

Spring 2018

Biosemiotics as an argument for the recontextualization of biological discoveries: A critical analysis of the biosemiotic model of marcello barbieri.

Augustus Morrissey Snyder
James Madison University

Follow this and additional works at: <https://commons.lib.jmu.edu/honors201019>

 Part of the [Biology Commons](#), [Cell Biology Commons](#), and the [Philosophy of Science Commons](#)

Recommended Citation

Snyder, Augustus Morrissey, "Biosemiotics as an argument for the recontextualization of biological discoveries: A critical analysis of the biosemiotic model of marcello barbieri." (2018). *Senior Honors Projects, 2010-current*. 626.
<https://commons.lib.jmu.edu/honors201019/626>

This Thesis is brought to you for free and open access by the Honors College at JMU Scholarly Commons. It has been accepted for inclusion in Senior Honors Projects, 2010-current by an authorized administrator of JMU Scholarly Commons. For more information, please contact dc_admin@jmu.edu.

Biosemiotics as an argument for the recontextualization of biological discoveries:

A critical analysis of the biosemiotic model of Marcello Barbieri.

An Honors College Project Presented
to the Faculty of the Undergraduate
College of Science and Mathematics
James Madison University

by Augustus M. Snyder

9 April 2018

I. Introduction

Science necessarily involves philosophical approaches to both make sense of its findings and provide purposeful direction for research. Biology as the scientific approach to the study of life is, therefore, bound to philosophy, especially regarding questions about the nature and treatment of life. The cell theory has effectively been a scientific grounding point for the former¹ since the nineteenth century, and it has certainly been advantageous for the rapid advancement of biological research and medical applications. Still, even today scientists are philosophically divided on the nature of life. Many biologists would likely argue that the difficult philosophical questions underlying their own discipline—for example, the problem of how one can logically (i.e. not just descriptively) account for something that is recognized and distinguished as “living” arising solely from “non-living” or abiotic components—have no place in formal scientific or biological research because they are not directly testable questions. However, while it may be true that these questions are not directly testable, researchers in scientific disciplines should not dismiss such inquiry entirely. Biological research relies—at least legally and financially, if not ethically—upon effective communication of its knowledge and application of that knowledge to non-scientific audiences, and awareness of these philosophical questions and proper treatment of them is essential for proper communication of the sciences to society. In particular, such philosophical questions are often what motivates and engages new learners to scientific disciplines, and it is often the case that the more one learns, the more questions one has. For

¹ The cell theory, credited to Schwann, Schleiden, and Virchow, states that:

- Organisms are composed of cells.
- The cell is the basic unit of life.
- All cells come from preexisting cells

As should be obvious, this theory provides descriptive parameters to account for what we recognize as living organisms. Without a sufficient account of the origin of the first cell of an evolutionary lineage as an exception to the rule, the third clause is at risk of an infinite regression.

example, what constitutes the recognition of a cell or organism as something “alive” and individual, something that is more than a mere sum of non-living parts? Biology recognizes that such a distinction between life and non-life exists in nature, but largely still fails to account satisfactorily for the seemingly paradoxical claim noted above. Thus, as biologists come to better acknowledge and understand the present philosophical inquiry concerning their content knowledge, the bonds of education and service between biology and society are strengthened.² Tangentially, it is worth noting that even founders of modern science and stark proponents of materialism—such as John Locke—have argued that the link between our sensory experiences of the natural world and our knowledge of it is not necessarily “direct” by any means,³ and modern sensory physiology would support this view. One might thus beg the question of how ‘direct’ our knowledge of the natural world can and should be.

Under the current paradigm, scientific knowledge is held to be the authority of our understanding of the natural world, but it cannot in its current state address questions of purpose or value in this domain. However, the scientific project assumes that there are objectively real values—such as human curiosity, consistency, and the pursuing knowledge of the natural world, to name a few—and purposes to describe reality. So, as it stands, science has a metaphysical foundation of values which it fails to validate, being limited primarily to descriptions of the physical world. Scientism—the claim that scientific knowledge is the most authoritative and/or

² This is especially relevant today with controversy over socioscientific issues such as climate change and stem cell research.

³ From these perspectives, the link between objects of the material world and the ideas or descriptive accounts we form of them from sensory experiences is not evidently one of necessity. Locke, for example, has argued that we only have a relative notion of substance rather than a positive one (Locke 1997—II xxiii 2). Consider something measured and quantified in science like charge. It is inferred from our sensory experiences and from physical investigations that such a thing exists in nature and operates in an ordered and describable way, but can we really say what such a thing *is*? Sure, charge comes from protons and electrons, and these particles get their charge presumably from something else, but what essentially *is* charge? A similar question can be raised for mass.

the only valuable knowledge—is thus incoherent.⁴ The question then is whether and how science and philosophy can somehow be merged in such a way that scientific knowledge is contextualized and applied towards a search for answers to these deeper questions. The rapidly emerging field of biosemiotics strives to meet this aspiration.

Marcello Barbieri is one biosemiotician who argues against the dominant paradigm in science generally and biology especially. In his view, current scientific practice is burdened by physicalism, as described in science and philosophy at least since the mid-60s by Chargoff and others (Barbieri, 2007). Barbieri describes physicalism or the physicalist thesis as one which attempts to account for all phenomena solely in terms of their physical quantities. While this approach has employed reductionism to great effect in furthering our understanding of natural causes for phenomena⁵, there are significant problems with a physicalist scientific approach. First, the critique of science in the preceding paragraphs still stands—science is limited to descriptive causal explanations, but for scientific findings to have significance, human ingenuity must come into play for their interpretation and application. Without this broadening perspective, for example, we would have no concept of evolution, the most unifying theory in biology. It is difficult to imagine a modern biological discipline with current technological advancements and no concept of evolution—indeed, some might say impossible, for scientific findings influence the development of technology and vice versa in an ongoing cycle. And it must be admitted that the physicalist thesis is quite radical, and Barbieri’s critique of the dominant paradigm may be

⁴ A critique often credited to Nietzsche in philosophy of science, though his critique of science is more complex (Babich 2010).

⁵ With advancements in technology, science is now capable of exploring (albeit indirectly) the natural world on the subatomic level, yet this is a scale which is almost incomprehensibly smaller than the scale of what is detectable by and relatable to the human senses; one is left to wonder whether we are approaching the boundaries of what is knowable at the physical level. Moreover, as the complexity of scientific findings increases in this regard, so too does the estrangement of science from society and other bodies of knowledge.

unfair. But, as a theory which might attempt to back the scientific project—and, perhaps even more dangerous, as a mood which subtly pervades and is propagated by scientific practice and culture—such stark flaws must be pointed out. The physicalist approach is necessarily limited by its reductionism to exclude any synthesizing of broader understandings from the scientific body of knowledge. For biology, were this conceptualization to be carried out to its extremes, the phenomena of each organism would appear to be isolated, from the microscopic to the macroscopic level. Every act of DNA transcription and translation to a gene product would seem independent from another, and ecology would cease to exist as a scientific discipline.

Secondly, it presents an effectively nihilistic outlook.⁶ This is because science through the physicalist approach not only distances itself from searching for any sort of transcendental or supernatural explanation of natural phenomena but discredits them entirely. In other words, if nothing beyond the realm of physical interactions is held to be ‘objectively real’ or of any fundamental importance for explaining phenomena except in a very superficial sense, the tendency may be to assume that there is no objective meaning or purpose in nature, and that life at any level is thus aimless. The physicalist thesis may permit only wonder at the complex depth of the human mind, the vast diversity of life and biotic processes on earth, and the very possibility of communication. It cannot thoroughly explain why these things occur; it can only concede that they do somehow because of complex physical and chemical interactions which science strives to describe. In fact, the physicalist thesis holds that there is no *why*—no overarching explanation beyond physical interactions. In other words, the physicalist thesis

⁶ The view that modern society and science are trending towards nihilism is another of Nietzsche’s famous remarks. A distinction between two types of nihilism is made clear by Bernard Reginster, where nihilism as disorientation is the view that there is no objective meaning, purpose, or values that are somehow *a priori* to life (2006). Nihilism as despair is the view that there are such objective values, but that they are ultimately unattainable. The former would seem to apply here.

prevents one from making any broader connections because even these connections in principle must be reducible to only purposeless physical interactions. As a scientific approach, this nihilistic embrace is paradoxical because science as a whole assumes that the universe is ordered and knowable and strives to describe its processes—the same applies in particular to biology and life processes. Simultaneously, any human values—including the most noble quests for knowledge and understanding—are undermined.

This is what Barbieri means when he says that modern science does not know how to cope with the meaning that scientists themselves and society at large nevertheless attribute to scientific discoveries (2007). He points out a paradox at the core of biology in the following way. The genetic code is held to be the fundamental basis of all life on Earth; according to the physicalist thesis, however, it is at most a “metaphor” constructed to make sense of complex but objectively meaningless physical interactions. Here, I would add that even the recognition of something as being meaningfully ‘alive’ and originating from abiotic components is paradoxical under a solely physicalist view. Thus, with the physicalist thesis rendered unsatisfactory, science is left in want of some other theoretical approach to back its project. Therefore, to realize this goal and to push the scientific understanding of life, a synthesis of the knowledge and methods of biology and philosophy becomes necessary. Alone, neither field is capable of effecting significant change in the current scientific practice, for biology in a strictly scientific sense lacks the methods, and philosophy lacks access to requisite knowledge and traction in the scientific community.

Biosemitics is perhaps the most significant attempt to bridge the gap between science and philosophy since they started to diverge in the modern era. This emerging field attempts to find evidence for natural sources of inherent and objective meaning or purpose in biologic life.

Proving this search to be futile or a worthwhile endeavor is not within the scope of this paper. Rather, this paper is an attempt to formally introduce biosemiotics and how the methods of biology and philosophy are synthesized therein to the scientific community it should concern the most. Furthermore, potential merits and detriments of this approach will be examined through analysis of the views of Marcello Barbieri who proposed in 1986 that cells have “ribotypes”⁷ which derive from the evolutionary impacts of early ribozymal entities and that the cell is a trinity of ribotype, genotype, and phenotype. I will first present a brief account of biosemiotics in general, noting how it came to be and what some of its prominent views are. I will then narrow the scope of my focus to the views of Barbieri on the nature of the cell. I will offer a critical examination of Barbieri’s semiotic model, presenting its strengths and weaknesses in its attempt to make biosemiotics relevant and viable in application to scientific research. In my opinion, Barbieri’s view is potentially of critical importance for the direction of biological research and education, having many component points worthy of both philosophical consideration and scientific testing. While his basis for the argument of a cell’s ribotype as its codemaker may not yet be definitively shown, the argument for a cell as a triadic entity seems self-consistent and plausible; beyond this, it is an interesting and radical conception which could reform our understanding of the origin of life. Still, even if a cell should be considered as a trinity of genotype, ribotype, and phenotype as opposed to a duality of genotype and phenotype, the argument for the cell as a self-contained semiotic system which produces its own meaning seems open for debate. Ultimately, I see this debate as one of which biologists should be made aware and to which they should contribute.

⁷ This will be explained and expanded upon in a later section, but a cell’s ribotype, defined as the ribonucleoprotein system of the cell, is essentially classified according to whether it has a prokaryotic (70s) or eukaryotic (80s) ribosomal system.

II. Biosemiotics in general

Biosemiotics is an attempt to reform our understanding of living systems by breaking with the view that life processes are essentially meaningless and mechanistic (Mullins, 2017). This is accomplished through the argument that “semiotic causation” and “semiotic scaffolding” plays a pivotal role in nearly every aspect of both the internal and external dynamics of organisms, from cellular processes like metabolism and reproduction to broad scale ecological processes. One of the clearest and most succinct accounts of this view is offered by Eliseo Fernandez (2014) in the following manner:

Within each living being there is an unceasing deployment of signaling interactions between and among its constituent parts. These internal exchanges are regulated and coordinated with the assistance of another equally complex semiotic interplay. The second interactional traffic takes place between the whole organism and the entities and events occurring within its habitat.

To summarize, there are at least two cases of semiosis occurring for every organism: one within the organism, and one between the organism and its environment.⁸ Both of these cases are held to be of equal philosophical merit for the production of new biologic meaning. The richness of this view becomes clear when terms like “semiotic causation” and “semiotic scaffolding” are unpacked. To do so, however, semiotic theory and the significant application of the theory to

⁸ For the purposes of this paper, the former is of primary concern. For any biosemiotics theory to have merit in modern biology, it would have to first demonstrate plausibility at the microscopic level of the cell, the fundamental unit of life. To illustrate the proposed applicability of biosemiotics to all biologic study, however, macroscopic cases of semiosis will be discussed where possible.

biological systems must first be made clear. At its core, a semiotic system is one that is concerned with the production of meaning (i.e. semiosis). As such, it takes the fact that meaning does exist as granted, and the ability for organisms to communicate in any sense is a testament to that. It should be of no surprise, then, that the theories which arose to account for this phenomenon were initially concerned rather heavily with linguistics and providing a sophisticated account of language, for it is the form of communication with which we are most intimately familiar.

The Saussure-Florkin Model

One semiotic model was developed by Ferdinand de Saussure, which Barbieri describes as a “duality of ‘signifier and signified’ or ‘sign and meaning’” (2007). In other words, a semiotic system according to Saussure has two essential components—namely, the sign, whatever it may be, and the meaning of that sign or what it represents. A good way to explain the basic relationship is through linguistics with the example of a phoneme. Phonemes are often depicted by a single letter or a unique pairing of letters, which translates to some vocal utterance. In this example, a particular phoneme would be considered the “sign” or “signifier,” and the vocal utterance it translates to would be the “signified.” However, this two-part account of a semiotic system is still unsatisfactory; being merely descriptive, it leaves open room for debate as to what links the two parts and how meaning is produced. We are still left in need of a way to distinguish semiotic systems, which are meaningful, from those that are not. In other words, what is a necessary and sufficient condition for something to be a case of genuine semiosis? Still, this view was significant in early biosemiotics as shown by the Florkin-Saussure model of 1974 which analogized “sign” to genotype and “signified” to phenotype in cellular systems (Barbieri,

2007). Barbieri points out that, in stark opposition to what was to come later in contemporary biosemiotics, Florin declared that a bioseme carries no meaning, rendering the application of Saussure's model useless from a practical standpoint. For the sake of communicating the conceptual links of the model, however, a biological sign at an ecological scale could be something like an abundance of resources for an organism. The signified aspect in this case would be the habitability of the environment to that organism, and perhaps others.⁹

The Peirce-Sebeok Model

Another major semiotic model—indeed, the most influential and commonly referenced in biosemiotic scholarship—comes from Charles Peirce. Peirce's philosophy includes interpretation as an essential component to the semiotic system, making it a triadic one of “sign, object, and interpretant” (Barbieri, 2007). To explain by way of linguistics again, consider morphemes—the simplest units of meaning in language. Any self-contained word, like run, is a free morpheme.¹⁰ So, under Peirce's semiotic account, the sign in an arbitrary case could be a particular morpheme (e.g. the word run—it could be written or verbal) because it is the interpretable part of the relationship. The object or referent in this case would be the thing or concept the morpheme represents in the language (e.g. the actual form of exercise or motion whereby a terrestrial organism propels itself to some increased velocity through the contact of its limbs with the ground), and the “interpretant” is the meaningful effect produced by the act of interpretation. For example, one might see or hear the word “run” (i.e. the sign) in some context, like in a training

⁹ Presumably, the organisms are made ‘aware’ of the signified aspect in some sense, but how this is accomplished is not at this point explicitly clear, hence the need for a more refined model.

¹⁰ As distinguished from bound morphemes which cannot function independently. Bound morphemes exist in the form of prefixes and suffixes; they affix new meaning to a word by adding plurality or action (e.g. the suffixes –s and –ing would change ‘run’ to ‘runs’ or ‘running’).

regimen for track and field. One then meaningfully ‘links’ the sign to one’s experience through the interpretant, in this case by performing the act of running for training—interpretation in context determines the appropriate response. Accounting for the production of meaning as a semiotic process in the context of mental activity and language as described above is in fact a deeply complex philosophical endeavor¹¹, despite the oversimplification for purposes of analogy. For this reason, an exhaustive investigation of Peirce’s philosophy is beyond the scope of this paper, however useful it might be in critiquing the claims of biosemiotics. What is especially of note from Peirce’s semiotics is that—whether correctly interpreted and applied to biology or not—a sort of natural teleology arises in Peirce’s semiotic system (Mullins, 2017).

The Peirce-Sebeok model, proposed in 1963 and developed into the 80s, was the first attempt to apply this understanding to biology and is still a popular model in biosemiotics today (Barbieri, 2007). Sebeok held that all cases of semiosis are triadic, and that interpretation is a necessary and sufficient condition for something to be a semiosis—in other words, for something to be meaningful or have purpose. According to this model, an organism’s genotype is a sign whose object is the organism’s phenotype, similar to the Saussure-Florkin model. The difference is that Sebeok holds that there is a self-contained act of interpretation in the system. Thus, at the most fundamental biologic level, the ribosomal machinery of the cell serves as the source of interpretation of the genetic code’s meaning which enables the translation of the genetic code. Interpretation in this case must necessarily be distinguished from a mental act, as it would be absurd to attribute mental activity to a mere molecular structure. So, in what sense would Sebeok say a ribosome ‘interprets’ the genetic code? Well, it processes the information contained in some portion of the genetic code and forms a product, and it does this in a consistent and

¹¹ For those interested in the philosophy of language and meaning, I would suggest reading Wittgenstein’s *Philosophical Investigations* especially.

predictable way. A computer program, for example, can be coded to mechanistically ‘interpret’ some input and reliably produce some output according to some algorithm—perhaps interpretation in the case of ribosomal activity is analogous to this. However, in the case of the computer program example, would it not be more reasonable to say that the original meaning of the program came not from the disposition of its mechanistic interpretation, but from the one who coded it?

In the contemporary biosemiotic view, the telos of any semiotic system is the production of an interpretant, and this can be realized as the formation of new signs or of habits and dispositions, among other things (Mullins, 2017). Biosemioticians thus apply a teleology to living systems and argue for a “dispositional account of causation,” which is, in some sense, a sophisticated way of reintroducing to modern science Aristotle’s notions of resident causal powers or intrinsic properties. Fernandez (2015) offers the following summation of the dispositionalist account:

According to the dispositionalist standpoint an event A causes an event B when causal powers (which are latent in A) manifest themselves in a well-defined manner to produce B, contingent upon the occurrence of activating circumstances of a well-defined kind. For instance, a match has an intrinsic disposition to ignite which does not become manifest under usual conditions. When specific triggering circumstances occur (friction, dryness, etc.) the disposition to ignite manifests itself: the match ignites.

So, in the biosemiotic view, the habits of organisms are the dispositions “to respond in a particular patterned manner when some particular thing or process...triggers that particular response.” These dispositions are the interpretants of biological semiotic systems (Mullins, 2017). One biosemiotician, Jesper Hoffmeyer (2007), suggests the following:

The apparently purposeful nature of living systems is obtained through a sophisticated network of semiotic controls whereby biochemical, physiological and behavioral processes become tuned to the needs of the systems. The operation of these semiotic controls takes place and is enabled across a diversity of levels. Such semiotic controls may be distinguished from ordinary deterministic control mechanisms through an inbuilt anticipatory capacity based on a distinct kind of causation that I call...‘semiotic causation’ to denote the bringing about of changes under the guidance of interpretation in a local context.

So, according to Hoffmeyer, the telos of living systems results from semiotic causation, and this involves interpretation in accordance with the Peirce-Sebeok model. Semiotic causation, then, appears to be opposed to the causation of abiotic systems because abiotic causation does not involve interpretation or habit formation. One of the strongest supporting examples of this in biology may be the discovery of anticipatory cephalic phase responses of the internal milieu of organisms—especially of the intestinal tract and circulatory systems—which enable control of things like blood-glucose levels in the face of a discontinuous supply of nutrients (Power and Schulkin, 2008). For Hoffmeyer, the ability of organisms to anticipate changes in environmental

or internal conditions and survive through responses to such stimuli is predicated upon this notion of semiotic causation as being normative for all living systems.

Regarding semiotic scaffolding, Fernandez (2015) quotes recent efforts of Favareau and Kull to clarify the term. Favareau offers the following account.

Semiotic Scaffolding consists in biologically instantiated sign relations interlocking with and reinforcing one another, and by so doing, providing directionality towards and away from other sign relations in the network, through the dynamic emergence and canalization of semiotic pathway biases and constraints. Such ongoing semiodynamic re-adjustment enables new scaffolds and new pathways within and between scaffolds to arise, increasing semiotic capacity exponentially.

Kull's suggestion is as follows.

Semiosis as an active meaning-seeking-making process results often with the building of some relatively static or even quite solid structures that somehow embed in themselves the findings of that active searching-event of semiosis. The resulting structure is scaffolding. It canalizes further behavior. It is the frame for habits.

What I make out of these two somewhat nebulous accounts is that semiotic scaffolding in biological systems often—though perhaps not always—has to do with the actual physical

structures that make interpretation and processing of internal or environmental information and stimuli possible. At one level, examples of semiotic scaffolding could be structures associated with DNA transcription and translation, like ribosomal complexes and transcription factors; at another level, examples could be structures associated with autocrine, paracrine, and endocrine signaling between cells; even further examples could be whole tissues and organ systems, and perhaps even trends towards cephalization or various body symmetries. Each of these could be taken as semiotic manifestations of the processes by which living systems meaningfully interact with information both internally and externally. In addition, the evolution of these structures would in-turn influence the evolution of increasingly sophisticated responses. Hoffmeyer's (2007) remarks on semiotic scaffolding seem to support this interpretation:

History thus not only matters to the cell, but literally operates inside the cell through the structural couplings—or semiotic scaffolds—that it has served to build into the system. And this is exactly what distinguishes living systems from non-living systems: the presence in the former of historically created semiotic interaction mechanisms which have no counterpart in the latter.

Though Hoffmeyer focuses on the cell's interior in the above quote, the idea of scaffolding is applicable to the structures of all living systems; as he says, "The operation of these semiotic controls takes place and is enabled across a diversity of levels." Thus, according to semiotic theory, the semiotic scaffolding manifested in biological structures reflect the telos of living systems to interpret information and respond through semiotic causation and serve as framework for the evolution of increasingly complex and adept responses.

But is the telos of a living system unique by case, or is there something richer about this view that is somehow fundamental to life? As described thus far, the particular habits formed by living things would certainly differ. However, Hoffmeyer argues for an aspect of this habit formation that is common to all living systems (2008). In his view, all living creatures are not just surviving in accordance with natural selection and responses to their environment—they are *striving* also¹². This striving seems to be concordant with the emphasis Michael Polanyi places in his works as well on the achievements and flourishing of living beings (Mullins, 2017). From a scientific perspective, though, it is difficult to see how this “striving” is distinct from mere anthropomorphizing of living systems. It is clear that biosemiotics would argue for a deeper understanding of the term, but it may not yet be able to express this in a testable way to the scientific community. As Hoffmeyer himself notes, “making scientifically responsible sense of this “striving” is one of the challenges that the emerging field of biosemiotics sets out to accept.”

In short, then, the carrying out of a habit or disposition of an organism is seen, in some general sense, as an act of interpretation of the organism’s surroundings, which is held to be a telos of living systems. The Peirce-Sebeok model argues in a similar way for a disposition of the cellular ribosomal machinery. Furthermore, Hoffmeyer explicitly states that “biological communication is more than just machine-like exchange of information,” and this is “because the sign embraces a process of interpretation” (2008). To biosemiotics, then, interpretation is something more than the previous computer program analogy permits, though how exactly this is to be argued is not quite clear. For while interpretation may be a necessary and sufficient condition for recognizing a case in which meaning is present, it seems less plausible that this

¹² Philosophically, this seems to have echoes of existential philosophers like Nietzsche, Heidegger, and Sartre. Nietzsche’s concept of *will-to-power* as a fundamental and normative will of all life to thrive through the exercise and expansion of ability may be especially applicable here to making sense of this “striving.” Still, this notion seems far from any scientifically testable justification.

would be responsible for the production of it, as with the computer program analogy. At the semiotic level between organism and habitat, like with the example of abundant resources used previously, this seems to be somewhat less of an issue; mental phenomena are also present in animals to some extent, and this would presumably be sufficient for the production of meaning in their responses to environments—the interpretants are the dispositions of the animals themselves. Still, what about semiotic interplays between whole organisms and environments in cases without well-documented mental phenomena and complicated neural networks—plants and bacteria, for example? How are the interpretations of their semiotic interplays fundamentally different from mechanistic information processing? Clarifying this matter is still a very challenging area for biosemiotics, especially with regard to cellular processes; Barbieri takes a somewhat different approach.

III. The Biosemiotic Model of Marcello Barbieri

The Ribotype Theory

Perhaps in anticipation of critiques similar to the challenge raised for the role of interpretation in the previous section, Barbieri's semiotic model differs quite significantly from that of the Peirce-Sebeok model. His argument for inherent meaning in a cell is fundamentally based on what he originally proposed in 1986 as the Ribotype Theory in which he argues that cellular "ribotypes" are evidence for natural codemakers rather than mere interpreters. The Ribotype Theory has three major components. First, it proposes a plausible case for the origin of the first cells, with their being shaped and brought about by the pre-cellular evolution of early ribonucleoproteins—what he calls "ribosoids"—and their quasi-replicative abilities. Secondly, it provides a rough sketch for a potential course of cellular evolution from the protocellular stage to

the prokaryotes and eukaryotes observable in the world today which serves to explain, for example, why prokaryotes and eukaryotes differ in ribosomal makeup (i.e. 70-S vs 80-S ribosomes, respectively) and in their transcription / translation processes. Thirdly, assuming that the two above cases or something very near it is true, the Ribotype Theory provides a radically different perspective on the nature of the cell than what is currently taken for granted in modern biology. Interestingly, the Ribotype Theory can be viewed as a special case and extension of the RNA World Hypothesis¹³ that, if true, leads to a novel conclusion about the nature of the cell. In this conclusion, Barbieri breaks from the traditional view of cells and organisms as dualities of genotype and phenotype, offering instead a view of cells as trinities of genotype, “ribotype,” and phenotype (1986). Interestingly, Barbieri argues that his account on the origin of life is better than others like the genotype theory and phenotype theory because it avoids the “chicken and the egg” paradox. In other words, due to their mutual dependence in living systems today, it remains unclear whether and how a genetic system of information storage could have originated before the structural development of the referenced information and vice versa. Barbieri attempts to address this issue through a semiotic account which proposes a role for ribosomal precursors in cellular evolution.

In this perspective, the cellular ribotype is considered to be a separate entity from genotype and phenotype that functions to bridge the “one-dimensional” flow of information from the genetic code to the three-dimensional actualization of that information in the form of proteins (Barbieri, 1986). This may be a step towards clarifying the issue with interpretation noted above. More importantly, however, Barbieri argues that these ribosomal complexes are not just

¹³ First proposed in 1962 by Alexander Rich and conceptually supported by the contributions of Francis Crick and Carl Woese, the RNA World Hypothesis states that RNA was likely utilized by the earliest life on Earth to store genetic information and to catalyze chemical reactions (Neveu, Kim, & Benner, 2013).

translation mechanisms for living systems, but that they were of primary importance in bringing about the system in the first place—even more so than DNA.¹⁴ Furthermore, he holds that biologic differences in ribosomal production were the impetus for the characteristic differences that allow for the modern distinction of prokaryotes from eukaryotes. In other words, he argues that prokaryotic and eukaryotic cells first arose from natural selection of ribosomal biogenesis mechanisms with the statement “one ribotype, one cell type” (Barbieri, 1986). The biological rationale of this account and perspective will be flushed out below in some detail, highlighting the potential application of modern biological research to test this theory.

Prokaryotes use 70-S ribosomal systems and have their origin of transcription linked in both time and space to the origin of translation; the two can happen simultaneously (Barbieri, 1986). Eukaryotes use 80-S ribosomal systems and have their origin of transcription separated in time and space from their origin of translation (nucleus vs. cytoplasm). In the Ribotype Theory, Barbieri makes a case for ribogenesis mechanisms causing the evolution of this dichotomy, such that 70-S type ribosomes are evolutionarily streamlined versions of 80-S type ribosomes. According to Barbieri, the dichotomy that is observed between prokaryotes and eukaryotes cannot be explained in full by the conclusion put forth by Carl Woese in 1980 that as the molecular weight of the ribosomal matrix increases, so does the accuracy of the translation; 70-S ribosomes and 80-S ribosomes differ in weight on average by nearly 2 MDa but have relatively equal translational accuracies (Barbieri, 1986). Instead, Barbieri thinks that the reason why prokaryotes with 80-S ribosomes and eukaryotes with 70-S ribosomes are not observed is due to natural selection on the ribosomal production processes. Specifically, his hypothesis is that the biogenesis mechanisms of the 80-S ribosomes in eukaryotes allows for their transport from the

¹⁴ Here, Barbieri comments on and dissents from the assertions of those like Richard Dawkins that organisms are DNA’s way of producing DNA.

nucleus to the cytoplasm, which prokaryotic mechanisms would not be able to accomplish (Barbieri, 1986). This separation in time and space of transcription and translation would allow for compression and compartmentalization of a larger genome, a greater diversity in cell types, and eventually multicellularity, evolutionarily balancing the increased energy expenditure for these ribotypes. In addition, Barbieri proposes that prokaryotes would be able to function with 80-S ribosomes, but that in their case, natural selection favored less energy expenditure, streamlining the ribonucleoprotein system and restricting the size of the genome. Thus, Barbieri views the two major ribotype systems that we see today as a sort of natural dichotomy.¹⁵ In addition, a critical factor upon which Barbieri's theory hinges is recognition of the comparatively greater metabolic resources given to maintaining a cell's ribonucleoprotein system than its genetic code.

Scientific Relevance of Barbieri's Model

The falsifiable assumptions of the Ribotype Theory are undeniably its most important aspects from a scientific standpoint and could serve to provide direction for modern cellular and molecular biological research. Barbieri argues that these falsification tests were beyond the scope of biology at the time because they would require "detailed elucidation of the structure and function of the ribosome components, a comparative analysis of the eukaryotic and prokaryotic ribosome biogenesis, and a precise account of what produces the transport of the eukaryotic ribonucleoproteins from nucleus to cytoplasm" (1986). Today, however, biology may be close to

¹⁵ Barbieri even goes so far as to say that this "natural dichotomy," as such, is analogous to that observed in the case of sex.

a point where it can test this view. In response to a question on the matter of falsification tests for his theory, Barbieri (1986) provides the following response:

Question 20: Do you regard falsification as an essential attribute of a respectable scientific theory? If so, what predictions does the ribotype theory make which could be falsified in the future?

[Response:] Some falsification tests should come from the study of ribosome biogenesis. The theory implies that the mechanisms which shift the ribonucleoproteins from nucleus to cytoplasm are intimately associated with the biogenetic processes, and a detailed comparison of 70s and 80s biogenesis should reveal if that is indeed the case. It should be possible, for example, to demonstrate that eukaryotes could not survive with 70s ribosomes because they would be unable to export them to the cytoplasm.

Other falsification tests may become possible when the function of most or all ribosomal proteins will be known and the significance of the differences which exist among various species will be clarified. This should also add much more substance and content to the relationship between ribotype and cell-type that is at the basis of the theory.

Finally, we can entertain the idea that one day the manipulation of ribosomal genes may produce ribosomes which are not just variants of the existing types but which form a class of their own. In this case the theory predicts

that we would have the basis for creating *in vitro* a different type of cell, a really new form of life.

Barbieri's response explicitly points out grounds for testing scientifically the plausibility of the evolutionary roles of ribotypes. He predicts that eukaryotes could not survive with genes for 70s ribosomes; modern labs may now be capable or very nearly capable of testing this with recombinant DNA technology and methods available for making transgenic eukaryotes—consider the yeast *Saccharomyces cerevisiae* as a potential model organism for this experiment. The relative ability of such a transgenic organism to survive could be easily measured against non-transgenic individuals of the same species.

In response to a question about quasi-replication, Barbieri notes that, while it has somewhat of a science-fiction flair, such a concept could be tested through the reconstitution *in vitro* of natural and artificial ribonucleoproteins (1986). The quasi-replicative ability of Barbieri's ribosoids is a critical component of their plausibility as codemakers. Experimenting with the hypothesis that such characteristics of ribonucleoproteins would emerge in prebiotic earth conditions prior to self-replication would perhaps be the most direct falsification test of the Ribotype Theory. Secondly, in his final response to the question, note the proposal for investigating the possibility of creating synthetic life. Creating synthetic life has not seen much significant laboratory attention since Miller and Urey's famous "prebiotic soup" experiment. Protocell simulations have been developing in recent times, however (Hanczyc, 2011). These simulations model how primitive cell-like bodies might have looked and behaved in the early stages of chemical evolution with conditions such as HCN polymer abundance. Such existing simulation techniques could be coupled with the reconstitution of natural and artificial

ribonucleoproteins in a modern version of Miller and Urey's experiment to test the Ribotype Theory and the RNA World Hypothesis by extension. As a founder of synthetic biology, Stéphane Leduc (1911), said over a century ago,

The synthesis of life, should it ever occur, will not be the sensational discovery which we usually associate with the idea. If we accept the theory of evolution, then the first dawn of the synthesis of life must consist in the production of forms intermediate between the inorganic and the organic world--forms which possess only some of the rudimentary attributes of life, to which other attributes will be slowly added in the course of development by the evolutionary action of the environment.

Connecting the Ribotype Theory to Barbieri's Overall Semiotic View

Barbieri's biosemiotic model differs notably from the Peirce-Sebeok model in that Barbieri's model entails scientifically testable predictions about the characteristics and biogenesis of ribosomal complexes in cells. It argues for the recognition of ribotype as separate from genotype and phenotype and proposes that the evolution of a primitive cellular ribonucleoprotein system may have been the impetus for the formation of the genetic code. As such, Barbieri sees fit to equate such a system to a potentially natural "codemaker." Similar to the Peirce-Sebeok model in which ribonucleoprotein systems occupied a central role as interpreters, Barbieri's model is triadic. However, Barbieri seems to avoid the question of the origin of biologic meaning with this view of ribotypes as natural codemakers. Thus, the issue of interpretation as pointed out in regard to the Peirce-Sebeok model is apparently resolved with

what Barbieri refers to as a separation of the semiotic threshold—the origin of semiosis—from the hermeneutic threshold—the origin of interpretation (2007).

Some concerns for applications of Barbieri's Ribotype Theory both in science and as a semiotic theory may need to be considered further. First, the most glaring limitation of the theory is that "ribotype class differences" only serve to justify the very general distinctions of organisms at the basic level of cellular organization which already exist. While it might be exceptionally useful for reframing understanding of the nature of a cell and thus for biological education, the ribotype theory cannot be applied with confidence for species' distinction in a similar manner to genotype and phenotype in classical genetics. In addition, while Barbieri anticipates the critique, he still leaves open the question of how to interpret the fact that ribonucleoproteins are encoded by the genotype and expressed in the phenotype of the cell. Perhaps most significant, Barbieri's semiotic model is weaker than the Peirce-Sebeok model in that it rests upon an unverified understanding of the evolutionary roles of cellular components. If it can be supported, it may result in a stronger biosemiotic claim, and its strength lies in its applicability to scientific research. Whereas the Peirce-Sebeok model makes fewer assumptions about the nature of the cell and simply strives to make sense out of the scientific knowledge currently available, its reach and potential impact are also weakened by its lack of scientifically testable components.

IV. Conclusion

The basics of contemporary approaches in biosemiotics to making sense of living systems have hopefully been sufficiently presented. Perhaps the most important distinction to make between current biologic practice and biosemiotics is that, in the latter, recognition of purposeful functions in living systems is viewed not as a fault or fantasy of human conception, but as a

justified awareness of an essential and emergent characteristic that is common to all life—both microscopic and macroscopic. Barbieri’s unique semiotic model has also been analyzed against the more common Peirce-Sebeok model, and it has been shown that Barbieri’s Ribotype Theory is applicable to scientific research—namely, in origin of life simulations that would parallel Miller and Urey’s experiments. In general, one of the most significant effects of a biology backed by biosemiotics could be a sophisticated justification of research guided by a search for purpose in living systems. For example, in the context of biosemiotics, Barbieri’s Ribotype Theory calls for a further investigation of the purpose of a cell’s ribonucleoprotein system; if purpose is similarly associated with all biological structures and systems, every aspect of life calls for investigation with renewed vigor. The danger, of course, is that such a biology may get lost trying to contextualize meaning where none exists. Furthermore, it would likely struggle to handle the increased risk of introducing bias in formal research.

In no way does this paper attempt to argue for a reformation of formal scientific or biologic methods of research. Rather, this project is an attempt to foster discussion of the roles of science and philosophy, and whether there is to be any overlap therein. Furthermore, it is an attempt to alert biologists to the developing field of biosemiotics and some of its potential merits as a budding area which calls for deeper scientific inquiry. Many questions, therefore, remain unanswered. Is it worthwhile to breakdown the modern divide between science and the humanities, and if so, in what respects? To what extent can non-scientific bodies of knowledge can be useful to scientific practice and applications?

References

- Babich, B. (2010). Towards a critical philosophy of science: Continental beginnings and bugbears, whigs, and waterbears. *International Studies in the Philosophy of Science*, 24(4), 343–391. <https://doi.org/10.1080/02698595.2010.543349>
- Barbieri, M. (1982). The ribotype theory of the origin of life. *Journal of Theoretical Biology*, 91, 545–601.
- _____. (2007). The Challenge of Biosemiotics [Editorial]. *Introduction to Biosemiotics*, p. ix – xii.
- Fernandez, E. (2014). Evolution of Signs, Organisms and Artifacts as Phases of Concrete Generalization. *Biosemiotics* 8 (1): 91-102. DOI 10-1007/s12404-014-9226-8.
- _____. 2015. Signs, Dispositions and Semiotic Scaffolding. *Progress in Biophysics and Molecular Biology* 119 (3): 602-606. DOI 10.1016/j.pbiomolbio.2015.08.011.
- Hoffmeyer, Jesper. 2007. Semiotic Scaffolding of Living Systems. In *Introduction to Biosemiotics* edited by M. Barbieri, 149-166. Dordrech: Springer Netherlands
- _____. (2008). *Biosemiotics: An Examination into the Signs of Life and the Life of Signs*. Donald Favareau (ed.). Translated by Jesper Hoffmeyer and Donald Favareau. Scranton, PA and London: University of Scranton Press.
- Hanczyc, M. M. (2011). Metabolism and motility in prebiotic structures. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1580), 2885–2893. <https://doi.org/10.1098/rstb.2011.0141>
- Leduc, S. (1911) The Mechanism of Life. Translated by Deane Butcher in *Science Progress in the Twentieth Century (1906-1916)*, 6(21):159-160.
- Locke, J. (1997). *An Essay Concerning Human Understanding*, ed. R. Woolhouse, London: Penguin Books.
- Mullins, P. (2017). Michael Polanyi's Approach to Biological Systems and Contemporary Biosemiotics. *Tradition & Discovery*, 43(1).
- Neveu, M., Kim, H. J., & Benner, S. A. (2013). The "strong" RNA world hypothesis: fifty years old. *Astrobiology*, 13 (4): 391–403.
- Power, M. L., & Schulkin, J. (2008). Anticipatory physiological regulation in feeding biology: Cephalic phase responses. *Appetite*, 50(2–3), 194–206. <https://doi.org/10.1016/j.appet.2007.10.006>

Reginster, B. (2006). *The Affirmation of Life*. Cambridge, Massachusetts; London, England: Harvard University Press. Retrieved from <http://www.jstor.org/stable/j.ctt13x0h6x>

Woese, C. R. (1980). Ribosomes, Structure, Function and Genetics (G. Chambliss, G. R. Craven, J. Davies, K. Davies, L. Kahan & M. Nomura eds), pp. 357-373. Baltimore: University Park Press.