Biosemiotics (2018) 11:167–180
https://doi.org/10.1007/s12304-018-9330-2

INTRODUCTION

Introduction: a Structural and Historical Approach to Understanding Advancements in Evolutionary Theory

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Received: 17 July 2018 / Accepted: 6 August 2018 / Published online: 18 August 2018

Introduction

In this paper, I discuss some of the ways that *structural realism* may assist our thinking about changes to evolutionary theory. In doing so, I consider previous philosophical developments that have already had an impact on earlier accounts of evolution. Before detailing these historical accounts, I summarize the motivations for structural realism and discuss some of the ways that framing the discussion on evolutionary theory in structuralist terms may better assist our understanding of the relationship between biosemiotics and the evolutionary extended synthesis.

From Entities to Structures

Science was once a hallmark of empiricism in its dealings with the observable world, but it now dedicates most of its time to things that are unobservable (in at least the traditional sense of 'observable'). Such developments have resulted in changes with regard to how the world is to be interpreted. Among these more radical shifts include seriously considering the possibility that nature is not comprised of objects, but is, instead, best understood in terms of structures (Ladyman and Ross 2007).

These *structural realists* maintain that we should not give up on science—even if it has undergone radical shifts (Ladyman 2016). Instead, they maintain that science should be concerned with describing nature's relevant structures rather than expecting science to be in the business of cataloguing nature's entities. What counts as a *structure* is itself a matter of contention that divides structural realists into disparate camps. For example, *epistemic* structural realists endorse the slogan "all that we can know are structures." On this view, structures are only understood in terms of the relations given

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by our best scientific theories, but there is no need to give an account of the natures of the objects that enter into those relations. *Ontic* structural realists, on the other hand, go further than their epistemic counterparts to maintain something like the view that "all that exists are structures." Structures are themselves comprised of relations, leaving room for the possibility that there is no fundamental level to reality.

The debate on structural realism is nowhere near settled and there are attempts to reconcile these disparate positions (Floridi 2008). One of the difficulties of taking on such a synthesis is that both accounts face challenges. First, for the epistemic structural realist, it is unclear how we can claim that there is something over and beyond the structures if all we can know are the structures themselves. Second, for the ontic structural realist, it is counterintuitive that relations would be given ontological priority to their respective relata. Third, not all structuralists endorse realist commitments to thinking that science correctly accounts for unobservable phenomena. Instead, *structural empiricists* maintain that structures can be appealed to for accommodating scientific change without requiring those structures saying anything beyond the empirical developments in those theories (Bueno 1999). While my own sympathies lie with the ontic structural realist camp, barring some revisions to its radical naturalism (Winters 2016), I do not need to currently resolve which of these views is correct. It may, however, be worthwhile at some later point to discuss which form of structural realism is best suited for biosemiotics. For present purposes, it is enough to see that there are promising attempts to still allow science its epistemically authoritative role without ignoring the paradigmatic changes through which science has undergone.

The recognition of there being such changes in science is nothing new (Kuhn 1977). Many of these changes are well known: The Copernican Revolution resulted in new understandings of our place in the solar system; Newton's understanding of gravity as a force led to dismissing Aristotelian and teleological explanations that all things were on their way to finding their proper place; and Einstein's relativity led to the dismissal of the Newtonian view that there is an absolute frame of reference against which everything moved. These historical developments offer important lessons about how to continue investigating nature and understanding its findings. Among these lessons is that science should not always be expected to make incremental changes and that contemporary science is not always contiguous with its predecessors. The discovery of anomalies can lead to revolutionary developments when they cannot be reconciled with the received scientific views (Kuhn 1962). Science may sometimes make leaps and bounds, leaving much of the past behind. The distance to be traversed between each development and the amount to be left behind, however, is determined by the details. More importantly, the ways that science has undergone changes places a responsibility upon those who concern themselves with understanding and interpreting scientific theories—they should be sensitive to the possibility that even their most treasured scientific theories may require revision (and sometimes even dismissal).

This is the very stance that structural realists have adopted with regard to accounting for scientific change. Even though some of the main tenants of scientific realism are untenable—the idea that science aims at giving accurate accounts of unobservable entities—structural realists maintain there is a way to overcome the *pessimistic meta-induction* (i.e., given the failure of past scientific theories, we should be skeptical of the claims that contemporary science advances). Instead, we should strive to offer naturalistic accounts of science's success without making appeals to miracles (Worrall 2011).

This naturalistic approach serves as the motivation for the structural realist's reason for emphasizing structures rather than individual entities. In making the shift from focusing on individuals to structures and relations, science can still get at something objective while acknowledging that it undergoes paradigm shifts. In particular, it is the structural configuration of nature that maintains consistency even when the content of the theories themselves is revised.

While much of the discussion in the structural realist camp is centered on physics, in particular quantum field theory, and in some cases chemistry (Hendry 2008), biology is no exception to the aforementioned concerns. French (2011) explores the possibility of extending structural realism to accommodate biological theories and Tulodziecki (2016) discusses the possibility of structural realism accommodating historical developments in pathology. Both of their discussions indicate that there is room, and a need, for considering the relationship between biology and structural realism.

Following their lead, I believe that we should also evaluate the relationship between biosemiotics, structural realism, and the extended synthesis. This is due to my belief that structural realism, in some form, is the most successful in detailing how science, despite its fallibility, provides our best methods for understanding the world, including evolution. The periodic rise and fall of shifting between the received biological theories and discovering anomalies has proven to be a hallmark trait of attempts to develop an adequate theory of evolution. Rather than dismissing a theory of evolution based on having discovered anomalies, an account of the structural similarities between the initial theory and the theory that accommodates the anomaly should be given. Second, biosemiotics explores many key features of the natural environment that are ignored by contemporary biologists. In particular, it attempts to explain how a nonteleological understanding of nature can still accommodate how living organisms exhibit goal-driven and intentional behaviors. These behaviors give pause to attempts at offering wide sweeping reductionist ontologies and require offering different, revisionist ontologies to accommodate the possibility that many of these organisms are both sign-carriers and sign-interpreters (Sharov 2018). Given that biosemiotics understands evolution to be a multi-level process (Sharov 2016), biosemiotics provides a route for developing a non-reductionist accounts for evolution. A non-reductionist approach involves looking at the natural sciences as well as the social sciences to develop a better account of evolution. Last, the evolutionary extended synthesis strives to accommodate empirical observations within an evolutionary framework that have not obviously fit within the previous evolutionary accounts. The extended synthesis also understands evolutionary processes in non-reductionist terms by considering what occurs in the organism's surrounding environment in addition to what occurs within the organism. For these reasons, the evolutionary extended synthesis, structural realism, and biosemiotics appear to have much in common that warrants evaluating their relationship.

There has already been substantive discussions on how to reconcile biosemiotics and evolutionary theory. For example, Sharov et al. (2015) discuss the relationship between evolution and semiosis. Deacon (2016) makes the case for two or more self-organizing processes to be coupled in a way that contributes to each other's boundary conditions, which allows to enable evolution. Markoš (2016) looks at how semiotic processes contribute to the evolution of cultures and culture-like systems. Like the structural realists, the discussion has been focused on relationships; relationships are ontologically prior (or more fundamental) than the organisms, cultures, and phenomena that emerge from those relations. Yet, there does not appear to be an explicit discussion on biosemiotics and structural realism and I am not aware of any biosemiotician self-identifying as also being a structural realist.

The essays in this issue do not explicitly make use of structural realism, but they do elucidate many key aspects of structural realism. In particular, they emphasize the structural continuity that is exhibited between the extended synthesis and earlier evolutionary theories. For this reason, the essays in this issue can be understood as being consistent with, and possibly operating within, a structural realist framework. There is certainly room for an independent study as to how structural realism fits into this discussion since much of biosemiotics is thought to be framed in a post-structuralist framework. It should be made clear, though, that structural realists, especially ontic structural realists, have more in common with post-structuralism since they strive to develop a nonbinary understanding of systems; they maintain that relations are ontologically more significant than their constituents. More work on the commonalities between structural realism and biosemiotics is warranted.

Structural realism is a byproduct of discussions occurring in the philosophy of science. Given the possibility of there being a relationship between biosemiotics and structural realism, there is stronger reason for thinking that biosemiotics will benefit from discussions in the philosophy of science. I acknowledge that this is likely obvious to and accepted by those who are already working on reconciling biosemiotics with a theory of evolution. More importantly, by allowing philosophy, in addition to biology, to contribute to the development of a successful evolutionary theory, it is more likely that other fields will also make meaningful contributions to this discussion. But why think that philosophy has the capacity to inform an account of evolution? Fortunately, there are already cases of philosophy making contribution to some of the core features of an adequate theory of evolution (i.e., inheritance, development, and adaptation). To further motivate this position, the next section outlines some of the historical contributions that philosophy has made to the core features of evolution.

Some Philosophical Influences

Philosophy is not an obvious source for our understanding of evolution, yet I believe evolutionary theory is the result of philosophical inquiries dealing with the origins and underlying causes of natural phenomena, including the existence and development of living organisms, going back to the Early Greek and, refined by, the Modern philosophers. My aim in this section is to show that philosophers have discussed how organisms come into existence and undergo change. In large part these contributions to evolutionary thinking are the result of philosophers being engaged in an ontological project to offer an account of the fundamental origins of organisms. Elsewhere I argue that this sort of project is ultimately a debate regarding whether we ought to endorse either a substance or process metaphysics (Winters 2017). For present purposes, by considering these historical discussions I aim to suggest we should not rule out the possibility that philosophy will continue to make meaningful contributions to evolutionary theory.

By considering the works of some of the Presocratic thinkers it is apparent that their thinking about origins are similar in spirit to contemporary evolutionary thinkers' own accounts. In particular, while not using the same terms, they provide the foundations for thinking about *inheritance* (the transmission of similarities between parents and their offspring), *development* (the implementation of a limited range of phenotypes), and *adaptation* (the modifications in the relative frequency of replicated entities), all of which are guided by natural selection (Walsh and Huneman 2017).

Without going too far into the details, the Early Greeks, specifically the Ioanians, Thales (c. 624–545 BCE), Anaximander (c. 610–546 BCE), and Anaximenes (c. 585–528 BCE), offered competing accounts of how organisms came into existence. For Thales, all organisms originated from moisture. For Anaximander the boundless, or *apeiron*, caused the constituent parts of organisms to be organized. For Anaximenes, it is through the processes of rarefaction and condensation of air that fire, wind, cloud, water, earth, and stone are formed.

Heraclitus of Ephesus (c. 535–475 BCE) has taken a similar approach to Anaximenes in allowing processes to serve a key role in how organisms have evolved. Heraclitus, however, has taken a different approach from his predecessors. Rather than relying upon some fundamental substratum to be acted upon, it is the very activity itself that serves as the means by which things come to exist. But Heraclitus' account is not one of origins—it is about the development and evolvability of a general system that has always existed (Graham 2010). Heraclitus maintains that fire, or *logos*, serves as the rational organizing principle by which things develop. Understood by Heraclitus as the cosmic fire by which all things are both spawned and consumed, this fire is not an element in the traditional sense. In particular, it is made up of the phases of an activity—in particular *need* and *satiety*. These are the driving forces that maintain an organism's livelihood. The extent to which an organism is able to express its needs and have those needs met will be constrained by the organism's capacities and the context in which it is situated. In other words, for Heraclitus, the survivability of an organism will be determined by the "world-order" in which it is situated. This account is very similar to our thinking about natural selection, since an organism's capacity to have its needs met and pass those capacities along to its offspring ensures the likelihood of the species' survival.

Empedocles (484–424 BCE) adopts a similar account to Heraclitus in maintaining that there are organizing principles that determine the ways in which organisms come into existence. In particular, he maintains that *friendship* brings things together and *strife* pulls things apart (Solmsen 1965). There are, however, both crucial differences and similarities between Heraclitus' and Empedocles' accounts. Whereas Heraclitus maintains that activity is prior to the organism and its constituent parts, Empedocles maintains that there are four basic elements (fire, water, earth, and air) upon which friendship and strife act. Friendship and strife, however, function in a similar way to Heraclitus' need and satiety. If an organism's need is not met, then the organism incurs strife, thus resulting in its inability to survive.

Democritus (c. 460–357 BCE) follows a similar line of reasoning to Empedocles, but rather than relying upon elements, Democritus identifies *atoms* as the constituent parts that make up the elements of fire, water, air, and earth. By referencing a single source for the origin of all other elements led him to develop a theory of *pangenesis*—in which semen is thought to originate from all organs of the body (O'Rourke 2004). Democritus still makes use of a mechanistic organizing principle to account for the ways in which atoms are arranged. In particular, "All things happen by virtue of necessity, the vortex being the cause of the creation of all things, and this … [is] necessity" (Laertius 1925, 455). Democritus's reference to the vortex is similar to Heraclitus' usage of logos, since both the vortex and logos are responsible for the organization of things.

While these pre-evolutionary concepts were discussed by the Presocratics, it was not until Aristotle (384–322 BCE), arguably the first biologist, that we get a more formalized account of how organisms develop and come into existence. In particular, we get a metaphysics of categories that determine the natural kinds to which organisms belong. In virtue of belonging to some kinds and not others, organisms possess essential properties that determine they develop (Aristotle 2015). In accordance with his teleological account of the cosmos, Aristotle maintained that organisms develop in a way to actualize their respective potentials. These potentials are the result of the essential properties that each organism possesses, as a result of being a member of a natural kind. While this developmental view is consistent with what we now understand as *epigenesis* (the process by which plants, animals, or fungi develop through a sequence of steps), Aristotle's essentialism appears antithetical to our understanding of evolution. In particular, keeping in line with the idea of *common descent* (the idea that a group of organisms share a most recent common ancestor), we may require the possibility of some natural kind not being wholly distinct from other natural kinds. What we will see in the historical narrative, however, is that something like Aristotle's essentialism is a key feature of evolutionary theories espoused by thinkers such as Blackmore (1712), Linnaeus (1735), and Lamarck (1809). Furthermore, there are more recent attempts to reconcile Aristotle's metaphysics with a theory of evolution (O'Rourke 2004).

Similar metaphysically informed naturalistic endeavors during the Early Modern period (c. 16th–18th Centuries) allowed thinkers such as Descartes (1596–1690), Leibniz (1646–1716), and Hume (1711–1776) to make significant, yet different, contributions to our thinking about the underlying mechanisms that drive evolutionary processes. While the acceptance of individual substances might suggest that Descartes was adopting an Aristotelian account of evolution, Descartes maintained that the development, change, and growth of nonhuman organisms was the result of non-teleological mechanisms that could be understood in terms of natural laws (Descartes 1972). Furthermore, Descartes' account can be distinguished from Aristotle's since Descartes argued for the existence of there being distinct mental and physical substances (Descartes 1990). Aristotle, on the other hand, adopted *hylomorphism*, which is the view that organisms are only one kind of substance, but their distinctions are the result of different combinations of form and matter (Aristotle 2015). Leibniz's own account incorporates elements found in both Aristotle's and Descartes' views. Like Descartes, Leibniz maintains a mechanistic worldview (Leibniz 1969) while at the same time allowing organisms to be understood in terms of both active and passive substances (Garber 1985). The active elements could be understood as the way, or form, that organisms express themselves, while the passive elements could be understood to be the matter that makes up those organisms. Given this interpretation of an organism being the expression both active and passive substances, Leibniz's account has many commonalities with Aristotle's own account of how organisms come into existence and undergo change. While both Descartes' and Leibniz's accounts of evolution involve individual substances and laws that are the result of a transcendent God, not all Early Modern thinkers required these assumptions for an account of evolution. We already saw in Heraclitus' account the discussion of a system that is not created, thus not requiring a creator, and ontological priority given to activities, thus not requiring individual fundamental substances. Hume adopts a similar attitude in at least being agnostic with respect to there being a creator, but more clearly gives voice to the possibility of organisms developing and changing within a developmental system that itself has no origin (Hume 1998). A constantly changing and developing system, which does not possess an origin, allows for thinking about evolutionary processes without positing the existence of substances—thus allowing for the possibility of relations or processes being ontologically prior to their respective entities.

Although the Presocratics had a noteworthy influence on how we made philosophical and naturalistic advancements in our understanding of evolution, philosophy's direct influence is more clearly seen in the mid-18th and early 19th Centuries as a result of the contributions that Aristotle, Descartes, and Leibniz had made. In Blackborn's epic poem *Creation*, he extols Aristotle's implementation of an Unmoved Mover as a preferable explanation for the existence of organisms to the naturalistic explanations put forward by the Ionians (Blackmore 1712). Lamarck had (incorrectly) critiqued Aristotle's hierarchy, whereas they agree animals had evolved from the simple to the more complex. While he does not directly cite them, it is likely that philosophers such as Descartes and Leibniz influenced Lamarck's views of the (observable) world as not being static, exhibiting gradual change, and possessing mechanistic laws. Specifically, Lamarck shares with Leibniz the *principle of plenitude*, according to which "any type of organism that is conceivable must exist, and the diversity of types must form a complete continuum without borders or gaps" (Mayr 1972, 243).

Linnaeus is perhaps most obviously impacted by the method of developing a taxonomy put forward by Aristotle. On Aristotle's view, living things were divided into two groups: plants and animals. The animal subgroup was then segmented into those animals that belonged either to land, water, or air. The plant subgroup was then divided into those that were either small, medium, or large. Linnaeus still segmented living organisms in terms of either plants or animals and still focused on their properties. These major groups made up *kingdoms*, with the organism's respective shape determining its *class*, *order*, *genus*, *species*, and *variety*. Unlike Aristotle, Linnaeus did not endorse essentialism. Furthermore, Linnaeus distanced himself from Descartes by claiming that animals did in fact have souls and were not mere machines (Magner 2002). While the influence of Aristotle and Descartes results in their differences, it is perhaps more likely that Leibniz's adoption of a continuum helped inform Linnaeus' view that many animals (esp., humans and apes) existed on a continuum rather than each individual species belonging to its own natural kind. Even with the shift of focus from a static to a dynamic understanding of nature, Linnaeus and his contemporaries, however, still emphasized the development of individual organisms.

In addition to the influence that philosophy had on early evolutionary thinkers, Blackmore, Lamarck, and Linnaeus, themselves, had significant impact on Charles Darwin's grandfather, Erasmus Darwin (hereafter 'E. Darwin') (Harrison 1971). In response to Linnaeus' view of plants engaging in anthropomorphic behaviors, E.

Darwin wrote his own salacious account of the romantic interests of plants (E. Darwin 1791). Harrison argues that E. Darwin presents an account that is very close to, and possibly influenced by, Hume's own views. In particular, the idea that the universe is autonomous and self-regulating without the aid of some deity is common to both Hume's and E. Darwin's accounts. The process of life, for E. Darwin, is itself mutable in a way that appears at odds with the earlier accounts put forward by the likes of Descartes and Leibniz. This appears to be a shift, then, from focusing on individual entities to understanding evolution as influencing a general system of life rather than simply acting upon individual organisms.

In the next section I discuss the structural elements that remain intact through changes in evolutionary thinking, as well as commonalities between non-Darwinian and Darwinian accounts. Thus, providing additional reasons for considering how developments in philosophy (esp., structural realism) can help make sense of evolution.

Contemporary Trends

Evolution involves multiple features at different levels, which has resulted in some confusion regarding the nature of evolution and the problem of determining the appropriate unit of selection upon which natural selection acts. An organism's surrounding environment is one of these features that influences the variable traits that organisms exhibit and inherit. Charles Darwin ('Darwin' hereafter) was himself aware of the multiple causal influences that shape the way organisms develop, including the organism's environment (Darwin 1859). Not only are there epistemic features of his theory resulting from his direct observations, but there is the positing of some metaphysical system that allows there to be causal factors that aid in bringing about new features in organisms. These features allow organisms to more likely survive within and shape their respective environments. This metaphysical system involves natural selection as the organizing principle that allows variation and inheritance to function in a way that ensures survival and the passing along of traits.

During the twentieth-century there was an attempt to reconcile the experimental and mathematical success of Mendel's ideas with Darwin's observations in, what has been called, the *modern synthesis*. While Darwin's own formulation has been profoundly successful, it was more theoretically prudent to build onto his theory of evolution instead of dismissing it altogether. The modern synthesis, then, has incorporated *gene mutation* (alterations to the DNA sequence), *Mendelian inheritance* (the passing along of traits in accordance with laws of segregation, independent assortment, and dominance), *population genetics* (mathematical modeling of genetic differences between and within populations), *contingency* (developmental sensitivity upon the state of the organism), and *speciation and trends* (the capacity for populations to become distinct species). The modern synthesis emphasizes genes, specific traits, laws, organisms, and species—each of these are individuated entities (or objects). This object-based account was criticized by Whitehead (1929) due to its inability to account for the directionality, or flow, of development. Bergson (1998) shared Whitehead's sympathies and maintained that Darwinian, as expressed in the modern synthesis, was unable to adequately account for novel developments.

More recently, there have been attempts to illustrate that the modern synthesis is not the final word on evolution. Similar to revisions to Darwinian evolution to develop the modern synthesis, it is not obvious that we have to start from scratch. Instead, there has been work to build upon the modern synthesis to develop what has been called the *extended synthesis* (Pigliucci and Müller 2010). In addition to the components found within early Darwinism and the modern synthesis, the extended synthesis also includes *evolutionary-development theory* (the capacity for development to change over time), *plasticity and accommodation* (the extent to which an organism changes its phenotype in response to its environment), *niche construction* (the process in which the metabolism, activities, and choices of an organism modifies or stabilizes its environment, thus affecting its own development and other species), *epigenetic inheritance* (transmission across generations of cellular states without modifying DNA sequences), *evolvability* (the potential of biological lineages for adaptive evolution), *multilevel selection* (emphasis on changes in populations and phenotypes in addition to genetic variation), and *genomic evolution* (capacity for entire genomes to change over time) (Laland et al. 2015).[1] Many of these aspects are consistent with a non-object based account of evolution. For example, by allowing capacities, processes, potentials, and changes to have a more significant role in evolutionary theory, the extended synthesis is able to accommodate many of the metaphysical challenges advanced by Whitehead and Bergson. In large part, the shift from individual objects to relations and systems allows the extended synthesis to have both metaphysical and empirical support.

Furthermore, while not explicitly stated, many of these developments in the extended synthesis have commonalities with Uexküll's own account. Interestingly, or oddly, the foremost text on the extended synthesis (Pigliucci and Müller 2010), does not even include 'Uexküll' in the index. Similar to Heraclitus, Hume, and E. Darwin, Uexküll allows the context in which an organism exists to play a significant role in determining how the organism develops and reproduces. Uexküll emphasizes, what he calls, *Umgebung*, which is the objective material surroundings of an organism. These surroundings shape the ways in which an organism develops, reproduces, and, for those organisms with the capacity for being a sign-interpreter, to appropriately pick out the relevant features of the environment that will contribute to its vested interests (esp., survival). These surroundings may also include other organisms and, for present purposes, organisms that have the capacity to modify their environment in a way that is conducive to their interests. Those organisms that intentionally modify their environments require both an awareness of how they experience the environment and an intention to modify the environment in a way that produces the desired environment. This requires the organism to possess the capacity to experience itself in that environment, what Uexküll calls *Umwelt* (Uexküll 2010). The capacity to modify its own environment in a way that impacts its own and other organisms' experiences indicates the extent to which an organism is capable of being a sign-transmitter. More importantly, this transmission is done intentionally when the organism's efforts are for the sake of bringing about some desirable situation for itself and others. But this account is

[1] Futuyma (2017) argues that additional empirical evidence is needed to warrant calling into question the modern synthesis and that evolutionary theory has regularly been extended since its inception. Even if it turns out the extended synthesis discusses elements that have already been found in the modern synthesis, it is still worthwhile to understand how biosemiotics accommodates these developments.

exactly the sort detailed by proponents of the extended synthesis who incorporate niche construction into their theories.

These similarities between the extended synthesis and early contributions to semiotics require looking at the relations exhibited by organisms. More importantly, these theoretical shifts require defining organisms and their respective developments in terms of their relations. Put simply, an organism cannot exist without a world. But this shift away from focusing on individual entities and emphasizing general relations and systems for an account of evolution does not mean that past evolutionary theories are hopeless. Instead, like other scientific theories, as the structuralist would recommend we ought to focus on the structural commonalities of the theories. French (2011) maintains that this can be done by thinking of evolutionary theories as models. By looking to the structural commonalities between these models, we can then begin focusing on those relations that hold continuously through theory change without having to focus on the individual entities that are described by the (potentially disparate) theories. As we progress, and I do believe it is a progression, from Darwinism to the modern synthesis to the extended synthesis, we see that looking to relations instead of entities allows us to develop a more empirically sound evolutionary theory. While this shift is consistent with structuralism, it is also consistent with what much of biosemiotics asks us to consider—the development of sign systems. For example, Cariani (1998) looks at how the relationships between signs, symbols, and signals serve as the basic constituents of the biological, psychological, and social.

There are additional reasons for thinking that biosemiotics and the extended synthesis should be discussed in relation to each other. They both treat evolution as being multi-level and non-mechanistic (in the Cartesian sense). As Love (2010) highlights, evolution was thought to only occur at the genetic and cellular level, but when looking at fitness, for example, evolutionary processes that occur at the ecological level also need to be considered. In their editorial, Sharov et al. (2015) maintain that

> the main idea of biosemiotics is that life and semiosis are coextensive. Here semiosis is understood as a sign process or sign exchange, where signs stand for something else in some respect or capacity. In particular, life has a semiotic nature because it is based on endless interpretation of environmental cues and transfer of life-related functional meanings vertically across generations and horizontally to neighboring organisms. Semiotic processes help organisms to perform their functions, preserve their habits, and pursue their agendas through generations.

These processes have the capacity to change over time. To account for the evolvability of these systems, cultural, social, and environmental factors, in addition to what occurs at the genetic and cellular level, must be discussed in relation to one another. And these considerations are already beginning to happen—although not, as far as I am aware, in the extended synthesis camp, biosemioticians have begun making these observations (Lindholm 2015).

These considerations are the result of having looked at the influence that philosophy has already had on evolutionary thinking. This awareness allows us to be more open to the possibility that philosophical advancements will further aid us in better understanding evolution. The philosophical advancement that will be of service is accepting the evolvability of scientific theories in terms of their (either partial or complete) structural continuity. Regardless of whether we treat these structures as being epistemic, ontic, or merely empirical, we can see that our understanding of evolution should also be focused on structures. In this case, this will also involve the structural relations, beyond their theoretical continuity, in which organisms exhibit the capacity to engage in triadic sign systems, to use the Peircean model (Hoffmeyer 2008).[2] By moving away from the view that we ought to treat organisms as individual gene carriers, we'll better understand how organisms and their respective environments influence each of other's capacity to evolve.

While the emphasis has so far been on discussing the role that philosophy has in shaping our understanding of evolution, this has been to show how we should not only look to biology. But we should also look beyond biology and philosophy to better understand evolution, given that there are specific sciences designated to the various contributing factors to an organism's development. As the papers in this issue indicate, the discussion of evolution benefits from also considering developments in anthropology, archaeology, ecology, mathematics, physics, physiology, and semantics.

Summary of Papers

In setting out to edit this special issue of *Biosemiotics* I intended to better understand to what extent biosemiotics is commensurate with the evolutionary extended synthesis. As the preceding discussion indicates, I have come to believe that they are quite commensurate when we think about theoretical change from within a structuralist framework. The papers in this issue further bolster this position. As mentioned above, while there have already been attempts from within the biosemiotics camp to make connections to the extended synthesis, these papers further advance the conversation.

In their paper, "Semiotic Mechanisms Underlying Niche Construction," Peterson et al. use developments in anthropology to argue that we can better understand niche construction by drawing upon semiotics. In the following paper "Assimilating an Associative Trait: From Eco-Physiology to Epigenetics" Kurismaa argues that we can make sense of epigenetic inheritance as it arises in the mammalian nervous system as an example of evolutionary code making. In "Evolution by Meaning Atribution: Notes on Biosemiotic Interpretations of Extended Evolutionary Synthesis" Švorcová follows a similar line of reasoning to Kurismaa to argue that organisms can participate in epigenetic modification by influencing the meanings of the sign systems in which the organisms participate. Drawing on findings in ecology, Heras-Escribano and de Jesus argue in "Biosemiotics, The Extended Synthesis, and Ecological Information: Making Sense of the Organism-Environment Relation at the Cognitive Level" that both biology and ecology can help us make sense of the relationship an organism has to its environment. But, more specifically, that niche construction is effectively understood as requiring both information transmission and recognition. They maintain that biosemiotics can help us understand the ways in which information is processed and

[2] This is not to say that Peirce is himself a structural realist. French argues that Peirce's model is still too coarse grained, but captures many key aspects of structural realism. French and Saatsi (2006) highlights how Peirce's own model, in particular the iconic relationship between a representation that exhibits similarities to the represented object and what is represented. Specifically, French argues that scientific theories are to be treated as icons of the world.

transmitted within the organism-environment system. Toman and Flegr look at the nature of evolution itself in "Macroevolutionary Freezing and the Janusian Nature of Evolvability: Is the Evolution (of Profound Biological Novelty) Going to End?" They consider the possibility of how evolvability may account for how semiotic systems, when they become more complex, reduce the likelihood of novelty for the system as a whole, but still allow for individual developments. In particular, they employ a concept of meta-stability, similar to that found in discussions of thermodynamics, to account for these seemingly contradictory aspects of evolving systems. Dobrovolska's "Interrelationship Between Fractal Ornament and Multilevel Selection Theory" argues that fractals that occur in ornaments are also indicators of both cultural and societal patterns. This observation leads her to make the connection between semiotics and multilevel selection as it is discussed in the context of the extended synthesis. The issue ends with Lacková's paper "A Biosemiotic Encyclopedia." New developments in the sciences often require developing a new vocabulary, or way of describing the phenomena under investigation. Lacková's paper provides a route for accomplishing this by framing Darwinian evolution in terms of semiotics as developed by Peirce and Eco.

The ideas presented in this issue are exciting and thought-provoking. In particular, they offer novel ways for thinking about evolution. The attention and concern for things like evo-devo and niche construction indicate an appreciation for Uexküll's *Umwelt* not found in contemporary discussions about the extended synthesis. Furthermore, our understanding of epigenetic inheritance gives credence to Peirce's semiotic view that we contribute to and pass along meaning. The resulting account is that while Darwinian evolution and biosemiotics had perhaps very different initial approaches to understanding evolution (Darwin's being focused on individuals while biosemiotics has been focused on relations) we see that as the Darwinian position has developed towards the extended synthesis, the view perhaps has more in common with Uexküll's vision than originally thought.

Acknowledgements The author declares that he has no conflicts of interest in relation to this article or special issue. This issue was inspired by conversations while participating in the 2014 International Conference in Code Biology at the Université Paris Descartes. In particular, Marcello Barbieri, Liz Swan, Morten Tønnessen, Peter Wills, and Jan-Hendrik Hofmeyr sparked my thinking about how to wed the seemingly disparate fields of biosemiotics and the extended synthesis. Thank you to Massimo Pigliucci, Otávio Bueno, Alex Levine, and Alan Love for subsequent conversations. The editor-in-chiefs, Timo Maran, Alexei Sharov, and Morten Tønnessen provided exemplary guidance and patience as we worked to pull the issue together. An anonymous referee provided extremely thorough feedback to help improve the connections between biosemiotics, the extended synthesis, and structural realism. Finally, thank you to the authors of the papers contained herein for providing substantive contributions to the evolutionary discussion.

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