CHAOS, CLIO, AND SCIENTISTIC ILLUSIONS OF UNDERSTANDING*

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ABSTRACT

A number of authors have recently argued that the mathematical insights of "chaos theory" offer a promising formal model or significant analogy for understanding at least some historical events. We examine a representative claim of each kind regarding the application of chaos theory to problems of historical explanation. We identify two lines of argument. One we term the Causal Thesis, which states that chaos theory may be used to plausibly model, and so explain, historical events. The other we term the Convergence Thesis, which holds that, once the analogy between history and chaos theory is properly appreciated, any temptation to divide history from the rest of science should be greatly lessened. We argue that the proffered analogy between chaos theory and history falls apart upon closer analysis. The promised benefits of chaos theory *vis-à-vis* history are either fantastic or, at best, an extremely loose heuristic which, while retaining nothing of the considerable intrinsic interest of nonlinear dynamics, easily seduces the unwary into taking at face value terms and concepts that have a specifically precise meaning only within the confines of mathematical theory.

According to a recent torrent of books and articles,[1] the mathematical insights and techniques of what has popularly become known as "chaos theory" are said to offer either a promising formal model or a significant analogy for at

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1. Among the works promoting this view are: Alan D. Beyerchen, "Nonlinear Science and the Unfolding of a New Intellectual Vision," *Papers in Comparative Studies* 6 (1990), 25–49; C. Dyke, "Strange Attraction, Curious Liaison: Clio Meets Chaos," *Philosophical Forum* 21 (1990), 369–392; N. Katherine Hayles, *Chaos Bound* (Ithaca, N.Y., 1990); *Chaos and Order*, ed. N. K. Hayles (Chicago, 1991); Donald N. McCloskey, "History, Differential Equations, and the Problem of Narration," *History and Theory* 30 (1991), 21–36; George Reisch, "Chaos, History, and Narrative," *History and Theory* 30 (1991), 1–20; *Review* (Fernand Braudel Center) 15 (1991), Special Issue: "The 'New Science' and the Historical Social Sciences"; Randolph Roth, "Is History a Process?" *Social Science History* 16 (1992), 197–243; Michael Shermer, "The Chaos of History," *Nonlinear Science Today* 2 (1993), 1–13.

least some historical events.[2] Not surprisingly, the character of the claims historians and others have made on behalf of the benefits of chaos theory in assisting historical understanding differ considerably, for instance depending on whether a nonlinear ("chaotic") dynamics is held to be literally driving historical processes or whether it provides only a suggestive analogy for fashioning a new genre of historical narrative. In what follows, we examine a representative claim of each kind regarding the application of chaos theory to problems of historical explanation and narration.

Among historians, excitement surrounds the alleged "new science of chaos"[3] inasmuch as it appears to provide a vivid model or analogy which preserves the qualitative nature of historical narratives in the face of the typically overwhelming complexity of the events recounted.[4] The basis of the comparison between historical narration and some recent and highly interesting developments in nonlinear dynamical modeling is an alleged parallel between the extreme sensitivity to initial conditions of nonlinear dynamical (and classically deterministic) systems and the massively disproportionate effects of seemingly insignificant incidents on the events chronicled in certain historical narratives. Recall that a dynamical system[5] is said to be chaotic if the system shows "sensitive dependence on initial conditions," that is to say, even the slightest departure from literally "perfect" precision in ascertaining the initial values of the system's variables or parameters leads to a time evolution which becomes "chaotic," resulting in the breakdown of predictability in anything more than the very short term.[6] Modeling some historical sequences as chaotic "systems," then,

2. Historian Alan Beyerchen offers this enthusiastic evaluation. "There is every reason to believe," he declares, "that the westernized world is in the early stages of an intellectual transformation of major proportions, perhaps as significant as the emergence of the modern world view in the fifteenth through seventeenth centuries" (Beyerchen, 25). "Chaos theory" may be defined as the qualitative (i.e., geometric) study of nonstable aperiodic behavior in deterministic nonlinear dynamical systems; for a readable discussion of this definition, see Stephen Kellert, *In the Wake of Chaos* (Chicago, 1993), chapter 1. On the term "dynamical systems," see note 5 below.

3. Like other recent sexily-named scientific developments which have correspondingly been subjected to inordinate amounts of journalistic inflation (one thinks of the fad in the mid-1970s over the mathematically-related "catastrophe theory"), some promoters of "chaos theory" are quick to claim a new *Weltanschauung* or at least science lies in waiting for those adventurous enough to cast off the shibboleths of tradition. Among those knowledgeable enough to form a considered opinion, one (usually, not always) finds a more balanced appraisal; on catastrophe theory, see for example, V. I. Arnol'd, *Catastrophe Theory*, 3rd ed. (Berlin and New York, 1992), while for chaos theory, see Morris W. Hirsch, "Chaos, Rigor, and Hype," *The Mathematical Intelligencer* 11 (1989), 6–8. Both Arnol'd and Hirsch are mathematicians who are leaders in dynamical systems theory.

4. Sociologist Immanuel Wallerstein, for example, declares, "The object is to construct an interpretation of complex reality by surpassing the simple generalizations, interweaving them, and defining the degree of their relevance. Quantitative methods have intrinsic scientific limits. One does not move from naive qualitative methods to sophisticated quantitative methods; the path is precisely the opposite." (Wallerstein, "Whither Social Science?," *Review*, 6.)

5. A dynamical system is a system of first order ordinary differential equations studied "in the large," i.e., on a manifold where it is possible to "patch together smoothly" differentiation processes performed on various "local" objects. The basic mathematics of dynamical systems is thus the calculus and topology of differentiable manifolds.

6. It is with respect to such a system that "sensitive dependence on initial conditions" can be defined. That is, the change in the state of the system at a not-so-distant time t is some exponential function—a Liapunov exponent—of an infinitesimal change in the state of the system at an initial

provides not only an ostensible rationale for the unpredictability of historical events, but also an apparent explanation of why some of the great dramas unfolded on the world stage are but the causal unraveling and amplification of the slightest perturbations, fortuitous circumstances, or oversights that litter the course of human events.[7] The analogy straightforwardly suggests how historical "systems" could be both deterministic, that is, not random, and yet exhibit non-predictable behavior.

Enthusiasm over the prospects of chaos theory supplementing historical understanding coalesces on two theses. The first we term the Causal Thesis. This holds that chaos theory can be used to plausibly model, and so explain, causal relations for at least some historical events. As a modeling or structuring device, it is said to be more attractive than the regnant Newtonian paradigm of causal relations which is taken to require a roughly linear proportionality between cause and effect.[8] According to Alan Beyerchen, "It is no longer necessary for historians to explain away the fact that small inputs can produce disproportionately large effects, while large-scale inputs can generate diminutive results; violation of proportionality is actually part of the natural order inherent in any interactive, nonlinear system."[9] In short, license to conceive historical events as nonlinear systems does away with what Donald McCloskey refers to as "The [causal] Dogma of Large-Large"—the compulsion to seek only major causes of significant events.[10]

Imagining some historical occurrences as nonlinear "systems" also is taken to legitimate what we shall call the Convergence Thesis. The Convergence Thesis states that, once the analogy between history and chaos theory is properly

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time t_0 (i.e., corresponding to lack of absolute precision in determining initial conditions).The rapid exponential divergence of trajectories in state space initially very close to one another is often taken to mark a previously unthinkable fissure in the Laplacian dream equating determinism and predictability. In fact, even though a system may exhibit such sensitive dependence, not everything about the system is unpredictable; indeed, "finding what is predictable in a background of chaos is a deep and important problem," according to David Ruelle, a leading figure in this field. See his *Chance and Chaos* (Princeton, 1992), 81.

7. Hayles in *Chaos and Order* characterizes this branch of chaos theory in the following way. "The second branch emphasizes the hidden order that exists *within* chaotic systems. Chaos in this usage is distinct from true randomness, because it can be shown to contain deeply encoded structures called 'strange attractors'" (9). See also Dyke, "Strange Attraction," 376.

8. Shermer states that, for historians, "chaos theory provides a new perspective of how the past changes" (1). Randolph Roth writes that the "problem for social science historians . . . is that processual metaphors drawn from classical science still captivate us with their assurance that history is orderly, repetitive, systematic, and predictable. . . . Our empirical and quantitative models of process remain rooted almost exclusively in the mechanical worldview of the seventeenth century and in the organic worldview of the nineteenth century" (200). See also Roth, "Is History a Process," 214 and Dyke, "Strange Attraction," 377. Both Shermer and R. Roth cite with approval McCloskey's work on this point.

9. Beyerchen, "Nonlinear Science," 45. See also Dyke, 375.

10. McCloskey, 32. McCloskey confesses that the "common opinion of those educated in a rhetoric of linear differential equations is that large results must have large causes. Certainly in economics that opinion is powerful. I have made a living for twenty years retailing it, attacking again and again the notion that little causes in economic history can have large effects" (31). On this point, Dyke agrees (382).

appreciated, any temptation to divide history from (the rest of?) science should be greatly lessened.[11] The analogy is intended to reconcile conflicting intuitions that history is unpredictable and that the universe is law-governed. McCloskey, Beyerchen, R. Roth, and Wallerstein, among others, have placed particular emphasis on this point.

In what follows, we examine arguments for each thesis found in two recent essays noted above, namely those by George Reisch and Donald McCloskey.[12] Interestingly, and despite their shared enthusiasm for the prospects of exploiting the comparison between nonlinear systems and history, Reisch and McCloskey present narrativist historians with alternative, and seemingly incompatible, recommendations. Reisch concludes that narrative appears to be the only explanatory method applicable to chaotic historical systems. By "narration" Reisch seems to intend just the recitation of a series of events without much pretense of ascertaining how it is that one follows upon the other. Historical laws, if any there are, must remain conjectural, an eternally opaque black box. In this regard, Reisch provides a case for deciding whether the Causal Thesis holds the promise some think it does.[13] McCloskey concerns himself with both the Causal and the Convergence Theses, but counsels a rather different moral than does Reisch. For his announced interest lies in exploring an aspect of the rhetoric of historical representation. McCloskey champions the Convergence Thesis because he perceives utility in exploiting chaos theory as a structuring metaphor which historians and for example engineers might share when framing their respective accounts of events. Convergence results, he maintains, because both humanists and engineers can (and should) avail themselves of the same stock of metaphors—some formal, some not—in constructing their respective stories.[14]

Close scrutiny of the arguments of Reisch and McCloskey undermines the plausibility of both the Causal and Convergence theses. For Reisch, chaos theory licenses telling the historical story in a certain way; for McCloskey, chaos theory provides a structuring metaphor which we never know if we are warranted in applying. Prompted by these contradictory recommendations, our examination of each author's argument concludes that neither can sustain the desired appeal to chaos theory in furthering historical understanding.

I

Reisch's paper files a brief against covering-law history, *prima facie* a peculiar enterprise given his admission that "covering-law history has been rejected" (2). But for the purist, bad theories must be rejected for the right reasons, and previous critics have (understandably) harped upon the failure of historians to

11. See Shermer 10, 12–13.

12. Page references in the body of this essay are to their works which are cited in note 1 above.

13. Shermer cites Reisch approvingly (3) as showing that chaos theory makes the search for covering laws *passé*.

14. Beyerchen (45) and Wallerstein also support convergence. See as well, R. Roth (237), who cites McCloskey approvingly on this point.

find and formulate suitable laws in the Hempelian sense—which does not yield a knock-down argument. But such an argument, "a fundamental refutation," is possible if the unviability of the covering-law model of historical explanation can be derived from an *assumption* of covering laws, that is, if the assumption of such laws leads to a *reductio*. Granting then, for purposes of argument, that there are known covering *laws* in history, Reisch argues that one still could not construct a covering-law *explanation* for historical events. This is because "history is chaotic" and "it is characteristic of events in chaotic systems that they cannot be explained with covering laws and initial conditions" (2). Moreover, Reisch contends that his argument "against covering-law history is simultaneously one in favor of narrative" (2), more exactly, that "covering-law explanations must be resolved into narrative temporal structures" (18). Reisch's ironic conclusion is that, given laws appropriate to historical events, the historian has no choice but to narrate.

Reisch's argument may be reconstructed as follows:

(R) Assume for purposes of argument that historians possess covering laws. In particular, these are differential laws such that, together with a specification of initial conditions, it is in principle possible to derive correct predictions about *any* future state of the historical "system."[15]

(1) Historical processes and events exhibit "sensitive dependence on initial conditions."

From (1) it follows "by definition" that

(2) "history is chaotic."

Reisch then appeals to certain facts about chaotic systems, namely

(3) Classical chaotic systems are causally deterministic (no appeal is made to "quantum chaos"), yet because perfect information about initial conditions is practically unattainable, it is almost always not possible to predict accurately the course of causally linked events beyond a very short temporal throw.

Now historians cannot be better positioned than natural scientists to acquire information about a given (say, initial) state of a system of interest. Indeed, for historians, the problem here seems exponentially worse. The level of accuracy the laws demand simply is not available for events temporally far removed from us, and would be very hard to come by even now (a point on which McCloskey insists as well). "In the social sciences, not to mention traditional history, this accuracy is hard—and probably impossible—to come by" (17; see also 18). So, to (R), (1), (2) and (3) Reisch adds

(4) It is, in practice, extremely difficult, if not in principle impossible, for historians to obtain the requisite detailed and extremely accurate information about initial conditions which laws in chaotic historical systems require in order to forecast outcomes accurately.[16]

15. Reisch (4): "By a 'system' I loosely refer to some discrete natural phenomenon whose behavior is governed by, and can be modeled with, certain laws or principles."

16. "It is not the intricacies of narrative sentences or descriptive categories that cripple covering law history. The *coup de grâce* lies in the unattainable standards of descriptive accuracy we would have to achieve if we had all the tools we needed to begin the program" (17, fn. 17).

Now it is merely a matter of turning the crank:

(5) Without literally perfect information about historical initial conditions, covering laws in history—assumed (via 2) to be nonlinear—cannot correctly predict future states or outcomes of historical processes.

Finally,

(6) Since the Hempelian account posits a symmetry between prediction and explanation, historical covering laws cannot be explanatory. Even if there were covering laws, historians could not construct covering-law explanations.

Summarizing, Reisch rightly considers that the necessary requirement of exact knowledge of initial conditions to be too high a price to pay for Hempelian explanation. This situation, however, suggests an alternative:

the chaotic dynamics . . . impose a trade-off. If we want to explain the behavior of the system with large-scale general laws, that is, laws that causally connect temporally distant states of affairs . . . , we must pay a price: assuming we have these laws, we can only do so if we have exact knowledge of initial conditions. But with less than exact knowledge the temporal span of the laws we invoke must be sharply curtailed; they can only be used to connect proximate, if not contiguous, temporal states. (15)

A historian's task is to reconstruct the small-scale steps that did lead to the known outcome.[17] Such small-scale explanations, Reisch believes, may in the very short term fit the Hempelian mold. But beyond the short temporal interval, the system is chaotic. As an example, Reisch cites the market crash of October 19, 1987:

Because of the sensitivity to initial conditions . . . , events like Reagan's budget cuts . . . could never be linked via a large-scale covering law directly to the market crash. But they could be linked indirectly, by a series of . . . calculations which, while taking necessarily small temporal steps, model the effects of those causes as they move forward in time and eventuate in Black Monday. This, however, is an essentially narrative explanation: a scene by scene description of the particular causal paths by which events are realized as consequences of certain causes and conditions occurring in their past. (17)

Historians may still construct *causal* accounts, even in the absence of the complete knowledge of historical initial conditions required by the laws allegedly governing the system as a whole, by restricting their ambitions. That is, they must partition the time span over which putative laws act into "many small consecutive intervals or scenes" (18). Hence, while a full covering-law explanation is practically impossible, a limited, *narratively framed causal type of explanation* remains a live option.

For if puny and unknowable details do in fact play an essential role in some particular history, narrative accounts of that history need not have access to that detail. The

17. As Reisch remarks, "Assuming that historical laws are available, covering-law history therefore stands or falls with access to historical details that are generally inaccessible. And the only way that it can remain standing is to divide the time over which its laws purportedly act into many small consecutive intervals or scenes. That is, covering-law explanations must be resolved into narrative temporal structures" (18).

narrator can still describe and emplot events and the effects of that detail even though the detail itself and its causal power is not recognized. As a causal explanation the resulting narrative would appear, from some ideal vantage, to be incomplete or incorrect. But at least it would remain parallel and in step with events that actually occurred. (18)

This means, essentially, that "covering-law explanations must be resolved into narrative temporal structures" (18). This resolution does not deny explanatory power to covering laws. Indeed it retains a role for them in providing the "global" contours within which particularist narratives of causally-related events can be only-too-fallibly embedded (Reisch does not reject outright the suggestion [of, for example, "social force" or structuralist historians] that stable, long-term factors and trends influence historical processes. However, such historians typically "confuse *constraint* with *determination*" (8). Within the "envelopes" constituted by such constraints, "all kinds of things happen" (8). Constraints of this kind do not determine, to use an example of McCloskey's, the outcome of the Battle of Gettysburg. In a chaotic system, a seemingly minor happening in the proverbial heat of battle can determine the outcome. Thus, although the event *may* be determined, *we* cannot know in advance how things will turn out. The *appearance* of indeterminacy stems from the fact that, due to "puny and unknowable details," it is not really possible for us to integrate over all the proximate or contiguous temporal states treated in our "scene by scene descriptions" as the Hempelian account demands.

Reisch's case for this restricted conception of historical explanation thus appears to conclude:

(7) By describing linkages between events over "necessarily small temporal steps" (17), causal accounts of events can be constructed.

(8) Narrative explanations are just such small-scale tracings of causal paths by which events in the actual world came about.

But now, if one grants (7) and (8), it follows that the only way to do history is to offer narratives: "covering-law explanations must be resolved into narrative temporal structures." The final conclusion is:

(9) The only explanatorily adequate histories must be in the form of narratives linking the temporally adjacent or nearby events to be explained.

Chaos theory shows why the causal structure of history is too complex to allow for the form of causal account a Hempelian demands. For Reisch, then, chaos theory sustains the Causal Thesis inasmuch as it suggests that the Hempelian model represents an impossible ideal even if in principle correct. Historical narratives represent a reasonable compromise in the face of the problems posed by history *qua* chaotic system.

II

McCloskey's paper is ostensibly concerned with an understandable human (Humean?) frailty, a stubborn willingness to project metaphors of linearity, with

their ease of comprehension and imputations of control, onto parts of the world in which we are interested. In this regard, he points to a correspondence between the clean analytic solution to the engineer's ordinary differential equation and the historian's thematization of events in a manner that favors "simply predictable histories" (25). Engineers, economists, and applied mathematicians generally have been educated in what McCloskey calls "a rhetoric of linear differential equations" which teaches a dogma that "large results must have large causes" (31). Historians, not known for their applications of mathematics, have been differently educated under the same dogma. Now chaos theory makes it disturbingly apparent that many parts of the physical world are not linear at all. McCloskey's concern is how the different, if not *exotically* different, rhetoric of nonlinearity can and should transform how we think about historical narrative.

McCloskey maintains that requisitely detailed state descriptions and dynamical laws are impossible to obtain and not merely for events of the historical past. McCloskey reasonably doubts that we could gather information of the needed degree of accuracy even for present events in order to forecast the future (33). Moreover, he notes, it is not only difficult to identify if a system is chaotic, but also to identify correctly the relevant variations of state for such a system. Thus which events are to be explained, which causes are to be invoked in their explanation, and whether the composite system is linear or nonlinear, is not readily determined (33).

McCloskey, then, differs from what Reisch believes regarding how chaos theory might be applied. For purposes of contrast, McCloskey can be understood as holding, not to (3) above, but:

(3′) For many systems, or "parts of the world," there is no way of knowing what sort of model accurately characterizes the system in question. Hence, there is no way of knowing whether the system is linear or nonlinear, where the ratio action/reaction is not constant, and, if nonlinear, which small effects will induce large changes. (32–35)

(3′) results in McCloskey's *rejecting* the views of narrative Reisch promotes at (7)–(9). Specifically, McCloskey maintains the "problem (and this is the main point) is that in nonlinear parts of the world the idea of storytelling is cast into doubt" (33). For *if* the system is chaotic, "*any* of an unbounded set of little people and little events could be brought into the story" (33). If a kingdom is lost for want of a nail, then an account of the blacksmith's inattention—the bad meal that upset his stomach, his two-year old's dirty nappy, the distraction outside his shop at a crucial moment—all become causally relevant to the (not too distant) future state of the system. Every conceivable detail or variation affecting same, in turn, potentially acquires causal significance regarding defeat in battle and so any explanation of why an empire was lost. Obviously, if *any* detail, no matter how apparently picayune, has potential relevance in a causal account of what happened, then, short of Divine Omniscience, the claims of history to portray the past are just so much moonshine. Here, if anywhere, is a situation in which the historian's version of Gresham's Law might apply.

This point is posed as a paradox[18]: if the best causal story is that the event seems the result of a system exhibiting chaotic behavior, then a causal story is untellable (34). Interminable detail defeats not just efforts to apply laws, but attempts as well to isolate causally significant factors within the welter of events. For chaotic systems, recall, the slightest inaccuracy in the description of a state variable may completely undermine forecasting the system's evolution for the very near future. To this initial paradox McCloskey adds another, a paradox of foreknowledge: "If the patterns of chaos were so simple then the actors in the history would see them, and would eliminate them by making use of their knowledge" (36). If patterns are discernible, they are alterable. Yet, where there is no demonstrated ability to recognize, predict, and alter causal patterns, this is most likely to be due to complexity of detail overwhelming attempts to tell the story. So, McCloskey concludes:

(5') When a system is chaotic, there is no story (scientific or traditional) we can hope to tell[19] (unless, *per impossible*, we already know its structuring metaphor).

Contrary to Reisch, McCloskey concludes that whenever historical events are chaotic then they are *not* narratable as causal stories.[20]

If McCloskey and Reisch disagree in their assessment of the Causal Thesis, wherein lies for McCloskey a reason for maintaining that chaos theory has something to offer the historian? The apparent answer is that by stressing that both historians and scientists can avail themselves of formal models as metaphors for structuring the domain of phenomena which concern them, one reveals the availability of a common mode of discourse across disparate disciplines.[21] Extending this point, McCloskey then maintains that parallel complexities arise for the humanist as for the scientist when confronting chaotic systems. "Here I want to give another example, of how life gets difficult for the engineer and the historian when the differential equation does. The big difficulty shows up when the differential equations are 'nonlinear'" (25). What supports the Convergence Thesis, then, is the suggestion that humanists, too, can avail themselves of formal analogs. Moreover, McCloskey sustains the Convergence Thesis even though he questions (correctly, we suggest) whether one could ever know that a system is chaotic.

Yet, or so we will now argue, one cannot deny the Causal Thesis and save Convergence. If the Causal Thesis fails, one is left with no good reason for

18. At least, as McCloskey notes (34), for those who subscribe to the Dogma of Large-Large.

19. "Narration in a nonlinear world is difficult regardless of whether the problem is numerical or not. One does not avoid nonlinearities by not knowing what they are called. . . . [W]hen variables feed back into themselves, we have an exciting story to tell, but unless we know its metaphors already we have no way to tell it" (36).

20. McCloskey emphasizes as well the extraordinary difficulty in identifying the differential equations which model such systems. In either case, i.e., in terms of identifying the requisite data or the needed equations, solutions are not to be expected. Where there is no model, there is no organizing structure, and so no story to tell.

21. McCloskey, 25.

believing that chaos theory has some interesting application to historical analysis. It is to the reasons for this that we now turn.

III

In what respect has Reisch "refuted" the classic Hempelian account of historical explanation? Recall, in this regard, that the positivist account of explanation is not brought forward as an *option* with regard to explanation. Rather, positivists claim that the covering-law model characterizes what it is to *be* a scientific explanation, so that *any* scientific explanation properly so-called must conform to it.[22] Reisch acknowledges this but claims that his *reductio* decisively shows Hempel to be wrong in this regard.[23] But Reisch's argument seems to produce a result far short of this. All he establishes is that "scientific" history will be one that moves in small steps:

> covering-law explanations must be resolved into narrative temporal structures. *Then accepted laws or regularities can be used – explicitly or implicitly – to link adjacent scenes in such a way that they follow one another intelligibly, even necessarily.* (18, our emphasis)

Or again,

> Because of the sensitivity to initial conditions that the economy manifests, events like Reagan's budget cuts, tax cuts, and so on could never be linked via a large-scale covering law directly to the market crash. But they could be linked indirectly, by a series of syllogisms or calculations which, while taking necessarily small temporal steps, model the effects of those causes as they move forward in time. . . . (17)

Here Reisch's account gives rather more of a qualified endorsement than a denial of the applicability of covering laws to historical explanation. Moreover, once Reisch concedes the applicability of covering laws to any historical explanation, then his general point is undercut as well. For what precludes linking such micro-explanations into a large-scale covering-law explanation of just the sort that he denies is possible, especially if such a linkage is accompanied by the reasonable claim that it is fallible?

The difficulty is not just that Reisch's argument fails to justify his conclusion. Questions arise regarding the plausibility of his premises as well. In particular, consider his claim (1), that historical events are chaotic systems. Reisch defends his characterization of historical events by imagining counterfactual situations from "near possible worlds." Given his contrary to fact antecedent – if the world had been different in such and such a way – a certain outcome, different in a

22. Hempel is quite explicit about this in "The Function of General Laws in History" (and elsewhere). See his remarks in *Aspects of Scientific Explanation* (New York, 1965), 233, fn. 1.

23. "But these problems, I think, would not surprise Hempel. His was a call for scientific explanation in history as well as for research to secure the kinds of laws and generalizations that covering-law historians . . . could use. The fact that none have been produced does not prove that there will never be any. . . . but it has now been shown to have defects which render it essentially unable to fulfill the goals Hempel designed it to meet" (2).

historically relevant sense from that of the actual world, is alleged to follow. But this counterfactual approach simply assumes as correct the very point at issue. If one knew, in the actual world, what was causally necessary for things being as they now are, much of the debate on historical explanation would change. Questions of which events are causally related and how—what caused the Civil War, the Great Depression, the First World War—would cease to be matters of dispute.[24] We would know, that is, what information, if we but had it, would make a difference. *But we do not even know that much.* We do not know that much because—*per* McCloskey—we do not know the sort of systems with which we are dealing.

Contrary to Reisch, covering laws of the type assumed in (R) would identify the story worth telling, by indicating what differences might make a difference and what difference they would make. This would profoundly influence the construction of historical explanations. Absent such laws, McCloskey's point is well-taken. Our problem is that there are endless arguments over which causal story to tell. Chaos theory does not refine intuitions or clarify debate here; it simply aggravates and *sidetracks* the issue. The primary problem with historical explanation is not simply a lack of sufficiently fine-grained knowledge (though that may also be the case). The issue is how to determine what relates to what, and which events are causally significant.

Additional problems attend Reisch's assumption that historical episodes are the result of a nonlinear (chaotic) dynamics. He concedes that historical entities are not closed or isolated systems.[25] But then there is no clear sense to be made of the implicit assumption that historical systems are deterministic.[26] In closed dynamical systems (namely, those which include all interacting parts and hence can be considered to be isolated from further physical influence), the history of the system can be described by the graph of the values of its state variables in an abstract representation that physicists term a (generalized) state space.[27] Now the evolution of a closed system is deterministic if and only if there is one and only one possible path in state space consistent with the values of its state variables at any arbitrarily chosen time. Unfortunately, determinism so understood specifically does not encompass *open* systems, systems subject to unspecified (from the point of view of the dynamical laws) physical influences.[28]

24. For a skeptical assessment of our ability (or need) to disentangle causal relations in the social realm, see Arthur Fine's "Causes of Variability: Disentangling Nature and Nurture," in *Midwest Studies in Philosophy Volume XV*, ed. P. French, T. Uehling, Jr., and H. Wettstein (Minneapolis, 1990), 94–113.

25. "for the stock market, like most historical entities we care about, is not a closed or isolated system" (16).

26. Recall that the present discussion concerns only classical dynamical systems, not the alleged indeterminism of quantum mechanics.

27. A "generalized" state or phase space is a set of "points" which are ordered sets of real numbers $\langle x_1, x_2, \ldots, x_n \rangle$ and is denoted R^n. In the more familiar Hamiltonian formulation, phase space is always R^{2n} dimensional, each "point" being represented by n coordinates of position and n coordinates of momentum. For a "popular" account of the latter, see R. Penrose, *The Emperor's New Mind* (Oxford, 1989), 174–184.

28. Notorious examples involve signals (causal influences) allegedly propagating at superluminal velocities, such as are theoretically permitted in some non-special relativistic worlds. The foregoing

Reisch's support for (1) is simply a litany of anecdotes followed by the assertion that historical systems show the extreme sensitivity to initial conditions characteristic of chaotic systems. But "sensitivity to initial conditions" has a precise meaning: the state variables of the system have been identified and are measurable, and a dynamical law governing the system's evolution has been defined. To be sure, Reisch *assumes* knowledge of such a law for the purposes of his argument, in which case it would be perverse for the knowledgeable historians to be blind to the difficulty of strong initial condition dependence of their laws. But Reisch must and does acknowledge that such laws and their variables are not known.[29] Given this lack of knowledge then the phrase "sensitivity to initial conditions" has only a suggestive *metaphorical* sense which lacks the cognitive authority required to undergird the purported fact that "history is chaotic" (19; cf. 6, 7, 9, 13, 17, 18).

It thus appears that Reisch can offer no serviceably precise sense to the claim that history is chaotic. Yet even if he could Reisch's conclusion against the applicability of the covering-law model to historical explanations still does not follow. Rather, it would follow only if we retain intact the Hempelian symmetry between explanation and prediction, a tenet much contested in the voluminous literature on scientific explanation.[30] For the very systems Reisch invites us to consider suggest that the symmetry thesis can be modified and yet the essentials of the covering-law model retained. Indeed, some current trends in the study of chaotic systems lead precisely to this juncture. Literal prediction—in the sense of a direct solution for a nonlinear dynamical equation for an arbitrary time—is nigh impossible, given inevitable inaccuracies in the statement of initial conditions. However, a number of leading researchers in the field appear to believe that the behavior of such systems can be "imitated." Specifically, they are currently working to develop and perfect computer simulations of the temporal evolution of the relevant nonlinear dynamics in such complex systems as stocks and commodities markets,[31] Reisch's paradigm example of an unpredictable

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account is, we believe, the only serviceable definition of classical determinism in the literature. For details and criticisms of Laplacian determinism in the context of classical physics, see J. Earman, *A Primer on Determinism* (Amsterdam, 1986), especially chapters III and IX. Incidentally, it is unwarranted to link unpredictability in classically deterministic systems (so defined) *solely* with inaccuracies (slight or otherwise) in fixing the initial data of the system. For unpredictability, even in the face of perfect initial information, can arise due to the thermodynamical tendency of the "flow" of the system to "spread out" in phase space, though its volume (theorem of Liouville) remains an invariant over time. As a rule, the problem worsens the higher the dimensionality of the representing phase space. If we, for the moment, indulge the conceit of viewing historical happenings in terms of (surely, *very* high dimensional) classical dynamical systems, we can readily see that unforeseen outcomes need have nothing to do with imperfect initial information.

29. Of course, this fact does not entail, as Reisch insists, their nonexistence.

30. For an up-to-date survey of these and other objections to the covering-law model, see *Scientific Explanation*, ed. P. Kitcher and W. Salmon (Minneapolis, 1989) and, in particular, Salmon's long introductory essay, 47–49, and 59.

31. See W. J. Broad's article, "Swords Have Been Sheathed," *New York Times* (February 5, 1992), 2. For more orthodox attempts to harness chaotic systems, see, e.g., Elizabeth Corcoran's "Ordering Chaos," *Scientific American* (August, 1991), 96–98, and, more recently, the August, 1993 issue of *Scientific American*.

system. Whatever the success of these pioneering efforts, it is surely rash to reject on *a priori* grounds the extension of notions of explanation without prediction currently underway in nonlinear dynamical modeling.

This leads us to McCloskey. McCloskey, as noted in the previous section, worries whether historians (or others) can identify which systems are chaotic, on the assumption that some are. He suggests, *contra* Reisch, that if we had laws of such a system for social situations, inquiry would know how to proceed. But historians do not have the requisite models in hand:

> Are we in a nonlinear and even chaotic world and if so what can be done to go on telling stories in it? . . . If one already knows the laws of motion then the strategy of simulation . . . is fine. But it has difficulties for historical narration, where what we know of a metaphorical and model-building sort does not come usually with laboratory-fitted magnitudes. (34)

The alternative to model building is to inspect the evidence to decide what sort of system is manifest. But the evidence, alas, does not wear this answer on its face (34–35). Indeed, the problem is worse than merely guessing, for example, the order of a differential equation. "The problem is that a simple model with horse-kick randomness looks much like a wholly deterministic but chaotic model. You often cannot tell the difference between old-fashioned randomness . . . and new-fashioned chaos" (35). Even if systems are chaotic, we could not know which ones are.

What does all of this imply for historical explanation? McCloskey might object that he is concerned only with the rhetorical uses of chaos theory, and that this has no fundamental connection with concerns about historical explanation. Note that the metaphor, or better, *rhetoric* of chaos is alluringly linked to aesthetic, political, or even moral considerations: "Chaos pleases us . . . by reintroducing a sense of magic, a sense of many possibilities. Chaos . . . can lead to activism" (32). But any wish to hold chaos *qua* metaphor aloof from epistemic considerations cannot be sustained. If chaos theory is to provide historians with a structuring metaphor, then it—no less than the idea of linear causal proportionality ("Large-Large")—necessarily must bring certain epistemic (and possibly metaphysical) commitments in its train. The metaphor, we maintain, cannot sustain the weight of this baggage, and collapses. For McCloskey's conclusion—that chaotic systems overwhelm attempts to construct a causal story—runs up against the fact that even in cases where, *or so it seems*, small details did make, or would have made, a vast difference, historical explanations are readily fashioned. So if the purpose of chaos theory is to legitimate the metaphorical imputation of a certain type of causal structure, then it simply fails in this task. Lacking any means to establish that historical occurrences *are* chaotic systems, McCloskey only succeeds in suggesting the replacement of one dogma (linear proportionality) by another (nonlinear dynamics).

Consider an example McCloskey uses to illustrate his point. In the mid-1850s, matters were too complex to *predict* correctly or confidently, given what could

then be known, that America's "peculiar institution" was bound to end.[32] "The problem of chaos, then, is the problem of unpredictable and inexplicable behavior. . . . The problem is intrinsic to narrating human life" (36).[33] As a result, he concludes that we cannot explain what happens in systems too complex to allow prediction within the bounds of conceivably obtainable information.[34] However, McCloskey undercuts his own argument by citing explanations given by historians in order to provide evidence that explanations cannot be given for the events in question. He *retrospectively* dubs the period in question "chaotic" because the outcome, he maintains, was not predictable given what was known (or knowable) at the time. But this is no proof that the events are as he characterizes them, and there is no independent method anyone can give, as McCloskey himself is the first to admit, to establish what type of system the events instantiate.[35] *Thus, the suggestion that an analogy to chaos adds something to historical knowledge for such cases is simply idle.* While alert to many of the problems noted in Reisch, McCloskey still cannot separate his views on metaphor—structures for storytelling—from those attending vexed controversies surrounding the relation of explanation and prediction. In consequence, he puts himself in the awkward situation of offering what he counts as good historical explanations of certain events as evidence for his claim that some historical happenings are the outcome of chaotic systems, hence, on his own admission, are unnarratable.

Neither Reisch nor McCloskey is able to make good on their initial claims that chaos theory will illuminate important problems concerning how to account for events historically. Chaos theory does not appear to legitimate important new ways of thinking about the causal relations among historical events. And as goes the Causal Thesis so goes Convergence. Deep conceptual difficulties

32. Thus McCloskey also appears to be held captive by the symmetry thesis, that explanation is logically equivalent to prediction.

33. Here the lack of any distinction between chaos as structuring metaphor and chaos as form of explanation, and the tie of chaos to the vexed issues of prediction, is explicit in McCloskey.

34. "The point is not that great oaks from little acorns grow. . . . The right acorn is impossible to see before the event. . . . Any one of numberless acorns may be chosen by chance. Chance of this unconventional sort is similarly difficult to narrate" (28). Also: "In some counterfactual world the Civil War and its outcome might have been governed by big, simple, linear metaphors. . . . But if, as Fogel and McPherson and many historians before them have persuasively argued, the correct models for 1856–1865 are models of nonlinear feedback then the story becomes unmanageable, untellable. It is a paradox, beyond the common opinion of Large-Large. . . . What we can do is look for times that seem chaotic and be forewarned. That is what engineers do. In regions or times that seem chaotic they note the pattern of onset but do not otherwise try to predict the motion of the swirling water" (34).

35. A further difficulty is raised here by Dyke, who also takes seriously the suggestion that chaos theory adds insight to our understanding of historical events. He takes very seriously the precise issue which McCloskey slights, namely under what conditions may we plausibly assume that some historical event is a nonlinear dynamical system (see especially 379–389). Dyke's suggestion here is that the most plausible sort of system to consider in this regard is periodicities of the sort considered by the *Annales* historians—the *longue durée*. Thus, on Dyke's account, McCloskey's examples lack plausibility because they are not of sufficient historical time. It is interesting to note how Dyke's extremely cautious conclusion contrasts with his enthusiastic initial pronouncements (compare, e.g., 369 and 389–390).

are inherent in the apparently suggestive analogy between nonlinear systems and historical events. The promised benefits of chaos theory *vis-à-vis* history are at best an extremely loose heuristic which easily seduces the unwary into taking at face value terms and concepts that have a specifiably precise meaning only within the confines of mathematical theory. Outside of this context the use of these terms and concepts furthers tendencies to promote pseudoscientific "accounts" of the character of history, accounts which some of the more circumspect exponents of the "chaotic paradigm" in historical studies take some pains to eschew.

Beyond this threatening obfuscation, the primary intellectual issue joined by the promotion of the chaotic paradigm in historical studies seems to be spurred by desires to resist the tired hegemonies of "global" meta-narrative histories, whether by driving yet another nail in the coffin of the Hempelian covering-law model of historical explanation (an enterprise we thought was long ago *passé*), or by opposing the viability of structuralist or "social force" theories of historical determinism. While we sympathize with these latter aspirations, we remain decidedly skeptical that any truly beneficial assistance to metahistorical studies will be rendered by over-blown comparisons with the dynamics of nonlinear systems.

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