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Review

Overcoming the Newtonian paradigm: The unfinished project of theoretical biology from a Schellingian perspective

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A R T I C L E I N F O

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A B S T R A C T

Defending Robert Rosen's claim that in every confrontation between physics and biology it is physics that has always had to give ground, it is shown that many of the most important advances in mathematics and physics over the last two centuries have followed from Schelling's demand for a new physics that could make the emergence of life intelligible. Consequently, while reductionism prevails in biology, many biophysicists are resolutely anti-reductionist. This history is used to identify and defend a fragmented but progressive tradition of anti-reductionist biomathematics. It is shown that the mathematico–physico–chemical morphology research program, the biosemiotics movement, and the relational biology of Rosen, although they have developed independently of each other, are built on and advance this anti-reductionist tradition of thought. It is suggested that understanding this history and its relationship to the broader history of post-Newtonian science could provide guidance for and justify both the integration of these strands and radically new work in post-reductionist biomathematics.

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1. Introduction

Theoretical biologists are intensifying their efforts to overcome reductionism in order to comprehend the reality of life. While mechanistic accounts of life were vigorously defended at the beginning of the Twentieth Century (Loeb, 1912), reductionism reached its zenith in the third quarter of the Twentieth Century with the synthetic theory of evolution embracing molecular biology, cybernetics and information theory. Evolution was equated with changes in populations of genes, identified with DNA, encoding information on how to produce survival machines to reproduce themselves. Biology was reduced to chemistry, which it was assumed would be explained by physics. Those reacting against this reductionism have revived earlier and established new anti-reductionist traditions of thought. The notions of system, complexity and semiotics are central to their work.

However, the concepts developed to overcome reductionism have been appropriated by reductionists to develop a more vigorous form of reductionism. Paul Weiss's and von Bertalanffy's

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notion of system was early on turned against their whole project of overcoming mechanistic thought, although those involved in doing this appear not to have understood what they were doing (von Bertalanffy, 1968, 25; O'Malley and Dupré, 2005; Trewavas, 2006). The notion of complexity, central to anti-reductionist thinking, has fared no better. It is clear from Warren Weaver's lecture given in 1947 in which the challenge of explaining complex organized systems was first posed, that Weaver saw this as a challenge for reductionist science, not a challenge to overcome reductionism (Weaver, 1948). Most complexity theorists have focused on and studied the order generated by the interaction between very large numbers of entities. This, when taken by itself, has been recognized by some as a further triumph of reductionism. Nonlinear dynamical systems are capable of representing the world as unpredictable and capable of generating macroscopic patterns; but this is at the level of appearance. The dynamics are deterministic effects of components and their interactions and would appear to rule out anything but the appearance of emergence. This is true also of the concepts used in relation to emergent phenomena. As Per Bak, a distinguished member of the Santa Fe Institute pointed out in 1994: '[W]hat is adaptability of a complex system? Since "purpose" and "rationality," and thus "learning" and "adaptability" do not really exist in deterministic dynamical system, the question should really be: which are the features of complex systems that an outside observer might interpret as adaptability?' (Bak, 1994, p. 492; Gare, 2000). While biosemiotics is still resolutely anti-reductionist, efforts have been made to provide a mechanistic explanation of codes and to account for semiosis through informatics based on the purely mechanistic notion of information deriving from Claude Shannon and Weaver. Living organisms, including humans, have been reconceived as information processing cyborgs (Brier, 2008, 22 and 35ff.).

While the resultant augmented reductionism has satisfied most researchers, others have vigorously opposed this conception of life. They had good reasons for this. Reductionism implies that science itself and the quest to comprehend nature and life are impossible. Despite efforts of reductionists to naturalize epistemology, understood reductionistically, cyborgs cannot comprehend anything. Reductionism is incoherent. For an account of the more specific deficiencies and manifest failures of the reductionist assumption, see for example Kauffman (2009). The bias towards reductionism has led anti-reductionists to investigate deeper assumptions that have continually channeled working scientists back to and reinforced their reductionism, despite its radical incoherence and its pernicious influence on the broader culture (where it has underlain a revived Social Darwinism and a form of managerialism that exacerbates and even engenders so many problems that they now have a name: 'wicked problems' (Rittel and Weber, 1973). We are scarcely advanced from the crisis in science and civilization described by René Thom in 1975 where science based technology had engendered a global ecological crisis while beneath triumphant proclamations celebrating scientific progress, there was a 'manifest stagnation of scientific thought vis-à-vis the central problems affecting our knowledge of reality.' The underlying reason for this stagnation, Thom argued, was that 'science [had sunk] into a futile hope of exhaustively describing reality, while forbidding itself to "understand" it' (Aubin, 2004, 95).

Confronting the failure to overcome this situation, anti-reductionists have re-examined the Seventeenth Century Cartesian and Newtonian reconception of the very idea of inquiry and explanation and the influence of this on the subsequent history of science, a reconception that now so permeates culture that it is usually assumed without question that only reductionist explanations have any scientific validity. Exemplifying this interrogation of embedded assumptions, Stuart Kauffman observed:

> We have lived with a world view dominated by reductionism. Yet recently, S. Hawking has written an article entitled "Gödel and the End of Physics." His observations raise the possibility that we should question our foundations. Core to this is reductionism itself. In turn reductionism finds its roots in Aristotle's model of scientific explanation as deductive inference. All men are mortal. Socrates is a man. Therefore, Socrates is mortal. With Newton's laws in differential form, reductionism snaps into place, for given initial and boundary conditions, integration of those equations is exactly deduction. Aristotle's 'efficient cause' becomes mathematized as deduction (Kauffman, 2009, 1.).

In a more recent paper, 'Answering Descartes: Beyond Turing', Kauffman again pointed to and questioned the pervasive reductionist assumptions which he claimed are now crippling efforts to characterize the mind. He noted that 'Two lines of thought, one stemming from Turing himself, the other from none other than Bertrand Russell, have led to the dominant view that the human mind arises as some kind of vast network of logical gates, or classical physics "consciousness neurons"' (Kauffman, 2012, 1). On this view, the mind-brain system is nothing but 'a network of classical physics neurons, with continuous variables, and continuous time, interacting in classical physics causal ways via action potentials, vast networks with classical physics inputs and outputs' (Kauffman, 2012, 3).

However, a more thoroughgoing examination of reductionist assumptions bequeathed by the Seventeenth Century scientific revolution had already been undertaken by the mathematician and theoretical biologist, Robert Rosen. Rosen observed:

> [T]he central concept of Newtonian mechanics, from which all others flow as corollaries or collaterals, is the concept of state, and with it, the effective introduction of recursion as the basic underpinning of science itself. … Thus, in my view, the *Principia* ultimately mandated thereby the most profound changes in the concept of Natural Law itself; in some ways a sharpening but in deeper ways, by imposing the most severe restrictions and limitations upon it (Rosen, 1991, 89f.)

The concept of an atom did not emerge from any analysis offered by Newton; rather, he simply presupposed particles without structure and devoted himself entirely to synthesis, asking what behavior can be manifested by such particles, individually or collectively. The formalism based on this procedure assumes that that almost everything of importance is unentailed. There is no place for final causes. Why? questions are ruled out. The only entailment is a recursive rule governing state succession. Causation is collapsed down to what can be encoded in a state transition sequence, as this is all the Newtonian language allows to be decoded back into causal language. Further strictures follow from the assumption that the universe is composed of structureless particles, that every system has a largest model from which every other model can be effectively abstracted by purely formal means, and 'this largest model is of an essentially syntactic nature, in that structureless, unanalyzable elements (the particles) are pushed around by mandated rules of entailment that are themselves beyond the reach of entailment' (Rosen, 1991, 103).[1] On the basis of this analysis of Newtonian science, Rosen defined a natural system as mechanical if it has a largest model, consisting of a set of states, and a recursion rule entailing subsequent states from the present states, and every other state of it can be deduced from the largest one by formal means. On this basis, Rosen argued that the idea that

1 It is important to note that field theory, which Rosen does not discuss, broke with this way of thinking in the Nineteenth Century.