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Basic Cable: Notes Toward Digital Ontology

Robbie Cormier
The University of Western Ontario

Supervisor
Nick Dyer-Witheford
The University of Western Ontario

Graduate Program in Theory and Criticism

A thesis submitted in partial fulfillment of the requirements for the degree in Master of Arts

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BASIC CABLE: NOTES TOWARD DIGITAL ONTOLOGY

(Thesis format: Monograph)

by

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The School of Graduate and Postdoctoral Studies
The University of Western Ontario
London, Ontario, Canada

Abstract

This thesis begins the work of constructing a fundamental ontology that employs the *network automaton*—a class of abstract computer program—as its model. Following a brief historical overview of the theory of network automata and its culmination in the work of Steven Wolfram, I examine how it bears on the ancient question concerning whether the continuous or the discrete has ontological primacy, consider the ontological status of materiality in consultation with Deleuzean ontology, and introduce the concept of *prescience* as a means of topologically mapping emergent patterns within the causal relations that compose the network. Finally, I will break the network automaton down even further into its most rudimentary functional operations, and consider preliminarily how this model might be adapted toward an atomistic theory of the subject.

Keywords

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Preface

Two circles that would not seem to have much in common, the burgeoning hacker movement and the original scientists of complexity theory, nonetheless share a fascination with a simple and curious little artifact. The glider (Figure 1), a grid-based pattern found in *The Game of Life* (a computer program developed by John Conway), is a three-by-three binary pattern—white cells correspond to 0s, black to 1s. When updated periodically by the rules specific to Conway's game (which update the state of each cell according to the state of the adjacent cells in the previous generation), the glider moves diagonally across the grid. It is,
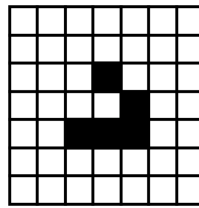
Figure 1: Glider

significantly, a concrete example of *emergent* behavior generated on the basis of very simple rules. Emergence describes the phenomenon whereby complex systems and patterns arise out of a number of simple and smaller-scale interactions. Conway's game prompted scientists—Stephen Wolfram at the forefront—to began to inquire into cellular automata (of which Conway's game was a specific, two-dimensional example, with a specific rule-set), and especially one-dimensional *elementary* cellular automata. They came to discover behaviour isomorphic to that of a glider in other, still more elegant automata. Cyberneticians, in turn, harnessed these findings towards other applications, especially those sociological and economic, led by Heinz von Foerster and Niklas Luhmann. Later, many hackers would, at the suggestion of Eric S. Raymond in 2003, adopt the glider as a symbol for their community—one likewise capable of surprising feats on the basis of simple, coordinated cooperation. The glider, like the individual hacker, is according to Raymond "abstract, at first a bit mysterious-seeming, but a gateway to a whole world with an intricate logic of its own."[1]

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[1] Eric S. Raymond, "How to Become a Hacker," *catb.org*, May 12, 2013, http://catb.org/~esr/faqs/hacker-howto.html (accessed June 20, 2013).

The question of the political was particularly divisive among the progenitors of cybernetics—in fact, it was the main point of contention between Francisco Varela and Humberto Maturana, the two theorists whose early collaborations yielded the key discursive touchstone of their field, *autopoiesis*. Varela, sensitive to the application of holist biological concepts to the social realm in order to justify authoritarian intervention (especially in the Chilean civil war, in which he had a personal stake), departs from Maturana in resisting the adaptation of autopoiesis to describe bodies politic—although he acknowledges that there may be "an extremely delicate passage between the two."[2] He would later try to illuminate this passage by drawing on the resources of phenomenology (Martin Heidegger and Maurice Merleau-Ponty especially), writing, in *The Embodied Mind*:

> The challenge posed by cognitive science to the Continental discussions, then, is to link the study of human experience as culturally embodied with the study of human cognition in neuroscience, linguistics, and cognitive psychology. In contrast, the question posed to cognitive science is to question one of the most entrenched assumptions of our scientific heritage—that the world is independent of the knower. If we are forced to admit that cognition cannot be properly understood without common sense, and that common sense is none other than our bodily and social history, then the inevitable conclusion is that knower and known, mind and world, stand in relation to each other through mutual specification or dependent coorigination.[3]

Mutual specification and *dependent coorigination* are compellingly enigmatic ideas. The latter suggests that the two terms of the subject/object binary share a common ancestor; the former, vaguely, that they are symbiotic—each fulfills the conditions of the other's endurance, two parts of a single machinery. One of these interfaces is the proper means of conceptually mediating the translation of subjective patterns into objective ones (and vice versa).

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[2] Francisco Varela, "Autopoïese et émergence," in *La Complexité, vertiges et promesses*, ed. Réda Benkirane (Paris: Le Pommier, 2002), qtd. in John Protevi, "Beyond Autopoiesis: Inflections of Emergence and Politics in Francisco Varela," in *Emergence and Embodiment: New Essays on Second-Order Systems Theory*, ed. Bruce Clarke and Mark B. N. Hansen, 94-112 (Durham: Duke University Press, 2009).

[3] Francisco Varela, Evan Thompson and Eleanor Rosch, *The Embodied Mind: Cognitive Science and Human Experience* (Cambridge: MIT Press, 1991), 150.

The concept of mutual specification seems to guide Mackenzie Wark's fusion of natural and political horizons in his book *The Hacker Manifesto*. The critique of capital hinges on *abstraction*, the capacity to deconstruct the world for the purposes of rebuilding it differently:

> Whatever code we hack, be it programming language, poetic language, math or music, curves or colorings, we are the abstracters of new worlds. Whether we come to represent ourselves as researchers or authors, artists or biologists, chemists or musicians, philosophers or programmers, each of these subjectivities is but a fragment of a class still becoming, bit by bit, aware of itself as such.[4]

If it is, broadly speaking, the task of philosophy to *abstract*, then the language of networks and graphs should be commensurate to that task. The goal we set ourselves—although it seems far removed from politics—is to understand the mechanics of abstraction, that is, relation at its most granular (for relation is perfectly fractal, and perfectly *abstractly* so). While the idealistic pursuit of large-scale political change is our initial motivation and our pet pursuit, our inquiry, which concerns fundamental ontology and the conditions for any relation whatsoever, is the rigorous preliminary work that may, in the end, prove too rarefied to generate any actionable political implications. We cannot know until we've tried it. Given the poverty of descriptive vocabulary with regard to networks, we will supplement this formal discourse with metaphors suited to guiding the reader into the shape or layout of the structures considered—where the tone veers from functional to metaphorical is where we retreat from the topic twofold to (with any luck) sharpen our vision tenfold.

Our starting point, and a constant reference throughout, will be Stephen Wolfram's *A New Kind of Science*. Written in 2002, the book speculates that the world may, at its lowest level, evolve in a way similar to a kind of automaton even more abstract than the aforementioned cellular automaton: a *network automaton*. This model replaces the grid of the cellular automaton with nodes and connections—it is purely formal, making no claims about the specific character of nodes or the relations that connect them, hence its abstractness. Rather than having the rules applied globally to every part of the automaton at each step, he proposes that nodes update *asynchronously*, one by one—the laws, therefore, are not of an entirely different order from that over which they govern, thereby sidestepping some of the problems of transcendentalism (although not all of them—illuminating the remaining

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[4] Mackenzie Wark, *A Hacker Manifesto* (Cambridge: Harvard University Press, 2004), [002].

problems will be the province of chapter three). Finally, the nodes of the network automaton are, in order to interact with the rules in such a way as to produce complex behavior, hypothesized to have a constant *valency* (i.e. the number of connections each node can support). The simplest form to which any network of this type can be reduced is a *trivalent* network (i.e. each node supports three connections), and so this is the network form that Wolfram uses as a heuristic to demonstrate some of the properties of network automata more generally. This last point might not seem especially compelling; but if we consider that the automaton, in its most elegant expression, would likely grow from an initial seed (as we will address in chapter two), it seems reasonable to expect that the nodes of subsequent generations would be produced according to a template.

Wolfram, however, does not go into great detail about the implications of such a framework, except to provisionally reconcile it with some of the major preoccupations of physics (elementary particles, quantum entanglement, etc.)—despite the fact that he is required to make a speculative leap in positing the automaton at the foundation of physical reality, Wolfram's approach otherwise bears all the hallmarks of standard scientific positivism. In contrast to his "physics-side" (*ontic*, following Heidegger) analysis, we will undertake one that is "ontology-side," concerned with the mechanics of the network automaton as such. Mutual specification and dependent coorigination, while not explicitly stated, will guide our inquiry. The goal is to take what is already a comparatively elegant system (the network automaton), reveal the complexity nonetheless inherent in its structure (its *enthymematic bases*, as we will go on to call them), and attempt to explain how this complexity can be resolved into even simpler processes. As mentioned before, given the profound abstractness of the subject material, we are obligated to draw metaphors and examples from a number of disciplinary domains—computational theory, physics, mathematics, and even biology and ecology.

The purpose of this thesis, in short, is to highlight the productive ways in which the language and concepts of automata theory can contribute to the study of fundamental ontology. In this sense, it is influenced by Alain Badiou's set-theoretical ontology; but where Badiou had to commit to a specific axiomatization of set theory (namely Zermelo-Fraenkel) in order to support his ontological architectonic, our approach is once removed in terms of abstraction. Specific axiom systems necessarily weigh completeness against consistency—in keeping

with Gödel's incompleteness theorem, they cannot achieve both universally—and Badiou's strategy, roughly, is to find one that approaches universal consistency and account for its concomitant incompleteness by means of the evental structure (expressed in terms of the errancy of the void, or the excess of inclusion over belonging). Wolfram, by contrast, applies automata to model not only the axiom systems behind set theory, but also the axiom systems for a number of classical, contemporary, and even as-yet unexplored branches of mathematics. Automata theory is thus capable, in effect, of historicizing the basis of Badiou's purportedly universalist project by treating it computationally. Instead of positing an axiomatization and exploring the consequences for ontology, we will begin the work of reverse-engineering the operations implicit in the automaton (in network form, especially), which appears to exercise a kind of scope over individual axiomatizations (one we might call, following Albert Lautman, *dialectical*).

That said, we are obligated to posit *something* as our starting point. There are thus three specific initial hypotheses we make to initiate the line of inquiry we intend to pursue:

1. The world is reducible to nodes and relations (the "general" hypothesis)
2. Each node has a constant valency (a "secondary" hypothesis; for the purposes of keeping our examples accessible, we will follow Wolfram in considering it trivalent)
3. There is no "global clock"; instead, nodes are updated asynchronously

We will proceed to describe each of these in more detail after contextualizing them within Wolfram's larger body of work and its historical influences in the first chapter following this introduction. The remaining two chapters will consist in "spinning out" the implications if these propositions are held to be true; with regard to constant valency, we hope to illuminate the mechanism whereby this apparent limitation translates into a force of accretion—one that not only facilitates the growth of emergent bodies *within* the automaton, but also guides the evolution and expansion of the automaton itself.

The second chapter will bring an ancient question—the one concerning whether reality is fundamentally discrete or continuous—to bear on our adopted model. Given that Wolfram's model quite clearly resembles the theory of monads developed by Gottfried Leibniz in the early 1700s, we will, in the course of critiquing Deleuze's interpretation of the monadology (which, given Deleuze's predilection towards the intensive, is framed precisely in terms of continuity), be able to situate Wolfram's model in the context of the current Continental-philosophical moment (especially the speculative realist movement), as well as explore

(provisionally) the nature of materiality under the network automaton. This will require an examination of the kinds of gradients that obtain in the automaton, gradients that not only help to stabilize emergent patterns, but that also have profound consequences with regard to how we understand causality.

Since the network can be further deconstructed into a number of rudimentary functional operations, the third chapter will conduct a kind of "ecological" study of these operations, so called given that the interaction of the automaton's elements are capable of producing metastable patterns analogous to species in an ecological environment—again, we will be looking at these functions in terms of their dependent coorigination or mutual specification. Given that a Turing machine is, in light of its computational universality (i.e. able to simulate any possible algorithm), capable of the same operations as the network automaton but less complex, we will attempt to show the functions of the former are manifest in the latter, but to a greater degree of abstraction. By breaking the automaton into active and passive components, and recognizing that the passive component is a *product* of the active component (analogous to a Turing machine that generates its own tape), we can begin to pry further into the anatomy of the active component and the "proto-logic" that governs it. Against the recursive (or reflexive) closure of systems under the cybernetic paradigm, we will explore the interface between nature and natural laws (known modestly as *rules* in a network automaton) in order to generate concepts that may help in describing interfaces more generally, especially one with the trappings of a subject.[5]

Why, personally, do I find computational physics compelling? It is not because technology (which has thrived on computation) "works," and should therefore serve to validate the science that went into it (or, in Wolfram's case, came out of it— *Mathematica*, the software

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[5] The cybernetic paradigm does little to conceptualize the *interfacial* aspect of the subject—how sense is in a sense *coextensive* with that sensed—and is, in that respect, insufficient as a theory of immanence. While Gilles Deleuze provides a more rigorous approach, chapter two will address the problems with his system, problems that stem primarily from the way in which the virtual is presumed to be scaled to and rendered pliable by the actual—what amounts to a retrojection of the actual onto the virtual. So, while Deleuze is sensitive to the transversal and circulatory nature of subjectivity under the doctrine of becoming-other (or insofar as he is a kind of panspsychist), he is ultimately confronted by the same issue: an inability to describe the interface (or, in other words, the coinstantiation of a certain kind of subjectivity with certain material configurations, especially those neurological). In chapter three, we marshal Heideggarian thought (including Albert Lautman's interpretation of it inasmuch as it applies to mathematics) to begin to address this impasse, as well as the problematic scientific dogma regarding the governing relation of law over matter.

he had developed prior to writing *A New Kind of Science*, was crucial towards formulating and exploring the central tenets of his theoretical paradigm). Instead, it is the technological adaptability of computational systems to different energetic forms (i.e. kinetic, heat, elastic, etc.), which could in turn interact with any known phenomenon through energy exchange, that I find salient. Our ability to theoretically project our influence to any region of physical reality by means of technology, to affect any given particle (without necessarily doing so "intentionally") through it, suggests that *the world can be reconfigured computationally*; we indulge this possibility by hypothesizing that *the world is configured computationally*. Once we consider a few models, it becomes clear that there may be, in fact, certain pockets of reality over which we can exert no control, on account of the peculiar causality that ensues from certain models.

Before engaging in the progressive abstraction of complexity into algorithmic simplicity, we shall conduct a brief historical overview of the field of cellular automata theory, the features of complexity that they reveal, and Wolfram's adaptation of these insights to fundamental physics. Additionally, we will look at some of the critical responses to his work in order to refine the parameters of our own approach.

Chapter 1

1   Automata

> Although the jury is still out on the cellular automata model, it may indeed prove
> to be a robust way to understand reality.
> —Katherine Hayles

In this chapter I will outline the history of *automata theory*—the study of "self-acting"
systems, following the etymology of the word "automata"—to its culmination in the
work of Stephen Wolfram. Automata have been tremendously successful as a means of
modeling a number of diverse physical processes (e.g. the structures of snowflakes,
leaves and flowers, and the structure and patterned pigmentation of mollusk shells). As a
result of this explanatory power and scope, some have begun to consider the possibility
that cellular automata (or an isomorphic system) may be adequate to describing the whole
of reality. Wolfram is perhaps the most vocal in this respect, and has experimented
extensively with automata in order to tease out the implications for empirical phenomena
and theoretical physics if it is indeed true that the physical world behaves like an
automaton. His speculative wager is that spacetime can be conceived of as a network that
expands from a simple set of initial conditions and rules. As it evolves, it develops a
complex, contorted internal structure that gives rise to spatiotemporal phenomena.

Before delving into more specialized automata, however, it seems pertinent to start with
the most familiar form, one no less capable of inspiring awe with its flickering,
cosmatesque[6] canvas: the two-dimensional *cellular automaton*. Katherine Hayles
describes the experience in *How We Became Posthuman*: "Programmed into a computer
and displayed on the screen, cellular automata give the uncanny impression of being
alive."[7] We will begin our history of the subject with "Conway's Game," a particularly
simple variety of cellular automaton capable of generating enormous complexity.

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[6] *Cosmati* is an ornate, geometrical arrangement of inlaid stone that was popular in Medieval Italy.

[7] N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and
Informatics* (Chicago, IL: The University of Chicago Press, 1999), 241.

1.1 *The Game of Life*

Martin Gardner, writing for the October 1970 edition of *Scientific American*, was the first to draw the public eye to a curious innovation contrived by a mathematician from the University of Cambridge. John Horton Conway had, at the time, already made significant contributions to the fields of group and number theory; but the article was not particularly concerned with his "serious work." Instead, it focused on a "fantastic solitaire pastime" Conway had recently developed as an exercise in so-called "recreational mathematics."[8] Christened *Life* (or *The Game of Life*) for the uncanny vitality of the emergent entities it generated, the game was an early instance of a computer-based cellular automaton. It consists in a grid of arbitrary size, with each cell capable of alternating between two states—"on" or "off," represented visually as black and white, respectively. The user is responsible for determining the initial state of the system, clicking on whatever cells they choose to toggle between their states and, if desired, setting the parameter that controls the time that elapses between each successive application of the rules (i.e. each *update*) once the automaton is initiated. When satisfied with their settings, the user initiates the automaton, and the rules take over. Conway's game operates on the basis of three extraordinarily simple rules applied to every cell on each periodic update: each "on" cell with two or three "on" neighbors (i.e. orthogonally or diagonally adjacent cells) remains "on" in the subsequent generation; each "off" cell with three "on" neighbors turns on; and each cell with fewer than two or more than three "on" neighbors turns off. In keeping with the decision to call the game *Life*, these three rules are described respectively as governing survival, birth, and death (by isolation or overcrowding). The ongoing appeal of Conway's game, beyond the analogies drawn to biological or vital processes, inheres in its capacity to generate sublime patters that overwhelm the eye with their complexity. In most cases, however, this dynamism peters out, eventually resolving into a finite collection of artifacts—some static, some oscillating periodically—scattered across the grid. These isolated, metastable configurations persist through all subsequent generations.

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[8] Martin Gardner, "Mathematical Games: The fantastic combinations of John Conway's new solitaire game 'Life'," *Scientific American*, no. 223 (October 1970): 120-3.

Despite his esteem for Conway's work, Gardner's trivialization of cellular automata belied close to three prior decades of research into and use of cellular automata as a means of modeling other processes. In the 1930s, John von Neumann adapted a lattice network model—employed by his friend Stanisław Ulam to study crystal growth—to his research on self-replicating systems. By using an abstract model, von Neumann could overcome the cost and technical limitations that would prevent him from actually manufacturing a machine that could build copies of itself. Von Neumann's lattice was composed of a two-dimensional grid of cells with 29 possible states for each, provisions for controlling the transmission of information similar to a Turing machine, and a smaller neighborhood—in contrast to *Life*'s "Moore neighborhood" of eight cells (four orthogonal and four diagonal), a "von Neumann neighborhood" consists of only four orthogonal cells. With this system, he was able to demonstrate the logical conditions for self-replications; however, it would later be discovered that Conway's game, despite its comparative formal simplicity, could also be used to create self-replicating systems. *Life* has since been shown to be Turing complete: it can emulate a universal Turing machine by means of crafting logical gates out of static configurations of artifacts and using "gliders" (patterns that translate diagonally across the grid) as a binary "tape" to convey information. Von Neumann also adapted his cellular automaton to the study of liquid motion—Wolfram would later do the same with his comparatively simpler model.

Under the influence of von Neumann and Ulam, Norbert Weiner (the father of cybernetics) and his research partner Arturo Rosenblueth developed a model for excitable media (especially cardiac impulses) in the 1940s with some of the characteristics of a cellular automaton, but relied on continuous (as opposed to discrete) values to account for the propagation of waves; however, J. M. Greenberg and S. P. Hastings demonstrated that this model could, in fact, be rendered as a true cellular automaton (i.e. with discrete values) in 1978. Cellular automata have also been adapted to the study of symbolic dynamics, thanks to the work of Gustav Hedlund in the late 1960s.

One application of this model—relevant to our purposes given its resonance with a problem in contemporary continental philosophy—was conceived by Edward Moore in 1962 in order to solve what was known as the "firing squad synchronization problem."

First proposed by John Myhill in 1957, the problem consisted in designing a set of rules for a one-dimensional cellular automaton that would, from a single starting active cell, eventually evolve to a state in which all cells became active—analogous to a system of rules whereby a firing squad could discharge their weapons simultaneously. In this case, the person designing the rules amounted to a general giving the order to fire. As we proceed through this chapter, however, it will become clear that cellular automata are in fact disposed towards a much less centralized, emergent internal self-organization more in line with the Deleuzean concept of the *war machine*. "The problem of the war machine, or the firing squad: is a general necessary for *n* individuals to manage to fire in unison?"[9]

1.2   *A New Kind of Science*

Research into cellular automata exploded in the 1980s, led by British scientist Stephen Wolfram. He began his work in 1983 at Princeton, undertaking the systematic analysis of the "elementary" cellular automata. Members of this subset are one-dimensional[10] and two-state, where the state of a given cell is determined by the state of *that cell* and its *two immediate neighbors* in the penultimate generation. Since the neighborhood is therefore effectively three cells, each of which can occupy one of two states at a given time, there are 8 (that is, 2^3) possible configurations for each neighborhood. A rule must specify the next-generational outcomes for each of these configurations—a single rule for an elementary cellular automaton, then, is really a set of eight rules corresponding to the eight possible configurations. There are thus 256 (2^8) elementary cellular automata in total, each with a unique rule and an assigned number from 0 to 255, in accordance with the standard "Wolfram code" naming convention. His principal discovery, as we shall see, is that even with such simple initiatory conditions, incredibly and irreducibly

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[9] Gilles Deleuze and Félix Guattari, *A Thousand Plateaus*, trans. Brian Massumi (Minneapolis, MN: The University of Minnesota Press, 1987), 17.

[10] One-dimensional cellular automata are often represented two-dimensionally as a single row of cells. With each generation, a new row representing the updated state of the automaton is often affixed to the bottom of the previous generation, in order to display the changes in the system over a number of generations.

complex behaviour resulted from some of these simple rules. In one case, that of Rule 110, this behaviour is Turing complete.[11]

The early research into elementary cellular automata demanded little in terms of computational power or algorithmic sophistication. But in order to move beyond these initial cases, Wolfram required software that could cope with more complicated configurations, one that could extrapolate the results of cellular automata to other systems of modeling and representation. In the late 1980s, he developed *Mathematica*, the software that would enable him to continue his research. Now capable of deepening his original insights into elementary automata, he began work on *A New Kind of Science* in 1992. The book's core premise is succinctly stated: complex worldly phenomena can be described in terms of programs that execute a simple set of rules, like a cellular automaton. That is not to say, as many detractors have leveled against Wolfram, that he believes the universe is actually a cellular automaton. We will return to this in the next section.

Measuring in at 1197 pages with indices excluded, Wolfram's magnum opus has become an object of intense controversy in the scientific community for its highly speculative approach and its deliberate accessibility to non-specialists—it is argued that Wolfram deviates from standards of methodological rigor in order to appeal to a popular audience. However, *A New Kind of Science* primary means of demonstrating its scientific merit, and the nature of its contribution to science, consists in demonstrating redundancies within existing theories—not only does it simplify for the layman, it also reduces existing theories to their most essential in a rigorous, mathematical sense. Wolfram's first major achievement was discovering a universal Turing machine even simpler than the seven-state four-colour version constructed in 1962, ending its forty-year tenure. His alternative requires only two states and five colours, and is designed to emulate the Rule 110 elementary cellular automaton—its universality is thereby proven transitively. He also

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[11] A Turing complete (or computationally universal) system if it can be used to simulate a single-taped Turing machine; more colloquially, it means that the system is capable of acting like any general-purpose computer.

reduces the Meredith's axiom system, derived in 1967 for propositional calculus (i.e. basic logic) and formulated in terms of NAND operators ($\overline{\wedge}$), from nine operators to six. Wolfram notes that prior to *A New Kind of Science*, "very little work appears to have been done on finding short axioms for logic in terms of NAND"[12]—the proficiency of Wolfram's modeling methods at simplifying NAND expressions, however, could have a very real impact on consumer electronics, which rely extensively on NAND (and its dual, NOR) logical gates as the basis for flash memory.

While these previous two contributions can be read as responses to specific historical instances (the 1962 Turing machine; Meredith's 1967 axiom system), the third major contribution pertains to the history of mathematics more generally. Wolfram generates a list of tenable alternatives to the traditional axiom system for propositional calculus— alternatives that are nonetheless ignored in contemporary mathematics—and in turn demonstrates that there are no specific qualities of the dominant axiom systems that make them more effective by comparison. Hence, he reasons, they must have been "selected for" more or less arbitrarily: "there is in a sense nothing fundamentally special about the particular axiom systems that have traditionally been used in mathematics […] in fact there are all sorts of other axiom systems that could perfectly well be used as foundations for what are in effect new fields of mathematics—just as rich as the traditional ones, but without the historical connections."[13]

1.3   Automata Theory Meets Ontology

1.3.1   Fredkin: Randomness, Seeds and Soups

When Conway decided to name his game *Life*, it was not to suggest that his creation accurately mimicked vital processes in all their complexity; but given the extraordinary explanatory power of Wolfram's analysis, it is tempting to believe that cellular automata might structure actual processes. In some specific cases, this has been all but confirmed: a

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[12] Stephen Wolfram, *A New Kind of Science* (Champaign, IL: Wolfram Media, 2002), 1175.

[13] Wolfram, *A New Kind of Science*, 816.

mollusk shell, for instance, is generated line-by-line (like a one-dimensional automaton) by a lip of soft tissue that secretes pigmentation according to activating and inhibiting chemical interactions (analogous to rules) between neighboring cells. The result is a pattern that closely resembles, especially in the case of so-called "divaricate" forms, a number of the elementary cellular automata. In fact, Wolfram also shows how the various shapes of shell produced are contingent on five simple parameters. In another example, he explains how the formation of snowflakes simulates a cellular automaton on a hexagonal grid. The exothermic effect of adding new ice to the snowflake inhibits the uniform growth of the crystal, thereby simulating rules similar to the ones in *Life* responsible for turning cells off. This accounts for the snowflake's characteristic intricacy.

But despite the fact that cellular automata can generate patterns remarkably similar to those found in some mysterious natural phenomena, it is a tall order to extend its principles to the very structure of being as such. Konrad Zuse, inventor of the first working computer (the Z3), was the first major proponent of the idea that the universe is itself a digital computer, an idea that would later be taken up and merged with insights from the study of cellular automata by Edward Fredkin, a physicist at Carnegie Mellon University, to form the field of *digital physics* (or, more holistically, *digital philosophy*). His "finite nature hypothesis" is essentially a synthesis of Leibnizian monist metaphysics and contemporary insights into computation—at the lowest level of "digital mechanics" (DM) there are, according to Fredkin, "atoms of energy, momentum and force. DM has no need for particles as entities separate from the theory; they arise from the theory. There is an absolute reference frame and there is angular anisotropy; both [are] accessible to the microscopic process."[14] For our purposes, "digital physics" will refer specifically to Fredkin's hypothesis that the universe can be conceived of as a runtime cellular automaton.

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[14] Edward Fredkin, "Digital Mechanics," *Digital Philosophy*, December 2000, http://64.78.31.152/wp-content/uploads/2012/08/digital_mechanics_book.pdf (accessed September 3, 2012), 11.

Wolfram agrees with Fredkin on the discreteness of all things, and goes to great lengths to reconcile the finite states that power automata with phenomena that have traditionally been treated as continuous—fluid dynamics especially. To this end, he relies on a very specific notion of randomness: not the natural science's notion of "ambient" or "environmental" randomness (i.e. noise or interference), nor chaos theory's randomness that percolates from random initial conditions, but rather a conception of randomness as intrinsically generated by or endogenous to a system. Such systems he terms *autoplectic*, as opposed to *homoplectic*. The difference between randomness from initial conditions and intrinsic randomness is subtle (i.e. both are sensitively dependent on initial conditions, such that randomness "unfolds" in a deterministic way), but the difference can be conceived in these terms: the former case always requires some analogue of a (primordial) *soup* in order to initiate a causal or genetic line, while the latter only requires a given *seed*[15] that behaves according to a few simple rules. The former requires recourse to another system in order to explain how and why its random initial condition (the soup) was able to, despite its randomness, *become a domain unto itself* (a *pool*). A seed, by contrast, already contains the principle of its domain, which it is able to extend to include other nodes in the network as it evolves.[16] Wolfram does not go to such lengths to differentiate the two *a priori*—he takes it for granted that a seed is not "given" in the same way as a soup—but he does proceed to show how these three stochastic mechanisms interact empirically, and how the effects of ambient or initial randomness are ultimately washed out by intrinsic randomness. Also obscured is the discreteness of the underlying structure: "continuous behavior can arise in systems with discrete components only when there are features that evolve slowly relative to the rate of small-scale random changes."[17]

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[15] Wolfram uses the word "seed" when describing randomness in computer systems in the appendix to *A New Kind of Science*, page 970.

[16] In other words, the *compossibility* of nodes is guaranteed *immanently*, as opposed to transcendentally. We will discuss this further in chapter two.

[17] Wolfram, *A New Kind of Science*, 333.

In addition to addressing the problem of continuity and "[taking] responsibility for explaining the *origins* of randomness,"[18] Wolfram's approach from intrinsic randomness seeks to reconcile the mechanistic nature of cellular automata with the probabilistic field of quantum mechanics. The randomness generated by autoplectic processes is, in many cases, *computationally irreducible*, such that it cannot be expressed or modeled more elegantly by any analytical approach. There is no short cut, no means of "reverse-engineering" the process or "outrunning" it as it unfolds temporally. This is a direct consequence of Wolfram's *Principle of Computational Equivalence*. The principle can be stated in a number of different ways, but Wolfram suggests the following as the most general formulation: "almost all processes that are not obviously simple can be viewed as computations of equivalent sophistication."[19] In other words, this principle simultaneously posits an *upper bound* and a *low threshold* for computational sophistication. As a result, our most rigorous methods of analysis are, in many cases, inadequate to the complexity generated by even elementary cellular automata—there are no formulae we can use to predict outcomes without knowing the initial rules, no direct means of accessing those rules, no incremental procedure to find them. The probabilistic elements of quantum mechanics, such as indeterminacy, are thereby attributed to a structural shortcoming in reason itself.

1.3.2   DeLanda: Mechanism-Independence and Isomorphism

Another implication of the Principle of Computational Equivalence is that cellular automata are not privileged as a means of modeling fundamental physics or ontology—just about any system of computation (or even a combination of them) could be used, seeing as they are (for the most part) commensurable and equally sophisticated. One of the most common misconceptions regarding *A New Kind of Science* is that it follows Fredkin in ascribing such centrality to cellular automata, when in fact Wolfram's affinity for the model is only with respect to its role in his own scholastic development and its

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[18] Ibid., 300. Emphasis added.

[19] Ibid., 716-7. This principle presumes that all processes, whether naturally occurring or produced by human effort, can be considered computations.

aesthetic appeal. When Wolfram turns to the problem of fundamental physics, he instead relies on a network model, given that cellular automata have "too rigid a built-in notion of space."[20] One notable scholar to have committed this error is Manuel DeLanda, whose book, *Philosophy and Simulation: The Emergence of Synthetic Reason*, sets a precedent in drawing the study of cellular automata within the ambit of continental philosophical thought. DeLanda explains how other physicists unwilling to dispense with continuous phenomena have, by contrast, affirmed a variant of cellular automata known as *lattice-gas automata*, which are capable of emulating differential equations.[21]

The study of lattice-gas automata, DeLanda argues, does not confuse *mechanism* (properties; the actual) with *mechanism-independent structure* (tendencies and capacities; the virtual); this, he continues, is an error committed by digital physics, which he mistakenly attributes to Wolfram.[22] As a result, he claims that "the assertion that class IV rules by themselves imply the emergence of complex automata" is unjustified;[23] however, class IV rules are *by definition* sufficient to generate complex automata (so long as certain, exceptional initial conditions are not given)—Wolfram himself invented the classification system. The distinction he makes between mechanism and mechanism-independence relies on the concept of *isomorphism*: different mechanisms that exhibit similar behaviour must have this isomorphism explained with reference to "a component that is independent of any particular mechanism."[24] Typically this involves mapping out the structure of a *possibility space*, wherein the distribution of singularities determines the probability of certain possibilities becoming actualized. When different mechanisms

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[20] Wolfram, *A New Kind of Science*, 467.

[21] Manuel DeLanda, *Philosophy and Simulation: The Emergence of Synthetic Reason* (London: Continuum, 2011), 30-1.

[22] DeLanda claims textual support for "the mistaken idea that the material universe itself is a giant cellular automaton using class IV rules in which all actual processes are the equivalent of simulations" (DeLanda 30) on page 845 of Wolfram's *A New Kind of Science*, but this idea is not present or implied in any form.

[23] DeLanda, *Philosophy and Simulation*, 30.

[24] Ibid., 13.

are isomorphic to each other, it is because their possibility spaces overlap. What makes certain phenomena *emergent*, then, is the fact that that they self-organize in a way that is not attributable to the interactions among their constituent parts; isomorphism, then, can be thought of as the *signature* of overlapping possibility spaces in the realm of the actual, similar to the way in which the Higgs boson is the signature of the inaccessible Higgs field that structurally imparts mass to particles. In fact, Wolfram makes a similar realization in a different way: he likens persistent structures in cellular automata to *real particles*, and intermediate structures (i.e. those that emerge from the collision of two or more persistent structures) to *virtual particles*.[25] It is important to note that the isomorphism DeLanda considers is *qualitative*—it must be recognized (presumably by a human subject) and is "highly improbable [and] cries out for an explanation."[26] Indeed, suspicious correlation is perhaps the strongest stimuli for scientific research, and one on which Wolfram's highly speculative approach is especially dependant.

DeLanda's critique of digital physics—which, again, he wrongfully levels against Wolfram—ultimately targets its lack of *cognitive significance* in light of its presupposition of computational universality:

> While it is relatively uninformative to say that a universal Turing machine built within a cellular automaton can simulate physical processes, to say that a lattice-gas automaton can directly simulate patterns of flow does generate a new insight: it adds the isomorphic behavior of automaton states to the already known isomorphism between the behavior of solutions to differential equations and the behavior of physical processes. And this added isomorphism needs to be explained.[27]

The logic of DeLanda's argument here is clearly flawed: his point is that *digital physics* is *mistaken*, but his proof is that *simulations* conducted on *universal Turing machines* are *uninformative*—a non sequitur. He seems to be suggesting that to treat automata as a model for fundamental physics by virtue of its computational universality is like trying to

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[25] Wolfram, *A New Kind of Science*, 540.

[26] DeLanda, *Philosophy and Simulation*, 13-5.

[27] Ibid., 31.

explain processes in a relentlessly holistic way (i.e. explaining a convection cell by means of a detailed census of the kinetic energy of each of the molecules in the population). If this level of detail were required in order to describe reality, how can we explain the purchase that our current theories have on reality? Wolfram's theory, however, makes no such concession—it does not imply that we cannot formulate general principles to describe patterns, but merely recognizes that these theories cannot ultimately be reconciled with each other *unless they are formulated in terms of their being features of an automaton*.

We can counter DeLanda's critique with two questions: How does the *empirical* recognition of a functional similarity between two systems guarantee the *a priori* commensurability of their respective possibility spaces? And given that the recognition of an isomorphism requires that we delimit the relevant aspects of the two systems being compared (accomplished by specialized analytical procedures), how does this not also presuppose computational universality (qua *perception*) adapted to a specific situation or object (and why, then, is it any more "informative" than simulation)?[28]

Regarding the first question, cultural theorist Steve Beard recognizes the same problematic "Lucretian swerve" in DeLanda's earlier work, *A Thousand Years of Nonlinear History*. Beard argues that DeLanda's overreliance on the Deleuzian notion of the diagram "makes it possible for him to say that a hurricane is powered by the same motor as a truck," an unwarranted mystification.[29] DeLanda might reply that the subjective apprehension of an isomorphism—the question as to whether it is present—is not distinct from its objective validity. It *is* the guarantor of the isomorphism. He would be following Deleuze, who writes:

> Neither the problem nor the question is a subjective determination marking a moment of insufficiency in knowledge. *Problematic structure is part of objects themselves*, allowing them to be grasped as signs, just as the questioning or

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[28] In other words: if the problem with cellular automata that they can be "rigged" to be isomorphic to processes (i.e. to simulate them), is perception not also guilty of "rigging" isomorphism by determining in what respects the systems are isomorphic?

[29] Steve Beard, *Aftershocks: The End of Style Culture* (London: Wallflower Press, 2002), 87.

problematising instance is a part of knowledge allowing its positivity and its specificity to be grasped in the act of learning. More profoundly still, Being (what Plato calls the Idea) 'corresponds' to the essence of the problem or the question as such. It is as though there were an 'opening', a 'gap', an ontological 'fold' which relates being and the question to one another. In this relation, being is difference itself.[30]

This tack is able to explain why isomorphism (as something *recognized*) is not homogenizing or analogical—it is inherently tied to being-in-difference. But this further complicates the second question: DeLanda's frame of reference is no longer *recognition* (of isomorphism) as a particular deployment of (computationally universal) *perception*, but rather *perception* as a particular deployment of (infinitely recombinant) *virtuality*. If anything, this alternative formulation of the problem makes it all the more incisive. While the virtual may at some point be a necessary component of mechanism-independent explanation, to access it with a key wrought from a small set of superficial resemblances between phenomena seriously risks misrepresenting it.

The above Deleuze quote actually does a good job of drawing together a number of themes that will be addressed in the coming chapters. In the second chapter, we will look at Deleuze's account of Leibniz in *The Fold* and how it bears on the discrete and the continuous. The quote also gestures towards Heidegger with his characteristic vocabulary—his influence on our ontological project will become more pronounced over the course of this essay.

So, while we are sympathetic to DeLanda's insistence on isolating the mechanism-independent features of a phenomenon (its unmanifested tendencies, its unexercised capacities), we reject his critique of digital physics on the grounds that his alternative fails to adequately differentiate simulation from isomorphism in terms of *analysis*—that is, the isolation of the specific aspects of a phenomenon to be simulated or compared. It need not require linguistic mediation; in fact, DeLanda goes on to show in chapter seven of *Philosophy and Simulation* that "pre-linguistic hunter-gatherers could perform

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[30] Gilles Deleuze, *Difference and Repetition*, trans. Paul Patton (New York: Columbia University Press, 1994), 63-4. Emphasis added.

perceptual analyses of situations using script-like structures."[31] It does, however, comprise a means of simplifying data, eliminating redundancies, and embracing regularities. But DeLanda seems much more confident in analysis as a means of progressing towards an understanding of the virtual and intensive structure of systems. He places much more stock in it than Wolfram, who arguably perceives much less redundancy and legitimate isomorphism in worldly processes, seeing them instead as irreconcilably divergent.[32]

And this is where I believe Wolfram's project differs, though subtly, from traditional mechanistic materialisms. Although he does not seem to recognize it himself, his Principle of Computational Equivalence implicitly favours *speculation* as a means of overcoming the limitations of analysis. We can speculate at some of the questions this might raise: If speculation is capable of "outstripping" analysis with much less computational expenditure, is there a naturally-occurring functional analogue to speculation that allows nature to "outpace itself" (perhaps in the form of subjectivity)? We might call it *errancy* and allow it to resonate vaguely with Badiou's "errancy of the void," although it is errant in a different sense. We might consider mutation in organisms to be a manifestation of this errancy, which may in turn be a response to other biological manifestations of errancy (i.e. in the environment). But does this errancy extend into the domain of fundamental physics? If so, does it consist in deviating from rules, reflexively influencing or altering rules, or skipping generations? We will be better equipped to approach or reformulate these questions after taking a closer look at the rudimentary operations of the network automaton, with which we will be concerned in chapter three.

Before proceeding to Wolfram's alternative model for fundamental physics, which will allow us to clarify the demands of an accompanying ontology, let us recapitulate: while we accept DeLanda's concern that emergent dynamics should be accounted for by means

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[31] DeLanda, *Philosophy and Simulation*, 152.

[32] Wolfram's system, in other words, is sensitive to the *undecidability* of processes, which impedes their being treated as isomorphic. Wolfram, *A New Kind of Science*, 753-5.

of mechanism-independence, we reject his critique of digital physics. We in turn follow Wolfram in rejecting Fredkin's conception of digital physics on the grounds that it already has too much structure in-built, specifically with regard to what Fredkin identifies as the number one "winning feature" of cellular automata: locality.[33]

1.3.3   Wolfram: Network Materialism and Asynchronous Causality

As previously mentioned, Wolfram does not hold to the notion that the universe unfolds like a cellular automaton—since the rules apply to *neighborhoods*, there is already a strong presupposition of spatial locality. Added to the list of surprising continental-philosophical currents in Wolfram, then, is a Bergsonesque awareness of the spatial as it inheres in natural-scientific and metaphysical discourses. As such, he reasons, "at the lowest level there will just be certain patterns of connectivity that tend to exist, [and] space as we know it will then emerge from these patterns as a kind of large-scale limit."[34] He goes on to elaborate a vision of space as a *trivalent network*, meaning that each node entertains exactly three connections.[35] A valency of three is sufficient given that "any node with more than three connections can in effect always be broken into a collection of nodes with exactly three connections."[36] It is possible for a network to evolve in a way similar to a cellular automaton (without the fixed underlying geometric structure) by adding new nodes with each generation. Complex, "class IV" behaviour is possible if the rules affecting each node are indexed to the number of nodes that are up to two connections away (i.e. less than or equal to network distance two).

Cellular automata also presuppose another feature that Wolfram's nominalism cannot abide: a global "clock" that updates all cells simultaneously. The alternative is to have

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[33] Fredkin, "Digital Mechanics," 24.

[34] Wolfram, *A New Kind of Science*, 468.

[35] At first glance, the recent proposal by Frank Wilczek that space-time can be instantiated in crystals (a team of physicists at Berkeley are attempting to physically implement this hypothesis) would give credence to Wolfram's theory—a trivalent network shares the regularity and relative simplicity of crystalline forms.

[36] Ibid., 476.

each node update *asynchronously*, as opposed to all of them *generationally*. Wolfram first illustrates his point using the simple model of a *mobile automaton*, in which the rule only applies to an "active cell" at any given step. The rule also stipulates the position of the active cell at each step relative to its position at the previous step, such that it can translate across the field. But while the mobile automaton is a visually simpler representation of asynchronous updating, it still demands the construct of an active cell and a rigid infrastructure compared to that of a network system.

Mobile automata, as it happens, can be conceived of as special cases of more general *substitution systems*, which do not require an active cell and are very amenable to being adapted into network form. A substitution system replaces blocks of elements with other blocks at each step. It does so sequentially, parsing the string of elements until it finds a substring that matches the schema in the rules, replaces it with the sequence defined by the rule, and leaving unchanged all elements that do not fall under the schema. To convert this to a network form, each updating event (not the elements themselves) can be considered a node, and connections are drawn between these events. The resulting structure is, in many cases, thoroughly rhizomatic (see Figure 1).
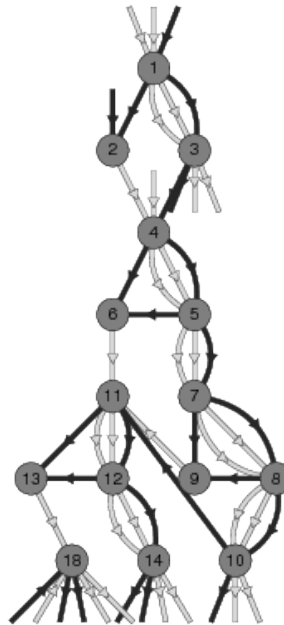

Figure 2: Network automaton

The implications of this *asynchronous causality* on theories of time, causality and epistemology are enormous. Wolfram reinstalls the virtual into the classical Humean "constant conjunction between two events" without relying on a human subject, as has the phenomenological tradition—an observer implicated in the causal system can be at *any* point, not necessarily a human subject, and yet "will never see all the individual steps in [the underlying evolution]. The most they will be able to tell is that a certain network of causal relationships exists—and their perception of time must therefore derive purely from the properties of this network."[37] In other words, the entire universe could, theoretically, be taken apart and reconstructed in a moment, between moments—more likely, certain sites in the cosmic network would undergo a number of subtle, discrete changes below the Planck scale—and we would be *structurally oblivious* to the microscopic forces at work in making effect from cause. But just as the randomness generated by fluid mechanics tends to "wash out" small-scale discreteness such that there is a macroscopic impression of flow, so the continuity of space and time manifests at a "higher order of magnitude" than the gnashing of causal machinery.

It could be called the *imperfection of the causal record*, following Charles Darwin's chapter in *The Origin of Species* entitled, "On the Imperfection of the Geological Record." Something similar is at work. In that chapter, Darwin offers a conjectural account of why there is no smooth paleontological record of the transitional forms between species that his theory of evolution demands. The fossils of certain species appear to emerge without any clear line of descent. Darwin accounts for this by claiming that strata rich with fossils indicate periods of *subsidence* (wherein thick sediment accumulates to protect the fossils). Outside of these short, intermittent periods of subsidence, fossils are eroded and destroyed. What we see then, upon excavation, are snapshots of evolutionary states separated by great lengths of time: "Each formation, on this view, does not mark a new and complete act of creation, but only an occasional

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[37] Ibid., 490.

scene, taken almost at hazard, in a slowly changing drama."[38] Likewise, if we conceive of each fossiliferous stratum as an update in our causal epistemology, we lose the many miniscule causal operations that mediate the transition between cause and effect. Again, it is not lost to *human* epistemology, but rather to the "world" of each node in the network as it is updated. Wolfram's is effectively a highly formalized formulation of Darwin's conjecture.

The network model of can also be adapted to represent elementary particles, multiple universes, and other concepts of quantum theory. In the case of the particle, *non-planar localized structures* within the network are capable of mobility and persistence despite autoplectic randomness—we will address these in chapter two. In a trivalent network these structures can be reduced to a single general form known in graph theory as $K_{3,3}$, which could thus be posited as the general form of any particle whatsoever. To express multiple universes (in keeping with the "many-worlds interpretation" of quantum mechanics), the network can be based on a broader version of a substitution system known as a *multiway system*, wherein replacements are applied in all possible ways at each step, yielding multiple output strings (i.e. worlds) instead of just one. Wolfram also goes on to explain quantum entanglement (i.e. "spooky action at a distance"), time dilation, the speed of light and gravity with reference to different features of the causal network (its proto-locality, its rate of expansion, its clocklessness and its curvature, respectively).

Wolfram's audacious theory, despite its elegance in purging itself of locality and a global clock, nonetheless presupposes a number of other constants that Wolfram does not recognize: the coherency and consistency of states, rules, and the application of rules (i.e. their "successful" application and their scope); repetition; and uniform dimensionality and valency. Most of these could be collected under the notion of *reliability*—the assumption is that rules are not capricious, that they do not deform themselves or the constants that allow the network to persist and grow. But there is still a question about the

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[38] Charles Darwin, *On the Origin of Species*, ed. Gillian Beer (Oxford: Oxford University Press, 2008), 232.

ontological status of states. In the case of cellular automata, states effectively filled the void posited by each cell; in network form, they fulfill the given valency and designate the kind or quality of a causal relation between two updating events. But what is the precise relationship between states and rules? Do the rules draw upon a reservoir of charge, or mass, or something else capable of marking the causal vector with a discrete state, and if so does this undermine Wolfram's hypothesis of universal discreteness with a more primordial instance of continuity? Or are rule, state and vector all modalities of a single machinery, absolutely interdependent and mutually generative? And what are the implications of the digital-logical phenomenon of *metastability*, wherein a continuous voltage value cannot be resolved into a 0 or a 1 by a logical gate (also closely linked to the phenomenon of *symmetry breaking*)? These questions will be explored in greater detail in the second chapter, especially in light of Deleuze's interpretation of Leibniz and the monadology in the former's book, *The Fold*, and his debt to fellow French philosopher Gilbert Simondon, whose concept of *individuation* at the foundation of his philosophy of technology explicitly relies on metastability.

1.4 Interdisciplinarity

The foregoing remarks reveal the close inter-referentiality of the fields of math, science, and technology proper that a philosophical exegesis of Wolfram's work demands. The chain whereby math is legitimized by scientific application and science in turn by technological exploitation is disrupted here—despite its scientific pretensions, the philosophical stakes of Wolfram's argument dislodge it from this particular dialectic, in a sense, despite his entrepreneurship (following Fredkin, he started a software company, Wolfram Research Inc., which nets an estimated annual revenue of $50 million). While both *Mathematica* and his new online "knowledge engine" *Wolfram|Alpha* are claimed to operate on the principles and algorithms outline in *A New Kind of Science*, their enormous market success have not in turn validated his Copernican ambitions—he still remains an object of contempt for many mathematicians, scientists, and technologists alike. Perhaps it stems from an elitist revolt against his pop-scientific overtures to nonexperts, or else retaliation on the part of the disciplines against Wolfram's

interdisciplinarity, perceived as an assault against their niche knowledge. The latter case might make him an attractive ally to practitioners of theory.

In light of their mutual implication, the following chapters will synthesize insights from mathematics (discreteness and continuity), science (intensity and extensity), and technology (metastability) in order to delve deeper into the structural conditions for Wolfram's *network materialism*. As such, I will be drawing on Leibniz, Gilbert Simondon and Henri Bergson by way of Deleuze (and in their own right). The tension in Leibniz's own work between his calculus and his interest in binary will be especially illuminating—Deleuze is largely dismissive of the latter tendency in *The Fold*, calling it an "adventure" undertaken by the "Chinese" Leibniz (as opposed to the later, "Baroque" Leibniz, who does not admit of voids).[39]

Before moving on, let us recapitulate. Wolfram offers a model of the universe as a particularly abstract version of automaton, expressed in terms of a network that grows and transforms according to a simple set of rules. All things are implicated within this network as configurations of discrete non-planar arrangements analogous to particles. This theory dispenses with the spatiotemporal presuppositions of Fredkin's model— locality and a universal clock—by having updating events occur asynchronously. Consequentially, he develops a unique model of intermittent causality (which I have described as a formalization of Darwin's geological conjecture) and formulates the so-called Principle of Computational Equivalence. But these observations, though fascinating and with numerous implications, do not adequately explain the material root of the system, especially regarding its status as discrete or continuous. It is to this question that we now proceed.

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[39] Gilles Deleuze, *The Fold: Leibniz and the Baroque*, trans. Tom Conley (Minneapolis: University of Minnesota Press, 1993), 36.

Chapter 2

2   Binary, Continuity, Prescience

The idea of *continuity* is one with which we are abundantly familiar—it refers to the state of being an unbroken or uninterrupted flowing whole. By contrast, the *discrete* is that which is divided into individual units. Aristotle was the first to take a systematic look at continuity and discreteness as they feature in mathematics in reply to the doctrine of atomism mounted by Leucippus and Democritus. In book six of the *Categories*, he argues that they are each modalities of the category of *quantity*, but ultimately siding with the continuous as proper to physical reality given the perceived continuity of space, time, and motion. In so doing, he initiated a debate that still rages well over two millennia later. Typically the stakes wagered on are these: on the one hand, the compelling empirical evidence of continua; on the other, the comparative mathematical elegance of the discrete. Leibniz was a thinker of the discrete (the binary) before developing his differential calculus and formulating his famous apothegm, *natura non facit saltus* ("nature makes no jump"); Bernhard Riemann, despite reservations with regard to what it would do to the previously unproblematic mathematical definition of distance, proceeded to extend the differential calculus into the branch of differential geometry that bears his name. The lineage favouring continuity extends into those working under the influence of Charles Sanders Peirce in the twentieth century, Peirce having named and defended the unconscious acknowledgement of the doctrine of continuity: *synechism*. The opposition between synechism and atomism has more recently taken the form of, respectively, an opposition between theorists of *intensive* and *extensive* multiplicity, the former most closely associated Bergsonian philosophy; the latter, most recently, in Badiouean circles.

As we discussed in chapter one, Wolfram commits himself to the ontological primacy of the discrete—countable nodes and edges, on his analysis, are sufficient to generate phenomena that appear continuous (his central example being fluid dynamics, which can be simulated by systems like cellular automata). Given computational equivalence, there is no degree of complexity characteristic of empirically continuous phenomena that outstrips the computational capacity of a discrete and Turing complete model. Our

primary goal with this chapter is to examine the possibility that a network automaton might draw upon a deeper continuity in order to sustain itself.

As it stands, Wolfram's model is, to use the Heideggerian term, *ontotheological*—it posits an entity (the *ex nihilo* appearance of a seed and a set of rules to guide its evolution into a network) as the fundament of other entities, instead of considering the deeper processes that give rise to it (i.e. the entity in its Being). In other words, we are trying to surpass the boundary imposed by scientific positivism, the one that claims to eschew metaphysics for logical analysis while simultaneously positing a metaphysical domain: the realm of the empirical. As we shall see in this chapter, there are *reclusive* regions of being that propagate their effects empirically and are causally contiguous with these effects, but which are not necessarily empirical themselves due to a phenomenon of network automata that we will come to call *differential prescience*. Additionally, we will consider two sites where continuity (especially in the form of *intensity*) could manifest in the network automaton: external to it as the matrix that gives rise to the initial seed (and potentially overcoming the problem of ontotheology), or internally as the "substance" of states or extension (similar to the way in which a continuous voltage is translated into a discrete state in computational logic gates). While there may be more than two binary states in a network automaton, this is not what is at issue. The key question is this: since more than one possible state is required to animate the system at all, we are denied the conceptual elegance of a "seed," but not the possibility that the two states are derived from a deeper continuity in a relation of "being-together-in-opposition" (*Auseinandersetzung*), like the poles of a magnet.

First, however, we will look at the current state of the discrete/continuous debate, specifically some approaches that have attempted to reconcile the two and the response this has prompted in the emerging field of object-oriented ontology, which will lead us into a discussion of a byproduct of emergent behaviour that I will call *prescience*.

2.1   Harman: Arbitrary Objects to Prescient Nodes

There have been a number of attempts to reconcile the discrete and the continuous. Graham Harman exposes a (relatively contemporary) lineage of such attempts in *The*

Quadruple Object, arguing that they share their origins in Anaxagoras, who believed that all things, as shards of a boundless *apeiron*,[40] harbour the information needed to recreate any other being—a lineage that includes Giordano Bruno's contractions of infinite matter, Gilbert Simondon's metastable individuation, and Manuel DeLanda's "heterogeneous yet continuous" plane of virtuality (influenced, in turn, by Henri Bergson and Gilles Deleuze).[41] These are all approaches that, Harman argues, *undermine* the ontological primacy of objects (his is, to that end, an object-oriented ontology, or OOO); on the other hand, fellow OOOist Timothy Morton accuses Einstein's student David Bohm of *overmining* objects[42] by positing the "implicate order," a sub-quantum crucible for the forging of objects that Morton elsewhere considers "a very beautifully worked out *apeiron*."[43] Overmining, which consists in treating objects as important "only insofar as they are manifested to the mind, or are part of some concrete event that affects other objects as well,"[44] is a tendency characteristic of *correlationism*—the term used by Quentin Meillassoux to describe any doctrine according to which we cannot think subject and object independently, only of the correlation between the two.

Setting aside the fact that the *apeiron*, according to practitioners of OOO, is said to both undermine (Harman) and overmine (Morton) objects, this chapter will demonstrate that their alternative—to insist on the "paradoxical" status of objects as *emergent* (i.e. not reducible to the sum of their parts) and *reclusive*[45] (i.e. ontologically deeper than any

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[40] *Apeiron* is the cornerstone of Anaximander's cosmology. It holds that ultimate reality [*arche*] is an infinite and eternal creator and destroyer of worlds and materials.

[41] Grant Harman, *The Quadruple Object* (Alresford: Zero Books, 2011), 9.

[42] Timothy Morton, "Of Houses: Object-Oriented Ecology, Continued," *Ecology Without Nature*, March 7, 2011, http://ecologywithoutnature.blogspot.ca/2011/03/of-houses-object-oriented-ecology.html (accessed May 7, 2013).

[43] Timothy Morton, November 5, 2012, https://twitter.com/the_eco_thought/status/265554242478170114 (accessed May 7, 2013). Emphasis added.

[44] Harman, *The Quadruple Object*, 11.

[45] Ibid., 39. Harman's reading of Heidegger expands the analysis of "readiness-to-hand" (i.e. the tool *in use*, such that its material properties "recede" in inverse proportion to its usefulness), rendering it a universal principle of the presentation of objects. Any object so presented, including Dasein, does not

relation with another entity can exhume)—while compelling, need not insist on paradox. Nor does it imply a perfectly granular mereology (i.e. that objects, following Bruno Latour, are arbitrary in their scale, composed of any number of things, and that all of them [at a given time?] reserve the same ontological status). We sympathize with Harman's argument that the appeal to pre-individuality is effectively an empty gesture and does not substantively resolve the tension between the discrete and the continuous:

> If this deeper reality contains seeds of individual things, then these seeds are either distinct from one another or they are not. If not, then we have monism. And if they are distinct, then we have the same situation as in the actual world of objects, with nothing gained but the *assertion* that they are "both connected and unconnected at the same time."[46]

It is a conceptual sleight of hand we should be careful not to invoke in charting an alternative course. We part with Harman and his peers in their decision to take objects, *defined paradoxically in terms of their own arbitrariness* (i.e. that they undermine the correlation between thought and being at the same time they are nominated as arbitrary objects by a conscious subject), as the proper focus of philosophy. More specifically, we believe that the insistence on the paradox of objects is less attractive than our alternative, which will postulate regions of being that, despite participating in the causal machinery of the world, consist of a great number of smaller-scale causal changes that do not, as a result of the structure of the network automaton, register with other regions in the

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present *all* of itself—"The readiness-to-hand of an entity is not exhaustively deployed in its presence-at-hand." This effectively wrenches Heideggerian phenomenology from its *correlationism*, the doctrine that human and world cannot be thought independently of each other. Where Harman's analysis nonetheless slips back into correlationist discourse often—to wit, "For there is already a failure of sorts when I simply turn my attention towards entities, reflecting consciously on my bodily organs or the solid floor of my home. But even when I do so, these things are not yet within my grasp…" While this lapse may be a deliberate attempt to illustrate, with more familiar examples, the general form of the argument, it has indirectly contributed to another fervent debate within the same philosophical circle, namely, concerning the subjective or agential status of non-human objects (i.e. how presence-to-hand manifests in relations between non-human objects). Our system, by contrast, is able to postpone the discussion of subjectivity by focusing on relations in the abstract, and can therefore account for reclusiveness more generally—rather than an *oscillation* that is *innate* to objects, reclusiveness is itself emergent, a feature of network automata at the lowest frame of reference. Nodes, as we shall see, are reclusive to other nodes in proportion to their *prescience*, a property that follows from the asynchronous causality described in the first chapter.

[46] Harman, *The Quadruple Object*, 9.

network. This manifests, at a higher frame of reference, as the reclusiveness of an object of study, but it *does not* testify to the object's relevance to ontology—we explain reclusiveness in terms of emergence, as opposed to explaining both in terms of paradoxical objects. Although Morton has admitted that the litanies OOOers draw up to illustrate the inclusivity of objects (for instance, postulating an object composed of the Mauritian finance minister, the world's supply of prosciutto, and the ghost of Mister Ed) are artifices intended to elicit a critical remove from mereologies based on "simple substances,"[47] the position that these objects actually exist at the absolute floor of reality is often paired with apathy toward the sources or processes that gave rise to them in their variable individuality and collectivity. Further, to assume that all objects are compatible as objects with other objects seems to presuppose a deeper unity—an apeiron, perhaps, or a common "operating system" or "platform"—to secure this compatibility.

We will thus explore an alternative in Wolfram's system that can, in fact, account for the emergent and reclusive aspects of objects *at their most fundamental* (i.e. as nodes) rather than committing ourselves to scalable objects and the litanies they invite. I have already discussed how the nodes in Wolfram's network automaton are mutually reclusive in light of the phenomenon of asynchronous causality—the causal record is incomplete from the perspective of any given constituent element of physical reality. And emergence is, of course, Wolfram's central concern; however, he does not really concern himself with the ontological status of emergence. In Harman's formulation of emergence as characterizing processes "over and above their pieces," emergent forces have a metaphysical inflection, ostensibly conceived of as transcendent "pseudo-laws" that are emergent both "from the top" (qua pseudo-laws, as a result of the complex formal interaction of the transcendent laws of physics) as well as "from the bottom" (qua "systems," as a result of the particular characteristics of matter upon which laws obtain). Emergence for OOO, then, is a pineal juncture for the material and ideal worlds.

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[47] See also Ian Bogost's "Latour litanizer," which he describes as a "little gadget [that] underscores the rich diversity of things": http://www.bogost.com/blog/latour_litanizer.shtml (accessed May 19, 2013).

It is difficult to isolate Wolfram's perspective on the nature of the relation that obtains between a rule and that to which it applies; however, as we discussed in chapter one, his nominalism is implicit in his substitution of asynchronous causality for a global clock. We will return to this problem in the third chapter; for now, we are concerned with Wolfram's position with regard to continuity and discreteness. As we discussed in the first chapter, Wolfram commits himself (as does Fredkin's digital philosophy) to the discreteness of reality insofar as it is resolvable into finite nodes and relations. His critique of continuity rests on two postulates: that randomness is autoplectic (i.e. generated internally), and that the small-scale discrete causal relations are "washed out" at higher frames of reference. By "washed out," Wolfram is specifically referencing the tendency of perception to regard the average behavior of many discrete elements as continuous, as in the case of fluid flow—however, we shall see how this is not merely a tendency of perception, but a general phenomenon which we can in part attribute to the asynchronousity of causality, insofar as micro-causal events retreat into pockets inaccessible to other nodes by *any* form of relation at any degree of abstraction.[48] The idea is that any perceptible causal event—be it an instantaneous discrete change (in the case of a binary switch) or one that is apparently continuous over time (like fluid flow)— is attributable to smaller-scale discrete changes.

There are two questions, then. The first is whether fundamental physical reality *is*, considered as a network, in fact composed of discrete parts—discrete rules, discrete states, discrete nodes and edges. For the purposes of this chapter, we will consider *rules* to be the most fundamental aspect of the network automaton, on the basis that all the functions that allow the network automaton to function (in addition to allowing it to function as the specific *kind* of automaton that it is, in accordance with the rules that govern its evolution) can be expressed as rules. If we were to consider the automaton as itself the result of deeper aleatory processes (a realm in which it is immersed, and one that is perhaps continuous), then rules would serve as the primary interface with that

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[48] It may be (although we will not address it here) that systems are at least in part defined by how they react to reclusivity, as though they were programs that responded in specific ways to missing data.

realm. This raises the question as to whether this interface is permeable, such that the aleatory forces of the outside (the virtual) penetrate into the automaton and interfere in (or facilitate) change within the network—a schema that is compatible with Deleuzean ontology—or if, instead, it is closed and insulated against the forces of the outside. We will return to this.

Secondly, with respect to perceptible changes (those discrete and those apparently continuous), does the degree to which they are perceived as continuous (and therefore at a remove from the discreteness of their underlying causal processes) in any way correlate to the reclusiveness of their causal machinery? We can imagine an emergent property— call it "strong asynchronous attraction"—that would describe a cluster of nodes updated (asynchronously) at a much higher frequency than what surrounds it, such that their collective internal causal mechanism is indiscernible by nodes outside the cluster. The nodes within this cluster could be described individually as being *more prescient*—given that they update more frequently than other nodes, they have (statistically speaking) a smaller causal "blind spot." A perfectly prescient node (a demigod node[49]) would be the hub in a hub-and-spoke network arrangement, one that would update immediately after any other node in the network (i.e. every second update) so that it would be immediately "notified" of every change in the network and would therefore have access to the full causal record; however, such an arrangement is a highly unlikely scenario—it would require that nothing in the world is causally related except through the mediation of a single particle, and this particle would be excused from the limitation on valency to which all other particles are subject (because it is connected to all others directly); to admit it would undermine the elegance of the model completely. Prescience is a property that nodes are endowed with as a result of metastable emergent patterns that result from the rules (analogous to the gliders and spaceships in Conway's game), it is not prescribed by or provided for in the rules themselves. Consider it in terms of the Higgs field, except that the topology of this field immanently imparts prescience to particles instead of mass. Individual nodes can update more frequently provided they are taken up in a system of

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[49] Demigod, rather than god, because a god would transcend the automaton.

nodes that "pass" the updating function among themselves a number of times before "relinquishing" it to the rest of the network. There is therefore a sort of impenetrable, mysterious causal core to these systems from the perspective of the nodes external to them.

From this, we can derive two major implications. First, these "systems" are causally reclusive in proportion to their asynchronous attraction as a system, but they are by no means closed loops—if they were, they would be all that is. At the level of the network, emergence can only be localized roughly, and not around a virtual singularity or topological attractor (such attempts would be frustrated by autoplectic randomness)—this is the second major implication, contra DeLanda (as we will see momentarily). While positing an attractor can be a useful heuristic in accounting for the perceived consistency and self-sufficiency of a system, it can and will always be undermined by the uncertain "boundary" of the system (by which I mean the point at which the updating function "escapes" the attractive system and reenters the larger field). DeLanda's "heterogeneous yet continuous" virtual realm is saturated with these singularities (each corresponding to a different machinic process) without adequately accounting for their source—similar to "real objects" in OOO, they just *are*, primordially and in the plural. He invokes the virtual as a means of reconciling the discrete and the continuous (the emergent body and the continuous gradient) without specifying *how* the problem is thus resolved.[50]

We have already seen that continuous gradients are not necessary for emergence to take place—cellular automata, after all, generate emergent entities using only discrete components. The proper site for the consideration of the problem of the continuous and

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[50] "I will argue that by extending each singularity into an *infinite series*, and defining these series without the use of metric or quantitative concepts, multiplicities can become capable of forming a heterogeneous continuum." Manuel DeLanda, *Intensive Science and Virtual Philosophy* (London: Continuum, 2002), 70. Singularities mark points where the virtual intervenes into the actual, a stationary point in a field of flux; however, if they exhaust their essence in maintaining a value of zero, then there is nothing to account for their differentiation within the actual—they exist as a set of homogenous, compossible particles. Unless, that is, a structure comes "pre-installed" in the actual that allows it to impose order on these particles. That structure is the subject—but there is no explanation offered as to its status within the actual as both compossible (such that it appears within the actual) and heterogeneous to singularities (i.e. not simply a zero-value). This is, we will go on to argue, the nature of Deleuze's correlationism.

the discrete is thus deeper than the stratum at which emergent behaviour takes place: in the rules themselves, specifically with regard to the strange materiality of the *states* they assign. It might be the case that states are rendered from a deeper continuity—at our (comparably macroscopic) frame of reference, the most compelling analog[ue] of this is the resolution, by a digital logic gate, of a continuous voltage into a discrete binary state (i.e. 0 or 1) that can in turn be sampled and processed. Gottfried Wilhelm Leibniz was responsible for the refinement of this binary system in the late 1600s. In keeping with my remarks at the end of the previous chapter, I will proceed to address this possibility from two different angles: first, from the philosophical approach of Gilles Deleuze, who synthesizes Leibniz, Simondon, Riemann and others in order to argue for the fundamentality of continuity qua *virtuality*, without relying dogmatically (apparently, at least) on an *apeiron* (although he is often caricatured as such); second, applying insights from physical and technological phenomena including metastability and the problem of its insolubility (i.e. "Buridan's Ass"), and spontaneous symmetry breaking. The following chapter will in turn synthesize these findings with insights from mathematics in order to address the problem of how rules have force.

2.2   Deleuze: Intensive Materiality

The Fold, first published in 1988, is one of Deleuze's last full-length manuscripts, and therefore represents a particularly well-developed expression of the ontology he had compiled, for the most part, in *Difference and Repetition* and *The Logic of Sense*. The central theme is that of individuation—that is, the transformation of a continuous intensive *plane of immanence* into discrete actualized forms by means of a single operation, namely folding. It is framed, in characteristic Deleuzean fashion, as an interpretation of another philosopher's work: in this case, the monadology and differential calculus of Leibniz. Deleuze argues that the early Leibniz, who conceived of the binary system in terms of "the full and void in Chinese fashion," is superseded by the late, "Baroque" Leibniz, whose differential calculus acknowledged that the void "always seems to be filled with a folded matter, because binary arithmetic superimposes folds that

both the decimal system—and Nature itself—conceal in apparent voids."[51] Perpetually
suspicious of voids, Deleuze fuses this late Leibnizean insight with his reading of Henri
Bergson to argue that *continuous intensity* is "something 'real' in matter that fills
extension (to be sure, a 'possible' reality) … that has inner characters whose
determination enters each time into a series of magnitudes converging toward a limit, the
relation between these limits being that of a new type, $\left(\frac{dy}{dx}\right)$, and making up a law.
Hermann Weyl will state that a law of Nature is necessarily a differential equation."[52]

The differential equation, as the expression of continuity, becomes manifest as the *real* of
matter—its *materiality* as such. We apprehend the intensive core of extension as,
according to Deleuze, the *texture* of a thing: "The thing in its texture surely contained the
asynchronous law that determined the play of its characters and the differential relation
between limits."[53] Extension is therefore a window onto the laws that structure it, and
these laws have a positivity that comes to suffuse extension with sensible material, for
instance, the greenness, or warmth, or hardness of a substance—not the secondary
qualities of the thing (i.e. that it is green, or warm, or hard), but rather the thing's capacity
to generate interpretable data about itself in forms compatible with modalities of sense.
Deleuze's examples are nonetheless somewhat misleading, obscured by the metaphysics
in language: in saying that color has *a* tint, *a* saturation, *a* value, it sounds as if he is
merely itemizing accidental properties rather than reflecting on them as pure modalities
of sensuousness.

Texture, the materiality of material, therefore serves as the "final conduit" for absolute
immanence under Deleuze's system, funneling substance into extension, whereby that
substance is expressed (in accordance with Deleuze's interpretation of Spinozan
metaphysics). But it must first pass through a higher filter, another level above the
material realm independent from material reality—precisely *that actuality that material*

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[51] Deleuze, *The Fold*, 36.

[52] Ibid., 47.

[53] Ibid., 50.

realizes. This level is that of the soul, the "subject as a metaphysical point"[54]: the *monad*. It can account, Deleuze argues, for what mechanical laws or extrinsic determinations (i.e. collisions) cannot, for instance, "the *unity* of a concrete movement, no matter how irregular or variable it may be. Unity of movement is an affair of the soul."[55] The monad, as "windowless," is insulated from external, mechanistic influence; by contrast, matter is porous—its windows, as windows into the virtual realm of intensity, are open to the forces transmitted among bodies. His move, viewed abstractly, is to transpose the traditional subject/object dichotomy onto a schema whereby they are derived from a common source and interdependent, but each independently governed by its own specific set of rules.[56] "[We] have rules of the world's composition in a compossible architectonic totality, but also rules of the world's actualization in the individuals of this totality at the upper level and, finally, as we shall observe, rules for the realization of the world at the lower level, in a materiality proper to this totality."[57]

Wolfram has already provided us with a supplement to mechanical laws that does not rely on a subject (even in its abstracted form as a "metaphysical point"): the intrinsic randomness generation, or autoplectic randomness, characteristic of a complex computational system and sufficient to impart a unified "prime movement" to the elements of the system. The texture of a node, however, is more difficult to account for—each individual node is not itself extensive, technically, given that extension only obtains as the network proceeds to grow (it "makes space"), and so the materiality of a state is not a matter of intensity filling extension. It is nonetheless a problem: how can we account for the capacity of matter to be sensuous—in short, its materiality? While it may seem disconnected from our initial question regarding the place of continuity in Wolfram's system, we must come to terms with it as it is a major corollary of Deleuze's ontological invocation of continuity. In order to show the advantages of adapting

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[54] Ibid., 25.

[55] Ibid., 13-4.

[56] Ibid.,137.

[57] Ibid., 75.

Wolfram's model to approach this question, we will first demonstrate the problematic station of the subject in Deleuze's theory of the fold.

Deleuze's Leibnizian transcendental philosophy,[58] which "bears on the event rather than the phenomenon" and "replaces Kantian conditioning by means of a double operation of transcendental actualization and realization (animism and materialism)"[59] nonetheless retains certain aspects of Kantianism: specifically, the mutual apprehension of worlding subjects under conditions of compossibility (for Kant, within the noumenal realm; for Deleuze, as a result of the "positive *possibility*"[60] of "*effectively* extend[ing the constitutive singularities of each world] in all directions up to the singularities of others, under the condition that the corresponding series converge, such that each individual includes the sum of a compossible world"[61]). The second-order cyberneticians would take a similar (though less nuanced) approach, influenced especially by the work of Heinz von Foerster: organizationally closed (i.e. windowless) cognitive systems arrive at a "consensus" on the world (i.e. *eigenbehaviors*) as a result of the recognition that other cognitions "inhabit" one's own.[62]

Insofar as each of these relies on a subject, they are susceptible to Quentin Meillassoux's critique of correlationism.[63] Although Deleuze's subject may escape the critique in its

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[58] His words. Many are quick to take offence to any insinuation that Deleuze is anything other than a philosopher of immanence, but it is important to note that he described his own project in *Difference and Repetition* as a "transcendental empiricism," alluding to Kant and Schelling.

[59] Ibid., 137-8. The content of the square brackets in the first sentence has been spliced in from a similar quotation on page 119 in order to reflect Deleuze's equation of bodies with matter and souls with monads.

[60] Ibid., 50. Emphasis added.

[61] Ibid., 72. Emphasis added.

[62] This argument is susceptible to a counterargument from solipsism. Von Foerster attempts, unsuccessfully, to refute this objection with his "Man with the Bowler Hat" argument—if the bowler-hatted solipsist encounters people "in many respects similar" to himself, he is compelled to believe both that these people are solipsists, but also that he, bowler hat and all, appears to them. In order to resolve this (false) problem, we posit a common world. The problem with this argument, of course, is that von Foerster conflates one's beliefs about the world with the actual state of affairs.

[63] "Correlationism consists in disqualifying the claim that it is possible to consider the realms of subjectivity and objectivity independantly of one another. … Generally speaking, the modern philosopher's

assertion of a sort of panpsychism (i.e. that it is not necessarily instantiated as an *animal*; that, instead, the world is *in* the monad, which is in turn *in* subjects[64]), our main issue with him is his inability to account for how the topological layout of subjectivity—its tendency to assume the status of *will* at some sites—entertains a correspondence with the material plane, wherein the sites at which will tends to appear are very strongly correlated with a particular configuration of matter, namely the animal. There is no explanation as to why the subject might "seek out" animal wills as a privileged site of expression, as a material site of resistance against mechanical laws. It is dogmatic to claim, as Deleuze does, that the subject "requires" a certain material "to complete it"—at the theoretical level, it implies that realization (in matter) is already implicit in actualization (in the monad) and there is no discernable reason why it should ever be "made explicit" as a second fold. In other words, it threatens to lapse into a *de facto* absolute idealism in its attempt to push past Kantianism. On the other hand, Deleuze relies on the *empirical observation* of the texture of an object as undeniably indicative of an intensive Real that somehow carries through each successive fold as if it were wet ink—but this basis for ontology is no less guilty of submitting to the correlation in its focus on subjective effects as opposed to ontological preconditions.

Barring this route, we are presented with three options, all of which satisfy or resolve certain aspects of Deleuze's ontology but none of which are wholly compatible with it. The first is the correlationist account, whereby materiality is bound up with the emergence of the subject—the two would be divergent yet interdependent configurations actualized within the network against a background of the network as a virtuality that is

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'two-step' consists in this belief in the primacy of the relation over the related terms; a belief in the consitutive power of reciprocal relation. The 'co-' (of co-givenness, of co-relation, of the co-originary, of co-presence, etc.) is the grammatical particle that dominates modern philosophy, its veritable 'chemical formula'." Quentin Meillassoux, *After Finitude: An Essay on the Necessity of Contingency*, trans. Ray Brassier (London: Continuum, 2008), 5-6. What distinguishes our current methodology from that of correlationism, then, is our embrace of *mutual specification* in addition to dependent coorigination—the two concepts, inherited from Varela, guide our inquiry as specified in the introduction.

[64] Deleuze, *The Fold*, 26.

nonetheless discrete, not intensive. With respect to the problems we raised with Deleuze, this could potentially resolve the issue of establishing correspondence between material and subjective expression, but this correspondence (whatever its nature, be it a "reflection" or "functional interdependence") would be achieved mechanistically, thereby throwing open the shutters of the monad. The "uncodeability" of materiality could, under these circumstances, be accounted for by the considerably greater prescience of materiality's generative processes relative to those processes whereby it is subjectively apprehended.

Alternatively, we could consider an anticorrelationist account that considers materiality as a process prior to, rather than parallel with, the emergence of the subject—this would approach the "naïve" or "unphilosophical" attitude toward matter. The problem of correspondence is rendered moot, if we allow that subjectivity emerges as an extension of (pre-sensuous) materiality. It retains the fundamental discreteness of the correlationist account, but it allows us to consider the possibility that emergent systems without any recognizable sensory apparatus (e.g. storms) are potentially (for what it's worth) as structurally incapable of apprehending the materiality of material as human subjects, without requiring us to posit that these systems are organized around a *subjective* singularity; empirically, this is a position to which Deleuze would probably be sympathetic, although he would probably happily submit that storms can possess some modality of subjectivity.

Finally, in addition to the correlationist and discrete anticorrelationist approaches, we might pursue a quasi-continuous anticorrelationism that treats materiality as epiphenomenal to the network itself (at its lowest level) and prior to the subject, allowing for the consideration of materiality as "realized but not actualized" and thereby taking it beyond the ambit of the Deleuzean paradigm (despite its sympathetic assertion of a continuity underlying the discrete). Nodes may not be extensive, but they might be subject to some intensive force that renders them "pre-material," a latency that only manifests as materiality in their connection—in this way, texture or materiality would be *minimally emergent* (i.e. two nodes are sufficient). The "source" of this pre-material charge would be either an intensive milieu in which the network is suspended or the

mobile complex comprised of rules and the updating function (the one that commutes throughout the passive network as its active supplement). For the sake of simplicity, we will henceforth refer to this mobile complex as the *shuttle vector*—to reflect not only its "vehicular" transmission along existing pathways, but also its active capacity to propagate a network (as do the plasmids after which it is named, although perhaps "vector" should here be understood in the physical sense, as opposed to the biological).

The third option is, theoretically speaking, a dead end. It functions (analytically, in other words, "in reverse") by bifurcating materiality into two arbitrary pieces that "just so happen" to be structurally compatible and reconciliatory, without giving a mechanism-independent account of *how* they are reconciled—the image of consummated materiality is retrojected onto its genetic conditions by means of this assumption of a felicitous harmony and cooperation between two radically contingent forces. Even if it is true that these forces are integrals of an intensive continuity (be it localized in the shuttle vector or a milieu), there is no compelling way to account both for their individuality *and* their compatibility without positing that their result is, pixel for pixel, a reconstituted primordial unity. It cannot not be dogmatic.

The only place for continuity in our system, it seems, would be as a means of accounting for the initial seed as an *individuated* entity. If this is an attractive alternative to the *ex nihilo* appearance of a seed, it is because we can conceive of this deeper underlying continuity as a volatile medium for pure experimentation that could, in the course of its unregulated churning, generate something [self-enclosed]. But against Deleuze, we do not allow that this non-mechanistic real can "take up residence" in extended objects as their constitutive substance (i.e. as something "real" in matter). There is a way in which this assumes that the real is "scaled" or "sensitive" to the world—it is one thing to have a seed that is able to endure the thrashing tidal forces that gave rise to it, and therefore to persist; but to open the floodgates and let these unstable forces rush into the world should certainly render their material support (i.e. extension) turgid and prone to rupture, like a cell lysing in a hypotonic solution or a lifeboat capsizing at sea. To assume otherwise requires an explanation as to how the virtual restrains or conditions itself in preparation for its encapsulation, which seems antithetical to its cataclysmic or catastrophic

significance as a "force of [beyond] nature." It is worth considering the intensive as an energy source to get the system going, but not as a boundless fuel source perpetually harnessed—that is, unless the shuttle vector relies on external energy (active transport) rather than the "gradients" that guide its movement (passive transport).

By contrast, then, our system completely prohibits any material interface with the real, if it is in fact true that there is this aleatory continuity underlying everything. Our virtuality is a structured virtuality, an extensive multiplicity as opposed to an intensive one (contra Henri Bergson). That it is an extensive multiplicity does not mean it presupposes *physical extension*—like the Platonic *khôra*, it is that which "gives space," although it is not, following the Pythagorean influence, a matrix comprised of triangles (which *does* presuppose extension); however, as a topological network arrangement, it is disposed to geometrical analysis. Just as persistent figures can emerge in cellular automata (for instance, the various characters in Conway's game), they can also appear in abstract form within network automata; however, this is difficult to visualize—for heuristic purposes, in order to represent a similar phenomenon two-dimensionally on the page, Wolfram considers the possibility of a network automaton that preserves *planarity*. He recognizes that this is likely not the case—the automaton is likely of a much higher dimensionality, which means that it could only, according to the Whitney embedding theorem, be laid out in a space with at least three dimensions[65]—but the idea is to present this simpler case to the reader in order for them to extrapolate the concept to a more complex situation. A
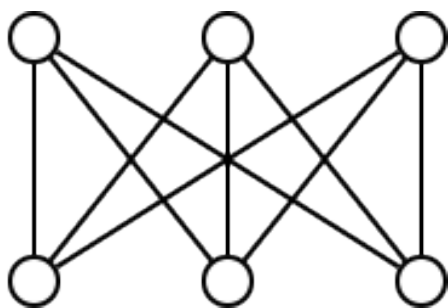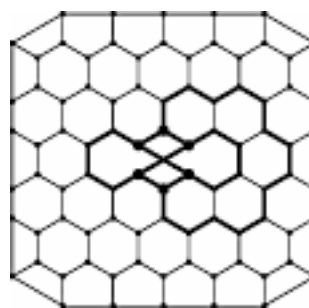

Figure 3: K₃,₃

Figure 4: K₃,₃ embedded

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[65] Wolfram, *A New Kind of Science*, 1045.

planar network is one that can be drawn two-dimensionally without any of its lines crossing (in a trivalent network, the most visually accessible arrangement is as a tiling of hexagons); if lines *do* cross, they are implicated in a "non-planar form" that, in a trivalent network (a network of any other uniform valency can be reduced to trivalency, which is why it is given priority), can only assume one form, known as $K_{3,3}$ (Figure 3). This minimally emergent form requires 28 nodes and a network size of 31. It is topologically homologous (*homotopic*) with other instances of the same form, but not necessarily the same network size—in the example provided in Figure 4, the $K_{3,3}$ embedded in the network assumes its simplest shape (with a network size of 31), but it could be expanded to any size provided it remains homotopic (i.e doesn't "uncross" itself). The salient source of the particle's functional capacities is not the singularity (i.e. the X) around which $K_{3,3}$ is organized, but rather the fluctuations in scale of the whole or its parts—the proper approach, then, is *morphological*, not machinic (contra DeLanda).

The main point here is that persistent forms within networks are associated with "tangles" within the network that implicate a number of nodes. As emergent forms that nonetheless persist in a context of autoplectic randomness, these particles are suited to explaining the emergence of materiality. To describe them as mere particles is less conceptually rich than recognizing their "particulating," the process whereby the complex mantle of a planar network automaton becomes occluded by a stratum of shifting yet persistent non-planar forms. We can venture a definition for materiality that does not make recourse to their subjective apprehension: as persistent yet scalable agglomerations of a collection of nodes, these particles remain immanent to their (virtual) planar "background" yet introduce a new "tier" of irreducibility, a higher-order discreteness that cannot yet be described as reflexive or closed (contra second-order cybernetics) that is topologically consistent but proportionally variable. But the analytical identification of these particles under circumstances where planarity is *not* preserved is, in keeping with the computational irreducibility of the system as a whole, a practical impossibility: "Ultimately what one wants to do is to find what possible types of forms for local regions are inequivalent under the application of the underlying rules. But in general it may be

undecidable even whether two such forms are actually equivalent … since to tell this one might need to be able to apply the rules infinitely many times."[66] This why planarity is useful as a way of envisaging tangles in the network—it assumes that the persistence of such a tangle assumes a singular *form* (i.e. $K_{3,3}$), whereas in actuality it may be the result of a computationally irreducible machinery that relies on the complex interaction of a number of such forms that may oscillate or deform between generations. In the former case, the particle can be identified *within* a generation (by simply seeking out the nonplanar forms); in the latter, the particle can only be identified as such over the course of a number of generations (as a *pattern*), but likely cannot have its constitutive machinery modeled in a simplified form.

We can now return to the problem of materiality. How do these particles, these tangles within the network, come to support sensual qualities? How do they cohere *as* material, as a body with sensual qualities, despite their suspension in a matrix of transient relations? We can offer only a hypothesis, as this question really demands a more nuanced understanding of phase changes within the system—Wolfram considers a few alternatives to the standard model of the resolution of metastability, which I will briefly touch on in the next section, but it is still uncertain how these could be structurally reconciled with or expressed by network automata. For now, we will posit that materiality is somehow connected to the interaction between "undecidable" particles and systems that command prescience (especially subjective ones). Recall: the only perfectly prescient node would be the hub in a hub and spoke arrangement, but this violates our constraint on valency; it is therefore the case that subjective systems are at best intermittent, and could be classified with respect to their relative command of prescience. So, it could be that materiality manifests in the form of extension for less prescient systems, and in multiple forms that are equally irreducible (i.e. sensory modalities) for more prescient systems. Insofar as the prescience of the system is intermittent, materiality could be what comes to occupy the gaps where nodes are forced to "decide" on the undecidable particle—a quasi-Badiouean operation. On this picture, we can account for

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[66] Ibid., 1045-6. Emphasis mine.

the receptivity of the automaton to sense without positing a sensing subject, which we presume, nonetheless, to be an immanent feature of the network, one whose characteristic features are derived from its ability to exploit prescience gradients. If we *do* grant the subject, this formula should remain rather compelling in their point of view: it describes the situation where one maintains an *actual* relation to something "in" extension (the so-called "real" of materiality), incapable of accounting for the irreducibility of this relation—for example, the greenness of such and such object of perception.

We thus have a possible alternative to Deleuze's conjecture that intensity grants extension its substantiality. But we have not yet resolved the "ontotheological" problem we initially raised, that is, is the network initially discrete, or condensed from a deeper underlying continuity? To provide the conceptual tools we need to broach the issue, we will turn to computational and physical phenomena: metastability in electronic circuits and spontaneous symmetry breaking.

2.3   Buridan: Breaking the Ass

In the appendices to *A New Kind of Science*, Wolfram conducts a brief history of discrete spaces as they pertain to the work of physicists—since the 1700s (the rise of differential calculus, which we touched on in our gloss at the beginning of this chapter), the standard physical paradigm has been one of continuity (and, specifically, continuous space). In addition to digital physicists (like Fredkin, Marvin Minsky and, "to some extent, Richard Feynman"), the "minor science" of the discrete has been practiced by Carl von Weizsäcker (ur-theory), John Wheeler (pregeometry), David Bohm (topochronology) and Roger Penrose (spin networks).[67] All of these, he argues, submit at some point to a "form of continuous averaging," summoning a kind of analogue to wave-particle duality in order to account for seemingly continuous phenomena (Wolfram, by contrast, pursues a mandate of discreteness all the way down). Elementary quantum mechanics are not, however, the only possible interface between the discrete and the continuous, and I would

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[67] Ibid., 1027.

like to raise an alternative that is all the more pertinent for being a feature of digital systems.

Metastability in digital systems is generally regarded as a technical problem. It occurs when a continuous voltage cannot be resolved into a binary state. If the input is in flux when sampled by a logic gate, the input stage acts like a comparator that is unable to determine the appropriate value. The situation is analogous to a classical problem of logic known as *Buridan's ass* (named after Jean Buridan, whose doctrine of moral determinism it was initially intended to satirize), a hypothetical situation in which an ass, equally hungry and thirsty, is equidistant from a stack of hay and a pail of water. The ass dies of starvation and dehydration because it cannot make a rational choice between the two options. In the case of the circuit, the solution would seem to consist in instructing the gate to select an *arbitrary* value, but this does not actually resolve the problem: in being so instructed, the gate is thereby presented with another binary—one between ambiguous values and unambiguous values—that it is likewise unable to decide on. As a result, the system either stalls or fails. What makes this especially relevant for our purposes is that it is an inherent feature of *asynchronous digital systems*, that is, systems without a global clock—just like the network automaton. Leslie Lamport grounded this phenomenon mathematically in 1984 with his formulation of Buridan's principle: "A discrete decision based upon an input having a continuous range of values cannot be made within a bounded length of time."[68] It is a universal principle: metastability is an inevitable result of any attempt to map a continuous domain to a discrete one.

What this suggests, first of all, is that the shuttle vector in the network automaton does not regularly draw on the continuity of the outside: if metastability were to occur once, the system would soon fail. Given the incomprehensible frequency of its operations and its apparent reliability, we can surmise that it is equipped with all of the resources it needs to perform its task, resources that are immanent to the network automaton (this is, of course, assuming that Buridan's principle applies to *all* instances of continuity,

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[68] Leslie Lamport, "Buridan's Principle," *Microsoft Research*, October 31, 1984, http://research.microsoft.com/en-us/um/people/lamport/pubs/buridan.pdf (accessed May 22, 2013), 1.

including that of the outside). But what if, instead of *instructing* the gate to select an arbitrary value, it would do so naturally? This is what appears to happen in the phenomenon of spontaneous symmetry breaking, most clearly illustrated with the idealized diagram in Figure 5. The leftmost system is at a high energy level, and the ball settles at the bottom. At lower energy levels (proceeding to the right), this position becomes metastable, and while the system is technically (as idealized) still symmetrical and the ball *should*, therefore, remain in place, it will inevitably roll into the gutter (the
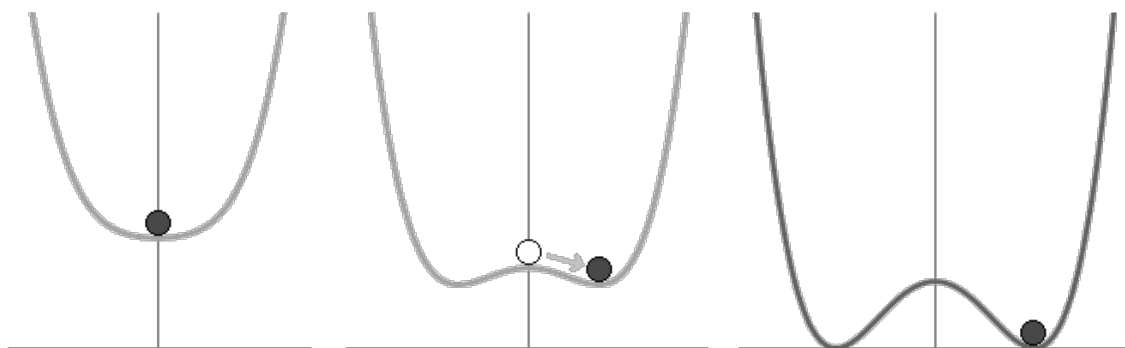

Figure 5: Spontaneous symmetry breaking

lowest point of energy). Its initial momentum cannot be attributed to any specific factor, and so the symmetry breaking is held to be spontaneous. This phenomenon has traditionally been invoked to explain the phases and phase transitions of matter (i.e. the discrete changes in matter), with exceptions (notably the so-called "topological phases" of matter, like the fractional quantum Hall effect).

Wolfram argues that this is an unsatisfactory model, and entertains alternatives like the Ising model (too complex to be described here in detail), lattice percolation, and the rate equations of chemical kinetics—both models that can be adapted to an automaton:

> The discrete nature of phase transitions was at one time often explained as a consequence of changes in the symmetry of a system. The idea is that symmetry is either present or absent, and there is no continuous variation of level of symmetry possible. Thus, for example, above the transition, the Ising model treats up and down spins exactly the same. But below the transition, it effectively makes a choice of one spin direction or the other. Similarly, when a liquid freezes into a crystalline solid, it effectively makes a choice about the alignment of the crystal in space. But in boiling, as well as in a number of model examples, there is no obvious change of symmetry. And from studying phase transitions in cellular

automata, it does not seem that an interpretation in terms of symmetry is particularly useful.[69]

Of course, this all refers to activity taking place *within* the network. What we are looking at is its genesis. And, while spontaneous symmetry breaking *could* be posited axiomatically as that which allows a continuous outside to resolve into a discrete seed, the likelier alternative is that the outside, as pre-computational and purely creative, is not subject to the logical strictures that would have it "weigh" its options—it would resolve itself into one of them arbitrarily. Countless "defective" worlds could emerge on its turbulent surface like bubbles, and countless likely ruptured (due to self-termination, not lysis) and were assimilated into the flux before they could ever expand or produce persistent substructures.

It could, after all this, be the case that the seed in fact *does* appear *ex nihilo*. But the conceptual appeal of a continuous productive matrix is its resonance with the productivity that we feel swept up in when we engage in philosophical and scientific analysis. Could it be that we, as philosophers and scientists, are not harnessing the creative power of the outside or witnessing firsthand its instantiation (as intensive) in extension (contra Deleuze), but rather (according to our hypothesis) that inquisitive subjects are, as a type of "analytical system," local manifestations of the general principle that the grand network in which we are embedded is "myopic" and "uninformed"[70] with regard to features of its own structure *by virtue* of its very structure—an *ontological existentialism*?

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[69] Ibid., 983.

[70] These epistemological concepts are "all-too-human" expressions of the much more profound kind of "knowledge" that the network could wield, which is provided for by the absolute abstraction of knowledge into its mere relational aspect (i.e. as a connection).

Chapter 3

3   Notes Toward an Ontology of Rules

Our previous chapter sought to clarify the contingency of worlds as structured extensive multiplicities. Superimposed on a primordial flux (something like the Deleuzean plane of immanence), we posited a "structured virtual"—the network in its simplest planar arrangement, within which complex computationally irreducible behaviour takes place—that serves as the "background" for particles (non-planar tangles of nodes). This virtuality could be said to be the domain of *force*, residing in the interstices of (actualized) particulate matter. Nonetheless, given that both registers—the virtual and the actual—have a common substance (i.e. nodes and relations), their causal interaction appears relatively unproblematic. The boundary between these two realms is practically indiscernible as it shifts generationally at the caprice of irreducibly complex autoplectic processes, but at least the intermediate steps can be broken down into a number of interdependent functional components and scrutinized. By contrast, the process of actualization for Deleuze is veiled—its contours can be suggested by means of a cluster of metaphors (question/answer after Bergson, derivative/integral after Weyl, world/monad after Leibniz, etc.), but none of these actively probe the internal mechanics of the transition. Such is our intention with the following chapter.

We hypothesized that the network automaton grows from a single seed, based on the intuition that insofar as the seed is a concrescence of functions, that concrescence indicates a force of cohesion that can be extended to the nodes subsequently generated to expand the network, thereby ensuring the structural integrity of the network as a whole and allowing it to persist upon the surface of creative-destructive flux—a constellation "like one constructed of spiders' webs: delicate enough to be carried along by the waves, strong enough not to be blown apart by every wind."[71] But as much elegance as Wolfram can install in his system by having it propagate from a seed as opposed to a soup, he is

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[71] Friedrich Nietzsche, "On Truth and Lie in an Extra-moral Sense," in *The Continental Aesthetics Reader*, ed. Clive Cazeaux, trans. Daniel Breazeale, 53-62 (London: Routledge, 2000).

still nevertheless beset by the problem concerning the relation that obtains between the automaton and the rules that structure it—although the periodic update function and the rule-set can be encoded into and therefore immanent to their material extensional embodiment, the rule set, in presaging its own conditional application to more than one object in more than one possible state, seem to undermine the seed insofar as they're effectively "pregnant with soup." Since we are only really looking at viable, complex systems, this problem is easily circumvented—any system that grows or evolves must have encoded the means of generating material that is compatible with it, the most familiar model being the replication of cells. As such, we will consider the growth of the network by considering the generation of new nodes as an abstract analogue to cellular division.

The other, less easily resolved problem concerns the nature of the cohesion of the functional components of the seed. Given that the automaton *generates* nodes and "pure" relations (i.e. purely formal, not intrinsically laden with transmittable information), there is a question as to whether the shuttle vector (which we have described as the mobile, active component of the network automaton containing the rule set that updates nodes one by one) is composed of relations that are "substantially" the same as those in the automaton, or if they are different (that is, proto-relations, meta-relations, or simply relations of a different kind). Ultimately, we will not resolve this here, but will touch on possible lines of inquiry that might be fruitful, such as an ontology of the conditional statement (or, alternatively, of the NAND logical gate, to which all other gates can be reduced).

Resolving the problem of the nature of a rule's immanence to the material system over which it has scope will concomitantly provide us with a means of approaching (if not resolving) the objection that Ray Kurzweil levels against Wolfram's model, namely that it only deals with one "tier" of complex behavior and cannot account for higher levels of complexity. While this formulation begs the question—the principle of computational equivalence prohibits any notion of degrees within class four (i.e. complex) behavior—it has served as ample fodder for the second-order cyberneticians, who have devised a number of dogmatic solutions to it (autopoietic reflexivity, Maxwellian demons, etc.).

We suspect that these workarounds—reflexivity especially—are summoned too hastily, and that a deeper analysis of the automaton in its most rudimentary operations may reveal the mechanisms underlying large-scale emergent behaviors.

Before proceeding to this phenomenological analysis, we will briefly touch upon the work of Albert Lautman, whose insights into metamathematics informed, to varying degrees, the theoretical approaches of Deleuze, Alain Badiou, and a number of other contemporary philosophers concerned with ontology. Lautman, against the prevailing neopositivism of his time (the legacy of the Vienna Circle, the verificationism of Ayer, etc.), sought to elaborate a theory of the "governing relation" that obtained between mathematical Ideas and the material world by drawing on the work of Martin Heidegger. Given its influence, we will briefly outline Lautman's position before offering our alternative, which will be motivated, in contrast to Lautman's transcendentalism, by immanence. Our entire theoretical enterprise thus far has been predicated on the idea that the network automaton updates asynchronously. It is a rigorously nominalistic thought that jettisons the assumption of the omnipresence of physical laws and their universal application for the much humbler model of a rule set that travels from node to node, imparting its wisdom on an individual basis. This model, we believe, is favourable to the project of grounding an immanent ontology of rules, one that can clarify the conditions for their capacity to assume dominion over matter (and, perhaps eventually, resolve this dichotomy into a more primordial operation underlying it).

3.1 Lautman: Governing Relation and Enthymemetic Bases

In "New Research on the Dialectical Structure of Mathematics," Albert Lautman considers the ontological status of the relation whereby rules are capable of exerting governance over the concrete:

> The most habitual sense of a governing relation between abstract Ideas and their concrete realization is the cosmological sense, and a cosmological interpretation of such a relation is based almost entirely on a theory of creation. The existence of a matter that is the receptacle of Ideas is not implied by the knowledge of the Ideas. It is a sensible fact, known by some bastard reasoning, as Plato said, or by a kind of natural revelation, as Malebranche thought. The Ideas are then like the laws according to which this matter is organized to constitute a World, but it isn't necessary that this World exist to realize in a concrete way the perfection of the

Ideas. … Such an epistemology can make sense in regard to physical reality; it certainly does not in regards to mathematical reality. The cut between the dialectic and mathematics cannot in effect be envisaged. It is necessary on the contrary to clarify a mode of emanation from one to the other, a kind of procession that connects them closely and does not presuppose the contingent interposition of a Matter heterogeneous to the Ideas.[72]

Lautman's is an enviable formulation of the problem. His solution draws on Heidegger's distinction between the ontic and the ontological, arguing that the dialectic (which represents the *virtual* of mathematics: the positive possibility of the reconciliation of existentially incompatible axiom systems) is necessarily *realized* in axiom systems (i.e. mathematics).[73] His approach is proto-Deleuzean in recognizing a kind of double fold: "the constitution of the being of the entity, on the ontological plane, is inseparable from the determination, on the ontic plane, of the factual existence of a domain in which the objects of a scientific knowledge receive life and matter."[74]

In fact, Lautman's essay helps us clarify the nature of the double fold as it features in Deleuze: given the latter's commitment to the creative plenitude of Being against any notion of a fundamental lack or void, the first fold (i.e. the soul-monad) *actualizes a lack (the* for-itself*, which we shall return to momentarily) whose complement is the real in matter*. The monad is "incomplete," as it cannot contain the law that determines its own distinction from other monads,[75] but this lack derives from a deeper plenitude (the positivity of a World) as opposed to a more profound lack. Actualization, then, is the positive production of lack, which is in turn "completed" in realization. The distinction between the monad and matter (the two folds) correlates to the distinction between the ontological and the ontic, the former of which is, according to Lautman, characterized by

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[72] Albert Lautman, *Mathematics, Ideas and the Physical Real*, trans. Simon Duffy (London: Continuum, 2011), 199-200.

[73] Ibid., 203.

[74] Ibid., 201.

[75] "Whereas monads in their folds, including the same world in one order or another, contain the infinite series, they do not contain the law of this unique series." Deleuze, *The Fold*, 57.

an "essential insufficiency."[76] In Deleuze, this takes the form of his resurrection of the concept of the *for-itself*, of *being-for*, in claiming "The world must be placed in the subject in order that the subject can be for the world. This is the torsion that constitutes the fold of the world and of the soul."[77] The for-itself is a void, a little pool of nothingness; but unlike Sartre, for whom this observation entailed a Hegelian reading of Heidegger, Deleuze derives his conception of being-for from older anti-Cartesians like Leibniz and Spinoza. This grants him an "external" view of *Dasein*, as opposed to Heidegger's internal view of *Dasein* as pre-subjective:

> When Heidegger tries to surpass intentionality as an overly empirical determination of the subject's relation to the world, he envisions how Leibniz's formula of the monad without windows is a way to get past it, since the *Dasein*, he says, is already open at all times and does not need windows by which an opening would occur to it. But in that way he mistakes the condition of closure or concealment enunciated by Leibniz; that is, the determination of a being-for the world instead of a being-in the world.[78]

But Lautman anticipates this as well (albeit in a less systematic way) by championing a reading of Heidegger that undermines his anthropocentrism, claiming that his anthropological preoccupations "should not prevent his conception of the genesis of notions relating to the Entity, within the analysis of Ideas relating to Being, from having a very general bearing … he himself applies them moreover to physical concepts."[79]

We can appreciate in Lautman's analysis (over Deleuze's) the relative austerity of the former—it is unburdened by the complex architectonics of the Deleuzean subject with which we took issue in the second chapter. We hesitate that the most fundamental error of the Deleuzean schema is its nested arrangement: the fold is an elegant means of milking difference from pure immanence, but the *Zweifalt* (the crease of the second fold, the differentiator of difference), cannot explain our world in its particularity in its natal

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[76] Ibid., 204.

[77] Deleuze, *The Fold*, 26.

[78] Ibid.

[79] Ibid., 202.

stages. Matter is in the world, the world is in the monad, the monad is in the subject… A fold at each frontier obscures the passage of one plateau into another. We can posture rhetorically to obscure that obscurity (call it a vanishing point, a horizon, our horizon, etc.), but if we posit a *Zweifalt*, we simultaneously posit that it possesses a means of mediating (translation, filtering, or otherwise) between the two "floors" or levels (i.e. mechanism and what is beyond it). Deleuze cannot account for the topological congruity between the two floors, between the soul and matter, without recourse to the subject within which they are both enveloped—as we suggested before, this is the nature of his correlationism. Rather than retrojecting this correspondence onto a higher body, our task is to clarify the *mode of emanation*, which we are attempting to do in the sparse language of networks without immediately resorting to reflexivity or autopoiesis as catch-all explanations.

Lautman inherits from Heidegger the latter's sensitivity to the *enthymematic bases* of taken-for-granted assertions. What this meant, in terms of Lautman's approach, is that he implicitly considered each complex logical operation in terms of the conditions of its being (its axioms, its construction, etc.)—a Kantian at heart, but one willing to speculatively engage with a "mode of emanation" instead of a transcendental threshold. While this is similar to saying that his approach is *deconstructive*, and therefore concerned with *aporia*, we prefer "enthymemetic bases" given its specificity in describing *conditional logic*—an elucidation of which, we will suggest, is one of the problems our ontology will eventually have to come to terms with. The conditional, which is the structure of the rules of the network automaton, must, in order to be grasped in its ontological role, somehow *define* its own terms (as opposed to merely presupposing them). It must have a mechanism for *positing* them existentially, as opposed to relying on the second-order conditional, "if *x* exists." This was, broadly speaking, Heidegger's concern in his later work (although he framed it in terms of *essence*).

Unfortunately, Lautman had only been exposed to the first twelve years of Heidegger's published work at the time "New Research on the Dialectical Structure of Mathematics" was published in 1939, so he did not have access to the full trajectory of Heidegger's thought and his attempts to push beyond his early work and the focus on intentionality. If

he had, he might have been able to cash out these insights in the language of mathematics, a task for which he had a facility. By contrast, Deleuze *did* reap the benefit of this hindsight, and *did* actively attempt to clarify and adapt Heidegger's later insights—but, as we've said before, we are attempting to elucidate the mechanics of actualization without immediate recourse to the subject, and Deleuze is problematic in this respect. With a view to the productive (for our sake) aspects of these two thinkers' approaches, we will offer our own account of this process.

3.2   Rudimentary Functions

In what follows, we intend to offer a glimpse into the network automaton with respect to its most rudimentary operations. This will consist in, first of all, dissecting the active component of the network automaton—the shuttle vector—into its functional constituents and, in turn, attempting to offer a rich description of their interactivity and interdependence. Acts that are relatively "unproblematic" for Wolfram—the creation of nodes, the interpretation of states—will be described in terms of their impact on the system, considered *ecologically*: we want to give a sense of the uncanny as it manifests in the complex interaction between these highly formalized elements. Despite their abstractness, they *behave* in specific ways; our task is to capture that behaviour. The ultimate aim is to approach a functional configuration that minimizes enthymematic presuppositions.

If we are committed to the elegance of having our automaton begin from a single, self-enclosed seed, we can consider, as a model, a Turing machine that is capable of synthesizing and differentiating its own parts. Recall that the Turing machine is traditionally separated into four components: a tape (divided into cells, each containing a symbol), a head (that can read and write symbols on the tape, as well as move the tape left or right), a state register (that stores the state of the Turing machine; it is initialized with a "start state"), and a table of instructions (for the head, based on the symbols it reads). Our automaton has a shuttle vector instead of a head, a network of inactive (or inert) nodes as a tape, and relational states as symbols. We hope to give an account of how the initial seed goes about differentiating these parts.

We'll begin by looking at all of the capacities implicit in the seed. It necessarily contains the rule set, valency specifications, as well as the capacity to generate nodes. The constraint on valency could be regarded as being part of (or of the same functional order) as the rule set, in order to simplify further. The rule set, in turn, contains some analytical mechanism to allow it to interpret the state of a given node (to compare it to the cases), determine the appropriate case, and initiate the prescribed action (to activate the mechanism responsible for generating nodes, if the rules specify it). It must also specify the direction to be taken by the shuttle vector after each update. Taken as a whole, the seed would be an *active node*—that is, an inert node plus the shuttle vector.

We appear to be missing two key functional components: the periodicity that governs updating events, as well as the capacity to generate *relations* between nodes. These, we hypothesize, are secondary effects of, respectively, valency and generativity. We will address these in turn, before looking at the "analytical" capacities of the shuttle vector (i.e. the "reading" that complements the writing).

3.2.1   Valency-Breaking | Ontology of the Conditional Structure

If the valency of the automaton is three—a compelling number, given the fact that a network of any consistent valency can be reduced to one with three, and given that a valency of three is conducive to complex behaviour in a network automaton—and we remain committed to an initial *seed*, then we're faced with the case of the first node being unable to observe the constraint on valency: it might self-connect, which occupies two "slots," but there remains a third, unconnected slot. In order to fulfill its mandate, the node is compelled to generate a new node. This provides an initial impetus for growth; but it must be countervailed by the disruptive, autoplectic intervention of the other rules, so that it doesn't lapse into a state of inertia when all valencies are fulfilled—we suspect that the expanse of being is littered with such aborted worlds, ones incapable of achieving the threshold of complexity specified by the Principle of Computational Equivalence. Provisionally, then, we will advance the hypothesis that rules are primarily responsible for *valency-breaking* in a network automaton exhibiting complex behaviour. By altering the configuration of connections, they render a node *hypovalent*, which spurs the production of nodes in order to resolve this (discrete) metastability. This resembles the

lack described by Lautman at the interface of the ontic and the ontological, the "essential insufficiency" that requires a supplement—however, the "lack" here (i.e. hypovalency) does nothing more than provide a direction for the creative act of nodal genesis. The lack is "necessarily incidental" to the process of generating a node.

What about the second generation? As seen in Figure 6, the self-connection of one of the nodes (the dotted red line) must be broken in order to stimulate the production of further
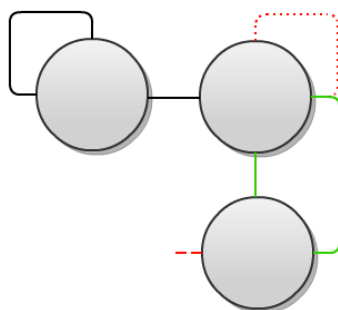

Figure 6: Valency-breaking

nodes and connections (the solid green lines)—this new node then becomes active and, given that it is not trivalent, generates a new node (which connects at the site marked by the dashed red line). Initially, this strikes us as a potential provocation against second-order systems theory, in the sense that the creative potential of the system is realized in *undermining* reflexive features within the system, as opposed to harnessing them. That said, the site of valency-breaking cannot be confined to self-connection—if this were the case, the system would exhibit little complexity, inevitably assuming a simple linear arrangement instead. Wolfram accounts for this in extending the domain over which the rules preside to nodes that are two connections away from the active node (i.e. nodes that satisfy $d = 2$, where d represents the network distance from the active node measured in number of connections):

> One simple scheme … is based on looking at the two connections that come out of each node, and then performing one operation if these two connections lead to the same node, and another if the connections lead to different nodes. … [With] this scheme … it turns out that the behavior is always quite simple—with the network having a structure that inevitably grows in an essentially repetitive way. … [Much] more complicated behavior immediately becomes possible … if the

rules are allowed to depend on the number of distinct nodes reached by following not just one but up to two successive connections from each node.[80]

In this case, the rule set encapsulated by the shuttle vector "has scope" over between one and ten nodes.[81] Upon reaching the third generation, the newly created node has a number of possible options. It can break one of its connections with the second node and self-connect (thereby pushing the shuttle vector back to the second node, in order to resolve the hypovalent state of the node); it can generate a new node; or, given that it has scope over two nodes, the shuttle vector can valency-break the first node by severing its self-connection and connecting it instead to the active node (rendering the first node hypovalent). Given that these are the sole three routes for the third-generation node, we have a potentially useful system for classifying possible rule sets: they can be sorted into three general categories (corresponding to the three possible routes) on the basis of which third-generation route they entail. This may or may not be of assistance in determining viable rule sets by allowing us to estimate the frequency of viable and complex rule sets in each category, thereby narrowing the field.

If it is indeed the case that rules consist in conditional valency-breaking, then this process could potentially describe the mechanism whereby periodicity emerges: it does not seem to be "encoded" into the shuttle vector as a kind of regimented clock, but rather derives organically from the rhythms set by the negative dialectic between rules and valency constraints. It is "forced" by the attempts by the system to resolve a node's hypovalency. To clarify this passage from static to dynamic, we could turn to Hume's notion of the "living present" (as summarized by Deleuze): "The past and the future do not designate instants distinct from a supposed present instant, but rather the dimensions of the present itself in so far as it is a contraction of instants."[82] The "time" in which the operations of

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[80] Wolfram, *A New Kind of Science*, 200-1.

[81] One in the case of the first generation; ten in the case where the shuttle vector has scope over the active node + the three inert nodes to which it is connected + the six peripheral inert nodes to which they are connected.

[82] Deleuze, *Difference and Repetition*, 71.

the network automaton unfold would be this inflated present, the realm of "sequential instantaneity." While Deleuze uses the living present as a component of his theory of time (more precisely, as the first passive synthesis of time), we cannot yet comment on whether and how periodicity factors into time—we suspect it is either precursory, a schema for time (in the Kantian sense that time synthetically resolves the problem of non-contradiction—in our case, the contradicting state of the network before and after an updating event), or else that time is a kind of myth (following Julian Barbour's thesis in *The End of Time*).[83] Unlike Deleuze, though, we derive out repetition (periodicity) from the underlying operations coordinating the network's evolution, rather than dogmatically positing repetition as the substance of substance.

From what we've covered so far, we can discern the logical chain of events undertaken by an active node at each step:

Trivalent node	⇨	Break valency according to rule	⇨	Generate new node	⇨	Occupy another node
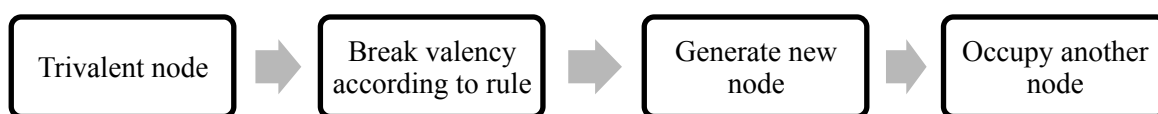
There remains a question as to the status of the causal relations in this chain, given that it appears to be the responsibility of the automaton to *establish* causal relations in the first place. This is, as well, as yet insoluble—the most we can say at this point is that the causal machinery that drives the active components of the network automaton appears to be of a higher order from those established between its passive elements; to push further, we would be required to undertake an ontological study of a logical operator: the

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[83] See Wolfram, *A New Kind of Science*, 520. Wolfram briefly speculates at how the network automaton is capable of time, claiming "the only thing that ultimately makes sense is to measure space and time taking each connection in the causal network to correspond to an identical elementary distance in space and elementary interval in time. … But whatever these values are, a crucial point is that their ratio must be a fixed speed, and we can identify this with the speed of light. So this means that in a sense every connection in a causal network can be viewed as representing the propagation of an effect at the speed of light." This, however, does not account for how the automaton unfolds (in) time, or the succession of its states.

conditional. This project is, to our knowledge, unprecedented—previous approaches have self-described variously as epistemological, semantic, or psychological, but none explore how a conditional structure could actually have a hand in constructing reality, as opposed to merely interpreting it. And while Lautman's approach to the governing relation may offer some clues as to what the ontology of the conditional might look like (especially with regard to the structure of *Auseinandersetzung*, which we will discuss in the following section), that endeavor must account for the conversion of pure potential into structure in terms of this operation which appears to be minimally structural.

Can a conditional, for instance, be decomposed into even more rudimentary operations? Wolfram notes that the "primitive function" NAND ($\bar{\wedge}$), which is commonly found in digital electronics (especially flash memory), can be used to express any other logical operator in any axiom system—in so doing, the complex interaction of various logical operators is offset onto one operator. NAND stands for NOT AND, and produces an output that is false if all its inputs are true. Wolfram, in order to demonstrate the efficacy of his findings, shows how NAND operators can be exploited to simplify the axiom system for basic logic (propositional calculus), previously given its simplest expression (containing nine operators) by Meredith in terms of NAND operators, to a formulation that requires only six NAND operators. Network automata can be configured to emulate NAND gates; however, given that the rules are ontologically anterior to such a process, the NAND, if it were indeed the primitive function governing the application of rules, would have to be explicated with recourse to a mode of organization more primordial than that of nodes and connections.

3.2.2   Nodal Meiosis | Separation and Relation

Let's take a closer look at the genesis of a node. The initial seed would, again, be a *hypovalent active node*, one that will imminently generate a node to resolve its own valency issues. The second node will have, in a certain sense, "come from" the seed; after this node is created, the network will comprise a single active node (i.e. the second node) and a single inert node (i.e. the first node). This inert node can later form an assemblage with the shuttle vector, thereby becoming an active node, but until then it subsists as a kind of digital record, maintaining its unique configuration of connections that the shuttle

vector will later interpret and have determine its actions—when we refer to "states" in a network automaton, we refer to nothing more than a node's constellation of relations: "The basic idea is to have rules that specify how the connections coming out of each node should be rerouted on the basis of the local structure of the network around that node."[84] The node is essentially a cell of Turing tape (in this case, fabricated by the machine itself) and its bundle of relations analogous to the symbol inscribed in the cell.

Given that the node produced is capable of joining up with the shuttle vector, it could be said that the active node undergoes a kind of *meiosis*, with the inert component of the active node (i.e. the part of it that is not the shuttle vector) creating a copy of itself—the duplication is technically *mitotic* with regard to just the inert component, but meiotic with regard to the entire apparatus of the active cell: the duplicate node is one germ, and the shuttle vector is another, transient germ. The active node is therefore *zygotic* in comprising the two. Logical operations (as opposed to cellular) subtend this entire process—the micro-operations of the conditional structure as it functions ontologically. (Conveniently, valency is also a property of meiotic structures in living cells, denoting the number of chromosomes that compose each.) That the active node is not as a whole self-reproducing, that it is only the inert component of the node that is replicated, offers us another angle for critiquing the autopoietic paradigm where it seeks to gain purchase in fundamental ontology or theory of the subject (i.e. beyond the domain of biology): in addition to the fact that the system thrives on breaking the self-connection of reflexive elements within it (i.e. self-connecting nodes),

What is it that binds the new node to the rest of the network? When a new node is formed the penultimate node is rendered inert, but is at the same time imbued with a positive charge that consists in its relative autonomy from the active complex and allows it to subsist in an inert state—it binds the node to the network to keep it from being, metaphorically speaking, swept away by the flux of unstructured being. But we do not have to think of this charge as a state, as a symbolic mark—as we mentioned before, the

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[84] Wolfram, *A New Kind of Science*, 197.

state is defined merely by a node's relations. The inert node's autonomy *consists in* its *relation to* the active node at any given time, either directly or transitively—they are, in a sense, *separated by a relation*. This is, of course, similar to a possible rudimentary definition for a network: there cannot be separate nodes without a transitive relation; otherwise you have more than one network. While this truism places the emphasis on the relation insofar as it secures the integrity of the network qua network, we are more interested in the functional integration of separation and relation (which we might, after Heidegger, refer to as *Auseinandersetzung*, "belonging-together-in-opposition"). This is another tension that, alongside the ontology of the conditional, warrants greater philosophical scrutiny.

While we have consistently referred to the shuttle vector as the "active component" of the network automaton, it is important to recognize the transversal nature of its activity—it does, after all, form a kind of assemblage with the nodes over which it has scope at a given time, and the gradient formed between its autonomy from and dependence on this local cloud of inert nodes is what, we suspect, facilitates its mobility. In other words, it is not self-propulsive, but relies on other features of the network (i.e. nodes that it itself generated in their autonomy)—as we hinted before, a system of *passive transport* as opposed to active transport.

3.2.3   Analyticity | Subjectivity

Given our contention that periodicity and relationality are secondary functions of valency and generativity, we are left with analyticity as the other major feature of the active component of the network automaton, the shuttle vector. Analyticity refers to its ability to read the state of a node's relations—this could include registering the hypovalency of a node or to match the state of relations to a corresponding rule (for example, according to Wolfram's suggested schema, by counting the number of distinct nodes within a radius of two connections). The significance of this capacity to read should not be understated: it is the *retrospective* capacity of the shuttle vector, a kind of functionally abstract memory. It operates upon a "local state" (i.e. the configuration of a "cloud" of nodes over which the rules have scope) within the "global state" (i.e. the configuration of the network as a whole in a given generation). In that sense, the inert

nodes that serve as a record of past updating events are a key functional component here—in addition to perhaps facilitating the *magnitude* of the shuttle vector (i.e. its capacity to move via passive transport), they also seem to supply the *direction* in their interaction with the analytical capacity (vectors, recall, are magnitudes with direction). It could be that an inert relation (i.e. one outside the local state) takes on a positive force once under the purview of the rule set as a specifically *vectoral relation*, imparting magnitude and direction to the shuttle and thereby rendering it a shuttle *vector*.

While some would be quick to attribute this retrospective capacity to a reflexive tendency on the part of the system as a whole (i.e. as a mechanism that complements the unbridled creativity of the system, one that "completes" discrete feedback loops and allows the system to direct its own behaviour), we will not yet make the same commitment— enforcing this critical distance, we will explore more closely the conditions for analyticity, careful not to project the all-too-human association of memory with autonomy (i.e. reflexive systemic closure) onto the virtual. Analyticity does not necessarily consist in the self-relation of the active node—recall that the rules, in order to be capable of generating complexity, require scope over at least one passive node (that the seed should effectively "contain" more than one node implicit in its rule set should not surprise us—multiplicity is, roughly speaking, the principle behind generativity). There is instead a sort of productive tension between the active node and the local configuration of inert nodes over which it has scope, meaning that the rule set is necessarily other-related. In the case of the first node (the seed), where there are no other nodes over which it may have scope, the rule set is inoperative anyway—if it is true that the rule set is not directly connected to the generative capacity of the active node, but is rather a *sub-routine* of the valency provision (i.e. the rule set engages in valency breaking in order to "activate" the valency provision, whose resolution consists in the generation of nodes) and therefore has a *mediated* relation to nodal generation, then, given the necessary hypovalency of the seed, the subroutine need not be executed. But even in this case, the "force" of analyticity lies in producing another node, not directly modifying the behaviour of the seed (i.e. reflexively).

Analyticity may, however, be tied to subjectivity. We can at this point only offer hypotheses (the high standard to which we've held ourselves thus far), and even these will be abstruse; we cannot establish a positive link between the two, but we can discern certain characteristics of the former that resemble the "logic" of subjectivity. First, the active node is *situated* (like a subject) in a field that reflects the state of evolutionary progress. Second, the active node is *projective*—it defines a sphere of influence beyond itself in a way similar to what we would expect from a subject. Third, the active node is, of course, *active*—the analytical component is directly linked to the generative capacity, and so every act of analysis has a material trace. These preliminary observations, however, in no way lend themselves to a conception of subjectivity as either *conscious* or *willed*. With respect to the latter, it would be incumbent upon us to show how an emergent system within the automaton would be capable of, as a system, "breaking free" from the constraints that structure the network at the lowest level—which is not to say that it breaks the rules, but rather that it is able to exploit them in order to execute the kind coordinated, influential gestures characteristic of willed action. But this is precisely what emergent systems *do*—they are coordinated systems that do not derive their coordination from being encoded into the fundamental laws of reality.

So we suspect that the cognitive system is, structurally speaking, more complex than the automaton itself—it does not, however, perform more sophisticated computations (in accordance with the principle of computational equivalence). While it may be of a higher "order" with respect to its being constructed out of particles (i.e. nonplanar nodal tangles) as opposed to being simply planar, this "higher order" is not essentially reflexive. While it seems to mimic certain aforementioned properties of the active node, consciousness, as *emergent*, is capable of more than its constituent parts; as such, there would be no inherent limitation (like a valency constraint) on its ability to project its sphere of influence. In fact, this seems like a capacity that may well be "selected for" in an evolutionary sense—to be capable of speculation, that is, to be able to influence things at an arbitrary distance (effectively "reaching through" the network to influence something

at a distance[85]), is an effective strategy for maintaining the integrity of a (living) system, allowing it to stave off or manipulate external forces that would seek to dismantle it, to decompose it into its elements.

The administration of this capacity to manage these external forces is properly *technological*, and while technology has served human beings well as a means of shaping and adapting to an environment, the proper status of technology has become obscured— while it is something like a circulatory system allowing informational exchange between "semi-permeable" emergent systems, it has assumed the ontological posture of being unilateral, as "acting-upon." This is roughly the enframing (*Gestell*) of which Heidegger spoke; however, this tendency is not, in our interpretation, inherent to technology, which is (as we've described it) too mercurial to have any explicit, summary intentional horizon (in the phenomenological sense; recall that enframing, as a destining, sets-upon [man, and intentionally so]). If technology has begun to operate, in a sense, *against* us, it is insofar as we have become insensitive to the reciprocal call of other living systems, the ways in which they speak to us technologically (and they do). It is almost as if we have colonized too much of the local virtual with our technological prostheses, choking off the informational traffic that allow other systems (and, by extension, our own) to coexist homeostatically. And so, while this feature of emergent systems would seem to be connected to the "higher functions" of subjectivity, they could well limit the expression of will just as soon as they enable it.

By this measure, though, language too is a technology. It is one capable of marshaling and arranging, with a (relatively speaking) remarkable degree of transmissibility (transmissive fidelity), a *bandwidth* of material subject to innumerable microscopic forces, in order to elicit the action, attention, response or ignorance of a remote entity (or region). And language, of course, is no less subject than any other technology to being exploited at the service of questionable ends—it enables subversion, inculcation, and

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[85] I have this image of a sort of "parting of the red sea" to causally interact with a distant site: the nodes "between" the projective system and the object it seeks to influence are rearranged in a line in order to transmit the causal "intent" of the former.

sustained authority. In fact, it may be the case that language (following the paradigm set out in "The Prose of the World," a chapter from Michel Foucault's *The Order of Things*), when it transitions from being the natural material expression of similitude[86] ("of the earth," as it were) into expressing the relation between signifier and signified ("making itself apparent," as it were), creates a barrier that moderates the linguistic expression of the extralinguistic—the two domains *mutually specify*, meaning that the problem is roughly analogous to the differentiation of mind and world we considered in the introduction. Within the bubble this barrier bounds, subjectivity can be cultivated. This could represent the first major step towards human beings' exceeding their bandwidth of informational exchange with their environment, thereby forming a kind of "unilateral centre" within the automaton, a generator of noise (understood in informational terms). Whether a return to what came prior to this event is ethically advisable is another matter altogether.

While will may consist, at least in part, in this projection of an emergent system to influence others on a macro scale, we still have not broached the specifically "conscious" aspect of subjectivity. We cannot yet offer a fully satisfying materialist account. It may be that as the shuttle vector crawls along the network and into certain material configurations (for instance, one that might correspond to a brain), that material system has a way of registering its presence, and translating that into a cognitive state that acknowledges the realm of possible action for the system at a given instant. Consciousness, then, could be an interface that assists in organizing these possibilities; but this still misses the experiential aspect of consciousness. While subjectivity may not "bottom out" in the cogito (as many contemporary theorists will affirm), it nonetheless remains an important aspect of the subject to be accounted for. We hope to do so eventually, perhaps as an extension of whatever insights we have generated here.

The conditional structure, *Auseinandersetzung*, subjectivity—these three problematics, corresponding to the three salient features of the shuttle vector, gesture towards the so-

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[86] Similitude is a form of relation.

called enthymematic bases of structure as such. We expect that the three are modalities of a single problematic, and therefore that insight into one of them should allow us to penetrate the others.

Chapter 4

4 Prelude to a Study of the Digital Subject

4.1 Bachelard: Cosmic Narcissism

> You know what I believe? I remember in college I was taking this math class, this really great math class taught by this tiny old woman. She was talking about fast Fourier transforms and she stopped midsentence and said, "Sometimes it seems the universe wants to be noticed." That's what I believe. I believe the universe wants to be noticed. I think the universe is improbably biased toward consciousness, that it rewards intelligence in part because the universe enjoys its elegance being observed. And who am I, living in the middle of history, to tell the universe that it—or my observation of it—is temporary?[87]
> —John Green

"The lake is a large tranquil eye."[88] Gaston Bachelard's *Water and Dreams: An Essay on the Imagination of Matter*, originally published in 1942, seeks out the uncanny manifestation of select, formal aspects of subjectivity in natural phenomena. It is an exercise in rendering the familiar alien—Bachelard seems to want to break subjectivity into its formal components and show how they subsist in niches independent of human consciousness (in such a way that they may have, at some point in history, assembled around the neurological substrate correlated with consciousness in order to give rise to subjectivity). His approach is therefore similar to ours in chapter three, where we suggested that the situated, projective, and active aspects of subjectivity are implicit within the network automaton. In the case of moonlight playing upon the surface of a body of water, the *reflective* capacity of the subject (not the ability to reflect upon itself, but rather its ability to represent the world from a particular perspective) is achieved in a rudimentary form. We needn't say, however, that this is indicative of a desire on the part of nature to be "given back to itself" (Bachelard calls it "cosmic narcissism")—we have consistently resisted these recursive loops that generate a false impression of systemic

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[87] John Green, *The Fault in Our Stars* (Boston: Dutton Books, 2012).

[88] Gaston Bachelard, *Water and Dreams: An Essay on the Imagination of Matter*, 3rd edition (Dallas: Dallas Institute of Humanities and Culture, 1999), 28.

closure.[89] Rather, whatever similarity we recognize in the functions of the subject and other "dumb" phenomena should be read as a testament to the *coextension* of subjectivity with the world; that is, it should be read in tandem with the recognition of the profoundly holistic "transversality" of perception: vision is not simply a neuronal firing, nor is it an eye—it is an entire causal chain, an assemblage of light + various transmissive media + (…). This recognition of similarity does not (contra DeLanda) immediately attribute that similarity to their being *products* of the same machinic phylum, but instead regards the two phenomena under comparison as *elements* of the same machinery, and to varying degrees interdependent.

The beauty of approaching the problem of the subject via the theory of network automata lies in its ability to describe how the subject is not confined to neural memory, but is instead coextensive with the tape (memory) from which the fabric of reality is woven. It shifts the focus from the insular system that contains the principle of its own self-preservation (i.e. the brain) to the complex topology of the network (especially considered in terms of the relative prescience of its nodes). The coincidence of conscious subjectivity with a brain can be cashed out in terms of operations that take place below the threshold of neuronal activity that can be empirically observed. It would take place, in a sense, "below the Planck scale"—which is not to say that subjectivity is a quantum phenomenon, but simply that it operates according to a different logic. More specifically, it does not rely on local interaction or proximal relations in the same way that a neural network does. It is the medium through which the brain is directly "plugged into" its environment, a complement to the sensory interface that leads us to believe we are immersed *in* the world, as subject to object.

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[89] Besides, there is a question as to whether the reflecting pool is even, at its essence, analogous to an eye—the reflection can itself be experienced from a number of different perspectives from anywhere along the bank, but an optic representation, even if it could be accessed and experienced by someone other than the viewer, seems limited to the one perspective (i.e. the one occupied by the viewer; unless, that is, a *limitation* of that experience, either by "lowering the resolution" or by blocking out parts of it, counts as a modification of perspective).

Relations of complementarity in the world (e.g. of organism and environment) should prompt the question as to why one independent being should ever split into two beings dependent upon each other. Divergent interdependence, or *Auseinandersetzung*, is, as we've suggested, a fundamental function of the network automaton, one characteristic of our world—the kind of world capable of supporting a *cogito* or a *Dasein* or whatever kind of subject. But insofar as this operation is part of the nucleus of the network automaton—the active shuttle vector—there is still work to be done to explain how or why it reproduces qualitatively similar features within the network upon which it works, like a spider spinning, out of its own web, live spiders to traverse the network it has built. The same goes for the other qualities or capacities of the subject (situated, projective, active)—in order to justify their status as precursory to subjectivity, we need to examine how they come to be reproduced at the order of particulate matter. It may be that the degree to which a system is *fractal*—that is, the degree to which the rudimentary, atomistic functions are emulated at larger and larger scales—lends to the relative stability of the system, allowing it to stave off the cataclysmic force of the outside and persist.

Persistence is a thorn in the side of ontological theories of radical contingency (pace Quentin Meillassoux). It is a problem that the theory of network automata comes prepared to address: stable configurations can emerge within an automaton, redundancies can protect these persistent patterns from disruption by other patterns, and non-planar particles buoyant upon these (wavelike?) patterns can express them in a discretely different state (i.e. the material). At bottom, the network itself is tossed about on the waves of the outside, self-enclosed and resilient like Nietzsche's glass palace on a strong current[90]—though "glass" with respect to its contingency, not its fragility. Radical contingency can only mean heat death. To say that the outside intervenes in one of many ways is to presume that the outside ultimately "presides over" the world, that it is dexterous enough to make incisions in the body of reality that will provoke an immune

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[90] "Self-enclosed" in the sense of being self-sufficient and not reliant on the substantiality of an intensive outside to suffuse extension. It is the windowless monad, but not, as in Deleuze, the soul. It is the seed that recreates, in the strength of its relations to the nodes it generates, its own resiliency against the outside, thereby securing it for the network as a whole.

response on the part of the world, allowing it to heal in a reconfigured state. But to recognize such a complementarity between the world and its outside is to dogmatically dispense with the problem of *Auseinandersetzung*, to erect an ontotheological horizon modeled after divine intervention. Too many political thinkers deemed (or self-described as) radical have trotted out this theme over the past half-century—Alain Badiou, Giorgio Agamben (following Carl Schmitt and Walter Benjamin). Even Gilles Deleuze, who, in *Foucault*, writes the following:

> The informal outside is a battle, a turbulent, stormy zone where particular points and the relations of forces between these points are tossed about. Strata merely collected and solidified the visual dust and the sonic echo of the battle raging above them. But, up above, the particular features have not form and are neither bodies nor speaking persons. We enter into the domain of uncertain doubles and partial deaths, where things continually emerge and fade (Bichat's zone). This is a micropolitics.[91]

As a formula for ontological change, it requires that substructures pass through the membrane that separates structure from the outside, and that the "points and relations of forces between these points" are expected to seek reentry through that membrane (into structure) in a new permutation that is compatible with that structure. Our position is oriented towards actualization and accretion, as reflected in the language and spatial metaphors in the discourse on networks—particles, patterns, and other forms of emergent behavior—while Deleuze defers to virtualization and dispersion, dressing it up in romantic connotations of liberation and vitality. But building a politics, a personal ethics, or a movement from dispersion, *as a process of building*, should require a sense for mechanisms of accretion and belonging-together-in-difference. This intuition inheres in the discourse with which we have been describing network automata.

So, rather than attributing subjectivity to a universal reflexivity (i.e. cosmic narcissism) or a local recursivity (i.e. autopoiesis), we intend to initiate a theory of the subject that recognizes its implication within the structural evolution of the network automaton, which does not require communion with an outside. It appears to be, from this vantage, a kind of *stratified panpsychism*, one that aligns the topology of subjective expression

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[91] Gilles Deleuze, *Foucault*, trans. Seán Hand (London: Continuum, 2006), 99.

insofar as it is responsive to the world with the material topology that structures certain beings to be capable of such responsiveness (and, as such, recognizes the qualitative difference of subjectivity as it manifests in animals as opposed to rocks). The reason we can function as being implicated within this computational universe without "knowing," reflectively, the physics behind it, is because of the informational matrix within which our material embodiment (and the environment we negotiate) is suspended. When Deleuze writes about learning that it "always takes place in and through the unconscious, thereby establishing the bond of a profound complicity between mind and nature,"[92] he is speaking of a subject that entertains a direct connection to the outside; but if we abstract the form of this statement, and replace this polarity of subject and outside with a region comprised of patches of variably rarefied network connections or patterns, we can describe that same complicity without the ironic recourse Deleuze makes to objective (albeit inherently problematic) Ideas. And it may lay the groundwork for a rethinking of micropolitics that places the emphasis on actualization—the conception of praxis offered by Mackenzie Wark (which we considered in the introduction) is, insofar as he recognizes abstraction as the production of "new concepts, new sensations, *hacked out of raw data*,"[93] not a practitioner of the politics of the outside (given that "data" is understood, in the network automaton, as that which is embedded *within* the network, not beyond it); however, insofar as the emphasis clearly seems to be on the transformative power of the subject (the hacker) over the world, and the hacker is implied to have derived this power from their relative proximity to the outside, there is a case to be made that he *is* a philosopher of the outside. In order to refine the concept of abstraction, then, and purge it of its subjectivist overtones, we will turn, in conclusion, to Michel Serres.

4.1   Serres: A New Atomism

At the same time as it produces physics, constituting it as a fundamental theory of elements and a threefold discipline faithful to the phenomena of experience, atomism resolves the radical question, that has always been asked and never

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[92] Deleuze, *Difference and Repetition*, 165.

[93] Wark, *A Hacker Manifesto*, [002].

straightened out: how is it that our laws, our hypotheses and our models are found to be in agreement with reality? Lucretius makes it comprehensible that the world is comprehensible. My text, my word, my body, the collective, its agreements and its struggles, the bodies which fall, flow, flame, or thunder like me, all this is never anything but a network of primordial elements in communication. … What, once again, is physics? It is the science of relations. Of relations in general between atoms of various families. Of conventions, assemblies, contests, coitus.[94]
—Michel Serres

The preceding quote describes the physics to which we have aspired: one that restores mereological depth to contemporary speculative thought, and one that recognizes abstract "relations in general" as the currency of physical inquiry. Additionally, with regard to another major theme in Serres' work, the decision to here describe things in terms of the operation of a network automaton does not, in theory, foreclose any other discursive approaches—given that computational universality can be expressed linguistically, computational equivalence entails that the model can be recreated in another medium, including one that conforms to the stylistic protocols of mythology (whether it is practical to do so is another matter). And since we are likely structurally blind to causality in many instances (as a result of prescience differentials), it may be advisable to employ rough metaphor in an attempt to capture the interstitial "range" of these reclusive causal sequences between moments. In our case, we drew on the discourse of cellular biology in our conjectural account of the rudimentary functions of the automaton to help illuminate a possible general schema for complex systems. And it may be that the system we have described could somehow be made to inflect in political discourse, such that the latter becomes especially expressive of the profound depths of complex interdependence and the mysteriousness of causality.

Serres mentions that the relations in general obtain "between atoms of various families." For the purposes of elegance, we have been treating all relations and atoms as being purely formal, not endowed with any determinate qualities that would differentiate them from other elements of the same kind. In other words, all determinate qualities were

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[94] Michel Serres, *The Birth of Physics*, ed. David Webb, trans. Jack Hawkes (Manchester: Clinamen Press, 2000), 123.

assumed to emerge from the various formations of substantially homogenous nodes and relations, as opposed to elemental *categories*—since everything was emergent, it was easy to account for immanence (in the sense that every thing is necessarily part of a single network, which establishes the domain of possible causal interaction, or relation of any kind whatsoever). It may be, however, that we eventually have to admit to our schema *types* of nodes or relations, in order to adequately describe certain features of reality.

Prior to admitting such *categories* of relation, we hope to have demonstrated that a reduction of scientific or philosophical analysis to *mere* relations does not undermine its complexity—in fact, it opens up a new domain that can be described in rich detail, that has a topological dimension in *prescience*, and with formal features that we can see manifested on a macroscopic scale in subjective phenomena. The network automaton offers us something to latch onto as we descend into the virtual, allowing us to describe its operations in more detail while emphasizing its coextension with the actual and, with respect to the computational irreducibility of virtual processes, recognizing the limitations on analysis as such.

Afterword

5   Reflections and Directions

5.1   Atomism, Connectionism, and Politics

I would like to briefly respond to two objections raised against my contention that the project I have undertaken represents a contribution to a new kind of atomism (following Michel Serres' conception of it).

The first objects to my characterization of atomism as a minor science. It regards atomism as an instance of "arborescent" thought—and, following Deleuze, a "major" science—concerned with discrete hierarchies, as opposed to a rhizomatic or minor science. Setting aside the fact that Michel Serres considers atomism to be a "science of flows," this objection ignores the context of my claim: within the discipline of physics and since Leibniz, the overwhelming preoccupation has been with the mathematics of the continuous. Despite reservations (for instance, in the case of Riemann, upsetting the previously unproblematic mathematical definition of distance), physicists have erred on the side of the intuitive recognition of continuous phenomena in their work, and to that end their findings have a human-scaled metaphysics underpinning them. I agree wholeheartedly that striation is typical of the current historical situation; but it is not for nothing that Deleuze himself made extensive recourse to *major* figures in the history of physics and mathematics in his work (Riemann, Leibniz, etc.), major figures that contributed to the major sciences (within the realm of physics) of continuity. The *minoritarian* is manifest, for the most part, in the *relation* of physics to other disciplines that have not come to terms with continuity in its various forms, not within physics itself.

The second, related objection concerns atomism as a political doctrine. If this ontology is to eventually set out a political program, does its commitment to atomism anticipate a political atomism wherein the individual is cast as the fundamental unit? The implication is that atomism is at the heart of profoundly conservative doctrines like neoliberalism and objectivism. Our reply, quite simply, is the following: to infer a political atomism from natural atomism is to subscribe to an outmoded, analogical line of naturalistic argument.

Every phenomenon that takes place above the threshold of individual nodes is, on our picture, emergent—it is more than the sum of its parts, and therefore political phenomena, which concern emergent *bodies* (biological and otherwise), are not properly atomistic insofar as they recognize that emergence. The discursive constitution of subjects as atomic units is distinct, we argue, from the conditions that give rise to this possibility.

Why, also, do I not consider *connectionism* instead of atomism? This is the doctrine associated with cybernetics and the model of the *neural net*. While I agree that the network automaton would qualify as a model for connectionism (being comprised, again, of nodes and *connections*), I would hesitate to use the term. I have been trying to tease out the subtle differences between my model and the recursive or reflexive paradigms of the cyberneticians, and I would be afraid of obscuring this difference by adopting one of their terms. The neural net is the model whereby this recusivity is implemented—DeLanda regards it as addressing the shortcomings of cellular automata as a means of modeling complexity, but we have elected to resolve these shortcomings in another way: by abstracting all of the formal attributes of the cellular automaton into a network form. This, we believe, grants us the opportunity to think about *where* recursivity fits in the system, rather than merely positing it as a force that acts upon different features of reality to different degrees.

5.2   Creativity and the Outside

How, under the paradigm I have developed, can we account for the introduction of novelty into being? Contemporary approaches have variously responded to this problem by drawing on the recombinant powers of an outside—*poiesis* for Heidegger, fidelity for Badiou, becoming for Deleuze, etc. Importantly, whatever previously incommensurable structures come into being are, in these instances, filtered through a subject or subjective formalism, regardless of their respective affiliations with transcendence (Heidegger) or immanence (Deleuze); hence, novelty is essentially equated with a kind of creativity.

At this stage in my project, given that I have not carved out a specific mechanism or site for the expression of subjectivity, I could not apply it to the problems of creativity or

novelty. My characterization of the outside is merely as an incomprehensible, infinitely combinatorial stage for the genesis of a seed that may, on condition that its structure is favourable to growth and complexity, persist as a world. I hesitate to recognize, at this point, any contribution on the part of the outside to the continued function or maintenance of the automaton, as one that would intervene in the course of the automaton's rule-bound evolution. We treat the outside as a realm of non-contextual bringing-into-relation. While the outside *may*, in fact, interfere with the evolution of the automaton (in a way analogous to the destruction of genetic codes by free radicals), we feel that to make this possibility (i.e. radical contingency) the cornerstone of our ontology distracts from the work of phenomenological exploration into *self-sufficient* processes of structuring—work that gains its bearings and its refined focus from the model we have selected (namely, the network automaton). This model has proven especially fecund with regard to the generation of concepts (asynchronous causality, prescience, etc.), which we feel are particularly lucid and tangible means of talking about very elusive processes.

The problem of pure immanence: if the roots of each ontic being extend to the absolute boundary of Being, if they touch upon the unified core of Being, then what keeps it from importing the untamed cataclysmic tendencies of Being? Does treating the outside as inclined toward surgical intervention in the world belie those cataclysmic tendencies? It is with an eye to this problem that we have installed a kind of transcendental break with the outside by treating it as a womb, and nothing else. However, we do not believe this does great harm to the concept of creativity. We do not intend to slight the dignity of creativity by regarding it as something that operates within the context of certain rules, because we do not regard rule-boundedness as something intrinsically undignified; further, we do not believe that a judgment on rule-boundedness at the level of ontology dictate a similar judgment on rule-boundedness at the level of sociopolitical organization—we simply have not yet crossed that "delicate passage." The beauty of network automata is that their rules generate phenomena *that exceed rule-based analysis*, that are computationally irreducible and that demand, perhaps, a kind of analysis that recognizes its own speculative license. It is the fault of political systems—insofar as they take cues from naturalistic concepts—that they purport to have access to deep truth; theirs is a form of analysis necessarily incommensurate to nature. But this does not

necessarily entail an anti-politics, for we suspect that the capacity for speculation is one of the truly remarkable aspects of our world, and that a politics that truly embodied the spirit of speculation (whatever this might look like) might represent a way forward.

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Curriculum Vitae

Name	Robbie Cormier
Post-secondary Education and Degrees	Queen's University Kingston, Ontario, Canada 2007-2011 BA Philosophy
Honours and Awards	Ontario Graduate Scholarship (OGS) 2012 Social Science and Humanities Research Council (SSHRC) Joseph-Armand Bombardier Canada Graduate Scholarship 2012-2013
Related Work Experience	Teaching Assistant The University of Western Ontario 2011 Research Assistant The University of Western Ontario 2012

Publications

Robbie Cormier, "On Machinic Protocol," in *The Imaginary App*, ed. Paul Miller and Svitlana Matviyenko (Cambridge: MIT Press, forthcoming).