

APPROACHES TO THE QUESTION ‘WHAT IS LIFE?’: RECONCILING THEORETICAL BIOLOGY WITH PHILOSOPHICAL BIOLOGY

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ABSTRACT: Philosophical biologists have attempted to define the distinction between life and non-life to more adequately define what it is to be human. They are reacting against idealism, but idealism is their point of departure, and they have embraced the reaction by idealists against the mechanistic notion of humans developed by the scientific materialists. Theoretical biologists also have attempted to develop a more adequate conception of life, but their point of departure has been within science itself. In their case, it has involved efforts to overcome the reductionism of scientific materialism to develop a form of science able to identify and explain the distinctive characteristics of living beings. So, while both philosophical biologists and theoretical biologists are struggling to overcome scientific materialism, they are approaching the question: What is Life? from different directions. Focussing on the work of Robert Rosen, I will try to show what revisions in our understanding of science theoretical biologists need to accept in order to do justice to the insights of the philosophical biologists. I will suggest that not only will this involve major revisions in what we understand science to be, but that scientists must accept that science is indissociable from natural philosophy, and that to properly comprehend life mathematics must ultimately be subordinated to stories.

KEYWORDS: Philosophical Biology, Theoretical Biology, Life, Biosemiotics, Process Philosophy, Robert Rosen, Hans Jonas, Jacob von Uexküll, Max Delbrück, C.H. Waddington, F.W.J. Schelling, C.S. Peirce.

INTRODUCTION

In the foreword to his influential work *The Phenomenon of Life*, Hans Jonas wrote:

[T]he following investigations seek to break through the anthropocentric confines of idealist and existentialist philosophy as well as through the materialist confines of natural sciences. ... The great contradictions in which man discovers in himself – freedom and necessity, autonomy and dependence, self and world, relation and isolation, creativity and morality – have their rudimentary traces in even the most primitive forms of life, each precariously balanced between being and not-being, and each already endowed with an internal horizon of “transcendence.” We shall pursue this underlying theme of all life in its development through the ascending order of organic powers and functions: metabolism, moving and desiring, sensing and perceiving, imagination, art, and mind – a progressive scale of freedom

and peril, culminating in man, who may understand his uniqueness anew when he no longer sees himself in metaphysical isolation.¹

In Chapter One of his influential work *Mind from Matter?*,² Max Delbrück, after quoting a diary entry from Søren Kierkegaard ridiculing the idea that scientists could see how consciousness came into existence by staring through a microscope, wrote:

In this essay I propose, and propose seriously, to do that ridiculous thing, “look through the microscope,” to try to understand how consciousness or, more generally, how mind came into existence. And with mind, how language, the notion of truth, logic, mathematics, and the sciences came into the world. Ridiculous or not, to look at the evolutionary origins of mind is no longer an idle speculation.²

Both Jonas and Delbrück were concerned to reject Cartesian dualism. They both opposed a conception of physical existence that makes mind unintelligible, and struggled to develop a conception of life which could make intelligible human life and mind. Although they emphasised different features of human existence, with Jonas focussing on emotion and freedom and Delbrück on the development of rational thought, they were both concerned to trace the development of life from its most elementary to its most complex forms. They covered much the same ground.

However, their points of departure were quite different. Jonas, a student of Martin Heidegger, began with efforts by hermeneutic phenomenologists to characterize human existence and then looked for the first glimmerings of such characteristics in nature. His work is grounded in the humanities. Delbrück, originally a quantum physicist, began with the evolution of the cosmos and recent developments in physics, biology and psychology to show how human capacities emerged from the physical world. His work is grounded in the sciences. Jonas is a foremost representative of a tradition of philosophical biology and Delbrück is a foremost representative of a tradition of theoretical biology. In this paper I will look at how these traditions have converged to supplement the insights of each other.

Each of these traditions has its strengths and weaknesses. The strength of the tradition of philosophical biology is that it draws on a long tradition of thought on the nature of human consciousness and experience, revealing dimensions of existence beyond the comprehension of mainstream science. The strength of the tradition of theoretical biology is that it utilizes the tradition of scientific inquiry into physical, biological and cognitive processes characterized by more rigorous conceptualization and testing of ideas, enabling humans to be comprehended in the much broader context of modern cosmology. The problem then is to reconcile these two traditions. I will argue that to fully integrate these traditions it is necessary to draw on the tradition of natural philosophy going back to the work of Herder, Goethe and Schelling. This

1. Hans Jonas, *The Phenomenon of Life: Towards a Philosophical Biology*, Chicago and London: University of Chicago Press, 1966, p.ix.

2. Max Delbrück, *Mind from Matter?*, Oxford: Blackwell, 1986, p.21.

was a tradition concerned to characterize the nature of physical existence to undercut the opposition between idealism and realism, spiritualism and materialism. It is the tradition of process metaphysics and includes Charles Sanders Peirce, Henri Bergson, Alfred North Whitehead and Ludwig von Bertalanffy. I will argue that it is through this metaphysics that it becomes possible to fully appreciate the advances in the sciences of the theoretical biologists while making sense of the insights of the philosophical biologists. In this way it provides the basis for overcoming the opposition between the sciences and the humanities and thereby to appreciate what it means to be free conscious agents as part of and creative participants within a dynamic, creative nature.

THE TRADITION OF PHILOSOPHICAL BIOLOGY

Modern philosophical biology emerged under the influence of Edmund Husserl and phenomenology, with deeper influences going back to Kant, and beyond Kant to Aristotle. To understand philosophical biology fully it is necessary to understand it in relation to Husserl's phenomenology. Husserl had set out to develop a presuppositionless science of experience, a science more primordial than the natural sciences since every other science could be mapped as only one of a number of domains of experience. While Husserl inspired a revolution in philosophy, many of Husserl's disciples became disaffected as he developed his philosophy in a more idealist direction. Husserl claimed that it was possible to bracket out all assumptions of existence and then examine how experiences acquired the accent of reality. The turn to philosophical anthropology and philosophical biology was a way of rejecting this idealist turn. However, those who took this turn maintained their appreciation of Husserl's achievements. They also took over his critical attitude towards the development of mathematical physics, and embraced ideas from neo-Kantianism and hermeneutics that Husserl had assimilated to his phenomenology and the Aristotelianism that Husserl had taken over from Franz Brentano. Going further than Husserl in this regard they revived Aristotle's biological notions, taking over Aristotle's distinction between and characterization of the vegetative, the animal, and the human 'psyche'. They retained Husserl's project of investigating experience and the insights gained from this, however, and insisted on recognizing a central place of experience, particularly the complex structure of temporal experience and the experience of embodiment, in at least some of the components of nature.

Philosophical biology was developed to provide a foundation for philosophical anthropology, the effort to answer the Kantian question 'What is Man?'. Max Scheler's book *Man's Place in Nature* exemplified this. To develop his conception of humans Scheler began with plants, characterizing them as the 'vegetative' aspect of life. While acknowledging their lack consciousness and sensation, his concern was to characterize plants as having proto-experience from which higher forms of experience could develop. He wrote of the plant, 'its existence fulfils itself in nourishment and growth, in reproduction and death, without any specific life-span for the species. Yet we find in the plant the

original phenomenon of *expressiveness*.³ He continued: ‘The rich variety of forms in the leafy parts of plants suggests, even more impressively than the forms and colours in animals, that the principle at the unknown roots of life may act in accordance with fanciful play, regulated by an aesthetic order.’⁴ He went on to argue that the ‘first stage of inner life’ is ‘present in all animals and also in man.’⁵ This vital feeling underlies ‘that primary experience of *resistance* which is the root of experiencing what is called “reality”’ which, claimed Scheler, is the origin of consciousness.⁶ This then provided Scheler with the basis for defining humanity.

A major source of ideas for these early philosophical biologists was Jacob von Uexküll. Influenced by both Kant and Husserl, von Uexküll argued that to understand animals it is necessary to appreciate their surrounding worlds (their *Umwelten*), that is, what in their environment has meaning for them.⁷ Husserl’s collaborator, Heidegger, influenced by von Uexküll, used his conception of organisms as inseparable from their worlds to develop his conception of human existence as temporally structured Being-in-the-World, claiming that ‘the stone is worldless, the animal is poor in world, man is world-forming.’⁸

Although from a different perspective, F.J.J. Buytendijk and Helmuth Plessner also rejected the imposition of traditional Cartesian assumptions onto the experience of living beings, arguing:

The body and its forms of movement, different for each biological species, form a unity of which one can neither say that it is physical nor that it is mental. It lies on neither of these two planes of reality, but is not therefore less real. ... The forms of (animal) movement are forms of behaviour, since they carry visibly in themselves and ‘delineate’ the relation of the body to the environment and conversely of the environment to the body.⁹

Building on his early work with Buytendijk, Plessner went on to characterize life as ‘taking a position in relation to the world,’ rather than being simply an effect of it. He then characterized humans in terms of their eccentric positionality, embodied beings who do not completely coincide with their embodied existence.¹⁰

The French phenomenologist Maurice Merleau-Ponty drew on the work of Scheler, Heidegger and Buytendijk to develop his concept of life. He observed that:

We speak of vital structures ... when equilibrium is obtained, not with respect to

3. Max Scheler, *Man’s Place in Nature* [1928], trans. Hans Meyerhoff, N.Y.: Noonday Press, 1968, p.12.

4. Scheler, *Man’s Place in Nature*, p.13.

5. Scheler, *Man’s Place in Nature*, p.13.

6. Scheler, *Man’s Place in Nature*, p.14.

7. See Jacob von Uexküll, *Theoretical Biology*, trans. D.L. MacKinnon, London: Kegan Paul, Trench, Trubner & Co. Ltd, 1926. On von Uexküll’s Husserlian background, see Han-liang Chang, ‘Semiotician or hermeneutician? Jacob von von Uexküll revisited’ *Sign System Studies* 32.1/2, (2004): 115-138.

8. Martin Heidegger, *The Fundamental Concepts of Metaphysics: World, Finitude, Solitude*, trans. William McNeill and Nicholas Walker, Bloomington: Indiana University Press, 1995, p.185.

9. F.J.J. Buytendijk and H. Plessner, “Die Deutung des mimischen Ausdrucks,” *Philosophischer Anzeiger*, Bern: Francke Verlag, 1925, p.83, trans. and cited by Grene, *Approaches to a Philosophical Biology*, p.124.

10. Grene, *Approaches to Philosophical Biology*, p.75ff.

real and present conditions, but with respect to conditions which are only virtual and which the system itself bring into existence; when the structure, instead of procuring a release from the forces with which it is penetrated through the pressure of external ones, executes a work beyond its proper limits and constitutes a proper milieu for itself.¹¹

This provided a starting point to develop a conception of humans as historically situated, incarnate consciousnesses ‘being-to-the-world’.

It was against the background of such work that Jonas sought to promote and advance philosophical biology, reviving Aristotelian thought, advancing this through the insights of phenomenology to oppose Cartesian thought. The language of mathematical physics fails when confronted with the sentience of one of the most elementary forms of life, the amoeba, he argued:

[T]he amoeba is part of the universe and must be accountable by it for its creative principle. Its minuteness is no disability in ontological relevance. Its intrinsic evidence, as one creation, forms part of the general evidence and must be heard all the more as in this instance “intrinsic” has a fuller meaning than applies to any other class of cosmic beings: it includes the fact of its own, felt inwardness.¹²

Life, he claimed, is characterized by three basic features. First, it is a metabolism with a double aspect, ‘denoting on the side of freedom, a capacity ... to change its matter, ... [while] equally the irremissible necessity for it to do so.’ Second, it must attain this matter from outside itself. It must thereby be ‘turned outward and toward the world in a peculiar relatedness of dependence and possibility’ thereby referring ‘beyond its given material composition to foreign matter as needed and potentially its own.’ Third, ‘there is an inwardness or subjectivity involved in [this] transcendence, imbuing all the encounters occasioned in its horizon with the quality of felt selfhood, however faint its voice.’¹³

Philosophical biology waned along with the influence of phenomenology.¹⁴ However, their program of research was continued by ethologists. Konrad Lorenz and W.H. Thorpe both attempted to characterize the worlds of different organisms, from the most primitive organisms to humans.¹⁵ Such work has continued up to the present.¹⁶ This work has been further advanced by biosemioticians and biohermeneuticists, both strongly influenced by the work of von Uexküll.¹⁷ Thomas Sebeok, Jesper Hoffmeyer

11. Maurice Merleau-Ponty, *The Structure of Behaviour*, [1942] trans. Alden L. Fisher, Boston: Beacon Press, 1963, p.145f..

12. Jonas, *The Phenomenon of Life*, p.65.

13. Jonas, *The Phenomenon of Life*, p.83f.

14. Marjorie Grene in a recent book on the history of the philosophy of biology discussed none of the thinkers she looked at in *Approaches to Philosophical Biology*. See Marjorie Grene and David Depew, *The Philosophy of Biology: An Episodic History*, Cambridge: Cambridge University Press, 2004.

15. See Konrad Lorenz, *Behind the Mirror: The Search for a Natural History of Human Knowledge*, trans. Ronald Taylor, London: Methuan, 1973; W.H. Thorpe, *Animal Nature and Human Nature*, London: Methuan, 1974.

16. See for instance Marc Berkoff, *Minding Animals: Awareness, Emotions, and Heart*, Oxford: Oxford University Press, 2003.

17. See Kalevi Kull and Toomas Tiivel (eds), *Lectures in Theoretical Biology 2*, Talinin: Estonias Academy

and Kalevi Kull among others have reformulated such work through the semiotics of C.S. Peirce, whose work was also devoted to transcending Cartesian dualism.¹⁸ Kull, following Martin Krampen, extended Uexküll's notion of *Umwelt* to plants. More recently, Sergey Chebanov, Anton Markoš and Gunther Witzany have developed hermeneutic characterizations of life.¹⁹ Markoš summed up the deep conviction underlying this whole tradition of philosophical biology when he wrote in conclusion to his book *Readers of the Book of Life*:

I strongly believe that an organism cannot be defined solely in terms of thermodynamics, biochemical, and information magnitudes. If we want to understand the difference between living beings and machines (however complicated), then meaning (i.e. an internal interpretation of the situation, not forced on us from outside) should become the central focus of our interest. It is here that, in my opinion, the border between the living and the non-living, lies.²⁰

THE TRADITION OF THEORETICAL BIOLOGY

Delbrück began his career as a theoretical physicist engaged in developing quantum theory before turning to biology. He did so under the influence of Niels Bohr. Bohr, whose father was a biologist, was deeply interested in biological problems, and like other figures involved in the early development of quantum theory, expected that having penetrated the innermost secrets of matter the 'secrets of life' would tumble forth as corollaries of this work.²¹ In a lectures 'Light and Life' first published in 1932, and 'Biology and Atomic Physics' first published in 1937 Bohr outlined the philosophical implications for the life sciences of the changes brought to the notion of natural law by quantum theory.²² Bohr had provided an interpretation of quantum theory that allowed different theoretical frameworks to function as complementary. Having allowed complementary theories in physics, he argued that it is necessary to give a place to a diversity of theoretical frameworks in grasping reality. In particular, he argued that biology should not be treated through the theoretical frameworks developed within physics but should give a place to theoretical frameworks appropriate to grasping the characteristics of life. Just as Scheler's work stimulated a number of philosophers, biologists and psychologists to

of Sciences, 1993, and Marcello Barbieri, *Introduction to Biosemiotics: The New Biological Synthesis*, Dordrecht: Springer, 2007.

18. See Jesper Hoffmeyer, *Signs of Meaning in the Universe*, trans. Barbara J. Haveland, Bloomington: Indiana University Press, 1996. See also the special edition of *Semiotica* devoted to Jacob von Uexküll, 134 (1), (2001).

19. See Sergey V. Chebanov, 'Biology and humanitarian culture: the problem of interpretation in biohermeneutics and in the hermeneutics of biology' in Kull and Tiivel (eds), *Lectures in Theoretical Biology*, pp.219-248; Anton Markoš, *Readers of the Book of Life*, Oxford: Oxford University Press, 2002; and Günther Witzany, *Life: The Communicative Structure: A New Philosophy of Biology*, trans. Michael Stachowitsch, Books on Demand GmbH, 2000.

20. Markoš, *Readers of the Book of Life*, p.221.

21. See Robert Rosen, *Essays on Life Itself*, New York: Columbia University Press, 2000, p.8f.

22. Niels Bohr, *Atomic Physics and Human Knowledge*, New York: John Wiley, 1958, pp.1-12 & 13-22.

grapple with the question What is life?, Bohr's work inspired a number of physicists associated with the development of quantum theory to turn their attention to biology and attempt to understand what is unique about life. After Delbrück's first work on biology, Erwin Schrödinger gave his famous lectures *What is Life?* and *Mind and Matter*.²³ Other quantum physicists who have turned to biology and grappled with the question What is life? include John von Neumann, Wolfgang Pauli, Nicolas Rashevsky, David Bohm, Walter Elsasser,²⁴ and Howard Pattee.²⁵

Not all theoretical biologists began as physicists, but in biology theoreticians have had to struggle to be heard. While research in biology is theoretically informed, apart from those opposing orthodox assumptions, usually theory is presupposed rather than being consciously recognized as theory. Orthodox biology is dominated by the synthetic theory of evolution according to which existing forms of life are the outcome of replication, variations in this replication, and selection of some variants over others, and biochemical or 'molecular biological' explanations of replication, generation of form, metabolism, defence, repair and movement. Selection is either taken for granted or seen as the outcome of a competitive struggle for survival and the conditions for reproduction. That is, biology has been dominated by ontological reductionism that is more committed to explaining away life as an effect of physical processes rather than grappling with the question 'What is life?' There was opposition to this reductionism, but prior to the twentieth century theorising on this issue was far less rigorous than theorising in physics.²⁶ Apart from dialectical materialists, almost all opponents of reductionism were vitalists, simply positing a vital force rather than making this force intelligible. It was the huge advances in physics that inspired biologists to challenge these reductionist assumptions and to attempt to develop biology on philosophical foundations which would do justice to life's uniqueness, and thereby give a place to mind in nature.

In Britain, the theoretical biology movement which began in the early nineteen thirties was also inspired by developments in physics, along with the philosophy of Alfred North Whitehead and D'Arcy Thompson's work on the development of biological form.²⁷ The main interest of this movement was in epigenesis, the differentiation of cells and the generation of form. Both C.H. Waddington and Joseph Needham, leading figures in this movement, wrote books attempting to characterize life,²⁸ and this was a major

23. Erwin Schrödinger, *What is Life?* [1944] and *Mind and Matter* [1958], Cambridge: Cambridge University Press, 1967.

24. See Walter M. Elsasser, *Reflections on a Theory of Organisms: Holism in Biology*, Baltimore: John Hopkins, 1987 and 1998.

25. See Howard Pattee, 'Physical Basis and Origin of Hierarchical Control', *Hierarchy Theory: The Challenge of Complex Systems*, ed. Howard H. Pattee, New York: George Braziller, 1973, pp.73-108.

26. Kalevi Kull traces theoretical biology back to Karl Ernst von Baer (1792-1876). See his introduction to *Lectures in Theoretical Biology*, Kalevi Kull and Toomas Tiivel (eds.), Tallinn: Valgus, 1988. These lectures describe the evolution of theoretical biology in Estonia, Russia and Germany as well as Britain.

27. See Prina G. Abir-Am, 'The Biotheoretical Gathering, Trans-Disciplinary Authority and the Incipient Legitimation of Molecular Biology in the 1930s', *History of Science*, XXV, (1987), pp.1-70.

28. Joseph Needham, *Order and Life* [1938] Cambridge Mass.: M.I.T. Press, 1968 and C.H. Waddington, *The Nature of Life*, New York: Atheneum, 1962.

theme in the four Serbelloni conferences organized by Waddington and published as four influential volumes *Towards a Theoretical Biology*, which Waddington edited.²⁹ While the research programme of these theoretical biologists was initially formulated as ‘mathematico-physico-chemical morphology’ their successors, the most prominent of whom has been Brian Goodwin, now promote their research as ‘process structuralism’.³⁰ Stuart Kauffman is closely aligned with this tradition while having become one of the major figures in the development of complexity theory. The most radical biologist associated with the process structuralists, Mae-Wan Ho, has made another attempt to characterize the nature of life in her book *The Rainbow and the Worm* developing ideas from the physics of David Bohm and the philosophy of Whitehead.³¹

A parallel tradition of theoretical biology originated in the work of the Austrian American philosopher and biologist Ludwig von Bertalanffy who, beginning in the 1920s, began to develop his general systems theory. This has been the focus of opposition to reductionist biology in USA.³² Further developments of systems theory by Herbert Simon and others, along with the non-linear thermodynamics of Ilya Prigogine and synergetics (the science of structure) of Hermann Haken have been points of departure for the development of complexity theory and further developments in theoretical biology.³³ The Santa Fe Institute, founded to examine complexity in general and complex adaptive systems in particular, has integrated all this work.³⁴ A different approach to complexity has been developed by hierarchy theorists, also influenced by Simon. The foremost hierarchy theorists, Howard Pattee, T.F.H. Allen and Stanley Salthe have developed a more radically anti-reductionist framework of ideas than the members of the Santa Fe Institute, based on their analyses of the partial autonomy and downward causation associated with emergent constraints of systems characterized by different process rates. This has aligned them with European complexity theorists.³⁵

29. C.H. Waddington (ed.), *Towards a Theoretical Biology*, (4 volumes), Edinburgh: Edinburgh University Press, 1968-72.

30. See Brian Goodwin and Peter Saunders (eds), *Theoretical Biology: Epigenetic and Evolutionary Order from Complex Systems*, Edinburgh: Edinburgh University Press, 1989. For a recent statement of Goodwin’s views, see Ricard Solé and Brian Goodwin, *Signs of Life: How Complexity Pervades Biology*, New York: Basic Books, 2000.

31. *The Rainbow and the Worm: The Physics of Organisms*, Singapore: World Scientific, 1993.

32. See Ludwig von Bertalanffy, *General System Theory: Foundations, Development, Application*, rev. ed., New York: George Braziller, 1968.

33. See Howard H. Pattee (ed.), *Hierarchy Theory: The Challenge of Complex Systems*, New York: George Brazillier, 1973. For a short account of synergetics, see Hermann Haken, *The Science of Structure: Synergetics*, trans. Fred Bradley, New York: Van Nostrand Reinhold, 1984 for a short statement of Haken’s research program.

34. An enormous amount of work in theoretical biology has come out recently under the banner of complexity theory, much of it published by the Santa Fe Institute. For an overview of the program of the Santa Fe Institute, see George A. Cowan, David Pines and David Meltzer (eds), *Complexity: Metaphors, Models, and Reality*, Reading: Addison-Wesley, 1994.

35. Apart from works by Pattee, see Stanley N. Salthe, *Evolving Hierarchical Systems*, New York: Columbia University Press, 1985) and Valerie Ahl & T.F.H. Allen, *Hierarchy Theory*, New York: Columbia University Press, 1996. On European complexity theory, see Peter Bøgh Andersen et.al. (eds), *Downward Causation*, Langelandsgade: Aarhus University Press, 2000; and Carlos Gershenson, Diederik Aerts and Bruce Ed-

Robert Rosen, who made one of the most thorough efforts so far to expose the failings of reductionism in biology and to promote the development of complexity theory also aligned himself with von Bertalanffy.³⁶ However, Rosen was more influenced by Nicholas Rashevsky, a physicist turned mathematical biologist who pioneered among other things the development of neural nets. In 1954, after having pioneered neural nets, Rashevsky came to the conclusion that his previous work in biology was fundamentally limited, that explanations of the workings of different aspects of organisms cannot be pasted together to account for the organism as a whole, and that what is needed is, as Rosen put it, ‘a principle that governs the way in which physical phenomena are *organized*, a principle that governs the organization of phenomena, rather than the phenomena themselves.’³⁷ Taking this insight as a point of departure, Rosen wrote of the machine metaphor and the reductionism associated with it: ‘I hope to convince the reader, in the course of the present work, that the machine metaphor is not just a little wrong; it is entirely wrong and must be discarded.’³⁸

Overwhelmingly, theoretical biologists are anti-reductionists. In one way or another they all argue that the whole is more than the sum of its parts, and that it is necessary to overcome the assumptions of traditional science to make sense of life. However, such work is marginal to mainstream biology which has been far more influenced by the reductionism of the molecular biologists and socio-biologists (Francis Crick, James Watson, Jacques Monod, W.D. Hamilton and Richard Dawkins) and those who have modelled cognition on artificial intelligence. As Rosen noted: ‘The question “What is life?” is not often asked in biology, precisely because the machine metaphor already answers it: “Life is a machine.” Indeed, to suggest otherwise is regarded as unscientific and viewed with the greatest hostility as an attempt to take biology back to metaphysics.’³⁹

There are two questions raised by the continued dominance of the machine metaphor. The first is: What is this metaphor? The second is: What should replace it? While there is not yet a final consensus by theoretical biologists on how the second question should be answered, Rosen’s work is particularly important for clarifying the first question, and thereby showing what assumptions have to be overcome.

ROBERT ROSEN: AGAINST REDUCTIONISM

There are two aspects to Rosen’s characterization of the machine metaphor. To begin with, Rosen noted that it presupposes that a system is intrinsically simple or can be analysed into simple components. Such a system is typically defined in terms of a fixed number of degrees of freedom represented as variables in the equations of motion. Once

monts (eds), *Worldviews, Science and Us: Philosophy and Complexity*, New Jersey: World Scientific, 2007.

36. See ‘Autobiographical Reminiscences of Robert Rosen’, *Axiomathes*, 16 (1-2), March, 2006: 1-23.

37. Robert Rosen, *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*, New York: Columbia University Press, 1991, p.113. See also N. Rachevsky, *Topology and life in search of general mathematical principles in biology and sociology*’ *Bulletin of Mathematical Biology*, 16 (1954): 317-348.

38. Rosen, *Life Itself*, p.23.

39. Rosen, *Life Itself*, p.23.

the initial conditions are specified for a given time, that is, the state of the system, integration of the equations of motion enables the state of the system at any other time to be determined. Nature can then be represented mathematically through analytic models which identify independently existing components which can be studied independently of the whole, and the whole then explained through knowledge of these components. This is the resolute-compositive approach to science defended as a general method by Hobbes under the influence of Galileo's physics.

However, Rosen argued that behind this model of explanation are deeper assumptions which have their origins in Pythagorean mathematics. These underlie Newton's mechanics, and Rosen argued that not even quantum theory has abandoned these more basic assumptions. It is these assumptions that Rosen was concerned to reveal, question, and replace. As he put it:

It is my contention that mathematics took a disastrous wrong turn some time in the sixth century B.C. This wrong turn can be expressed as an ongoing attempt, since then, to identify effectiveness with computability. ... From that original mistake, and the attempts to maintain it, have grown a succession of foundation crises in mathematics. ... The impact of that wrong turn, made so long ago, has spread far beyond mathematics. It has entangled itself into our most basic notions of what science is. It might seem a far cry from the ultimately empirical concerns of contemporary science to the remote inner world of mathematics, but at root it is not; they both, in their different ways, rest on processes of measuring things, and on searching for relations ("laws") between what they measure. From this common concern with measurement, concepts pertaining to mathematics have seeped into epistemology, becoming so basic a part of the adjective *scientific* that most people are quite unaware they are even there.⁴⁰

Pythagoras' wrong turn involved, firstly taking mathematical truth 'as the best truth – independent of the mathematician, independent of the external world, unchangeable even by God himself, beyond the scope of miracle in a way that the material world never was.'⁴¹ Secondly, Pythagoras attempted to account for geometrical qualities through a simple recursive procedure of counting (what, Rosen argued, he really meant by claiming that 'all things are numbers', and in which he failed because of with irrational numbers), then to account for the quality of musical harmonies in the same way. This provided a springboard to account for the entire cosmos. The quest for objectivity in mathematics and science by only allowing a simple recursive procedure runs through the whole history of their development. It found expression in Hobbes' claim that all reasoning is merely adding and subtracting.⁴² In mathematics, the full implications of this quest was clarified when it led to Hilbert's formalist programme of dispensing with referents in mathematics and characterizing it as the manipulation of symbols according to formal rules, and to the Church-Turing thesis, that every physically realizable process

40. Robert Rosen, 'The Church-Pythagoras Thesis' in *Essays on Life Itself*, New York: Columbia University Press, 1999, Ch.4, p.63.

41. Rosen, 'The Church-Pythagoras Thesis', p.64.

42. Thomas Hobbes, *Leviathan* [1651], Harmondsworth: Penguin, 1968, Ch.5.

is computable by a Turing machine, an extremely simple device for processing symbols according to a mechanical algorithm which involves moving from one state to another. Effectively, what Hilbert was arguing is that semantics could be completely replaced by formally describable syntactical operations that reduce to instructions on how to proceed from one symbol to another, and Church and Turing conjectured that all such operations could be performed by a simple, recursively functioning machine. Rosen noted the implications of accepting this: 'Once inside such a universe ... we cannot get out again, because all the original external *referents* have presumably been pulled inside with us. The thesis in effect assures us that we never *need* to get outside again, that all referents have indeed been internalised in a purely syntactical form.'⁴³

Rosen's argument is these strictures on what is to count as objective and scientific knowledge were embraced by Newton. This is essentially what Newtonian mechanics amounts to, and this is what underlies and defines almost all subsequent science. As he put it:

[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.⁴⁴

Newton did not analyse the world into atoms, as had the ancient atomists, but simply took over their conclusions and presupposed atomism. He began with structureless particles and then devoted his work entirely to synthesis, asking what behaviour can be manifested by such particles, individually or collectively. This procedure has remained unchanged in modern physics. A feature of the formalism he developed is that almost everything of importance in it is unentailed. The only entailment is a recursive rule governing state succession. In the world seen through this kind of model, 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. There are further strictures in this procedure associated with the assumption that the universe is composed of structureless particles. 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.'⁴⁵ On the basis of this analysis of Newtonian science, Rosen defined a natural system as mechanical if it possesses the following properties: '(1) it has a largest model, consisting of a set of states, and a recursion rule entailing subsequent state from present state; and (2) every other state of it can be obtained from the largest one by formal means.' Natural law, as it came to be redefined on the basis of

43. Rosen, 'The Church-Pythagoras Thesis', p.77.

44. Rosen, *Life Itself*, p.89f.

45. Rosen, *Life Itself*, p.103.

these assumptions by Newton and as it is still understood ‘boils down to the assertion that *every natural system is a mechanism*.⁴⁶

Rosen argued that this whole approach to achieving objective knowledge was undermined when Gödel refuted Hilbert’s formalist account of mathematics and showed that Number Theory is not a closable, finite system of inferential entailment. It cannot be freed of all referents and remain mathematics. More generally, whatever is modelled by a formal system in which all entailment is syntactic entailment, is different from, richer and more complex than its formal model. It is impossible to reduce quality to quantity, or equivalently, semantics to syntax. Rosen then pointed out the implications of this for science. Having identified the deep assumptions of modern science, Rosen argued that not only is its mathematical ‘rigor’ and commitment to ‘objectivity’ and ‘context independence’ illusory, but because of its assumptions none of the present scientific formalisms are adequate to reality.⁴⁷ Science based on these assumptions has produced not only a too limited universe of discourse to characterize life, but a surrogate universe of discourse inadequate to understand the material world.⁴⁸ Far more can be learned about the material world through a careful study of biology than can ever be learned from physics, he argued.

To open the path to a more adequate biology, Rosen examined entailment, modelling and measurement. While entailment between propositions is relatively straightforward, the more problematic question is, Can we ascribe entailment between phenomena? Semantic language, Rosen noted, ‘by its very nature imputes hordes of entailments to the ambience, without going dramatically astray.’⁴⁹ In arguing this, Rosen was supporting Aristotle’s criticisms of Pythagoras for failing to give a proper place to causation, and he supported Aristotle’s claim that it is necessary to recognize four different forms of causation: material, formal, efficient and final.⁵⁰ That is, it is necessary to allow far richer forms of entailment in nature than Newtonian physics had allowed.

Modelling, which Rosen took to be the essence of science, is bringing entailment patterns between a model and that which is modelled into congruence. Rosen used his own version of category theory to analyse what is involved in modelling. As Rosen noted:

Category Theory comprises ... the general theory of formal modelling, the comparison of different modes of inferential or entailment structures. Moreover, it is a stratified or hierarchical structure without limit. The lowest level, which is familiarly understood by Category Theory, is ... a comparison of different kinds of entailment in different formalisms. The next level is, roughly, the comparison of comparisons. The next level is the comparison of these, and so on.⁵¹

46. Rosen, *Life Itself*, p.103.

47. Rosen, ‘The Church-Pythagoras Thesis’, p.63.

48. On this see Robert Rosen, ‘On the Limitations of Scientific Knowledge’, *Boundaries and Barriers: On the Limits of Scientific Knowledge*, John Casti and Anders Karlqvist (eds), Reading, Mass.: Addison Wesley, 1996, Ch.8.

49. Rosen, *Life Itself*, p.56.

50. Rosen, ‘The Church-Pythagoras Thesis’, p.67 and *Life Itself*, p.48.

51. Rosen, *Life Itself*, p.54.

To relate what is to be modelled to a model is a matter of encoding, while relating the model to what is modelled is decoding. Encoding, involving measurement, is a form of abstraction, an act of replacing the thing measured by a limited set of numbers, while decoding, is an inverse measurement, a 'de-abstraction' going from propositions to events.⁵² These procedures are inseparable from recognition, discrimination and classification and cannot be formalized. Encoding and decoding is an art, and this is true of all modelling. If modelling is successful, then what is modelled is a realization of the model. While normally we regard a formal system as a model of a natural system, it is possible to regard the natural system as a model of the formal system, and to regard natural systems as models of each other. This is a relationship of analogy. Rosen argued that the mathematical machinery currently regarded as the only way to carry out this process is far too narrow. What it allows us to capture about the world around us, necessarily misses most of what is really going on, and most importantly, misses out on life.⁵³

To develop science adequate to life, Rosen showed how, by rejecting assumptions of traditional science, it becomes possible to give a place to functions and final causes and to ask Why? questions as well as How? questions. Essentially, he refurbished and defended an Aristotelian form of science giving a place to all the four causes, including final cause. While in mechanisms, such causes can be examined in abstraction from each other, in life the four causes are so intertwined that they cannot be treated in this way. Rosen showed how to represent systems through synthetic models in which functional components are the direct products of the system. In such models the components are context dependent and cannot be reduced to parts without being destroyed. These are able to represent systems in which functional organization cuts across physical structures and physical structures are simultaneously involved in a variety of functional activities. These are modelled mathematically by sets in which addition of sets does not equate to the addition of the members of sets. That is, in place of a science that focuses on identifying independent material parts and showing how they operate, but which then obliterates any appreciation of the organization of the whole, Rosen developed a science of organization in which organization could be treated independently of its material instantiation. It focussed on 'life itself' rather than the mechanisms utilized by life.

While Rosen characterized his work as a contribution to complexity theory, it is important to appreciate that Rosen's notion of complexity was far more radical than that of most people who have embraced this term. For Rosen the use of genetic algorithms, Boolean networks, cellular automata, artificial neural networks and related approaches are merely implementations of the Newtonian paradigm made possible by modern computers. This for Rosen is merely complication, not complexity. Rosen defined a complex system as a system that requires multiple formal descriptions, which are not derivable from each other, to adequately capture all its properties. That is, there is no ultimate model of a complex system from which the other models, which can be for-

52. Rosen, *Life Itself*, p.60.

53. See Rosen, *Essays on Life Itself*, p.324.

mally identified and abstracted from the system, can be deduced. Rosen had developed a ‘metabolism-repair’ model of life which illustrates this.⁵⁴ This model consists of three algebraic maps, one of which represents the efficient cause of metabolism in a cell, another, the efficient cause of repair (the process that repairs damage to the metabolic process from environmental insult), and the third representing replication which repairs damage to the repair process. Stephen Kercel explicated this:

These three maps in the (M,R)-system each have a peculiar property. Each map has one of the other two as a member of its co-domain, and is itself a member of the co-domain of the remaining map. Thus, the metabolism map is a member of the co-domain of the repair map, and the repair map is a member of the co-domain of the replication map... As can be seen, the three maps form a loop, but not just any loop. Note that the map does not merely entail the result; more resticively, it *contains* it. The maps form a loop of mutual containment.⁵⁵

In this way a system is modelled which is ‘closed to efficient causation’, that is, which generates its own components and is an immanent cause of itself so that an explanation of the component can only be answered in terms of the system. Or, as Rosen put it: ‘a material system is an organism if, and only if, it is closed to efficient causation. That is, if f is any component of such a system, the question “why f ” has an answer within the system, which corresponds to the category of efficient cause of f .”⁵⁶ On the basis of such models it is possible to appreciate the ability of complex systems to incorporate a model of their environment into their behaviour, anticipating future events and correcting their behaviour as new information sheds light on the anticipatory process.⁵⁷ Such models cannot be simulated by a computer.

While Rosen’s ideas are only beginning to have an impact on theoretical biology, his work supports most efforts in this field to overcome reductionism and do justice to life. In particular, he has pointed out the relevance of his work for the study of protein folding and morphogenesis, which have always been deeply troubling to physicists.⁵⁸ As Kepler and Newton freed science from the assumption of earlier astronomers that all planetary motion is in circles, Rosen has freed science, and biology in particular, from assumptions about mathematical modelling which effectively made life itself unintelligible. Just as Kepler and Newton enabled us to see that circular motion is only one kind of regular motion approximated in rare cases, we can now see that the kind of order revealed by scientists working within the constraints of Newtonian assumptions is a very limited range of possible order approximated in rare cases, for instance in the solar system or in experimental situations where conditions are carefully controlled.

54. R. Rosen, ‘Some Relational Models: The Metabolism-Repair Systems’, in *Foundations of Mathematical Biology*, R. Rosen (ed.), New York: Academic Press, 1972, Vol.2, pp.217-253.

55. See Stephen W. Kercel, ‘Entailment of Ambiguity’, *Chemistry & Biodiversity*, 4 (2007): 2369-2385, p.2370.

56. Rosen, *Life Itself*, p.244.

57. Rosen, *Essays on Life Itself*, p.199.

58. Rosen has examined the implications of his work for other developments in biology in the last chapter of *Life Itself*, ‘Relational Biology and Biology’.

And as we no longer assume circular motion and motion as deviations from this, we no longer need to treat closed systems consisting of independent parts as a reference point for scientific explanation. As Rosen noted, ‘in physics, the closed system is still taken as primary, and opening the system is regarded as some kind of perturbation.’⁵⁹ But, as he pointed out, a closed system is, in dynamical terms, so extremely non-generic that there is not much which can be said in general along this line. It is much more reasonable to regard the closed system as an extremely degenerate case of open systems. For providing the basis for such a radical reorientation of science Rosen has been called with some justification by one of his expositors, Donald Mikulecky, ‘biology’s Newton.’⁶⁰

However, Rosen was doing more than this. He aligned himself with and contributed to the development of ‘endophysics’, the view that scientists must see themselves as part of the world they are striving to understand.⁶¹ At the same time Rosen appreciated that this world is autonomous, characterized by immanent causation by which life has been fabricated.⁶² And as Mikulecky noted, he was also rejecting the assumption of mainstream science that there is ‘an “objective” real world outside ourselves that we have access to without any ‘contamination’ from our mental processes.’⁶³ We can achieve objective knowledge, but this cannot be counterposed to the subjective, but must include the subjective.⁶⁴ Rosen noted in concluding *Life Itself* that:

As Einstein kept insisting, science involves a free creative act of their intellect; ultimately, it involves wisdom. It involves the ability to select what is important about a problem from what is irrelevant or incidental, and to follow that. There is no algorithm for this, just as there is no algorithm for making a model.⁶⁵

By showing the impossibility of reducing semantics to syntax, Rosen allowed a place not only to life itself but to the creative acts of the intellect and to the wisdom of great thinkers.

Granting a place to creative acts and wisdom does not equate to making these intelligible, however. And while Rosen has made a convincing case that life itself cannot be understood by pasting together our understanding of the components of life, he has not shown how life itself could have come to be. Theoretical biology still needs philosophical biology, and the problem is: How can the insights of the philosophical biologists be integrated with theoretical biology?

59. Robert Rosen, ‘Some epistemological issues in physics and biology,’ *Quantum Implications: Essays in Honour of David Bohm*, J.J. Hiley and F.David Peat, London: Routledge, 1991, pp.314-317, p.316.

60. See Donald C. Mikulecky, ‘Robert Rosen (1934-1998): a snapshot of biology’s Newton,’ *Computers and Chemistry* 25 (2001): 317-327.

61. See George Kampis and Peter Weibel (eds) *Endophysics: The World From Within: A New Approach to the Observer-Problem with Applications in Physics, Biology and Mathematics*, Santa Cruz: Aerial, 1994.

62. Rosen, *Essays on Life Itself*, p.268.

63. Donald C. Mikulecky, ‘Causality and Complexity: The Myth of Objectivity in Science,’ *Chemistry & Biodiversity*, 4 (2007): 2480-2491, p.2489.

64. For Rosen’s views on objectivity, see ‘On the Limitations of Scientific Knowledge,’ *Boundaries and Barriers: On the Limits of Scientific Knowledge*, John Casti and Anders Karlqvist (eds), Reading, Mass.: Addison Wesley, 1996, Ch.8.

65. Rosen, *Life Itself*, p.280.

UNITING PHILOSOPHICAL BIOLOGY AND THEORETICAL BIOLOGY: SCHELLING AND THE TRADITION OF PROCESS PHILOSOPHY

The way I have proceeded so far is to have presented philosophical biology as taking its starting point in the experiencing subject and striving to overcome the idealist tendencies of this by showing how organisms can be seen as experiencing meaning, and then to have presented theoretical biology as taking its starting point in the objective world and striving to overcome the reductionist tendencies of this by showing how it is possible to give a place to life in an objective world. Both the meaning of 'subjective' and 'objective' have been brought into question and transformed in this process. But despite moving towards the same end point, overcoming Cartesian dualism and reviving Aristotelian themes that had been dismissed with the rise of the mechanistic world view, there is still a gap between these two approaches. Recognizing this gap should indicate what needs to be done. It is necessary to recognize a realm more primordial than the division between the subjective and the objective from which these could have emerged. This, essentially, is the path proposed by Friedrich Schelling (1775-1855) although this has seldom been appreciated, as he continues to be classified as an Idealist. In pioneering this path, Schelling, reviving and advancing the evolutionary cosmology of Giordano Bruno and developing the philosophy of nature of Johann Herder and Goethe, began the modern tradition of process philosophy.

Schelling began as an Idealist as a disciple of Fichte. Kant had argued that the free, unified self-conscious transcendental ego (the unified 'I think' which accompanies all perceptions) is a condition for posing questions to nature and performing experiments accordingly, thereby achieving knowledge of the world. Fichte argued that only through mutual recognition between people, whose thought emerges first in relation to action in a world which resists their will, could such self-consciousness be achieved. Schelling accepted this argument but (following Hölderlin) concluded that it had to be taken further. It is also necessary to conceive the ego as part of and within an independently existing nature to make intelligible the possibility of self-consciousness. To show that consciousness as conceived by Fichte could have emerged within nature it was necessary to reject not only the mechanistic world-view but also Kant's solution to the incompatibility of the mechanical view of the world and the assumption of free agency, holding that the mechanical world is mere appearance, the outcome of the organization of the sensory manifold by the productive imagination, the forms of intuition (space and time) and the categories of the understanding. Instead, Schelling argued that our comprehension of human consciousness has to be based on the philosophy of nature, replacing the mechanistic conception of the physical world with a conception of nature as dynamic and creative within which humans as social, self-conscious, creative beings, could have evolved.

To account for the emergence of subjects living in a world of objects Schelling argued that it is necessary to reject both the approach to nature which begins with the subject and then appends objective reality to it, and the approach which begins with the objective world and then appends subjective experience to it. It is necessary to identify a more primordial realm from which subjects and objects could emerge. His procedure was to

subtract from self-consciousness to arrive at the lowest conceivable potential, and then construct the path upward through a successions of limits to show how the conscious self could emerge from this as its highest potential. The lowest potential arrived at was the 'pure subject-object', which Schelling equated with nature, and, he claimed, the 'unconscious' stages through which consciousness emerges can only become conscious to an 'I' which has developed out of them and realizes its dependence upon them. On this basis Schelling conceived nature to be essentially self-constraining or limiting activity, simultaneously 'productivity' (or process) and 'products'. Insofar as nature is productivity, it is subject; insofar as it is product, it is object.

As Schelling conceived it, productivity consists in opposed activities limiting each other. He proclaimed, 'give me a nature made up of opposed activities ... and from that I will bring forth for you the intelligence, with the whole system of its presentations.'⁶⁶ From opposed activities emerge force and matter, space and time, chemicals and non-living and living organisms. Whatever product or form exists is in perpetual process of forming itself. According to Schelling, the process of self-constitution or self-organization, rather than being a marginal phenomenon, must be the primal ground of all reality. Causal 'community' in which a whole maintains itself by reciprocal causation, instead of being treated as a derivative form of causation, as in Kant, was taken as the primary form of causation, with the cause-effect relations of mechanistic thought taken as derivative. Dead matter, in which product prevails over productivity, is a result of the stable balance of forces where products have achieved a state of indifference. Schelling characterized living beings as inherently unbalanced and thereby of necessity actively engaged with their environments. '[L]ife must be thought of as engaged in a constant struggle against the course of nature, or in an endeavour to uphold its identity against the latter' Schelling wrote.⁶⁷ Living beings must respond to changes in their environments creatively to form and reform themselves as products. Schelling argued that higher developments of life are associated with greater imbalances, requiring of organisms greater awareness of the world around them, more active responses to this world and greater levels of creativity. The senses are an essential component of such creative activity. From senses that gave organisms an awareness of their immediate environment, organisms have evolved other senses enabling them to perceive at successively greater distances. This conception of living organisms provides the basis for defining the specific characteristics of humans. With humans we have much more complex forms of semiosis facilitating greater levels of intersubjectivity and reflexivity, the transcendence of egocentric perspectives and the appearance of the world as objective, shared by other subjects (the *mitwelt*). That is, with humanity we have the emergence of culture, and with culture, the development of philosophy, mathematics and science.

While it is generally appreciated that Schelling had a significant influence on the development of hermeneutics and on Heidegger in particular, Schelling's problematic

66. F.W.J. von Schelling, *System of Transcendental Idealism* [1800], trans. Peter Heath Charlottesville: University Press of Virginia, 1978, p. 72.

67. Schelling, *System of Transcendental Idealism*, p.127.

and evolutionary cosmology also inspired directly or indirectly the work of C.S. Peirce, Henri Bergson, Aleksandr Bogdanov, Alfred North Whitehead and Ludwig von Bertalanffy, each of whom has had an influence on the development of philosophical biology or theoretical biology, or both of these.⁶⁸ While philosophical biology and theoretical biology emerged in the early decades of the twentieth century, against the background of the influence of Schelling it is now possible to see them as divergent developments of the anti-mechanistic naturalism of Schelling. It is also possible to see the basis of this divergence. It is easier to develop a conception of the subject that simultaneously gave a place to the objective realm, firstly, by construing the subject as embodied, and secondly, as seeing the objective realm as part of the world of the subject defined in relation to it, than it is to develop a conception of the objective that simultaneously gives a place to the subject. This can only be done by qualifying the notion of objective without denying its ontological status. Firstly, to account for emergence, and most importantly emergence involving semiosis and awareness, it is necessary to appreciate that this involves immanent causation at different levels, and that this causation involves limiting or constraining. Secondly, and more fundamentally, as Schelling concluded and came to appreciate more as he got older, and as virtually all process philosophers have argued, it is necessary to appreciate that such immanent causation involves creative becoming and that this underlies all else, and this cannot be entirely objectified.

ROSEN, BIOSEMIOTICS AND PHILOSOPHICAL BIOLOGY

Since in discussing theoretical biology I have focused on the work of Rosen, it is mainly in relation to his work that I will attempt to clarify what process philosophy implies for theoretical biology, and how this could realign it with philosophical biology and its developments, particularly developments associated with biosemiotics and biohermeneutics. To begin with, it should be noted that Schelling's *Naturphilosophie* has had a tremendous influence on science.⁶⁹ Oersted's work on chemistry and electro-magnetism was strongly influenced by Schelling.⁷⁰ The principle of 'conservation of energy' was formulated by scientists who had been influenced by Schelling.⁷¹ Schelling had a significant influence on the work of Hermann Grassmann, the brilliant nineteenth century German mathematician (who strongly influenced Alfred North Whitehead).⁷² And it

68. See Arran Gare, 'The Roots of Postmodernism: Schelling, Process Philosophy and Poststructuralism,' *Process and Difference*, Anne Daniell and Catherine Keller, (eds.), New York: State University of New York Press, 2002.

69. On this, see Joseph L. Esposito, *Schelling's Idealism and the Philosophy of Nature*, Lewisburg: Bucknell University Press, 1977.

70. Barry Gower, 'Speculation in Physics: The History and Practice of *Naturphilosophie*', *Studies in the History and Philosophy of Science*, 3 (4), 1973, 301-356.

71. Kuhn, Thomas (1977 'Energy Conservation as an Example of Simultaneous Discovery', *The Essential Tension*, Chicago: University of Chicago Press, 1979, pp.66-104.

72. Marie-Luise Heuser, 'Geometrical Product – Exponentiation – Evolution' in *Hermann Günther Grassmann (1809-1877): Visionary Mathematician, Scientist and Neohumanist Scholar*, Gert Schubring (ed.), Dordrecht: Kluwer, 1996, pp.47-58.

has been argued that Schelling is the precursor of systems theory.⁷³ So it is not as though Schelling's philosophy can be regarded as merely a complement to science. Modern science, to the extent that it has transcended Newtonian physics, is largely built on ideas deriving from or developed by Schelling. To a considerable extent Rosen was building on developments in science deriving from Schelling's work. Furthermore, where Rosen was not building on this work his ideas converged with Schelling's philosophy. While defending Aristotle's notion of causation, Rosen also alluded to and defended 'immanent causation', which is essentially Schelling's notion of 'community of causation.' Although Rosen did not elaborate on what he meant by immanent causation and instead used Aristotelian notions of causation, he modified Aristotle's notions by deploying the notion of 'constraint'. As Stephen Kerckel pointed out:

It must be appreciated that Rosen's notion of efficient cause is slightly different from Aristotle's. ... In Rosen's parlance, the constraint characterizing a map is an inferential entailment. By congruency of entailment, the corresponding cause entailment, the constraint that entails a specific material effect as the result of a given material cause, is what distinguishes efficient cause. ... The map is characterized by the constraint it imposes on transformations. The corresponding efficient cause is the ontological constraint on the transformation of material cause into material effect.⁷⁴

Although it has entirely different origins,⁷⁵ this notion of constraint accords with Schelling's notion of 'limit'. Finally, Rosen embraced the notion of emergence,⁷⁶ which as I have argued elsewhere, also has its roots in Schelling's philosophy of nature.⁷⁷

Early in his career, Rosen was centrally concerned with how living organisms develop heritable internal models that direct metabolism and reproduction, behaviour patterns and new functions. Working closely with Howard Pattee, they each came to the conclusion that these could be modeled by physical laws, provided they are augmented by local boundary conditions that constrain the dynamics of the system defined by them. At this stage both Rosen and Pattee were concerned with the dual issue of how organisms could control physical processes through internal models and how scientists could understand life through models. Both came to believe that non-integrable or non-holonomic constraints (first studied by Heinrich Herz) could model informational and biological systems. Pattee utilized the notion of non-holonomic constraints to account for the emergence of symbols through which control is achieved over lower level com-

73. Marie-Luise Heuser-Kessler, *Die Produktivität der Natur: Schellings Naturphilosophie und das neue Paradigma der Selbstorganisation in den Naturwissenschaften*, Berlin: Duncker & Humblot, 1986.

74. Stephen W. Kerckel, 'Entailment of Ambiguity', *Chemistry & Biodiversity*, 4 (2007): 2369-2385, pp.2380 & 2382.

75. On the origins and significance for the notion of causation of 'constraint' see Alicia Juarrero, 'Causality as Constraint', in *Evolutionary Systems: Biological and Epistemological Perspectives on Selection and Self-Organization*, Gertrudis Van De Vijver, Stanley Salthe and Manuela Delpos, (eds), Dordrecht: Kluwer Academic Publishers, 1998.

76. Rosen, 'On the Limitations of Scientific Knowledge', p.213.

77. Arran Gare, 'Process Philosophy and the Emergent Theory of Mind: Whitehead, Lloyd Morgan and Schelling', *Consciousness: The Australasian Journal of Process Thought*, 3 (2002): 1-12.

ponents of a system and generalized this notion of constraint to account for hierarchical order in general. On the basis of his and further work on hierarchical order, particularly work that has examined hierarchical order based on different spatio-temporal scales, it is now appreciated that constraints and constraining can be facilitative and creative, that, as Alicia Juarrero put it: ‘constraints not only reduce the alternatives – they also create alternatives. Constraints ... can also create properties which a component exhibits in virtue of its embeddedness in a system, properties it would not otherwise have.’⁷⁸ Hierarchy theory has been embraced and developed by a number of other theoretical biologists (notably, Salthe) and ecologists and has provided the means to account for emergence and a bridge between theoretical physics, theoretical biology and biosemiotics.⁷⁹ As with Schelling’s notion of limit, the notion of constraint is seen as a way of explaining life and mind without postulating additional vital forces and thinking substances able to control matter or explaining away life and mind.

Rosen abandoned his early study of the microphysical basis for the specificity of organisms, that is, genetic information, when he came to realize that it is impossible to divide an active information site in an organism from everything else.⁸⁰ Pattee wrote a long critical review of Rosen’s later work, tracing the development of his more critical attitude to mainstream science.⁸¹ He suggested that Rosen’s greater interest in formalism led him in a more idealist direction, which led him to ignore the physical basis of life. Given the place Rosen granted to causation, however, this characterization is questionable. What does seem to have occurred is that Rosen came to the conclusion that it was a mistake to make biology subservient to physics. As he argued in a *Festschrift* for David Bohm: ‘In every confrontation between universal physics and special biology, it is physics which has always had to give ground.’⁸² While lauding von Bertalanffy’s observation that open systems exhibited many parallels with morphogenetic phenomena in biology and the great advances by Rashevsky, Turing and Ilya Prigogine following from this observation (dissipative structures, stability theory, catastrophe theory, bifurcation theory etc.), he noted that the physical basis of these phenomena is in an extremely unsatisfactory state. He concluded that open systems should be taken as paradigmatic in science rather than being treated as problematic perturbations of closed systems, and on this basis developed his new approach to identifying components which did not start with the components that could be identified as context free, fractionable physical elements.

78. Juarrero, ‘Causality as Constraint’, p.234.

79. See H.H. Pattee, ‘The Necessity of Biosemiotics: Matter-Symbol Complementarity’, In Burbieiri (ed.) *Introduction to Biosemiotics*, Ch.4. For further development of these ideas, integrating hierarchy theory with non-linear thermodynamics, other developments of complexity theory and Peircian biosemiotics, see Stanley N. Salthe, *Development and Evolution: Complexity and Change in Biology*, Cambridge, Mass.: MIT Press, 1993. See also J.L. Lemke, ‘Material Sign Processes and Emergent Ecosocial Organizations’, in Anderson, *Downward Causation*, pp.181-213.

80. Rosen, ‘Some epistemological issues in physics and biology’, p.316f.

81. Howard H. Pattee, ‘Laws, Constraints, and the Modeling Relation – History and Interpretations’, *Chemistry and Biodiversity*, 4 (2007): 2272-2295.

82. Robert Rosen, ‘Some epistemological issues in physics and biology’, *Quantum Implications: Essays in Honour of David Bohm*, B.J. Hiley and F.David Peat (eds), London: Routledge, 1987, p.315.

It would seem that in this regard, Rosen abandoned Pattee's and the hierarchy theorists' approach to accounting for emergence as simple a matter of the interpolation of a new level of constraining of previously existing entities and thereby deviated from Schelling's natural philosophy. Rosen's relational model of life is not equivalent to a constraint controlled dynamic model. The relationship between emergent levels of organization, which Rosen claimed do exist, and the kinds of entities that are studied by physicists and chemists, must be seen as far less simple than hierarchy theorists have supposed. However, there is no reason why Rosen's work should be taken as implying that there are no constraints operating on fractional components at all, or that the work of hierarchy theorists on the relationship between levels of organization characterized by greatly different process rates and temporal and spatial scales is invalid. Conversely, Pattee has acknowledged the possible contribution that the relational model could make to science.⁸³ What is really brought into question by Rosen's later work is the assumption that simple physical systems can be properly understood in abstraction from their contexts, while the case that wholes cannot be understood by adding together knowledge of simpler systems is strengthened. In questioning these assumptions Rosen was allying himself with physicists such as David Bohm. However, Rosen made no effort to accommodate the ideas of the hierarchy theorists, and in fact appeared to lack any appreciation of the relative autonomy of different temporal levels of organization in complex systems.⁸⁴

There is another problematic aspect of Rosen's account of life. Both Pattee and Rosen characterized science as modeling systems, with Rosen equating success with establishing a congruence between the model and that which is modeled. Both characterized life as having internal models of the world. That is, they appear to have accepted a representational view of knowledge and perception, a view which emerged with the mechanistic world-view. Construing knowledge and science as modeling the world is usually developed in opposition to approaches to knowledge and perception that emphasize the development of schema through which the world is interpreted. The latter approach, deriving from Kant, avoids the problem of establishing a dualism between the model and the modeled.⁸⁵ On this issue, Schelling was aligned with Kant, as was Delbrück who followed the genetic epistemologist, Jean Piaget, in this regard.

The potentially problematic aspects of the notion of modeling can be avoided to some extent by conceiving of modeling through Peircian semiotics. Peirce, in developing his theory of semiosis, began as a Kantian and later claimed to be a Schellingian of some stripe, and was particularly concerned to avoid the dead-ends that resulted from dualistic thinking.⁸⁶ For Peirce, a model is an iconic sign, and as such involves a dyadic relation. However, Peirce always understood the production and interpretation of signs

83. Pattee, 'Laws, Constraints, and the Modeling Relation – History and Interpretations', p.2293.

84. On Rosen's deficiencies in this regard, see Ron Cottam, Willy Ranson and Roger Vounckx, 'Re-Mapping Robert Rosen's (M,R)-Systems', *Chemistry & Biodiversity*, 4 (2007): 2352-2368.

85. For a good analysis of this opposition, see Ben Martin, 'The Schema' in *Complexity: Metaphors, Models, and Reality*. Cowan et.al (eds), pp.263-285.

86. See Arran Gare, 'The Semiotics of Global Warming', *Theory & Science*, 9 (2) (2007). <http://theoryand-science.icaap.org/content/vol9.2/Gare.html>.

as a triadic relation. Models are produced and interpreted as signs, requiring the triadic relation between the sign produced, the object signified, and the interpretation of the sign. Further, examining the iconic relation between models and what is modeled is to have gone beyond this dyadic relation to a triadic relation of the object (or system) modeled, the model, and the interpretation of the relationship between these. Interpreting modeling in accordance with Peirce allows us to appreciate Rosen's careful studies of modeling while providing a better understanding of the semantic aspects of this. Rosen interpreted the modeling relation through category theory, noting that not only can there be no algorithm for encoding and decoding models, but that category theory cannot be formalized and for this reason is sometimes not seen as part of mathematics.⁸⁷ However, it can be easily accommodated within Peircian philosophy, as this reflection on mathematical structures can itself be appreciated as a triadic relation.

When Rosen's work is interpreted through Peircian semiotics, it can be related more easily to biosemiotics, and from there to the core ideas of the philosophical biologists. Biosemioticians, most importantly Thomas Sebeok, Jesper Hoffmeyer, Kalevi Kull and Alexai Sharov have interpreted the work of Uexküll as a semiotician, interpreting his work through Peircian semiotics. As Sharov argued:

The main idea of Uexküll is that each component of Umwelt has a functional meaning for an organism; it may be food, shelter, enemy, or simply an object that is used in orientation. An organism actively creates its Umwelt through repeated interaction with the world. ... The Umwelt-theory also implies that it is not possible to separate mind from the world (matter) because mind makes the world meaningful. The theory of meaning developed by Uexküll is consistent with the ideas of semiotics (theory of signs) proposed earlier by Charles Sanders Peirce. ... Translating the theory of Uexküll into the language of semiotics, we can say that Umwelt is not a set of objects in the environment but rather a system of signs interpreted by an organism.⁸⁸

That is, interpreted through Peircian semiotics, organisms can be understood as beings in a meaningful world in a way that is irreducible to physics.

However, for Peircian semiotics to make sense there are other dimensions which have to be brought into theoretical biology. These are, firstly, the temporality of existence, and secondly, a better appreciation of hierarchical ordering associated with such temporality. To fully understand the capacity of organisms to define their environments as worlds with enduring potentialities that they can respond to on the basis of anticipated effects of their responses, it is necessary to appreciate, along with the complex interdependencies focussed on by Rosen, the durational nature of becoming and the hierarchical ordering of this becoming.⁸⁹

Temporality is central to what it is to be a subject. Kant appreciated this and had

87. See Rosen, *Life Itself*, p.54.

88. Alexai Sharov, 'Umwelt-theory and pragmatism', *Semiotica*, 134(1/4) (2001): 211-228, p.211.

89. On this, see Arran Gare, "Process Philosophy and the Emergent Theory of Mind: Whitehead, Lloyd Morgan and Schelling", *Concrescence: The Australasian Journal for Process Thought: An Online Journal*, 3 (2002). http://concrescence.org/ajpt_papers/volo3/03_gare.pdf.

characterized time as the inner form of sense. In the final phase of his philosophical career Schelling argued that time is central to the unprethinkable being which precedes all reflection, logic and mathematics. Following Schelling, process philosophers all take time as becoming as irreducibly basic to existence. This is evident in Peirce for whom semiosis is essentially temporal. However, appreciation of temporality is even more central to the philosophy of Bergson and Whitehead. Bergson argued that time as duration is different than the spatialized time as measured by physicists. As durational it cannot be conceived as a point moving along a line but involves memory and anticipation. Whitehead largely concurred with Bergson on this issue and emphasised that nature is creative advance. Such work provides support for the place accorded to and the treatment of temporality in phenomenology and hermeneutics, particularly in the work of Heidegger, who in characterizing human existence as being-in-the-world, emphasised its temporal nature and also characterized human existence as being-towards-death. Philosophical biologists embraced this emphasis on temporality and mortality of existence, taking it as central to life that it is always threatened with death. Plessner's notion of 'positionality' of living beings presupposes and implies that organisms are in process of becoming revealing and responding to the possibilities of their environments. This is also the case with Merleau-Ponty's notion of vital structures where 'equilibrium is obtained, not with respect to real and present conditions, but with respect to conditions which are only virtual and which the system itself bring into existence...'⁹⁰ Jonas, following Heidegger, argued that emotion in animals is a manifestation of their appreciation of their mortality.

All this is inconsistent with mainstream science for which time as becoming is an illusion, since the equations of motion do not have a privileged direction. This is not the case with open systems in which negative entropy is being transformed with increase of entropy. Their development is irreversible. Rosen, by privileging open systems over closed systems is in a much stronger position to account for the temporality of life. And unusually, he has examined senescence and mortality in organisms.⁹¹

To account for the experience of meaning, however, something more than merely durational becoming is required. Being-in-the-world or taking a position involves, as Jonas pointed out, transcendence of some kind. In Kant, the transcendental ego stands outside the time through which it organizes the sensory manifold. Bergson, Husserl and the phenomenologists appreciated that experience is more complicated than this dualism allows for. It is necessary to appreciate that experience involves multiple levels of anticipation and retention to account for the sense of enduring self-hood temporally transcending the immediate situation. This in turn requires that there be multiple levels of durational becoming if the ontological status of this experience is to be taken seriously.

Rosen did grapple with this issue, suggesting in an interview about his work on anticipatory systems and complexity not long before he died:

You have to have more than one time scale, more than one thing that you could

90. Merleau-Ponty, *The Structure of Behaviour*, p.145f.

91. See Rosen, 'Order and Disorder in Biological Control Systems', *Essays on Life Itself*, Ch.16.

call “real time” in an anticipatory system. In my first approaches, the anticipatory system was based on predictive models, as I’ve said before. Something in the system is running faster than real time in the system, or else you have no anticipation-- the system is not anticipating what its own subsequent behavior is going to be. So, you have to have more than one inherent time scale.⁹²

It is in dealing with all the implications of this that Rosen’s apparent failure to deal adequately with levels of organization at different scales and their relationships becomes manifest. However, Ron Cottam, Willy Ranson and Roger Vounckx who pointed out weaknesses in Rosen’s characterization of hierarchy, have argued that Rosen’s ideas on relational biology can be modified to give a place to scalar hierarchies.⁹³ At the same time, they have rejected Rosen’s binary separation of assemblies into mechanisms and organisms and called for a threefold segregation so that the organism is seen as the complex interface between its structural aspect or mechanism and ecosystem. With this modification, Rosen’s work fully supports Uexküll’s and the philosophical biologists’ characterization of living beings as inseparable from their surrounding worlds, and, associated with this, Uexküll’s argument that organization of life transcends its material instantiations. As Uexküll put it:

Imagine that we had a number of living bells, each capable of producing a different tone. With these we could make chimes. The bells could be operated either mechanically, electrically or chemically, since each living bell would respond to each kind of stimulus with its own “ego-quality” [ich-ton]. ... Chimes composed of living bells must possess the capacity to let their tune resound, not only because they are driven by mechanical impulses, but also because they are governed by a melody. In this manner, each ego-quality would induce the next one, in accordance with the prescribed tone-sequence created by the melody.⁹⁴

This clearly accords with Rashevsky’s and Rosen’s argument that life itself has to be understood at its own level, with the significant components being products of the system rather than being the separable parts into which the organism can be broken down. When Rosen’s argument is combined with Cottam et.al.’s arguments that it is necessary to see the organism with its mechanisms within its ecosystem to comprehend it, then we can see that the meaningful world of the organism in relation to which it positions itself as a subject, is a product of this whole system of the organism within its ecosystem. Living beings must be appreciated in their own terms, defining and transcending their surrounding worlds, and cannot be identified or explained in terms of interactions between independently identifiable physical components or processes.

Yet not even Rosen’s treatment of life captures the experience of an organism threat-

92. Transcript of a videotaped interview of Dr. Robert Rosen by Judith Rosen, July, 1997, corrected July 14, 2000, p.3. (<http://www.people.vcu.edu/~mikuleck/rsntpe.html>, viewed on August 7th, 2008)

93. See Ron Cottam, Willy Ranson and Roger Vounckx, ‘Re-Mapping *Robert Rosen’s (M,R)*-Systems, *Chemistry & Biodiversity*, 4 (2007): 2352-2368.

94. Jacob von Uexküll, ‘The Theory of Meaning’ *Semiotica* 42(1), (1982): 25-82, p.34f. quoted by Jesper Hoffmeyer, *Signs of Meaning in the Universe*, trans. Barbara J. Haveland, Bloomington: Indiana University Press, 1993, p.55.

ened with death. Temporality as lived, as creative advance into the future characterized by real novelty, and temporality that brings new systems and new kinds of system into existence, is something more than and deeper than can be represented by even complex mathematical models. It is here that the semantic dimension of what is modelled as something more and richer than its model is most pronounced. It is here the limits of mathematical modelling are reached. Creative becoming cannot be fully represented through mathematics, even the kind of mathematical models developed by Rosen. The very nature of mathematics is to objectify and pre-specify what is possible. It cannot grant a place to real creativity.⁹⁵ However, the ‘objective’, that which can be grasped through mathematics, can be seen to have a place in this creative becoming if it is understood relationally as a product of the co-becoming of processes of differing durations. That is, considered in relation to Rosen’s arguments, the semantic aspects of being that cannot be reduced to syntax are not merely referents, but can only be fully appreciated in relation to the appreciation of being as a multi-leveled process of becoming involving real creativity. To do justice to the experience of mortality, to memory of the past, imaginative responses to the present and to creative advance into the future it is necessary to complement even the most advanced mathematical modelling with polyphonic stories.⁹⁶

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95. As argued by Stuart Kauffman in ‘Emergence and Story: Beyond Newton, Einstein and Bohr?’, *Investigations*. Oxford: Oxford University Press, 2000, p.134f. and Anton Markoš, ‘In the quest for novelty: Kauffman’s biosphere and Lotman’s semiosphere’, *Sign Systems Studies*: 32.1/2, (2004): 309-327.

96. For further arguments along these lines see Arran Gare, ‘The Primordial Role of Stories in Human Self-Creation’, *Cosmos and History*, 3(1) (2007): 93-114. <http://www.cosmosandhistory.org/index.php/journal/article/viewFile/161/81>.