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CHAOS, HISTORY, AND NARRATIVE

GEORGE A. REISCH

In philosophy of history, logical empiricism has aged no better than it has in philosophy of science. While philosophers of history continue to respond to Carl Hempel's proposal of some fifty years ago—that history revise its methods and enter the big league of science proper—few, if any, earnestly wave the banner of "covering-law" history. While some, such as Arthur Danto and Maurice Mandelbaum, have tinkered with Hempel's deductive model of historical explanation and granted it some value, almost all reject the essentialist claim behind Hempel's proposal that, strictly speaking, the *only* explanation (scientific, historical, or other) is a deductive-nomological explanation. Louis Mink and Paul Roth, for instance, both endorse a pluralism in historical epistemology which holds that accounts of events need not answer to any singular and supreme model of explanation. But this pluralism has no particular fondness for covering-law history; the most general trend in recent philosophy of history has been to exalt the epistemic powers of narrative. Mink has called it "a primary cognitive instrument." W. B. Gallie and Robert Richards have even relegated covering laws and deductive explanation to incidental and justificatory roles in historical accounts. The real vehicle of historical knowledge, they maintain, is narration.

2. Mandelbaum and Danto both emphasize that only descriptions of events, not events themselves, can be formally entailed by general laws and initial conditions. Covering-law history does not therefore displace the historical work of describing and characterizing events so that their underpinning by generic causal mechanisms can be understood. See Maurice Mandelbaum, "Historical Explanation: The Problem of "Covering Laws,"" *History and Theory* 1 (1961), 233-238; Arthur Danto, *Narration and Knowledge* (New York, 1985), chapters 10 and 11.
4. Mink, 185.
5. The central function of deductive explanations, Gallie says, is "to enable us to follow a narrative when we have got stuck, or to follow again more confidently when we had begun to be confused or bewildered." W. B. Gallie, *Philosophy and the Historical Understanding* (New York, 1968), 107. Richards also takes them only to justify narrative explanations (or sections thereof) whose logic is essentially *post hoc ergo propter hoc*. "To explain something is altogether a logically different activity than to justify its explanation." Robert Richards, "The Structure of Narrative Explanation in History and Biology," forthcoming in *Evolutionary Biology and History*, ed. M. Nitecki (Chicago).
Covering-law history has been rejected. That is clear. What is less clear is the substance of this rejection. Various arguments against the viability of covering law history have, of course, been offered; the strongest of these (that I have run across) are Danto's—that descriptions of events which include future-referring sentences would be required to explain or predict events with historical covering laws (if they were available)—and this much simpler argument (recently reiterated by Anthony Flew): there are no historical laws. 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 (who cannot foresee the future) could use. The fact that none have been produced does not prove that there will never be any. Covering-law history may well be less desirable than narrative history, and we may not have useful historical laws. But it has not been shown to have defects which render it essentially unable to fulfill the goals Hempel designed it to meet.

In this essay I will attempt just such a fundamental refutation of covering-law history. I will describe an insurmountable obstacle that it faces, one that will come to light after I have granted (for argument's sake) just what the objections above deny—that perfect and precise laws of history are available (to quell the latter objection) and that these laws cover events exclusively in terms of available descriptive categories. A crystal ball, that is, is not required. Hempel hoped to make historical explanation more scientific; my argument will grant his program all the tools and laws it requires to become so. One question, however—one that Hempel's concern for "the methodological unity of empirical science" might have obscured, and one his historical circumstance certainly did obscure—is what kind of science should history become? For in recent years there has been a bifurcation of sorts in the natural sciences, namely, the emergence of chaos theory—the science of physical systems governed by nonlinear dynamical laws. In addition to explaining some rudiments of chaos theory, I will argue that any science of history should fall into this new branch of physical theory. For history, I will show, is chaotic. And, I will demonstrate, it is characteristic of events in chaotic systems that they just cannot be explained with covering laws and initial conditions as Hempel believed they could. In fact, this argument against covering-law history is simultaneously one in favor of narrative. For if one is determined to fashion a covering-law explanation of an historical event, success will come only, I will show, when that explanation's temporal structure has become essentially narrative.

I. HEMPEL'S PROPOSAL

The essay in which Hempel first detailed his account of proper historical expla-

6. Danto, 255–256. In notes 17 and 18 I discuss this and other arguments of Danto's in greater detail. 7. Flew intends to better Popper's refutations of historicism, but his claims apply equally to Hempel's covering-law history. He insists that "there neither are nor could be any inexorable laws of historical development; because there neither are nor could be any laws of nature determining the senses of individual human actions." Anthony Flew, "Popper and Historicism Necessitates," Philosophy 65 (1990), 63. 8. Hempel, 243.
nation, "The Function of General Laws in History," is well known. And I will continue to assume that these elements of covering-law explanations are familiar: covering laws, initial conditions, deduction of *explananda* from *explanans*, symmetry of prediction and explanation. What I will review, however, is a more subtle feature of covering laws as Hempel depicts them, namely, what could be called their "temporal scale." By this I refer to the length of time between initial conditions and the event to be explained and sometimes, additionally, to the time events or initial conditions themselves consume. Hempel says very little about this aspect of covering laws. It has, after all, little bearing on the logical structure exhibited by explanations of events, a structure which was Hempel's central concern. My argument, however, will pivot on just this question of temporal scale, so I will try to piece together Hempel's views on the matter.

A "universal hypothesis," he says, connects a cause and an effect each occurring at its own "place and time." One would expect, however, that historical covering laws would connect causes and effects which span a much greater time than that covered by physical laws—the kind Hempel upholds as ideal exemplars for history. Usually stated as differential equations, physical laws describe changes occurring only between contiguous instants of time; their application to longer, macroscopic phenomena require that they be integrated through time—the time of the events they explain. But the time of scientific events (especially the time in which a radiator cracks, to use Hempel's example) is generally much less than the time consumed by historical events in the lives of people, nations, and cultures. If there are laws that can "cover" historical events, it would follow that these laws govern processes that span years, generations, even centuries.

Hempel confirms this expectation when he mentions (evidently) Marxist contentions that "economic (or geographic, or any other kind of) conditions 'determine' the development and change of all other aspects of human society." He reminds us that such assertions "[have] explanatory value only in so far as [they] can be substantiated by explicit laws which state just what kind of change in human culture will regularly follow upon specific changes in the economic (geographic, etc.) conditions." But laws which connect changing economic or geographic conditions with changes in human culture would surely act over spans of time at least as great as those in which such gradual changes unfold. And Hempel seems to believe that such large-scale laws might someday be available, for he remarks, "the elaboration of such laws with as much precision as possible seems clearly to be the direction in which progress in scientific explanation and understanding has to be sought." The impression Hempel gives is that if historians knew such laws, most of which would come from the social sciences, then they would be fully equipped to practice covering-law history.

What I will show, however, is that this feature of covering-law history, that is, its anticipated use of laws or "universal hypotheses" which connect temporally distant or temporally diffuse causes and effects, runs up against a feature of his-

tory itself, namely, its chaotic nature. After looking at some details of chaos theory and after considering why history should be thought of as chaotic, we will be able to appreciate the specific character of the problem covering-law history faces.

II. CHAOS AND CHAOTIC SYSTEMS

What follows is a primer on chaos theory, so I must define some terms. 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. These are all such systems: a simple pendulum; an island colony of organisms whose population in any given season is a certain function (given below) of the previous season's population; the particles of smoke rising from a cigarette or a candle in a windless room. Depending on the nature of the laws (or, equivalently, the "dynamics") which govern a system, its evolution or behavior through time will be, generally, either chaotic or non-chaotic. The pendulum's behavior is not chaotic; the island colony's is chaotic; and cigarette smoke vividly illustrates both kinds: the smooth and slender stream of smoke particles rising from the cigarette evolve non-chaotically. But the eventual mushroom of smoke in which particles swirl every which way instantiates chaos. And by the "state" of a system is meant a (usually) quantitative description of the system or its constituents at a particular time. State descriptions of these three systems could be, respectively: the instantaneous position and velocity of the pendulum; the number of organisms; and the instantaneous position and velocity of every particle of smoke in that room.

The definition and hallmark of "chaotic" behavior is just this: if the state of a system typically turns out to be very sensitive to its earlier states—one of which could be called the system's "initial condition"—then that system is chaotic. This sensitivity to initial conditions is easiest to appreciate if we forget momentarily about the different physical or biological dynamics of these examples. Since the state of a system is usually represented numerically, we can best appreciate chaotic behavior by looking at a generic, numerical example. Consider, for example, a simple input-output machine into which we place a number (that is, an initial condition or initial state) and from which, say, an hour later, we receive a number back (that is, a final state). The final state is determined according to some equation, some numerical rule or law, that is programmed into the machine. It takes the input number, inserts it into this equation, and computes a new number. Then it repeats the same operation with the new number to compute a third, and uses this third number and the same equation to compute a fourth, and so on. After an hour, the machine stops calculating and gives us back its current number, that is, its final state. Imagine we are presented with both such a machine and this question: do the numbers it churns out exhibit chaotic or non-chaotic histories?

We can answer this question just by examining several pairs of initial and final numbers. Imagine we put in "10" and receive, an hour later, "595." And then
we enter "20" and receive "607"; and "15" yields "603." It looks as though initial conditions of roughly "15" will produce final states around "600." Suppose we also found that initial conditions around "100" consistently evolve to final states more or less near "2000" and that similar clumps of neighboring initial conditions take the system to corresponding neighborhoods of final states. In this case, the final states do not appear to be very sensitive to initial conditions: slightly altering initial conditions only slightly alters the system's final states. The numerical histories the machine produces, therefore, are not chaotic.

But suppose after putting in "10" and receiving "595" we put in "11" and received, an hour later, "480." And suppose that entering "9.8" yielded "1342"; and "9.9" yielded "50." This kind of behavior indicates that the system's numerical history is chaotic: small differences among initial conditions produce very great differences in its final states; or, conversely, the machine's final states are extremely sensitive to its initial conditions. Figure 1 visually represents this relationship between initial and final states in both cases: for non-chaotic systems, small differences among initial conditions yield small differences in final states. But with chaos, small initial differences typically give way to very great differences among final states.

This abstract feature of physical systems qualifies them as chaotic. In the cigarette example, consider two particles of smoke originating from nearly identical places in its burning tip. As they rise through the initial smooth column they remain neighbors, as we would expect, sharing very similar velocities and positions at each moment of their journey. Here, similar initial conditions yield similar final states; the dynamics governing the smoke's journey are not chaotic. But when the smoke begins to billow and spread, the underlying dynamics have changed: they have become chaotic. Now those two particles will eventually take very different courses through the room, despite their nearly identical histories.
up to that point. The tiny differences in their initial positions and velocities yield drastic differences in their final (or just later) states once the dynamics of the system become chaotic.

A simple pendulum, on the other hand, does not behave chaotically. No matter what the differences in the direction or violence with which we set it moving, it will eventually come to rest in precisely the same (trivial) state—hanging motionless. Here, final states (and there is only one) are utterly insensitive to initial conditions. If friction were absent, these initial differences would remain manifest. But they would not cause nearly identical state histories to diverge and become radically different.

Chaotic behavior, it should be emphasized, is determinate and law-governed. Here, "chaotic" does not mean "random" or "given to chance" as if events were understood simply to occur without cause. Chaotic systems may look as though they evolve randomly, but they are still governed by laws—mathematical laws in the case of the input-output machine, physical laws in the case of the smoke particles. It is just the sensitivity of final states to initial states—given their determinate connection—that is captured by the term "chaotic." My argument that history is chaotic, which I will make shortly, will assume similarly that historical processes and events are ultimately underpinned by, or supervene on, causal physical mechanisms. And it also admits that we may even discover high-level historical or social-scientific laws of the sort that Hempelian history requires. I will not therefore be suggesting that covering-law history is impossible because history is random, indeterminate, or "chaotic" in that sense.

III. HISTORY AND CHAOS

One beauty of chaos theory is its generality, its concern with the general and global features of systems as diverse as cigarette smoke, the weather, and (as we will see later) biological populations. And, I suggest, it does not distort the technical meaning of "chaos" too much to understand history and everyday life as being chaotic, either. My life—and I bet most others—has been pretty chaotic, for its present "state" was facilitated by a particular chemistry of factors and events. And had this chemistry been just slightly different, it almost surely would have launched me down some other road. If my dormitory neighbor at college had not on that day happened to mention that "interesting, but weird" philosophy of science course she began taking, and if I had not wanted to take the ever-popular abnormal psychology seminar which—my being a lowly sophomore—left me in need of a course, I would probably still be timing white mice running through mazes, or (preferably) flipping burgers, and, in any case, I would not now be particularly concerned about the structure of historical explanation. And who knows what today's unplanned encounters or the whimsical decisions I make tomorrow (before morning coffee) will bring in another ten years.

Just as my history is chaotic, so too is history in general. "For want of a nail . . . the kingdom was lost" goes the familiar story of chaotic history. Consider for example what the world might look like today if a person only slightly more
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As combative than Khrushchev had been at the Soviet helm during the Cuban missile crisis—certainly very different if nuclear war had ensued. Pascal probably performed a parallel thought experiment when he mused “Darwin” not being an (almost) household name if circumstances had not led to his famous voyages, just as the “Father of modern philosophy” might well have been sterile, so to speak, had Descartes and Isaac Beeckman not chanced to stop together on a certain Dutch street to mull over a mathematical problem described in a contest advertisement.

If, as Carlyle believed, history is just “the essence of innumerable biographies,” then it is clearly chaotic. For the way the effects of minor and at first insignificant events propagate through time, eventually shaping the very cast of life, is most vivid in individual lives. We have, after all, a privileged epistemic position in our own lives. We know what we say and do, and we can observe its effects on ourselves, others, and our surroundings. Just as we can know the mathematical operations in our chaotic input-output machine and can see for ourselves—with a pad and pencil—the way that the 0.1 separating 9.9 from 10 grows more and more with each iteration to produce very different final states, so we can see our own particular histories shaped by certain chance encounters and singular decisions that we would otherwise simply forget. We may not know exactly what laws of physics, psychology, or society govern our experience, but we can still be sure that our experience is chaotic. Even in the course of a day, the mere six or eight extra minutes I took this morning to heave myself out of bed, for instance, is analogous to that all important 0.1: I was not six or eight minutes behind my usual daily schedule, for I missed the bus and got to work an hour late!

But history is more than biography. We read and write histories of races, of nations, corporations, ideas, and ecosystems. And in these arenas we lack this intimacy with causes and their effects, an intimacy which helps legitimate my use of this technical term—“chaotic”—to describe something—life—which is not a scientific system. It is therefore more difficult to argue that history is chaotic when history is understood in these larger senses. While I am sure that sufficient conditions for my present vocation were laid by that one conversation with my dorm neighbor, I cannot be sure, for instance, that Khrushchev’s particular temperament during the missile crisis was as tightly related to the fact that we have

12. Beeckman stimulated Descartes’s early researches into mechanics and other topics. As Dan Garber suggested to me, had Descartes not met Beeckman he would have been recorded by history, if at all, “probably as a military engineer of no great distinction.” Their meeting is mentioned by C. De Waard in his introduction to Beeckman’s Journal (The Hague, 1939), xii.
13. 150 years ago Carlyle depicted history as a turbulent, chaotic flow of events: “let any one who has examined the current of human affairs, and how intricate, perplexed, unfathomable, even when seen into with our own eyes, are their thousandfold blending movements, say whether the true representing of it is easy or impossible. Social Life is the aggregate of all the individual men’s Lives who constitute society; History is the essence of innumerable Biographies.” Thomas Carlyle, excerpted from “On Heroes, Hero-Worship, and the Heroic in History” in The Varieties of History: From Voltaire to the Present, ed. Fritz Stern (New York, 1957), 93.
not seen World War III. Maybe he had been anticipating this encounter with the U.S. for years and had decided long beforehand just how far he would go to get missiles based in Cuba. Even more damaging to my argument is the possibility that his particular actions during the crisis were just expressions of larger and more stable social and economic forces whose particular strength and direction were insensitive to his idiosyncrasies. On this view it might not even have mattered if the Kennedys, Khrushchev, McNamara, and the rest were the principal actors in the affair. Had others been in their places subsequent history might not have been significantly different.

Perhaps the structuralists are right. Perhaps history is shaped not by individuals and all their idiosyncrasies but rather by environmental, economic, social, and even ideological structures, such as those of Braudel's *longue durée*: "As hindrances they stand as limits ('envelopes,' in the mathematical sense) beyond which man and his experiences cannot go. Just think of the difficulties of breaking out of certain geographical frameworks, certain biological realities, certain limits of productivity, even particular spiritual constraints: mental frameworks too can form prisons of the *longue durée.*"14 Along these lines one might reason that even if Darwin never did get to sail on the Beagle someone else would have sooner or later discovered natural selection. In fact, someone did, and we might therefore speak of the "Wallacite" theory of evolution. And, we might think of "Hobbesian atomism" in much the same way we think of "Cartesian physics." Perhaps, structuralism suggests, history is actually quite insensitive to the ripples on its surface, to the particular details of historical circumstance, and that history, therefore, is not chaotic at all. Other celebrated instances of simultaneous discovery in the history of science might suggest the same, as might Karl Jaspers's "axial period" theory which interprets cultural developments in China, India, and the West as similar, and their temporal proximity as no mere coincidence.15 Other suggestive examples could surely be brought in, but I think for a number of reasons my claim that history is chaotic is nonetheless sound.

First, while there is an appealing simplicity and elegance to this notion that certain social and economic structures will hold sway over the details of historical situations, there are, I think, some falsehoods buried under some of its truth. There should be little doubt, for instance, that the course of historical events is constrained by social, economic, technological, and other factors. But the mistake structuralism makes in rejecting *l'histoire événementielle* is to confuse constraint with determination. As Braudel suggests, geographic, economic, social, ideological, and other sorts of structures surely limit historical and future possibilities for any given people. But within those "envelopes" of possibility all kinds of things happen. Descartes's physics, for instance, is actually quite different from Hobbes's even though they are both captured under "seventeenth-century cor-

puscularism." Such differences alone justify nonstructuralist historical narratives which discern for us what actually obtained within structural constraints. And the subject matter of those narratives, again, is typically chaotic.

But history—writ large—is still chaotic, despite the strength of the social and economic forces that help shape events. For histories etched within structural parameters can overflow those boundaries, affecting the very character of the supposedly primary forces that channel events. If, for instance, a slightly altered mood of one of the actors in the missile crisis had precipitated a third world war, then it is quite likely that subsequent history would have flowed through different economic, ideological, and geographic constraints. After all, structures in history not only affect but are affected by events coursing through them. Obviously not just any pin-drop can literally change the demographics of the world as would the one that precipitates a nuclear war. But there are times when circumstances and their inherent possibilities give rise to very unstable situations whose outcomes are selected by what might seem at the time the most trivial of factors. And it is just that feature of the historical world which qualifies it as chaotic. Often enough, the state of the world is hypersensitive to the conditions of its past. Or, put differently, the present might well be wholly different if the past were just slightly different.

Of course I cannot demonstrate that history is chaotic in the same way that we decided our input-output machine was. There we could start the machine over, slightly change its initial condition, and see the drastic differences that resulted among final states. But we cannot roll back time, get Cleopatra to a plastic surgeon, and set the gears in motion again to see if the shape of her nose was as determinative as Pascal thought, or, if it was just a truly insignificant detail—a bit of noise, we might say, among historical events. The subjects of histories do not constitute isolated systems, and even if they did their histories are not repeatable. But I will stand by the claim nonetheless, for I am only applying a technical term to highlight what is an obvious feature of history: the way particular factors and events come together in just the right proportions to realize their end. This is the very thing that can make history so captivating. A good history, after all, is a good story which surely, but delicately, weaves its way from beginning to end, or as I am describing it, from initial conditions to final state.

**IV. CHAOS AND HISTORICAL EXPLANATION**

Now we can consider just what constraints are placed on historical explanation by this feature of history. To this end, I will construct an example of a chaotic system whose historical evolution will contain some noteworthy event which can and should be explained. But given the two general styles of explanation that philosophers of history have debated, namely covering-law history on one hand and scene-by-scene narration on the other, I will show that only the latter is up to the task. And this is because of the chaotic quality of history.

The system is an animal colony on an island which is ideally isolated except for the arrival of a hard-working graduate student who sets up camp to study
the seasonal population history of these animals. Since one of the central difficulties with Hempel's proposal is our lack of laws and generalizations that might actually be used to cover historical events, this example gives Hempel the benefit of the doubt. Since these animals' ambitions are to eat, sleep, and reproduce (probably not in that order), they manifest hardly any of the intricacies of more conventional historical subjects. All our student needs to know is how many animals there are each season. And, he knows the laws that govern their season to season variation. From prior study of these animals, we will say, he has induced a specific pattern in their reproduction habits: other things being equal, if there are X of them one season (X being more than one, of course) there will be 4X the next. And, as Malthus knew, such proliferation will be checked by limited resources. So, prior research has shown that the island can support at any one time no more than some number \( X_{\text{max}} \). Therefore we can scale all our population numbers down to more convenient numbers \( P \), ranging from 0 to 1, defined as

\[
P = \frac{X}{X_{\text{max}}}
\]

so that \( P(\text{season } s) \), or \( P(s) \), will equal 4\( P(s-1) \). Or, what is the same,

\[
P(s+1) = 4P(s).
\]

But there will be deaths, disease, and maybe territorial fighting—all of which will decrease the population. Assume the number of deaths occurring during any season has been accurately modeled. It is equal to four times the square of this number \( P \). The law that governs the season to season population of these organisms is therefore

\[
P(s+1) = 4P(s) - 4P(s)^2
\]

or, in simpler form

\[
P(s+1) = 4P(s)(1 - P(s)).
\]

This expression, granting as we are that it governs the population dynamics of these animals, can function as a covering law of just the sort Hempelian history requires. It mathematically connects initial states and final states just as the law "all copper conducts electricity" logically connects initial conditions—"this wire is made of copper" for instance—with an outcome which is thereby explained—"this wire conducts electricity." Knowing \( P(s) \) and this expression, our graduate student can similarly explain why \( P(s+1) \) was in fact what it turned out to be; or he could predict what \( P(s+1) \) would be beforehand. For example, if one season's \( P \)-value is 0.25 and the next's is 0.75, he can explain the occurrence of that later value just by plugging 0.25 into the population law: four times 0.25 is 1, times (1 - 0.25), or 0.75, equals 0.75—Q.E.D. And if challenged to predict the next season's population, the same procedure will produce a prediction.

By repeating these calculations, any two states of the system can be connected in this way. In fact, on the basis of just one \( P \)-value and this population law the entire future population history of the island can be calculated. This population
law, in other words, is a flexible covering law, capable of causally connecting any two states of the system, regardless of their temporal distance. Any $P(s)$ in conjunction with the expression constitute an *explanans* and any $P(s+n)$—where $n$ is any positive integer—can be an *explanandum*.

So, our student sets up camp and sets out to describe the initial population condition of the island. He tags and tags and counts and counts and finds that the island has 676 of these animals, out of a maximum value of 1000. So his first $P$-value, $P(0)$, is 0.676. Soon, the next season is upon him and he counts $P(1)$, and the next he counts $P(2)$ and so on, and so on. As his population history grows, he finds that the populations are pretty erratic, jumping around from season to season. But then "an historic event" occurs. After season 30 the population plummets, only a few animals remain, and the colony narrowly avoids extinction. Over the next few seasons, however, these survivors slowly build up the population and eventually things are back to normal. The population history and this event is depicted in Figure 2.

Like any good scientist, our naturalist's first impulse is to explain this striking event. There is certainly no obvious feature of the population law that would suggest such population decimations should occur. Maybe, he thinks, there is something going on that the theory ignores. So, like a good Hempelian, he tries
OBSERVED AND CALCULATED P-VALUES

**Figure 3**

The continuous line represents an attempt to "cover" the population drop with the population law and the initial condition $P(0) = 0.676$. If the line coincided with the plotted points, the observed history would be perfectly explained.

to "cover" and explain the event with his theoretical machinery. Out comes the trusty lap-top, programmed to calculate P-values according to the population law, and into it goes the initial condition he observed some thirty seasons ago, $P(0) = 0.676$. He obtains the theoretical population history shown in Figure 3 where it is superimposed on the observed population history of Figure 2. Muttering something about "going to law school after all," our graduate student is stumped. This calculated history of P-values looks hardly anything like the actual history he spent a large chunk of his life constructing! Not only is there no such population dip where he observed it, there is no such extended population dip at all. For the first several seasons, this theoretical history and the actual one coincide. But beyond season 6 or 7 the two are wholly different.

The problem is this: the law which governs the population history of this island gives rise to chaotic behavior.\(^\text{16}\) Final states are extremely sensitive to initial conditions, and we are now in a position to see precisely how this happens. The culprit is the "$P(s)$" term in the population law. If, without this term, the law

\[^{16}\text{This relation and its use for modeling population dynamics is borrowed from Leo Kadanoff, "Roads to Chaos," Physics Today (December 1983), 46–53. Also, for certain P values (namely 0.75) the subsequent populations generated by this relation are constant.}\]
were \( P(s+1) = 4P(s) \) then subsequent \( P \)'s would not be so sensitive to earlier \( P \)'s. For example, if \( P(1) = 1 \), then \( P(15) = 4^{15} \). And if \( P'(1) = 1.001 \), then \( P'(15) = (1.001)^{4^{15}} \). In this case, the relative size (or ratio) of the final \( P \) values—as big as they are—is the same as that of the initial values:

\[
\frac{P'(15)}{P(15)} = \frac{4^{15} \times 1.001}{4^{15}} = 1.001 = \frac{P'(1)}{P(1)}
\]

But because of the \( P(s)^2 \) term, the ratio of final \( P \)'s is changed by these iterations and it will not remain equal to the initial ratio. Consider the behavior of the equation \( P(s+1) = P(s)^2 \) in this regard with the same initial conditions:

\[
\frac{P'(15)}{P(15)} \approx \frac{1.3 \times 10^7}{1} \neq 1.001 = \frac{P'(1)}{P(1)}
\]

Here, this residuum of 0.001 folds into, and is amplified by, each iteration. So after 15 seasons the ratio of final \( P \) values loses all similarity to that of the initial values. It is all in the exponents: if they are greater than 1—that is, if the dynamics are not linear—then chaos will eventually set in.

For just this reason we could have concluded that our input–output machine was programmed with a nonlinear equation, one which took those small differences among initial numbers and, by repeated iterations, amplified them so curiously. Similarly, we can conclude that the laws that govern lives and history are nonlinear.

"Aha!" yells our naturalist. "My population law is nonlinear. It's no wonder these populations have been jumping around as if at random. And since my observed and calculated histories initially coincide and eventually become completely different, there may be some inaccuracy in my initial condition that's preventing me from modeling the actual history." That is, he must have counted wrong that very first season. "But it couldn't have been by much, just one or two," he guesses. Setting \( P(0) \) at 0.677, he calculates a new history, shown in Figure 4. But again, the calculated history only coincides with the observed one for the first few seasons. "Maybe I overcounted by one, these critters are just about identical," he says while setting \( P(0) \) at 0.675. Bingo! There is the observed dip, at just the right season, as shown in Figure 5.

The anomalous event is explained by the theory after all. No extra factors need be hunted down, no diseases, no sunspot effects or what have you need to be folded into the population law. It correctly explains the observed population history, but only when the initial conditions are known exactly. This is the crux of the matter: for Hempelian explanation to work here, because the law the system obeys is nonlinear, the initial condition from which the explanandum is to be calculated must be known with complete precision. If it is incorrect, as we saw in this case, the small difference between the actual initial condition and the observed one will engender calculated final states which are very different from those observed.

Now the truth about this little story must be told. The "observed" population history shown in Figure 2 (and 3, 4, and 5) was actually generated from the popu-
The continuous line represents another attempt to explain the population drop, this time with $P(0) = 0.677$ as the initial condition.

Of course our graduate student might first have chosen for his initial condition a seasonal population much closer to the event, say the P-value of season 28 or 29. If so, then the temporal distance between the initial condition and the event would be small enough to avoid this chaotic effect. That is, even if his initial condition was off by a small amount, the divergence between his actual and calculated histories will be small at the time of the event—just as the histories in Figures 3 and 4 coincide for the first several seasons. Soon, however, the actual and calculated histories would diverge and there would then be a certain awkwardness in the explanation: after the event in question, the theoretical population begins to behave very differently than the population it is supposed to model. So, in order to reduce or, at least, mask this clumsiness, the time which the expla-
With $P(0)$ set to 0.675, the calculated history matches the observed history. (Both plots are identical to that shown in figure 2).

In other words, the chaotic dynamics of this system 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 (like $P(0)$ with $P(30)$), 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. If our graduate student were a chronically poor counter, and his recorded populations consistently off by a few percent, he could have explained the population dip only in a piecemeal fashion: he could show that his theory entails such a dip, say, two seasons after season 29; and then he could show that $P(29)$ is explained in terms of the observed $P(27)$, and $P(27)$ in terms of $P(25)$, and so on back to some observed $P$-value accepted as an initial condition. Of course we might accept the explanation in terms of $P(29)$ alone and be satisfied, but we would probably want to know why $P(29)$ obtained as well. Like the inquisitive (but pesky) child questioning every answer given ("and why is that?")), we would want to anchor the population dip to some initial state of affairs that we can
accept as given, like the fact that the colony had 675 animals when our student got to it, or that he in fact brought just that many to a barren island in the first place.

This trade-off will be imposed on any historian possessed of large-scale covering laws and who intends them to explain chaotic events. For another example, imagine that an omniscient economist produced a set of equations representing the actual forces that govern the evolution of U.S. stock markets. What might these equations look like? Because of its scope and complexity (and the obviously non-linear behavior of traders who buy and sell at the first whiff of expected gains or losses), the market is chaotic. These formulae would therefore be non-linear, and they would also be very imposing. Probably, they would contain variables representing the behavior of every trader, Wall Street journalist, CEO, and investor connected in any way with the markets. But since these agents often gauge their decisions by relatively external factors like the state of the economy in general or world political developments, these laws would contain even more variables indexing environmental, agricultural, and other such factors on which the state of the market rests. In this respect, this example is actually more realistic than that of the animal colony. For the stock market, like most historical entities we care about, is not a closed or isolated system.

Imagine that a covering-law economic historian has a hunch that the market crash of October 19, 1987 can be explained in terms of economic developments occurring during Reagan's tenure. To see if this is true, he or she would have to know, as initial conditions, exact values for all the laws' variables at the start of "Reaganomics," as well as exact values accounting for all internal and external developments which influenced the market prior to Black Monday itself. Internal factors would include Reagan's tax cuts, deregulation legislation, and so on, while external variables might index the market effects of events like the Grenada invasion, the Ethiopian famine, or the Chernobyl accident. Because of the market's sensitivity to its initial and intervening conditions, all of this information must be known exactly if any explanatory power is to be squeezed from these laws. As with the graduate student, if this information is recorded even slightly incorrectly then it is most likely that calculated indicators for October 19 would not match those that actually obtained. So, like the graduate student, our econo-

17. It would appear that covering-law historians utilizing large-scale laws would need to have Dantoian Ideal Chronicles in order to formulate sufficiently accurate initial conditions. Danto explains, however, that there can be no ideal and complete account of events compiled by a contemporary witness (an Ideal Chronicler) simply because many descriptions of events will become available only after those events have occurred. But Ideal Chronicles being unavailable does not necessarily mitigate covering-law explanations or predictions of events. My argument grants that historical laws might be available which, like scientific laws, specify precisely which descriptions of events need be constructed, descriptions which need not be couched in future-referring sentences (that is, Danto's "narrative sentences"). See Danto, chapter 8.

Paul Roth claims that the very notion of an Ideal Chronicle is incoherent, that any description of events requires a priori categories whose use renders the description less than ideal. This problem as well does not create problems for covering-law explanations if it is granted that covering laws are available. Again, those laws could supply their own categories of event descriptions. See Roth, 8-12.
myst would have to explain the crash by calculating it from market conditions obtaining a day or two before, for this would lessen the chaotic divergence of calculated and actual states. But then, in order to tie the crash to particular features of Reaganomics, he or she would have to explain those prior conditions in terms of yet earlier conditions, and so on, and so on, until the causal linkages (or lack of them) between those features and Black Monday itself could be established.

V. CHAOS AND NARRATION

The trade-off illustrated by these examples is once again this: provided the laws which govern a chaotic system are known, the greater the temporal distance between initial (and intervening) conditions on the one hand and the event to be explained on the other, the greater the accuracy with which those conditions must be known. This predicament rests on the nonlinearity of the laws governing chaotic systems. But even when we do not know what the laws that govern a system might be, if that system exhibits extreme sensitivity to initial or prior conditions—as does history, I suggest—then we can be certain that those laws are nonlinear. Consequently, the temporal scale of the covering-law explanations we might wish to make must be diminished given the extreme accuracy with which initial and intervening conditions must be known.

In the social sciences, not to mention traditional history, this accuracy is hard—and probably impossible—to come by. Without it, covering-law explanations will work only when they cover events and their immediate conditions. Again, if it were true that Black Monday was caused predominantly by certain aspects of Reaganomics, then a covering-law historian could only explain this with a series of linked covering-law explanations. 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 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.18

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.

18. This definition of narrative matches Danto’s definitions of “atomic” and “molecular” narratives. Danto invokes “molecular” narratives qua chains of linked covering-law explanations (each of which is an “atomic” narrative) to show that historical developments can be explained without large-scale general laws, as I have been calling them. He says, “no general law need be found to cover the entire change covered and explained by a narrative” (235). My point, however, is that atomic or molecular narratives are the only viable incarnation of covering-law explanation available. See Danto, 215–255.
As history is chaotic, these paths are intricate and tangled. They typically thread through what might seem the most insignificant of factors, like Cleopatra's nose, Descartes' fondness (perhaps) for taking walks, or the umpteenth "insignificant" decimal in variables required by ideal historical or social-scientific laws (which we lack anyway). While this sensitivity of events to the details of their past cripples covering-law explanations of even modest temporal reach, it imposes no real burden on narrative explanations. 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 narrator can still describe and employ 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. The covering-law historian, on the other hand, armed with every true historical law one can imagine, will not even be able to do this. For unavoidable inaccuracies in his or her statements of initial conditions will burgeon and drive a wedge between events as they really were and events as they are theoretically entailed by those laws. Chaos and time together erode the logical rigor that is covering-law history's most salable feature.

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. 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. And when events to be explained turn on some retrospectively all-important detail, that detail and its effects can be nestled inside the account at any of its causal joints: "And that morning, a stranger knocked on her door. . . ."

VI. HEMPEL'S PROPOSAL (AGAIN)

In the light that chaos theory sheds on historical processes we can see just why

Danto's broader argument against the possibility of deterministic, "substantive" philosophy of history also dovetails with my present claims. "Even supposing," he writes, "we had really extraordinary historical laws, involving vastly many variables and covering immense stretches of time," predictions of the future made on their basis "would at best tell us what would happen only under certain highly general descriptions providing that certain initial conditions—again under highly general descriptions—sequentially hold" (255). It is the generality of these laws that Danto uses to preempt substantive philosophy of history. But my argument undermines determinist predictions of the future without restricting the precision of covering laws that might be available. Imagine a determinist who has the most detailed historical law possible, say, a grand equation which—as Laplace dreamed—connected the states of all particles in the universe with their states at any later time. Accurate predictions of future states of chaotic processes in the universe would require increasingly accurate knowledge of initial conditions as the time of predicted events recedes into the future. Determinists who are not omniscient—except for knowing this law—might be able to forecast the next few seconds or perhaps minutes of those processes (which include history), but that's about all.
Hempel's proposal has a certain plausibility. His explanation of the exploded radiator, after all, is a mini-narrative: "Once upon a time, there was a radiator. Then, it got really cold and the radiator burst because it couldn't withstand the pressure exerted by the freezing water it contained." It comprises two contiguous scenes, and they are causally linked by regularities in the thermal behavior of water that we accept as true. The explanation works partly because the event it explains is instantaneous, more or less, and is caused by temporally and spatially contiguous factors (the ambient temperature, the molecular properties of water, and so on.) Unlike more diffuse and protracted historical events, this event has no time, so to speak, in which to be affected by the countless causal agencies and details that permeate historical reality. There is no time, that is, for chaos to set in.

But if Hempel's example featured a more protracted event, then chaos would have reared its head. If instead the event were the cracking of the car's frame as its driver failed to negotiate a pothole, then Hempel would have been in the position of our graduate student or our economic historian. Surely, the immediate cause of the event would be the extreme forces imposed on the chassis as one wheel hit the pothole. And this feature of the event could be covered by an appropriate law-like statement. But why was the frame unable to withstand that force? These reasons lie further back in time with, for instance, its owner's decision not to have the undercarriage rustproofed; and this turned on his resolve to move out of this wet, northern, pothole ridden city—a resolve later dissolved by his winning the lottery and buying a second home in the Bahamas.

Here, as with the varied kinds of temporally extended processes that historians study, causes and their effects are not always contiguous in space and time, and they are not always point-like. This motorist's decision to pass on rustproofing the car occurred well before the event in question. And the chemical process, rusting, responsible for weakening the car's frame was occurring for years. And the orchestrated effect of these causes, that is, the event in question, was mediated not just by scientific laws but also by the actions and behavior of one person. And, as Pascal suspected, peoples' actions can hinge on the most trivial and unlikely of factors.

We will probably never have large-scale laws or generalizations which can be used reliably to connect: winning the lottery with having one's car fall apart; federal budget cuts with Wall Street crashes; or the shapes and sizes of women's noses with the features of subsequent history. But that, I have tried to show, is only one obstacle to covering-law history. For if we did have such large-scale covering laws, we would never be able to explain anything with them given the near-omniscience that accurate statements of initial conditions would require. Ironically, Hempel himself notes that "the complete description of an individual event . . . can never be completely accomplished." In light of chaos theory, and the fact that history is chaotic, this is precisely why covering-law history is

19. For a different interpretation of covering-law explanation as narrative, see Richards's essay.
not viable. Chaos theory helps us conceptualize the difference that one-nail-too-few can make for subsequent historical events. It also warns us that our covering laws must be sensitive to such differences. But for these laws to do any explanatory work, we would unfortunately need to know just how many nails there really were. And no one will be able to know that.

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