Reconstructing Human-Computer Compatibility in Cold War Cybernetics and Social Sciences:

A Play in Two Acts and an Intermission

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This paper contributes to and plays with the puzzle animating my larger project *Reconstructing Information in Cold War Cybernetics and Social Sciences*, of which this is only part. While this paper asks how humans become computer-compatible, the larger project asks in more detail how did the keyword *information* become computer-compatible? For a moment of context, the term *information* has not always meant—as it can now—a purely symbolic substance capable of being automatically manipulated independent of human intelligence: how, then, did modern humans come to understand information as such? In the seventeenth century, John Milton used root of the word *information* to refer to the process by which material gains form, or is literally in-form-ed. He takes survey in *Paradise Lost* of the planets comprising the solar system as “all alike inform’d/With radiant light, as glowing Iron with fire” (Milton 1968/1674, 115; Book IlI, line 593). Immanuel Kant fulfilled and, in the process, put out of business classic empiricism of knowledge-based information, making space in the process for rationalism and idealism to coexist for a period. For Kant, the term came to refer to the relevant facts of rational human beings in communication one with another. In other words, in Milton's age, *informed* meant *shaped by*, attesting to some internal or cosmological ordering, but after Kant discarded any order independent of sensation, information became lodged in the contemporary sense of *received reports from*.

Yet, modern thinkers understand *information* as still something else: information in the third and most modern sense is the lifeblood of all dynamic systems and decision-making—the computational backdrop against which all intelligent action at the level of the individual, the organization, the network, or the market is analyzed and set into relief. In distinction from the Miltonian sense of information as material-shaping form, Kantian sense of information as relevant facts communicated or reports received, I am, for my present purposes, calling this third type of information *computer-compatible (or cybernetic) information*,[1] by which I mean information that exists independent of both Miltonian form and Kantian epistemologies. Ours is an information as contemporary scholars interested in self-reinforcing dynamics generally understand it: a symbolic abstraction fit for automated and interoperable processes of computation and translation. Yes, information in contemporary usage may still importantly shape action and even material as Milton had it; and yes, information may still refer to Kantian *reports received*. But as I contend throughout, cybernetic information means something more: cybernetic information can exist only in what I call "self-symbolizing systems," or systems that involves self-reinforcing processes of representation: all modern information systems must be able to read, rewrite, and delete parts of themselves. They all involve feedback or self-representation. How did information get to this point, what are the stakes of self-reinforcing dynamics of these

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[1] By "cybernetic" I mean throughout two things: one, computer-compatible and two, modern human-machine interdependence. This sense is taken from Norbert Wiener's 1948 definition of cybernetics as "the study of control and communication in the animal and the machine" as a lens for focusing thought through a history that extends far before and after the postwar period.

systems, and where to next—these are some of the larger (if unanswerable) questions motivating my current project *Reconstructing information in cold war cybernetics and social science*.

The paper puts aside the question of how information became computer-compatible for a moment to ask a related and perhaps more fundamental question: how did humans become computer-compatible? Instead of providing a direct answer, this paper takes account of some of the key scientific and social scientific concepts that relate to the self-reinforcing dynamic between human relationships embedded in computer-compatible systems. Namely, what interests me here is how ideas change over time about how people should think about calculating systems.

In specific, by casting light on a small host of hugely important if often overlooked historical thinkers—from late nineteen-century natural and philosophical scientists such as George Boole, Charles Sanders Peirce, Bertrand Russell, Josiah Royce, and Norbert Wiener—the reader may better understand the birth of the self-reinforcing science of mathematical logic to the social sciences in the computer age. The reader may also better understand the intellectual inheritance of path-dependency, field theory, and embeddedness theory from the theoretical and cybernetic sciences. In terms of motive, this paper does not aim to offer or to reconstruct any single coherent or canonical intellectual genealogy. Instead it looks to press our own thought through assembling a few of the fascinating complex of significant and often overlooked figures whose intellectual affinities and influences can still be felt in the present.

The circularity implicit in the organizational intelligence in feedback mechanisms and the pattern extension of circuitry mechanisms are not accidental. Any dynamic system must contain some internal source of purposive instability, and the loop in particular helps cast light on a series of developments in self-reflective mechanisms in the rise of thought on self-reinforcing systems, beginning with the natural and theoretical sciences and extending through twentieth-century social science. The theoretical upshot of this investigation is that no modern study of dynamic systems is complete without the presence of some self-reinforcing variable or element. If analysts hope to understand the behavior of complex organizations, networks, and markets over time, they too must leave space for the system to reflect upon itself. This ruling in favor of the inevitably recursive agents in our daily lives raises challenges to long-standing and often significantly powerful analytical traditions, such as neoclassical macroeconomics and generally the libertarian political tradition associated with personal computers. These analytic frameworks all too often fail to include the possibility that the variables it takes into account may themselves be altered by that accounting, or fluctuate based on a complex, heterarchical interdependencies between the analyst and the object. The lesson is not a particularly new one: along with the host of ideas investigated here, the observer effect, Schrodinger's cat, the Heisenberg indeterminacy principle can also be considered early twentieth-century precursors and participants in this scientific rise of a self-reinforcing dynamic between humans and computers. However, as this paper attempts to show, in cybernetic questions and beyond, the flow of self-reinforcing dynamics techniques and concepts has tended to creed over generations from the natural and theoretical sciences to the social sciences. It is high time we, modern analysts of organizational dynamics, reconsider our positions and perspectives on the self-reinforcing dynamic relations between computers and humans against the backdrop of the longer tradition that midwived into being this cybernetic consciousness itself.

I will begin to make this argument in the following paper. It is divided into two major parts—the first and second acts. The first act explores the evolution of self-reinforcing and self-referential logic in pioneering computer work of George Boole, Kurt Goedel, and Alan Turing, the forgotten philosophy of feedback in early American pragmatism, and the disciplinary origins and synthetic scope of cold war cybernetics. An intermission on a Soviet cybernetician that never was follows. The second act touches upon a number of relevant social scientific theories that often bear on self-reinforcing dynamics between human and computer calculation, and that more often draw on the theoretical and physical sciences to do so. A brief conclusion on the past, present, and future of the modern study of the self-reinforcing human-computer complexes follows the second act.

Act I: The Early Theoretical Sciences of Self-Reinforcing Human-Machine Dynamics

The self-educated George Boole (1815-1864) spent his adolescence making shoes with his father, a cobbler. No one is sure what—perhaps these simple circumstances—inspired him in his early 30s in the 1840s to formulate a symbolic algebra so simple that it could consist of only two states, 0 and 1, and with the algebraic operations of multiplication, addition, and negation and the engineer's logic gates AND (multiplication), OR (addition), and NOT (negation). In 1913, the logician Henry Sheffer reduced this still further, showing that one operation was sufficient to construct all Boolean operations: the NOR gate, equivalent of our "neither… nor…" phrase in English. Using only this basic syntactical unit of difference of "not this," it is possible to construct AND, OR, and NOT logic gates. The consequences of Boole's breakthrough would not be immediate however: 25 years later C.S. Peirce realized that circuits speak Boolean; and almost a century after Boole in his 1935 master's thesis, Claude Shannon formalized the insight that electronic circuits model Boolean logic gates—they are either open or closed, on or off, 1 or 0—and can thus be arranged in ways that can carry out Boolean algebraic operations.

According to Boole, so long as our premises are valid, then our conclusions—whatever the complexity of the intervening calculation—will also be valid as long as our calculations adhere within the Boolean system of thought. In other words, Boole discovered the irreducibly basic grammar with which machines could be made to speak logic and, thus, to carry out our human acts of calculation independent of our intervention. This does not mean that the information contained therein is somehow infallible. A sentence can be grammatically correct and still wrong. It does mean, however, that the structural operations with which digital information are manipulated cannot be doubted on logical terms. Leibnitz' dream of discovering a universal and computer-compatible language had come one major step closer to reality.

The two key concepts for understanding the effects of Boolean logic upon the theoretical and later social sciences are, first, the relationship between a class and object and, second, the analysis of difference. I will touch on each briefly below. First, William Stanley Jevons, grandfather of neoclassical economics, picked up on Boole's work and described a machine before the British Royal Society in 1870 that could reproduce the logical inferences mechanically. He eventually build such a machine, which he called the Logical Piano because it looked like a piano. Gottlob Frege (1848-1925), in turn, created much of modern logic based on a twist in Boole's work. Instead of trying to reduce logic to calculation, as Leibniz and Boole had done, Frege tried to reduce mathematics to logic, introducing in the process of proof into modern logic. And, as will be noted below in more detail, when Russell discovered Frege's error, producing "Russell's paradox" in which a class of elements at once must both contain itself and not contain itself, he did so by abstracting the idea of class, which Frege had intended to contain objects or actual content, into classes of classes. The abstraction from a class of objects to a class of self-aware classes becomes important not only later in computer history but had already long been recognized as a key step in differentiating between form and content.

The concept of classes is of significant consequence. To illustrate their difference in human language, we may consider the difference between a proper name and a descriptive noun. Take Daniel Defoe’s 1719 novel *The Life and Adventures of Robinson Cruesoe*. The proper name “Robinson Crusoe,” for example, is an object in a class of names in the story and it is more or less trivially interchangeable for any other; however, a descriptive noun such as "adventure" participates in the form of the story. Exchanging the noun “adventure” with, say, the noun “colonialist ambitions” would change the title—and interpretation—of the story substantially. By inference we may assume that the same abstraction of certain types of symbols into separate classes allowed for the mechanization of mathematical logic into a base categories of classes fit for modern-day information processing.[2] Boole began this mechanization process by defining "a sign [as] an arbitrary mark, having a fixed interpretation and susceptible of combination with other signs in subjection to fixed laws dependent upon their mutual interpretation."[3] In the science of signs, of which the science of numbers is only one small part, signs take on the character of an empty vehicle whose significance, or content, can only be formed by its relationship to the formal language, or surrounding environment, that in turn dictates the rules of the behavior of any object subject to the commands of that science of signs.

The second important contribution of Boole is that of the irreducible unit difference. In Boolean logic, this symbols is the “not” sign. Almost nothing more is needed to spell out Boole’s symbolic language of analytic difference. The analytic difference of symbols is one of the defining characteristics of computer-compatible information, unlike Kant or Milton’s ages.

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[2] M.J. Beeson, "the mechanization of Mathematics" in *Alan Turing*, 2004, p. 82-85.

[3] Boole, *An Investigation of the Laws of Thought*, p. 25.

Namely, in the age of Boole, all computer-compatible information is quantitative, and all quantities are simplifications. In fact both units of measurements (e.g., the bit) and numbers (e.g., 0 or 1) are at once theoretically exact yet empirically approximate representations of the messy stuff we call reality. The point will not surprise but it remains essential: to capture meaning in symbols is to reduce them, and if the symbols are numerical, the differences *between* those symbols can thus be known and exact. In turn machines can deal with known, exact symbols because all components involved behave consistently. On the other hand, questions of non-numerical differences remain largely subject to humanistic interpretation and debate.

Curiously, computer science and information theory was not the first discipline to exploit Boolean irreducible different: structural linguistics developed an equivalent of the Boolean bit, the phoneme, in 1932, eight years before the coining of the bit.[4] Building on Saussurean structuralism, Russian linguistcs and émigrés, Nikolai Trubekzkoi and Roman Jakobson, found the Prague school of structural linguistics based on Trubekzkoi's 1932 definition (in his *Grundzüge der Phonologie*) of the phoneme as the smallest distinctive unit of meaning in language. In this sense, the phoneme is a conceptual predecessor and linguistic parallel to the bit. The phoneme is not binary in the same way the bit is, but it is similarly codified, discrete, and based on irreducible, observable differences. Sound ceases to be a question of analog waves and analysis: instead phonology is all about putting sounds into discrete, scripted registries (such as phonetic markings). What the ear can hear suddenly became subject to what the eye can read. In other words, the phoneme does to sound what Boole’s bit did to fully automated computer processing: established a base unit of symbolic difference. In the parallels of information theory

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[4] In the Fall of 1940 John Tukey jokingly coined the portmaneau "bit” from *binary* and *digit* over a lunch table at Bell Labs. Physicists knew each atom was already more empty than our solar system at that time. It seems linguistics and computers were headed toward the same astronomical reduction.

and structural linguistics, the stochastic definition of waves of otherwise heavenly motion and music could for the first time be held still and understood in the static of world-bound analysis.

Since the mid 1940s, vast intellectual scaffoldings for phenomenological analysis have been built out of this tendency to reduce analysis to the differential level of the Boolean unit. In the light of French excesses around Derridian différance (a play on *to defer* and *to differ*) and Claude Levi-Strauss incorporation of it into French theory, which drew directly from Roman Jakobson's cybernetic work in the 1940s and 1950s,[5] we can assert the Boolean insight remains fundamental in contemporary thought: as Gregory Bateson—a cybernetic anthropologist—put it in the 1950s "what we mean by information—the elementary unit of information—is a difference that makes a difference" (*Steps toward an Ecology of Mind,* 1972, p. 459).

Boole's most ambitious project—to provide a universal language for logic—would be dealt a blow in the late nineteenth century from which it almost did not recover. That blow: a turn toward self-reinforcing and almost self-defeating logic. The first to deal a blow toward Boole's first-order logic was Bertrand Russell, who turned a set upon itself in 1902. And some attention will also be paid below to the successive blows dealt by the incompleteness theorems of Kurt Goedel and Alan Turing's thought experiments about human-computer dynamics.

Before Russell entered the scene, Gottlob Frege, a German mathematician who had pioneered the field of logic titled his 1879 magnum opus *Begriffsschrift, a formula language, modeled upon that of arithmetic, for pure thought*. Frege (followed by Peano) attempted to extend beyond Boole's earlier attempts to build an abstract logic in formulas. Frege wanted as he wrote, "to express content through written signs in a more precise and clear way than it is possible to do through words. In fact, what I wanted to create was not a mere *calculus*

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[5] Cite: lafontaine, strauss, and geoghegan's new paper.

rationcinator but a *lingua characterica* in Leibniz's sense" (Van Heijenoort, p. 2). Frege's logic, unlike that of his predecessors, would be free of intuitive logic—free to formalize the foundation of all arithmetic thought.

However, in 1902, the young Bertrand Russell (1872-1970) sent a polite letter to Frege in which he noted the following contradiction concerning a self-reinforcing class in logic: "Let w be the predicate: to be a predicate that cannot be predicated of itself." Then he asked "Can w be predicated of itself? From each answer its opposite follows. Therefore we must conclude that w is not a predicate. Likewise there is no class (as a totality) of those classes which, each taken as a totality, do not belong to themselves. From this I conclude that under certain circumstances a definable collection [*Menge*, set] does not form a totality." The layman's version of Russell's paradox are diverse. A classic example: suppose a barber who shaves only all the people in a town that do not shave themselves—should he shave himself? If he does not shave himself, then he must shave himself. And if he does shaves himself, than he cannot. As another example, consider a list of lists that do not list themselves as their own elements: should this list include itself? Or take Groucho Marx's jest that he will refuse to belong to any organization that would have him as their member. In each example, an actor is one who acts only on those actors who do not do the same. Is that actor therefore still an actor? What does one do with unstable classes? Late nineteenth century logicians were dismayed to discover that logic—the style of thought was supposed to quiet the storms of human error—refuses to sit quietly. Worse it refused to do so on its own terms.

Six days after Russell dated his later, Frege replied on 22 June 1902: "Your discovery of the contraction caused me the greatest surprise and, I would almost say, consternation, since it has shaken the basis on which I intended to build arithmetic. It seems, then,… that my rule V is false…. And with the loss of my Rule V, not only the foundations of my arithmetic, but also the sole possible foundations of arithmetic, seem to vanish." He then adds, "in any case your discovery is very remarkable and will perhaps result in a great advance in logic, unwelcome as it may seem at first glance."[6] Ah, such restraint! It caused Frege "consternation," almost, to learn that his lifework to build a pure arithmetic had been irreparably frustrated. No longer could the human intellect enter a specific sphere of thought called pure logic where any rule could apply to any element. No longer could any class describe any collection of elements equally.

The intellectual consequence of Russell's paradox has, in fact, been profound, if understudied, effects on the longer tradition of self-reinforcing dynamics no preoccupying the the social sciences. Many thinkers, including Russell, have since tried to resolve the paradox by proposing a "theory of types" that looked to distinguish between a class and a class of classes. With this he introduced an endless hierarchy of objects: numbers, classes of numbers, classes of classes of numbers, etc. In short, distinguishing between classes of, say, questions prohibits one from logically asking the question "does the barber shave himself" since it is no longer necessary for the question to both the class of barbers and the classes of people whom the barber shaves. If each could be held separate, then the problems of analytical self-reference could be avoided. The upshot should come as no surprise to organization theorists: a hierarchical organization of thought—classes upon classes upon classes—made it possible to govern a formally defined system of rule-based interaction between elements. Computer science, since Russell, has done much with an infinitely expandable hierarchy of classes in effort to perpetually postpone the problems of circular self-reference.

This much, it should be said, has been the lot of much organizational theory ever since Russell. Those interested in organizing elements within rule-governed environments—be it at

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[6] (Van Heijenoort, p. 127-8)

analytical level of market, network, organization, individual—will not be surprised to hear that the conundrums of rule-based government extend all the way down to arithmetic. In Russell's formulation, the paradox of self-referentiality is that some elements, no matter what, will refer to themselves–and that this inevitability can only be solved by opening a potentially endless (and, for this reason, perhaps equally troubling) hierarchy of class distinctions between elements to keep their organizational arrangements from leading to contradictions.

David Hilbert (1862-1943), one of the foremost mathematicians in the early twentieth-centry, took a similar approach to geometry, stating that points, lines, planes, and similar objects could be switched with "tables, chairs, and glasses of beer." All one need to know about an object was the definite relationships that constrained it. (In a sense explored below, Hilbert's approach should also remind of both Einstein's theory of relativity and Bourdieu's field theory.) In his own work, Hilbert followed after Boole and Frege in that, like Boole, he first reduced mathematics to logic through formal languages and then, like Frege, reduced logic to computation. Logical proofs were for him objects in classes, objects whose finite structure, like graphs, groups, and surfaces, to be studied and mapped onto algorithms. Moreover, as the continuity of the keywords object, class, and algorithm suggests, Hilbert's work was preliminary and seminal to the modern invention of computer programming languages.

Hilbert's work led to his famous 1928 formulation of the *Entscheidungsproblem* (German for decision problem) which asked, in brief, whether it is always algorithmically possible to determine whether a (first-order) logical statement is universally valid. Put in other words, he asked whether it was possible for an algorithm, given a formal description of a language and a problem posited in that language, to correctly provide a true or false statement about that problem. At stake in Hilbert's *Entscheidungsproblem* beats the heart of most decision theory since: what are the best principles for making consistent and correct decisions available to man and machine? The formal answer to Hilbert's question—no, no such algorithm can exist—came in at least two forms, Goedel's incompleteness theorems in 1931 and Alan Turing's Turing machine in 1936. First, in 1931, the German logician and philosopher, Kurt Goedel would take Russell's paradox to a new level with his incompleteness theorems. The expression of these theorems—that any axiomatic system cannot be at once consistent and complete—was a profound a debilitating expression of the inexpressibility of logical totality for the vast majority of positivist and rationalist thinkers in his age. It might be noted that for Goedel personally, however, his theorems were elevated form of expression about truth: that is, that self-reference may be, for Goedel, a precondition to truth, as well as in separate cases the symptom of logical error or over-extension.

In 1937, Alan Turing followed Goedel by answering Hilbert in the negative by brute force of a thought experiment with a Turing machine—or computer that can read, write, delete, and calculate Boolean symbols. Let us suppose, he reasoned by proof by contradiction, we had a general decision algorithm for statements in a first-order language. The question whether a given Turing machine halts or not can be formulated as a first-order statement, which would then be susceptible to the decision algorithm itself. (Notice how Turing uses self-reference to reduce the output of Hilbert's question into an input for Turing's machine here.) But Turing had already proven that no general algorithm can decide whether any given Turing machine halts. Thus, since there exists a self-referential statement that cannot be solved, Turing answer Hilbert *Entscheidungsproblem* in the negative: an algorithm cannot exist that can solve all problems in all formal languages. These limitations to logic, it should be noted, were discovered by means of self-reference. Goedel discovers a new order of true statement in proving that axioms cannot contain all true statements. Turing turns the question he is trying to solve into input into his machine, and the machine consumes itself. The significance of this will be touched upon below.

Both Turing machines, which he introduced in 1936 as "universal computing machine," and the Turing test, which he proposed in 1948, and then 1950 and 1952, have been the subject of much writing in recent years, but much of it has been misplaced.[7] On the whole, Turing is rightly remembered for being a founder of modern-day computing, a brilliant logician, wartime cryptologist, possibly the first famous computer hacker, and tragic victim of the cultural pressures of his time. However, it is worth noting that in much of his work, Turing cared about human computability, more than he did computer algorithms. His 1950 paper "On Computable Numbers," as often overlooked as not, was concerned about what numbers were calculable by humans, not machines. So, when it turned out, somewhat ironically, that his own Turing machine offered an analogue answer to the question of human computability—namely, that if a set of recursive functions could be spelled out in binary, then a Turing machine could theoretically and mathematically could compute them—Turing began to be remembered as a welder of man and machine, a sort of celibate father of cyborgs.

This is an unfortunate reading of Turing, however. The Turing machine is something more and something less than a blurring of man and machine. Instead the Turing machine thought experiments demonstrate how the human-machine shared capacity to calculate in fact distinguishes humans from machines. His intellectual work was mathematical in nature, and not route computational as it is with the Turing machine. As a result, Turing the man was able to capture all that may "naturally be regarded as computable." The "natural" function of computing is interesting, for Turing, since it allows humans to encode certain function and machines to

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[7] (See footnotes in Copeland and Proudfoot, "the Computer, Artificial Intelligence, and the Turing Test" as well as footnote turing dump including JDP, 233-237)

compute them for us. This model espoused a natural distinction between human and machine, although, for Turing and for the rest of us, it is less clear whether computation itself is in any meaningful sense natural. Surely, computation in the sense of overt reckoning and logical processes does not occur in writing in nature. However, it clearly can occur in modern self-conscious beings. The fact that computation has been defined, for centuries, by reference to an abstract model of mathematical axioms and their symbolic manipulation suggests that Turing's breakthrough discover that a universal computing machine may be analogous to that very abstract model, underscores that computation is natural, and independent of a human-machine dichotomy.

After all, a Turing test asks us to distinguish a human from a machine, not because it is impossible, but because it is almost always possible. By carving out an imaginative space in the Turing test in which one human cannot tell the difference between a human and a computer conversant, the Turing test succeeds in demonstrating not so much the shared logic of human and machine behavior itself (after all, machines are far superior calculators, while humans retain many deep, abiding pecularities of their own), but rather the very logical perspective one much adopt before even asking whether a machine is indistinguishable from a human interlocutor. The question is exceptional in its retreat to logic, for in logic and the formal sciences—and not in those social sciences or humanities, where complexes of embodied culture rule—can one openly assume to treat indistinguishables as identicals.

Again, what is crucial about the Turing test is less that it blurs human and machines, but rather that it points out a language of logic common to both humans and machines as distinct species in the natural process of computation. Humans program, computers calculate; one requires the conscious reflection upon and mathematical manipulation of abstract models and axioms, the other simply stores rules that replicate a model within which numbers can be turned endlessly. From the computational perspective, Turing observes that a computer is more like a mathematical ignoramus than a mathematician. Thus beginning with the goal of distinguishing between human and the machine, Turing ends as an analyst of types of humans.

It is a disservice in my view, then, to read Turing as a proto-computer, viewing the world through a computational lens, whereas the reader may instead finding value in his finding computational qualities in certain humans that are not found in the machine. Turing may be productively read as not privileging the computer at all, but rather using the computer as a control group, or other side of the cybernetic analogy, through which to stop privileging that unsatisfying umbrella category of "the human," and instead to find within it useful modes of thought that do not intrinsically belong to the category "human." Artificial intelligence is a misnomer. It need not be artificial at all.

Lastly, Turing's machine and Turing test speak something to the overarching theme of uniting series and analogies in the cybernetic and computer sciences. Namely, the construction of a Turing machine reflects the qualities of series, while the operation of a Turing test on the basis of successful imitation can be characterized as an enhanced form of analogy. A Turing machine is very simple, formal device for teaching that the practice of calculating self-reference is not only what makes modern humans modern, it is what makes modern humans computers. As I will repeat in the conclusion: perhaps our modern era is so flummoxed with articulating a hard and fast division between humans and computers exactly because, in practice, the fundamental difference is missing: what makes the computer as useful is what makes modern humans modern, the art and artifice of self-representative calculation.

The Forgotten Philosophy of Feedback: An American Pragmatist Approach

Each of the European thinkers above—Russell, Goedel, and Turing—concern the problem of self-reference in logic and what we might call organizational arithmetic. Russell's paradox, Goedel's incompleteness theorems, and Turings machines all lead to the conclusion that, so far as self-referential sets and systems were concerned, there definitely is such a thing as an unsolvable problem. However, a separate although related line of thought—with sibling applications in the age of computers—was developing during the same period that emphasized not self-reference so much as the self-representation. Below I call trace this forgotten line of thought, which I call the philosophy of feedback, through the early American pragmatist philosophers, namely, C.S. Peirce, the idealist-turned-Peircean work of later Josiah Royce, and Royce's protégé, the mathematician and founder of cybernetics, Norbert Wiener. Unlike the European stewards of self-referential logic, the self-representation posed rich analytical opportunities for rehabilitating logic within the limits of a robust Jamesian relativism. The logical veracity of truth was not the greatest concern for this world—truth had to work to be meaningfully true. And as the rich applications of feedback have since proven in the computer age and will be explored below, their applied philosophy of self-representation has been put to much fruitful work.

Charles Sanders Peirce (1839-1914) was one of America's most versatile nineteenth century logicians, philosophers, and scientists and is remembered for having founded both pragmatism and semiotics (the "quasi-necessary, or formal doctrine of signs" or philosophical logic pursued by signs).[8] He has also been credited with first proposing, in as early as 1886 or 1887 no less, an electrical general-purpose programmable computer. Although his ideas about the electrical circuitry of logic did not seem to have any measurable effect, his ideas on logic,

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[8] Peirce, C.S., *Collected Papers of Charles Sanders Peirce,* vol. 2, paragraph 227.

signs, and philosophy most certainly did. Namely, we can trace his effect upon his colleague Josiah Royce who, between 1910-1913 at Harvard, had direct interaction with and influence on Norbert Wiener who would found cybernetics in 1947.[9] Peirce's influences are veiled in many places in subsequent American intellectual history: in probability, in logic, in quantum mechanics, and certainly in the two fields he founded semiotics (of which he considered logic only a formal branch) and pragmatism. Peirce can also be found in Josiah Royce's later work on self-representative systems characterizing much of philosophical inquiry—including the universe, numerical sets, science, maps and other media of representation, and even being itself—Royce names Dedekind as his source of inspiration, although it is much more likely that Peirce's correspondences with Royce constituted the initial intellectual influence.

Peirce's influence can also be found veiled in the work of Norbert Wiener—who has been called "America's second Leibnitz after Charles Sanders Pierce" as well as "Peirce's heir." In 1913 (a year before Peirce died) at the age of 17, Wiener defended his dissertation under Josiah Royce at Harvard's Philosophy Department. The dissertation was titled "A comparison on the algebra of relatives of Schroedinger and of Russell and Whitehead," and in it he came down in favor of Schroedinger, a position he would maintain even while studying under and publishing corrections to Russell at Cambridge in 1913-1914. Here it seems clear in retrospect that Wiener's formative "algebra of relatives" owes as much to Peirce and August de Morgan as it does to Ernst Schroedinger.[10] Even one of Wiener's key cybernetic insights—that circuits were organic

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[9] Kenneth L. Ketner, "The Early History of Computer Design: Charles Sanders Peirce and Marquand's Logical Machines." *Princeton University Library Chronicle*, no. 3, 186-211. Arthur W. Burks, *The first electronic computer: the Atanasoff story*, University of Michigan Press, Ann Arbor, MI, 1987, see Appendix A, pp. 293-354.

[10] Peirce's contributions to the algebra of relations were numerous. A list a few of those collected and reprinted in *Charles S. Peirce, Collected Papers* (1933), edited by Charles Hartshorne and Paul Weiss, Harvard University Press, Cambridge, follows: "On the Algebra of Logic: A Contribution to the Philosophy of Notation", *American Journal of Mathematics* 7; *Description of a notation for the logic of relatives, resulting from an amplification of the conceptions of Boole's calculus of logic,* Memoirs of the American Academy of Sciences 9 (1870), pp. 317-378; On *the algebra of logic,* American Journal of Mathematics 3 (1880), pp. 15-57; *Brief description of the algebra of*

before they were artificial—can be traced back to Peirce's work on biosemiotics. In both cases, however, cybernetic circuits proved to be electric, be they in the machines culminating in the modern central processor or in the nervous systems culminating in the modern mind. Reality for Peirce—and by implication for William James, Josiah Royce, Erwin Schroedinger, Norbert Wiener, and developments in quantum mechanics—was electric and composed of discrete and relational signals.[11] For these early cybernetic thinkers, there was no final hierarchy, no immutable ranking, no permanent logical relationship that governed all other interactions between elements of our world.

Yet, most of these pragmatist philosophers and scientists were also attracted to a certain self-reinforcing process—or a cumulatively circular arrangement of elements—that did good work: the relative relationship defined by self-representative process and an internal checks-and-balance system that has since come to be known as feedback. Feedback—defined as any process that turns part of its output back into an input in order to inform further output—can be observed in all sorts of phenomena—from inorganic, to biological, to social, to astronomic.

It would not be until 1943 that Wiener would observe that negative feedback—or a process by which an entity may checks its behavior—can be observed in all purposeful behavior. As early as 1899, however, Josiah Royce would observe much of the same Wiener would draw from the technical practices of control engineering and military terms of feedback mechanisms between the 1920s and 1940s. For the late Royce—who by the late nineteenth century had abandoned his ideas of absolute idealism in place for the logical, pragmatic, and semiotics of

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relatives, privately printed, 1882. Reprinted in [Peirce1933], pp. 180-186; Studies in Logic by Members of the Johns Hopkins University (1883), edited by C. S. Peirce, Little, Brown, and Co., Boston; *Note B: the logic of relatives,* in [Peirce1883], pp. 187-203; *On the algebra of logic; a contribution to the philosophy of notation,* American Journal of Mathematics 7 (1885), pp. 180-202.

[11] See for example famous examples of relationalism, such as James' essay on soft determinism, Royce's community of interpretation, the classic thought experiment of Schroedinger's Cat, Norbert Wiener's early essays between 1913-1917.

Peirce—the question of self-representation was one of strong philosophical gravity, and by the late nineteenth century, Royce would see feedback mechanisms, or what he called "self-representative systems," as the fundamental quality of purposeful beings, ranging from infinite and finite sets, to the infinitely representative dynamics of a map within a map (which Jorge Luis Borges and Charles Lutwidge Dodgson, who wrote Alice in Wonderland under the pseudonym Lewis Carroll would later take certain delight in), to his bold conception of science as the "community of interpretation" which would progress stepwise by means of the scientific method toward an absolute truth.

In all, the tantamount position of representation can be seen Wiener's lifework to develop a universalizable model for organic and mechanical systems, throughout Royce's later philosophy, and as early as Peirce's first paper "On a New List of Categories" (which he published as a 27 year old in 1867). In it, Peirce held "representation" as the highest form of category and one fit for studying habit, laws, generalities, continuities through signs—as opposed to other non-representational categories which were reduced at a lower level of studying reactions, dyadic relations, and isolated facts, or at a lowest level ideas, chances, possibilities, vagueness of "some" and "such," and other monadic states. Suffice it to say that this under-explored genealogy of thought from Peirce to the present, which I develop in detail elsewhere, can be conceived as an additional thread of theoretical and natural scientists concerned with those questions of self-representation that occupy the contemporary, computer-informed social sciences.[12]

In a quick summary, the pages above illustrate how in the late nineteenth century and early twentieth century, a cluster of theoretical scientific fields—namely, in Cambridge east of

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[12] My second dissertation chapter develops the largely unexplored relationship between Peirce, Royce, Wiener in further detail.

the Atlantic mathematical logicians and philosophers and in Cambridge west of the Atlantic mathematicians and pragmatist philosophers of science—developed a fundamentally rich language for the analysis of self-reinforcing dynamics in systems. Mathematical logic was confronted with the instability of a set or class that must, by definition, include and exclude itself; and philosophy of a new science was enraptured by concepts of self-representation. In the section below, I will argue how these various strands came together to inform and advance work on self-reinforcing information systems in the postwar meta-discipline called cybernetics. Still further cybernetics tells an important moment in this history not because of its direct effects so much as its disciplinary incoherence that allows it to blur into and thus inspire related work in the mid-twentieth century social sciences. Finally, I will explore how Anglophone cybernetics essentially dissipated during the cold war but continues to influence contemporary understanding of self-reinforcing processes.

Cold War Cybernetics: An Aqueduct from the Theoretical Sciences to the Social Sciences

In the wake of World War II, the brilliant mathematician and polyglot Norbert Wiener formalized first-order cybernetics as the study of “communication and control in the animal and the machine.”[13] Although later discovered that the term had already been used in the 19th century, Wiener coined *cybernetics* in 1947 from the Greek for “steersman” (a predecessor to the English word *governor*) to signify a discipline concerned with “the problems centering about communication, control and statistical mechanics, whether in the machine or in living tissues” (Wiener, 1961, p. 16). By the late 1950s, what had begun as a theoretical and highly technical science of cybernetics had blossomed into politically and sociologically sensitive projects on

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[13] See the subtitle of Wiener’s 1948 *Cybernetics, or Control and Communication in the Animal and the Machine*.

both sides of the Atlantic. Cybernetics helped shape state-sponsored projects developing mainframe computers, wartime robots, satellite surveillance projects, the Soviet space station Mir, and later Reagan's Star Wars project.[14]

In each of these early attempts to graft human action on to grids as well as to bind mechanism to human intelligence, we see the essence of early Cold War cybernetics: the blending of human, mechanical, and natural phenomena on a common canvas. During World War II, Wiener was pulled between the desire to publicize his work on behaviorist probability and the desire to reserve it only for the few mathematicians that could understand it. On one hand, as he wrote at the end of his key work, *Cybernetics*, "The best we can do is to see that a large public understands … this work" (*ibid.*, 29). On the other hand, in his mind the inscrutable abstractions of mathematical theory allowed him and his colleagues "the advantage of looking down on [their] subjects from the cold heights of eternity and ubiquity." That is, Wiener posited that an omnivorously intellectual scientist in a metadiscipline of math could somehow observe the world without influencing his (and invariably *his*) observations. According to this belief, first-order cybernetics observations somehow did not run the risk of becoming "an artifact of [their] own creation" (*ibid.*, 164). With the natural scientist as steersman, his work promised to help centralized organizations such as bully states and military industries navigate, simplify, and unify the noise, chaos, and multiple meanings associated with transatlantic wartime politics.

However, discredited by nearly every academic since Heisenberg, Wiener's dream of a natural science, capable of converting all the shades of behavior into a common language of information packets, prefaces the Cold War tragedy of first-order, or early, cybernetics. (Second-order cybernetics, which incorporates the scientist as an actor within her information system

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[14] Approximately following 10 paragraphs are adapted form my article "Betrothal and Betrayal: The Soviet Translation of Norbert Wiener's Early Cybernetics" in *International Journal of Communications* (2:1), 2008; www.ijoc.org.

model, still flourishes in much of the former Soviet Union today.) The promise of objectivity made cybernetics an ideal and ironic fit with the closed world of Cold War academics, for the scientific hope for objective truth (paired with its obvious antithesis: falsehood) readily avails itself for hijacking into a binary vocabulary of black and white, good and bad, East and West. This article investigates these and other ironies of Wiener as an actor within the information system of the Cold War.

In 1942, the Applied Mathematics Panel (AMP) within the National Defense Research Committee was formed as a clearing house for military projects. The panel employed world-class mathematicians such as John von Neumann, Richard Courant, Garrett Birkhoff, Oswald Veblen, and Norbert Wiener to work on the question of how the few can control the many — a concern central to the World War I and II experience with propaganda and weapons of mass destruction. Engineer Claude Shannon, neuropsychiatrist Warren McCulloch, neurobiologist Arturo Rosenblueth, polymathic genius Walter Pitts, and many others joined Wiener in developing the cybernetics, and von Neumann in developing information theory.

Later during the postwar (1946-1953) Macy conferences on cybernetics and after cybernetics had more or less already been formulated and formalized, these theoretical and natural scientists were joined by representatives from the human sciences such as Lawrence K. Frank (social science), Margaret Mead (anthropology), Gregory Bateson (social science), and later Paul Lazarsfeld (sociology), Kurt Lewin (psychology), and Roman Jakobson (linguistics) (Heims, p. 12). At these gatherings, some of the world’s top minds gathered to study and confront the message — be it encased in a warhead or an advertisement — as the unit for controlling and communicating. As a direct response to a quarter decade of wartime messages, the cybernetics group meant to help, as David Mindell argues, “recast military control in a civilian mold,” to give control to the many (Gerovitch, 2002, p. 54). If war was the product of aggravated entropy and information loss at the hands of the military, then a regulated informational environment would be a peaceful one. So was the hope at least.

The AMP Group asked key questions of anti-aircraft gunnery as part of a larger project to improve rocket, bombing, and gunfire accuracy: namely, how can gunner and gun account for the unpredictability of an approaching enemy aircraft? (Edwards, 1996, pp. 113-146). Stemming from his mathematical model of uncontrolled motion of minute particles immersed in fluid — which is still known in Brownian motion studies as the “Wiener model” — Wiener derived a general theory of information control that led to a central supposition of cybernetics (Galison, 1994, pp 228-266): that under the certain intense circumstances of battle, the enemy pilot, ally gunner, and ally bullet would all respond more or less predictably (Wiener, 1954, pp 61-63). That is, at near instantaneous intervals, human reaction on the battlefield becomes as predictable, even mechanical, as a bullet’s behavior. This central insight made it possible to deduce response patterns in battle and thus, to control for some of the stochastic chaos of war by accounting and controlling for all behavior — be it human, machine, or natural — as a probabilistic problem.

Probability reduces decision errors resulting from inaccurate assessments of an environment. Its power lies in letting a mathematician know how much she does not know, or more specifically, how likely it is that one observation will apply to another. The expansive self-conceptualization of the metadiscipline as a bringer of peace depends on this probabilistic turn, as probability makes all behavior calculable and subsequently animates a statistical equivalent for a state of harmony and peace, or “information homeostasis.” This fundamental vision — with science as the steersman ready to navigate the world out of chaos — underpins the historical resonance of cybernetics during the World and Cold Wars. Although employed to control war, Wiener meant it to usher in peace. With a new behavioral calculus in hand, the dance of death between gunner and aircraft became a matter of calculation.

With mathematics as the common language, the interdisciplinary science subsumed a wide range of keywords and theoretical and natural scientific fields. Consider a few in passing: *information*, *signal*, and *noise* from communication engineering, *feedback* and *control* from control engineering, *reflex* and *homeostasis* (again, a near synonym for *peace* in social contexts) from physiology, *purpose* and *behavior* from psychology, *entropy* and *order* from thermodynamics, *teleology* from philosophy, and *extrapolation* from mathematics. These and other terms united for the first time under Wiener's tutelage into a full-service discipline capable of describing human, machine, and natural behavior into a common metadiscipline. Protein-based genetic code transmission, heredity, fertilized eggs — all were interpreted as integrated control systems of feedback loops and control signals. The field was a metadiscipline, a Foucauldian "episteme," that bounded with "punctuated leaps" from the study of matter, to energy, to information (Kay, p. 84). With the publication of Wiener's popular summary of cybernetics, *The Human Use of Human Beings*, American scholars across the board — from neurology, to endocrinology, biology, political science, economics, anthropology, and linguistics, among others — turned enthusiastically to the new metadiscipline and harbinger of peace.

To the dismay of Wiener and his pacifist peers, the military investment was high and the theories fit military applications perfectly. Their pacifist work tended to end up, Wiener dismayed, "in the hands of the most unscrupulous" (Wiener, 1961, p. 29). In *Cybernetics,* Wiener detested "the large and the lavish" State institutions, passing strict sentence on cumbersome governments: "Like the wolf pack … the State is stupider than most of its components” (Wiener, 1961, p. 162). Yet while ideally developed within small, sharing, and open groups of researchers such as he enjoyed at MIT and Columbia — the cybernetics group work found support at the behest of the military. His autobiography, *I am a Mathematician* (1964), novel *The Tempter*, and the conclusion of *The Human Use of Human Beings* each resonate with a deep disappointment with the formal successes of his cybernetics projects and his personal failures as a pacifist.

He writes “There is no homeostasis [read: peace] whatsoever. We are involved in the business cycle’s boom and failure, in the successions of dictatorship and revolution, in the wars which everyone loses, which are so real a feature of modern times” (Wiener, 1961, p. 161). The ultimate irony of cold war cybernetics follows that, originally intended as a discipline of peace, cybernetics was initially picked up by the American military-industrial complex, which it served well in the 1940s and 1950s, until the Soviet scientific academy adopted and adapted the field for its own uses. This took place in the Soviet Union in the mid 1950s through 1960s and on, just as American cybernetics was diffusing throughout a number of social scientific and natural scientific fields. What began for Wiener in the postwar period as a pacifist science meant to show to competing enemies how computably compatible they could become wound up, by the end of his life in 1964, having served one and then the other superpower, two Manichean masters.

My analysis of Wiener’s end-of-life pessimism concerning his life work is based on an extension and gentle correction of Geof Bowker’s theory of cybernetics universality (1993). Bowker rightly grounds his understanding of cybernetics universality in its capacity to content-shift and pirate freely from other disciplines. However, with the surprisingly rapid dissolution and dispersion of cybernetics as a coherent discipline (or even metadiscipline) in the 1950s, Bowker and other interpreters of cybernetics have neglected the fact that the very openness of cybernetics to all mathematically rigorous disciplines allowed it to serve as a sort of intellectual aqueduct to a series of compatible social sciences ranging from sociology, to operations research, to anthropology, to economics, to linguistics that continue to benefit in part from a largely unrecognized cybernetic inheritance of principles about self-reinforcing human-machine dynamics.

Cybernetics marshaled together several keywords for the systematic study of self-reinforcing dynamics, namely purposeful (negative) feedback, neural networks, and rational automation of stochastic processes. These keywords would prove productive in fields ranging from modernist political science, to artificial intelligence, to biology. However, perhaps most influential of all was the self-reinforcing analogy between the organic and the mechanical system central to the nature of almost all cybernetic investigations. Feedback, neural networks, and automation were simply lens for focusing the early cybernetic study of the living organism as a natural fit within a mechanized, behaviorist world. Anti-aircraft gunner and gun were conceived of as one human-machine system; neural and mental pathways were mapped homologically with computer networks; DNA became thought of as computer source code in the mechanical reproduction of the animal world; life, order, and information became local anomalies on the vanguard against the crushing forces of entropy and chaos; the cyborg emerged in fiction and then in the limb replacement labs; in a word, by translating organisms into mathematical terms, cybernetics involved life itself in a self-reinforcing dance of animal-machine interdependencies.

However, before I explore how self-reinforcing systems of cybernetic informed the social sciences, it may be worth noting a counter-study to my historical thesis. Namely, the case study of Aleksandr Bogdanov’s lifework, tectology a universal organizational science, offers enough distinct parallels with cybernetics as well as important differences, to allow us to theorize more generally about the intellectual influence of the theoretical and natural sciences upon the social sciences. Namely, Bogdanov's tectology can be understood as a proto-cybernetics in its intellectual universality, yet the fact that it, in contrast to the mathematician's cybernetics, drew initially from the social sciences—namely, Marxian economics—can help explain both the untimely politicization and demise of the field as well as offer cautions for our own contemporary work.

Intermission: Why Cybernetic Movement Did Not Start in the Soviet Union: the Bogdanov Case

In the few following pages, I pause from the general thread of argument to compare Aleksandr Bogdanov's 1922 *Tectology: a Universal Organization Science* and Wiener's 1948 *Cybernetics* on conceptual and political terms. While Bogdanov began his "universal organizational science" by analogizing the natural sciences and Marxian economics a few years ahead of the Russian revolution (1912-1922), Wiener founded his science on the analogy between "the animal and the machine" at a time ripe with Taylorism, on both sides of the Atlantic. Both shared deep concerns about deriving laws for organizing society—although Wiener did so originally in the individualist terms of machine and animal, while Bogdanov did so in socialist economics terms; both also shared Leibnitzian catholicity of intellectual interests and socialist/left-leaning concerns about the automatization of social labor.

Among other ignored Eastern European cybernetic scholars,[15] we may begin with Aleksandr Bodganov (1873-1928)—the old Bolshevik revolutionary, Marxian philosopher, and compelling Eastern European counter-point to Wiener's universalizing cybernetics. While Bogdanov's 1912 *Tectology: a Universal Organization Science* began by analogizing the natural sciences and Marxian economics a few years ahead of the Russian revolution, Wiener's 1948 *Cybernetics* founded his science on the analogy between "the animal and the machine" at a time ripe with Taylorism on both sides of the Atlantic. The resulting comparison of their scientific means for organizing society, creative production, and social labor prove particularly suggestive. Namely, by comparison, both Bogdanov and Wiener developed universalizing sciences based on the common organization of elements in systems; both advanced theories of feedback

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[15] One other pre-cybernetic Eastern European scientist is the Romanian Stefan Odobleja (1902 – 1978). However, were we to widen the focus a bit, we discover a host of intellectuals engaged in the totalizing organization known in Western Marxism. Martin Jay's synthetic intellectual history *Marxism and Totality*, for example, sweeps from the Hungarian literary critic Gyorgy Lukacs (1885-1971) to the German sociologist, Jurgen Habermas (1929 - ?) in a tour de force of the adventures the concept has led in Western Marxism. The last thing Jay should be faulted for is narrowness of intellectual scope. Nevertheless, the absence of any focus on Eastern European in such a notably comprehensive book points to the startling general lack of inquiry into the contemporary state of Eastern Europe thinkers, despite the fact that many western Marxian thinkers had roots in Eastern Europe. Among others in Jay's parade of thinkers, Georg Lukacs grew to his class consciousness during the same "Hungarian phenomenon" in the late nineteenth and early twentieth centuries Budapest that produced the social scientists Karl Polanyi, Oscar Jaszi, and Karl Mannheim, as well as a surge of brilliant scientists for the West during the World Wars such as John von Neumann, Edward Teller, Eugene Wigner, Theodore von Karman, Leo Szilard, and others. It may also be interesting to note that others like Lucien Goldmann, who brought Lukacs' work to France, grew up in Bucharest, Romania, and more classic German thinkers, like Theodor Adorno, Ernst Bloch, and Karl Korsch, among many others, were personally (as well as intellectually) affected by the growing specter of Marxism to their east. To push the scope one step further, some of the greatest foundations of western thought on totality were laid much earlier by Nicholas Copernicus (1473-1542) from Torun, Poland and Immanuel Kant (1724-1804) from Koenigsberg, Prussia, present-day Kalingrad, Russia. It cannot hurt the dominant paradigm of thought, namely the Western tradition, by noting how often and how clearly its origins lie outside itself. In fact, to find origins outside of oneself, according to Remi Brague, author of Eccentric Culture, is the defining characteristic of Europeanness. European (and thus, by adoption, Western) identity depends on its tracing its origins back to the Greeks. To trace one's identity back to the Greeks defined what it meant to be Roman, however: thus, he concludes, Europe is in a strong sense Roman, not Greek, because it thinks it is Greek. This also animates the longer history of strife seen in present-day negotiations over Turkey's ascendancy into the European Union. The trouble, of course, arises out of the fact that modern Greece disdains Turkey, despite the fact it contains more native Greek ruins on its soil than any else. History ensures that the binary question, Who is Greek (i.e. European) and who is not, does not cleanly compute. It seems unimpeachable, then, to assert that in order to better understand the emergence of totality in philosophical and scientific thought in Marxism, or more interestingly in the utopian hope for a socially, scientifically, and technologically improved future, scholars would do well to look at a more total picture of Europe, one that inevitably extends beyond it.

mechanisms and organizational analogies; and both caution again the mechanization of social labor. However, by contrast, Bogdanov’s organizational science began with a collective metaphor between the economy and society, while for Wiener, science began with the individualist metaphor between the animal and the machine. In addition, Wiener’s universalizing science was heavy in mathematics, while Bogdanov’s was non-mathematical. Combining the universal symbolic power of mathematics with the politics-free metaphor of individual would spell the initial success of Wiener’s cybernetics (as well as accidentally secure its subsequent politics-free translatability across cold war political discourses). On the other hand, the socially resonant terms and times of Bogdanov’s non-quantifiable, non-mathematical theory of tectology (1913-1922) resulted in its unfortunate politicization and early censorship immediately before and following the Russian revolution. Bogdanov’s idealistic political perspectives and the unfortunate reactions it raised are touched upon below.

In the epilogue of his 1908 science fiction novel and the first piece of Bolshevik utopian fiction *Red Star*, Bogdanov has his character double, Netti, lay "the foundations of Universal Organizational Science": "no matter how different the various elements of the Universe—electrons, atoms, things, people, ideas, planets, stars—and regardless of the considerable differences in their combinations, it is possible to establish a small number of general methods by which any of these elements joins with another, both in spontaneous natural processes and in human activity...." He continues: "Thus was born Universal Science, which soon embraced the entire organizational experience of mankind" whose "scientific analysis that resembled mathematical calculations" allowed for swift reform of the social order. "Just as natural science had earlier served as a tool of scientific technique, now Universal Science became a tool in the scientific construction of social life as a whole."

These idealized and admittedly (science) fantastical sentences sum up the whole thrust of Bogdanov's lifework, which he called tektology. In real life and in narrative, he conceived of radical social reform as the process to be understood and carried out in universalizing science. The details of the rest of the book—like his life—are something of a mixed adventure. In his fiction and non-fiction alike, his characters seek out communist utopia, in which pure logic, social equality, and natural “equilibria.” He imagines a world in which enormous calculating machines determine the whole of the economy (a precursor to the 1950s and 1960s Soviet economic cyberneticists’ attempts to do the same which I discuss elsewhere). The government—interestingly including all parties (including the Communist party one assumes)—and all other organs of violence have withered away: only kind and correctly-minded physicians and teachers are charged with enforcing behavior among aberrants (young children and the insane). Money, prejudice, and hierarchy do not exist. Medicine has extended life on Mars indefinitely. And in *Engineer Menni,* his 1913 sequel to *Red Star,* Bodganov’s character double, Netti, joins the revolution and, in the epilogue, founds "Universal Organizational Science" to forward the great cause (still a decade away when Bogdanov was writing) of the great Marxist revolution on the Earth.

Bodganov’s worldview is not entirely straightforward, even in idealized fiction: There are elements of dystopia built into both his organizational thought and utopian fantasy. In *Red Star*, as in the late Tsarist Russia, machine-run industries have become so dangerous they must be kept underground[16]; the population is out-running food supplies in Malthusian proportions; voluntary suicide clinics are becoming increasingly popular and nervous disorders have not disappeared; radioactive matter—namely atomic and anti-matter—are running in scarce supply, as the Martians are forced into massive deforestation and strip-mining of Mars; lastly, colonialism itself

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[16] I wonder if director Fritz Lang’s *Metropolis* (1927) was influenced by Bogdanov in German translation.

(an idea usually reserved only for the most abhorrent of late Capitalist societies) figures prominently in the strategies of Bogdanov's socialist Mars.

In the nonfictional world, so too were times troubled. From 1913 to 1922 Bogdanov wrote *Tektology: an Universal Organizational Science*. A decade before the 1917 Russian Revolution, Bogdanov had for a time been poised to become the second most influential intellectual and right-hand man to Vladimir Lenin himself. However, he quickly found himself—together with other leading figures such as Trotsky, Plekhanov, Valentinov, and others—subjected to Lenin's attack against empiriocentrism in defense of materialism (namely Marxist-Leninist dialectical materialism so iconic in the subsequent Soviet Union). Lenin critiqued and cast Bogdanov from influence for being unable in part to admit that, among other sins of admission, thinking is a function of the brain, or of a material object, since Bogdanov treated physical objects as products of thinking.[17] As a consequence, Bogdanov permanently fell from official favor. In the 1970s, his work enjoyed only partial rehabilitation—and by then it was too late: Wiener's cybernetics had swept the Soviet Union from 1955 to the mid 1960s during Khrushchev's thaw.

Bogdanov's theories were surely abstract and perhaps utopian, but hardly anti-materialist as Lenin had claimed. Bogdanov did not simply reduce materiality to cognition; instead he sought to provide a universal set of rules for organizing and assembling distinctly material objects. According to *Tectology*, "holistic," emergent phenomena could achieve "stability" of "dynamic complexes" through assembling themselves according to generalized laws of the character of any material objects. While Marxian economics was a convenient vehicle for implementing these laws at the time, it was not a necessary one. Instead, Bogdanov foresaw a

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[17] Lenin, *Materialism and Empiriocentrism* (1908). See also Leszek Kolawkowski's *The Alienation of Reason*, p. 126-131.

day when no hierarchical organization—be it capitalist or Leninist-socialist—would be able to implement his technocratic vision of the future social reform. Unfortunately, it was the political circumstances of both his life and times, combined with his work's opposition to Lenin's dialectical materialism, that ensured his inevitable and eventually his critique and dismissal on political terms. Had he carried out his work in the universalist mathematical terms, instead of local Marxist ones, the result may have been different—as it was for Norbert Wiener, who publicly espoused his left-leaning political sentiments only after the international success of his cybernetics. In short, Bogdanov's universal organizational science remains for the most part a forgotten counterpoint except as a potent reminder of the dangers of political science to the global success of cold war cybernetics.

Act II. A Series of Social Scientific Vignettes on Self-Reinforcing Cybernetic Dynamics

In an influential article reviewing the intellectual genealogy of management studies, Kunda and Barley (1994) propose a clean chronological typology with alternating normative and rational emphases for the field, stretching from periods of industrial betterment (1870-1900: normative) to scientific management (1900-1923: rational) to welfare capitalism/human relations (1923-1955: normative), to systems rationalism (1955-1980: rational), to organizational culture (1980-1994: normative).[18] It should come as no surprise that the four period—systems rationalism, with its disciplinary complexes circumscribing operations research, management science, process theory, and contingency theory can be grouped as the organizational studies heir of cybernetics. These and other related "new systemizers" drew directly from the same "logistical work"

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[18] Barley, Stephen R. and Gideon Kunda, "Design and Devotion: Surges of Rational and Normative Ideologies of Control in Managerial Discourse," *Administrative Science Quarterly*, Vol. 37, No. 3, (Sep., 1992), pp. 363-399

completed by mathematicians, physicians, and statisticians during World War II that inspired cybernetics. Often the work had to do with programming computer to—in simultaneous coordination with a human gunner—help predict an enemy's pilot flight and focus anti-aircraft ground-to-air fire, the genesis of the coming cold war anti-missile warfare by closed computer systems. This work of control engineering transferred bodily to the work of organizational planning, forecasting, and prediction—the new postwar watchwords of the American manager. Theorists and management scientists sought out the same "orderly body of knowledge" (Luthans, 1973: 67) and universalizing principles of cybernetic behavior and organization (Newman, 1951; Drucker, 1954; Koontz and O'Donnell, 1955).[19] Planning and control techniques had became centrally quantitative in organizations and major universities alike with the rise of computer-animated fields such as queuing theory, linear and dynamic optimization programming, network analysis, and simulation theories in the mid 1960s.

That the period of systems rationalism drew close connections to cybernetics—and more specifically to the cybernetic concept of incorporating the human manager as a rational actor within a highly structured computerized system—is well known and not surprising. What is less well known however is the genesis and spread of self-reinforcing processes originally observed in the theoretical and natura sciences and transferred in part through cybernetics to the social sciences. Consider, to take a few examples among many, the theoretical scientific roots of path-dependency theory in feedback, Bourdieu's field theory, and even Granovetter's embeddedness theory.

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[19] Luthans, Fred. "Contingency Theory of Management: A Pathway out of the Jungle" Business Horizons, 16: 67-72, 1973. Newman, William H. *Administrative Action: The Technique of Organization and Management*. Englewood-Cliffs, NJ, Prentice Hall, 1951. Peter F. Drucker. *The Practice of Management*. New York: Harper and Row, 1954. Harold Koontz and Cyril O'Donnell. *Principles of Management: An Analysis of Managerial Functions*. New York: McGraw Hill, 1955.

Path-dependence theory can be explained in brief by the effects of positive feedback loops limiting sequential behavior: it says the decisions you face today are limited by the choices you made yesterday. Before classic examples of path-dependence (such as the Betamax and the QWERTY keyboard), the history of path dependence theory—stretching from Joseph Schumpeter's early evolutionary economics to the mid-century structural-functional blurring of institutions that accompanied systems rationalism—ran parallel with cybernetic scientists observing very similar phenomena. Only the cyberneticists called them positive feedback loops. Curiously, the same blurring of institutions made room for counter-rationalist explanations of institutions such as evolutionary economics and historical institutionalism, ranging from the work of Karl Polanyi to Charles Tilly.

The path dependence of path dependence theory itself can be understood as a an extension of the broader concept of feedback: or a process by which part of an output of a system becomes an input in that system with the purpose of influencing future output. Since the 1920s, engineers have developed two categories of feedback: positive and negative, and only negative feedback is capable of reproducing purposeful or goal-oriented behavior. The terms *positive* and *negative* here refer to an arithmetic multiplier and carry none of the normative sense arises when, say, a businessman speaks of receiving "positive feedback" from a client. A positive feedback system is one in which the feedback loop (output that has become an input) impacts the system's by amplifying (cf. positive) the action at that instant moment. As Wiener and Rosenblueth write, "the fraction of the sign of the signal that which reenters the object has the same sign as the original input signal. Positive feed-back adds to the input signals, it does not correct them."[20]

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[20] Rosenblueth, Wiener, Bigelow, "Behavior, Purpose, Teleology," in: Philosophy of Science, 10(1943), S. 18–24, 1943.

Examples of positive feedback systems include avalanches, decay, snow melting on black mountain soil, audio feedback loops between microphone and loudspeaker, and any other system that will continue to escalate until some external force subdues it. Graphed as a function of degrees of decision freedom over time, the behavior of these natural phenomena resembles almost exactly the type of behavior described by path dependence theory. In each case, each successive step along a certain pathway is increasingly limited. If you are the monopoly owner of a locked-in franchise, path dependence serves your short-term self-interest (at least until the anti-trust lawyers show up). If you are skiing downhill to avoid a cascading avalanche, path dependence is not so desirable.

Path dependence and its positive feedback corollary is, however, only half of the story. There is just as much to be learned from the story of negative feedback. Consider the corrective qualities of a negative feedback loop capable of diminishing the current “behavior” of an poorly performing organization. In engineering terms, the sign of the signal fed back into the system is the opposite (cf. negative) of the original output signal. Negative feedback systems, unlike path dependent positive feedback loops, are capable in theory of achieving what Walter Cannon called “homeostasis” in 1926 and then popularized in his 1932 book *The Wisdom of the Body*. Homeostasis, a Greek neologism combing *similar* (homeo) with *standing* (stasis), roughly translates as “standing still” and refers in an organism to a dynamic yet stable state of equilibrium. Healthy organisms and organizations are a prime example of automatically self-correcting systems. Much of management theory can be understood as the attempt to develop principles of self-correcting organizations. Negative feedback is one such understudied concept.

Feedback can be traced ranging from ancient practice to peculiarly modern contexts. In modern organizations, negative feedback loops are omnipresent, ranging from financial audits, to performance appraisals, marketing research, shareholder's meetings, labor strikes, and employer lockouts. The practice of feedback is at least as old as the art of aiming—such as the atlatl and archery (which gave us the term *stochastic*). Neurophysicians now believe human learning owes much to feedback processes: we learn to walk through a coupled feedback loop between our appendages and sense organs, and we learn to talk through the coupled feedback loop between our ears and voices. Feedback mechanisms date back at least to the water clocks in 300 BC Greece that used float regulators (not entirely unlike innards of a modern toilet) to let water pour at a constant rate, and thus to measure time. The industrial age saw the rise of feedback mechanisms in James Watts' 1769 steam engine, methods for pouring grain onto grindstones in windmills, and other feedback tools for regulating temperature and pressure.

With the concept in hand, it is also easy to find the idea of *feedback* in modern thought: we may remember Abraham Maslow's law of the instrument: "When the only tool you have is a hammer, it is tempting to treat everything as if it were a nail."[21] Feedback is certainly one such hammer, if only we give it a chance. Madisonian theories of representational democracy calls for a population to govern itself by electing representatives and in turn subjecting their careers to future election review. This is negative feedback in action. The origins of the concept in modern thought can be traced to implicit descriptions of closed systems in David Hume's political economics, Malthus' doomsayer predictions of the positive feedback loop between exponential population growth and arithmetic food supply growth, or Adam Smith's mention of wages, populations, and supply and demand, all social feedback mechanisms.[22] Charles Darwin's mid-nineteenth century theory of natural selection has since come to be understood, thanks to evolutionary biologists like Ernst Mayr and Theodore Dobzhansky, as a self-selecting ecological

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[21] Abraham H. Maslow (1966). *The Psychology of Science*, p. 15.

[22] See Stuart Bennett, *A history of control engineering, 1800-1930*, especially chapter 1, "Feedback: the Origins of the Concept," IET, 1986, pp.

feedback system. Claude Bernand, a nineteenth century French physiologist known for his objectification on the blind experiment in the scientific method and controversial promotion of vivesection, also coined the term *milieu interieur* (internal environment), which lead to Cannon's *homeostasis* or dynamic equilibrium. The desired state of almost all dynamic systems can only be achieved through negative feedback systems. Feedback is shorthand for automated mechanisms for self-regulation.

Here again the history of the social scientification of feedback impinges at moments on cybernetics. As David Mindell (2005) ably demonstrated, the term—which was already used by electrical and control engineers at Bell Labs, naval fire control, Vannevar bush's MIT laboratory, and the Sperry gyroscope company in the 1920s and 1930s—did not transfer bodily into popular scholarly discourse until the President Roosevelt established the National Defense Research Committee at the start of World War II. In 1943 Norbert Wiener together with colleagues Arturo Rosenblueth and Julian Bigelow would articulate their vision of purposeful negative feedback loops. This source of inspiration has gone entirely overlooked in the standard history of cybernetics, which relies heavily on the 1943 article "Behavior, Purpose, and Teleology" by Norbert Wiener, Arturo Rosenblueth, and Julian Bigelow as one of two articles to found cybernetics.[23] Wiener's article pointed out that negative feedback loops could endow system behavior with goal-oriented (teleological) purpose. But like most foundational texts, the 1943 article is often remembered and rarely read. Modern inheritors of this negative feedback tradition in the social sciences would be shocked to take in the behaviorist tone of the 1943 article: as philosopher Jean-Pierre Dupuy points out, subsequent cybernetics has too often be reinterpreted

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[23] The two founding articles were Arturo Rosenblueth, Norbert Wiener, Julian Bigelow's "Behavior, Purpose, Teleology," in: *Philosophy of Science*, 10(1943), S. 18–24, 1943, and Warren Mcculloch and Walter Pitts' "A logical calculus of the ideas immanent in nervous activity" *Bulletin of Mathematical Biology*, Vol. 5, No. 4. (21 December 1943), pp. 115-133.

as a break from behaviorism, as a move toward anthropomorphizing the machine, whereas in the early period, Wiener, Rosenblueth, Bigelow and others adopted an “eliminativist” or reductionist approach to accounting for behavior. Early cyberneticists intentionally reduced organic behavior to the mechanical system, not the other way around. The regular staples of popular psychology—beliefs, desires, consciousness, will, intentions—were of no use to the early cybernetic stewards of feedback. Yet this fact has been poorly understood, especially by second-order cyberneticians such as Heinz von Forester: in a telling example, when the 1943 article was translated into French twenty years later, the central term “purpose” was mistranslated as “intention,” which ignores the central assertion of the article: that negative feedback, not intention, puts purpose to work.

Since cybernetic, the self-reinforcing dynamics of positive feedback (or path depenence) and negative feedback alike summarize much of modern innovations in the organizational management. In addition to the theories of path dependence, Malcolm Gladwell’s bestselling *Tipping Point: How Little Things can Make a Big Difference* popularizes notions known well to sociologists since 1969 when cold war game theorist Thomas Shelling built on the 1957 work of Morton Grozhdin about sudden shifts, or “white flight,” in neighborhood racial demographics.[24] Here again the primary sources for this type of vocabulary and the network theoretic conception that underlies the term stems from the natural and theoretical sciences. Before “Tipping point”—meant anything to students of society and organization, it had earlier equivalents in the natural and theoretical sciences, namely: *threshold* (as a piece of timber the lies across the entrance into a house, which William James picked up on to set a low “difference-threshold” in 1902

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[24] Schelling, T. C. “Neighborhood tipping. Harvard Institute of Economic Research *D*iscussion Pap*er* Analysis of Segregation Indexes,” America_No. 100, Harvard University, Cambridge, Mass., December, 1969, to appear in A. H. Pascal article contains several references to the ea (Ed.), *The American Economy in Black and White*. See also: Grodzins, M. *Metropolitan segregation*. Chicago: University of *C*hicago press, 1957.

psychology), *boiling point* (in cooking and chemistry), and *critical mass*, the minimum amount of fissile material to sustain a nuclear reaction. Similarly, "tipping points" can be simply described as, again, positive feedback loops in control theory or as the "inflection point" in the mathematics, the moment at which a given function changes signs. All of these sociological innovations are rooted in some theoretical, natural, or material science.

Self-reinforcing dynamics can also bear fruit when applied to the study of hierarchical organizations. One simple fact is that all hierarchies tend to self-reinforce their own structures, tending toward a single, static state of internal order. In short, rankings—whether found in hierarchical or heterarchical or other regimes—are inveterate examples of self-reinforcing phenomena. Consider two everyday examples of self-reinforcing ranked hierarchies: click on buy a book in Google books to see one book sold by, say, 25 different sellers. Some will have five stars and many ratings, a few will have one star and as few as one rating. Of course, the consequence is a path dependence dynamic: One bad rating early on is enough to sink an otherwise fine service; many good ratings, on the other hand, can justify later claims to near organizational immortality (consider that Harvard's motto "Veritas" is in Latin, a language that fell out of scholarly predominance in seventieth-century Europe at the same time Harvard was founded). Or in an arena a little closer to home, consider the fact that the common demographical element of starting players in the world cup is that they were old for their grades when they began to play football in elementary school. Marginalia size and strength differences grow and reinforce themselves in many competitive arenas.

In contrast to "hierarchy," Columbia sociologist David Stark has recently theorized the concept of "heterarchy" as a "non-bureaucratic" and "organized dissonance." In the specific context of asset ambiguity in postsocialist Hungarian firms, Stark shows how the theory of heterarchy poses ample opportunity for understanding entrepreneurialism within transitional economies—some parts of which remain under state subsidized enterprises, other parts of which are blazing the trial toward free market competition. Stark's use of the term *heterarchy* helps clarify matters somewhat: "In contrast to the vertical authority of hierarchies, heterarchies are characterized by more crosscutting network structures, reflecting the greater interdependencies of complex collaboration. They are heterarchical, moreover, because there is no hierarchical ordering of the competing evaluative principles."[25] To put this even more simply: heterarchy exists wherever the same set of objects can be ranked in zero or multiple ways. Heterarchy describes situations where multiple regimes of internal ordering may coexist and compete.

If the ranking of the set of objects or events is subject to and changes with the perspective of the outsider observer, then the roots of the term heterarchy—*rule of the alien*—make perfect sense at even a superficial level. For example, Dmitri Bondarenko, a Russian anthropologist, employs the term *heterarchy* (as well as, his contribution, *homoarchy*) to describe the "non-state supercomplex society" of Benin between the 13th and the 19th centuries. Given his analysis is separated by a continent as well as over a century of time, he is free to do so as a bona fide outsider observer—i.e., as an alien. However, when the objects within the set act for themselves and have some say over the rankings—such as, say, the many actors within the complex non-state society of Benin itself—the term *heterachy* becomes a much more fitting description for complex, self-reflective cybernetic entities that are governed by many forces within and thus by the whole.

When heterarchical environments are solved—or calculated to an optimum according to given standards—multiple optimal solutions inevitably result; whereas hierarchical environments should have, in theory, only one optimal solution. In heterarchical designs, Stark notes,

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[25] Stark, The Sense of Dissonance, p. 29.

increasingly complex interdependencies result in increasingly complex coordination problems, and the intelligence and authority in an organization is subsequently increasingly distributed in nonhierarchical patterns. Stark is not the first social scientist to contrast the term *heterarchy* to the more traditional term *hierarchy*—which can be understood as simply as the existence of rank within a given set of relationships, meaning a certain set is nested within another set. However Stark is the first to develop it in ways amenable to network theoretic study.[26]

The surprising origins of the idea of heterarchy—with its rich potential to reform and innovate theories of organizational structure, market classifications, asset ambiguities—has what I hope will no longer appear such a surprising original source: namely, the early cybernetics. This time the term heterarchy comes from the American neurophysiologist Warren McCulloch. McCulloch used the term in 1943 to refer to mixed multiplicities of neural network structures. Heterarchy for him refers to his extracting the circular processes in natural occurring neural networks in which, for example, object A is preferred to object B, object B is preferred to object C, but while object C is preferred to object A. Like the three-body problems in quantum and classical physics,[27] McCulloch's heterarchy (like Stark's) cannot be solved through finite calculation or simple typologies. Rather reflexive logics in sociology and cybernetics alike can be understand as dynamic circular process constantly in its own making.

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[26] As Stark writes: Gunnar Hedlund introduced the term to the social sciences with application to the multinational corporation. See Gunnar Hedlund, "The Hypermodern MNC: A Heterarchy," 1986; and Gunnar Hedlund and Dag Rolander, "Action in Heterarchies: New Approaches to Managing the MNC," 1990. See p. 29, Stark, chapter 1. *The Sense of Dissonance: Accounts of Worth in Economic Life*. Princeton UP, 2009. Still other uses of the term heterarchy can be found in information sciences, biology, and political theory. * See also Dmitri Bondarenko. 2005. A Homoarchic Alternative to the Homoarchic State: Benin Kingdom of the 13th - 19th Centuries. Social Evolution & History. Vol. 4, No 2. pp. 18-88; and Bondarenko D.M. 2007. What Is There in a Word? Heterarchy, Homoarchy and the Difference in Understanding Complexity in the Social Sciences and Complexity Studies. In K.A. Richardson and P. Cilliers (eds.). Explorations in Complexity Thinking: Pre-Proceedings of the 3rd International Workshop on Complexity and Philosophy. Mansfield, MA: ISCE Publishing. P. 35–48. Warren McCulloch (1945): A Heterarchy of Values Determined by the Topology of Nervous Nets. In: Bulletin of Mathematical Biophysics, Vol. 7, pp. 89-93

[27] It is not clear to what degree, if at all, McCulloch's 1945 term influenced Robert H. Dahl's introduction of the term *polyarchy* to refer to a form of government with three or more actors in his 1956 *Introduction to Democratic Theory*.

Another classic, if often overlooked, case is the debt that great reflexive sociologist Pierre Bourdieu’s field theory owes Albert Einstein’s 1906 special and 1915 general theories of relativity. In the basic strokes, the resemblance is striking. Bourdieu proposes an organized and differentiated field in which sociological events and objects can be distinguished entirely relationally. The fact that the changing of states of one object in the field can effect the state and position of another Bourdieu shares some affinity with the Scot James Maxwell’s seminal 1891 *Treatise on Electricity and Magnetism* (Einstein spent his whole career trying to do for gravity and electromagnetism what Maxwell had done with electricity and magnetism. Alas, the unified field theory still evades modern physicists). Early in his career he compared social fields to magnetic fields, in the sense that social forces like institutions warp and bend the space in which social objects would otherwise be free to (re)act independently (e.g., 1969, p. 161); later in his career, perhaps after the metaphor had been stretched too far, he came criticized those who did the same (1988, p. 149).[28] The German Gestalt psychologist Kurt Lewin founded field theory for social psychology, and his Gestalt definition of field as “a totality of coexisting facts which are conceived of as mutually dependent” also had some influence Bourdieu, although it is unclear how much of Lewin’s work draws on Einstein’s whom he credits for inspiration (1951, p. 240).[29] It is clear, in any case, that the philosopher of science Ernst Cassirer influenced both Kurt Lewin, who took a course with Cassirer, and Pierre Bourdieu, with his supplementary work *Einstein’s Theory of Relativity Considered from the Epistemological Standpoint*.[30] In this 1923 work,

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[28] Bourdieu, Pierre. 1969. "Intellectual Field and Creative Project." *Social Science Information* 8:189-219. 1988. Homo Academicus, translated by Peter Collier. Stanford, Calif.: Stanford University Press.

[29] Lewin, Kurt. 1951. *Field Theory in Social Science*, edited by Dorwin Cartwright. New York: Harper & Brothers.

[30] John Levi Martin cites the following in his “What is Field Theory?” (The American Journal of Sociology, Vol. 109, No. 1 (Jul., 2003), pp. 1-49): Kurt Lewin (1949) 1999b, "Cassirer's Philosophy of Science and the Social Sciences." in *The Complete Social Scientist*, edited by Martin Gold. Washington, D.C.: American Psychological Association, pp. 32; and Marrow, Alfred J. 1969. *The Practical Theorist: The Life and Work of Kurt Lewin*. New York: Basic Books, p. 9. See also Cassirer, Ernst. *Einstein’s Theory of Relativity Considered from the*

Cassirer provides a cogent examination of Einstein's worldview that allows simultaneously detailed analysis of real objects in full relational activity as well as a justification for the very form of (social or otherwise) physics. Throughout, it appears the self-reflexive source of field theory in both sociology and psychology in the latter half of the twentieth-century owes its origins to a physicist Albert Einstein and his interpreter Ernst Cassirer.

Not only has sociology been influenced by cybernetics, Philip Mirowski believes the whole of neoclassical economics has as well. In his recent and fascinating *Machine Dreams: Economics Becomes a Cyborg Science*, Mirowski traces the complex and multiple influences of physics, mathematics, and computational sciences in the late nineteenth and early twentieth century on twentieth-century neoclassical economic thought. The very neoclassical concept of market equilibrium, for instance, owes its vocabulary and computational cut to the nineteenth century thermodynamics—equilibrium originally belonging to the balancing of energy as heat sought by physicist and physician Hermann Helmholtz, chemist Ludwig Boltzmann, as well as quantum "minmax" mechanics of John von Neumann whose rudimentary notions found von Neumann architecture in contemporary personal computers. To oversimplify Mirowski's history, it took several scientifically-trained economists like Paul Samuelson and Friedrich von Hayek before the thermodynamic science of balancing heat flows calculations could transfer wholly to the calculated balancing of economic information flows. The calculating abstractions of von Neumann and Morgenstern's cold war game theory, with its dummy players alternating between cooperation and competition strategies, also played a central role in freshly formulating the calculative and complex neoclassical economics as a new computational chimera of the man-machine hybrid—as, in Mirowski's title, a cyborg science. One does not have to agree with

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Epistemological Standpoint, supplement to his 1923 *Substance and Function*, Open Court Publishing Company: Chicago, (1923, reprinted 1953) pp. 351-465.

Mirowkski's conclusions or his critique of neoclassical economics to appreciate the force of the historical argument: the social sciences, in this case economics, inherit their techniques often a decade to a century behind cutting edge of theoretical and natural sciences.

Lastly, among the many popular theories in organizational and management studies in recent generations that share some sort of untapped intellectual affinity and homologous inspirations with earlier advances in the theoretical and natural sciences, Mark Granovetter's theory of embeddedness may deserve one closing moment of attention. Granovetter's famous 1985 article attempts to strike a middle way for theorizing how social relations affect behavior and institutions between the "under-socialized" economic approach and the "over-socialized" sociology. He asserts usefully that human decisions can be understood as neither entirely subject to market forces nor social roles, but instead the nature of human agency is "embedded" in these socio-economic complexes.[31] Granovetter associates his seminal theories with the Karl Polanyi's "'substantivist' school of anthropology," who in his masterpiece of economic sociology *The Great Transformation* first used the term "embedded" to refer to the position the market used to occupy within society. Before the nineteenth century, Polanyi argued, economic life was subject to and embedded within, not the market, but society more generally; whereas, he writes in 19??, economic life then was increasingly beholden only to the market. "Ultimately, that is why the control of the economic system by the market is of overwhelming consequence to the whole organization of society: it means no less than running the society as an adjunct to the market. Instead of the economy being embedded in social relations, social relations are embedded in the economic system."[32] Granovetter's embeddedness seems to stem from this enriched notion of Polanyi's rich economic sociology, with its reliance on thickly described social behavior, not the

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[31] Granovetter, Mark. "Economic Action and Social Structure: the Problem of Embeddedness" *American Journal of Sociology*, Vol. 91, Issue 3 (Nov., 1985), pp. 481-510.

[32] Karl Polanyi, *The Great Transformation: the Political and Economic Origins of Our Time*, 1944, p. 60.

thin factors of economic rationality, profit maximalization, exchange relations. Only Granovetter insight is in reading economic logic themselves as one partial element in the socially embedded economic behavior. Curiously, however, this intellectual history affords a critique of Granovetter. It is not a middle way consistent with Polanyi's use of the term, since Polanyi's asserts the irreparably a-sociological logic of economic thought. This hard divide in Polanyi's work complicated Granovetter's attempt to straddle both camps, and his middle way appears in the end more sociological than economic (the economic logic, according to Polanyi, would be incapable of accepting a compromise with its totalizing logic of value abstraction).

While here the intellectual genealogy is directly not natural or theoretical scientific in origin, the case of Granovetter may serve as a useful reminder of two contradictory tendencies at once: one, that not all intellectual influences sweep from the theoretical to the social sciences, but sometimes the more humanistic social sciences may influence the systematic ones, as in the case of Polanyi's substantivist anthropology influencing Granovetter, and two, that, nonetheless, the verb "embed" derives from eighteenth and nineteenth century sources in geology, biology, optics, and engineering material science. Like the computer term *interface* which sprung from the shared plane between two rocks, "embed" owes its core significance to the physical sciences (OED).

Conclusion

In summary, central to my argument is the contention that this early twentieth-century cluster of natural and theoretical sciences compelled, accompanied, and informed a concomitant mid-century shift in thought about self-reinforcing symbolic systems in the social sciences. A wide range of social scientific theories—ranging from feedback-inspired path dependence to Stark's cybernetic theory of heterarchy, to Gladwell's tipping point, to the cyborg science of neoclassical economics, to Bourdieu's field theory, to Granovetter's embeddedness theory—directly impinge on contemporary understanding of self-reinforcing dynamic systems. Moreover, each of these theories draws deeply from an early thread of theoretical and natural sciences concerned with the quintessential cybernetic metaphor about the self-reinforcing relationship between animal and machine, or more often than not, between man and computer. That early thread of thought—which I explored in the first half of this paper—winds its way through the work of Boole, Russell, and Wittgenstein, through the pragmatist philosophy of C.S. Peirce, Royce, and Wiener into cold war cybernetics. Cold war cybernetics, in turn, served as a kind of intellectual aqueduct for watering many of the social scientific disciplines. In each case, I have attempted to reread constitutive moment as another step toward illuminating the modern understanding of self-reinforcing logics.

As the second act of this paper has demonstrated, core developments in the last few generations of social sciences have built on a century-old cybernetic or computer-compatible legacy of human thought. If nothing else, the trend-spotting reader may take by extension from this history the suggestion that those who wish to understand the interdisciplinary social sciences in a generation or two should begin by studying the cutting-edge of the contemporary interdisciplinary physical and theoretical sciences. A couple of generations ago that project was called cybernetics; in the early twenty-first century, it is probably the convergence of nanotechnology, biotechnology, information technology, and cognitive science in what Jean-Pierre Dupuy calls "the NBIC convergence." As summarized in one of the first reports of the National Science foundation, the movement's credo can read in haiku form:

> If the Cognitive Scientists can think it,
> The Nano people can build it,
> The Bio people can implement it, and
> The IT people can monitor and control it.[33]

Such NBIC people, if we may call them that, are leading the contemporary heir movement to cold war cybernetics on the frontier of fields where only the very small in very large arrangements—bits, atoms, neurons, and genes—rule the future of both the human-computer condition and of the interdisciplinary study of self-reinforcing dynamics. Their work pushes the boundaries of both ethical and scientific research, going where neither human nor nanorobot has gone before.

But this is not all. At stake in the history of ideas is more than intellectual edification, the broadening of horizons, and the opportunity to peer by inference into any of our possible futures—although any of these alone should be enough. At stake in this first act of this paper is a larger claim about the contemporary imagination of organizational dynamics—moreover a claim about the contemporary state of things: that is, the modern relationship between the human and the computer itself is perhaps the key self-reinforcing dynamic worthy of our study. This paper does not answer the question, but it does take one step closer in addressing the pressing question, Why is the human-computer relationship becoming more and more integral to modern life? Is this an inevitable expression of cybernetic path dependence? Our path does not only appear to lead to some future convergence of mechanic-human complexes: as this paper has shown, this path has been in development for a long time. We have already long been cyberneticists.

In some ways, it is no longer possible to ask the fundamental questions about human

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[33] See Jean-Pierre Dupuy's *On the Origisn of Cognitive Science: The Mechanization of the Mind,* MIT, 2009, p. xi.

behavior, organization, and identity—“what do humans do” or “how do humans arrange themselves around action” and “what does it mean to do what humans do” without asking the same of computers. We cannot be modern sociologists, organizational theorists, or humanists any longer without also being willing to acknowledge the fundamental ways in which we are also all computers: Boole taught us the grammar of machines well before there were any to speak it. Russell, Goedel, and Turing advanced thought about that logical grammar until logicians could no longer refute the fallibility of their project: Russell showed arithmetic to be incomplete, Goedel showed that the stubborn truth about all axiomatic systems—that they do not contain all truth; and Turing in turn showed that the computer-mathematician distinction blurs when computers mediate human communication. Perhaps our modern period is so flummoxed with articulating a hard and fast division between humans and computers exactly because the fundamental difference is missing: for the same thing that makes the computer useful today also makes modern humans modern—the art and artifice of self-reinforcing calculation.

Bibliography

Coming soon….