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Multi-Level Semiosis: a Paradigm of Emergent Innovation

Luis Emilio Bruni[1] · **Franco Giorgi**[2]

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Abstract In this introductory article to the special issue on Multi-level semiosis we attempt to stage the background for qualifying the notion of "multi-levelness" when considering communication processes and semiosis in all life forms, i.e. from the cellular to the organismic level. While structures are organized hierarchically, communication processes require a kind of processual organization that may be better described as being heterarchical. Theoretically, the challenge arises in the temporal domain, that is, in the developmental and evolutionary dimension of dynamic semiotic processes. We discuss the importance of this fundamental difference in order to explain how levels, domains and orders of magnitude, on the one hand, and synchronic and diachronic processes, on the other, contribute to the overall organization of every living being. To account for such multi-level organization, semiotic freedom is assumed to be a scalar property that endows living systems at different levels and domains with the capacity to ponder selectively the overall structural coherence and functional compatibility of their heterarchical processing, which is increasingly less conditioned by the underlying molecular determinism.

Keywords Multi-level · Semiosis · Hierarchy · Heterarchy · Domain · Biological processes · Cognitive processes

Introduction

Living and cognitive systems are considered multi-level entities organized hierarchically (Bechtel 2006). However, what comes to constitute a level within these organizations vary widely according to the particular stand taken. Their "multi-levelness" may be qualified according to the canonical descriptions of efficient causality and

✉ Luis Emilio Bruni
leb@create.aau.dk

[1] Aalborg University, Copenhagen, SV, Denmark

[2] University of Pisa, Pisa, Italy

structural hierarchies. From this perspective, a level may be characterized by being in a part–whole relationship within a hierarchical organization, in which wholes at one level function as parts at the next levels (Wimsatt 1994). However, in a previous work (Bruni and Giorgi 2015), we argued that while living systems are structurally organized in a hierarchy, the communication processes embedded in their organization can be better described as being heterarchical. Therefore, in order to explore the "multi-levelness" of semiosis we invite the readers of this special issue to keep in mind this fundamental difference. In the following pages we will briefly summarize how levels, domains and orders of magnitude, on one the hand, and synchronic and diachronic processes, on the other, contribute to the overall organization of every living system (for further details we refer to Bruni and Giorgi 2015).

The reason why living systems are structurally organized in hierarchies is because their internal architecture is composed of many levels: from the smallest cell organelle, to the largest organism, to different communities. However, to explain how these structural organizations work in their temporal dimension, i.e. emerge as innovations from simpler levels, requires us to understand their developmental dynamics according to a "heterarchy of values", rather than to a simple "hierarchy of values" (McCulloch 1945). This key distinction stems directly from the observation that no choices or decisions are allowed to take place in the physical domain, since molecular processes are simply quantitative changes abiding to a hierarchical scale of transitive values, whereas the possibility for living systems to experience alternative options in their developmental dynamics emerges directly from the heterarchy of values they locally select according to varying contextual parameters (Bruni and Giorgi 2015).

Because of heterarchically organized multiple levels, living systems have become progressively more complex during their evolutionary transition from unicellular to multicellular life forms. The resulting structural hierarchy has thus become diachronically framed into a number of nested levels, all causally interconnected within each other and highly integrated into the emerging whole. Several cellular mechanisms are known to operate in living systems for the successful integration of structurally independent hierarchical levels into new individual units. These range from the differential spatial compartmentalization of intracellular proteins (Ovádi and Saks 2004), to the temporal dynamics of downstream signaling networks in cell populations (Kholodenko 2006; Bruni 2007) and the formation of morphogen gradients during developmental patterning (Wartlick et al. 2009). For a growing cellular community to become permanently integrated into new emerging wholes, each individual cell is required to renounce its capacity to replicate independently. This entails that all levels must adopt a cooperative behavior, along with the ability to develop distinctive pathways and reduce their own fitness for the survival or reproduction of the emerging whole (Traulsen and Nowak 2005; Maliet et al. 2015).

In multi-cellular organisms, cells communicate via ligand-receptor interaction, junctional coupling and microvesicle shedding (see Giorgi and Auletta 2016). Each of these communication channels may be implemented in multiple ways due to the molecular heterogeneity of their constituting elements (Dbouk et al. 2009; Byrne et al. 2014) and their capacity to exhibit different heritable fitness (Clarke 2013, 2016). For instance, cells merge into cohesive groups through gap junctional coupling, and relate to other cell clusters as units by virtue of the ensuing interfacial properties. As a result, cells remaining structurally continuous through gap junctional coupling migrate in a "sheet-

like" manner during either embryonic development or wound healing. Cells impeded to maintain this coupling detach from the migrating sheet and internalize their junctional plaques (Defranco et al. 2008). Much the same thing can be said about cells responding to ligand binding. Hlavacek et al. (2003) talk about "conditional multivalent binding" to refer to the cell's capacity to modulate their response to ligand-receptor interaction by assembling differentially a number of modular complexes underneath their plasma membrane. On the whole, these multivalent interactions provide cells with the capacity to control their specific sensitivity toward ligand binding and, consequently, with the possibility of adapting their responding repertoire to different contextual settings (see Bruni 2007).

Two additional factors may be expected to affect the emergence of cooperative behaviors in cell communities. Along their way to multicellularity, living systems may have overcome a semiotic threshold such as to enhance their semiotic freedom and be no longer conditioned by their underlying molecular determinism (Bruni 2015). The second factor concerns the multi-level selectivity by which living systems self-organize their heterarchical architecture from within, i.e. through processes that ponder selectively their overall structural coherence and functional compatibility as they grow in complexity (Hanschen et al. 2015). Both these factors will be discussed in the following section.

Heterarchical Semiosis

Physical processes don't deal with options or choices. Only living organisms that sense differences develop and act upon response-repertoires that involve two or more potential options. This implies that two or more potential acts are incompatible and that there is some level of volition to enact one or the other (McCulloch 1945). The nature and degree of semiotic freedom of the response-repertoire – i.e., the kind of options that it affords – and the way cells and organisms enact the selected option in response to assessment or interpretation of contextual cues varies widely depending on the level of organization in question. This has led us to conceptualized semiotic freedom as a scalar property, i.e. graduated along a continuum – not a matter of "either or" but of "more or less" (Bruni and Giorgi 2015). At whatever level of the scale of semiotic freedom in which choices – based on assessment of the context – are enacted by the system, there is the possibility of having a "value anomaly" (McCulloch 1945) between the options of the repertoire. It is precisely the "process of decision" itself that is central for understanding the difference between a "heterarchy of values" and a "hierarchy of values" (von Goldammer et al. 2003). Antinomies (i.e. paradoxes, contradictions) and value anomalies are never part of the description of physical systems. They occur only in semiotic processes within systems endowed with discrimination and/or interpretation capacity.

Another important distinction is that transitive logical statements can always be constructed for comparison of physical attributes and quantities (e.g. comparative statements on weight, distance, temperature, concentration, etc.), whereas this is not always the case in multi-level living processes that present heterarchies of values and the possibility of enacting choices (von Goldammer et al. 2003). It is assumed that hierarchical systems reflect the validity of the transitivity law of the classic-logical implication postulated for a

hierarchy of values which only admits a notion of super- or sub-ordination (e.g.: Russell's theory of types, implication hierarchies, etc.). Biological models based on (physical) states and transitions between (physical) states conform to the transitivity law and therefore tend to be described as being modularly hierarchical (for example, biochemical kinetic reaction networks that consider sets of hundreds of thousands of reactions described by nonlinear ordinary or partial differential equations). Because the multi-scale aspects are invariably postulated to be hierarchical, these models or explanations exclude recursiveness and self-referentiality in a fundamental logical sense. In the perspective of multi-level hierarchical systems, this logic is extrapolated to the higher levels of the hierarchy (e.g. perception, cognition, behavior, etc.), giving place to the "epiphenomenon hypothesis" (Jonas 1984). Under this logic, biochemical processes and informational processes are dealt with the same logical operators and from the same standpoint – that of efficient causality. The transitivity law cannot deal with the possibility of pondering two or more values in simultaneity, which is constitutive of choices and processes of selection. This distinctive characteristic of living systems entails a synchronous dialectics between context assessment (i.e. proto-cognition or cognition proper) and response-enaction (i.e. proto-volition or volition proper) in deciding among values that are not presented or compared one after the other but simultaneously. In contrast, in physical systems simultaneity is not linked to choices or decisions: three simultaneous physical events may be in relation to each other, or together determine a particular outcome, but that outcome will be the only possible one. There is no possibility for error.

Another salient characteristic of living processes that becomes problematic in hierarchical descriptions is the observable ubiquitousness of complex feedbacks, reentry processes and self-referentiality across levels and irreducible domains – for instance cellular signal transduction, synaptic synchronization of local neural populations, large-scale synchronization of global electrical brain signals, coordination of neurocognitive activity with endocrine and immunological responses, and full-blown subjective phenomenological experience. Since the notion of level has somehow come to imply some sort of hierarchical ordering (i.e., the consideration of higher and lower levels), in a heterarchical perspective it seems to be more appropriate to refer to irreducible domains, which may be synchronized or be in communication (for example, subjective experience in relation to an immune-system's response). These domains represent multiple standpoints, or "contextures" (Günther 1973) in a living system. A mechanical deterministic world view is "mono-contextural" and offers no place for any degree of proto-subjectivity or semiotic freedom. The complexity of the system is reduced to a single standpoint. A heterarchical perspective that recognizes semiotic freedom as a scalar property accepts the distribution of different degrees and kinds of subjectivity, and the constant negotiation of indefinite standpoints in nature, not only in the phenomenological worlds of organism (umwelt) but also in their biological processes. In this view, subjectivity in its most elemental meaning entails the possibility of selecting alternatives evaluated from a particular standpoint. A heterarchically embedded system puts into relation different *contextures* from multiple logical levels or standpoints that synchronically represent irreducible qualitative domains. A multilevel approach to semiosis should consider the heterarchical relations and communication between different levels of proto-subjectivity from the standpoint of hierarchical structural levels such as cells, tissues and organs, up to the full-blown subjectivity of

whole organisms with their history and social context. Also it should take into consideration the self-referential processes of each level and the possibility, or impossibility, of resolving communicational challenges and incongruences at the appropriate domains (Bruni and Giorgi 2015).

From a evo-devo point of view compatible with a "developmental plasticity" perspective (see Affifi 2016; Švorcová 2016), multi-level organizations are not causally pre-determined nor guided or pulled towards specific attractors, but merged dynamically into coherent wholes by some kind of context dependent selection. Though initially comprised of structurally uniform constituents, many levels become progressively heterogeneous in structure as the development proceeds to completion. In line with Jablonka and Lamb (1998), we view development as guided by selective processes, rather than being simply implemented by instructive and predetermined information. When looked at from this perspective, multi-level organizations cannot be resolved in simple hierarchical terms as if comprised of objects spontaneously self-assembled into coherent wholes (Johnson 2009). The adoption of this hierarchical paradigm would necessarily imply assuming a ranked disposition of descending types whereby higher levels impose some kind of synchronic constraints on lower levels. This synchronic formulation would not take into account such features as the diachronic development and the contextual dependence of many inter-level relationships.

A diachronic formulation of complex hierarchies brings into question the role played by selection in the emergence, stability and integration of their inter-level relationships. From this standpoint, multi-level organizations become progressively more complex because changes occurring on one level are sensed as structurally congruent and temporally coincident with changes occurring in adjacent levels (Maturana and Varela 1980). This implies that multi-level organizations persist or even grow in complexity if functions displayed by every level are continuously monitored for their capacity to satisfy other levels' "needs" (Auletta et al. 2008). Selection is thus the key process by which inter-level relationships are first explored and then eventually adjusted and made compatible for the stability of the whole.

If the role played by group selection is taken into account, the emergence of a coherent whole may then be conceived as an enhanced possibility for inter-level relationships to extend beyond individual variations (Bijma et al. 2007; West et al. 2015). Levels do not act on each other by virtue of their causal properties, but as heterogeneous units capable of undergoing differential clustering, depending on the contextual cues that prevail in various inter-linked domains. Whenever clustering occurs, the resulting bounded collectives may be gradually shifted toward higher levels of integration and eventually be led to the emergence of new individualities (Heylighen 1999). This way of conceiving inter-level relationships provides a biological basis for understanding or, at least appreciating, heterarchy. A strict logical confrontation – in the sense of either/or alternatives – does not suffice to solve historical contradictions or discrepancies arising between incompatible developmental constraints (Kull 2015). The problem lies in the difficulty of reconciling those developmental differences that may gradually emerge from homogeneity and build unsolvable incompatibilities (Klingenberg 2005; Brigandt 2007). Interpreting these discrepancies heterarchically makes inter-level relationships solvable with respects to different contextual settings. Thinking heterarchically thus means that relationships and their contexts are as important as the interactant's properties. At the same time, it indicates that the discrepancies

cannot be solved by rejecting one or the other on the basis of a contextual uniformity, but more wisely by embracing larger contextual perspective outside of the paradoxical situation in which incompatible relationships are confronted (Bruni and Giorgi 2015).

Perspectives in Multi-Level Semiotics

The papers collected in this special issue reflect the widely shared need in the biosemiotic community to discuss the semiotic nature of living beings with particular focus on the historical becoming of their multi-level and multi-domain semiosis. Let us present them in the order they appear in this issue and, without pretending to be exhaustive, try to point out some possible interconnections.

Markoš and *Das* examine how living beings differ from inanimate things by coming into the world as newly born entities. They differ from fully determined or cybernetic systems because endowed with the ability to inherit the dynamical history of their predecessors, and, as such, to live under conditions dictated by their genetically and physically experienced variations. In this sense, they claim, history is the actual dimension that makes newly born individuals highly rooted in their memory. Nature is too complex to be accounted for by using exclusively the cybernetic metaphors of life scripts and programs. To take history as the foundational claim for life entails to rediscover the role played by the reader of these programs and, in turn, to highlight experience as the inter-subjective dimension through which a cenoscopic type of knowledge can be eventually acquired. Categorization of specific domains in mechanical, cybernetic, dynamic and historical systems is therefore not defined by any kind of insurmountable static condition, but by the possibility to be conceptualized in view of their evolutionary flexibility. To endorse an evolutionary approach to semiosis entails therefore to envision the living world in its becoming and to consider the emergence of genuine novelties through their ability to remain incessantly embedded in an experienced Umwelt. For this very reason, cells and organisms are so adaptable to their environment to reinterpret their script programs at every new generation. Markoš and Das get inspiration from Havel (2001) to challenge the notion of "levels" and contrast it with that of "causal domains", which cannot be reduced onto one another. The interfaces at which domains interact represent areas of ambivalence, "negotiations", emergence of novelties never observed before, even of new domains. For these interactions (or changes of perspectives) Markoš and Das use the term "reciprocal forming". Based on this reasoning they decline to build a perspective that prescribes a hierarchical or supervenient relationship between domains, which would imply an upward or downward ranking. In this sense their approach has coincidences with the view developed in Bruni and Giorgi (2015) on heterarchies and heterarchical embeddedness, following ideas from McCulloch (1945) and Günther (1973). In this perspective, there is also a dialectical relation between irreducible domains that represent specific "standpoints", without necessarily rejecting the existence of levels in the heterarchical processes embedded in structural hierarchies. However, Markoš and Das are also keen to stress in their perspective the role of "evolutionary memory" (a notion introduced by Kilstrup 2016).

Švorcová considers how the old fashion gene-centered view of heredity is being replaced by more updated views of inheritance systems, including epigenetics,

holobiont transmission and body memory. Heredity has usually been interpreted as a process of transferring unaltered gene information from generation to generation. By contrast, epigenetic inheritance deals with the transmission of all developmental variations in gene expression that are not related to either allelic or mutational differences. Epigenetic modifications operate by activating or silencing genes that affect transmissible phenotypic traits for a number of generations in both eukaryotes and bacteria. The idea that biological information is not restricted to gene transmission suggests that selection acts on a community level both in pro- and eukaryotes. Švorcová holds the view that bodily memory is also another case of inheritance hosting all habitual and heritable interpretations that maintain the species' coherence. Given the variety of hereditable mechanisms potentially available to all living beings, taking a heterarchical approach proves more adequate than a hierarchical perspective to understand how different levels of description interact with one another. Selection may in fact work not only by random gene mutation, but also by processing information in a highly distributed manner on many different hierarchical levels. Therefore, inheritance and development cannot be fully explained by some sub- or super-ordination and such descriptions are merely heuristic tools that do not reflect the nature of such processes. Different codes may in fact be required to integrate domains at different hierarchical levels and interpret them as meaningful cues through a heterarchical processing of different contextual settings. In this perspective, such individual entities as cells, organisms, human beings, or communities may play different roles or even belong to different organizations.

Affifi's contribution is an interesting study centered on one of the most widely debated topics of modern science. As is well known, the current reductionist approach takes transgenic manipulation to be conceptually equivalent to phenotypic selection. The multi-level analysis provided by Affifi is thus an illuminating example of how a semiotically grounded approach can actually reveal the complexity of the technical and ethical issues that are implicated in the use of molecular biology to modify living beings. Of all possible relationships involved in the process of gene manipulation particularly important is the role played by the human responsibility in handling the cultural evolution of the biosphere. With this in mind, Affifi dissects the concept of "side effects" that result from genetic interventions, looking into it from different perspectives that consider the active role of organisms in their own development. In his view, once the role of living systems in constructing and modifying their various developmental resources is taken into account, the canonical concept of "side effect" needs to be thoroughly reformulated. In this reformulation a biosemiotic perspective becomes a valid tool for including the organism's own agency in accommodating the novelty in its particular context. He acknowledges that the incipient conceptualizations on "developmental plasticity" and "niche construction theory" (also appearing in Švorcová 2016) go in this direction. However, these concepts need to be complemented by a semiotic perspective that considers the heterarchical embeddedness of the complex communication loops in multi-level processes. The fact that the new artificial interventions by-pass complex heterarchical communications loops in different domains poses new challenges in our understanding and our ecological relations with our own and other species.

Giorgi and *Auletta* offer a novel case of multi-level cell semiosis centered around one of the least investigated signaling mechanisms in multicellular organisms, i.e. the

extracellular release of microvesicles, which in their view is changing the way cell communication is being conceptualized in cell biology. They argue that intercellular vesicular transfer is substantially different from other types of cell communication, allowing cells and molecules to interact on different levels (and with a different logic). Vesicular traffic allows donor cells to carry out a horizontal type of gene transfer (Skinner et al. 2009) and target this information over long distances via independently controlled mechanisms. Because of this independence, cells interacting via vesicular traffic are not expected to adapt their signaling correspondences (at the receptor-signal level), but to control instead the efficiency of their cargo delivery irrespective of the receptor repertoire expressed by the target tissue. The authors state it metaphorically by comparing this communication process to a postal service where messages may be delivered as either post-cards or sealed envelopes. In both cases the destination of the message is known throughout the system; but whereas the content of the message in the case of the postcard is known to anyone in the communication line of the system (like a hormone in cellular communication), in the case of the sealed envelope the content will be disclosed only to the addressee (i.e.: the target cell). So addresses in the envelopes and their contents may be assorted in multifarious possible combinations, which are not causally predetermined but rather instantiate a level of semiotic freedom for combining cell-targets (the envelop' address) and possible expressed functions (the envelope's content). Seen in this way, the prime level of selection is defined by the nature of the cell-to-cell relationship, while the effects of this selection are instantiated only secondarily at the lower molecular level by the contingent expression of its information content. This means that interactions (i.e., relations) ought to precede expression of the interactant's properties. Having to explain how relationships work, a reductionistic view would have to rely on the assumption that the interactant's properties are to be expressed and mechanistically determined prior to the establishment of their interaction.

In his paper on "*Synergy of energy and semiosis*", *Fernández* examines how life on Earth has evolved toward higher levels of integration. He shows and compares how the resulting increase in complexity and diversification can be accounted for from different perspectives by concepts such as (1) semiotic freedom, (2) evolutionary transitions and (3) life inventions. By combining their divergences in a more comprehensive perspective, he advocates for the view that major evolutionary steps toward complexity have been propelled by cooperation and synergy. Any increase in complexity, as driven by semiotic freedom, can be attributed to the growing capacity of living beings to respond to environmental signals according to situated contexts. Major evolutionary transitions are also understood as forms of cooperation emerging from changes in information storage and processing, as from the capacity of independent replicators to be integrated into higher-level wholes. Life may also increase in complexity by inventing radically new ways of making the most efficient use of energy resources, rather than simply dealing with stepwise transition through structurally different forms. Cooperation can thus be taken as a common ground or a shared milieu to account for the energetic and semiotic causation of all life forms. While changes produced in the physical world depend on the amount of energy involved, semiotic causation has great impact on the habit-taking of autonomous agents. It is through the cooperation of these forms of causation that living beings evolve toward higher levels of organization and retain some of the essential elements of past novelties, a process of cosmological evolution that

Fernández refers to as a form of concrete generalization. Working its way through the multiplicity of levels in organic evolution, the article concludes proposing an analogy between conceptual generalizations and the synergy of ideas. These compelling examples represent a seminal bonus for future work in theory of science and the history of ideas.

Organisms become progressively more complex by virtue of their ability to diachronically change inter-level relationships. As underlined in the contribution by *Sharov*, the diversity of these relationships has gradually emerged during evolution from life's capacity to make use of self-constructing semiotics. While semiotics is focused on the role played by relationships between signs and interpretants as they are presently employed in logic and linguistics, it ignores the question of how these relationships have emerged during evolution. In his paper, Sharov highlights the principles of constructivism whereby the emergence of multi-level semiosis in the living world can be explained as being due to the organisms' capacity to respond to external disturbances by modifying their sign relations with the environment. From this perspective constructivism makes our biosemiotic understanding of life more centered on the agent's ability to self-construct its own sign relationships with the environment and to modify preexisting interactions by employing already tested tools. In previous work Sharov has already advocated for a view that sees living systems as eminently constructive and self-constructive agents actively transforming themselves in the process of transforming their environment. In this article he takes a step further in order to account for the emergence of evolutionary novelties at successive levels of organizational complexity. This constructivist perspective resonates with the incipient work on "niche construction" and "developmental plasticity" as treated by Švorcová (2016) and Affifi (2016) in their respective contributions to this issue (see above).

A significant and very relevant contribution to the issue of multi-level semiosis has come from the philosophy of individuation as elaborated by Simondon. As reported in the paper by *Kataray* et al., the process of Simondon's individuation can be understood as an "axiomatisation" of ontogenesis whereby organisms and environment do not preexist as specific substantive entities, but co-emerge in the reciprocal tendency of creating a common ground for interaction. Through this process, organisms may unfold their potentials by transforming some initial unstructured conditions into new metastable domains and, as a result, develop more complex internal structures. As stated by Simondon, relationships are not established between pre-existing structural identities, but rather emerge from the gradual individuation of pre-individual beings. When looked at in this perspective, hierarchical levels can be more appropriately understood as dynamical entities actively involved in a constant state of becoming through the progressive reshaping of their interactive communication, rather than as top-down entities stably anchored in their organization. Therefore, the process of individuation starts and continues via the establishment of an interactive communication between "disparate orders of magnitude". This communication creates congruence between these orders and thus shapes both the *topology* and *chronology* of the emerging physical individual, a process that Simondon calls *internal resonance*. These ideas on interactive communication between disparate orders of magnitude and the resulting internal resonance somehow relate with the ideas on "irreducible domains" in "heterarchical processes" in the McCulloch/Günther tradition as reviewed in Bruni and Giorgi (2015) in the context of biosemiotics. The Simondonian "congruence" that

results in a new mode of individuation presented by Kataray et al. emerges when the organism's *affectivity fails to resolve the disparity* between itself and the milieu, or even aggravates it. Under such conditions a resolution is sought via the development of more complex internal structures that will constitute the substructure of the *psychic* domain. The resolution or irresolution of such disparities may have crucial implications for the emerging multi-level individualities.

Ostdiek provides further insights on how living relationships entail processes of reciprocal incorporation, eventually resulting in the emergence of novel levels of being. He reasons that the notion of past is somehow immortalized in present forms as long as past events are incorporated in new opportunities to be developed in the future. In the absence of this incorporation, past events are not simply repeated, but remain mired in their failure to be adapted to new circumstances. Considering that experience begins outside the self and produces its effects inside the self, Ostdiek sees it as a process capable of generating new interpretants every time new interpretations are proffered. In the end, the ability to incorporate its own interpretation makes it more likely for the living system to survive. In this sense, interpretation becomes a mechanism furthering its own existence out of experience, a condition that makes life continuous along all scales of the "self-identity" organization. Arguing against the conceptualization of static hierarchies, Ostdiek supports the view that life is a scale-thick heterarchy. There is not "up and down" in evolution, but rather "in and out". Living complexes are more or less tangled together. In no case is the behavior of an organism to be interpreted in terms of individual psychological processes. Through the biosemiotic lens, Ostdiek exemplifies this perspective by bringing together seemingly disparate domains, connecting parasitic infections with autonomic nervous systems, and changes in social behavior, wherein degeneration or habituation on one scale of life allows for generative or novel interactions on another.

In his paper on Peirce's concept of semiosis, *Auletta* offers a critical appraisal of how information should be conceptualized at various levels of complexity, depending on how codes, signs and symbols are understood in relation to the control of information flow. Auletta's thesis is that physical sciences have always been assumed to deal with material *tokens*, while information per se can only be applied to *type* systems. As a result, a semiotic understanding of a physical occurrence may be erroneously understood as having an indexical relation to an object. By contrast, Peirce's notion of sign envisions living systems as encoded models susceptible of being controlled. To have a code controlling different environmental signals entails the possibility of attributing functional meanings to the system's intrinsic needs. To satisfy these needs the organism must be shielded from the external environment and treat different environmental factors as functionally *equivalent*. Whenever these conditions are satisfied, the crucial point for the organism is to have a reliable representational flow from the exterior to the interior and to complement it with a reaction in the opposite direction capable of updating its adaptive capacities. By exerting this control on the external reality, organisms verify their ability to match needs and environmental resources and, at the same time, learn how to share their interpretation rules or corresponding codes with conspecifics.

Kilstrup's contribution based on Peirce's interpretation of signs, provides an insightful analysis of how humans and other biological organisms ought to rely on signs continuously modulated, tested or even rejected. He infers that the process by which

signs are first established should be logically distinguished from their subsequent interpretation. While signs are established by habits or systemic memory, they may later appear to be inappropriate for relating various inputs to each other in learned semiotic interpretations. This entails that those signs that prove to be useful in the long run have been evolutionarily selected on the basis of their fitness for specific environmental settings. By assuming evolution as a memory generating process, it may be further suggested that the way memories are selected is driven by their compatibility with the niche affordances they have acquired during the establishment phase. In this direction the article introduces a new concept of *evolutionary memory* which is applicable to both human and biological semiosis. Kilstrup discusses a number of examples from systems biology that analyze how signs corresponding to these criteria are actually selected. When understood according to these criteria some of the signs appear as "forbidden" because essentially incompatible with the niche's requirements. He presents an analysis of the forbidden sign categories with examples from "occult semiotics" in order to draw analogies to offer examples of forbidden signs in biological semiosis, where the faulty interpretation of signs may lead to decimation of entire evolutionary lines of organisms. This leads to the interesting conclusion that every semiotic-scaffolding developed along the life span of a living being has to prove adequate for its interpretation competences or should otherwise be rejected if proved wrong in its testing capacity.

As well known, the study of multilevel systems faces the challenge of having to explain how molecular mechanisms and semiotic processes interact as complementary aspects across and within all levels of every heterarchical organization. With this special issue we have made a contribution to address the increasing interest with which these processes are studied in Biosemiotics. We sincerely hope to have offered a unified view of how various types of communications become integrated as meaningful sign-systems of every living organization.

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