Vanderbilt Law Review

Volume 49
Issue 6 *Issue 6 - November 1996*

Article 2

11-1996

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Recommended Citation
J. B. Ruhl, The Fitness of Law: Using Complexity Theory to Describe the Evolution of Law and Society and Its Practical Meaning for Democracy, 49 *Vanderbilt Law Review* 1406 (1996)
Available at: https://scholarship.law.vanderbilt.edu/vlr/vol49/iss6/2

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49 Vand. L. Rev. 1407 (1996)

Why does law change, and how does that process unfold? In this Article, Professor Ruhl examines those questions using tools from the emerging field of Complexity Theory. Complexity Theory involves the study of change in dynamical systems. Its findings of unpredictable change in a variety of natural and social settings have profoundly effected the theoretical foundations of many fields of study. In particular, Complexity Theory has revisited the Darwinist theory of biological evolution and used it as a platform for developing a general theory of system evolution that focuses on the concept of fitness landscapes. The fitness, or sustainability, of each system component—in the case of biological evolution, each species—depends on the possible combinations of variables that define the component (for example, speed, weight, and strength). Those combinations and their associated fitness levels form a landscape of possibilities over which the system component can move to attempt to improve its fitness. Moreover, because the fitness of each combination will depend in part on the behavior of other system components, the fitness landscapes of all system components are coupled such that as one component evolves to different levels on its landscape, the landscapes of other components may be altered. By developing and studying the model of coupled fitness landscapes, Complexity Theory has provided new insights into the why and how of evolution in a variety of contexts.

The history and process of change in law exhibits many of the traits of coupled fitness landscapes. This Article begins by illustrating how legal theory has embraced Darwinism as one of its models of legal change, and thus how legal theory is ripe to integrate what Complexity Theory has to offer that model. Using examples from environmental law, the Article unfolds the analogy between Complexity Theory's general fitness landscape model and the record of legal change. Finally, the Article develops the general principles of what the fitness landscape model suggests will be the most fit sociolegal systems and compares them to the present condition of the modern administrative state, concluding that significant and fundamental reforms are necessary in order to take full advantage of the fitness traits our constitutional system offers.

The Fitness of Law: Using Complexity Theory to Describe the Evolution of Law and Society and Its Practical Meaning for Democracy

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I. INTRODUCTION

Does law evolve? If so, why, how, and to where? The answer to the first question seems self-evident given real-world experience: law scarcely stands still; thus, it must be evolving. But not all change necessarily fits our conception of evolution in the Darwinian[1] sense. It may be, for example, that "law as law has no 'tendency' whatever, any more than a quantity of bricks has a tendency to become a house. Strictly it never changes, but is changed from without; it does not develop, but it is developed."[2] Whether law evolves through some definable internal process or merely changes in response to events

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1. Darwinism has heen descrihed as "much like Christianity and Marxism, in that everybody 'knows' what it means, and yet on not very close inspection it turns out that everybody's meaning is slightly different." Michael Ruse, *Darwinism*, in Evelyn Fox Keller and Elisaboth A. Lloyd, eds., *Keywords of Evolutionary Biology* 74 (Harvard U., 1992). I do not attempt in this Article to explore all the nuances of Darwinism and the broader field of evolutionary biology. Some refinements beyond the rudimentary lay notions of "natural selection" and "survival of the fittest" are provided, however, in order to evaluate the influence of evolutionary biology theory on legal theory, see Part II, and to identify what significance the emergence of Complexity Theory might have to botlı fields, see Parts III and IV. For an excellent survey of the finer points and raging debates of present day evolutionary biology theory, see generally, Ruse, *Darwinism*, in Keller and Lloyd, eds., *Keywords* (cited in this note).

2. Edwin B. Gager, Book Review, 28 Yale L. J. 617, 617-18 (1919) (reviewing Albert Kocurek and John H. Wigmore, *Formative Influences of Legal Development* (Little, Brown, 1918)).

around it depends on our understanding of the why, how, and to where of the changes that take place. Much of legal theory has been devoted to the ambitious undertaking of answering those questions.[3]

Answering the *why* part of the equation does not appear so tricky at first—law changes because society changes, and thus no matter how "perfect" law may seem at any instant, society will eventually change sufficiently to require changes in law. But we also can sense from simple observation that society changes itself in response to changes in law. Surely, for example, if changing social conditions were to lead us to eliminate federal income taxes in the United States, changes in society beyond those which prompted the tax law change could be expected to occur as a result of those changes to the law, some by design and some not. Hence, it seems intuitive that change in society leads to change in law, and that change in law leads to change in society.

Elsewhere I have used the analogy to the science of nonlinear dynamical systems,[4] otherwise known as Complexity Theory,[5] to make

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3. As Professor Herhert Hovenkamp has pointed out, "[t]oday every theory of jurisprudence worth contemplating incorporates a theory of change." Herbert Hovenkamp, *Evolutionary Models in Jurisprudence*, 64 Tex. L. Rev. 645, 646 (1985). On the other hand, "not every theory of jurisprudence that includes a theory of legal change qualifies as 'evolutionary,'" and "Darwin need not be an essential ingredient in evolutionary jurisprudence." Id. at 646-47. It would be difficult to improve on Professor Hovenkamp's and several other commentators' examinations of the late-nineteenth and twentieth century American legal theorists who have expressly used Darwinian and other evolutionary models to explain the development of legal rules. See also E. Donald Elliott, *The Evolutionary Tradition in Jurisprudence*, 85 Colum. L. Rev. 38 (1985) (theorizing the evolution of legal rules); 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) (same); M.B.W. Sinclair, *The Use of Evolution Theory in Law*, 64 U. Detroit L. Rev. 451 (1987) (same). I do not attempt to do so here. Rather, the purpose of this Article is to explore how legal theory has attempted to explain change in law through analogy to evolutionary biology in general—that is, through pre-, neo-, and post-Darwinian models—so as to allow a detailed explanation in this Article of the analogy to evolutionary dynamics offered by the important new development of Complexity Theory.

4. A system exists whenever two or more phenomena interact. The system is dynamical if the interactive relationship changes over time, and the system is nonlinear if the relationship of change is not strictly proportionate and thus cannot be graphed by a straight line. Peter Coveney and Reger Highfield, *The Arrow of Time: A Voyage through Science to Solve Time's Greatest Mystery* 184, 361 (Allen, 1990). Thus, the statement $x = 1$ does not describe a system because only one component is described and it remains constant. The statement $x = 2y$ does define a system consisting of the components x and y, but the system is linear because any change in x results in a proportional change in y according to a constant multiple. Nonlinear systems are described by the dreaded differential equations.

5. Complexity Theory has been described as "the study of behavior of macroscopic collections of [interacting] units that are endowed with the potential to evolve over time." Peter Coveney and Reger Highfield, *Frontiers of Complexity: The Search for Order in a Chaotic World* 7 (Faber, 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

the case that law and society coexist interdependently and dynamically, approximating the behavior of nonlinear systems as they exist in the physical world.[6] My principal objective in that exercise was to demonstrate that American legal theory and legal institutions have been built upon premises which obscure the dynamical behavior of the sociolegal system. The analogy to Complexity Theory demonstrates why dynamical forces will inevitably lead to unpredictable, unanticipated behavior in a sociological system, and that such phenomena are necessary for the system to thrive and adapt in a dynamically fit manner.

Complexity Theory also reveals why communities in the physical world, such as ecosystems and the weather, possess varying degrees of dynamical fitness and sustainability. On the spectrum between rigid stasis and chaotically random change, some systems sit in a dynamic region poised on the edge of chaos, but are kept from falling all the way into chaos by the reins of stability and simplicity. These systems, in other words, maintain a balance between stasis and change. Research suggests that such systems are the most successful at holding themselves together for the long run, withstanding the surprises their environments throw at them. Ironically, however, such systems must maintain a chaotic, random component in order to achieve this level of self-sustainability and hence they defy prediction througlı the reductionist tenets of Classical Science.[7]

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bebavior of nonlinear dynamical systems. Although tbe study of such systems can be quite technical in substance, see, for example, Stuart A. Kauffman, *The Origins of Order: Self Organization and Selection in Evolution* (Oxford U., 1993), many of the recent and most influential works in the field focus on the almost intuitive applications of the technical theory to real world phenomena, including biological evolution. See, for example, Jobn L. Casti, *Complexification: Explaining the Paradoxical World Through the Science of Surprise* (Harper Collins, 1994); Jack Cohen and Ian Stewart, *The Collapse of Chaos: Discovering Simplicity in a Complex World* (Viking, 1994); Coveney and Highfield, *Arrow of Time* (cited in noto 4); Coveney and Highfield, *Frontiers of Complexity* (cited in this note); Murray Gell-Mann, *The Quark and the Jaguar: Adventures in the Simple and the Complex* (Freeman, 1994); Brian Goodwin, *How the Leopard Changed Its Spots: The Evolution of Complexity* (Orion, 1994); John H. Holland, *Hidden Order: How Adaptation Builds Complexity* (Addison-Wesley, 1995); Stuart Kauffman, *At Home in the Universe: The Search for Laws of Self-Organization and Complexity* (Oxford U., 1995); George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models, and Reality* (Addison-Wesley, 1994).

6. See J.B. Ruhl, *Complexity Theory as a Paradigm for the Dynamical Law-and-Society System: A Wake-Up Call for Legal Reductionism and the Modcrn Administrative State*, 45 Duke L. J. 849 (1996).

7. By reductionist I mean the "doctrine according to which complex phenomena can be explained in terms of something simpler." Coveney and Highfield, *Frontiers of Complexity* at 432 (cited in note 5). Reductionism leads to the belief tbat an observable, complex phenomenon can be studied and fully understeod by first reducing it te the simplest, indivisible subcomponents in operation during the phenomenon, then studying each of those subcomponents, and then reassembling them to gain a full understanding of the rules of

I have posited that a similar stream of reductionism is evident in American legal theory of all walks and in the foundations of American legal institutions and that it also has prevented full illumination of the dynamical qualities of a healthy sociolegal community.[8] It is impossible to understand and manage the dynamical qualities of law and society by dividing them into separate spheres, subdividing those spheres into separate compartments, and so on. Doing so allows legal theory and legal institutions to divine sets of rules which facilitate prediction and orderliness through rough approximation of human sociolegal behavior, but which in the long run will cause us to be surprised when the system departs from the purported rules, as it surely will. As legal theories and institutions repeatedly have developed yet more reductionist-bred rules to address the system's surprises, they have become top-heavy in rules and short on explanations. Complexity Theory reveals why the surprises inevitably will happen, why we will never be able always to predict them, and why reductionism leads us in the wrong direction for responding to them. A healthy sociolegal community must sit poised on the edge of chaos, but in so doing will defy the predictivist goals of American legal theory and legal institutions in the long run.

Having made that argument at length elsewhere,[9] in this Article I explore the next level of analysis offered by Complexity

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operation of the whole phenomenon. That form of reductionism has long predominated as an organizing principle for classical scientific inquiry. See id. at 11-13; Cohen and Stewart, *Collapse of Chaos* at 33-34 (cited in note 5).

8. See Ruhl, 45 Duke L. J. at 893-916 (cited in note 6).

9. I summarize the argument's basic foundations herein. See text accompanying notes 131-66. For additional descriptions of how Complexity Theory or branches of it help explain why law evolves generally, see Thomas Earl Geu, *The Tao of Jurisprudence: Chaos, Brain Science, Synchronicity, and the Law*, 61 Tenn. L. Rev. 933 (1994) (discussing the potential siguificance of chaos and emergence to legal theory); Andrew W. Hayes, *An Introduction to Chaos and the Law*, 60 UMKC L. Rev. 751 (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) (offering a theory of legal evolution); Robert E. Scott, *Chaos Theory and the Justice Paradox*, 35 Wm. & Mary L. Rev. 329 (1993) (applying chaos theory to the 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, *From Random Walks to Chaotic Crashes: The Linear Genealogy of the Efficient Capital Market Hypothesis*, 62 Geo. Wash. L. Rev. 546 (1994); Lawrence A. Cunningham, *Capital Market Theory, Mandatory Disclosure, and Price Discovery*, 51 Wash. & Lee L. Rev. 843 (1994) (applying chaos theory to capital market regulation); Glenn Harlan Reynolds, Essay, *Chaos and the Court*, 91 Colum. L. Rev. 110 (1991) (explaining Supreme Court constitutional jurisprudence using chaos theory); Michael J. Gerhardt, *The Role of Precedent in Constitutional Decisionmaking and Theory*, 60 Geo. Wash. L. Rev. 68 (1991) (explaining Supreme Court constitutional jurisprudence using, among other mediums, a discussion of chaos theory); William H. Rodgers, Jr., *Where Environmental Law and Biology Meet: Of Pandas' Thumbs,*

Theory—describing *how* the community members coevolve towards fitness. In other words, how do we get the sociolegal system to the edge of chaos without falling all the way in? The answer is not as simple as pointing out that legislatures pass new legislation, courts decide new case principles, and agencies promulgate new regulations. Those institutions could do that all day long every day and not move the community one iota closer to fitness; indeed, regression into stasis or chaos would be more likely. Evolution is not always a success story in the jungle, nor is it so in the law.

Indeed, the very notion of law as evolving is borrowed largely from biology,[10] and in Part I of this Article I explore that intersection of disciplines. Legal theory has found evolutionary biology an intoxicating paradigm for explaining why and how law changes. When Darwin's theory of natural selection[11] shattered the Rational Morphologists' enlightenment age concept of fixed and unchanging species,[12] the door was opened to using the metaphor of evolution to ex-

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Statutory Sleepers, and Effective Law, 65 U. Colo. L. Rev. 25 (1993) (discussing chaos theory surfacing in evolutionary biology commentary as a metaphor for evolution of environmental law).

10. To be fair, it is also true that evolutionary biology has borrowed from other disciplines in shaping its theory of change. For example, Charles Darwin was influenced profoundly by Thomas Malthus's writings on population and food supply, see Hovenkamp, 64 Tex. L. Rev. at 651-52 (cited in note 3), and by Adam Smith's economic theory of laissez-faire, see Stephen Jay Gould, *Dinosaur in a Haystack* 329 (1995).

11. See Charles Darwin, *The Origin of Species by Means of Natural Selection: Or the Preservation of Favored Races in the Struggle for Life* (Hurst, 1859). The central tenet of Charles Darwin's theory, the concept of natural selection, has been described as being "that certain hereditary types within a species (the 'favoured races') survive at the expense of others and in so doing transform the makeup of the entire species across generations." Edward O. Wilson, *The Diversity of Life* 51 (Harvard U., 1992). The distinction between evolution and natural selection is subtle: Evolution "is absolutely a phenomenon of populations. Individuals and their offspring do not evolve." Id. at 75. Natural selection, which operates predominantly or exclusively at the individual level, see note 44, is the mechanism by which populations evolve. It has often been noted, therefore, that Darwin did not invent the notion of biological evolution, but rather supplied the model of natural selection to explain the mechanics of what several insightful biologists before him had observed. For commentators crediting Darwin's predecessors in this regard, see Gould, *Dinosaur* at 430 (cited in note 10); Robert J. Richards, *Evolution*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 95-105 (Harvard U., 1992); Ruse, *Darwinism*, in Keller and Lloyd, eds., *Keywords of Evolutionary Biology* at 77-78 (cited in note 1). Many other biologists helped Darwin reach that discovery during the 20 years from the time he first observed finches and other species on the Galapagos Islands to when he first published his theory of natural selection. See Jonathan Wiener, *The Beak of the Finch: A Story of Evolution in Our Time* 17-36 (Knopf, 1994). Nevertheless, Darwin is the overshadowing figure in the field, and it is no exaggeration to say that "[t]he discipline of evolutionary biology can be defined to a large degree as the ongoing attempt of Darwin's intellectual descendants to come to terms with his overwhelming influence." John Horgan, *The End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age* 114 (Addison-Wesley, 1996). For a thorough and enlightening biography of Darwin, see Adrian Desmond and James Moore, *Darwin* (Warner, 1992).

plain other systems of change, both physical and social,[13] and of both individuals and groups.[14] Legal theory wasted no time accepting that invitation.[15] As the neo-Darwinian synthesis of natural selection and

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12. For a description of the "laws of form" theory of Rational Morphology which predominated in eighteenth century biology, see Kauffman, *Origins of Order* at 3-5 (cited in note 5). See also text accompanying notes 33-37.

13. For example, Darwinism spawned the rise of many of the social sciences during the early 1900s, such as psychology, sociology, anthropology, and economics, each of which in turn had a powerful influence on law and legal theory. See Hovenkamp, 64 Tex. L. Rev. at 653 (cited in note 3). Darwin's theory was "modified in various ways to apply to economics and politics, to the explanation of the origins and the significance of art, and even to the history of ideas themselves." Goodwin, *How the Leopard Changed Its Spots* at ix (cited in note 5).

14. There has been considerable debate as to whether natural selection transpires only at the level of the individual or also at the population group level. Individual-centered, or "selfish-gene," evolutionary theory argues that genes transmitted through generations help only individual organisms adapt to be fittest, whereas genetic group selection theory—also known as sociobiology—posits that natural selection sometimes preserves inherited physical and psychological traits that aid groups of organisms, even at the expense of individuals in those groups. See Alexander Rosenberg, *Altruism: Theoretical Contexts*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 19-33 (Harvard U., 1992); David Sloan Wilson, *Group Selection*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 145-48 (Harvard U., 1992); Bruce Bower, *Ultrasocial Darwinism*, 148 Sci. News 366 (1995); Bruce Bower, *Return of the Group*, 148 Sci. News 328 (1995). Darwin clearly believed that "natural selection is about advantages ... that accrue to individuals, explicitly not to species." Gould, *Dinosaur* at 329 (cited in note 10). The species as a group may benefit only as "side consequences of natural selection's causal mechanism: differential reproductive success of individuals." Id. In either case, however, natural selection theory boils down to the process of species transformation taking place through gradual selection of genes which offer the most advantageous chances of survival and reproduction given environmental conditions. See John A. Elder, *Natural Selection: Current Usages*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 220-24 (Harvard U., 1992). The bigger debato in evolutionary biology since Darwin has been over the extent to which natural selection processes explain all of biological evolution, whether through individual or group mechanics. See Ruse, *Darwinism*, in Keller and Lloyd, eds., *Keywords* at 77-80 (cited in note 1). See generally Parts II.B to D. For a discussion of legal evolution through the eyes of sociobiology theory, a focus which I am fundamentally not taking in this Article, see John H. Beckstrom, *Evolutionary Jurisprudence: Prospects and Limitations on the Use of Modern Darwinism Throughout the Legal Process* (U. of Illinois, 1989); John H. Beckstrom, *Sociobiology and the Law: The Biology of Altruism in the Courtroom of the Future* (U. of Illinois, 1985). Another important field of study is known as law and biology, whose adherents examine the relationship between the biological evolution of human behavior and legal rules and institutions. See, for example, Margaret Gruter, *Law and the Mind* (Sage, 1991); William H. Rodgers, Jr., *Deception, Self-Deception, and Mythology: The Law of the Salmon in the Pacific Northwest*, 26 Pac. L. J. 821 (1995). Although sociobiology, and law and biology may have important insights to offer about evolutionary influences in law, the focus of this Article is on the underlying mechanics of sociolegal evolution, whatever variables of influence may be involved.

15. For reviews of the early works adopting the theme of evolutionary biology as a paradigm for legal theory, see Neil Duxbury, *Patterns of American Jurisprudence* 25-32 (Oxford U., 1995); Peter Stein, *Legal Evolution: The Story of an Idea* (Cambridge U., 1980); Robert Clark, *The Interdisciplinary Study of Legal Evolution*, 91 Yale L. J. 1238 (1981); Elliott, 85 Colum. L. Rev. at 38 (cited in note 3); Horowitz, 42 Am. J. Comp. L. at 233 (cited in noto 3); Hovenkamp, 64 Tex. L. Rev. at 645 (cited in note 3); Sinclair, 64 U. Detroit L. Rev. at 451 (cited in note 3). See also text accompanying notes 38-43.

its supporting cast of gene transmission theory, chromosomal germ plasm theory, and population genetics theory progressed into a grand theory of evolution,[16] legal theory continued to build upon biological evolution as a paradigm for legal change.

But the neo-Darwinian synthesis has come under attack more recently as allegedly failing to explain some very evident realities of biology and history. For example, the Darwinian picture of evolution as gradual and progressive departs from the evidence that some species—for example, the lowly cockroach—appear to have survived in morphological stasis for eons while others appear to have sprung up rapidly from out of nowhere. The historical record is that of successive orgies of evolution followed by long periods of minute species variations interrupted by catastrophic episodes of extinction, what many biologists call punctuated equilibrium.[17] On another front, the normative implications often attributed to Darwinism—the notion of survival of the *fittest,* thus leading species in a particular direction towards higher quality[18]—have been challenged by the evidence that species also evolve because of nonselective *micro*evolutionary properties inherent in the organism, rather than solely as a result of external forces of natural selection. These so-called species selection processes suggest that *macro*evolution may emerge in part from a neutral and, most significantly, random drift at genetic levels.[19] At the same time, new views of ecosystem dynamics have surfaced indicating that the concept of evolution of species—even the natural selection proc-

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16. For a description of the neo-Darwinian synthesis of how natural selection operates at these levels, see Kauffman, *Origins of Order* at 5-9 (cited in note 5). See generally text accompanying notes 47-51.

17. One of the leading proponents of the punctuated equilibrium model is the noted biologist Stephen Jay Gould. See, for example, Gould, *Dinosaur* at 127-29, 135-37 (cited in note 10). See also text accompanying notes 86-90.

18. The description of the criteria used to define and measure evolutionary fitness "is perhaps the most contentious concept in evolutionary biology." Diane Paul, *Fitness: Historical Perspectives,* in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 113 (Harvard U., 1992). See also John Beatty, *Fitness: Theoretical Contexts,* in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 115 (Harvard U., 1992) ("The precise meaning of 'fitness' has yet to be settled, in spite of the fact—or perhaps because of the fact—that the term is so central to evolutionary thought."). It was the Victerian scientist and commentator Herbert Spencer, not Darwin, who coined the phrase "survival of the fittest" to describe the principle of natural selection. See Paul, *Fitness,* in Keller and Lloyd, eds., *Keywords* at 113 (cited in this note); Stephen Jay Gould, *Ever Since Darwin* 36-40 (Norten, 1977). See generally Herbert Spencer, *Principles of Biology* (Appleton, 1866). The criteria for defining and measuring "fitness" are a continuing source of controversy in evolutionary biology and a central focus of Complexity Theory. See text accompanying notes 167-72. Of course, one point of this Article is to define what fitness means in the sociolegal system. See generally text accompanying notes 173-78.

19. See Kauffman, *Origins of Order* at 10 (cited in note 5). See generally text accompanying notes 99-104.

ess—takes place in the context of complex, chaotic environments fostering the horizontal splitting of species. Darwin's model, which mainly focused on vertical transformation of a species to new forms, does not provide complete insight to the macroevolutionary level of such biodiversity dynamics.[20] Hence, classical evolutionary biology is being tested today by the demands to explain both the nongradual phenological record and the nonequilibrium states found to be prevalent in the natural world as a result of species selection and ecosystem biology.

Similarly, legal theory has grappled with how to explain the presence of both order and change in law and society, and thus has challenged its neo-Darwinian paradigms as well. There is, of course, no one-to-one correspondence between the theoretical developments of evolutionary science and law. Indeed, many theories of legal change make no explicit reference to Darwinism or biological evolution. Nevertheless, where legal theory has progressed on the question of evolution of law, this progression is in no small measure a remarkable mirror image of the refinement of evolutionary biology from Darwin to the Ecosystem Age. It is useful, therefore, to trace those parallels in order to appreciate what Complexity Theory may add to the pot.

For example, many Legal Formalists[21] fully embraced the ordered vision of natural selection and helped transfer it into the laissez-faire doctrines of Social Darwinism.[22] Legal Realism shattered that view as effectively as the record of punctuated equilibriums made it plainly obvious that gradual natural selection cannot explain everything in evolutionary biology.[23] From there, the dichotomy between order and indeterminacy in evolutionary biology provides a close parallel to the reemergence of highly formalistic schools of legal theory, such as Law and Economics, versus those focusing on the inde-

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20. One of the leading proponents of the ecosystem and biodiversity fields of science and their importance to evolutionary biology is the noted biologist Edward O. Wilson. See, for example, Wilson, *Diversity of Life* (cited in note 11). See also Weiner, *The Beak of the Finch* at 224-303 (cited in note 11). See generally text accompanying notes 117-23.

21. I apologize up front for collapsing American legal theory into a few "major" schools of thought—Formalism, Realism, Law and Economics, and Critical Legal Studies. I recognize that doing so tends to overemphasize their differences and imply that they have "battled" one another for prominence and adoption. For a comprehensive history of American legal theory, centered around the thesis that its story is not one simply of a revolt against the revolt against the revolt against Formalism, see Duxbury, *Patterns of American Jurisprudence* (cited in note 15).

22. See text accompanying notes 52-85.

23. See text accompanying notes 91-98.

terminacy factor, such as Critical Legal Studies.[24] And more recently, the teachings of ecosystem biologists have been adopted explicitly by several legal commentators as a model for legal structures.[25] To the extent that biological evolution thus has served as a metaphor for sociolegal evolution, Complexity Theory may have much to offer to the extent it advances the analytical value of the metaphor.

Part II of this Article thus explores how Complexity Theory offers a way of reconciling the order and chaos that appear to coexist within the evolutionary biology model,[26] and what meaning that revelation may have for theories of how the sociolegal system evolves. Complexity Theory's discovery that dynamical systems must experience randomness to maximize self-sustainability is essential to the explanation of why the Darwinian concept of gradualism in natural selection fails to explain the full dimension of biological evolution. Complexity Theory demonstrates why and how gradual changes in system structure can lead to large changes in system outcome and why we ought to expect a record closer to punctuated equilibrium than gradualism.

The real feat of Complexity Theory, however, is in accommodating the competing order and chaos themes of evolutionary biology in one unified theory. The insight of Complexity Theory is to describe how evolution occurs not as movement along a gradual, straight, uphill slope, but over a topography of fitness peaks, valleys, and planes—a fitness landscape.[27] Movement across the landscape takes

24. See text accompanying notes 105-16.

25. See text accompanying notes 124-29.

26. The most cogent and comprehensive application of Complexity Theory to evolutionary biology, upon which the bulk of the description thereof provided in this Article is based, appears in Kauffman, *At Home in the Universe* (cited in note 5). See also Cohen and Stewart, *Collapse of Chaos* (cited in note 5); Coveney and Highfield, *Frontiers of Complexity* (cited in note 5); Goodwin, *How the Leopard Changed Its Spots* (cited in note 5). For the more technical counterpart to those works, see Kauffman, *Origins of Order* (cited in note 5). The fundamental difference between neo-Darwinian theory and Complexity Theory is on the level of focus: Darwin's theory works best for the small-scale, fine-tuning aspects of evolution, whereas Complexity Theory focuses on large-scale mechanics. See Goodwin, *How the Leopard Changed Its Spots* at x-xi (cited in note 5). Many of the evolutionary biologists associated with Complexity Theory research thus agree with what neo-Darwinism has to say about evolution, but consider the theory "incomplete." See Horgan, *The End of Science* at 135 (cited in note 11).

27. 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." *At Home in the Universe* at 154 (cited in note 5). See also Coveney and Highfield, *Frontiers of Complexity* at 108 (cited in note 5) (defining a fitness landscape as "[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"); Goodwin, *How the Leopard Changed Its Spots* at 156 (cited in note 5) ("[O]rganisms are constantly striving to climb up to the higher peaks in the fitness landscape that represent the various possibilities for

place in two forms: walking and jumping. Walking, the bulwark of natural selection, allows certainty of direction up or down, but is inefficient and slow. Jumping implies a more random, and thus more risky movement pattern, but with risk comes the possibility of large incremental movements up or down the fitness regime. The longer the jump, moreover, the higher the chances of radically altering the ruggedness of the nearby fitness landscape. Both forms of movement are complicated by the fact that the landscape, despite the image suggested by that metaphor, is not static. Rather, a fitness landscape for any species is constantly reforming in response to changes in its surrounding environment. The image, once time is added to the picture, thus is more of a boat navigating a seascape of ever-undulating waves. Complexity Theory uses these concepts, demonstrated through observed evolutionary patterns as well as modeled physical environments, to assimilate the apparently competing streams of evolutionary biology theory into a unified, consistent paradigm.

But Complexity Theory is not just about evolutionary biology; it is about evolution of all dynamical systems, biological, physical, and social. Indeed, the foundations of Complexity Theory were developed by observation of physical and computer-modeled systems, not of organisms and ecosystems.[28] The Complexity Theory fitness landscape paradigm is simply a powerful way of explaining dynamical system evolution generally. Indeed, law and society being, as I analogize, in a dynamical system relationship, the concept of an evolving fitness regime for the sociolegal system seems worth exploring.

Throughout the description of the fitness evolution model, therefore, I use the development of environmental law to provide an example of the explanatory power of the Complexity Theory paradigm for the sociolegal system. Environmental law has long had to face the challenge of providing ordered legal solutions to its chaotic subject,

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survival."). The notion of such a terrain of adaptive fitness originated with evolutionary biologist Sewall Wright in the 1930s and remains important to current research programs as a way of describing the dispositive factors of natural selection processes. See Weiner, *The Beak of the Finch* at 152, 192-94 (cited in note 11). Complexity Theory moves the concept of adaptive landscapes beyond the descriptive purpose for which it has been used thus far in evolutionary biology and towards a more explanatory role tbat the Complexity Theory model offers for describing *how* a system evolves. See text accompanying notes 179-201.

28. For histories of the development of Complexity Theory, which has been brought about largely through the efforts of the Santa Fe Institute, see generally James Gleik, *Chaos* (1987); Roger Lewin, *Complexity: Life at the Edge of Chaos* (Macmillan, 1992); M. Mitchell Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos* (Simon & Schuster, 1992). For an account of the figures who are at the forefront of Complexity Theory today, see Horgan, *The End of Science* at 191-246 (cited in note 11).

the environment, and has often witnessed results far off the intended target.[29] The landscape of common law nuisance provided the early realm of experimentation, but the challenges of environmental management were perceived to be too tall for the plodding evolutionary march of nuisance law.[30] Environmental law's extended period of common law tradition thus was eclipsed by a long jump to federal regulatory structures in the 1970s.[31] Since then, we have been exploring the landscape near the initial landing spot with ever finer adjustments of the regulatory model. All along, however, the rest of the sociolegal system has been evolving in part as a response to environmental law's transformation, and in turn causing the landscape of environmental law to alter as well. Indeed, it appears that the regulatory approach of environmental law is beginning to suffer a fitness "catastrophe" of sorts, just as nuisance law did.[32] New themes such as market economics, private property rights, environmental justice, risk-benefit analysis, and local control are challenging the entrenched federal regulatory apparatus. The nearby landscape of regulatory structures, however, does not compete well against those themes. We may need another *long* jump for environmental law to test and adapt to these new approaches.

Part III of this Article then offers several observations for the practical operation of democracy which appear to emerge from the theoretical model of evolving fitness landscapes and the example of its application to legal issues provided by environmental law. The principal difference between biological evolution and sociolegal evolution is that the actors in the sociolegal system have the power to make long or short jumps across fitness landscapes at will. Sex and accidents are the most expedient ways biological organisms have of doing so. Human society, on the other hand, has everything from resolutions to revolutions at its disposal. The capacity to make long jumps is desirable, but there is high risk inherent in doing so whimsically. In other words, we come right back to the theme of order and chaos, and the revelation that the edge of chaos is where a system performs best.

Based on Complexity Theory's research into what characterizes the most adaptive system for navigating rugged, correlated, changing fitness landscapes, sociolegal regimes that favor less hierarchical, flatter, and more decentralized power structures will tend to

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29. See text accompanying notes 152-66.
30. See text accompanying notes 185-91.
31. See text accompanying notes 202-12.
32. See text accompanying notes 222-26.

outperform competing models in that respect. It is uncanny how close the common law and the American constitutional form of government *as originally conceived* come to that model. A cause for concern, therefore, is how far the modern federal regulatory state has pulled us away from those conceptions through such mechanisms as the non-delegation doctrine, the expansive commerce power, administrative discretion, and similar power-centralizing, reductionist-bred legal structures which have swelled the federal administrative creature to ungainly proportions. The centralized federal regulatory state, in other words, is taking the "sex" out of democracy and thus impeding the adaptiveness of the American sociolegal system. With Complexity Theory as a foundation, I make the case that it may be time for a long jump out of those outmoded structures and towards a more adaptive system which may be realized through greater reliance on common law and other nonfederal initiatives.

II. EVOLUTIONARY BIOLOGY AND THE SEDUCTION OF LEGAL THEORY—FROM DARWIN TO THE ECOSYSTEM AGE IN SCIENCE AND LAW

Charles Darwin's publication of *The Origin of Species* in 1859 has left such a permanent bookmark on the pages of science and law that little is remembered today about what preceded Darwin in either field in the way of an explanation of the why, how, and to where of system change.[33] In science, for example, it is no exaggeration to say that "the serious purposes of pre-Darwinian biologists have receded from our collective scientific mind, not merely by passage of time but also by passage from relevance."[34] Yet serious they were, as late-eighteenth- and early-nineteenth-century biology sought to develop a teleological theory of fixed, unchanging species brought about by a rational Creator.[35] The research program of the so-called Rational

33. As Professor Hovenkamp observes, Darwinism "was a model . . . that infected everything." Hovenkamp, 64 Tex. L. Rev. at 645 (cited in note 3). Others have described Darwinism as the "quintessential theory of change within Western science." Gould, *Dinosaur* at 134 (cited in note 10). To be sure, Darwinism was not instantly accepted by the entire scientific community as the only theory of evolutionary change. Indeed, natural selection theory was being criticized by preeminent biologists well into the 1900s as being either too scientific because of its nonteleological message, or too *un*scientific because it was incapable (at the time) of being observed at work. See Weiner, *The Beak of the Finch* at 129-31 (cited in note 11); Ruse, *Darwinism*, in Keller and Lloyd, eds., *Keywords* at 78-79 (cited in note 1).

34. See Kauffman, *Origins of Order* at 3-4 (cited in note 5).

35. Id. A leading figure in this effort was the Swedish botanist Karl von Linné, writing under the name Carolous Linnaeus, who "tried, as a monumental act of religious devotion, to

Morphologists, which focused on comparative anatomy and systematic taxonomy, was based on the logic that the apparent similarity and groupings of organisms was built upon combinations of a small number of naturally ordered principles waiting to be decoded.[36] The reductionist premise of that search thus was consistent with the coherent philosophical tradition of Newtonian scientific method and of the Enlightenment in general. And just as Newton was able to advance scientific understanding of physics tremendously, so too were the Rational Morphologists able to make great strides in the comprehension of the living world.[37]

Meanwhile, the natural law tradition of eighteenth century English legal theory "used man's rational and social nature everywhere as the basis on which it founded both his moral and his legal obligations."[38] Thus, much as the Rational Morphologists were doing for biology at the time, English natural law theorists "were seeking to prove the existence of certain general principles which bound every man by his nature, and which were themselves unchanging."[39] During this period only Scottish legal theorists, most notably Adam Smith and his student John Millar,[40] and German historical law theo-

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work out the relationships of all the living forms on earth. By doing so, Linné had hoped to glimpse the plan of the Creator. . . ." Weiner, *The Beak of the Finch* at 23 (cited in note 11).

36. For example, Karl von Linné did so by "designating species as basic units and establishing principles for their uniform definition and naming . . . [and] by arranging species into a wider taxonomic system based on a search for natural order rather than human preference or convenience." Gould, *Dinosaur* at 421 (cited in note 10). Linné's system "divided life on earth into kingdoms, kingdoms into classes, classes into orders, orders into genera, and genera into species." Weiner, *The Beak of the Finch* at 23 (cited in note 11).

37. Indeed, far from being irrelevant to today's science, Rational Morphology laid the foundation for modern taxonomic classification of species. Linné's taxonomic method, first published in 1758, has been used ever since as the official method of naming organisms. Modern science has simply added two levels: phylum below kingdom, and family below order. Weiner, *The Beak of the Finch* at 23 (cited in note 11).

38. See Stein, *Legal Evolution* at ix (cited in note 15).

39. Id. at 5.

40. Adam Smith and John Millar were members of a "salon" of Scottish legal thinkers, which included Henry Home (Lord Kames) and David Hume, who during the late eighteenth century distinguished sharply between morality and law and pursued the theory, the foundations for which were laid by Montesquieu and Machiavelli, that "legal development is related to the mode of subsistence of society, which passes through certain well-defined stages." Id. at 29. The focus of Smith in particular was on property law, based on the premise that property plays different roles in the sociolegal system according to the state of progress a society has reached. Id. at 29-38. Whereas "writers 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, 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 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 Norr, *Technique and Substance: Remarks on the Role of Roman Law at the End of the*

rists such as Gustav Hugo and Friedrich Karl von Savigny,[41] were giving serious attention to the question of change in law as a reflection of change in society, though their theories postulated only a deterministic form of evolution.[42]

At the dawn of the nineteenth century, therefore, the search for ahistorical, teleologically derived laws of form, both biological and legal, dominated scientific and legal theories.[43] Many of the important names and developments of that era have been largely forgotten outside of history studies. Nevertheless, the tradition they laid down was critical to the emergence and definition of evolutioinism in both

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20th Century, 20 Syracuse J. Intl. L. & Comm. 33, 34 (1994) (explaining the importance of property law to the Scottish school).

41. Friedrich Karl von Savigny's and Gustav Hugo's theories, like those of the Scottish school, echoed the earlier writings of Montesquieu, as well as of the Irishman, Edmund Burke. See Stein, *Legal Evolution* at 54-60 (cited in noto 15). 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 creato or extinguish rights and duties .... People consider them as part of their special way of life." Id. at 60. Savigny thus posited that this "organic connection of law with tbe character of the people is preserved as societies develop ... [and] is an inseparable part of the nation's life." Id. Savigny's "organic connection" became the dominant model of the German historical school. Id. at 63. See also Elliott, 85 Colum. L. Rev. at 41-43 (cited in note 3) (discussing the influence of Savigny's German historical school on late nineteenth century English 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").

42. In his thorough examination of tbe Scottish and German historical evolution theories, Peter Stein concludes that they claimed "to explain legal change not merely in historical terms but as proceeding according to certain determinative stages, or in a certain pre-determined manner .... They were produced by thinkers who were, on the whole, satisfied with the state of the law as it was." Stein, *Legal Evolution* at 122 (cited in note 15). See also Norr, 20 Syracuse J. Intl. L & Comm. at 34 (cited in note 40) (noting that the Scottish "theory of stages ... took on deterministic traits"); M.H. Hoeflich, *Law & Geometry, Legal Science from Leibniz to Langdell*, 30 Am. J. Legal Hist. 95, 106-07 (1986) (describing Savigny as fitting a "geometric" paradigm of law, in that he portrayed laws as derived from history and society rather than from natural law truths, but also that "[o]nce so derived ... they could function as mathematical axioms in the hands of the jurists"); Horowitz, 42 Am. J. Comp. L. at 246-47 (cited in note 3) (concluding that Savigny's and others' "evolutionary and developmental thinking ... conduces to fixed ideas about where the law must be headed and vague ideas about how it moves from one point to another. General outcomes are foreordained, methods underspecified").

43. Stein, *Legal Evolution* at 69 (cited in note 15). To be sure, the tide started to turn in this regard before Darwin, largely through the efforts of Jeremy Bentham, who argued the decidedly un-British view that "law was what the legislator commanded in statutes" and that "legal change ... should be made expressly and rationally by legislators who had been trained ... for the purpose." Id. at 69-70. Both Bentham and his disciple, John Austin, were influenced largely by the natural law theory of Reman law espoused by the German Pandectist scholarship, which was anathema to Savigny, and, though their efforts led to tremendous leaps of law codification reform in England, they did not produce a distinct theory of legal evolution. See id. at 70-72. See also Hoeflich, 30 Am. J. Legal Hist. at 110-11 (cited in noto 42).

fields. And, as we can see through Complexity Theory, ultimately the message of a natural system of order beyond the chance and necessity of natural selection may not be as much total nonsense as we have smugly come to believe. To come to that revelation, however, requires a brief recounting of the historical unfolding of scientific and legal evolutionism from Darwin to the Ecosystem Age.

A. Natural Selection and Gradualism—Foundations for Legal Formalism

Proponents of the common theme of order—the rationally, naturally, and ahistorically derived order which drove Rational Morphology and English natural law theory in the eighteenth century—must have felt threatened by Darwin's works. Darwin's innovation, and the threat it posed to natural order theory, was twofold. First, he used the concept of natural selection to explain how a species evolves into another species as a result of variants of individual members of the first.[44] Second, he developed the picture of branching speciation, or "descent with modification," to describe the vertical evolution of a population and the proliferation of different species under a common phylum.[45] Thus, "[s]pecies, genera, families,

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44. It is important to emphasize that Darwin's theory of natural selection "is a theory of ultimate individualism. Darwin's mechanism works through the differential reproductive success of individuals who, by fortuitous possession of features rendering them more successful in changing local environments, leave more surviving offspring." Gould, *Dinosaur* at 329 (cited in note 10). See also Ruse, *Darwinism*, in Keller and Lloyd, eds., *Keywords* at 78 (cited in note 1) ("Darwin . . . believed ardently that selection works solely for tbe benefit of tbe individual."). Because of the important role reproductive success plays in the mechanism of transferring individual survival advantages to the species, most Darwinians, including Darwin, also accept as a subsidiary mechanism that of *sexual* selection—the struggle to reproduce as opposed to natural selection's struggle to survive. See Helena Cronin, *Sexual Selection: Historical Perspectives*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 286 (Harvard U., 1992); Hamish G. Spencer and Judith C. Masters, *Sexual Selection: Contemporary Debates*, in Evelyn Fox Keller and Elisabeth A. Lloyd, *Keywords of Evolutionary Biology* 294 (Harvard U., 1992). See generally Charles Darwin, *The Descent of Man, and Selection in Relation to Sex* (Appleton, 1871). Although many Darwinians lump sexual selection into natural selection, see Ruse, *Darwinism*, in Keller and Lloyd, eds., *Keywords* at 78 (cited in note 1), the existence of traits which offer sexual reproduction advantages while at the same time reducing the chances of survival—for example, the male peacock's tail feathers and the mail guppy's tail colors attract both females and predators—suggests that sexual selection can be a powerful independent factor in evolution. See Weiner, *The Beak of the Finch* at 85-93, 159-72 (cited in note 11).

45. See Richard M. Burian, *Adaptation: Historical Perspectives*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 8 (Harvard U., 1992); John A. Endler, *Natural Selection: Current Usages*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 220-24 (Harvard U., 1992). As Edward O. Wilson explains, "[t]he two patterns of evolution are vertical change in the original population and speciation, which is vertical change plus the splitting of the original population into multiple races or

order, and the other higher taxa cluster hierarchically because they express the pattern of branching speciation, not because they reflect a timeless and universal Plan of Creation."[46]

Darwin thus provided the first leg of the modern, though far from universally accepted, concept that natural selection is the single explanatory force of biological evolution. Three other essential legs were needed to support that contemporary neo-Darwinian view. First, the rediscovery in the early 1900s of Mendelian genetics explained how "some form of steady state is reached in which each organism has a constant number of the hoped-for hereditary atoms"[47] and led to an understanding of the distinction between the description of an organism based on internal hereditary factors, genotype, versus its observable physical qualities, phenotype.[48] Second, research in organism development helped bond the concept of a history of the species' lineages, phylogeny, to the process of the species individual's growth, ontogeny. This refinement led to a better understanding of the germ plasm, which is passed from parent to offspring and contains both the hereditary atoms and the blueprint for organism development.[49] Finally, advancements in understanding of population biology and genetics have helped explain how a mutant gene arising in a single individual and conferring only a slight selective advantage over the normal gene could spread throughout a population by virtue of the selective advantage it offered.[50]

The convergence of these four legs of theory, when "united with paleontological evidence and the experimental transmission and developmental genetics, forms the core of the contemporary neo-

species.... Speciation requires vertical evolution, but vertical evolution does not require speciation." Wilson, *Diversity of Life* at 51 (cited in note 11). Darwin's focus was on vertical change, see id. at 51-52, though his theory of natural selection is critical to an understanding of how speciation occurs, for speciation is "simply the evolution of some difference—any difference at all—that prevents the production of fertile hybrids between populations under natural conditions." Id. at 56.

46. Kauffman, *Origins of Order* at 6 (cited in note 5).

47. Id. at 7.

48. See Lindley Darden, *Character: Historical Perspectives*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 40-44 (Harvard U., 1992); Richard C. Lewontin, *Genotype and Phenotype*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 137-44 (Harvard U., 1992).

49. See Kauffman, *Origins of Order* at 7 (cited in note 5); Peter Bowler, *Lamarckism*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 188, 191 (Harvard U., 1992).

50. Kauffman, *Origins of Order* at 9 (cited in note 5). See also Burian, *Adaptation: Historical Perspectives*, in Keller and Lloyd, eds., *Keywords* at 10 (cited in note 45).

Darwinian Synthesis."[51] Needless to say, as this theory unfolded it left no place in biology for the "laws of form" premise of Rational Morphology, and it posed a serious assault on the search for natural, teleologically-derived order which formed the foundation of Enlightenment philosophy, including that of natural law theory.

This is not to say, of course, that there were none in science and other disciplines who were ready to accept Darwinism with open arms. Indeed, many did so for the very reason that it offered a way out of the entrenched enlightenment dogma. The springboard for that infusion of new blood into Anglo-American legal theory can be traced to Henry Maine's 1861 publication of *Ancient Law*.[52] Maine presented his influential study of Roman Law much more in the tradition of the German historical school, particularly of Friedrich Karl von Savigny, than was the custom of English natural law theory.[53] *Ancient Law* thus provided the first English version of the notion that "the law of civilised societies was the product of a development through a series of identifiable stages related to, but distinct from, the development of society itself."[54] Although Maine was not at that time greatly influenced by Darwin,[55] and *Ancient Law* contained no overtly Darwinian themes, English readers readily saw the parallel as did Maine himself eventually.[56] The stage thus was set for Darwinism to provide the vehicle for jettisoning natural law theory's melding of law and morality, a process which unfolded in the United States largely through the works of the Legal Formalists.

Legal Formalists looked to experimental science as a tool for divining the imperishable truths of "legal science."[57] Accordingly, they

51. Kauffman, *Origins of Order* at 9 (cited in note 5). Similarly, Edward O. Wilson describes neo-Darwinism as "[t]he modern study of the evolutionary process that assigns a central role to natural selection . . . now informed by substantial new knowledge from genetics, ecology, and other modern disciplines of biology." *Diversity of Life* at 403 (cited in note 11).

52. Henry Sumner Maine, *Ancient Law: Its Connection with the Early History of Society, and Its Relation to Modern Ideas* (Beacon ed. 1963).

53. Stein, *Legal Evolution* at 89 (cited in note 15) (noting that Maine was "concerned with the histery of legal institutions in the manner of Savigny, whose influence on him is clear"); Elliott, 85 Colum. L. Rev. at 43 (cited in note 3) ("Savigny's histerical approach to the evolution of legal systems was extended and refined by . . . Maine.").

54. Stein, *Legal Evolution* at 99 (cited in note 15). In this sense, Maine perpetuated the German histerical school's depiction of legal evolution as a progression through pre-determined stages of development. See Elliott, 85 Colum. L. Rev. at 43-44 (cited in note 3) ("Maine identifies successive stages through which all 'progressive societies' must pass.").

55. The prevailing view today is that "[t]he science which provided the model for Maine was geology." Stein, *Legal Evolution* at 88 (cited in note 15). See also Elliott, 85 Colum. L. Rev. at 43 (cited in note 3) (stating that Maine's ideas were only "mildly evolutionary" in the Darwinian sense).

56. Stein, *Legal Evolution* at 100 (cited in note 15).

57. Hoeflich, 30 Am. J. Legal Hist. at 96 (cited in note 42).

portrayed law as "a structure of positivised, objective, formally defined rights."[58] The central precepts of this "legal science" approach, which was pursued to its highest form in Langdell's case study method at Harvard,[59] were that laws are commands, legal decisions can be deduced logically from predetermined rules, and the law as it is actually laid down is separate from the law as it should be.[60] Although "[t]he flesh is arranged differently by different positivists . . . [d]ifferent versions differ chiefly in their descriptions of the fundamental test of pedigree a rule must meet to count as a rule of law."[61]

Professor Herbert Hovenkamp describes how different Legal Formalists, in pursuit of their science of legal rules, embraced Darwin through three different schools of thought: (1) Apolitical Darwinism; (2) Social Darwinism; and (3) Reform Darwinism.[62] Apolitical Darwinism was characterized by the giants of the Langdellian "legal science" brand of jurisprudence, such as John Henry Wigmore[63] and Arthur Corbin.[64] In general, however, their discourses on the subject tended, like much Formalist writing, "to lapse into dry, complicated, and endless classification schemes"[65] and to be "concerned with largely historical, and thoroughly academic questions about how the law evolves."[66] Their influence in developing a broadly followed theory of legal evolution thus was not tremendous outside the academic

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58. Scott, 35 Wm. & Mary L. Rev. at 337 (cited in note 9) (quoting Elizabeth Mensch, *The History of Mainstream Legal Theught*, in David Kairys, ed., *The Politics of Law: A Progressive Critique* 18, 23 (Pantheon, 1982)).

59. See Duxbury, *Patterns of American Jurisprudence* at 9-64 (cited in note 15).

60. H. L. A. Hart, *Positivism and the Separation of Law and Morals*, 71 Harv. L. Rev. 593, 601-02 n.25 (1958). For a concise discussion of the different versions of legal positivism advanced by the leading figures in the school of what is now called Legal Formalism, see Joseph Raz, *The Concept of a Legal System: An Introduction to the Theory of the Legal System* (Oxford U., 2d ed. 1980).

61. Ronald M. Dworkin, *The Model of Rules*, 35 U. Chi. L. Rev. 14, 18 (1967). See also Duxbury, *Patterns of American Jurisprudence* at 22 (cited in note 15) (describing Formalism as fundamentally reductionist in approach); id. at 79 ("The Langdellian legal scientist had a clear objective: to reduce legal doctrines to their core elements and thereby remove from the law all unnecessary complexity.").

62. See Hovenkamp, 64 Tex. L. Rev. at 656 (cited in note 3).

63. See Elliott, 85 Colum. L. Rev. at 46-50 (cited in note 3). See generally Albert Kocourek and John H. Wigmore, eds., *Evolution of Law: Select Readings on the Origin and Development of Legal Institutions* (Little, Brown, 1915).

64. See Elliott, 85 Colum. L. Rev. at 55-59 (cited in note 3). See generally Arthur L. Corbin, *The Law and the Judges*, 3 Yale L. J. 234, 249 (1914) ("[T]he growth of the law is an evolutionary process.").

65. Hovenkamp, 64 Tex. L. Rev. at 662 (cited in note 3).

66. Id. at 663.

world.[67] Indeed, the fascination of the Apolitical Darwinists with evolutionary theory led many of their pronouncements to appear anti-Formalist and almost "proto-realist."[68]

As much as the Apolitical Darwinists may have bred interest in the field of academic jurisprudence, of far more excitement to the day was the debate between Social and Reform Darwinists. Social Darwinism was the brainchild of the English commentator Herbert Spencer, who blended the evolutionary theory of cultural development espoused in August Comte's *Course of Positive Philosophy*[69] with Darwinian evolutionary theory and thus "wrote the concept of rights based on natural law out of existence."[70] Spencer's thesis replaced natural law with the highly individualist "belief[s] that every person may expect nature to take its course free from unreasonable private or state interference" and that legal rights thus "were the products of evolutionary development from economic necessity."[71] His views were trumpeted in the United States most vocally by William Graham Sumner, who advanced the notion of "rights as rules of the game of social competition"[72] and described the role of jurisprudence as "to develop a legal theory of the state that would permit natural selection

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67. One influential writer who Professor Hovenkamp includes in the Apolitical Darwinism category is Oliver Wendell Holmes, see id., hut Justice Holmes may he harder te classify in this regard. Justice Holmes "had a lifelong interest in the theory of evolution as applied to law," id., and was the first in the United States to systematically advance the notion that law adapts to the times, as characterized hy his observation that "legislation . . . like every other device of man or beast, must tend in the long run to aid the survival of the fittest." Duxbury, *Patterns of American Jurisprudence* at 43 (cited in note 15) (quoting Oliver Wendell Holmes, Jr., *Summary of Events: The Gas Stokers' Strike*, 7 Am. L. Rev. 582, 583 (1873) (unsigned)). Justice Holmes's work in the field, exemplified by his masterpiece *The Common Law*, thus is seen as having "strong evolutionary undercurrent." Elliott, 85 Colum. L. Rev. at 51 (cited in note 3). But although Justice Holmes speaks often of or about evolution of law, Darwin's name and Darwinism seldom are mentioned. Indeed, in many important respects Justice Holmes can be viewed more as a positivist who subscribed to August Comte's theory of evolution of thought, which is in no sense Darwinian. See Patrick J. Kelley, *Was Holmes a Pragmatist?: Reflections on a New Twist to an Old Argument*, 14 So. Ill. L. J. 427, 453 (1990).

68. For example, Professor Corbin held firm to the Langdellian tradition, but his focus on legal evolution through judicial creativity won him an anti-Formalist following. See Duxbury, *Patterns of American Jurisprudence* at 140-41 (cited in note 15).

69. August Comte, *Cours de Philosophie Positive* (Hermann, 1975). Hovenkamp explains how Spencer used Comte's work to develop his own pre-Darwinian theory of cultural evolution. See Hovenkamp, 64 Tex. L. Rev. at 664-67 (cited in note 3).

70. Hovenkamp, 64 Tex. L. Rev. at 667 (cited in note 3). One commentator observed not long after Spencer published his theories that "[s]o deeply did Spencer impress his stamp upon the social thought of his age that to most students of social phenomena evolution means Spencerian evolution." A.G. Keller, *Law In Evolution*, 28 Yale L. J. 769, 772 (1919).

71. Hovenkamp, 64 Tex. L. Rev. at 669 (cited in note 3).

72. Id. at 670 (quoting William Grabam Sumner, *Rights*, in 1 *Essays of William Graham Sumner* 362 (1934)).

to run its course."[73] The Social Darwinist focus on the rational, egotistic, autonomous, acquisitive individual as a moral and economic ideal to be promoted through a laissez-faire economy[74] certainly corresponded to Darwin's description of natural selection as a mechanism at work on the individual rather than species level.[75] The unmistakable bottom line message of the Social Darwinists, however, was decidedly un-Darwinian in its normative focus—that allowing sociolegal evolution to proceed by natural selection, that is, unfettered by state intervention designed to convert "natural" rights into state-enforced rights, would produce progressively "superior" societies.[76]

By contrast, the Reform Darwinists embraced Darwin's norm-free depiction of evolution to develop a theory of a more active state than the one conceived by the Social Darwinists.[77] In his 1901 publication of *Social Control*,[78] for example, Edward Ross explained how legal rules evolve in order to identify the means of controlling this evolutionary mechanism to produce desired social outcomes.[79] For Roscoe Pound, therefore, the reason to understand a law's evolutionary development was to use it as a tool for social control.[80]

By the early 1900s, Reform Darwinism, with its emphasis on developing working theories in social science and jurisprudence, was

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73. Id. at 671. For the Social Darwinists, this meant that "[w]hile everyone will share an equal right to compete in the market under a system of *laissez-faire*, not everyone will in fact compete equally." Duxhury, *Patterns of American Jurisprudence* at 27-28 (cited in note 15).

74. Duxbury, *Patterns of American Jurisprudence* at 26 (cited in note 15).

75. See note 44.

76. See Hovenkamp, 64 Tex. L. Rev. at 671 (cited in note 3). Natural selection tbeory has been used to advocate normative models of directional cbange based on "tbe unstated belief that evolution is always going somewhere and that we would especially like to know where such a universal process will lead." Gould, *Dinosaur* at 136 (cited in note 10). Darwin insisted "that organic change led only to increasing adaptation between organisms and their own environment and not to an abstract ideal progress defined by structural complexity or increasing heterogeneity." Gould, *Ever Since Darwin* at 37 (cited in note 18). Ironically, however, natural selection theory was easily melded into Victorian Age notions of progress to a higher ideal, epitomized by Spencer's brand of Social Darwinism and taken to insidious extremes in some racist theories of human evolution. See id. at 36-38, 214-21.

77. Hovenkamp, 64 Tex. L. Rev. at 671 (cited in note 3).

78. Edward Alsworth Ress, *Social Control: A Survey of the Foundations of Order* (Macmillan, 1922).

79. Hovenkamp, 64 Tex. L. Rev. at 674 (cited in note 3).

80. Id. at 679. Roscoe Pound observed, for example, that "[i]n constitutional law . . . [i]t is felt that a law cannot be constitutional now if it would have been unconstitutional one hundred years ago. *In fact* it might have been an unreasonable deprivation of liberty as things were even 50 years ago, and yet be a reasonable regulation as things are now." Roscoe Pound, *Liberty of Contract*, 18 Yale L. J. 454, 469 (1909). See generally Duxbury, *Patterns of American Jurisprudence* at 54-59 (cited in note 15).

firmly entrenched in the universities.[81] In contrast, Social Darwinism's emphasis on laissez-faire economics had become a creature of the courts.[82] In his *Lochner v. New York* dissent, Oliver Wendell Holmes may have started the death of Social Darwinism with his observation that the "Fourteenth Amendment does not enact Mr. Herbert Spencer's Social Statics."[83] This view later became the sword that brought down the Supreme Court's flirtation with substantive due process to make room for the New Deal.[84] And the case can be made that the rise of Reform Darwinism in the academy, which turned out lawyers who believed in the importance of state control, provided the bridge out of Formalism as the prevailing jurisprudence and into the New Deal-era emergence of Legal Realism.[85] Nevertheless, it was the Formalist school that first put Darwinism firmly on the jurisprudential map, leaving it for later schools of jurisprudence to figure out what to make of the role of natural selection in sociolegal evolution.

B. Punctuated Equilibriums—Legal Realism Challenges Social Darwinism

The role of natural selection became a topic in science as well. The neo-Darwinian model suggests, or at least allows the suggestion, that evolution through natural selection should occur at a uniform rate in a continuous, gradual manner.[86] The fossil records can be interpreted to suggest, however, "that the evolution of individual species takes place in well-defined steps (the punctuation marks) separated by long periods of stability (equilibria or stasis)."[87] The founda-

81. See Hovenkamp, 64 Tex. L. Rev. at 673-74 (cited in note 3).

82. See Duxbury, *Patterns of American Jurisprudence* at 3, 25-32 (cited in note 15).

83. 198 U.S. 45, 75 (1905) (Holmes, J., dissenting).

84. See Duxbury, *Patterns of American Jurisprudence* at 30-32 (cited in note 15).

85. See id. at 149-59.

86. Stuart Kauffman explains tbat "[t]he classical neo-Darwinist position favors phyletic gradualism, in which small phenotypic changes accumulate slowly in a species." *Origins of Order* at 19 (cited in note 5) (citation omitted). See also Weiner, *The Beak of the Finch* at 181 (cited in note 11) ("Darwin was emphatic that all complex adaptations arise by the gradual agency of natural selection."); Gould, *Dinosaur* at 149-50 (cited in note 10) ("Darwin's own preferences for gradualism were . . . extreme."). The case for gradualism is made most forcefully today by Richard Dawkins. See generally Richard Dawkins, *The Blind Watchmaker* (Norten, 1986).

87. Coveney and Highfield, *Frontiers of Complexity* at 232-33 (cited in note 5). The most significant gap in this respect, and the one which most vexed Darwin, was the lack of sufficient evidence of a flourishing diversity and abundance of life forms prior to the diversification of life during the Cambrian Era to support the theory that the Cambrian Era represented simply another stage of a smooth evolutionary transition. See Stephen Jay Gould, *Wonderful Life: The Burgess Shale and the Nature of History* 55-60 (Norton, 1989).

tions of neo-Darwinian theory are left explaining that observed record of so-called punctuated equilibrium by positing either the existence of undiscovered fossil records that would close the gaps in data,[88] or the existence of maximally fit life forms existing in a dominantly stable environment upset by occasional happenstance events—for example, meteors.[89] In other words, in response to those who proclaimed or implied that conventional Darwinism could not explain the historically aberrational record, neo-Darwinism has had to describe more and increasingly complicated refinements of its theory to accommodate the observed exceptions.[90]

Similarly, though it transpired well before the emergence of punctuated equilibrium theory in science, Legal Realism laid the observed record of legal decisions on the Formalists' laps and demanded an explanation. Indeed, Professor Donald Elliott comments

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88. For example, the explanation Darwin offered was that the pre-Cambrian fossil records are incomplete and would fulfill the gradualist theory once discovered, a notion that may have been plausible in Darwin's time but no longer is so given advancements in paleontology. See Gould, *Wonderful Life* at 57-58 (cited in note 87). Jay Gould argues that the genotypic stasis found in the fossil records is evidence of stability in individual species one would expect as an indicia of success in the species' evolution. Gould, *Dinosaur* at 136-37 (cited in note 10). Accordingly, "stasis should be an expected and interesting norm (not an embarrassing failure te detect cbange), and . . . evolution should be concentrated in brief episodes of branching speciation." Id. at 128. This is not to say, of course, that natural selection, which operates at the *individual* level, see note 44, is not always at work. Rather, "natural selection is daily and hourly scrutinizing." Weiner, *The Beak of the Finch* at 37 (cited in note 11). Indeed, current research provides strong evidence of a phenomenon known as stabilizing selection: the operation of natural selection forces leading to minor, short-lived evolutionary swings in species composition which rapidly balance out over observable time and thus would not be expected to appear in fossil records. See id. at 103-11. Thus, ironically, we can observe evolution happening, but may not see its imprint as evidence of gross species transformation in the fossil records. As Jonatban Weiner puts it: "[T]he closer you look at life, the more rapid and intense the rate of evolutionary change. The farther back in time you stand, the less you see." Id. at 111.

89. See Kauffman, *Origins of Order* at 20 (cited in note 5). This explanation is difficult to accept given the relative scarcity of steady-state environments in nature. In the present, for example, among the only environments approaching the kind of equilibrium that might *force* long-term genotypic stasis are hot sulfur springs and deep ocean hot vents, where organisms known as extremophiles appear metabolically similar to those found from the same environments over three billion years ago. See Gell-Mann, *The Quark and the Jaguar* at 236-37 (cited in note 5).

90. See Coveney and Highfield, *Frontiers of Complexity* at 400 n.109 (cited in note 5). The debate between the gradualism and punctuated equilibrium theories is by no means over in the scientific community. See Ruse, *Darwinism*, in Keller and Lloyd, eds., *Keywords* at 79-80 (cited in note 1) (describing competing theories); Weiner, *The Beak of the Finch* at 181 (cited in note 11) (same). The debate has captured popular attention as well. See, for example, J. Madeline Nash, *When Life Exploded*, Time Magazine 66, 71-72 (Dec. 4, 1995). Some evolutionary biologists take issue with the very existonce of the debate, as a unified theory of alternating rapid and slow evolution is perfectly consistent with neo-Darwinian models and the punctuated fossil record. See text accompanying notes 197-200.

that "[f]or reasons that remain somewhat mysterious, references to evolution in Anglo-American jurisprudence are few and far between during the half-century from the middle 1920s to the middle 1970s."[91] The reason is Legal Realism.

Legal Realism "challenged Social Darwinism in the courts just as it challenged Langdellian legal science in the law schools."[92] Legal Realists were the paleontologists of law. They ostensibly rejected the formal deductive method of Formalism and replaced it with the inductive search for rules "that existed in the real world of every day transactions."[93] The Legal Realists may thereby have challenged the Langdellian legal science tradition of the Legal Formalists. In so doing, however, Legal Realism gradually developed into just another branch of empiricist social science.[94] Always "with an eye to increasing the predictability of judicial decisions,"[95] its central focus became analysis of the "inherent . . . patterns of relationships that one could observe and record in the commercial world."[96]

Ironically, the heroes of the early Legal Realists were the Apolitical Darwinists, who could be called Formalists as much as anything else,[97] and the Reform Darwinists, who focused jurisprudential attention on the social sciences.[98] The abhorrence Legal Realists held for Social Darwinism, however, led them to abandon natural selection as a metaphor for their predictivist social science mission. Thus, as Professor Elliott observes, references to Darwin and natural selection all but disappeared from jurisprudence during the middle decades of the twentieth century—Legal Realists were interested in uncovering the "paleontological" reality of law, not in describing the mechanism of legal change.

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91. Elliott, 85 Colum. L. Rev. at 59 (cited in note 3).

92. Duxbury, *Patterns of American Jurisprudence* at 32 (cited in note 15).

93. Scott, 35 Wm. & Mary L. Rev. at 338 (cited in note 9).

94. Legal Realism attempted "to create a 'responsible law' on the basis of empirical data gathered and interpreted with a little help from the social sciences." Gunter Frankenberg, *Down By Law: Irony, Seriousness, and Reason*, 83 Nw. U. L. Rev. 360, 385 (1989).

95. Theodore M. Benditt, *Law as Rule and Principle: Problems of Legal Philosophy* 16 (Stanford U., 1978). Neil Duxbury is more direct, concluding that "[t]he prediction theory of law was to become a cornerstone of realist jurisprudence," *Patterns of American Jurisprudence* at 37 (cited in note 15), and that "[t]he essential purpose behind the realist stress on predictivism was the promotion of certainty in law." Id. at 130. Hence "realism, certainly in its predictive guise, appears to attempt to discredit one formalist conception of law only to replace it with another." Id. at 131.

96. Scott, 35 Wm. & Mary L. Rev. at 341 (cited in note 9). Thus, "[f]or all that realism constituted a general sense of unease concerning legal formalism . . . it could not be described as an outright distaste for scientific methods." Duxbury, *Patterns of American Jurisprudence* at 79 (cited in note 15).

97. Id. at 44-47.

98. See text accompanying notes 77-85.

C. Random Drift Through Species Selection—A Role for Indeterminacy in Law?

Neo-Darwinism's natural selection theme has been used to imply that there is some normative quality to evolution—that is, that evolutionary change is driven by selective *advantages*.[99] Studies in population genetics have shown, however, that selectively neutral genes with low frequency in a species can nonetheless develop a high frequency in breeding populations isolated from other populations of the species by sheer chance, and then in turn appear within the entire species after reintroduction of the population isolate.[100]

This "random drift" of gene composition results in a "tendency of genomes to change gradually with time in ways that do not profoundly affect the viability of the phenotype."[101] This so-called neutral theory of species selection thus demonstrates how, even in large populations, evolution at the molecular level is due largely to random drift of non-selective gene variants.[102] It is entirely possible, moreover, that through such random drift the genotypes defining a species may reach an unstable situation in which small genetic changes can lead to large phenotype changes for better or worse.[103] The chance occurrences of genetic transmission, in other words, do not always support evolution of a phenotype into the normatively fittest species through exploitation of selective differences, nor do they necessarily have anything to do with environmental pressures. Some component of evolution is "pure chance."[104]

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99. See Kauffman, *Origins of Order* at 10 (cited in note 5). This normative quality led to the emergence of Social Darwinism. See text accompanying notes 69-76.

100. See Kauffman, *Origins of Order* at 10 (cited in note 5).

101. Gell-Mann, *The Quark and the Jaguar* at 239 (cited in note 5). For a detailed explanation of random drift theory, see John Beatty, *Random Drift*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 273-81 (Harvard U., 1992); Motoo Kimura, *Neutralism*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 225-30 (Harvard U., 1992); Wilson, *Diversity of Life* at 81-84 (cited in note 11).

102. Kauffman, *Origins of Order* at 10 (cited in note 5).

103. Gell-Mann, *The Quark and the Jaguar* at 239 (cited in note 5). For example, Edward O. Wilson explains that the genetic differences brought about in populations by random drift, "combined with geographical isolation and the exigencies of a new and different environment, can propel populations inte new ways of life, new adaptive zones. It can also lead them more quickly to the formation of reproductive harriers and full species status." *Diversity of Life* at 84 (cited in note 11).

104. Wilson, *Diversity of Life* at 81 (cited in note 11). Thus, genetic drift can be thought of as "[e]volution in the genetic constitution of a population by chance processes alone." Id. at 399.

The indeterminacy of evolution suggested by the neutral species selection theory exposes dichotomies between order and randomness and between normative and nonnormative processes which have dominated debate in legal theory as well. Nothing could illustrate this more than the emergence of Critical Legal Studies ("CLS") as a purportedly coherent school of jurisprudence. Adherents to CLS expose the contradictions in law and legal institutions in order to promote leftist political ideology.[105] And yet, as much as criticism of formalism and objectivism is central to CLS, their method involves purely instrumental use of legal practice and legal doctrine.[106] Hence, what appears nonlinear on its surface in CLS theory is, at bottom, "as doggedly deterministic and 'scientific' in the old sense as any thinking to come out of the nineteenth century."[107] In other words, CLS is legal science with a normative twist.

Although there is little attention given in CLS literature to evolution of law in the Darwinian sense, the CLS themes of legal indeterminacy and equality of rights raise strong parallels to evolutionary biology. The obsessive deconstructionist focus on indeterminacy in law which is central to all variants of CLS "is an attempt to disassemble rationalistic constructions into their individual parts, in order to bring into light fissures, tensions, hidden components, buried tools, and compulsively simplifying antitheses."[108] And just as random drift theory focuses evolutionary biology away from the individual level and towards population dynamics, one of the central objectives of CLS is structuring legal rights to protect communities rather than individuals.[109] Thus, CLS challenges the very underpinnings of Legal Realism, with its focus on prediction, and of Formalism, which found its roots in individualist natural selection theory. In so doing,

105. Scott, 35 Wm. & Mary L. Rev. at 345 (cited in note 9).

106. Roberto Mangabeira Unger, *The Critical Legal Studies Movement* 3-4 (Harvard U., 1986).

107. Reynolds, 91 Colum. L. Rev. at 113 (cited in note 9).

108. Frankenberg, 83 Nw. U. L. Rov. at 372 (cited in note 94). To the Crits, in other words, "[i]ndeterminacy *infects* the legal system." Duxbury, *Patterns of American Jurisprudence* at 459 (cited in note 15) (emphasis added). In fairness, the Legal Realists "discovered" indeterminacy in the law, using it as the means of breaking down the Formalists' view of the judge as merely applying rules of law in a scientific, deductive manner. See John Hasnas, *Back to the Future: From Critical Legal Studies Forward to Legal Realism, or How Not to Miss the Point of the Indeterminacy Argument*, 45 Duke L. J. 84, 86-95 (1995) (providing a brief history of the indeterminacy argument). The CLS school reintroduced the indeterminacy principle as a more far-reaching element of their political assault on the legal system—that is, that rampant indeterminacy in law "reveals that the social structure generated by the legal system is not the embodiment of justice it purports to be, but an illegitimate hierarchy." Id. at 98.

109. Hasnas, 45 Duke L. J. at 99-103 (cited in note 108).

however, CLS raises important questions, though perhaps not explicitly in its literature, about sociolegal evolution.

The parallel between the unfolding histories of jurisprudence and of evolutionary biology takes yet another step in the development of one of the dominant modern schools of jurisprudence, Law and Economics, which can be viewed as the neo-Formalist counterpart to the current-day neo-Darwinian defenses of natural selection. Law and Economics was founded on the notion that "one can determine the legal implications of any choice or action by looking at the consequences, and then measuring those consequences against some normative criteria—usually efficiency or the aggregation of total social welfare."[110] Hence, the dominant theme of Law and Economics is the "repair" of market failure.[111] In terms not surprisingly reminiscent of Adam Smith's historical theory of legal evolution,[112] Law and Economics thus portrays the common law as an attempt to achieve economic efficiency[113] and posits that efficient rules will be reached regardless of the underlying bases for judicial decisions.[114] Individuals, in the Law and Economics view, will simply continue to relitigate inefficient rules until the rules are eventually changed by the courts.[115] The individual drive towards rational efficiency savings, in other words, produces an evolutionary process driving law towards economically efficient rules despite judicial motivations.[116] The Law

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110. Scott, 35 Wm. & Mary L. Rev. at 343 (cited in note 9). Contrary to CLS, therefore, "modern law and economics, '[l]ike the old-fashioned formalism . . . reestablishes the lawyer as scientist with a norm-free calculus.'" Duxbury, *Patterns of American Jurisprudence* at 303 (cited in note 15) (quoting David Gray Carlson, *Reforming the Efficiency Criterion: Comments on Some Recent Suggestions*, 8 Cardozo L. Rev. 39, 39 (1986)).

111. Jules Coleman and Jeffrey Lange, 1 *Law and Economics* xii (New York U., 1992). It has been said of Law and Economics and other postrealist schools of American legal theory that

> [a]ny halfway scientific means was good enough for [them], as long as it promised to guarantee, more or less, the determinacy of judicial decisions and the autonomy of the law. To this end, the postrealists engaged in an unrestrained plundering of neighboring disciplines, where they discovered the policymaking model for jurists and the economic analysis of the law for judicial decisions.

Frankenberg, 83 Nw. U. L. Rev. at 385 (cited in note 94).

112. See note 40.

113. Paul Rubin, *Why Is the Common Law Efficient?*, 6 J. Legal Stud. 51, 51 (1977). For a thorough discussion of the legal evolution theories of major Law and Economics writers, including Professors Paul Rubin, George L. Priest, and Judge Richard Posner. See Elliott, 85 Colum. L. Rev. at 62-71 (cited in note 3).

114. Rubin, 6 J. Legal Stud. at 55 (cited in note 113).

115. Elliott, 85 Colum. L. Rev. at 65 (cited in note 3).

116. Id. In this sense, the Law and Economics evolutionary theory has been criticized as a reversion to the teleological foundations of eighteenth century thinkers such as Friedrich Karl von Savigny. See notes 40-42. Donald Horowitz, for example, explains that "there has been much criticism of the telos of efficiency, on the ground, among others, that ideology and

and Economics view of sociolegal evolution thus is expressed in words that could have been written a century ago by the most ardent Darwinian Formalist, with an increased dose of economics to help ground the theory in "real world" experience.

D. Ecosystem Nonequilibrium—Recognizing Dynamical Legal Systems

Despite what Law and Economics has to say about rational individual choices, to many of us it seems that getting ahead in life is all timing and location. Nowhere could that be more true than in biological evolution. For example, the lion is the king of the jungle, but put one in Antarctica and the penguins will have him for lunch. The lion would also not be very successful if transported back to a time when only plant species existed. Whether a species is fit, in other words, depends on where the species is, what other species are there with it, and when it got there relative to the other species.

Darwinian models have never ignored the importance of environment to evolution. In Darwin's theory, the actions of environmental forces on individuals are the engine of natural selection.[117] However, the emergence in environmental biology of the concept of unpredictable, dynamically changing ecosystems[118] has injected a heightened awareness of the role of indeterminacy and randomness into evolutionary theory. As Edward O. Wilson has put it, "whether a particular species occurs in a given suitable habitat is largely due to chance, but for most organisms the chance is strongly affected—the

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interests apart from efficiency cannot be written out of the process of legal change." Horowitz, 42 Am. J. Comp. L. at 248 (cited in note 3).

117. Many modern biologists credit Darwin with helping to establish the science of ecology through his recognition that a " 'web of complex relations' binds all of the living things in any region. . . ." Weiner, *The Beak of the Finch* at 225 (cited in note 11). See also Peter Taylor, *Community*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 52 (Harvard U., 1992) (describing Darwin's acknowledgment of the importance of ecological contexts).

118. Geneticist John Holland has observed that "[e]cosystems are continually in flux and exhibit a wondrous panoply of interactions such as mutualism, parasitism, biological arms races, and mimicry . . . . Matter, energy, and information are shunted around in complex cycles. Once again, the whole is more than the sum of its parts. Even when we have a catalog of the activities of most of the participating species, we are far from understanding the effect of changes in the ecosystem." Holland, *Hidden Order* at 3 (cited in note 5). See also Cohen and Stewart, *Collapse of Chaos* at 366-89 (cited in note 5). The past thirty years of research in biology have spawned this "new paradigm of ecology, mothballing the old notion of a 'balance of nature' and unveiling a vibrant new replacement focusing on flux." William Stolzenburg, *Building a Better Refuge*, Nature Conservancy 18, 21 (Jan./Feb. 1996). The new focus on dynamic change has led scientists te reevaluate the premises upon which many legal and policy decisions have been based. See generally Judy L. Meyer, *The Dance of Nature: New Concepts in Ecology*, 69 Chi. Kent L. Rev. 875 (1994).

dice are loaded—by the identity of the species already present."[119] Thus we see examples of the spread of species of common ancestry into different niches of the same ecosystem, known as adaptive radiation,[120] and examples of the occupation of the same niche in different ecosystems by different species, known as evolutionary convergence,[121] all based on timing and location. Evolutionary biologists call these phenomena the assembly rules of an ecosystem.[122] Ecological science, particularly the study of biological diversity, thus leaves little question that ecosystem dynamics and pure chance have much to do with the fitness of species. Unfortunately, "[w]hat we understand best about evolution is mostly genetic, and what we understand least is mostly ecological."[123]

Unlike Realist and other post-Realist schools of jurisprudence, which have largely eschewed explicit mention of evolutionary biology as a metaphorical reference point, the legal commentary flowing from the emergence of ecology dynamics fully embraces the message of evolution. This jurisprudential development is taking place at two levels. First, many commentators are calling attention to the need for environmental law to accept the dynamic nature of its subject—the environment.[124] For example, Professors Dan Tarlock and Fred

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119. Wilson, *Diversity of Life* at 164 (cited in note 11). The importance of ecological context to evolutionary processes had been developed beyond Darwin's intuitive observations as early as the 1940s, principally by G. Evelyn Hutchinson. See Taylor, *Community*, in Keller and Lloyd, eds., *Keywords* at 55 (cited in note 117).

120. Classic examples of adaptive radiation include the variety of finch species on the Galapagos Islands and the cichlids of Lake Victoria. In these cases one or very few ancestral species that originally colonized the habitat have since radiated into many species that now fill almost all the usual niches of birds, in the case of the Galapagos finches, or freshwater fish, in the case of the cichlids. Had those niches already been filled by other species, evolution would have taken a different course. See Wilson, *Diversity of Life* at 94-130 (cited in note 11); Weiner, *The Beak of the Finch* at 207-10 (cited in note 11).

121. Convergent evolution is "the increasing similarity during evolution of two or more unrelated species." See Wilson, *Diversity of Life* at 395 (cited in note 11). For example, in ecosystems around the world that lack true woodpeckers, such as some recently (in geological time) formed islands, adaptive radiations of the bird species which originally colonized the ecosystems have led to evolutionary convergence of different new species towards the woodpecker niche. Id. at 98-101.

122. Wilson explains that "[a]ssembly rules determine which species can coexist in a community of organisms (such as bird species occupying a forest patch). The rules also determine the sequence in which species are able to colonize the habitat." Id. at 171 (cited in note 11).

123. Id. at 93 (cited in note 11). See also Taylor, *Community*, in Keller and Lloyd, eds., *Keywords* at 52 (cited in note 117) ("At present . . . the structure and dynamics of this ecological context have not been well integrated into evolutionary theory.").

124. See, for example, Fred P. Bosselman and A. Dan Tarlock, *The Influence of Ecological Science on American Law: An Introduction*, 69 Chi. Kent L. Rev. 847 (1994) (analogizing to ecological evolution in the progress of the law); William H. Rodgers, Jr., *Adaptation of Environmental Law to the Ecologists' Discovery of Disequilibria*, 69 Chi. Kent L. Rev. 887 (1994)

Bosselman observe that "[c]urrent environmental law . . . rests on a simple ecological paradigm which the science has now rejected and replaced with a more complex, open-ended model."[125] Thus, posits Professor Jonathan Wiener, "[e]nvironmental laws based on a distinction between 'natural order' and any change in that order are clearly in for a bout of selection pressure themselves as the new ecology sweeps through policy."[126]

Professor Wiener notes that the new ecology approach "is evident in several strands of our evolving environmental law,"[127] and thus the deeper-level question also is beginning to be posed—whether the legal framework for regulating environmental protection *itself* exhibits the nonequilibrium evolutionary qualities of its subject matter. Professor William Rodgers believes, for example, that "laws will have life histories, which means attention should be paid to how they are likely to change over time; and laws seek to influence human behavior, which means that lawmakers invariably must speculate about what people will do."[128] Professor Rodgers points to the many maladaptations and other misfirings that occur when lawmakers attempt to play in this legal ecosystem.[129]

Perhaps, as Edward O. Wilson observes with respect to evolutionary biology, the theory of sociolegal evolution has focused too long on the "genetics" of law and not enough on the "ecology" of law. Darwinism, it seems, is back on our jurisprudential minds, with all the old and the many new questions that remain to be answered in evolutionary biology. It may be too soon to announce the emergence of a "Legal Ecologism" school of jurisprudence to address those questions; the nascent theories of law embrace the ecosystem as a metaphor for the sociolegal community, but lack a coherent metaphor for describing sociolegal change. Complexity Theory provides that missing element. Indeed, the example of environmental law—where law

(same); Rodgers, 65 U. Colo. L. Rov. at 25 (cited in note 9) (same); A. Dan Tarlock, *The Nonequilibrium Paradigm in Ecology and the Partial Unraveling of Environmental Law*, 27 Loyola L.A. L. Rev. 1121 (1994) (same); Jonathan B. Wiener, *Law and the New Ecology: Evolution, Categories, and Consequences*, 22 Ecol. L. Q. 325 (1995) (same).

125. Bosselman and Tarlock, 69 Chi. Kent. L. Rev. at 847 (cited in note 124).

126. Wiener, 22 Ecol. L. Q. at 354 (cited in note 124). For a discussion of how the "new ecology" already is sweeping through policy, see J.B. Ruhl, *Biodiversity Conservation and the Ever-Expanding Web of Federal Laws Regulating Non Federal Lands: Time for Something Completely Different?*, 66 U. Colo. L. Rev. 555 (1995).

127. Wiener, 22 Ecol. L. Q. at 355 (cited in note 124).

128. Rodgers, 65 U. Colo. L. Rev. at 56 (cited in note 9).

129. Id. at 57-75. See also William H. Rodgers, *The Lesson of the Owl and the Crows: The Role of Deception in the Evolution of Environmental Statutes*, 4 J. Land Use & Envir. L. 377, 387-88 (1989) (discussing the insights evolutionary biology holds for increasing specialization in law); William H. Rodgers, 1 *Environmental Law: Air & Water* v-vii (West, 1986) (same).

and biology intersect—provides the medium for my study of what Complexity Theory says about the sociolegal community and its evolution.

III. Complexity Theory and the Navigation of Evolutionary Fitness Landscapes in Law and Society—A Case Study of Change in the Environmental Law Ecosystem

Edward O. Wilson emphasizes that "[t]he unpredictability of ecosystems is a consequence of the particularity of the species that compose them. Each species is an entity with a unique evolutionary history and set of genes, and so each species responds to the rest of the community in a special way."[130] Understanding biological evolution, therefore, requires an understanding of the process by which each species responds to the rest of its community, and how the community as a whole evolves as a result of all species responding to each other.

Jurisprudence, I have shown, has long searched for a metaphor to explain legal evolution, and in doing so has traced the developments in evolutionary biology with uncanny parallels. Thus far, however, the evolutionary biology metaphor has failed to provide the full grasp of evolution in the sociolegal system, and so the questions that are suggested by the metaphor remain to be answered: If we liken the sociolegal system to an ecosystem, and laws to species, how will each law, with its unique historical origins and set of legal genes, respond to and be affected by the rest of the sociolegal community, and how will the sociolegal community as a whole evolve as a result of all or any of the laws doing so? Those are precisely the kinds of questions Complexity Theory has endeavored to solve.

A. Complex Adaptive Systems and Their Surprises—Order and Indeterminacy in Environmental Law

Complexity Theory attempts to explain why some systems work and others don't. That is, of course, far too simplified a mission statement for the discipline, but it captures the bare essence of the

130. Wilson, *Diversity of Life* at 182 (cited in note 11). See also Gell-Mann, *The Quark and the Jaguar* at 237 (cited in note 5) ("An ecological community consists . . . of a great many species all evolving models of other species' habits and how to cope with them.").

subject matter under study. More precisely, Complexity Theory studies nonlinear dynamical systems—collective interactions occurring with nonproportionate relationships of change—and the factors leading to their sustainability and demise.

The great puzzle of the past millennium of scientific inquiry has been to explain why physical and biological systems such as ecosystems and weather are sustainable notwithstanding that they appear to be in constant flux. Human nature being what it is, we have attempted through the centuries to understand these dynamical systems and predict their behavior, by reducing them to their irreducible components, so as to convince ourselves that we know their "laws" of motion and change. Isaac Newton provided this service for the fields of optics and mechanics, and is considered by many to be the greatest and most influential scientist who ever lived.[131] As powerful as reductionist-bred scientific inquiry can be, however, it has failed, even in the age of high-speed computers, to crack the code of many dynamical systems. Ecosystems and the weather continue to defy our predictions.

The first great feat of Complexity Theory has been to develop a "science of surprises" to explain why classical reductionism cannot fulfill its mission of producing predictive certainty when faced with such dynamical systems.[132] The properties of snowflakes, snow, and avalanches are useful in summarizing the Complexity Theory doctrine and lexicon on this subject.[133] First, snowflakes form according to fixed rules of physics and chemistry, yet no two look alike. The reason no two look alike is because no two undergo the exact same conditions of formation, so that even though the same rules of formation apply, the results are often very different. This is the *chaos* property—sensitive dependence on conditions in a system based on deter-

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131. See Michael H. Hart, *The 100: A Ranking of the Most Influential Persons in History* 41-46 (1987) (ranking Isaac Newton second of all persons, behind Muhammad and ahead of Jesus Christ).

132. John Casti uses the metaphor of surprise as a means of explaining the subject matter of Complexity Theory. See Casti, *Complexification* at 260-78 (cited in note 5). The surprises result from the fact that reductionism leads to "models of reality departing in noticeably important ways from reality itself." Id. at 268. Hence one objective of Complexity Theory "is to get a handle on the limits of reductionism as a universal problem-solving approach." Id. at 273.

133. This Article sets forth only a brief explanation of how Complexity Theory doctrine can be used to describe the behavior, as opposed to the evolutionary mechanics, of the sociolegal system. A more detailed explanation is provided elsewhere. See Ruhl, 45 Duke L. J. at 875-80 (cited in note 6). The discussion of nonlinear dynamical systems that follows in the text is derived largely from Casti's work in Complexity Theory. See Casti, *Complexification* at 43-115, 212-60 (cited in note 5).

ministic rules produces what appears to be random behavior.[134] Now consider snow, the accumulation of many snowflakes. Whatever we might be able to deduce from a reductionist examination of a snowflake, we could not possibly predict all there is to know about snow. Snow packs, drifts, hardens, flows, and behaves in other ways not readily apparent from the examination of a single snowflake. This is the *emergence* property—the appearance of unforeseen qualities from the self-organizing interaction of large numbers of objects, which cannot be understood by studying any one of the objects.[135] Finally, the fate of some snow is the avalanche. Avalanches give little warning. The moment before an avalanche all is calm, but one last snowflake of mass, or one extra tenth of a degree rise in temperature, and the snow moves quickly to a new resting spot. That last snowflake or incremental rise in temperature was the proverbial straw that broke the camel's back. This is the *catastrophe* effect—a sudden qualitative

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134. Chaos behavior thus has been described as "order masquerading as randomness." Gleick, *Chaos* at 22 (cited in note 28). Classic examples of chaos in physical systems run by deterministic rules are the erratic dripping patterns from water faucets, see Tom Mullin, *Turbulent Times for Fluids*, in Nina Hall, ed., *Exploring Chaos: A Guide to the New Science of Disorder* 59 (Norton, 1993), and the motion of a pinball, see Ian Percival, *Chaos: A Science for the Real World*, in Nina Hall, eds., *Exploring Chaos: A Guide to the New Science of Disorder* 11 (Norton, 1993). 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 interpretation of the rules by mere observation. Thus, chaotic behavior "only looks complicated because you don't know what the rule is." Cohen and Stewart, *Collapse of Chaos* at 197 (cited in note 5).

135. 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 George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models, and Reality* 516 (Addison-Wesley, 1994). Jack Cohen and Ian Stewart explain that the key to understanding why emergence occurs lies in the number of system components and their interaction: with increasing numbers of system components (snowflakes), eventually the sum effect of the interactions between the components becomes a dominating characteristic of the system. *Collapse of Chaos* at 182 (cited in note 5). For example, a system consisting of 10 components has 45 possible one-te-one pair combinations; a system of 1,000 components has almost 5,000,000 sucb combinations; and a system of 1 million components has almost 5 billion such pairings. 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 not 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. Hence, the multitude of genetic pair combinations in sexual reproduction, for example, can lead to biological evolution because "influential hereditary traits are *emergent properties* of species . . . translated upwards into the species-level patterns we call macroevolution." Wilson, *Diversity of Life* at 90 (cited in note 11) (emphasis added). A more observable example in biology is offered by Brian Goodwin's report of Brian Cole's lab studies of ant colonies: when ant population densities were held low, their individual behavior was erratic, but "[a]s the density of the colony was increased by adding more ants to the defined territory, Cole observed a sudden transition to dynamic order [as] patterns of activity and rest over the colony as a whole . . . suddenly changed from chaotic to rhythmic. . . ." Goodwin, *How the Leopard Changed Its Spots* at 66 (cited in note 5).

change in a dynamical system brought about by an arbitrarily small increment of continuous change in a system variable.[136]

It takes little imagination to think of physical, biological, and social systems that experience behavior resembling one or more of these surprise-inducing qualities. Complexity Theory uses the concept of "attractors" to represent the behaviors that flow from forces of order and disorder that might exist within a system, and which thus regulate the surprise generators of chaos, emergence, and catastrophe.[137] Some relationships of change within a system are ordered; they could be charted with a fixed point or repetitive cycle.[138] These "fixed attractors" lend stability and predictability to the system, but they are brittle and can crumble when faced with external forces of disruption.[139] Other relationships of change in the system are more susceptible to forces of chaos, emergence, and catastrophe and are

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136. See Casti, *Complexification* at 43-85 (cited in note 5); Cohen and Stewart, *Collapse of Chaos* at 209-12 (cited in note 5). 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 change in the system parameter, however, can be an arbitrarily large and irreversible, shift in the system position.

137. An attractor is simply a model representation of the behavioral results of a system. See Coveney and Highfield, *Arrow of Time* at 360 (cited in note 4). 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 and Stewart, *Collapse of Chaos* at 206-07 (cited in note 5). The distinction is illustrated by a lake draining a watershed. 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 with geography, and so on, but is not itself a force of attraction for the rainfall. See Kauffman, *At Home in the Universe* at 78 (cited in note 5).

138. Systems such as a ball dropping from a wall are described as stable steady states defined by fixed point attractors, meaning simply that they move towards a fixed point then achieve a stable state when they reach the point. Systems such as a clock, which repeat a cyclic trajectory around a fixed point, are described as stable periodic cycle states defined by limit cycle attracters. See Casti, *Complexification* at 28-33 (cited in note 5). As John Casti says, "these are both pretty simple kinds of behavior from what, in essence, is a very simple system." Id. at 32.

139. John Casti describes simple system characteristics as: (1) predictable behavior; (2) few interactions and feedback/feedforward loops; (3) centralized decisionmaking; and (4) decomposable. Id. at 271-72. Thus,

> [t]here are no surprises in simple systems; simple systems give rise to behaviors that are easy te deduce if we know the inputs . . . acting upon the system and the environment. If we drop a stone, it falls; if we stretch a spring and let it go, it oscillates in a fixed pattern; if we put money in a fixed-interest bank account, it grows to a predictable sum in accordance with an easily understood and computable rule.

Id. at 271. On the other hand, if we bat the stone before it hits the ground, or stretch the spring twice as far, or change the interest rate in a bank account, the system embarks on a new path with no hope of returning to its original path. Simple systems have difficulty adapting, because they consist of few variables, and thus few interactions. By contrast, the feedback loops made possible by complex system interactions "enable the system to restructure, or at least modify, the interaction pattern among its variables, thereby opening up the possibility for a wider range of behaviors." Id. The absence of such forces of adaptation in simple systems "threatens their ability to absorb shocks." Id. at 272.

thus subject to arbitrarily large fluctuations in a response to arbitrarily small perturbations; any attempt to map them would look like a ball of yarn or bowl of spaghetti.[140] These "strange attractors" lend flexibility and resilience to the system, but they are inherently unpredictable given their susceptibility to surprise behavior.[141] Examples of complex systems and orgainizations exhibiting a variety of different attractors abound in nature and human society, including proteins,[142] immune systems,[143] brain circuits,[144] economies,[145] cultures,[146] and ecosystems.[147]

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140. See id. at 29 (cited in note 5). The presence of chaos, emergence, and catastrophe in the system means that small perturbations can result in large system changes, thus tending to "amplify tiny differences hidden far along the decimal tail, well below any error threshold you may care to set." Cohen and Stewart, *Collapse of Chaos* at 191 (cited in note 5). Classic examples of strange attractor systems include weather and predator-prey food webs. See id. at 184-93; Casti, *Complexification* at 93-98 (cited in note 5); Coveney and Highfield, *Frontiers of Complexity* at 243-49 (cited in note 5).

141. To illustrate the unpredictability of strange attractor systems flowing from their sensitivity to environmental conditions, consider what would happen to two raisins dropped close together on a hread dough being mixed in a bread making machine. Although the bread kneading procedure follows deterministic rules of motion, it would be very difficult to predict where the two raisins would be relative to one another after, say, five minutes of kneading. Moreover, if we had a map of the raisins' motions, it would be very difficult for someone unaware of the machine used for the exercise to divine the rules of motion that produced the map. See Casti, *Complexification* at 91-92 (cited in note 5) (using the example of a taffy pulling machine). Hence, "strange attractors show incredible sensitivity to the initial conditions: unless the system is started out with initial conditions of hterally infinite precision, it will end up being completely unpredictable." Coveney and Highfield, *Arrow of Time* at 206 (cited in note 4).

142. See Hans Frauenfelder, *Proteins as Adaptive Complex Systems*, in George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models, and Reality* 179 (Addison-Wesley, 1994).

143. See Alan S. Perelson, *Two Theoretical Problems in Immunology: AIDS and Epitopes*, in George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models, and Reality* 185 (Addison-Wesley, 1994).

144. See Charles F. Stevens, *Complexity of Brain Circuits*, in George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models, and Reality* 245 (Addison-Wesley, 1994).

145. See W. Brian Arthur, *On the Evolution of Complexity*, in George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models, and Reality* 65 (Addison-Wesley, 1994). For the stery of Professor Arthur's struggle to gain recognition of his ideas among classical economists, see Waldrop, *Complexity: The Emerging Science* (cited in note 28). Today Professor Arthur's revolutionary economic concepts on "increasing returns" and the nature of global economies are widely accepted. See, for example, Phillip W. Anderson, Kenneth J. Arrow, and David Pines, eds., *The Economy as an Evolving Complex System* (Wesley, 1988); Holman W. Jenkins, Jr., *Apple Obituaries May Be Premature*, Wall St. J. A15 (Feb. 6, 1996); *Chaos Under a Cloud*, The Economist 69 (Jan. 13, 1996); Amanda Bennett, *Sugarscape Model Shows Flaws in Textbook Economics*, Wall St. J. B1 (Nov. 21, 1994).

146. See Marcus W. Feldman, Luigi L. Cavalli-Sforza, and Lev A. Zhivotovsky, *On the Complexity of Cultural Transmission and Evolution*, in George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models, and Reality* 47 (Addison-Wesley, 1994).

147. See James H. Brown, *Complex Ecological Systems*, in George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models, and Reality* 419 (Addison-Wesley, 1994).

Indeed, the prevalence of strange attractor systems in nature suggests something which classical science, because of its reductionist premises, could not accept, but which Complexity Theory fully embraces: chaos, emergence, and catastrophe are inevitable components of sustainable dynamical systems.[148] To be sure, a system defined by nothing but these qualities of randomness would spiral out of control. But rigid, immovable, perfectly ordered structure would allow no adaptation at all. Somewhere between total order and total chaos, therefore, is a regime of sustainable system behavior. Complexity Theory aptly names that regime the region of complexity, and a key proposition of Complexity Theory is that at least some chaos, emergence, and catastrophe must be experienced in the system in order to keep the system in that region.[149] If contained and controlled by some counter-measure of order and repetition, the right doses of chaos, emergence, and catastrophe become the forces of environmental adaptation within a dynamical system.[150] When a "community" of fixed and strange attractors is assembled in the proper balance, therefore, the forces of order and disorder combine to allow the system to operate at optimal adaptability, that is, to operate as what is known as a Complex Adaptive System.[151]

As has been the case with its application to economics, see note 145, classical ecology has not embraced Complexity Theory without some struggle. See Dennis Farney, *Natural Questions*, Wall St. J. A1 (July 11, 1994); Janet Stites, *Ecological Complexity Takes Root: Profile of Jim Brown*, Bull. of the Santa Fe Inst. 10 (Spring 1995).

148. The whole point of describing and studying chaos, emergence, and catastrophe is to explain why it is that dynamical systems are unpredictable. The reductionist foundations of Classical Science "focused on a description in terms of deterministic, time-reversible laws" in order to fulfill the goal of perfect predictability. Coveney and Highfield, *Arrow of Time* at 16 (cited in note 4). By showing that deterministic rules can lead to random behavior, Complexity Theory "demolishes the centuries-old myth of predictability and [time-symmetric] determinism." Id. at 37.

149. See Kauffman, *Origins of Order* at 31 (cited in note 5).

150. Adaptation is associated with the feedback and feedforward loops made possible by multiple paths of interactions between system components, see note 139, and thus "is an emergent property which spontaneously arises through the interaction of simple components." Gleick, *Chaos* at 339 (cited in note 28). Adaptation allows the system to "restructure, or at least modify, the interaction pattern." Casti, *Complexification* at 271 (cited in note 5). Similarly, evolutionary biologists define adaptation as "the evolutionary modification of a character under selection for efficient or advantageous (fitness-enhancing) functioning in a context or set of contexts." Mary Jane West-Eberhard, *Adaptation: Current Usages*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 13 (Harvard U., 1992).

151. Complexity Theory reveals that there is a "completely decisive property of complexity: that there exists a critical size [of a system] below which the process of synthesis [between components] is degenerative, but above which the phenomenon of synthesis . . . can be explosive." Steven Levy, *Artificial Life: A Report from the Frontier Where Computer Meets Biology* 100 (1992). 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 able to respond to changes in their environment." Kauffman, *Origins of Order* at 29 (cited in note 5). See also

I have used ecosystems and the weather as examples of Complex Adaptive Systems for two reasons. First, it is almost intuitively obvious that they contain forces both of disorder and order.[152] Second, they are components of the environment, and humans, after centuries of perfecting ways to exploit the environment, now are very much in the business of trying to protect the environment from the destructive forces of human activity. Although the history of environmental protection regulation is replete with narrowly focused "command-and-control" legislation,[153] more recent policies have relied on new regulatory paradigms centered around "market approaches" and fluid notions of "biodiversity conservation" and "sustainable development."[154] These new models of regulation explicitly recognize the breadth, flux, and complexity of the subject matter. Recognizing the shift in ecological understanding and the desire to shape legal structures accordingly, a number of commentators have raised the important question of how such laws should approach a regulatory target that is inherently chaotic.[155] I raise a more fundamental jurispruden-

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Goodwin, *How the Leopard Changed Its Spots* at 183 (cited in note 5) ("In this partially ordered regime the system is dynamic and changeable, neither chaotic nor 'frozen' but richly patterned with activity that extends across the whole space in which the [system] operates."). Complexity Theory refers to these systoms as Complex Adaptive Systems or CAS. See Holland, *Hidden Order* at 4 (cited in noto 5). It is the discovery and explanation of the similar patterns of complex adaptive activities that surface in systems differing greatly in composition and components that is the central focus of Complexity Theory. See Goodwin, *How the Leopard Changed Its Spots* at 77-78 (cited in note 5).

152. Edward O. Wilson describes this reality for ecological sciences:

> Before us now is the overwhelmingly important problem of how biodiversity is assembled in the creation of ecosystems. We can address it by recognizing two extreme possibilities. One is that a community of organisms . . . is in total disorder . . . . The second possibility is perfect order . . . . Ecologists dismiss the possibility of either extreme. They envision an intermediate form of community organization, something like this: whether a particular species occurs in a given suitable habitat is largely due to chance, but for most organisms the chance is strongly affected—the dice are loaded—by the identity of the species already present.

Wilson, *Diversity of Life* at 164 (cited in noto 11). It is no exaggeration to say that "[t]he complexity of ecological systems is rivaled only by such systems as the brain and the global economy." Brown, *Complex Ecological Systems*, in Cowan, Pines, and Meltzer, eds., *Complexity* at 419 (cited in note 147). The same balance of order and disorder in complex, adaptive applications is found at the microbiologic level as well. For example, researchers attempting to synthesize spider dragline silk, which is lighter than cotton but ounce for ounce stronger than steel, have found that "dragline silk's strength and elasticity derive from a blend of ordered and disordered components. The silk's amorphous polymer, resembling a 'tangle of cooked spaghetti,' makes the fiber elastic, while . . . two types of protein give it toughness." Richard Lipkin, *Artificial Spider Silk*, 149 Sci. News 152, 152 (March 9, 1996).

153. See text accompanying notes 206-12.

154. See text accompanying notes 223-24.

155. See text accompanying notes 124-29.

tial question, one that I believe must be raised if Complexity Theory is on the mark in its description of surprise behavior in dynamical systems: Can any system of laws designed to protect the environment (or accomplish any other objective) avoid encountering the qualities of chaos, emergence, and catastrophe *in itself*?

I posit that the answer to that question is an emphatic negative, at least not if the system of laws is expected to exist for very long, and that it is precisely because we have approached the regulation of the environment (and almost everything else) in the reductionist manner of Classical Science that we have encountered more surprises than the legal system can bear in the long run. It is more difficult than we realize to construct a coherent macro-legal system by applying a micro-legal focus.[156] For example, when we set our sights on controlling water pollution, we often generate more air or land pollution (and vice versa);[157] when we set out to clean up contaminated properties, we condemn some properties to protracted toxic oblivion;[158] and when we attempt to stem the tide of land

156. This follows from the presence of emergent properties in complex systems. "The ascending levels of hierarchy of complexity demonstrate emergent properties at each level which appear to be nonpredictable from the properties of the component parts. Thus the commonly held expectation that we should be able to derive macroeconomics from microeconomics is probably unrealistic." George A. Cowan, *Conference Opening Remarks*, in George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models, and Reality* 4 (Addison-Wesley, 1994).

157. For example, in weighing the need for land disposal regulation, Congress observed that water and air pollution control laws had led to "the federal government spending billions of dollars to remove pollutants from the air and water, only to dispose of such pollutants on the land in an environmentally unsound manner." Resource Conservation and Recovery Act of 1976, H.R. Rep. 94-1491, 94th Cong., 2d Sess. 4 (1976). More broadly, "[t]he history of environmental law is filled with examples of air pollution being 'solved' by dumping the residue into the water, water pollution 'eliminated' by diverting the residues to the land, and land pollution 'cleaned up' by incineration or underground injection." William H. Redgers, *Environmental Law* § 1.4 at 59 (West, 2d ed. 1994). In its 1978 study of the issue, the United States General Accounting Office concluded that "[p]ollution control produces pollutants which must be disposed of in the air, in water, or on land. Unfortunately, environmental protection laws and programs have such single rigid control requirements that pollution control tradeoffs are not usually considered." U.S. G.A.O., Pub. No. GAO/RCED-78-148B, 16 Air and Water Pollution Issues Facing the Nation 89 (1978). See generally Lakshman Guruswamy, *The Case for Integrated Pollution Control*, 54 L. & Contemp. Probs. 41, 42 (Autumn 1991).

158. The Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA"), 42 U.S.C. §§ 9601 et seq. (1994 ed.), 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 (BNA Books, 1991) (discussing the imposition of strict liability under CERCLA); Mehron Azarmehr, *Status of Joint and Several Liability Under CERCLA After* Bell Petroleum, 24 Envir. L. Rptr. 10250 (1994). The Environmental Protection Agency's regulations implementing CERCLA, see 40 C.F.R. pt. 300, involve a complicated and lengthy process of sito investigation, remedy selection, and negotiation between the government and responsible parties. See Light, *CERCLA Law and Procedure* §§ 3.2.5 to 3.3.6 (cited in this note). The average cost of completing an investigation and remedy selection at a CERCLA site is $1.3

development in sensitive ecosystems, we actually promote more development.[159]

These and other backfirings of blunt command-and-control regulatory approaches bear uncanny resemblance to the forces of chaos, emergence, and catastrophe at play in physical dynamical systems, thus strengthening the analogical power of Complexity Theory in sociolegal application.[160] I believe these backfirings occur in excess

million, and the average cost of implementing the remedy is around $30 million. Jerry L. Anderson, *The Hazardous Waste Land*, 13 Va. Envir. L. J. 1, 10-11 (1993). 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 and Sy Gruza, *The Redevelopment of Brownsites*, Nat. Resources & Envir. 57 (Spring 1995). See generally E. Lynn Grayson and Stephen A. K. Palmer, *The Brownfields Phenomenon: An Analysis of Environmental, Economic, and Community Concerns*, 25 Envir. L. Rptr. 10337 (1995); Julia A. Solo, *Urban Decay and the Role of Superfund: Legal Barriers to Redevelopment and Prospects for Change*, 43 Buff. L. Rev. 285 (1995) (asserting that CERCLA is detrimental to the economy); R. Michael Sweeny, *Brownfields Restoration and Voluntary Cleanup Legislation*, 2 Envir. L. 101 (1995). The Environmental Protection Agency recently issued a "Brownfields initiative" to combat the problem by reducing uncertainty in liability exposure at appropriate sites, see 60 Fed. Reg. 9684 (1995), and has identified pilot projects for examining how to address the issue. See *11 New "Brownfield" Pilot Projects Announccd*, 26 Envir. Rptr. (BNA) 1884 (1996). See generally *President Calls for "Brownfield" Incentives, Stronger Laws on Communities' Right to Know*, 26 Envir. Rptr. (BNA) 1796 (1996); *Clinton Unveils Tax Incentive Plan to Restore 30,000 "Brownfields" Sites*, 26 Envir. Rptr. (BNA) 2140 (1996). Congress has sought te address the issue as well through measures designed to amelioratc tbe risks faced by redevelopment projects under CERCLA. See, for example, H.R. 2178, 104th Cong., 1st Sess. (1995). See generally *Amendment to Pending House Superfund Bill Would Set Grants, Loans for "Brownfields"*, 26 Envir. Rptr. (BNA) 1882 (1996).

159. Professor David Dana describes the "race to develop" that occurs when environmental preservation regulations impose nonretroactive land development restrictions witbout hope of compensation for the landowner. Landowners respond by seeking to develop before additional restrictions are imposed, which in turn prompts more regulation, which in turn prompts more development, and so on. The system-wide effect of not compensating landowners for the effects of environmental regulation, therefore, is to risk promoting the very behavior we intend to restrict, perhaps thereby imposing social costs in the form of diminished resources that are far in excess of the costs of providing landowner compensation. See David A. Dana, *Natural Preservation and the Race to Develop*, 143 U. Pa. L. Rev. 655 (1995) (discussing the social costs associated with accelerated development).

160. See Ruhl, 45 Duke L. J. at 880-86 (cited in note 6). The presence of unanticipated emergent behavior in environmental law has not gone unnoticed. For example, Professor 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." Rodgers, *Environmental Law* § 1.3 at 43 (cited in note 157). Professor Rodgers provides many otber examples of surprise behavior in the sociolegal community, though using his lexicon of "sleepers" and "maladaptations" in law. See Rodgers, 65 U. Colo. L. Rov. at 56-74 (cited in note 9). See also Cass R. Sunstein, *Congress, Constitutional Moments, and the Cost-Benefit State*, 48 Stan. L. Rev. 247, 261-62 (1996) (providing examples of "unintended consequences" that result when regulations are based on "partial perspectives that emerge from close attontion to mere pieces of complex problems"). To be sure, sometimes the unexpected result is beneficial in the sense of promoting a desirable goal

under the traditional environmental law culture because we are committed to achieving predictive Nirvana[161] through the use of reductionist tools of regulation.[162] The regulatory apparatus is premised on the belief that it can isolate a problem of environmental degradation, say water pollution, make it disappear by imposing coercive regulatory decrees, and depend on all else remaining constant. Even putting aside the probability that the environment

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of environmental protection. The point is, however, that so long as the results are unanticipated and unpredictable, we cannot be sure the result will be beneficial and thus cannot weed out the adverse results ahead of time.

161. For example, William Futrell has identified predictivist goals as the reason for our ironic cascade ever deeper into command-and-control regulation in environmental law:

> In each session of Congress, the environmental laws are criticized for excessive reliance on command-and-control regulation. With all the criticism, why does the United States hesitate from creating an integrated environmental law—one that uses appropriate instruments in the appropriate circumstances? The major players in environmental administration, including affected industries, tend to prefer command-and-control regulation over the alternatives [such as tert law] because it is a known evil.

J. William Futrell, *The Transition to Sustainable Development Law* 14 (Environmental Law Institute, 1994). It goes too far, of course, to say that the entire regulated community favors this approach. Newspapers and journals are filled with "horror stery" complaints by industry about the irrationality of many of the outcomes of this byper-regulatory condition. See, for example, Norman J. Wiener, Clifford B. Olsen, and Jerry B. Hodson, *Clear the Air: A Case History of EPA Overkill*, 25 Envir. L. 1327 (1995) (relaying story of massive penalties sought for apparently harmless, good faith actions that violated regulations); *Review & Outlook: The Emotional Species Act*, Wall St. J. A22 (Nov. 2, 1993) (tiny snail shuts down Idaho farming); Ike C. Sugg, *California Fires—Losing Houses, Saving Rats*, Wall St. J. A20 (Nov. 10, 1993) (preservation of small rat causes fires in California); Leslie Spencer, *No Dream House for Mr. Burris*, Forbes Magazine 78 (July 18, 1994) (small songbird shuts down home building in central Texas); *A Fairy Shrimp Tale*, Wall St. J. A14 (Oct. 21, 1994) (tiny shrimp brings California irrigation to halt).

162. Reductionism permeates our legal system down to its structural approach of dividing the administration function into many discrete agencies with specific missions. In the environmental law field, for example, there are over fifteen congressional committees, over fifty executive branch agencies, and at least eight independent agencies, each with some jurisdiction over a defined set of environmental issues. National Wildlife Federation, *1996 Conservation Directory* (41st ed. 1996). As Professor Jerry Anderson has observed:

> [E]nvironmental 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, *The Transition to Sustainable Development Law* at 17 (cited in note 161) ("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."). Recently, serious proposals te overhaul federal environmental law through a unified, comprehensive statute bave begun to reemerge. See *Panelists Debate Merits of Unified Statute in Reforming Environmental Management System*, 27 Envir. Rptr. (BNA) 228 (1996); *Recommendations on Unified Environmental Law Expected Before End of 1996, EPA Official Says*, 26 Envir. Rptr. (BNA) 1125 (1995) (discussing progress of an EPA task force on the tepic); Rebert D. Sussman, *An "Integrating" Statute*, Envir. Forum 16 (Mar./Apr. 1996) (former EPA official outlines the likely components of a unified statute).

itself, as the paradigm of nonlinear dynamical systems, is usually not amenable to such overt manipulation, the misguided basis of that approach is that the entire sociolegal system can be manipulated without concern that the "all else remains equal" premise will fail.

The reductionist environmental law machine, stuck on its fixed attractor of regulation, became a prolific source of regulation that often exhibits the indeterminancy characteristic of chaotic behavior.[163] To be sure, it also has succeeded in significantly reducing air, water, and land pollution, as well as protecting many sensitive species.[164] Most of those accomplishments, however, reflect the fact that the targets were easy and the marginal benefits of regulation were large, whereas now the returns on investment are fast diminishing[165] and

163. See Richard J. Lazarus, *Meeting the Demands of Integration in the Evolution of Environmental Law: Reforming Environmental Criminal Law*, 83 Geo. L. J. 2407, 2431 (1995) (indeterminacy is "a description that fits many of environmental law's key provisions, especially the jurisdictional terms of art that determine the scope of the laws's applicability"). The statistics in this regard are astounding. 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." 26 Rutgers L. J. at 413 (cited in note 162). He reports further that "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 Redgers 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. Redgers, Jr., *Environmental Law Trivia Test No. 2*, 22 B.C. Envir. Affairs L. Rev. 807, 812, 816 (1995). The paperwork burden estimated to be imposed on the regulated community by the environmental law maze is 55 million hours annually at a cost of nearly $3 billion each year. *23 Percent Increase in Industry Paperwork Reported in Chemical Manufacturers' Study*, 26 Envir. Rptr. (BNA) 2339 (1996). The burgeoning administrative state is by no means limited to environmental law. For example, Professor Epstoin 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 (Harvard U., 1995). And Professor 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 completo Shakespeare." Bernard Schwartz, *Administrative Law* 168 (Little, Brown, 3d ed. 1991).

164. For example, companies subject to the toxic release reporting provisions of the Emergency Planning and Community Right-to-Know Act, 42 U.S.C. § 11023 (1994 ed.), reported the total release of 10.4 billion pounds of specified toxic chemicals into the environment in 1987—including 3.9 billion to landfills, 3.3 billion to other treatment and disposal facilities, 2.7 billion into the ambient air, and 550 million to surface waters. See Robert V. Percival, *Environmental Regulation: Law Science and Policy* 464 (2d ed. 1996). For 1993, the total reported had fallen to 2.8 billion pounds—including 1.7 billion to the air, 289 million disposed on land, and 271 million into surface waters. Id. at 465.

165. There is a growing bedy of research indicating that the costs of regulating toxins in the environment and occupational settings has outstripped the benefits to human and environmental welfare by several orders of magnitude in many cases, and that the marginal benefits of additional regulation in such cases is often infinitesimal compared to the marginal costs. See,

the problems growing more complex.[166] Thus, we must achieve a far broader and much deeper understanding of how laws affect and are affected by their subject matter in order to manage environmental protection and other complex social issues through legal mechanisms. In short, although we appear to have made strides in the appreciation of the flux and complexity of the environment, we seem to have little comprehension of the flux and complexity of law itself. Without a better grasp of those qualities, we cannot be sure of landing and remaining in the region of complexity where a Complex Adaptive System must stay poised.

B. Schemata, Conflicting Constraints, and the Peaks and Valleys of Fitness Landscapes—The Evolving Fitness of Common Law in Environmental Policy

To say our legal system is tumbling out of the region of complexity, if we have not already fallen out altogether, leads to the ques-

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for example, Center for Risk Analysis, *Reform of Risk Regulation: Achieving More Protection at Less Cost* (Harvard School of Public Healtb, Mar. 1995); John D. Graham, *Reform of Risk Regulation: Achieving More Protection at Less Cost*, 1 Hum. and Ecological Risk Assessment 183 (1995); John D. Graham, National Center for Policy Analysis, *Comparing Opportunities to Reduce Health Risks: Toxic Control, Medicine and Injury Prevention*, Policy Rep. No. 192 (1995). These studies have opened a vigorous policy debate with many contrasting views represented over the role risk-benefit analysis sbould play in environmental and public health law and policy. See Stephen Breyer, *Breaking the Vicious Circle: Toward Effective Risk Regulation* (Harvard U., 1993); John D. Graham and Jonathan Baert Wiener, eds., *Risk v. Risk: Tradeoffs in Protecting Health and the Environment* (1995); Kenneth J. Arrow, *Is There a Role for Benefit-Cost Analysis in Environmental, Health, and Safety Regulation?*, 272 Sci. 221 (1996), Symposium, *Risk Assessment in the Federal Government*, 3 N.Y.U. Envir. L. J. 251 (1995); Sunstein, 48 Stan. L. Rev. at 257-60 (cited in note 160); Symposium, *Risk Symposium*, 63 U. Cin. L. Rev. 1533 (1995).

166. 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." Percival, *Environmental Regulation* at 893 (cited in note 164). 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 mucb thornier administrative and political challenges. See id. at 766-68. Similarly, nonpoint sources of water pollution, which include diffuse runoff from streets, farms, mines, and other areas, "are the most important sources of tbe nation's remaining water quality problems." Id. at 880. Estimates are tbat such nonpoint pollution accounts 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 969-70, 993-95. See generally Environmental Protection Agency, *National Water Quality Inventory: 1994 Report to Congress* (1995); David Zaring, *Federal Legislative Solutions to Agricultural Nonpoint Source Pollution*, 26 Envir. L. Rptr. 10128 (1996); John G. Mitchell, *Our Polluted Runoff: Widespread as Rain and Deadly as Poison*, National Geographic 106 (Feb. 1996).

tion of how we head back in that direction. That, of course, is a question about the mechanics of evolution of the sociolegal system.

Complexity Theory uses the metaphor of a topographic landscape to describe the mechanics of dynamical system evolution and the resulting fitness of a species relative to its environment.[167] Most biological definitions of species fitness involve some measure of a species' propensity to contribute offspring.[168] The whole point of evolutionary theory is determining whether such fitness changes with variations in the behavior and structure of the organism, and if so, in what direction and to what degree.

Two factors suggest that a species' fitness level will change in both direction and amplitude with behavioral and structural changes in the organism. First, each organism must construct a schema of its environment that includes a description of the other species in the organism's environment and how they are likely to react to different forms of the organism's behavior.[169] A species' fitness may be fundamentally altered if its schema is inaccurate and remains unchanged, or if changes to its schema are misguided. Second, the species' biological structure generally is not entirely discretionary, and the benefits of changes to one trait may be limited by conflicting constraints of other traits.[170] In considering how it should be structured, therefore,

167. The metaphor of a topographic landscape to describe relative fitness levels has been used in evolutionary biology for some time. See noto 27. Complexity Theory uses the fitness landscape as a model not only for representing biological fitness levels, but also for explaining the evolutionary and coevolutionary processes within all physical, biological, and social nonlinear dynamical systems. For more complete descriptions of fitness landscape models discussed in the text that follows, see Kauffman, *At Home in the Universe* (cited in note 5); Gell-Mann, *The Quark and the Jaguar* (cited in note 5).

168. See Beatty, *Fitness: Theoretical Contexts*, in Keller and Lloyd, eds., *Keywords* at 116-19 (cited in note 18). Alternative postulations are that fitness depends on the species' actual success in producing offspring, id. at 115-16, or the species' expectod time to extinction, id. at 119.

169. Gell-Mann, *The Quark and the Jaguar* at 237 (cited in note 5). Murray Gell-Mann elaborates that "[a]n ecological community consists, then, of a great many species all evolving models of other species' habits and how to cope with them." Id. Gell-Mann posits that an organism "gathers information about its surroundings and about itself and its own behavior," then "identifies perceived regularities of certain kinds in the experience," and then "the perceived regularities are compressed into a schema .... Each schema provides, in its own way, some combination of description, prediction, and (where behavior is concerned) prescriptions for action." Murray Gell-Mann, *Complex Adaptive Systems*, in George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models, and Reality* 17, 18 (Addison-Wesley, 1994). The use of the term schema dates back to Plato, who used it to report a discussion between Socrates and Galaucon concerning the nature of appearance and reality. See Ben Martin, *The Schema*, in George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models, and Reality* 263, 264 (Addison-Wesley, 1994).

170. As Professor Kauffman explains:

the organism has to evaluate the effects of changing one trait based on the overall effects on fitness taking all other traits into consideration.[171] Thus we can envision a landscape of varying fitness level potentials for the organism in a given environment, with the peaks, valleys, and planes of the landscape representing the fitness potential of different combinations of behavioral schemata and biological organism structures. Indeed, we can construct such a landscape for any system of connected interactions, or couplings, and it is the presence of such conflicting constraints that makes the "coupled" landscape rugged and multipeaked. When many constraints are in conflict, the landscape exhibits a large number of rather modest peaks rather than an obvious superb solution.[172]

Of course, no organism has a God's eye view of its entire fitness landscape.[173] Species do not have menus of behavioral schemata and biological structures from which to choose at will, and certainly

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> 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 stato of one trait may depend in very complex ways on the states of many other traits.

Kauffman, *At Home in the Universe* at 170 (cited in note 5).

171. Evolutionary biologists call the phenomenon, which occurs at the genetic level since that is where traits are determined, "genes epistasis or epistatic coupling, meaning that genes at other places on the chromosomes affect the fitness contribution of a gene at a given place.... We can think of this phenomenon of genes affecting the fitness contributions of other genes as a network of epistatic interactions." Id. at 170.

172. The study of interconnected systems is a major research focus of Complexity Theory. The general model is of so-called *NK* systems, where *N* is the number of system components and *K* is the degree of coupling—the number of inputs from other components that each individual component needs in order to know what to do next in the system. By constructing computer models of *NK* systems, Complexity Theory researchers can study the effects of altering *N* and *K* in different combinations. The conclusion, consistent with the empirical evidence from evolutionary biology, is that "increasing *K* increases conflicting constraints" and thus "as *K* increases, the heights of [fitness] peaks decrease, their numbers increase, and evolving over the landscape becomes more difficult." Id. at 173. As coupling increases, in other words, life becomes more chaotic.

173. See id. at 154. It is this point that many treatments of evolution of law miss. For example, in his second study of evolution of law, Professor Sinclair notes that while biological selection is based only on locally available information, "[l]egal decision makers can, if they choose, look beyond the local context to geographically or politically distant, hypothetical, or any other source of information they deem relevant. These differences are of such consequence as to draw into question the usefulness of any analogy between legal and biological evolution." M.B.W. Sinclair, *Evolution In Law: Second Thoughts*, 71 U. Detroit Mercy L. Rev. 31, 54 (1993). Sinclair's point, which is made in the context of an overall analysis containing many useful insights on evolution of law, overstates the degree to which legal policy makers can actually know how their decisions will turn out. Hence, while the choice of schemata may be more varied for law, and the decisions about legal structure are more deliberate than could be possible in the biological evolution of, say, guppies, we are nonetheless limited in setting our course of sociolegal evolution in much the same way as are species in their biological evolution.

do not know ahead of time what fitness level is associated with particular combinations. By contrast, human beings, in making laws, do have choices available to them. There are for example, menus of different targets of regulation, bases of regulation, and standards of regulation, such that we can construct a law around a certain preferred "organism" structure.[174] We also develop a statement of findings and purposes for many laws, thus expressing our schema for the social behavior we intend to induce or repel by enacting the law.[175]

Fitness of laws, just as for species, is measured in terms of how successful the law is in meeting its goals.[176] The goals of laws are those expressed as the motivation for legislative enactment or judicial decision—what we might call the law's policy.[177] A law is fit if it achieves its policy.

Evaluating fitness in that sense does not permit normative evaluations for laws any more than it does for species. Biologists do not ask whether a species has been "good" for its ecosystem when evaluating the single species' fitness. Similarly, questions of morality and overall public policy have no place in measuring the fitness of a particular law, although the policies underlying laws certainly are normatively designed. Indeed, it is crucial that we disaggregate questions of fitness from questions of desirability in law, for it is important to know as an independent matter whether a law is or is not successful in fulfilling its goals on a sustainable basis. The point, of course, is that the fitness of a normatively undesirable law—a law the policy for which no longer is (or perhaps never was) one we wish to

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174. See Percival, *Environmental Regulation* at 148-58 (cited in note 164) (discussing the menus of regulatery targets, hases of controls, and types of regulation used in environmental laws); Office of Technology Assessment, Congress of the United States, Environmental Policy Tools (1995) (describing the "environmental policy toolbox").

175. For example, most environmental regulation statutes contain statements of findings, goals, purposes, and policies that help guide implementation of the law's structural provisions. See, for example, Endangered Species Act, 16 U.S.C. § 1531 (1994 ed.); Federal Water Pollution Control Act, 33 U.S.C. § 1251 (1994 ed.); National Environmental Policy Act, 42 U.S.C. § 4321-22 (1994 ed.); Clean Air Act, 42 U.S.C. § 7401 (1994 ed.). Courts often use those schemata in deciding how the law is supposed to behave in the sociolegal system. See, for example, *Tennessee Valley Authority v. Hill*, 437 U.S. 153, 179-80 (1978) (using the stated findings and purposes of the Endangered Species Act as the starting point for defining the scope and effect of the regulatory structure).

176. For example, Professor Richard Lazarus posits that the "evolutionary pattern" of environmental law is one of a "process of transformation in response te the public's desire to have a legal system that better reflects the public's environmental protection goals." Lazarus, 83 Geo. L. J. at 2419 (cited in note 163).

177. See Beckstrom, *Evolutionary Jurisprudence* at 28 (cited in noto 14) ("Goals emerge, in the American legal system, from the process called policy-making.").

pursue in the sociolegal system—may lead us to consider the need for modifying or repealing the law more immediately and more thoroughly than if the law were relatively unfit.

The problem is that when designing a law or legal principle seldom can we know how fit it will be in terms of meeting its objectives and surviving in the sociolegal community. Indeed, in this respect it is apparent that our choices of schemata and structures of laws often are limited by significant, and often unanticipated, conflicting constraints posed by other sociolegal realities.[178] We cannot import the successful "gene" of one law—the structural approach that has led to its fitness as a law—into other laws and expect necessarily to duplicate the experience of the former. The different combinations of schemata and structures of laws, therefore, produce different fitness levels, which can be envisioned as a fitness landscape of law. But we do not have a God's eye view of that fitness landscape of law. Despite the promises of policy consultants, we cannot feed different combinations of regulatory goals, targets, bases of control, and types of regulation into a computer model to test their relative fitness levels, at least not with any degree of predictive reliability. Hence we find law in the same boat as species—having to grope around on the fitness landscape searching for higher peaks and trying to avoid the valleys.

178. A classic statement of such a conflicting constraint pitting one legal structure against another is the so-called "regulatory takings" doctrine under the Fifth Amendment's requirement that private property not be taken for public use without just compensation—that is, "if [governmental] regulation [of privato property] goes too far it will be recognized as a taking." *Pennsylvania Coal Co. v. Mahon*, 260 U.S. 393, 415 (1922). Constraints on legal structure choices might also be posed by social and political forces. For example, I believe most observers would agree that the enforcement of 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 Ruhl, 66 U. Colo. L. Rev. at 582-601, 632-42 (cited in note 126) (discussing the property rights motivated backlash against the Endangered Species Act); J.B. Ruhl, *Section 7(a)(1) of the "New" Endangered Species Act: Rediscovering and Redefining the Untapped Power of Federal Agencies' Duty to Conserve Species*, 25 Envir. L. 1107, 1137-43 (1995) (same). Even though such regulation 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. Envir. L. J. 439 (1993), today's political reality is that it is highly unlikely that any law relying on increased and more coercive command-and-control forms of species protection on privato lands would be a "fittor" 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 such regulation is perceived as having "gone too far" with respect to private property rights. See David Coursen, *Property Rights Legislation: A Survey of Federal and State Assessment and Compensation Measures*, 26 Envir. L. Rptr. 10239 (1996).

Complexity Theory explores how an organism—used here broadly to mean laws, species, or components of any system—moves around on its fitness landscape. One mode of travel across the landscape of biological evolution is the gradual walk—uphill, downhill, or across planes—brought about as natural selection sifts through species mutations.[179] The neo-Darwinian model, particularly the normative model prevalent in Social Darwinism, was of a gradual slope that allows only uphill travel.[180] On a fitness landscape, however, such an uphill march comes to a halt at the top of whichever peak on which the species finds itself, and there may be higher peaks in the landscape which are then missed opportunities.[181] The only place to go from the top of the peak, when limited to walking, is downhill. Indeed, the historical record of randomized genetic drift in species selection suggests that two-way traffic is a reality of evolution.[182]

Hence, the fitness landscape model of Complexity Theory, by unifying the uphill march of natural selection with the downhill error catastrophe made possible by species selection, begins to adjust the neo-Darwinian theoretical features to the reality of evolution. The real point, however, is that whether the species is on the way up or down a peak, marching across a fitness landscape is a pretty inefficient way of searching for higher fitness peaks.[183] It may be a deadly

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179. 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, *At Home in the Universe* at 166 (cited in note 5).

180. See id. at 151-52, 167-68. See also text accompanying notes 69-76.

181. Professor 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 maximum. Adaptive walks stop on such local peaks .... [T]hey are trapped, with no way to get to the distant high summits.

At Home in the Universe at 167 (cited in note 5). The more rugged the local landscape, the more likely the species will be trapped on a lower peak. Id.

182. Downhill travel is the result of mutation continuing at a rate "so high that it causes the population to 'diffuse' away from the peak faster than selective differences between less fit and more fit variants can return the population to the peak." Id. at 184. This phenomenon, a result of rapid genetic drift, is known as an "error catastrophe," in that "the adapting population cannot assemble useful genetic variants inte a working whole." Id. Such a melting of the species' fitness level is particularly likely on smoother landscapes, where the distinctions in fitness are less evident. Id.

183. As Professor Kauffman explains, the adaptive walk of natural selection "confronts twin limitations: it is trapped or frozen inte local regions of very rugged landscapes, and, on smooth landscapes, it suffers the error catastrophe and melts off peaks, so the genotype becomes less fit." Id. at 184-85. In his discussion of the related field of path dependence theory, Professor Roe offers a look at how sociolegal systems evolve over time in light of their dynamical, dissipative qualities and get "trapped" in the same sense that Professor Kauffman

game also, as the time spent in fitness valleys wandering between peaks is when a species risks extinction.[184]

Laws, like biological species restricted to walking their way from peaks to higher peaks, must be pretty lucky to start out on Mount Everest. Consider, for example, the initial success, but eventual failure, of tort law as a means for regulating environmental protection. The earliest examples of using *any* sort of law to protect the environment relied on common law tort remedies, particularly nuisance.[185] It is no exaggeration to say that "[n]uisance theory and case law is the common law backbone of modern environmental law."[186] To

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means. See Roe, 109 Harv. L. Rev. at 641 (cited in note 9). Path dependence theory examines how decisions made in the past commit a system to certain paths, thus limiting other options, perhaps even irreversibly. As Professor Roe explains using the metaphor of a winding present day road that tracks a fur traders' trail from the past, "[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. Professor Roe blends path dependence theory, chaos theory, and evolutionary theory to develop a model that closely resembles the peaks and valleys of Professor Kauffman's adaptive walk. Id. at 644. The difference is that Professor Kauffman also focuses on how and why the landscape forms the way it does, thus shaping the paths taken, and how the landscape itself evolves over time.

184. See Kauffman, *At Home in the Universe* at 211-19 (cited in note 5).

185. A non-trespassory nuisance is the invasion of another's interest in the privato use and enjoyment of land. See Rostatement (Second) of Torts § 821D (1979). For comprehensive histories of environmental law, including examination of the early role of nuisance law, see J. William Futrell, *The History of Environmental Law*, in Environmental Law Instituto, *Sustainable Environmental Law* ch. 1 (1993); Percival, *Environmental Regulation* at ch. 2 (cited in noto 164); Arnold Reitze, *Air Pollution Law* § 1.1(a) (1995); Rodgers, *Environmental Law* at ch. 2 (cited in noto 157); Frank F. Skillern, *Environmental Protection Deskbook* ch. 1 (2d ed. 1995). Some nuisance cases dating from as far back as the sixteenth century address what today would be considered appropriate targets of environmental regulation. See, for example, *William Alred's Case*, 77 Eng. Rep. 816 (1611) (holding that stench from pig sty was a nuisance). See generally Rodgers, *Environmental Law* § 2.1 at 113 (cited in noto 157); Reitze, *Air Pollution Law* § 1-1(a) n.1 (cited in this note).

186. Redgers, *Environmental Law* § 1.1 at 2 (cited in note 157). Most comprehensive treatments of the evolution of environmental law begin with nuisance law as the first meaningful stage of development. See, for example, E. Donald Elliott, et al., *Toward a Theory of Statutory Evolution: The Federalization of Environmental Law*, 1 J. L. Econ. & Org. 313, 315 (1985) (the first period of environmental law evolution is "the period of common law ascendancy"). Within common law the nuisance doctrine developed into a powerful means of regulating the environment, so much so 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 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.

Rodgers, *Environmental Law* § 2.1 at 112-13 (cited in note 157). Through the nuisance doctrine, for example, courts have enjoined operation of industry found to cause pollution of agricultural land, *Whalen v. Union Bag and Paper Co.*, 208 N.Y. 1, 101 N.E. 805 (1913); enjoined operation of a municipal sewage disposal plant because of its emission of noxious odors, *Costas v. City of Fond Du Lac*, 24 Wis. 2d 409, 129 N.W.2d 217 (1964); enjoined operation of a municipal landfill the extent nuisance law is still that backbone, however, it is quite evident that the whole organism of environmental law no longer resembles its first form.

Not long into the history of nuisance as the legal mechanism of environmental protection, its deficiencies became apparent. The hurdles plaintiffs faced in proof of causation, fault, injury, and damages posed significant barriers to suit. Courts became reluctant to enjoin prosperous businesses to spare relatively insignificant economic factors from the effects of nuisance; multiple sources of pollution and their distant, sometimes latent effects made identification of defendants difficult; the requirement of injury to private property interests left pollution of public resources often without a plaintiff.[187] In other words, the very nature of nuisance as a common law remedy imposed inherent conflicting constraints on just how far nuisance law could go in addressing the full range of environmental protection problems. Its schema of protecting private property interests and its structure as a common law cause of action became increasingly maladapted to the growing industrialization of society and the corresponding problem of pollution.

To be sure, nuisance law evolved, but only slowly, through a landscape walk to nearby peaks. For example, the use of public nuisance causes of action allowed consolidation of widespread injuries into one lawsuit and improved the chances of obtaining an injunction against the offensive activity.[188] The development of strict liability principles relieved some of the proof of fault problems.[189] The problem

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because of fires and odors, *Steifer v. Kansas City*, 175 Kan. 794, 267 P.2d 474 (1954); and awarded damages caused by municipal pollution of a stream, *Harrisonville v. W.S. Dickey Clay Manufacturing Co.*, 289 U.S. 334 (1933).

187. See Percival, *Environmental Regulation* at 72-102 (cited in note 164); Reitze, *Air Pollution Law* § 1-1(a)(1) to (3) (cited in note 185); Skillern, *Environmental Protection Deskbook* § 1.07 (cited in note 185).

188. A classic example of this evolution to higher fitness is illustrated by two cases discussed in Percival, *Environmental Regulation* at 77-80, 96-101 (cited in note 164). In *Madison v. Ducktown Sulphur, Copper & Iron Co.*, 113 Tenn. 331, 83 S.W. 658 (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. 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, and the Supreme Court eventually issued an injunction restricting the level of pollution discharge. See *Georgia v. Tennessee Copper Co.*, 237 U.S. 474 (1915).

189. The genesis of this evolutionary event is traced to the decision te apply strict liability to "nonnatural uses" of land. *Rylands v. Fletcher*, 3 H.L. 330 (1868) (construction of reservoir, allowing water to enter and flood plaintiffs mine, held to be strictly liable in tort). This application of strict liability has since evolved in the United States to form the principle that

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.[190] Through such judicial refinements, nuisance law became an increasingly potent weapon of environmental protection.[191]

In the long run, however, to resolve all of the factors that made nuisance law deficient in the regulation of environmental pollution would result in the formation of something other than nuisance law. We would have created, in essence, an entirely new species of environmental law. As Complexity Theory demonstrates, however, that degree of evolution is hard to attain when the species is limited to walking from peak to peak. A faster way to new and higher fitness peaks was needed.

C. Niches, Correlated Landscapes, Peak Jumping, and Gateway Events—Environmental Law's Rapid Transition From Common Law to the Federal Regulatory State

We have seen that a fitness landscape for any one species is not a random set of peaks and valleys. Rather, it is defined by the schema that the species uses to cope with its environment and by the conflicting constraints posed by structural limitations, other species, environmental conditions, and the like. What is "fittest" for a species is not determined independent of these environmental forces—forces that define the species' "niche."[192] So long as the species stays within the boundaries of its niche, it is unlikely that minor incremental changes in the species' schema and structure will dramatically alter its fitness. The niche occupied by a species thus can be represented by an area of landscape roughly correlated in terms of ruggedness and altitude. If there are higher peaks nearby, in other words, they are probably not much higher, and the chances of finding one higher than

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any "abnormally dangerous" activity is subject to strict tort liability. See Restatement (Second) of Torts §§ 519-20 (1977).

190. See Robert V. Percival, *Environmental Federalism: Historical Roots and Contemporary Models*, 54 Md. L. Rev. 1141, 1152-55 (1995).

191. See Rodgers, *Environmental Law* § 2.1 at 113 (cited in note 157).

192. Evolutionary biologists define niche as "the place occupied by a species in its ecosystem—where it lives, what it eats, its foraging route, the season of its activity, and so on. In a more abstract sense, a niche is a potential place or role within a given ecosystem into which a species may or may not have evolved." Wilson, *Diversity of Life* at 403 (cited in note 11). See also James R. Griesemer, *Niche: Historical Perspectives*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 231 (Harvard U., 1992); Robert K. Colwell, *Niche: A Bifurcation in the Conceptual Language of the Term*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 241 (Harvard U., 1992).

the one on which the species already finds itself diminishes as fitness increases.[193] A species might "feel around" its correlated landscape through long natural selection walks, but can expect no dramatic long term changes in its relation to its niche through that marching process.

Beyond the correlated landscape, however, may lie much higher peaks, much deeper valleys, vast plateaus, and so on. Hence, the degree to which a species can significantly alter its chances of hitting the Mt. Everest (or Death Valley) of fitness levels depends on how far out of its environmental niche it can travel. We have seen that the adaptive walk mode of natural selection travel offers a very poor way of testing faraway prospects.[194] Another mode of travel is necessary to test those horizons.

That other mode of travel across fitness landscapes, jumping, allows movement outside the confines of natural selection by mutation. Jumps across fitness landscapes happen through environmental accidents, such as happened to the first bird blown off course to the newly formed Hawaiian Islands,[195] and through sex—that is, through genetic recombination. Biological mates, each of which has attained some altitude on a fitness peak, combine their genes and parachute their offspring onto different (but not necessarily better) drop zones.[196]

193. This is an inherent feature of an adaptive walk across a correlated fitness landscape, in that "with every step uphill, the number of directions leading higher is cut by a constant fraction . . . so it becomes harder to keep improving." Kauffman, *At Home in the Universe* at 178 (cited in note 5).

194. See notes 179-85 and accompanying text.

195. For a discussion of the role of accidents in the evolutionary history of the biota of the Hawaiian Islands, see Wilson, *Diversity of Life* at 94-100 (cited in note 11). See generally text accompanying notes 117-122. The power of accident—of the chaos, emergence, 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. If 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." Kauffman, *At Home in the Universe* at 186 (cited in note 5).

196. 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." Kauffman, *At Home in the Universe* at 180 (cited in noto 5). 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. In contrast, 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. See also Gell-Mann, *The Quark and the Jaguar* at 253 (cited in note 5) ("What are males really good for?"). There must he 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.

Now and then, the offspring land very far away, and, if they are lucky, on a higher fitness peak, allowing a longer march up the natural selection hill.[197]

Hence, when a species makes a long jump outside the correlated landscape and lands in an area of higher peaks, the species can experience a quantum leap in fitness advancement. Additional long jumps, however, present diminishing chances of finding yet higher peaks.[198] Thus, after a fortuitous landing on a much higher peak, the species' evolution risks less by favoring shorter jumps, or even walks, to search for only slightly higher peaks in the (new) nearby correlated landscape.[199] The long term record should be, in other words, one of punctuated equilibrium.[200]

The description of Complexity Theory's model of evolution thus far has focused on descriptive qualities of a coherent model of fitness landscapes and how species travel across them. That model permits a synthesis of what heretofore have been ostensibly conflicting theories of how natural selection works. In the landscape model, we see that punctuated equilibriums can occur without contradicting any premise of natural selection in the neo-Darwinian model.[201]

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197. This is precisely the effect that is occurring with respect to hybrids of the Galapagos finches, which often appear to attain fitness levels exceeding the parent species. By hybridizing their genes, the finches "make combinations that could take off, that could he the starting point of a new evolutionary direction not easily within reach of either species." Weiner, *The Beak of the Finch* at 209 (cited in note 11).

198. Professor 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." Kauffman, *At Home in the Universe* at 193 (cited in note 5). Professor Arnold Reitze has insightfully captured the impact of this diminishing returns effect in his study of the continuing effectiveness of existing environmental policy structures. See Arnold Reitze, *Environmental Policy It Is Time for a New Beginning*, 14 Colum. J. Envir. L. 111 (1989). His work is a perfect example of how many commentators have already "seen" and described the effects for which Complexity Theory now provides a theoretical context and foundation for explanation.

199. 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." Kauffman, *At Home in the Universe* at 195 (cited in note 5). The rule of thumb, therefore, is that "[a]s fitness increases, search closer to home. On a correlated landscape, nearby positions have similar fitness. 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.

200. See id. at 195-201. Thus, as we see from the historical record, the Cambrian period saw incredible asymmetric expansion of phyla, the taxonomic level below animal and plant orders; followed by a long period of gradual, symmetric speciation filling out the phyla; followed by the Permian period of massive refinement through extinction; and so on. See text accompanying notes 86-90.

201. Indeed, Edward O. Wilson takes the position that "the possibility of swift evolution was already a cornerstone of traditional evolutionary theory and therefore in no sense a

Complexity Theory brings far more to the table in terms of theoretical advancement of evolutionary mechanics, however, through its insight into chaos, emergence, and catastrophe behaviors in dynamical systems as a means of explaining *how* punctuated equilibriums occur. Species have no control over environmental accidents and mutations, nor do they have any control over the genetic recombinations brought about by their sexual reproduction. Those events, however, can be the source of dramatic change within both a species and its environment. Complexity Theory demonstrates why even minor perturbations in dynamical systems can lead to arbitrarily large alterations of system trajectory. Not every environmental accident, mutation, or act of reproduction will do so, but some will. These perturbations are the "gateway events" allowing jumps to new fitness landscape horizons.[202] Thus, when the first finches were blown onto the Galapagos Islands, they landed far outside the correlated landscape of their prior finch world. And eons ago, after eons before that of gradual change in environment and species, the right mix of environmental conditions and species development came together in the Cambrian period to allow an explosion of long jumps. When Complexity Theory's model of chaos, emergence, and catastrophe is overlaid upon the model of fitness landscapes in this manner, we understand why natural selection *must* lead to punctuated equilibriums rather than uniform gradual change. It is not only possible for species to make long jumps across fitness landscapes, it is *inevitable* that they will so long as accidents and sex continue to happen.

That being said, it still remains true that long jumps in biological evolution are a chance event, not a deliberate plan of a particular species. By contrast, the sociolegal system can attempt to experience gateway events setting the stage for a long jump deliberately. Few instances of legal transformation illustrate this point better than the environmental law revolution of the 1970s. As I have shown, nuisance law is fairly well confined in its niche, defined by a schema based on protection of private property and by a structure based on the common law model.[203] Prior to 1960, the federal legislative role in

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challenge to it.... The [neo-Darwinian] models also allow for stasis, or long periods with little or no evolution of a kind detectable in fossils." *Diversity of Life* at 89 (cited in note 11).

202. See Gell-Mann, *The Quark and the Jaguar* at 240 (cited in note 5) ("[G]ateway events... open up whole new realms of possibility, sometimes involving higher levels of organization or higher types of function.").

203. See text accompanying notes 186-92.

pollution control had been largely passive,[204] and state and local governments restricted their legislative efforts principally to smoke ordinances and other local impact regulatory programs.[205] By the 1960s, however, pollution had taken on a national, transboundary dimension, and it was apparent for the reasons already discussed that none of the peaks in its correlated landscape of nuisance law was high enough to allow an effective response to those challenges. Something more was needed.

That something more came in the form of a long jump that landed environmental law in the realm of federal command-and-control legislation. During a period described as the "explosion of environmental law,"[206] from 1970 through 1976, Congress newly enacted or substantially amended ten major environmental regulation statutes covering air, water, and land pollution, project planning, workplace safety, manufacturing, species protection, and public drinking water.[207] That record was nearly duplicated during the same period in the field of natural resources protection.[208] In six years, a mere drop in the bucket compared to the centuries-long history of nuisance law, environmental protection law had been transformed into nothing less than a new species—a punctuated equilibrium if ever there was one. Nuisance law was still a part of this new creature, but anyone mistaking the new species for nuisance law would have been rudely awakened.

What triggered this disequilibrium of legal evolution—what was its gateway event? Many commentators point to the synthesis of two major sociolegal developments. First, beginning in the 1960s environmentalism swelled because of a change in public perception, so that what had previously been treated as environmental amenities

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204. 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, 54 Md. L. Rev. at 1149-52, 1155-59 (cited in note 190).

205. See id. at 1148. See, for example, *Huron Portland Cement Co. v. Detroit*, 362 U.S. 440 (1960) (holding that application of a local smoke ordinance to federally licensed river barges did not unconstitutionally interfere with interstate commerce).

206. Futrell, *History of Environmental Law*, in Environmental Law Institute, *Sustainable Environmental Law* § 1.2(I)(1) at 43 (cited in note 185) (collecting statutes); Percival, 54 Md. L. Rev. at 1160-63 (cited in note 190) (same).

207. Futrell, *History of Environmental Law*, in Environmental Law Institute, *Sustainable Environemntal Law* § 1.2(I)(1) at 44-45 (cited in note 185).

208. Id. § 1.2(I)(3) at 48 (collecting statutes). The process continued into the 1980s, albeit at a slower pace. See Percival, 54 Md. L. Rev. at 1163 (cited in note 190) (collecting statutes). Some laws were changed more than once, each time boosting the degree of federal dominance. See John P. Dwyer, *The Practice of Federalism Under the Clean Air Act*, 54 Md. L. Rev. 1183, 1183-85 (tracing changes to federal air pollution control legislation).

came to be perceived as highly desired property rights.[209] Second, the desire to promote civil rights legislation in the 1960s prompted the judicial expansion of Congress's commerce power, thus opening the door to federal expansion into other areas of regulation formerly held as a sacred ground for the states.[210] The triggering event, several commentators have posited, was President Nixon's laying down of the gauntlet to his Democratic rivals in Congress. In July 1970, President Nixon issued an executive order creating the Environmental Protection Agency as a challenge to see which political party would take command of the environmental protection agenda in a way that placated public demand.[211] To be sure, many other factors must have contributed to the paradigm shift in approach, but it is unlikely the new species of environmental law would have emerged when it did, in the form it did, and as rapidly as it did had these critical developments not come together simultaneously.[212]

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209. Futrell, *History of Environmental Law*, in Environmental Law Institute, *Sustainable Environmental Law* § 1.2(H)(2) at 40 (cited in note 185). See, for example, Peter Cleary Yeager, *The Limits of Law: The Public Regulation of Private Pollution* 98-110 (Cambridge U., 1991) (tracing the surge in public mood and concluding that "the growing environmental movement was to stimulate relatively radical changes in law, most notably at the federal level"); Dinah Bear, *The National Environmental Policy Act: Its Origins and Evolutions*, Nat. Resources & Envir. 3, 3-4 (Fall 1992) (describing public mood as a critical facter in the enactment of the National Environmental Policy Act); C. Peter Gopelrud III, *Water Pollution Law: Milestones From the Past and Anticipation of the Future*, Nat. Resources & Envir. 7, 8 (Fall 1995) (describing public mood as a critical facter in the enactment of the Clean Water Act).

210. As William Futrell describes this facter, prior to 1970

> Congress used creeping federalism rather than direct regulation in the environmental area because it was unclear whether the federal government could constitutionally operato air and water pollution programs. The expansion of the commerce clause in support of federal regulatory power was a long process and was not completed until the Civil Rights Act of 1964 . . . . The Supreme Court's vindication of the 1964 Civil Rights Act opened the door for sweeping environmental health and safety regulation.

Futrell, *History of Environmental Law*, in Environmental Law Institute, *Sustainable Environmental Law* § 1.2(G)(1) at 38 (cited in note 185).

211. Elliott, 1 J. L. Econ. & Org. at 326-38 (cited in note 186) (describing in detail the "competitive credit-claiming" behavior of presidential aspirants as being the central force that opened the door to the statutery revolution of environmental law); Yeager, *Limits of Law* at 114-18 (cited in note 209) ("Nixon was also eager to show both leadership on and responsiveness to the elevated environmental expectations."); Futrell, *History of Environmental Law*, in Environmental Law Institute, *Sustainable Environmental Law* § 1.2(I)(2) at 44 (citod in note 185); Rosemary O'Leary, *Environmental Change: Federal Courts and the EPA* 4-14 (Temple U., 1993); Bear, Nat. Resources & Envir. at 4 (cited in note 209).

212. The notion that there are profound gateway periods in legal reform has been advanced before. For example, Professor Bruce Ackerman has outlined the characteristics of "constitutional moments" that act as gateways to foundational change in constitutional theory and structure. Bruce Ackerman, 1 *We the People: Foundations* 6 (Cambridge U., 1991). Clearly, the 1970s were environmental law's "statutory moment."

The new species looked and acted very different from nuisance law: it carved up environmental protection policy into different media, manufacturing sectors, and groups of chemicals; it established administrative agencies and gave them power to impose direct regulations on polluters and other sources of environmental degradation; it initiated preventive regulation rather than waiting to respond to past injury; it disaggregated injury to private property from the basis for regulatory action.[213] And this new kid on the block wasted no time flexing its muscles—setting policy, issuing regulatory commands, pursuing enforcement actions, and so on—with substantial results to show for its efforts.[214] To be sure, the environmental regime evolved from roots in nuisance law, but it quickly demonstrated that it was far more fit than nuisance law could ever have hoped to become. The long jump appeared to have landed environmental law in the Himalayas.

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213. In other words, the command-and-control environmental law regime was born. See Percival, *Environmental Regulation* at 102-14 (cited in note 164); Futrell, *History of Environmental Law*, in Environmental Law Institute, *Sustainable Environmental Law* § 1.2(I)(2) at 45 (cited in note 185). Some commentators appear to suggest that because legal transformations of this magnitude are not born out of accident or sex, as in the natural setting, evolutionary models of sociolegal change are not valid. For example, in his examination of path dependence theory, chaos theory, and evolutionary theory as models of legal change, Professor Roe contends that "[b]ecause we can consciously move ourselves from one mountain to another, pure analogies to natural selection are inapt." Roe, 109 Harv. L. Rev. at 665 (cited in note 9). See also note 183. To be sure, our ability consciously to attempt to jump across our sociolegal system landscape distinguishes sociolegal evolution from evolution of the Galapagos finches, but that distinction does not make the analogy to natural selection as inapt as Professor Roe suggests. The point of Complexity Theory is that a component of any dynamical system, sentient or not, has very little idea what its landscape looks like beyond the nearby peaks, and has very little control over how that landscape will evolve over time in response te evolution of other components and outside environmental forces. Hence, even we the sentient cannot, in Professor Roe's words, "consciously re-engineer our . . . system . . . by returning to a branch node and going down another path." 109 Harv. L. Rev. at 665 (cited in note 9). For example, it would be impossible to unravel present day environmental laws to take us back to the gatoway events of the late 1960s that primed society for a turn from nuisance law to command-and-control legislation. That "branch node" simply doesn't exist anymore, and, as the path of a strange attractor system never intersects with itself, we can never recreate that decision node. Even if we could recreate that point in terms of system dynamics, we would have absolutely no idea of the long term consequences of choosing, say, market-based approaches to environmental law instead of the command-and-control approach we took. The best we can hope for—and on this point I agree with Professor Roe—is that sometimes we can sense when we are trapped on an unfit local peak and then try consciously to get off of it. We also can establish a sociolegal system that improves our chances of identifying unfit positions and of reaching higher peaks, which is the focus of the remainder of this Article.

214. See note 164.

D. Competition, Cooperation, and Coevolution Towards the Edge of Chaos—Long-Jumping Beyond the Regulatory State to New Approaches of Environmental Law and Policy

Complexity Theory accommodates the last piece of the evolutionary biology puzzle—ecosystem nonequilibrium dynamics—by the recognition that as one species evolves through either mode of travel across its landscape, it necessarily changes the landscapes of other species with which it interacts and prompts them to make the jumps necessary to search for higher peaks. It turns out, in other words, that the metaphor of a fitness landscape, because of the static image a landscape implies, does not present the whole picture.[215] As one species travels across its seemingly static landscape, its travels necessarily alter the landscapes of other species in the relevant ecosystem. Time, therefore, adds a new dimension to the fitness question which Complexity Theory refers to as coupling. Fitness landscapes of various species in the ecosystem are coupled by their temporal interactions, requiring that all species reconstruct their schemata and structures continually—a sort of perpetual exercise in game theory.[216]

The two predominant models of how species cope with other species' evolutions are competition and cooperation. Competition is "predicated upon the collective demand for a common resource when

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215. As Professor Kauffman explains, "[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 and prey, coevolve. Each adaptive move by the bats deforms the landscape of the frogs." Kauffman, *At Home in the Universe* at 208 (cited in note 5). When taking the level of analysis from a single system component to the full system, therefore, it is necessary to modify the *NK* landscape model, see note 172, to take into account the number of connection inputs between the landscapes of different system components, which we can designate *C*. The landscape for each species in the ecosystem, then, is an *NKC* function coupled (by C) to the landscapes of other species. When *C* is low, for example, landscapes of coupled species in the ecosystom do not deform much when one species' landscape evolves, but when *C* is high, the coevolution process becomes chaotic. See Kauffman, *At Home in the Universe* at 224-27 (cited in note 5).

216. See Kauffman, *At Home in the Universe* at 217-21 (citod in note 5). Professor Kauffman notes that in a single game of the famous "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 te understand the coordinated nature of their choices. This effect, posits Professor Kauffman, provides an analogy to the coevolution of fitness landscapes, though coevolution in biological organisms takes place without conscious predecision. See id. For an excellent discussion of how game theory can be used to explain the evolution of environmental law in the 1970s, when competing presidential aspirants contributed to a statutory frenzy none would have selected as his outcome if acting individually, see Elliott, 1 J. L. Econ. & Org. at 321-26 (cited in note 186).

the available supply is inadequate for all of the organisms,"[217] and can lead to character displacement—the evolution of two species away from one another[218]—or full competitive exclusion—the "extinction of one species by another in a habitat through competition."[219] Species in collision need not always resort to an arms race, however, as compromises may assure two competing species' mutual survival rather than each risking its demise in all-out warfare. Through ecological displacement—species yielding part of an environment to competitors—more species can be accommodated, the overall biodiversity of the ecosystem rises, and the ecosystem as a whole approaches the region of dynamical complexity.[220] Some shifting blend of competitive and cooperative behaviors, therefore, can be expected in evolving dynamical systems.[221]

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217. Robert McIntosh, *Competition: Historical Perspectives*, in Evelyn Fox Keller and Elisabeth A. Lloyd, eds., *Keywords of Evolutionary Biology* 67 (Harvard U., 1992). Competition, of course, does not require that two species combat over tbe same morsel of food. "Even if [two species] never actually jostle and joust, never once collide physically over a . . . seed or a nesting sito . . . natural selection will gradually magnify their differences." Weiner, *The Beak of the Finch* at 142 (cited in note 11).

218. As the species move apart, "[a]t last the two varieties will move so far apart that competition will slack off. It will slack off when the two varieties have evolved in new directions: when they have diverged." Weiner, *The Beak of the Finch* at 142 (cited in note 11). This is what leads to character displacement and ultimately, to adaptive radiation of new species. See id. at 142-56.

219. Wilson, *Diversity of Life* at 394 (cited in note 11).

220. Id. at 172-73. Edward O. Wilson explains that an ecological

> community shifts continuously, and by an unconscious trial and error, through innumerable fits and starts, its biodiversity slowly rises. Species excluded earlier at last find room, symbiotic pairs and trios are fitted together, the forest grows deeper and richer, new niches are prepared. The community thus approaches a mature state, actually a dynamic equilibrium with species forever arising and disappearing and the total species numbers bobbing up and down inside narrow limits.

Id. Wilson's model of ecosystems is precisely the Complexity Theory model of a dynamical system's coevolutionary transition towards the region of complexity. Wilson, for example, describes "assembly rules" dictating how the species of an ecosystem wind up there. See note 122. Similarly, Professor Kauffman explores the issue of "community assembly" as one of coevolution of fitness landscapes which produces a " 'community landscape', in which each point of the torrain represents a different combination of species [and] the peaks will represent points of high fitness—combinations that are stable." *At Home in the Universe* at 211-14 (cited in note 5).

221. Murray Gell-Mann posits that "[a]lthough competition among schemata is a characteristic of complex adaptive systems, the systems themselves may indulge in a mixture of competition and cooperation in their interactions with one another. It is often beneficial for complex adaptive systems to join together to form a collective entity that also functions as a complex adaptive system." *The Quark and the Jaguar* at 242 (cited in note 5). Ecosystems are an example, see Weiner, *The Beak of the Finch* at 200-02 (cited in note 11), and another might be "when individuals and firms in an economy operate under a government that regulates their behavior in order to promote values important to the community as a whole." Gell-Mann, *The Quark and the Jaguar* at 242 (cited in note 5). See generally John L. Casti and Anders Karlqvist, eds., *Cooperation and Conflict in General Evolutionary Processes* (Wiley, 1995).

The fittest species in a particular ecosystem does not necessarily remain so indefinitely and may need to jump out of its niche in order to survive in its ever-dynamic environment.[222] Some long jumps fail, and species go extinct, but others succeed. The point is, however, that whatever one species does necessarily alters the landscapes of other species in the ecosystem, and hence the entire ecosystem of species experiences dynamic *co*evolutionary change through which it adds and deletes species as needed to continue to exist at the edge of chaos.[223] It behooves each species in that game to remain elastic as well.[224]

This reality should be ignored no more in law than it has been in biology. Nuisance law, for example, seemed a fit response to the pollution problem in the seventeenth century. Time was the enemy of nuisance law, however, as the ever-evolving sociolegal system gradually outpaced the ability of nuisance to adapt to its deforming fitness

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222. The Galapagos finches have heen recorded as experiencing this flip-flop in what constitutes the fittest organism, as environmental change from drought to deluge favored opposito schemata and structures within the finches. See Weiner, *The Beak of the Finch* at 104-06 (cited in note 11).

223. When Professor Kauffman and fellow researchers studied the coevolving interactions of complex genetic nets over time, they found an "ordered regime near the phase transition between order and chaos, the edge-of-chaos 'complex regime.' In the ordered regime near the phase transition, complex but nonchaotic cascades of activities can propagate across a network, allowing coordination of complex sequences of events." Kauffman, *At Home in the Universe* at 223 (cited in note 5). Thus, "highest average fitness occurs precisely at the transition from order to chaos. Deep in the ordered regime, fitness peaks are low because of conflicting constraints. Deep in the chaotic regime, fitness peaks are high, but are too few and move too rapidly to be climbed . . . . So the transition between order and chaos appears to be the regime that optimizes average fitness for the whole ecosystem." Id. at 230. See also Stuart A. Kauffman, *Whispers from Carnot: The Origins of Order and Principles of Adaptation in Complex Nonequilibrium Systems*, in George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models, and Reality* 83 (Addison-Wesley, 1994).

224. As Wilson says, "closely similar species [in an ecosystem] can fit together when their requirements are elastic." *Diversity of Life* at 173 (cited in note 11). The elasticity of whole ecosystems is tested by severe perturbations such as the introduction of new species that disrupt the "fit" of the ecosystem, otherwise known as an "exotic introduction" or "bioinvasion." See Chris Bright, *Understanding the Threat of Bioinvasions*, in Worldwatch Institute, *State of the World* 95, 101 (Norton, 1996) ("The effects of an invasion can ripple through an ecosystem, upsetting relationships that would appear to be far removed from the invader itself."). Amy J. Benson, *The Exotic Zebra Mussel*, Endangered Species Bull. 14 (Mar./Apr. 1996) (tracing the history of the zebra mussel's phenomenal invasion of the Great Lakes). The term used in Complexity Theory to describe the elasticity of system components, and of whole systems, is self-organized criticality, meaning that a mature Complex Adaptive System evolves towards a critical state—the edge of chaos—and once there devises ways te avoid experiencing so many big avalanches by integrating numerous smaller avalanches as release valves. Such elasticity has been observed in tbe distribution of avalanches in sand piles and the distribution of earthquakes in fault zones. See Kauffman, *At Home in the Universe* at 235-43 (cited in note 5); Per Bak, *Self-Organized Criticality: A Holistic View of Nature*, in George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models, and Reality* 477 (Addison-Wesley, 1994).

landscape. Nuisance in environmental law did not go extinct, but its niche has certainly shrunk and been contained.

A similar fate appears to be awaiting the command-and-control environmental law regime as well, if it does not adapt more rapidly to its changing fitness landscape. The rest of the sociolegal system did not simply sit still as the environmental regulation organism grew to leviathan proportions. Through competition, cooperation, and coevolution, some components retreated, some were extinguished, but some adapted to new fitness peaks. As that process unfolded, the fitness landscape of the federal regulatory program itself deformed. Thus, it would have been naive and foolish for anyone to assume that environmental law would not itself need to evolve from its command-and-control roots in order to stay in the game.

The more recent history of environmental law bears witness to that reality for the sociolegal system. The environmental law Himalayas of the 1970s have eroded, and may no longer be the highest peaks for tackling the environmental protection challenges of the day and future. The rest of the sociolegal system, in its newly evolved forms, is demanding accountability of the command-and-control environmental regulation regime—accountability in the form of attention to economic rationality, attention to risk-benefit results, attention to private property rights, and so on.[225] The question is, can the command-and-control structure compete successfully with those new demands, or will it have to evolve. We have already seen the regulatory state attempting to evolve through walks to new peaks. The program under the Clean Air Act for trading of sulphur dioxide emission rights, for example, has successfully integrated market dynamics within a regulatory program.[226] The species is evolving, but is it

225. The recent literature is replete with commentary addressing the degree of sensitivity of the present environmental law regulatory systom to matters of economic efficiency, risk allocation, and private property rights. For a sampling, see the materials cited in notes 165 (risk allocation), 178 (private property rights), and noto 226 (economic efficiency). For a current and comprehensive overview of the thrust of reform proposals on these fronts, see Robert L. Glicksman and Stephen B. Chapman, *Regulatory Reform and (Breach of) the Contract with America: Improving Environmental Policy or Destroying Environmental Protection?*, 5 Kan. J. L. & Pub. Policy at 9 (1996). Professor Sunstein has examined whether the 104th Congress represents the crescendo of a gateway into a new constitutional structure, arguing that such a conclusion would be premature at this point. See Sunstein, 48 Stan. L. Rev. at 251-57 (cited in note 160).

226. See Pub. L. No. 101-549, § 401, 104 Stat. 2399, 2584 (1990), codified at 42 U.S.C. § 7651 (1994 ed.). The Clean Air Act sulfur dioxide emissions trading program is widely regarded as the most successful example of integration of market efficiencies into the regulatery structure. See, for example, Percival, *Environmental Regulation* at 824-29 (cited in note 164); Timothy A. Wilkins and Terrell E. Hunt, *Agency Discretion and Advances in Regulatory Theory: Flexible Agency Approaches Toward the Regulated Community as a Model for the Congress-*

evolving fast enough? Is a long jump of the proportion that transformed nuisance law into the regulatory state now in order for the regulatory state? If so, how do we bring that about?

IV. THE PRACTICAL MEANING OF EVOLUTIONARY FITNESS FOR AN OPERATING DEMOCRACY—DESIGNING SOCIOLEGAL ECOSYSTEMS THAT LAST

> It is one of the happy incidents of the federal system that a single courageous state may, if its citizens choose, serve as a laboratory; and try novel social and economic experiments.[227]

If it is time for a long jump in environmental law, and possibly in many other fields of regulation, the question is how to do it. More broadly, how do we structure the sociolegal system to make long jumps possible, particularly when the landscape is changing below our feet? The answer is sex, that is, the sociolegal version of sexual reproduction—democracy.

Agency Relationship, 63 Geo. Wash. L. Rev. 479, 491 (1995) (discussing the Clean Air Act's permit system); Timothy N. Cason and Charles R. Plott, *EPA's New Emissions Trading Mechanism: A Laboratory Evaluation*, 30 J. Envir. Econ. & Mgmt. 133 (1996). The need for greater reliance on market forces to bring about more efficient protection of environmental factors has been forcefully argued by many commentators. See, for example, David Malin Roodman, *Harnessing the Market for the Environment*, in Worldwatch Institute, *State of the World* 168 (Norton, 1996); Sunstein, 48 Stan. L. Rov. at 260-61, 303-05 (cited in noto 160); Daniel J. Dudek, Richard B. Stewart, and Jonathan B. Wiener, *Environmental Policy for Eastern Europe: Technology-Based Versus Market-Based Approaches*, 17 Colum. J. Envir. L. 1 (1992); Robert W. Hahn and Robert N. Stavins, *Incentive-Based Environmental Regulation: A New Era from an Old Idea?*, 18 Ecol. L. Q. 1 (1991); Richard B. Stewart, *Reconstitutive Law*, 46 Md. L. Rev. 86 (1986); Bruce A. Ackerman and Richard B. Stewart, *Reforming Environmental Law: The Democratic Case for Market Incentives*, 13 Colum. J. Envir. L. 171 (1988); Robert W. Hahn and Gordon L. Hester, *Marketable Permits: Lessons for Theory and Practice*, 16 Ecol. L. Q. 361 (1989). The EPA has responded recently with initiatives that extend the pollution credit trading concept of the Clean Air Act program to other arenas. See, for example, *Effluent Trading in Watersheds Policy Statement*, 61 Fed. Rog. 4994 (1996); *Effluent Trading Document to Discuss Various Possible Schemes, Official Says*, 27 Envir. Rptr. (BNA) 362 (1996). See generally Glenn L. Unterberger, *Let's Make a Deal: Structuring the Transaction to Transfer Pollution Reduction Credits*, Nat. Resources & Envir. 26 (Spring 1996). As evidence of a potential conflicting constraint to this trend, however, some groups contend that market-based emission trading programs will concentrate pollutants in minority and low income areas and thus should be restrained. See Environmental Protection Agency, National Environmental Justice Advisory Council, *Achieving Environmental Protection: Compliance, Enforcement, and Environmental Justice* (1996); Percival, *Environmental Regulation* at 188 (cited in note 164) ("[I]t is necessary to consider not only how efficient [environmental] policies are, but also how equitable.").

227. *New State Iee Co. v. Liebmann*, 285 U.S. 262, 311 (1932) (Brandeis, J., dissenting).

Sexual reproduction and democracy are both high stakes games. Biological parents endure the trials of mating, and then cast perfectly good genes off into the uncertainty of genetic recombination. Why? As Professor Glenn Reynolds notes, "[t]he answer that evolutionary biologists have developed is that sex offers the primary advantage of increasing resistance to parasites."[228] This is simply another way of saying, in Complexity Theory terms, that as parasites and other environmental hazards continue to deform a species' fitness landscape, sexual reproduction keeps a species moving across its evolving landscape to continually test new fitness peaks.[229] Likening special interest groups to "parasites of the body politic,"[230] Professor Reynolds observes that "just as the fitness of an organism has a lot to do with its ability to resist biological parasites, the 'fitness' of a political system stems in no small part from its ability to resist these political parasites."[231] So, "democracy *is* like sex, insofar as electoral turnover, properly structured, can help limit the influence of special interests in much the same fashion that sex is believed to reduce the viability of parasites."[232]

Professor Reynolds's parasite theory is intriguing, not only because of where it leads him with respect to the role of democracy in politics, but also because it invokes the concept of fitness, which is central to Complexity Theory.[233] For purposes of his essay, Professor Reynolds takes the role of sex in promoting parasite resistance, and the correlation of parasite resistance as one factor contributing to fitness, as givens. He does not purport comprehensively to explore the underlying dynamical coevolutionary forces at play in either respect.[234] As I have shown, Complexity Theory has a lot to say about why and how that coevolutionary process unfolds, that is, about why sexual reproduction leads to evolutionary fitness in species. That democracy might lead to political parasite resistance suggests that an analogous coevolutionary process unfolds in the sociolegal system, a process in which parasite resistance is just one component of fitness.

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228. Glenn Harlan Reynolds, *Is Democracy Like Sex?*, 48 Vand. L. Rev. 1635, 1639 (1995).

229. See note 197.

230. Reynolds, 48 Vand. L. Rev. at 1642 (cited in note 228).

231. Id. at 1643.

232. Id. at 1660.

233. That connection is certainly no accident, as Professor Reynolds confesses, like me, to harboring an "ongoing interest in applying what is variously called 'complexity theory' . . . te the complex, dynamic, and sometimes chaotic behavior of legal and political institutions." Id. at 1637 n.7.

234. I do not point this out as a flaw in Professor Reynold's work by any means, as he is quite up front about not covering these topics (no doubt to allow him to get te his point in a mercifully short essay style). See id. at 1641.

Professor Reynolds's insightful commentary thus sets the stage for what I wish to explore in the remainder of this Article—where Complexity Theory leads when contemplating the why and how of the coevolution of law and society.

A. The Common Law, the Constitution, and the Joy of Sex in Democracy

Stuart Kauffman's work in Complexity Theory suggests a counterintuitive quality about the prospect of adaptive behavior in law and politics: "flatter, decentralized organizations—business, political, and otherwise—might actually be more flexible and carry an overall competitive advantage."[235] By flatness Professor Kauffman means an organization designed around a relatively flat fitness landscape—one without many jagged peaks and valleys, but not a pool table either. By decentralized Professor Kauffman means an organization broken "into 'patches' where each party attempts to optimize for its own selfish benefit, even if that is harmful to the whole."[236] Such a structure "can lead, as if by an invisible hand, to the welfare of the whole organization."[237]

That theme, of course, is nothing new—it dates back at least as far back as Adam Smith—but the underlying explanation for why flatness and patches work in an organizational context offers a new paradigm. Professor Kauffman's work with coupled systems models[238] has suggested that 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. Because changes in each patch will alter the problems confronted by 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 of coevolving ecosystems.[239]

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235. Kauffman, *At Home in the Universe* at 246 (cited in note 5).
236. Id. at 247.
237. Id.
238. See notes 172, 215.
239. Kauffman, *At Home in the Universe* at 252-53 (cited in note 5).

We then must ask what patch sizes and what degree of coupling define the highest average fitness across the system.[240] Professor Kauffman finds that the answer lies again in the region between order and chaos—the complex region—where patch size is intermediate and coupling is just low enough to prevent the spiral into chaos.[241] Most interestingly, however, Professor Kauffman finds that as coupling increases and thus drives the system towards chaos, an ameliorating effect is derived by slicing the system up into smaller patches.[242] In other words, "[h]ard problems with many linked variables and loads of conflicting constraints can be well solved by breaking the entire problem into nonoverlapping domains. Further, . . . as the conflicting constraints become worse, patches become ever more helpful."[243]

One might accuse Professor Kauffman's theory of "patches" of falling into the trap of reductionism, as it relies on dividing the system into parts. What Professor Kauffman has in mind, however, is not reductionist, but rather just the opposite. In ecological terms, for example, Professor Kauffman's notion of patches corresponds to what Edward O. Wilson refers to as biological diversity—that is, the diversity of the components of an ecosystem.[244] A monoculture-based ecosystem has only one patch, and thus must confront the challenges of its environment based on the strength of that patch alone. A highly

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240. See id. at 247-52.

241. See id. at 252-62. The choice of the term "coupling" to describe this phenomenon is perhaps unfortunate, as to the lay person coupling may suggest a tying down, in which case more coupling could be perceived as leading to overall system rigidity. A bettor analogy may be an index of the "signals" each system component must receive in order to know what to do next. To a point, overall system behavior becomes more dynamic as the number of signals required increases. The following model illustrates this property: Take a grid of 100 squares (patches) each of which can be black or white. In the simplest model, on each systom "move" each square will choose the color of the square to its left, directly below it if there is no square to the left, or directly above it if there is no square to the left or below. It is easy to envision how quickly such a loosely-coupled model will "freeze" into a fixed pattern after any square's color is flipped. Now alter the model so that each square's color depends on the dominant color of the three squares to its left, of the three below it if there are not three to the left, or of the three above it if neither previous rule can apply. When any square's color is flipped in this model, the result can be a cascade of effects throughout the grid reverberating back and forth with each system "move." As we increase the coupling the number of squares used to determine each square's color the system eventually will exhibit utterly chaotic behavior following the flip of a square. Thus, low coupling leads to rigidity, high coupling leads to chaos, and somewhere in between is the optimal degree for fostering adaptive behavior.

242. See id. at 262-64.

243. Id. at 264.

244. See Wilson, *Diversity of Life* at 393 (cited in note 11) (defining biodiversity as "[t]he variety of organisms considered at all levels . . . includ[ing] the variety of ecosystems, which comprise both the communities of organisms within particular habitats and the physical conditions under which they live").

diverse ecosystem, by contrast, is composed of many patches, and thus inherits the resilience of each patch plus the adaptive forces created by the interaction of patches. The number of system patches thus is a relevant factor in understanding how the system operates, but neither Professor Kauffman nor Edward O. Wilson is saying that we can understand an ecosystem, or any system, by studying each patch in isolation of the system, as a reductionist would do.[245]

So what do Professor Kauffman's findings mean for the sociolegal system? I believe they lead inexorably to the conclusion that the common law and the Constitution, when melded as they were in the United States, created a sociolegal system that allowed for unusually high levels of system-wide fitness. Neither of these observations escapes Professor Kauffman. He names the British common law system as one of his prime examples of a Complex Adaptive System,[246] and he posits with respect to our patchwork constitutional system that "the apparently disjointed, opportunistic, fractured, argumentative, pork-barrel, swap, cheat, steal-a-vote, cluttered system may actually work pretty well because it is a well-evolved system to solve hard, conflict-laden problems and find, on average, pretty good compromises."[247] And, I will add, the common law flourishes in that patchwork system. About all else I can add to Professor Kauffman's insightful statements is some legal "proof" of his thesis.

As for the common law, it would be difficult to conceive of a system for making law that more closely corresponds to Professor Kauffman's "coupled patches" model of adaptive organizations. The common law inherently is a patchwork of nonoverlapping and overlapping jurisdictions. Couplings between the patches—such as through the hierarchy of courts, the principle of stare decisis, and sensitivity to persuasive authority from other courts—are diffuse but present in sufficient quantity to prevent rigidity. Through this

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245. The fact of coevolution in dynamical systems is the ultimate demise of reductionism. No one component can be extracted from the system, studied in isolation of the system, altered to fit whatever ideal is in operation for the system, and then inserted back into the system with the expectation that we can predict the subsequent behavior of either the component or the system. The alterations of the one component's schema and structure will reverberate through the system, causing other components to alter their schemata and structures, with who knows what as the end result.

246. Kauffman, *At Home in the Universe* at 169 (cited in note 5).

247. Id. at 270. In short, the "United States Constitution and Bill of Rights create a federal system, where the whole is broken into parts, or patches, called states. States themselves are composed of patches—counties, municipalities." Id.

design, as Professor Lon Fuller put it, the common law "mirrors the variety of human experience; it offers an honest reflection of the complexities and perplexities of life itself."[248] In a similar vein, Professor Richard Epstein has posited that "traditional judge-made conceptions of common law are, if anything, more attuned to a complex world than to the simpler bygone age in which they were formulated."[249] In other words, the common law tends to expand and contract with the breathing of its subject matter.[250]

The common law can do so because it is in essence a system of simultaneous processes—of patches, the various jurisdictions, seeking to optimize their individual bodies of law—not of a pile of inflexible rules.[251] These qualities have led some legal commentators to posit an "analogy between pure Chaos Theory and the common law."[252] For example, case outcomes are generated by the application of relatively simple legal principles to a given set of facts and yet are unpredictable. The importance of facts to this process of deterministic randomness, therefore, "can be analogized to initial conditions to which chaotic systems have extreme sensitivity."[253] Hence, through its system of patched jurisdictions and various loose and strong couplings, the common law offers reasonable expectations of evolving towards the region of complexity—to the edge of chaos.[254]

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248. Lon L. Fuller, *Anatomy of the Law* 106 (Praeger, 1968).

249. Epstein, *Simple Rules for a Complex World* at 16 (cited in note 163).

250. In the context of environmental law, for example, "[a] striking aspect of nuisance law is its stasis (long term stability), recorded in familiar modes of judicial expression, common analytical techniques, and custom-bred indicators of decision .... The key to nuisance law, one might suppose, is found in the empirical lessons of its application recorded over time, less so in the articulated rules of decision." Rodgers, *Environmental Law* § 2.1 at 113-14 (cited in note 157).

251. See Frederick Schauer, *Playing by the Rules* 177 (Clarendon, 1991). Frederick Schauer explains:

> What is central to the common law is the way in which what had previously been thought to be a rule is a rule only in a very peculiar sense, for it will be applied to new cases if and only if that application is consistent with the full array of policies and principles that, in a more complex rule system, occupy the same place that justifications occup[y] .... The common law appears consequently to be decision according to justification rather than decision according to rule. It abounds with rules of thumb, but avoids the use of rules in a strong and constraining sense.

Id. at 178.

252. Geu, 61 Tenn. L. Rev. at 941 (cited in noto 9).

253. Id. at 942.

254. In his first study of legal evolution, Professor Sinclair takes the opposite view of the common law, arguing that it "works in an evolutionary fashion to produce states of law that achieve most of what is required, but in an indirect and less than perfect fashion" as compared to the legislative process. 64 U. Detroit L. Rev. at 472 (cited in note 3). Sinclair's thesis, however, depends on the depiction of evolution in a classically neo-Darwinian framework that fails to accommodate "revolutionary" change as part of evolution. Id. at 455, 477. Based on that premise, he posits that legislation can take revolutionary turns and the common law cannot.

As for the Constitution, Professor Reynolds's political parasite theory corresponds closely with Professor Kauffman's adaptive organization model. He posits that democracy's "reshuffling" of lawmakers leads to the unpredictability, irrationality, and inconsistency of decisionmaking that "disrupts the sort of cozy back-scratching relationships between politicians and interest groups that favor special interests."[255] And Professor Reynolds also recognizes that too much of a good thing can mean falling all the way into chaos, and thus tempering forces must be a part of the system as well. He observes that the obvious solution to the problem of special interests—more democracy—does not necessarily hold up when taken to the extreme,[256] just as Professor Kauffman would tell us that coupling of patches increases adaptiveness only to a point before collapsing the system into chaos.

Using this premise, he argues that legislation is a fitter system and evolutionary theories of legal change suffer from the defects of the common law in that regard. His thesis suffers in three respects. First, as Complexity Theory plainly shows, the forces of chaos, emergence, and catastrophe—revolutionary forces—are an integral part of adaptive, evolving systems. The historical record of punctuated equilibrium in biological evolution demonstrates that reality. Evolution and revolution thus are not mutually exclusive; indeed, evolution requires revolution. Second, the common law does contain revolutionary potential. Professor Sinclair contends that "the common-law courts have only the old form of action to work with and cannot design a new, perfectly adapted one [and thus] will tend to carry with them extraneous maladaptive features." Id. at 477. But evidence of revolutionary transformation in common law is provided by the massive overhaul of nuisance law that transpired from the sixteenth to twentieth centuries. See text accompanying notes 186-191. The fact that legislation eventually was needed to supplement common law in the pollution context does not mean that common law is no longer relevant. For example, common law continues to be a primary force of regulation regarding the standards of liability for personal injury in the tobacco and health care industries. Finally, Professor Sinclair is unduly enamored of the legislative process as capable of producing a "perfectly adapted" sociolegal outcome. The primary examples Professor Rodgers and I offer of maladaptation in environmental law are legislatively (and, by delegation, administratively) originated, see toxt accompanying notes 157-60, and Complexity Theory teaches us in general that whatever we believe today to be perfectly adapted will most likely prove us wrong sooner or later.

255. Roynolds, 48 Vand. L. Rev. at 1648 (cited in note 228).

256. As Professor Reynolds observes, " 'more democracy' only plays an anti-parasitic role when it is aimed at expanding the role of democracy in selecting decisionmakers. When it aims at expanding the ability of constituents to influence the decisions that those elected officials will make, a more democratic approach may actually make thing worse. After all, it is primarily special interests—parasites—who will make use of those new points of contact." Id. at 1649. With respect to the way in which the constitutional design balanced this property, Professor John McGinnis observes that "[j]ust as part of the Constitution was structured to facilitate the gains from trade that could result from the operation of self-interest in the private sphere, much of the rest was designed to restrain the bad effects of the operation of self-interest in the public sphere." John O. McGinnis, *The Original Constitution and Our Origins*, 19 Harv. J. L. & Pub. Pol. 251, 254 (1996).

And why is that democratic component so effective at controlling parasitism? Professor Kauffman, I expect, would say that the patchiness of our representational government, which spreads power out between separate federal branches, and then between them and the states, combined with the flexible couplings that exist between the federal branches and federal and state sovereigns, keeps the system flat and decentralized. That system, therefore, is able to respond quickly to the evolving behaviors of other sociolegal components, like special interest parasites, and keep its own fitness at a high level.

The common law and the Constitution thus combine to form a sociolegal ecosystem—a system of making rules—which is remarkably adaptive. It is within this system that democracy acts as a force of change. Professor Reynolds focuses on democracy's ability to promote parasite resistance, but its adaptive qualities run far deeper. Democracy is the means by which we can motivate long jumps in the system towards higher fitness levels, or away from peaks that are dissolving into valleys as the fitness landscape deforms in response to external threats. Simply put, democracy, as an agent of change from within, allows the system to adapt to change from without. In that sense, democracy *is* like sex.

B. The Contraceptive Effects of the Federal Administrative State

Based on Complexity Theory, I have identified the two key variables for designing a sociolegal ecosystem—patchiness and coupling. Patchiness refers to the degree of dispersal of lawmaking power, and coupling refers to the degree of interrelatedness between the units into which that power is dispersed. I have also posited that the reason the common law and the Constitution form such an adaptive system of lawmaking is that they achieve optimum levels of patchiness and coupling, thereby allowing the agent of chaos—democracy—to operate at a sort of "controlled burn" level of change. The result is a sociolegal system poised on the edge of chaos, able to roll with the punches, adapt to change, and achieve high average fitness across the system.

To be sure, not every outcome in such a system is the best possible outcome. We may need to sacrifice optimizing each individual decision taken in isolation in order to optimize system-wide average fitness. Of course, this is where our reductionist tendencies return to haunt us. Reductionism blinds our eyes to the fact that as we make individual decisions, we deform the fitness levels of other individual decisions. Reductionist legal institutions treat sociolegal decisions as if each were made in isolation rather than as if each is a part of a system of decisions, which Complexity Theory shows us will only increase the likelihood of system-wide disruption from chaos, emergence, and catastrophe. In other words, as we plug one hole, others begin to appear as a result, thus reinforcing our urge to continue plugging holes.

The reductionism that permeates our legal theory and institutions in this manner has led us to alter the sociolegal ecosystem drastically, by centralizing power in the federal government and reducing the interrelatedness of what remains as the lawmaking units. That is, we have set the levels of patchiness and coupling too low, stifling the system into an ordered regime where it is incapable of taking advantage of the adaptive qualities of democracy. The two most visible mechanisms for this campaign of contraception are the expansion of the federal power to regulate interstate commerce[257] and the erosion of the so-called nondelegation doctrine.[258] The expanded federal commerce power has set the stage for gradual but unmistakable centralization of lawmaking power in the federal government at the expense both of the common law and of lawmaking by state and local governments.[259] In other words, the patchiness of the system is

257. 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. 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).

258. Based on the fiction of "Congress . . . obtaining the assistance of its coordinato branches," *Mistretta v. United States*, 488 U.S. 361, 372 (1989), delegation of legislative power from Congress te agencies has been upheld consistently so long as not 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." *Yakus v. United States*, 321 U.S. 414, 426 (1944). The standard of what is required thus is also known as the "intelligible principles" test. See *J. W. Hampton, Jr., & Co. v. United States*, 276 U.S. 394, 409 (1928) (stating that Congress must "lay down by legislative act an intelligible principle to which the person or body authorized to [exercise the delegated authority] is directed to conform"). See generally Richard A. Epstein, *The Proper Scope of the Commerce Power*, 73 Va. L. Rev. 1387 (1987).

259. For example, Professor Rebert Beck summarizes where the jurisprudence of the Commerce Clause has led by suggesting that the provision 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 & Envir. 24, 25 (Fall 1995). He observes that "the actual wording of the Commerce Clause has become so unimportant that most courts applying it do not bother to quote it any more." Id.

collapsing. The elimination of the nondelegation doctrine in all but name has allowed Congress, flush with its power grab, to shift decision making authority out of its adaptive forum and into unelected, bureaucratic administrative agencies.[260] The system has become decoupled by the proliferation of power from Congress into the executive and independent agencies which, in turn, have expanded their regulatory influence outward as far as they can reach.[261] In particular, Congress routinely provides agencies virtually unfettered discretion to control the scope of their own power by leaving it largely to the agencies to define key jurisdictional terms found in regulatory statutes.[262] Instances of "micro-management" by Congress, in which

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260. The courts have supported a finding of proper delegation based on legislative directives as abstract and compassless as the "public interest, convenience, or necessity." See, for example, *National Broadcasting Co. v. United States*, 319 U.S. 190 (1943). In Justice Scalia's words, therefore, "[w]hat legislative standard, one must wonder, can possibly be too vague to survive judicial scrutiny, when we have repeatedly upheld, in various contexts, a 'public interest' standard?" *Mistretta*, 488 U.S. at 416 (Scalia, J., dissenting).

261. The present-day reality is thus much as Professor Bernard Schwartz has described:

> When the twentieth-century administrative state arrived, its appetite for legislation was of a magnitude of which neither Bentham nor the Founding Fathers could have dreamed. The legislature itself could not directly perform its new tasks of regulation and guardianship. Rulemaking came into its own as a potent weapon in the government arsenal. If it has become trite to point out how we have become a society that is regulated from the cradle to the grave, that is true because so much of our life has come to be supervised by administrative rules and regulations. By now, administrative legislation completely dwarfs the primary legislation of Congress and the state legislatures.

Schwartz, *Administrative Law* at 168 (cited in note 163). Timothy Wilkins and Terrell Hunt argue that "the popular notion of unconfined delegation is a myth and that Congress virtually always prescribes the policy structures in sufficient detail so that agency choice of regulatory method is narrowed significantly." 63 Geo. Wash. L. Rev. at 518 (cited in note 226). Their thesis is that Congress usually prescribes the method of regulation—say, "the choice between food stamps and money vouchers, the choice between public housing and subsidies, the choice between mandatory pollution control technologies and an emissions tax," id. at 481 n.6—and thus it is inaccurate to allege that the nondelegation doctrine is an empty principle. To be sure, Congress usually does describe the schema and structure of a regulatory program, thus preventing the agency from transforming it into something else. By doing so, however, Congress can hardly be said to have resisted the practice of unconfined delegation, as tremendous discretion often is embedded in the agency to define the organism's final form and behavior. See, for example, notes 262-63. Congress's practice after creation of the agency is more one of deism than close supervision, at least in terms of laying down the regulatory implementation standards in statutory text.

262. For example: Congress has left it to the Corps of Engineers and the Environmental Protection Agency to define "wetlands" for purposes of implementing section 404 of the Clean Water Act. See 33 U.S.C. § 1344 (1994 ed.); 40 C.F.R. § 230.3(t) (providing agency definition). Congress has left it to the Fish and Wildlife Service to define what constitutes "harm" of endangered species. See 16 U.S.C. § 1532(19) (1994 ed.); 15 C.F.R. § 17.3 (providing agency definition). Congress has left it to the Environmental Protection Agency to define many of the components of "solid waste" for purposes of the Resource Conservation and Recovery Act. See 42 U.S.C. § 6903(27); 40 C.F.R. pt. 261 (agency definition). Because of the broad deference courts give te agencies in establishing those regulations, see *Chevron U.S.A., Inc. v Natural Resources Defense Council, Inc.*, 467 U.S. 837 (1984), agencies thus are empowered to expand

statutory text tightly constrains agency regulatory discretion in that or any other regard, are few and far between.[263] In Complexity Theory terms, both patchiness and coupling in our system are on the wane, which can only lead to rigidity.

As the system erodes further into this consolidated, simplified state of being, democracy loses its adaptive qualities. Indeed, if anything, the chaotic forces inherent in democracy may pose a serious threat to the ossified, brittle administrative state. The reaction by the administrative state and its followers to, of all things, a change in power in Congress in 1994, was not uniformly cozy. Consider what one of the great voices of reason in environmental policy, William Ruckelshaus, twice former EPA Administrator and currently CEO of a major waste disposal company, has to say about the Republican takeover of environmental policy in the current Congress:

> [T]he current rhetorical excess is yet another phase in a dismaying pattern. The anti-environmental push of the nineties is prompted by the pro-environmental push of the late eighties, which was promoted by the anti-environmental excess of the early eighties, which was prompted by the pro-environmental excess of the seventies, which was prompted by the.... So what is wrong with this picture? Aren't such changes in emphasis part of the fabric of democracy? Yes, but in the case of environmental policy, these violent swings have had an unusually devastating—perhaps uniquely devastating—effect on the executive agency entrusted to carry out whatever environmental policy the nation says it wants.[264]

He is right, of course, that as the pendulum of democracy swings it generates some chaos along its path, but is that so bad? Complexity Theory demonstrates that the adaptive qualities of democracy cannot be retained if the unpredictable forces that make it adaptive are removed. When the pendulum of democracy stops swinging, in other

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their regulatory scope tremendously simply by refining their definitions of statutory terms. See, for example, *United States v. Riverside Bayview Homes, Inc.*, 474 U.S. 121 (1985) (approving Corps of Engineers's regulation defining "wetlands" to include areas adjacent to wetlands); *Babbitt v. Sweet Home Chapter of Communities for a Great Oregon*, 115 S. Ct. 2407, 132 L. Ed. 2d 597 (1995) (approving Fish and Wildlife Service's definition of what constitutes "take" of endangered species as including modifications of habitat).

263. For example, following many years of the Environmental Protection Agency's failure to designate hazardous air pollutants under section 112 of the Clean Air Act, in 1990 Congress amended the statute so as to specifically designate 189 chemicals as such. 42 U.S.C. § 7412(b). Even so, Congress allowed tbe agency to add to and delete from the list depending on whether the agency finds the chemical is "reasonably anticipated to cause adverse health effects to humans or adverse environmental effects." 42 U.S.C. §§ 7412(b)(3)(B) and (C). Congress has not defined what is meant by that standard.

264. William H. Ruckelshaus, *Stopping the Pendulum*, Envir. Forum 25 (Nov./Dec. 1995).

words, you do not have democracy anymore. Another perspective on the situation Ruckelshaus describes would be that the administrative state, now that it has reached an advanced, mature state of power, is simply too rigid and thus not equipped to work hand in hand with a dynamic, adapting democracy. Democracy in the administrative state, it seems, is something to be feared, not savored. Which will prevail?

There is no question, fortunately, that public sentiment still favors a strong environmental protection policy.[265] The issue is not the policy, however, it is the fitness of the means we use to achieve that policy. Ruckelshaus and other leading thinkers can say all they want about "reinventing" regulatory behemoths like the EPA,[266] but

265. Even following the election of a Republican Party-led Congress in November 1994, which was expected to soften the command-and-control blow of federal environmental law, public opinion has remained decidedly in favor of a strong environmental protection policy. See Mark Wexler, *Americans Speak Out*, National Wildlife 34 (Apr. 1995); George Pettinico, *The Public Opinion Paradox: Most of Us Are Environmentalists—Until We Get in the Voting Booth*, Sierra 28 (Nov. 1995); *Environment Called "Important Priority" by 71 Percent, Clean Air Trust Says*, 26 Envir. Rptr. (BNA) 1965 (1996); *Survey Says Majority of Voters Support Laws to Protect Environment, Resources*, 26 Envir. Rptr. (BNA) 1692 (1996). That sentiment also appears te remain strong at the international level. See David Bloom, *International Public Opinion on the Environment*, 269 Sci. 354 (1995). Many polls confirming this trend can be found in the POLL-C database of the Westlaw electronic research service.

266. William Ruckelshaus is leading a private initiative to do just that. See *Ruckelshaus to Head Initiative on New Statutory Mission for Agency*, 26 Envir. Rptr. (BNA) 2093 (1996). The theme of "reinvention" has begun to permeate reform rhetoric throughout the federal agencies. See Jerry L. Mashaw, *Reinventing Government and Regulatory Reform: Studies in Neglect and Abuse of Administrative Law*, 57 U. Pitt. L. Rev. 405 (1996). For example, the Environmental Protection Agency "is committed to reinventing environmental regulation to provide greater protection at less cost." 60 Fed. Reg. 60604 (1995). See generally *Notice of Availability of Permits Improvement Team Concept Paper on Environmental Permitting and Task Force Recommendations*, 61 Fed. Reg. 21856 (May 10, 1996); James R. L. Jones, *Beyond the Beltway Buzzwords*, Envir. Forum 33 (Sept./Oct. 1995); *Push to Streamline EPA Rules Reflects "Reinvention" Effort of Administration*, 26 Envir. Rptr. (BNA) 1369 (1995). The EPA has focused these efforts through "Project XL," which is designed to allow the regulated community and local communities access te alternatives to command-and-control regulatory mechanisms. See 60 Fed. Reg. 55569 (1995). See generally Daniel J. Fiorino, *Toward a New System of Environmental Regulation: The Case for an Industry Sector Approach*, 26 Envir. L. 457 (1996); William H. Freedman and Karen A. Caffee, *EPA's Project XL: Regulatory Flexibility*, Nat. Resources & Envir. 59 (Spring 1996); *Project XL Launched with Announcement by President of First Eight Participants*, 26 Envir. Rptr. (BNA) 1179 (1995); *Communities Sought for Participation in Project XL for Streamlining Rules*, 26 Envir. Rptr. (BNA) 1155 (1995); *EPA Lets Florida Company Combine Permits*, 26 Envir. Rptr. (BNA) 2146 (1996) (Project XL case). EPA has also launched the "Common Sense Initiative," which will examine "performance and market-based regnlation, setting regulatory priorities based on sound science, cutting the paperwork burden on industry, moving environmental decisions and accountability to state or local governments, and flexible enforcement approaches and compliance incentives." *Budget Uncertainty Underlies EPA Regulatory Activity in 1996*, 26 Envir. Rptr. (BNA) 1888, 1889 (1996). See, for example, *Instrument Panel Suppliers for Autos Sought by EPA for Common Sense Initiative*, 27 Envir. Rptr. (BNA) 10 (1996). Nonetheless, the agency's agenda of recently finalized and proposed regulatory measures could not be mistaken for anything but a command-and-control program. See 60 Fed. Reg. 60604, 60605-717 (1995) (semi-annual regulatory

there is no evidence that the administrative state is apt to part willingly from its underlying sources of power. The theme heard throughout the environmental regulation community, for example, is that "with some fine-tuning, current laws can form the basis for a system capable of meeting the challenges of the 21st century."[267] But "fine-tuning" suggests no fundamental reexamination of the premises upon which the administrative state was based. Rather, fine-tuning suggests only a walk around the nearby fitness landscape to find a somewhat higher peak.

Indeed, the expansive commerce power and contracted non-delegation doctrine have become such sacred cows of the federal administrative state, even the most feeble of objections from the courts are met with hyperbolic rhetoric. For example, the Supreme Court's recent suggestion in *United States v. Lopez*[268] that there may actually be a limit to the federal commerce power has been severely criticized.[269] The recent appellate court decision in *South Dakota v. United States Department of the Interior*[270] finding a statute to constitute an excessive delegation of administrative authority has been cast as out of touch.[271] It is quite apparent that most of legal

agenda). There is discussion in Congress of legislation which would allow the EPA to waive strict adherence to the regulations upon a demonstration that alternative approaches would protect the environment as much. See *Congress Said to Consider Legislation to Let EPA Enter Alternative Agreements*, 26 Envir. Rptr. (BNA) 1581 (1996).

267. Adam Babich, *What Next?*, Envir. Forum 48 (Nov./Dec. 1994).

268. 115 S. Ct. 1624, 131 L. Ed. 2d 626 (1995). In *Lopez* 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 sixty years. See, Regan, 94 Mich. L. Rev. at 663-72 (cited in note 257). The decision has triggered a "*Lopez*-watch" in the legal community to see where the decision will lead, but in general the Court and lower courts have taken it nowhere. See, for example, *Cargill, Inc. v. United States*, 116 S. Ct. 407, 133 L. Ed. 2d 325 (1995) (Thomas, J., dissenting) (lower court allowed 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). See generally *News from the Circuits*, Admin. and Reg. News 4 (Fall 1995) (collecting cases decided since *Lopez* refusing to strike down federal legislation on commerce power grounds). But see *United States v. Olin Corp.*, 927 F. Supp. 1502 (S.D. Ala. 1996) (ruling that application of Superfund in specific context of case was beyond federal interstate commerce power).

269. See Tom Stacy, *What's Wrong with* Lopez, 44 U. Kan. L. Rev. 243, 244-45 (*Lopez* is "profoundly unsatisfying" and "remarkably insensitive to" Federalism values); Richard Lazarus, *Environment Protected from* Lopez, Envir. Forum 8 (Jan./Feb. 1996).

270. 69 F.3d 878 (8th Cir. 1995). The *South Dakota* court found that a provision allowing the Secretary of the Department of the Interior to "acquire . . . any interest in lands . . . within or without existing reservations . . . for the purpose of providing lands for Indians" was an excessive delegation of legislative authority. Id. at 882. The court noted that the provision "would permit the Secretary to purchase the Empire State Building in trust for a tribal chieftain as a wedding present." Id.

271. See Lazarus, Envir. Forum at 8 (cited in note 269).

academia believes there is no limit to the federal commerce power and there is no such thing as an excessive delegation of legislative power, period.[272] Those views can only lead to suppression of the very dynamical qualities for which the common law and the Constitution are so often revered.

I find some comfort that I am not alone in my heresy on this point, as a growing body of commentary joins me in identifying these two doctrines as the culprits of the paralysis of democracy.[273] With

272. Professor Donald Regan observes, for example, that "[i]t is a common view among constitutional law scholars that we should abandon the idea of limits on federal power. We have become a unitary nation with an omnicompetent central government, and we should just admit it." Regan, 94 Mich. L. Rev. at 558 (cited in note 257). Similarly, Professor John McGinnis notes that "[w]ith the demise of any restraints on Congress's power under the Commerce Clause, federalism has passed away .... These enormous changes in the constitutional architecture in turn gave rise to the success of noninterpretivist theories of the Constitution, because Court decisions could no longer be justified on any plausible originalist grounds." McGinnis, 19 Harv. J. L. & Pub. Pol. at 256 (cited in note 256).

273. Professor Reynolds, for example, posits that "[t]he abandonment of commerce-clause limitations on federal power has led to greater special interest pressure, in no small part, because it has made the federal government more attractive to lobby" and that "delegation moves decisionmaking from elected lawmakers, subject to the electoral turnover effects outlined above, to unelected bureaucrats (or congressional staff) who are much more insulated from such effects." Reynolds, 48 Vand. L. Rev. at 1653 (cited in note 228). For Professor Reynolds, therefore, the commerce power and nondelegation doctrines are the chief contributors to the erosion of democracy in the United States, meaning that "to reestablish the necessary immunity" from political parasites, we must "restor[e] the very constitutional safeguards whose removal has led to the current problem." Id. at 1653-54. Professor Reynolds demonstrates that one objective of the constitutional design was to provide "structural means for dealing with the problem of 'factions' through federalism." Id. at 1644 n.30. Professor Reynolds's themes are echoed by environmental law commentators such as Bill Futrell, who observes that "[t]his focus on Washington fuels the proliferation of interest groups and increases the power of federal agencies .... It does not have to be this way." Futrell, *History of Environmental Law*, in Environmental Law Institute, *Sustainable Environmental Law* at 15 (cited in note 185). Similarly, Chief Justice Rehnquist has opined that the courts "ought not to shy away from our judicial duty to invalidate unconstitutional delegations of legislative authority solely out of concern that we should thereby reinvigorate discredited constitutional doctrines of the pre-New Deal era." *Industrial Union Dept. v. American Petroleum Inst.*, 448 U.S. 607, 686 (1980) (Rehnquist, J., concurring). See also id. at 646 (Stevens, J., plurality opinion) (observing tbat the statutory requirement that the agency establish worker chemical exposure standards which reduce harm "to the extent feasible," if not interpreted by the Court to require the agency first to make a finding of significant risk, "might be unconstitutional"); *American Textile Manufacturers Inst. v. Donovan*, 452 U.S. 490, 547-48 (1981) (Rehnquist, J., dissenting) (finding that the authority to decide how much chemical exposure risk to allow in the workplace is a " 'quintossential legislative' choice" which was "unconstitutionally delegated ... to the Executive Branch").

Professor Keith Werhan offers a compelling discussion of the way in which

> changes in the practices of federal courts with respect to their review of agency action have reinforced [a] transformation of the administrative process from the legal to the political .... These revisions ... challenge the traditional model of administrative law by compromising the role of the judiciary as guarantor of the legality and legitimacy of agency action.

Keith Werhan, *Delegalizing Administrative Law*, 1996 Ill. L. Rev. 423, 424-25. And Professor David Schoenbrod has proposed that "[l]awmakers should take direct responsibility for laws by each further reduction in the number of patches of power, and with each disconnection of couplings between those patches, we draw ourselves further from the edge of chaos and closer to a brittle, nonresilient order. While we may find comfort in the apparent predictability of that state, we will face an increasingly ominous threat of a major catastrophe.

C. Making the Long Jump to New Landscapes of Democracy

If it is too late to reverse the constitutional law doctrine and require a turnaround in this respect—a question which constitutional scholars no doubt will argue roundly after *Lopez* and *South Dakota*—it is certainly not too late for the federal government voluntarily to loosen its grip around democracy. Critics of the policy underlying *Lopez* and *South Dakota* decisions appear to believe, however, that a restricted commerce power and reinvigorated nondelegation doctrine threaten the formulation of effective policy, and hence they are unlikely to support a federally-induced relaxation of the status quo. But these criticisms fail to make the important distinction between the fitness of law and the policy of law. There is no inherent policy outcome embedded in the commerce power and nondelegation doctrine questions. Rather, those doctrines merely shape the environment of lawmaking. To be sure, as the commerce power and nondelegation doctrine expand and contract in scope, different political entities will play larger or smaller roles in setting policy, and the dose of democracy allowed to enter into that process will be different as the patchiness and coupling variables of the lawmaking environment change. But those effects do not necessarily dictate which policies will be chosen.[274]

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enacting them themselves. If they aren't sure what regulations to enact, they can tell the agency bureaucrats to hold hearings and make proposals." David Schoenbrod, *On Environmental Law, Congress Keeps Passing the Buck*, Wall St. J. A15 (Mar. 29, 1995). In short, it is no longer heresy to observe that the most potent force of adaptive, evolutionary change in the sociolegal system is put squarely at risk by our incessant reliance on more and more concentration of power in the federal administrative state.

274. Professor Richard Lazarus states the issue correctly when he explains that *Lopez* may affect "the *vulnerability* of laws, like the Clean Water Act, that have long enjoyed an expansive reading of Commerce Clause authority." See Lazarus, Envir. Forum at 8 (cited in note 269). Such laws may become vulnerable in the sense that their schemata and structure are based on a fitness landscape that no longer exists. Indeed, although polls overwhelmingly show broad support for the environment, see note 265, polls also show substnatial support for having state and local governments be primarily responsible for implementing that policy objective. See

So, what motivates the intense fear of a patchier, more coupled lawmaking environment—one in which democracy's force of change reigns with more potency? The mantra heard time and again in response to that question is that the states—presumably the beneficiaries of a patchier, more coupled context of federalism—will inherently compete with one another for economic domination, and thus will make poorer choices than will the federal administrative organism on questions of national policy significance. For example, the arguments given in the 1970s—and they were probably accurate at the time—in support of the statutory revolution in environmental law were that this so-called "race to the bottom" between the states would subvert any coherent environmental protection program for the nation, and hence federal domination of environmental protection policy is needed.[275] In order to make that federal domination possible, the argument goes, the commerce power must be interpreted expansively, and the nondelegation doctrine must be pushed aside to allow transfer of substantive policymaking authority to administrative agencies.[276]

The conclusion to this chain of reasoning for today's purposes is that because the administrative state has achieved measurable success in environmental protection, none of the mechanisms that brought it into being should be tinkered with, lest we spiral back into environmental Armageddon. The result is that today, "[s]o much political power has been reallocated to the federal government that, at times, the states could be mistaken for vassals of the federal government."[277]

Jonathan H. Adler and Kellyanne Fitzpatrick, *For the Environment, Against Overregulation*, Wall St. J. A12 (July 29, 1996).

275. See Richard L. Revesz, *Rehabilitating Interstate Competition: Rethinking the "Race-to-the-Bottom" Rationale for Federal Environmental Regulation*, 67 N.Y.U. L. Rev. 1210 (1992); Jerome M. Organ, *Limitations on State Agency Authority to Adopt Environmental Standards More Stringent than Federal Standards: Policy Considerations and Interpretive Problems*, 54 Md. L. Rev. 1373, 1388-93 (1995). There is plenty of reason to conclude that, "[l]ike civil rights law, environmental law hecame federalized only after a long history of state failure to protect what had come to he viewed as nationally important interests." Percival, 54 Md. L. Rev. at 1144 (cited in note 190). See also Dwyer, 54 Md. L. Rev. at 1221 (cited in noto 208) ("It is prohably . . . true that in 1970 most statos could not be relied upon to establish an adequate environmental policy."). Anderson, 26 Rutgers L. J. at 418 (cited in note 162) ("Federally mandated controls worked better than state discretionary controls hecause they were not subject to the competitive economic pressures facing states."). What was true then, however, may not necessarily he true today.

276. See Dwyer, 54 Md. L. Rev. at 1188-90 (cited in note 208).

277. Id. at 1185. This sentiment surfaced most pointedly in the 104th Congress under the banner of unfunded federal mandatos. See, for example, Unfunded Mandates Reform Act of 1995, Pub. L. 104-4, 109 Stat. 48, to be codified in scattered sections of 2 U.S.C. See generally Jerome L. Wilson, *States Need a Simple Guarantee of Rights*, Nat'l L. J. A21 (Feb. 13, 1995);

To be sure, the federal administrative state in the past has adopted measures that substantially improved the quality of life in many ways,[278] but the question is whether it remains the "fittest" sociolegal system for taking on the challenges of the future. Complexity Theory demonstrates that the schemata and structure that lift a species to the title of "fittest" in an ecosystem are temporal. Other species will respond, and evolve, and thus deform the former species' fitness landscape. In other words, the premises upon which the fittest species' schema and structure were based do not remain valid forever, and unless that species adapts to changes it causes in other species, it will be passed by eventually.

Even accepting, therefore, that the administrative state was at one time the "fittest" system for tackling the sociolegal problems of its day, there is every reason to believe that the premises upon which it was designed are no longer true. Through competition, cooperation, and coevolution, the other species in the sociolegal ecosystem have adapted to the federal administrative state: they have absorbed its policies, dealt with its problems, suffered at its hands, and prospered where opportunities arose. In other words, they have evolved. Indeed, the centralization of power in the federal government and coercion of state policy through that process—disguised as the so-called "delegation" of authority—may very well have facilitated an improvement in state environmental awareness and expertise.[279]

Advisory Commission on Intergovernmental Relations, *The Role of Federal Mandates in Intergovernmental Relations* (1996). As much as that perception may prevail with respect to the relation between the federal and stato governments in the United States, the degree of central control in environmental regulation is potontially far more pronounced in the relationship between the European Union and its member nations, where central "directives" encroach upon member nations' authority in ways which have been flatly declared unconstitutional in the United States. See James Pfander, *Environmental Federalism in Europe and the United States: A Comparative Assessment of Regulation Through the Agency of Member States*, in *Environmental Policy with Political and Economic Integration* 59 (1994).

278. See, for example, note 164.

279. See Dwyer, 54 Md. L. Rev. at 1223-24 (cited in note 208) (describing how federal legislation served as a template for innovative state programs, and how federal funding helped jump-start that process). This "education" of the states was promoted by the delegation feature of many of the federal environmental laws, under which implementation of the federal program could be assumed by a state if it agreed to a morass of conditions, restrictions, and oversight. See, for example, Adam Babich, *Our Federalism, Our Hazardous Waste, and Our Good Fortune*, 54 Md. L. Rev. 1516 (1995) (describing delegation under hazardous waste laws). I expect those who favor the federal dominance scheme may point to the delegation program as evidence that federal domination has not subverted state involvement to the degree I allege, but rather defines an aura of "cooperative federalism." See Percival, 54 Md. L. Rev. at 1174-75 (cited in note 190). As much as the delegation program has inculcated the states to environmental protection policies, however, the strings attached to delegation appear to stand in the way of them doing very much with that education. See Babich, 54 Md. L. Rev. at 1540 (cited in this

Thus, as the assembly rule principle of evolutionary biology would tell us, the evolution of state policy may not have been possible without the previous federal regulatory state phase. But perhaps now it is time the federal government let its children fly from the nest.

For example, today it is the case that the states with the strongest economies are those with the strongest environmental protection programs, which is contrary to the premise of the federal environmental regulation program.[280] In general, the states are widely regarded as the source of some of the most innovative, progressive, and effective environmental policies.[281] The states are far out in

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note) ("For states, [the] cooperative federalism program is part of a pattern of complexity that has generally prevented them from attempting significant innovation."); Organ, 54 Md. L. Rev. at 1376-93 (cited in note 275) (explaining that many states, partially in response to the complexity of the federal program, simply adopt the federal standards as the maximum state standard and leave it at that, thus suppressing any impetus to innovate); Oliver Houck and Michael Rolland, *Federalism in Wetlands Regulation: A Consideration of Delegation of Clean Water Act Section 404 and Related Programs to the States*, 54 Md. L. Rov. 1242 (1995) (explaining why the costs and complexity of delegation of federal wetlands protection programs have deterred states from assuming such authority, and calling for revisions that would provide the states greater jurisdictional authority).

280. See California Senate Office of Research, *Myths of Jobs vs. Resources: Environmental Protections and Economic Growth* (1996); *Analysis by California Research Unit Says Strong Rules Benefit Economy, Jobs*, 26 Envir. Rptr. (BNA) 2338 (1996); MIT Project on Environmental Politics and Policy, *Environmentalism and Economic Prosperity: Testing the Environmental Impact Hypothesis* (1992); *Study of Pacific Northwest Concludes Economy Aided by Environmental Protection*, 26 Envir. Rptr. (BNA) 1615 (1996); *Regulatory Reform: Analysis of Studies Says Strong Rules Benefit Economy, Jobs*, Daily Envir. Rptr. (BNA) D5 (Apr. 8, 1996).

281. One leading environmental law commentator goes so far as to say that "[o]ne need only look to America's own states—its environmental test tubes—for signs of important environmental goings on." Bud Ward, *The Train Moves On*, Envir. Forum 41, 46 (Nov./Dec. 1994). See also Henry N. Butler and Jonathan R. Macey, *Using Federalism to Improve Environmental Policy* 64 (1996) (arguing that states "will compete to offer residents better environmental quality"); John Pendergrass, *You Say You Want a Devolution*, Envir. Forum 8 (Nov./Dec. 1995) ("[M]any, if not most, of the best and most innovative ideas in environmental and natural resources protection have come from the states."); John Pendergrass, *A Rich History of State Innovation*, Envir. Forum 12 (Nov./Dec. 1995) (describing several of the ideas emanating from states which eventually became embedded in federal requirements applicable to all states); Robert L. Rhodes, Jr., *Where Do We Go from Here? Reforming U.S. Environmental Laws in Congress*, 26 Envir. Rptr. (BNA) 991 (contending that "state governments are more able to take on a large role in protecting the environment"); *State Cleanup Systems More Effective than Federal Superfund Program, Report Says*, 26 Envir. Rptr. (BNA) 982 (1995) (former EPA official contends "[s]tates are cleaning up contaminated waste sites 'at a fraction of the time and cost' of the federal superfund program"). Recently, in order to share with each other their innovations and successes, the states formed the Environmental Council of the States ("ECOS"). Mary E. Gade, the director of the Illinois Environmental Protection Agency and first president of ECOS, contends that "the environmental system that has given us unprecedented and extraordinary environmental progress to dato, is now outmoded and unable to meet the challenges ahead. And that is where the states come marching in—somewhat brazenly and clearly in lockstep." See Mary E. Gade, *When the States Come Marching in*, Nat. Resources & Envir. 3 (Winter 1996). Another step down the chain lies the role of citizens in enforcing and shaping environmental policy directly, which has been a powerful force under the citizen suit provisions found in many federal environmental laws. See David R. Hodas, *Enforcement of*

front of the federal government in programs dealing innovatively and effectively with such thorny issues as ecosystem protection policy,[282] growth management,[283] and nonpoint source water pollution.[284] Indeed, states often find the federal policies to be the source of the problems they must confront and of restrictions on their innovative solutions, as has been the case with remediation and redevelopment of contaminated lands.[285] And these themes are by no means limited to environmental law, as they are being played out today in a wide variety of fields that have come to be characterized under the federal dominance scheme.[286] The so-called race to the bottom has been

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Environmental Law In A Triangular Federal System: Can Three Not Be A Crowd When Enforcement Authority Is Shared By the United States, the States, and Their Citizens?, 54 Md. L. Rev. 1552 (1995).

282. See Douglas P. Wheeler, *An Ecosystem Approach to Species Protection*, Nat. Resources & Envir. 7 (Winter 1993); Sara Parker, *The CRM Approach: Protecting Missouri's Natural Heritage*, Nat. Resources & Envir. 10 (Winter 1993).

283. See George E.H. Gay, *State Solutions to Growth Management: Vermont, Oregon, and a Synthesis*, Nat. Resources & Envir. 13 (Winter 1993).

284. See M. Allison Hamm, *The Massachusetts Experience with Nonpoint Sources: Regulators Beware!*, Nat. Resources & Envir. 47 (Winter 1993).

285. See Mark D. Anderson, *The State Voluntary Cleanup Program Alternative*, Nat. Resources & Envir. 22 (Winter 1993); Anne Slaughter Andrew, *Brownfield Redevelopment: A State-Led Reform of Superfund Liability*, Nat. Resources & Envir. 27 (Winter 1993); Karen Hansen, *Minnesota's Landfill Cleanup Program: A New Superfund Paradigm*, Nat. Resources & Envir. 32 (Winter 1993); Elizabeth Glass Geltman, *Recycling Land: Encouraging the Redevelopment of Contaminated Property*, Nat. Resources & Envir. 3 (Spring 1996); John Pendergrass, *The Maturing of Cleanup Programs*, Envir. Forum 6 (May/June 1996); *Mayors Release Proposal on Brownfields; President Urges Support for Tax Incentives*, 26 Envir. Rptr. (BNA) 1871 (1996); *State Brownfields Redevelopment Law Scraps Strict, Joint and Several Liability*, 26 Envir. Rptr. (BNA) 1587 (1996) (discussing Illinois law). See generally Office of Technology Assessment, *The State of the States on Brownfields: Programs for Cleanup and Reuse of Contaminated Sites* (1995).

286. See Marshall J. Breger, *Government Accountability in the Twenty-First Century*, 57 U. Pitt. L. Rev. 423, 432 (1996) ("Recent years have shown innumerable examples of how devolution to the states and privatization have created not only more efficient government but one far more accountable to the public."). Project, *Federal and State Coordination: A Survey of Administrative Law Schemes*, 46 Admin. L. Rev. 391 (1994) (examining proposals for altering the federalism balance in fields such as aviation, housing, wetlands, job training, Medicaid, occupational health and safety, child support enforcement, disaster relief, and education of disabled persons); Dana Milbank and Laurie McGinley, *While Washington Fiddles, Many States Devise Solutions to Problems of Welfare and Health Care*, Wall St. J. A12 (May 31, 1996). Notwithstanding these numerous examples, the "race to tbe bottom" rhetoric, see note 175, has resurfaced as the principal response of entrenched federal and environmental interests against calls for devolution of environmental regulation authority to states, largely on the basis that the states' record falls short of perfection. See, for example, Vickie Patton, *A Balanced Partnership*, Envir. Forum 16, 17 (May/June 1996) (EPA official contends that "[s]tatos have made tremendous progress over the past quarter century in developing enhanced capabilities to protect local environmental quality. Nevertheless, there are still shortcomings"); Robert Housman, *The Devil Is in the Exogenous Variables*, Envir. Forum 32, 33 (May/June 1996) (attorney for environmental group says "[s]tato and local governments can serve as laboratories for finding and testing ways to achieve greater environmental protection while spending

replaced by a race to the top, with the federal government not only being left behind, but holding back the other competitors.

That being so, we should reexamine the schemata and structures of our laws. To the extent they are premised on the need for centralized federal administrative control and that need has been reduced or eliminated, laws based on those premises may not be fit for much longer. We have seen that the environmental quality problems facing us in the future are different than those we tackled through the federal regulatory scheme.[287] They are more ubiquitous and complex. They will cost more to solve at the margin. Solutions not permitted in the federal domination scheme may prove more fit, but we are hindered from reaching them while stuck in the local landscape of the administrative state and trying as hard as we might to keep it from changing below our feet. We need, in other words, to evolve, and to do so expeditiously through long jumps to new schemata and structures.

I hope it is understood that my point is not that we should return to some eighteenth century ideal of total state primacy—a strange attractor never intersects with its past. Indeed, it is interesting that at the same time calls for devolution of power back to the states are on the rise, the European Union countries, which started from an organizational structure much patchier than ever experienced in the United States, have gravitated towards increased centralization of environmental regulation.[288] There appears to be something to Professor Kauffman's thesis that the intermediate point between order and chaos, between patchiness and homogeneity, is where adaptiveness is optimized and we are naturally drawn.[289]

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less . . . . However, bear in mind that the overall record of the states in this area is mixed"). Presumably, these commentators expect us to agree that the record of the federal government is blemish free, or at least so much superior to that of the states that any talk of devolution as the course of evolution is folly. In any event, the question is a choice about the future and the long run, and which system will prove most adaptive. It should say something about the states' potential in that regard that they have proven so adaptive and innovative in the past decade even in the face of daunting federal domination.

287. See notes 166-67.

288. See Cliona J.M. Kimber, *A Comparison of Environmental Federalism in the United States and the European Union*, 54 Md. L. Rev. 1658 (1995).

289. In Bill Futrell's words, for example, there is every reason to believe that the sociolegal system's response to new challenges that face environmental law (and other areas of sociolegal policy)

> is actually aided by the American political system of divided powers, shifting interest groups, and private sector preference. Indeed, unexpected advantages in environmental protection accrue from our system of dispersed authority. Changing coalitions of interest groups will form around different issues in different sectors. While we have a government of separated powers prone to gridlock, we have a society of shared powers seeking consensus and renewal. Even when Congress and the Executive Branch are at a stalemate on a specific issue, the political mobilization of passionate new recruits, the

Hence, we need to shed our preconceived premises and devise completely new premises of federalism and democracy, redefining the roles of the various patches to fit the challenges of the future.[290] I believe simply that we will have a better chance of that evolution unfolding if we return to greater reliance on common law mechanisms of lawmaking and if we show greater respect for the original constitutional design when achieving policy goals requires more than the common law.

The difficulty in fulfilling that vision is that it will take more than just a wave of the wand—there is more to it than, say, having the Supreme Court overturn the decisions that led to the bloated commerce power and the puny nondelegation doctrine. Those measures are necessary, but not sufficient. I place great emphasis, for example, on the legislative creature being fitter than the administrative state, but I am not so naive as to believe that Congress in its present form is such a creature. Congress has decayed to a shell of its constitutional potential because it has fallen deeply into the reductionist trap of lawmaking and thus has devised rules of politics that perpetuate that structure. Congress is a part—some might say the source—of the problem. Reform measures dealing with campaign financing, committee structure, term limits, third party access, and the like need to be given serious consideration if we expect Congress to take back some of the responsibilities it has frittered away to agencies and exercise them adaptively. Similarly, the states, used to being vassals of the federal government and competing with one another for the scraps of federal entitlement and grant programs, must relearn

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> pace of experimentation in the states, and the search for new engineering solutions by industry work to erode the gridlock and assist the transition.

Futrell, *History of Environmental Law*, in Environmental Law Institute, *Sustainable Environmental Law* at 17 (cited in note 185).

290. Elsewhere I have argued, for example, that the complex problems associated with the protection of ecological biodiversity cannot be solved either through a federal domination or a state domination model. Rather, a system of shared power, with federal resources devoted te data gathering, goal setting, and performance measuring, and state authorities charged with the design and implementation of local regulatory standards, will work much more effectively in the long run. See Ruhl, 66 U. Colo. L. Rev. at 555 (cited in note 126). What I am proposing is far different from the "partnership" rhetoric prevailing at the EPA and other federal environmental agencies, which boils down to having the federal regulators take care to be more "sensitive" to the states' frustrations, but which does not include any fundamental redistribution of decision making power in its agenda. See, for example, Patton, Envir. Forum (cited in note 286) (EPA official); *Partnerships with State, Local Governments Envisioned By EPA, Regional Administrator Says*, 27 Envir. Rptr. (BNA) 364 (1996); Ira Michael Heyman, *Property Rights and the Endangered Species Act: A Renascent Assault on Land Use Regulation*, 25 Pac. L. J. 157 (1994) (Department of tbe Interior official).

what it means to behave as meaningful, responsible patches in a system, sometimes cooperating and sometimes competing. States must be willing, if they wish to avoid falling back into the race to the bottom that led to federal dominance in the first place, cooperatively to shed some sovereignty in order to address cross-cutting transboundary issues. Whereas now our options are national versus state politics, greater reliance on interstate compacts and other forms of regional organizations of states will be necessary in order to adjust the levels of patchiness and coupledness that are available for responding to each challenge.[291]

Reform of the scale I suggest may seem extreme, but it is not rocket science. We know how to do it, the question is whether we have the will to do it after so much investment in the "the system" as we know it. While leaving discussion of the exact scope and structure of these reform measures for another day, I have attempted in this Article to provide a nonideological, nonnormative basis in the form of Complexity Theory for recognizing that these kinds of reforms are necessary in order to achieve a fitter, more adaptive sociolegal system.

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291. One of the difficulties posed by the federal versus state dichotomy of environmental regulation is that those two levels of patchiness often prove ineffective for dealing with intraregional pollution issues. For example, recent efforts by the Federal Energy Regulatory Commission to deregulate the electric power generation industry have met resistance from northeastern states concerned that increased power generation will result in increased transboundary air pollution into their territories. See *State Officials Call for Federal Control of Air Impacts from Utility Deregulation*, 26 Envir. Rptr. (BNA) 2052 (1996); *FERC Rule Deregulating Electric Utilities Sent to White House Council on Environmental Quality*, 27 Envir. Rptr. (BNA) 259 (1996). For similar reasons New England states have opposed the EPA's relaxation of nitrogen dioxide emission levels for industrial boilers. See *New England Attorneys General Urge EPA to Impose Stricter NOx limits on Boilers*, 26 Envir. Rptr. (BNA) 2183 (1996); *New York Files Seventh Circuit Challenge to NOx Exemption Granted to Midwest States*, 26 Envir. Rptr. (BNA) 2248 (1996). For the evolution of environmental law to lead to significantly higher peaks, it may be necessary for it to break free of the limited options we perceive are available for structuring the system dynamics. See J.B. Ruhl, *Interstate Pollution Control and Resource Development Planning: Outmoded Approaches or Outmoded Politics*, 28 Nat. Resources J. 293 (1988).

V. CONCLUSION

The law must be stable, but it cannot stand still.[292]

What has impressed me most after writing this Article is that there are so many emerging bodies of thought from diverse disciplines which seem to be saying the same thing, but which do not appear to have spent much time discussing the subject among themselves. Stuart Kauffman, for example, with no legal training, has come to some strikingly profound conclusions about the American sociolegal system. Edward O. Wilson's assembly rules of ecosystems are perfectly suited to Professor Kauffman's model of coevolving dynamical systems. And after sifting through piles of legal commentary on the topics of common law, constitutional interpretation, and the changing environmental law, I have found that a growing body of legal theory is emerging which coincides uncannily with Wilson's and Kauffman's ideas without showing much evidence of having ever heard of them. All of these coalescing galaxies of thinking have been waiting, perhaps, for the organizing principles that Complexity Theory may offer.

The jury is still out on what Complexity Theory will deliver to science, law, and society. Maybe it offers nothing more than a new way of looking at familiar problems.[293] Even so, if all Complexity Theory does is prompt us to ask questions about the sociolegal system with new vigor, while offering no immediate answers, that is enough. But Complexity Theory, in my view, does offer answers, though not packaged in the reductionist boxes with which legal theory and legal institutions are used to dealing. Through Complexity Theory, we can gain a deeper appreciation of the need for allowing dynamic, unpredictable processes in the sociolegal system to prosper. Those who say "Stop the pendulum!" thus have it all wrong. It is the dynamical

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292. Roscoe Pound, *Interpretations of Legal History* 1 (1967).

293. Horgan contends that Complexity Theory "will not achieve any great insights into nature certainly none comparable to Darwin's theory of evolution or quantum mechanics. [It] will not force any significant revisions in our map of reality or our narrative of creation." Horgan, *The End of Science* at 226 (cited in note 11). But he concedes that Complexity Theory has "slightly extended the borders of knowledge in certain areas, and sharply delineated the boundaries of knowledge elsewhere." Id. The fact that Horgan devotes an entire chapter of his dissertation of the present state of science in the world to Complexity Theory suggests he is hedging his bets and that even he leaves open the possibility for more from Complexity Theory. I certainly do.

effect of the pendulum of democracy that allows a sociolegal system to adapt and evolve to its ever-changing environment.

Even knowing this, it is difficult to resist the power of reductionism inherent in the federal administrative state. It is comfortable, and comforting, to wrap ourselves in the blanket of centrally-dictated regulation woven in a simplified, easy-to-predict environment. All that we have learned from Complexity Theory, however, points in the direction of relaxing the grip of federal administrative control of the lawmaking process. It is as if Darwin has returned to remind us of the power of evolution. The question is whether we will listen before it is too late.