analyzing relationship between evolutionary theory of deception and self-deception as applied to laws regulating salmon fishing).

<sup>63</sup> Kauffman explains that adaptive walks

proceed uphill until a local peak is reached. Like a hilltop in a mountainous area, such a local peak is higher than any point in its immediate vicinity, but may be far lower than the highest peak, the global optimum. Adaptive walks stop on such local peaks. . . . [T]hey are trapped, with no way to get to the distant high summits.

peaks are precarious places. They rise, fall, and change in ruggedness with the undulating fitness landscape. The decision must be made whether to stay, if a rising trend is anticipated, or move on, if the opposite is expected. But the chances of finding higher peaks, even via a long jump, diminish as the system's fitness level goes up.<sup>64</sup> More system energy is expended to make the same incremental step up the fitness landscape as the last one, because with every step up, the number of higher peaks necessarily falls and thus the distance to higher peaks more likely becomes further. In other words, following the up arrow has its ever-increasing price: because of the irreversibility of the system, decisions leading to reduced fitness cannot be "taken back," returning the system to its pre-decision conditions. Because of the increased expenditure required for every incremental step of increased fitness, the system experiences diminishing returns on its investments of energy.

The properties of diminishing returns and irreversibility are found in many applications.<sup>65</sup> Complexity theory and its fitness

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KAUFFMAN, *supra* note 2, at 167. The more rugged the local landscape, the more likely the species will be trapped on a lower peak. *See id.*

<sup>64</sup> This is an inherent feature of an adaptive walk across a correlated fitness landscape, in that "with every step one takes uphill, the number of directions leading higher is cut by a constant fraction . . . so it becomes ever harder to keep improving." *Id.* at 178. Kauffman explains that "[a] very simple law governs such long-jump adaptations. The result, exactly mimicking adaptive walks via fitter single-mutant variants on random landscapes is this: every time one finds a fitter long-jump variant, the expected number of tries to find a *still better* long-jump variant doubles!" *Id.* at 193. Thus, "[a]s this exponential slowing of the ease and rate of finding distant fitter variants occurs, then it becomes easier to find fitter variants on the local hills nearby." *Id.* at 195. The rule of thumb, therefore, is that "[a]s fitness increases, search closer to home. On a correlated landscape, nearby positions have similar fitnesses. Distant positions can have fitnesses very much higher and very much lower. Thus optimal search distance is high when fitness is low and decreases as fitness increases." *Id.* at 196 (providing Figure 9.2 as graphical illustration).

<sup>65</sup> For example, long before complexity theory emerged, scientists devoted considerable thought to the diminishing returns and irreversibility of effects associated with the entropy of energy. According to the Second Law of Thermodynamics, energy — that with which work is done — in the universe is constant and entropy — the measure of inability to do work with that energy — in the universe is always increasing towards its ultimate maximum value, the state of thermodynamic equilibrium. *See* COVENEY & HICHFIELD, *supra* note 24, at 147-81 (discussing alternate theories of thermodynamics). Many scientists point to this property as the basis for the nonreversibility, or arrow, of time, though even this proposition has not been free of controversy. *See, e.g.,* HUW PRICE, *TIME'S ARROW AND ARCHIMEDES' POINT* 22-43 (1996) (tracing early developments in thermodynamic theory). The classical view has been that thermodynamic equilibrium is also the point of maximum



landscape model offers a unifying theoretical perspective for all such applications. The implications this property of fitness landscapes has for law is the subject of the remainder of this Article.

*B. Lessons for the Law on Diminishing Returns and Increasing Risks in Complex Adaptive Systems*

The general model of system change offered by complexity theory fits the sociolegal system. Whether that fit is direct or simply one of analogy, the model provides a new and powerful analytical tool for assessing the process of sociolegal evolution. Researchers in other disciplines embraced the model long before legal theorists have. They have been using the model to make important findings about the fate of complex structure and behavior in various settings, including proteins,<sup>66</sup> immune systems,<sup>67</sup> brain circuits,<sup>68</sup> economies,<sup>69</sup> cultures,<sup>70</sup> and

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disorder. However, beginning with Ilya Prigogine in the 1940s, a number of researchers have questioned whether entropy and disorder have any necessary ultimate relation. See, e.g., KAUFFMAN, *supra* note 2, at 20-21 (examining contrast between systems in equilibrium and nonequilibrium); MICHAEL MACKEY, *TIME'S ARROW: THE ORIGINS OF THERMODYNAMIC BEHAVIOR* 101 (1992) (stating that quest for dynamic foundations of thermodynamics and functioning of second law is far from over); see generally COVENEY & HIGHFIELD, *supra* note 24, at 206-07 (suggesting that structure can spontaneously emerge from disorder); JIM HOUGAN, *DECADENCE* (1975) (suggesting that industrial society is doomed to unavoidable collapse); PRICE, *supra*, at 40-48 (discussing possibility that entropy will decrease toward future). We tend towards the view, which we posit from the implications of Chaitin's work on provable truths in axiomatic systems, that the arrow of any continuously transient (constantly perturbed) nonlinear system has a direction. See Chaitin, *A Random Walk*, *supra* note 31, at 196 (asserting that possibility of chaos is ever-present factor). With every change in the system state such a perturbation generates, the number of components in the axiomatic system that defines the physical system necessarily increases and renders any prior set of truths, including those along the earlier trajectory, obsolete and incalculable. We connect the increase in entropy of the physical system with this increase in the structural complexity of the axiomatic system. In other words, once the system is perturbed, it has a richer set of provable truths but leaves where it was behind forever. Whether it has thus moved closer to order or disorder is a different question. See Ruhl, *Brief Discussions*, *supra* note 3.

<sup>66</sup> See Hans Frauenfelder, *Proteins as Adaptive Complex Systems*, in *COMPLEXITY: METAPHORS, MODELS, AND REALITY*, *supra* note 2, at 179 (applying model to study of protein function and control); Maureane Hoffman et al., *Blood Coagulation is a Complex System*, in *1993 LECTURES IN COMPLEX SYSTEMS*, *supra* note 46, at 487 (portraying blood coagulation as complex system).

<sup>67</sup> See Alan S. Perelson, *Two Theoretical Problems in Immunology: AIDS and Epitopes*, in *COMPLEXITY: METAPHORS, MODELS, AND REALITY*, *supra* note 2, at 185 (applying model to problems in immune system interactions).

<sup>68</sup> See Olaf Sporns, *Neural Models of Perception and Behavior*, in *1993 LECTURES IN COMPLEX SYSTEMS*, *supra* note 46, at 171 (applying model to brain function and behavior);

ecosystems.<sup>71</sup> To illustrate how those findings might be transported to legal theory, we focus on advancements in theories of archaeology and technology. These applications are particularly important to refining the model of law as a complex adaptive system.

### 1. Archaeology — Decreasing Returns and the Collapse of Complexly Structured Societies

One of the great questions of archaeology has been why societies fail. The archaeological record shows that “[h]uman history as a whole has been characterized by a seemingly inexorable trend toward higher levels of complexity, specialization, and sociopolitical control, processing of greater quantities of energy and information, formation of ever larger settlements, and development of more complex and capable technologies.”<sup>72</sup> One might reasonably imagine that lasting social stability comes with such increasing structural complexity. In fact, “[c]ollapse is a recurrent feature of human societies.”<sup>73</sup>

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Charles F. Stevens, *Complexity of Brain Circuits*, in COMPLEXITY: METAPHORS, MODELS, AND REALITY, *supra* note 2, at 245 (applying model to analysis of brain functions).

<sup>69</sup> See W. Brian Arthur, *On the Evolution of Complexity*, in COMPLEXITY: METAPHORS, MODELS, AND REALITY, *supra* note 2, at 65 (applying model to discussion of evolution, using examples from economics); Philip E. Auerswald & Jan Tai Tsung Kim, *Transitional Dynamics in a Model of Economic Geography*, in 1993 LECTURES IN COMPLEX SYSTEMS, *supra* note 46, at 415 (applying model to study of transitional dynamics and evolution of economic systems).

<sup>70</sup> See Marcus W. Feldman et al., *On the Complexity of Cultural Transmission and Evolution*, in COMPLEXITY: METAPHORS, MODELS, AND REALITY, *supra* note 2, at 47 (applying model in study of transmission and evolution of cultural traits); Liane M. Gabora, *Meme and Variations: A Computational Model of Cultural Evolution*, in 1993 LECTURES IN COMPLEX SYSTEMS, *supra* note 46, at 471 (applying model to study of cultural evolution).

<sup>71</sup> See James H. Brown, *Complex Ecological Systems*, in COMPLEXITY: METAPHORS, MODELS, AND REALITY, *supra* note 2, at 419 (applying model to study of ecological complexity); Robert Costanza, *Modeling Complex Ecological Economic Systems: Toward an Evolutionary, Dynamic Understanding of People and Nature*, 43 BIOSCIENCE 545, 545 (1993).

<sup>72</sup> TAINTER, *supra* note 4, at 3.

<sup>73</sup> *Id.* at 5. Collapse is principally a political process occurring when a society “displays a rapid, significant loss of an established level of sociopolitical complexity.” *Id.* at 4. Collapse is manifested by such effects as

a lower degree of stratification and social differentiation; less economic and occupational specialization, of individuals, groups, and territories; less centralized control; that is, less regulation and integration of diverse economic and political groups by elites; less behavioral control and regimentation; less investment in the epiphenomena of complexity, those elements that define the con-

Could it be that increasing the complexity of social structure, at some level, undermines adaptive social behavior and thus leads, ultimately, to the collapse of the society? Indeed, that is the thesis emerging from applications of complexity theory in archaeology. Joseph Tainter, a leading researcher of this question, has meticulously studied structural complexity and behavioral collapse in societies throughout history, and has found remarkable correlations between the two. This counterintuitive finding — structural complexity is associated with behavioral collapse — holds important implications for law's role in society.

Tainter explains that structural complexity "is generally understood to refer to such things as the size of a society, the number and distinctiveness of its parts, the variety of specialized roles that it incorporates, the number of distinct social personalities present, and the variety of mechanisms for organizing these into a coherent, functioning whole."<sup>74</sup> A complex society thus can be measured by its levels of such factors as inequality (the differentiation and unequal access to material and social resources) and heterogeneity (the number of distinctive parts or subcomponents and the distribution of the population among them).<sup>75</sup> Societies experience these and other traits of structural complexity as they attempt to solve the stresses confronting them. For problems of nutrition, they establish agricultural practices; for problems of aggression, they establish a military; for problems of resource distribution, they establish economies; for problems of communication, they establish media; for problems of organization, they establish a means of governance; and so on. Hence, "[c]omplex societies are problem-solving organizations, in which more parts, different kinds of parts, more social

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cept of 'civilization': monumental architecture, artistic and literary achievements, and the like; less flow of information between individuals, between political and economic groups, and between a center and its periphery; less sharing, trading, and redistribution of resources; less overall coordination and organization of individuals and groups; a smaller territory integrated within a single political unit.

*Id.*

<sup>74</sup> *Id.* at 23.

<sup>75</sup> *See id.*

differentiation, more inequality, and more kinds of centralization and control emerge as circumstances require."<sup>76</sup>

Although "there is no point on the scale at which complexity can be said to emerge,"<sup>77</sup> Tainter's detailed review of major societies in history demonstrates that those which achieved a level of lasting success all experienced high levels of inequality and heterogeneity associated with highly developed social structures. However, each such society eventually collapsed because of the very complexity that initially led to its success.<sup>78</sup> While other theories have explained how collapse occurred in a particular society, Tainter has "develop[ed] a general explanation of collapse, applicable to a variety of contexts, and with implications for current conditions."<sup>79</sup> Complexity theory provides this explanation.<sup>80</sup>

<sup>76</sup> *Id.* at 37.

<sup>77</sup> *Id.* at 5.

<sup>78</sup> *See id.* at 5-18. The list of collapsed societies Tainter describes include the Western Chou Chinese dynasty (1122-771 B.C.); the Harappans of the Indus Valley (2400-1750 B.C.); the city states of Mesopotamia (2350-614 B.C.); the Egyptian Old Kingdom (3100-2181 B.C.); the Hittite Empire (1792-1200 B.C.); the Minoan civilization of Crete (2000-1380 B.C.); the Mycenaean civilization of Greece (1650-1050 B.C.); the Western Roman Empire (300 B.C.-476 A.D.); the Olmec civilization of Mexico (1000-400 B.C.); the lowland Mayan civilization (1000 B.C.-900 A.D.); the Mesoamerican Highland civilization of Mexico (600-1200 A.D.); Casas Grandes in Mexico (1060-1340 A.D.); the Chacoans of the New Mexico area (500-1300 A.D.); the Hohokam of the Arizona desert (1300-1500 A.D.); the Eastern Woodlands civilizations of North America (200 B.C.-1250 A.D.); the Huari and Tiahuanaco Empires of Peru (200 B.C.-1100 A.D.); the Kachin of Burma (ongoing); and the Ik of Uganda (ongoing). *See id.* at 5-18.

<sup>79</sup> *Id.* at 3. Tainter describes other theories of collapse which have been used to explain how this occurred. Identifying 11 major themes of analyses, he finds them all unsatisfactory in that they "focus on a particular society or civilization, rather than approach the global process [of collapse]." *See id.* at 42-90. The different themes focus on resource depletion; new resources; catastrophes; insufficient response to circumstances; other complex societies; intruders; conflict, contradictions, and mismanagement; social dysfunction; the mystical; chance concatenation of events; and economic explanations. *See id.* at 42. However, Tainter believes the general explanation of collapse must subsume the 11 themes that have been dominant in other theories of collapse, so that one can account for what is worthwhile in each. *See id.* at 90. It is his effort to do so which has won his book much acclaim among his peers. *See, e.g.,* P. Nick Kardulias, *The Collapse of Complex Societies*, by Joseph Tainter, 93 AM. J. ARCHAEOLOGY 599, 600-01 (1989) (book review).

<sup>80</sup> In his original treatment of the subject, Tainter did not explicitly correspond his definition and analysis of social complexity to complexity in the dynamical systems sense, though the two are compatible. *See supra* notes 4-5 (explaining how sociolegal system can be portrayed as complex adaptive system and how findings of complexity theory can contribute to understanding of system behavior and evolution). In his more recent work, Tainter has provided the textual links between complexity theory and his archaeological

By reexamining the history of social collapse with complexity theory's insights into system dynamics, Tainter identified four qualities of complex social structures that he believes lead to behavioral collapse of social systems. These qualities are the following: (1) human societies are problem-solving organizations; (2) sociopolitical systems require energy for their maintenance; (3) increased structural complexity carries with it increased costs per capita; and (4) investment in sociopolitical structure as a problem-solving response often reaches a point of diminishing returns.<sup>81</sup>

Using the historical record to unfold his theory,<sup>82</sup> Tainter describes how the convergence of the first three of these features leads to the fourth. Initially, societies increase in structural complexity and use more energy to do so along the way.<sup>83</sup> One sector of the society, such as the economy, cannot increase in structural complexity without the support of others, such as technology and communications. A society thus becomes more highly structured as a system through "the interlinked growth of the several subsystems that comprise a society."<sup>84</sup> The problem-solving qualities of this investment in social structure, however,

research. See Joseph A. Tainter, *Prehistoric Societies as Evolving Complex Systems*, in *EVOLVING COMPLEXITY AND ENVIRONMENTAL RISK IN THE PREHISTORIC SOUTHWEST* 1, 3-4 (Joseph A. Tainter & Bonnie Bagley Tainter eds., 1996).

<sup>81</sup> See TAITNER, *supra* note 4, at 93.

<sup>82</sup> See *id.* at 93-126 (stating that four qualities provide explanations for societal collapse).

<sup>83</sup> See *id.* at 119. Tainter provides the example that when

complexity increases to regulate regional subsistence production, investments will be made in hierarchy, in bureaucracy, and in agricultural facilities (such as irrigation networks). The expanding hierarchy requires still further agricultural output for its own needs, as well as increased investment in energy and minerals extraction. An expanded military is needed to protect the assets thus created, requiring in turn its own increased sphere of agricultural and other resources. As more and more resources are drained from the support population to maintain this system, an increased share must be allocated to legitimization or coercion. This increased complexity requires specialized administrators, who consume further shares of subsistence resources and wealth. To maintain the productive capacity of the base population, further investment is made in agriculture, and so on.

*Id.*

<sup>84</sup> *Id.*

are not boundless. Rather, they exhibit a cost-benefit relationship that exists within outer-bound limits of declining marginal returns.<sup>85</sup>

A society is in trouble when the feature of declining marginal returns emerges. When "investment in further complexity yields increased returns, but at a declining marginal rate, . . . a complex society enters a phase where it becomes increasingly vulnerable to collapse."<sup>86</sup> Eventually, a society facing this dilemma reaches a point at which adding complexity becomes a less attractive problem-solving strategy.<sup>87</sup> As the marginal costs of complexity begin to exceed its benefits, "productive units across the economic spectrum increase resistance (passive or active) to the demands of the hierarchy, or overtly attempt to break away."<sup>88</sup> The society's final gasp is reached when "increasing complexity may actually bring decreased overall benefits, as the

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<sup>85</sup> *See id.* at 19-20. Tainter explains the underlying forces creating the cost-benefit relationship as follows:

[S]ociety . . . responds to stress by increasing complexity. In so doing, it increases investment in agricultural and other resource production, in hierarchy, in information processing, in education and specialized training, in defense, and so forth. The cost-benefit curves for these investments increases at first favorably, for the easiest, most general, most accessible, and least expensive solutions are attempted first. As these solutions are exhausted, however, continued stresses require further investments in complexity. The least costly solutions having been used, evolution now proceeds in a more expensive direction. The hierarchy expands in size, complexity, and specialization; resource production focuses increasingly on sources of supply that are more difficult to acquire and process; agricultural labor intensifies; information processing and training requirements become less generalized; and, most likely, an increased military apparatus is seen as the solution to these problems.

*Id.* at 120.

<sup>86</sup> *Id.* As Tainter explains:

To meet . . . major stresses the society must have some kind of net reserve. This can take the form of excess productive capacities in agriculture, energy, or minerals, or hoarded surpluses from past production. Stress surges of great magnitude cannot be accommodated without such a reserve. Yet a society experiencing declining marginal returns is investing ever more heavily in a strategy that is yielding proportionately less. Excess productive capacity will at some point be used up, and accumulated surpluses allocated to current needs. There is, then, little or no surplus with which to counter major adversities.

*Id.* at 120-21.

<sup>87</sup> *See id.* at 121.

<sup>88</sup> *Id.*

economic system and the sustaining base are taxed to the point where productivity declines. All segments of the society compete for a shrinking economic product. This is the realm of extreme vulnerability."<sup>89</sup> Indeed, Tainter believes that every complexly structured society in history reached this point and, ultimately, collapsed as a result. The principle of declining returns on investment in social structure thus provides the general theory of social behavioral collapse for which Tainter was searching.

Although we must consider the danger of squeezing history to fit a new theory, Tainter tests his theory against the historical record in excruciating detail.<sup>90</sup> Moreover, his specific application also squares neatly with the predictions of the general complexity theory model — that system adaptiveness increases near the border between order and chaos and decreases as a system moves out of that balance into either extreme. As the general complexity theory model of system evolution predicts, with each addition of structural complexity in one sector of society, the fitness landscape of systems elsewhere in society change. These systems may in turn require investment in structure just to stay current. And each step up the fitness landscape gained by the overall social investment in structural complexity reduces the chances that an equal additional investment in structure will lead to another equal step up the fitness landscape. Therefore, each new investment in structural complexity has less chance of benefitting the system equally or more than the last investment. Further, the investment creates more opportunities for emergence of unforeseen properties in system behavior. Tainter's work in archaeology has suggested that these principles hold true for human social systems.<sup>91</sup>

Although Tainter does not focus specifically on law, it clearly is at the core of the dynamics he unveils. Collapse for Tainter is

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<sup>89</sup> *Id.* at 122.

<sup>90</sup> *See id.* at 127-92 (discussing Western Roman Empire, Classic Maya, and Chacoan).

<sup>91</sup> Political theorists studying more recent history believe there is ample evidence of the most acute effect of diminishing returns on advanced state systems. *See, e.g.,* MASTERS, *supra* note 4, at 185-212. Masters uses evolutionary social biology and inclusive fitness theory to diagnose modern bureaucratic states. *See id.* Because of the strong parallels between his social evolution method and complexity theory, *see supra* note 62 and accompanying text, it comes as no surprise that Masters's analysis of ancient complex societies is compatible with Tainter's.

a political process,<sup>92</sup> and law is one of the raw ingredients in sociopolitical complexity.<sup>93</sup> So, because it necessarily is part of the larger adaptive social system, law must play a role in the theory of declining returns on investment in social structure. We can modify Tainter's four features to focus on law: (1) human societies use law as a tool of the problem-solving organization; (2) legal systems require energy for their maintenance, in such forms as courts, codes, lawyers, legislatures, regulatory and enforcement agencies, and other apparatus of legal institutions designed to distribute legal justice; (3) increased structural complexity of law and its institutions carries with it increased legal costs per capita; and thus (4) investment in the structures of the legal system as a problem-solving response can lead to declining marginal returns on law's benefits.

Society may think that the next incremental law is very important for solving a particular problem. But when law and society in general have become highly structured, each new law has effects, some of which are unanticipated and unintended. These effects spread out beyond the law's specific target to add yet more structural complexity (including its defining social characteristics of inequality and heterogeneity) to society. Whatever its effect on the target, the impacts of the law throughout society, as well as the increased complexity it adds to the system (and thus energy it drains from the system), must be included in the analysis of its overall effects. Any new law added to the pot of existing laws is likely on average to produce less marginal net benefits to society than did the previous law. Lawmakers in a complexly structured society must deal with the law of declining returns.

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<sup>92</sup> See TAINTER, *supra* note 4, at 4 (stating collapse is political process).

<sup>93</sup> See *id.* (enumerating characteristics of collapse). Several other legal commentators have focused on the link between the burgeoning of law and social collapse, principally in descriptive terms. See, e.g., Bruce Bartlett, *How Excessive Government Killed Ancient Rome*, 14 CATO J. 287 (1994) (identifying Roman economic policies as main factor contributing to end of economic and political stability); John W. Ragsdale, Jr., *The Rise and Fall of the Chacoan State*, 64 UMKC L. REV. 485 (1996) (discussing rise and fall of ancient Chaco Canyon civilization).



## 2. Technology — Increasing Risk as the Price of Convenience

Focusing on why societies experience decreasing returns on their investment in problem-solving structural complexity, Tainter's archaeological theory includes among the indicia of social structure and behavioral collapse the degree and pace of technological advancement.<sup>94</sup> Others who have considered the role of technology in society, particularly those researchers who have used complexity theory to explain the process of technological advancement, have reached conclusions remarkably similar to Tainter's. Indeed, perhaps more than any other aspect of society, technology offers a clear lesson about the chaotic fragility that can be experienced in a complexly structured society — a lesson that we believe has obvious applications to law.

Technological advancement is a nonlinear process. Technology is often portrayed in reductionist terms as progressing through discrete time and theme phases and through the efforts of individual "inventors." But, as James Burke concludes in his epic study of the technological developments that have shaped modern society, this is seldom the case.<sup>95</sup> Burke's detailed history of events shaping technological change shows that these periodic, thematic, and heroic treatments tend to ignore the overlapping nature of so-called periods. Instead, these portrayals imply a degree of foreknowledge where none exists, and exaggerate the influence of individuals over events.<sup>96</sup> In reality, the triggering factor in technological advancement "is more often than not operating in an area entirely unconnected with the situation which is about to undergo change."<sup>97</sup> A linear view of technological change misses many of the major points and distorts what it does reveal.<sup>98</sup>

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<sup>94</sup> See TAINTER, *supra* note 4, at 123-24 (discussing technical innovation in different societies).

<sup>95</sup> See JAMES BURKE, CONNECTIONS 288 (1978).

<sup>96</sup> See *id.*

<sup>97</sup> *Id.* at 289.

<sup>98</sup> Burke points out that

[a] linear view of the past would, for instance, place the arrival of the chimney in a sequence of developments relating to change in domestic living. Yet the alteration of life-style brought about by the chimney included year-round administration and increased intellectual activity, which in turn contributed to a

The reductionist, linear view of the past also influences our understanding of how technological advancement influences society, both in the present and future, in what Edward Tenner calls the perils of extrapolation.<sup>99</sup> For example, when eminent American men and women were asked in 1893 to describe life in 1993, many correctly anticipated weapons of mass destruction and global communication, but none foresaw the rise of the automobile. Indeed, the automobile seemed a rather impractical, expensive contraption until the discovery of oil in Texas in 1901 led to cheap gasoline and a fire at the Olds plant in Detroit that same year prompted Olds to create the assembly line process in its new plant.<sup>100</sup> Similarly, throughout history, despite the prevailing linear conception, the major events of technological advancement are the result of "a fascinating mixture of accident, climactic change, genius, craftsmanship, careful observation, ambition, greed, war, religious belief, deceit, and a hundred other factors."<sup>101</sup> We have every reason to believe the future will unfold in like fashion.

Technology's nonlinear evolution suggests that technological advancement may exhibit the behavior of a complex adaptive system. To some extent this is intuitive through simple observation of the historical record Burke and other researchers have revealed. Long before complexity theory hit the scene, for example, the philosopher Jim Houghan described technology in terms reminiscent of the strange attractor model.<sup>102</sup> More recently,

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general increase in the economic welfare of the community to a point where the increase in the construction of houses brought about a shortage of wood. The consequent need for alternative sources of energy spurred the development of a furnace which would operate efficiently on coal, and this led to the production of molten iron in large quantities, permitting the casting of the cylinders which were used in the early steam engines.

*Id.* Burke's wonderfully written book carries the reader through the decidedly nonlinear development and cultural impacts of a rich variety of technologies, including clocks, looms, buttons, money, and the zoopraxiscope. Beginning in November 1995, his writings on the subject can be followed in monthly installments in *Scientific American*. See James Burke, *The Silk Road*, SCI. AM., Nov. 1995, at 109, 109 (explaining that "[r]eductionism simply does not begin to describe this complex, serendipitous process [of technology innovation], in which even apparently trivial elements have the most important effects").

<sup>99</sup> See TENNER, *supra* note 8, at 272.

<sup>100</sup> See *id.*

<sup>101</sup> BURKE, *supra* note 95, at 13.

<sup>102</sup> Houghan writes:

Stuart Kauffman has described technological change using the core concepts of complexity theory.<sup>103</sup> Indeed, Kauffman points to the decreasing returns that are present in the historical record of technological change, just as Tainter has revealed that decreasing returns are an agent at work in the social system.<sup>104</sup> Precisely as the model of rugged fitness landscapes would predict, “the rate of finding fitter variants — of making incremental improvements — shows exponential slowing.”<sup>105</sup> That this phenomenon appears in the records of both archaeological and technological change is difficult to ignore.

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Any consideration of the technical phenomenon rapidly leads to the conclusion that it's a *chreod*. That is, a system whose components interact with each other in such a way that the system changes as time passes; and the interactions are of such a nature that the pathway of change is “buffered” from external influence by its internal rules or organization; if an outside force shoves the system in a direction contrary to its nature or rules, the system will *automatically* redirect itself along its natural path.

HOUGAN, *supra* note 65, at 63. In other words, technology's response to human input often exhibits the sensitivity property of strange attractor systems. However, technology is sufficiently adaptive as a system to resist human efforts to control it over the long run.

<sup>103</sup> Kauffman, whose work adapting complexity theory to evolutionary biology has been highly influential, posits that

[b]oth organisms and artifacts confront conflicting design constraints. As shown, it is those constraints that create rugged fitness landscapes. Evolution explores its landscapes without the benefit of intention. We explore the landscapes of technological opportunity with intention, under the selective pressure of market forces. But if the underlying design problems result in similar rugged landscapes of conflicting constraints, it would not be astonishing if the same laws governed both biological and technological evolution.

KAUFFMAN, *supra* note 2, at 192. Although society explores technology with “intent,” we question whether the decision to explore is voluntary. Does society have a choice?

<sup>104</sup> Kauffman explains that

during the initial phase of rapid improvements, investment in the new technology yields rapid improvement in performance. This can yield what economists call increasing returns, which attract investment and drive further innovation. Later, when learning slows, little improvement occurs per investment dollar, and the mature technology is in a period of what economists call diminishing returns. Attracting capital for further innovation becomes more difficult. Growth of that technology sector slows, markets saturate, and further growth awaits a burst of fundamental innovation in some other sector.

*Id.* at 203. Of course, some technologies simply die out when “attacked” by competing technologies. See Carl W.I. Pistorious & James M. Utterback, *The Death Knells of Mature Technologies*, 50 *TECH. FORECASTING & SOC. CHANGE* 133 (1995).

<sup>105</sup> KAUFFMAN, *supra* note 2, at 204.

The implications of this view of technology lead inevitably to consideration of how society responds to the presence of emergence, chaos, sensitivity, and catastrophe in relation to technological change. Most of our modern technology is highly interdependent and beyond the average person's understanding.<sup>106</sup> When technology "goes wrong," therefore, society is vulnerable to unintended and unanticipated consequences having no readily apparent remedies. Tenner dubs this the "revenge effect,"<sup>107</sup> and explains that a machine can only be understood when it is viewed as "a system, not just a device. It needs parts that interact in unexpected and sometimes unstable and unwanted ways."<sup>108</sup> The behavior of technology cannot be predicted because "[t]he complexity of mechanical systems makes it impossible to test for all possible malfunctions and makes it inevitable that in actual use, some great flaws will appear that were hidden from designers."<sup>109</sup> Tenner observes that as technology becomes tightly coupled — highly interdependent — "[c]omplexity makes it impossible for anyone to understand how the system might act; tight coupling spreads problems once they begin."<sup>110</sup>

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<sup>106</sup> Look around the room in which you are reading this Article. Can you explain how all of the apparatus in the room works? Could you build all of it from scratch? See BURKE, *supra* note 95, at 6 (hypothesizing what individuals would do if they had to start over after massive system failure).

<sup>107</sup> TENNER, *supra* note 8, at 7-9. Tenner is joined by several other current-day authors writing on the subject of society's increasing vulnerability to increasingly slight perturbations in technology. See, e.g., DIETRICH DÖRNER, *THE LOGIC OF FAILURE: WHY THINGS GO WRONG AND WHAT WE CAN DO TO MAKE THEM RIGHT* (1996); IVARS PETERSON, *FATAL DEFECT: CHASING KILLER COMPUTER BUGS* (1996). This emerging body of literature is changing perceptions of risk management methods and expectations of how successful risk management can be. See John Adams, *Mistakes Were Made*, *SCI. AM.*, Oct. 1996, at 120, 120-22 (reviewing Edward Tenner and Dietrich Dörner). The literature is also leading social commentators to reexamine the importance of the unanticipated consequences of social action. See David Whitman, *The Law of Welcome Surprises*, *U.S. NEWS & WORLD REP.*, Dec. 30, 1996, at 78.

<sup>108</sup> TENNER, *supra* note 8, at 13.

<sup>109</sup> *Id.*

<sup>110</sup> *Id.* at 16. Burke offers the example of the 1965 power outage in the northeastern United States as an illustration of how "failure in one area can mean failure in all areas." See BURKE, *supra* note 95, at 2. Hougan also has captured this quality of highly advanced technologies, positing that

[t]he fragility of contemporary technique, its total dependence upon an increasing number of components, its accelerating *complexification*, increases the probable magnitude of any technical disruption we may experience. When anything is changed in such a whole-system as our own, everything is

Illustrating this effect, Tenner documents example after example of a supposedly beneficial technological event — the invention of a device designed to improve safety or the introduction of a predator species to eradicate a pest species — having disastrous consequences outside (and often inside) the intended target zone of the technological “breakthrough.”<sup>111</sup> He concludes that this technological backlash is so prevalent today that society has come to accept a certain background level of technological vulnerability. As a result, to be counted as a “catastrophe,” the tragic event must register on the global rather than local scale.<sup>112</sup>

Society’s vulnerability to technology raises important themes similar to those Tainter developed in his studies of the archaeological record. As Burke has observed, society’s response to problems associated with technology is usually to increase technology because that is what society knows best how to do, and that is what was done before.<sup>113</sup> Technological advancement

changed. . . . It seems reasonable to suppose that, as the whole-system’s functioning comes to depend upon more and more parts, it becomes increasingly likely that the system will break down, assuming the fragility of each part remains about the same.

HOUGAN, *supra* note 65, at 45.

<sup>111</sup> See TENNER, *supra* note 8, at 26-253 (recounting incidents in medicine, environment, pest control, computerization, and sports).

<sup>112</sup> Tenner concludes from the historical record that

[l]ooking back over the last two hundred years, we can see a pattern. The nineteenth and early twentieth centuries were an age of crisis, a time when people were awed by technological scale and intensity, when people would come at great expense to world’s fairs to ogle steam engines, and when artists painted new furnaces and forges in romantically outsized dimensions. . . . The combination of scale and the complexity of technological systems guaranteed that catastrophes happened far more often than they had in previous centuries. . . . Classic disasters were deterministic. Cause and effect were linked. An exploding boiler killed those it killed, and spared those it spared. Late-twentieth-century disasters are expressed as deviations from a baseline of “normal” background tragedy. The truth is not in immediate view. It emerges from the statistical inference of trained professionals; to see it, lay people must learn at least the basics of their language. The old disasters were localized and sudden. New ones may be global and gradual, from radioactive isotopes in milk in the 1950s to climate change in the 1990s.

*Id.* at 24-25.

<sup>113</sup> As Burke stated:

breeds yet more technological advancement. Tenner calls this the “intensiveness” effect — addressing disaster by intensifying the technological apparatus.<sup>114</sup> Because of decreasing returns on that investment, however, each successive wave of investment requires more intensity to yield the same payoff.

This is precisely the theme Tainter develops in connection with collapse of societies generally. As Tainter’s decreasing returns theory would predict, social vulnerability to technology increases as technological complexity increases. As early as the mid-1970s, foretelling Tainter’s archaeological theme of centralization of power in society, Hougan suggested that society’s increasing vulnerability to technology could lead to “the gradual surrender of popular authority to technical elites within the administrative, or military, branches of government.”<sup>115</sup> When viewing technology through the complexity theory model of complex adaptive systems, therefore, society’s responses to technological advancement appear only to exacerbate the predicted emergence, chaos, sensitivity, and catastrophe behaviors.<sup>116</sup>

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[M]ost of us take the only available course: we ignore the vulnerability of our position, since we have no choice but to do so. We seek the security in the routines imposed by the technological systems which structure our lives into periods of work and rest. In spite of the fact that any breakdown in our interdependent world will spread like ripples in a pool, we do not believe the breakdown will occur. Even when it does, . . . our first reaction is to presume that the fault will be rectified, and that technology will, as it always has, come to the rescue.

BURKE, *supra* note 95, at 6.

<sup>114</sup> See TENNER, *supra* note 8, at 273-74 (discussing “intensification” and interplay among nature, society, and technology). Hougan refers to this response as part of the social “technique” of managing technology, under which “the natural path of the system as a whole is toward the most efficient rationalization of all activity in every area of endeavor.” HOUGAN, *supra* note 65, at 63. Continuing technological improvement towards the goal of rational efficiency becomes the central tenet of the social technique, such that “most people are unable to distinguish between technical innovation and ‘progress.’” *Id.* at 64. When technical innovation and social progress become synonymous in society’s perception, Tenner’s intensification effect is inevitable. Although it may seem trite to observe how fast technology has “progressed” in recent history, the fact of the matter is that the pace of technological evolution is breathtaking compared to evolution in biological systems. See W. Brian Arthur, *How Fast Is Technology Evolving?*, SCI. AM., Feb. 1997, at 105, 105, 107. We contend that when social perceptions of legal innovation and progress merge a similar “intensification effect” leading to rapid legal evolution also occurs.

<sup>115</sup> HOUGAN, *supra* note 65, at 185.

<sup>116</sup> We are not advocating as a solution to this phenomenon any form of active attempt to “reverse” technological advancement, as that could be as unpredictable in outcome and

Could this insight on the effects of technology have some application to law? We believe so. On one level, law contributes to the technological revenge effect when it endorses or promotes a particular technological development, for "only when we anchor [technology] in laws, regulations, customs, and habits does an irony reach its full potential."<sup>117</sup> On another level, however, the lesson from technology says something about law itself, in that the overall level of sociolegal structure can be understood as carrying with it an analogous interdependence. The success of any one law depends on the proper functioning of the many other laws. The catapult for carrying law to that point, we believe, is the federal administrative state.

The increasing centralization of power that has been a characteristic of the federal administrative state tends to decouple legal policy decision-making by promoting stratified, reductionist legal institutions, such as specialized federal agencies.<sup>118</sup> The various arms of the central state, endlessly proliferating and effectively

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thus as risk prone as the alternative of unchecked technological transformation. See BURKE, *supra* note 95, at 293. As complexity theory demonstrates, there is no way for society to alter technological advancement while all else remains the same, nor is there any way of knowing what would not remain the same and how it would change. Rather, the focus must be on how society can arrange itself as a system so as to best manage the effects of sub-systems such as technology and, the subject of this Article, law.

<sup>117</sup> TENNER, *supra* note 8, at 7. In other words, often law mandates or gives preference to the use of a certain technology, thereby decreasing the ability of society to reject the technology in the event it poses unanticipated adverse effects. For example, some commentators posit that the tradition in pollution control laws of prescribing technology-based regulatory standards "tend[s] to freeze technological improvements and stifle innovation." See John Atcheson, *Can We Trust Verification*, ENVTL. F., July-Aug. 1996, at 15, 17.

<sup>118</sup> In the environmental law field, for example, there are over 15 congressional committees, over 50 executive branch agencies, and at least 8 independent agencies, each with some jurisdiction over a defined set of environmental issues. See NATIONAL WILDLIFE FEDERATION, 1996 CONSERVATION DIRECTORY (41st ed. 1996). Professor Jerry Anderson has observed that

environmental law is hopelessly muddled because Congress focused on individual environmental problems rather than the environment as a whole. The piecemeal approach — responding to each separate crisis and treating distinct resources separately and differently — simply has not worked very well. Environmental law cries out for coordination and integration in order to be more effective.

Jerry L. Anderson, *The Environmental Revolution at Twenty-Five*, 26 RUTGERS L.J. 395, 410 (1995); see also Futrell, *supra* note 59, at §§ 3.1-3.5 (stating that "this 'piecemealism' has resulted in a checkerboard pattern of conflicting, confused overregulation for some activities and gaps where major environmental insults go unchecked by the law").

isolated from each other, thus become extremely skilled at promulgating laws. But a decision to make law by any one sub-sector (for example, an agency with jurisdiction over health care) is not sensitive to decisions made elsewhere in the system (for example, an agency with jurisdiction over transportation). As this fractionalization persists, the number of entities making law increases, and they become separated from each other and from their total environment. Each entity increasingly focuses on its own jurisdictional "turf." Its performance is measured by how many laws or the legal results it produces in that narrow realm, more being better. As a result, the law-making system becomes increasingly fixed (as in fixed point attractor behavior) on doing one thing — making laws.<sup>119</sup> The system eventually begins to ooze laws.

As the sheer "mass" of laws grows, however, a reverse of decoupling happens at another level of social structure. The multitude of laws becomes fully interactive as their fabric becomes increasingly intertwined with other social institutions. This interconnection is not the result of any conscious design, but

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<sup>119</sup> For example, Professor Jerry Anderson reports, presumably based on first-hand experimentation, that "[i]f you stack on the floor the volumes of the Code of Federal Regulations that contain environmental regulations, they measure over three and a half feet high." Anderson, *supra* note 118, at 413. He reports further that "[t]he EPA alone published almost 3500 pages of proposed and final regulations in the Federal Register during the first six months of 1994," and that the many federal agencies with some environmental jurisdiction combined "churn out over 35 pages of new or proposed regulations every working day." *Id.* Similarly, Professor William H. Rodgers reports that EPA's RCRA program fills 697 pages of the Code of Federal Regulations and 19,500 pages of informal guidance. See William H. Rodgers, Jr., *Environmental Law Trivia Test No. 2*, 22 B.C. ENVTL. AFF. L. REV. 807, 812, 816 (1995). These pages of law translate into a measurable labor and capital compliance burden. See, e.g., *Sources Spend 5.3 Million Hours Meeting Operating Permit Requirements, EPA Says*, 27 Env't Rep. (BNA) 987 (1996) (reporting statistics based on study of 25,659 sources of air pollution); *NSP Information Collection Requirements Top 46,000 Hours Annually for Gas Producers*, 27 Env't Rep. (BNA) 1342 (1996) (reporting statistics based on study of 332 facilities subject to specific federal air pollution controls). The burgeoning administrative state is by no means limited to environmental law. For example, Professor Richard Epstein reports that, largely as a result of the expansion of administrative powers and rules, the annual pages of the Federal Register have grown in number from 2,411 in 1936 to 67,716 in 1991. See RICHARD EPSTEIN, *SIMPLE RULES FOR A COMPLEX WORLD* 7 (1995). Professor Bernard Schwartz notes that in 1989, "to check all the federal regulations, one had to search the Code of Federal Regulations, with its 196 paperback volumes, containing 122,090 pages. The C.F.R. now contains over 60 million words — about seventy times as many as in the Bible and sixty times as many as in a complete Shakespeare." See BERNARD SCHWARTZ, *ADMINISTRATIVE LAW* 168 (3d ed. 1991).



develops from the undercurrents of emergent properties in society. As society begins to structure itself based on the large and growing volume of laws, society's success increasingly depends on the success of laws in meeting their goals. Thus, the system reaches chaotic interdependence. When any one law in such a complexly structured legal system fails to work as planned, society is vulnerable to more than just the failure of that law. Society is also faced with the unpredictable ripple effects the law's failure will have on the proper functioning of many other laws and, consequently, the other social institutions with which the laws are intertwined. As this failure reverberates through the legal system, society responds with more inherently (but not intentionally) interdependent laws designed to patch up the system, adding to the vulnerability of the system. Structural complexity breeds vulnerability, which breeds more structural complexity, which breeds more vulnerability, and so on.

## II. THE MODERN ADMINISTRATIVE STATE — HAS THE PROBLEM-SOLVER BECOME THE PROBLEM?

The applications of complexity theory in the study of archaeology and technology discussed in the previous Part of this Article demonstrate that structural complexity, despite its powerful problem-solving qualities, can lead to problems. As dependence on a more highly developed structure increases, the return on each incremental investment in structure decreases and the vulnerability to system-wide behavioral failure increases. Society responds to these problems with more investment in structural complexity, thus exacerbating rather than relieving the cycle towards breakdown. To determine the model's implications for law, in this Part we explore the emergence of decreasing returns and increasing vulnerability in a sociolegal system in which structural complexity has risen to the highest level in the history of societies — the modern administrative state.

As accustomed as modern society is to itself, "[t]he citizens of modern complex societies usually do not realize that *we* are an anomaly of history."<sup>120</sup> Many disciplines of study have been fas-

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<sup>120</sup> TAINTER, *supra* note 4, at 24. As Tainter explains:

minated with explaining the process that led to the emergence of states. These disciplines generally agree on the major characteristics of states that set them apart from other societies — territorial organization, differentiation by class and occupation rather than by kinship, monopoly of force, authority to mobilize resources and personnel, and legal jurisdiction — but they disagree over how these characteristics emerged from “simpler” societies.<sup>121</sup> For example, one approach — the typological approach to explaining the process — is based on the assumption “that as societies increase in complexity, they do so by leaps from one structurally stable level to another.”<sup>122</sup> This approach was taken by many eighteenth century legal theorists, such as Adam Smith and his fellow Scottish legal thinkers,<sup>123</sup> and

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Throughout the several million years that recognizable humans are known to have lived, the common political unit was the small, autonomous community, acting independently, and largely self-sufficient. . . . It has only been within the last 6000 years that something unusual has emerged: the hierarchical, organized, interdependent states that are the major reference for our contemporary political experience. Complex societies, once established, tend to expand and dominate, so that today they control most of the earth’s lands and people, and are perpetually vexed by those still beyond their reach.

*Id.*; see also MASTERS, *supra* note 4, at 198 (arguing that “while the modern nation-state may resemble . . . ancient forms [of developed bureaucracies] in its bureaucratic infrastructure, the leaders of some states or state-like systems did not rely on the kind of centralized institutions we take for granted”). References to an “administrative state” in the United States began to proliferate in the 1940s. See, e.g., JOSEPH ROSENFARB, FREEDOM AND THE ADMINISTRATIVE STATE 75 (1948) (asserting that “[w]e are on the threshold of what should be called the administrative state”).

<sup>121</sup> TAINTER, *supra* note 4, at 29.

<sup>122</sup> *Id.*

<sup>123</sup> Smith was a leading member of a “salon” of Scottish legal thinkers, which included Henry Home (Lord Kames) and David Hume as other leading figures. During the late eighteenth century, these legal scholars distinguished sharply between morality and law. They pursued the theory, the foundations for which were laid by earlier figures such as Montesquieu and Machiavelli, that “legal development is related to the mode of subsistence of society, which passes through certain well-defined stages.” PETER STEIN, LEGAL EVOLUTION: THE STORY OF AN IDEA 29 (1980). The focus of Smith in particular was on property law, based on the premise that property plays different roles in the sociological system according to the state of progress a society has reached. See *id.* at 29-38. “[W]riters in the natural law tradition . . . stressed the will of the individuals involved in a transaction, and set it against the good of the community as a whole.” *Id.* at 39. In contrast, Smith and his group held that

[n]atural liberty implies . . . a set of laws and institutions designed to make the self-interested actions of individual men work to the advantage of all. The appropriate analogy for such laws is no longer mathematics, as it was for the

Friedrich Karl von Savigny, leader of the German historical school of legal evolutionary theory at the time.<sup>124</sup> An alternative approach “is that as societies increase in complexity they do so on a continuous scale, so that discrete, stable ‘levels’ will be difficult to define, and indeed may not exist.”<sup>125</sup> The influence of Darwin’s theory of gradual evolution by natural selection led many legal theorists to adopt this approach in explaining legal change.<sup>126</sup> Each approach has its explanatory advantages, but no theory has fully explained why states emerge and collapse.<sup>127</sup>

We are not attempting to resolve all those questions, but rather to identify the properties of law that contribute to sociolegal evolution and, if not contained, possibly to sociolegal collapse. The structure of law in society — its level of complexity — appears to play a role in that process. Using a typological approach for a moment allows some correlation between the structural complexity of legal institutions and types of societies. We have added legal structure complexity to Tainter’s heteroge-

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rationalist natural law theorists. It is rather the rules of grammar, established by a slow process of social consensus, and subject to human alteration.

*Id.* at 46; see also Knut Wolfgang Nörr, *Technique and Substance: Remarks on the Role of Roman Law at the End of the 20th Century*, 20 SYRACUSE J. INT’L L. & COM. 33, 34 (1994) (explaining importance of property law to Scottish school).

<sup>124</sup> Savigny’s and Hugo’s theories, like those of the Scottish school, echoed the earlier writings of Montesquieu, as well as of the Irish theorist, Edmund Burke. See STEIN, *supra* note 123, at 54-60 (naming Montesquieu and Burke as influences on Savigny’s and Hugo’s writings). Hugo’s fascination was with Roman law, which he regarded as evidencing a strong “power . . . to adapt itself to changes in Roman society.” *Id.* at 55. For Savigny, who also focused on Roman law as the model of evolution in law, the Roman experience demonstrated that “[l]aw at first is not formulated in abstract rules; rather it is manifested through special forms, symbolic acts, which create or extinguish rights and duties. . . . People consider them part of their special way of life.” *Id.* at 60. Savigny thus posited that this “organic connection of law with the character of the people is preserved as societies develop . . . [and] is an inseparable part of a nation’s life.” *Id.* Savigny’s “organic connection” became the dominant model of the German historical school. See *id.* at 63; see also Elliott, *supra* note 22, at 40-43 (discussing influence of Savigny’s German historical school on Anglo-American theorists); Mathias Reimann, *Nineteenth Century German Legal Science*, 31 B.C. L. REV. 837, 858 (1990) (reviewing Savigny’s theories and noting that “[a]ll German legal thinkers after Savigny built on his work”).

<sup>125</sup> TAINTER, *supra* note 4, at 29.

<sup>126</sup> See STEIN, *supra* note 123, at 100 (describing how emerging theories of legal evolution paralleled developing theories of biological evolution).

<sup>127</sup> See TAINTER, *supra* note 4, at 31-38 (acknowledging inadequate understanding of rise and collapse of complex social institutions and describing two main theories).

neity (number of groups and evenness of distribution between groups) and inequality factors for defining social structure complexity. The resulting array of society types is as follows:<sup>128</sup>

<i>Society Type</i>	<i>Number of Groups</i>	<i>Distribution Between Groups</i>	<i>Level of Inequality</i>	<i>Complexity of Legal Structure</i>
<i>Hunter-Gatherer</i>	low	even	low	low
<i>Chieftdom</i>	low	uneven	medium	medium
<i>Modern State</i>	high	uneven	high	high
<i>Tyranny</i>	low	uneven	high	high
<i>Anarchy</i>	low	uneven	high	low

We do this not to advance a new airtight theory of classification of societies, but rather to make several points about the structural complexity of sociolegal institutions.<sup>129</sup> First, legal structure complexity can help explain the difference between

<sup>128</sup> Our reference to the hunter-gatherer, chieftdom, and complex state society types and description of their relative levels of heterogeneity and inequality are a summation of Tainter's more detailed descriptions. *See id.* at 26-31 (describing states and contrasting states with other types of societies). We have added the comparative measure of legal complexity and based our comparison of relative levels for those three society types on Tainter's general discussion of the role of law in each. Our descriptions of the tyranny and anarchy types of society are our inventions for illustration purposes. However, they are based generally on Tainter's description of conditions during and after the collapse of a number of societies. *See id.* at 39-90 (describing reasons for collapse of various literate societies).

<sup>129</sup> Other commentators have found the same exercise useful as a means of exploring the relationship between law and social structure. *See, e.g.,* DONALD BLACK, *THE BEHAVIOR OF LAW* (1976). There are strong parallels between Black's theory of legal system behavior and the five-step cyclic model we describe in Part II.B *supra*. Black focuses on three law-society relationships that bear some analogy to key ingredients of our model: vertical stratification (our inequality factor), horizontal differentiation (our two heterogeneity factors), and organization (our complex legal structure factor). *See id.* at 11-59, 85-103 (describing stratification, morphology, and organization in different societies). He uses these indices to describe types of social control structures. *See id.* at 105-30 (discussing methods of social control within different societies). Where we depart from Black, however, is in the explanation of the evolution of these relationships. *See infra* note 156 and accompanying text (explaining Black's assertion that indices allow us to forecast quantity of law that will exist in given setting).

types of societies, such as tyranny and anarchy, that otherwise share characteristics used by social scientists to define social types. Second, increasing structural complexity appears to correlate with increasing heterogeneity and inequality, as seen in the array of society types from hunter-gatherer to chiefdom to complex state (the exception is tyranny, in which most of the sociolegal complexity is devoted to maintaining a privileged class at the expense of the vast majority of the population). Third, history provides no examples of societies in which structural complexity of law is high and the number of groups is high, but the distribution of population across groups is even and the level of inequality is low. Therefore, the structural complexity of law and its institutions is a defining characteristic of societies and an index — we believe also an agent — of structural complexity throughout society. In this Part, we explain why this is the case.

#### A. *The Problem-Solving Side of the Cycle of Law*

The proposition that law should be used as a problem-solving tool for society runs long and deep in American legal theory and legal institutions.<sup>130</sup> For example, the evolution of American environmental law from a nuisance-based common law system to a highly developed federal statutory structure<sup>131</sup> was an exercise in problem solving. Society invested heavily in complex legal structures in order to address large problems associated with pollution and other sources of environmental degradation, problems that nuisance law was not adequately addressing. The proliferation of federal environmental laws in the 1970s seems like a “revolution” in law. However, in retrospect, the underlying

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<sup>130</sup> One of the earliest proponents of using law to fulfill social ends was Roscoe Pound. As early as the 1920s, he portrayed law “as a social institution to satisfy social wants” and proposed that it should be used to carry out “a continually more efficacious social engineering.” ROSCOE POUND, INTRODUCTION TO THE PHILOSOPHY OF LAW 47 (2d ed. 1954). Pound and other champions of the so-called Legal Realists were influential in advancing social regulation as a principle objective of legal theory and institutions. See NEIL DUXBURY, PATTERNS OF AMERICAN JURISPRUDENCE 149-59 (1995) (explaining role of legal realism in New Deal legislation).

<sup>131</sup> See *supra* text accompanying notes 58-60 (explaining evolution from nuisance law to environmental law and continued reform of command-and-control approach).

investment in the increasingly complex legal structure which caused the revolution had a long, gradual history.<sup>132</sup>

The statutory revolution of the 1970s did not appear out of nowhere. At the same time further investment in nuisance law was beginning to experience decreasing returns in terms of problem solving benefits, society was beginning to experiment with statutory approaches, albeit cautiously, mainly at the state and local level.<sup>133</sup> In the 1960s, Congress entered the field. Its

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<sup>132</sup> For example, long before 1970, nuisance law had been evolving in order to address increasingly troublesome environmental problems. The use of public nuisance causes of action allowed consolidation of widespread injuries normally adjudicated through multiple private nuisance actions into one lawsuit and improved the chances of obtaining an injunction against the offensive activity. Robert V. Percival provided a classic example of this increase in legal structure, as illustrated by two cases. See ROBERT V. PERCIVAL ET AL., ENVIRONMENTAL REGULATION: LAW, SCIENCE, AND POLICY 77-80, 97-99 (1992) [hereinafter PERCIVAL, ENVIRONMENTAL REGULATION]. In *Madison v. Ducktown Sulphur, Copper & Iron Co.*, 83 S.W. 658 (Tenn. 1904), several farmers brought suit to enjoin a smelter from damaging their timber and crops. Although the court found the smelter unquestionably had caused a nuisance with respect to the plaintiffs, it declined to enjoin the pollution to any degree. See *id.* at 667. Three years later, in *Georgia v. Tennessee Copper Co.*, 206 U.S. 230 (1907), the State of Georgia brought an action in public nuisance against the same smelter on behalf of its citizens. The Supreme Court issued an injunction restricting the level of pollution discharge. See *id.* at 239.

Similarly, the development of strict liability principles relieved some of the proof of fault problems posed to the nuisance plaintiff. The genesis of this evolutionary event is traced to the decision to apply strict liability to "nonnatural uses" of land in *Rylands v. Fletcher*, L.R. 3 H.L. 330 (1868) (Eng.) (holding company constructing reservoir strictly liable in tort for allowing water to enter and flood plaintiff's mine). This decision has since evolved in the United States to form the principle that any "abnormally dangerous" activity is subject to strict tort liability. See RESTATEMENT (SECOND) OF TORTS §§ 519-20 (1977) (discussing abnormally dangerous standard). The problem of transboundary pollution between states, which could complicate the rights of injured parties in the downwind or downstream receiving state, was combated through the development of federal common law remedies. See Robert Percival, *Environmental Federalism: Historical Roots and Contemporary Models*, 54 MD. L. REV. 1141, 1152-55 (1995) [hereinafter Percival, *Environmental Federalism*] (tracing protection of state interests using federal common law). Through such judicial refinements, nuisance law became an increasingly complicated and potent weapon of environmental protection. See RODGERS, *supra* note 38, § 2.1, at 112 (contending that nuisance theory and case law compose common law backbone of modern environmental law). Of course, the common law itself emerged as the result of a gradual increase in legal structure that took place during the eleventh century in England as the centralization of power in the royal courts allowed them to dominate the local, customary-law courts. See JOHN HUDSON, THE FORMATION OF THE ENGLISH COMMON LAW 19-23 (1996) (discussing social, legal, and political developments that shaped common law); Harry W. Jones, *Our Uncommon Common Law*, 42 TENN. L. REV. 443, 450 (1975) (stating that movement towards centralized court system afforded greater jurisdiction).

<sup>133</sup> State and local governments restricted their legislative efforts principally to smoke ordinances and other local impact regulatory programs. See Percival, *Environmental*

efforts centered on studying issues and coordinating states' planning efforts. While those efforts would be considered timid today, at the time they were novel ideas.<sup>154</sup> The initial returns in terms of increased understanding of the problems and of ways to approach them were tremendous, and fed directly into the emergence of the "tougher" statutory responses taken in the 1970s.<sup>155</sup> During the glide pattern of the 1980s, aggregate returns on this investment in legal complexity were substantial.<sup>156</sup>

The statutes of the 1970s thus were an example of emergence, chaos, sensitivity, and, some might say, catastrophe effects surfacing in the environmental law system. The history of American environmental law truly meets Tainter's standard of "a seemingly inexorable trend towards higher levels of complexity."<sup>157</sup> It is in every sense the manifestation of the unpredictable surprise behavior a dynamical system can exhibit as a variable of the system moves smoothly, slowly, and gradually along a continuum of change.

In the 1990s, however, we find environmental law again bumping headfirst into decreasing returns. The command-and-control approaches taken in the 1970s and 1980s have fallen short of the goal of eliminating environmental degradation. These approaches are proving ineffective at tackling many of the

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*Federalism*, *supra* note 132, at 1148-49 (noting that smoke abatement ordinances were among first regulations imposed by local governments); *see, e.g.*, *Huron Portland Cement Co. v. City of Detroit*, 362 U.S. 440, 448 (1960) (holding that application of local smoke ordinance to federally licensed river barges did not unconstitutionally interfere with interstate commerce).

<sup>154</sup> Except for a few narrowly targeted pollution control programs, federal legislative activity prior to 1960 relied principally on establishing planning and coordination programs in the states, in the hope that the states would pick up and run with the ball. *See* Percival, *Environmental Federalism*, *supra* note 132, at 1149-52, 1155-59 (discussing limited increase in federal assistance to local governments in their environmental protection efforts after World War II).

<sup>155</sup> *See supra* note 59 and accompanying text (discussing emergence of command-and-control statutory frameworks during 1970s).

<sup>156</sup> One of the unquestionable success stories of command-and-control regulation is the reduction by 96% of airborne lead from transportation sources since 1984, principally through direct federal regulation of lead additives in gasoline. *See* COUNCIL ON ENVIRONMENTAL QUALITY, *ENVIRONMENTAL QUALITY: TWENTY-FOURTH ANNUAL REPORT 8* (1993). In addition, from 1983 to 1992, vehicle emissions of carbon monoxide dropped 37% even though vehicle miles traveled increased 34%. *See id.* at 6.

<sup>157</sup> TAINTER, *supra* note 4, at 3.

remaining major pollution issues, such as mobile sources of air pollution and nonpoint sources of water pollution.<sup>158</sup>

In his thorough analysis of the current environmental regulation policy's failure to solve environmental degradation problems, Professor Arnold Reitze has captured the phenomenon of decreasing returns in environmental law. He posits that the increasingly specialized efforts of command-and-control regulatory style that has predominated since the 1970s are "limited by the law of diminishing returns. Pollution control programs usually bring further improvement at very high marginal cost, with continued environmental destruction occurring despite extraordinary efforts at control."<sup>159</sup> Going further down the path of

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<sup>158</sup> As Percival suggests, command-and-control style environmental regulation started "with the easiest targets of opportunity: the most serious environmental problems that could be most easily cured get addressed first. We are now working our way down the list to problems that are either less serious or more intractable." PERCIVAL, ENVIRONMENTAL REGULATION, *supra* note 132, at 8. For example, federal regulation of air and water pollution in the 1970s and 1980s focused on so-called "end-of-the-pipe" controls on stationary, discrete "point sources," largely because "pollution control technology emphasized end-of-the-pipe solutions," but also because such sources were "easier to control, both politically and administratively." *See id.* at 885. Today, however, the majority of carbon monoxide and a significant portion of the volatile organic compounds and nitrogen oxide emitted into the ambient air are from mobile sources such as automobiles, the regulation of which poses much thornier administrative and political challenges. *See id.* at 766-68 (discussing complexities of legislation designed to control emissions from mobile sources). Similarly, nonpoint source water pollution, which includes diffuse runoff from streets, farms, mines, and other areas, accounts for "nearly 100 percent of sediment, 82 percent of nitrogen, and 84 percent of phosphorous reaching the nation's surface waters." *See id.* at 944. Estimates are that such nonpoint pollution "account[s] for 65 percent of the contamination in polluted rivers, 76 percent in impaired lakes, and 45 percent in damaged estuaries." *Id.* Controlling the diffuse and numerous sources of nonpoint source water pollution has proven difficult at both the federal and state levels. *See id.* at 945-48 (discussing extension of jurisdiction of Clean Water Act to wetlands); U.S. ENVTL. PROTECTION AGENCY, NATIONAL WATER QUALITY INVENTORY: 1994 REPORT TO CONGRESS 403 (1995) (explaining that diffuse sources are more difficult to control than traditional point sources); John G. Mitchell, *Our Polluted Runoff: Widespread as Rain and Deadly as Poison*, NAT'L GEOGRAPHIC, Feb. 1996, at 106 *passim* (discussing pervasiveness and lack of regulation of nonpoint source pollution).

<sup>159</sup> Arnold W. Reitze, Jr., *Environmental Policy — It Is Time for a New Beginning*, 14 COLUM. J. ENVTL. L. 111, 116-17 (1989); *see also* Daniel J. Fiorino, *Toward a New System of Environmental Regulation: The Case for an Industry Sector Approach*, 26 ENVTL. L. 457, 459 n.11 (1996) (maintaining that "economists agree that the costs of reducing each unit of pollution nearly always increase as more stringent controls are required"). Possibly in an effort to defend the economic rationality of its programs, the Environmental Protection Agency recently has released reports purporting to show that pollution control laws yield substantially more economic benefits than costs. *See, e.g., Draft Report Concludes Air Act*



more coercive, narrowly-targeted regulation in response to newly-perceived environmental problems is costing society more and getting it less.

Therefore, the story of environmental law is the story of society increasing legal structure to solve problems, but facing diminishing returns along the way. The legal structure's dominant form may change.<sup>140</sup> But the underlying theme, operating gradually and below the surface of what may appear to be punctuated bursts of legal development, explains the history of these changes. That theme is increasing investment in legal structure. And while investment in legal structure as a strategy unquestionably has solved many problems of environmental degradation, it also has spawned large new regulatory bureaucracies, breathtakingly complicated regulatory schemes, masses of specialized legal and engineering consultants, new curriculums in law and engineering schools, new technologies and methodologies, and so on.

Thus, problem solving through increasing structural complexity in the style of modern environmental law requires additional investment in the infrastructure of the modern administrative state. Environmental law is but one example of the approach that becomes the default position of the modern administrative state generally. This reality leads to the question of whether the

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*Benefits \$6 Trillion Greater than Associated Costs*, 27 Env't Rep. (BNA) 373 (1996); *Economic Benefits from Clean Water Amount to Billions Annually, EPA Says*, 27 Env't Rep. (BNA) 391 (1996). While these claims of aggregate benefits versus costs may be true, they do not address the point we raise, which focuses on the *marginal* benefit of new law. In that regard, evidence is that new environmental regulations often have a net negative effect. See, e.g., David Bennett, *Zero Emission Vehicles: The Air Pollution Messiah? Northeastern States Mandate ZEVs Without Considering the Alternatives or Consequences*, 20 WM. & MARY ENVTL. L. & POL'Y REV. 333, 362 (1996) (explaining that electricity for car batteries often comes from fossil fuel power plants); *Environmental Harm May Outweigh Benefits of Mandated Electric Car Sales, Report Says*, 27 Env't Rep. (BNA) 1035 (1996) (explaining that air pollution benefits of electric cars may be offset by lead discharge effects of vehicles' use of lead-acid batteries). Hence, the fact that regulation may produce more good than harm in the aggregate does not alone justify continued addition to the pot of regulation.

<sup>140</sup> For example, the transition from nuisance to statutes, which gives rise to efforts to describe the "phases" of the evolution of environmental law. See, e.g., PERCIVAL, ENVIRONMENTAL REGULATION, *supra* note 132, at 103-12 (recounting chronology of federal environmental legislation); E. Donald Elliott et al., *Toward a Theory of Statutory Evolution: The Federalization of Environmental Law*, 1 J.L. ECON. & ORG. 313, 315-25 (1985) (characterizing evolution of environmental law as series of six stages, each associated with distinctive pattern of organization and incentives).

problem-solving feature of law in the modern administrative state could lead to its own set of problems.

### B. *The Problem-Creating Side of the Cycle of Law*

In the history of the modern administrative state, we find the problem of decreasing returns from law popping up again and again. The strategy of shifting to new forms of legal structure (e.g., nuisance to command-and-control to something new) to enhance the effectiveness of legal complexity can only work so long before decreasing returns take over again. As each new shift involves a quantum boost in the complexity of legal structure, decreasing returns come faster and harder.

We believe this general theme of increasing investment in legal structure leading to decreasing returns and increasing vulnerability plays out through a five-step cycle of social change. This cycle is predicted by Tainter's work in archaeology, by Tenner's examination of technology, and by complexity theory in general. For the first step in the cycle, pick up the story at any point at which structural complexity has been added to the sociolegal system, such as with the statutory revolution in environmental law of the 1970s described above. The immediate consequence of that addition (Step 2) is to create a new set of "winners" and "losers" with respect to the new law's economic and social impacts.<sup>141</sup>

As those new categories of winners and losers are added to the preexisting arrays of winners and losers, the level of social heterogeneity caused by legal complexity increases (Step 3). This increase is the result of each person's unique accumulation of winner and loser outcomes under the increasingly complicated,

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<sup>141</sup> See, e.g., PERCIVAL, ENVIRONMENTAL REGULATION, *supra* note 132, at 188 (asserting that "[i]n the 1990s, it is undeniably obvious in a way that it was not in 1970 that environmental policy produces winners and losers and, generally, that it has significant costs"). For example, in the environmental law realm, "the costs of pollution control are not distributed evenly among governmental entities, individuals, and businesses." *Id.* Indeed, the costs are not distributed evenly within any of those broad sectors. For example, Yeager's comprehensive study of the EPA's pollution control regulatory regime concluded that coercive regulations imposing technology and other capital compliance investments "tend to be regressive, disproportionately burdening the smaller companies with expensive implementation duties." See YEAGER, *supra* note 55, at 292. Enforcement of the rules "reproduces economic inequality . . . [and] the conditions creating structural bias in law." *Id.*

intertwined set of laws. Thus, each person moves closer and closer to becoming a separate group, increasing the probability that the person will voluntarily exit or involuntarily be excluded from membership in other groups.<sup>142</sup> The immense proliferation of environmental interest groups in the past two decades provides evidence of this in the environmental policy world.<sup>143</sup> Interest groups increasingly define their respective missions based on increasingly small differences of position with other groups about increasingly narrow issues of policy.<sup>144</sup>

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<sup>142</sup> At the broader sociological level, this phenomenon has become sadly evident in the emergence of America's "bowling alone" culture — more people are bowling than ever, but bowling league membership is down significantly. Mounting evidence suggests that the so-called "cultural social capital" of a society — the ability of people to work together for common purposes in groups and organizations — is depleted with the decline in cross-group membership in nonfamily based social groups such as civic and hobby clubs, churches, sports leagues, and other volunteer organizations. See FRANCIS FUKAYAMA, *TRUST: THE SOCIAL VIRTUES AND THE CREATION OF PROSPERITY* (1995) (discussing implications of America's decline of sociability in relation to economic life); James S. Coleman, *Social Capital and the Creation of Human Capital*, 94 AM. J. SOCIOLOGY 95 (1988) (characterizing social acts of individual as being governed by social norms, rules, and obligations as well as independent and self-interested motivations); Robert D. Putnam, *Bowling Alone: America's Declining Social Capital*, 6 J. DEMOCRACY 65 (1995) (discussing phenomena of declining civic engagements in American communities); John J. Fialka, *The Folks at Lodge 88 Are Trying to Build a Better Moose Trap*, WALL ST. J., Nov. 8, 1996, at A1 (describing changes fraternal organizations, like Moose Lodges, undergo as they seek to replenish older and declining memberships by offering more family-oriented activities to attract increased family participation); Jill Lawrence, *Wanted: Good Citizens, Close Communities*, USA TODAY, Dec. 16, 1996, at 1A (suggesting decline in church, school, volunteer, and other community-based groups may have led to "incivility" in society). Legal order, because it purportedly does the work of conflict resolution and capital building for us, has the propensity to displace social capital. However, "[w]hile governments can enact policies that have the effect of depleting social capital, they have great difficulties understanding how to build it up again." FUKAYAMA, *supra*, at 11.

<sup>143</sup> This is true on both "sides" of the environmental politics spectrum. For example, the so-called "wise use movement" is a loosely organized coalition of dispersed property rights and anti-regulation advocacy groups that is by far more "grass roots" than its environmentalist foes. The umbrella League of Private Property Voters lists over four hundred participating groups as diverse as the Alaska Loggers Association, New Mexico Cattle Growers Association, and the Wyoming Wool Growers. See LEAGUE OF PRIVATE PROPERTY VOTERS, 1995-96 PRIVATE PROPERTY CONGRESSIONAL VOTE INDEX 19-22 (1996). On the other side, the National Wildlife Federation now lists over 600 environmental protection advocacy groups in its annual directory. See NATIONAL WILDLIFE FEDERATION, *CONSERVATION DIRECTORY* (1996).

<sup>144</sup> As groups splinter and proliferate, stronger polarization is inevitable, as has been the experience in recent years with respect to environmental policy. See *Group's Environmental Score Card Shows Most Congressional Polarization in 25 Years*, 26 Env't Rep. (BNA) 2028 (1996) (reporting wide divergence of views on environmental issues).

Selection in the market place may be good to a point, but it is a harbinger of increasing inequality across society. As the number of laws and associated winner-loser outcomes increase, over any normal distribution, some people will wind up being losers far more often than winners, and vice versa. As the number of laws increases, the potential spectrum of disparity widens (Step 4).<sup>145</sup> In environmental law, for example, even if the total cost to society imposed by regulation is exceeded by the benefits derived therefrom, that would not ameliorate the uneven *distribution* of costs and benefits across the population.<sup>146</sup> Indeed, the premise of the environmental justice movement is that certain subpopulations — usually minority and low income groups — have borne most of the costs and received none of the benefits of environmental regulation.<sup>147</sup> These inequalities

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<sup>145</sup> For example, Professor Robert Frank has studied the emergence of America's "winner-take-all" culture, in which more and more citizens compete for ever fewer and bigger prizes, thus encouraging economic waste, income inequality, and an impoverished cultural life. See ROBERT H. FRANK & PHILIP J. COOK, *THE WINNER-TAKE-ALL SOCIETY* (1995) (arguing that unequal distribution of opportunities has accounted for huge income disparities and resulting social problems); ROBERT H. FRANK, *CHOOSING THE RIGHT POND* (1987) (explaining that people's concern about their economic status affects their behavior in systematic ways). To the extent that legal structure creates or enforces social winner-loser outcomes, law serves to strengthen these effects. American culture has made the mistake of acting as if increasing aggregate national economic growth — growth often facilitated by increasing legal structure — necessarily translates into greater socioeconomic equality and justice. But "[t]he concept of inequality deals with relative difference. . . . Inequality refers to the shape of the pyramid, not the absolute level of the pyramid." MURRAY MILNER, JR., *THE ILLUSION OF EQUALITY* 36 (1974) (documenting increased investment in social structure designed to foster equality of educational opportunity, which has not led to increased economic equality). Thus, while household income is on the rise and the number of people in poverty is falling in the United States, income stratification in the United States is widening at an alarming rate. See David J. Lynch, *Widening Income Gap Divides USA*, *USA TODAY*, Sept. 23, 1996, at 1B; Haya El Nasser, *Income Up for 1st Time Since 1989*, *USA TODAY*, Sept. 27, 1996, at 1A. A larger pie of wealth is being divided in an increasingly uneven manner.

<sup>146</sup> As Percival puts it, "to understand the development and implementation of environmental policy, it is necessary to consider not only how efficient policies are, but also how equitable." PERCIVAL, *ENVIRONMENTAL REGULATION*, *supra* note 132, at 188. But doing so requires consideration of the pre-existing order of winners and losers and the likely modification of that order caused by the new rule, a task that quickly becomes dauntingly complicated as the winners and losers become increasingly stratified both vertically (inequality) and horizontally (heterogeneity). See MASTERS, *supra* note 4, at 205 (explaining that the "definition of . . . new rules is of ever-increasing complexity because the new norms must consider both the novel behaviors that manipulate the existing system for private benefit and the original goals of the law").

<sup>147</sup> One of the founders and leading advocates of the environmental justice movement

created by environmental law will increase further as the structural complexity of environmental law increases.

Increasing inequality is, of course, generally inconsistent with broad sociolegal goals. Whatever reasons there may be for increasing structural complexity in environmental law to solve environmental problems, if the result creates other social problems and increases social inequality, what have we achieved? In

describes its central thesis as being that “[c]ommunities consisting primarily of people of color continue to bear a disproportionate burden of this nation’s air, water, and waste problems” and that such “[e]nvironmental racism exists within local zoning boards as well as the Environmental Protection Agency.” Robert D. Bullard, *The Threat of Environmental Racism*, NAT. RESOURCES & ENV’T, Winter 1993, at 23, 23. Several studies suggest that local authority zoning practices often result in exclusion along race and income lines. See Note, *State-Sponsored Growth Control Management as a Remedy for Exclusionary Zoning*, 108 HARV. L. REV. 1127, 1129-39 (1995) (discussing local exclusionary zoning practices in various states and judicial or state legislative responses). The contention that environmental protection regulation has led to racial and income inequality has been challenged, however, as paying too little attention to effects other than alleged discrimination. See Vicki Been, *Locally Undesirable Land Uses in Minority Neighborhoods: Disproportionate Siting or Market Dynamics*, 103 YALE L.J. 1383, 1385 (1994) (criticizing studies that examine only current racial make-up in affected communities, but fail to observe racial make-up at time sites were chosen). The topic of environmental justice, and whether injustice truly exists, has exploded in the last decade in legal and social commentary. See, e.g., DAVID E. NEWTON, ENVIRONMENTAL JUSTICE (1996); Symposium, *Race, Class, and Environmental Justice*, 63 U. COLO. L. REV. 839 (1992) (observing that environmental practices lead to structure of racial subordination and domination that has characterized American policy-making); Symposium, *Urban Environmental Justice*, 21 FORDHAM URB. L.J. 431 (1994) (analyzing administrative solutions to inequitable destruction of environmental hazards). Several legal academic texts also examine this topic. See, e.g., KENNETH A. MANASTER, ENVIRONMENTAL PROTECTION AND JUSTICE (1995) (discussing alleged failure of environmental enforcement and cleanup programs to respond to needs of poor and minority communities). Furthermore, various governmental programs were designed to identify and address instances of environmental injustice. See, e.g., Exec. Order No. 12,898, 59 Fed. Reg. 7629 (1994) (directing executive agencies to develop strategy for identifying and addressing instances of environmental injustice); 40 C.F.R. § 7.35 (providing EPA rules to implement Title VI of Civil Rights Act of 1964 in connection with environmental justice claims); UNITED STATES ENVTL. PROTECTION AGENCY, ENVIRONMENTAL JUSTICE STRATEGY: EXECUTIVE ORDER 12,898, EPA/200-R-95-002 (1995) (reporting on implementation of Executive Order 12,898 by EPA Office of Environmental Justice); Environmental Justice in EPA’s NEPA Compliance Analysis, 61 Fed. Reg. 36,727 (1996) (providing EPA draft guidance on integration of environmental justice analysis into environmental impact analysis documents). For a thorough bibliography of commentary on the environmental justice issue, see Adam D. Schwartz, *The Law of Environmental Justice: A Research Pathfinder*, 25 ENVTL. L. REP. 10,543 (1995), which argues that poor and minority populations in the United States bear a disproportionate share of the burdens of pollution. Information on environmental justice issues change rapidly and updates are available at EPA’s web page on the topic, *Environmental Justice Home Page* (last visited November 8, 1996) <<http://www.epa.gov/swerosps/ej/>>.

short, society has created another problem to solve according to the prevailing social agenda.

The experience has been that society's response to those new maladaptations, as Tainter and Tenner would predict, is to intensify legal complexity (Step 5). For example, the response to the "brownfields" problem,<sup>148</sup> which the environmental justice movement has pointed to as a visible example of the inequality of impact, has been a heavy dose of administrative programs and legislative solutions which inevitably will add to structural complexity.<sup>149</sup> That response may solve the brownfields

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<sup>148</sup> See *supra* note 38 (describing federal environmental reforms).

<sup>149</sup> The Environmental Protection Agency recently issued a "Brownfields Initiative" to combat the problem by cleaning contaminated properties and revitalizing communities containing such sites. See 60 Fed. Reg. 9684 (1995) (announcing EPA's Brownfields Initiative). It has identified pilot projects for examining how to address the issue. See *11 New "Brownfield" Pilot Projects Announced*, 26 Env't Rep. (BNA) 1884 (1996). The EPA has also shown how effective redevelopment grants could be. See *Superfund: Brownfields Grants from \$90,000 to \$200,000 Awarded to 16 Blighted Urban Industrial Areas*, 27 Env't Rep. (BNA) 1241 (1996); see generally *General Policy: President Calls for "Brownfield" Incentives, Stronger Laws on Communities' Right to Know*, 26 Env't Rep. (BNA) 1796 (1996) (discussing President Clinton's dual goals of cleaning up brownfields and limiting liability for polluters); Richard A. Horsch et al., *Brownfield Redevelopment*, NAT. RESOURCES & ENV'T, Summer 1996, at 55 (discussing problem with brownfields and Environmental Protection Agency's efforts to encourage redevelopment). Congress has sought to address the issue through measures designed to ameliorate the risks faced by redevelopment projects under CERCLA. See, e.g., H.R. 2178, 104th Cong. (1995) (introducing legislation to clean up brownfields and reduce liability for investors and bankers); see generally *Superfund: Amendment to Pending House Superfund Bill Would Set Grants, Loans for "Brownfields,"* 26 Env't Rep. (BNA) 1882 (1996) (discussing amendment which would provide more fiscal certainty for investors involved in cleanup). Information on brownfields issues changes rapidly and updates are available at EPA's web page on the topic, *Brownfields Home Page* (visited November 8, 1996) <<http://www.epa.gov/swerosps/bf/>>. Many states have also established regulatory programs to deal with the issue. See Mark D. Anderson, *The State Voluntary Cleanup Program Alternative*, NAT. RESOURCES & ENV'T, Winter 1996, at 22, 22-24 (discussing various states' voluntary cleanup programs); Anne Slaughter Andrew, *Brownfield Redevelopment: A State-Led Reform of Superfund Liability*, NAT. RESOURCES & ENV'T, Winter 1996, at 27, 27-30 (explaining brownfields problem and midwestern states' responses); Elizabeth Glass Geltman, *Recycling Land: Encouraging the Redevelopment of Contaminated Property*, NAT. RESOURCES & ENV'T, Spring 1996, at 3 (detailing different states' approaches to brownfields and voluntary cleanup laws); *Hazardous Waste: Mayors Release Proposal on Brownfields; President Urges Support for Tax Incentives*, 26 Env't Rep. (BNA) 1871 (1996) (discussing United States Conference of Mayors's proposal on brownfields and President Clinton's tax incentives plan); see generally OFFICE OF TECH. ASSESSMENT, *THE STATE OF THE STATES ON BROWNFIELDS: PROGRAMS FOR CLEANUP AND REUSE OF CONTAMINATED SITES* (1995) (discussing state programs addressing brownfields clean up); Michael J. Fleck, *The Illinois Brownfields Law: Environmental Protection Meets Economic Productivity*, 84 ILL. B.J. 400 (1996); Karen Hansen,

problem, but could lead to the emergence of other problems in its place.<sup>150</sup> Thus the cycle begins anew.

To summarize, we posit that a cycle of increasing structural complexity in the sociolegal system exists due to many of the factors Tainter and Tenner identified when applying complexity theory to other social settings. The cycle has five steps:

1. Society responds to a perceived problem by increasing the complexity of legal structures — for example, a new law, a new agency, a new precedent, or a new administrative program.
2. The increasingly complex legal structure distributes costs and benefits, both directly and through unforeseen mechanisms, unevenly throughout the population, thus increasing heterogeneity.
3. With each additional increment of legal structure, each individual moves closer to a unique set of costs and benefits, thus increasing the number of groups and decreasing the cross-membership between groups.
4. As heterogeneity increases, the spectrum of inequality across the population widens, thus leading to other perceived problems for social response.
5. Society responds to the new problems through further investment in legal structure.

Step 5 is different from Step 1 in the important respect that the decreasing returns effect requires the intensification of investment in legal structure at Step 5.<sup>151</sup> Hence, the phenomenon

*Minnesota's Landfill Cleanup Program: A New Superfund Paradigm*, NAT. RESOURCES & ENV'T, Winter 1996, at 32 (explaining Minnesota's cleanup program).

<sup>150</sup> For example, if the solution to brownfields redirects investment back to the affected urban areas, what about the suburban or rural "greenfield" areas where the investment was being directed before the solution? Will those areas become depressed? If the new investment in urban areas spurs economic development in urban settings, will traffic, smog, and housing scarcity become a larger urban problem? Unfortunately, no one can know.

<sup>151</sup> Howard calls this "responding by convulsions," meaning that "[g]overnment, believing it can only act through specific dictates, lurches again to solve yesterday's problems." HOWARD, *supra* note 10, at 47. The diminishing returns effect means that the convulsions get worse each time. See MASTERS, *supra* note 4, at 201 ("It follows that policy implementation by the bureaucracy has feedback effects on coercive law enforcement: each new strategy for securing the collective good defines new alternatives for violating the laws and thereby creates a new excuse for expanding the bureaucratic apparatus."); Harry V. Jaffa, *The Party of Lincoln vs. the Party of Bureaucrats*, WALL ST. J., Sept. 12, 1996, at A14 (contending that "[o]ne need not be cynical to see that the poor were not the reason for the expansion of bureaucracy; the expansion of bureaucracy was the reason for the poor. Every failure to reduce poverty was always represented as another reason to increase expenditures on the poor.").

of decreasing returns — the demand it poses for increasing investments of sociolegal complexity — drives the legal complexity cycle toward the creation of the modern administrative state. Once there, maintaining the fitness of the sociolegal system requires ever-increasing investments in structural complexity. The resulting structure ultimately reaches levels of interconnectedness and intensity that pose the problem of increasing vulnerability to collapse. We do not know when the threshold into dangerous levels of vulnerability is crossed, but all indications are that the arrow of law in the modern administrative state is pointed in that direction.

### III. BREAKING THE CYCLE OF COMPLEX LEGAL STRUCTURE — TWO MAXIMS FOR SUSTAINING LAW'S PLACE IN SOCIETY

The preceding discussion leads to two questions yet unanswered: first, what happens when structural complexity of law and its institutions becomes materially higher than that experienced in the modern administrative state to date; and second, can the cycle of increasing legal complexity be controlled? We do not yet know the answer to the first question, but we suspect sociolegal collapse will occur in any society that increases the complexity of its legal structure significantly beyond the present levels experienced in developed nations. So, our real concern is the second question.

In that regard, by now an astute reader may have detected what appears to be an incongruity in our analysis: how is it, one might reasonably ask, that societies acting as complex adaptive systems adapt to stress in a way that leads to collapse? Why do societies not use the means other complex adaptive systems use to stay poised on the edge of chaos? These are good questions, but the problem is not with complexity theory or our model. Rather, the problem is human behavior. Societies en route to collapse are behaving just as complexity theory suggests complex adaptive systems will under the circumstances, because human behavior is suppressing the behavioral qualities that keep these systems robust.

As complexity theory demonstrates, successful complex adaptive systems acting free of human influence breed as much com-



plexity of structure as they need to stay poised in an adaptive state. How do they manage to do that? Complexity theory researchers believe they have found the answer in what is known in their literature as self-critical behavior. Simply put, self-critical behavior is a means of relieving system stress by integrating small “avalanches” into the regular system behavior rather than waiting for the big crash to do the job — the way an area of tectonic activity might produce thousands of small tremors in order to avoid a severe earthquake.<sup>152</sup> Systems thus regulate structural complexity by avoiding it in the first place or shedding it in small doses when needed to avoid buildup of unmanageable stress levels.

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<sup>152</sup> Self-organized criticality is “[a] generic pattern of self-organized nonequilibrium behavior in which there are characteristic long-range temporal and spatial regularities.” COVENEY & HIGHFIELD, *supra* note 2, at 432. An example is provided by physicist Per Bak, who is credited as being the founder of the principle:

Bak asks us to consider a tabletop onto which sand is dropped at a uniform rate. As the sand piles up, it begins to slide off the edges of the table. Eventually, the system reaches a steady state at which the mean rate of dropping sand onto the pile equals the mean rate at which sand falls over the edges. At this stage, the slopes from the peak to the edges of the table are near the rest angle for sand. Bak asks the following question: If one adds a single grain of sand to the pile at a random location and thereby starts an avalanche, what will the distribution of avalanche sizes be? He finds a characteristic power-law distribution relating the frequencies and sizes of avalanches, with many tiny avalanches and few large ones.

KAUFFMAN, *supra* note 2, at 255; *see generally*, Fred Gutertl, *Riddles in the Sand*, DISCOVER, Nov. 1996, at 104 (describing current research on Bak’s theory and into unexplained behavior of sand and beads generally); I. Peterson, *Shaken Bead Beds Show Pimples and Dimples*, 150 SCI. NEWS 135 (1996) (reporting on formation of strange “puddles” during vibrating beads experiments); *Science with Brass*, SCI. AM., Nov. 1996, at 28 (noting curious patterns formed from vibrating oscillons). Bak has demonstrated how the principle might apply to earthquakes, clouds, solar flares, biological evolution, and economies. He posits that it is a necessary feature for integration of any system component into a highly complex system. *See* Per Bak, *HOW NATURE WORKS: THE SCIENCE OF SELF-ORGANIZED CRITICALITY* (1996); Per Bak, *Self-Organized Criticality: A Holistic View of Nature*, in COMPLEXITY: METAPHORS, MODELS, AND REALITY, *supra* note 2, at 477-93 (discussing theoretical work on models displaying self-organized criticality); B. Kean Sawhill, *Self-Organized Criticality and Complexity Theory*, in 1993 LECTURES IN COMPLEX SYSTEMS, *supra* note 46, at 143-47 (discussing complexity pattern formation in nature). We have elaborated elsewhere on our belief that an externally-, or, in the case of human organizations, self-imposed structural error could prevent this adaptive behavior from occurring, thus allowing other forces to move the system out of the complex behavior region. *See* Ruhl, *Brief Discussions*, *supra* note 3 (explaining complexity theory’s applications to society).

Humans pose two obstacles to self-critical behavior in the sociolegal system. First, because it is the easiest way of understanding much (but not all) of what happens around them, humans are incessantly reductionist in approaching problems of society. Thus, their behavior obscures the underlying dynamical qualities of social mechanics in the first place.<sup>153</sup> Second, humans resist incorporating self-critical behavior as a means of regulating structural complexity because self-critical behavior in a social context requires voluntary sacrifice and restraint, neither of which has proven to be a successful political platform in the administrative state.<sup>154</sup> These effects work against the complex adaptive nature of society as a system. Only deliberate steps to intervene on behalf of adaptiveness will cut short the cycle towards collapse.<sup>155</sup>

In this final section we offer two maxims designed to begin that intervention. With all the criticism we have leveled thus far at legal complexity, a reader might anticipate that we are about

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<sup>153</sup> See Ruhl, *Complexity Theory as a Paradigm*, *supra* note 3, at 893-95 (discussing general fallacies in reductionist thinking).

<sup>154</sup> This is patently obvious in the environmental protection realm, where self-critical behavior might begin with the exercise of restraint in environmental degradation, which, as a consequence, may ease the compulsion politically to impose additional sociolegal structure to address the problem. Unfortunately, "[i]n their roles as consumers and producers, members of the social classes most favoring increased environmental protection have lifestyles intimately associated with massive waste-generating activities including, for example, the serious environmental problems associated with solid waste, automobiles, and the advances of technology." YEAGER, *supra* note 55, at 307; see also Arnold W. Reitze, Jr., *Federalism and the Inspection and Maintenance Program Under the Clean Air Act*, 27 PAC. L.J. 1461 (1996) (explaining that "Americans are not eager to sacrifice to protect the environment. They want both a clean, safe environment and the freedom to behave in a manner that makes protecting such an environment very difficult.").

<sup>155</sup> Of course, the collapse of societies may itself be a form of self-critical behavior. The collapse sustains adaptability of the human species as a whole over time by preventing one dominant society from ruling the world or large parts of it for very long. That possibility, however, is not very comforting for the members of the collapsing society to make the self-critical effect for the larger system possible. Our approach is to embed self-critical behavior at the single-society system level, perhaps making the need for collapse of individual societies obsolete. For example, a purposefully cyclic economy built and fluctuating around an adaptively mean size may mitigate economic and environmental problems associated with the increasing population and resource consumption levels of "growth" economies while maintaining the change necessary to foster new enterprises. Of course, this requires voluntary sacrifice, self-restraint, and self-critical behavior, which Americans have not often exhibited in the environmental protection realm. See *supra* note 154 (pointing out that consumers want to protect their environment yet maintain lifestyles that create waste and environmental problems).

to propose that society “trash” law and legal structure. That is not the case. We do not want to give the impression that law is “evil” or always a drain on society; rather, as we have stated, law has powerful problem-solving dimensions that are essential to any successful society. Hence, we propose that society take steps to enhance the problem-solving side of law and suppress the problem-creating side.

#### A. *Make Less Law — A Self-Imposed Self-Criticality*

The root cause of the increasing structural complexity of law is additions to the “mass” of laws. As this mass grows, the interdependence between laws and society grows. Compliance with laws becomes more complicated, and regulatory and enforcement infrastructures become increasingly necessary. Centralization of the entire law-making machinery becomes a more efficient (but in the end disastrous) means of governing. Quantitatively, therefore, an index of the structural complexity of law might measure such factors as the number of laws, the number of pages in the code books, the number of regulatory proscriptions stated in the laws, and the cost of complying with the laws.<sup>156</sup> Whatever indices might be devised, their purpose must

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<sup>156</sup> As Black posited:

Law is a quantitative variable. It increases and decreases, and one setting has more than another. It is possible to measure the quantity of law in many ways. . . . More generally, the quantity of law is known by the number and scope of prohibitions, obligations, and other standards to which people are subject, and by the rate of legislation, litigation, and adjudication. As a quantitative variable, law is all of this and more.

BLACK, *supra* note 129, at 3. He contends that “the more stratification a society has, the more law it has.” *Id.* at 13. Further, the “law increases with differentiation to a point of interdependence but declines with symbiosis.” *Id.* at 39. Finally, “[t]he quantity of law varies with the organization of its environment.” *Id.* at 86. His explanation of these relationships is largely descriptive in focus. However, he goes beyond this explanation to suggest that the condition of society — its levels of stratification, heterogeneity, and organization — may be used as a sort of exogenous variable that allows us to predict the quantity of law that will exist in a given setting. *See, e.g., id.* at 131 (arguing that “[i]f these [social] trends continue into the future, law will increase all the more. . . . Everywhere, law increases with the evolution from tribal to modern life . . .”). His observations are, nonetheless, astute. Complexity theory allows us, we believe, to explain the relationships Black says exist. A theory of interrelated feedback loops reveals why the quantity of law is more akin to an affirmative agent of increasing social inequality, heterogeneity, and complexity, rather than simply a function of those conditions.

be to measure the structural load the legal system places on society.

Without proposing such an index, we believe we are safe in proposing that measures which reduce the mass of laws would also reduce the complexity of legal structures. We do not mean to suggest that existing laws should simply be discarded and none put in their place — our model is not a Libertarian manifesto.<sup>157</sup> Rather, we propose that the structure and philosophy of our law-making apparatus must be transformed so that the objective of controlling legal complexity is a foremost concern.

Structurally, for example, Tainter's work in the study of complexly structured societies suggests that a principal indication that social structure is approaching critical levels is centralization of government.<sup>158</sup> Further, he indicates that one of the first signs of social collapse is the forced wresting of control from central government to smaller, outlying units of government.<sup>159</sup>

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<sup>157</sup> Wholesale deregulation simply for the sake of reducing sociolegal structure would be as unpredictable in result as, say, unplugging all computers so as to relieve the stresses caused by technology structure. As our critique of path dependence theory demonstrates, deregulation would not unwind the system back to pre-regulation days. See *supra* notes 15-18 and accompanying text (explaining that once society decides to travel down one branch of decision node, it cannot later simply retrace its steps to that node and choose another branch). Rather, because the entire system evolves along with the buildup of sociolegal structure, the process becomes "reversible only under great hardship." See Tainter, *supra* note 80, at 3. Thus, Masters explains, "as more people become dependent on the goods and services of the bureaucracy, individuals and groups consider past benefits to be a part of the natural environment and defend their specific advantages against reductions justified in the name of the collective good." MASTERS, *supra* note 4, at 210-11. Ironically, however, deregulation in complexly structured societies often becomes an attractive political goal, because

government adds complexity to people's lives, through behavioral regulation and increases in the number and diversity of activities in which people must engage. So strong is the [public's] aversion to hierarchically imposed complexity that politicians in our day successfully base their careers on exploiting the discontent it creates, and journalists win prizes for exposing it.

Tainter, *supra* note 80, at 12. As the 104th Congress perhaps best illustrates, once politicians of this ilk are ushered into office on a raw deregulation bandwagon, they soon discover that the process is much more complicated, unpredictable, and painful than the political rhetoric suggests, and so do the citizens who supported them. Hence, although deregulation may at times be a part of the process of controlling the growth of sociolegal structure, it must be carried out very carefully, and without unyielding expectations of success.

<sup>158</sup> See Tainter, *supra* note 4, at 123.

<sup>159</sup> See *id.* It is difficult to ignore the emergence in recent years of a "devolution" sentiment in American society. See Symposium: *To Devolve, or Not to Devolve?: The (D)evolution*

The same story is unfolding in the history of American federalism, as the gradual dilution of the nondelegation doctrine<sup>160</sup>

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of *Environmental Law*, 27 PAC. L.J. 1457 (1996). Although public support for strong environmental protection policies remains high, polls suggest that increasingly the public wishes that primarily state and local governments are responsible for actual policy decision-making. See *Americans Favor State, Local Controls, Poll Says*, 27 Env't Rep. (BNA) 801 (1996) (citing poll showing 65% of participants prefer state or local control of environmental issues to federal control); Jonathan H. Adler & Kellyanne Fitzpatrick, *For the Environment, Against Overregulation*, WALL ST. J., July 29, 1996, at A12 (quoting statistics which reflect 67% who favor state and local responsibility for protecting water quality in rivers, lakes, and streams, and 77% who favor state and local responsibility for maintaining water quality). Recent opinion surveys suggest a broadening dissatisfaction with the federal government and increasing faith in local government. See *Government Gets Poor Marks*, USA TODAY, Jan. 23, 1996, at 4A (citing Gallup poll of 2000 people). As this mood has emerged, entrenched federal interests and groups basing their platform on the preservation of centralized power have resisted even opening the debate. See, e.g., Robert Housman, *The Devil Is In the Exogenous Variables*, ENVTL. F., May-June 1996, at 32, 33 (noting that market pressures to maintain federal environmental laws are even greater now with global economy, and that decentralized environmental regulatory scheme would lead to hodgepodge of laws that powerful local industrial actors could easily infuse with protectionism); Vickie Patton, *A Balanced Partnership*, ENVTL. F., May-June 1996, at 16, 17 (criticizing arguments championing state regulation in lieu of federal regulation because they unduly attack cooperative federalism, which is sound foundation of current national environmental policy). As one state environmental agency official recently complained, "EPA, despite all its professions of a desire for flexibility, for new approaches, for a greater state authority and autonomy, is taking the same old centralized Washington-knows-best attitude." See *EPA's Approach Toward State Audit Law Shows No Flexibility*, 27 Env't Rep. (BNA) 1446 (1996) (quoting chairman of Texas environmental agency). The devolution debate is brewing in other areas of social regulation as well. See, e.g., Peter H. Schuck, *Some Reflections on the Federalism Debate*, 14 YALE L. & POL'Y REV. 1 (1996) (providing an overview of the devolution topic); Note, *Devolving Welfare Programs to the States: A Public Choice Perspective*, 109 HARV. L. REV. 1984, 1994-2000 (1996) (describing debate about whether federal or state governments should have responsibility for welfare regulations).

<sup>160</sup> Based on the fiction of "Congress . . . obtaining the assistance of its coordinate branches," delegation of legislative power from Congress to agencies has been upheld consistently. See *Mistretta v. United States*, 488 U.S. 361, 372 (1989). The only limitation is that the delegation not be done with "an absence of standards for the guidance of the [agency's] action, so that it would be impossible in a proper proceeding to ascertain whether the will of Congress has been obeyed." *Id.* at 379 (quoting *Yakus v. United States*, 321 U.S. 414, 425-26 (1944)). The standard of what is required is also known as the "intelligible principles" test, see *J.W. Hampton, Jr., & Co. v. United States*, 276 U.S. 394, 409 (1928), which insisted that Congress "lay down by legislative act an intelligible principle to which the person or body authorized to [exercise the delegated authority] is directed to conform." The courts have supported a finding of proper delegation based on legislative directives as abstract and compassless as "public interest, convenience, or necessity." See, e.g., *National Broad. Co. v. United States*, 319 U.S. 190, 217 (1943) (upholding delegation of power to FCC to promulgate regulations in accordance with its view of public interest). In addition, Justice Scalia asks, "What legislated standard, one must wonder, can possibly be too vague to survive judicial scrutiny, when we have repeatedly upheld, in various contexts,

and expansion of the federal commerce power<sup>161</sup> have facilitated the growth of a central federal government at the expense of state and local authority. The question is whether society can exercise self-critical behavior by restoring the Constitution's structural controls on unchecked centralization. If it cannot, not a single example in the history of societies suggests that the sociolegal system's collapse into radically simpler, decentralized forms will be averted. The difference between the two outcomes — decentralization through self-imposed restraint versus through catastrophic restructuring — is the intensity of pain and disruption society feels along the way. We suggest the former route.

The decentralization of law-making power is only one step towards managing the mass of laws. Along with decentralization must come a catharsis from the reductionist approaches of law-

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a 'public interest' standard?" *Mistretta*, 488 U.S. at 416 (Scalia, J., dissenting).

<sup>161</sup> Virtually the entire body of federal pollution control legislation, for example, is based on the power of Congress to "regulate Commerce . . . among the several states." U.S. CONST. art. I, § 8, cl. 3. The expanded federal commerce power has set the stage for gradual but unmistakable centralization of law-making power in the federal government at the expense of both the common law and state and local government law-making. For example, Professor Robert Beck summarizes where the jurisprudence of the commerce clause has led by suggesting that it could be rewritten as follows: "The Congress shall have Power . . . To regulate Commerce, articles in commerce, and anything that substantially affects Commerce, and to prohibit commerce in certain articles . . . among the several States." Robert E. Beck, *Setting the Course for the Surface Mining Control and Reclamation Act of 1977*, NAT. RESOURCES & ENV'T, Fall 1995, at 24, 25. He observes that "the actual wording of the Commerce Clause has become so unimportant that most courts applying it do not bother quoting it any more." *Id.* In *United States v. Lopez*, 115 S. Ct. 1624 (1995), the Court struck down a federal law prohibiting the possession of guns in designated school zones as beyond the commerce power, the first such invalidation of a federal law on commerce power grounds in over 60 years. *See id.* at 1634. The decision has triggered a "Lopez-watch" in the legal community to see where it leads, but in general the Court and lower courts have taken it nowhere. *See, e.g.,* *Cargill, Inc. v. United States*, 116 S. Ct. 407, 408 (1995) (mem.) (Thomas, J., dissenting) *denying cert. to* *Leslie Salt Co. v. United States*, 55 F.3d 1388 (9th Cir. 1995) (questioning lower court assertion of federal regulation over isolated wetlands based on the possibility that migratory birds traveling across state boundaries could land there to rest or feed). *But see* *United States v. Olin Corp.*, 927 F. Supp. 1502, 1503 (S.D. Ala. 1996) (holding that application of Superfund to specific case was beyond federal commerce power). *See generally* *News from the Circuits*, ADMIN. & REG. NEWS, Fall 1995, at 4 (collecting cases decided since *Lopez* refusing to strike down federal legislation on commerce power grounds). For an extremely thorough, current description of the original intent of that provision of authority, its history, its current doctrine, and its possible future, see Donald H. Regan, *How to Think About the Federal Commerce Power and Incidentally Rewrite United States v. Lopez*, 94 MICH. L. REV. 554 (1995).

making. Attention must be given to the unpredictable properties of the sociolegal system in general. A new philosophy of law-making is needed, one in which the mass of law is increased not as the presumptive response to all social problems, but only when it is determined to be absolutely necessary.

To do so, the law-making process must begin to address the underlying sociolegal forces from which social problems emerge, rather than simply throwing new laws at the problems that bubble to the system's surface. For example, Professor Arnold Reitze argues that the command-and-control environmental law regime has failed to control environmental degradation because it has completely missed the underlying sources from which environmental degradation emerges — increasing population and consumption.<sup>162</sup> So long as overall sociolegal policy remains passive with respect those underlying forces, or even promotes

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<sup>162</sup> See Reitze, *supra* note 139, at 117. For a comprehensive discussion of the challenges human population and consumption patterns pose to social policy, see JOEL E. COHEN, *HOW MANY PEOPLE CAN THE EARTH SUPPORT?* (1995). Reitze points out elsewhere that the administrative state's response to its continuous failure to respond to these challenges is, of course, to promulgate yet more regulation. See Reitze, *supra* note 139, at 120-21 (stating that increases in population, consumption, and as a consequence, pollution, put pressure on environmental regulators to constantly increase stringency of pollution control measures). This problem explodes exponentially in effect when the costs and benefits are assessed at the global rather than national level. At recent meetings of the United Nations Commission on Sustainable Development, for example, the Commission noted the trend towards a global consensus on the importance of changing consumption and production patterns and highlighted the critical linkages between population, consumption, and the environment. See *One Year Before the Review*, 26 ENVTL. POL'Y & L. 138 (1996). The ultimate conclusion was that "levels of population, consumption patterns, and the nature of technology are the three major factors which determine the effects of development on the environment." *Id.* at 141. A serious obstacle to approaching issues of this magnitude in any long-term, comprehensive manner is the tendency of advanced state structures to perpetuate and protect themselves. State lawmakers find they can best protect themselves by using law to take "an essentially reactive stance to acute (rather than chronic) social crises to secure a certain political legitimacy, the currency of statehood." See YEAGER, *supra* note 55, at 323. This approach can work over the short run to prop up the regime, because citizens in general tend to respond to the short run, but over the long run it leads to the state ignoring the chronic underlying problems of its existence. As Masters indicates, "[t]he centralized state is vulnerable over the long run precisely because it can be so successful in generating mutual benefits and collective goods in the short-term horizon of an individual's conscious decision making." MASTERS, *supra* note 4, at 185. But "[s]ooner or later, political systems decline and collapse as it becomes impossible for them to provide the collective goods needed to convey a sense of legitimacy and to extract resources from the populace." *Id.* at 211.

them, command-and-control environmental regulation will be mired by increasing structural complexity.

Similarly, the law-making process must recognize that it can be the source of social problems, and that it could solve some social problems by reducing sociolegal complexity. For example, defining abandoned urban industrial sites as the "brownfields" problem<sup>163</sup> obscures the fact that brownfields did not exist prior to Superfund and indeed were the direct result of Superfund. The response has been to address brownfields as a discrete problem requiring new laws for its solution. Had the problem been defined as one with Superfund, however, the law-making process may have more successfully addressed the problem through fewer laws.

In general, therefore, those making laws must alter their focus from reductionist, problem-specific approaches to system-level approaches. They must also recognize that the complexity of legal structure itself is often the cause of social problems. Both structurally and philosophically, therefore, self-critical measures can be taken to stem the tide of increasing legal structure before social collapse does so instead. To do this, initially, the law must ignore some of society's problems and let them play out and be solved, if they can be solved, through other social mechanisms and conventions. Law is not the only problem-solving tool society has at its disposal. When law steps in, it risks displacing other forms of resolution that society has devised over long periods of trial and error, without any guarantee doing a better job.<sup>164</sup> Of course, society cannot know ahead of time which

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<sup>163</sup> See *supra* notes 149-50 and accompanying text (discussing Environmental Protection Agency's attempt to reduce uncertainty in liability exposure at appropriate sites through "Brownfield Initiatives").

<sup>164</sup> It is remarkable, for example, that techniques of mediation are only recently beginning to meaningfully influence the highly litigious world of environmental law. See Frank P. Grad, *Alternative Dispute Resolution In Environmental Law*, 14 COLUM. J. ENVTL. L. 157, 159-62 (1989) (summarizing applicability of mediation to environmental disputes in light of fact that parties generally have no prior negotiating relationship and disputes tend to be interorganizational rather than interpersonal); Charlene Stuckenberg, *The Proper Role of Alternative Dispute Resolution (ADR) in Environmental Conflicts*, 19 U. DAYTON L. REV. 1305, 1309-28 (1994) (asserting that low acceptance of alternative dispute resolution in environmental litigation stems from experimental nature of ADR procedures in this field). Law did not invent mediation; rather, law practically destroyed it. It is ironic that law portrays mediation, a social convention that has been around for quite a while, as the "alternative" method of dispute resolution. See JEROLD S. AUERBACH, JUSTICE WITHOUT LAW



social problems can best be resolved through nonlegal social mechanisms and conventions. But unless society facilitates their operation, it will never know which social problems would have been resolved without resort to law.

Similarly, when society cannot resist the urge to step in with law as the problem-solving tool, it should consider ways of minimizing the disruption of existing social conventions or even ways of taking advantage of them. After twenty years of command-and-control style of environmental law, for example, we are only now beginning to rediscover the value of laws that promote the use of the market<sup>165</sup> and the dissemination of information into

(1983) (tracing history of mediation as social convention and its gradual displacement by legal institutions).

<sup>165</sup> See Pub. L. No. 101-549, § 401, 104 Stat. 2399, 2584 (1990) (codified at 42 U.S.C. § 7651 (1994)). The Clean Air Act sulfur dioxide emissions trading program for electric utilities is widely regarded as the most successful example of integration of market efficiencies into the command-and-control regulatory structure. See, e.g., PERCIVAL, ENVIRONMENTAL REGULATION, *supra* note 132, at 830-32 (discussing different approaches of private and public entities); Dallas Burtraw & Byron Swift, *A New Standard of Performance: An Analysis of the Clean Air Act's Acid Rain Program*, 26 ENVTL. L. REP. 10,411 (1996) (concluding that program has outperformed previous command-and-control approaches); Timothy A. Wilkins & Terrell E. Hunt, *Agency Discretion and Advances in Regulatory Theory: Flexible Agency Approaches Toward the Regulated Community as a Model for the Congress-Agency Relationship*, 63 GEO. WASH. L. REV. 479, 491 (1995) (explaining successful permit system for emissions); *Utilities Achieve 100 Percent Compliance with EPA Acid Rain Program, Report Says*, 27 Env't Rep. (BNA) 885 (1996) (reporting that utilities met emissions standards under trading program). The program is nonetheless unmistakably part of the command-and-control regime, as the "market" for emission trading is created by regulatory fiat. See Roger K. Raufer, *Market-Based Pollution Control Regulations: Implementing Economic Theory in the Real World*, 26 ENVTL. POL'Y & L. 177, 184 (1996) (noting that "market-based systems have relied heavily upon the [command-and-control] framework already in place"). Many commentators have forcefully argued the need for even greater reliance on market forces to bring about more efficient protection of environmental factors. See, e.g., Bruce A. Ackerman & Richard B. Stewart, *Reforming Environmental Law: The Democratic Case for Market Incentives*, 13 COLUM. J. ENVTL. L. 171 (1988) (advocating market incentives over bureaucracy); Kenneth J. Arrow et al., *Is There a Role for Benefit-Cost Analysis in Environmental, Health, and Safety Regulation*, SCI., Apr. 12, 1996, at 221 (discussing cost-benefit analysis as method to guide decision-makers); Daniel J. Dudek et al., *Environmental Policy for Eastern Europe: Technology-Based Versus Market-Based Approaches*, 17 COLUM. J. ENVTL. L. 1, 8-11 (1992) (arguing for market-based approach in environmental regulation); Robert W. Hahn & Gordon L. Hester, *Marketable Permits: Lessons for Theory and Practice*, 16 ECOLOGY L.Q. 361 (1989) (analyzing marketable permit program); Robert W. Hahn & Robert N. Stavins, *Incentive-Based Environmental Regulation: A New Era from an Old Idea?*, 18 ECOLOGY L.Q. 1 (1991) (discussing new market-based approaches and their likely future success); Richard B. Stewart, *Reconstitutive Law*, 46 MD. L. REV. 86 (1986) (urging federal government to reconstitute existing subsystems to achieve health, safety, and welfare goals). The Environmental Protection Agency is no stranger to that trend and has several programs for

the market<sup>166</sup> to accomplish its goal. If law does no more than enhance the problem-solving capacity of another social institution in such a manner, it has added very little to society's structural load. Hence, whether by simply staying out of the fray, or by propping up some other social convention, the use of self-critical approaches in the sociolegal system opens up much untested territory.<sup>167</sup>

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expanded emissions trading under consideration. See *Emissions Trading Guidance for States to Be Released this Fall*, EPA Official Says, 27 Env't Rep. (BNA) 525 (1996) (discussing guidance for states to develop air emission trading programs); *Effluent Trading Options Described in 'Framework' Document Released by EPA*, 27 Env't Rep. (BNA) 415 (1996) (explaining guidance for trading pollution reduction credits within watersheds).

<sup>166</sup> For an example of the potential effectiveness of an information-based approach to environmental regulation, companies subject to the toxic release reporting provisions of the Emergency Planning and Community Right to Know Act, 42 U.S.C. § 11023, reported the total release of 10.4 billion pounds of specified toxic chemicals into the environment in 1987 — including 3.9 billion pounds in landfills, 3.3 billion pounds in other treatment and disposal facilities, 2.7 billion pounds into the ambient air, and 550 million pounds in surface waters. See PERCIVAL, ENVIRONMENTAL REGULATION, *supra* note 132, at 464. For 1993, the total reported release had fallen to 2.8 billion pounds — including 1.7 billion pounds to the air, 289 million pounds disposed on land, and 271 million pounds into surface waters. See *id.* at 465; see also *Toxic Chemical Releases Decrease by 8.6 Percent in 1994*, Report Says, 27 Env't Rep. (BNA) 531 (1996); *Toxic Chemical Releases Cut by 400 Million Pounds*, Chemical Manufacturers Association Reports, 27 Env't Rep. (BNA) 501 (1996). Industry sources attribute the reporting requirement as having galvanized industry into voluntary pollution reduction goals that in many cases exceed anything required by law. See *CMA Initiative Cuts Toxic Emissions 49 Percent Over Six Years*, Official Says, 27 Env't Rep. (BNA) 11 (1996) (attributing decrease in toxic emissions and transportation accidents to industry's Responsible Care initiative, not federal reporting requirements). Recent economic analysis of the reporting program suggests that it creates powerful market incentives to alter firm behavior with no direct regulation other than the reporting requirement. See Shameek Konar & Mark A. Cohen, *Information as Regulation: The Effect of Community Right to Know Laws on Toxic Emissions*, 32 J. ENVTL. ECON. & MGMT. 109 (1997).

<sup>167</sup> On the rare occasion when a bipartisan, objective analysis of issues has been accomplished in the decision-making forum, the instinctive response appears to be one which is entirely consistent with the operation of self-critical behavior. For example, the President's Council on Sustainable Development, a bipartisan, diverse group charged with recommending a national action strategy for sustainable development, has recently issued its report recommending "reforming the current system of environmental management and building a new and efficient framework based on performance, flexibility linked to accountability, extended product responsibility, tax and subsidy reform, and market incentives." See THE PRESIDENT'S COUNCIL ON SUSTAINABLE DEVELOPMENT, *SUSTAINABLE AMERICA: A NEW CONSENSUS* 25 (1996). Tainter's thesis suggests that the entrenched centralized power structure will resist any such effort to be "rebuilt." Indeed, the word the Environmental Protection Agency prefers is "reinvent," as in from the inside, and it has launched several efforts, with names such as "Project XL," the "Common Sense Initiative," "Enterprise for the Environment," and the "Environmental Leadership Program," to project an image of greater flexibility in its command-and-control programs without

*B. Pay Attention to Winners and  
Losers — Avoiding the Inequality Trap*

We will be the first to admit that no matter how strictly society follows our first maxim of law making, mistakes will happen. Complexity theory tells us this is inevitable even in an adaptive, robust society, because chaos, sensitivity, emergence, and catastrophe are inherent and necessary features of such complex adaptive systems. Most complex adaptive systems, of course, do not attach normative values to those mistakes. The weather, for example, does not dread hurricanes and crave sunny days. Members of society, by contrast, do attach normative values to the unpredicted results of sociolegal activity. The problem that complexity theory reveals, however, is that society cannot weed out the normatively bad surprises ahead of time and reserve only the good — after all, they are all surprises.

Notwithstanding this limitation on improvements in law making, Tainter's work in the history of complexly structured societies suggests that one social effect flows generally and forcefully from increasing social structure complexity — inequality. We posit that as social complexity leads to increasing inequality, society turns to further increases in complex legal structures to reduce inequality, which only adds to social complexity and thus

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departing substantially from their structure or its role in implementing them. *See* Regulatory Reinvention (XL) Pilot Projects, 60 Fed. Reg. 27,282 (1995) (announcing EPA pilot program to develop innovative alternatives to current regulatory system); Common Sense Initiative Council Federal Advisory Committee, Establishment, 59 Fed. Reg. 55,117 (1994) (providing notice of EPA's establishment of advisory committees to recommend improvements in protection framework); Camilla Day Buczek, *EPA Moves to Cooperative Approach*, NAT'L L.J., Oct. 14, 1996, at C13; Rena I. Steinzor, *Regulatory Reinvention and Project XL: Does the Emperor Have Any Clothes?*, 26 ENVTL. L. REP. 10,527 (1996) (reporting on site-specific, alternative compliance programs). Industry representatives have criticized the programs as not going far enough. *See, e.g.,* *GOP Staff Says Effort to Reinvent EPA Falls Short, Agency Denounces Findings*, 27 Env't Rep. (BNA) 1151 (1996) (stating that executive initiatives have failed to improve environmental policy); *Concern About Common Sense Program Prompts Michigan Officials to Withdraw*, 27 Env't Rep. (BNA) 567 (1996) (noting failure of EPA's Common Sense Initiative with Michigan authorities); *3M Decides to Drop Out of Project XL Process After Disagreement Over Performance Guarantees*, 27 Env't Rep. (BNA) 1045 (1996) (noting 3M's withdrawal from EPA program to avoid jeopardizing jobs and operations). Environmentalists and environmental justice advocates contend that the programs do not sufficiently protect their interests either. *See, e.g.,* *Concern About Common Sense Program Prompts Michigan Officials to Withdraw*, 27 Env't Rep. (BNA) 567 (1996) (reporting that Michigan official stated that environmental justice groups were impeding progress).

to more inequality. Thus, inequality drives the feedback loop between the complexity of social structure and complexity of law and its institutions. If there is any root principle lawmakers should stay aware of, therefore, it is to avoid increasing inequality any more than is absolutely necessary to implement laws that pass the muster of our first maxim of law making. Lawmakers must be aware, also, that inequality can surface even from good-minded laws. For example, most environmental laws are enacted with virtuous goals in mind. Yet many commentators contend that these laws have contributed to the stark inequality of environmental protection the environmental justice movement claims to exist.<sup>168</sup> Law-making must seek to avoid such results.<sup>169</sup>

The movement toward increasing use of cost-benefit analysis is not a sufficient response in this regard. This method can be fraught with problems that exacerbate rather than ameliorate inequalities.<sup>170</sup> First, aggregate costs and benefits produced by

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<sup>168</sup> See *supra* note 147 and accompanying text (arguing coercive regulations disproportionately impact smaller companies). Environmental justice advocates, however, are also concerned that market-based approaches to environmental regulation will impose unequal benefits. See U.S. Environmental Protection Agency Office of Environmental Justice, *In the Matter of the Fifth Meeting of the National Environmental Justice Advisory Council*, 9 ADMIN. L.J. 623, 695-97 (1996) (reporting that council members expressed concern regarding the "consequences of [emissions] trading in communities of color, particularly urban communities and low-income areas").

<sup>169</sup> Even assuming that all laws are good-minded, the problem is that we cannot know their impacts in terms of social inequality. Presumably, society's decision to enact a law is based on the conclusion that a provable or demonstrated truth has been identified and that the law will make it so. See *supra* note 130 and accompanying text (discussing proponents of law as tool for change). The problem in complex adaptive systems is the infinite universe of unprovable and experimentally unverifiable, yet nonetheless valid, truths out there just waiting to happen. See Ivars Peterson, *Basins of Froth*, 142 SCI. NEWS 329 (1992) (discussing unknowns of dynamical systems); Ivars Peterson, *Finding Riddles of Physical Uncertainty*, 144 SCI. NEWS 180 (1994) (discussing unpredictable result with slight change in system's initial condition). These truths happen in society often because of the increase in legal structure. When they do happen, they lead to stress as our assumptions, based as they were on what we thought were provable and demonstrated truths, are proven incomplete or just plain wrong.

<sup>170</sup> Amassing research indicates that in many cases, the cost of regulating toxins in the environment and workplace has outweighed the benefit to human and environmental welfare by many orders of magnitude. The research further indicates that in these cases, marginal benefits of additional regulation is often infinitesimal compared to the marginal costs. See, e.g., CENTER FOR RISK ANALYSIS, *REFORM OF RISK REGULATION: ACHIEVING MORE PROTECTION AT LESS COST* (1995); John D. Graham, Ph.D., *Reform of Risk Regulation: Achieving More Protection at Less Cost*, 1 HUM. & ECOLOGICAL RISK ASSESSMENT 183 (1995)

laws cannot be fully estimated because of the unanticipated effects the laws will have outside of the zone of cost-benefit study.<sup>171</sup> Hence, cost-benefit analysis is prone to generating inaccurate estimates of aggregate costs and benefits and thus the potential for inequality. More importantly, however, even if aggregate costs and benefits could be accurately estimated, inequality may nonetheless unexpectedly emerge if the distributional impact of proposed laws is not explicitly measured and accounted for. Aggregate costs and benefits may weigh in favor of a law-making initiative, but if the distribution of costs and benefits is uneven, inequality grows.<sup>172</sup> Finally, even when net distributional impacts are spread evenly, cost-benefit analysis has the tendency to exacerbate the problem of inequality simply by

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(reporting that many regulations focus on minute risks and ignore much larger ones); JOHN D. GRAHAM, NATIONAL CTR. FOR POL'Y ANALYSIS, POL'Y REP. NO. 192, *COMPARING OPPORTUNITIES TO REDUCE HEALTH RISKS* (1995) (arguing that toxin control spending has wastefully diverted resources at cost of human lives). These studies have opened a vigorous policy debate, representing many contrasting views over the role that risk-benefit analysis should play in environmental and public health law and policy. See STEPHEN BREYER, *BREAKING THE VICIOUS CIRCLE: TOWARD EFFECTIVE RISK REGULATION* (1993) (discussing problems with risk regulation and advocating more centralized coordination); *RISK VERSUS RISK* (John D. Graham & Jonathan Baert Wiener eds., 1995) (advocating importance of "risk-risk tradeoffs" in making informed policy decisions); Adam M. Finkel, *A Return to Alchemy*, ENVTL. F., Sept-Oct. 1996, at 15; Symposium, *Risk Assessment in the Federal Government*, 3 N.Y.U. ENVTL. L.J. 251 (1995) (addressing current risk regulations as well as need for future reform); Symposium, *Risk Symposium*, 63 U. CIN. L. REV. 1533 (1995) (discussing problems with risk assessment in formulating environmental policies); David A. Wirth & Ellen K. Silbergeld, *Risky Reform*, 95 COLUM. L. REV. 1857 (1995) (evaluating use of risk assessment in policy formulation); Kenneth J. Arrow et al., *Is There a Role for Benefit-Cost Analysis in Environmental, Health, and Safety Regulation?*, 272 SCI. 221 (1996) (explaining need for cost-benefit analysis in policy evaluation). Congress has joined in the fray as well. See, e.g., H.R. 9, 104th Cong. §§ 401-461 (1995) (passed House of Representatives March 3, 1995) (requiring federal agencies to compile risk assessment, cost-benefit analysis, and peer review for specified major rules).

<sup>171</sup> See, e.g., *Corrosion Proof Fittings v. EPA*, 947 F.2d 1201, 1227 (5th Cir. 1991) (rejecting EPA cost-benefit analysis of health risks posed by asbestos-containing products as insufficiently precise and comprehensive).

<sup>172</sup> Robert R. Kuehn and Cass R. Sunstein provide a comprehensive analysis of this potential in two recent articles. See Robert R. Kuehn, *The Environmental Justice Implications of Quantitative Risk Assessment*, 1996 ILL. L. REV. 103 (comparing risk assessment with environmental justice); Cass R. Sunstein, *Congress, Constitutional Moments, and the Cost-Benefit State*, 48 STAN. L. REV. 247, 293 (1996) (indicating that cost-benefit analysis must take into account "whether the risk is equitably distributed or concentrated on identifiable, innocent, or traditionally disadvantaged victims").

assigning explicit “winner” and “loser” labels to subpopulations on discrete factors of analysis.<sup>173</sup>

An overarching principle of all law-making, therefore, must be to consider aggregate and distributional impacts of each law and fashion the best law possible to achieve the most even levels, knowing full well that there will be instances when even that approach leads to unanticipated sources of inequality. To fully close the loop on this second maxim, moreover, society must apply the first maxim in those instances when inequality does surface. That is, it should not automatically address emerging inequality with more legal structure, but consider first whether new law absolutely is required to address the problem.

When put into operation as a team, the first and second maxims should apply a filtering gateway test to new additions to the mass of laws. By embedding bias against law-making into the philosophy and structure of law-making bodies, the first maxim ensures that legal structure surfaces only after society deems it necessary. By embedding distributional impact sensitivity in the law-making process, the second maxim ensures that laws that pass the first test add as little as possible to the social complexity-inequality feedback loop. Together these maxims may allow society to control the increasing legal structure of the modern administrative state.

## CONCLUSION

*Unless we change our direction, we are likely to end up where we are headed.*<sup>174</sup>

The single largest threat to the modern administrative state is itself.<sup>175</sup> Complexity theory has helped us explain why. Complexity theory is, however, just a theory. We propose no equations for predicting how many laws to enact or when society will

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<sup>173</sup> As Yeager explains, cost-benefit analysis “outcomes tend to identify winners and losers. Once the losers have been identified, societal notice must somehow be taken of them.” YEAGER, *supra* note 55, at 325. Once cost-benefit analysis is chosen as a decision-making tool, there is a need to be precise, and the more precise it becomes the more certain society becomes of who is winning and who is losing.

<sup>174</sup> Chinese proverb.

<sup>175</sup> Or, as Masters puts it, “the seeds of the decline of bureaucratic institutions lie in their very success.” MASTERS, *supra* note 4, at 211.

collapse. Indeed, one of our points is that attempting to do so would be a waste of time. History, however, is hard to ignore, and complexity theory offers a novel analytical method for understanding why history has unfolded through a progression of collapsing societies and what role law has played in this process. We believe that with that analytical method we have made a strong case for reexamining the structure and philosophy of law making in the modern administrative state. A serious question — one we have not attempted to bite off — is whether society is too far down the road to change the direction in which the modern administrative state is headed.

As Joseph Tainter says in the conclusion of his study of the collapse of complexly structured societies, “[m]uch of the foregoing may read like . . . doom and gloom.”<sup>176</sup> The reality is, however, that most highly successful societies of the past ended in collapse. People are arrogant, though, and “tend to believe that such events could only happen in history books.”<sup>177</sup> The modern administrative state, with all its advanced technological and organizational apparatus, may believe that it is the pinnacle of social development and, thus, here for the duration. However, it has existed on this planet only a few hundred years. No guarantees of perpetual existence come with that relatively meager accomplishment.

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<sup>176</sup> TAINTER, *supra* note 4, at 123.

<sup>177</sup> MASTERS, *supra* note 4, at 212. For the view that massive social crises are a regular and cyclical occurrence in recent history and that one is due in America very soon, see WILLIAM STRAUSS & NEIL HOWE, *THE FOURTH TURNING* (1997).