Juan R. Coca
Claudio J. Rodríguez *Editors*

APPROACHES TO BIOSEMIOTICS

Biosocial World: Biosemiotics and Biosociology

Vol. 1
2023

Universidad de Valladolid

APPROACHES TO BIOSEMIOTICS

Biosocial World: Biosemiotics and Biosociology
Vol. 1

Approaches to Biosemiotics / Juan R. Coca & Claudio J. Rodríguez H. / Valladolid: Ediciones Universidad de Valladolid, ed. 2023

165 p. ; 24 cm. Biosocial World ; 1

ISBN 978-84-1320-235-8

1. Biología. 2. Semiótica. I. Universidad de Valladolid, ed. II. Serie

519.76:57
57:519.76

JUAN R. COCA & CLAUDIO J. RODRÍGUEZ H.
(Eds.)

APPROACHES TO BIOSEMIOTICS

Biosocial World: Biosemiotics and Biosociology Vol. 1

EDICIONES
Universidad
de
Valladolid

En conformidad con la política editorial de Ediciones Universidad de Valladolid (http://www.publicaciones.uva.es/), este libro ha superado una evaluación por pares de doble ciego realizada por revisores externos a la Universidad de Valladolid.

Style and language edition by Daniel Kopecký.

Funding for the present publication was provided by the Czech Ministry of Education, Youth and Sports for specific research (IGA_FF_2022_027).

Preimpresión: Ediciones Universidad de Valladolid

ISBN 978-84-1320-235-8

Diseño de cubierta: Ediciones Universidad de Valladolid

CONTENTS

The modern rift between scientific modes of production and the humanities relies largely on the tacit acknowledgment that the things one may be able to say about one cannot translate to the other. That is to say, biology, as a modern area of science, is framed within what is expected of scientific research. Subjectivity, or at least the subjectivity espoused by semiotics, seems unattainable as a research principle when we only allow biology to act on the third person. Yet, the subjectivity of the humanities and the descriptive ideal of biology are not incompatible as long as our view of subjectivity is clear, descriptive and functional. Biosemiotics does not resist the divergence between the sciences and the humanities. Instead, it tries to bridge both areas by providing terminology that encompasses a biological understanding of subjectivity with a semiotic understanding of biological processes.

This volume, the first in the Biosocial World collection, contains a series of articles on what biosemiotics does, how it does it and what its long-term objectives may be. As a more specialized discipline in the boundaries of linguistics, the philosophy of biology and the sciences, we hope to offer a point of entry into the world of biosemiotics through articles that deal with general topics from within the field. Our aim is, thus, to contribute to the biosemiotic landscape by opening a door to its recurring themes, problems and descriptions.

More often than not, the concerns of biosemiotics are an intuitive given: Living organisms display so many features that pair well with the idea of subjectivity. This concept, however, is not to be understood simply as a point of view, but rather, as a way to acknowledge the organism's subjective existence. What biosemiotics does is bring a terminological and philosophical dimension to the table in a way that allows us to abstract what meaning-making does for organisms. Meaning-making, or the capacity of organisms to make sense of their worlds and assign meaning and relevance, is the cornerstone of biosemiotic research, and as such, biosemioticians develop a language to refer to all meaningful events in biology, from large-scale social formations to microscopic interactions of organisms with their environments.

Biology and meaning-making are inextricably connected. Living organisms are perceptual by nature, and it is through their perception that they build their worlds. The articles contained in this book offer a glimpse into the dynamics of biology, perception, meaning and the world. We explore multiple branches of biosemiotic research and give an overview of the state of the art in terms of research paradigms, current notions and problems faced by the field. The authors involved in this volume are all involved in biosemiotic research, representing the multiple axes on which we can talk about some sense of meaning in biology.

It is our sincere hope that this volume will open up a door for those interested in what biosemiotics has to offer. As the sciences and the humanities continue their rapprochement, and as how we understand social cognition in both biological and semiotic ways evolves, we believe that the inauguration of the *Biosocial World* series with this volume on biosemiotics presents a good entry point into how biology, culture and meaning can be explored through the synthesis of methodologies and ontologies, adjusting our scientific progress to the need to put the subject as an active part of its biological development.

What Is It Like to Be a Biosemiotician

Lukáš Zámečník
Palacky University Olomouc, Czech Republic

Abstract

This chapter deals with the conceptual analysis of the nature of biosemiotic research. It examines biosemiotics through the demands of the philosophy of science. It uses the approaches of Larry Laudan (the departure of ontology, methodology, and axiology of scientific research) and Stephen Kellert (conceptual borrowing analysis in science). The chapter classifies biosemiotics as a cross-discipline at the intersection of traditional biology and semiotics. It pays particular attention to whether central conceptual borrowings—the sign and interpretation— are collectively transferable to biology, without being conceived as mere metaphors. The chapter also treats whether it is possible to maintain inferential relations between these conceptual borrowings within the new context presented by biosemiotics. Two complementary approaches to biosemiotics are taken into account as case reports, i.e. Marcello Barbieri's Code Biology, which attracts biosemiotics to its original scientific nature, and the philosophical approach of Claudio Rodríguez, who seeks to build a consistent metaphysical foundation for biosemiotics.

Keywords: biosemiotician, cross-disciplinarity, code biology, philosophy of life

1. LAUDANIAN QUESTIONS CONCERNING BIOSEMIOTICS

Biosemioticians aim to add a new semiotic dimension to traditional biology. Living systems are seen as semiotically active (Kull et al., 2011: 2): according to them, the sign character is, in addition to chemical, informational, and code-based (Barbieri, 2015: 19), another necessary characteristic of life. Biosemiotics is a pluralistic cross-discipline – the intersection of biological sciences (molecular biology, evolutionary biology, but also ecology, etc.) and the humanities (philosophy, semiotics, hermeneutics, etc.).

I am not a biosemiotician and so the title of the chapter may sound inappropriate because, as an outsider, I can only provide a third-person (perhaps unbiased) perspective on the nature of biosemiotic research. From the perspective of the philosophy of science, I will try to perform a partial conceptual analysis of biosemiotics as a new science of living systems. As a science, normative demands should apply to it in some of the forms that the philosophy of science offers.

Because I believe that the prevailing view among biosemioticians is that biosemiotics is a science, it seems appropriate to me to take the normative demands from Larry Laudan – namely, that every science should have an ontology, methodology, and axiology (Laudan, 1984). 1) Every science introduces ontological commitments – it selects theoretical entities, which then serve it for explanations. 2) Every science respects the (more or less pluralistic) canon of scientific methods on which the members of the scientific community agree (and also agree on ways to apply them correctly). 3) Every science also has several goals to which its research aims.

If biosemiotics were not a science, but a certain new branch of the humanities, then it could hardly be an alternative to biology.[1] Instead, if it represents this alternative, then we must quite adequately ask what its theory looks like, what ontological commitments it creates. We should also ask whether this theory is accepted by the scientific community and whether it is accepted to some degree. I believe that there is only a very general agreement between biosemioticians and it

---

[1] "The distinction between two classes of sciences as applied to biology can be illustrated by the central question they are asking:

– in biology as a natural science: how are organisms built?

– in biology as biosemiotics: what do organisms know?

Knowledge in contrast to things and processes are ontologically so very different objects of study that they evidently require rather different methods and methodology in research." (Kull, November 2020, personal communication) lies precisely in the above-mentioned characteristic that living systems are in principle semiotic systems of interpretation of signs in the biosphere.[2]

Let us admit that we can define such an alternative theory of biology and ask whether and in what sense the theory of the sign nature of the living systems provides us with explanations of biological phenomena and whether it allows us to predict phenomena hitherto unknown. Here, too, biosemioticians provide only very general answers—in principle, biosemiotics is a new way of explaining life as such, in all its manifestations. A common thread here is that without the semiotic dimension, living systems are not actually living; they are merely chemical and information-coding models of living systems.

Again, let's admit that this answer is valid (although we have completely left aside the issue of predictions in science) and ask what applications this new semiotic concept of biology brings. What can it offer compared to bioinformatics, molecular biology, genetic engineering, etc.? Here we reach an unknown place: I don't know of any biosemiotician who would purposefully think about biosemiotic applications. Again, in very general terms, perhaps biosemiotics is a therapy for "biological reason" that has focused too much on quantifiable features of life and forgotten that life is primarily about living creatures (not their DNA and other codes) (see Markoš, 2002: 51) and their interactions in a shared world.

Were we not interested in presenting biosemiotics as science and instead leave it solely as part of the humanities, we would greatly simplify our task, as the difficulties in answering the questions we just asked would disappear. In that case, we could just call biosemiotics a new *Naturphilosophie*, a new philosophy of life.[3] However, such a solution would run counter to the beliefs of the biosemiotic community, which is a factor that cannot be overlooked. We will therefore try to define the specific nature of biosemiotics as a cross-discipline.

2. CONCEPTUAL BORROWING AND CROSS-DISCIPLINARITY

The term of 'cross-disciplinarity' indicates that biosemiotics should stand outside the hierarchy of traditional disciplines. Instead, it takes place within a network of disciplines. We have been observing a certain levelling of traditional hierarchies of scientific disciplines for a long time, at the latest since the 1990s, associated with the concept of interdisciplinarity. At the same time, there has been a growing effort for a pluralistic approach to research areas, characterized by the emergence of many

---

[2] For the discussion about the Peircean semiotics and its role in contemporary biosemiotics see Rodríguez Higuera (2019).

[3] However, it would be necessary to define the biosemiotics against Naturphilosophien, which discusses Wouter Hanegraaff in the context of the so-called "New Age science" (Hanegraaff 1996, 62–76).

"studies", which, especially within the humanities, has interlaced traditional disciplines.

In the case of biosemiotics, we used the term cross-disciplinarity, which is examined in detail by Stephen Kellert (2008). At the same time, we must justify our preference for this term instead of all the other possible X-disciplinarities. Their use is not specifically established, but they form a range: transdisciplinarity, interdisciplinarity, multidisciplinarity, cross-disciplinarity, post-disciplinarity, and anti-disciplinarity.

The term transdisciplinarity is mostly used in cases of research programs that go beyond specialized research and focus on very general problems. Therefore, the role of philosophy can be considered as transdiciplinary.[4] During the cognitive revolution (since the 1990s), cognitive science acted as a transdiscipline, bridging research on the issue of knowledge across the spectrum of sciences from the philosophy of mind and psychology to neuroscience and AI.[5]

Multidisciplinarity is the closest to cross-disciplinarity because it benefits from the cooperation of several disciplines to investigate a specific problem. Bioinformatics can be mentioned as a suitable example of a multidiscipline. Computational modelling of living systems and their investigation through information flow models (see Davies, 2018) brought biology new insights and several specific applications (Ross, 2016). At the same time, however, in bioinformatics there is indeed no change (again with Laudan) in the ontology of biology. Biology benefits from the application of information methods. In the case of cross-disciplines (as in biosemiotics), however, the ontology changes.

The last two terms are associated with various types of "studies" that have developed in the humanities and Social Sciences since the end of the 20th century. In the humanities, research projects in media studies, cultural studies, gender studies, etc. are often built as post-disciplinary projects that play a remedial role, so they are often politically engaged. From this perspective, it is as if the original humanities were losing their legitimacy (hence post-disciplinarity). In some aggravated cases, it is a complete rejection of the original disciplines (anti-disciplinarity).

However, biosemiotics does not fulfil the characteristics of "studies," it is not a free interconnection of source areas, but a directed connection, unifying concepts following a certain key. We can, therefore, trace the main pathways of disciplinary interaction among different areas of interest and observe the emergence of clusters, which in the future may represent elements in a hierarchy of a new type. The key to the creation of these clusters is, we believe, *conceptual borrowing*.

---

[4] Especially the role of the philosophy of science, although in recent decades it has diversified to individual disciplines (see Humphreys, 2016).

[5] This idea was presented many times by Czech cognitive scientist and philosopher Ivan Havel.

The term "borrowed knowledge" is chosen by Stephen Kellert (2008) in the context of the popularity of chaos theory in the 1980s and 1990s.[6] However, his conclusions can be generalized: In fact, they serve to depict what Kellert calls "the context of pursuit" (Kellert 2008, 46). We can define this as a clash and competition of various conceptualizations in the emergence of new theories and scientific disciplines themselves.[7] Kellert, thus, complements the new "context" to the traditional pair of the context of justification and the context of discovery, which were typical of the received view in the philosophy of science.[8]

Kellert shows what conditions have to be met in conceptual borrowing so that it is not just a metaphorical expression, but a real transfer of the concept from the source area to its new scientific context. It is not enough to start using the term in a new context (1); instead, it is necessary to transfer the corresponding concept with everything (operationally speaking) that belongs to it (to the maximum extent possible) (2); and finally, it is necessary to transfer inference schemes from the source area so that it can work within a new context in a literal sense (3).[9]

Kellert's examples are mentioned in note 6. In our opinion, molecular biology is an example of the successful emergence of a cross-discipline: the code concept has been used literally at the biological level (in linearity, segmentation, combinatorics, etc.) and even with inference schemes (in that sense, code complexity, entropy, redundancy, etc. can be measured).[10] On the contrary, in the case of memetics, it has only been possible to transfer the concept literally (meme as an analogy of a gene), but not as inferential schemes. The meme has remained a metaphor (What is its carrier? What is the analogy of a gene pool standing for?).

3. CROSS-DISCIPLINARITY OF BIOSEMIOTICS

We have already said that the term multidisciplinarity does not apply to biosemiotics because the ontology of biology changes with it. This much seems to be the case: A semiotic basis is added to the chemical, informational, and coding basis

---

[6] Kellert examines borrowings from the chaos theory in Economics, Law and Literary Studies; see Kellert (2008, 81–102).

[7] Historically, this is how molecular biology, for example, is created in order to cross the theory of information and biology when with the help of information conceptual borrowing it was possible to define the concept of the genetic code (and subsequently to find it empirically). However, some borrowings failed – e.g. when molecular biology crossed psychology in the 1980s to create memetics, e.g. Blackmore (1999).

[8] E.g. Kellert (2008, 45–47, 75–76).

[9] E.g. Kellert (2008, 25–55).

[10] Of course, there is also bioinformatics today - this is another extension of conceptual borrowing. In fact, in the opposite direction – biological systems (regulatory gene networks, etc.) are a type of information networks, e.g. Davies (2019).

of biology. According to biosemiotics, living systems are semiotic systems, that is, systems in which signs are created, shared, and recognized. This brief definition brings a serious ontological commitment that must be sufficiently thought out and analyzed. It is necessary to consider (1) which concepts are taken from semiotics and used as conceptual borrowings in biology, (2) whether these concepts are brought with all the essentials, and (3) whether they are transferred from semiotics with all the commitments, i.e. whether the possibility of building inference schemes between transferred concepts is also transferred.

The concepts that are borrowed from semiotics include, for example: sign, code, interpretation, semiosis, subject of semiosis, Umwelt, Innenwelt, and so on. When it comes to using individual terms, these may be, as Kellert (2008: 103-120) points out, metaphorical borrowings. One of the pluralities of biosemiotics lies in how we find approaches within it that create just such metaphorical relationships. Simplifying matters, we can say that the whole fact of biosemiotic research could be understood at the first level as a language metaphor of life (see Markoš, Faltýnek 2010). We believe that the hermeneutics of life of Anton Markoš also falls within this sphere (see Markoš 2002).[11]

However, metaphorical borrowing is not a sufficient guarantee of the creation of a new viable ontology for the scientific discipline. When we declare that life has a language-like nature, then it can only mean that the variety of interactions that take place between living systems and their parts is so great that it can be approximated by the diversity of the levels of language, including its use in communication.[12]

Let us, therefore, ask, for at least three selected concepts, if they can be transferred to biology, including all essentials: Can signs (1) be considered as symbols (in Peirce's or de Saussure's sense) in biology? Can (2), for example, the process of DNA transcription be understood as an interpretation of a text in a semiotic sense? Is it possible (3) to think of organisms or individual cells as *parole* in the linguistic sense? We admit that our choice is limited and not entirely representative, but these are valid examples that allow us to further examine the third inference level of conceptual borrowings in biosemiotics.

In the first case, this is a key decision: without having symbols, we can hardly speak of a full-fledged semiotic conception of biology. Therefore, a large part of biosemiotic analyses focuses on understanding symbols in living systems – currently mainly through the means of Peircean semiotics (see again Rodríguez Huguera 2019) The second case also seems to be binding, because without the interpretation of symbols, according to many biosemioticians, only the traditional concept of code

---

[11] There was an interesting influence of hermeneutics of life present in “eidetic biology” of Zdeněk Neubauer.

[12] Below we will see literal use of the concept of language in the semantic biology of Marcello Barbieri.

would remain available, which is insufficient to define the semiotic nature of the living system. Kalevi Kull even states:

> "Accepting Barbieri's definitions of code and arbitrariness, I have shown that code is insufficient for meaning making. The main source of arbitrariness is interpretation, while the arbitrary-relation is afterwards preserved by a code. A code alone is insufficient for semantics. A code is not semiosis." (Kull 2020, 139)

The third case is more strongly connected with one of the varieties of biosemiotics – the hermeneutics of life (see again Markoš 2002) – and it cannot be considered universal for the whole biosemiotic community.

As the last stage of our conceptual analysis, consider whether the mentioned cases of borrowed concepts can be connected in the context of biology so that a valid inference scheme is created. If this succeeds, we have at least a basic outline of new ontological commitments; otherwise, conceptual borrowing returns to the level of metaphors. Consider firstly the connection of the other two concepts (interpretation and parole): we must literally state that reading and transcribing DNA as a process of textual interpretation leads to a new living system – the result of interpretation – which connects with other existing results of interpretations of genetic texts and creates a universe of interpretations, namely, the *parole* of life.

We believe that the limitations of conceptual borrowings from the side of the hermeneutics of life are quite obvious here, namely, to consider cells and, more broadly, organisms as the results of the interpretation of biological texts presupposes that we are thinking of someone who performs the interpretation. However, this subject of semiosis can hardly be understood literally as an intentional actor. We cannot construct intentionality at the level of the cell and the organism other than metaphorically.

As for the first pair of borrowed terms – sign and interpretation – we can try to accurately transfer inference schemes only if we have a concept of interpretation without the assumption of the subject of semiosis. We are convinced that the majority of the biosemiotic community believes that signs exist in the biosphere and are interpreted by living actors, and this interpretation is not conceived as the activity of a conscious intentional actor. Interpretation can be thought of as a certain biological function that is not identical to the recognition of arbitrarily established code. The semiotic nature of the living system seems thus built into the ontology of biology.

Nevertheless, as we have already mentioned, the plurality of the biosemiotic community is great. Yet, a potential rupture that has shifted the landscape of the biosemiotic consensus has emerged on the status of the interpretation of the meaning of codes. The prevailing interpretation, expressed by Kalevi Kull (2020), as we have already stated, does not understand the code as a sufficient condition for semiotic biology. However, many authors who originally felt an affinity for biosemiotics and now adhere to code biology do not recognize interpretation as a part of semantic biology.[13]

We performed a conceptual analysis of the nature of the cross-disciplinarity of biosemiotics based on Kellert's criteria for successful conceptual borrowings. In this respect, our constructive critique of biosemiotics differs from the more traditional critique of some philosophical naturalists (see Gálik 2013) and biologists.[14] As a final step in our analysis, we will focus on a brief evaluation of two (among many) potential paths that biosemiotics could take in the future to refine its status as a science (with ontological commitments) or, conversely, as a full-fledged philosophy of life. The first path is represented by Barbieri's semantic theory of evolution (and code biology) and the second, by Rodríguez's philosophical analysis of the lower threshold of semiotic systems.

4. TWO DIRECTIONS FOR BIOSEMIOTICS

We offer Barbieri's "The Semantic Theory of Evolution" (1985) and "Code Biology" (2015) on the one hand and Rodríguez's "The Place of Semantics in Biosemiotics: Conceptualization of a Minimal Model of Semiosic Capabilities" (2016) on the other as two approaches that can serve as forerunners for the future of biosemiotics. The first direction would distinctly determine the affiliation of biosemiotics to science, while the second direction would provide biosemiotics with a solid philosophical conceptual foundation.

The two approaches are also valuable because they illustrate the methodological tension within the biosemiotic community. While Barbieri explicitly speaks of semantic biology only as new scientific modeling of living systems, Rodríguez's conceptual analysis is intended to provide a solid foundation for semiotic biology as a faithful representation of life. Here we see the distinction between the moderate idea of designing a new scientific model that cannot be identified with researched facts, and on the other side, the search for a suitable metaphysics that will allow signs to become an irreducible part of reality.

We can notice Barbieri's statement about the nature of the mechanisms that give rise to the explanatory means of code biology:

> "It has been suggested that semiosis in general – and codes in particular – cannot be explained by a mechanistic approach, (…). (…) What code biology is saying,

---

[13] Some researchers are willing to consider the formal definition of semantic biology, e.g. Igamberdiev, Brenner (2021). Also the analysis of the lower threshold of the semiotic system has a high importance, e.g. Zámečník, Krbec (2019).

[14] The strategy of ignoring the whole research area.

> however, is that mechanism must be ‘extended’. More precisely, we must ‘extend’ it by introducing ‘meaning’ as a fundamental component of life – a new observable – just as molecular biology has introduced the new component of ‘information’.” (Barbieri 2020, personal communication)

Elsewhere, Barbieri clearly defines the role of mechanisms as scientific models:

> “Mechanism, in short, is virtually equivalent to the scientific method. The difference is that the hypotheses of the scientific method are replaced by models, i.e., by descriptions of fully functional working systems. Mechanism, in other words, is ‘scientific modelling’.” (Barbieri 2015, 16)

Barbieri's goal, then, is to reform biology in such a way as to implement meaning as an integral part of mechanistic models of living systems. Organic meaning is to be made part of biology through code:

> “(…) the rule of the genetic code that a group of three nucleotides (a codon) corresponds to an amino acid is equivalent to saying that that amino acid is the organic meaning of that codon. Anywhere there is a code, be it in the mental or in the organic world, there is meaning. We can say, therefore, that meaning is an entity which is related to another entity by a code, and that organic meaning exists whenever an organic code exists (Barbieri 2003; Artmann 2007, 2009).” (Barbieri 2015, 26)

Barbieri's semantic biology or code biology, as a model for biosemiotics, would mean a return to – or an evident affinity for – science. The victim of this approach, however, is the concept of interpretation, which for Barbieri is clearly connected with the biologically inadequate activity of the conscious intentional actor. It is interesting to read this key distinction in the original version of The Semantic Theory of Evolution:

> “When the nucleus sends a messenger-RNA to the cytoplasm, the messenger ‘is’ the message. It is as if Nature writes the word ‘apple’, for example, and then the word folds itself up and becomes a real apple. This deep unity of structure and function gives a material reality to life that does not exist in the abstract world of a language, and makes it difficult for us to realize not just that life has a language, but the more subtle idea, that life is a language.” (Barbieri 1985, 170)

As a perspective for biosemiotics, Barbieri, therefore, offers us a semantic extension of biology that is fully compatible with the perspective of research within science: a view of semantic biology based on extended mechanisms that do not need conceptual means of Peircean semiotics.

In the case of Rodríguez (2016), we have an equally important but completely different appeal for biosemiotics. With the consistency of an analytical philosopher, Rodríguez encourages biosemioticians to revise metaphysical assumptions so that a match can be found between physicalist traditional biology and the semiotic extension of biology. This consistency is to be provided by the Minimal Model of Semiosic Capabilities.

He encourages the biosemiotic community to incorporate much more "basics of the humanities" than what is part of the official canon of biosemiotics. To reconcile the physicalist ontology of biology and the sign nature of the living, he offers several solutions, the most promising of which appears to be the weakly emergent account of signs,[15] which:

> "(…) gives us the chance to do so by not affirming either that signs are merely reducible to their physical constituents (which are only partial), but that they nevertheless depend on the physical aspect to exist. This is in line with Peircean realism while doing away with some of its metaphysical claims." (Rodríguez 2016, 91)

This appeal is important because if biosemiotics is to be further profiled as an extension of traditional biology, then it must clarify how the sign nature of the living systems can be related to the chemical, informational, and code nature of life as studied in mainstream biology. At the same time, however, we see that biosemiotics, viewed from this perspective, displays more features of philosophy and thus becomes part of the Humanities. It is as if Rodríguez offered the search for a consistent philosophy of life as a task for biosemiotics.

5. CONCLUSIONS AND VISIONS FOR THE FUTURE

We focused on the conceptual analysis of biosemiotics as we wanted to understand what it is like to be a biosemiotician. This was done through Larry Laudan's classical perspective, which seeks and describes the nature of the ontology, methodology, and axiology of a chosen scientific discipline. In the case of biosemiotics, the key question was whether it counts as an extension of science or if

---

[15] Rodríguez offers also different strategy: "P-Semantics, thus, is conceptually the non-deterministic implemented mapping of relevance for an organism within a given environment. P-Semantics closes the loop of value realization, but this closure is not of a fixed value. That is, as meaning is not proposed as a unambiguous one to one correspondence between objects and concepts, we are left with what could be characterized as stochastic processes of selection between elements that integrate actions towards or against them." (Rodríguez Higuera 2016, 105)

it is a part of the Humanities. We mapped the nature of the ontology, methodology, and axiology of biosemiotics and decided to examine its ontological commitments.

Since biosemiotics is not a traditional discipline, but arises at the intersection of traditional biology and semiotics, we have examined the nature of conceptual borrowings on which it has been built. We used Stephen Kellert's typology for this. Here we took stock of individually borrowed concepts, but also of their important components within the source discipline (semiotics). Finally we examined whether these concepts are borrowed with all the commitments that allow us to find inferential relations between them, or in other words, whether they let us build inference schemes.

We have seen that some disciplines have been successfully created in the past thanks to cross-disciplinary borrowings (e.g. molecular biology), but the emergence of a new discipline is not always successful (e.g. memetics comes up as a failed project). We have shown that in the case of biosemiotics, it is crucial that the concept of the sign (as a symbol) and the concept of interpretation, including their relationship, can be considered literally in the context of biology. We have argued that the concept of interpretation must be free from the influence of the concept of the subject of semiosis. And we have stated that the biosemiotic community is generally united in the fact that the concepts of sign and interpretation can be implemented in biology.

However, we have also pointed out some difficulties associated with the acceptance of the literal meaning of the sign and interpretation, and we introduced some alternative approaches within the plurality of biosemiotic approaches. Finally, we have presented two significantly different approaches that we believe could direct the future development of biosemiotics towards mainstream biology (in the case of Barbieri's code biology) and, conversely, towards a consistent philosophy of life (in the case of Rodríguez's weakly emergent account of signs). The most important thing is that Barbieri builds code biology as a set of models of living systems without the ambition to penetrate reality itself. Rodríguez, in turn, builds a solid philosophical basis for the concept of sign within physicalist biology.

Our analysis does not provide a definitive conclusion, as it only focuses on two possible scenarios for the future of biosemiotics. However, we would like to end with something positive, yet based on empirical evidence. As part of data science, Dashun Wang and Albert-László Barabási (2021) performed a thorough analysis of quantifiable trends in the development of scientific research. One of the conclusions concerned the analysis of the impact of the growth of multidisciplinary research, where we can certainly include biosemiotics at the moment.

Their data analysis (Wang, Barabási 2021, 192) shows that an increase in the degree of multidisciplinarity in scientific research leads, on average, to a significantly higher rate of failures. However, at the same time, there is a greater degree of variance in results, so, in a surprising turn of events, as the average growth of failures increases, so does the number of innovations that can be described as breakthroughs.[16] If we combine this finding with others, such as the positive impact of the diversity of scientific teams, or the correlation between the small size of a scientific team and its ability to carry out a conceptual revolution in a given scientific field, etc. (Wang, Barabási 2021: 116, 131), then we can expect a positive future for biosemiotics.[17]

Acknowledgments

Thanks to Hana Owsianková for proofreading of the English version of the text. The funding for the present publication was provided by the Czech Ministry of Education, Youth and Sports for specific research (IGA_FF_2022_027).

REFERENCES

Artmann, S. (2007). Computing Codes versus Interpreting Life: two alternative ways of synthesizing biological knowledge through semiotics. In: Barbieri, M. (ed.) *Introduction to Biosemiotics: the new biological synthesis* (pp. 209-233). Dordrecht: Springer.

Barbieri, M. (2015). *Code Biology: A New Science of Life*. Dordrecht: Springer.

Barbieri, M. (2003). *The Organic Codes: an introduction to semantic biology*. Cambridge: Cambridge University Press.

Barbieri, M. (1985). *The Semantic Theory of Evolution*. London: Harwood Academic Publishers.

Blackmore, S. (1999). *The Meme Machine*. Oxford: Oxford University Press.

Davies, P. (2018). *The Demon in the Machine*. New York: Penguin Books.

Gálik, D. (2013). Biosemiotics: A New Science of Biology? *Filozofia 68*(10): 859–867.

Hanegraaff, W. J. (1996). *New Age Religion and Western Culture: Esotericism in the Mirror of Secular Thought*. Leiden: Brill.

Humphreys, P. (2016). *The Oxford Handbook of Philosophy of Science*. Oxford: Oxford University Press.

Igamberdiev, A. U. and Brenner, J. E. (2021). Mathematics in biological reality: The emergence of natural computation in living systems, *BioSystems 204*. https://doi.org/10.1016/j.biosystems.2021.104395

Kellert, S. H. (2008). *Borrowed Knowledge: Chaos Theory and the Challenge of Learning across Disciplines*. Chicago: The University of Chicago Press.

---

[16] However, these results should be taken with caution, as they are based on an analysis of the degree of innovation of patents. For more details, see Wang, Barabási (2021, 189–193).

[17] Thanks to Hana Owsianková for proofreading of the English version of the text.

Kull, K. (2020). Codes: Necessary, but not sufficient for meaning-making, *Constructivist Foundations 15*(2): 137–139.

Kull, K., Emmeche, C., and Hoffmeyer, J. (2011). Why Biosemiotics? An Introduction to Our View on the Biology of Life Itself. In: *Towards a Semiotic Biology* (pp. 1-21). London: Imperial College Press.

Laudan, L. (1998) Dissecting the Holist Picture of Scientific Change. In: Curd, M. and Cover, J. A. *Philosophy of Science: The Central Issues* (pp. 139-169). New York: W. W. Norton & Company.

Markoš, A. (2002). *Readers of the Book of Life: Contextualizing Developmental Evolutionary Biology*. Oxford: Oxford University Press.

Markoš, A. and Faltýnek, D. (2010). Language Metaphors of Life, *Biosemiotics 4*(2): 171–200.

Rodríguez Higuera, C. J. (2019). Everything seems so settled here: The conceivability of post-Peircean biosemiotics, *Sign Systems Studies 47*(3/4): 420–435.

Rodríguez Higuera, C. J. (2016). *The Place of Semantics in Biosemiotics: Conceptualization of a Minimal Model of Semiosic Capabilities*. Tartu: Tartu University Press.

Ross, A. (2016). *The Industries of the Future*. New York: Simon & Schuster.

Wang, D. and Barabási, A. L. (2021). *The Science of Science*. Cambridge: Cambridge University Press.

Zámečník, L. and Krbec, J. (2019) Describing Life: Towards the Conception of Howard Pattee, *Linguistic Frontiers 2*, 1. https://doi.org/10.2478/lf-2018-0012

Ecosemiotics: Signs in Nature, Signs of Nature

Riin Magnus
Universität Tartu

Abstract

The paper gives a synthetic overview of the current state of ecosemiotic research and proposes some new theoretical as well as applicational research vistas for the research field. Modern ecosemiotics has merged investigations of human interpretations of the environment and the semiotic activity of other species. In the era of the Anthropocene, humans are often the ones who determine the conditions of semiotic existence for other species. Furthermore, the symbol systems that humans use for interpreting the natural world form an integral part of such conditions. This paper therefore seeks for shifts in the existing symbolic systems that might help to relate to the environment as a semiosis based and regulated phenomenon. In more detail, it will explore the possibilities of dialogical approaches to support such a relation. Although several textual approaches to nature can be considered as potentially hegemonic and supporting the right of humans to treat nature from the grounds of ownership, this article will suggest that the perspectives on communication and dialogue offered by authors such as Mikhail Bakhtin may help to provide the necessary shifts of interpretation. Moreover, these kinds of interpretational grounds suggest ways for bridging the recognition of more-than-human semiotic relations with certain conservation ethics and practices of nature conservation.

Keywords: ecosemiotics, human-environment relations, Mikhail Bakhtin, conditionality of semiosis.

Modern ecosemiotics finds itself in a paradoxical situation. Despite the growing number of studies focusing on the meanings, values, and stories that relate humans with their environment, the ultimate cause of the current ecological crisis has at the same time been lamented as a remarkable lack of such relations. Alienation, estrangement, and disembedding are the labels one commonly finds imputed to the modern conditions of human-environment relations, although these concerns have occupied the minds of numerous philosophers from different traditions and eras of thought—from Rousseau to Hegel and Marx, from Novalis to Heidegger. In this paradoxical light there are several alternative tasks that ecosemiotic research may pose for itself, depending on how the 'semiotic relation' itself is understood—it may look for the oases of meaning still existing in the desert of estrangement, it may argue for alienation as one kind of a semiotic relation and analyze the semiotic mechanisms that underlie it, or it may subject the idea of alienation itself to criticism and demonstrate how the categories that it operates within (above all nature and culture) are themselves products of certain ideologies. Even if the last, critical stance is taken, ecosemiotics cannot ignore the oppositions and distinctions prevalent in the social embeddings it aims to analyze.

In the following paper, then, I hope to demonstrate at least some of the ways human-environment relations are and can be subjected to semiotic analysis by bringing out the major developments in ecosemiotics throughout its nearly 30 years of existence. I will also suggest some further potentials for the discipline in theoretical terms while bearing in mind the social outcomes. Although research conducted under the title of ecosemiotics is still meager, a great deal more is to be found when the subject field of study—referred to in the title of this article as *signs in nature and signs of nature*—is put under scrutiny. Beginning with the ecosemiotic research tradition *sensu stricto*, the paper thus also engages authors and disciplines that do not figure under the title of ecosemiotics, but still bear relevance for the research foci discussed.

1. ECOSEMIOTIC RESEARCH: ORIGINS AND FOCUS

Ecosemiotics is a rather recent subfield of semiotics—the first papers using this name as a research field were published in the 1990s (Kull, 1998; Nöth, 1996, 1998).[1] However, as Kalevi Kull (1998) has noted, there were already attempts to develop ecological semiotics in the early 1980s by St. Petersburg and Tartu scholars (pp. 347–348). The birth of ecosemiotics coincides with the rise and spread of other environmental humanities research fields, such as more-than-human geography, ecological anthropology, environmental sociology, and ecocriticism. By that time,

---

[1] Other brief histories of ecosemiotics have been published earlier, e.g., in Maran & Kull, 2014; Maran, 2018, 2021.

biosemiotics and cultural semiotics had to a certain extent taken their own independent paths with their own canon of theories as well as predecessors. In a way, the birth of ecosemiotics provided a moment for their integration and gave an impetus to look for common grounds once again. By combining the research objects of the two sub-disciplines of semiotics—signs in the natural world and in human culture—ecosemiotics managed to avoid some of the incompatibilities that had taken bio- and cultural semiotic ontologies apart. Above all, this concerns questions about the threshold of semiosis and whether there is anything beyond human culture that can be subjected to semiotic research.

As the authors who have contributed to ecosemiotic research have often come from adjacent fields (e.g., Alf Hornborg from anthropology, Almo Farina from ecology, and Alfred Siewers from literary studies), ecosemiotics has, since its very beginning, been finely intertwined with other disciplines that have likewise defined human-environment relations as their research object. This integration of different disciplines has at the same time been used for a variety of empirical studies, both in terms of investigated species as well as methods of research. To name a few, an ecosemiotic approach has been used to study halibut fishing by Greenland fishermen (Roepstorff, 2001), the local reception of the European jackal as a new species to Estonia (Maran, 2015), bird soundscapes (Farina, Pieretti, & Malavasi, 2014), and the variety of sign types used by Amazonian communities (Hornborg, 2001). The premise about the presence of other species' *umwelten*[2] is a unifying factor for most of these studies. This is supplemented with an observation that the umwelten and semiotic activity of the other species bears relevance for human relations with those species. In other words, it is the meeting point of human umwelten (the possibilities of semiosis grounded in human biology), the semiosphere, and the non-human sign-based activities that serves as the focal point of ecosemiotic studies.

The crisscrossing of human and non-human umwelten is well exemplified by Andreas Roepstorff's (2001) study on Greenlandic halibut hunting. This fish species is fond of living in places with deep water and active glaciers or large icebergs. These icebergs frequently break into pieces, explode, and cause gigantic waves and turbulences. Thus, the halibut hunt is not an activity of the safest kind. However, in the same marine hunting grounds one may also encounter seals, and apparently, a group of seals swimming near icebergs is a good sign of safety. These mammals, having a very good sense of hearing, register the sounds that icebergs emit and react to changes in these sounds, which are inaudible to humans. Thus, Roepstorff's study finely demonstrates how the sensory capabilities of other species can extend to those

---

[2] *Umwelt* is a term coined by Jakob von Uexküll to designate an organism's subjective world of perception and action that is based on sign use (see von Uexküll 1921, 1934/1992).

of humans, and how the marine environment as a *taskscape*[3] entertains a multitude of intersecting umwelten.

In the light of the premise about the coupling of the human and non-human umwelten, one might wonder about the status of the non-living environment, which *per se* does not evince a semiotic character; neither from a bio- nor from a cultural semiotic perspective. Following an Uexküllian line of thinking, an environment is always someone's (be it a human or non-human) environment in a (bio)semiotic study, and hence does not exist as a neutral entity. It may not possess semiotic agency, but it is worth a semiotic look as far as it is an object of such agency.

In the early days of ecosemiotics, authors whose academic identity was more related to the discipline of semiotics contributed with theoretical reflections, aiming to specify the object of ecosemiotic research. As a result, two alternative sub-fields of ecosemiotics were developed, outlined as *biological ecosemiotics* and *cultural ecosemiotics* by Winfried Nöth (2001). According to this division, biological ecosemiotics focused on the relations between organisms and environments, while cultural ecosemiotics studied human-environment relations. This differentiation has faded as the field has developed, and in his recent monograph, Timo Maran (2020) has delineated the following focus of ecosemiotics: "The focus of ecosemiotics is thus on the interactions between environmental conditions and semiotic processes and the diversity of life stories, meaning-making strategies, and narratives that spring from these intertwinings" (p. 4). Here, humans are placed on an equal standing with other sign-using creatures, and human narratives are placed side by side with other meaning-making strategies. Even if ecosemiotics "studies sign processes as responsible for ecological phenomena" (Maran & Kull, 2014, p. 41), that does not exclude human-environment relations from the field's research focus. Such a merging of biological ecosemiotics and cultural ecosemiotics finds support from the developments that extend beyond semiotics, namely the nearing of humanities and natural sciences in the studies of the Anthropocene, where by definition, human presence is ubiquitous. Simultaneously with the recognition of the extent of the human impact on the natural environment, the humanities have developed self-critical programs about the uniqueness of human agency, exploring its merging and intertwining with the agencies of other species or even the non-living environment (e.g., Kohn, 2013; Urbanik, 2012; van Dooren, Kirksey, & Münster, 2016; Whatmore, 2002).

Authors specifying the research agendas of ecosemiotics have also referred to concepts, trends, and authors that ecosemiotics shares with other fields of semiotics or that are characteristic to ecosemiotics specifically. Nöth (2001) has proposed that

---

[3] *Taskscape* is here used *sensu* Ingold (1993) and is related to his dwelling perspective on landscapes. Taskscape is "an array of related activities" (p. 158) and landscape "a congealed form of the taskscape" (p. 162).

ecosemiotics is characterized by a "very low 'semiotic threshold' between signs and non-signs if it does not reject such a threshold altogether" (p. 72). This remark points to an ontology that ecosemiotics shares with biosemiotics. In addition, Nöth (1998) has suggested the following theoretical sources for ecosemiotics: Charles Sanders Peirce and his differentiation between dyadic and triadic relations, Charles Morris with his pragmatic dimension of signs, and Jakob von Uexküll and his umwelt model. Peirce's distinction allows to differentiate non-semiotic (those resulting from mere chance or as *brute facts*) and semiotic interactions (Nöth, 2001, p. 76), Morris's pragmatic dimension allows for the focus on the use of sign (probably thus stressing the observable part of sign use), and von Uexküll's umwelt model turns attention to the individual and species-specific meaning formation and sign use of animals. These are hence all sources and pieces of theory that extend semiotic analysis beyond human culture. When comparing these early suggestions for ecosemiotic theory with the most recent comprehensive work on ecosemiotics—Maran's monograph *Ecosemiotics: The Study of Signs in Changing Ecologies*—then all three authors have a place there too, but with somewhat different foci. For example, Maran (2020) stresses the importance of the Peircean concept of *ground* for ecosemiotics (p. 49). He also encompasses all three dimensions of semiosis—syntactics as the form of signs, semantics as the meaning of signs, pragmatics as the use of signs—from Morris to ecosemiotic research (p. 30). In addition, Maran (2020, 2021) has introduced Yuri Lotman's legacy to the ecosemiotic research agenda, adapting, for example, the concepts of semiosphere and (auto)communication, thereby marking the importance of the cultural semiotic tradition for ecosemiotic research.

When placing ecosemiotics against the wider background of the environmental humanities, one could ask about the traits that distinguish ecosemiotics from the other sub-disciplines of the environmental humanities. As a research field that per definition focuses on semiosis and signs, it lays stress on cognition, modelling, and interpretation beyond only humans. Maran (2020) has noted that as the sign itself is a relational concept, it offers a conceptual tool for an ecological understanding of culture (p. 4). Elsewhere, he has phrased the research methodology of ecosemiotics as follows: "[…] the necessity to integrate two branches of ecosemiotics should result in the formation of research methodology that allows both *the representations of nature in culture and nature in its own semiosic activity to be covered* [emphasis added]" (Maran, 2007, p. 280). By encompassing the perspectives of other species, ecosemiotics aligns with other disciplines of the environmental humanities that argue for the agency of other species besides humans. However, agency in those fields might carry different meanings, sometimes encompassing only its etymological meaning—*to do*—whereby other species become integrated with human history through their ability to act (see Brown, 2016, p. 13). Like biosemiotics, an ecosemiotic perspective considers semiosis to be the foundational process for agency. As Morten Tønnessen (2015) has pointed out, "most biosemioticians appear to agree that core attributes of an agent include goal-directedness, self-governed activity, processing of semiosis and choice of action" (p. 140). Also, ecosemiotics may be interested in the activity part of non-human agency, but in order to be counted as ecosemiotics, the premise behind these observations should be that certain interpretations, recognitions, and choices (which in turn might also be seen as activities) ground those actions. This distinguishes ecosemiotics from actor-network theory, cultural materialism, and object-oriented ontology, which do not necessarily assume such processes from the actors they investigate.

2. LANGUAGE BARRIER AND SHARED MODALITIES

Even if the semiotic abilities and/or agency of other species is recognized, the way humans relate or find themselves capable of relating to this agency may vary to a significant extent. Certain behavioral tendencies or characteristics may be interpreted as mere symptoms of semiotic capabilities to a human observer. Semiosis is recognized to be present, but there are no means to relate with or respond to it. In that case, there is not a semiotic void that separates humans from other species but rather a symbolic barrier that obstructs real mutual attendance to one another. This stance is exemplified, for example, in Jacques Derrida's and John Berger's works on human-animal contacts that reflect the mysterious, *there-beyond* feeling that a human is left with when facing the presence of a non-human subject. In his essay "Why Look at Animals" Berger (1992) writes: "The animal scrutinizes him across a narrow abyss of non-comprehension… The man too is looking across a similar, but not identical, abyss of non-comprehension" (p. 5). There is no language to bridge the abyss, and hence the animal is to remain distant and distinct from humans. Yet, the animal of Berger's essay has *a look*. Derrida's (2008) *The Animal That Therefore I Am*, another famous piece of writing on a philosopher's estrangement when being faced with an animal's look, describes an epoch of Western thinking, starting from Descartes, that has remained ignorant and inattentive to the look of an animal: "They have taken no account of the fact that what they call 'animal' could *look at* them, and *address* them from down there, from a wholly different origin" (p. 13). Yet, despite meeting the look of an animal as another and recognizing its presence, Derrida himself still enters an endless spiral of self-reflections, with the *addressing* remaining without a response.

The *curse of symbols* has been also a concern in several ecosemiotic papers, including claims that ecosemiotic research should break the symbolic barrier between humans and the rest of the semiotic community and explicate the indexical and iconic grounds of human interactions with the environment (see Maran, 2020; Maran & Kull, 2014; Nöth, 2001). As Maran (2020) has noted, "communication, however, presumes shared understanding of, or overlap in, vocabularies, codes, and communication media, so there need to be some levels or modalities in the human semiotic system that make interaction with other species possible" (p. 29). Maran and

Kull have even made a jump from ontology to ethics with that claim, arguing that human symbolic semiosis underlies current human-induced environmental destruction (Maran, 2020, pp. 19–25; Maran & Kull, 2014, p. 45). At the same time, they stress that such a focus on the non-symbolic has contributed to the rise of ecosemiotic research in the first place: "Ecosemiotics has partly emerged due to the deepened understanding of the non-symbolic sign processes' role in the research objects both in biology and the humanities" (Maran & Kull, 2014, p. 42).

Although focus on the means of communication that humans share with other species might help to overcome primary contact barriers, this is not sufficient for large-scale transformations of human relations with other species. One cannot ignore the symbolic if real dialogue with other species is sought for, and hence the task for ecosemiotics should at the same time encompass the discovery and analysis of those traits of culture that enhance the richness of multispecies interactions. In the following, I will therefore ask: What kind of a cultural and semiotic embedding might allow for the establishment of the mutually attentive and responsive relations between humans and other species?

3. THE CONDITIONALITY OF SEMIOSIS

The recognition that not only humans orient themselves in their environment with signs as mediators has been demonstrated to be an integral part of various indigenous worldviews (Viveiros de Castro, 1998; Kohn, 2013). Further parallels have been drawn between such vernacular perspectives and the biosemiotic relationality exemplified by von Uexküll's umwelt theory (Kohn, 2013). Such insights of different origin do not simply turn attention to the multiplicity of subjects and their perspectives but refer to the possible status of humans as a relational object in the umwelten of other species (see also Willerslev, 2007). Although von Uexküll's investigations of the subjectivity of organisms sought for a revolution in biology, from where the distinctiveness of the phenomenon of life had disappeared (von Uexküll, 1992[1934]), above all it thereby related with a set of biological theories and presumptions. Such a crisscrossing of vernacular and scientific perspectives, then, is rather to be seen as a fruitful and complementary endeavor to understand the multiplicity of semioses in the living world. As Dorothy Kwek (2018) has proposed, such a meeting point should transfigure "the ways in which we imagine, think and approach non-humans" (p. 27).

Both scientific formulations and the indigenous ways of relating with other beings can be seen as certain practices through which reality is being enacted. A stance of this kind is characteristic also to a research platform that an actor-network theoretician John Law (2009) has termed as *material semiotics* (pp. 150–151). Such a performative approach (to signs and signification) has been suggested as a possible alternative to constructivist imaginations (Law, 2009; Law & Lien, 2012). By turning away from the representational framework and the schism of the signified and signifier, it aligns with the *ontological turn*—a shift that has shaken mainly anthropological theory for somewhat more than a decade.[4] Yet, at the same time such a performative approach brings along repercussions in ethical and axiological considerations. It supports the contention that the semiosis of living beings is not a given but that it is also a characteristic that is subjected to and comes forward in certain conditions. While trying to determine the factors that contribute to the maintenance of the conditions of semiosis nowadays, human choices and ways of living appear to matter disproportionately more so. In the Anthropocene, human management of the environment seems to more or less determine whether other species can exist as semiotic beings—that is, whether the environments where living beings choose their food, partner, and habitat are preserved, whether they stay free from stress and are able to learn, predict, assess, and so forth. Moreover, the *semiotic freedom*, which Jesper Hoffmeyer (2015) has defined as "the capacity of species or organisms to derive useful information by help of semiosis or, in other words, by processes of interpretation in the widest (Peircean) sense of this term" (p. 153), should not be taken as the capacity of the organism only, as it is just as much an upshoot of the affordances of the environment the species is living in. In other words, semiotic freedom, too, needs to be enacted or else it remains a mere potential that is not realized due to the lack of an appropriate environment. Modern fragmented and transformed landscapes provide numerous examples of the constriction of territories, loss of habitats, and the ensuing inter- and intraspecific competition that lead to the restriction and transformation of the semiotic abilities of organisms to such an extent that impoverished existence or extinction follows.

However, the recognition that semiosis is a conditional state is not only a post-modern revelation of the consequences of the activities of modern humans. As the anthropological works of Marilyn Strathern (1988), Irving Hallowell (1960), Rane Willerslev (2007), and others have pointed out, this premise about the relationality of agency and personhood underlies the ontologies of several indigenous communities. To translate that into semiotic terms, semiosis as their foundational process is thereby also deprived of essentialism. Yet, there a human being is not the outstanding and dominant figure who sets the ultimate conditions for interspecific relations.

Highlighting the role of human activity in determining the kind of existence of other beings might nowadays raise criticism along the lines of human hubris, which is thereby pushed forward (see a similar critique of the Anthropocene notion Hettinger, 2014). Furthermore, an ensuing ethical stance might be reminiscent of Biblical motifs concerning the stewardship of nature (see also White, 1967). In order to avoid these arrogant or anthropocentric implications when arguing for the

---

[4] The beginning of the turn has been associated with the edited volume *Thinking Through Things* (2006) (Heywood, 2018).

necessity to preserve the conditions for the semiotic existence of other species, the presence of a component of addressing in the discourses with which humans *do things* is crucial. In other words, what matters here is whether such discourses contain a potential for dialogue or not. While maintaining that an ecosemiotic perspective should encompass such a focus on the dialogic relations between humans and other living beings, in his monograph on ecosemiotics, Maran (2020) has argued that "the problem at stake here is that it is not easy to evoke the other as a *true other* in a way that would not be just a mere reflection or amplification of one's own image" (p. 37). Such a seemingly inevitable solipsistic and self-reflective existence of culture has been a concern for environmentalists and philosophers alike (Jonas, 1966/2001, pp. 211–234; Zapffe, 1933/2004). Yet, returning to the previous observation that it is the symbolic frame of culture that is crucial for establishing and maintaining the conditions of semiosis for other beings, one can also find traditions in Western thinking that help to avoid mere self-reflective traps.

4. RESPONSIVE AUTHORSHIP FOR HUMAN-ENVIRONMENT RELATIONS

In this light, the works of Mikhail Bakhtin are worth consideration even when more-than-human subjects are involved. While fully acknowledging his original contributions to literary theory and the philosophy of language and the limits that are thereby set in transposing his ideas to a fairly different field, I believe Bakhtin can provide significant impetus for the quest for dialogism beyond humans. Previously, the works of Bakhtin have received ecological interpretations from various theoretical and disciplinary angles; for example, ecocriticism (Müller, 2010, 2016), social ecology (Bell, 1994), or organicist theory (Mandelker, 1994). The focus in these approaches has been laid on the interpenetration of social, individual, and environmental factors with the body serving as the point of connection; the idea of the chronotope as an ecological totality and the ideas behind the concepts of *foreign voice* and *polyphony* as something that allows for the independence of various interactors. In semiotics, Susan Petrilli and Augusto Ponzio's contention that *semiosis is dialogue* along with the subsequent development of what they call *semioethics* is based on a strong Bakhtinian underpinning (Petrilli & Ponzio, 2005). They have set their focus on the idea of *otherness* in Bakhtin's work, which is itself tied to the inevitable dialogism of word. Petrilli and Ponzio (2005) characterize Bakhtinian dialogue as follows:

"…t is the place of the I's very formation and manifestation. Dialogue is not the result of the I's decision to respect the other or listen to the other. On the contrary, dialogue is the *impossibility* of closure, of indifference; it is the impossibility of not becoming involved, and it is especially evident in attempts at closure, at indifference that simply prove to be tragico-comical. . . . Dialogue as depicted by Dostoevsky and as theorized by Bakhtin is the impossibility of being indifferent to the other." (p. 377)

From the complex set of ideas that surround dialogism in Bakhtin's works, I have picked one—authorship as expressed in Dostoevsky's novels—through which to hint towards some possibilities of furthering an ethical model for dialogic human-environment relations.

In their paper "Ethnography Beyond the Human: The 'Other-than-Human' in Ethnographic Work," Marianne Elisabeth Lien and Gísli Pálsson have placed Bakhtin's translinguistics, a field specifically meant to deal with discourse, individual utterances, and their dialogical relations (Todorov, 1984, pp. 25–26), in the light of human interactions with non-humans: "The conviviality of humans and other living beings should be seen as a polyphonic chorus where speakers and context mutually develop a long and noisy conversation. This is what Bakhtin referred to as 'translinguistics'" (Lien & Pálsson, 2021, p. 12). When analyzing Dostoevsky's dialogical novel in his "Problems of Dostoevsky's poetics," Bakhtin (1999) includes among the speakers not only the characters of the novel, but also the author. He demonstrates through the concept of a *voice* how the author in Dostoevsky's creation carries a special, yet equal role to those of the characters of a text. Being a voice among other voices, the author is both receptive and responsive. Bakhtin (1999) therefore maintains that the position of an author in Dostoevky's novel is that of dialogue, "one that affirms the independence, internal freedom, unfinalizability, and indeterminacy of the hero. . . The great dialogue of Dostoevsky is organized as an *unclosed whole* of life posed *on the threshold*" (p. 63). As Michael Holquist (1983) has noted, Bakhtin was influenced by the Russian physiologist Alexei Ukhtomsky when he modelled the mind's relation to the world after his account about the body's response to the environment. Just as the organism's coordination of responses to environmental signals was grounded by the constant monitoring of the current state of the organism, the mind was likewise active in tracking and yet creating the social world: "Homeostasis is the body's mechanism for actively responding to the other, utterance is the mind's. In both cases, authorship is a means for shaping meaning in a long and complex chain of interactions" (Holquist, 1983, p. 317).

In a similar way, von Uexküll's umwelt concept reflects the authorship of an organism of the world it responds to. Such a constructivist position has raised further elaborations along representationalist (Fultot & Turvey, 2019) as well as experiential or phenomenological lines of investigation (Feiten, 2020). The latter stance is the one that allows to juxtapose the perspectivism of Dostoevsky, as explicated by Bakhtin, with the making-of-worlds as expressed in von Uexküll's umwelt model (von Uexküll, 1921, 1934/1992). Moreover, it is exactly the specific expression of authorship that Bakhtin unfolded in Dostoevsky's works that helps to abstain from the solipsist implications of the authorship concept if translated into the terms of human-environment relations. According to Bakhtin, the Dostoevskyan author hears the character and can answer him. In a similar vein, the symbolic net that humans spin around the world they encounter should ideally be a product of their creation and at the same time their answer to the state of the world, a part of which they are.

Answering as an integral part of authorship, however, is often omitted in modern human-environment relations, causing the all-encompassing effect of human dominion, while also making such relations similar to the monological novel that Bakhtin used to contrast against a Dostoevsky's dialogical novel. Responsive authorship is thus the position that might be sought for in human-environment relations too, when trying to combine the idea of the human symbolic impact on the natural world and the recognition of the existence of other in(ter)dependent perspectives in this world.[5] It should be stressed that in such a wording, humans are not authors of the natural world as such but authors of the symbolic setting that grounds their actions in this world. Whether this setting allows for the voices of other beings to be uttered, bears real consequences for the living conditions of their human as well as non-human co-inhabitants. Additionally, the Dostoevskyan or Bakhtinian dialogical authorship idea also helps to abstain from the determinist corollaries of the productive activity it designates—an author in such a rendition is not someone who fixes the way of living for other species but the one who attentively creates and maintains the conditions for certain ways of being, which still remain the products of the organism's or character's own making.

5. CONCLUSION

Ecosemiotics as a subfield of semiotics is distinguished by its simultaneous attendance to the sign usage of other species and the human relations to such semiotic diversity. After years of searching for the 'right' object of ecosemiotics, this is a position held at least by some authors, even though alternative understandings still exist. Although this is above all a methodological stance for ecosemiotics, it is grounded upon certain ontological and epistemological premises—that other species besides humans do use signs and that humans possess the means of relating to such forms of semiosis. Furthermore, the two sides of ecosemiotic research can be co-opted for developing an ecosemiotic ethics for human-environment relations.

The semiotic diversity of other species that ecosemiotics seeks to describe is not a given, independent of the relations the subjects find themselves embedded in. The central concerns of nature conservation such as the preservation and restoration of habitats and the protection of the diversity of life forms are thus not only means of preserving life in its physical forms, but also means of guaranteeing the extent of semiotic freedom the other species can entertain. Constriction and impediment of the semiotic existence of other beings bears consequences also for the human world, as

---

[5] A somewhat similar mindset is embodied in Maran's (2021) call for *semiotic stewardship*, the task of which he has expressed as follows: ". . . to ask about what culture could offer nonhuman species, or how culture could by semiotic means raise the integrity, stability, and resiliency of the rest of the ecosystem" (p. 527).

the loss of other umwelten leaves humans alone with theirs, with a solipsist bearing reinforcing the inevitability of a solipsistic existence.

The symbolic networks of human world-making are thus also the frames that determine a great deal for other species. It is therefore perhaps not a futile endeavor to seek concepts for guidance from the humanities that were initially not meant for such purposes but that exhibit enough flexibility to be co-opted for a different setting. Although authorship, if transposed to the context of human-environment relations, may raise reluctance due to its dominionistic and deterministic implications, not to speak of the incompatibilities of the textual world and the living world, an alternative discussion of authorship, as found in the works of Bakhtin on Dostoevsky's novel, may help to develop a dialogical model of interactions for humans and other species. While acknowledging the symbolic as the primary tool of world-making for humans, it places them in the midst of attendances and utterances that are of various biological origins. The human voice thereby articulates a response to the non-human others, which serve as its respondents and receivers. It can thus be shaped by knowledge about other umwelten and express the right for their existence. If one turns the latter into a value, it becomes an axiological ground for the enhancement and enrichment of the semiotic possibilities of other beings and potentially also the semiotic reality of humans themselves. By paying attention to the presence of choices, meaningful objects, and relations, the potential of putting an ecosemiotic research agenda into practice in nature conservation and animal welfare is raised. As a result, not just a shift in defining the subject matter of conservation may follow, but the ubiquitous economic ecosystem services discourse in human-environment relations might thereby be replaced with a discourse that is attentive to the non-human modes of relating with the natural world.

REFERENCES

Bakhtin, M. (1999). *Problems of Dostoevsky's poetics* (C. Emerson, Ed. and Trans.). Minnesota: University of Minnesota Press.

Bell, M. M. (1994). Deep fecology: Mikhail Bakhtin and the call of nature. *Capitalism Nature Socialism*, *5*(4), 65–84. doi:10.1080/10455759409358610

Berger, J. (1992). Why look at animals? In J. Berger, *About looking* (pp. 1–26). New York: Vintage International.

Brown, F. L. (2016). *The city is more than human: An animal history of Seattle.* Seattle: University of Washington Press.

Derrida, J. (2008). *The animal that therefore I am*. New York: Fordham University Press.

Farina, A., Pieretti, N., & Malavasi, R. (2014). Patterns and dynamics of (bird) soundscapes: A biosemiotic interpretation. *Semiotica 198*: 241–255. doi:10.1515/sem-2013-0109

Feiten, T. E. (2020). Mind after Uexküll: A foray into the worlds of ecological psychologists and enactivists. *Frontiers in Psychology 11*: 1–10. doi:10.3389/fpsyg.2020.00480

Fultot, M., & Turvey, M. T. (2019). von Uexküll's theory of meaning and Gibson's organism–environment reciprocity. *Ecological Psychology*, *31*(4): 289–315. doi:10.1080/10407413.2019.1619455

Hallowell, A. I. (1960). Ojibwa ontology, behavior, and world view. In S. Diamond (Ed.), *Culture in history: Essays in honor of Paul Radin* (pp. 49–82). New York: Columbia University Press.

Hettinger, N. (2014). Valuing naturalness in the "Anthropocene": Now more than ever. In G. Wuerthner, E. Crist, & T. Butler (Eds.), *Keeping the wild: Against the domestication of Earth* (pp. 174–179). Washington: Island Press.

Heywood, P. (2018). The ontological turn: School or style? In M. Candea (Ed.), *Schools and styles of anthropological theory* (pp. 224–235). New York: Routledge.

Hoffmeyer, J. (2015). Introduction: Semiotic scaffolding. *Biosemiotics 8*(2): 153–158. doi:10.1007/s12304-015-9236-1

Holquist, M. (1983). Answering as authoring: Mikhail Bakhtin's trans-linguistics. *Critical Inquiry 10*(2): 307–319.

Hornborg, A. (2001). Vital signs: An ecosemiotic perspective on the human ecology of Amazonia. *Sign Systems Studies 29*(1): 121–152. doi:10.12697/SSS.2001.29.1.09

Ingold, T. (1993). The temporality of the landscape. *World Archaeology 25*(2): 152–174.

Jonas, H. (1966/2001). *The phenomenon of life: Toward a philosophical biology*. Evanston: Northwestern University Press.

Kohn, E. (2013). *How forests think: Toward an anthropology beyond the human*. Berkley: University of California Press. doi:10.1525/california/9780520276109.001.0001

Kull, K. (1998). Semiotic ecology: Different natures in the semiosphere. *Sign Systems Studies 26*(1): 344–371. doi:10.12697/SSS.1998.26.15

Kwek, D. H. B. (2018). The importance of being useless: A cross-cultural contribution to the new materialisms from Zhuangzi. *Theory, Culture & Society 35*(7–8): 21–48. doi:10.1177/0263276418806381

Law, J. (2009). Actor network theory and material semiotics. In Turner, B. S. (Ed.), *The new Blackwell companion to social theory* (pp. 141–158). Oxford: Blackwell. doi:10.1002/9781444304992.ch7

Law, J., & Lien, M. E. (2012). Slippery: Field notes in empirical ontology. *Social Studies of Science 43*(3): 363–378. doi:10.1177/0306312712456947

Lien, M. E., & Pálsson, G. (2021). Ethnography beyond the human: The 'other-than-human' in ethnographic work. *Ethnos 86*(1): 1–20. doi:10.1080/00141844.2019.1628796

Mandelker, A. (1994). Semiotizing the sphere: Organicist theory in Lotman, Bakhtin, and Vernadsky. *PMLA 109*(3): 385–396. doi:10.2307/463075

Maran, T. (2007). Towards an integrated methodology of ecosemiotics: The concept of nature-text. *Sign Systems Studies 35*(1/2): 269–294. doi:10.12697/SSS.2007.35.1-2.10

Maran, T. (2015). Emergence of the "howling foxes": A semiotic analysis of initial interpretations of the golden jackal (Canis aureus) in Estonia. *Biosemiotics 8*(3): 463–482. doi:10.1007/s12304-015-9244-1

Maran, T. (2018). Two decades of ecosemiotics in Tartu. *Sign Systems Studies 46*(4): 630–639. doi:10.12697/SSS.2018.46.4.11

Maran, T. (2020). *Ecosemiotics: The study of signs in changing ecologies.* Cambridge: Cambridge University Press. doi:10.1017/9781108942850

Maran, T. (2021). The ecosemiosphere is a grounded semiosphere. A Lotmanian conceptualization of cultural-ecological systems. *Biosemiotics 14*(2): 519–530. doi:10.1007/s12304-021-09428-w

Maran, T., & Kull, K. (2014). Ecosemiotics: Main principles and current developments. *Geografiska Annaler: Series B, Human Geography 96*(1): 41–50. doi:10.1111/geob.12035

Müller, T. (2010). Notes toward an ecological conception of Bakhtin's 'chronotope'. *Ecozon@: European Journal of Literature, Culture and Environment 1*(1): 98–102. doi: 10.37536/ECOZONE.2010.1.1.327

Müller, T. (2016). The ecology of literary chronotopes. In Zapf, H. (Ed.), *Handbook of ecocriticism and cultural ecology* (pp. 590–604). Berlin: De Gruyter. doi:10.1515/9783110314595-032

Nöth, W. (1996). Ökosemiotik. *Zeitschrift für Semiotik 18*(1): 7–18.

Nöth, W. (1998). Ecosemiotics. *Sign Systems Studies 26*: 332–343. doi:10.12697/SSS.1998.26.14

Nöth, W. (2001). Ecosemiotics and the semiotics of nature. *Sign Systems Studies 29*(1): 71–81. doi:10.12697/SSS.2001.29.1.06

Petrilli, S., & Ponzio, A. (2005). *Semiotics unbounded: Interpretive routes through the open network of signs.* Toronto: University of Toronto Press. doi:10.3138/9781442657113

Roepstorff, A. (2001). Thinking with animals. *Sign Systems Studies 29*(1): 203–218. doi:10.12697/SSS.2001.29.1.13

Strathern, M. (1988). *The gender of the gift: Problems with women and problems with society in Melanesia.* Berkeley: University of California Press.

Todorov, T. (1984). *Mikhail Bakhtin: The dialogical principle*. Minneapolis: University of Minnesota Press.

Tønnessen, M. (2015). The biosemiotic glossary project: Agent, agency. *Biosemiotics 8*(1): 125–143. doi:10.1007/s12304-015-9229-0

Urbanik, J. (2012). *Placing animals: An introduction to the geography of human-animal relations.* Lanham: Rowman & Littlefield.

van Dooren, T., Kirksey, E., & Münster, U. (2016). Multispecies studies cultivating arts of attentiveness. *Environmental Humanities 8*(1): 1–23. doi:10.1215/22011919-3527695

von Uexküll, J. (1934/1992). A stroll through the worlds of animals and men: A picture book of invisible worlds. *Semiotica 89*(4): 319–391.

von Uexküll, J. (1921). *Umwelt und Innenwelt der Tiere.* Berlin: Springer.

Viveiros de Castro, E. (1998). Cosmological deixis and Amerindian perspectivism. *The Journal of the Royal Anthropological Institute 4* (3): 469—488. doi:10.2307/3034157

Whatmore, S. (2002). *Hybrid geographies: Natures cultures spaces*. London: Sage.

White, L., Jr. (1967). The historical roots of our ecologic crisis. *Science 155*(3767): 1203–1207. doi:10.1126/science.155.3767.120

Willerslev, R. (2007). *Soul hunters: Hunting, animism, and personhood among the Siberian Yukaghirs.* Berkeley: University of California Press. doi:10.1525/california/9780520252165.001.0001

Zapffe, P. W. (1933/2004). The last messiah (G. R. Tangenes, Trans.). *Philosophy Now* 45: 35–39.

On the Grammar and Grammatical Categories of the Genetic Code

Suren Zolyan
Immanuel Kant Baltic Federal University, Kaliningrad, Russia.
Institute of Scientific Information on Social Sciences of the Russian Academy of Sciences, Moscow, Russia.

> "When I first came across linguistic terms in the biological literature, I said to myself: we need to check whether this is just a manner of speech, a metaphoric usage, or whether there is something deeper here. I must say that what biologists have done is quite legitimate from a linguistic standpoint, and in fact, we can take things even further." (Jakobson, 1968, as cited in Katz, 2008)

Abstract

We address the possibilities of the description of the genetic code as a sign system. We make a differentiation between *language* and *speech*, that is, between a system of abstract syntagmatic and paradigmatic relations, and its actual manifestation. This can also be represented as a dichotomy of biochemical substance and semiotic form. As the minimal unit of the alphabet, we consider the distinctive features of nuclei acids (number of bonds and type of the base—purine or pyrimidine). Positions within triplets (first, second, or third) are considered as grammatical categories and each of them is endowed with its codon-forming functions regardless of which nucleotide it is filled with. The distinction between alphabet (nucleotides), vocabulary (amino acids), and grammatical categories allows us to identify the formation rules for the significant units of the genetic code (doublets and triplets) and explicate their compositional semantics (correspondence rules between codons and amino acids). The grammar of the genetic code may be represented as a system of operations or one-side dependencies, regulated by left or right contexts of the nucleotide in the central positions. The principle of context sensitivity allows us to describe cases when biochemically the same sequence of nucleotides, depending on their location, acquires a different meaning and performs a different function.[1]

Keywords: genetic code, its alphabet, dictionary, vocabulary, grammar, categories.

1. INTRODUCING THE PROBLEM

The analogies between language and genetic information are not new. Even before discovering the genetic code, but already from the discovery of DNA, an analogy arose between language and text.[2] However, this association was superficial—it meant that a limited number of letters could be used to construct an infinite number of texts. Francis Crick has also repeatedly compared the genetic code to language:

> "The elucidation of the genetic code is indeed a great achievement. It is, in a sense, the key to molecular biology because it shows how the two great polymer languages, the nucleic acid language and the protein language, are linked together." (Crick, 1966, p. 9)

However, these comparisons may demonstrate that from the point of view of linguistics, it remains unclear what exactly is meant by language: Whether it is a dictionary between two languages or whether it is a relationship between signifiers (nucleotides) and signified (proteins) or between two levels of genetic information organization. At the same time, Crick never referred to the concept of grammar, which is fundamental for describing a language. Of course, it was not Crick's task to explicitly describe what he meant by language. The description of the genetic code as a language, that is, as a vocabulary and grammar, was the objective of linguists. Yet, except for the article by Roman Jakobson, who outlined the prospects for the actual linguistic description of the genetic code, such a possibility remains far from being realized enough.

---

[1] This research is a continuation and expansion of research previously published on (Zolyan 2021b); its development from evolutionary stands is given in (Zolyan2022)

[2] The concept of a genetic *text* and *alphabet* has been used in genetics since the discovery of DNA by Friedrich Miescher, although without a proper correlation with DNA's linguistic and semiotic content: "In [these huge molecules] all the wealth and variety of heredity transmissions can find expression just as all the words and concepts of all languages can find expression in twenty-four to thirty letters of the alphabet" (Trifonov, 2000, p. 5).

Despite that, numerous attempts were made in this direction.[3] These descriptions, however, did not explicate the basic notion of grammar—grammatical categories and their functional relevance for producing significant sequences. The point is not that an infinite number of different combinations of the same elements is possible. Maybe, the situation should be treated in the opposite manner. If one compares the processing of genetic information with grammar and language, in this case, one must explicate some set of restrictions, as any grammar imposes certain constraints on the combination of elements. As for the possibility of generating an infinite number of units, in language, unlike in arithmetic, new structures emerge not by induction (n, n+1, n+1+1), but due to the multilevel hierarchical relations—sounds combine into morphemes, morphemes into words, words into phrases and sentences, and so on. Based on this, we intend to elucidate the constraints and regularities controlling these processes.

2. THE METHODOLOGY AND METHODS

Attempts to extrapolate the patterns of linguistic organization to genetic information sometimes did not go beyond metaphorical comparisons since they did not consider the most important methodological postulates of language description, primarily, the distinction between language and speech, or, in general terms, between an abstract system and its actual manifestation.[4] We intend to apply the cardinal principles of linguistic description to the initial and, at the same time, the fundamental level of organization of genetic information—the genetic code.

The main distinctions of our approach from the previously suggested grammars are:

1. We make a differentiation between language and speech, between a system of abstract syntagmatic and paradigmatic relations, and its actual manifestation. This can also be represented as a dichotomy of biochemical substance and semiotic form.

Let us mentioned only those researches works where some grammar of the genetic code was suggested: Gimona, 2006, Ji (1997, 1999), López-García (2005), (Ratner (, 1993),; Searls (, 2010); Ji, 1997; 1999; Gimona, 2006; Lopez-Garcia, 2005).

[4] Something similar to the distinction between language and speech was proposed by Ervin Schrödinger (2012): “The term code-script is, of course, too narrow. The chromosome structures are at the same time instrumental in bringing about the development they foreshadow. They are law-code and executive power – or, to use another simile, they are architect’s plan and builder’s craft – in one” (p. 22). Schrödinger linked the mechanisms of heredity with chromosomes, which later turned out to be incorrect. Nevertheless, it is further confirmed the correctness of his idea of the functional duality of the process of transferring genetic information. Thus, in the implementation of protein synthesis, the functions of *legislator* and *executor*, or *architect* and *builder*, are assigned to different mechanisms: Information (scheme) is stored in DNA, which is then duplicated in messenger RNA, based on which the actual recognition of amino acids occurs already in transport RNA.

We will consider the main conceptual components of the grammatical theory of the genetic code (alphabet, vocabulary, rules, categories) following this distinction.

2. The Saussurean distinction between form and substance, speech and language, as well as his principle of differentiation, is supplemented by the basics of the systemic theory of Niklas Luhmann; through this, it becomes possible to bring dynamism into intersystem relations (for more see Zolyan, 2021a).

3. Instead of linear context-free linguistic models, we suggest using some form of categorial grammar, where items are context-dependent variables and, simultaneously, context-forming operators (as it was foreseen by Jakobson (1970, p. 439). We used the simplest form of categorial grammar when syntactic and semantic properties coincide (Lewis, 1983).

3. ON THE SEMIOTIC PECULIARITIES OF THE GENETIC CODE: THE ARBITRARINESS, LINEARITY, AND CONTEXT-DEPENDENCE

It is necessary to distinguish between the element as a certain material entity, and its functions in the system. The principle of differentiation operates within a system, and an element is determined only through its difference from others. Within the coding system, the matter (biochemical or stereochemical characteristics) ceases to play a decisive role; it may be relevant as a mode to make a distinction between different semiotic entities. It leads to such an unusual property of the genetic code as arbitrariness. Francis Crick pointed this out at the very beginning.[5] Since that time, the assumption of arbitrariness of the genetic code has been repeatedly confirmed despite the still existing prevalence of the opposite stereochemical point of view:

> "It has been shown that there is no deterministic link between codons and amino acids because any codon can be associated with any amino acid. This means that the rules of the genetic code do not descend from chemical necessity, and in this sense, they are arbitrary. Today, in other words, we have the experimental evidence that the genetic code is a real code, a code that is compatible with the laws of physics and chemistry but is not dictated by them." (Barbieri, 2018, p. 2)

Thus, the genetic code reproduces two main characteristics of the language sign system: the arbitrariness of the sign and the linearity of the signifier. Context-dependence and arbitrariness are not entirely reducible to each other. Still, they are

---

[5] Cf. "The Periodic Table would be the same everywhere in the universe. The genetic code appears somewhat arbitrary, or at least partly so. Many attempts have been made to deduce the relationship between the two languages from chemical principles, but so far none have been successful. The code has a few regular features, but these might be due to chance." (Crick, 1981, p. 46–47)

interrelated in essential features—combining the same elements but in a different order leads to different results and effects. The linear organization of semiotic entities presupposes the contextual relevance of positions within ordered sequences. It makes sense to mention that de Saussure considered linearity and arbitrariness of the linguistic sign to be the main characteristics of the language system:

> "The linguistic sign, as defined, has two primordial characteristics. In enunciating them I am also positing the basic principles of any study of this type. *Principle I: The Arbitrary Nature of the Sign. . . . Principle II: The Linear Nature of the Signifier*." (de Saussure, 1916/1959, pp. 67–70)

This statement, despite several modifications, continues to be the axiom of linguistic theory. However, pointing out the arbitrariness of the genetic code is not a solution but rather its formulation. The arbitrariness of the genetic code leads to highly significant consequences: Through these attributes, biochemical and semiotic characteristics of the genetic code may obtain some autonomy from each other. The intersystem functions and relations may operate following a semiotic value of biochemical entities. For example, from the point of view of the system, six, four, or two codons may be variants of the same entity while encoding the same higher-level element (let us refer to the so-called degeneracy of the genetic code). Thus, six codons (UCU; UCC; UCA; UCC; AGU; AGC) encode the same amino acid: serine.

In contrast, the same AUG nucleotide sequence within the system represents two different elements since in other contexts, it can be associated with both a start codon and a methionine.

The process of gene expression is based on the principle of contextual dependence: The same coding unit appears in different manifestations, depending on which strand (in which context) it is located. In linguistic terms, this can be represented as the result of the simultaneous application of two types of transformations:

1. Permutations—when a triplet of elements is replaced by its symmetrical mirror form: [XYZ] → [ZYX].
2. Substitutions—when each of the three nucleotides is replaced by a complementary one; in DNA: A ↔ T, C ↔ G; in RNA: A ↔ U, C ↔ G.[6]

---

[6] Abbreviations: G—guanine, C—cytosine, A—adenine, U—uracil, R—purine (A or G), Y—pyrimidine (C or U), N—any of them. They encode 20 amino acids: glycine (Gly), alanine (Ala), arginine (Arg), proline (Pro), threonine (Thr), serine (Ser), cysteine (Cys), glutamic acid (Glu), glutamine (Gln), aspartic acid (Asp), asparagine (Asn), lysine (Lys), histidine (His), valine (Val), leucine (Leu), isoleucine (ILe), methionine (Met), phenylalanine (Phe), tyrosine (Tyr), tryptophan (Trp), and the nonsenses: start—initiation codon; stop—three termination codons.

So, the abovementioned methionine is encoded by the following codons, which are complementary mirror transformations of each other:

- ATG (in the non-transcribed strand of DNA).
- TAC (in the transcribed strand of DNA).
- AUG (a codon in a messenger RNA).
- UAC (anticodon on transfer RNA).

If in the above example, the triplet of symbols denoting nucleotides (ATG—TAC—AUG—UAC) is replaced by the name *methionine*, then the whole process of transferring genetic information may be described as a repetition of the same sign: *methionine* (as it is encoded on an untranscribed DNA strand)—*methionine* (as encoded on the transcribed DNA strand)—*methionine* (as encoded on mRNA)—*methionine* (as encoded on tRNA). This form of notation ceases to reflect the biochemical composition of the triplet but instead explicates the identity of its semiotic function.

This also demonstrates the connection between the contextual dependence of the genetic code and its arbitrariness: Different trinucleotide triplets (the signifiers) may be associated with the same amino acid (the signified), and, at the same time, the same signified may be associated with different signifiers (UAC is associated with Met in a transfer RNA and Tyr in a messenger RNA). Thus, in addition to arbitrariness, the genetic code the same signified can be associated with different signifiers and vice versa. This may be associated with the principle of the asymmetric dualism of a linguistic sign— (cf.: Karcevski, 1929).

This furthermore presupposes the need to consider the principle of contextual dependence, which is why we suggest shifting from the usually used context-free grammars for formalized languages to context-sensitive rules and categories.

4. THE ALPHABET, VOCABULARY, AND GRAMMAR OF THE GENETIC CODE

4.1. General Remarks

As usual, the genetic code is represented as a list of correspondences (dictionary) between codons and amino acids, which is quite acceptable given the small size of such a dictionary (64 possible variants).[7] However, the question—how can the formation of codons be described?—remains unclear. This process appears as a free

---

[7] Cf. “The genetic code is the small dictionary which relates the four-letter language of the nucleic acids to the twenty-letter language of the proteins.” (Crick, 1981, p. 171)

combination of the four essential elements, not binding with any constraints. With this understanding, the genetic code cannot be treated as a language since it does not have grammar. Grammar is an abstract system of rules to generate acceptable (or well-formed) strings of symbols. If, as it is in the case of the genetic code, all combinations are acceptable, it may seem that there is no grammar. As we will demonstrate, the grammar is present, but it is "packed" into the rules of linear ordering and, simultaneously, the contextualization of the initial elements. For this, we suggest describing the genetic code as a language consisting of (a) non-meaningful (non-coding) units of the alphabet (nucleotides); (b) the grammar, that is, an abstract system of rules based on categories to produce meaningful units; (c) the vocabulary, which includes meaningful items and the rules of correspondence between units of different levels (codons—amino acids); and possibly also (d) something like an interface between the dictionary and the grammar—these are the rules of structural correspondences between the characteristics of units of the alphabet and units of the dictionary (nucleotide's profiles). Such a description reveals some previously undescribed structural and semantic characteristics.

4.2. The Alphabet of the Genetic Code

The combination of the principles of contextual dependence and arbitrariness of the sign leads to the conclusion that the primary elements of the genetic code (nucleotides) can be considered not as biochemical constants but as semiotic or, more precisely, grammatical variables: They acquire their functional relevance only while being located in some position within some structure and without affecting it.[8] Otherwise, if they were stable and fixed features, they should be identified in a rigid non-arbitrary way and could not be transformed under contextual conditions. From this point, the functional relevance of a nucleotide, or its categorization, is not its substantial characteristic but is determined by whichts position within a codon.

It is evident which entities to consider as a primary alphabet of the genetic code: the four nucleotides. However, their systemic status within the genetic code is not appropriately clarified; there may be two principally different categorizations. The first is based on the immanent characteristics of these elements) and the second on the functions they perform.

---

[8] Cf. "Genes are strings of only four characters (nucleotides) that are read sequentially, transcribed sequentially into other strings (messenger RNA), and translated sequentially into strings of a larger character set (amino acids). The gene strings can be described as a formal language with a set of variables (structural genes, operators, promoters, terminators, etc.) perhaps comparable in size to the syntactic classes of natural language, and a phrase-structure grammar (Waters 1982) that looks like a simple programming language grammar." (Pattee, 2012, p. 171)

Since any nucleotide can occupy any position in the triplet, this means that the biochemical properties of the nucleotide itself are in no way related to the position. It is therefore natural to take functional characteristics (namely the functions in the code) as a guiding principle. These characteristics will become more salient if correlated with the minimal units of the language system.

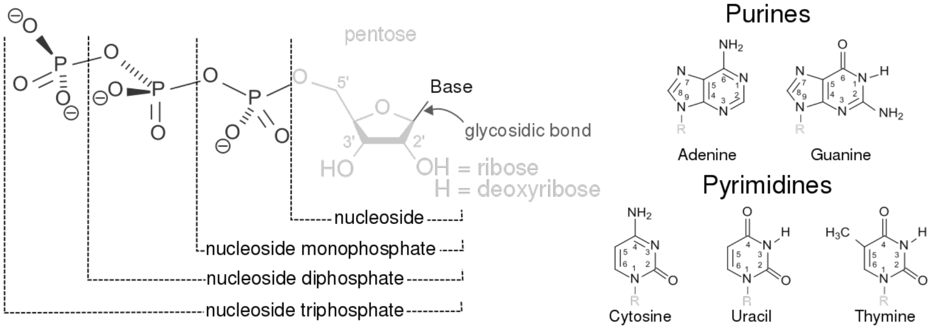
The most common practice is identifying the minimal units of the genetic code, nucleotides, with letters. Nucleotides are designated by letters as well as sounds of a language, but this is where the analogy ends since letters are not elements of the language system. The only one who likened nucleotides to phonemes was Jacob (1977), probably influenced by his partner, Jakobson, who made a very explicit clarification:

> "Since our letters are mere substitutes for the phonemic pattern of language, and the Morse alphabet is but a secondary substitute for letters, the subunits of the genetic code are to be compared directly with phonemes. We may state that among all the information-carryings systems, the genetic code and the verbal code are the only ones based upon the use of discrete components which, by themselves, are devoid of inherent meaning but serve to constitute the minimal senseful units, i.e., entities endowed with their own, intrinsic meaning in the given code." (Jakobson, 1970, p. 438)

Referring to the classic work of Nikolai Trubetskoy, *Fundamentals of Phonology*, Jakobson pointed to the distinctive and delimiting functions performed by these minimal units of language and the genetic code. This profound idea did not receive proper development, apparently because further researchers preferred to consider units of the genetic code by analogy with letters, but not with sounds and phonemes. Meanwhile, this analogy can be deepened and supplemented. The contrast between language (*langue*) and speech (*parole*) concerning nucleotides manifests itself as a distinction between the biochemical substance (nucleotides as they are) and those distinctive intersystem characteristics that are essential for coding amino acids and regulating protein synthesis.

This property can also be considered as an additional argument in favor of the possibility of describing genetic information processes as linguistic and semiotic processing. The biochemical structure of a nucleotide is a rather complicated entity. Still, all other components, except the base, are irrelevant for forming a triplet, its transformation into a codon/anticodon, and the recognition of amino acids.

Figure 1. On the left is the base of the nucleotide, on the right is the nucleotide. (Source: Boris & Sjef, 2005), https://commons.wikimedia.org/wiki/File:Nucleotides_1.svg (accessed: 11/29/2022)



The relationship between the biochemical substance of the genetic code and its semiotics resembles the relationship between phonetics and phonology. The nucleotide as the integrity of all its characteristics can be correlated with a sound, and its base with a phoneme. Moreover, one can continue this analogy: The nucleotide base itself (the left side of Fig. 1) can be abstracted from its substance and presented as an abstract unit—a set of two differential features. Only the base of the nucleotide is the unit of the genetic langue, language system, and only it plays a functional role in protein synthesis. In contrast, the units of the genetic parole, speech, are nucleotides in their full-fledged manifestation. It is evident that a part of the nucleotide cannot be manifested independently without its non-distinctive (or facultative) features. This resembles the relationship between the acoustic characteristics of sound and the differential features of the phoneme. Similar to the countless attributes, without which a sound cannot be pronounced in speech, the subunits of the language (phonemes) include only those features capable of performing a distinctive function. All other characteristics of nucleotides will play a certain role in the processes of protein synthesis. Still, they turn out to be irrelevant if one describes “genetic reading,” that is, the formation of triplets and the recognition of amino acids, as semiotic operations (just as the characteristics of sounds that are insignificant for meaningful distinction can be dominant in other processes—for example, timbre when singing, or intonation in expressive speech).

The role of nucleotides in genetic translation is determined exclusively by their bases, which are reducible to only two differential features: (a) the number of hydrogen bonds and (b) belonging to the purine or pyrimidine group. These features may be distinguished based on their syntagmatic and paradigmatic characteristics within the genetic code; these are crucial for the genetic transcription, translation, reading, and complementary pairing when, during mirror transformations (A/U ↔ T, C ↔ G), a purine nucleotide R is replaced by a pyrimidine nucleotide Y with the same number of hydrogen bonds (two or three), and vice versa (the paradigmatic relation). In the process of codon–anticodon pairing, purine nucleotides are associated with pyrimidine nucleotides, and this can be considered as a syntagmatic relation. In some cases (third position), these features can also play a significant role in recognizing various amino acids. In the third position, neutralization of these features can also occur (in 32 cases, both are irrelevant, in 30 cases, the opposition by the number of bonds is irrelevant, and only in two cases (the tryptophan and methionine) are both significant—more details below).

This once again confirms the accuracy of Jacobson′u anticipation:

> "The interrelations of phonemes are decomposable into several binary oppositions of the further indissociable distinctive features. In an analogous way, two binary oppositions underlie the four 'letters' of the nucleic code" (Jakobson 1970, 438)

The relevant differences between nucleotides can be represented as two pairs of binary oppositions based on two distinctive features. One of them is a number of carbon ring bases; purines R (adenine and guanine) have two-carbon nitrogen ring bases, while pyrimidines Y (cytosine and thymine/uracil) are one-carbon nitrogen ring bases. The second feature is the number of hydrogen bonds: three (G, C) or two (A, T / U). Thus, each of the four nucleotides in semiotic terms appears as a set of two features: R/Y and 2/3:

- G, guanine—(R, 3).
- A, adenine—(R, 2).
- C, cytosine—(Y, 3).
- U, uracil—(Y, 2).

Semiotic (sign-distinguishing) and intersystem syntagmatic and paradigmatic characteristics of a nucleotide are exhausted by these two differential features, abstracted from the whole complex of its biochemical and structural characteristics. In relation to gene expression processes, this gives grounds to considering a nucleotide as an abstract unit of a system (the genetic code), consisting exclusively of its differential features. As with any sign system, also in the case of the genetic code, "*language is a form, and not a substance*" (de Saussure, 1916/1959, p. 122; cf. Pattee, 2007).

4.3. Positions as Categories

The grammar of the genetic code determines the formation of triplets (codons). We draw a rigid distinction between units of the alphabet (nuclei acids) and the categories of grammar: the empty positions within triplets (first, second, third), each of them endowed with its codon-forming functions regardless of which nucleotide it is filled with. Nucleotides perform different functions depending on their position within a triplet. Researchers have already noted this inequality of first, second, and third positions and designated it linguistic terms: as a prefix, root, and ending, respectively (Rumer, 1966; Ratner, 1993); or subject, predicate, and complement (López-García, 2005). The triplet's positions perform a function of a grammatical category: Regardless of what this position is filled with, it performs the function assigned to it. Therefore, any nucleotide N in the genetic code appears in three forms: N_1; N_2; N_3.

A category is not only a means of classification but a functional element in a system. So, words in a language are usually divided according to morphological features and, depending on this, the syntactic functions they perform. However, there are languages in which both the syntactic function and categorical semantics are determined not by the word but by their position. In these so-called isolating (amorph) languages (e.g., Chinese, Vietnamese) with rigid restrictions on the structure and size of a syllable, syntactic functions are determined almost exclusively by the order of words, mainly monosyllabic ones (as is the case in the sentence *Bill bill*(*s*) *bill*, where the word *bill* is used in three different functions and with different meanings). These characteristics are not inherent in the word itself, but they appear when interacting with the abstract sentence structure subject–predicate–object. In this case, the word in the process of actualization must appear in one of these manifestations; otherwise, it ceases to be meaningful (for example, in isolation, outside of a syntactic structure, the sequence of the sounds *bill*, *bill*, *bill* ceases to be any semantic or functional unit).

From this point, the functional relevance of a nucleotide, or its category, is not its substantial characteristic but is determined by its position within a codon. As one can see, it is not a nucleotide by itself that is important, but the position it occupies: Uracil in the first, second, and third positions can perform entirely different functions. In the second position, it selects a specific class of five amino acids and start-codon (Met, Lie, Val; Phe, Leu). In the first position, it selects from a particular class given by the second position a specific amino acid: U_1—if CA_2—then Tyr or stop-codon; if C_2—then serine; if U_2—then Phe or Leu; if G_2—then Cys, or Trip, or stop-codon. In the third position, U_3 may not have any distinctive capacity ($U_1C_2N_3$), or, as the other pyrimidine nucleotide C opposes to purines R(C or U) and provides a distinction between two amino acids ($U_1U_2\,R(A \text{ or } G)_3$ → Leu; $U_1U_2Y(C \text{ or } U)_3$ → Phe), or between amino acids and stop- or start-codons ($U_1A_2Y(C \text{ or } U)_3$ → Tyr; $U_1A_2R(A \text{ or } G)_3$ → stop).

The functional distinction between units of the alphabet (nucleotides), dictionary (amino acids), and categories of grammar (positions within a triplet) allows us to identify the formation rules for the meaningful units of the genetic code (doublets and triplets) and explicate their compositional semantics. Instead of above mentioned linear context-free linguistic models (footnote 3), we suggest using a three-level categorial grammar, where items are considered context-dependent variables and, simultaneously, context-forming operators (Zolyan & Zdanov, 2018). From this point of view, nonsense codons and so-called meaningful codons are different types of operations or instructions. Coding codons are associated with the operation to select and transfer amino acids, and nonsenses are merely operational codons serving to initiate or terminate processes of gene expression.

4.4. The Rules of the Grammar of the Genetic Code

The rules of the grammar of the genetic code determine the formation of triplets (codons). They operate with two variables—X and Y—which can be interpreted as any nucleotide in the initial position (X and the resulting codon Y). These micro-grammar rules describe the derivation of Y from X based on the empty positions. These rules are represented as the left and right context of X—they are operators (or functions) correlating this X with Y. Correspondingly, the initial central position may be considered as the basic unit X. The first position, or the left context functions as an operator that transformed a singlet X into a doublet (X/Y), something that in conjunction with X generates the new entity (X/Y). This may be formalized as an assignment to the first position the category [X; (X/Y)]. The association of the first and second positions into a doublet can be represented as an inference: (X; X/(X/Y)) → (X/Y). The third position may be considered as an operator of the category (X/Y)Y, it transforms the doublet (X/Y) into the triplet Y: (X/Y); (X/Y)Y → Y.

Thus, the formation of the triplet is identified as a three-step composition:

1. X
2. X; (X/Y)
3. (X; X/Y)Y

A triplet can be viewed not only as a combination of three positions but as a hierarchically ordered three-component structure, which is formed through the recursive composition of positions: 2; 2 + 1; (2 + 1) + 3 (nucleotide in the second position, doublet, triplet). This hierarchical and compositional structure can be represented as a tree of its constituents. The triplet decomposes into such structural units as a triplet itself, a doublet, and a singlet stem. Unlike oligonucleotides, codons are no longer a three-element sequence but a certain hierarchically organized structure, manifested as a linear three-element string. This structure can also be interpreted as a context: A triplet/codon can be considered a form of a context-dependent connection between the stem-nucleotide and the encoded amino acid (or nonsense). The first and third positions together act as the left and right contexts for the stem (or as a root, prefix, and ending; cf. Rumer, 1966). This context determines its significance: Which amino acid will be assigned to the stem nucleotide B_2 in the left context of A_1 and the right context C_3, where A, B, C are any nucleotides. Thus, each nucleotide is, on the one hand, context-dependent (the position in the triplet determines its significance). On the other hand, it is a context-changing operator (the left and right contexts determine the semiotic characteristics of the stem, and, vice versa, the stem turns out to be significant in combination only with the left context in 32 cases and with left and right in the remaining 32 cases).

In general, this can be represented by a rather simple formula: any of the nucleotides (C or G or A or T/U) in its left X/(X/Y) and right (X/Y)Y contexts. The four units of the alphabet (A, T/U, G, C) can stand for any position and be assigned one of the categories N_X; $N_{(X;\ (X/Y)}$; $N_{(X;\ X/Y)Y}$. As these categories coincide with positions within codons correspondingly, they can be rewritten in a simpler way: N_2; N_1; N_3. Each of the empty positions within triplets (first, second, third) is endowed with codon-forming functions regardless of which nucleotide it is filled with.

Based on the element in the second position, all amino acids can be divided into four non-overlapping classes:

- C_2—(Tre; Ala; Ser; Prol).
- A_2—(Lys; Asn; Glu; Asp; Tyr; Gln; His).
- G_2—(Arg; Ser, Gly; Cys).
- U_2—(Phe; Leu; Val; Ile, Met).

The only intersection is the serine (it can be encoded through six codons with either C_2 or G_2). Thus, the second position distinguishes a particular class of amino acids; the first position or the first and third positions differentiate a specific amino acid within this class.

It is not easy to identify the biochemical significance of the specified classes. We would venture to put forward two assumptions based on analogies with language. The proposed class division is based on the second position, which can be considered an analog root. Therefore, the resulting codon classes act as cognate words. In language, this indicates either a common source of these words and/or the semantic similarity of their meanings. However, the convergence within the group can also be functional. In this case, it can be expected that the amino acids included in one or another group perform specific functions already at a higher level—in the production of protein sequences (just as the construction of syntactic structures is based on the functional differentiation of parts of speech—names, verbs, etc.).

We can offer other analogies that additionally confirm the recursive nature of the formation of genetic information units. As we have demonstrated earlier, the formal rules for codon formation are based on recursion: The next element is determined by its relation to the previous ones (a doublet is based on the singlet, a triplet is based on the doublet). Highlighted groups make it possible to see the recursion process already at the semantic level. Thus, in natural language, recursion determines not only the construction of syntactic structures, such as *boy → the/a boy → the/a clever boy → the/a very clever boy*, but it also produces differentiation within the designated semantic class: In the class of boys, a subclass of smart boys stands out, and already within it there is a subclass of very smart boys.

A similar procedure is applicable here: In 32 cases, the second position selects a class, the first - a subclass, and in 32 cases, the third position also selects a subclass within a subclass. For example, guanine in the second position allocates a class of four amino acids, which, through to the first, is subdivided into four subclasses consisting of four amino acids. In the case of adenine in the second position, the differentiation goes one step further and, as a result, eight subclasses of two amino acids are formed.

As one can see, the description of the genetic code appears as correspondence rules that determine the relationship between the nucleotide in the second position and the corresponding triplets (contexts for a given nucleotide in the second position). To use syntax analogies, these are rules of correspondence between predicates and their subject–object contexts, transforming each of these predicates into a sentence—the grammar functions as a model describing the transfiguration of nucleotides into codons and correlating it with amino acids. Accordingly, the rules of this grammar are recursive operations of converting one unit to another. The positions of the triplet/codon can be described as steps in forming a codon from nucleotides (if we continue the analogies with a sentence, then the second position can be considered a predicate, the first as a subject, and the third as a complement; cf. López-García, 2005).

This additionally indicates that in relation to the genetic code, there is no such entity as *an immanent nucleotide* or something like *an adenine in general*—any nucleotide appears only in a certain position and therefore manifests itself differently depending on this. The second position provides maximum opportunities for the realization of individual characteristics of nucleotides; the first one provides limited possibilities; and the third one either none or minimal, and if so, only to the extent that the previous ones allow it. At the same time, it becomes obvious that all these characteristics are no longer determined by the biochemical properties of nucleotides but follow from the intersystem relationships. Rules of grammar (operations) and elements under operations become indistinguishable, and the genetic code functions as a dynamic unity, or auto- (semio-) poietic system, in accordance with Luhmann's definition.[9] In this extremely economical grammar, minimalism reaches its apogee.

---

[9] Rules of grammar (operations) and elements under operations can be considered as the same entities. Cf. "By operation, I mean the actual processing of the reproduction of the system. In dynamic systems—which consist of their operations—operations and elements become indistinguishable. Moreover, in *autopoietic systems*, everything that is used as a unity by the system, including the elementary operations, is also produced as a unity by the system." (Luhmann, 1990, p. 82)

The grammar of the genetic code is an optimal self-executing recursive system capable of generating an infinite set of hierarchically organized multilevel information entities from a minimal set of rules and alphabet units.

5. RESULTS

1. The distinction between vocabulary (nucleotides) and categories of grammar (empty positions within triplets regardless of their biochemical substance) allows us to identify the formation rules for the significant units of the genetic code (doublets and triplets) and explicate their compositional semantics (correspondence rules between codons and amino acids).

2. The principle of context sensitivity allows us to describe cases when biochemically the same sequence of nucleotides, depending on their location, acquires a different meaning and performs another function. This explains why sequences of identical nucleotides but in a different order are associated with different amino acids (AUG ≠ GUA ≠ UAG), as actually they consist of functionally different operators ($A_1U_2G_3 \neq G_1U_2A_3 \neq U_1A_2G_3$). In this notation, it becomes obvious that this sequence consists of completely different elements despite these elements being manifested as the same nucleotides.

3. Regardless of which nucleotide it is filled with, the positions perform the following functions:

3.1. Distinctive—the order of the nucleotide (first, second, and third positions) distinguishes the semantics of one sequence from another. The triplet positions are categories with their semantic–syntactic functions: The second position determines some group of amino acids, the first one identifies the specific amino acid within it.

3.2. Delimitative—the third position marks the end of a three-element sequence of nucleotides correlated with a particular amino acid. For half of the triplets, the third position plays only a delimitative role; for the other half, it plays both the delimitative and distinctive roles.

3.3. Structural—it relates especially to the third position. In half of the cases, it is redundant from the semantic point of view but is necessary as a structural unit since it complements the doublet to the required triplet structure.

3.4. Selective-syntagmatic—it is performed by all three positions when, in the next stage, a complementary pair (codon–anticodon) is formed. In the so-called wobbling situation, the third position may lose selective characteristics and fail to determine which nucleotide of the first anticodon's position will be attached.

6. CONCLUSION

The grammar of the genetic code may be represented as a system of operations or one-side dependencies, regulated by left or right contexts of the nucleotide in the central positions. Thus, for any nucleotide N_2, there is a possibility to be located in 16 contexts. Any of them is associated with some class of amino acids, and, in a few cases, with nonsenses. As one can observe, each nucleotide has its peculiar functional profile, and this is a decisive factor for the type of coding. Thus, all codons in which the cytosine occupies the second position are of the semi-triplet (or doublet) type, where the third position has no function. In contrast, all codons where the second position is occupied by the adenine belong to the quasi-triplet type, where all three positions are significant and the synonymy is limited to only two variants. In other cases, when the second position is occupied by uracil or guanine, all four types of coding occur, and the profile of the nucleotide in the first position determines this. This correlates with the structure of nucleotides: C and G have three hydrogen bonds, and A and U have two. The biochemical difference between them becomes a key feature of their semantic capacity to distinguish between amino acids assigned to the codon.

It is possible to supplement the characteristics that distinguish genetic processes from biochemical ones and bring them closer to semiotic ones. In addition to linear order, arbitrariness, and contextual dependence, the fourth fundamental property can be added—the recursiveness of the rules for producing structural units. It is generally considered as a decisive and universal characteristic of language and linguistic ability (Hauser, Chomsky, & Fitch, 2002). In the light of the abovementioned, recursive relations can be associated not so much with human language faculty as with the processing of complex messages. This seems to be not only a property of human consciousness or language faculty (Hauser et al., 2002), but primarily a property of the grammatical system determined by semiotic self-organization emerging in complex information systems (cf. Deacon, 2011).

7. ACKNOWLEDGMENTS

This research is supported by the grant from the Russian Science Foundation (project Nº 22-18-00383 “Methodological design of extended evolutionary synthesis”) at the Institute of Scientific Information on Social Sciences of the Russian Academy of Sciences (Moscow).

REFERENCES

Barbieri, M. (2018). What is code biology?. *BioSystems 164*: 1–10. doi:10.1016/j.biosystems.2017.10.005

Bel-Enguix, G., & Jiménez-López, M. D. (2012). Natural language and the genetic code: From the semiotic analogy to biolinguistics. In *Proceedings of the 10th World Congress of the International Association for Semiotic Studies (IASS/AIS)* (pp. 771–780). A Coruña: Universidade da Coruña.

Boris, & Sjef. (2005). Nucleotides 1 [Image]. San Francisco: Wikimedia Foundation. https://commons.wikimedia.org/wiki/File:Nucleotides_1.svg

Crick, F. H. C. (1966). The genetic code—yesterday, today, and tomorrow. *Cold Spring Harbor Symposia on Quantitative Biology 31*: 3–9. doi:10.1101/SQB.1966.031.01.007

Crick, F. H. C. (1981). *Life itself: Its origin and nature*. London: Simon & Schuster.

de Saussure, F. (1916/1959). *Course in General Linguistics* (C. Bally & A. Sechehaye, Eds.; W. Baskin, Trans.). New York: McGraw-Hill.

Deacon, T. W. (2011). *Incomplete nature: How mind emerged from matter*. New York: W. W. Norton & Company.

Gimona, M. (2006). Protein linguistics – A grammar for modular protein assembly? *Nature Reviews Molecular Cell Biology 7*(1): 68–73. doi:10.1038/nrm1785

Hauser, M. D., Chomsky, N., & Fitch, W. T. (2002). The faculty of language: What is it, who has it, and how did it evolve? *Science 298*(5598): 1569–1579. doi:10.1126/science.298.5598.1569

Jacob F. (1977). *The linguistic model in biology*, in Armstrong D., van Schooneveld C.H. (eds.), *Roman Jakobson. Echoes of his scholarship* (pp. 185-192), Lisse: Peter de Ridder.

Jakobson, R. (1970). Linguistics. In *Main trends of research in the social and human sciences: Part one: Social sciences* (pp. 419–463). Paris: Mouton.

Ji, S. (1997). Isomorphism between cell and human languages: Molecular biological, bioinformatic and linguistic implications. *Biosystems 44*(1): 17–39.

Ji, S. (1999). The linguistics of DNA: Words, sentences, grammar, phonetics, and semantics. *Annals of the New York Academy of Sciences 870*: 411–417.

Karcevski, S. (1929). Du dualisme asymétrique du signe linguistique. [On the asymmetric dualism of the linguistic sign]. *Travaux du Cercle linguistique de Prague 1*, 88–93.

Katz, G. (2008). The hypothesis of a genetic protolanguage: An epistemological investigation. *Biosemiotics 1*(1) : 57–73. doi:10.1007/s12304-008-9005-5

Lewis, D. (1983). *Philosophical Papers Volume I*. New York: Oxford University Press. doi:10.1093/0195032047.001.0001

López-García, Á. (2005). *The grammar of genes: How the genetic code resembles the linguistic code*. Frankfurt: Peter Lang.

Luhmann, N. (1990). *Essays on self-reference*. New York: Columbia University Press.

Pattee, H. H. (2007). The necessity of biosemiotics: Matter-symbol complementarity. In M. Barbieri (Ed.), *Introduction to Biosemiotics* (pp. 115–132). Dordrecht: Springer. doi:10.1007/1-4020-4814-9_4

Pattee, H. H. (2012). Cell psychology: An evolutionary approach to the symbol-matter problem. In H. H. Pattee & J. Rączaszek-Leonardi, *Biosemiotics: Vol. 7. Laws, language and life: Howard Pattee's classic papers on the physics of symbols with contemporary commentary* (pp. 165–179). Dordrecht: Springer. doi:10.1007/978-94-007-5161-3_11

Ratner, V. A. (1993). Geneticheskiy yazyk: grammatika, predlozheniya, evolyutsiya. [The genetic language: Grammar, sentences, evolution]. *Genetika*, *29*(5): 709–719. (In Russian)

Rumer, Y. B. (1966). O sistematizatsii kodonov v geneticheskom kode. [About the systematization of codons in the genetic code]. *Doklady Akademii Nauk SSSR*, *167*(6): 1393–1394. (In Russian)

Searls, D. B. (1999). Formal language theory and biological macromolecules. In M. Farach-Colton, F. S. Roberts, M. Vingron, & M. Waterman (Eds.), *DIMACS Series in Discrete Mathematics and Theoretical Computer Science* (pp. 117–140) USA: AMS. doi:10.1090/dimacs/047/06

Searls, D. B. (2002). The language of genes. *Nature*, *420*(6912) : 211–217. doi:10.1038/nature01255

Searls, D. B. (2010). Molecules, languages, and automata. In J. M. Sempere & P. García (Eds.), *Grammatical inference: Theoretical results and applications*, *ICGI 2010, LNAI 6339* (pp. 5–10). Berlin: Springer.

Schrödinger, E. (2012). *What is life? With mind and matter and autobiographical sketches*. Cambridge: Cambridge University Press.

Zolyan, S. T. (2021a). Kak primirit' Lumana s Sossyurom: printsip vnutrisistemnoy differentsiatsii kak osnova neostrukturalistskogo podkhoda. [How to reconcile Luhmann with Saussure: The principle of intrasystemic differentiation as a basis for the neo-structuralist approach]. *Voprosy yazykoznaniya 1*: 121–141. doi:10.31857/0373-658X.2021.1.121-141 (in Russian)

Zolyan, S. T. (2021b). On the context-sensitive grammar of the genetic code. *BioSystems 208*: 1–7. doi:10.1016/j.biosystems.2021.104497

Zolyan, S. (2022). From matter to form: the evolution of the genetic code as semio-poiesis. *Semiotica* 2022(245): 17-61. https://doi.org/10.1515/sem-2020-0088

Zolyan, S. T., & Zdanov, R. I. (2018). Genome as (hyper)text: From metaphor to theory. *Semiotica 2018*(225): 1–18. doi:10.1515/sem-2016-0214

Necessary conditions for semiosis: A study of vegetative subjectivity, or phytosemiotics

Kalevi Kull
Department of Semiotics, University of Tartu, Estonia

Abstract

We provide a critical analysis of minimal conditions for the semiotic triad, to be identifiable in organisms. Semiosis is the process of meaning-making, which means that it creates relations unusual for physical and chemical descriptions. Since the semiosic relations emerge in complex organic systems of certain kind, we require a list of necessary and sufficient conditions for identification of the system capable for semiosis. After briefly characterizing some rather universal features of semiosis (triadicity, irreducibility, umwelt, double description, codes, arbitrariness, learning, relation-process duality, etc.), we suggest a core structure for minimal model of semiosis which is necessary for the relation of difference. We also review some earlier work on the topic.

Keywords: biosemiotics, choice; code; function circle; meaning-making; phytosemiotics; semiosis; sentience; simultaneity; umwelt

In order to be capable of identifying semiosis, we should know its necessary and sufficient conditions. This will be our topic for the next few pages.

An example to consider is the behaviour of a plant shoot apex. The apex is supplied by receptors of various specificity – some react to light, others to gravity, some others to mechanical touch. Their responses have traditionally been described as phototropism, gravitropism, and thigmotropism. Via transmitters, like certain signaling molecules, changes to the receptors' states are conveyed to the elongation zone of the shoot, which is situated some distance away from the apex. As a result, the growth of cells at the elongation zone changes the curvature or angle of the shoot. Since the signals from different receptors may "request" opposite reactions, the system has to "negotiate" the resulting behaviour. Is this a case of semiosis or not?

An analogical situation can be identified in the behaviour of a single-cell eukaryote, if its different membrane receptors are related to the initiation of opposite reactions which cannot be executed concurrently. In order to identify whether what is going on is semiosis, we need a model of semiosis that operationally describes its features. As it appears, we do not have such a model yet.

At least since the publication of the article about plant semiosis by Martin Krampen (1981), the processes of meaning-making in non-neural organisms have received much attention – the whole field of biosemiotics (Hoffmeyer 2008; Favareau 2010) has grown up under the presupposition that it deals with more than animals, more than zoosemiotics, that semiosis also exists in other kingdoms of living beings besides *Animalia*.[1] In addition to articles directly dealing with the semiotics of plants, i.e. on phytosemiotics, many published works analysed semiotic phenomena in non-animal living beings. Remarkably, only few of these have addressed the differences in meaning-making between taxa. Most of them, instead, have dealt with general problems of simple forms of semiosis, while sometimes providing examples in which the behaviour of particular species is interpreted on the basis of semiotic concepts. In addition, several works have been published about the phenomena of communication and signaling in these organisms. However, though using the terms "communication" or "signal", it is often not precisely clear what this adds to a chemical description or in what sense these interactions carry *meaning*. In other words, many of these works lack an explicit reference to semiotic models. Thus, the existence of meaning-making in cellular, or plant-fungus, etc., processes is still a problem.

In parallel, an interest towards communication (and existence of a kind of mind) in trees, other plants, and fungi has rapidly grown in the popular science literature of the recent decades (e.g., Chamovitz 2012). This concern has also made an impression in the arts (e.g., Gapševičius *et al*. 2018; Maher 2017). Such current interest looks

---

[1] On an early account of "semiotics as a biological science" in Charles Morris, see also Rossi-Landi 1975: 167–169.

somewhat analogical to the interest in "psychobotany" a century ago (see Ingensiep 2001).

Biosemiotics – the study of "simple" forms of semiosis – has disclosed a series of insufficiently analysed problems in general semiotics. Despite long and rich traditions in semiotics, the earlier semiotic research simply has not addressed the non-linguistic, non-cultural semiosis seriously enough. As a result, the task of biosemiotic research has grown remarkably – together with the analysis of semiotic aspects of various living systems, i.e. developing the empirical and theoretical studies in biology, biosemiotics has to rework the fundamentals of semiotics.

I define here *vegetative semiosis* as semiosis in living beings without nervous system (as in Kull 2009). It should certainly be noted that this is but a tentative term, since it is not precisely clear what kind of feature of neural tissue distinguishes semiosis in nerve cells from semiosis in other tissues, to name only an example (see Kull, Favareau 2022). Nevertheless, the term *vegetative* semiosis is currently useful because not much is known about the *semiosic* differences between plants, fungi, and protists, all belonging to vegetative life. It is not even clear which (and how extensive) are the semiotic differences between prokaryotic and eukaryotic cells.

As concluded earlier, semiosis is coextensive with the subjective present (Kull 2018a: 137). This is an implication from the analysis of the phenomena of indeterminacy and interpretation as necessary aspects of semiosis. It has been concluded that these are counterparts or implications of choice. Thus, we bring in the process of choice to the core of semiotic theory (Kull 2018b). Accordingly, in the case of vegetative semiosis, we should focus on the processes that are responsible for what we may call the *vegetative present*, i.e. subjectivity in non-neural organisms, insofar as the criterion of *subjectivity* is the "subjective" present or the *simultaneity of options* that defines the conditions for choice. A re-analysis of these primary conditions for semiosis lies at the centre of the current article. In its introduction, we also briefly review the history of phytosemiotics and various approaches to the problem of meaning in vegetative life, updating our earlier study on phytosemiotics (Kull 2000).

1. SOME EARLIER STUDIES OF VEGETATIVE SEMIOSIS

The early history of sentience (formerly referred to as 'soul') in plants has been reviewed at length and with many details by Hans Werner Ingensiep (2001). His account includes approaches to plant behaviour from antiquity to the end of the 20th century.

In their remarkable book, *The Power of Movement in Plants*, Charles and Francis Darwin wrote about the behaviour of the plant shoot apex:

> "Two, or perhaps more, of the exciting causes often act simultaneously on the tip, and one conquers the other [...]. The course pursued by the radicle in penetrating the ground must be determined by the tip; hence it has acquired such diverse kinds of sensitiveness. It is hardly an exaggeration to say that the tip of the radicle thus endowed, and having the power of directing the movements of the adjoining parts, acts like the brain of one of the lower animals; the brain being seated within the anterior end of the body, receiving impressions from the sense-organs, and directing the several movements." (Darwin, Darwin 1880: 573)

This work of Charles and Francis Darwins has received renewed attention in recent decades (Baluška *et al.* 2009) in the context of "plant neurobiology", as the mechanisms of plant movement have become better understood (e.g., Stolarz 2009).

It is also appropriate to recall the book *Mental Evolution in Animals*, by Georg Romanes, in which he writes:

> "I began by showing it necessary to define Mind as the power of exercising Choice [...]. I pointed out that the physiological or objective equivalent of Choice is found to occur in its simplest manifestations at least as low down as the insectivorous plants [...]. [N]either feeling nor Choice appears upon the scene of life suddenly. [...] And this is my justification for tracing back the root-principles of Feeling and Choice into the vegetative kingdom. If it is true that plants manifest so little evidence of Feeling that the term can only be applied to them in a metaphorical sense, it is also true that the power of Choice which they display is of a similarly undeveloped character; it is limited to a single act of discrimination, and therefore no one would think of applying the term to such an act, until analysis reveals that in such a single act of discrimination we have the germ of all volition." (Romanes 1888: 54–55)

Martin Krampen was the first to publish an article on 'phytosemiotics'; he analysed the possibility of applying an Uexküllian approach of meaning-making to plants (Krampen 1981; 1986a; 1986b; 1992).[2] The concept was taken up by John Deely (1982; 1986) and was followed by several works on the topic.

Soon after, probably by influence of Thomas A. Sebeok, review articles were published about semiosis in fungi (Kraepelin 1997), plants (Krampen 1997), inside organisms (Uexküll, T. *et al.* 1993), in cells (Yates 1997), and also in bacterial communication (Sonea 1990).

Extensive work has been done by Günther Witzany in collecting empirical work on the communication-like processes of soil microorganisms (2011), in fungi (2012a), plants (Witzany, Baluška 2012b) and other organisms. Witzany has applied

---

[2] However, the term 'phytosemiotics' appears already in an article by Ferruccio Rossi-Landi (1975: 181), where he wrote: "Whether or not a phytosemiotics dealing with codes and messages in the vegetable kingdom is also possible, is for future research to decide".

the concept of interpretation to vegetative processes (Witzany 2012b), and together with František Baluška, specified the concept of meaningful communication:

> “[...] the most recent definition of biocommunication is this: sign-mediated and rule-governed meaningful interactions that depend on a communally shared repertoire of signs, codes and rules. Importantly, these features are lacking in any abiotic physical interaction.” (Witzany, Baluška 2012a: v)

Accordingly, biocommunication and interpretation should be a rather complex processes, as these are the processes in which meanings emerge.

In addition to the works previously mentioned, a number of other publications on phytosemiotics has recently come out (Affifi 2013; Cvrčková *et al.* 2009; Faucher 2014; Gare 2022; Marder 2017; Witzany 2006; 2008). A special edition of the *Semiotic Review* was dedicated to phytosemiotics (Marder 2018; Hendlin 2020), and in addition, the *Journal of Consciousness Studies* published a special issue on “Plant Sentience: Theoretical and Empirical Issues”, edited by Vicente Raja and Miguel Segundo-Ortín (Baluška, Reber 2021; Brown, Key 2021; Ginsburg, Jablonka 2021; Hiernaux 2021; Maher 2021; Mediano *et al.* 2021; Nani *et al.* 2021).

Further steps in the application of semiotic models on vegetative life and understanding the sentience of plants, fungi, etc. are dependent on understanding the structure of semiosis and improvements of models of semiosis, since the existing models are not sufficiently operational. This is the point of our discussion below.

2. SEMIOTIC TRIAD: PEIRCE

Charles Peirce noticed that the “property of protoplasm is that of taking habits” (CP 6.254) and tried to analyse what makes this possible. Thus, with the task of finding the necessary and sufficient conditions for the identification of semiosis, we are on the same page with Peirce when he says:

> “For forty years, that is, since the beginning of the year 1867, I have been constantly on the alert to find a *genuine* triadic relation – that is, one that does not consist in a mere collocation of dyadic relations, or the negative of such, etc. (I prefer not to attempt a perfectly definite definition) – which is not either an intellectual relation or a relation concerned with the less comprehensible phenomena of life.” (CP 6.322)

Together with Peirce, we separate for a while the concept of semiosis from the concept of life:

> “the problem of how genuine triadic relationships first arose in the world is a better, because more definite, formulation of the problem of how life first came about; and no explanation has ever been offered except that of pure chance, which we must suspect to be no explanation.” (CP 6.322)

In this way, we state that the irreducible semiotic triad is a clearer concept to look for than either the concepts of life or cognition and, as such, it is also easier to define it clearly as the main condition for meaning-making.

2. EVOLUTION AND TRIAD: DEELY

John Deely (2016) discussed Peirce’s previous statement on genuine triadicity. Deely defines semiosis, the genuine triad, as a directional change, the change in the sign relation (Deely 2016: 78). Since there exists a directed evolution in the prebiological world, he concluded that there should be physiosemiosis – semiosis without life (although towards life). For were there no thirdness, “then no evolution of the universe would be possible in the first place,” writes Deely (2016: 79).

There are, however, two very different kinds of evolution. Cosmic evolution, which is related to cooling, i.e. the decreasing of temperature in some areas of the universe, provides conditions for many more stable structures, many more chemical substances. The decrease of temperature in early planets turns out to be a precondition of life, while entirely without triadic processes in Deely’s (or Peirce’s) sense yet. The second kind of evolution happens due to triadic structures, semiosis, which “requires simultaneous existence of the three terms of the triadic relation” (Deely 2016: 78). It should be noted that Deely does not make this distinction between the two kinds of evolution, and his need for the acceptance of physiosemiosis is precisely a consequence of not making this distinction. After accepting the difference between increasing diversity because of stabilization due to lower temperature and, on the other hand, the increase in diversity because of the accumulation of varieties due to inheritance, the idea about physiosemiosis can be abandoned, yet phytosemiosis secured.

3. UMWELT AND SEMIOSIS: UEXKÜLL

Jakob von Uexküll stated that the mechanism responsible for meaning-making is the functional circle (*Funktionskreis*). He described it by mainly using multicellular animals as examples, but he also studied the behaviour of some unicellular eukaryots: *Amoeba*, *Didinium*, and particularly *Paramecium caudatum* (a species of *Infusoria*) (Uexküll 1921: 32–44), which are protists and do not belong to the kingdom

Animalia.[3] He says of *Paramecium* that it is an organism with only one functional circle. This means, according to Uexküll, that a single cell has enough complexity for having a *Funktionskreis*. Uexküll also explicitly attributes functional circles and subjectness (*Zellsubjekt*) to the cells of multicellular organisms[4] (Uexküll 1928: 192).

In another publication, Uexküll provides an illustration that makes a comparison between the environment (*Umgebung*) and the umwelt of *Paramecium* (Uexküll 1992 [1934]: 342). Uexküll states that both functional circle and umwelt appear together. Only in cases where an organism counts with both receptor and effector organs, it may construct and command its umwelt (Uexküll 1982 [1940]: 33). Following this, a cell may have a functional circle and an umwelt. In this respect, it is instructive to read what Uexküll writes about slime mold (*Schleimpilz*), belonging to *Dictyostelia*:

> "We are forced to attribute an umwelt, however limited, to the free-living fungus-cells [*Amöben*], an umwelt common to each of them, in which the bacteria contrast with their surroundings, as meaning-carriers, as food and, in doing so, are perceived and acted upon. On the other hand, the fungus, composed of many single cells, is a plant that possesses no animal umwelt — it is surrounded only by a dwelling-integument [*Wohnhülle*] consisting of meaning-factors." (Uexküll 1982 [1940]: 35–36)

What Uexküll means here is that single cells that possess receptor and effector organs, and thus a functional circle, may also have an umwelt, while a collective of cells like the fruit body of a mushroom or a multicellular plant need not have an umwelt as a whole. A vegetative living body as a cell colony may lack a colony-level functional circle, while the cells of the colony themselves do have their own functional circles and umwelten (see more on Uexküll in this respect in Kull 2020).

What Uexküll describes as 'dwelling integument' (*Wohnhülle*) is a situation with feedback, but without synchronicity, while the latter would be necessary for the emergence of umwelt, and thus for semiosis itself. Therefore we can state: umwelt is co-extensive with semiosis.

---

[3] However, following the naming by an older taxonomy, Uexküll calls *Paramecium* an animal (*Tier*; e.g., in Uexküll 1921: 42), as its German name is *Pantoffeltierchen*.

[4] For instance: "Wir finden eine Wiederholung des bekannten Prozesses innerhalb des Organismus bei den einzelnen Zellsubjekten, deren Funktionskreise zum Teil unterdrückt, zum Teil gesteigert sind" (Uexküll 1928: 191–192).

4. EMERGENCE AND IRREDUCIBILITY

Based on the concept of lower threshold of semiosis introduced by Umberto Eco (1976; see also Rodríguez Higuera, Kull 2017), semiosis is seen as an emergent phenomenon (see discussion in Brown, Key 2021; El-Hani *et al*. 2009; Emmeche *et al.* 2000; Deacon 2014; Brioschi 2019; Rodríguez Higuera 2016). This is in concordance with the understanding of irreducibility of the semiotic triad by Peirce, which we have related to the feature of simultaneity of the components of the triad (Kull 2018b). Both emergence and irreducibility, of course, require specification and explanation.

5. DOUBLE DESCRIPTION AND ABDUCTION: BATESON

Gregory Bateson asserted that the appearing of meaning as an emergent property can be based on double description. He writes that "[in] principle, extra "depth" in some metaphoric sense is to be expected whenever the information for the two descriptions is differently collected or differently coded" (Bateson 1979: 70). Bateson relates it to abduction: "Every abduction may be seen as a double or multiple description of some object or event or sequence" (Bateson 1979: 143).

Julie Hui *et al.* (2008: 82–84) pointed out that Bateson's and Peirce's descriptions of abduction are incompatible: Bateson assumes that abduction requires double description, while for Peirce, the description itself would require abduction. However, there exists an important way to interpret their views as compatible. For this to be possible, Bateson's 'description' should be understood in a very general sense – assuming even a single receptor as if it would be capable of "describing", like a degenerate code which has lost its abductive aspect. Then two receptors related to different functional circles can be seen as exploring a double description. This would lead to a useful modification of Bateson's formulation: something will be turned into a sign by simultaneous double operation of it.

6. CODES

It has been proposed by some scholars that meaning-making begins with, or even is co-extensive with, the existence of codes. Codes are arbitrary mediated relationships. Here it is important to pay attention to the fact that the concept of code is used in semiotics in two different meanings.

(1) Code is the same as habit, as for instance behavioural, mental, social or cultural habits. Habit always includes the possibility of not following the rule, it

always has some element of actual freedom, regardless of whether the possibility to do otherwise is used or not.

(2) Code is the same as fixed algorithm. An algorithm has no freedom. In its realization, some inexactness may sometimes appear, but it is then purely random.

However, code as an algorithm usually originates and become established as a result of the automatization of a former habit, thus it is an arbitrary action that turns into an algorithm. I.e., code in the second sense is often a derivative of code in the first sense. A fixed code is a degenerate habit, and a habit is a degenerate form of semiosis.

A code can thus be identified with semiosis only in the first sense, that is, as a habit, and not in the second sense, as an algorithm. In order for a code to be a habit, i.e. including the possibility for doing things differently, for arbitrariness, the code has to consist of at least two participant codes, as this was emphasised by the principle of code duality (Hoffmeyer, Emmeche 1991) or by the principle of double description (Bateson, see above). This means, a code as semiosis should be a plural code. Accordingly, code plurality is a necessary condition for semiosis.

7. ARBITRARINESS VERSUS CHANCE

Semiosis presupposes arbitrariness. This is another complex feature that may be left unnoticed or hidden when using a simplified account of semiosis. Arbitrariness should be distinguished from randomness.

For a relation to be a code (in either sense, as described above), it should be arbitrary. Arbitrariness presupposes choice, as different from chance. In order to make an arbitrary relation, some work must be done first. Arbitrary relations are always mediated (Kull 2022).

8. LEARNING AND MEMORY

Semiotic learning can be defined as leaving a trace from a choice that will influence further choices. This trace will be memory. Learning leads to habits.

Learning is a rather universal feature of semiosis. However, in the case of the simplest act of semiosis, learning may be almost absent, the change of memory being so small that it will remain unnoticeable. Thus, the capacity for learning may not be the best criterion for empirical detection of vegetative semiosis. Moreover, a purely algorithmic adjustment such as “machine learning” does not use semiosis, as opposed to semiotic learning.

9. RELATION-PROCESS DUALITY OF SEMIOSIS

Semiosis importantly includes two aspects – the relational and the processual. Relations are a-temporal and a-spatial, and these are what comprise subjective time and space; the umwelt consists of (semiotic) relations. On the other hand, there are also physi(ologi)cal processes that are localizable and have a measurable duration, which comprise the mechanism that enables the emergence of relations. The necessary coexistence and complementarity of these two aspects we will call the relation-process duality (Kull, Favareau 2022: 20–22).

10. COMPLEXITY OF VEGETATIVE UMWELT AND SEMIOSIS

The complexity of the umwelt (the structure of semiotic relations) has to correspond to the logical complexity of behaviour and the physiological processes that are responsible for this behaviour. This correspondence provides the key for accessing other umwelten. Direct access to the subjective world of the others is impossible, but knowing this correspondence makes it possible to both have indirect access to it and to model it.

There are two basic methods to construct a model of another organism's umwelt. One is emonic, imitational, empathic, with the researcher remodeling or emulating the context and behaviour of the other via one's own behaviour and feelings. This method works well only if the organism under study is similar enough to the researcher. We use this kind of relational method in everyday life, enabling us to understand other people. The second method is based on studying the processes that enable the emergence of relations in the other, their sense organs and motor organs, and the context of their work. This method was introduced by Jakob von Uexküll for studying the umwelten of other animals. This method requires a model of semiosis, which we find, for instance, in Uexküll's *Funktionskreis*. We are going to follow the second method below.

11. A MODEL OF MINIMAL SEMIOSIS: INTERPRETATION ASSUMING SIMULTANEITY AND CHOICE

As based on the list of features and discussion above, we present here an idea for a minimal model of semiosis. This is described as a triadic circle ("triadic circle"), with a special kind of closure. Its scheme is presented in *Figure 1* as the semiosic triad for the minimal perception of difference.

In order to perceive a difference – evidently this is minimally required to perceive anything at all –, the system should have at least two *perceptual components*

(p and q, in our scheme). The state of each perceptual component can be altered by a specific input (represented as arrows at p and q).

The perceptual components should be somehow linked (in order to work together for the perception of difference). Moreover, each perceptual component should be linked to an *action component* – the condition that makes it "perceptual". A natural linkage between the perceptual components then occurs via a shared action component (represented as a).

The link between perception and action components is contiguous – two-way, with feedback. Thus the states of the perceptual and acting components are mutually dependent. We call such linkage *function circle*. Accordingly, there are two function circles in our model (represented as F_p and F_q in our scheme).

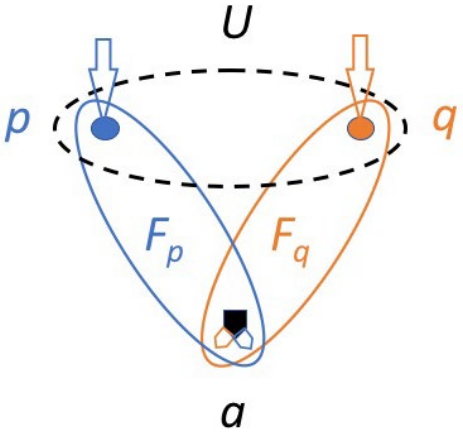


Figure 1. The minimal model of semiosis for the emergence of a relation of difference. This system includes the necessary components for semiosis: p and q – perceptual components; a – action component; F_p and F_q – functional circles; U – umwelt.

Each perceptual component effects (turns) the action component in its specific way. We assume that the action component cannot be in two states at the same time. Thus the function circles F_p and F_q are *incompatible*. This incompatibility is necessary for creating indeterminacy. Moreover, we need to assume that the function circles work synchronically. This means that the state of the action component works simultaneously with both perception components. In these conditions, due to the incompatibility of F_p and F_q, p and q are *both independent and interdependent*. They are superimposed.

The simultaneity between the two functional circles, and accordingly between p and q, turns the "virtual link" – the *relation* – between the two into what is perceived, i.e. creating a minimal *umwelt* (marked as a dashed ellipse U in our scheme). The umwelt here is really minimal, consisting of nothing else than a single difference.

Due to synchronously linked function circles, *indeterminacy* emerges (since the "objects" at p and q are "presented" simultaneously, not sequentially, therefore their order is free). The duality of incompatibles, based on working circles, provides a "problem", the situation where a *choice* (about how to turn a: either according to F_p or F_q) has to happen.

We see here that free choice is a rather simple phenomenon that emerges before any goal is set. I.e., goals or purposes are not necessary for a situation of choice. When it comes to choice (either p or q), however, the situation of simultaneity of options (p and q) is required – we call this the *subjective present*.

The model (Fig. 1) can also be described as consisting of two activity structures (F_p and F_q) as constraints (this terminology borrowed from Valsiner 2011). The system of mutual constraints is a precondition – yet it is insufficient – for meaning-making (in this formulation, we see some analogy with Terrence Deacon's model of the autogen). Given a condition of certain co-dependence of constraints – additionally simultaneous and incompatible –freedom emerges.

It should be noticed that this model provides the necessary conditions for the recognition of differences at a simple level without yet identifying what kind of difference it may be, nor the objects between which this difference is made. The models for recognition of an object and reference, namely, the models of iconic and indexical semiosis, should therefore be more complex. However, even at this primary stage, a new dimension – semiotic relations, or perhaps even umwelt – emerges. However, the umwelt will show its more common features – as subjective space – in the case of a more complex kind of semiosis with multiple perception components linked to multiple and polyvalent action components.

We have thus described the necessary conditions for semiosis. Some details have been omitted, so these, though necessary, are not quite sufficient.

12. CONCLUDING REMARKS

We have focused on the conditions of meaning-making or the emergence of semiotic relations and umwelt in vegetative life. Despite the fact that the precise mechanism of semiosis – and the conditions for minimal semiosis – have yet to be finally discovered, several of their features are established firmly enough in order to argue for the existence of semiosis at least in some non-neural organisms.

We briefly described a list of necessary features of semiosis, demonstrating with it that the minimal model of semiosis, which must include all these features, cannot be simple.

13. ACKNOWLEDGEMENTS

I thank Claudio Rodríguez for his proposal to write this article and helpful comments, and appreciate support from the grant PRG314.

REFERENCES

Affifi, R. (2013). Learning plants: Semiosis between the parts and the whole. *Biosemiotics* 6(3): 547–559.

Baluška, F., Mancuso, S., Volkmann, D. and Barlow, P. W. (2009). The "root-brain" hypothesis of Charles and Francis Darwin: Revival a er more than 125 years. *Plant Signal Behavior* 4(12): 1121–1127.

Baluška, F. and Reber, A. S. (2021). The biomolecular basis for plant and animal sentience: Senomic and ephaptic principles of cellular consciousness. *Journal of Consciousness Studies* 28(1/2): 34–59.

Bateson, G. (1979). *Mind and Nature: A Necessary Unity*. New York: E. P. Dutton.

Brioschi, M. R. (2019). Does continuity allow for emergence? An emergentist reading of Peirce's evolutionary thought. *European Journal of Pragmatism and American Philosophy* XI(2). https://doi.org/10.4000/ejpap.1647

Brown, D. and Key, B. (2021). Plant sentience, semantics, and the emergentist dilemma. *Journal of Consciousness Studies 28*(1/2): 155–183.

Chamovitz, D. (2012). *What a Plant Knows: A Field Guide to the Senses*. New York: Scientific American, Farrar, Straus and Giroux.

Cvrčková, F., Lipavská, H. and Žárský, V. (2009). Plant intelligence: Why, why not or where? *Plant Signaling & Behavior 4*(5): 394–399.

Darwin, C. and Darwin, F. (1880). *The Power of Movement in Plants*. London: John Murray.

Deacon, T. (2014). Semiosis: from taxonomy to process. In: Thellefsen, T. and Sørensen, B. (eds.), *Charles Sanders Peirce in His Own Words: 100 Years of Semiotics, Communication and Cognition* (pp. 95-104) Boston: De Gruyter Mouton.

Deely, J. (1982). On the notion of phytosemiotics. In: Deely, J. and Evans, J. (eds.), *Semiotics 1982* (pp. 541-554). Lanham: University Press of America.

Deely, J. (1986). On the notion of phytosemiotics. In: Deely, John N.; Williams, Brooke; Kruse, Felicia E. (eds.), *Frontiers in Semiotics* (pp. 96-103). Bloomington: Indiana University Press.

Deely, J. (2016). Thirdness in nature. *SCIO. Revista de Filosofía 12*: 75–80.

Eco, U. (1976). *A Theory of Semiotics*. Bloomington: Indiana University Press.

El-Hani, C. N., Queiroz, J. and Emmeche, C. (2009). *Genes, Information, and Semiosis*. (Tartu Semiotics Library 8.) Tartu: Tartu University Press.

Emmeche, C., Køppe, S. and Stjernfelt, F. (2000). Levels, emergence, and three versions of downward causation. In: Andersen, Peter Bøgh; Emmeche, Claus; Finnemann, Niels Ole; Christiansen, Peder Voetmann (eds.), *Downward Causation: Minds, Bodies and Matter* (pp. 322-348). Aarhus: University of Aarhus Press.

Faucher, K. (2014). Phytosemiotics revisited: Botanical behavior and sign transduction. *Semiotica 202*: 673–688.

Favareau, D. (ed.) (2010). *Essential Readings in Biosemiotics: Anthology and Commentary.* (Biosemiotics 3.) Berlin: Springer.

Gapševičius, M., Tredinnick-Rowe, J., Diaz, J. P., Rukevičiūtė, L. and Degger, B. (2018). Semiotic thresholds, between arts and biological science: Green technology and the concept of phytomining. *Semiotic Review* 6. [Includes a chapter: 2.1. Phytosemiotics.]

Gare, A. (2022). Vegetative semiosis. In: Favareau, Donald; Velmezova, Ekaterina (eds.), *Tunne loodust! Knowing Nature in the Languages of Biosemiotics* (pp. 137-140). (Epistemologica et historiographica linguistica Lausannensia 4.) Lausanne: UNIL.

Ginsburg, S. and Jablonka, E. (2021). Sentience in plants: A green red herring? *Journal of Consciousness Studies 28*(1/2): 17–33.

Hendlin, Y. H. (2020). The ensemblist nature of plant plurality. *Semiotic Review* 6. https://www.semioticreview.com/ojs/index.php/sr/article/view/49

Hiernaux, Q. (2021). Differentiating behaviour, cognition, and consciousness in plants. *Journal of Consciousness Studies 28*(1/2): 106–135.

Hoffmeyer, J. (2008). *Biosemiotics: An Examination into the Signs of Life and the Life of Signs*. Scranton: Scranton University Press.

Hoffmeyer, J. and Claus E. (1991). Code-duality and the semiotics of nature. In: Anderson, Myrdene; Merrell, Floyd (eds.), *On Semiotic Modeling* (pp. 117-166). (Approaches to Semiotics 97.) Berlin: Mouton de Gruyter.

Hui, J., Cashman, T. and Deacon, T. (2008). Bateson's method: Double description. What is it? How does it work? What do we learn? In: Hoffmeyer, Jesper (ed.), *A Legacy of Living Systems: Gregory Bateson as Precursor to Biosemiotics* (pp. 77-92). (Biosemiotics 2.) Berlin: Springer.

Ingensiep, H. W. (2001). *Geschichte der Pflanzenseele: Philosophische und biologische Entwürfe von der Antike bis zur Gegenwart.* Stuttgart: Kröner.

Kraepelin, G. (1997). Mykosemiose. In: Posner, R., Robering, K. and Sebeok, T. A. (eds.), *Semiotics: A Handbook on the Sign-Theoretic Foundations of Nature and Culture, vol. 1* (pp. 488-507). Berlin: Walter de Gruyter.

Krampen, M. (1981). Phytosemiotics. *Semiotica 36*(3/4): 187–209.

Krampen, M. (1986a). Phytosemiotics. In: Deely, J. N., Williams, B. and Kruse, F. E. (eds.), *Frontiers in Semiotics* (pp. 83-95). Bloomington: Indiana University Press.

Krampen, M. (1986b). Phytosemiotics. In: Sebeok, T. A. (ed.), *Encyclopedic Dictionary of Semiotics* (pp. 726-730). Berlin: Mouton de Gruyter.

Krampen, M. (1992). Phytosemiotics revisited. In: Sebeok, T. A. and Umiker-Sebeok, J. (eds.), *Biosemiotics: The Semiotic Web 1991* (pp. 213-219). Berlin: Mouton de Gruyter.

Krampen, M. (1997). Phytosemiosis. In: Roland P., Robering, K. and Sebeok, T.A. (eds.). *Semiotics: A Handbook on the Sign-Theoretic Foundations of Nature and Culture, vol. 1* (pp. 507-522). Berlin: Walter de Gruyter.

Kull, K. (2000). An introduction to phytosemiotics: Semiotic botany and vegetative sign systems. *Sign Systems Studies 28*: 326–350.

Kull, K. (2009). Vegetative, animal, and cultural semiosis: The semiotic threshold zones. *Cognitive Semiotics 4*: 8–27.

Kull, K. (2018a). On the logic of animal umwelten: The animal subjective present and zoosemiotics of choice and learning. In: Marrone, G. and Mangano, D. (eds.), *Semiotics of Animals in Culture: Zoosemiotics 2.0* (pp. 135-148). (Biosemiotics 17.) Cham: Springer.

Kull, K. (2018b). Choosing and learning: Semiosis means choice. *Sign Systems Studies 46*(4): 452–466.

Kull, K. (2020). Jakob von Uexküll and the study of primary meaning-making. In: Michelini, F. and Köchy, K. (eds.), *Jakob von Uexküll and Philosophy: Life, Environments, Anthropology* (pp. 220-237). (History and Philosophy of Biology.) London: Routledge.

Kull, K. (2022). Freedom in living beings: Arbitrariness and the forms of semiotic indeterminacy. In: Biglary, A. (ed.), *Open Semiotics*. Paris: L'Harmattan (in press).

Kull, K. and Favareau, D. (2022). Neurosemiotics: A brief history of its development and key concerns. In: García, A. M. and Ibáñez, A. (eds.), *The Routledge Handbook of Neurosemiotics* (pp. 13-29). London: Routledge.

Maher, C. (2017). *Plant Minds: A Philosophical Defense*. New York: Routledge.

Maher, C. (2021). The indeterminacy of plant consciousness. *Journal of Consciousness Studies 28*(1/2): 136–154.

Marder, M. (2017). Voiceless speech, or vegetal logos without logos. *Qui Parle: Critical Humanities and Social Sciences 26*(2): 367–369.

Marder, M. (2018). Phytosemiotics: A fork in the road [Preface to the special issue of Semiotic Review on "Phytosemiotics"]. *Semiotic Review* 6. https://www.semioticreview.com/ojs/index.php/sr/article/view/39

Mediano, P. A. M., Trewavas, A. and Calvo, P. (2021). Information and integration in plants: Towards a quantitative search for plant sentience. *Journal of Consciousness Studies 28*(1/2): 80–105.

Nani, A., Volpara, G. and Faggio, A. (2021). Sentience with or without consciousness. *Journal of Consciousness Studies 28*(1/2): 60–79.

Rodríguez Higuera, C. J. (2016). Just how emergent is the emergence of semiosis? *Biosemiotics 9*: 155–167.

Rodríguez Higuera, C. J. and Kull, K. (2017). The biosemiotic glossary project: The semiotic threshold. *Biosemiotics 10*(1): 109–126.

Romanes, G. J. (1888). *Mental Evolution in Animals*. London: Kegan Paul.

Rossi-Landi, F. (1975). Signs about a Master of Signs. *Semiotica 13*: 155–197.

Sonea, Sorin (1990). Bacterial (prokaryotic) communication. In: Sebeok, T. A. and Umiker-Sebeok, J. (eds.), *The Semiotic Web 1989* (pp. 639-662). Berlin: Mouton de Gruyter.

Stolarz, M. (2009). Circumnutation as a visible plant action and reaction: Physiological, cellular and molecular basis for circumnutations. *Plant Signaling & Behavior 4*(5): 380–387.

Uexküll, J. von (1921). *Umwelt und Innenwelt der Tiere*. 2te vermehrte und verbesserte Auflage. Berlin: Julius Springer.

Uexküll, J. von (1928). *Theoretische Biologie*. 2te gänzlich neu bearbeitete Auflage. Berlin: Verlag von Julius Springer.

Uexküll, J. von (1982) [1940]. The theory of meaning. (Stone, Barry; Weiner, Herbert, trans.) *Semiotica 42*(1): 25–82.

Uexküll, J. von (1992) [1934]. A stroll through the worlds of animals and men: A picture book of invisible worlds. (Schiller, Claire H., trans.) *Semiotica 89*(4): 319–391.

Uexküll, T. von, Geigges, W. and Herrmann, J. M. (1993). Endosemiosis. *Semiotica 96*(1/2): 5–51.

Valsiner, J. (2011). Semiosis and activity: Towards theoretical synthesis. [*Keynote lecture at the International Society for Cultural and Activity Research (ISCAR) Congress "Enhancing the cultural and activity approach for the new generation development in a global world"*. Rome, September 10, 2011.]

Witzany, G. (2006). Plant communication from biosemiotic perspective. *Plant Signaling & Behavior 1*(4): 169–178.

Witzany, G. (2008). The biosemiotics of plant communication. *The American Journal of Semiotics 24*(1): 39–56.

Witzany, G. (ed.) (2011). *Biocommunication in Soil Microorganisms*. Springer.

Witzany, G. (ed.) (2012a). *Biocommunication of Fungi*. Springer.

Witzany, G. (2012b). Key levels of biocommunication in plants. In: Witzany, G. and Baluška, F. (eds.), *Biocommunication of Plants* (pp. 1-9). Heidelberg: Springer.

Witzany, G. and Baluška, F. (2012a). Preface: Why biocommunication in plants? In: Witzany, G. and Baluška, F. (eds.), *Biocommunication of Plants* (pp. v-viii). Heidelberg: Springer.

Witzany, G. and Baluška, F. (eds.) (2012b). *Biocommunication of Plants*. (Series: Signaling and Communication in Plants.) Heidelberg: Springer.

Yates, F. E. (1997). Microsemiosis. In: Posner, Roland; Robering, Klaus; Sebeok, Thomas A. (eds.), *Semiotics: A Handbook on the Sign-Theoretic Foundations of Nature and Culture, vol. 1* (pp. 457-464). Berlin: Walter de Gruyter.

Biosemiotic systems theory: an embodied and ecological approach to culture

Alin Olteanu[1] and Cary Campbell[2]
[1] RWTH Aachen University, Käte Hamburger Kolleg *Cultures of Research*, Germany
[2] Simon Fraser University, Faculty of Education, Canada

Abstract

This chapter explores the avenues that biosemiotics opens for cultural studies. While the most common use of semiotic theory consists in cultural criticism, what a biosemiotic approach to culture entails has been considered only seldomly. In this regard, Paul Cobley's (2016) contribution stands out as explicitly addressing culture from a fully biosemiotic perspective. We take this framework as our starting point to explicate how specific concepts in biosemiotics can help bridge the divide between cultural and cognitive approaches to behavior and learning. One of the reasons that explains, in part, the hesitation towards a biosemiotic approach to culture, despite the attention that biosemiotics is currently enjoying, is its non-relativist epistemology. Mainstream notions of culture, as exhibited in anthropology, discursive theory and other semiotic approaches, advocate epistemological relativism as necessary for cultural diversity and tolerance. While this perspective was the target of some criticism recently, it still remains the most influential notion of culture in both academia and policy. Starting from its notion of meaning as coextensive with life, biosemiotics can help bridge the divide between cognitive and cultural approaches, which pervaded the cultural and linguistic theories of the last century. By construing language as based on embodied and schematic modelling systems, biosemiotics avoids the relativism of the linguistic turn, supporting the recent iconic turn in semiotic theory. As such, we propose that biosemiotics is compatible with the multimodality framework associated with social semiotics and the "new literacies" movement, which it can equip and extend conceptually with a construal of learning, meaning-making and modality as embodied, as well as broadly resonant with intellectual movements in posthumanism and non-representational theory and research. The paper concludes by reflecting on the implications of this reorientation for cultural theory through locating three persistent fallacies/misconceptions displayed by traditional semiotic approaches to culture, which notably overlooked that cultural agents are embodied and biological organisms.

Keywords: cultural studies, biosemiotic, embodied, modelling systems

1. INTRODUCTION: CULTURE AND SEMIOTICS

The most common enterprise of semiotic theories has been cultural criticism. Inspired by Charles S. Peirce's logic and Ferdinand de Saussure's semiology, semiotics gathered momentum after the second world war, alongside information theory (Shannon 1948, Weaver 1998 [1949]) and other trends in complexity and systems theory. Distinctively, through its roots and connections with the humanities and social sciences, semiotics has always adopted what might be broadly called a *qualitative systems theory* outlook on culture. However, despite coming from a shared scholarly tradition and explicitly *being* a systems theory, *bio*semiotics has not addressed culture explicitly, until recently.

Only in the past decade, Paul Cobley (2010, 2016) addressed the "cultural implications of biosemiotics". By this, Cobley did not mean that biosemiotics only has implications for culture and cultural studies extrinsic to the theory itself, but that the notion of culture intrinsic to biosemiotics is nested in a broad view on meaning that exceeds cultural phenomena. Culture, as well as language, as Sebeok (1991, 2001) argued, are only particular cases of the broad spectrum of semiotic phenomena, the latter being coextensive with life. The profound implications of this view to conceptualize socio-cultural emergence (a typical concern for systems and complexity theories) "as meaningful responses to an environment" (Marais 2019: 158) have only recently been explored by Marais. We find great insight in Marais' (2019) argument that biosemiotics explains cultural emergence in light of a notion of translation that is not bound to monomodal and/or mono-medial construals of language.

Here, we present the main premises that biosemiotics brings for a theory of culture. We start from Cobley's (2010, 2016, see also Cobley and Stjernfelt 2015) considerations to explain how some specific concepts in biosemiotics can help bridge the divide between cultural and cognitive approaches to understanding behavior, adaptation and learning. By bridging this enduring divide within the humanities and social sciences, we argue, biosemiotics can avoid certain widespread fallacies or, at least, unfounded assumptions in cultural studies.

Particularly, we identify three main fallacies (see Section 5) displayed by traditional semiotic approaches to culture, which notably overlooked that cultural agents are embodied and biological organisms, labelled:

- The applicationalist fallacy;
- The representationalist fallacy, and;
- The sign-hierarchy fallacy

These fallacies are widespread, in general, in cultural theory, aside the strictly semiotic scope. Because biosemiotics does not follow some of the main questions and inquiries of cultural studies, it is understandable why scholars hesitated to approach culture explicitly from this perspective. At the same time, it is surprising that an explicitly biosemiotic approach to culture (from within biosemiotics) was only developed recently, after decades of biosemiotic theory development and empirical research. This chapter proposes some possibilities towards the actualization of a biosemiotic theory of culture that is widely relevant to both researchers in the social sciences, education but also biology, ecology, ethology and animal studies broadly.

2. THE SEMIOTIC APPROACH TO CULTURE

Throughout the second half of the 20th Century, semiotic theory developed in inspiration of Saussure's (1959 [1916]: 16) observation that *semiology* can study "the life of signs within society", in general. His notion of sign and of language as a system of signs lies at the foundation of structuralism (Barthes 1972 [1957]) and of cultural criticism, broadly (see Danesi 2010).

Construing culture as a system of signs has opened a panoply of fruitful analysis methods that account for the semiotic stratification of culture. For instance, Barthes (1972 [1957]) observed how, in culture, the signs of a language (or system) become, in time, the signifiers of a new semiotic system, which he termed *myth,* described through a process of *connotation*. Cultures are largely constituted by myths, in this broad understanding. Later, in the 1970s, Yuri Lotman (1990) founded what is now labelled *cultural semiotics* by explicitly defining culture as a *secondary modelling system*, based on natural language, which serves as the *primary modeling system*.

The core assumptions of this line of semiotic theory are common for cultural criticism broadly, in most of its 20th Century forms. Overlooking the epistemological role of the body, semiotics contributed to justifying and mainstreaming these assumptions, of which we are critical. The starting assumption consists in supposing an intimate link between language and culture. The claim is that since language is construed as a bounded system, culture, too, is clearly bounded. Rigid views of language as fixed codes with a fixed grammar and syntax often imply a view of culture as clearly bounded code.

A recent critique of this enduring view of language, particularly as entrenched by Saussure (1959 [1916]), was developed in social semiotics and the "new literacies" approach (Hodge, Kress 1988; Kress, van Leeuwen 2001; van Leeuwen 2005; Kress 2003, 2010). In this framework, sign systems are construed as pools or repertories of *semiotic resources*, not lists of interrelated skills/outcomes/ competencies. Notably, this social semiotic approach opened up a construal of meaning as *multimodal*, that is, meaning as *multiply articulated* through the diversity of representation modalities and media-types available to the student/agent (thus bringing semiotics and educational research more in line with the then new and emerging digital/multi-media cultures associated with the rise of the world wide web).

Unavoidably, a recognition of multimodality implies and necessitates the further recognition that meaning-making relies on sense perception channels and, in general, embodied positioning; sensorimotor action within dynamic environmental circumstances. Nonetheless, while Kress (2010: 76) noted that "[i]n the reception of a sign the materiality of modes interacts with the physiology of bodies", social semiotics did not explicitly acknowledge nor explore the mutuality of the notion of multimodality with that of embodiment. This is not unexpected or wanting, as social semiotics does not have the necessary theoretical apparatus for this inquiry. The breaking away from the old Saussurean notion of sign system, in favor of multimodality, is already a remarkable achievement. As we also argued with Kalevi Kull (Campbell *et al.* 2019), the notions of semiotic resource and competence can be approached simultaneously also from a socio- and bio-semiotic perspective to develop a more theoretically encompassing framework (see Section 5), that can account for meaning-making and learning across human-animal divides, with important implications for educational research in particular (some of which we discussed with Nataša Lacković in Campbell *et al.* 2021b). Moreover, this view can be enriched by arguments in favour of multimodality coming from cognitive semiotics (e.g., Mittelberg 2007: 225, 2013, Zlatev *et al.* 2017).

Aside from semiotics, the notion of language-culture as a fixed code has had a thorough and enduring support in the humanities and social sciences. First, influenced by German Romanticism (see Herder's 1772 *Treatise on the origin of language* in Herder 2004: 65-164, Humboldt 1999 [1836], see also Barnard 2003), early

American anthropology (e.g. Boas 1938 [1911]) advocated a notion of culture by which individual cultures can be clearly differentiated one from another. This further inspired the paradigm of linguistic relativism championed by the following generation of American anthropology, often referred to as the Sapir-Whorf hypothesis (see Hill and Manheim 1992), indicating the two Boasian scholars who founded linguistic relativism. It posits that language and culture are the central or main determinants of behaviour and personality traits in individuals. Here, culture is understood as a system of conventions that appear as *natural* to the member of the culture, who is a native speaker of the corresponding language. Around the same time and attuned to the state of the art in anthropology, analytical philosophy became the dominant epistemological framework, as language, instead of immaterial ideas, came to be considered the main tool of epistemology, a move referred to as the *linguistic turn* (Rorty 1967). The philosophy of language of the 20th Century, linguistic relativism and structuralism have been mutually supportive in regard to the central role of language for knowing and the language-culture inseparability.

3. SEMIOTICS AS SYSTEMS THEORY OF CULTURE

The development of the semiotic approach to culture as based on Saussurean semiology parallels historical developments and general tendencies in systems theory, which has guided the evolution of 20th Century scientific discourse in general (see Herbert 2008). The development of biosemiotics, in fact, also parallels this evolution, keeping up with the contributions and impact of systems theory on the natural sciences and *vice versa*. Semiotics can be described, in a certain sense, as the humanities and qualitative-driven uptake of systems theory in the 20th century. Yet, biosemiotics hesitated to explicitly approach culture, perhaps largely due to divergent theoretical frameworks and strong disciplinary territoriality between the natural and social sciences. Sebeok (e.g. 1991, 2001) developed biosemiotics as a full-fledged theory in light of his initial aim to contribute to the field of animal communication (Sebeok 1965) and, further, ethology. Below, we explain both this hesitation and, furthermore, how biosemiotics offers a cultural theory attuned to both the state of the art in the natural sciences as well as to areas of the humanities and social sciences where forms of evolutionary theory have been commonplace for many decades already.

In the first place, Saussure's semiology is part of the historical development of systems theory. Particularly, his scope for semiology to study the "life of signs" (Saussure 1959 [1916]: 16) and the "life of languages" (1959 [1916]: 20) displays vitalism. Vitalism is the doctrine that living organisms are governed altogether by different principles than non-living entities, such as a supposed immaterial spirit, as the terminology of the Romanticists was inherited here. This was a common view in the early, pre-war systems theory, and it is vehemently contradicted by modern molecular biology (Herbert 2008: 249), as well as other empirical scientific findings (see Emmeche *et al.* 1998, Stjernfelt 2007: 51). Vitalism implies that cultures behave like organisms, having a mind of their own (see Eriksen and Stjernfelt 2010, 2012). Further, as implicit with holism (Emmeche *et al.* 1998, Herbert 2008: 249-250), this view claims that individuals cannot think and behave aside the patterns of the (mono-)culture to which they belong. Also, neither can (sub-)communities be differentiated within culture. Saussure's semiology is, indeed, holistic as primarily displayed through his principle of arbitrariness. Because sign systems, such as primarily language, have to be social and not individually enacted phenomena, they must be unitary wholes. Their unity is assured through the principle of arbitrariness: unless the units of a sign system are purely arbitrary, they are subject to the accidental use of individuals, which would make a system useless for establishing reference. Defining the linguistic sign as purely arbitrary, Saussure considered that language, as a sign system, has primacy in the semiological and hierarchical buildup of society. From this perspective, the emergence of socio-cultural reality coincides with the emergence of language, which coincides with agreeing on a system of conventions. The old Enlightenment view of society as a contract (e.g., Hobbes 1909 [1651], Rousseau 1998 [1762]) endured, hence, in Saussure's theory of language.

Thus, the glottocentrism (read: language-centrism, we take this term from Cobley 2016) of 20th Century cultural criticism, from structuralism to discursive theory, has its roots in the conventionalist view that languages are perfectly arbitrary. The arbitrariness of the sign consists in the nature of the relation between its form and content, what Saussure termed *signifier* and, respectively, *signified* (Saussure 1959 [1916]: 65-67). Saussure's point was that if the signifier intuitively suggests the signified, then the sign is subject to its accidental and individual use and the sign system does not stand as a whole. Rather, the value of a sign is derived from how exactly the respective sign is positioned within a broader system, that is, how it relates to all other signs of the system (Saussure 1959 [1916]: 88, 111-122). In this view, the sign system is a fixed and unitary whole that clearly defines how its parts function. Parts of the system cannot be considered to have agency or dynamics of their own. In the case of language, this conceptualization does not leave room for dialects, idiolects and the emergence of unique linguistic communities, each with their own use of what is the same language. The first convincing refutation of this theory is Labov's (e.g., 1972) sociolinguistics, where variation was empirically observed as intrinsic to language. As holism has been, in general, empirically disproved as an underpinning epistemology for systems theory, first of all in molecular biology, monolingualism, too, has been disproved by recent applied linguistics (e.g., Lähteenmäki et al. 2011). Alongside Labov, we note Bakthin's (1981) work, particularly his notion of *heteroglossia*, as pioneering and still not fully explored in this regard. Also, we remark on similar recent trends, away from homogenous and towards heterogenous notions of language and culture, in fields such as acculturation psychology (for an encompassing review see Erentaitė *et al.* 2018).

4. BIOSEMIOTICS AS MODELLING SYSTEMS THEORY

A main reason that explains, at least in part, the hesitation towards a biosemiotic approach to culture despite the attention that biosemiotics is currently enjoying, is its non-relativist epistemology. Mainstream notions of culture, as exhibited in anthropology, discursive theory and other semiotic approaches, advocate epistemological relativism as necessary for cultural diversity and tolerance. While this perspective has been the target of some criticism recently (e.g., Vertovec 1996; Eriksen, Stjernfelt 2010, 2012), it still remains the most influential notion of culture in both academia and policy. Relativism has been deemed essential in intercultural communication by the glottocentric construal of culture because it opposed settler-colonial practices that violently undermined and diminished Indigenous peoples and their cultural ways of life. Our critique here is not to undermine these essentially humanitarian and anti-racist efforts in the early and mid-20th century, but rather to locate certain hidden assumptions in this linguistically oriented culture theory. The core argument, originating in early American anthropology, is that to understand what constitutes flourishing or wellbeing for a community, one must understand the culture of that community in its full complexity. From this holistic perspective, understanding only aspects of a culture is impossible because the parts only make sense within the whole. In light of linguistic relativism, to understand a culture, one must first understand its respective language and master it, ideally, as a native-speaker. As such, becoming fully and completely acculturated into a new culture is unexplainable, if at all possible. Also, it is impossible to tell when an individual is fully a member of the respective culture. Since understanding a new culture is close to impossible, so is understanding/assuming the culture-relative wellbeing of the respective community. This notion of culture has been assumed in many areas of research, such as the psychology of acculturation (Berry 1980) and multiculturalism theories (Taylor *et al.* 1994, Kymlicka 1995, 2001). Also, recently, these classical views have been challenged, both in light of empirical evidence and theoretical criticism of epistemology and methodology (Eriksen and Stjernfelt 2010, 2012; Werbner and Modood 2015; Olteanu 2019). However problematic cultural relativism is, its lasting legacy has made non-relativist approaches to culture controversial, often labeling them as belonging to the ideological “right”.

Biosemiotic theory can offer a firmer theoretical justification to critics of language-culture relativism and holism. It helps explain that, while we would not deny that language is an important or even central aspect of culture, many other aspects of ritual and culture extend well beyond the realm of language (including non-human animal cultures, cf. Laland & Janik 2006, Laland 2008, Sastre 2018, Maran 2020).

Another reason, connected to the first, for which biosemiotics arguably hesitated to address cultural matters is the prevailing legacy of vitalism. Early vitalism, with its racist implications, was discarded from holistic and relativist discourses after the Second World War (see Herbert 2008; Eriksen and Stjernfelt 2010). Cultural theory, then, has strongly resisted any types of interference from biology. A remarkable example is the non-scientific passionate resistance against the uptake of evolution theory in a social research concern, in what is now sociobiology (see Alcock 2001: 3-4). In semiotics particularly, there has also been skepticism about accepting evidence for the category of meaning (as well as culture) in non-human animals. A prominent and influential example is Umberto Eco's (1976) early general semiotic theory, where semiosis was considered confined within human culture. Such resistance is possibly due also to the reality that vitalist assumptions are not entirely absent from the pedigree of biosemiotics. Jakob von Uexküll's (1926) theoretical biology, which is one of the pillars of Sebeok's biosemiotics, was aligned with some of the vitalist assumptions of its time (see Stjernfelt 2007: 225). Estonia, where von Uexküll was active at the time, was not unique in Europe in having a rather strong eugenics movement (Kalling 2007). Caution is needed to avoid such assumptions, in light of state-of-the-art natural sciences. Moreover, a too little discussed matter: Charles S. Peirce's writings, who provided the semiotic backbone of Sebeok's theory, illustrate some instances of racism (see Peirce 1929 in Sebeok, Umiker-Sebeok 1979: 209) from the logician's behalf, at least in terms of a contemporary definition of racism. Therefore, attentiveness is needed also to observe and remove such historical prejudices and assumptions from semiotic theory.

All of this considered, we argue that contemporary biosemiotics can offer a rich notion of culture that avoids several biases, traditional both in cultural studies, broadly, and in semiotics, particularly -- mainly *by recognizing the embodied, preverbal, multimodal, and ecological aspects of culture.* As such, we shall point to some recent developments in biosemiotics, particularly as inspired by recent cognitive sciences (Stjernfelt 2014; Cobley, Stjernfelt 2015; Olteanu *et al.* 2020; Campbell et *al.* 2021a), that reconsider some earlier positions in this field. Mostly, our re-evaluation of biosemiotics regards dismissing a supposed parallelism between complexity of meaning and complexity of cognition (see Section 5, on the *sign-hierarchy fallacy*).

To begin with, biosemiotics starts with Sebeok's observation, in the 1960s-1970s that, as a modeling systems theory of meaning, semiotics could incorporate insights that the natural sciences were bringing to light at the time. A salient example in this regard is the uptake of the differentiation between adaptation, in a strictly Darwinian sense, and exaptation (Gould, Vrba 1982), as a species' employment of an evolutionary feature for a purpose other than its initial, biological purpose. The evolution of hominids offers many such examples, among which Sebeok highlighted language. Verbal communication shaped language as a modelling system for humans, at both individual and collective levels, because humans' capacity to articulate phonemes proved to be useful for communicating and, hence, was transmitted intergenerationally. The capacity to articulate phonemes, however, is only the accidental result of a successful adaptation of the human respiratory and circulatory systems to better breath in bipedal position and, we also indicate here, the likely evolutionarily coalescing with proto-musical capacities/competencies (e.g. auditory scene analysis; perception of periodic rhythms or beat-based processing; perception of discrete pitch-levels (or intervals) and octave equivalence, etc.) deeply rooted in hominin evolutionary history, which, in turn are intimately connected with the evolution of human language (see Tomlinson 2015). The point is that language, as exapted through the inter-generational employment of articulated speech, cannot be the fundamental modelling system.

Sebeok insisted on understanding semiotics as a systems modelling theory. He was directly inspired by the Tartu-Moscow approach to semiotics, as championed by Lotman, but offered a critical addition/extension. He (Sebeok 2001: 26–27) agreed that sign systems behave like modeling systems but fundamentally disagreed that natural languages function as primary modelling systems, which has direct consequences for both modelling and culture theories:

> "A concept of 'modelling systems' has been central to the semiotics of the so-called Moscow-Tartu school since the 1960s, but, having been derived from a representation of language in structural linguistics, it focused on culture to the exclusion of the rest of nature." (Sebeok 2001: 26–27)

Thus, on the one hand, Sebeok adopted Lotman's (1977) concept of model as a semiotic production. However, Sebeok's biosemiotics is arguably not in full agreement with Lotman's (1977: 7) definition of model as "a structure of elements and of rules for combining them that is in a state of fixed analogy to the entire sphere of an object of knowledge, insight or regulation." In brief, Sebeok's modelling theory does not share Lotman's linguistically oriented holism, as expressed by the claim that modelling supposes analogy to the "entire sphere of an object of knowledge". Also, Sebeok argued that because intra-organism communication throughout the animal world and nature is overwhelmingly nonverbal, the primary modeling systems of living organisms, including humans, have to be nonverbal (Sebeok 1994, 2001). For this modeling systems theory, Sebeok found Charles S. Peirce's semiotics as a proper theoretical underpinning. Sebeok employed Peirce's notion of sign and classification of signs to differentiate between models in a way that explains how meaning structures cooperate in the construction of environments. In this framework, Peirce's notion of iconicity rejects the Saussurean arbitrariness hypothesis. The main idea is that things beget their utility and, thus, become *meaning carriers* (see Thure von Uekull 1986: 204 in Sebeok 1991: 154) for an organism, in an environment, because of simple signs, termed icons (EP2, 13, 273), which rely only on similarity. Far from implying that modeling is exclusively iconic, the argument here is that meaning-making is made possible through the means in which organisms can interact with their environment, which they make sense of through the perception and sensory-motor possibilities of their own body. Simplifying through an example, a stone that I can hold in my hand is similar to my action of grasping. In light of this possibility, I might bestow upon a stone a "weapon tone", if I am to throw it at an enemy, or a "tool tone", if I am to use it to hammer something (see Uexküll 2010 [1934]: 93). Furthermore, in light of more recent scholarship on Peirce (Stjernfelt 2014; Hoffmeyer, Stjernfelt 2016), we also argued, together with Sebastian Feil (Olteanu *et al*., 2020; Campbell *et al.* 2021) that, in modeling, complexity of meaning does not parallel complexity of cognition (see Section 5, the *sign-hierarchy fallacy*). This argument is in partial disagreement with Sebeok's initial modeling theory (particularly as presented in Sebeok, Danesi 2000). However, Sebeok's Peirce-based modeling theory, given the critical role that it attributes to icons in modeling, opened the possibility for a view on language and culture as emerging extensions of biology. This elegantly avoids both vitalism and reductivism.

From this point of view, language is rather labelled a secondary modelling system, made possible and also restricted by primary modelling systems. To use the contemporary terms of cognitive linguistics, *language is embodied.* Some features that have been traditionally deemed as defining for the articulated language of humans now appear as universal modeling patterns, basic for survival. A remarkable example is that of the proposition structure, both in logic and grammar, considered as peculiar to language. In a strict Peircean view, Subject-Predicate structures are not only linguistic (Stjernfelt 2014) but also widely embedded within biological systems. This is because, according to their embodied competences for meaning-making, organisms interpret the *co-localization of two entities* in such a (propositional) manner. That is, when two entities are co-located in space-time (according to the organism's species-specific conception of space and time), one is interpreted to describe the other in some regard. For example, if I perceive that an apple is in the tree, I know that *the apple is in the tree* irrespective of any linguistic formulation of this relation. In this example, the apple is an indexical sign, functioning as subject for the rhematic (predicative) sign "in the tree". To be applied as such to the subject, the predicate has to be understood, primarily, in its iconic, that is, descriptive potentiality. Following this semiotic consideration on modelling, language depends on prelinguistic semiotic competences. Moreover, language is such a successful modeling system precisely because of its affordance to store and represent the types of signs and semiotic resources that are necessary for survival in general, particularly propositions.

These observations weaken, if not collapse altogether, the dichotomy between communication (intra-organism) and thinking (inter-organism) as two different justifications of language. Notably, (post)structuralism inherited Saussure's justification of language as collective (intra-organism communication), which overlooked the individual's freedom and capacity to creatively employ the resources made available by language and culture. Sebeok rejected the Saussurean notion of language as strictly social and psychological, meant only for inter-organism communication. Arguably, modelling, in the Sebeokian sense, subsumes inter- and intra-organism communication. Simply put, to make meaning of something is to have an operational model that makes certain actions possible and this happens both individually and collectively. Building a modelling system in inspiration of Peirce's semiotics, instead of Saussure's, Sebeok (2001: 187) defined model as, generally, "a semiosic production with species-specific biological features for its utilization." As we will address later on in Section 5, Peirce's notion of iconicity provides a contrary perspective on modelling, based not on fixed rules, but rather "correspondences" and "structural resemblances".

Sebeok (e.g., 2001: 27) founded biosemiotics on Peirce's triadic model of the sign, where modelling can be seen as akin to the action of signs, namely what Peirce termed *semiosis* (EP2 411). The other pillar of Sebeok's theory is von Uexküll's theoretical biology, which explains meaning as resulting from perception and action loops (functional cycles) that any animal undergoes by interacting with the environment which, in turn, it constructs/enacts. According to Uexküll (1926), repeated and continuous loops of perception and action result in a species-specific environment or, in the original German, *Umwelt*. Sebeok explained that the Uexküllean notion of *Umwelt* is in fact a model -- his specific contribution consisting in the fine-grained explanation of the modelling process in terms of signs.

This leads to the cornerstone of this paper, as explained by Cobley (2016: 28), namely that within biosemiotics "answers to questions about human affairs", including culture, "are sought in the interrogation of modelling". While also taking a modeling perspective on culture, Tartu-Moscow semiotics of the 20th Century critically missed the importance of biological and environmental considerations -- construing cultures as closed sign systems, namely, on the one hand, unrestricted by outer factors and, on the other, strictly limited to their *autopoiesis*.

Cobley (2010, 2016) lays out how a biosemiotic notion of culture avoids the relativism and glottocentrism that discursive theories entrenched in the humanities usually follow. Most importantly, dismissing glottocentrism from the academic construal of culture is a step to overcoming ideological anthropocentrism. This is necessary for overcoming several modern dualisms from cultural studies, as required to align the humanities with state-of-the-art notions from the natural sciences:

> "In the sphere of culture, there is a series of binaries that biosemiotics abolishes or modifies by treating life as continuous and by discerning semiosis across the realm of nature; namely: individual/collectivity, agent/subject, verbal/nonverbal, human/non-human, mind/matter, culture/living nature." (Cobley 2016: xii)

Marais (2019) observes that translation studies, which are intrinsic to construing culture and communication, are limited by language-centrism in linguistics generally. Here he explains that the language-focus bias in translation studies is at odds with some directions that translation studies have recently indicated. Of particular importance here is Marais' (2019: 122) consideration that "the profusion of new terms suggests that the multimodal/medial nature of communication will only grow in future, leaving a purely interlingual translation studies with less and less to study. Translation studies will also become incapable of studying interlingual translation, because almost no communication is purely linguistic." Indeed, the bias to construe interlinguistic translation as strictly linguistic feeds the notions of language and, consequently, culture as closed sign systems in the form of conventional codes (see Olteanu 2020). Marais finds a way forward in translation studies through the biosemiotic rejection of glottocentrism. Implicitly, Peirce's notion of semiosis offers an appropriate framework to think about translation, as it renders meaning-making as an infinite process. From this point of view translation is not the (precise or approximate) correspondence between the terms of two distinct systems. As Olteanu (2020) also argues, a Peircean perspective justifies that translation is inherent to thinking, in general. Like Marais (2019), Olteanu (2020) also finds that biosemiotics problematizes Jakobson's (1959) differentiation of translation as intralingual, interlingual and intersemiotic, agreeing with O'Halloran *et al.* (2016:199) that, in brief, this classic theory misses "the translation of multisemiotic texts". The main point is that the language-centrism in translation studies perpetuates the notion of language and culture (as well as texts) as homogenous and clearly bounded sign systems.

The full implications of a biosemiotic approach to culture are comprehensively illustrated by Nils L. Elliot's (2019) motivation in adopting this theory as a framework for observing wildlife, an empirical endeavour that is translation *par excellence*. Elliot (2019: 20) explains that biosemiotics allows for avoiding both culturalism and biologism in understanding the behaviour of non-human species:

> "Those who eschew causation tout court, or who reject empirical research or indeed scientific realism without further ado, run the risk of relativism, idealism, or what is equally problematic, a rampant culturalism. As the cultural critic Terry Eagleton [(Eagleton 2000)] puts it, culturalism is the doctrine that everything in human affairs is a matter of culture. Culturalism is the obverse of biologism, the stance adopted by those who attempt to reduce everything in human affairs to a transcendental biology. Culturalism is no better than biologism; on the contrary, when culturalism takes over, then it becomes rather difficult to explain why academics' bodies (as distinct from some of their/our theories) don't simply float away." (Elliot, 2019: 20)

Starting from its notion of meaning as coextensive with life, biosemiotics can help bridge the divide between cognitive and cultural approaches to meaning, which have accordingly polarized the cultural and linguistic theories of the last century into two camps. By construing language as based on embodied and schematic modelling systems, biosemiotics avoids the relativism of the linguistic turn, supporting the recent iconic turn in semiotic theory, which asserts that all signification has an iconic ground or foundation. As such, we propose that biosemiotics is compatible with the multimodality framework associated with social semiotics and the “new literacies” movement, which indeed, it can equip and extend conceptually by offering a construal of meaning and modality as pre-verbal, embodied and not only or simply psychological, representational, or linguistic. Similarly, biosemiotics finds many parallels and resonances with post-humanist and non-representational theory and research.

5. DISCUSSION, THROUGH FALLACIES

In order to advance our proposal for a biosemiotic theory of culture, we need to be clear that not any old conception of semiotics is up to the task. Hence, we facilitate this discussion through locating *three prevalent misconceptions and fallacies associated with “cultural” semiotic research*, to which biosemiotics responds in several key ways. As this is a short chapter, we will not extensively discuss or unpack the full dimensions of each misconception/fallacy, but simply try to locate it within the broader scholarly discourse.

5.1. The applicationalist fallacy

Biosemiotics cannot ultimately or philosophically be understood as an applied method of analysis, in the sense that signs are not merely tools of analysis but coextensive with the life process. If living is fundamentally expressed in communication (including basic forms of organism-environment communication and sign-use) then semiotics, from the biosemiotic perspective, is not simply semiotics applied to the analysis of biological phenomena.

In a connected example, what has often been referred to as edusemiotics is not semiotics *applied* to education –rather, it is semiotic philosophy as the basis for educational theory – as in Stables and Semetsky’s (2015) foundational work *Edusemiotics: semiotic philosophy as educational foundation* (cf. Olteanu & Campbell 2018). Within the Vygotskyian social-constructivist tradition, semiotics has always had an important place. However, here, signs are considered primarily as tools or mediating artefacts to be employed in pedagogy and cultural development, arguably, neglecting the phenomenal, qualitative, action-oriented aspects of *perception-action cycles*. We observe that one of the most interesting aspects of this branch of educational philosophy has been its convergence with biosemiotics through developing a general *semiotic theory of learning* that is notably non-anthropocentric, but rooted within a more common frame of animal learning, as developed in participation with biosemiotics scholars. Campbell *et al.* (2019: 394) elaborate the significance of this theoretical convergence, specifically through revealing a host of shared, jointly ecological and educational concepts (specifically, learning, memory, resources, competences, affordances, and scaffolding):

> "The convergence of the semiotic theory of education and the semiotic theory of biology reveals one of the most interesting features of semiotics in general: its *implied theory of knowledge.* Signs, as basic semiotic units, are not units of measurement, but rather refer to *meaningful relationships* that sustain, enable and constrain the organism's interactions – thus, they are ultimately qualitative and subject to dynamic change and growth [...] Following trends in ecosemiotics and biosemiotics, it is possible to consider that semiotics itself is increasingly becoming a theory of knowledge, as it describes the diversity of models and modelling phenomena across different organisms' umwelten, and thus the "forms of knowledge" (Sebeok, Danesi 2000) expressed by life's diverse interactions. The interactions of living organisms and ecosystems create new forms (scaffoldings and resources) for meaning-making. These basic biological forms (*scaffolding structures*) appear to be signs (or, sign-vehicles) that organisms endow with meaning through coming to *know* them in their own species-specific ways. In this way, "biology accounts for a spectrum of meanings that a form *affords* within the horizon of an organism's *competences* for meaning- making" (Olteanu & Stables, 2018, p. 411, [emphasis added])."

By approaching meaning-making and semiosis through the general framework of animal-learning, as this biosemiotics-informed approach to learning theory calls us to do, we come to reckon with the basic observation that, beyond human linguistic articulation and representation, semiosis represents more broadly a "special kind of *animal* interaction with the world" (Tomlinson, 2019 [our emphasis]; an interaction that is fundamentally embodied and ecological. Interestingly, various fields like cognitive ethnology, field ecology, as well as bio- and eco-semiotics have shown since the 70's, that animal sign-use is not only common, it is widespread and fundamental in ecology. As noted by Timo Maran (2020: 5) in his recent *Elements of Ecosemiotics*:

> "Animals using semiosis or mediated relations to make sense of the environment is a phenomenon so widely present that it is very easily overlooked. Let us recall that, for an animal, a sign is anything that indicates, shows the way, or makes evident something that would otherwise remain concealed or inaccessible. Even if we skip the philosophical question whether all perceptions of environmental objects are mediated by our senses and thus semiosic, we will find animals relying on mediated relations everywhere. A huge number of predatory species from snakes and sharks to big cats use smell or tracks to trace down the location of their prey. Many animals – fish, insects,

> birds, and mammals – rely in their movement and migration on various types of environmental signs: memorized landmarks; stellar constellations; chemical traces in air and water; and so on. Many birds gather and synthesize different qualities of the environment to decide on where to build their nest". (Maran 2020: 5)

For educational theory and research, recognizing the ubiquity and centrality of animal-learning and animal semiosis calls for us to observe and understand *more-than-human* aspects of learning (and hence, teaching, pedagogy, curriculum, literacy, schooling, etc.) – not what makes us humans distinct from other beings, but how we exist in continuity and relation with the animal and the ecological. Thus, biosemiotics opens up pathways for posthumanist (Snaza & Weaver [eds.], 2014; Herbrechter, 2018) and ecological directions (Campbell, 2018; Carvalho et al., 2020) in educational research and practice, that recognize more-than-human dimensions to culture and cultural processes like learning and teaching.

5.2. The representationalist fallacy

Just as biosemiotics is inherently broader and more all-encompassing than the application of semiotic theories, concepts and methods to biology, and just as edusemiotics is not semiotics *applied* to education, semiotics cannot only deal with systems or structures of signs, but also must come to grapple with how meaning-making and signification processes are connected to action-perception cycles (hence the focus on Umwelt, ethology, animal learning, adaptation, and communication in biosemiotics). Following from this, we must, in cultural research, recognize that the sign is not only, or necessarily, a *representation*; by being meaningful to some animal perceiving it, it is *also* a prompt for action and response (it is enacted, remembered, and anticipated). By fully adopting the Peircean notion of sign, comprehensive also of the Interpretant, and not only of the Representamen, neither do we align in all regards with anti-representationalist perspectives, such as implied in enactivism (Varela et al. 1993).

Stables (in Stables et al. 2018: 27) elaborates in the co-written volume *Semiotic Theories of Learning*:

> "Generally, accounts of the sign tend to ascribe two principal functions to it. In addition to the representational, there is the signifying function: by meaning something, a sign implies its response, acting as a prompt. A sign effectively says *that* . . . [something] *to* . . . [someone or something]. I argue that a fully semiotic account is impeded by representationalism, but that anti-representationalism does not amount to anti-realism. That is, we can reject the assumption that the sign always stands for some other entity, whether phenomenal or noumenal (in Kantian terms) without denying the sign's connection to the real world."

We can see how recognizing signs as real-world units that animals respond to and enact in their environments calls us to question the limits of representationalism as a form of human-centered idealism. We are not denying that signs do in fact function as representations. In fact, the basic materiality of semiosis – the realist observation that signs, in order to be interpreted at all, must have some material or enacted-embodied form – ensures that signs will always have representational potential. Rather, we are observing the crucial point that semiosis transcends purely representational phenomena and is, importantly, for education and the social sciences more broadly, *always connected with a particular being or subject that learns and interprets*.

Generally underlying representationalist assumptions is an insistence on representations being governed by fixed rules or codes, and thus easily culturally transmissible in the form of internal mental representations and closely connected to natural language. Ingold (2000: 353-354 [our emphases]) explains the implications of this representationalism for theories of social and intergenerational learning in anthropology and the social sciences:

> "Traditional models of social learning separate the intergenerational transmission of information specifying particular techniques from the application of this information in practice [...] Now I do not deny that the learning of skills involves both observation and imitation. But the former is no more a matter of forming internal, mental representations of observed behaviour than is the latter a matter of converting these representations into manifest practice [...] Through repeated practical trials, and guided by his observations, he gradually gets the 'feel' of things himself [...] in this process, each generation contributes to the next not by handing on a corpus of representations, or information in the strict sense, but by introducing novices into contexts which afford selected opportunities for perception and action [...]."

From this perspective, what is non-genetically handed over intergenerationally, i.e. culture, does not consist in a fixed system of symbols. Knowledge is anything meaningful to an organism in the here-and-now – the immediacy and situatedness of experience unfolding in an environment. In this sense, knowledge is never simply *there* (Hoffmeyer 2018), in advance of our needing it – it is something evoked, enacted, emerging in the act of coming to know and correspond with the world.

Here, we would like to observe that through this implicit recognition that a sign is both a unit of meaning as well as a contextual prompt for action and response, biosemiotics opens up pathways for collaborations and resonances with non-representational research in the social sciences. Non-representational research is closely associated with currents in embodiment philosophy, the work of contemporary artists and arts practitioners, as well as posthumanist and ecological philosophy. As Lorimer (2005: 83) concisely puts it "[n]on-representational theory is an umbrella term for diverse work that seeks to better cope with our self-evidently more-than-human, more-than-textual, multisensual worlds.” In many ways, biosemiotics is responding to similar intellectual trends and currents as a non-representational theory -- to embed and locate meaning-making beyond the narrowly human, linguistic, and text-based. Vannini (2015: 2) observes plainly, in the introduction to *Non-representational research methodologies,* that “[n]on-representational theory is now widely considered to be the successor of postmodern theory, the logical development of post-structuralist thought, and the most notable intellectual force behind the turn away from cognition, symbolic meaning, and textuality.” As has been sketched throughout this chapter, we can observe that the same claims can be made about biosemiotics as a research movement, with the additional contribution that biosemiotics offers an explicitly non-relativistic philosophical grounding, something much non-representationalist research arguably lacks.

5.3. The sign-hierarchy fallacy

As we have been outlining, from a biosemiotic perspective, semiotic relations are not arbitrary or relativistic, but the outcome of evolving interactions of lifeforms. This is the reason why signs are not *just* tools of analysis but essential aspects of the life-process. This realism (as opposed to conventionalism) about semiosis is implied in Peirce’s late emphasis on the primacy of icons. Peirce stated that an icon is a sign “from which information may be derived,” (Syllabus 1903, EP2 275).

However, this recognition of the primacy of icons in meaning-making and animal-learning as articulated in Peirce’s late writings (post 1900) sharply diverges from the traditional culturalist tradition in semiotics and the social sciences at large, which consistently explain human natural language as a primary modelling system and thus construct their theory on a (non-Peircean) relativistic notion of symbols, understood as signs whose meaning is arbitrary and purely the result of cultural (human) convention.

This anthropocentric orientation is even prominent in neo-Peircean semiotic theory. For instance, over the last several decades, a framework influenced by Peirce’s phenomenological categories (Firstness, Secondness, Thirdness) has become significant in several research areas interested in learning, cognition, and development (including research in cognitive semiotics, cf. Zlatev 2009; cf. 2018). Here, following a particular reading of Peircean semiotics (cf. Deacon 1997; Sebeok and Danesi 2000), modeling has mostly been thought of as ascending from simple, basic sign types to complex ones (iconic – indexical – symbolic; Firstness – Secondness – Thirdness). As we have explored in previous research (see Olteanu *et al.* 2020; Campbell *et al.* 2021), while this reading of Peirce has supported some highly interesting and relevant research orientations, the stratified conception of three modeling systems also opens the way for a tempting reduction of Peirce's semiotics, in view of its typical three categories (CP 7.528).

This developmental and hierarchical three-step modeling theory is often used to justify *a direct correspondence between complexity of cognition and complexity of signification*, implying that cognitive modeling is aligned to sign hierarchies and sign dependencies. This is what we refer to as the *sign-hierarchy fallacy*, which is the basic assumption that learning, development and meaning-making proceed from basic iconic forms to more complex symbolic forms. This theoretical perspective is perhaps most overtly on display in Sebeok and Danesi's (2000) (post)modern classic *The Forms of Meaning*. While very insightful in their use of Peircean concepts, Sebeok and Danesi's theory of modeling established a mainstream reading of Peirce where "representational activities" are "undergirded by three different, but interrelated, modeling systems present in the human brain, corresponding *grosso modo* to what Charles Peirce called Firstness, Secondness, and Thirdness" (Sebeok and Danesi 2000: 9–10). They illustrated what they mean explicitly through the example of a child's early learning and development, arguing that the development and enculturation of an infant (1) starts from early strategies of knowing through the senses, which they termed a primary modeling system; (2) proceeds by vocal imitation, gestures and indexing, and other strategies for joint attention, a secondary modeling system; and (3) further develops to comprehend the use and production of culture-specific names and symbols, hence mastering a tertiary modeling system. From this perspective, icons are fundamental in nature, and are in fact the most basic and fundamental sign relationships. For instance, in his recent (2018) book *Culture and the Course of Human Evolution*, Yale professor Gary Tomlinson presents a view of culture that explicitly builds off of the neo-Pericean three-step modelling theory. Clearly articulating the hierarchical and developmental aspects of this theory in a lecture, Tomlinson (2019) states that: "[a]n Icon is the simplest kind of sign, but it is a foundation from which a hierarchy of more and more complex signs will be built".

However, we must acknowledge that this perspective is actually divergent from Peirce's semiotic theory, which is deliberately non-hierarchical in its approach. For Peirce, symbols are not the natural apex of meaning-making or cultural evolution, but a central component of how an organism establishes and maintains continuity in an environment through the maintenance and formation of habit. In fact, for Peirce pure icons, indices, and symbols, are "marginal phenomena." In isolation, these signs signify nothing, and thus can make no possible truth claims (see Stjernfelt 2014: 143) about the world. Such sign relationships must be revealed in perception-action cycles, or interpretative processes (habitual and emergent forms of organism-environment interaction). In other words, "in order to be understood, a symbol must bear information in the shape of an icon and relate that information to an object by means of an index" (Stjernfelt 2014: 143). In this sense, symbols are signs that might cause us to act in a certain way in the future, representing previously established habitual connections (scaffolding, see Hoffmeyer 2007; Cobley, Stjernfelt 2016) that make something appear as possible according to some future orientation. Stjernfelt (2014: 142 [our emphases]) explains: “symbols are signs which are general as to their object, they possess an *esse in futuro*, referring to a potential continuity of future objects; they refer to their object by means of a habit, *natural or cultural*; they comprise icons for their understanding and indices for their object reference.”

6. CONCLUSIONS

Peirce’s late semiotic, upon which biosemiotics is partly founded, suggests an approach to both learning and cultural theory that is non-hierarchical and non-accumulationalist, in the sense that knowing and learning are more than the accumulation of competencies, skills or representations. Thus, from this perspective, biosemiotics recognizes that widely divergent lifeforms, with very different Umwelt structures are able to achieve similar levels of semiotic competency, and enact a shared repertoire of affordances and resources, accomplishing this in widely divergent ways. This *thesis of convergent evolution* has strong implications for cultural theory: a fully symbolic competency that may bypass indexical and iconic embodiments could be seen to find “its highest degree of articulation in human language” (Stjernfelt 2014: 159; see also Campbell *et al.* 2021a: 190)). However, the necessary diversity of animal body forms and corresponding semiotic competences requires that we recognize this as “an important *achievement* rather than a possible starting principle” (Stjernfelt 2014: 159). What the sign-hierarchy fallacy suggests, that humans are not simply or reductively “on top” (Jaroš and Maran, 2019), has profound implications for social science research and educational theory in particular, which has often proceeded from strongly anthropocentric-centric foundations, that separate humans from animals precisely for their capacity to use language and undergo educational processes (see Olteanu & Campbell 2018: 248).

In brief, the crux of the contribution that biosemiotics can offer cultural studies consists in a rich conceptual framework that notably avoids several relativistic and anthropocentric assumptions of mainstream cultural theories (including semiotics) that assume human-animal/nature-culture discontinuity and which further imply problematic notions of culture. Through the notion of umwelt and species-specific modelling, biosemiotics embeds the human within the more-than-human to acknowledge and account *for* the embodied, preverbal, multimodal, and ecological aspects of culture, that are often neglected or diminished by language and anthropocentric theory.

7. ACKNOWLEDGEMENTS

The Käte Hamburger Kolleg *Cultures of Research*, where Alin Olteanu is based, is entirely funded by the German Ministry for Education and Research (*Bundesministerium für Bildung und Forschung*).

Cary Campbell would like to thank Professors Michael Ling and Maria Spychiger for discussing and providing inspiration for this article (particularly the three fallacies discussed).

REFERENCES

Alcock, J. (2001). *The triumph of sociobiology.* Oxford: Oxford University Press.

Bakhtin, M. M. (1981). *The dialogic imagination by M.M. Bakhtin*: Four essays. Edited by M. Holquist. Trans. Emerson, C., Holquist, M. Austin: Univ. of Texas Press.

Barnard, F.M. (2003). *Herder on nationality, humanity and history.* London: Routledge.

Boas, F. (1938) [1911]. *The Mind of Primitive Man*. New York: The Mac-Millan Company.

Barthes, R. (1972) [1957]. *Mythologies*. Trans. A. Lavers. New York: The Noonday Press.

Campbell, C. (2018). Returning 'learning' to education: Toward an ecological conception of learning and teaching. *Σημειωτκή-Sign Systems Studies*, *46*(4), 538-568.

Campbell, C., Olteanu, A. and Kull, K. (2019). Learning and knowing as semiosis: Extending the conceptual apparatus of semiotics. *Sign Systems Studies*, *47*(3/4), 352-381.

Campbell, C., Olteanu, A., and Feil, S. (2021a). Peircean anti-psychologism and learning theory. *Chinese Semiotic Studies*, *17*(1), 175-197.

Campbell, C., Lacković, N. and Olteanu, A. (2021b). A "strong" approach to sustainability literacy: Embodied ecology and media. *Philosophies 6*(1), 14.

Carvalho, I. C. D. M., Steil, C. A., and Gonzaga, F. A. (2020). Learning from a more-than-human perspective. Plants as teachers. *The Journal of Environmental Education*, *51*(2), 144-155.

Cobley, P. (2010). The cultural implications of biosemiotics. *Biosemiotics 3*: 225-244.

Cobley, P. (2016). *Cultural implications of biosemiotics.* Springer: Dordrecht.

Cobley, P., and Stjernfelt, F. (2015). Scaffolding development and the human condition. *Biosemiotics 8*(2): 291–304.

Danesi, M. (2010). Semiotics of media and culture. In: Cobley, P. (Ed). *The Routledge Companion to Semiotics* (pp. 135-149). London: Routledge.

Deacon, T. (1997). *The symbolic species: The co-evolution of language and the brain.* London & New York: W. W. Norton.

Eagleton, T. (2000). *The idea of culture.* Oxford: Blackwell Publishing.

Eco, U. (1976). *A theory of semiotics*. London: Indiana University Press.

Elliot, N. L. (2019). *Observing wildlife in tropical forests 1: A geosemiotic approach.* Delome Publications.

Erentaitė, R., L. Lannegrand-Willems, O., Negru-Subțirică, R., Vosylis, J., Sondaitė, and Raižinė, S. (2018). Identity development among ethnic minority youth: Integrating findings from studies in Europe. *European Psychologist 23*(4): 324–335.

Eriksen, J. M. and Stjernfelt, F. (2010). Culturalism—From idea to un-conscious presupposition. *Sociologija 2*(4): 359–376.

Eriksen, J. M. and Stjernfelt, F. (2012). *The Democratic Contradictions of Multiculturalism*. New York: Telos Press.

Gould, S. J. and Vrba, E.S. (1982). Exaptation—A missing term in the science of form. *Paleobiology 8*(1): 4–15.

Herbrechter, S. (2018). Posthumanism and the ends of education. *On Education: Journal for Research and Debate*, *1*(2). https://doi.org/10.17899/on_ed.2018.2.2

Herbert, S. (2008). Alternative views of complexity. In: Bedau, M. A. and Humphreys, P. (Eds.) *Emergence: Contemporary Readings in Philosophy and Science* (pp. 249-258). Cambridge, MA: The MIT Press.

Herder, J. G. von. (2003) [1765-1797]. *Philosophical writings*. Cambridge: Cambridge University Press.

Hill, J. H. and Manheim, B. (1992). Language and world view. *Annual Review of Anthropology 21*: 381-406.

Hobbes, T. (1909) [1651]. *Leviathan*. London: Oxford University Press.

Hodge, R. and Kress, G. (1988). *Social semiotics*. Ithaca: Cornell University Press.

Hoffmeyer, J. (2007). Semiotic scaffolding of living systems. In Barbieri, M. Ed. *Introduction to biosemiotics* (pp. 149–166). Berlin: Springer.

Hoffmeyer, J. (2018). Knowledge *is* never just *there*. *Biosemiotics 11*(1), 1–5.

Hoffmeyer, J. and Stjernfelt, F. (2016). The great chain of semiosis. Investigating the steps in the evolution of semiotic competence. *Biosemiotics 9*: 7-29.

Humboldt, W. von. (1988). O*n language: The diversity of human-language structure and its influence on the mental development of mankind.* Translated by P. Heath. Cambridge: Cambridge University Press.

Ingold, T. (2000). *The perception of the environment: Essays on livelihood, dwelling and skill.* Abingdon: Routledge.

Jaroš, F. and Maran, T. (2019). Humans on top, humans among the other animals: Narratives of anthropological difference. *Biosemiotics 12*(3), 381-403.

Kalling, K. (2007). The self-perception of a small nation: The reception of eugenics in interwar Estonia. In: Turda, M., and Weindling, P. J. *Blood and homeland: Eugenics and racial nationalism in Central and Southeast Europe 1900-1940* (pp. 253-262). Budapest: Central European University Press.

Kress, G. (2003). *Literacy in the New Media Age*. New York: Routledge.

Kress, G. (2010). *Multimodality: A Social Semiotic Approach to Multimodal Communication*. New York: Routledge.

Kress, G. and Leuween, T. van. (2001). *Multimodal Discourse: The Modes and Media of Contemporary Communication*. London: Arnold.

Kymlicka, W. (1995). *Multicultural citizenship: A liberal theory of minority rights*. Oxford: Oxford University Press.

Kymlicka, W. (2001). *Politics in the vernacular*. Oxford: Oxford University Press

Labov, W. (1972). *Language in the inner city: Studies in the black English vernacular*. Philadelphia: University of Pennsylvania Press.

Laland, K. N. (2008). Animal cultures. *Current Biology*, *18*(9): R366-R370.

Laland, K. N. and Janik, V. M. (2006). The animal cultures debate. *Trends in ecology & evolution*, *21*(10), 542-547.

Lähteenmäki, M., Varis, P. and Leppänen, S. (2011). Editorial: The shifting paradigm: Towards a re-conceptualisation of multilingualism. *Apples—Journal of Applied Linguistics 5*(1): 1–11.

Leeuwen, T. van. (2005). *Introducing social semiotics.* London & New York: Routledge.

Lorimer, H. (2005). Cultural geography: the busyness of being more-than-representational. *Progress in human geography 29*(1), 83-94.

Lotman, J. (1977). Primary and secondary communication-modeling systems. In: Lucid, D. P. (ed.), *Soviet Semiotics: An Anthology* (pp. 95-98). Baltimore: Johns Hopkins University Press.

Lotman, J. (1990). *Universe of the Mind*. (Shukman, Ann, trans.; Eco, Umberto, intr.) London: I. B. Tauris.

Maran, T. (2020). *Ecosemiotics: The study of signs in changing ecologies*. Cambridge University Press.

Marais, K. (2019). *A (bio)semiotic their of translation: The emergence of social-cultural reality*. New York: Routledge.

Mittelberg, I. (2007). Methodology for Multimodality. In: Gonzalez-Marquez, M., Mittelberg, I., Coulson, S. and Spivey, M. J. (Eds.) *Methods in Cognitive Linguistics* (pp. 225–248). Amsterdam: John Benjamins.

Mittelberg, I. (2013). The exbodied mind: cognitive-semiotic principles as motivating force in gesture. In: Müller, C., Cienki, A., Fricke, E., Ladewig, S.H., McNeill, D. and Teßendorf, S. (Eds.) *Body – Language – Communication: An international handbook on multimodality in human interaction, Volume 1* (pp. 755-784). Berlin: De Gruyter Mouton.

O'Halloran, K. L., Sabine T., and Peter W. (2016). Intersemiotic Translation as Resemiotization: A Multimodal Perspective. *Signata: Annales des Sémiotiques/Annals of Semiotics 7*(3): 199–229.

Olteanu, A. (2019). *Multiculturalism as multimodal communication: A semiotic perspective*. Cham: Springer.

Olteanu, A., and Campbell, C. (2018). A short introduction to edusemiotics. *Chinese Semiotic Studies 14*(2), 245-260.

Olteanu, A., and Stables, A. (Eds.). (2018). Learning and adaptation from a semiotic perspective (special issue). *Sign Systems Studies 46*(4), 409–434.

Olteanu, A. (2020). Translation from a contemporary media perspective: Avoiding culturalism and monolingualism. *Social Semiotics 32*(1): 143-161. DOI: 10.1080/10350330.2020.1714204.

Olteanu, A., Campbell, C., and Feil, S. (2020). Naturalizing models: New perspectives in a Peircean key. *Biosemiotics*, *13*(2), 179-197.

Peirce, C. S. (1929). Guessing. *The Hound and Horn* 2, 267-282.

Peirce, C. S. (1998) [1893-1913]. *The Essential Peirce, Volume 2 (1893-1913).* Bloomington and Indianapolis: Indiana University Press.

Rorty, R. (Ed.) (1967). *The Linguistic Turn: Essays in Philosophical Method with Two Retrospective Essays*. Chicago: University of Chicago Press.

Rousseau, J. J. (1998) [1762]. *The social contract or principles of political right.* Trans. Hozer, H.J. Ware, Hertfordshire: Wordsworth.

Saussure, F. de. (1959) [1919]. *Course in General Linguistics*. Trans. Wade Baskinm, ed. Charles B. and Sechehaye, A. New York/Toronto/London: McGraw-Hill.

Sastre, E. M. C. (2018). Signs of Culture? A Critical Transdisciplinary Approach to the Study of Animal Cultures. *Crossways Journal*, *2*(2). https://crossways.lib.uoguelph.ca/index.php/crossways/article/view/4968

Sebeok, T. A. (1965). Animal communication. *Science 147*: 1006-1014.

Sebeok, T. A. and Umiker-Sebeok, J. (1979). "You know my method": A juxtaposition of Charles S. Peirce and Sherlock Holmes. *Semiotica 26*(3-4): 203-250.

Sebeok, T. A. (1991). *A Sign is Just a Sign: Advances in Semiotics*. Bloomington and Indianapolis: Indiana University Press.

Sebeok, T. A. (2001). *Signs: An introduction to semiotics*. Toronto: University of Toronto Press.

Sebeok, T. and Danesi, M. (2000). *The forms of meaning: Modelling systems theory and semiotic analysis*. Berlin: Mouton de Gruyter.

Snaza, N. and Weaver, J. (Eds.). (2014). *Posthumanism and educational research*. Routledge.

Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal 27*: 379–423.

Weaver, W. (1998) [1949]. Recent contributions to the mathematical theory of communication. In *The mathematical theory of communication* (pp. 1–28). Urbana & Chicago: University of Illinois Press.

Stables, A., Nöth, W., Olteanu, A., Pesce, S., and Pikkarainen, E. (2018). *Semiotic theory of learning: New perspectives in the philosophy of education*. Routledge.

Stables, A. and Semetsky, I. (2015). *Edusemiotics*: *Semiotic philosophy as educational foundation*. London: Routledge.

Stjernfelt, F. (2007). *Diagrammatology. An Investigation on the Borderlines of Phenomenology, Ontology and Semiotics*. Dordrecht: Springer.

Stjernfelt, F. (2014). *Natural Propositions: The Actuality of Peirce's Doctrine of Dicisigns.* Boston: Docent Press.

Taylor, C., Appiah, K.A., Habermas, J., Rockefeller, S. C., Walzer, M. and Wolf, S. (1994). *Multiculturalism: Examining the politics of recognition*. Princeton, NJ: Princeton University Press.

Tomlinson, G. (2015). *A million years of music: The emergence of human modernity*. Princeton: MIT Press.

Tomlinson, G. (2018). *Culture and the course of human evolution*. University of Chicago Press.

Tomlinson, G. (2019). "The Third Algorithm: The Evolution of Human Culture". Lecture: presented at Yale University (May, 2019) as part of the *Franke Program in Science and the Humanities*. Accessed (Aug, 2021): https://www.youtube.com/watch?v=HFwUDBYLo9g

Uexküll, J. von. (1926). *Theoretical Biology*. London: Kegan Paul, Trench, Trubner & Co.

Uexküll, J. von. (2010) [1934]. *A foray into the worlds of animals and humans with A theory of meaning.* Trans. O'Neil, Joseph D. Minneapolis: University of Minnesota Press.

Vannini, P. (Ed.). (2015). *Non-representational methodologies: Re-envisioning research*. Abingdon: Routledge.

Varela, F. J., Thompson, E. and Rosch, E. (1993) [1991]. *The embodied mind: Cognitive science and human experience.* Cambridge, MA: Massachusetts Institute of Technology.

Vertovec, S. (1996). Multiculturalism, culturalism and public incorporation. *Ethnic and Racial Studies 19*(3): 49-69.

Werbner, P., Modood, T. (Eds.) (2015). *Debating cultural hybridity: Multicultural identities and the politics of anti-racism*. Foreword by H. K. Bhabha. London: Zed Books.

Zlatev, J. (2009). The semiotic hierarchy: Life, consciousness, signs and language. *Cognitive Semiotics*, *4* (Supplement), 169-200.

Zlatev, J. (2018). Meaning making from life to language: The semiotic hierarchy and phenomenology. *Cognitive Semiotics*, *11*(1).

Zlatev, J., Wacewicz S., Zywiczyinski P. and Weijer, J. vaan de. (2017). Multimodal-first or pantomime-first? Communicating events through pantomime with and without vocalization. *Interaction Studies 18*(3), 465-488.

Biosemiotics and Evolution

Claudio J. Rodríguez H.
Palacký University, Olomouc, Czechia

Abstract

In this chapter we will discuss the biosemiotic view of evolution. In order to understand the role that sign action may play in the evolution of organisms, we attempt to provide an explanation encompassing an overview of what biosemiotics does, how its concepts play out in a naturalistic view of organisms, and what dimension these concepts open in regard to functional explanations in biology.

The semiotic view of evolution is informed by the consideration that meaning-making is an essential feature of organisms with a causal role in behavior and evolution both at the individual level and in long time scales. Biosemiotic theory tries to uncover how exactly meaning-making builds and is built upon networks of relevance for organisms that act as markers for behavior, which is in turn inherited and an active participant in the long-term changes of organisms.

Keywords: biosemiotics, evolution, perception, scaffolding.

1. INTRODUCTION

Biosemiotics, as a general theory of semiotics with a biological backdrop, makes claims related to how organisms use signs and generate meaning in their environments and individually, and about how these signs may be causally relevant in multiple respects, including changing their environments, adapting through behavior, and forging meaning scaffolds that persist through time.

Essentially then, semiotics can study situations at the present level (such as finding the specific value of a certain element in the environment of an organism) and at a structurally longer range (such as finding what specific meaning scaffolds persist and to what end). Evolution, not being a spur-of-the-moment sort of thing, is mostly part of the latter, though both aspects are intrinsically connected and dependent on each other.

In this chapter, we will explore how biosemiotics studies evolution and what exactly is semiotic about evolution itself. In the first part of the chapter, we will establish some terminological ground for the different axes in which biosemiotics can make itself useful when studying evolution and we will later follow with different ways in which biosemiotic research has made claims about evolution. Finally, we will discuss the more fundamental problems regarding the status of semiosis as evolutionary or as a fixed process *within* evolution.

2. THE AXES OF BIOSEMIOTIC STUDY

Though biosemiotics is not monolithic in its approach to the question of meaning in biology, there are fundamental concepts of semiotics that translate well to how we tackle biological questions regarding the relevance of meaning and sign usage. Some of these concepts can be found in *sign* and *text* as specific units of analysis for semiotic systems, the first as specific instances of sign relations and the second as groups of signs working together. Signs may, however, not exist individually without the existence of a support system—i.e., texts and ways for them to persist—and so texts may provide us with a good way to analyze semiotic phenomena beyond language (Kull, 2002). In other words, one of the fundamental elements of a semiotic analysis of biological entities is *semiosis*, that is, the process through which signs are used and become meaningful for organisms, and this process can be analyzed in terms of *texts* insofar as that kind of language allows us to refer to sign compositions, their coherence, and usage.

One of the advantages of this language is that it allows us to categorize temporal distinctions as paradigmatic and syntagmatic, a division often related to the analysis of semiotic texts. The Saussurean heritage present in this particular pair of concepts leads us to generalizations on how the parts of semiotic systems interact with each other—contiguous differentiation versus immediate association, two fundamental aspects of the practice of semiotics as a kind of research. In one particular usage of the concepts, T. von Uexküll, Geigges, and Herrmann (2010) focus on the immune system and see the paradigmatic axis as dealing with cells and pathogens involved in the immune process, whereas the syntagmatic axis is characterized here as the *interaction* between pathogens and immune cells (p. 298). Taking a step back, we see paradigm and syntax when applied to biological phenomena as opening up a way to analyze the semiotic dimension of interspecies interaction. This can be done both at a certain point in time and across longer spans of time. It can also be applied to intraspecies usage of signs within a certain context and as a longer evolutionary thread. As semiotics allows a rather wide area for affixing its subjects and specific interests, it is possible to pinpoint different areas where a syntagmatic and paradigmatic axis can interact and give us relevant information on sign usage as indicative of meaning-making.

The process of *semiotic scaffolding* is one of the most useful concepts for biosemiotic analysis to keep in mind because it brings our attention to these two dimensions in a handy theory. Basically, semiotic scaffolding is defined as the construction and fixation of sign-usage across time, where the signs and their meanings used by organisms become an integral part of their world and survival, leading to signs that become possible only because those previous signs have existed in place before. This principle, originally formulated by Hoffmeyer (2007), provides us with an intuitive assessment of how signs are relevant and present for organisms as individuals and as part of a wider community in evolutionary terms.

The question of whether semiotics has anything interesting to say regarding biological evolution partly depends on the things that semiotics is capable of saying and whether these are in any way useful in understanding some aspect of evolution itself. In this sense, biosemiotic terminology gives us a way to look at how signs may be recognizable across time.

Perhaps one important, almost axiomatic condition of biosemiotics is the assumption that life is coexistent with the ability to use signs—Sebeok's thesis that *to be alive is to be semiotically active* (Kull, Emmeche, & Hoffmeyer, 2011, p. 2)—or, to put it in a different way, life necessitates *perception* to sustain itself. Instead of talking about *cognition*, biosemiotics trades in sign usage as a way to frame perception, meaning, and action. Though the mechanisms of sensory perception in unicellular organisms may be vastly different from those of multicellular ones, the unifying terminology of semiotics helps us bridge their differences at least theoretically. If cellular perception as well as its potential misperception can be qualified externally by behavior and chemistry (Mitchell & Lim, 2016), the task of biosemiotics is to present the case as concerned with *meaning* characterized by sign usage. The concepts of biosemiotics, then, can help us understand sign usage across species and throughout time, working with its different axes and by examining the scaffolds built by organisms.

Facing the possibility of signs is, however, different to understanding the causal role they take in a biological setting. In the next section, we will examine how signs may play out particularly in evolution and what the case could be for assigning a causal role to *meaning* in evolution and behavior.

3. EVOLUTION AND MEANING

Building a theory of biological meaning requires us to have at least some sense of what *meaning* is supposed to convey. As we mentioned earlier, biosemiotics tries to develop theoretical tools to talk about meaning through *signs*. That is to say, what we usually refer to with the concept of meaning is more or less a way to talk about the unaccountable assignation of value to some element in an environment for a given organism.

Meaning is a loaded word, and it is one where consensus may be hard to arrive at. Invoking it when dealing with non-human animals stirs the conversation in odd directions if there are no proper caveats put in place to stop anthropomorphism from making concepts confusing. Anthropomorphism of cultural and psychological concepts into non-human animals is exactly one sort of hurdle biosemiotics must avoid to make a clear case of its applicability as a way to expand our knowledge and perspectives on biology.

When we talk about meaning in a biosemiotic sense, what must stand out is that this talk is far from an understanding of meaning as what is *signified* conceptually. Biosemiotics traditionally sees a problem in leaving meaning outside of biology (Barbieri, 2009), with the latter accepting the quantifiable concept of information without referring to meaning as a different, but just as relevant dimension of what happens with organisms. If we start by the idea that perception can be characterized through the usage of signs, our theoretical tool lies in the way a sign is composed, and how we theorize the form of the sign will dictate what *meaning* will actually mean. The commonly taken form of the sign as composed by an *object*, a *representamen*, and an *interpretant*—owing to Charles S. Peirce's philosophy—is a good starting point to think of meaning as a *process* or an *activity*, that is, instead of limiting our concept of meaning to, for instance, what a word means to a person, we want to see what the implications are of certain perceptions for an organism.

One of the immediate issues we come across is reportability: When we deal with human perception, we have a sense of what is being perceived because of the possibility of reporting what is going on with us. However, when it comes to perception in non-linguistic animals—and this is particularly true for life-forms that are further removed from humans in terms of evolutionary lines—just what exactly is perceived remains much less clear. A theoretical disposition that takes into account what externally lies in relation to an organism and what effects it may have on it becomes much more revealing. Signs in their tripartite form seem to give us a coherent picture of how perception and action are related and what the potential *value* of this pair is when observed in context.

Meaning, when construed this way, becomes less of a linguistic feature and more of a relational expression of things that populate the worlds of organisms and have some direct incidence on their existence and survival, but which resists a directly quantitative nominalization.

Satisfying the conditions for the existence of signs does not lead to particularly strenuous circumstances for our objects of study. In order for us to posit signs, we need indications of life, and though defining what life is entails a very different discussion, we may have a more or less axiomatic view (though qualified through evidence) on this topic by considering cells as the most basic organism capable of semiosis (Barbieri, 2007). By using the Peircean nomenclature to describe signs as relations pertaining organism and environment, we avoid the caricature of anthropomorphization that plagues attempts like these and we build theoretical devices for at least recognizing the different dimension that meaning entails. That is, the main reason for adding signs to the picture lies in the recognition that functional biological explanations may not be able to or even desire to take into account a fairly fuzzy factor such as *subjective relevance* for organisms.

3.1. The Problem of Teleology

If meaning in any shape is relevant to the evolution of organisms, the subjective dimension should be taken seriously as a factor of change. A burning question here is whether *subjectivity* can play a role in what clearly is the process of groups across long periods of time. Going by the numbers makes subjectivity less important than a data point, as it does not provide an explanation of anything specific in the change of an organism's evolutionary line, or so it would seem.

Having some directedness towards something, some specific aim, and acting with the intention of a specific outcome is usually called *teleology*. The immediate issue of desiring an outcome for evolution makes teleology, at face value, irreconcilable with how evolution by natural selection happens. An organism does not desire for some evolutionary outcome and obtains it. Instead, functional explanations in biology take hereditary variability and differential reproduction, genetically and statistically speaking (Ayala, 1970), as some of the main points to consider when trying to understand evolutionary processes.

Traditional Darwinism has been, however, greatly expanded to include population and quantitative genetics for understanding selection pressure, but developmental processes and niche construction have caused a great impact on the theory (Laland et al., 2015). This expansion is not a unified effort across the board (Lewens, 2019), and the gene-centrism of the various views on evolution, as well as the varied relevance of niche construction as an important evolutionary factor, may still require further efforts for the coalescence of future theory (Noble, 2021).

One thing that seems certain from this is that organisms do not display a functional intention towards an evolutionary end—if that were the case, humans would most likely have developed the ability to fly without airplanes!—and so subjectivity, when equated with intentionality of some sort, seems to be an unlikely factor for evolutionary theory. Teleology, for the most part excised from biological theory, cannot account for macroscopic evolutionary events, and so talk of *intention* and *final causes* in the Aristotelian sense does not provide explanatory power for evolutionary traits.

Yet, teleological thinking seems to find a way into our biological explanations: Adaptations *for* specific uses, changes *towards* certain advantageous traits—this language provides heuristics for visualizing how evolutionary events respond to a number of possibilities for and needs of organisms. In terms of natural selection, though traits are not selected *for* a certain property, as a mechanism it may lead to the increase of reproductive efficiency and the sustainability of end-directed organs and processes (Ayala, 1970, p. 10). Teleological-like explanations, often characterized as *teleonomy*, attempt to bypass the issues of teleology by issuing a less committed vision of end-directedness, removed from its causal inflection. This language attempts to deal with the perception of intention and purpose in organisms as related to how we understand evolution in biology. Not without issues, teleonomy may not offer a concrete solution to the perception that biological processes are goal-oriented and in fact it may conflate explanation and description (Thompson, 1987), without a pragmatic consensus on a property-based distinction between teleology and teleonomy. Thompson instead offers a concept of teleonomy as "the descriptive study of organizational properties of processes and structures without reference to any particular explanatory system" (p. 273). A more recent proposal by Nicholson (2021) considers stepping away from the concept of teleonomy itself to discuss purposive behavior in organisms as the expression of their particular organization.

In the already mainstream biosemiotic view, the idea of teleonomy offered by Deacon (2011) is conceptually altered and extended through the development of *entention*. For Deacon, entention is a descriptive shorthand for "phenomena that are intrinsically incomplete in the sense of being in relationship to, constituted by, or organized to achieve something non-intrinsic" (p. 26). Instead of talking about endpoint-like actions and developments in an organism, the idea is that absential features are part of the logic of development—this helps him differentiate between cognitive and noncognitive processes that may show similar features in terms of teleonomic thought.

Biosemiotics generally intends to maintain a naturalistic view of evolution as well as of meaning-making. This implies that explanations that involve some sort of intentionality cannot be given as a strong sense of intention. Instead, the commitment to scientific thought requires a nuanced language that makes sense of both the idea that meaning-making is an essential biological feature and the reduction of meaning-making to a cause that is not describable as psychological intention.

That meaning-making participates in evolution is one of the strongest claims biosemiotics can make. As such, biosemiotics invokes an understanding of evolution that is compatible with our current biological knowledge and theories as well as our semiotic theories. Whether biology is incomplete biosemiotics or biosemiotics is complementary to biology is a matter to be solved in the development of competing theories. As theories of evolution keep developing, so will do theories of *biosemiotic influence* on evolution.

In the following section, we will try to understand the principle of *semiosis* for biosemiotics, its general applicability, and whether it is compatible with our concept of evolution in biology.

3.2. Semiosis as a Principle

Some semiotic concepts are intuitive and graspable. The sign as something that stands for something else to someone is easily digestible—the idea of the sign in its Saussurean conception makes sense out of the box as well. The problem comes when the concepts become more fine-grained and dependent on other aspects of theory that may not be accounted for at first. The concept of semiosis is one such example. Usually, the concept is defined as *the action of signs*, whatever that may mean. In principle, the idea is that semiosis can be defined as some *process* through which multiple signs are part in a chain of meaning generation. This definition does not do much more to answer questions about what semiosis *is* exactly, though.

Drawing from Peircean thought, semiosis is introduced to biosemiotics as synonymous with meaning-making. Because a sign is a singular relation that includes some perception and some action, there must be something that unifies multiple signs as we realize that one sign leads to multiple others. But this conceptualization is still tricky and not uniform in its usage because it does not do much explanatory work, if any. Having a working concept of semiosis entails having a notion of its origin, internal mechanisms, and, hopefully, its application. Semiosis presented as *the action of signs* does not clear any of those areas, and presenting it as *meaning-making* does little to clear them up. For our concept of semiosis to be functional, we need it to do more than being a reformulation. Semiosis, it seems clear, includes sign relations to some degree. We can ask how these come to be and what they do, and if our concept of semiosis is to be strong enough, it will have to shed light on both of these questions.

Semiosis is, when fleshed out, the principle by which a sign generates another sign and grounds a specific meaning in a potentially psychosocial environment. A sign is not possible individually: There needs to be an infrastructure it can utilize, and it has to come as a consequence of something else that has stood as a sign earlier. If semiosis is the theoretical background for semiotics, and if biosemiotics assumes that semiosis is an essential element of evolution, then we need to connect both ends to have a credible story about the interaction of signs and change in species across time.

Whether semiosis as we have described it earlier is a metaphysical principle or a terminological shorthand only matters in the more fine-grained discussion on whether semiotic principles have ontological value on their own. What is more important here for us, however, is understanding *how* signs can effect change in species.

Immediate change is par for the course when it comes to sign: Suddenly seeing smoke from afar when you're on your way home will stop you in your tracks, and the thought of fire will indeed make you act in a different way. Signs and behavior are inextricably linked (Morris, 1946) when considering the direct psychological implications of dealing with different kinds of signs in everyday life, at least when it comes to humans. As humans are able to retain symbolic meaning and pass it along easily through linguistic communication, it would be easy to see how signs can have a long-term impact on the way humans behave. When, however, it comes to organisms that cannot rely on a material grounding of linguistic meaning, the claim that signs can influence behavior in the long term becomes harder to prove. Zoosemiotic models of communication do some work in letting us understand the extent of relevance of signs for behavior and ecological interaction, and this is one of the keys for our own understanding of the place of semiosis in evolution. If organisms can join their peers in a specific kind of comprehension of specific signs, then their behavior can be said to be influenced by semiosis, which can eventually lay claim to the ability of semiosis to cause some level of influence on evolution, as long as these shared signs produce some consistent behavior across long periods of time.

3.3. Behavior and Shared Signs

The previous description we have just used is insufficient to make claims about the relevance of semiosis for evolution. We need to find the mechanisms through which signs can be shared and the way in which they can persist through time, all without a linguistic system to affix signs to specific meanings. From a biosemiotic point of view, this could be achieved minimally via some world-building function coded biologically. If perception in organisms is given through signs in some sense, and the biological structure of the organism is causally linked to the specificity of some of the most relevant signs in their world, then at least we have a working hypothesis on how behavior can be linked to specific perceptions within a species.

Are behavioral factors enough to make evolutionary claims, though? Going back to evolutionary theory, detached from semiotic concepts, we stumble into the issue of whether semiosis by behavioral impact can be evolutionary at all or proximate to evolutionary causes. One of the hurdles faced by the extended evolutionary synthesis lies in showing, either by addition or replacement, that developmental features and niche construction can be considered evolutionary causes altogether (Laland et al., 2015). This translates into another issue for a biosemiotic evolutionary theory in that the structure of signs and their material (and social) grounding may be finicky enough not to enact any evolutionary change. After all, finding consistency in signs across evolutionary scales may prove an important challenge for biosemioticians.

Behavior may make sense for a semiotic theory of evolution at a higher level of study in any case. Biosemiotic theory usually makes the claim that an organism and its behavior are directly linked to their perception, following Jakob von Uexküll's theoretical biology. Conceptualizing an organism's way of interaction with the world as morphologically dependent and within one particular action-reaction cycle means that the concept of sign gains some relevant explanatory power. In this sense, what remains to be proven is how signs endure for multiple organisms.

If species share a set of physiological characteristics, including their perceptual organs, we may want to conceptualize how an individual organism relates to their perceived world in order to get a picture of how signs become affixed for it in the abstract. *Umwelt* theory provides us with a tool for taking this leap. Essentially, the Umwelt of an organism is the description of its perceptual world as marked by the elements that are relevant to it, relevance construed as the needs of the organism and its perceptual capabilities (J. von Uexküll, 2010). The constitution of an Umwelt can be described as pertaining specific signs—that is, representations of things *as they seem for the organism*, not necessarily as what they may *actually* be. Guided by a Kantian approach to epistemology, the proposer of this theory, Uexküll, figured that organisms do not perceive things as they are in their totality, but they only have access to a certain aspect. This aspect would be akin to an understanding of *signs* construed as aspectual presentations of objects to an organism. However, Uexküll also makes the point that the sensory apparatus is not independent from response cycles in organisms. Instead, he believes, they are a connected whole. The takeaway for us is that, when taken a step further, we can see how a shared physiology of organisms can lead to shared perceptions as well as kinds of behaviors. There is room for interpretation understood as a free association within the sign-action cycle (which Uexküll calls the *functional cycle*), but there are determinant factors in perception, biological needs, and so on that limit the range of possibilities within this free association. For instance, it seems quite unlikely that in the Umwelt of a tick, butyric acid will fail to elicit a reaction within the range it usually does (such as movement towards its concentration and finding sources of heat around it). When it comes to behavior as a more external factor for evolution, biosemiotics can claim that the

Umwelt and its appended functional cycle of an organism within a species is what fixes the grounding relation of a sign and thus makes it available for organisms to use and change patterns in their behavior, which can, eventually, lead to change in the species itself.

3.4. Internal Semiotic Mechanisms for Change

If what we mentioned previously is related to external pressures on organisms that can lead to change, we are still leaving open a wide door for the internal mechanisms of evolution. These, usually treated in informational terms, have also been a subject of interest for biosemioticians. The idea that information pertains to genetic mechanisms raises questions on the potentially metaphorical nature of the concepts used. The question here is whether genetics can have a semiotic dimension, or, conversely, whether semiotics has any tool at its disposal to say anything meaningful about genetics.

A variety of options have been offered for this sort of thinking, many involving Peircean terminology but some independent of it as well. To determine whether semiotic mechanisms can play a role in evolution, we first need to understand how they can be described at the level of microbiology, if at all. In the Peircean varieties, we see how what takes precedence is finding sign-like connections between components involved in information transmission. For instance, we can conceive of genes as signs within the Peircean terminology. This would imply cashing out an object, representamen, and interpretant relation in the analysis of genetic mechanisms. El-Hani, Queiroz, and Emmeche (2009) find correlates of the parts of the sign with DNA strings, their interpretation by a cell, and the reconstruction of a sequence of amino acids as a way to present a semiotic analysis of genetic information. More specifically, they believe genes to be signs (representamina), with genetic information being a process of semiosis by which an object, such as a functional protein, is given to an interpretant, such as the reconstruction of a sequence of amino acids in a cell, through a representamen in DNA (p. 136).

Parallel lines of research on meaning-making as a relevant part of biology have also conceptualized what may be construed as semiotic processes in genetic information, unencumbered by sign terminology. The line of research of code biology seeks a nuanced understanding of the genetic code as “a mapping between codons and amino acids that is implemented by transfer-RNAs” (Barbieri, 2018, p. 6). The most striking aspect here is that codes, as per the definition given by code biologists, are a set of correspondences or mappings between elements that belonging to two different worlds, connecting them through translational or adaptive elements. This mapping is arbitrary, following arbitrary rules of correspondence—that is, the relations of correspondence are not derived directly from physics *qua* laws; instead, they seem to be nomological relations that do not exist by necessity.

What may be of relevance for biosemioticians in both cases is that there seems to be a story about meaning-making at the internal level, as long as we understand that this form of meaning-making is much more basal than those of behavior and cognition in organisms. Building a semiotic account of internal mechanisms that elicit change has as one of its challenges uncovering the relevance of the otherwise ignored relations between meaning-like events and genetic changes.

Sharov, Maran, and Tønnessen (2016) identify a relevant issue in trying to find correlates of perceptual and communicative processes in organisms with a central nervous system and those without one. Biosemiotics should, by their account, focus on *agency* in cells, finding demonstrable forms of their manipulation of signs. In developing this line of thought, biosemioticians may build on concepts of the sign, semiotic scaffolding, code correspondence, and so on, in order to find what particular elements of semiotic theory may fit the apparent sign action of cells. It may be possible that metabolism is one of the basic components of interpretation at the biological level—a position that can be seen in Prodi (2010) or Stjernfelt (2012)—and so biosemiotics is called to understand how these processes wherein organisms seem to utilize information can be described within a sign-rich terminology.

In making sense of these internal processes, describing potentially semiotic aspects of evolution at the genetic level goes hand in hand with modeling semiotic mechanisms in the abstract. Biosemioticians who believe semiosis happens at the molecular level may frame information conveyed as interpretation of Peircean signs (Kawade, 1996) and will liken these processes to those belonging to the realm of complex cognitive organisms. Tracking these processes may be harder to cash out as organisms become more complex, opening a host of issues that come with the assumption that semiotic processes do indeed take place across the board (Rodríguez Higuera, 2019). However, the promise of biosemiotics lies in that, by opening a line of research that allows interpretive properties in diverse configurations, we will be able to find relevant traits for evolution in a different dimension than mechanistic explanations.

4. CONCLUSIONS

Change across time is an inevitability in biology. In considering the possibility of multiple mechanisms that take part in this process, we may assume that interpretive properties in organisms, be those internal or external, may be of relevant use in our theories. Biosemiotics offers one such option in tying evolution to different theories of biological meaning-making, including the usage of signs and the relevance of codes. As such, we may describe certain elements of evolution as being semiotically involved, though to what extent may be a matter of discussion. One important claim of biosemiotics is the *persistence of signs* across time-frames for species. Signs used by organisms become markers that influence their behavior, as well as their environment, being a point of potential change. On the other hand, biosemioticians may also argue that there exist *molecular* semiotic mechanisms that may play a part in genetic change. These usually depend on conceptualizing information exchange in the form of signs and arguing that interpretation has a role in making that information effective for the survival and eventual change of organisms.

Biosemiotics offers a potential window into a different conceptualization of evolution, and part of its research program relies on assuming a non-reductive position within biology. The development of such a research program may eventually lead to a more generalized understanding of subjectivity in organisms and the potentially profound impact of interpretation across all levels of biological development.

5. ACKNOWLEDGMENTS

I would like to thank Juan R. Coca for his support and to Daniel Kopecký for his helpful corrections. The funding for the present publication was provided by the Czech Ministry of Education, Youth and Sports for specific research (IGA_FF_2022_027).

REFERENCES

Ayala, F. J. (1970). Teleological explanations in evolutionary biology. *Philosophy of Science*, *37*(1), 1–15. doi:10.1086/288276

Barbieri, M. (2007). Is the cell a semiotic system? In M. Barbieri (Ed.), *Introduction to biosemiotics: The new biological synthesis* (pp. 179–208). Dordrecht: Springer. doi:10.1007/1-4020-4814-9_8

Barbieri, M. (2009). A short history of biosemiotics. *Biosemiotics*, *2*(2), 221–245. doi:10.1007/s12304-009-9042-8

Barbieri, M. (2018). What is code biology? *Biosystems*, *164*, 1–10. doi:10.1016/j.biosystems.2017.10.005

Deacon, T. W. (2011). *Incomplete nature: How mind emerged from matter*. New York: W. W. Norton.

El-Hani, C. N., Queiroz, J., and Emmeche, C. (2009). *Tartu semiotics library: Vol. 8. Genes, information, and semiosis*. Tartu: University of Tartu Press.

Hoffmeyer, J. (2007). Semiotic scaffolding of living systems. In M. Barbieri (Ed.), *Introduction to biosemiotics: The new biological synthesis* (pp. 149–166). Dordrecht: Springer. doi:10.1007/1-4020-4814-9_6

Kawade, Y. (1996). Molecular biosemiotics: Molecules carry out semiosis in living systems, *Semiotica*, *111*(3/4), 195–216. doi:10.1515/semi.1996.111.3-4.195

Kull, K. (2002). A sign is not alive – a text is. *Sign Systems Studies*, *30*(1), 327–336. doi:10.12697/SSS.2002.30.1.21

Kull, K., Emmeche, C., & Hoffmeyer, J. (2011). Why biosemiotics? An introduction to our view on the biology of life itself. In C. Emmeche & K. Kull (Eds.), *Towards a semiotic biology: Life is the action of signs* (pp. 1–21). London: Imperial College Press. doi:10.1142/9781848166882_0001

Laland, K. N., Uller, T., Feldman, M. W., Sterelny, K., Müller, G. B., Moczek, A., Jablonka, E., and Odling-Smee, J. (2015). The extended evolutionary synthesis: Its structure, assumptions and predictions. *Proceedings of the Royal Society B: Biological Sciences*, *282*(1813). doi:10.1098/rspb.2015.1019

Lewens, T. (2019). The extended evolutionary synthesis: What is the debate about, and what might success for the extenders look like? *Biological Journal of the Linnean Society*, *127*(4), 707–721. doi:10.1093/biolinnean/blz064

Mitchell, A., & Lim, W. (2016). Cellular perception and misperception: Internal models for decision-making shaped by evolutionary experience. *BioEssays*, *38*(9), 845–849. doi:10.1002/bies.201600090

Morris, C. (1946). *Signs, language and behavior*. New York: Prentice-Hall.

Nicholson, D. J. (2021, June 28–29). Does the concept of teleonomy solve the problem of organismic purposiveness? Presentation at *Evolution 'on Purpose': Teleonomy in Living Systems*, online international meeting organized by the Linnean Society of London.

Noble, D. (2021). The illusions of the modern synthesis. *Biosemiotics*, *14*(1), 5–24. doi:10.1007/s12304-021-09405-3

Prodi, G. (2010). Signs and codes in immunology. In D. Favareau (Ed.), *Essential Readings in Biosemiotics: Anthology and commentary* (pp. 328–335). Dordrecht: Springer. doi:10.1007/978-1-4020-9650-1_10

Rodríguez Higuera, C. J. (2019). Some challenges to the evolutionary status of semiosis. *Biosemiotics*, *12*(3), 405–421. doi:10.1007/s12304-019-09366-8

Sharov, A., Maran, T., & Tønnessen, M. (2016). Comprehending the semiosis of evolution. *Biosemiotics*, *9*(1), 1–6. doi:10.1007/s12304-016-9262-7

Stjernfelt, F. (2012). The evolution of semiotic self-control. In T. Schilhab, F. Stjernfelt, & T. Deacon (Eds.), *The symbolic species evolved* (pp. 39–63). Dordrecht: Springer. doi:10.1007/978-94-007-2336-8_3

Thompson, N. S. (1987). The misappropriation of teleonomy. In P. P. G. Bateson & P. Klopfer (Eds.), *Perspectives in ethology: Vol. 7. Alternatives* (pp. 259–274). Boston, MA: Springer. doi:10.1007/978-1-4613-1815-6_10

von Uexküll, J. (2010). *A foray into the worlds of animals and humans: With a theory of meaning*. (J. D. O'Neil, Trans.). Minneapolis: University of Minnesota Press.

von Uexküll, T., Geigges, W., & Herrmann, J. (2010). Endosemiosis. In D. Favareau (Ed.), *Essential readings in biosemiotics: Anthology and commentary* (pp. 279–321). Dordrecht: Springer. doi:10.1007/978-1-4020-9650-1_9

Biosemiotics & Environmental Health

Yogi Hale Hendlin
Assistant Professor, Erasmus School of Philosophy, Erasmus University Rotterdam. Core Faculty, Dynamics of Inclusive Prosperity Initiative, Erasmus University Rotterdam. Research Associate, Environmental Health Initiative, University of California, San Francisco

Abstract

The field of public health focuses on how health is not merely an internal affair, from the skin-in, but is a socially and environmentally determined phenomenon. Biosemiotic analysis of the organism-*Umwelt* relationship, and interactions between exosemiotics and endosemiotics, affords a unique perspective on how given chemicals and other toxins affect humans and other organisms. Biosemiotics also provides insights regarding how meaning-making at all levels emerges through the content, arrangement, and quality of habitat. Attending to organism health according to the biopsychosocial medical model provides an opportunity for biosemiotics to supplement current public health methods by attending to how environmental factors and their co-creation by inhabitants organize meaning, and to examine how different environmental states potentiate or depress health. A biosemiotic approach to public health has the potential to expand public health to be not just an anthropocentric field of inquiry, but an interspecies and elemental question of planetary health, where the health of a given species or organism is contingent upon the condition of that organism's network of relations.

Keywords: social determinants of health, public health, toxins, organism, planetary health.

1. INTRODUCTION

The academic world—out of necessity, as we approach planetary limits—is slowly awakening to the realization that everything is hitched to everything else.[1] Thus, the disciplinary silos that make up scientific study (sociology, biology, chemistry, medicine, etc.) have been strained on their own to make sense of the piling up social and ecological harms confronting us. These "remainders" have been diagnosed as the gap between the "real" and the "rational" (Derrida, 1997; Serres, 1995). Such siloing has not made things better, or understanding richer; but instead has exacerbated the problems these disciplines were designed to face. Just like the umpteen United Nations Framework Convention on Climate Change (UNFCCC) conferences, with every passing one, the situation becomes more dire rather than ameliorated.[2]

The interdisciplines of biosemiotics and environmental health both recognize that to address the problems of meaning and health requires going beyond getting lost in downstream details, and instead demands pulling back the aperture to recognize the context in which communication and biological interfaces occur. Descriptions of organism behavior cannot be generalized; sign action always occurs in an *Umwelt*. Take the rat out of its habitat and into a lab, and it ceases to be the same rat (Rader, 2004). It now becomes a different sort of organism, engineered as much by its lack of evolutionary affordances (e.g., burrows in the ground, leaves, the weather) as by the artificially designed environment of the laboratory. These differences show up behaviorally, but also physiologically. A rat fed a mono-diet of lab food rather than feeding on its normal forage (insects, seeds, fallen fruits, fungi, stems, and leaves) is biologically and ontologically a different rat. Taxonomies of the family *Muridae* or even the specific species of rat is poorly suited as a designation to detail the enormous biological, ecological, and cultural differences between a wild rat and a lab one. In the *Origins of the Species*, Darwin (2009) wrote:

> "I look at the term species, as one arbitrarily given for the sake of convenience to a set of individuals closely resembling each other, and that it does not essentially differ from the term variety, which is given to less distinct and more fluctuating forms. The term variety, again, in comparison with mere individual differences, is also applied arbitrarily, and for mere convenience sake." (p. 52)

---

[1] To paraphrase the ecologist John Muir.

[2] For instance, more carbon has been emitted since the first Intergovernmental Panel on Climate Change (IPCC) report in 1990 than in the entire prior history of our species (Frumhoff, Heede, & Oreskes, 2015; Kartha, Kemp-Benedict, Ghosh, Nazareth, & Gore, 2020).

In other words, our environment matters to who we are. We are differences all the way down. And Gregory Bateson (2000) reminds us, such differences make a difference in the world. Food, in this case, leaves a mark on our bodies (including our cognitive selves; Barad, 2007); the intersection of food and body changes the body beyond the interaction, and thus the trace of the food persists in the body (and actions) of the organism. Causal modifications of bodies by substances in the environment also work in terms of the familiarity or uprootedness of environmental surroundings, or the toxins that creep up in the substances with which we interact.

Environmental health examines how environmental factors such as habitat, infrastructure, and ambient temperature, for example, influence health outcomes at both the personal and population levels. It is part of a cluster of public health foci including the social, environmental, and corporate determinants of health, which see health as largely a social question of design, rather than a phenomenon solely of personal choice. The fact that the built environment has drastically changed the semiotic scaffolding (the stimuli we see, smell, taste, feel, touch, etc.) in our daily lives—often unintentionally poisoning our designed habitats as a byproduct of industrialization—has lasting implications for understanding human disease and mental health.

Biosemiotics focuses primarily on nonhuman organisms. Increasingly, however, biosemiotics has taken a *human turn*, focusing on the human animal through a theoretical biology perspective (Deacon, 2012; Hendlin, 2020). This supports allied approaches such as human ethology, evolutionary psychology, and environmental health. Treating humans as subject to evolutionary and environmental pressures, but not wholly determined by them, provides large enough of a frame to hold together both human agency and how our instincts are integrated with environmental stimuli, largely controlling our behavior. By emphasizing the structural and systematic causes of human action, we do not diminish human agency, but rather make humans aware of the true scope and ramifications of our agency for the first time. By not hating the fact that we are environmentally determined, but seeing our environments as part and parcel of our history, and indeed our being (the classical counterpoint of organism and Umwelt)—including our ecological habitat as the grounding for many of our cultural distinctions—we can honor our environmental conditions that brought our semiotic world into being and evaluate whether they are generative of the sort of life we desire.

Out of the semiosphere of our regional Umwelt, our specific culture's semiosphere was born. From the cultural nuances—keyed in with local flora, fauna, and, unbeknownst to most, also our microscopic parasites, commensalists, and mutualists—these gave us our specific semiotic structures of perceiving the world. As planetary cultural diversity waxed with the proliferation of biotopes and human cultures, and then waned with industrialism–colonialism's destruction of the biosphere, dominating and homogenizing forces, and censorship of modes of semiosis hegemons failed to grasp, we arrive at our current quandary of a pandemic of human health harms caused by the selfsame drivers of ecocide and semiocide.

The essay discusses some of the interfaces between the fields of biosemiotics and environmental health, suggesting that the political and policy implications of environmental health science can find a secure foundation in biosemiotic analyses of etiology and relational ontologies of organisms and their Umwelten.

2. METHODS

One aspect of taking a theoretical biology approach to environmental health entails attending to how different aspects of the environment constitute a given organism. Jakob von Uexküll's Umwelt theory focuses on how species-specific traits, including anatomic, physiological, and behavioral elements, make up the interface between organism and environment. This aspect of Uexküll's theory Carlo Brentari (2013) calls the "endosemiotic" portion. While the physical functioning of an organism is highly important for its health, the interlinkages between biosemiotics and environmental health most felicitously converge according to the second aspect of Uexküll's semiotics: the "exosemiotic" role of signs and interactions occurring outside the skin or membrane of the organism. Both biosemiotics and environmental health locate health not only from the skin-in, but as an extension of relating and interaction with a host of animate and inanimate actants and stimuli.

While environmental health focuses on how environmental factors influence (only) human health, this essay complicates these tidy assumptions by taking a planetary health perspective, showing that human health is predicated on the flourishing of an incredible number and diversity of organisms and biotopes. It also questions the individual ontology of species (Gilbert, Sapp, & Tauber, 2012), linking human and nonhuman health according to the larger holobiont concept of flourishing espoused by the new (and powerfully funded) paradigm of planetary health. By concentrating on the exosemiotic aspects of biosemiotics as applied to humans, such studies can inform and biologically ground environmental health research and policy. The looping effects in which organisms create niches and niches create organisms suggest that when instrumentalization of the local ecology is not at hand—i.e., when the inhabitants in a given ecology are mutualistic or commensal rather than parasitic—the activities of organisms of all phyla present are engaged in processes that unconsciously maintain the homeostasis of the habitat (Odling-Smee, Laland, & Feldman, 2003).

3. RESULTS

3.1. Situating Environmental Health

With the arrival of big data, healthcare is changing, especially epidemiology. We have come a long way since John Snow used dots on a map to determine the origin of London's cholera outbreak in 1854 (Tulchinsky, 2018, Chapter 5). Both personalized medicine (Prainsack, 2018) and population health (Valles, 2018, pp. 4–5) have their roots in large data science. They have fundamental differences, however. To make sense of these tensions between personalized medicine and population health, the latter on which environmental health is based, is to balance different biosemiotic aspects of health; those that are inherited and instinctual, with those having to do with individual specificity. Both are crucial to understanding why certain specimens flourish and others deteriorate in the same milieu, and why certain xenotoxins can disrupt entire trophic cascades, micro (as in the case of our gut microbiome and glyphosate) and macro (as in the case of Rachel Carson's *Silent Spring*).

Population health deals with averages. Epidemiology is a science of aggregation, and, like all big data science, it marks tendencies. Such tools are powerful in diagnosing population-level differences that might otherwise go unnoticed or be mistaken for other causes. But this level of abstraction, like any other, illuminates as much as it obscures. The different bodies of people, their habits, their diets, their traditions, their microbiome, are not fully taken into account. Yes, the more data collected, the more differences can be discerned, the more variables there are to have potential singular, synergistic (or dysergistic), or confounding effects. But population health data alone can only ever tell part of the picture of health. It is, for example, the diametric opposite optic as personalized medicine that takes for granted that individual genetics, epigenetics, and environmental, social, and psychological conditions contribute substantial variation to the way that medicine affects bodies, and thus that every person should be seen as an individual case of health or disease. Personalized medicine holds that we should match and adapt treatment to the characteristics of the specific patient as no two patients are alike.

Another fundamental difference is about where the action lies. Personalized medicine, like traditional medicine, still is reactive. The patient is the one approaching the healthcare system. With population health, like public health, this is the other way around. We know that with personalized medicine, extensive care is taken to identify and treat individual differences, yet this is largely only available to those few who can pay the extensive costs. And, personalized medicine's patient-based demand means that it is not preventative, but responds to complaints. In other words, it deals with downstream problems instead of addressing their root upstream causes. In a world increasingly advertising medicines directly to patients, with medical care ever-increasingly a for-profit business, when we personalize public health problems, then not only do we balloon medical costs, but, in directing our attention to treating personal disease, we detract from funds and efforts that could have gone to addressing the larger public health causes. The medicalization of health—turning collective issues into personal instances of disease—hurts everyone, even those able to pay. Conversely, public health approaches are a form of "targeted universalism"—addressing public harms that help all, but especially benefit those worst-off in society (as a byproduct of preexisting social inequality; powell, 2012).

In his article "Justice, Health, and Healthcare" Norman Daniels (2001) argues for the special status of health from a Rawlsian theory of justice. In John Rawls' conception, equality of opportunity is very important to a just society, a just distribution of resources; people should have equal opportunities. The problem with health, and therefore the reason it has special status, is that it not only is something to value in itself but it can also limit other opportunities in life. Being ill will hinder the ability to follow education, participate in politics, travel, and so on. It is therefore important to protect the health of all members of society as to prevent further inequality of opportunities between different populations in society. Akin to Gibson's (1979/2015) notion of affordances, health is the affordance that affords all other affordances. Without health, social learning, meaning, and habituation are attenuated.

As long as public health is keyed to environmental health, the health commons flourish, and medicine is reserved for accidents and unfortunate events. As these health commons deteriorate along with environmental commons, however, the abundance of health becomes more of a scarcity, and individuals are treated chronically to manage their disease on a mass level.

With the medicalization of society, health becomes literally an affordance that only those well-off can afford. Instead of justly distributing health, it then becomes something that you get if you can pay for it. Money buys freedom from a decrepit default world full of environmental toxins, advertisements, dust, and polluted water, via secluded housing in the freshest parts of nature, not in the dirty slums (Serres, 2010). It affords transports in the hermetically sealed personal commodity bubble of the car (Szasz, 2007), rather than walking, cycling, or using public transport, which exposes one to the potpourri of noises, particles, viruses, and so on, that percolate through the air.

Environmental health builds out of this notion that our environments influence health. Yet, how do we create healthy environments for all involved? If bodies are different, how do we reconcile generalized approaches to health?

One answer to this question comes from biosemiotics. Against the biomedical model of health, which is "restricted to solely biological, chemical, and physical phenomena" (Krieger, 2011, p. 130), a biopsychosocial model of health—not just for humans but for all organisms—takes into account the organism-Umwelt relationship and everything that makes up that Umwelt. Health cannot be understood solely by focusing on sub-components, such a specific organ like a kidney or a liver. Such diseases are symptoms rather than causes, epiphenomena rather than the sources of disease. Organisms are not machines with interchangeable parts; but even machines break down at specific joints according to global stressors that wear out their weakest links the fastest. As Valles' (2018) investigation of population health reveals, "social context exerts a staggering amount of power over individuals' health" (p. 48). Just as a healthy environment leads to organisms with more capacities, affording them more options, so too for humans social empowerment allows communities to make better decisions about their own environment, including being able to stand up to polluting companies and refuse to permit continued contamination of their habitat.

Thus, social and environmental approaches to health interlink with biosemiotic approaches of understanding the organism as part of a larger milieu, rather than reducing organism ontology or pathology to personal or genetic malfunctions. The *social determinants of health* attend to the

> "non-medical factors that influence health outcomes. They are the conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life. These forces and systems include economic policies and systems, development agendas, social norms, social policies and political systems." (WHO, n.d.)

In looking beyond merely the medicalized context, the social determinants of health allow the possibility to stave off collective harms through accidental byproducts of health reductionism. Environmental health could be viewed as a subset of the social determinants of health, focusing on "the relationships between people and their environment" (American Public Health Association, 2021), in an effort to reduce adverse exposures to toxins.

Environmental risk factors may account for up to 80% of World Health Organization (WHO) reported diseases, and between a fourth and a third of the total disease burden (Prüss-Üstün & Corvalán, 2006). As the WHO first defined it,

> "environmental health addresses all the physical, chemical, and biological factors external to a person, and all the related factors impacting behaviors. It encompasses the assessment and control of those environmental factors that can potentially affect health. It is targeted towards preventing disease and creating health-supportive environments." (WHO, 1993)

Environmental health is often the result of the *commercial determinants of health*, which are the way in which for-profit industries undermine human health as an externality of their business and the industrial model (WHO, 2021). As industrialism globalized, *global health* "emphasises transnational health issues, determinants, and solutions" (Koplan et al., 2009, p. 1995), especially in regards to inequity between countries. Finally, *planetary health*—which we will return to later on—aims to improve human health "through judicious attention to the human systems—political, economic, and social—that shape the future of humanity and the Earth's natural systems that define the safe environmental limits within which humanity can flourish. Put simply, planetary health is the health of human civilisation and the state of the natural systems on which it depends" (Whitmee et al., 2015, p. 1978). In the medicine and public health paradigm, planetary health acts as the bridge between the anthropocentric paradigm of environmental health, and biosemiotics.

3.2. Triangulating Experience: From Symptoms to Disease

Part of population health science is the distinction between causes of cases and causes of incidence (Rose, 2001). The former asks about the cause of the illness of a specific individual where the latter looks at causes why a certain population is more prone to a certain disease.

Another part of the issue of identifying the problems in environmental health is the disjunct between "the private symptom *(subjektives Zeichen)* and the public sign *(objektives Zeichen)*" (Sebeok, 1992, p. 334). The subjective experience of something being wrong often predates public acknowledgement and communication of a harm. Those subjected to environmental toxins develop symptoms of toxicity before the companies or the state validates that, indeed, they have been exposed. In industrialized culture—which has become globalized—denial, disinformation, cover-up, and lack of due diligence has been the rule rather than the exception (Aronowsky, 2021; Bardon, 2019; Cohen, 2001; Oreskes & Conway, 2011; Speth, 2021). Denial tends to refer back to the level of causes of cases and tends to ignore the causes at the incidence level. For example, when an individual has a heart attack, the attribution is to the individual being overweight, not the neighborhood with food providers that peddled (especially enticing) food options that encouraged unhealthy eating practices. Sebeok describes that the mismatch between felt experiences and public recognition of disease carries "grave consequences," as diagnostically, symptoms often show up as a "signifier with multifarious and often hard-to-sort-out signifieds" (1992, p. 334). The chief question in such cases is how to disambiguate the possible causes from the available signifiers.

Figuring out the correct disease to fit the symptoms is no trivial task. Mistreatment of disease can have fatal consequences (Makary & Daniel, 2016), and not taking someone's symptoms seriously enough because, say, they might be Black or a woman—systematic discrimination—is unfortunately common (Institute of Medicine, 2003; Perez, 2019). Indeed, medical anthropology is full of examples of the misapplication of symptoms from one group of people applied to another (such as the telltale signs of a heart attack being quite different for men than for women, but popular recognition only being transmitted for male symptoms of clutching the heart and tingles down the left hand; Perez, 2019). Or White doctors downplaying the pain symptoms of Black patients because of erroneous beliefs that people of African descent are more robust to pain (Hoffman, Trawalter, Axt, & Oliver, 2016). So, while the public would be better served to differentiate heart attack symptoms across the sexes, on the one hand; on the other, less people would experience pain if racial bias were extinguished. In this way, specificity linked with discrimination does more harm than generalization. Thus, attending to individual differences in health, exposures, preexisting risk factors and dispositions, and other personalized issues can, in some cases, hinder medical treatment and intervention, rather than aid it.

So too with environmental health, the factors in our environment that protect us from or expose us to disease must be distinguished. Protective factors can include more greenery in a given neighborhood, offsetting proximity of liquor stores from schools, and stricter air quality standards for factories. Environmental health can also mean not concentrating polluting manufacturing in poor neighborhoods, but instead distributing such industries equally in rich neighborhoods. This way, the political class will be more likely to use their privilege to regulate industries rather than merely experiencing the problem as out of sight, out of mind. Enacting anti-NIMBY (*not in my backyard*) laws requiring the equal siting of polluting industries in rich neighborhoods (Hendlin, 2021), for example, may have a much larger impact on permanently revolutionizing clean production than any other intervention.[3]

One example of what this new approach brings to the table is the new field of *attribution science*, analogous to the quandary faced with the causes of health harms. Attribution science is a method of chemically specifying which forms of pollution came from which manufacturers, through spectrographic analysis (Hickel, 2020). For a given concentration of CO_2, say, one can detect distinct isotopes, which can be traced back to specific factories and their owners. Thus, even in our most diffuse of media, air and water, we can overcome the age-old protective device of diffusion and dilution to arrive back at the original source of the effluent. Epidemiology works similarly.

Despite the difficulties in showing causation for health harms in environmental factors (themselves the product of industrial arrangements that are part of an unexamined social contract), epidemiology increasingly is able to provide stochastically for various exposures. Two populations, one exposed directly to organophosphates—a class of compounds found in, for example, herbicides, insecticides, nerve agents, and flame retardants—will never have all background variables equal. But when there is large enough of a divergence in health outcomes

---

[3] When the children of elites start regularly having birth defects, the until-present acceptance of pollution as a necessary byproduct will change, and the narrative will prove to have been always an empty justification for senseless cost-cutting and responsibility-shirking.

from the exposed group versus the non-exposed (control) group, with a large enough number of participants, certain etiologic patterns surface (Hertz-Picciotto et al., 2018). Thus, the attribution science of epidemiology can help detect environmental determinants of health, which otherwise might be lost when disease is individualized.

Human health harms from environmental exposures are a major factor in human disease, and may contribute to far-reaching physical, mental, and emotional changes. Researchers from the US National Center for Environmental Health, for example, estimate that the current policies preventing lead exposures save over $213 billion dollars annually in the US alone (Grosse, Matte, Schwartz, & Jackson, 2002), though there has been backsliding, as seen with the catastrophe in Flint, Michigan. Environmental health chronicles—and aims to ameliorate—the ways in which perturbed ecosystems and ill-built environments harm human health.

Human health harms also involve what Ivar Puura calls "semiocide" (Maran, 2013)—the degradation of semiotic habits. Attending to the way in which environmental health harms impact both conscious and unconscious semiosis is important in making sense of the question of *what are health harms?* For biosemiotics, the main conceptual advance of including Uexküll's theoretical biology is the foregrounding of the importance of the organism's Umwelt in composing particular organisms. Such relationships also take on specific couplings, *contrapuntal* reciprocal composition and meaning making between organisms, as in Uexküll's example of the orchid and the wasp. Neither orchid nor wasp exists ontologically separate from the other; instead, as a structural coupling, their interactions make up the reality (Umwelt) and communicative understanding of the world (Deleuze & Guattari, 1987).

Medical semiologist Eugen Baer (1988) describes how public health is a "res publica" (pp. 82–83), a public object that concerns everyone. According to Baer, our concept of public health is always already co-determined with our environment, as our concepts of public health could or should be are introjected: "constituted and modified through environmental pressures" (p. 111). In this way, both biosemiotics and environmental health are fundamentally inclusive of the total interactions in the environment —noticed and unnoticed— which interact with, guide, and supervene upon the organism, and, our notions of health and disease.

Getting beyond the biological/social divide is more veridical, yet it also opens up new avenues of misinterpretation: "The notion of interaction presupposes the existence of entities that are at least ideally separable—i.e., it presupposes an a priori space between component entities" (Keller, 2010, p. 6). This brings us back to the opening question posed by Darwin about individual species, and more pointedly, Gilbert et al.'s (2012) contention that "we have never been individuals." Early pragmatists such as G. H. Mead, working in psychology and sociology, laid down the foundation for a philosophy of the self with a radically different point of departure than Cartesian or Kantian *ex nihlo* autonomous selves. From Piaget to Vygotsky, virtually all scientists working with actual people rather than working from a priori categories of armchair philosophy take as given that the development of one's sense of self, emotionally and intellectually entwined, comes from social interaction in which the bodily mimetic practices of gaze and imitation play a principal role (Argyle, 1988; Cole & Spalding, 2009; Seitz, 2000; Zlatev, Persson, & Gärdenfors, 2005). Biosemiotics goes further than the pragmatists to suggest, along with the holobiont theory, that individuals are not the most interesting nor accurate mode of assessing health or ontology.

Environmental health also takes this phenomenological approach, which biosemiotics grounds in theoretical biology as its starting point. The primacy of environmental factors in public health has been present since its inception. One of the progenitors of public and environmental health, Florence Nightingale (1860), emphasizes the appearance of disease as a "reparative process" (pp. 1–3), signaling disbalance in environmental conditions. Such an Umwelt-attentive conception already shifts the notion of disease to be something that individuals should shield themselves from, to an overarching sign of ecological disruption. This echoes vividly what David Abram (1996) writes in *The Spell of the Sensuous*:

> "Only those persons who, by their everyday practice, are involved in monitoring and maintaining the relations *between* the human village and the animate landscape are able to appropriately diagnose, treat, and ultimately relieve personal ailments and illnesses arising *within* the village. Any healer who was not simultaneously attending to the intertwined relation between the human community and the larger, more-than-human field, would likely dispel an illness from one person only to have the same problem arise (perhaps in a new guise) somewhere else in the community." (p. 6)

Rather than just displacing disease around the community—using many resources that destroy the environment and harm locals to make someone else, somewhere else, recuperate—a biosemiotic approach to health acknowledges the interlinking of illness as a collective interspecies phenomenon. Nightingale (1860) too saw the role of nurses as more than just "the administration of medicines and the application of poultices" (p. 2), but instead also assisting with addressing the cause rather than symptoms of disease, which she understood to be rooted in environmental conditions. She notes "bad architectural, and bad administrative arrangements often make it impossible to nurse" (p. 3), signaling that medicine has limited value unless the milieu of the patient is also remediated.

Attention to the built environment is important for determining health; but so too attending to the externalities or side-effects of building an unhealthy build environment. In her quaint wording, Nightingale writes that the keen observer of disease notices that

> “the symptoms or the sufferings generally considered to be inevitable and incident to the disease are very often not symptoms of disease at all, but of something quite different—of the want of fresh air, or of light, or of warmth, or of quiet, or of cleanliness, or of punctuality and care in the administration of diet, of each or of all of these.” (Nightingale, 1860, p. 2)

This upstream approach to disease, where disease only manifests after a long festering period of unseen or unnoticed, suggests that etiology would benefit from micro-biosemiosis, predicated on a more field or ecotone approach to environmental health. This work across these two interdisciplines will be highly productive for understanding the planetary health dimensions of flourishing.

Thus, environmental health and the treatment of disease from this perspective ought to look beyond the proximate cause of biological agents in the case of infectious disease, or failing physiologies in the case of chronic disease, and upstream to ecosystem health and social design, respectively. The obsession with diagnosing and treating itself has obscured the environmental components of disease. The social determinants of health reposition the distal factors of disease as central rather than ancillary, and asks *under which conditions did this particular person contract the disease?* In this figure–ground shift (Schaetzle & Hendlin, 2021), the relevant unit of analysis widens from the individual organism (or direct sub-area of disease, such as the lungs or heart) to the total environment with which that organism interacts—in short, its Umwelt.

As such, environmental health is a subset of the social determinants of health, and both of these disciplines contribute to planetary health, which in essence is the medical community’s reaction against the Anthropocene. As industrialization has continued to create a larger gap between the collateral environmental damage and the quality of life-enhancing goods produced from it, the health gap is widening. Industrialization, through sanitation, food, and shelter, is only able to provide for a part of the gain in health. After a certain level has been reached, the social inequality created by industrialization takes over as the main driver of health differences among people (Wilkinson & Pickett, 2010). As we move away from social Darwinist models of health claiming that it is only right, according to some misinterpretation of the naturalistic fallacy, that the (economically) strong persist while the weak (or oppressed) perish, medicine is beginning to realize that high technology medicine for those who can pay will never be a replacement for a livable environment.

Public health as a profession has always focused on improving the commons—through sanitation, cleaner water, reducing air pollution, and so on—as a means to better the health of all. Nightingale (1860), for instance, did not believe that the knowledge of nursing should be specialized nor medicalized, but that it is an innate knowledge of one’s own organism and its optimal state of health. Knowledge of living in and creating a healthy environment is a public commons, according to her.

Nightingale also believed such knowledge of health commons to be of higher priority than the medical knowledge of experts, as it was more routinely necessary and universally accessible. This suggests that basic environmental knowledge should be taught in schools to improve the health and environment of the population. Such education would help everyone be healthier, but especially those worst-off—those already subject to degraded environmental health conditions, and subject to the myriad discriminations that allow for health disparities. Public health and public policy interventions that favor those most disadvantaged communities—such as providing free public transport—end up helping all members of society that choose to use those commons; but they especially lift up those who are most dependent on them and cannot afford an expensive, private alternative (such as an automobile; see powell, 2012, on targeted universalism).

3.3. Allostatic Load

All organisms are impacted by chronic as well as acute stressors in their environments, whether they be the result of scarce food, water, minerals, predation, lack of affordances for working out their instincts, or reproductive success. The more degraded environments are, from a baseline of flourishing for a given species, the higher the allostatic load for all members. Yet, while humans have devised especially asymmetric modes of assigning resources and off-burdening stressors, all organisms exist in more or less homeostatic collectives with certain members receiving different stimuli and amounts than their peers.

Allostasis[4] forms the process by which organisms respond to stressors to reestablish homeostatic conditions enabling flourishing. But when the allostatic load is too much, the capacity for resilience or regeneration decreases, sometimes permanently. Chronic stress leading to allostatic overload ultimately decreases the capacities of an organism or group of organisms to remediate the circumstances that cause such allostasis in the first place. Thus, according to biosemiotic ethics, we can claim that exogenous allostasis over a certain hormetic zone (Calabrese, Agathokleous, Kozumbo, Stanek, & Leonard, 2019; Parsons, 2001) constitutes a harm to the organism, disabling those effected from taking sufficient action to reduce or eliminate the source of stress.

Industrialization is effectively increasing the allostatic load for all organisms, including humans, reducing our capacities (including mental and emotional) to deal with and clean up our messes. The undermining of adaptation to changed environments by severe allostatic loads affects our limbic system, decreasing plasticity and decreasing the ability to anticipate novel demands on the body/mind

---

[4] Allostasis is also termed heterostasis when disbalances are limited and discrete.

(Krieger, 2011). Allostatic load, as originally defined, means "wear-and-tear from chronic over-activity or underactivity" leading to degradation of bodily systems "that protect the body by responding to internal and external stress," including "the autonomic nervous system, the hypothalamic-pituitary-adrenal (HPA) axis, and cardiovascular, metabolic, and immune systems" (McEwen, 1998, as cited in Krieger, 2011, p. 193). The distribution of adverse physical, social, and psychological stressors and protective elements is socially patterned and can be mediated through different entryways or organs of the body (Krieger, 2011, p. 198). Heightened allostatic load in one area (i.e., psychologically) can influence susceptibility to disease or increased allostatic load in other areas (i.e., vulnerability to infectious disease), thus foreclosing compartmentalization of disease.

Disease in one domain affects the health of other domains. Gibson's concept of affordance can explicate this point: Affordances are those things/signs an entity or an environment furnishes or provides unto another entity or environment, for better or worse (1979/2015, p. 119). For biosemiotics and environmental health, it is important that we make sure that our actions are not undermining our capacities to make sense and use of our world.

4. DISCUSSION

Taking an ecological approach to life means decentering the organism as the most relevant unit of analysis. Gilbert et al.'s (2012) provocative review plainly states that the myth of the biological individual is as much of an abstraction as the Vitruvian Man; animals and plants are completely dependent on our symbionts. Without these interspecies symbionts, there is no such thing as a given organism in those kingdoms.

Organisms are porous to our environments—even to those stimuli and circumstances that we cannot consciously perceive. Being aware of a circumstance is not necessary for materials to interact with us. But since we perceive things matched with other stimuli, often the unnoticed stimuli's effects are mapped onto those circumstances that we *can* perceive, in a phenomenon Dawn Nowlin (2021) calls "errant defense" (p. 158), when the immune system misascribes the results of one stimuli to another. Thus, what we attribute as the cause of a symptom often has its genesis in an unnoticeable event elsewhere. Such misattributions complicate the explanation and cure of pathologies; explaining why increasingly medical interventions are not curing disease, but instead "managing" it. When situations (like springtime pollen) get paired with biochemical influences (like being exposed to a certain endocrine-disrupting chemical), the body may map harm on to the situation as pollen is more evolutionarily graspable for the body systems than a never-before-encountered chemical. Thus, while exposure to per- or poly-fluoroalkyl substances (commonly known as PFAS or *forever chemicals*) may be to blame for an auto-immune response, the body may code spring pollen as an ersatz for the harm, erroneously. Such pathological physiological responses to normally benign stimuli put into question the host–agent–vector pathway model of disease. Acknowledging such complications presses us to rethink the proximate and distal causes of disease, and to revisit standard diagnosed etiologies.

Attention to how the body—and medicine—can misinterpret the drivers of disease is a key contribution of a biosemiotic understanding of public health. As semiosis, like hermeneutics, does not assume digital copy coding, but rather takes for granted the miscoding and diffractive nature of analogizing, introducing the awareness of the existence of error and systematic error (habits based on misunderstanding) into medicine and public health is essential to overcome our current overconfidence and underdelivering (e.g., Hastings, 2012; Makary & Daniel, 2016; Whiting et al., 2011).

5. CONCLUSION

One could say that biosemiotics is the biological bedrock for the science of environmental health, and that the social care practices of environmental health are a logical extension of biosemiotics. The coronavirus pandemic has shown us clearly that we are only as healthy as our next-door neighbor; or indeed, those on the other side of the planet. If we are to stop breeding black swans—unanticipated events that threaten all of our health—we need to take better care of our environment, which requires not presuming that we know which habitat or Umwelt best suits the other organisms whose fates ours are bound up with. Instead, together with the findings of the extended evolutionary synthesis, we must realize that our individual health is bound up with the natural selection of groups—group selection occurring endo- and exosemiotically, skin-in and skin-out. While personalized medicine is doing an admirable job better understanding and attending to the specificity of endosemiosis and particularity's relationship to individual health, these advances so far have been bought at the expense of public health's dereliction of duty sustaining a healthy environment.

As Graeber and Wengrow (2021) muse, many indigenous communities have historically demonstrated a "reluctance ever to let anyone fall into a condition of poverty, hunger, or destitution. It was not so much that they feared poverty themselves, but rather that they found life infinitely more pleasant in a society where no one else was in a position of abject misery" (p. 20). Environmental health concerns itself with our shared Umwelt, and accounting for the health of others is the only way to secure our own health. Medical semiotics, but also biosemiotics, presents us with tools to make better preventative decisions about the needs to eradicate NIMBYism thinking from our toolbox. There is no "away," "trash," or "sandboxing" of harms without such "contained" actions affecting us as well, however unequal those exposures remain. The pipedream of containment of chemical hazards has no bearing in the porosity of materiality. Instead, accepting our porosity as semiotic beings means taking responsibility for the effects of our actions and ways of achieving our ends on others, be they human or more-than-human. Pathogens thrive in a vacuum; and when we undercut our own ecologies for some distant end, we ignorantly sacrifice fancy for health, ambition for life.

Reconnecting medicine to public health, grounding public health in environmental health, and understanding the interspecies biosemiosis of health can help regenerate our biosphere, currently running at ten percent its biodiversity and flourishing possibility (MacKinnon, 2013). Such redemption from the intertwined loss of semiocide and ecocide admits a long horizon; but recognizing and learning from the web of life on which our own depends will get us there.

REFERENCES

Abram, D. (1996). *The spell of the sensuous: Perception and language in a more-than-human world*. New York: Vintage Books.

American Public Health Association. (2021). Environmental health. Retrieved from https://www.apha.org/Topics-and-Issues/Environmental-Health

Argyle, M. (1988). *Bodily communication* (2nd ed.). London: Routledge.

Aronowsky, L. (2021). Gas guzzling Gaia, or: A prehistory of climate change denialism. *Critical Inquiry*, *47*(2), 306–327. doi:10.1086/712129

Baer, E. (1988). *Medical semiotics*. Lanham: University Press of America.

Barad, K. (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. Durham: Duke University Press.

Bardon, A. (2019). *The truth about denial: Bias and self-deception in science, politics, and religion*. New York: Oxford University Press.

Bateson, G. (2000). *Steps to an ecology of mind* (University of Chicago Press ed.). Chicago: University of Chicago Press.

Brentari, C. (2013). How to make worlds with signs. Some remarks on Jakob von Uexküll's Umwelt theory. *Rivista Italiana di Filosofia del Linguaggio*, *7*(2), 8–21. doi:10.4396/20130701

Calabrese, E. J., Agathokleous, E., Kozumbo, W. J., Stanek, E. J., & Leonard, D. (2019). Estimating the range of the maximum hormetic stimulatory response. *Environmental Research*, *170*, 337–343. doi:10.1016/j.envres.2018.12.020

Cohen, S. (2001). *States of denial: Knowing about atrocities and suffering*. Cambridge: Polity.

Cole, J., & Spalding, H. (2009). *The invisible smile: Living without facial expression*. Oxford: Oxford University Press.

Daniels, N. (2001). Justice, health, and healthcare. *The American Journal of Bioethics*, *1*(2), 2–16. doi:10.1162/152651601300168834

Darwin, C. (2009). *The annotated* Origin*: A facsimile of the first edition of* On the Origin of Species. Cambridge: Harvard University Press.

Deacon, T. W. (2012). Beyond the symbolic species. In T. Schilhab, F. Stjernfelt, & T. Deacon (Eds.), *The symbolic species evolved* (pp. 9–38). Dordrecht: Springer. doi:10.1007/978-94-007-2336-8_2

Deleuze, G., & Guattari, F. (1987). *A thousand plateaus: Capitalism and schizophrenia* (B. Massumi, Trans.). Minneapolis: University of Minnesota Press.

Derrida, J. (1997). *Of grammatology* (G. C. Spivak, Trans.). Baltimore: Johns Hopkins University Press.

Frumhoff, P. C., Heede, R., & Oreskes, N. (2015). The climate responsibilities of industrial carbon producers. *Climatic Change*, *132*(2), 157–171. doi:10.1007/s10584-015-1472-5

Gibson, J. J. (1979/2015). *The ecological approach to visual perception*. New York: Psychology Press.

Gilbert, S. F., Sapp, J., & Tauber, A. I. (2012). A symbiotic view of life: We have never been individuals. *The Quarterly Review of Biology*, *87*(4), 325–341. doi:10.1086/668166

Graeber, D., & Wengrow, D. (2021). *The dawn of everything: A new history of humanity* (First American edition). New York: Farrar, Straus and Giroux.

Grosse, S. D., Matte, T. D., Schwartz, J., & Jackson, R. J. (2002). Economic gains resulting from the reduction in children's exposure to lead in the United States. *Environmental Health Perspectives*, *110*(6), 563–569. doi:10.1289/ehp.02110563

Hastings, G. (2012). Why corporate power is a public health priority. *BMJ*, *345*, 26–29. doi:10.1136/bmj.e5124

Hendlin, Y. H. (2020). The human turn in biosemiotics. In Ľ. Lacková, C. J. Rodríguez, & K. Kull (Eds.), *Gatherings in Biosemiotics XX*, 50–71. Tartu: University of Tartu Press.

Hendlin, Y. H. (2021). Surveying the chemical Anthropocene: Chemical imaginaries and the politics of defining toxicity. *Environment and Society*, *12*(1), 181–202. doi:10.3167/ares.2021.120111

Hertz-Picciotto, I., Sass, J. B., Engel, S., Bennett, D. H., Bradman, A., Eskenazi, B., Lanphear, B., & Whyatt, R. (2018). Organophosphate exposures during pregnancy and child neurodevelopment: Recommendations for essential policy reforms. *PLOS Medicine*, *15*(10), 1–15. doi:10.1371/journal.pmed.1002671

Hickel, J. (2020). Quantifying national responsibility for climate breakdown: An equality-based attribution approach for carbon dioxide emissions in excess of the planetary boundary. *The Lancet Planetary Health*, *4*(9), e399–e404. doi:10.1016/S2542-5196(20)30196-0

Hoffman, K. M., Trawalter, S., Axt, J. R., & Oliver, M. N. (2016). Racial bias in pain assessment and treatment recommendations, and false beliefs about biological differences between blacks and whites. *Proceedings of the National Academy of Sciences*, *113*(16), 4296–4301. doi:10.1073/pnas.1516047113

Institute of Medicine. (2003). *Unequal treatment: Confronting racial and ethnic disparities in health care*. Washington: National Academies Press. doi:10.17226/10260

Kartha, S., Kemp-Benedict, E., Ghosh, E., Nazareth, A., & Gore, T. (2020). *The carbon inequality era: An assessment of the global distribution of consumption emissions among individuals from 1990 to 2015 and beyond*. Oxfam. doi:10.21201/2020.6492

Keller, E. F. (2010). *The mirage of a space between nature and nurture*. Durham: Duke University Press.

Koplan, J. P., Bond, T. C., Merson, M. H., Reddy, K. S., Rodriguez, M. H., Sewankambo, N. K., & Wasserheit, J. N. (2009). Towards a common definition of global health. *The Lancet*, *373*(9679), 1993–1995. doi:10.1016/S0140-6736(09)60332-9

Krieger, N. (2011). *Epidemiology and the people's health: Theory and context*. New York: Oxford University Press. doi:10.1093/acprof:oso/9780195383874.001.0001

MacKinnon, J. B. (2013). *The once and future world: Nature as it was, as it is, as it could be*. Toronto: Random House Canada.

Makary, M. A., & Daniel, M. (2016). Medical error—The third leading cause of death in the US. *BMJ*, *353*, 1–5. doi:10.1136/bmj.i2139

Maran, T. (2013). Enchantment of the past and semiocide. Remembering Ivar Puura. *Sign Systems Studies*, *41*(1), 146–149. doi:10.12697/SSS.2013.41.1.09

Nightingale, F. (1860). *Notes on nursing: What it is, and what it is not*. Harrison.

Nowlin, D. M. (2021). The role of biosemiosis and dysfunctional signaling processes in human pathology. In Y. H. Hendlin & J. Hope (Eds.), *Biosemiotics: Vol. 22. Food and medicine* (pp. 155–182). Dordrecht: Springer. doi:10.1007/978-3-030-67115-0_9

Odling-Smee, F. J., Laland, K. N., & Feldman, M. W. (2003). *Niche construction: The neglected process in evolution*. Princeton: Princeton University Press.

Oreskes, N., & Conway, E. M. (2011). *Merchants of doubt: How a handful of scientists obscured the truth on issues from tobacco smoke to global warming* (Reprint edition). New York: Bloomsbury Press.

Parsons, P. A. (2001). The hormetic zone: An ecological and evolutionary perspective based upon habitat characteristics and fitness selection. *The Quarterly Review of Biology*, *76*(4), 459–467. doi:10.1086/420541

Perez, C. C. (2019). *Invisible women: Data bias in a world designed for men* (First Printing edition). New York: Abrams Press.

powell, j. a. (2012). *Racing to justice: Transforming our conceptions of self and other to build an inclusive society*. Indiana University Press.

Prainsack, B. (2018). The "we" in the "me": Solidarity and health care in the era of personalized medicine. *Science, Technology, & Human Values*, *43*(1), 21–44. doi:10.1177/0162243917736139

Prüss-Üstün, A., & Corvalán, C. (2006). *Preventing disease through healthy environments: Towards an estimate of the environmental burden of disease*. World Health Organization.

Rader, K. A. (2004). *Making mice: Standardizing animals for American biomedical research, 1900-1955*. Princeton: Princeton University Press. doi:10.2307/j.ctv346rzn

Rose, G. (2001). Sick individuals and sick populations. *International Journal of Epidemiology*, *30*(3), 427–432. doi:10.1093/ije/30.3.427

Schaetzle, E., & Hendlin, Y. (2021). Between teleophilia and teleophobia. *Biosemiotics*, *14*(1), 95–100. doi:10.1007/s12304-021-09421-3

Sebeok, T. A. (1992). 'Tell me, where is fancy bred?': The biosemiotic self. In T. A. Sebeok & J. Umiker-Sebeok (Eds.), *The semiotic web 1991: Biosemiotics* (pp. 333–344). Berlin: De Gruyter Mouton. doi:10.1515/9783110871388-018

Seitz, J. (2000). The bodily basis of thought. *New Ideas in Psychology*, *18*(1), 23–40. doi:10.1016/S0732-118X(99)00035-5

Serres, M. (1995). *The natural contract* (E. MacArthur & W. Paulson, Trans.). Ann Arbor: University of Michigan Press.

Serres, M. (2010). *Malfeasance: Appropriation through pollution?* (A.-M. Feenberg-Dibon, Trans.). California: Stanford University Press.

Speth, J. G. (2021). *They knew: The US federal government's fifty-year role in causing the climate crisis*. Massachusetts: MIT Press.

Szasz, A. (2007). *Shopping our way to safety: How we changed from protecting the environment to protecting ourselves*. Minneapolis: University of Minnesota Press.

Tulchinsky, T. H. (2018). *Case Studies in Public Health*. Amsterdam: Elsevier.

Valles, S. A. (2018). *Philosophy of population health: Philosophy for a new public health era* (1st edition). London: Routledge.

Whiting, P., Westwood, M., Beynon, R., Burke, M., Sterne, J. A., & Glanville, J. (2011). Inclusion of methodological filters in searches for diagnostic test accuracy studies misses relevant studies. *Journal of Clinical Epidemiology*, *64*(6), 602–607. doi:10.1016/j.jclinepi.2010.07.006

Whitmee, S., Haines, A., Beyrer, C., Boltz, F., Capon, A. G., de Souza Dias, B. F., Ezeh, A., Frumkin, H., Gong, P., Head, P., Horton, R., Mace, G. M., Marten, R., Myers, S. S., Nishtar, S., Osofsky, S. A., Pattanayak, S. K., Pongsiri, M. J., Romanelli, C., Soucat, A., Vega, J., & Yach, D. (2015). Safeguarding human health in the Anthropocene epoch: Report of The Rockefeller Foundation–*Lancet* Commission on planetary health. *The Lancet*, *386*(10007), 1973–2028. doi:10.1016/S0140-6736(15)60901-1

Wilkinson, R. G., & Pickett, K. (2010). *The spirit level: Why equality is better for everyone* [With a new chapter responding to their critics]. London: Penguin Books.

World Health Organization. (n.d.). *Social determinants of health*. Retrieved from https://www.who.int/health-topics/social-determinants-of-health

World Health Organization. (1993). *Action plan for environmental health services in Central and Eastern Europe and the newly independent states* (EUR/ICP/CEH 123; Report on a WHO Consultation, Sofia, Bulgaria, 19–22 October 1993). WHO Regional Office for Europe.

World Health Organization. (2021, November 5). Commercial determinants of health. Retrieved from https://www.who.int/news-room/fact-sheets/detail/commercial-determinants-of-health

Zlatev, J., Persson, T., & Gärdenfors, P. (2005). Bodily mimesis as "the missing link" in human cognitive evolution. In *Lund University Cognitive Studies*, *121*.

Mapping Zoosemiotics

Pauline Delahaye
Université Paris Sorbonne (Paris 4) – EA 4509, STIH
Linguistics PhD

Abstract

As the field of semiotics becomes wider and more diverse, it is important to clearly establish which subject is studied by which subfield or branch. In this paper, we will introduce not only the branch of zoosemiotics—which is already quite well-known—but also all the different branches that can be found within this field. We will first start with a summary of the history of the field and the connections to other branches of semiotics, such as biosemiotics or ecosemiotics. Then, we will introduce its different subfields, at least as they are defined by the French school of thought: intraspecies semiotics, interspecies semiotics, zoolinguistics, semiotics of non-human cultures, and semiotics of animal subjects in human cultures. These categories are open to discussion as they are very recent, sometimes overlapping each other, and as there are still few studies and works in each one—not enough to say we have the borders of the field clearly defined. Finally, we will open our conclusion by underlining how this mapping can be clarified, extended, or contradicted.

Keywords: zoosemiotics, biosemiotics, ecosemiotics, subfields

1. INTRODUCTION

From the point of the history of sciences, zoosemiotics is a young discipline. Traditionally, it is traced back to the biologist Jakob von Uexküll (1923), but some of its core principles can be attributed to the ethologist Konrad Lorenz (Allen & Bekoff, 1999), the naturalist Charles Darwin (1872), or, regarding to the sciences of language component, to the semiotician Charles Sanders Peirce (Eco & Sebeok, 1983). None of them take us further than two centuries ago. This is a major advantage for those who want to map the field, as its history is still recent, quite well-known, and documented. Moreover, the discipline itself has not yet extended much into multiple subdomains and a complex genealogical tree. The field can be seen as even younger than that if we decide to choose not the origin of the core concepts as the date of birth but the emergence of the word used to name the field. The word *zoosemiotics* is only somewhat more than half a century old, with the very first registered mention in 1963 (Maran, 2010).

The term was coined by the linguist Thomas Sebeok (1968a, 1972), who wrote considerably about zoosemiotics and who is one of the few major authors to do so. Peirce (1931–1966) explained multiple times how his semiotic triad could be applied to various forms of communication but never really wrote in detail about the implications for animal studies. While Uexküll wrote substantially about animals, their communication, and their semiotic world, he never mentioned zoosemiotics properly, and is rather considered to be the father of biosemiotics (Kull, 2001), the mother-discipline of zoosemiotics. The word appeared occasionally in some works of the semiotician Umberto Eco (1999), but it was more a curiosity than a real subject of study. After the death of Sebeok, the discipline, as it was intended by him, entered a sort of academic sleep or intellectual hibernation for lack of a leader.

This kind of discontinuity is not unique in the academic field; many disciplines are experiencing the phenomenon, having a few decades without a major discovery or a fundamental paper, but it can be fatal to very young disciplines—and zoosemiotics was indeed very young. In this case, however, the discontinuity was not really an absence or disappearance of the academic field but rather a metamorphosis. Sebeok, if we owe him for having created the disciplinary field, remained very centred on the human, the comparison of the other animals with us, and looked at things from a very anthropocentric point of view. Thus, his major work on the subject, *Animal Communication: Techniques of Study and Results of Research* (1968b), comprises 24 chapters, but only 9 are essentially devoted to animal communication—the rest being devoted to humans—sometimes with categories as vague and broad as *land mammals* or *fishes*. The reason his work was not continued after his death is mainly because zoosemiotics mutated with new researchers, new ways of studying, new problematics, or centres of interest. It developed a more complex and tighter link with other disciplines as well—biosemiotics, without doubt, but also semiotics of culture, or the still younger ecosemiotics.

A new paradigm for a field usually leads to a need for proper mapping. This is currently missing but will become more necessary over time, as neighbouring areas, common issues, and specialised subbranches appear. In this article, I wanted to propose an attempt at mapping this field. Mapping a discipline comes down to making the family tree as complete as possible: What links does it have with its mother-discipline (does it have a single and unique mother-discipline?)? What are currently its sister-disciplines and what issues, questions, or subjects do they share? Does it already have daughter-disciplines, or is it too young? In the latter case, is it still possible to find in it some branches or subbranches? Admittedly, like all categorisations, it will have some partially arbitrary borders and taxons. This paper will also introduce another element already mentioned in the introduction—the cultural aspect.

Indeed, it appeared to me during my thesis work (Delahaye, 2019) and it was later confirmed by other works (Kerbrat-Orecchioni, 2021) that certain countries and academic traditions—the case of France seems particularly concerning—communicated little or badly with the rest of the researchers involved in the discipline all around the world. Everyone, therefore, finds themselves reinventing the wheel in their own corner. The same discipline, then, as if left in isolation in a different ecosystem, does not evolve in the same way from one academic system to another. There is nothing technically wrong with that, as it does not prevent doing quality research, but the situation has two damaging aspects: lack of efficiency—different people will find themselves doing the same work where pooling would enable them to do more, on a wider scale, or explore further—and the lack of standardisation—particularly in terms of terminology, which further impedes good academic communication. In this article, I, therefore, wanted to address this problem by proposing a multicultural mapping, which would show the common points, the points of similarities, but also the divergences that we can find between the existing ways of working in zoosemiotics nowadays.

2. METHODS

This article is a theoretical paper. It intends to propose a general mapping of the field called zoosemiotics by using three kinds of mappings:

- *External mapping*: The paper will explain the relationships that the target field has with other disciplines, be they related disciplines, subdisciplines, or superdisciplines.
- *Internal mapping*: The paper will detail the different branches or subbranches that can be found in zoosemiotics.

- *Intercultural mapping*: The paper will point out national particularities, cultural specificities, or variations in terminology between the academic institutions and traditions from different countries.

To do the above, I used the available corpus in biosemiotics, zoosemiotics, cultural semiotics, and ecosemiotics in English and French, as these are the only two languages I can access without third-party assistance. This linguistic issue is a limitation that will be addressed properly in the Discussion section.

The corpus is composed mainly of peer-reviewed articles. However, to access the biggest amount of data possible without compromising the quality of the whole, the corpus also includes the following documents:

- Doctoral thesis work, provided that it has been successfully defended and the work has been validated by an academic structure.
- Books and chapters of books, provided that they have been written and/or directed by authors who are authorities in their field and who moreover have a respectable number of peer-reviewed articles on the subject.
- Communications to conferences, provided that these are reputable, relevant, and major events in their field.

In this article, an important place will be devoted to the introduction of the French-speaking corpus and methodologies, which are relatively isolated from the rest of the international corpus and which would benefit from harmonisation with the work of researchers from other academic regions. As much as possible, this corpus has been translated and lexical proposals have been made so that its terminology can fully integrate with the mainly English-speaking corpus. When certain particularities seemed too difficult to integrate, standardise, or transpose, they were subjected to particular attention and proposals were formulated to reach a coherent and exhaustive mapping.

The main aim of this article is to draw up a general, intercultural, and extensive cartography that facilitates communication and exchanges between researchers of different languages and academic origins. At no time does it claim to be a definitive analysis of the subject, but rather a support for work and collaboration for future research. In its construction and its objectives, it particularly targets multicultural research teams, whose work may be slowed down or hindered by different conceptions and lexicological habits, as well as by difficulties in identifying these points of divergence.

3. RESULTS

I will now introduce the mapping I propose for zoosemiotics and the related fields. For the sake of clarity, I will use a genealogical tree metaphor to explain the nature of relationships between two fields:

- *Mother-discipline*: A discipline which is clearly the origin of another one. Methodologies and tools, in particular, are strongly related.
- *Daughter-discipline*: A discipline which is a branch or a subdivision of another. Methodologies and tools are very close, but subjects are usually more specific, especially when the disciplines have multiple parents.
- *Sister-disciplines*: Disciplines which have the same mother-discipline(s) but evolved in a specialised way each on their own.
- *Cousin-disciplines*: Disciplines which only have one of their multiple parents in common.

3.1. Link with Mother-Disciplines

As I said in the introduction, the first mother-discipline we can think of for zoosemiotics is biosemiotics. The subject is regularly treated and published in reference journals (*Biosemiotics*) or conferences (*Gatherings in Biosemiotics*). More specifically, it is admitted by authorities in the field that zoosemiotics more or less came from the need for a specialisation in animal communication *stricto sensu* in the more general field of biosemiotics. This idea is very well summarised by Kull (2014):

> "Zoosemiotics is semiotic zoology – a semiotic approach to the study of animal life. More precisely, it is appropriate to define zoosemiotics as the study of *animal semiosis… Cultural semiosis* is excluded from the scope of zoosemiotics, as this is a specific type of semiosis in one species of animals – humans (or potentially in any species that is capable of using and generating sign systems with symbols)." (pp. 47–48)

This heritage, however, is recent, perhaps too recent to be completely functional. As I said before, zoosemiotics is a young field, but biosemiotics is also quite young, and it usually takes time for a discipline to mature and then split into other, younger and more specific academic fields of research.

Rather than considering biosemiotics as a mother-discipline of zoosemiotics, it might be better to leave this role to semiotics itself. Indeed, several major papers, special journal issues, or books in zoosemiotics (Kull, 2014; Martinelli and Lehto, 2009; Maran, Martinelli, & Turovski, 2011) are published in journals or collections specialised in general semiotics (*Semiotics*; *Sign Systems Studies*; *Semiotics,* *Communication and Cognition*). Consequently, even if zoosemiotics is indeed more specialised in its subjects, while biosemiotics is more general, it makes more sense to consider them as daughters of the same mother-discipline—semiotics—in the same way that cardiology does not descend from general practice; these are two different branches of medicine and one being more specialised than the other does not change this state of affairs.

This is an important point but it is not enough. Biosemiotics and zoosemiotics are closely related, closer than other branches of semiotics. It is possible to state that this is because they share a dual heritage—semiotics and ethology. Indeed, zoosemiotics and biosemiotics have tools, concepts, and methodologies closely related to these two fields; they can both be seen as the introduction of the theory of sign in ethology (Smith, 1974). This quite unique dual heritage allows these two disciplines to have a very particular position, standing on the border between humanities and life sciences.

3.2. Link with Sister-Disciplines

If biosemiotics can be seen as a sister-discipline rather than a mother-discipline, does zoosemiotics have other sisters of this kind?

First, we can think of ecosemiotics. Being a semiotics of ecosystems, it seems to be closely related. But, if ecosemiotics and zoosemiotics clearly have semiotics as a common mother-discipline, it is not exactly as clear regarding ethology. Ecosemiotics do use ethological concepts and tools, but they are usually part of a larger, vaster whole. Ecosemiotics is not linked to ethology to such an extent as biosemiotics or zoosemiotics can be, mainly because it is also closely linked to other disciplines such as anthropology, ecology, urbanism, or cultural semiotics (Maran, 2020) and because the more diversity a discipline gathers, the more various its heritage and influence are. But ecosemiotics and zoosemiotics clearly share some common subjects and interests, so even if the relationship between them is not as strong as it is between zoosemiotics and biosemiotics, they are related fields, sharing common problematics and part of their tools. They probably do not influence each other very strongly, but they could undoubtedly work well together. In the metaphor of the genealogical tree used for this mapping, they can be seen as cousins.

The same could apply to another branch of semiotics—cultural semiotics. If we remember this part of the quotation from Kull (2014), we can see that, even if cultural semiotics is not a priori in the scope of zoosemiotics, it is not formally excluded:

> "*Cultural semiosis* is excluded from the scope of zoosemiotics, as this is a specific type of semiosis in one species of animals – humans (or potentially in any species that is capable of using and generating sign systems with symbols)." (pp. 47–48)

The only condition would be to find species in which we can find evidence of "what we want to be necessary and sufficient condition in order to call a behaviour a culture". I will not get into this debate right now because it is not the subject of the present article. But, if this possibility exists, even only theoretically, that means that zoosemiotics and cultural semiotics are perfectly legitimate in their collaboration, at least in order to investigate the existence of such cultural behaviours in non-human species. This can be, indeed, a very strong common ground, but it is still not very well established, and the relationship is still not that strong between the two disciplines—I will develop this aspect in the next section, because, for French theorists, this link is in fact very strong, but only between cultural semiotics and some branches of zoosemiotics. In the same way as for the case of ecosemiotics, they are rather cousins than sisters.

3.3. Subbranches

There have not been many articles in the international corpus that deal with the different branches of zoosemiotics. This is certainly due to the fact that it is a small discipline and there are not enough researchers entirely dedicated to its practice to see the different currents emerging. The most obvious, or at least the most probable branches, were theorised by Astrid Guillaume (2013a, 2013b), the co-founder of the French Society of Zoosemiotics (Delahaye, 2018). It seemed interesting to me to present this classification in order to see how it could fit into our proposal for international cartography.

3.3.1. Intraspecies semiotics

The first branch we can find, and the one that most spontaneously comes to mind, is what Guillaume calls the study of intraspecies communications. This branch of zoosemiotics studies exchanges between individuals of the same species, how they communicate, what they communicate about, how this communication is learned through early life, and what abilities can be inferred from the study of this communication. Sometimes, it can also include the ways different groups of the same species communicate and interact with each other when they encounter in more or less usual situations, such as migration, unique water point during a drought, and reduction of both territories due to deforestation or human activity.

This branch is a field strongly shared with ethologists, for both subjects and tools, and it aims to understand more completely a precise species—how its individuals function, what they can express, what kind of relationship they have with other individuals, and what linguistical and cognitive abilities they possess. Any ethological study focusing on the language aspect can be seen as falling under this branch, and an important number of methodologies and tools are logically shared with biosemiotics.

In France, Michel Kreutzer (2014; Kreutzer & Aebischer 2015) or Sabrina Krief (Cibot, Bortolamiol, Seguya, & Krief, 2015) can be considered to be working in this branch.

3.3.2. Interspecies semiotics

The second branch we can find is what Guillaume calls the study of interspecies communications. Again, this can have two aspects. The first is the study of how individuals or groups from different species communicate and interact with each other. These interactions through communication are part of the vast variety of interactions between species constantly happening in any ecosystem. Therefore, ecosemiotics is a partner of choice for this discipline, since they have subjects in common but also similar methods and tools, although still sufficiently different to be complementary and to multiply their results.

The second aspect is the study of communication aspects through different species in order to see how some elements, like syntax, arbitrary signs, or the phatic function of discourse, are widespread within the different species, what forms these elements can take according to the biological characteristics of the species—aquatic species, with or without sight, and so on—and which evolutionary path these elements seem to have taken.

These two aspects are, once again, extremely linked to ethology, with which they share a large part of the subjects and tools, but also to biosemiotics, which has a particular attraction for situations of complex interactions and for the evolutionary history of the elements of human language.

In the French corpus, this branch is mainly represented by the works of Cédric Sueur (Martinet et al., 2021) and Georges Chapouthier (2009). To note, both have an academic training primarily as primatologists.

3.3.3. Metazoosemiotics

The third branch is clearly not as common as the first two. I tried to propose an explicit translation of what Guillaume named (2013a) and defines today as the study of what is "around / beyond species: lexicon, terminology, neology, semantics.[1]"

---

[1] Translation made by the author from the definition given by Guillaume in the manifesto of the French Society of Zoosemiotics.

This branch is much more linguistics-oriented than the first two. It aims to study the different ways we—human beings—utilise to talk about language, communication, and animals. Its main objectives are to

- erase potential biases due to terminology,
- create a relevant and precise terminology to talk about animal communication in a scientific and accurate manner, and
- improve communication between specialists by improving the terminology related to a species.

Even if this branch can also end up being at the service of ethology, it is methodologically very far from it, being much closer to the classic disciplines of linguistics, simply applied to a different subject. It was also proposed not to include it in the zoosemiotics scope since it could just as easily be considered a simple specific theme of lexicology or semantics. To be relevant, though, it still requires detailed knowledge of the subject of study rarely approached by linguists, and this requirement has led to it remaining integrated.

In the French corpus, Astrid Guillaume (2014) is the main researcher on this subject, but some others, like Kerbrat-Orecchioni (2021), are starting to work on it, too. Both are academically trained primarily as linguists.

3.3.4. Animal cultural semiotics

The fourth branch could be seen as an answer to the question asked before: Is cultural semiotics included or excluded from the scope of zoosemiotics? For Guillaume, it is included but it must be a separate branch, as its subject is so particular.

Obviously, this branch has a lot in common with classical cultural semiotics in the tools, the concepts, or the methodologies; they could almost be seen as twin-disciplines. But the subject of animal cultural semiotics is so different that it would be coherent to consider them as two distinct disciplines, at least until more numerous and strong pieces of evidence about animal cultures are revealed and backed up.

Eric Baratay (2017) is one of the authors who can be linked to this field.

3.3.5. Cultural semiotics with animal as a subject

The last branch is in a different situation. When Guillaume described it, it involved gathering studies about animal rights, biomimetic engineering, alimentary studies, and many other subjects that are more classical cultural semiotics with a focus on the animal in all these forms. It seemed to me that these subjects, if they are not completely addressed, are nowadays quite common in cultural semiotics, political studies, or in sociology. In consequence, I chose not to include it in the recapitulative graph bellow.

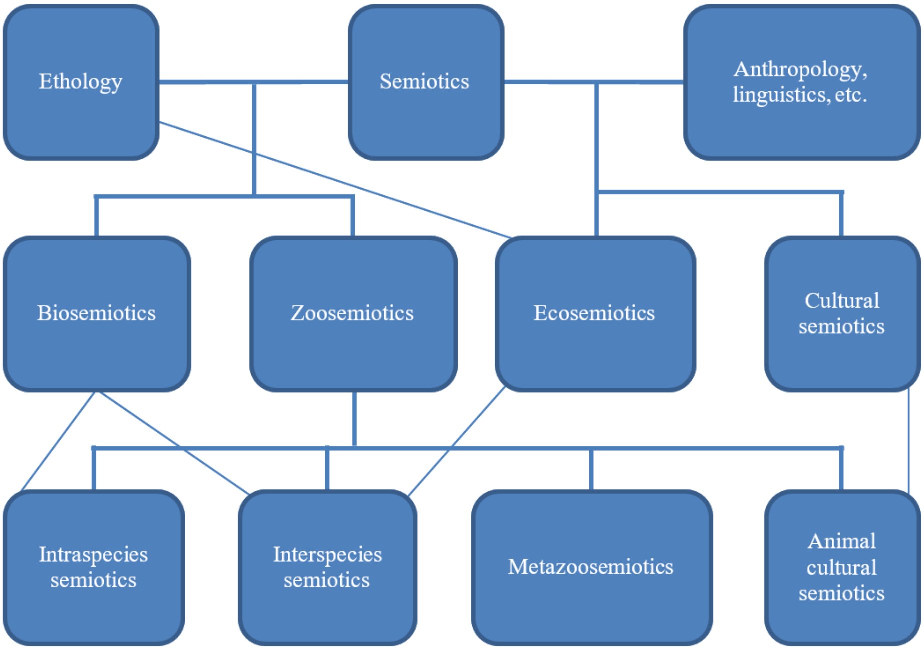


Figure 2. Proposition of general mapping of zoosemiotics and related fields. Bold links refer to major relationships (mother-daughter disciplines/branches), thin links refer to minor relationships (influences, shared subjects, common tools, etc.).

4. DISCUSSION

As is the case with any classification, part of this classification is based on quite arbitrary distinctions. The disciplines, especially in such young fields and with so many subjects in common, are not at all as compartmentalised as this mapping might suggest. Many studies and works often lie on the fringe of several disciplines and are categorised as falling within one or another academic discipline in a more or less arbitrary manner. This is, however, not specific to semiotics and its branches in particular; the phenomenon is found in most fields, but it is important to be aware of it and to mention it in a mapping proposal like the one attempted in this article.

This phenomenon is undoubtedly amplified by the difficulties of linguistic coherence mentioned in the Methods section. The translation proposals made, especially in the section of branches and subbranches, may not be shared internationally, or may cover areas and concepts otherwise defined by their equivalent term in another language. This lexicological ensemble must therefore be considered as likely to evolve and still to be improved from the point of view of standardisation.

Having a standardised cartography of zoosemiotics and adjacent disciplines is particularly important in today's academic context, which is becoming increasingly interdisciplinary. The subjects of zoosemiotics are also widely treated, integrated, or approached by related disciplines. Understanding the interactions, the common points, but also the specificities of each is therefore a methodological imperative. The goal is, of course, not to delimit the disciplinary fields to ensure that everyone remains strictly in their speciality but to promote cohabitation and interdisciplinarity, in order to allow future research work to be more comprehensive and rigorous. Mapping the disciplines also means knowing more precisely which methods, tools, or concepts are the most appropriate to study a given subject, and to be able to call upon them in a relevant way whenever necessary.

5. CONCLUSIONS

This mapping proposal shows, first of all, that zoosemiotics and other related disciplines are closely connected; they share the subjects, methods, tools, and centres of interest. Logically, the increase in interdisciplinary studies observed in recent years will be of great benefit to this collection of disciplines, which have much to gain from working with each other, especially in the current context. Biodiversity crisis, problems of cohabitation between species, zoonoses, endangered species— many of the subjects studied by these disciplines are critical points. Improving interdisciplinarity is important, and I hope that this kind of article will help to ensure more collaborative works in our fields, in an easier way.

Obviously, this proposition of mapping is not, and should not be considered as, a definitive classification. This is mainly due to the fact that, as I said in the introduction, zoosemiotics is an extremely young discipline. Relationships between its related disciplines are yet to be strengthened and developed. Some of the branches or subbranches described in section 3.3 will probably disappear, merge, or split again in the future, depending on the variety of subjects, the number of researchers involved, and the nature of collaboration with other fields. This article should in consequence be rather considered as the current state of the art for zoosemiotics.

REFERENCES

Allen, C., & Bekoff, M. (1999). *Species of mind: The philosophy and biology of cognitive ethology*. Cambridge: MIT Press.

Baratay, E. (2017). *Biographies animales.* Paris: Editions du Seuil.

Chapouthier, G. (2009). *Kant et le chimpanzé: Essai sur l'être humain, la morale et l'art.* Paris: Belin.

Cibot, M., Bortolamiol, S., Seguya, A., & Krief, S. (2015). Chimpanzees facing a dangerous situation: A high-traffic asphalted road in the Sebitoli area of Kibale National Park, Uganda. *American Journal of Primatology, 77*(8), 890–900. doi:10.1002/ajp.22417

Darwin, C. (1872). *The expression of the emotions in man and animals.* London: John Murray.

Delahaye, P. (2018). Founding of the French Zoosemiotics Society. *Sign Systems Studies*, *46*(2/3), 401–402. doi:10.12697/SSS.2018.46.2-3.14

Delahaye, P. (2019). *Des signes pour les dire: Etude sémiotique des émotions complexes animales.* Rennes: Presses Universitaires de Rennes.

Eco, U. (1999). *Kant and the platypus: Essays on language and cognition* (A. McEwan, Trans.). San Diego: Harcourt.

Eco, U., & Sebeok, T. (1983). *The sign of three: Dupin, Holmes, Peirce.* Bloomington: Indiana University Press.

Guillaume, A. (2013a). Question de définitions: Humanité versus animalité? Sémiotique de l'animal. *Droit Animal, Éthique & Sciences*, *79*, 22–24.

Guillaume, A. (2013b). Humanity and animality: A transdisciplinary approach. *Human and Social Studies*, *2*(3), 13–30. doi:10.2478/hssr-2013-0010

Guillaume, A. (2014). Animal: « Être sensible » unanimement désensibilisé. Sémiotique du sensible. *Droit Animal, Éthique & Sciences*, *81*, 35–37.

Kerbrat-Orecchioni, C. (2021). *Nous et les autres animaux.* Paris: Labyrinthes.

Kreutzer, M. (2014). Un demi-siècle de chants d'oiseaux. In M. Clouzot & C. Beck (Eds.), *Les oiseaux chanteurs: Sciences, pratiques sociales et représentations dans les sociétés et le temps long* (pp. 25–45). Dijon: Editions Universitaires de Dijon.

Kreutzer, M., & Aebischer, V. (2015). The riddle of attractiveness: Looking for an 'aesthetic sense' within the hedonic mind of the beholders. In T. Hoquet (Ed.), *Current perspective on sexual selection. What's left after Darwin?* (pp. 263–287). Dordrecht: Springer. doi:10.1007/978-94-017-9585-2_12

Kull, K. (2001). Jakob von Uexküll: An introduction. *Semiotica*, *2001*(134–1/4), 1–59. doi:10.1515/semi.2001.013

Kull, K. (2014). Zoosemiotics is the study of animal forms of knowing. *Semiotica*, *2014*(198), 47–60. doi:10.1515/sem-2013-0101

Maran, T. (2010). Why was Thomas A. Sebeok not a cognitive ethologist? From "Animal Mind" to "Semiotic Self". *Biosemiotics*, *3*(3), 315–329. doi:10.1007/s12304-010-9079-8

Maran, T. (2020). *Ecosemiotics: The study of signs in changing ecologies*. Cambridge: Cambridge University Press. doi:10.1017/9781108942850

Maran, T., Martinelli, D., & Turovski, A. (2011). *Semiotics, Communication and Cognition: Vol. 8. Readings in Zoosemiotics.* Berlin: De Gruyter. doi:10.1515/9783110253436

Martinelli, D., & Lehto, O. (2009). Special Issue: Zoosemiotics. *Sign Systems Studies*, *37*(3/4). doi:10.12697/37.3-4

Martinet L, Sueur C, Hirata S, Hosselet J, Matsuzawa T, & Pelé M. (2021). New indices to characterize drawing behavior in humans (Homo sapiens) and chimpanzees (Pan troglodytes). *Scientific Reports, 11*(1):3860. doi: 10.1038/s41598-021-83043-0.

Peirce, C. S. (1931–1966). *Collected papers of Charles Sanders Peirce.* (C. Hartshorne, P. Weiss, & A. W. Burks, Eds.). Cambridge: Harvard University Press.

Sebeok, T. A. (1968a). “Zoosemiotics”. *American Speech*, *43*(2), 142–144. doi:10.2307/454548

Sebeok, T. A. (1968b). *Animal communication: Techniques of study and results of research.* Bloomington: Indiana University Press.

Sebeok, T. A. (1972). *Perspectives in Zoosemiotics.* The Hague: Mouton.

Smith, W. J. (1974). Zoosemiotics: Ethology and the theory of signs. In T. A. Sebeok (Ed.), *Current Trends in Linguistics* (Vol. 12, pp. 561–626). The Hague: Mouton. doi:10.1515/9783111659916-015

von Uexküll, J. (1923). Weltanschauung und Gewissen. *Deutsche Rundschau*, *197*, 253–266.

Biosemiotics' Relevance of Niche Construction Theory for the Sociality[*]

Juan R. Coca[1], Borja Romero[1], and Adolfo Cordero[2]
[1] Social Research Unit on Health and Rare Diseases. University of Valladolid, Faculty of Education of Soria, Campus Universitario s/n, 42004, Soria, Spain.
[2] Universidade de Vigo, ECOEVO Lab, Escola de Enxeñaría Forestal, Campus Universitario, 36005, Pontevedra, Spain.

Abstract

The main objective of this article is to argue for the crucial importance of biosemiotics in sociality. The research is framed in the theory of niche construction, which poses that evolution of organisms is actuated by altering their own local environment. By using the niche construction theory, we can better understand what a social niche is and what factors are involved in its configuration. Through a series of previous works related to the aim of this research and selected *ad hoc*, we will be able to better apprehend the biosemiotic elements related to sociality in different organisms, including humans. Sociality is connected with the capacity of organisms to relate to their own environment and to other beings (agency). Our hypothesis is that these phenomena are based on the existence of biological codes from which biosocial signs are generated, allowing individuals to interpret the world and other organisms. In this paper, we extend the understanding of these elements but consider that further research is necessary to better understand the codes involved, as well as the biosocial symbols.

Keywords: signs, social systems, biosociology, niche construction theory, agency

---

[*] J. R. Coca would like to thank Irene Nooren for her review and comments.

1. INTRODUCTION

Sociality is a capacity shared by organisms that can organize themselves into social structures. The social systems vary their conformation in function of the internal structure and the social organization. That is, organisms with the capacity to generate colonies (ants, bees, among others) are usually considered to be social. In the same way, organisms that have the capacity to relate and form more or less stable structures (clans, families, groups, or societies *sensu stricto*), will also be social. Now, Peirce already showed us, when he espoused his ideas about synechism, that there is continuity in nature. Following Peirce's reasoning, we can affirm that sociality is a process that was already present, in one way or another, in the *world of life*.

Social systems refer to the size of own structure, sexual composition, spatiotemporal cohesion (Aureli & Schino, 2019), and ethodiversity (Cordero-Rivera, 2017). From a sociological perspective, we could also include semiotic/symbolic agency. In this sense, Blumer (1966) affirmed that "the essence of society lies in an ongoing process of action – not in a posited structure of relations" (p. 541). However, this action must be relational in order to become social. Otherwise, no action will end up promoting any social structure.

Biosemioticians know that action is based on the capacity for agency. Hence, the latter has been studied on several occasions and is one of the fundamental concepts of this scientific discipline. In fact, Sharov (2017) and Tønnessen (2015) showed that the main characteristics of agents are goal-directedness and self-governed activity (autonomy). Among agents, it could be found in living organisms (eukaryotes, including animals, plants, fungi and protozoans, and bacteria and archaea), interacting groups of organisms (societies, colonies, populations, and consortia), and in living cells. Also, Sharov (2017) recognized certain agential capacity in structures named cellular subagents (e.g., organelles, molecular complexes, and genes), and viruses. Therefore, if we find the capacity for agency in molecular and cellular structures, we can affirm that the cells themselves could present a certain degree of sociality. Evidently, this would have to be related to the interaction with their environment and to the mechanisms of common structuring with their peers. Furthermore, Szathmáry and Smith (1995) revealed that social groups originate in biological evolution.

In line with that, a social organization *lato sensu* can be characterized by actional, genetic, ecological, and non-inheritance factors. We have first mentioned action to refer to the different activities carried out by organizations. Depending on them, the processes of communication and transmission of information will be more complex. Secondly, we indicated that genetic factors also characterize a social system. In this sense, genetic functionality is important for neural development and for the implementation of information transmission capabilities and knowledge acquisition. Thirdly, there are ecological aspects that are closely related to the evolution of organisms. In this regard, it is known that there is exchange of information between agents and their environment. Depending on this relationship, the social system will have certain characteristics and not others (for example, a microscopic social system is not the same as a macroscopic one). Finally, we have mentioned non-heritable factors. These include, fundamentally, factors of a cultural nature. As is well known, cultural developments are different depending on the organism in question. These factors let us to structure a bio-socio-semiotic construction of sociality. This is the general objective of our research.

2. METHODOLOGY

In this paper, we have developed a theoretical analysis of the theory of niche construction related to sociality. This theory is the basis for understanding the social niche and the social manifestations in different organisms. Then we were able to study some biosemiotic aspects of sociality and the configuration of social systems. The work is not a systematic review but a comprehensive work that is framed within traditional theoretical studies. For this reason, the selection of the bibliography has been ad hoc, with the aim of achieving the general objective set out in this work. Our criterion for selecting articles was determined by the subject matter. We thus looked for articles in which biosemiotics, sociality, and niche construction theory were related in some way.

3. RESULTS AND DISCUSSION

3.1. Niche and Sociality

The organization into a social system creates higher-order properties that may change individual behavior and also create a recursive relationship. A paradigmatic example is the influence of relatives in human social groups. This phenomenon strongly influences the evolution of social behavior through kin selection and may therefore be an important determinant in social association (Couzin, 2006). This means that constructed human social environments may affect behavioral development in a conceptual framework named niche. This concept is analogous to the *umwelt* widely extended in biosemiotics. However, we prefer to use the niche concept because it is more widely accepted in biology than umwelt.

Fuentes (2017) affirms that a niche is a concept in which organisms' development is conditioned by the spatial, ecological, and social sphere. Then, it could be considered as a complex network in which the social partners, the structural ecologies, and other species of organisms, among other factors, affect the evolution of the members of the niche and also the evolution of the niche itself. There are additional factors to consider: the development and reinforcement of perceptual/behavioral patterns, a particularly information-rich communication system, and the wide range of complex pressures and affordances introduced to the niche and to different modalities of human cultures.

The construction of niche implies that it can have, after such alteration, a *positive* effect on the fitness of the organisms present in the niche or a *negative* one (Griffiths, 2005). In this sense, we can consider that the niche, due to its ecological character, is co-participated among the organisms that cohabit the niche. However, those organisms with a greater capacity for alteration will obviously have greater relevance in the dynamics of evolution. This capacity does not stem exclusively from mental development but is also related to the number of individuals in the population. In this regard, bacteria and even viruses can have great relevance in the processes of niche construction since they have the capacity to decimate a population and make it disappear.

Based on that, we could say that niche is strongly conditioned by the agency capacity of different organisms present in a niche. In this sense, an organism can be influenced by and modify a given environment through its capabilities. However, the characteristics (physical and biological) of this environment can alter over time. In addition, the internal biological capacities of a population or an individual can also vary with age, accidents, stress, and so on. Therefore, depending on the aforementioned factors, an individual will have a greater or lesser capacity to alter the niche in which it is found. If an organism has a higher capacity for agency, its possibilities of survival and of having offspring will be increased. On the other hand, following our argument, we could think that if the capacity for agency is increased, a greater viability of the individual is made possible. Hence, it would be plausible to think that this capacity would increase the viability of the group and the cohesion of the niche. Several studies have shown us, however, that this linear view of agency is not correct, especially in organisms with a low sociality level.

Remember that sociality is the propensity of individuals to live in groups (Avilés, Harwood, & Koenig, 2012). For this, the authors analyzed the behavior of spiders and alike social organisms and developed the following formula to quantify sociality:

$$Sociality(S) = \frac{(\frac{A_d}{A_a}) + \left(\frac{N_g}{N_g + N_p + N_i}\right) + (\frac{I_n}{I_r + I_n})}{3} + \cdots$$

Figure 1: equation of sociality in organisms (Avilés, Harwood, & Koening, 2012).

In this equation, A_d = age at dispersal, A_a = age when adulthood is reached, N_g = number of groups, N_p = number of mating pairs, N_i = number of solitary adults of the sex whose sociality index is being estimated, I_r = the number of reproducing adults, and I_n = the number of non-reproducing adults.

Avilés et al. (2012) considered organisms with simple behaviors and focused their proposal on age, reproduction, or solitary behavior. But if we understand sociality as a concept that includes agency, relationships, and death, then the above equation is not enough to comprehend a *complex view of sociality*. According to Crema (2014), a model could be established where cooperation, reproduction, death, spatial interaction, payoffs, and resources are all relevant factors in comprehending social construction. Also, these authors researching about the mobility of a population in an archaeological perspective, shows that niche construction theory led to the development of studies linked the dynamics of, for instance, cultural transmission with fission–fusion dynamics of populations. Hence, it could be argued that non-inheritance phenomena, such as culture, also contribute to the dynamics of fission and fusion, but the cultural factor only operates in complex organisms (i.e., primates, humans, etc.).

Aureli and Schino (2019), Aureli et al. (2008), and Ramos-Fernandez et al. (2018) considered that fission–fusion dynamics are related to spatiotemporal cohesion and temporary changes in size and composition, all of which are characteristic of any social system. Then, these dynamics has a conceptual frame in which it is possible to explain social dynamics from a socioecological perspective. In this one, they takes into account several actions such as grouping patterns, range use, mating behavior, dispersal tendencies, and also inter- and intrasexual social relationships.

Models of population fission–fusion dynamics and work on niche construction clearly show that there is a relationship between the levels of organisms' sociality and the niche. In fact, niche construction can increase the abundance of individuals of the same species (Odling-Smee, Erwin, Palkovacs, Feldman, & Laland, 2013), something that is more likely in those with greater implementation of their sociality. Aureli et al. (2008) affirmed that communication patterns may reflect distinct evolutionary routes and they presented a framework for the evolution of social signaling in which cohesion and differentiation are two main factors in population dynamics.

These ideas, from a theoretical perspective, are closely related to agency—without it, there would be no sociality. Well, we have said that sociality increases cohesion in different populations of living beings. Therefore, organisms with a greater capacity for agency and, consequently, for sociality, will be more cohesive. This makes them act in groups and modify, to a greater extent, their niche. These alterations, in turn, will condition the evolutionary processes of the organisms themselves. This is, thus, an essential ecological perspective for a better understanding of the theory of evolution.

In this sense, interaction between social and biological knowledge has been shown to be highly relevant to understand the *gene–culture coevolution* (Gintis, 2011; Ross & Richerson, 2014). This coevolution of gene and culture lead to the understanding that humans are biological beings (sometimes social sciences forget that, for example, when sociobiological knowledge is neglected). Moreover, human behavior is conditioned by social factors as well as by our own cultural constructions. For this reason, it could be argued that human beings are complex organisms, framed in bio-socio-cultural contexts, in which biological and social determinants are equally important.

Neal and Neal (2013) presented an interesting work from ecological systems theory. They related Simmel's theory of intersecting social circles to Bronfenbrenner's work on social networks and proposed a modification to the structuring established by the theory of ecological systems. According to it, we can differentiate between a microsystem, mesosystem, exosystem, macrosystem, and chronosystem. In the microsystem, the individual is of great importance and his actions play a direct role in the system. In the mesosystem, nesting occurs between several microsystems, and individual actions are less important. The exosystems would be, in turn, formed by the nesting of several mesosystems, and the macrosystems would be formed by several exosystems. The chronosystem, according to Bronfenbrenner's work, would be the one that shows the changes that occur over time and that influence the different systems mentioned. The result of all this a nested ecological structure that can easily be interpreted as a scaffold.

The authors (Neal and Neal, 2013) update Bronfenbrenner's proposal by focusing it on the processes of social interaction that occur in humans. This means that the relationship patterns between the different systems (micro-, meso-, exo-, macro-, and chronosystem) do not have an overlapping layered structure but are dynamic. Thus, we can say that, depending on the social relationships that can be established between organisms, the structure will change and the nesting between systems will change as well. With this in mind, we could also think about the possibility of revising the concept of scaffolding, which would, then, not be understood as a rigid structure but as a dynamic and changing structure depending on social relations.

3.2. Social Evolution and Non-Genetic Inheritance

In the context of social sciences, we are aware that there is non-genetic inheritance, which includes the transmission of information, culture, or education, among others. Social evolution clearly depends on this process, wherein the theory of niche construction allows us to explain phenomena that were not clear in the classical theories of evolution and even in the neo-Darwinian paradigm.

This paradigm has been refined in the last forty years and it defines the (co)evolutionary phenomenon as the confluence of different factors in the same evolutionary process: natural selection, genetic drift, mutation, and gene flow (Fuentes, 2017). However, it has recently become clear that this approach failed to explain all the phenomena involved in evolution. In fact, non-genetic evolution itself, as we have indicated, was not contemplated.

The paradigm is based on Mendelian inheritance and Darwinian natural selection, both of which shaped population genetics (Admunson, 2005). As a result of that, the logical core of the neo-Darwinian synthesis was, according to Admunson, the formal description, of populations established thanks to the knowledge of population genetics. In other words, the neo-Darwinian synthesis centered the concept of population in its analysis and formed a paradigm of population thinking with which the evolution of organisms was explained. From there, natural selection was conceived as the main evolutionary mechanism. For this reason, other elements (such as those developed through developmental biology or those of a more ecological nature, such as the niche) were not taken into account in the neo-Darwinian paradigm.

In the last years, the extended evolutionary synthesis (EES) has been developed, complementing the neo-Darwinian perspective. EES assumes that natural selection plays a main role in evolution but is not the only element to be considered. There also exist other factors of organisms' evolution, namely epigenetics heredity, genetic drift, evo-devo, and also the social construction of niche.

Laland et al. (2015) showed the limitations posed by the synthetic theory of evolution and defended the extended version since it incorporates elements that allow a better understanding of components that were not considered before. We are referring to the idea of constructive development of the environment. This concept refers to the capacities of an organism (or a population) to change its own development. This is done in two ways, either by altering internal elements or its environment. It is important to note that these capacities do not have to imply intentionality (rationality) but simply show this possibility. In relation to internal modifications, we know that epigenetic studies have shown, for example, in humans that our way of life generates epigenetic alterations (Alegría-Torres, Baccarelli, & Bollati, 2011). External variations, on the other hand, refer to the set of modifications in the niche of individuals or of a given population.

In this sense, the idea of constructive development is not limited exclusively to the quantitative genetic concept of the co-relational interaction between genetics and the environment. This approach is broader and conceives the organism as part of an environment and not separable from it. In the same way, any environment has certain characteristics resulting from the organisms within it (Laland et al., 2015). According to that, we could say that EES considers that development shoulders a constructive role and causation of evolution that does not run in a linear direction. Then, we could assert that there exists a pluridirectional transmission of information between the organisms and the environment. The external environment (niche), construed by the organisms, will be one of the most important factors in the evolution of populations, conditioning the development of individuals and populations.

These biological ideas are of great importance for sociology. The social sciences must be aware that everything human affects its environment and vice versa. These effects may be related to internal biological codes but also to the constructions of meaning that we establish socially. In this context, our relationship with the environment is influenced by parameters that are not strictly biological. Thus, for authors such as Farina (2010), the niche is an ecological concept limited to the abilities of a species to maintain a viable population. Farina therefore believes that it is more appropriate to speak of the *landscape domain*.

For him, the landscape is a major element of evolution since it is the spatial, temporal, and cultural context in which different agents (humans, animals, plants, bacteria, viruses) find possibilities to live. In this framework, it will also be possible to exchange information with the abiotic and biotic elements of the shared space. In this sense, Farina (2021) claims that the justification for using the landscape as a structuring element in the understanding of life comes from the universality with which landscape processes are considered by all organisms.

Farina’s (2021) proposal, as he also indicates in his work, maintains a certain relationship with the theory of niche construction discussed above. However, the author introduces a feature that helps to clarify evolutionary elements. He speaks of the existence of a *latent landscape* that could be interpreted as the biosemiotic world of future possibilities. He says that when a species is in a context of low uncertainty (stability), it will not need a great deal of information exchange with the environment (regardless of whether it is a generalist species or not). In this regard, the evolution of organisms tends to have a certain stability.

The approach to the landscape as a biosemiotic element is excellent and suggestive. Moreover, it may have great relevance for human studies. It opens a multitude of possibilities for analysis and it is a broad concept that is highly useful in macroscopic studies. The problem arises when we enter the study of small populations or even population groups. At this mesoscopic level, the concept of landscape loses part of its explanatory capacity. This is when the concept of niche becomes more important. In line with this, we can make some clarifications. The theory of niche construction implies the acceptance that organisms alter their environment. However, the landscape may be unaltered, even if the niche is altered. An example of this is represented by organisms that live underground, such as some arthropods, annelids, or fungi. These organisms have a reduced impact on the landscape. In contrast, they generate notable alterations in their niches. On that account, it will be more useful to use the concept of niche rather than that of landscape for our work. Moreover, as we have indicated, landscape analysis is relevant to organisms with a high capacity to alter the landscape. Our research, though, focuses on the study of sociality, and organisms with this capacity may alter the landscape quite a bit or not at all.

For all these reasons, we consider that the use of the concept of landscape is not sufficient to analyze all the complexity related to the social and sociality. We have opted for the concept of niche because, as indicated by Laland (2017), this term is not restricted to the classical aspects of biology and has also been extended to cognition, to the mind, and even to life itself (which in social organisms includes sociality):

> "Cultural niche construction did not just impose selection on our bodies, thereby shaping our physical appearance, skin color, susceptibility to disease, and ability to digest foodstuffs, but it also transformed the human mind, leaving our cognition specifically adapted for cultural life." (p. 230)

Niche construction incorporates different elements from biological and cultural evolution. In this sense, genes can be altered by culturally driven activities. In fact, it is not excluded that some rare diseases have increased in frequency due to social transformations. On the other hand, cultural processes may lead to favoring prosocial behaviors, that is, the maintenance of altruistic behaviors (Müller, 2017).

Nevertheless, the evolution of hominids has shown us that cultural activities (tools, domestication, etc.) have influenced the biological evolution of these organisms. For all these reasons, Müller considers that the interconnections between biological and cultural evolution cannot be left aside.

From a similar perspective, Parker, Polman, and Allen (2016) emphasize the need for scientists to develop research in a biosocial framework, in which historical, political, social, and economic relations shape power relations. This framework could have an impact on local biologies which influence this framework. According to this, it could be possible to affirm that there exist non-genetic factors that affect the evolution of social systems. Even so, we think there are biosocial factors that influence non-genetic inheritance.

Mesoudi et al. (2013) ask themselves about the role played by the non-genetic inheritance in evolution and they appeal to social knowledge in order to defend their approach. According to them, the human behavioral and social sciences, in particular, have been highly critical of gene-based approaches to the study of human behavior (such as sociobiology or, more recently, evolutionary psychology) because social dynamics are beyond the gene. The dynamics of language transformation and creation, the dynamics of religious beliefs, sociopolitical institutions, and so on, cannot be said to be under direct genetic control. These and other changes, the authors claim, can only be explained as phenomena of cultural adaptation that arise through processes of cultural evolution, which we could call trans-subjective.

Subsequently, Mesoudi et al. (2013) assert that an extended evolutionary theory (not centered on genes) that encompasses different intervening phenomena, including inheritance systems and the interactions between them, is much more compatible with sociocultural phenomena. This would not be restricted to humans alone but would be extended to other non-human organisms with the capacity to socialize. For that, the niche construction theory (NCT) could be a good option. This theory has been defined around a biological model of our reality. NCT integrates ecological and evolutionary phenomena in order to explain how niche modification feeds back to affect evolution of the organism (Buser, Newcomb, Gasket, & Goddard, 2014; Odling-Smee et al., 2013). Odling-Smee et al. (2013) show that NCT includes three types of resources: abiota (physical resources), biota (biotic components of ecosystems), and artifacts (nests, burrows, webs, and also the houses, cars, factories, and computers of humans). For this reason, NCT has a heuristic capacity to elucidate the phenomena of social/behavioral reality, namely languages, cultural dynamics, technologies, religious, institutions, and so on. The human niche is then a conjunction of the spatial and interactional environment in the biosocial sphere (Fuentes, 2017).

3.3. Niche Construction Theory, Social Niche, and Sociality

We have previously indicated that niche construction theory is an important epistemic framework for biological and social evolution. According to Kawade (2001, 2009), every living organism presents a determinate grade of sociality, and its subjectivity is structured as the triad: individual, umwelt (niche), and society. This approach incorporates non-genetic inheritance as another element involved in evolution. In this sense, culture is one of the most representative social phenomena of this type of non-genetic information transmission. From this perspective, it is easy to understand the importance of semiotics (specifically biosemiotics) as one of the explanatory factors of evolution. Likewise, biosemiotics also allows us to understand other internal elements of life like behavior or the relationship with the environment. On the other hand, the theory of niche construction has given rise to the concept of the social niche. This concept, as we shall see, provides some interesting conceptual elements that make it possible to complement the NCT from a social perspective.

Saltz, Geiger, Anderson, Johnson, and Marren (2016) published a review of this concept and showed that some authors define social niche as social groups, social environments, and different patterns of social interactions. The authors establish an integrative definition and consider two fundamental elements in their designation of social niche—social environment and fitness. Social niche, then, according to Saltz et al. (2016), refers "to the set of social environments in which the focal individual has non-zero inclusive fitness" (p. 349). In other words, the social niche is the surroundings where a population relates to its environment and manages to be biosocially effective in that niche. The authors therefore make a difference between social environments and social niche. Furthermore, they designate social environments as the set of behaviors (or other interactions) by one or several individuals. From a social perspective, we could say that an individual or a group is in an environment where there is a plurality of behaviors. There, this group of organisms will have to adjust their behavior through processes of conflict or cooperation. These processes can occur, in the first place, within any social group, although they can also occur in the interaction between individuals or social groups.

As it is said above, social niche includes social environments, and this concept also enhances inclusive fitness (Wilson, 2014), which represents the contribution of each individual to future generations through several biosemiotic phenomena.

The different social systems of organisms are maintained by social organization, social structure, mating processes, and care phenomena (Kappeler, 2019; Kappeler, Clurron-Brock, Shultz, & Lukas, 2019) but it also includes elements of their own character such as the *inherent normativity*. Remember that social norms are habits, often studied by biosemiotics, and such norms also strengthen the social structure and increase fitness, increasing the possibilities of survival in different environments. However, it can be difficult to quantify the fitness in complex social systems because in the same niche, there is interdependence between different organisms. This dependence can be positive or negative, therefore having an effect (positive or negative) on the replication of their genes (Cronk, Steklis, Steklis, van den Akker, & Aktipiset, 2019). This phenomenon, though, is greater than the genetic one since it also includes situations in which individuals have shared interests, shared agency, shared lives, or other dependencies that give rise to fitness interdependence. If the fitness interdependence is positive, then one individual will benefit another (i.e., symbiosis or mutualistic relationships). In turn, if the fitness interdependence is negative, then the success of one individual implies necessarily the defeat of another (i.e., host–pathogen or predator–prey relationships) (Cronk et al., 2019). This phenomenon of interdependence becomes even more complex in human societies, in which we find behaviors such as marriage, health care, and even institutions that influence the fitness of humans and organisms directly related to them (i.e., dogs, cats, sparrows, among others).

Saltz et al. (2016) affirm that the potential role of social niches is the maintenance of variability in behaviors, analogously to permanence of niche differences supporting species coexistence. One might inquire whether human-related niches are determined by the collective hermeneutics structured in different human societies. In this sense, it might be suggested that the actual *human social world* operates at the core of the human social niche. Then, it could also be asserted that social institutions, normalized social processes, social structure, and even the citizenry's sense of self, are part of this niche. For this reason, and following this argument, *human social fitness* will also depend on these elements. From this perspective, it will be possible to analyze the different social groups and study whether the indicated elements increase or reduce their fitness.

Neal and Neal (2013) argue that all ecological systems should be conceptualized as a network where each defined subsystem has social relationships surrounding a focal group of individuals and where these subsystems at different levels relate to one another in an overlapping but non-nested way. The social niche could be conceptualized as a network in which individuals are not unique elements. In fact, non-genetic inheritance such as geography, language, or memes can be included in the social niche. Danchin and Wagner (2010) developed a mathematical model in order to learn the trait variances of organisms. In their model, they take into account genetic variance and non-genetic transmitted variance (which includes epigenetic variance, transmitted parental effects variance, transmitted habitat inheritance, and transmitted social variance). This could incorporate environmental conditions, psychological health, political conditions, economic conditions, and so on (Troyer, 2002) as part of social niche but it could also encompass human behaviors, human perceptions, or even all cultural factors potentially inherited (Laland & Brown, 2011; Tóth & Szigeti, 2016).

3.4. Inheritance Sings in Social Systems

Memes are cultural structures analogous to biological genes and they are defined as replicators, therefore being any *quantum* of information that is copied with variations or errors and whose nature influences its own probability of replication (Dawkins, 1976). Culture and communication are transmitted through these structures of imitation because any meme is a unit of information residing in a brain (Dawkins, 1982). Its phenotypic effects, affirms Dawkins, may be in the form of words (language), music, visual images, and so on. Dawkins further admitted that success in memes may not have any connection with genetic success. Also, the replication process of memes is different and much more imprecise than that of genes. However, according to Dawkins (1976, 1982), genes and memes are selfish structures (independent even of humans) that are using humans for their own transportation and perpetuation.

Portin (2015) exposes that considering memes as self-sufficient entities is contradictory to the fact that humans create culture and are rational actors. Human beings act rationally and irrationally, and these acts allow the transmission of different behaviors among people and also to new generations. In this context, irrationality is equivalent to the emotional psychological process. In fact, Evans (2014) and Pan, Han, Dauber, and Law (2007) have shown that rational or irrational behaviors depend in part on a perceived individual process. Portin (2015) affirms that learning of behavioral habits also involves irrational structures like imitation. In this last context, according to this author, memes are justified. But he considers that *language* (in the broad sense) is a better candidate for a cultural replicator. Accordingly, it could be possible to say that the cultural replicator is the sign (remember that a sign leads to an object and to a relationship), and so we are now talking about semiotics.

Memes are abstractions related to behaviors and physical structures in the brain (Blackmore, 2001), a heuristic entity that can explain how evolution operates in culture through human behavior. It would be possible to make the same statement by changing the term meme to sign. The dramatic difference would be that the sign also allows to extend the action of the entity that has the capacity of/for sense and that can be transmitted. Signs, then, are inside the social learning, which is involved, as mentioned above, in the adjusting of different strategies of behaviors related with the imitative process (Laland, 2004; Bentley, Ormerod, & Batty, 2011). These processes facilitate the generation and the implementation of different norms and beliefs into one's own group and between groups (Boyd, Richerson, & Henrich, 2010).

Signs, when transformed into symbols, have the capacity to perpetuate or modify the social niche. Therefore, symbols are the basic structure with which a cultural species can coevolve in an environment–genes feedback dynamic. However, for this to happen, it is essential that the sociality of a given organism allows the development of some cultural outline, as well as the effective transmission of information among the individuals of a given group. This approach allowed us to recognize the relevance of the social environment, its capacity to build the niche, and its consideration of the niche as a causal factor in social evolution. Remember that the niche construction focused on the ability of any organism to alter the environment and, therefore, its natural selection (Laland, Odling-Smee, & Feldman, 2000). Thus, the organisms construct their own niche, create and reproduce their signs and symbols previously constructed.

If we extend the ecological niche concept to include culture inherited through signs and symbols, then the tools or behaviors that organisms develop to modify the environments can play a crucial role in their non-genetic inheritance and in the survival of their offspring (Hardisty & Cassill, 2010). Niche and symbols are two fundamental factors in the configuration of the cultural phenotypes, which therefore have an active role in modifying natural selection pressures through niche construction mechanisms that are generated through the ontogenetic development of culture and which have direct feedbacks on cultural change (Bradie & Bouzat, 2016).

The social niche is constructed and altered according to the social organisms living in it. We have also indicated that the niche is conditioned by the signs and symbols that intervene in the biosocial processes involved. We are now faced with a challenge. We believe that it is necessary to establish stable processes that help to understand how biological signs end up being transformed into social symbols or, in other words, how biological codes become social codes and affect the social evolution (or, if preferred, cultural evolution).

Ellis (2015) exposes four major theoretical frameworks in the studies of human culture evolution: sociobiology, gene–culture coevolution, gene–culture coevolution plus niche construction, and memetics. Sociobiology elucidates behavior genetically and it is obvious that genetics determines behavior. However, there is also a coevolution of gene and environment with the consequent double inheritance and double determination. Indeed, niche construction generates determinants of evolutionary phenomena. Sociobiology tries to explain evolutionary phenomena without considering the social niche inheritance, and niche theory allows to understand other socioecological aspects. Memetics generally ignores interactions with niche construction and with ethological diversity, but as Hardisty and Cassill (2010) say, in certain way both frameworks can dialogue.

Biosemiotics could even, as we have said before, encompass memetics. However, it is worth bearing in mind that biosemiotics has a linguistic character (we refer to the term linguistic in the broad sense, so it is possible that someone may consider this aspect to be more pre-linguistic than linguistic), whereas memetics has a more informational character. For this reason, our approach to biosemiotics is very close to what we could call biosociology of the code of biological and social signs. The conjunction of these perspectives indicates that culture (or social) evolution can comprehend and integrate this phenomenon including genetic, epigenetic, biosemiotics, niche construction and also could be correlated with biosocial research.

The social niche is formed, in part, by behavior that responds to the selective pressure of the environment. This process could allow to increase the social opportunities for successful coevolution with the environment. However, it could also reduce the chances of a given organism. In this sense, Coca, Soto, Mesquita, Lopes, and Cordero-Rivera (2021) have shown the importance of the concept of ethodiversity in understanding this. This concept shows the diversity of behaviors that different organisms have. This diversity is due to the different biosocial mechanisms that occur in organisms, which seek to increase their fitness in a given environment. This idea raises some complexity in human societies. The major difficulty lies in establishing that greater ethodiversity is related to a greater capacity for adaptation and an increase in social fitness. In human societies, there are institutions that can play an important role in increasing such fitness.

On the other hand, the existence of certain signs or symbols helps to maintain the framework of social normativity and to stabilize behaviors, social learning, and so on. This fact reduces the possibilities of alternative behaviors. Hence, a social institution that increases the fitness of a given human society could reduce alternative social codes. However, the social evolution can also generate disruptive signs that can potentially generate social innovations, social conflicts, and social disruptive behaviors. All of these behaviors will be eliminated or maintained by social evolution in relation with environment. It is necessary to make clear that cultural inheritance is quite different to genetic transmission because cultural inheritance is gradually lost along cultural transmission (Turner & Machalek, 2018). For this reason, it is extremely important to be aware that social learning allows humans to copy cultural elements or symbolic behaviors and modify different cultural or behavioral factors (innovation) (Laland, 2017).

We must continue to investigate how the biological code, through the generated signs, intervenes in the process of sociality of different organisms, including, of course, humans. It is also necessary to understand the process of generation of social codes, as well as their symbols and the evolution of both. This will have special importance in the biosocial understanding of the internal dynamics of societies.

4. CONCLUSIONS

The theory of niche construction is an epistemological framework of great interest for biosocial studies. It is based on the idea that organisms mediate in their own evolution through the transformations carried out in their own niche. Thus, the niche will be an important element in the evolution of organisms. In social organisms, society itself operates as part of the niche. Depending on the type of society in question, the niche will be more or less complex. This is due to the capacity of organisms to intervene in their own environment and in their own organism (agency). We can conclude that all these phenomena are based on the existence of codes from which biosocial signs are generated, allowing individuals to interpret the world and other organisms. These signs end up operating as symbols when the phenomena of sociality are more complex and when social interactions are greater. However, research needs to continue to better understand the codes involved, as well as the biosocial symbols.

REFERENCES

Admunson R. (2005). *The changing role of the embryo in evolutionary thought.* England: Cambridge University Press.

Alegría-Torres, J. A., Baccarelli, A., and Bollati, V. (2011). Epigenetics and lifestyle. *Epigenomics*, *3*(3), 267–277. doi:10.2217/epi.11.22

Aureli, F., Schaffner, C. M., Boesch, C., Bearder, S. K., Call, J., Chapman, C. A., … van Schaik, C. P. (2008). Fission–fusion dynamics: New research frameworks. *Current Anthropology*, *49*(4), 627–654. doi:10.1086/586708

Aureli, F., & Schino, G. (2019). Social complexity from within: How individuals experience the structure and organization of their groups. *Behavioral Ecology and Sociobiology*, *73*(1), 1–13. doi:10.1007/s00265-018-2604-5

Avilés, L., Harwood, G., & Koenig, W. (2012). A quantitative index of sociality and its application to group-living spiders and other social organisms. *Ethology*, *118*(12), 1219–1229. doi:10.1111/eth.12028

Bentley, R. A., Ormerod, P., & Batty, M. (2011). Evolving social influence in large populations. *Behavioral Ecology and Sociobiology*, *65*(3), 537–546. doi:10.1007/s00265-010-1102-1

Blackmore, S. (2001). Evolution and memes: The human brain as a selective imitation device. *Cybernetics and Systems*, *32*(1–2), 225–255. doi:10.1080/019697201300001867

Blumer, H. (1966). Sociological implications of the thought of George Herbert Mead. *American Journal of Sociology*, *71*(5), 535–544. doi:10.1086/224171

Boyd, R., Richerson, P. J., & Henrich, J. (2010). Rapid cultural adaptation can facilitate the evolution of large-scale cooperation. *Behavioral Ecology and Sociobiology*, *65*(3), 431–444. doi:10.1007/s00265-010-1100-3

Bradie, M., & Bouzat, J. L. (2016). Patterns and processes in cultural evolution. *Evolutionary Biology*, *43*(4), 516–530. doi:10.1007/s11692-015-9342-7

Buser, C. C., Newcomb, R. D., Gaskett, A. C., & Goddard, M. R. (2014). Niche construction initiates the evolution of mutualistic interactions. *Ecology Letters*, *17*(10), 1257–1264. doi:10.1111/ele.12331

Coca, J. R., Soto, A., Mesquita, C., Lopes, R. P., & Cordero-Rivera, A. (2021). Biosociological ethodiversity in the social system. *BioSystems*, *210*(2), 1–6. doi:10.1016/j.biosystems.2021.104552

Cordero-Rivera, A. (2017). Behavioral diversity (ethodiversity): A neglected level in the study of biodiversity. *Frontiers in Ecology and Evolution*, *5*, 1–7. doi:10.3389/fevo.2017.00007

Couzin, I. D. (2006). Behavioral ecology: Social organization in fission–fusion societies. *Current Biology*, *16*(5). doi:10.1016/j.cub.2006.02.042

Crema, E. R. (2014). A simulation model of fission–fusion dynamics and long-term settlement change. *Journal of Archaeological Method and Theory*, *21*(2), 385–404. doi:10.1007/s10816-013-9185-4

Cronk, L., Steklis, D., Steklis, N., van den Akker, O., & Aktipis, C. A. (2019). Kin terms and fitness interdependence. *Evolution and Human Behavior*, *40*(3), 281–291. doi:10.1016/j.evolhumbehav.2018.12.004

Danchin, É., & Wagner, R. H. (2010). Inclusive heritability: Combining genetic and non-genetic information to study animal behavior and culture. *Oikos*, *119*(2), 210–218. doi:10.1111/j.1600-0706.2009.17640.x

Dawkins, R. (1976). *The selfish gene*. New York: Oxford University Press.

Dawkins, R. (1982). *The extended phenotype: The gene as the unit of selection*. San Francisco: Freeman.

Ellis, E. C. (2015). Ecology in an anthropogenic biosphere. *Ecological Monographs*, *85*(3), 287–331. doi:10.1890/14-2274.1

Evans, J. St. B. T. (2014). Rationality and the illusion of choice. *Frontiers in Psychology*, *5*, 1–4. doi:10.3389/fpsyg.2014.00104

Farina, A. (2010). *Ecology, cognition and landscape. Linking natural and social systems*. Dordrecht: Springer. doi:10.1007/978-90-481-3138-9

Farina, A. (2021). *Ecosemiotic landscape: A novel perspective for the toolbox of environmental humanities*. Cambridge: Cambridge University Press. doi:10.1017/9781108872928

Fuentes, A. (2017). Human niche, human behavior, human nature. *Interface Focus*, *7*(5), 1–13. doi:10.1098/rsfs.2016.0136

Gintis, H. (2011). Gene–culture coevolution and the nature of human sociality. *Philosophical Transactions of the Royal Society*, *366*(1566), 878–888. doi:10.1098/rstb.2010.0310

Griffiths, P. E. (2005). Review of 'Niche Construction'. *Biology and Philosophy*, *20*(1), 11–20. doi:10.1007/s10539-004-1605-0

Hardisty, B. E., & Cassill, D. L. (2010). Memes and the ecological niche. *Biological Theory*, *5*(2), 109–111. doi:10.1162/BIOT_a_00026

Kappeler, P. M. (2019). A framework for studying social complexity. *Behavioral Ecology and Sociobiology*, *73*(1), 1–14. doi:10.1007/s00265-018-2601-8

Kappeler, P. M., Clutton-Brock, T., Shultz, S., & Lukas, D. (2019). Social complexity: Patterns, processes, and evolution. *Behavioral Ecology and Sociobiology*, *73*(1), 1–6. doi:10.1007/s00265_018-2613-4

Kawade, Y. (2001). Subject–Umwelt–society: The triad of living beings. *Semiotica*, *2001*(134), 815–828. doi:10.1515/semi.2001.054

Kawade, Y. (2009). On the nature of the subjectivity of living things. *Biosemiotics*, *2*(2), 205–220. doi:10.1007/s12304-009-9041-9

Laland, K. N. (2004). Social learning strategies. *Learning & Behavior*, *32*(1), 4–14. doi:10.3758/BF03196002

Laland, K. N. (2017). *Darwin's unfinished symphony: How culture made the human mind*. Princeton: Princeton University Press. doi:10.1515/9781400884872

Laland, K. N., & Brown, G. (2011). *Sense and nonsense: Evolutionary perspectives on human behaviour*. Oxford: Oxford University Press.

Laland, K. N., Odling-Smee, F. J., & Feldman, M. W. (2000). Niche construction, biological evolution, and cultural change. *Behavioral and Brain Sciences 23*(1), 131–146. doi:10.1017/S0140525X00002417

Laland, K. N., Uller, T., Feldman, M. W., Sterelny, K., Müller, G. B., Moczek, A., ... Odling-Smee J. (2015). The extended evolutionary synthesis: Its structure, assumptions and predictions. *Proceedings of the Royal Society B*: *Biological Sciences*, *282*(1813), 1–14. doi:10.1098/rspb.2015.1019

Mesoudi, A., Blanchet, S., Charmantier, A., Danchin, E., Fogarty, L., Jablonka, E., … Pujol, B. (2013). Is non-genetic inheritance just a proximate mechanism? A corroboration of the extended evolutionary synthesis. *Biological Theory*, *7*(3), 189–195. doi:10.1007/s13752-013-0091-5

Müller, G. B. (2017). Why an extended evolutionary synthesis is necessary. *Interface Focus*, *7*(5), 1–11. doi:10.1098/rsfs.2017.0015

Neal, J. W., & Neal, Z. P. (2013). Nested or networked? Future directions for ecological systems theory. *Social Development 22*(4), 722–737. doi:10.1111/sode.12018

Odling-Smee, F. J., Erwin, D. H., Palkovacs, E. P., Feldman, M. W., & Laland, K. N. (2013). Niche construction theory: A practical guide for ecologists. *The Quarterly Review of Biology*, *88*(1), 3–28. doi:10.1086/669266

Pan, X., Han, C. S., Dauber, K., & Law, K. H. (2007). A multi-agent based framework for the simulation of human and social behaviors during emergency evacuations. *AI & Society*, *22*(2), 113–132. doi:10.1007/s00146-007-0126-1

Parker, M., Polman, K., & Allen, T. (2016). Neglected tropical diseases in biosocial perspective. *Journal of Biosocial Science*, *48*(S1), 1–15. doi:10.1017/S0021932016000274

Portin, P. (2015) A comparison of biological and cultural evolution. *Journal of Genetics*, *94*(1), 155–168. doi:10.1007/s12041-015-0482-4

Ramos-Fernandez, G., King, A. J., Beehner, J. C., Bergman, T. J., Crofoot, M. C., Di Fiore, A., Lehmann, J., Schaffner, C. M., Snyder-Mackler, N., Zuberbühler, K., Aureli, F., & Boyer, D. (2018). Quantifying uncertainty due to fission–fusion dynamics as a component of social complexity. *Proceedings of the Royal Society B: Biological Sciences*, *285*(1879), 1–10. doi:10.1098/rspb.2018.0532

Ross, C. T., & Richerson, P. J. (2014). New frontiers in the study of human cultural and genetic evolution. *Current Opinion in Genetics & Development*, *29*, 103–109. doi:10.1016/j.gde.2014.08.014

Saltz, J. B., Geiger, A. P., Anderson, R., Johnson, B., & Marren, R. (2016). What, if anything, is a social niche? *Evolutionary Ecology*, *30*(2), 349–364. doi:10.1007/s10682-015-9792-5

Sharov, A. A. (2017). Composite agency: Semiotics of modularity and guiding interactions. *Biosemiotics*, *10*(2), 157–178. doi:10.1007/s12304-017-9301-z

Szathmáry, E., & Smith, J. M. (1995). The major evolutionary transitions. *Nature*, *374*(6519), 227–232. doi:10.1038/374227a0

Tønnessen, M. (2015). The biosemiotic glossary project: Agent, agency. *Biosemiotics*, *8*(1), 125–143. doi:10.1007/s12304-015-9229-0

Tóth, G., & Szigeti, C. (2016). The historical ecological footprint: From over-population to over-consumption. *Ecological indicators*, *60*, 283–291. doi:10.1016/j.ecolind.2015.06.040

Troyer, M. E. (2002). A spatial approach for integrating and analyzing indicators of ecological and human condition. *Ecological indicators*, *2*(1–2), 211–220. doi:10.1016/S1470-160X(02)00044-4

Turner, J. H., & Machalek, R. S. (2018). *The new evolutionary sociology: Recent and revitalized theoretical and methodological approaches*. London: Routledge.

Wilson, E. O. (2014). *The meaning of human existence*. New York: Liveright.