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John Pier

▶ To cite this version:

John Pier. Complexity: A Paradigm for Narrative?. Per Krogh Hansen, John Pier, Philippe Roussin, Wolf Schmid, eds. Emerging Vectors of Narratology, De Gruyter, pp.533-565, 2017, Narratologia, 978-3-11-055378-9. halshs-03958187

HAL Id: halshs-03958187

https://shs.hal.science/halshs-03958187

Submitted on 26 Jan 2023

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John Pier. "Complexity: A Paradigm for Narrative?" In *Emerging Vectors of Narratology*. Per Krogh Hansen, John Pier, Philippe Roussin and Wolf Schmid, eds. Narratologia 57. Berlin and Boston: De Gruyter, 2017, pp. 553–565.

John Pier (Tours and Paris)

Complexity: A Paradigm for Narrative?

The renewal of narratological studies since the early 1990s has been accompanied by a wealth of changes in epistemological outlook, ranging from possible worlds theory to artificial intelligence, the cognitive sciences and more. The field has also seen a broadening of disciplinary focus resulting from the so-called narrative turn as well as closer attention to the contextual determinants of narrative discourse, not to speak of an expansion of the corpus stretching beyond literary narratives. The result was a passage during the 1990s from "classical" to "postclassical" narratology, the latter a proliferation of theories and models which, according to Jan Alber and Monika Fludernik (2010), can now be seen as breaking down into two phases: one a period of multiplications, interdisciplinarities and transmedialities; the other a period of consolidation and diversification.

The goal of this essay is neither to consolidate nor to diversify research in the field but to investigate some of the implications of complexity theory underlying the principles of narratology itself. My claim is not that complexity theory forms the basis for yet another double-entry narratology—a so-called complex systems narratology—but rather that narrative itself is a complex system and that narratology, in at least some of its past and more recent phases and dimensions, is implicitly or latently a complexity theory in its own right. This is admittedly a tall claim and one that cannot be fully substantiated in these few pages. Although there is much to separate complexity theory and narrative theory, it is safe to say, as Richard Walsh (2012) has observed, that both "are concerned with ways of modeling temporal processes"; and while it is true that "these paradigms are not in competition with each other," it may be overstating the case to say that the two are "locked together in mutual dependence."

1 Paradigm

In this essay, the questions surrounding narrative theory and complexity studies will be considered in light of the notion of *paradigm*. It was Thomas Kuhn who defined a scientific paradigm as "universally recognized scientific achievements that, for a time, provide model problems and solutions for a community of practitioners" (2012 [1962], 10). In this sense, a paradigm undergirds "normal science," prompting further articulation and elaboration of that paradigm, evaluation of facts and testing the points at which empirical data merge with the theory in

DOI 10.1515/9783110555158-025

question. A *paradigm shift* occurs when it is determined that anomalies must be accounted for within a new conceptual and methodological framework, as occurred with the transition from Newtonian to Einsteinian physics or, in the case of the social sciences, with the transition from behaviorism to the cognitive sciences.

In these pages, however, it is another aspect of paradigm that will come into play: *commensurability* or *incommensurability* between paradigms (see Kuhn 2000 [1991]; Oberheim and Hoyningen-Huene 2013 [2009]). Two paradigms are said to be incommensurable when there are no uniform and historically invariant standards for appraising scientific theories. This can result not only in a change of paradigm, but in a change of worldview, as occurs, for example, with the passage from Ptolemaic to Copernican astronomy. Incommensurability does have its degrees, of course, Aristotelian physics being largely incommensurable with Newtonian physics, for instance, while classical dynamics is partly commensurable with nonequilibrium thermodynamics. At the same time, incommensurability does not preclude comparability between historically separate paradigms or between competing paradigms that are contemporaneously situated. Indeed, the absence of any neutral observation language into which competing paradigms can be translated may well open the way to reasoned comparison and disagreement.

These principles carry over, *mutatis mutandis*, to "softer" sciences such as narrative theory. Historically, it is possible, for example, to regard the succession of "research traditions" that have dominated Occidental poetics based on the mereological model,[1] in an analysis by Lubomír Doležel (1990), as paradigms possessing various degrees of commensurability. Starting with Aristotle's stratificational poetics and its emphasis on universal generic "essences," the conceptual reference passed on to the organic model during Romanticism which yielded a morphological poetics that developed into, *inter alia*, narratology. This model, in turn, was followed at the beginning of the twentieth century by the rise of a semiologically-based theory which, freed from organic-morphological poetics, regards literature as a form of signification through semanticization.[2] In a similar way, though over a much shorter historical span, the more than thirty varieties

1 Mereology: "The abstract study of relations between parts and wholes" (Oxford Dictionaries Online: https://www.oxforddictionaries.com/definition/english/mereology).

2 "The semanticization of the poetic structure," notes Doležel in commenting on the mereological model of the Prague Linguistic Circle, "affects not only its 'vertical' (stratificational) but also its 'horizontal' (linear) dimension. The linear progression of the poetic text is not only a 'meaning-creating process occurring in time' but a process of *semantic accumulation*, of a bidirectional 'growth' of sense within the sentence and beyond" (Doležel 1990, 156).

of "context-oriented" postclassical narratologies inventoried by Ansgar Nünning (2003), which are set off from classical "text-centered" narratology, are paradigms that extend from an "undertheorized" to an "overtheorized" pole, open to comparison according to their degree of commensurability. As any researcher in the field knows only too well, proponents of these various theories speak of concepts such as narrator, implied author, sequence or perspective in ways that range from the overlapping to the well-nigh incommensurable.[3]

This essay will not seek to demonstrate that narratology and complexity theory share a common disciplinary paradigm or that complexity theory can serve as a model for narratology; nor will it, in the fervor of certain tendencies in recent research, endeavor to "narrativize" this theory. Rather than the "export" of concepts and principles from one branch of knowledge to another, it will focus primarily on how certain paradigms of sequence and sequentiality, a bedrock feature that permeates all aspects and forms of narrative, are reflected in complexity theory and how this theory, thanks to its own categories and configurations, might serve to frame sequence and sequentiality as complex narrative phenomena. In itself, this will not enable us to conclude that narrative is a complex system; but by raising the question through the confrontation of certain aspects of narratology and complexity theory, it is possible to highlight a number of ways in which narratology can effectively enable us to apprehend narrative as a complex phenomenon.

2 Complexity

2.1 General

Before looking more closely at the connections between narratology and complexity theory, a few words are in order with regard to the notion itself. Complexity, which originally evolved out of the natural sciences, is not itself a unified science with a distinct set of axioms, theorems and methodologies, but a loose *ad hoc* federation of sciences, both natural and social, resulting from advances in

3 In his contribution to this volume, Roy Sommer outlines a model for paradigm change in narratology based on "backward," "forward" and "sideways" compatibility. Commensurability, the framework adopted for the present essay, is concerned less with questions of evolution than with how complexity theory can serve to highlight latent and not fully realized underlying dimensions that span a variety of existing narratological paradigms.

fields ranging from physics, cybernetics, biology, immunology, cognitive science and meteorology to sociology and the study of organizations including ant colonies and multinational corporations as well as economics, the stock market, city planning and traffic patterns.[4] Complexity studies are not a discipline in their own right, nor are they bound by the criteria of any single discipline.[5] For this reason it has been stated that complexity is "not a theory with a set of axioms and theorems that can be applied across disciplines" and that most definitions "are only applicable to a limited context" (Bertuglia and Vaio 2005 [2003], 275 and 286); and elsewhere that "complexity is one of those ideas whose definition is an integral part of the problems that it raises. [...] the possibility of performing transitions among various modes of behavior remains the principal fingerprint of complexity" (Nicolis and Prigogine 1989, 38 and 232). It has also been observed that "there is not yet a single science of complexity but rather several different sciences of complexity with several different notions of what complexity means. Some of these notions are quite formal, and some are still very informal" (Mitchell 2009, 95). Even though complexity lacks a generally acknowledged definition, however, complex systems (or complex behavior, as Prigogine and Stengers, among others, would have it), in whatever field they are found, do share a number of general characteristics. According to MIT physicist Michel Baranger (2000), six typical properties can be singled out, as synthetically summarized below:

1) Complex systems contain many constituents interacting nonlinearly.
   Both chaos and complexity are anti-reductionist to the extent that, contrary to the premise of calculus, in neither case do all objects become simpler when analyzed into smaller and smaller parts (e. g., analysis of ocean waves into the chemical composition of water). Moreover, both are *dynamical systems* or *nonlinear dynamics* whose very configuration and variables may change over time such that "sensitivity to initial conditions" results in uncertainty growing exponentially and nonlinearly over time to the point of unpredict-

4 It is not helpful in this context to consider "complex" to be synonymous with "complicated" in the dictionary sense of "consisting of interconnected parts" (Holland 2014, 3). Complexity, unlike complication, is unpredictable, even when one has thorough knowledge of the components of a complex phenomenon (cf. Bertuglia and Vaio 2005 [2003], 282–283).

5 Much the same can be also said of structuralism. In narratological circles, however, where structuralism is often associated exclusively with French structuralist narratology, it is often forgotten that structuralism was first formulated by Tynjanov and Jakobson in a set of theses entitled "Problems in the Study of Literature and Language" (2002 [1928]); that it embraced a variety of disciplines (see Ducrot et al. 1968; Dosse 1997 [1991]); and that within structuralist narratology itself, research was diversified and positions were subject to change and evolution (see Pier, forthcoming).

ability (e. g., the butterfly effect). Complexity differs from chaos in that its constituents are far more numerous.[6]

2) The constituents of a complex system are interdependent.
Example: when 20 % of the gas in a container is removed, the remaining gas is redistributed; when 20 % of a human body is removed (e. g., a leg), the consequences are far more dramatic.
3) A complex system possesses a structure spanning several scales.
Unlike chaotic systems, which exist on one scale only, complex systems involve several, as is the case of the human body consisting of (a) head, trunk, limbs; (b) bones, tendons, muscles; (c) organs; (d) cells; (e) chromosomes containing DNA. Each scale possesses its own structure.[7]
4) A complex system is capable of emerging behavior.
Emergence occurs when attention is switched from one scale to a coarser scale above it. Example: walking, which involves the interaction of several scales. Moreover, when combined, structure and emergence result in *self-organization*, the production of a new structure. *Complex adaptive systems* (unlike *complex physical systems*) are capable of adapting to their environment, and some of them, notably biological organisms, are *self-reproducing*.[8]
Complexity presupposes chaos, but not vice versa. Thus if chaos occurs on level *n*, it may be that the coarser scale above it ($n - 1$) is self-organizing—the opposite of chaos.
5) Complexity involves an interplay between chaos and non-chaos.
Most nonlinear systems are not entirely chaotic but operate "at the edge of chaos," a point at which long-range correlations come into play and where self-organization is most likely to occur. In other terms, complexity occurs at an intermediate position between order and disorder, poised between equilibrium and chaos and tending toward new forms of internal self-organization (cf. Bertuglia and Vaio 2005 [2003], 279, 282 and 287).

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6 Note, however, that research on networks focuses on relationships between entities rather than on the entities themselves, leading some biologists to suggest that complexity in organisms arises out the *interactions* between genes, not as a result of the number of genes (cf. Mitchell 2009, 233).

7 "The interaction of components on one scale can lead to complex global behavior on a larger scale that in general cannot be deduced from knowledge of the individual components" (Crutchfield et al. 2008, 386).

8 "An adaptive complex system is an open system, made up of numerous elements that interact with one another in a nonlinear way and that constitute a single, organized and dynamic entity, able to evolve and adapt to the environment" (Gandolfi 1999, 19; quoted in Bertuglia and Vaio (2005 [2003], 276).

6) Complexity involves an interplay between cooperation and competition.
   In the interaction between scales, competition on scale n is dependent on cooperation at the finer scale $n + 1$ below it. This occurs in ant and termite colonies as well as in many types of social organization.

A broad view of complexity theory will show that, historically, it has developed out of a series of challenges to Newton's physics and classical mechanics during the nineteenth and twentieth centuries with manifestations in nonequilibrium thermodynamics, cybernetics, information theory and general systems theory,[9] but also that the principles of complexity have spread to biology, sociology, the cognitive sciences, organizational theory, philosophy and more. It has been observed that if the theory of relativity reconceptualized the relations of time and space, decisively breaking with Euclidean geometry, and that if quantum physics concluded with the intrinsic indetermination of measurement of the state of a particle-wave, fundamentally altering the position of the observer in relation to the observed, the findings in the respective sectors involved, namely cosmic and subatomic, do not readily extend to other disciplines.[10] Complex systems, by contrast, enjoy a greater degree of "transversality" (cf. Bertuglia and Vaio 2005 [2003], 266–279; Prigogine and Stengers 1984, 218–222) or, as Kuhn would say, commensurability.

2.2 Complexity and literature

But what, now, is the role of complexity theory in the humanities and, more particularly, in literature? To gain a sense of this connection, we can refer to Katherine Hayles's *Chaos Bound: Orderly Disorder in Contemporary Literature and Science* (1990) and to an anthology edited by her entitled *Chaos and Order: Complex Dynamics in Literature and Science* (1991). Hayles draws attention to the parallels between the paradigm shift brought about in the sciences by the attempt to come to terms with the complexities of nonlinear or dynamical systems (as opposed to the linear dynamics of classical mechanics) and the new forms of literary theory

9 These four domains constitute the field of systems theory. Central to all of them is the principle of entropy which, through Prigogine's work on the topic, bring them together into what Bailey (1994, 121) calls the transdisciplinary field of a "new" complex systems theory. For an overview, see Clarke (2011).

10 See, however, Ryan (2006b) who confronts the many-worlds cosmology of quantum physics and the possible vs. actual worlds of possible worlds narratology as exemplified in transworld, alternate history and time-travel narratives.

and criticism that arose during the 1960s. Where the New Criticism, for example, focused on the bound and finite verbal object, the new approaches saw textual boundaries as arbitrary and porous, and texts as unstable constructs that are no longer deterministic or predictable. "The well-wrought urn, it seemed, was actually a reservoir of chaos" (Hayles 1990, 2). Without there being any direct or conscious disciplinary influence between chaos theory and the humanities, Hayles does nevertheless point out the existence of a "cultural matrix" that has emerged out of the co-presence of developments in the two fields which she describes as "an archipelago of chaos [...] triangulating among chaos theory, poststructuralism, and contemporary fiction" (3).

Hayles provides many well-informed observations on the conceptual links between the two domains as well as on works from antiquity to present in which chaos is thematized, thereby underscoring the cultural and historical resonances between scientific and humanistic developments. She also points out the two sharply opposed strands of chaos theory as represented by James Gleick's *Chaos: Making of a New Science* (2008 [1987]), which is concerned with the order hidden in chaos (a view held by many scientists), and by Ilya Prigogine and Isabelle Stengers's *Order Out of Chaos: Man's New Dialogue with Nature* (1984), which argues that entropic disorder is a spontaneous self-organizing force that creates order, a position that has proved conducive to philosophical and other types of reflection beyond the natural sciences (cf. Hayles 1990, 11–13 and 91–114; 1991, 12–14). The perspective adopted by this approach (including the essays in the anthology *Chaos and Order*) is that of the relations between chaos theory and poststructuralism/deconstruction (see esp. 1990, chap. 7) with an overall focus on theme and interpretation. At the same time, however, little is said in these two volumes—or in publications in this area generally—about the implications of chaos with regard to the theories, concepts and analytical practices that are typically associated with narratology or about the relations that narratological research might have with the questions taken up by complexity studies. The apparent neglect of these matters is perhaps due to the fact that during the early nineties research in narratology was undergoing significant mutations that were not well known outside narratological circles.[11]

A survey of the relevant literature will show a number of not unrelated tendencies in the ways authors perceive the relations between complexity theory

11 More recently, the situation has begun to evolve. The University of York's Interdisciplinary Centre for Narrative Studies now includes a research group devoted to Narrative and Complex Systems. Homepage: http://www.york.ac.uk/narrative-studies/research-themes/complex-systems/

and narratology, three of which can be mentioned within the present context. Briefly (as only a sampling can be discussed here), we will find those who seek to formulate narrative theory along the lines of complexity systems; those who consider the concepts and principles of complexity more adequate than those of narratology when examining at least some types of narrative; and those who, indirectly or even unconsciously, single out or evoke aspects of narrative that are compatible with certain principles of complexity theory.

Regarding the first tendency, Bruce Clarke (2008) observes that narrative, discourse and narration (*sensu* Genette) anticipate systems-theoretical concepts, and he proposes to rearticulate these categories according to Mieke Bal's three-layered distinction between text, story and *fabula*. Clarke draws attention to the unrealized potential of narratological theories to achieve "the self-consistent epistemological constructivism of systems theory" (33). Stressing the emergent and self-referential quality of both systems and narrative, he establishes a connection between Bal's criteria for *fabula* construction and Niklas Luhmann's axiom that (in Clarke's words) "a system must reduce its own complexity relative to that of its environment" (34). In this way, he concludes, "it may be that narratives connect to worldly systems not in their putative representative verisimilitude [...] but in the ways that, at their deepest levels of abstraction, [...] allow the construction of functional homologies to real processes of life, mind, and society" (35).

In her dissertation entitled "Before or Beyond Narrative? Towards a complex systems theory of contemporary films" (2011), Maria Poulaki examines a corpus of films that came to be known, starting in the 1990s, as "complex films." Arguing that these films (especially "forking path," "puzzle" and "network" narratives) "do not reflect complex systems, but function themselves as such, in the context of their complex environments" (13), Poulaki advocates a change of approach for analysis "from the narratological to the complex systems framework" in order to demonstrate "how three 'post-narrative' characteristics—self-reflexivity, loose causality and description—perform an organizational, rather than disorganizing, function in relation to the diegetic world" (213). Existing narratological approaches, she contends, are hampered by their "tendency to prioritize the 'linear' causal-logical and temporal succession of events in [their] definition of narrative," making them unsatisfactory for accommodating "the complex and non-linear structure of complex films" (4). The critique is understandable to the extent that one might define narrative as "a way of organizing spatial and temporal data into a cause-effect chain of events with a beginning, middle, and end" (Branigan 1992, 216; quoted in Poulaki 2011, 106) or subscribe to "the notion of causality as an organizing principle that arranges events in causal-logical sequences" (133). Indeed, this position is widely held among narrative theorists.

Nevertheless, a variety of alternatives have been put forth, so that the solution does not, in my estimation, consist in making "a shift of theoretical and methodological framework from narratology to complex systems theory" (124) in order to accommodate a corpus such as the one studied by Poulaki, a corpus that extends "before and beyond narrative." Some branches of narratology already incorporate certain aspects of complex systems theory. This is a situation which, as I will argue, invites further reflection so as to determine the nature and extent of the links between the two fields and what this might contribute toward clarifying various issues of narrative theory. Indeed, Poulaki's discussion of Tzvetan Todorov's five-stage model of the narrative sequence, reinterpreting it in accordance with the complex systemic criteria of emergent, nonlinear causality (108–118), effectively acknowledges a degree of commensurability (as Kuhn would put it) of narratological concepts with complexity theory, thereby casting doubt on the need to put forward an alternative to narratology. More broadly speaking, this informative study, by expanding reflection on narrative to englobe "anti-narrative" forms of film that are open-ended ("before" narrative) as well as films that include and surpass narrative, identifies three areas of complexity studies that, in some way and to some degree, converge with key concerns of narratology: *reflexivity,*[12] *emergence*[13] and *pattern-based forms of self-organization* in which order merges with randomness.[14]

Finally, in a discussion of "denaturalized" forms of narrative causality, Marina Grishakova (2011) evokes questions that point in the direction of dynamical systems, but without addressing them as such. She opposes "natural causality," based on "the relation of antecedence-subsequence and necessary implication" that carries over to "'naturalized' socio-historical connections," and several forms of "interpretive" or "intentional" causality instilling "an intelligible order" in the narrative text through the various effects of prospective and retrospective ordering. These forms include fuzzy causality, zero-degree causality, retrograde or backward causality, causal closure and causal loop, the effect of which is, in various ways, to "restructure the 'natural' order of time and experience" (129, 135 and 143). In a brief discussion of Martin Amis's novel *Time's Arrow* (1991), where the events of the story are narrated in reverse chronological order, Grisha-

12 Poulaki's focus is on metanarration and metafiction in the context of Niklas Luhmann's brand of cybernetics drawn from systems theory.

13 At issue are nonlinear forms of causality and the spontaneous self-organization of complex reactions between the units of a system.

14 "A simple kind of emergent property of a system, where the pattern is a property of the system as a whole but is not a property of small parts of the system" (Bar-Yam 2011; quoted in Poulaki 2011, 191).

kova refers to entropy, the principle of the irreversibility of time according to the second law of thermodynamics, and she observes that Amis's novel, by inverting the entropic passage from order to disorder, "closes off causality and precludes the further propagation of effects and their causes" (138). It remains unclear, though, how the two causalities, natural and interpretive, come into play here.

3 Sequentiality and Irreversibility

For my part, I wish to argue that when confronting the elements of complexity theory with narratological principles, narrative, by its very sequentiality, can be regarded in terms of irreversibility, also known as the *arrow of time*, coming from the second law of thermodynamics.[15] From this perspective, I will attempt to provide some insight into narrative processes as they reflect three key dimensions of complex systems: *stochastic processes*, *dissipative structures* and *spontaneous self-organization*. The framework of reference adopted for this trio of concepts comes largely from Ilya Prigogine and his colleagues at the "Brussels school" who have consistently argued that the sciences, long dominated by the static view of the physical universe propounded by the classical mechanics of Newtonian physics as opposed to the evolutionary view associated with entropy, began evolving early in the nineteenth century away from a strictly deterministic, reversible conception of natural phenomena toward a conception that also seeks to incorporate stochastic and irreversible processes. "What has changed since the beginning of this century is our evaluation of the relative importance of these four types of phenomena: *reversible versus irreversible, deterministic versus stochastic*" (Nicolis and Prigogine 1989, 2; emphasis added).[16] The repercussions

15 "All arrows of time in nature have the same orientation: They all produce entropy in the same direction of time, which is by definition the future" (Prigogine 1997 [1996], 102). Two principles underlying this basic concept of nonequilibrium thermodynamics that should be borne in mind are as follow:

- Irreversible processes (associated with the arrow of time) are as real as reversible processes described by the fundamental laws of physics; they do not correspond to approximations added to the basic laws.
- Irreversible processes play a fundamental constructive role in nature. (27)

16 Determinism is defined as "[t]he viewpoint that evolution is governed by a set of rules that, from any particular initial state, can generate one and only one sequence of future states" (Prigogine 1997 [1996] 201). In Prigogine's system, determinism is broken down into the interaction of necessity and chance in the description of nonlinear systems far from equilibrium (Prigogine and Stengers 1984, 14, 170 and 176). Stochastic processes are processes "whose dy-

of this reconfiguration of forces are considerable, for as it is argued elsewhere: "The artificial may be deterministic and reversible. The natural contains essential elements of randomness and irreversibility. This leads us to a new view of matter in which matter is no longer the passive substance described in the mechanistic world view but is associated with spontaneous activity" (Prigogine and Stengers 1984, 9).[17]

Focusing on narrative sequentiality in its relations of partial commensurability with complexity theory is a privileged vantage point from which to gain insight into the relevance of this theory for narrative. Against the backdrop of Baranger's six typical properties of complexity and the emergence of reversible versus irreversible processes together with deterministic versus stochastic processes in the physical and social sciences, the discussion will proceed by foregrounding the phenomena of nonequilibrium, instabilities, dissipative structures and self-organization and their possible correlates in narrative sequentiality. The comments on sequence, centered mainly on Tzvetan Todorov's model, and those on sequentiality, drawing from Meir Sternberg's treatment of the subject, though relatively brief, are intended to frame the issues in a significant way and highlight them for further discussion and research.

3.1 From classical mechanics to non-equilibrium thermodynamics

Various developments in the sciences during the nineteenth and twentieth centuries that culminated in the complex concepts of stochastic processes, dissipative structures and spontaneous self-organization can serve to shed light on certain narratological concepts and principles. To this end, a brief account of the evolution from classical dynamics to thermodynamics and nonequilibrium thermodynamics is instructive.

The foundations of classical mechanics were laid by Newton with the three laws governing force and mass, which run as follow:

namics is nondeterministic, probabilistic, even completely random and unpredictable" (Nicolis and Prigogine 1989, 2).

17 For a discussion of the implications of this momentous shift in outlook that extend beyond the "hard" sciences to the "soft" sciences as well as to philosophy and the history of ideas, see the numerous passages in Prigogine and Stengers (1984) which, notably in Book Three, discuss the physics of "being" and the physics of "becoming." See also Toffler (1984) and Prigogine (1997 [1996]).

1) Constant motion: Any object not subject to a force moves with unchanging speed.
2) Inertial mass: When an object is subject to a force, the resulting change in its motion is inversely proportional to its mass.
3) Equal and opposite forces: If object A exerts a force on object B, then object B must exert an equal and opposite force on object A. (Mitchell 2009, 19; cf. Prigogine 1997 [1996] 109–110)

In the "clockwork universe" of classical mechanics, trajectories of all scales—atoms, planets, stars—are subject to the same forces of gravity. These trajectories are governed by *lawfulness*, *determinism* and *reversibility*. To calculate a trajectory, one need only know the "initial state," from which that trajectory and all ensuing states can be deduced, just as in logic the conclusion can be deduced from the premises (Prigogine and Stengers 1984, 60). Due to the inherent stability of the system, natural processes are predictable and thus deterministic and reversible, following the example of the perpetual movement of a pendulum (characterized by "structural stability") or that of ideal thermal machines. Reductionist, classical mechanics failed to account for randomness and irreversibility, yielding a "static view of nature" in which "future and past become equivalent" (11).[18] More generally, classical science, from the time of Newton on, can be characterized by the features of *equilibrium* (mechanisms are aimed at achieving states of stability), *linear causality* (direct proportionality between cause and effect: a cause external to the system changes the system's structure) and *negative feedback* (as in first-order cybernetic systems such as the mechanical governor employed by the steam engine which feeds information about the state of energy back into the process in order to limit the loss of usable energy in a closed system) (Bertuglia and Vaio 2005 [2003], 261–265; cf. Clarke 2011, 216–217).

When turning now to narrative, one cannot but be struck by the affinity of these principles of classical mechanics and science with current narratological conceptions of sequence. Such is the case, for example, of the widely acknowledged model proposed by Todorov:

> An ideal narrative [and the narrative sequence] begins with a stable situation which is disturbed by some force. From this there results a state of disequilibrium; by the action of a

18 "In the classical view the basic processes of nature were considered to be deterministic and reversible. Processes involving randomness or irreversibility were considered only exceptions" (Prigogine and Stengers 1984, xxvii).

> force directed in the opposite direction, equilibrium is re-established; the second equilibrium is quite similar to the first, but the two are never identical. (1973, 82; my translation)[19]

Indeed, this schema, which has taken on various forms since it was first formulated, extending from structural narratology to text grammars and linguistics as well as to possible worlds narrative theory and cognitive narratology, follows the pattern of equilibrium, linear causality and negative feedback rather closely. At the same time, Todorov's sequence (and ideal narrative [*récit idéal*], to which we will return) reflects the principle of *conservation of energy*, an outgrowth of the first law of thermodynamics according to which, in an isolated system (such as the pendulum in the absence of friction), kinetic energy and potential energy are continuously converted into one another so that total energy remains constant and undiminished.[20] The pervasiveness of this and comparable schemas in narratological theory building, both classical and postclassical, can hardly be overstated.[21]

But this is not all. What happens when a mechanical system encounters friction? Classical mechanics is not armed to answer this question, for it is concerned with gravity, not heat, and with the conservation of energy, not with the dissolution or loss of energy. This is where the second law of thermodynamics enters the picture, stressing the irreversibility of processes in nature: over time, the differences of temperature, pressure and chemical potential in a closed system level out, the measure of how far this process has progressed being known as entropy, the maximum value of which is situated at thermodynamic equilibrium.[22] During the nineteenth century, the age of the machine (marked, *inter alia*, by attempts to

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19 For lack of space, the present commentary will be carried out with reference only to Todorov's model. Another influential model, developed by Claude Bremond, corresponds to a triad marked by the development of a process involving virtuality, actualization or non-actualization of an act and achievement or non-achievement of a goal, wherein each posterior term stands in logical implication of the anterior term (1973, esp. 131–136; see also Pier, forthcoming).

20 As Prigogine and Stengers have pointed out, the cultural implications of this principle are far-reaching and long-lasting: "With the conservation of energy, the idea of a new golden age of physics began to take shape, an age that would lead to the ultimate generalization of mechanics" (1984, 110–111).

21 For a recent synthetic overview of approaches to narrative sequence, see Prince (2016).

22 The original definition of the second law was formulated by Rudolf Clausius in 1865: "The energy of the universe is constant. The entropy of the universe is increasing" (quoted in Prigogine 1997 [1996], 19). This definition is based on the conservation of energy and marks the transition from mechanics (the world of motion) to thermodynamics (the world of increasing entropy), which was later to become nonequilibrium thermodynamics, characterized by dissipative structures and spontaneous self-organization.

counter the loss of energy in steam-driven engines with the use of the mechanical governor), the notion of heat death (and ultimately the death of the universe) entered the popular imagination as witnessed, for instance, by H. G. Wells's novel *The Time Machine* (1895).

At the same time, however, and continuing into the twentieth century, numerous developments in the sciences were taking place that were to put the second law in a new light, transforming it, as Prigogine was later to argue, into a constructive force that occurs in natural processes, thereby effectively dissociating entropy solely from an increase in disorder. One important step was taken with the development of statistical dynamics: how large-scale properties such as heat emerge from trillions of molecules cannot be calculated by determining the position and velocity of each and every molecule (as would be required by classical dynamics), but must be projected in terms of possibilities and probabilities, thus replacing the deterministic treatment of trajectories at the individual level in closed systems with probability distribution in ensembles at the statistical level as well as breaking the symmetries of classical mechanics and giving rise to uncertainty relations (cf. Mitchell 2009, 47–51; Prigogine and Stengers 1984, 243 and 274; Prigogine 1997 [1996], 11, 42 and 73–74).[23]

These considerations regarding the transition from the static view of classical dynamics to the evolutionary paradigm of thermodynamics are of particular interest for narrative sequentiality in its various dimensions, following, as already stated, the principles of irreversibility or the arrow of time. Among the most pertinent aspects of these developments for our purposes are the thermodynamic principles of *equilibrium*.

3.2 Equilibrium

In mechanics, equilibrium is a state in which velocity and acceleration at all points in a system are equal to zero: only if the balance is disturbed is the equilibrium broken. As for equilibrium in thermodynamics, one form occurs in isolated systems in which neither energy nor matter interact with their environment and probability is at a maximum (e. g., the crystal, an "equilibrium structure" which is inert, atemporal and not subject to evolution[24]). Systems that do interact

23 A "statistical view of entropy," notes Hayles, questions "the absoluteness of a predicted 'heat death' by giving entropy an interpretation that was overtly probabilistic rather than deterministic" (1990, 41–42).
24 "For a biological system," by contrast, "equilibrium equals death" (Bruni 2011, 229).

with their environment, however (this is true especially of living organisms and social organizations), behave quite differently, with the smallest of fluctuations in *near-equilibrium* states being amplified in *far-from-equilibrium* phenomena (Nicolis and Prigogine 1989, 54–55; Prigogine and Stengers 1984, 127, 131–132 and 286; on adaptive complex systems, see Bertuglia and Vaio 2005 [2003], 275–277).

What characterizes these two types of equilibrium is their degree of instability. Take, for instance, a population whose birthrate and death rate are equal and whose unchanging environmental conditions are adequate for it to meet its needs (equilibrium). A small increase in the number of births, but with no change in the number of deaths or in the environment, will result in near equilibrium with little overall effect—merely a slight increase in sensitivity to initial conditions. The situation will be quite different if the birthrate were to double, the death rate remained stable and, due to an unforeseen drought, the food supply were to dwindle. Due to increased sensitivity of the initial conditions, variations will be amplified exponentially (cf. the butterfly effect), new patterns of behavior will emerge, and the system will reorganize spontaneously—all this in ways that cannot be deduced or predicted on the basis of the more stable forms of equilibrium: in this case it is the system *itself* that has undergone change.[25] More generally, while phenomena in near equilibrium remain relatively "linear," those that are far from equilibrium are subject to a new norm: fluctuations and instabilities (Prigogine 1997 [1996], 63–65).

Returning now to Todorov's sequence, we see a starkly different situation. Here, an initial equilibrium and a final equilibrium are set off from one another by an intervening state of disequilibrium caused by and succeeded by symmetrically opposing forces. To this "Newtonian" model of narrative sequence can be opposed a thermodynamic "nonequilibrium" conception: unstable, fluctuating and unpredictable relations of varying degrees between subsystems interact with their environment as a narrative is deployed in its irreversible sequentiality. In place of the reductive balance between equilibrium and disequilibrium of Todorov's model, we propose near equilibrium and far from equilibrium, features whose effect is to infuse the narrative sequence with instabilities and asymmetries.

In light of these considerations, the opening sentences of the following novels can be characterized as expressing states near equilibrium, each with a specific sensitivity to initial conditions:

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25 Adapted from Toffler (1984, xvi). For further comments on self-organization in human systems, see Nicolis and Prigogine (1989, 238–242).

> It is a truth universally acknowledged that a single man in possession of a good fortune must be in want of a wife. (Jane Austen, *Pride and Prejudice* [1813])

> Happy families are all alike; every unhappy family is unhappy in its own way. (Leo Tolstoy, *Anna Karenina* [1877])

> Mrs Dalloway said she would buy the flowers herself. (Virginia Woolf, *Mrs Dalloway* [1925])

The ironic tone of the first example, the aphoristic nature of the second and the use of indirect speech in the third bear witness not only to the great variety of initial conditions that pertain in narratives but also to their varying degrees of sensitivity and to the highly diverse and potentially multiple paths yet to come. It is equally noteworthy that the told and the telling in these sentences do not interrelate in a neutral or balanced fashion, for each sentence is colored by various perspectival, generic and grammatical features, thereby creating a state of near equilibrium from the start.

4 Intersequentiality

Examples such as those above suggest that, in narrative, nonequilibrium conditions arise not out of a sequence (or multiple sequences) of events or happenings *per se*, but that these conditions are generated in the "gaps" encountered between two sequentialities: that of "the absolute dynamics of the causally propelled action" (*fabula*) and that of "the variable dynamics of the reading process" (governed by the *sjuzhet*) (Sternberg 1978, 13). On this basis, Sternberg contends, narrative sequence is not a given but emerges from "intersequential relations, or dynamics, whereby gaps open between the order of the telling/reading ('discourse') and the told ('action')" (2003, 612). Elsewhere it is stated that such intersequential relations give rise to an "interplay between temporalities [that] generates the three universal effects/interests/dynamics of prospection, retrospection, and recognition—suspense, curiosity, and surprise, for short" (Sternberg 2001, 117). Key to this system is inferential reasoning, the process by which conflicting hypotheses are entertained about what will happen next, conclusions are drawn as to why such-and-such occurred, and the parts are tied together into a whole. Sternberg thus rejects the numerous "objectivist" models and their variants that define sequence solely by the causal links binding events together, opting, instead, for a functionalist "means-ends" position: the process of inferencing between the actional and the communicative in the filling of gaps.

Among the models of sequence examined by Sternberg in his critique of theories of narrativity, Todorov's is singled out as being compatible with his own functionalist or intersequential paradigm. The five successive steps in Todorov's sequence, passing from equilibrium to disequilibrium and interspersed by symmetrically opposed forces, constitute, according to Sternberg, a "three-implying-five" schema: it is through this schema that the inferential operations of prospection, retrospection and recognition are engaged (Sternberg 2010, 642). Clearly, though, this inferential perspective on sequence is a departure from Todorov's more "mechanistic" model in that it is formulated according to irreversible, nondeterministically ordered processes. On the other hand, due to its teleological nature, Sternberg's version of intersequentiality sets itself off from the various degrees of nonequilibrium that are fundamental to the more probabilistically-oriented theories of complexity.[26]

This point can be corroborated if we look at network-based hypertext narratives whose digitally-based organization opens up parameters that are unavailable to print-based narratives. Here, according to Marie-Laure Ryan, sequence is located at the story level, where it unfolds in a random way. "Suspense, curiosity, and surprise," she argues, are incompatible with randomization because they

> are highly dependent on a controlled management of information that determines what the reader knows and does not know when he reaches a certain point in the story. With a hypertext based on a network, however, the reader might reach a certain node through different routes: in one case, he might learn the identity of the murderer before discovering the body; in another case, he first finds the body and then learns who did it [...]. (Ryan 2016, 188–189)

What we see here are not, strictly speaking, narrative sequences but rather various chronological successions of events and actions that can be shuffled around at will, unconstrained by a pre-established format or a set of instructions. Such chronological successions, occurring more or less randomly, may very well not elicit suspense, curiosity and surprise, yet they do underscore the entropic processes that occur in hypertext narratives due to two factors: exchanges between the network and the outside world through the interventions of the hypertext reader and the irreversible processes set in motion within the network, a system that self-organizes in response to the choice of routes adopted (cf. Prigogine and Stengers 1984, 118). Although the point cannot be adequately argued here, it is

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26 In an earlier discussion of Sternberg's intersequentiality and its appropriation of Todorov's sequence, I espoused the latter's criteria for equilibrium and disequilibrium (Pier 2016, 22–28). Re-examination of the issues in light of complexity theory has since led me to adopt another view.

certainly the case that such entropic processes are not confined to hypertext narratives alone.

Taking things a step further, the question can be considered within the framework of information theory, which itself is closely linked to complexity theory through the principles of probability.[27] Nicolis and Prigogine provide a telling example. As reading advances temporally in a fixed direction from the starting point (cf. the arrow of time), unpredictable elements may pop up that cannot be determined from what is known at any given point. In this way, information is generated out of stochastic processes. In support of this idea, the authors point out the high improbability of devising an algorithm that would enable a reader of Euclid's *Elements* or of Newton's *Principia* to infer or predict the second half of these treatises from reading the first half (Nicolis and Prigogine 1989, 186). Only in a state of absolute structural stability would it be possible to design such an algorithm; in this case, however, the level of information transmitted would be nil and entropy at its maximum. Referring this principle back to the narrative contexts of the opening sentences of the novels discussed in the previous section, we can see that the states of near equilibrium incorporated into the initial conditions also give rise to probability relations within each of the global narratives in question.[28]

From these comments it can be concluded that intersequentiality exists in two forms. One, through the use of inference, involves prospection, retrospection and recognition in the processing of gaps between the actional and the communicative. The other, more commensurable with the principles of complexity theory, results from the probabilistic relations that arise in narrative contexts as a result of near-equilibrium and far-from-equilibrium situations. One operates

27 For an overview of information theory, see Nöth (1995). In this context, probability is a statistical concept and is thus not to be confused with verisimilitude. Example: what is the missing letter in the word "ax–"? The only possibility (in the system of English spelling) is the letter "e," resulting in "axe," so that the addition of "e" transmits a low level of information. Consider now "a–e," which can be completed in several ways: "ace," "age," "ale," "ape," "are," "ate." Choosing one of these possibilities is more informative than completing the letters "ax–" with the letter "e." Needless to say, the probability that one or another of these words will appear at a certain point in time varies according to the grammatical environment.

28 The logic of narrative probability is thus distinct from that of *langue* and *parole* as employed in structural narratology. According to Claude Bremond: "It is starting from the *terminus a quo*, which opens up in the general language [*langue*] of narratives a network of possibilities, and no longer from the *terminus ad quem*, in view of which the particular word [*parole*] of the Russian folktale makes its selection between the possibilities, that we must construct our sequences and functions. The implication of *Struggle* by *Victory* is a logical requirement; the implication of *Victory* by *Struggle* is a cultural stereotype" (1973, 25; my translation).

in conformity with the cognitive and semiotic dimensions of narrative, the other along the lines of narrative's information theoretical and entropic processes.

These forms of intersequentiality are not mutually exclusive or incompatible. Indeed, narrative as a complex system relies on both, for the two function concurrently. Although an in-depth corpus-based analysis is required to clarify and modulate this point, it would seem that probabilistic intersequentiality forms the undercurrent of narrative generally. This is true of the three works already mentioned, whose initial conditions open up a situation of near equilibrium and which, at the same time, are conducive to the operations triggered by inferential intersequentiality. Probabilistic intersequentiality can be made salient, as in hypertext narratives, but this is also true of print-based narratives such as Marc Saporta's *Composition No. 1* (1961) with its randomly ordered pages; William Gass's *Willy Masters' Lonesome Wife* (1968/69) with its elaborately metareferential use of graphic devices (see Pier 2011); or Laurence Sterne's *The Life and Opinions of Tristram Shandy, Gentleman* (1759–67) with its startling compositional permutations.

5 Instabilities

If entropic states near equilibrium and far from equilibrium prevail in narrative sequentiality (rather than equilibrium and disequilibrium), then three additional properties of complex systems must be taken into account that contribute to instabilities: *nonlinearity*, *positive feedback* and *bifurcations*.

5.1 Nonlinearity

As we have already seen, what characterizes the linearity of a system is the proportionality between cause and effect (e. g., 'an event A brings about an event B'). Such is the case in the individual trajectory forming the object of study in mechanics. This postulate generally holds in classical science, with carryovers into other fields, but it was brought into question by, among others, Henri Poincaré, one of the pioneers of statistical thermodynamics. When trying to solve the so-called three-body problem, Poincaré discovered that the moon's motion, influenced by the gravitational pull of the earth and the sun, could not be calculated using Newton's laws, thus demonstrating that dynamical systems are not isomorphic (Prigogine and Stengers 1984, 72). In such instances, where asymmetrical relations arise, nonlinearity provokes disproportionality between initial conditions and results.

> A striking difference between linear and nonlinear laws is whether the property of superposition holds or breaks down. In a linear system the ultimate effect of the combined action of two different causes is merely the superposition of the effects of each cause taken individually. But in a nonlinear system adding a small cause to one that is already present can induce dramatic effects that have no common measure with the amplitude of the cause. (Nicolis and Prigogine 1989, 59)

Nonlinearity, then, occurs with the spanning of scales rather than along a single level (cf. Baranger's third property of complexity) and, unlike in linear relations, introduces elements of fluctuation and unpredictability into a system. Climate patterns are a clear example of nonlinear systems.

It is important when considering narrative sequentiality from the perspective of irreversibility to bear in mind that the latter notion does not equate with linearity in a spatial sense, such as that of 'linear time' in which time is said to follow a unilinear path. Irreversibility is a time-bound phenomenon that moves from past to future, and it is thus linked to probabilistic processes which themselves evolve over time, resulting in various states of nonequilibrium and, in the case of far-from-equilibrium states, increased complexity. There is in fact a fundamental difference between space and time to the extent that it is possible to move from and return to a given point in space, but not to exchange past and future (as in the putatively frictionless pendulum). The separation of time and space is a consequence of the second law of thermodynamics that runs counter to the principles of classical mechanics to the extent that it results in an "infinite entropy barrier" in which permitted states remain distinct from prohibited states: only after the initial state has been selected (cf. the initial conditions set out in the opening sentences of the three novels mentioned above) can irreversible probabilistic processes get underway or the inferential operations of prospection, retrospection and recognition be triggered by actional and communicative processes. Because of the probabilistic nature of irreversibility, moreover, space acquires a temporal dimension, leading Prigogine and Stengers to adopt a term from geography to describe this process: "timing of space" (1984, 16–17, 272, 277–280 and 295–297). The timing of space contrasts significantly with the various narrative theories, structuralist and otherwise, that seek to "spatialize" narrative through, for example, "spatial form," effectively immobilizing the process of irreversibility.[29]

29 Poulaki identifies spatial form with pattern-based forms of self-organization in her corpus of films (the other two complexity-based criteria in her model being reflexivity and emergence). In this connection, she cites Joseph Frank's "space-logic" of reflexive reference which makes it necessary "to suspend the process of individual reference temporarily until the entire pattern of internal references can be apprehended in a unity" (1977, 232; quoted in Poulaki 2011, 198).

5.2 Positive feedback

Another factor that comes into play with nonlinearity is feedback. Negative feedback, we have seen, pertains in closed or isolated systems where a control mechanism is used for the purpose of maintaining equilibrium in the system in question. Nonlinearity, however, is associated with positive feedback, the effect of which is to push the system far from equilibrium by amplifying fluctuations in unexpected ways, leaving it open to unpredictable change. Although it exists in the inorganic world, positive feedback, as confirmed by research in molecular biology, is more prevalent in living systems; it is also a critical factor in biological evolution as well as in social interactions. Moreover, the role of cybernetics in conceptualizing nonlinearity is not to be overlooked, for this was the first science to make extensive use of self-regulation by means of internal feedback cycles in closed or isolated systems. It was, in fact, Norbert Wiener, the pioneer of cybernetics, who decisively ushered in the idea of nonlinear causality, although cybernetics was subsequently overtaken by complexity studies which, in the case of open systems, incorporate emergence and self-organization as well as nonlinearity (Prigogine and Stengers 1984, 153–154; Nicolis and Prigogine 1989, 56–61; Bertuglia and Vaio 2005 [2003], 264 and 273–274; Poulaki 2011, 130–131).

5.3 Bifurcations

We see, then, that nonlinearity and positive feedback draw phenomena away from equilibrium. But how far can this process go? What are the limits? It is here that the expression "at the edge of chaos" gains relevance, a notion synonymous with states far from equilibrium and near disintegration, but which at the same time refers to an order implicit in the system (Bertuglia and Vaio 2005 [2003], 270, 279 and 282; cf. Baranger's fifth property of complexity).

However, the attempt to assimilate temporality into spatial relations ("the sequential or temporal principle is replaced by the principle of 'reflexive reference': that is, suspension of meaningful reference until the whole pattern is perceived"; Holtz 1977, 272–273; quoted in Poulaki 2011, 199) not only duplicates the principle of reversibility in classical mechanics, but it also overlooks the entropic principles of irreversibility and their connections with dissipative structures and spontaneous self-organization.

See also Ryan (2016, 176–182) who extends her critique of spatial form for its neglect of plot to the use of distributed networks in narrative experiments such as Marc Saporta's *Composition No. 1* (1961) and to Roland Barthes's "plural text," a "network" with a "thousand entries" but no root node and no beginning, middle and end, thus precluding the possibility of narrativity.

The mechanism through which the edge of chaos functions is known as bifurcation. In primary or "pitchfork" bifurcations, to take the simplest example, as fluctuations in an irreversible process are amplified and the thermodynamic branch becomes increasingly unstable, a "choice" between two solutions pops up within the open system itself, a choice that can in no way be determined when referring to the nonlinearities and constraints of the macroscopic dimension of the system concerned: at this point, the system has been pushed "beyond the threshold of stability." Bifurcation can be characterized as a source of diversification and innovation.

There is more, however. Bifurcation possesses distinct symmetry breaking properties which, as the dissymmetries of many phenomena in nature show, serve as one of the prerequisites of complex behavior. Together with their symmetry breaking effects, bifurcations

> are the manifestation of an intrinsic differentiation between the parts of the system itself and the system and its environment. Once a dissipative structure is formed, the homogeneity of time [...] or space [...], or both, is broken. (Prigogine 1997 [1996], 69; cf. Nicolis and Prigogine 1989, 74)[30]

Bifurcations in a system are not isolated, of course, but come in successions. Between bifurcations, the process advances deterministically while the choice of branch at any given bifurcation point occurs probabilistically,[31] thus giving the process a historical dimension in a mixture of necessity and chance (see also Prigogine and Stengers 1984, 170 and 176). At the same time, it should be noted that bifurcations reflect Prigogine's reformulation of the principle of entropy not as an increase in disorder but as an irreversible process taking place inside the system, on the one hand, and exchanges of the system with the outside world, on the other (118; cf. Hayles 1990, 94). It must also be emphasized that symmetry breaking introduces an element of randomness between the macroscopic dimension of a system, which provides no basis for determining the path the system

30 Modern science was born when "the homogeneous and isotropic space of Euclidean geometry" replaced Aristotelian space (Prigogine and Stengers 1984, 171), a feature characteristic of classical mechanics; symmetry breaking, however, "brings us from a static, geometrical view of space to an 'Aristotelian' view in which space is shaped or defined by the functions going on in the system" (Nicolis and Prigogine 1989, 13).

31 With respect to information theory, this means that bifurcation points are richer in information than the more deterministic stretches in between. A similar situation arises in narrative theory, where Boris Tomashevsky's "free motifs" vs. "bound motifs," just as Roland Barthes' "kernels" vs. "catalysts," can be recast in information theoretical terms (Tomashevsky 1965 [1928]; Barthes 1977 [1966]).

will follow, and microscopic description, which is unable to predict the long-term outcome (Prigogine and Stengers 1984, 162 and 180). "Complexity," write Bertuglia and Vaio, "is characterized by the breakdown of symmetry [...] due to the fact that no part of the system is able to provide sufficient information to predict, even statistically, the properties of the other parts" (2005 [2003], 289).

What are the implications of the above principles for sequence and for the broader, underlying phenomenon of narrative sequentiality? From the perspective of complexity studies, sequence operates within states near equilibrium and far from equilibrium in an irreversible process from past to future. This occurs probabilistically (cf. footnote 27) rather than in a linear trajectory, as in Todorov's sequence where "a stable situation [...] is disturbed by some force." Given that the starting point of the sequence is a set of initial conditions, and not a state of equilibrium, positive feedback tends over time to cause the system to evolve toward a state far from equilibrium, toward greater complexity and thus toward greater unpredictability.[32] Unlike Todorov's sequence, modeled after closed or isolated systems, in this conception there occurs not a disturbance "by some force" but a bifurcation point, an alternative which is determined neither at the microscopic level (e. g., a series of actions by narrative agents guided by desires, goals, etc.) nor at the macroscopic level (e. g., an overarching structure such as that of the quest narrative or a love story). In narrative, as in complex systems, bifurcations are probabilistic while the stretches of discourse between these points unfold according to criteria of a deterministic nature. By functioning this way, narrative sequentiality breaks down symmetries such as that of "the action of a force directed in the opposite direction," the supposed effect of which is to re-establish equilibrium. The relations between microscopic and macroscopic scales thus become random to some degree or even stochastic, raising a fundamental question that can be but mentioned within the limit of this essay: to what extent might necessity and chance take precedence over or in some way intermingle with cause and effect in narrative contexts?[33]

32 This can be illustrated, on a scale larger than the sequence, by Vladimir Nabokov's *Pale Fire* (1962) in which a poem by John Shade entitled "Pale Fire" is commented on in a "Foreword," "Commentary" and "Index" by Charles Kinbote. As the reading of the various sections of the book advance, it becomes apparent that the paratext takes on a life of its own in such a way that it becomes increasingly undecidable as to whether it is the commentary that forms the paratext of Shade's poem or the poem that forms the paratext of Kinbote's commentary. For an analysis, see Pier (1992).

33 It is worth noting that Aristotle's *Poetics* lays stress on necessity linked either to probability or verisimilitude and on chance rather than on cause and effect. Causation in narrative remains one

6 Dissipative Structures

Bifurcations, together with their symmetry breaking effects, are one of the formative factors of dissipative structures, a key concept in Prigogine's thermodynamics. Defined as "[s]patiotemporal structures that appear in far-from-equilibrium conditions" (Prigogine 1997 [1996], 202), dissipative structures are inseparable from irreversibility. Moreover, they associate "structure and order on the one side, and dissipation or waste on the other. [...] The interaction of a system with the outside world, its embedding in nonequilibrium conditions, may become in this way the starting point for the formation of new dynamic states of matter—dissipative structures" (Prigogine and Stengers 1984, 143). Unlike conservative structures, in which kinetic energy and potential energy are converted into each other with total energy remaining constant (cf. section 4.1 above), dissipative structures, provoked by far-from-equilibrium states and occurring beyond the bifurcation point, produce a new situation, effectively leaping from disorder to order in a choice that is not deterministically inscribed within the system. "Nonequilibrium," says Prigogine, "leads to concepts such as self-organization and dissipative structures" (1997 [1996], 27).

As a complex system, narrative can be considered a dissipative structure rather than, in line with Todorov's sequence and ideal narrative, a conservative structure.

7 Ideal Narrative, or Emergence and Self-Organization?

These considerations bring us now to the supposed isomorphism in Todorov's model between sequence and the "ideal narrative" (*récit idéal*), an isomorphism rooted in the principles of classical mechanics which, when viewed through the lens of complexity studies, calls for considerable re-examination. On the whole, narratology appears not to have addressed in an explicit or sustained way the questions raised by the passage from a sequence to a narrative in its entirety.[34]

of the most controversial topics in narrative theory. For a nuanced and keenly argued discussion, see Göran Rossholm's contribution to this volume.

34 This is true particularly of structural narratology, but it pertains also to many of the more recent currents of research, due in part to the holdover of the story/discourse dichotomy in its various avatars. A case in point is unnatural narratology, one version of which treats unnatural

Complexity theory, on the other hand, having devoted a great deal of research to the questions surrounding the relations between parts and wholes in the natural and the social sciences, offers a number of takes on the issues from a different angle, notably through the concepts of emergence and self-organization. In my estimation, these findings open up potentially fruitful lines of reflection for the narratologist.[35]

In a historical and conceptual overview of emergence and self-organization, Tom De Wolf and Tom Holvoet distinguish between the two phenomena as follows, stressing that, although interconnected, they must not be confused:

> the essence of emergence is the existence of a global behaviour that is novel with regard to the constituent parts of the system. The essence of self-organisation is an adaptable behaviour that autonomously acquires and maintains an increased order (i. e., statistical complexity, structure, etc.). (De Wolf and Holvoet 2005, 9)

Moreover, emergence is characterized as "a global behaviour that arises from the interactions of the local parts and that [...] cannot be traced back to the individual parts" (3). Emergents are novel because they arise as the system evolves over time, cannot be predicted or deduced from local parts and are decentralized, with no part of the system controlling or directing macroscopic behavior. The principles of emergence, as they began to be applied in complexity studies during the 1980s, have been integrated in various forms into complex adaptive systems theory, nonlinear dynamical systems theory and chaos theory, synergetics and, most pertinent for our purposes, far-from-equilibrium thermodynamics, where emergent phenomena arise as dissipative structures out of far-from-equilibrium conditions. As for self-organization, De Wolf and Holvoet define it as "a dynamical and adaptive process where systems acquire and maintain structure themselves, without external control" (7). Self-organization is thus characterized by autonomy, adaptability to perturbations and far-from-equilibrium dynamical processes. What binds emergence and self-organization together is nonlinearity

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or antimimetic *fabulas* separately from unnatural *syuzhets* (i. e., texts that are not ordered in the conventional linear way). Doing so, however, rules out the entropic processuality of narrative that results from nonequilibrium states and intersequentiality. At the same time, severing *fabula* from *syuzhet* in this way tends to underestimate narrative discourse as a complex system as well as to overlook exchanges of narrative as system with the outside world through positive feedback and dissipative structures. (See Richardson 2013 and Richardson's contribution to this volume.)

35 Path-breaking work on narrative understanding and emergent behavior has been undertaken by H. Porter Abbott (2008) and by Richard Walsh (2011) on emergent narrative as a form of simulation in digital and non-digital environments.

and positive feedback, the result of which is to amplify initial fluctuations, thus producing the "small cause, large effect" phenomenon on the macroscopic scale in the form of emergents (cf. Baranger's first, third and fourth properties of complexity).

The term emergence, it should be noted, does not appear in nonequilibrium thermodynamics. In place of this concept are dissipative structures which require, and occur in, far-from-equilibrium conditions, themselves a prerequisite for the process of self-organization (cf. Prigogine and Stengers 1984, 175 and 189; Prigogine 1997 [1996], 70). Dissipative structures are caused by bifurcations, "the manifestation," as stated in section 6.3 above, "of an intrinsic differentiation between the parts of the system itself and the system and its environment." In an open system, bifurcations have a symmetry breaking role, infusing the relations between microscopic and macroscopic scales with stochastic processes.

It should be fairly evident at this point why narrative sequence, once it is viewed in terms of the principles of complexity rather than in those of classical mechanics and science, cannot be isomorphic with ideal narrative. Indeed, narrative sequence itself is in a state of nonequilibrium, wavering between near equilibrium and far from equilibrium (rather than a passage from equilibrium to disequilibrium and back to equilibrium). Due, furthermore, to the instabilities generated out of fluctuations (inherent to one degree or another in initial conditions) as well as to the symmetry breaking effects of bifurcations (i. e., critical turning points) and the dissipative structures resulting therefrom, the global narrative cannot be predicted on the basis of its sequences, any more than the sequences can be formally deduced from the global story. This being the case, the very notion of "ideal narrative," according to which the properties of the micro scale are reduplicated on the macro scale, must be abandoned. As a result of dissipative structures (or emergence), the parts do not add up to the whole, just as the whole cannot be broken down into parts. A complex system, narrative is self-organizing to the extent that, through its exchanges with the outside world, the system itself evolves irreversibly, adapting in a nondeterministic, probabilistic, random or unpredictable way so as to either maintain or increase its levels of organization and complexity.[36]

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36 The intensification of narrative self-organization can be seen in John Barth's *Lost in the Funhouse* (1968). Reading this work in the conventional way, from the first page to the last, poses serious difficulties of cohesion between the fourteen stories. However, closer examination reveals an intricate *serialization* of the text into seven alternate paths which can be read in any order. The highly ordered symmetries that emerge from these various paths and their different combinations as well as the multiple interactions resulting from these combinations open up numerous symmetry breaking bifurcation points which, according to the order of paths chosen (cf. initial

8 The Two Intersequentialities

The correlate of the nonisomorphic relation between sequence and the global narrative resulting from symmetry breaking forces, the random relation between microscopic and macroscopic scales and the disproportion between parts and wholes is that narrative sequence, a reductive or summative notion, ultimately gives way to the overriding principle of sequentiality, understood as an irreversible process, the arrow of time.[37]

This being the case, however, it is essential to bear in mind that sequentiality, as it pertains to narrative, differs from irreversibility in nature in at least one fundamental respect. The subject matter of the natural sciences is natural phenomena, and the goal of these sciences is to formulate testable laws about these phenomena. Such is not the case of narrative theory, whose object of study is narrative, a certain form of semiotic representation. In narrative, the instabilities and other factors that trigger nonequilibrium, nonlinearity, positive feedback, bifurcations and dissipative structures occur within the culturally situated artifact, not in nature. It is for this reason that narrative sequentiality, in its irreversibility, ultimately consists in intersequentiality, both inferential and probabilistic. On the one hand are the differential relations, or gaps, occurring between the communicative and the actional—generators of the sense-making inferences peculiar to narrativity. On the other hand are the probabilistic or, more broadly, stochastic relations that arise between the arrow of time and nonequilibrium conditions with their fluctuations and instabilities—generators of information and entropic processes.[38] While the latter form does not pertain directly to all aspects of narrative, it does underlie processes of all kinds, in both nature and culture, and thus in narrative—processes that unfold reversibly and irreversibly, determinis-

conditions), produce a nonlinear assembly of long-range correlations at the edge of chaos where self-organization is most likely to occur. For an analysis, see Pier (2011).

37 In his contribution to this volume, Richard Walsh also views narrative in terms of sequentiality, defining narrative cognition as "*the semiotic articulation of linear temporal sequence*." He further states that spatial modeling and temporal modeling are two distinct modalities in themselves and that they are not assimilable into narrative cognition, thus calling into question holistic conceptions of narrative worlds. Walsh's cognitive-semiotic system thus runs parallel in several regards to the positions advanced in this paper, notably as concerns the separation of time and space through the second law of thermodynamics (cf. section 6.1 above), although the criteria do not fully coincide.

38 In light of these considerations, the definition proposed by Herbert Grabes is underspecified: "Sequentiality is the linear, unidirectional succession of elements or events, either reversible (as with motion in space) or irreversible (as in the flow of time)" (2014 [2013], vol. 2, 765).

tically and stochastically (cf. section 4 above), following a set of criteria that are distinct from those evoked in current narratological debates about the "natural" and the "unnatural," for example.[39] Together, the two forms of intersequentiality in narrative not only represent a potentially fruitful way to reframe critical issues in narrative theory, but they also open the way to positioning narratology in a way that addresses the barrier between the "two cultures," the sciences and the humanities. Such a positioning would be tantamount, for narratology, to what Kenneth Bailey (1994) describes as the passage from "the age of equilibrium" to "the age of entropy."

9 Conclusion

Narrative is a complex system, but complexity theory as it has been developed in the natural and social sciences does not represent a paradigm for narratology or serve as a master discipline for the study of narrative. By outlining some of the ways in which narratology might be commensurable with complexity theory, I have refrained from the attempt to "export" categories, concepts and methodologies wholesale from one discipline to another (cf. section 1 above). At the same time, the lines of reasoning adopted in these pages follow neither rigorous deductive procedures such as those of Greimasian semiotics nor loose inductive techniques of the type practiced by unnatural narratology. This is due partly to the fact that complexity studies have yet to achieve the status of a well-defined or unified discipline, for complexity is "one of those ideas whose definition is an integral part of the problems that it raises" (Nicolis and Prigogine 1989, 38 and 232). Complexity manifests and configures itself in different ways according to the field concerned, and for this reason its theorization and analysis must be adapted accordingly. Moreover, narrative theory, in its various approaches, has developed many sophisticated and fine-grained methods of analysis that stand on their own merits, oftentimes with disciplinary allegiances of other sorts. Consequently, when turning to complexity studies, the most promising way to proceed is to seek

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39 Defined by Jan Alber as "physically impossible scenarios and events, that is, impossible by the known laws governing the physical world, as well as logically impossible ones" (2009, 80), the unnatural is predicated on a number of unspoken scientific and philosophical postulates that, as the principles elaborated on this essay suggest, are challenged by the theory of complexity. For starters, unnatural narratology regards the natural and the unnatural in ways that are almost diametrically opposed to the complex conception, where the natural is random and irreversible and the artificial is deterministic and reversible.

out in what ways and to what degree narratology might be commensurable with that theory. As stated at the beginning, complexity theory does not serve as a paradigm for yet another narratology. In conjunction with narrative theory, this line of reasoning can nonetheless offer ways to capture some of the underlying complex processes that occur in narrative while at the same time bringing to light various features of complexity that are implicit in a range of narrative theories or, in other cases, underscoring issues that might call for re-examination from the perspective of complex phenomena.

The testing ground for any narrative theory is of course the going-and-coming between theory and analysis and the comparative study of narratives included in an appropriately selected corpus.[40] The present essay, by seeking to determine the aspects of complexity studies that are relevant for the theory of narrative, has not chosen this route, focusing instead on formulating a set of issues open for further research and debate. Among the features of narrative potentially concerned by these lines of inquiry are narrative progression (e. g., Phelan 2007),[41] narrative tension (Baroni 2007), dialogism (Bakhtin 1981 [1934–35]), eventfulness (Schmid 2010 [2005], 1–21, and Schmid's contribution to this volume; Hühn 2014 [2009]), the "open work" (Eco 1989 [1976]), cognitive processing of narrative (e. g., Herman 2013) as well as the highly diversified phenomena now coming under scrutiny by the burgeoning field of media studies along with transmedial and intermedial approaches to narratology (e. g., Grishakova and Ryan 2010; Jenkins 2006; Rippl 2015; Ryan 2006a; Thon and Ryan 2015). The list does not stop here, however, for complexity in narrative exists in many forms yet to be explored, and the study of narrative remains an open-ended endeavor.[42]

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40 See, for example, Valery Timofeev's fine-grained discussion in this volume of Nabokov's "Ultima Thule" (1942) which, though working with a different set of criteria from those employed here, shows how the creative process engages processes of monitoring, regulating and controlling narrative progression.

41 Also concerned in this regard is work by, for example, Kafalenos (1999) and Toolan (2009).

42 I wish to thank José Ángel García Landa, Per Krogh Hansen and Wolf Schmid for their insightful reading of this article and their suggestions.

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