BIOSEMIOSIS AND CAUSATION: DEFENDING BIOSEMIOTICS THROUGH ROSEN'S THEORETICAL BIOLOGY OR INTEGRATING BIOSEMIOTICS AND ANTICIPATORY SYSTEMS THEORY[1]

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ABSTRACT: The fracture in the emerging discipline of biosemiotics when the code biologist Marcello Barbieri claimed that Peircian biosemiotics is not genuine science raises anew the question: What is science? When it comes to radically new approaches in science, there is no simple answer to this question, because if successful, these new approaches change what is understood to be science. This is what Galileo, Darwin and Einstein did to science, and with quantum theory, opposing interpretations are not merely about what theory is right, but what is real science. Peirce's work, as he acknowledged, is really a continuation of efforts of Schelling to challenge the heritage of Newtonian science for the very good reason that the deep assumptions of Newtonian science had made sentient life, human consciousness and free will unintelligible, the condition for there being science. Pointing out the need for such a revolution in science has not succeeded as a defence of Peircian biosemiotics, however. In this paper, I will defend the scientific credentials of Peircian biosemiotics by relating it to the theoretical biology of the bio-mathematician, Robert Rosen. Rosen's relational biology, focusing on anticipatory systems and giving a place to final causes, should also be seen as a rigorous development of the Schellingian project to conceive nature in such a way that the emergence of sentient life, mind and science are intelligible. Rosen has made a very strong case for the characterization of his ideas as a real advance not only in science, but in how science should be understood, and I will argue that it is possible to provide a strong defence of Peircian biosemiotics as science through Rosen's defence of relational biology. In the process, I will show how biosemiotics can and should become a crucial component of anticipatory systems theory.

KEYWORDS: Biosemiotics; Anticipatory Systems; Code biology, Relational biology; C.S. Peirce; T. Sebeok; Jesper Hoffmeyer, Marcello Barbieri; Robert Rosen; Rom Harré; Schelling

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INTRODUCTION

In the late 1990s a number of theoretical biologists influenced by Thomas Sebeok's call for a fusion of biology and semiotics formed a new international research program, biosemiotics, giving rise to annual conferences or 'Gatherings' beginning in 2001, and then in 2008, a new journal, *Biosemiotics.*[2] Strongly influenced by C.S. Peirce, Sebeok was the world's most influential proponent of semiotics as a bridge between the sciences and the humanities.[3] The term biosemiotics was coined by Friedrich Rothschild in 1962, and was embraced and promoted by Sebeok after his discovery of the work of the theoretical biologist Jakob von Uexküll and meeting his son, Thure von Uexküll. It was taken up and developed at a number of meetings between Sebeok, Thure Uexküll and others in Germany in the 1980s and early 1990s, and then in Denmark, most importantly, by Jesper Hoffmeyer, Claus Emmeche, Frederik Stjernfelt and Søren Brier. The Danes in particular were strongly influenced by Peirce, and Peircian biosemiotics was effectively launched with the publication of Hoffmeyer and Emmeche's essay 'Code-Duality and the Semiotics of Nature' in 1991, the 1991 edition of *The Semiotic Web* as *Biosemiotics* in 1992, the first book with 'Biosemiotics' in the title, and Hoffmeyer's *Signs of Meaning in the Universe* published in Danish in 1993.[4] The

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[2] The history of biosemiotics has been written from different perspectives by its founders, notably Kalevi Kull, 'Semiotic Paradigm in Theoretical Biology'. In: K. Kull and T. Tiivel (eds.) *Lectures in Theoretical Biology: The Second Stage,* Tallinn: Estonian Academy of Sciences, 1993: pp.52-62; Kalevi Kull, 'Biosemiotics in the twentieth century: a view from biology', *Semiotica* 127(1/4), 1999: 385-414; Thomas A. Sebeok, 'Biosemiotics: Its Roots, Proliferation, and Prospects', in Thomas A. Sebeok, *Global Semiotics*, Bloomington: University of Indiana Press, 2001, ch.3; Claus Emmeche, 'Taking the semiotic turn, or how significant philosophy of biology should be done', *Sats - Nordic Journal of Philosophy,* 3 (1), 2002: 155-162; Claus Emmeche, Kalevi Kull and Frederik Stjernfelt, *Reading Hoffmeyer, rethinking biology,* Tartu: Tartu University Press, 2002; Donald Favareau, 'The Evolutionary History of Biosemiotics', *Introduction to Biosemiotics: The New Biological Synthesis,* ed. Marcello Barbieri, Dordrecht: Springer, 2008, pp.1-68; Marcello Barbieri, A Short History of Biosemiotics', *Biosemiotics*, Issue 2, 2008: 221-245; and Jesper Hoffmeyer, 'A short history of Gatherings in Biosemiotics', *Gatherings in Biosemiotics,* ed. Silver Rattasepp and Tyler Bennett, Tartu: University of Tartu Press, 2012, pp.55-60.

[3] Thomas A. Sebeok, 'Semiotics as Bridge Between Humanities and Sciences', in *Semiotics as Bridge Between The Humanities and the Sciences,* ed. Paul Perron et.al. N.Y.: Legas, 2000, 76-100. Earlier, Sebeok had promoted Peircian semiotics as the basis for unifying the sciences. See Thomas A. Sebeok, *The Sign & Its Masters,* Austin: Uni. of Texas Press,1979, p.64ff.

[4] Jesper Hoffmeyer and Claus Emmeche, ''Code-Duality and the Semiotics of Nature', in *On Semiotic Modeling,* ed. Myrdene Anderson and Floyd Merrell, Berlin: Mouton de Gruyter, 1991, pp.117-166, and Thomas A. Sebeok and Jean Umiker-Sebeok eds, *Biosemiotics: The Semiotic Web of 1991,* Berlin: Mouton de

extension of semiotics to biology had been promoted in the 1970s by a number of figures along with Sebeok, including René Thom in France (also influenced by Peirce) and Giorgia Prodi and Umberto Eco in Italy, but also by Yuri Lotman in Estonia, the founder or the Tartu/Moscow school of semiotics.[5] Estonia was also the original homeland of Jakob von Uexküll. Estonia thus provided a receptive environment for Peircian biosemiotics which was taken up and vigorously promoted by Kalevi Kull, who visited Hoffmeyer in Denmark in 1994.

Peircian biosemiotics was and is a radical challenge to mainstream thinking in biology, and as such has had to struggle for recognition. In place of the centrality presently accorded to biochemistry and molecular biology, taking life to be a special kind of chemical process, the biosemioticians argue that it is signs which define life, and that it is only through understanding these signs, how they are produced and responded to, that life can be understood. Initially great progress was made. Code biologists (or 'semantic biologists') and biohermeneuticists had developed parallel research programs to Peircian biosemiotics, and the code biologists led by Marcello Barbieri and the biohermeneuticists led by Sergey Chebanov and Anton Markoš joined forces with the biosemioticians. Later, inspired by these developments, Günther Witzany developed another approach to biology based on the pragmatics of language focussing on communication, and also joined the biosemiotics movement. Barbieri co-edited the first edition of *Biosemiotics* with Hoffmeyer, and edited the first issue, much of it devoted to the codes of life. In 2008 Jesper Hoffmeyer published a major work of synthesis, *Biosemiotics: An Examination into the Signs of Life and the Life of Signs,* which along with Donald Favareau's anthology *Essential Readings in Biosemiotics* and later, Vincius Romanini and Eliseo Fernández's *Peirce and Biosemiotics: A Guess at the Riddle of Life*, could function as textbooks for courses on biosemiotics.[6]

Gruyter, 1992, and Jesper Hoffmeyer, [1993] *Signs of Meaning in the Universe,* trans. Barbara J. Haveland, Bloomington: Indiana University Press, 1996.

[5] See Kalevi Kull, 'Towards biosemiotics with Yuri Lotman', *Semiotica,* 127 (1/4), 1999, 115-131.

[6] Hoffmeyer, *Biosemiotics: An Examination into the Signs of Life and the Life of Signs,* trans. Jesper Hoffmeyer and Donald Favareau, Scranton: University of Scranton Press, 2008, Favareau, (ed.) *Essential Readings in Biosemiotics*, Dordrecht: Springer, 2010, and Romanini and Fernández (eds.) *Peirce and Biosemiotics: A Guess at the Riddle of Life*, Dordrecht: Springer, 2014.

Then in 2012, Barbieri withdrew from the movement, resigning his editorship of *Biosemiotics.* He claimed that the influence of Peircian semiotics had resulted in biosemiotics research moving away from genuine science, and that this was standing in the way of biosemiotics gaining acceptance by mainstream biologists. He claimed he had been unsuccessful in convincing Peircians to move on to a more genuinely scientific form of biosemiotics.[7]

This charge raises the question again, What is science? and How can any research justify its claim to being scientific?

Here I will not only defend the claim of Peircian biosemiotics to being scientific, but argue that it involves a revolution in scientific thought that requires us to alter to some extent our understanding of what science is, and that this should have been undertaken long ago. This revolution was called for by Friedrich Schelling at the end of the Eighteenth Century in his effort to develop a philosophy that would unite science, history and the arts. The failure to fully carry through this revolution, required to make life and mind intelligible, is now hindering not only the advance of biology (and medicine), but all science, and also, the humanities. It is also damaging major economic, social, political and cultural institutions, including universities which have abandoned the Humboldtian model and ideal of education that inspired academics in the sciences and humanities for nearly two hundred years, and blocking effective action in response to the global ecological crisis. As Sebeok argued, biosemiotics is required to spearhead a revolution to bridge and overcome the division between science and the humanities and to revive the values that the humanities originally were designed to promote. And as Hoffmeyer argued in *Signs of Meaning in the Universe*, a book that became a manifesto for Peircian biosemioticians, biosemiotics is required for us to appreciate the signs of life in the global ecosystem and to appreciate and respond properly to these signs, which now, with a global ecological crisis facing us, should be regarded as imperative.[8]

According to Barbieri in his 2014 critique of Peircian biosemiotics, there are

[7] Marcello Barbieri, 'From Biosemiotics to Code Biology', *Biological Theory,* 9(2), June 2014: 139-149. doi 10.1007/s13752-013-0155-6

[8] As I have tried to show in 'The Semiotics of Global Warming: Combating Semiotic Corruption', *Theory and Science,* 2007: 1-35.

three schools of biosemiotics, one aligned with Saussure's structuralist semiology (originating in the work of Marcel Florkin), one aligned with Peircian semiotics, and one aligned with code theory, although he had acknowledged other approaches in his study of the history of biosemiotics in 2008, including a line developed from physics by Howard Pattee.[9] Structuralist semiotics as it was developed by the Russian Roman Jakobson accorded a central to place to codes and can be seen as linking while adding another dimension to Peirciean biosemiotics.[10] Barbieri himself is a leading exponent of code biology, inspired by the discovery of the genetic code to find other biological codes.

The genetic code, based on arbitrary, or conventional rules, in the sense that any sequence of DNA can be associated to any amino acid without a deterministic link between them, is now almost universally accepted as a major achievement of science. Barbieri has achieved international recognition for his work explaining how the genetic code works. He identified the 'ribotype', the 'ribonucleoprotein system' as the code maker of the genetic code which, and argued it could account for the origin of life before the sharp differentiation between genes and proteins, and should be recognized as having equal standing with the genotype and the phenotype.[11] He has offered an explanation for how the code could have formed in the first place through 'ambiguity reduction', and has been involved in the discovery of other codes. His standing in science as a leading spokesperson for code biology is relatively secure.[12]

Hoffmeyer himself discussed Barbieri's claims for code biology in his 2008 publication, *Biosemiotics*, and while arguing that he still underestimated the complexity of the relationship between DNA, RNA, the production of proteins and other aspects of heredity, and that codes do not entirely explain the

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[9] Marcello Barbieri, 'From Biosemiotics to Code Biology', *Biological Theory,* 9(2), June 2014: 139-149. doi 10.1007/s13752-013-0155-6 and Barbieri, 'A Short History of Biosemiotics.'

[10] Structuralism developed in different directions, with mainstream structuralism following Saussure and focussing on the relationship between signs leading to post-structuralism and extreme skepticism, while the genetic structuralism of Jean Piaget, focussing on the actions of organisms and people and attempting to account for the development of language, science and mathematics on this basis, was more commensurate with Peircian semiotics and biosemiotics.

[11] Marcello Barbieri, 'The Ribotype Theory on the Origin of Life', *J. Theor. Biol.* 91, 1981: 545-601, and Marcello Barbieri, *The Organic Codes: An Introduction to Semantic Biology*, Cambridge: CUP, 2003.

[12] For a review of his book, *The Organic Codes,* see Arnon Levi and Eva Jablonka, 'Book Review', *Acta Biotheoretica*, 52: 2004: 65-69.

production of proteins, he accepted that this was a major advance in genetics. Tacitly, he was claiming that Peircian biosemiotics provides a unifying framework in which the achievements of all the other biosemioticians can be appreciated and integrated, while other approaches are limited in one way or another.[13] Barbieri denies this, claiming there is no unifying principle among biosemioticians and that Peircian biosemiotics is merely a different way of looking at the same facts without being able to produce new facts and without the power to predict, or even to have its own experimental field.

The significance of Barbieri's claim made from his standpoint as an established scientist that much of Peircian biosemiotics is 'unscientific' cannot be underestimated. It is to brand Peircian biosemiotics, which includes much of the work of Hoffmeyer and which now has the allegiance of a number of leading theoretical biologists around the world, as fake science. This is a paradoxical claim when one considers that the main goal of C.S. Peirce as a logician was to characterize and defend genuine science. In a culture in which science has almost completely monopolised claims to cognitive validity (deconstructive postmodernists in the humanities having effectively capitulating to technoscience), it is to eliminate the challenge of Peircian biosemioticians to deep assumptions of modernity put in place by Descartes and Newton which have generated a culture of nihilism indifferent to life and humanity.[14]

Defences of Peircian biosemiotics have been offered. It has already been pointed out by Søren Brier that what is really at issue is what counts as science.[15] Then in 2018 Frederico Vega published a paper arguing that Peircian biosemiotics and Barbieri's code biology could be reconciled through the work of the theoretical biologist and mathematician Robert Rosen on relational biology modelling anticipatory systems.[16] Barbieri quickly responded to this, rejecting this claim and also criticising various claims Rosen had made,

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[13] See 'The Semiotics of Heredity', in Hoffmeyer, *Biosemiotics*, ch.2, p.139f.

[14] Arran Gare, *Nihilism Incorporated: European Civilization and Environmental Destruction*, Bangalore: Eco-Logical Press, 1993.

[15] S. Brier, 'Can biosemiotics be a "science" if its purpose is to be a bridge between the natural, social and human sciences?', *Progress in Biophysics & Molecular Biology,* 119(3), December 2015: 622-633.

[16] Federico Vega, 'A Critique of Barbieri's Code Biology Through Rosen's Relational Biology: Reconciling Barbieri's Biosemiotics with Peircian Biosemiotics, *Biological Theory*, 14 (1):21-29 (2019). doi: 10.1007/s13752-018-0312-z

particularly the claim that mechanistic explanations are reductionist.[17] He also rejected Rosen's claim that his mathematical model of life itself cannot be simulated on a computer and so is radically different from a Turing machine. He defended mechanistic explanations as a defining feature of genuine science while still being opposed to ontological reductionism. He also argued also that genuine science requires the identification of observables by virtue of which theories can be verified or falsified. My main concern here is defend the scientific status of Peircian biosemiotics, and I also will use the work of Rosen to do this. However, my approach to this is somewhat different from that of Vega. I will attempt to interpret Rosen through Peirce's philosophy primarily as a clarification of what science is, and then use this characterization of science to interpret and defend Peircian biosemiotics.

In doing so, I will offer minor amendments to both Rosen's arguments and to Peircian philosophy and to positions taken by biosemioticians. As an original mathematician concerned to advance both mathematics and mathematical biology in a way that accords a place in science to final causes, greatly clarifying the role of mathematics in science, Rosen defended a conception of science that I will show can also be used to reveal the limits of mathematics in science and to justify the cognitive value of both non-mathematical scientific models and to narratives. Against Rosen I will argue that mechanistic explanations are not necessarily reductionist, that is, that all appearances are nothing but the effects of the actions and interactions between component entities used to explain these appearances, but against Barbieri that genuine science is not defined by its capacity to provide mechanistic explanations. What is required, I will argue, is that explanations be in terms of models of causation, and not all causation is mechanistic. The importance of Rosen's work was to both clarify the nature of causation and also what is involved in modelling it, and through his work in mathematics, to reveal new dimensions of causation that can give a place to final causes. It is through this more complex understanding of causation, with a central place accorded to immanent causation or self-organization of processes that are components of each other

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[17] Marcello Barbieri, 'Code Biology, Peircian Biosemiotics and Rosen's Relational Biology', *Biological Theory* 14 (1):21-29 (2019). doi. 10.1007/s13752-018-0312-z

without being reducible to each other, that I will try to explain and, in so doing, defend Peircian notions of semiosis. At the same time, I will suggest that Peirce was deficient in not giving an adequate place to immanent causation, presupposing rather than offering an analysis of the causation involved in semiosis.[18]

In making these arguments, relating Peircian biosemiotics and Rosen's relational biology, I will suggest that both should be understood as part of and contributions to a broader tradition of philosophy and science going back to the work of Schelling, the originator of the modern tradition of process metaphysics.[19] This accords with Peirce's own characterization of his work in a letter to William James: 'My views were probably influenced by Schelling … by all stages of Schelling, but especially by the *Philosophie der Natur*. I consider Schelling enormous … If you were to call my philosophy Schellingianism transformed in the light of modern physics, I should not take it hard.'[20] Taking as his point of departure the conception of life developed by Kant in *Critique of Judgement* along with Kant's dynamic conception of matter and constructivist philosophy of mathematics, Schelling called for a speculative physics to replace Newtonian physics, and more fundamentally, Cartesian dualism, developing new concepts adequate to the reality of life so conceived, and through that, to the reality of mind.[21] This involved inverting the status accorded to physics and biology, making biology the reference point for defining what is science. It is this above all else that Peircian biosemiotics and Rosennean relational biology have in common.

There are more reasons than this for identifying and relating biosemiotics and relational biology to a Schellingian tradition of natural philosophy and science, however. Part of the current crises in science, in physics as well as

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[18] I have argued this at greater length in Arran Gare, 'The Semiotics of Global Warming: Combating Semiotic Corruption', *Theory & Science,* 2007, pp.1-32, p.5f.

[19] See Arran Gare, 'From Kant to Schelling to Process Metaphysics: On the Way to Ecological Civilization', *Cosmos and History: The Journal of Natural and Social Philosophy*, 7(2), 2011: 26-69.

[20] Letter dated January 28th, 1894, quoted by Joseph L. Esposito, *Schelling's Idealism and Philosophy of Nature,* Lewisburg: Bucknell University Press, 1977, p.203.

[21] F.W.J. Schelling, *First Outline of a System of the Philosophy of Nature,* trans. Keith R. Petersen, 2004, p.193ff.

biology, is the failure to recognize this tradition.[22] Virtually every major advance in the natural sciences since Schelling is a realization and validation of this alternative tradition, as Joseph Esposito, Marie-Luise Heuser-Kessler and Keith Peterson have pointed out.[23] Thomas Kuhn showed that all the major figures who laid the foundations for thermodynamics with its first law, the conservation of energy, were influenced by Schelling's *Naturphilosophie.*[24] Advances in thermodynamics, including efforts to understand life through thermodynamics inspired by the energeticists who took energy or mass-energy as the basis for defining and comprehending physical existence, including Aleksandr Bogdanov's Tektology, Alfred Lotka's biophysics, Ludwig von Bertalanffy's notion of open systems and Ilya Prigogine's notion of dissipative structures, are the outcome of this development, now generally recognized as major achievements in science. Schelling's call for a new physics integrating the study of light, electricity and magnetism was also successful. Michael Faraday was indirectly influenced by the *Naturphilosophen* and Schelling embraced the work of Faraday with his notion of force fields as the fulfilment of *Naturphilosophie.*[25] Maxwell's achievement of explaining light through electro-magnetic fields took Schelling's project even further. It was efforts to reconcile Maxwell's work with Newtonian mechanics that generated the theories of relativity and then quantum theory. These should also be understood as field theories.[26] Schelling's conjecture that chemicals and chemical processes could be understood as the result of opposing forces balancing each other underlies

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[22] See Arran Gare, 'Overcoming the Newtonian paradigm: The unfinished project of theoretical biology from a Schellingian perspective', *Progress in Biophysics and Molecular Biology,* 113, December: 5-24, and Arran Gare, 'Natural Philosophy and the Sciences: Challenging Science's Tunnel Vision', *Philosophies,* 3(4), Dec. 2018: 1-29. https://www.mdpi.com/2409-9287/3/4

[23] Esposito, *Schelling's Idealism and Philosophy of Nature*, Marie-Luise Heuser-Kessler, *Die Produktivität der Natur: Schellings Naturphilosophie und das neue Paradigma der Selbsorganization in den Naturwissenschaften*, Berlin: Duncker & Humblot, 1986, and Keith Petersen, 'Translator's Introduction' to Schelling, *First Outline of a System of the Philosophy of Nature*, pp.xi-xxxv. See also Gare, 'Overcoming the Newtonian paradigm'.

[24] Thomas S. Kuhn, 'Energy conservation as an example of simultaneous discovery'. In: Thomas Kuhn, *The Essential Tension.* Chicago: University of Chicago Press, 1977, ch.4.

[25] Michael Faraday, 'Letter 836 – William Whewell to Faraday, 23rd November 1835'. In: *The Correspondence of Michael Faraday*, Volume 2: 1832-1840; Frank, A.; James, J.L., Eds.; The Institution of Electrical Engineers: London, 1991, p.296-297.

[26] See Arran Gare, 'Chreods, Homeorhesis and Biofields: Finding the Right Path for Science through Daoism', *Progress in Biophysics and Molecular Biology,* 131, December 2017: 61-91.

the notion of valency, which became the core concept of chemistry.

What is important to appreciate is that for Schelling, this reconceptualization of physical existence was seen by him as necessary to account for the emergence and evolution of life, including consciousness and self-consciousness. He was arguing for a conception of the world as self-organizing and evolving, and as 'endophysicists' are now arguing, that scientists are part of and within the world they are trying to understand. Karl Ernst von Baer and Charles Darwin were deeply indebted to this Schellingian tradition, as Robert Richards has pointed out.[27] While Darwinism was formulated in an increasingly mechanist direction by mainstream biologists, a minority developed a holistic form of Darwinism that echoed and advanced Schelling's understanding of evolution.[28] This could incorporate von Uexküll's argument that organisms can only be understood in the context of their *Umwelten*, their surrounding worlds, or environments as sensed by them. This tradition also inspired the notion of homeostasis and the notion of morphogenetic field in biology. Electro-magnetic fields and quantum field theory, integrated with thermodynamics (by Herbert Fröhlich), are now central to the development of biophysics, including neurophysics, in efforts to explain the emergence of consciousness.[29] What ties all this together is the move from an ontology of things to an ontology of processes, the importance of which is being rediscovered again in the philosophy of biology.[30] Brian Josephson has argued that the further development of Peircian biosemiotics is required to deal with the measurement problem in quantum theory.[31]

Less noticed is that the most important developments in mathematics

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[27] Robert J. Richards, *The Romantic Conception of Life: Science and Philosophy in the Age of Goethe*, Chicago: University of Chicago Press, 2002, ch.14.

[28] See for instance Peter A. Corning, *Holistic Darwinism, Synergy, Cybernetics, and the Bioeconomics of Evolution,* Chicago: Uni. Of Chicago Press, 2005.

[29] See Giuseppe Vitiello, *My Double Unveiled: The dissipative quantum model of brain.* Amsterdam: John Benjamins, 2001, Kuio Yasue, Mari Jibu and Tarcisio Della Senta eds. *No Matter, Never Mind,* Amsterdam: John Benjamins, 2001, and Gare, 'Chreods, Homeorhesis and Biofields'.

[30] See Daniel J. Nicholson & John Dupré eds, *Everything Flows: Towards a Processual Philosophy of Biology,* Oxford: Oxford University Press, 2018.

[31] Brian Josephson, 'Biological Observer-Participation and Wheeler's 'Law without Law', in *Integral Biomathics: Tracing the Road to Reality',* ed. P.L. Simeonov, L.S. Smith, A.C. Ehresmann, Springer-Verlag, 2012, pp.245-252.

underpinning modern science originated with the call by Schelling for a new mathematics adequate to a dynamic nature that includes life. This was prior to the development of catastrophe theory and complexity theory in the second half of the Twentieth Century, when again mathematics was called upon to develop mathematics adequate to life, beginning with the work of René Thom and then further developed at the Santa Fe Institute in their effort to model complex adaptive systems.[32] The project was embraced originally by Justus Grassmann, who inspired the development of Hermann Grassmann's extension theory in the mid-Nineteen Century, a geometric calculus serving as a universal instrument for geometric research, anticipating most of the mathematics utilized in modern physics.[33] Category Theory can be seen as a further advance in Hermann Grassmann's extension theory. As William Lawvere, a leading figure in the development of Category Theory, wrote:

> Looking more closely into Grassmann, Stephen Schanuel and I found numerous ways in which it could be justified to say that Grassmann was a pre-cursor of category theory. The general algebraic operations which he discussed have become the explicit object of a particular developed theory, and those general concepts, general operations, systems of operations and systems of equations in invariant coordinate free form have been made into a part of category theory.[34]

As developed by Rosen and others, Category Theory has been a major advance in the quest, originally inspired by Schelling, to develop mathematics adequate to life.

Peirce's work, and biosemiotics, should be seen as advancing this whole project to conceive nature in such a way that knowledge of it, including predictions about the future, is possible, and that there are beings within nature

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[32] Thom described this in *Mathematical Models of Morphogenesis,* trans. W.M. Brookes and D. Rand, Chichester: Ellis Horwood, 1983. Six chapters of this book were devoted to semantics, language and semiotics. On the work of the Santa Fe Institute, see George A. Cowan, David Pines and David Meltzer eds. *Complexity: Metaphors, Models and Reality*, Proceedings Volume XIX, Santa Fe Institute Studies in the Sciences of Complexity, Reading, Mass.: Addison-Wesley, 1994.

[33] Mircea Radu, "Justus Grassmann's Contributions to the Foundations of Mathematics: Mathematical and Philosophical Aspects", *Historia Mathematica,* 27 (2000): 4-35; and David Hestenes, 'Grassmann's Legacy'. In: *Herman Grassmann: From Past to Future: Grassmann's Work in Context*, ed. Hans-Joachim Petsche, Basel: Springer, 2011, pp.240-260.

[34] Lawvere, F. William. 'Grassmann's Dialectics and Category Theory', in Gert Schubring ed., *Hermann Günther Grassmann (1809-1877): Visionary Mathematician, Scientist and Neohumanist Scholar,* Dordrecht: Kluwer, 1996, pp.255-264, p.256.

able to achieve this knowledge. The evolution of life, and then self-conscious life-forms capable of developing literature, philosophy and science, should then be able to be comprehended, so that life, through us, can be seen as advancing by comprehending itself and its place in a self-organizing, creative universe. This conception of nature should enable us to participate more effectively in not only comprehending but also creating the future.

Peirce advanced this whole project by focussing first of all on the development of logic, conceived by him the core of science and the quest for knowledge, conceiving this as a form of semiosis, the production and interpretation of signs in a never ending process. Semiosis as conceived by Peirce involves a triadic relation between a sign, an object, and an interpretant, which then becomes another, possibly more developed sign, and Peirce also referred to this triadic relation itself as a sign. As such, semiosis can go on endlessly and creatively, generating increasing levels of complexity. Through understanding semiosis, Peirce argued, it becomes possible to not only understand all other domains of culture, including art and literature, but the emergence of self-hood, and beyond this, to grasp the nature of life itself, its origin and evolution, including the evolution of humanity.

Problems in science have arisen because rather than carrying through this revolution in science, there has been a strong tendency to retain assumptions about what is science put in place by Cartesians and Newtonians, and this has stood in the way of appreciating how diverse advances in radical science, and also in natural philosophy, actually support each other.[35] This is what I am attempting to show here by relating to each other Peirce's and Rosen's work in mathematics and theoretical biology.

ROSEN'S THEORY OF MODELLING

Robert Rosen was a major figure in the development of Category Theory. He was simultaneously a mathematician, a theoretical biologist, and although he did not claim to be such, a philosopher who, based on his work in mathematics and theoretical biology, utilized Category Theory to develop and defend new

[35] Stuart A. Kauffman and Arran Gare, 'Beyond Descartes and Newton: Recovering life and humanity', *Progress in Biophysics and Molecular Biology*, Issue 119, December 2015: 219-244.

conceptions of both mathematics and of science, and of the relationship between them. Category Theory originated in the work of Samuel Eilenberg and Saunders Mac Lane in algebraic topology. They introduced the concepts of categories, functors and natural transformations in order to understand the processes that preserve mathematical structure. Category Theory began with the observation that many properties of mathematical systems can be unified and simplified through a presentation with a diagram of arrows between 'objects' (which can be sets, groups or rings, or can be unspecified), where each arrow represents a function. The most important property of these arrows is that they can be 'composed', that is, arranged in a sequence to form a new arrow. The focus is then not on 'objects', but on the structure preserving mappings or 'morphisms' between these 'objects'. These mappings, which reveal the possible transformations of structures, can themselves be studied in this way. If the structures are themselves categories so that the morphisms revealing possible transformations are between categories, these are referred to as 'functors', and are represented as arrows between the categories. There can also be a category of functors. The morphisms that transform one functor into another while respecting the internal structure of the categories involved, thereby bringing into focus their mutability, are 'natural transformations'.

It was later shown that every branch of modern mathematics could be described in terms of categories, and doing so often yielded deep insights into and similarities between seemingly different areas of mathematics. For this reason, William Lawvere promoted Category Theory as an alternative to set theory as the foundation for mathematics, effectively, redefining mathematics in doing so. Rosen, who studied mathematics at the University of Chicago with Eilenberg and Mac Lane, argued that Category Theory is essentially modelling one branch of mathematics by another, and there is no essential difference between doing this and modelling the world beyond mathematics.[36] In each case, what is being modelled is entailments. This was the basis of his general theory of modelling, and his characterization of science as modelling. He equated such models with analogical thinking.

Category Theory as conceived by Rosen can then be interpreted as a major development of the Whiteheadian/Peircian conception of mathematics - as the

[36] Robert Rosen, 'On Models and Modeling', *Applied Mathematics and Computation,* 56, 1993: 359-372.

study through abstraction of possible patterns of connectedness and their transformations, utilizing diagrammatic reasoning.[37] The modelling relation, where something is learned about one system by studying another which is analogous to it, is ubiquitous and characteristic of everyday life as well as of both theoretical and experimental science, Rosen argued.[38] While offered as an aside, this characterization of modelling as analogical thinking is an extremely important argument, allowing Rosen's conception of mathematical modelling to be understood through Peircian semiotics as offering potential interpretants based on iconic signs.

All enquiry is concerned with systems of entailment, Rosen argued, causal entailment in the phenomenal world, inferential entailment in the mathematical. But inferential entailment in mathematics is really about entailment in the material world. That 3 sticks + 2 sticks = 5 sticks is a truth about the material world. Mathematics has always been concerned with discovering such entailments, and this is true in the present with efforts to understand chaos, turbulence and the emergence of new order. Mathematics goes profoundly astray when it dissociates itself from the world beyond mathematics, formalizing it by striving to provide the foundations for all mathematics in one very limited domain of mathematics, and then equating mathematical truths with what can be computed, as when the Pythagoreans attempted to reduce geometry to arithmetic on the assumption that any two line segments are commensurable, or Frege, Russell and Whitehead attempted to reduce arithmetic to symbolic logic and set theory. As Rosen argued, this ends up attempting to eliminate semantics, that is, what mathematics is about, and reduces mathematics to purely syntactic relations which can be specified purely formally. This was most fully manifest in Hilbert's formalist program of achieving consistency in mathematics by reducing all mathematics to formally defined rules for the manipulation of meaningless symbols. The impossibility of this program was demonstrated by Gödel. As Rosen put it, 'Mathematics, like

[37] Arran Gare, 'Creating a New Mathematics', *Intuition in Mathematics and Physics*, ed. Ronny Desmet, Anoka: Process Century Press, ch.7, pp.167-186.
[38] Robert Rosen, *Anticipatory Systems: Philosophical, Mathematical, and Methodological Foundations*, 1985. 2nd ed. New York: Springer, 2012, p. 82.

language itself, cannot be freed of all referents and remain mathematics.'[39]

It is the failure to appreciate that mathematics is analogical reasoning and should be judged as such that has led to the belief that objectivity implies the use of models that are formalizable and thereby to the reduction of biology to chemistry and physics, and to forms of mathematics that make life itself unintelligible. As Rosen diagnosed source of this problem:

> [T]hese ideas [that every model of a material process must be formalizable] have become confused with *objectivity* and hence with the very fabric of the scientific enterprise. Objectivity is supposed to mean observer independence, and more generally, context independence. Over the course of time this has come to mean only building from the smaller to the larger, and reducing the larger to the smaller. … In any large world, such as the one we inhabit, this kind of identification is in fact a mutilation, and it serves only to estrange most of what is interesting from the realm of science itself.[40]

Characterizing modelling through Category Theory did not mean that Rosen saw modelling as exclusively mathematical modelling. Rosen rejected the opposition noted by C.P. Snow between the two cultures: science and the humanities, or hard science and soft science.[41] What the failure of formalism and other efforts to establish rigorous foundations for mathematics demonstrates is that models do not have the qualitative richness of what they attempt to model. Abstract models are taken to be 'hard' relative to that which is 'soft'. On this basis, the axioms of logic and set theory are 'hard', relative to arithmetic which they model; arithmetic is 'soft'. However, the same relation applies lower down. Quantitative models, that is arithmetical models, appear to be 'hard' relative to qualitative mathematics. In each case, what is deemed to be 'soft' captures more of the richness of reality than what is deemed to be 'hard'.

Although Rosen did not make this argument, it should be seen that qualitative mathematics appears to be hard relative to stories, and structuralist analyses of stories appear to be hard relative to the diversity of actual and potential stories. So, in defending new forms of mathematics in order to do

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[39] Rosen, *Life Itself*, p.8.

[40] Rosen, *Essays on Life Itself*, 2000, p.80.

[41] Robert Rosen, *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*, New York: Columbia University Press, 1991, p.1ff.

justice to the reality of life through his interpretation of modelling through Category Theory, Rosen was led to reject the identification of science with what can be known through mathematics, even a mathematics liberated from earlier assumptions that had rendered it incapable of acknowledging the reality of life. It is necessary to develop new non-mathematical models based on semiosis, as Kalevi Kull called for.[42] It is also necessary to recognize the more fundamental representative capacity of stories. Stuart Kauffman argued in 'Emergence and Story: Beyond Newton, Einstein and Bohr' that all mathematics is limited by its quest to pre-state the configuration space of all possibilities, and this is impossible. There will always new or adjacent possibles coming into existence with the evolution of the universe, and this creative dimension of reality cannot be modelled through mathematics.[43] Rosen's arguments against formalism provide support for Kauffman's arguments. As Anton Markoš et al. noted in an essay on biosemiotics, stories are 'based on events, unique chances, irreversible decisions, individual cases and occurrences of "once and never more" type.'[44]

ROSENNIAN ANTICIPATORY SYSTEMS AND PEIRCIAN PHILOSOPHY

Rosen did not defend stories, or semiotics; his interest was in freeing mathematics and science from strictures deriving ultimately from Newtonian science that had elevated an impoverished surrogate universe of excessively abstract notions as the basis for characterizing the whole of reality. The only entailment allowed by Newtonian science is a recursive rule governing state succession. Causation (if one can call it that) 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 and that every system has a largest model from which every other model can be

[42] Kalevi Kull, 'Advancements in Biosemiotics: Where we are now discovering the basic mechanisms of meaning making'. In: *Gatherings in Biosemiotics*. Ed. Silver Rattasepp and Tyler Bennett, Tartu: University of Tartu Press, 2012, pp.11-24, p.21.
[43] Stuart Kauffman, 'Emergence and Story: Beyond Newton, Einstein and Bohr?' In: *Investigations*. Oxford: Oxford University Press,2000, pp.119–140.
[44] Anton Markoš et al. 'Towards a Darwinian Biosemiotics: Life as Mental Understanding', *Introduction to Biosemiotics: The New Biological Synthesis*, ed. Marcello Barbieri, 2008, ch.10, p.239.

effectively abstracted by purely formal means. This, he argued, has tended to cripple the advance of science, and most importantly, has made it impossible for science to comprehend life itself by denying the reality of final causes. He argued that the focus of biology should be on organization, not on the material components. Organization includes relations between material parts, relations between the effects of interactions of the material parts, and relations with the organism's ambience or environment and, very importantly, with time or temporal processes and possibilities associated with these unrepresentable in purely spatial terms. This is the condition for giving a place to final causes.

Recognizing a place for final causes, Rosen set out to model anticipatory systems, systems which do not simply react to their environments but anticipate and respond to what will happen in the future through a predictive model. He argued 'that an anticipatory behaviour is one in which a change of state in the present occurs as a function of some predicted future state, and that the agency through which the prediction is made must be, in the broadest sense, a model.'[45] A system capable of such behaviour is an anticipatory system. Rosen defined an anticipatory system as 'a system containing a predictive model of itself and/or of its environment, which allows it to change state at an instant in accord with the model's predictions pertaining to a later instant.'[46] Modelling anticipatory systems involves modelling systems that produce and repair their own components (in accordance with how Kant and Schelling understood living organisms), and to do so, have models of themselves and their environments (as von Neumann argued), and these models must also be modelled.

Such systems, Rosen showed, can be represented through synthetic models in which functional components are the direct product of the system.[47] In these models the components are context dependent, and cannot be reduced to

[45] Rosen, *Anticipatory Systems*, p.8.

[46] See Rosen, *Anticipatory Systems*, p.313.

[47] For a lucid exposition of the mathematics involved by one of Rosen's students, see A.H. Louie, 'Relational Biology' and 'Mathematical Foundations of Anticipatory Systems' in *Handbook of Anticipation: Theoretical and Applied Aspects of Use of the Future in Decision Making*, ed. Roberto. Poli, Springer, 2019, ch.10 & 45, pp.191-218 & 937-964. For another exposition, examination, partial critique but otherwise strong endorsement of Rosen's model, see Letelier, J.-C., Soto-Andrade, J., Abarzua, F.G., Cornish-Bowden, A., Cardenas, M.L., 'Organizational invariance and metabolic closure: analysis in terms of (M, R) systems', *J. Theor. Biol.*, 238, 2006: 949–961.

fractional parts conceivable independently of the models. Such systems are complex, but not as mainstream complexity theory understands complexity. Genuinely complex systems, Rosen argued, require multiple formal descriptions which are not derivable from each other, but presuppose each other, to capture all their properties. The example Rosen produced to illustrate this was his metabolism, repair, reproduction models (the M-R systems). These models consist of three algebraic maps, one of which represents the efficient cause of metabolism in a cell, another, the efficient cause of repair (that repairs damage to the metabolic processes), and the third represents replication which repairs damage to the repair process.[48] Each of these maps 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. The maps thus form a loop of mutual containment, and it is in relation to this system as a whole that it is then possible to identify functions. 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.'[49] Such models require the use of circular definitions or 'impredicativities' associated with sets which are members of themselves. In the past such definitions have been taken as defects to be eliminated from rigorous thinking in logic, mathematics and science, as in Bertrand Russell's theory of types as the solution to Russell's Paradox concerning the status of the set of all sets that are not members of themselves. On the basis of such models it is possible to appreciate the ability of complex systems to incorporate models of themselves in their environments into their behaviour, anticipating future events and correcting their behaviour as new information sheds light on the anticipatory process.[50]

Rosen's work concurs with Peirce's philosophy and biosemiotics in a number of ways. Viewing mathematics through Category Theory, especially as interpreted by Rosen, supports Peirce's claim that mathematics is essentially diagrammatic reasoning, and that it is about relations. His argument that mathematics cannot be reduced to syntactical relations but must have a

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[48] Rosen, *Life Itself*, p.248ff.
[49] Rosen, *Life Itself*, p.244.
[50] Robert Rosen, *Essays on Life Itself*, New York, Columbia University Press, 2000, p.199.

semantic aspect, that is, reference in some sense to 'objects' that are being modelled, conforms to Peirce's notion of semiosis as involving triadic relations between signs, objects and interpretants. That is, it enables mathematics itself to be understood through Peirce's notion of semiosis, and is more 'Peircian' than Peirce's characterization of mathematics as the science that draws necessary consequences from purely hypothetical states of things.

In the case of an anticipatory system, the system must have a model of itself in its relation to its environment with the model differentiating the organism from its ambience and defining this ambiance as the external world in terms of itself.[51] This model must be included in the model of this system. This accords with von Uexküll's notion of *Umwelt* constituted and delimited by 'functional circles' and biosemioticians' interpretation of this through Peircian semiotics, as Kalevi Kull and Howard Pattee have noted, [52] with the model being a sign or complex of signs in Peirce's sense.[53] In both Rosen's notion of modelling involving models and in Peirce's notion of signs defined through signs, there is self-reference, involving circular definitions or impredicativities. Such self-reference involves relations to relations, and both Rosen and Peirce upheld relational realism, in which physical reality is held to be essentially relational. On this view, relations have equivalent ontological status to what in the past had been regarded as totally sub-subsistent individuals, while individuals are now regarded as only existing through their relations.[54]

Most importantly, and on the basis of such relational realism, Rosen defended the reality of immanent final causes. And as Lucia Santaella Braga

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[51] Rosen, *Life Itself*, p.41.

[52] Kalevi Kull, 'Jakob von Uexküll: An introduction', *Semiotica* 134±1/4, 2001: 1-59, p.1, and Howard H. Pattee and Kalevi Kull, 'A biosemiotics conversation: Between physics and semiotics', *Sign Systems Studies*, 37(1/2), 2009: 311-331, p.326f.

[53] For an interpretation of von Uexküll's concepts of *Umwelt* and functional circles through Peircian semiotics, see Frederik Stjernfelt, *Diagrammatology: An Investigation on the Borderlines of Phenomenology, Ontology, and Semiotics*, Springer, 2007, ch.10, 'A Natural Symphony?'.

[54] The significance of such a relational view of nature and how this relates to Peirce's notion of semiosis as well as Rosen's relational biology has been greatly clarified by Eliseo Fernández in 'Taking the Relational Turn: Biosemiotics and Some New Trends in Biology', *Biosemiotics*, 3, 2010: 147-156. On the connection between relational biology and self-reference, see Eliseo Fernández, 'Biosemiotics and Self-Reference from Peirce to Rosen', *Eighth Annual International Gatherings in Biosemiotics*, June 23-28, 2008. https://www.yumpu.com/en/document/read/26655021/1-biosemiotics-and-self-reference-linda-hall-library (viewed 10th Sept. 2019).

has shown, Peircian semiosis presupposes final causation.[55] The reality of final causes in nature has been denied in the past by those taking mathematical physics based on Newtonian assumptions as the model for all science and identifying real science with the use of traditional mathematical models of reality. Other than diehard followers of Peirce, few people have accepted his effort to characterize the fundamental laws of nature as the product of habits in a way that implies a telos, and Peirce himself appears to have abandoned this view, if he ever held it, writing that 'it is unnecessary to suppose that habit taking is a primordial principle of the universe.'[56] Very few biologists took Jakob von Uexküll's defence of final causes based on his vitalism seriously. By advancing mathematics to be able to give a place to final causes, Rosen countered effectively what had become and still is a dogma.

ROSEN, THE PHILOSOPHY OF SCIENCE AND CAUSATION

However, it is not this that is most important for this argument since the argument does not involve equating science with the deployment of mathematics. What is more important for defending the scientific credentials of Peircian biosemiotics is Rosen's characterisation of the role of mathematics in science and work on causation and what is involved in modelling it, and through this work, his characterization of science.

The main goal of the logical positivists had been to define what is genuine science, and taking their model from physics their conclusion that science is essentially about making verifiable predictions using mathematics, associated with the deductive-nomological model of explanation, was largely based on the characterization of mathematics by Frege, Bertrand Russell and the early Ludwig Wittgenstein.[57] In assuming the goal of science is theory reduction, in which all particular theories would eventually be deducible from more general theories, they were implicitly committed beyond this epistemological

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[55] Lucia Santaella Braga, 'A new causality for the understanding of the living', *Semiotica,* 127(1/4), 1999: 497-519.

[56] C.S. Peirce, *Collected Papers*, 8 Vols. ed. Charles Hartshorne, Paul Weiss, A. W. Burks, Cambridge, MA.: Harvard University Press, 1931-1966, (electronic version), 6.262.

[57] This might seem like a caricature of logical positivism in light of Michael Friedman's effort to reassess it in *Reconsidering Logical Positivism,* Cambridge: CUP, 1999, but still I believe it does capture its essence.

reductionism to strong ontological reductionism, that all phenomena should be explained completely through physics, treating mathematics as a means for making measurable predictions or identifying reality with mathematical structures. This not only eliminated formal and final causes, but as Russell had already pointed out, efficient and material causes, and along with these, any place for agency or consciousness.[58] This characterization of genuine science was not really challenged by the early work of Karl Popper who argued that propositions are only scientific if they can be falsified through falsifiable predictions rather than be verified.

It was pointed out that logical positivism was logically incoherent because its foundational assumption, that only verified observational statements or logically valid deductions have any claim to providing knowledge cannot be verified either observationally or by logical deduction, and therefore cannot be defended by logical positivists. However, what really eliminated logical positivism from being taken seriously in the philosophy of science was that historians of science were able to show that the logical positivist's characterization of what science is and how it develops does not accord with real science. What they showed was that far from science being opposed to metaphysics, as Peirce argued, science is always based on metaphysics, either unexamined or critically examined. 'Find a scientific man who proposes to get along without metaphysics' Peirce wrote, 'and you have found one whose doctrines are thoroughly vitiated by the crude and uncriticized metaphysics with which they are packed' (CP: 1-129).

The demolition of logical positivism by historically oriented philosophers of science such as Ernst Cassirer, Alexander Koyré, Gaston Bachelard, Norwood Russell Hanson (who was strongly influenced by Peirce), Stephen Toulmin, Thomas Kuhn, Dudley Shapere, Imré Lakatos, Gerd Buchdahl and Paul Feyerabend, characterized by Nick Jardine as 'Kantians on wheels',[59] revived Kant's insight that observations presuppose questions that are formulated in terms of conceptual frameworks and focussed attention on the creation and evolution of concepts, in the case of Lakatos in *Proofs and Refutations*, on

[58] Bertrand Russell, 'On the Notion of Cause', *Mysticism and Logic,* Unwin: London, 1917, ch.9.

[59] See Nick Jardine in 'Hermeneutic strategies in Gerd Buchdahl's Kantian philosophy of science', *Studies in History and Philosophy of Science,* 34, 2003:183-208, 205.

mathematical concepts, challenging the focus by philosophers of mathematics on the axiomatization of mathematics.[60] In so doing, Hanson revived and accorded a central place to Peirce's notion of abduction, Kuhn introduced along with his famous distinction between normal and evolutionary science, the notion of 'exemplars', exemplary achievements which define good science,[61] and Lakatos introduced the notion of research programs based on commitment to hard-cores, basic ideas that subsequently are placed beyond questioning and assumed in research. Research programs are progressive when they lead to new questions, insights and predictions, and degenerating when they merely re-describe the achievements of other research programs. However, Feyerabend pointed out that research programs deemed to be stagnant can prove themselves in the long run.

These philosophers of science also challenged the logical positivists' characterization of the goal of science, arguing that it is comprehension or understanding rather than just making predictions. This demolition of logical positivism also demolished the defence of strong reductionism, the idea that science progresses by showing how more specific theories can be deduced from more general theories, ultimately from theories in physics, the form of reductionism Rosen was really arguing against. The main problem engendered by these anti-logical positivist philosophers was that in defending constructivism they tended to relativism, with Feyerabend explicitly defending a form of relativism (although this was not genuine relativism).

This relativism was challenged by Alasdair MacIntyre who argued that major advances in science could be judged as such through the historical narratives they made possible of past science, accounting for its achievements but also revealing why it failed, and why its failures could not be solved without a radical break with the assumptions of this earlier science.[62] Relativism also led to a revival of efforts to defend realism of various kinds, the most important of which involved giving a place to models in science and/or privileging causal

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[60] Frederick Suppe, 'Introduction', *The Structure of Scientific Theories,* 2nd ed. ed. Frederick Suppe, Urbana: Uni. of Illinois Press, 1977, pp.3-241.

[61] This was the original aspect of the notion of 'paradigms'. There was little new in either the notion conceptual frameworks or in the notion of traditions of enquiry into which scientists have to be socialized.

[62] Alasdair MacIntyre, 'Epistemological Crises, Dramatic Narratives and the Philosophy of Science', *The Monist,* 60(4), 1977: 453-472.

explanations as the defining features of science and required to achieve comprehension or understanding.[63] The later Karl Popper, defending the reality of propensities in nature, could be included here.[64] Mary Hesse reviving ideas on modelling from R.N. Campbell published in 1920,[65] Nancy Cartwright focussing on the capacities of nature, modelling and defending 'experimental realism',[66] Richard Boyd defending the role of metaphors and arguing for real causes, and Rom Harré defending the reality of causal powers and liabilities while also claiming a central role for analogies and models in science, were leading figures in this development. Harré argued for the identification of the powers and liabilities of kinds of beings, and explanations of these through analogies and models, as a defining feature of genuine science. He is particularly important because, along with defending realism and the role of modelling and causal explanations, he argued for emergent powers and liabilities and made significant contributions to post-reductionist science. His work was part of a revival of natural philosophy. As an opponent of the reductionism of the logical positivists, he strongly influenced psychology while influencing theoretical biologists such as Brian Goodwin.[67] Roy Bhaskar, a strong defender or realism and opponent of reductionism in social theory and the human sciences who inspired the critical realists, had been his student.

Harré defended the importance of metaphysics to science and aligned himself with Boscovich's dynamism. He argued the major task of science is to identify the powers and liabilities of natural kinds of being, including their

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[63] The change of direction and preoccupation with realism in the philosophy of science is evident in the comprehensive anthology produced fourteen years after Suppe's anthology, Richard Boyd, Philip Gasper and J.D. Trout, *The Philosophy of Science,* Cambridge: MIT Press, 1991. This trajectory should have led to the revival of natural philosophy, which it did in some cases but efforts along these lines had only very limited success. See Gare, 'Natural Philosophy and the Sciences', *Philosophies,* 3(4), Dec. 2018: 1-29. In this way Twentieth Century philosophy of science would have repeated the sequence from Hume's empiricism, to Kant's constructivism to Schelling's natural philosophy.

[64] For the similarities and differences between Peirce and Popper on propensities, see Richard W. Miller, 'Popper or Peirce?', *Brit. J. Phil. Sc.* 26, 1975: 123-132.

[65] Mary B. Hesse, *Models and Analogies in Science,* Notre Dame: Notre Dame Press, 1966.

[66] Nancy Cartwright, *Nature's Capacities and their Measurement,* Oxford: OUP, 1989, and *Nancy Cartwright's Philosophy of Science,* ed. Stephen Hartmann, Carl Hoefer and Luc Bovens, New York: Routledge, 2008.

[67] Gerry Webster and Brian Goodwin, *Form and Transformation: Generative and Relational Principles in Biology,* Cambridge: Cambridge University Press, 1996, *passim.*

powers to maintain themselves in existence.[68] These in turn were to be explained through generative mechanisms understood in terms of the powers and liabilities of other kinds of beings while still recognizing the emergent powers and liabilities of what is being explained.[69] In making this argument, Harré defended the notion of natural necessity. Recognizing natural kinds and natural necessity accords with Peirce's argument against nominalism that we must accept the reality of universals in each object being studied for science to be possible, the condition for recognizing the reality of relations and relations between relations, including possible relations. This new characterization of science, giving a privileged place to causation, led to a focus by philosophers of science on the nature of causation and causality. Bhaskar defended 'transcendental realism', claiming to be able to make claims about physical existence and causation associated with it on the grounds that these are the conditions for their being scientific explanations.[70] Effectively, this was a revival of Schelling's effort to 'naturalize the transcendental', without the dialectical dimension developed by Schelling under the influence of Fichte. Later, Bhaskar embraced and defended a form of dialectics.

Rosen characterized science as the quest to provide models of causal entailment, and this view can be seen in relation to these philosophers of science as a further advance in the philosophy of science, at the same time, recovering and advancing the earlier work on this by Schelling and then Peirce. Neither Hesse, Cartwright, Boyd, Harré nor Bhaskar offered a characterization of what is mathematics along with their characterization of causation and modelling, let alone explain its success and its limits in science. Nor have they explained the possibility of final causation emerging in nature where previously it did not exist. All this was provided by Rosen, who in doing so was also advancing a theory of modelling.[71]

It is in the context of these developments in the philosophy of science that the re-examination of Peirce's work on causation, and beyond that, Schelling's

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[68] See Rom Harré, *The Principles of Scientific Thinking*. Chicago: University of Chicago Press, 1970, p.110ff.

[69] R. Harré and E.H. Madden, *Causal Powers: A Theory of Natural Necessity*, Oxford: Blackwell, 1975.

[70] Roy Bhaskar, *A Realist Theory of Science*, Hassocks: Harvester Press, 1978.

[71] Rosen began his work in this area with, *Fundamentals of Measurement and Representation of Natural Systems*, New York: Elsevier North-Holland, 1978.

work on causation should be seen of as of major importance. In particular, the importance of Schelling's prioritizing the notion of 'community of causation', introduced by Kant in the second edition of the *Critique of Pure Reason,* over cause effect relations, which Schelling argued were abstractions from this community of causation, should be appreciated. Schelling then characterized causation within this community of causation as 'self-limiting' of activity, effectively prioritizing immanent causation. As Schelling put it, 'The chief problem of the philosophy of nature is not to explain the active in Nature (for, because it is its first supposition, this is quite conceivable to it), but the resting, permanent. Philosophy of Nature arrives at this explanation simply by virtue of the presupposition that for Nature the permanent is a limitation of its own activity.'[72] While Peirce offered an acute analysis and critique of received views of causation, pointing out the confusion between Aristotelian and post-Newtonian notions of causation, and offered definitions of efficient causation and final causation[73], it is also evident that he had not revived Schelling's notion of immanent causation. Existents are briefly mentioned by Peirce as 'entities' associated with 'the germ of a law', seen as emerging in nature through chance.[74] (Peirce, 1992: 210). This is the origin of those parts of nature which, through taking on habits, have become predictable and so can be characterized by generals. However, Peirce offered only brief suggestions about the general characteristics of these existents, despite acknowledging the importance of individuation and claiming that defining such characteristics is a major task of metaphysics. While he aligned himself with dynamism (defending Boscovich) and argued for the reality of dynamic atoms, suggested that matter might 'consist of vortices in a fluid which itself consists of far minuter solids, these, however, being themselves vortices of a fluid, itself consisting of ultimate solids, and so on in endless alternation',[75] gave a place to points and instants, mentioned objects of various kinds, referred to possibles, occurrences and collectives, molecules, organisms, minds and communities, no general claims

[72] Schelling, *First Outline,* p.17

[73] C.S. Peirce, *The Essential Peirce: Selected Philosophical Writings Volume 2 (1893-1913)*, ed. the Peirce Edition Project, Bloomington: Indiana Uni. Press, 1989, p.120.

[74] Charles Sanders Peirce, [1898] *Reasoning and the Logic of Things.* Ed. Kenneth Laine Ketner, Cambridge: Harvard University Press, 1992, p.210.

[75] Charles Sanders Peirce, *Philosophical Writings of Peirce*, ed. Justus Buchler, New York: Dover, 1955, p.68.

were made about existents as such or any consideration given to how existents sustain themselves in existence. Their endurance was accounted for as the habits of nature, rather than the immanent causation of existents themselves as self-limiting activities as in Schelling.

The absence of interest in immanent causation accounts for Peirce's concomitant lack of interest in the endurance of existents in nature, either in a static form generated by a balance of opposing forces, as with crystals, or actively, in the case of organisms which do not have such a balance and must continually exchange matter with their environments to maintain a balance and, as Schelling argued following Kant, are always actively engaged in maintaining (and developing) their forms. Consequently, Peirce could suggest that 'all this universe is perfused with signs, if it is not composed exclusively of signs',[76] failing to draw a distinction between the signs of death of an organism and its death. Peircian biosemioticians, who almost universally have integrated Peirce's ideas on semiotics with systems theory, Gregory Bateson's bioanthropology[77] and later, Maturana and Varela's notion of autopoiesis (bringing their ideas closer to Schelling), have ignored this gap in Peirce's work.

CAUSATION AS CONSTRAINT

For biosemioticians, the most significant work on causation or causality, although it has not always been characterized as such, has been Howard Pattee's notion of enabling constraints, a notion that echoes without being influenced by Schelling's notion of 'limiting' of activity (which is likely to have been influenced by Anaximander's conception of the cosmos as evolving through the limiting of the unlimited). In the context of dealing with the measurement problem in quantum theory, Pattee took up the notion of constraints from Michael Polanyi and argued that it is the peculiar constraints associated with making measurements that transform matter into symbols.[78] Such measurement cannot be explained in terms of laws of physics and

[76] C.S. Peirce, *The Essential Peirce*, 2, p.394

[77] Hoffmeyer, ed., *A Legacy of Living Systems: Gregory Bateson as Precursor to Biosemiotics,* Biosemiotics Volume 2, Springer, 2008.

[78] Howard Hunt Pattee and Johanna Rączascek-Leonardi. *Laws, Language and Life: Howard Pattee's classic papers on the physics of symbols with contemporary commentary*, Dordrecht: Springer, 2012, p.69ff.

involves an epistemic cut whereby constraints are put in place in order to make measurements. He generalized the notion of such constraints to characterize what is involved in all hierarchical order, arguing that new constraints could be enabling, creating new possibilities. The higher orders with their new possibilities exist in the process of constraining the lower orders and cannot be understood in terms of the lower orders. As Polanyi pointed out, it is impossible to understand a machine through the study of the chemistry of its components; there is a different level of ordering involved in the organization of the machine. It is by conceiving causation or causality through constraining that downward causation can be made comprehensible.[79] Pattee argued that with life, such downward causation takes an unusual form. While the constraints in the hierarchical order in atoms, molecules, crystals, mountains and stars are based on forces generated by their configuration, in living organisms, 'the upper level exerts a specific, dynamic constraint on the details of the motion at lower levels, so that the fast dynamics of the lower level cannot simply be averaged out.'[80] These are 'non-holonomic' constraints.

The notion of hierarchical order through constraints was taken up by a number of theorists, including Tim Allen, Stan Salthe and Alicia Juaerro. Salthe argued that emergence, in both development and evolution, is associated with interpolation of new constraints between processes of shorter and longer scales and faster and slower rate processes, modifying both the longer and the shorter scale processes. Granting a place to scalar hierarchies was then used to characterize and explain final causes. As Salthe observed: 'constraints from the higher level not only help to select the lower level-trajectory but also pull it into its future at the same time. Top-down causality is a form of final causality.'[81] He argued that the ultimate final cause is to transform negative entropy into entropy. Building on this work, Juaerro

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[79] See H.H. Pattee, 'Causation, Control, and the Evolution of Complexity', In: *Downward Causation,* ed. Peter Bøgh Andersen et.al., Langelandsgade: Aarhus University Press, 2000, ch.4. See also J.L. Lemke, 'Material Sign Processes and Emergent Ecosocial Organization' in the same anthology, ch.9. This links hierarchy theory to semiosis.

[80] Pattee and Rączascek-Leonardi. *Laws, Language and Life*. p.93.

[81] Stanley N. Salthe, *Development and Evolution: Complexity and Change in Biology*. Cambridge: MIT Press, 1993, p.270.

explicitly argued that all causation is constraining.[82]

Effectively, this notion of causation as constraining was a rediscovery of Schelling's characterization of causation as limiting of activity generating individuals which, like eddies in a stream, are to some extent self-causing, with living individuals asserting themselves against their environments and exchanging material with their environments, actively maintaining their forms, being both cause and effect of themselves, and in so doing, defining their environments as their worlds. As Schelling put it, '[t]he organism has an external world because there is an original duplicity within it' while '[d]ead matter has no external world, it is absolutely identical and homogeneous with the whole whose part it is.'[83] This notion of "world" clearly anticipates the notion of *Umwelt* developed by Jakob von Uexküll.

While Pattee himself found the work of the biosemioticians problematic,[84] Salthe who first used this notion of constraints to link Pattee's work with that of the Peircean biosemioticians continues to defend their work.[85] The notion of causation as constraining was also deployed by the biosemiotician Terrence Deacon in *Incomplete Nature: How Mind Emerged from Matter.*[86] Such explanations did not satisfy Barbieri. Salthe was one of the targets of Barbieri's critique of biosemiotics.

Early in his career, Rosen worked with Pattee, and also characterized causation as constraining. Pattee wrote a long critical review of Rosen's later work, tracing the development of his more critical attitude to mainstream science.[87] 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,

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[82] Alicia Juarrero, *Dynamics in Action: Intentional Behaviour as a Complex System.* Cambridge: MIT Press, 2002, p.131ff.

[83] F.W.J. Schelling, *First Outline of a System of the Philosophy of Nature,* trans. Keith R. Petersen, (New York: SUNY Press, 2004), p.112n. and Arran Gare, 'From Kant to Schelling to Process Metaphysics: On the Way to Ecological Civilization', *Cosmos & History: The Journal of Natural and Social Philosophy*, Vol.7(2), 2011: 26-69, p.55.

[84] H.H. Pattee, 'Response' by H. H. Pattee to Jon Umerez's Paper: 'Where Does Pattee's "How Does a Molecule Become a Message?" Belong in the History of Biosemiotics?', *Biosemiotics,* 2, 2009: 291-302.

[85] Salthe, *Development and Evolution*, p.13ff. Salthe, S. 2012. 'On the Origin of Semiosis'. *Cybernetics and Human Knowing,* 19(3): 53-66.

[86] Terrence W. Deacon, *Incomplete Nature: How Mind Emerged from Matter*, New York: Norton, 2013, passim.

[87] Howard H. Pattee, 'Laws, Constraints, and the Modeling Relation – History and Interpretations', *Chemistry and Biodiversity,* 4 (2007): 2272-2295.

ignoring the work they had done together. 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.'[88] Rosen never abandoned the notion of causation as constraint. In 1988 he published an essay 'Constraints and the Origin of Life',[89] defending the role of constraints after having published his book *Anticipatory Systems* in 1985. Similarly, he continued to develop the notion of anticipatory systems after having changed his focus to life itself, defending it in *Essays on Life Itself* published in 1999 after having published *Life Itself* in 1991.[90] However, Rosen did show a lack of interest in 'material' causes as these had been characterized by Aristotle, and I will suggest later that this could be grounds for complaint.

Seen as building on his work on constraints, Rosen's later work can be seen as dealing with multiple, co-extensive processes operating on much the same scale and so are not simply in hierarchical order. They are components of each other while not being reducible to each other, constraining each other while being the conditions for each other. That is, it is a heterarchical order, a notion that has been developed by Y.P. Gungi, K. Sasia and S. Wakisaka in a way that accords with and further supports Rosen's work.[91] The hard core of Rosen's research program (in Lakatos' sense) that led him to this conclusion was the argument of John von Neumann that living beings must have models of themselves, together with the view that the goal of science is successful modelling and that therefore it is necessary in modelling life to model systems that have models of themselves. Recognizing the need to model processes that are components of each other but not reducible to each other, in such a way that this sustains and is organized through a model of itself, is associated with a

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[88] 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.

[89] R. Rosen, 'Constraints and the Origin of Life', *Lectures in Theoretical Biology*, ed. Kalevi Kull and Toomas Tiivel, Valgus: Tallinn, 1988, pp.22-26.

[90] Robert Rosen, *Essays on Life Itself,* Columbia: Columbia Uni Press, 1999, p.'s 85 & 199.

[91] See Y.-P Gunji, K. Sasai, and S. Wakisaka, 'Abstract heterarchy: time/state-scale next term re-entrant form', *BioSystems* 91, 2008: 13–33

complex temporality of becoming incomprehensible through mechanistic explanations. 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 these assumptions by Newton and as it is still understood 'boils down to the assertion that *every natural system is a mechanism*.'[92] Living beings cannot be modelled through a largest model. While questioning Rosen's characterization of reductionism as mechanistic, my contention is that it is acknowledging this complexity with this more complex notion of causality that makes intelligible semiosis as it was characterized by Peirce and deployed by Peircian biosemioticians.

Attempting to defend this through Rosen's modelling of anticipatory systems is problematic in one respect; Rosen clearly regarded his work as unfinished. He intended to write a book on ontology completing his work on his theory of life itself, but he died before writing this. I have argued elsewhere and suggested earlier that this ontology would have been a form of process metaphysics, giving a place to processes that are essentially relational and not only in hierarchical order, but which can also be heterarchical, co-extensive and co-durational components of each other.[93] That is what his models were modelling.

INTERPRETING PEIRCIAN BIOSEMIOTICS THROUGH ROSEN'S NOTION OF CAUSATION

It is this notion of complexity that is required to model the causation associated with semiosis as conceived by Peirce. Although Peirce referred to efficient and final causes when discussing semiosis and grappled with the nature of causation, he did not offer a causal analysis of semiosis, although he frequently referred to causation in the context of discussing semiosis. Menno Hulswit in the one major study of Peirce's work on causation and causality pointed out that the reason for this lack was that Peirce followed Comte and took

[92] Rosen, *Life Itself*, p.103.

[93] See Arran Gare, 'Overcoming the Newtonian paradigm: The unfinished project of theoretical biology from a Schellingian perspective', *Progress in Biophysics and Molecular Biology*, 113 (2013): 5-24.

mathematics, which included logic (which he characterized as semiosis), as the most abstract and therefore the ultimate science, above metaphysics and the natural sciences, providing the foundations for them, and therefore not explicable through the categories of metaphysics or explicable through the natural sciences.[94] If this is the case, I am suggesting that Comte's hierarchical organization of knowledge should be rejected for Schelling's (and Hegel's) conception of the organization of knowledge as circular, in which the premises have to be defended by the conclusion or conclusions developed on the basis of these premises.

Peirce's starting point, building on the work of Kant and Schelling but utilizing the new developments in symbolic logic, was in characterizing the logic of science. To achieve this, he characterized logic as semiosis and characterized semiosis so that the highly developed signs associated with science could be seen to have evolved from more basic signs and more primitive forms of semiosis. In 1907 Peirce offered his most general definition of a sign as that which 'mediates between an object and an interpretant; since it is both determined by the object *relatively to the interpretant,* and determines the interpretant *in reference to the object,* in such wise as to cause the interpretant to be determined by the object through the mediation of the "sign"'.[95] He also suggested that what is communicated is a form, or as he put it:

> That which is communicated from the Object through the Sign to the Interpretant is a Form; that is to say, it is nothing like an existent, but is a power, is the fact that something would happen under certain conditions. …. In the Sign it is embodied only in a representative sense, meaning that whether by virtue of some real modification of the Sign, or otherwise, the Sign becomes endowed with the power of communicating it to an interpretant.'[96]

It is important to emphasize here 'this tri-relative influence', based on Peirce's fundamental categories of Firstness, Secondness and Thirdness, is not 'in any way resolvable into actions between pairs'.[97] Peirce argued that it is this triadic relation associated with signs that characterizes life, and it is only in terms of the origin of this triadic relation that the origin of life can be explained. As he

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[94] Menno Hulswit, *From Cause to Causation: A Peircian Perspective*, Dordrecht: Kluwer, 2002, p.198.
[95] *The Essential Peirce*, 2, p.410.
[96] C.S. Peirce, MS 793:1-3, c. 1905, *The Essential Peirce, 2,* p.544, n.2.
[97] Peirce, *Philosophical Writings of Peirce*, p.282.

argued,

> [T]he problem of how genuine triadic relationships first arose in the world is a better, because more definite, formulation of the problem of how life first came about; and no explanation has ever been offered except that of pure chance, which we must suspect to be no explanation, owing to the suspicion that pure chance may itself be a vital phenomenon. In that case, life in the physiological sense would be due to life in the metaphysical sense.[98]

Integrated with Jakob von Uexküll's claim that living organisms have an *Umwelt* and cannot be fully understood unless this tri-relative influence is acknowledged, is the hard core of the Peircian biosemiotics research program, underpinned by Peirce's metaphysics.

Elsewhere Peirce refers to a sign as 'representamen', a 'representation' or a 'ground,' and some Peircians now refer to it as a 'sign vehicle' to clarify that for Peirce, it is only some element of this which enables it to signify. The term 'interpretant', which functions as another sign, implies there is some kind of comprehension (implying 'grasping', mental or otherwise) involved. Peirce's identification and classification of ten different sign types has been brilliantly explicated by Torkild Thellefsen, utilizing Peirce's basic categories to show how all these signs are related to each other, with the signs of culture presupposing and being based on the more primitive signs that humans have in common with animals and plants. However, what this study reveals is the need to revise these if they are to be applicable to elementary forms of life.[99] For instance, the most basic sign of all, a 'Qualisign' as Firstness of Firstness as a mere quality, cannot be the bare experience of a colour, but could be a discernible difference, or more fundamentally, a felt attunement or discordance associated with resonance or absence of it, which might equate to the feelings of 'yum' or 'yuk'.

As noted, Hulswit interpreted Peirce as believing that while it is possible to characterize this causal process through semiosis, he did not believe that semiosis requires a causal explanation. It is not possible to treat semiosis as one or more dyadic causal relations, either between a substance (i.e. agent) and its effects, or between events. For instance, Peirce would not accept that if an

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[98] CP 6.322, c.1909, quoted by Vincicius Romanini and Eliseo Fernández, 'Introduction', *Peirce and Biosemiotics: A Guess at the Riddle of Life*, Dordrecht: Springer, 2014, pp.1-8, p.2.

[99] Torkild Leo Thellefsen, 'C.S. Peirce's Evolutionary Sign: An Analysis of Depth and Complexity within Peircian Sign Types'. *Semiotics, Evolution, Energy, and Development.* 1(2): December 2001.

event A causes event B and event B causes event C, then C is the interpretant of 'sign' B with respect to 'object' A. This is just a sequence of dyadic relations. Nor would he accept that semiosis occurs when the initial state of a system results in a final state, since the final state simply replaces the initial state. For Peirce, the final state has to retain its relation to the initial state. It is for this reason that, as David Lidov put it, 'Peirce pictures signs in the mind as overlapping like fields or waves.'[100] Hulswit concluded from this: 'Object, sign, and interpretant cannot be causally related one to another, because together they constitute what it is to be a sign. Since semiosis is irreducibly triadic, its elements cannot, *qua* semiosis, be causally related.'[101] While Peirce did refer to causes, Hulswit argued he really thought in terms of causation or durational causal processes as defended by philosophers such as C.D. Broad and Alfred North Whitehead and (later elaborated and defended in more detail by Dorothy Emmet),[102] rather than cause effect relations.[103] A durational causal process, rather than being merely a sequence of events, involves 'complexity, teleology, and coherence.'[104] In this, semiosis provides the formal structure of causation, but Hulswit does not show how causality can generate complexity, teleology and coherence, although in a later work he pointed out that Peirce although never explicitly formulated a theory of causation, was offering an .ingenious middle way between Aristotelian and the modern scientific concept of causation.[105]

While Hulswit is certainly right in claiming that Peirce believed that it is impossible to give a causal account of semiosis in terms of dyadic cause-effect relations, Peirce does refer to Dynamical Objects determining the significant character of a sign.[106] As he argued 'we have to distinguish the Immediate Object, which is the Object as the Sign itself represents it, and whose Being is

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[100] David Lidov, 'Music and Consciousness', *Semiotics as a Bridge Between the Humanities and the Sciences,* ed. Paul Perron et.al. New York: Legas, 2000, pp.229-241, p.235.
[101] Hulswit, p.197.
[102] Dorothy Emmet, *The Effectiveness of Causes,* London: McMillan, 1984, and *The Passage of Nature,* Houndmills: Macmillan, 1992, p.35ff.
[103] Hulswit, p.68 & p.174ff.
[104] Hulswit, p.200.
[105] Meno Hulswit and Vincius Romanini, 'Semiotic Causation and the Breath of Life', in *Peirce and Biosemiotics,* ed. Romanini and Fernández, pp.95-126, esp.p.105.
[106] C.S. Peirce, *The Essential Peirce,* 2, p.409.

thus dependent upon the Representation of it in the Sign, from the Dynamical Object, which is the Reality which by some means contrives to determine the Sign to its Representation.' [107] Dynamical Objects were further characterized as that which Dynamical or Objective science can investigate.[108] They are presupposed by Immediate Objects (perceived, imagined or thought about), but can only be indicated by a hint or by being indicated, leaving the interpreter to find them by 'collateral experience'.[109] Peirce also characterizes a sign as a power of communicating a form to its interpretant, that is, as a formal cause. [110] While the notion of causation as used here might appear problematic, it is clearly important to Peirce, and it does need to be examined. The formal structure of causation in semiosis needs to be investigated and characterized.

The problem in achieving this is the inadequacy or lack of development of Peirce's characterization of causation (or causality). After criticising received views about causation, pointing out the confusion due to the failure to properly appreciate the radical difference between and then confusing Aristotle's and Newton's understanding of causation, Peirce suggested there are three forms of causation whereby events come to pass: external compulsion, inward nature and irregularity.[111] Later, reworking Aristotle's doctrine of four causes, Peirce divided causes according to whether they were defining or individuating, and whether they were internal or external. He characterized efficient cause as the individuating external cause and the final cause as the defining external cause, and the formal cause or form as the defining internal cause and the material cause as the individuating internal cause. Peirce held these internal causes to be part of what is caused.[112] 'Internal cause' appeared to correspond to what earlier he had referred to as 'inward nature'. However, Peirce had little to say on these internal causes. It appears that Peirce lacked the notion of 'self-organization', or dealt with it as only self-reinforcing habits.

My claim is that such internal causes understood as immanent causation

[107] C.S. Peirce, *Collected Papers*, 8 Vols. Ed. Charles Hartshorne, Paul Weiss, A. W. Burks, Cambridge, MA.: Harvard University Press, 1931-1966, (electronic version), 4.536.
[108] C.S. Peirce, *The Essential Peirce*, 2, p.495.
[109] C.S. Peirce, *The Essential Peirce*, 2, p.480.
[110] C.S. Peirce, *The Essential Peirce, 2,* p.544, n.22.
[111] C.S. Peirce, *The Essential Peirce*, 1, p.299.
[112] C.S. Peirce, *The Essential Peirce*, 2, p.395f.

can be understood through Rosen's characterization of causation. Rosen's understanding of causation as entailment built on the notion of causation as constraining, thereby giving a place to downward causation, offered a conception of the world in which along with hierarchically ordered processes there are also heterarchically ordered co-becoming processes irreducible to each other while being components of each other. Such complex processes and the causation associated with these can anticipate the future, constraining activity in the present to respond to what is anticipated rather than simply reacting to what is in the present. While semiosis can be explained as a special kind of causality, it is only through the highest form of semiosis involving symbols, including developments in mathematics, that such causality can be comprehended; that is, that nature though us can comprehend itself to this extent.

To begin with, as I have argued, Rosen accepted Pattee, Salthe and Juarrero's conception of causation as constraining and thereby capable of forming emergent hierarchies. However, beyond this, Rosen allowed a place for heterarchical causality associated with processes of a system being components of each other but irreducible to each other, constraining by continuously modulating each other in accordance with a model predicting future states. As noted, Rosen was pre-eminently concerned to model systems that have models of themselves. The model, which is, as Rosen put it, the agency through which the prediction is made, and so is the equivalent of a Peircian sign. What is involved in life as modelled by Rosen is a complex triadic causality in which there is an entanglement of metabolic processes and regulating processes, differentiating and maintaining the system from its ambient environment, generating a model of itself as an essential part of this, anticipating thereby its own future possibilities within its ambience and reflexively regulating this whole process to realize possibilities. As an anticipatory system it maintains its metabolism and repairs itself and the repair process in this way and in doing so, reproduces the model of itself. This exemplifies the triadic nature of semiosis as it was characterized by Peirce, with the model being a sign of the living system and its ambience and the realized possibility or possibilities, which includes the model, being the interpretant. As such the model functions again as a sign, although represented mathematically there can be no place for creativity of the interpretant in response to unanticipated possibilities. Nevertheless, Rosen's characterization of this shows how signs can emerge, and with the emergence of signs, this process opens up a new dimension of not just individual signs and their interpretants, but of sign relationships. Ultimately, as Karl-Otto Apel put it in his exposition of Peirce's philosophy, the triadicity of semiosis opens up 'the entire field of intersubjective communicative understanding.'[113] This triadic causality, I claim, in accounting for Peircian semiosis, is the missing dimension that in conjunction with hierarchy theory can account for the emergence and evolution of life, including the evolution of humanity, human cultures, philosophy, mathematics and science.

What Rosen added to the hierarchy theorists' conception of life through his conception of processes co-existing as components of each other but not reducible to each other, was self-reference in which, as Eliseo Fernández put it, 'relata relate to themselves through their partial relations to other relata.'[114] While Salthe showed one of the conditions for final causes, that is, downward causation through emergent constraints, his characterization of the inexorable tendency to degrade energy gradients as the telos of life misses something, just as does treating end-points modelled in mathematics as attractors as final causes. Rosen introduces into the picture some primordial interest by the living organism through this self-reference in maintaining and developing its own organization against the tendencies within its environment or 'ambience' to eliminate it, anticipating the future in relation to itself, enabling it to utilize its present environment for its own ends; that is, to maintain and impose its form and reproduce itself. This accords with the conception of life defended by the philosophical biologist Hans Jonas.[115]

This is a stronger and more adequate notion of final cause than provided by Salthe. As Stuart Kauffman pointed out, self-reference in relation to the future is the condition for the organism to 'manipulate the world on their own behalf.'

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[113] Karl-Otto Apel, *Charles S. Peirce: From Pragmatism to Pragmaticism,* trans. John Michael Krois, New Jersey: Humanities Press, 1995, p.129.

[114] Eliseo Fernández, 'Taking the Relational Turn: Biosemiotics and Some New Trends in Biology', *Biosemiotics,* 3, 2010: 147-156, p.154.

[115] Hans Jonas, *The Phenomenon of Life: Toward a Philosophical Biology,* Chicago: Uni. of Chicago Press, 1966, Fourth Essay and Fifth Essay.

Kauffman argued 'semantics enters the universe as the agents coevolve and behave on their own behalf with one another in the unfolding of the biosphere.'[116] This self-interest is manifest in organisms distinguishing 'yum' from 'yuk' and responding accordingly, Kauffman argued. He noted that with 'yuk and yum, we are not far from C.S. Peirce's meaning laden semiotic triad'.[117] While the language is slightly different, with Rosen referring to this self-reference as the organism's model of itself in its environment, Rosen's characterization of life concurs with that developed by the biosemioticians. By adding the extra dimension to the notion of causation as constraining to give a place to self-reference and thereby a more adequate account of final causes he was able to explain Peircian semiosis.

To apply Rosen's notion of causation to explaining semiosis requires some modification of the traditional Peircian categorization of sign, object and interpretant. In a generally favourable review of Søren Brier's book, *Cybersemiotics,* a major work in biosemiotics, Salthe argued against the usual application of the categories of Firstness, Secondness and Thirdness in characterizing semiotics, with the sign being Firstness, the object Secondness and the Interpretant Thirdness:

> While all three categories would in principle be present simultaneously in all situations, there is a sense of First being — first!, in some sense a primordial ground, even if it is temporally synchronic with the other categories in many applications. A materialist cannot feel the justness of a sign that 'stands for' something to some other entity ["... whereby a first and a second are brought into relation..." (Peirce CP, 6.32-3)] implicitly antedating that which it stands for. … [C]learly the object (which could be a process or relationship) would need to be First, and, furthermore, it needs to be confronted by a material / physical system of some kind if it is to be interpreted. This is why I have advanced the 'system of interpretance' … as the creator of interpretants and as co-creator, with the object, of the sign, which then becomes Third.[118]

While this does not accord with Peirce's usual way of categorizing the components of semiosis, it does accord with Peirce's evolutionary cosmology in

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[116] Stuart Kauffman, 'A Physics of Semantics', *Investigations,* Oxford: OUP, 2000, p.114.
[117] Kauffman, 'A Physics of Semantics', p.111.
[118] Stanley N. Salthe, 'Inside/Outside: Review of *Cybersemiotics: Why Information Is Not Enough*', by Søren Brier, University of Toronto Press, 2008', *Biosemiotics,* 2(2), July 2009: 247-253.

which he characterized 'germinal being', a flux of 'absolutely undefined and unlimited possibility -- boundless possibility'[119] as Firstness, with 'Actual reactive existence' of 'objects' or 'existents' that resist actions emerging from this, forming a dyadic relation, belonging to the category of Secondness. This Secondness was then seen as the precondition for the emergence of signs by which these 'objects' could be related to each other and thereby their behaviour predicted. Here, as Salthe argued, signs belong to the category of Thirdness rather than Firstness.

Rather than being materialist or Idealist, this accords with Schelling's characterization of his philosophy as overcoming the oppositions between materialism and spiritualism, realism and Idealism. My contention is that this is how Peirce's philosophy should be understood, germinal being corresponding to Schelling's 'unprethinkable Being' and perhaps to the quantum vacuum, or to John Archibald Wheeler's notion of quantum foam. Furthermore, as I have suggested, Peirce should have paid far more attention to how existents, which should be thought of as enduring processes maintaining structures or forms rather than 'things' or 'objects', continue in existence, following Schelling in recognizing some existents as 'dead matter' characterized by stable balances of opposing forces, others chaotic, and others, alive, actively maintaining their form in interaction with their environments.

It is important to emphasise that Rosen, like Schelling, was totally rejecting Cartesian dualism, so that organism's 'ambience' as he characterized its environment, was not seen as totally separate from it, but as a differentiation within a broader process by which the organism separates itself and maintains this separation within this process, in so doing, dividing the subjective from the objective.[120] In this process, the organism has to maintain a model of itself, with this model being part of this process while being partially autonomous and having this autonomy maintained. The model as the condition for the organism to differentiate itself from the ambient environment, modelling this differentiation and the relationship between the organism and its ambiance, not

[119] C.S. Peirce, *Collected Papers*, 8 Vols. Ed. Charles Hartshorne, Paul Weiss, A. W. Burks, Cambridge, MA.: Harvard University Press, 1931-1966, (electronic version), 6.127.

[120] This is described by Rosen in 'Drawing the Boundary Between Subject and Object: Comments on the Mind-Brain Problem', in: *Essays on Life Itself*, New York: Columbia University Press, 1999, ch.5.

just in the present but in the future, thereby anticipating developments in this ambience and in itself and responding to what has been anticipated, is not just a sign but a sign complex of ' Dicisigns'. Dicisigns are signs combining two signs, relating to the same object but in different ways and forming an irreducible whole.[121] Sign complexes can consist of codes and cognitive structures. As such they facilitate the production of more specific signs involved in a process of distinguishing significant aspects within the organism and within its ambient environment, anticipating and then responding to what is anticipated by constraining activity in the present. In doing so, organisms produce chemicals, grow, move and act, and in some cases, internalizing action to think and engage in critical dialogue. This 'activity' involves creating, maintaining, modifying and then reproducing structures which make such semiotic 'activity' possible. This 'activity' in turn creates, maintains, modifies and reproduces these structures, including models in all their complexity.

What is responded to and to some extent causes the response can be characterized as the 'Dynamical Object', following Peirce, but following Schelling, would be better characterized as the 'dynamical process', a 'community of causation' that includes the differentiation by the organism from its environment and also what is differentiated in this environment. That is, following Schelling, Peirce should have addressed the fundamental problem of individuation (a problem which he clearly recognized) as a condition for, and what can be augmented by, semiosis. This 'dynamical process' appreciated as such can allow that we ourselves, in trying to understand this process, are part of what we are striving to understand, achieving thereby self-understanding.[122]

In light of advances in the Schelling tradition of science, this dynamical process should be seen as, among other things, a transformation of negentropy into entropy as characterized by Ilya Prigogine, with the organism organized to

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[121] That Dicisigns are central to biology has been argued by Frederik Stjernfelt. See 'The Evolution of Semiotic Self-Control: Sign Evolution as the Ongoing Refinement of the Basic Argument Structure of Biological Metabolism', *The Semiotic Species Evolved*, *Biosemiotics 6*, ed. Thresa Schilhab, Frederik Stjernfelt and Terrence Deacon, Springer, 2012, ch.3, p.44f.

[122] This whole issue was taken up again by Gilbert Simondon who, while focusing on information, defined it is such a way that it could be seen as commensurable with Schellingian thought and thereby with Peircian biosemiotics. See Yuk Hui, 'The Parallax of Individuation: Simondon and Schelling', *Angelika: Journal of the Theoretical Humanities*, 21(4), 2016: 77-89.

partially control and utilize this transformation to maintain structures able to control this transformation to serve its own continued existence. In being taken into account and responded to by the organism, which is also a component of this dynamical process, aspects of this dynamical process come to be accorded significance as one or more Immediate Objects, or 'proto-objects' in the case of single-celled organisms, plants and simple multi-celled organisms (such as the appreciation by paramecium of acidity associated with carbonic acid, which functions as a sign of where food can be found and ingested). The response based on anticipation through the model, or specific signs facilitated by this model, is the interpretant of the object or proto-object (in the case of paramecium, making more turns to keep it in the vicinity of food), reproducing this specific sign and the entire model, or possibly, a modified, improved sign, conforming to Peirce's triadic characterization of semiosis.

It is through explaining this process and interpreting it as an example of semiosis that Rosen's notion of causation explains not only the triadic nature of semiosis as characterized by Peirce, but how the end of the semiotic process remains related to the beginning. In the differentiation of systems from their ambience and maintaining this through models of themselves in their environments, aspects of dynamical objects of this community of causation of which organisms are part are accorded significance through modelling activity, and to some extent the dynamical objects are the efficient causes of the interpretants of what is signified, without being completely separate from or being completely determined by them. They are caused by them only insofar as the interpretants conform to some extent to pre-existing models which, also through constraining of activity, are sustaining the partial autonomy of these living systems from their ambience, enabling them to respond effectively to what has then become their worlds. The models, which are not only signs but also interpretants (or complexes of these), are maintained and developed over a longer duration than particular instances of semiosis, linking together each act of semiosis.

As signs or sign systems, models also relate to each other as signs, that is, in Rosen's terminology, syntactically, while simultaneously being produced as signs by dynamical objects or processes and signified aspects of these. Retaining a memory of the past and anticipating the future of what they model and being kept in existence, models also are involved in constraining (without completely determining) the activities of these living systems, responding to what is anticipated, facilitating their survival, repair and reproduction. In the process they can be further developed, along with the living systems of which they are a part. Metabolism, repair and reproduction as processes are components of each other made possible by models that constrain them, but not reducible to each other, keeping each other in existence, each performing a function. They are 'closed to efficient causation', in Rosen's sense. As such, a living process with its semiosis cannot be reduced to nothing but the change from one state of a system to another, which simply replaces the original state (as physicists since Newton have conceived physical processes). It is a process that involves a triadic causation with relations between relations. As Eliseo Fernández has cogently argued, such relations can only be recognized as possible when relations are recognized as real, and entities are only real in relation to other entities.[123] Models continue to guide by constraining activities of the living system to realize selected possibilities, and possibly, reveal new possibilities. And as Fernández pointed out, this is 'modulation', a 'more general form of regulation, in which *one process exerts continuous regulation upon another process*.'[124] This is semiosis as Peirce characterized it, with models as signs being continually active as constraints and relating the beginning of any instance of semiosis to its end, the completed interpretant.

AVOIDING THE 'FALLACY OF MISPLACED CONCRETENESS'

This interpretation of Peircian semiosis through Rosen's characterization of causation and vice versa is simplified for clarification, incorporating the simplifications of both Rosen's and Peirce's own theories. These simplifications should be recognized as abstractions, and as Alfred North Whitehead warned in identifying the fallacy of misplaced concreteness, should not be taken as concrete reality. In developing his theory, Rosen began by considering models in relation to basic forms of life, while Peirce characterized semiosis to begin

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[123] Eliseo Fernández, 'Taking the Relational Turn: Biosemiotics and Some New Trends in Biology', *Biosemiotics*, 3, 2010: 147-156, p.151.

[124] Eliseo Fernández, 'Evolution of signs, organisms and artifacts as phases of concrete generalization', *Biosemiotics*, 8, 2015:91-102, p.94.

with as one semiotic act in abstraction from all other acts of semiosis, although his whole approach was designed to show how each semiotic act, resulting in an interpretant as sign, paved the way for further semiosis. Furthermore, Rosen's relational approach to life focusing on heterarchy abstracted away from material causes and from different hierarchical levels which are both essential to heterarchical levels and interact with them. Such simplifying abstractions and simplifications are necessary to illuminate the principles that are operating. Simplifying abstractions are a necessary part of science, the fruitfulness of which is exemplified in the work of Galileo and Newton, particularly in Newton's explanation of the observations of Mars as due to its elliptical orbit around the Sun explained by his three laws of motion, ignoring all other bodies in the solar system. Such abstractions were enormously fruitful in Bohr's initial model of the atom based on quantum theory, focussing on the simplest atom, hydrogen, and initially ignoring relativity theory.

In reality, there is more to even the most primitive forms of life than metabolism, repair and reproduction and the model that is an essential component of these processes. And semiosis involves complexes of semiotic acts usually in hierarchical order, with particular semiotic activities taking place in the context of broader semiotic activities (or, using the language of von Uexküll, functional circles), and models as characterized by Rosen and interpreted as Peircian signs should be understood accordingly. This is one reason why Peircian biosemioticians embraced the work of Gregory Bateson, who in seeing living beings as communicative systems by themselves had also implicitly recognized the triadicity of relations in semiosis without using this vocabulary.[125] What Bateson added along with cybernetics was an appreciation of the complexity of semiosis. As L.E. Bruni wrote in his contribution to the biosemioticians' anthology on Bateson, *A Legacy of Living Systems*, characterizing Bateson's appreciation of this complexity:

> Semiosis or communication processes are multidimensional, i.e., innumerable semiotics processes occur at the same time in multiple directions and emergent levels. Some of them may intersect; others may not … Semiotic networks can be temporally and spatially separated and still be in communication. Or they can be causally linked although they belong to (or can be identified at) different levels of

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[125] See Jesper Hoffmeyer, 'From Thing to Relations. On Bateson's Bioanthropology', in *A Legacy of Living Systems*, ed. Jesper Hoffmeyer, 2008, ch.2, p.30ff.

> the biological hierarchy. Therefore it is not an easy task to delimit a semiotic network.[126]

Some idea of this complexity can be gained by thinking about the most primitive multi-celled organism, the slime mould which spends part of its life as a single-celled organism and part as a multi-celled organism.[127] Single cells which germinate from spores function as individual amoeba until they run short of food. They all produce a chemical, acrasin, to which they are attracted, and an enzyme, acrasinase which destroys the acrasin, and increase the production of acrasin as they run short of food. The resulting concentration of acrasin destabilizes the homogenous distribution of acrasin, and thereby of amoebae. A dissipative structure which attracts the amoebae into an aggregate has been formed. This aggregate forms a plasmodium in which the number of cells is conserved and are largely unaltered, but which then differentiate. The fluctuations generated by the interaction of acrasin and acrasinase and the effect of these on individual cells have generated a morphogenetic field in which cells develop differently according to their positions in the field. In this way a foot, a stem and a seed pod are formed. The pod eventually produces new spores which are then disseminated into its environment. From Rosen's perspective, each cell will have a model of itself, but there will also be an emergent model of the multi-celled organism. Each cell will have an *Umwelt* based on sensitivity to food, to acrasin and to other cells, which in turn will be influenced by the response of the multi-celled organism to its own emergent *Umwelt*. Analysing all this into individual acts of semiosis will be impossible without taking into account hierarchy and heterarchy, and each act of semiosis, including protosemiosis, will only be fully comprehensible in this context.

How each cell develops and behaves, both as a separate amoebae and as part of a multi-celled organism will be partly interpretants of its DNA and its codes which can be regarded as signs or sign complexes of the environment in which this organism has to survive and reproduce. Hoffmeyer argued on the

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[126] Luis Emilio Bruni, 'Gregory Bateson's Relevance to Current Molecular Biology', in *A Legacy of Living Systems,* ed. Jesper Hoffmeyer, 2008, ch.6.

[127] This is described by Ilya Prigogine, 'Organization through Fluctuations; Self-Organization and Social System', *Evolution and Consciousness: Human Systems in Transition*, ed. Erich Jansch and Conrad H. Waddington, London: Addison-Wesley, 1976, ch.5, p.107ff.

basis of an enormous amount of research into heredity, there is no simple relation between the sequence of nucleotide bases in DNA and proteins produced, let alone phenotypic characteristics.[128] Alexei Sharov argued that endosemiosis involving communication between molecules as the most primitive form of semiosis or 'protosemiosis' (as opposed to 'eusemiosis'), without anything like objects being referred to, requires a more basic theory of semiosis than provided by Peirce, and invoked the work of the Italian semiotician Giorgio Prodi.[129] However, Prodi was strongly influenced by Peirce and formulated his ideas through Peirce's triadic categories of Firstness, Secondness and Thirdness although he was critical of a residual Cartesianism in Peirce, and Sharov still utilized Peircian categorizations of signs, arguing for recognition of proto-icons, proto-indexes and proto-symbols among proto-signs.[130]

What is defined as the 'external world' in the process of an organism differentiating itself from its ambience will vary immensely between organisms. The *Umwelt* of a cell or plant will not consist of anything as complex as an 'object', and there is a complete absence of spatiality, while the *Umwelt* of an animal or person which does consist of immediate objects and spatiality, these objects are what are focussed on as part of *Gestalten.* They are recognized against a background, including the proprioceptive sense of being spatially positioned as embodied agents with a shared world in process of becoming within a complex of processes in which these immediate objects are situated and related to each other.

Signs as interpretants as Peirce conceived them involve and incorporate increasingly rich interpretative schemes. Such schemes have been described by Jean Piaget, someone whose work tends to be ignored by biosemioticians but whose significance has been recognized in the study of anticipatory systems.[131]

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128 Hoffmeyer, 'The Semiotics of Heredity'.

129 Alexei A. Sharov, 'Molecular Biocommunication' in *Biocommunication: Sign Mediated Interaction Between Cells and Organisms*, ed. Richard Gordon and Joseph Seckbach, London: World Scientific, 2017, pp.3-33.

130 See Felice Cimatti, *A Biosemiotic Ontology: The Philosophy of Giorgio Prodi,* Cham, Switzerland: Springer, 2018, esp. p.41. This concluded with a postscript by Kalevi Kull 'Biosemiotics by Giorgio Prodi: A Postscript', in which Kull affirmed his view that semiosis to count as such must by triadic. See p.142.

131 Jean Piaget, *Biology and Knowledge: An Essay on the Relations between Organic Regulations and Cognitive Processes,* Chicago: University of Chicago Press, 1971. See also Fabián Labra-Spröhnle, 'Where to Begin? Surveying

The immediate objects signified by these signs themselves develop with the development of signs. This can be seen with the evolution of the notion of the atom as a theoretical object in physics and chemistry, but they could also be seen in the evolution of *Umwelten* of primitive organisms. Furthermore, all this takes place in the context of and as part of other processes operating over a vast range of scales from the expanding universe to quantum fluctuations in the vacuum, along with the processes and structures they maintain with various degrees of stability. These are the material causes of semiosis and life, largely ignored by Rosen, along with the structures and mechanisms utilized in semiosis and life, including the chemical bonds of DNA and its code and the interactions between the genome and the developing organism.[132] Different scales are operative in life itself, with DNA within a cell in a multi-celled organism, along with its code, being relatively stable, functioning as a sign vehicle (or at least part of a sign vehicle) for the semiosis of the cell, for the organism as a whole (with the interpretant being the ontogenetic trajectory of the fertilized egg), for the organism's species where each individual organism is an 'experiment' of the species, and for the ecosystem in which the species itself is an 'experiment'.

Another important aspect of semiosis not brought out by Rosen's modelling is their 'social' dimension – semiosis involves communication with interpretants being by different individuals. Rosen's starting point is the role of models in repair, and this does not appear to involve communication or be social in any way. However, it is this capacity for repair of the repair process that makes reproduction possible, in which the model of the original organism is

Anticipation in Neuroscience: An Essential Roadmapping Toolkit', in Poli ed. *Handbook of Anticipation*, ch.9, pp.164-189, and from another perspective, showing the common roots of Piaget's and Peirce's thought, see Michael Otte, 'The Limits of Constructivism: Kant, Piaget and Peirce', *Science & Education*, 7(5), 1998:425-450. On the other side, Michael D. Smith in 'On Peirce and Piaget: Signs of a Common Ground', *Semiotica*, 1993/4, 1977: 271-279 shows how Piaget misunderstood Peirce, failing to appreciate the constructivism in Peirce's philosophy, particularly in relation to symbols.

[132] While Rosen paid little attention to these material causes, including DNA, being more interested in the formal relations of life, it has been shown by Jan-Henrik S. Hofmeyr that the production of proteins utilizing DNA conforms to Rosen's model of life, with different causal processes being components of each other each other and being closed to efficient causation. See his 'Basic Biological Anticipation', in R. Poli ed., *Handbook of Anticipation*, ch.11, pp.219-223. In showing this, Hoffmeyer draws heavily on the work of Barbieri.

bequeathed to its progeny, functioning as a sign of the progeny's environment in which it must survive and the means to do so, and the developing progeny is an interpretant.[133] This accords with Peirce's suggestion that 'a Sign may be defined as a Medium for the communication of Form.'[134] Repair can be seen as a form of communication between the organism at different times, integrating and thereby individuating the life of the organism. That is, semiosis associated with repair by virtue of a Rosennean model is a form of communication, even if only between different stages in the life of a particular organism. The model associated with this could be seen as the most primitive iconic sign and the condition for all other signs and forms of semiosis in organisms, illuminating how semiosis opens a new dimension of existence in sign relations, introducing formal causes as well as final causes. This concurs with Fernández's characterization of such semiosis: 'No pattern exists in disembodied forms, but the same pattern may become successively embodied into different vehicles of form communication.'[135]

Semiosis as communication is absolutely central to the functioning and evolution of ecosystems, and it has been argued that organisms themselves are tightly integrated ecosystems.[136] The bonds of ecosystems are semiotic bonds, niches are largely (although not entirely) semiotic niches, and as Hoffmeyer argued, their development involves semiotic scaffolding which is the condition for further evolution.[137] It is semiosis that makes possible increasingly complex forms of symbiosis and of the synergies these make possible. Acknowledging this should not involve blindness to other dimensions of evolution. Niches are also made up of structural forms made possible by physical processes, by what is edible (animals can't eat coal), and so on, and along with symbiosis, there is also some competitive struggle for survival, with semiosis often being associated

[133] Charbel Nino El-Hani, João Queiroz and Claus Emmeche, *Genes, Information, and Semiosis,* Tartu: Tartu University Press, 2008.
[134] C.S. Peirce, *The Essential Peirce, 2,* p.544, n.22.
[135] Eliseo Fernández, 'The Convergence of Kantian and Aristotelian Intuitions', *Biosemiotics,* 1, 2008: 347-359, p.356.
[136] David J. Depew and Bruce H. Weber, *Darwinism Evolving: Systems Dynamics and the Genealogy of Natural Selection,* Cambridge, Mass.: MIT Press, 1996, p.445f.
[137] J. Hoffmeyer & F. Stjernfelt, 'The great chain of semiosis. Investigating the steps in the evolution of semiotic competence', *Biosemiotics*, 2016, 9(1), pp.7–29.

with deception. In the case of humans, the 'symbolic species' as Terrence Deacon characterized them, 'objects' can also be imagined, hypothetical entities or totally unreal, and new levels of semiotic distortion and deception are made possible.[138] 'Objects' in the 'external worlds' of humans include 'self' and communities, institutions, money, nation-states, texts, ideals and imaginary worlds created by art and other such entities that only exist as social realities through being symbolically signified, a dimension of reality only comprehensible when the triadicity of semiotic relations are acknowledged (as it was by George Herbert Mead, influenced indirectly by Peirce, along with the symbolic interactionists Mead inspired).[139] This is what makes humans peculiar, as Walker Percy pointed out.[140] While Peirce always acknowledged that semiosis is associated with communication, even his analysis of communication is still abstract when compared to the work of semioticians such as Yuri Lotman and Mikhail Bakhtin focussing on cultural life, including fictional narratives, as Oliver Laas has pointed out.[141] Recognizing narratives is essential to properly understanding human communities as anticipatory systems, since it is through 'anticipating narratives' that humans anticipate the future and respond to what they anticipate. As Mario Giampietro pointed out, 'Narratives play the same role in the semiotic process of human societies as schemata play in biosemiotics.'[142]

Once the basic principles have been understood through abstract models it becomes possible to model mathematically much more complex forms of life, and work is underway in this regard. André Ehresmann and Jean-Paul Vanbremeersch have developed more complex models exploiting the deeper potential of Category Theory in their study of 'memory evolutive systems'

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[138] Terrence W. Deacon, *The Symbolic Species: The Co-evolution of language and the brain*, London: Norton, 1997.

[139] See Hans Joas, *G.H. Mead, A Contemporary Re-examination of His Thought,* trans. Raymond Meyer, Cambridge, Mass.: MIT Press, 1997, p.37. That Mead was specifically influenced by Peirce's categories, see Apel, *Charles S. Peirce*, p.199n.19. As Apel put it, 'Peirce's doctrine of categories gave him [Mead] insight into the 'reductive fallacy' of Materialism, Positivism, and Behaviourism.'

[140] Walker Percy, *The Message in the Bottle: How Queer Man Is, How Queer Language Is, and What One Has to Do with the Other*, N.Y.: Farrar, Straus and Giroux, 1975, p.19.

[141] Oliver Laas, 'Dialogue in Peirce, Lotman and Bakhtin: A comparative study', *Sign Systems Studies* 44(4), 2016: 416-493.

[142] Mario Giampietro, 'Anticipation in Agriculture', in Poli ed. *Handbook of Anticipation*, ch.52, pp.1111-1145, p.1117.

involving hierarchy, emergence and the development of cognition.[143] Guided by Gerald Edelman's work in neuroscience, most importantly, his explanation of experience as being a 'remembered present',[144] this brings out even more clearly how interpretants of signs are realizations of previous anticipated possibilities. Along similar lines but completely independently it has been argued by Sonoda, Kodam and Gunji that awareness is made possible by heterarchy.[145] Rosen himself has considered the models utilized by societies to define reality and make decisions, arguing for the value of his work for democratic politics.[146]

However, understood as Peircian signs, models are not simply maintained and reproduced in repairing and reproducing organisms, but as interpretants can differ in significant ways from the original models as signs responded to by interpretants. As Peirce suggested, interpretants, having to deal with random perturbations and chance as well as predictable tendencies, can be more developed signs. It is impossible to fully capture creative responses mathematically since new possibilities come into existence. Semiosis can result in an interpretant grasping an adjacent possible different from any possibilities realized in the past, creating new niches and opening up new possibilities for evolution. As Stuart Kauffman argued, there can be no entailing laws for this.[147] Also, as the Estonian semiotician, Yuri Lotman, argued, the triadic forms of semiosis focussed on by Peirce can be superseded by pluralist forms.[148] Finally, as Salthe showed, through the interpolation of new constraints that reproduce themselves, new kinds of beings can come into existence.

Such complexes of semiotic acts and emergence of new levels need to be

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[143] André Ehresmann and Jean-Paul Vanbremeersch, *Memory Evolutive Systems: Hierarchy, Emergence, Cognition, Volume 4,* Amsterdam: Elsevier, 2007.

[144] Gerald M. Edelman, *The Remembered Present: A Biological Theory of Consciousness*, New York: Basic Books, 1989.

[145] Kohel Sonoda, Kentaro Kodama and Yukio-Pegio Gunji, 'Awareness as observational heterarchy', *Frontiers in Psychology,* 4(686), Oct. 2013: 1-12.

[146] Robert Rosen, 'Some Temporal Aspects of Political Change', *Int. J. General Systems,* 1, 1974: 93-103.

[147] Stuart Kauffman, 'From Physics to Semiotics', In: *Gatherings in Biosemiotics,* ed. Silver Rattasepp and Tyler Bennett, Tartu: University of Tartu Press, pp.27-46, p.36ff.

[148] On this see Kalevi Kull, 'Advancements in Biosemiotics: Where we are now discovering the basic mechanisms of meaning making'. In: *Gatherings in Biosemiotics.* Ed. Silver Rattasepp and Tyler Bennett, Tartu: University of Tartu Press, 2012, pp.11-24, p.16.

described through semiotic models and through stories to capture this complexity. Here, 'signs' can be 'texts', and have been characterized as such utilizing Peircian semiotic theory by Paul Ricoeur.[149] That is, it is necessary to recognize the value to biology not only of traditional Peircian biosemiotics, but also of the biohermeneuticists, exemplified by the work of Anton Markoš.[150] Through Rosen's work it is now possible to defend scientifically and clarify through mathematics both the limitations of mathematics and the cognitive value of non-mathematical semiotic models, literary texts and stories.

Semiosis as it is now understood by biosemioticians involves the production of various chemicals in cells (and turning on and off such production), changing the permeability of membranes, producing and reproducing and developing particular structures and swarming or bonding with other cells, the growth of plants and also other multi-celled organisms, for instance, growing down to water and up towards sunlight using gravity as a sign, or growth of animals into forms enabling effective action in their environments which are then 'experienced' as their *Umwelten*,[151] the actions of animals and humans as responses to what is recognized in these *Umwelten*, for instance, avoiding predators and obtaining food, and in the symbolic activities of humans as cultural beings. Semiosis involving the more complex forms of signs, the signs of culture; that is, symbols which can generate cultural entities such as narratives, idealizations and ideologies and abstract terms associated with these. It is this realm that the insights of the structuralist semioticians influenced by Saussure achieve some relevance. The signs of culture can create the illusion that signs and subjects are disembodied, but as Kalevi Kull noted, 'Humans possess simultaneously vegetative, animal, and cultural semiosis.'[152] The series of semiotic thresholds, vegetative, animal and culture, could be explained as the

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[149] Paul Ricoeur, 'What is a Text? Explanation and Understanding'. In *Paul Ricoeur: Hermeneutics & the Human Sciences,* ed. and trans. John B. Thompson, Cambridge: CUP, 1981, ch.5, p.163.

[150] Anton Markoš, *Readers of the Book of Life: Contextualizing Developmental Evolutionary Biology,* Oxford: Oxford University Press, 2002, and with others, 'Towards a Darwinian Biosemiotics: Life as Mutual Understanding', *Introduction to Biosemiotics,* ed. Barbieri, 2008, ch.10.

[151] See Daniel Chamowitz, *What a Plant Knows: A Field Guide to the Senses,* New York: Scientific American, 2012.

[152] Kalevi Kull, 'Vegetative, Animal, and Cultural Semiosis: The Semiotic Threshold Zones', *Cognitive Semiotics,* Issue 4, Spring, 2009: 8-27: p.24.

emergence of new levels of heterarchy, combining hierarchy and heterarchy, associated with not only new levels of constraint but new forms of reflexivity supervening over but only made possible through the functioning of more primitive forms of semiosis. The expansion of semiotic capacities associated with these new levels involve a concomitant increase in organisms' powers for causal intervention and active engagement with their environments. Humans are, as Maurice Merleau-Ponty and later Mark Johnson and George Lakoff argued, embodied subjects. Signs, and we as subjects relating signs to each other in worlds that are largely the products of signs, such as texts, money, states, political movements, scientific research programs, nations and civilizations, even when simply reflecting without acting, are inescapably incarnate and are built on and require the continued semiosis of individual human cells.

Human semiosis includes everyday practical activities such as transformations of the physical world, the production of goods, speech acts, the production and interpretation of narrative texts, and the development, deployment and utilization of more abstract models, including mathematical and other scientific models, opening up new levels of freedom.[153] 'Subjects' and worlds of Immediate Objects co-emerge with the capacity of organisms for greater anticipation involving more complex models, more complexly differentiated worlds, and greater capacity to respond to what is anticipated, and also a greater capacity to modify their models and their worlds. This is associated with more complex kinds of signs as described by Peirce and explicated by Thellefsen. The development of human culture characterised by 'with' worlds (*Mitwelten*) or life-worlds (*Lebenswelten*) involving the dialectics of labour, recognition and representation crystalized in institutions, again being components of each other without being reducible to each other, magnify the possibilities for freedom and creative semiosis.[154] These in turn make possible reflexivity, generating 'self' worlds (*Eigenwelten*) in which people come to

[153] The transformations of the physical world to produce built-up environments are not usually characterized as semiosis, but I have argued they should be with reference to and interpreting the work of the architectural theorist, Christopher Alexander. See 'The Arts and the Radical Enlightenment: Gaining Liberty to Save the Planet', *The Structurist,* 47/48, 2007/2008: 20-27, esp. p.24f.

[154] See Arran Gare, 'Philosophical Anthropology, Ethics and Political Philosophy in an Age of Impending Catastrophe', *Cosmos & History: The Journal of Natural and Social Philosophy*, Vol.5 (2), 2009: 264-286

understand themselves as individuals living out unfinished stories that can be reflected upon and modified, taking responsibility for themselves and their communities. Understood through biosemiotics, all this can be seen as participation in the semiosphere of the Earth whereby the Earth as a living being is becoming conscious of itself and its significance through humans. As Giampietro argued, anticipatory narratives explicitly acknowledging this are required to put in place the constraints necessary for preserving the ecosystems in which we are participants.[155]

BARBIERI, CODE BIOLOGY AND PEIRCIAN BIOSEMIOTICS

What are the implications of this Rosennean perspective for code biology, and for Barbieri's criticisms of Peircian biosemiotics? Barbieri's main objection to Peircian biosemiotics is that it involves simply playing with words, deploying a vocabulary that attributes far more to biological processes than is justified on the basis of a strictly scientific investigation, and that it does not lead to any new observations or any new conjectures that are testable. Most importantly, Barbieri objects to the attribution of interpretation to these processes. His main argument against this pertains to codes, the focus of his own interests. Identifying a code ubiquitous in biology for producing proteins from DNA, for instance, but also many other codes, does not require anything like interpretation. Furthermore, he argues that this code can be seen as part of a mechanism for producing proteins, and he objects to the opposition claimed by Peircian biosemioticians between their own position and mechanistic explanations, and to the assumption that mechanistic explanations are reductionist. In his defence of his critique of Peircian biosemiotics, he includes Rosen as someone who conflates mechanistic explanations with reductionism.

I will begin with what I believe to be a valid claim by Barbieri – that mechanistic explanations are not reductionist. Michael Polanyi pointed out that this is not the case. No matter how much we study the chemistry of a machine we will never understand the machine because the machine involves ordering principles that utilize the boundary conditions of chemical interactions.[156]

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[155] Giampietro, 'Anticipation in Agriculture', in Poli ed. *Handbook of Anticipation*, ch.52.

[156] Michael Polanyi, 'Life's Irreducible Structure', in Michael Polanyi, *Knowing and Being*, ed. Marjorie Grene, Chicago: Uni. of Chicago Press, 1969, ch.14.

Scientists who believe they are upholding reductionism fail to appreciate this because they tacitly presuppose the reality of the higher level of ordering that they are trying to explain, and ignore the boundary conditions (or constraints) they put in place in constructing their experiments. This insight was one of the main starting points for Pattee's own work. Subsequently, leading opponents of reductionism have endorsed the quest for mechanistic explanations. Roy Bhaskar, for instance, a vigorous opponent of reductionism in the human sciences, argued that the aim of science is to discover the generative mechanisms that produce various outcomes.[157] Barbieri pointed out that the code for translating DNA into protein could not be understood through physical laws; the code is in a sense conventional. It is 'as set of rules that establish *a correspondence between two independent worlds*.'[158] However, coding and decoding are still operations that can be explained mechanistically - for instance, there are mechanisms for the production of particular kinds of proteins utilizing DNA and coding rules. They are some of the material causes of life, and as such, are largely ignored by Rosen's relational biology and by many (but not all) biosemioticians. Hoffmeyer for instance refers with approval to Brian Goodwin's observation that one gene in the hair cell of the inner ear of a chick can produce 576 proteins by reading the sequence of bases in the DNA in different ways.[159]

The point though is that mechanistic explanations already assume a telos that mechanisms in some sense serve. They are products of life. The heart, for instance, is a mechanism for pumping blood through the body, and is significant as necessary for all the other ends the organism might have. And the muscle cells of the heart contain the mechanisms that serve this goal of the heart. On Venus where there is no life there are no mechanisms and so no place for mechanistic explanations. Regulation through feedback, the basis of cybernetics, is also a mechanism, although as Søren Brier argued, it can be integrated with semiosis to produce cybersemiotic systems.[160] If properly understood, even information only really makes sense in relation to living

[157] Bhaskar, 1978, *passim.*
[158] Barbieri, *The Organic Codes,* p.94.
[159] Hoffmeyer, 'Introduction: Bateson the Precursor' in *A Legacy for Living Systems,* p.7f.
[160] Søren Brier, *Cybersemiotics: Why Information is not Enough,* Toronto: Uni. of Toronto Press, 2010.

beings,[161] or more abstractly, to 'memory evolutive systems'.[162] As Bateson characterized information, it is a difference that makes a difference. 'Information' as conceived by Shannon, is the material condition for such information. The proponents of the synthetic theory of evolution, exemplified in its extreme form by Richard Dawkins, attempted to eliminate the need for recognizing such a telos by explaining existing mechanical order as the outcome the survival of the fittest machines, but they either surreptitiously reintroduced teleology (for instance, Dawkins treating DNA as having a purpose) or the theory became a tautological claim that what survives must be the fittest for survival because it survives.

Barbieri is clearly not guilty of such incoherence, but his book *The Organic Codes* shows how difficult it is to account for the origins of life and explain the 'Eigen's paradox' (how the complexity required for the DNA code to function as such could have originated) within the framework of his code biology alone (although his latest work on ambiguity reduction grapples with this problem).[163] Granting a place to mechanisms, recognizing that mechanistic explanations are not reductionist, still requires acknowledgement and explanation of final causes to identify them as having a function, which was Rosen's main concern. Functions and the quest to fulfil them precedes the development of mechanisms, including codes, and once developed, mechanisms can be appropriated for other functions, as when swim bladders were utilized to absorb oxygen and became lungs, or when human language was used to create philosophy. Characterized as 'exaptation', this is now recognized as central to evolution.

The early stages of the emergence of life as dissipative structures are most likely to have involved the autocatalytic sets characterized by chemical

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[161] Rosen defines it as 'a possible answer to an interrogative, a question.' 'Genericity and Information', *Essays on Life Itself,* ch.9, p.147.

[162] Andreé C. Ehresmann and Paul Vanbremeersch, *Memory Evolutive Systems: Hierarchy, Emergence, Cognition, Volume 4,* Amsterdam: Elsevier, 2007, p.178.

[163] Barbieri, *The Organic Codes*, p.142ff. As Brier and Joslyn pointed out, there is a problem for Barbieri in accounting for any new code. See Søren Brier & Cliff Joslyn, 'What Does it Take to Produce Interpretation? Informational, Peircian and Code-Semiotic Views on Biosemiotics', *Biosemiotics* 6, 2013: 143-159, p.153. The whole of this issue of *Biosemiotics* was devoted to examining the problematic concept of information underlying diverse versions of biosemiotics.

reactions mutually catalysing each other as described by Stuart Kauffman, but achieving endurance and effectiveness through emergent constraining activities in hierarchical order as described by Pattee and Salthe (for instance, associated with the formation of a semipermeable membrane enclosing these reactions). Here, energy transformations would be controlled to some degree, storing energy in usable form such that its transformation could be triggered, to hasten the overall transformation of exergy into entropy and its dissipation. This would be the condition for the more complex processes involving heterarchy as well as hierarchy, and thereby reflexivity as characterized by Rosen associated with the capacity to anticipate and respond to future possibilities, bringing the final causes of life and semiotic controls into the world. This would be associated with the development of *Umwelten*, later including 'objects' and then spatiality, and correspondingly, the development of subjectivity associated with increasing levels of curiosity, emotional engagement and freedom of agency. With the concomitant emergence of functions, anything that better serves a useful function, including functioning as a sign vehicle or code, would have survival value and be selected for and refined. The role of DNA would be, as Salthe argued, 'to stabilize spontaneously emergent material forms and to provide access to structural attractors, which is to say, to harness informational constraints present generally in nature.'[164] This would include the tendencies of physical processes to generate forms, such as the rigid forms of chemical structures utilized in producing bones of skeletons, or the transparent slightly modified spheres of eyes, the focus of theorists of morphogenesis such as Brian Goodwin.[165] It is almost certain that analogue codes pre-existed the digital codes of DNA with RNA functioning as a messenger, with these being utilized to provide greater stability to vegetative semiosis, although if, as Barbieri argues, life originated with ribonucleoproteins, there could have been elements of digital coding in the original analogue coding of life. Hoffmeyer argued that analogue codes continue to play a role as codes, interacting with digital codes,

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[164] Stanley N. Salthe, 'What is the Scope of Biosemiotics? Information in Living Systems'. In *Introduction to Biosemiotics*, ed. Barbieri, 2008, ch.5, p.145.

[165] For a summary of such work, see Brian Goodwin, *How the Leopard Changed its Spots,* London: Weidenfeld & Nicolson, 1994, esp. ch.'s 4 & 5.

all the way up to human culture.[166] Final causes are also the condition for the Baldwin effect and semiotic scaffolding, without which the evolution that has taken place could not be explained.[167]

Recognizing that mechanistic explanations through the fractionated components of a living system are also necessary and are not reductionist, as Rosen thought, is not a major argument against Rosen, because the emergence of final causes or teleology still requires the kind of functional order which he showed cannot be understood in terms of fractionated components. There is still a requirement for the kind of modelling of anticipatory systems that Rosen offered. Such models lead to testable predictions because it can be shown that organisms are responding to what is anticipated rather than simply reacting to their environments. From this perspective, the codes and coding and decoding mechanisms identified by Barbieri that do not require any ascription of interpretation, can only be identified as codes, that is, as having a function, because they serve as instruments for a system which is more than a sum of the mechanisms it utilizes. Furthermore, recognizing them as having a function does not imply that the 'meaning' Barbieri associates with codes are nothing but functions. It can be argued that meaning is an emergent aspect of life required for it to function.

If this is right, Barbieri's argument that genuine science always involves constructing mechanistic models, that 'Mechanism, in short, is virtually equivalent to the scientific method … Mechanism, in other words, is scientific modelling'[168] cannot be accepted. There are a variety of forms of explanation that have been accepted at times in science: deductive-nomological, mechanistic, causal, probabilistic, dynamical, functional, semantic and topological, to name a few. Barbieri's claim would not only rule out major work in biology, such as C.H. Waddington's and Brian Goodwin's work on

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[166] Jesper Hoffmeyer, 'Code-Duality', *Biosemiotics: An Examination into the Signs of Life and the Life of Signs,* trans. Jesper Hoffmeyer and Donald Favareau, Scranton: University of Scranton Press, 2008, ch.4.

[167] Jesper Hoffmeyer and Kalevi Kull, 'Baldwin and Biosemiotics: What Intelligence Is For', In: *Evolution and Learning: The Baldwin Effect Reconsidered,* ed. Bruce H. Weber and David J. Depew, Cambridge: MIT Press, 1983, pp.253-272.

[168] Marcello Barbieri, 'From Biosemiotics to Code Biology', *Biological Theory,* 9(2), June 2014: 139-149, p.141.

epigenesis invoking morphogenetic fields with their immanent dynamics[169] and Walter Freeman's and Giuseppe Vitiello's work in neuroscience utilizing quantum field theory and invoking cortical fields, but most of physics since Faraday. In developing his notion of force fields, Faraday was upholding the tradition of Schellingian science in rejecting not only the pre-eminence accorded to Newtonian physics, but also the idea that explanations have to be mechanistic. James Clark Maxwell was under the influence of the older tradition of science, and while advancing Faraday's work, occasionally lapsed into this earlier assumption and attempted to explain these force fields with mechanistic models, but abandoned this attempt.[170] The development of relativity theory and then quantum theory put an end to such quests. The problem now is, as David Bohm noted at a conference on theoretical biology in 1969: 'just when physics is… moving away from mechanism, biology and psychology are moving closer to it. If the trend continues… scientists will be regarding living and intelligent beings as mechanical, while they suppose that inanimate matter is too complex and subtle to fit into the limited categories of mechanism.'[171] Bohm was describing the triumph of the Schellingian tradition of speculative physics, and biosemiotics should be seen as at the forefront of advancing the tradition of Schellingian science.

Even if Rosen were wrong in equating reductionism and mechanistic explanations, his argument that the kinds of mathematical models he was developing to understand anticipatory systems could not be simulated on a computer does offer a new insight into life, even if simulations have been offered. It is part of Rosen's argument that mathematics should not be reduced to mere syntactical relations so that operations could be specified for the

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[169] Waddington noted that it was the influence of Alfred North Whitehead's concept of concrescence that freed him from the assumption that there had to be biochemical switches to account for the development by an embryo along one path rather than another, and that instead such selection could be the effect of the dynamics of the entire morphogenetic field, an insight that inspired René Thom's catastrophe theory. See C.H. Waddington, 'The Practical Consequences of Metaphysical Beliefs on a Biologist's Works: An Autobiographical Note', *Sketching Theoretical Biology,* ed. C.H. Waddington, Vol.2 [1969], New Brunswick: AldineTransaction, 2010, pp.72-81, p.81.

[170] R.M. Harman, *The Natural Philosophy of James Clerk Maxwell,* Cambridge: Cambridge University Press, 1998, p.5f.

[171] 'David Bohm, 'Some remarks on the notion of order'. In C. H. Waddington (ed.), *Towards a Theoretical Biology*, vol. 2. Sketches. Edinburgh Press, Edinburgh, 1969, pp. 18-40, p.34.

manipulation of symbols without any reference beyond these symbols. Mathematics is important because it can give some insight into what is modelled by it. This is part of a broader argument, that living beings are not Turing machines. It is hardly surprising that defenders of mainstream biology and mathematics have treated this claim as a challenge and have made a number of efforts to simulate Rosen's models on computers,[172] some of which were discussed by Vega. Barbieri took issue with Vega on this point, claiming that simulations have been successful. However, what is centrally important for Rosen's argument is not whether simulations are possible, but rather, whether such simulations could offer any insight into the causal entailments active in what they are simulating. Nowadays with powerful computers it is possible to simulate anything; but without providing insight into what is simulated, this is Ptolemaic science, simply adding the equivalent of epicycles to save the appearances rather than explaining these.[173] Rosen's ideas on mathematical modelling were focussed on how real entailments are modelled, knowing that all such modelling simplifies what is modelled.[174] What is really important is that through his mathematical modelling Rosen revealed something about the nature of causation where multiple processes are operative simultaneously, being components of each other without being reducible to each other, and showing how these are required to explain final causes of anticipatory systems. It is this form of complexity that can then explain the triadic nature of semiosis. Furthermore, as I have also suggested above, Rosen's study of modelling justifies recognizing the limits of all mathematics. To understand these and the semiotic activities they are describing it is also necessary to give a place to semiotic models as called for by Kull that accord a place to indeterminacy and creativity that cannot be acknowledged in mathematical models. And as Kauffman argued, it is necessary to invoke stories to characterize the creativity of the evolution of the biosphere where these cannot be accounted for through

[172] See Derek Gatherer and Vashi Galpin, 'Rosen's (M,R) system in process algebra', *BMC Systems Biology*, 2013, 7:128.

[173] On this difference, see H.H. Pattee, 'Simulations, Realizations, and Theories of Life', In: *Artificial Life, SFI Studies in the Sciences of Complexity*, ed. C. Langton, Addison-Wesley Publishing Company, 1989. Pp.63-77.

[174] See A.H. Louie, *More Than Life Itself: A Synthetic Continuation of Relational Biology*, Frankfurt: Ontos Verlag, 2009, p.91ff.

entailing laws because they involve new possibilities, including exaptation.[175] Stories are also important for describing and appreciating striving, exploring new possibilities, conflicting goals, and the emotions involved in living, even in the case of single celled organisms such as the Stentor, as Kauffman argued.[176]

However, it is still possible to accept Barbieri's criticism of the loose use of anthropomorphic terms such as 'interpretation' that are taken to always imply some sense of subjectivity. This charge is connected to Barbieri's scepticism about Peirce's Objective Idealism, but even more importantly, his charge that biosemioticians are incoherent in accepting notions that are defensible if one accepts Objective Idealism, but are mere adornments to scientific theory when added to what he takes to be genuine scientific knowledge. It is a real problem when what purports to be research is merely redescribing what is already known in an obscurantist vocabulary, or alternatively, in the comforting vocabulary of folk biology. This problem has already been recognized by Claus Emmeche, a leading biosemiotician, who pointed out the parallels in this regard between complexity theory and biosemiotics on the one hand, and general systems theory in the 1960s and 70s on the other.[177] However, biosemiotics is more than this, and this can be appreciated when Peirce's claim to being an Objective Idealist is rejected. It is true that Peirce characterized himself as an Objective Idealist, perhaps seeing this as consistent with characterizing himself as a 'Schellingian of some stripe'.[178] However, as I have pointed out, Schelling in his struggle against Cartesian dualism (and reacting against Fichte's Idealism) was developing a philosophy to overcome the oppositions between materialism and spiritualism, realism and Idealism. Building on the work of Schelling, Peirce was defending, although without explicitly stating this and not entirely consistently, what C.D. Broad later

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[175] Stuart A. Kauffman, 'A Creative Universe: No Entailing Laws, but Enablement in the Evolution of the Biosphere', *Humanity in a Creative Universe,* Oxford: OUP, 2016, ch.4.

[176] Kauffman, 'A Creative Universe', p.250, referring to the work on the evolution of the emotions of Katherine Peil. See Katherine T. Peil, 'Emotion: The Self-regulatory Sense', *Global Advances in Health and Medicine,* 3(2), March 2014: 80-108.

[177] Claus Emmeche, 'Closure, Function, Emergence, Semiosis, and Life: The Same Idea?'. In Jerry R. Chandler and Gertrudis van de Vijver, (eds), *Closure: Emergent Organizations and Their Dynamics,* N.Y.: The New York Academy of Sciences, 2000, pp.187-197, p.187.

[178] C.S. Peirce, *Collected Papers*, 8 Vols. Ed. Charles Hartshorne, Paul Weiss, A. W. Burks, Cambridge, MA.: Harvard University Press, 1931-1966, (electronic version), 6.605.

characterized as 'emergent neutralism', developing an ontology by abstracting from the attributes of both mentality and matter in such a way that both the attributes of mentality and of matter could then be shown to have emerged from being so conceived.[179] In his later work, when he was struggling to generalize the notion of sign by removing its anthropomorphism, this clearly characterizes Peirce's own philosophy. This is the essence of process metaphysics which takes creative relational processes with real possibilities as the fundamental reality.[180] And as Sandra Rosenthal has pointed out, despite Peirce's claim to be an Idealist, but also a realist and a pragmaticist, none of these adequately characterize his philosophy.[181] Rosenthal, like Nicholas Rescher, characterized it as process metaphysics.[182] Advancing science through process metaphysics in opposition to science based on different metaphysical assumptions, accounting for their achievements, and going beyond these achievements, is a major challenge, and it has been in striving to meet this challenge that the hard cores of the research programs of biosemiotics and relational biology were formulated and are being defended here.

Defending such a research program in a culture and social order embodying Cartesian dualism is difficult, and it is necessary to develop a language more basic than the language used to characterize either matter or mentality. In characterizing semiosis, Peirce used the term 'interpretant' rather than interpretation for precisely this reason (although not always consistently).[183] As such, this concept can be applied to the production of proteins or the generation of form by an anticipatory system, that is, 'vegetative semiosis' that Barbieri assumed was precluded by the notion of 'interpretation'.[184] Given the demonstrated incoherence of Cartesian dualism in which mind and matter are defined in such a way that any relationship between them, causal or otherwise, is incomprehensible (as demonstrated by

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[179] See C.D. Broad, *The Mind and its Place in Nature,* London: Kegan Paul, Trench, Trubner, 1925, p.632.
[180] Arran Gare, 'Process Philosophy and the Emergent Theory of Mind', *Concrescence,* Vol.3, 2002: 1-12.
[181] Sandra B. Rosenthal, *Charles Peirce's Pragmatic Pluralism,* N.Y.: SUNY Press, 1994, ch.5.
[182] Nicholas Rescher, Process Metaphysics: An Introduction to Process Philosophy, N.Y.: SUNY Press, 1996, p.14.
[183] The inconsistencies in Peirce's characterization of signs, interpretants and life are brought out by John Collier in 'Signs Without Minds', in Romanini and Fernández, *Peirce and Biosemiotics,* pp.183-197.
[184] Barbieri, 'A Short History of Biosemiotics', *Biosemiotics,* 2, 2009: 221-245, p.234.

Princess Elizabeth of Austria and then Spinoza), the absurdity of reductionist materialism, denying the reality of our consciousness which is the condition of there being philosophy and science, and the implausibility of Idealism in the light of the success of evolutionary cosmology in which life is seen to have evolved from a universe originally without living beings, emergent neutralism is clearly the most plausible and defensible ontology. Barbieri can hardly claim that accepting emergent neutralism is incompatible with science, and this is surely what a good many of the Peircian biosemioticians have been upholding, even if occasionally lapsing into the language of Idealism or using language loosely. In fact it is clear that Barbieri is also engaged in this project, and his claim that the operation of codes in single celled organisms requires the ascription of 'meaning' to what is produced is part of the attempt to bridge this gap.

There is far more at stake in overcoming Cartesian dualism than being able to develop biology. It is required to overcome the two cultures referred to by C.P. Snow - science on the one side, the humanities and the arts on the other, and to recognize that in developing our understanding of ourselves and our place in nature, including advancing our understanding of life, we are participating in creating the future. Biosemiotics is at the centre of this struggle to overcome Cartesian dualism and to overcome the rift between science and the humanities. Facing a global ecological catastrophe largely as a consequence of a culture dominated by Cartesian dualism, overcoming this opposition could be a necessary condition for humanity to continue having a future. And as Mario Giampietro has recently argued, the integration of biosemiotics with anticipatory systems theory provides the means to critically examine and revise our current anticipatory narratives in order to put in place the semiotic constraints required for maintaining this future.[185]

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[185] Giampietro, 'Anticipation in Agriculture', in Poli ed. *Handbook of Anticipation*, ch.52.