***Semiotic modeling of biological processes: Multi-level model of emergent semiosis***

João Queiroz[a,b] & Charbel El-Hani[a,b,c]

a. Research Group in History, Philosophy, and Biology Teaching, Institute of Biology, Federal University of Bahia, Brazil.
b. Graduate Studies Program in History, Philosophy, and Science Teaching, Federal University of Bahia/State University of Feira de Santana, Brazil.
c. Graduate Studies Program in Ecology and Biomonitoring, Federal University of Bahia, Brazil.

**General abstract:** Here we introduce biosemiotics as a field of research that develops models of life processes focusing on their informational aspects. Peirce's general concept of semiosis can be used to analyze such processes, and provide a powerful basis for understanding the emergence of meaning in living systems, by contributing to the construction of a theory of biological information. Peirce's theory of sign action is introduced, and the relation between 'information processing' and sign processes is discussed, in fact, a semiotic definition of information is introduced. Three biosemiotic models of informational processes, at the behavioral and molecular levels, are developed, first, a model of genetic information processing in protein synthesis; second, a model of signal transduction in Bcell activation in the immune system; and, finally, a model of symbolic non-human primate communication. We also address some perspectives for the development of applied semiotic research in fields such as Artificial life, cognitive ethology, cognitive robotics, theoretical biology, and education.

In this lecture, we propose that the emergence of semiosis of different kinds can be understood as resulting from fundamental interactions in a triadically-organized hierarchical process. To grasp these interactions, we develop a model grounded on Stanley Salthe's hierarchical structuralism.

## 1. Levels of semiosis: A general model

Salthe's (1985) "hierarchical structuralism" was conceived as a coherent and heuristically powerful way of representing natural entities. A fundamental element in hierarchical structuralism is the "basic triadic system", clearly influenced by Peirce. This system plays a fundamental role in this approach, aiming at the discovery of general rules and principles of constraint within which natural regularities must operate.

According to the basic triadic system, to describe the fundamental interactions of a given entity or process in a hierarchy, we need (i) to consider it at the level where we actually observe it, or, as we can say, where it can be meaningfully perceived ("focal level"); (ii) to investigate it in terms of its relations with the parts described at a lower level (usually, but not necessarily always, the next lower level); and (iii) to take into account entities or processes at a higher level (also usually but not always the next higher level), in which the entities or processes observed at the focal level are embedded. In Salthe's triadic system, both the lower and the higher levels have constraining influences over the dynamics of the entities and/or processes at the focal level. These constraints allow us to explain the emergence of entities or processes (*e.g.*, semiosis) at the focal level.

In a manner which is consistent with Peircean pragmatism, the choice of the focal, lower, and higher levels depends on the research goals. Therefore, it results from a decision made by a researcher on the grounds of a theoretical framework and methodological approach. The theoretical and methodological bases chosen by a researcher are, in turn, partly (and, often, strongly) influenced by the epistemic practices accepted as scientifically adequate and, typically, also standardized by the scientific community.

At the lower level, the constraining conditions amount to the "initiating conditions" for the emergent process, while constraints at the higher level are related to the role of a selective environment played by the entities at this level, establishing the boundary conditions that coordinate or regulate the dynamics at the focal level.[i]

In this model, an emergent process at the focal level is explained as the product of an interaction between processes taking place at lower and higher levels. The phenomena observed at the focal level should be "… among the possibilities engendered by permutations of possible initiating conditions established at the […] lower level" (Salthe 1985, p.101). Nevertheless, processes at the focal level are embedded in a higher-level environment that plays a role as important as that of the lower level and its initiating conditions. Through the temporal evolution of the systems at the focal level, this environment or context selects among the states potentially engendered by the components those that will be effectively actualized. As Salthe (id. ibid.) puts it, "what actually will emerge will be guided by combinations of boundary conditions imposed by the […] higher level". These boundary conditions can be treated, as discussed below, as exerting a downward determinative influence on the behavior of a system's parts at a lower level. Figure 2 shows a scheme of the determinative relationships in Salthe's basic triadic system.

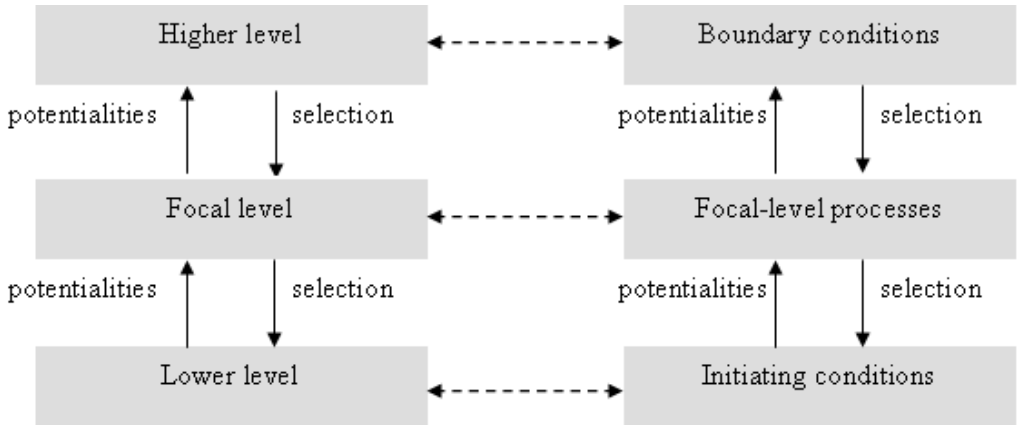


Figure 2: A scheme of the determinative relationships in Salthe's basic triadic system. In a perfectly nested hierarchy, the focal level is not only constrained by boundary conditions established by a higher level, but also establishes the potentialities for constituting the latter. In turn, when the focal level is constituted from potentialities established by a lower level, a selection process is also taking place, since among these potentialities some will be selected in order to constitute a given focal-level process.

For the sake of our arguments, let us begin by taking as the "focal level" that level in which a given semiotic process is observed. Semiotic processes at the focal level are described here as chains of triads. We can treat, then, the interaction between semiotic processes at the focal level, potential determinative relations between elements at a lower level ("micro-semiotic level"), and semiotic processes at a higher level ("macro-semiotic level"). In the latter, networks of chains of triads which embed the semiotic process at the focal level are described.

The micro-semiotic level involves the relations of determination that may take place within each triad S-O-I. The relations of determination provide the way the elements in a triad are arranged in semiosis. According to Peirce, the Interpretant is determined by the Object through the mediation of the Sign (I is determined by O through S) (MS 318:81). This is a result from two determinative relations: the determination of the Sign by the Object relatively to the Interpretant (O determines S relatively to I), and the determination of the Interpretant by the Sign relatively to the Object (S determines I relatively to O) (De Tienne 1992).

At the micro-semiotic level, we consider that, given the relative positions of S, O, and I, a triad $t_i = (S_i, O_i, I_i)$ can only be defined as such in the context of a chain of triads $T = \{..., t_{i-1}, t_i, t_{i+1},...\}$ (see Gomes, Gudwin & Queiroz 2005; Gomes et al. 2003a, b). Semiosis, as the action of Signs, entails the instantiation of chains of triads. As Savan (1986, 134) argues, an Interpretant is both the third term of a given triadic relation and the first term (Sign) of a subsequent triadic relation. This is the reason why semiosis cannot be grasped as an isolated triad; it necessarily involves chains of triads (see Merrell 1995) (see Figure 3).

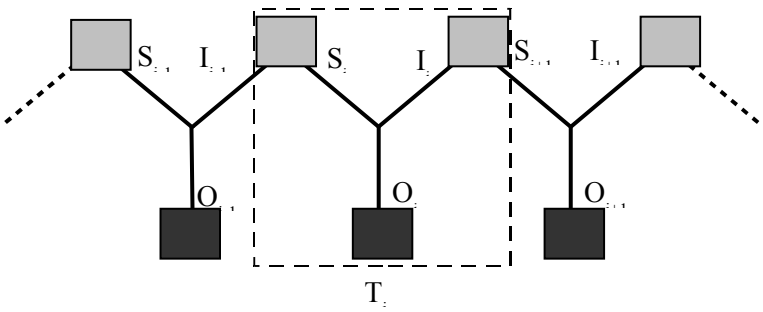

Figure 3: Scheme showing that a triad can only be defined within a chain of triads. The grid at the bottom part of the figure shows that $O_{i-1}$, $O_i$, and $O_{i+1}$ are Immediate Objects of the same Dynamical Object.

In short, given the framework of Salthe's hierarchical structuralism, we should analyze semiosis by considering three levels at a time. Each chain of triads will be located at a focal level, and, correspondingly, we will talk about focal-level semiotic processes. Micro-level semiotic processes will involve the relations of determination within each triad. Macro-level semiotic processes, in turn, will involve networks of chains of triads, in which each individual chain is embedded. Focal-level semiosis will emerge as a process through the interaction between micro- and macro-semiotic processes, i.e., between the

relations of determination within each triad and the embedment of each individual chain in a whole network of Sign processes.

Following Salthe's explanation of constraints, micro-semiosis establishes the initiating conditions for focal-level semiotic processes. To expand more on this issue, we should consider a distinction made by Peirce with regard to the nature of the Object:

> "We must distinguish between the Immediate Object – i.e., the Object as represented in the sign – and [...] the Dynamical Object, which, from the nature of things, the Sign *cannot* express, which it can only *indicate* and leave the interpreter to find out by *collateral experience*" (CP 8.314. Emphasis in the original).

Or else:

> "... we have to distinguish the Immediate Object, which is the Object as the Sign itself represents it, and whose Being is thus dependent upon the Representation of it in the Sign, from the Dynamical Object, which is the Reality which by some means contrives to determine the Sign to its Representation" (CP 4.536).

The Immediate Object of a Sign is, thus, the Object as it is immediately given to the Sign, the Dynamical Object in its semiotically available form. The Dynamical Object, in turn, is something which the Sign can only indicate, something that the interpreter should find out by collateral experience (see also EP 2:498; CP 8.178).

Each chain of triads always indicates the same Dynamical Object, through a series of Immediate Objects, as represented in each triad (see Figure 3). The possibilities of indicating a Dynamical Object are constrained by the relations of determination within each triad. That is, the way O determines S relatively to I, and S determines I relatively to O, and then how I is determined by O through S leads to a number of potential ways in which a Dynamical Object may be indicated in focal-level semiosis, i.e., to a set of *potential* triadic relations between Immediate Objects, Signs, and Interpretants.

We need to consider, thus, the distinction between *potentiality* and *actuality* in the context of our analysis. For this purpose, we introduce the definitions of *potential* Signs, Objects, and Interpretants. A "potential Sign" is something that *may* be a Sign of an Object to an Interpretant, i.e., it may stand for that Object to an Interpretant. A "potential Object" is, in turn, something that *may* be the Object of a Sign to an Interpretant. And, finally, a "potential Interpretant" is something that *may* be the Interpretant of a Sign, i.e., it may stand for that Sign. The micro-semiotic level is the domain of potential Signs, Objects, and Interpretants.

We should consider, then, a whole set *W* of possible determinative relations between these three elements, which can generate, in turn, a set of possible triads. These triads cannot be fixed, however, by the micro-semiotic level, since it establishes only the initiating conditions for chains of triads at the focal level. To fix a chain of triads, and, consequently, the individual triads defined within its context, boundary conditions established by the

macro-semiotic level should also play their selective role. Chains of triads are actualized at the focal level by a selection of those triads which will be effectively actualized amongst those potentially engendered at the micro-semiotic level by networks of chains of triads which constitute a semiotic environment or context. That is, triads are actualized, realizing a specific chain at the focal level, through the operation of two constraints. First, potential determinative relations (*initiating conditions*) at the micro-semiotic level constrain the universe of potential chains of triads, given that the whole set *W* of potential determinative relations between Signs, Objects, and Interpretants is always smaller than the universe *U* of *all* potentially existent triads. That is, given the initiating conditions established at the micro-semiotic level, a given chain of triads realized at time *t* will be among the elements of a set $W = U - x$ of potential chains of triads that might be actualized at *t*.[ii] Then, a second kind of constraint acts on the set *W*, namely the boundary conditions established by the macro-semiotic level, in the context of which a given chain of triads will be effectively realized. The boundary conditions will select, among all the potential chains of triads which could be realized from the set *W* of potential determinative relations *S-O-I*, a specific chain $T_i = \{..., t_{i-1}, t_i, t_{i+1}, ...\}$ to be actualized.[iii]

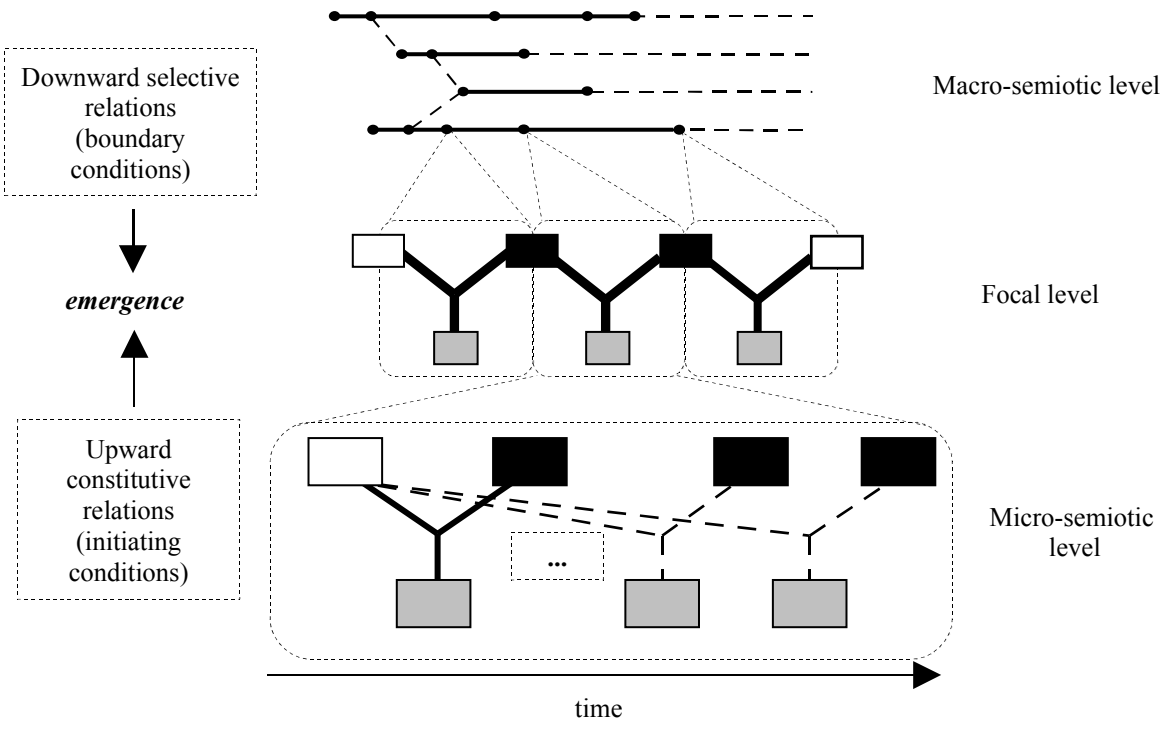


Figure 4: A model of semiosis in three levels. The upward arrow shows the constitutive relation from individual triads to chains of triads, corresponding to Salthe's initiating conditions. The downward arrow shows selective relations from networks of chains of triads to chains of triads, corresponding to Salthe's boundary conditions. For the sake of simplicity, we did not consider all the relations sketched at Figure 2.

It is in this sense that the emergence of semiotic processes at the focal level, in which chains of triads are actualized, is explained in this model as resulting from an interaction between the potentialities established by the micro-semiotic level and the selective, regulatory influence of the macro-

semiotic level. The general ideas involved in this model of semiosis in three levels are shown in Figure 4.

## 2. Answering the questions about semiosis

*What is a semiotic system?*

Let us consider, first, the following question: (1) what is a semiotic system? First of all, we should offer a definition of 'system', in more general terms. A system is usually defined as a set of elements that maintain relations with one another (Pessoa Jr. 1996, p.30). By 'elements' we mean primitive entities which are found at each instant in one among several possible states. Elements establish 'relations' when the state of an element depends on the state of another one.

Some definitions of system include other items, such as Bunge's (1977) definition, in which a system ***x*** is defined by its composition – the set of its components –, structure – the set of relations between its components –, and environment – the set of other systems with which ***x*** establishes relations.

A significantly related but slightly more refined way of defining systems is found in dynamical systems theory, in which systems are conceived as sets of interdependent variables. By "variable" we mean some entity that can change, i.e., that can be in different states at different times – it is obvious that the concepts of "variable" and "elements", as stated here, are quite similar. The state of a system is simply the state or value of all its variables at a given time *t*. The behavior of a system, in turn, consists of transitions between states (Van Gelder 1998, p. 616).

Now we can turn to a definition of what is a "semiotic system". Fetzer (1988) called "semiotic system" a system that produces, transmits, receives, and interprets Signs of different kinds. Such systems can be regarded as the embodiment of semiotic processes (see CP 5.314).[iv] Fetzer considers that what makes a system "semiotic" is the fact that its behavior is "… causally affected by the presence of a sign because that sign stands for something else iconically, indexically, or symbolically, for that system. Those things for which signs stand, moreover, may include abstract, theoretical, non-observable, or non-existent objects and properties, which may be incapable of exerting any causal influence on a system themselves" (Fetzer 1997, p.358).

Semiosis can be defined as a self-corrective process involving cooperative interaction between three components, S-O-I. Therefore, as a straightforward consequence of the nature of semiosis, semiotic systems show self-corrective behavior, or some kind of goal-directed activity (see Ransdell 1977, p.162). They are capable of using Signs as media for the conveyance of a form or the transference of a habit embodied in the Object to the Interpretant, so as to constrain the interpreter's behavior (EP 2:544, n.22; see also EP 2:391, EP 2:477).

*Are semiotic systems exclusively physically constituted?*

A second question concerns the nature of semiotic systems: (2) are they exclusively physically constituted? Semiotic processes can only be realized through physical implementation or instantiation (see Ransdell 1977). Therefore, semiotic systems should be physically embodied (Emmeche 2003). If a Sign is to have any active mode of being, it must be physically instantiated.[v] Peirce considered the material qualities of the Sign as the characters that belong to the Sign in itself: "Since a sign is not identical with the thing signified, but differs from the latter in some respects, it must plainly have some characters which belong to it in itself, and have nothing to do with its representative function. These I call the material qualities of the sign" (CP 5.287).[vi]

*Are semiotic systems new?*

A third question asks (3) whether semiotic systems can be regarded as forming a new class of systems, with new structures, instantiating new properties, processes, behaviors, dispositions, etc. We do not intend here to define where is the threshold beyond which semiotic systems are found in the history of the universe. We assume, for the sake of our arguments, that there was a period in which systems capable of using Signs did not exist. Therefore, even though irreducible triadic relations may have preceded the origins of semiotic systems, we postulate that this class of systems arose in the course of evolution. We consider, then, that before the emergence of semiotic systems, only reactive systems existed, which were not capable of interpreting, and, thus, using Signs. Surely, there were things in the world to which physically embodied natural systems reacted, but these systems were not able to use Signs as media for the conveyance of forms, i.e., they were not interpreters. Nothing but a dynamics of systems and things diadically coupled existed, with no interpretative processes taking place. Given this reasonable set of assumptions, we can say that semiotic systems are a new class of systems, with a new kind of structure, capable of producing and interpreting Signs, and, thus, of realizing semiosis, as a new kind of (emergent) process.

The emergence of the competence to handle Signs changed the dynamics of the evolution of natural systems. After all, we can claim that semiotic systems show modes of evolution not found among merely reactive systems. For instance, living systems which possess Signs in the form of DNA can evolve by a process in which past successful interactions between a system and its environment are represented in Signs which are passed over to the next generations, influencing the future evolution of the lineage to which the system pertains. Furthermore, after the competence to handle Signs, and, thus, instantiate semiosis emerged, the evolution of semiotic systems did not cease, but, rather, new kinds of such systems emerged, operating with different classes of signs (e.g., iconic, indexical, symbolic) and evolving in different manners (see Fetzer 1988, 1997; Queiroz & El-Hani 2004 ).

At first, the idea that semiotic systems constitute a new class of systems seems to be incompatible with a basic feature of Peirce's metaphysical framework, namely synechism. After all, the doctrine of emergence is committed to the idea that the evolution of the universe shows

discontinuities, and synechism is a "tendency to regard everything as continuous" (CP 7.565). According to Peirce (CP 6.169), synechism is "… that tendency of philosophical thought which insists upon the idea of continuity as of prime importance in philosophy and, in particular, upon the necessity of hypotheses involving true continuity."[vii]

We claim, however, that this incompatibility is only apparent, since an emergentist philosophy can be seen as providing precisely a way of overcoming the dichotomy between continuity and discontinuity. Such emergentist philosophy can accommodate, in our view, Peirce's synechism. For instance, Morgan's (1923) Emergent Evolution, regarded by Blitz (1992) as the founding work in the tradition of emergentism, provides an emergence theory that combines the ideas of continuity and discontinuity.

Among the fundamental theses of Morgan's theory of emergent evolution, we find two which are directly consequential to our present discussion: the theses of the co-occurrence of emergents and resultants, and of quantitative continuity and qualitative novelty.[viii] For Morgan, emergent properties were never instantiated at a given level without occurring along with resultant properties, which could be predicted on the grounds of theoretical knowledge about the previous level and conferred continuity to the evolutionary process. Thus, even though emergence concerns the appearance of genuinely new properties that could not be predicted from knowledge about preexistent entities described at a lower level, it does not amount in Morgan's theory to a gap in the evolutionary process. Therefore, it is not in the sense of some sort of leap in evolution, which would be indeed incompatible with synechism, that Morgan put forward the claim of qualitative novelty in evolution. Rather, he conceived qualitative novelty in terms of a qualitative change of direction or a critical turning point in an otherwise continuous evolutionary process. In Morgan's (1923, p.5) own words, "… through resultants there is continuity in progress; through emergence there is progress in continuity."

Consider, also, that it is the very process of gradual and quantitative change of natural systems which creates, in Morgan's framework, the conditions for the qualitative change related to the notion of emergence. This qualitative change, in turn, has the character of a critical turning point because it establishes new kinds of relatedness among pre-existent entities or events, and, thus, changes the mode of evolution of natural systems. It is clear, then, that emergence is related to punctuations in a continuous process, rather than to a mere jump in the evolutionary process.

A number of quotations from Morgan's seminal work on emergence will suffice to show that property emergence is related to critical turning points in which new patterns of organization (and, thus, constraints) are established in the evolution of systems. Morgan characterizes "emergent evolution" as follows: "Evolution, in the broad sense of the word, is the name we give to the comprehensive plan of sequence in all natural events. But the orderly sequence, historically viewed, appears to present, from time to time, something genuinely new. Under what I here call emergent evolution stress is laid on this incoming of the new" (Morgan 1923, p.1). He also states that "... the emergent step [...] is best regarded as a qualitative change of direction,

or critical turning point, in the course of events" (Morgan 1923, p.5). Emergent events are related to the "... expression of some new kind of relatedness among pre-existent events" (Morgan 1923, p.6), and "when some new kind of relatedness is supervenient (say at the level of life), the way in which physical events which are involved run their course is different in virtue of its presence – different from what it would have been if life had been absent. [...]. I shall say that this new manner in which lower events happen – this touch of novelty in evolutionary advance – depends on the new kind of relatedness which is expressed in that which Mr. Alexander speaks of as an emergent quality" (Morgan 1923, p.16; Emphasis in the original).

An emergent property should, therefore, be genuinely new under the sun; it should be closely connected with the appearance of a new kind of relatedness (a new organizational pattern) among pre-existent events or entities, entailing a modification in the way lower-level events run their course, and, thus, some sort of downward determination; and, finally, it should change the mode of evolution, due to the change in the way pre-existent events or processes run their course in the context of that new kind of relatedness.

Morgan's theory does not postulate jumps in the evolutionary process that, given the central role of synechism in Peirce's thought, might spoil any prospect of a joint emergentist and Peircean account, as we are developing here. Rather, his theory – and, by extension, any emergentist philosophy that subscribes to a similar rendering of the relationship between continuity and novelty – explicitly claimed that resultant properties provided a quantitative continuity in evolution, upon which qualitative novelties arose from time to time as changes in the direction of evolution, rather than as saltationist leaps.

An example derived from currently accepted theories about the origins of life illustrates the above arguments. These theories claim that, in the pre-biotic world, a set of physical and chemical processes, collectively known as "chemical" or "pre-biotic" evolution, gave rise to a soup of chemical and physical resources, including complex molecules formed by the polymerization of simpler molecules, thanks to energy sources such as lightnings, UV rays and volcanic eruptions. In that chemical soup, complex organic molecules with synthesis rate greater than their degradation rate accumulated. Nonetheless, nothing lived in that soup, and, if there was something we could call "evolution" (cf. Sterelny 2001, p.17), it would not be the same as biological evolution, since those chemical substances changed through time as individual entities, passing through a sequence of transformational stages. In short, the kind of change observed in that chemical soup was a transformational, not a variational process (Lewontin 1983), as in the case of biological evolution.

But, in that transformational evolution, a gradual and quantitative change was taking place, in which polymers were becoming more and more complex, by the addition of a growing number of monomers. The continuous transformational evolution of polymers established the conditions for a qualitative change or critical turn in evolution, when it gave rise to a particular kind of molecule, which was something genuinely new under the sun. That molecule was a replicator, which came into existence by chance,

through the gradual quantitative increase in the complexity of pre-biotic polymers. A replicator, as defined by Dawkins (1976), is a molecule that shows the extraordinary property of making copies of itself, or, in more general terms, it is any structure that in the right environment can act as a template for its own copying (Sterelny 2001). A current influential hypothesis about the nature of the first replicators states that they were molecules analogous to RNA, possessing both a genetic memory and an enzymatic activity related to their own replication.

The origin of the first replicator qualifies as an emergent event, given the conditions drawn from Morgan's seminal work. As Sterelny (2001, pp.17-18) writes, "the formation of the first active replicator is a world-shaking event. It is truly something new under the sun, for it introduces natural selection and hence evolution in the world".[ix] The appearance of the first replicator involved the instantiation of a new kind of relatedness among preexistent monomers, and changed all future evolution, introducing a new kind of evolutionary process in the world, variational evolution, based on natural selection. This change in the nature of evolution was related to two emergent properties of replicators, the property of being an enzyme and the property of being a template for its own replication. These properties were as new as the replicators themselves and were related to the way pre-existent processes took place in the context of the new kind of relatedness that characterized those molecules.

In this account, we find no leap which might be incompatible with Peirce's synechism. Rather, the very qualitative change we perceive in the origins of replicators is described as a product of gradual quantitative change. Symptomatically, Morgan (1923, p.7) argues both for a "resultant continuity between the not-living and the living", the value of which "no evolutionist is likely to under-estimate", and for a qualitative novelty which is not incompatible with such continuity: "But one may still ask whether there is not at some stage of this process a new emergent character of life […]. There does seem to be something genuinely new at some stage of the resultant continuity" (Morgan 1923, p.7).

We hope these arguments are enough to show that there is no necessary contradiction between Peirce's doctrine of synechism and an emergentist philosophy. We can speculate that the competence to handle Signs appeared in the evolution of systems as a product of a continuous process. Nevertheless, when semiotic systems appeared, they exhibited a way of behaving which was significantly different from that of reactive systems, as they could go beyond a mere coupling to their circumstances, being able to interpret them. It is reasonable to suppose, then, that that difference in behavior entailed a distinct mode of evolution in the case of semiotic systems, as compared to reactive systems. Thus, we can hold that a qualitative change, a critical turn in evolution, took place with the appearance of semiotic systems. After all, a system which is capable of interpreting the world through the mediation of Signs evolves in a manner which is determined by the fact that they are capable of using Signs to obtain information about the environment in such a way that those Signs perform functions favoring their survival and/or reproduction (Emmeche 1997).

*Is semiosis a systemic process?*

We should turn now to our fourth question: (4) can semiosis be regarded as a systemic process? Consider, first, that according to the model developed above the actualization of potential chains of triads depends on boundary conditions established by a macro-semiotic level amounting to networks of chains of triads. It is possible to conceive of the macro-semiotic level as corresponding to the whole semiotic system, based on the idea that the latter can be treated as the embodiment of semiotic processes. Therefore, although semiosis is instantiated at the focal level, it should be understood as a systemic process, given that the macro-semiotic level establishes the boundary conditions required for its actualization. To put it differently, the very instantiation of semiosis at the focal level depends on a constraining influence from the semiotic system as a whole (i.e., the macro-semiotic level).

As to the fifth question – (5) How should we describe the levels in a semiotic system –, section 1, above, can be seen, as a whole, as an answer to it.

*Is semiosis synchronically determined by the properties and arrangement of the parts in a semiotic system?*

Sixthly, we asked: (6) in what sense can we say that semiosis, as an emergent process, is synchronically determined by the properties and arrangement of the parts in a semiotic system? In our hierarchical model, semiosis is located at the focal level, instantiated as chains of triads, while individual triads are situated at a lower level, and networks of chains of triads, at a higher level. Therefore, while considering the idea of synchronic determination, we have to focus our attention on the relationship between chains of triads, at the focal level, and individual triads, at the micro-semiotic level.

Semiosis is described by Peirce as a pattern of determinative relationships between functionally specified correlates. We consider, here, that this description entails the idea that semiosis is synchronically determined by the microstructure of the individual triads composing a chain of triads, i.e., by the relational properties and arrangement of the elements S, O, and I.[x] There cannot be any difference in semiosis without a difference in the properties and/or arrangement of S, O, and I. The arrangement of the elements S-O-I is specified by the triadic relations of determination between them. Otherwise, it would be a mere juxtaposition of three elements (see CP 1.371, 1.363; see Brunning 1997).

The properties of S, O, and I are relational because these elements are engaged in irreducibly triadic ordered relations. As Savan (1987-88, p.43) writes, “the terms interpretant, sign and object are a triad whose definitions are circular. Each of the three is defined in terms of the other two.” In fact, the only property of S, O, and I, as functional roles, is to be in a specific position in an irreducible triadic relation to one another, namely to be the first, the second, or the third terms in such a relation (see De Tienne 1992).

One should also consider the modal strength of the relation of synchronic determination between chains of triads and triads. We will consider here four standard possibilities (see Bailey 1999): (i) weak necessity, in which the determinative relation holds in the actual world, but need not hold in any other possible world; (ii) Natural, or physical, or nomic, or nomological necessity, in which the determinative relation holds in the actual world and in all naturally possible worlds, which can be described, very roughly, as all worlds in which the physical laws sufficiently resemble actual laws; (iii) Metaphysical necessity, in which the determinative relation holds in the actual world and in all metaphysically possible worlds, which comprise all worlds where *a posteriori* necessary truths (such as "water is H2O") hold; and (iv) Logical necessity, in which the determinative relation holds in the actual world and all logically possible worlds, roughly, those where *a priori* necessary truths hold – this is the set of all possible worlds.

In the case of semiosis, we propose that the determinative relations between the elements of individual triads, as well as between triads, in a chain of triads, hold with logical necessity.[xi] Initially, consider that the demonstration that S-O-I constitute an indecomposable relation should be first carried out logically (see Houser 1997, p.16). The reason for the precedence of a formal treatment of relations over the empirical and metaphysical treatments lies in the fact that only formally one can perform an analysis of the properties of completeness and sufficiency of Peirce's categories (Parker 1998, pp.3, 43). It is only subsequently that the property of logical irreducibility should be checked in the empirical and metaphysical domains. The precedence of the logical treatment has methodological consequences. An analysis of the formal properties, in contrast with the material properties[xii], should precede any empirical or metaphysical investigation of the categories. In other words, a logical-mathematical analysis of the categories should be previous to any formulation in the domains of phenomenology, normative sciences, and metaphysics[xiii], which employ mathematical techniques and results to validate the categories established by the logic treatment of relations (see Hookway 1985, p.182; Parker 1998).

Therefore, in our discussion about the modal strength of the relation of synchronic determination between chains of triads and triads, we will begin with a logical treatment of the relations between the elements of semiosis. We will focus our attention, first, on the functional roles of S, O and I, as established in a logical analysis of their relations.

The functional roles of S, O and I are logically determined in each triad, as regards both the relationships within a triad and the constitution of chains of triads. Therefore, these determinative relations hold with logical necessity: in a world substantially different from the actual world in its physical laws, i.e., a world nomologically distinct from the actual world, the logical relationships between S, O and I would still be the same.

If we are right in our arguments, then these relations hold in the set of all possible worlds, provided that the conceived world allows the existence of physical entities or processes. After all, there is an important constraint for

something to be a semiotic system, namely that it should be physically embodied (see above). This does not mean that the determinative relations between S, O, and I in a semiotic process might be only nomologically valid, but rather that any logically conceivable world in which semiosis can take place is a world in which natural laws allow the existence of physical entities or processes, which are a necessary condition for semiosis. In any such world, then, the determinative relations between S, O and I hold with logical necessity. If we suppose, for the sake of our argument, that there are logically conceivable worlds where no physical entities or processes are present, it will be simply the case that such worlds will not show any semiotic process or system, and, thus, no determinative relation at all between the elements involved in semiosis will take place there.

In the empirical domain, in turn, we should focus our attention not only on the functional roles of S, O and I but also on how these functional roles may be embodied, and how the relations between them may be instantiated in the actual world. In this case, notice that while the functional roles are logically determined, the occupants of the functional roles of S, O and I are contingent. For instance, that the word "elephant" is a Sign for that big animal in the world can be treated as a contingent fact; that is, it is not logically necessary that the word "elephant", as an occupant of the functional role of a Sign (S), stand through the Interpretant (I) for that big animal, the occupant of the functional role of the Object (O) in the example at stake. But the determinative relationships between these elements are logically determined, and, consequently, are also the functional roles of S, O, and I. Thus, in a world sufficiently distinct from the actual world in its physical laws, entirely different entities or processes might be playing the functional roles of S, O, and I in distinct semiotic systems. We can conclude that the fact that a given class of entities or processes plays a functional role in a semiotic process holds with nomological rather than logical necessity, even though the functional role itself holds with logical necessity.

*In what sense is semiosis irreducible?*

Among the several properties related to semiosis (processuality, CP 5.484; irreversibility, CP 5.253, 5.421; continuity, MS 875, see also Parker 1998, p.147; tendency to the infinitum, CP 2.92, 2.303; vagueness, CP 5.447; generality, CP 6.172, see Potter 1997, p.89; regularity; growth; lawfulness), we can say that the relational irreducibility of the triad is one of the most, if not the most, important. Thus, the next question (7) is particularly important, since it concerns the interpretation of the principle of the irreducibility of semiosis. The semiotic triadic relation is regarded by Peirce as irreducible, in the sense that it is not decomposable into any simpler relation:[xiv]

> "... by 'semiosis' I mean [...] an action, or influence, which is, or involves, a cooperation of three subjects, such as a sign, its object, and its interpretant, this tri-relative influence not being in any way resolvable into actions between pairs" (CP 5.484).

As Peirce carefully discusses the irreducibility of triads, we will consider in the following arguments what we defined above as the micro-semiotic level. We will argue, first, that the semiotic relation is not irreducible because the

condition of analyzability is violated. Peirce would accept, in our view, that from the behavior of the elements of a triad it must follow the properties the triad possesses, including the very property of being semiotic. If we know the relations in which any three elements are involved, then we will be able to know also whether the process in which they are engaged is semiotic, since we will know whether or not the elements play the logical-functional roles of S, O, and I. To put it differently, non-analyzability or what Boogerd et al. (2005) call the vertical condition for emergence is not the reason why we should consider, in a Peircean framework, semiosis as an irreducibly triadic relation.

We can understand why a semiotic relation is irreducible, in a Peircean framework, on the grounds of the second notion of irreducibility discussed in the previous lecture, based on the non-deducibility of the behavior of the system's parts. In this case, we should show that the specific behavior of the elements of a triad does not follow from the elements' behavior in simpler relations. We think that semiosis can be even regarded as the best example of a class of relations in which this second condition for reducibility is violated, since the behavior of the elements of a semiotic relation does not follow from the behavior they show in isolation or in dyadic relations.

The functional roles of the elements in a semiotic relation cannot be identified in structures simpler than a triadic relation. The functional role of S can be identified only in the mediative relation that it establishes between O and I. Similarly, the functional role of O is identified in the relation by which it determines I through the mediation of S. And, finally, the functional role of I is identified by the fact that it is determined by O through S. Therefore, if we consider only dyadic relations, S-I, S-O, or I-O, or the elements of a triad in isolation, we cannot deduce how they will behave in a triadic relation, S-O-I (EP 2:391). Therefore, the irreducibility of semiosis should be understood in terms of the non-deducibility of the behavior of the elements of a triad, in the logical-functional roles they play in semiosis, on the grounds of their behavior in simpler relations. Or, to put it differently, rather than the vertical, the horizontal condition for emergence (Boogerd et al., 2005) holds in the case of semiosis.

*Is downward determination involved in semiosis?*

We will turn, now, to another question about the understanding of semiosis as an emergent process: (9) can we describe any sort of downward determinative relation in semiosis?

It is very interesting to discuss the problem of downward determination in the context of Peirce's philosophy, since, as Hulswit (2005) remembers, Peirce himself may have been the first to suggest that downward causation can be regarded as a sort of formal causation (see EP 2:115-32). Even if we move here from downward causation to downward determination, Peirce's contribution to the current debates on this issue is still very relevant, since the problem of the influence of wholes over parts is addressed in a more consistent way in terms of dynamical interactions between processes at different levels. In Hulswit's words, it "… requires an ontological framework

that breaks through the constraints imposed by the Western 'substance addiction'. Indeed, it should do full justice to the primacy of processes and events, along the lines of suggestions made by C. S. Peirce and A. N. Whitehead" (Hulswit, 2005).

If we consider, first, the relationship between the macro-semiotic level and semiosis at the focal level, we can argue that it involves a determinative downward relation. More specifically, as the model presented in section 1 shows, downward determination in semiotic phenomena can be conceptualized as boundary conditions which select, among the potentialities established by the micro-semiotic level, those semiotic processes which will be actualized at a given time *t*.

If we focus, rather, on the relations between elements within a triad, then we will be able to see that, in a precise sense, Signs, Objects, and Interpretants constrain each other's behaviors. Moreover, a Sign can be defined as a medium for conveying the form of an Object to an Interpretant. It seems, thus, that an interpretation of downward determination in terms of formal constraints applies smoothly to the determinative relations in triadic-dependent processes. Surely, a proper interpretation of downward determination in semiotic phenomena demands more elaboration. We shall leave, however, this issue for future works.

*Is the structure of semiotic systems or processes unpredictable?*

The last question we should discuss is the following: (8) is the structure of semiotic systems or processes in principle theoretically unpredictable?

The structure of triads and chains of triads can be indeed regarded as unpredictable, since Peirce advocated that indeterminism, spontaneity, and absolute chance are fundamental factors in the universe. Thus, the behavior of the elements in a semiotic process is also unpredictable from the behaviors they may exhibit in simpler systems. In a Peircean framework, we can claim, thus, that semiosis is a process the structure of which is in principle unpredictable due to the indeterministic nature of the evolutionary process. This argument is grounded on the Peircean thesis of tychism, the metaphysical defense of "absolute chance" as a real factor in the universe (see Murphey 1993, Potter 1997). Tychism plays an essential role in Peirce's account of cosmological evolution, to the extent that he regards it as the only explanation of the multiplicity and irregularity found in the universe.

The most important point for our arguments here is that, according to a Peircean evolutionary cosmology, everything should be explained as a product of an evolutionary process which has states of indetermination and chance as its starting points. In a paper about tychism and mental processes, Pape (2002, p.226) comments that "matter, time, space, and the laws of nature themselves – they all have to be explained as emergent regularities of interaction arising from a state of indeterminateness". This suggests, once again, the compatibility of emergentist thought with central doctrines in Peirce's metaphysics, as synechism and tychism.

Consider, moreover, that Peirce's categories constitute a system of necessary presupposition (see Hausman 1993, p.97), and, thus, it is impossible to conceive thirdness without secondness, and secondness without firstness. Therefore, as firstness entails indetermination, novelty, independence, and, consequently, unpredictability, the latter becomes a necessary component also in thirdness, and, thus, in semiosis.

The arguments developed here lead to the conclusion that a strong emergence theory can be supported in the case of semiotic phenomena. In conformity with Peirce's theory of Signs, this theory should include (1) a concept of irreducibility based on the non-deducibility of the behavior of Signs, Objects, and Interpretants in semiotic relations from their possible behaviors in simpler relations, and (2) a concept of in principle theoretical unpredictability of the structure of semiotic processes, based on the doctrine of tychism.

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*Next lecture (Semiotic systems): In the next lecture we introduce James Fetzer's notion of semiotic system and explore biological examples of his conception.*

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[i] The regulation of a focal-level process by higher-level boundary conditions is interpreted here as a kind of selective process. Suppose that the causal relation between a given element of a system, *A*, and another element of the same system, *B*, is regulated. This is understood, in this framework, as the selection of *B* as the most probable effect of *A*, among other possible effects, by boundary conditions established by a level higher to the level where the causal relation at stake is taking place. This is connected with ideas found in Polanyi (1968) and Campbell (1974), and is also related to the problem of downward causation.

[ii] The term "*x*" indicates a set of potential chains of triads which *cannot* be actualized at *t*, given the set of potential Signs, Objects, and Interpretants at stake.

[iii] Even though we will not pursue this issue in this lecture, we should emphasize that there is a clear correspondence between the hierarchical structure proposed by Salthe and Peirce's categories. The micro-semiotic level – at which processes relating S, O, and I are initiated – gives Sign processes an inevitable character of indeterminacy. It is straightforward, then, to associate the micro-semiotic level with firstness. Salthe himself stresses that this level exhibits a fundamentally stochastic behavior. At the focal level, specific, particular processes are spatiotemporally instantiated, as *tokens*, which are cases of secondness. The macro-semiotic level, in turn, gives Sign processes their *generality* and *temporality*, making them historical and context-dependent. We can say, thus, that the macro-semiotic level shows the nature of thirdness. The stochastic behavior at the micro-semiotic level establishes *potentialities* for the particular Sign processes that are instantiated at the focal level. These potentialities are not the same as mere *possibilities*. For the sake of our arguments, consider Peirce's treatment of Quality as a "mere abstract potentiality" (CP 1.422). Quality has the nature of firstness, being essentially indeterminate and vague. But we can also talk about a generality of Quality. In this case, we are beyond the realm of pure firstness, since generality refers to some law-like tendency, and thus shows the nature of thirdness. Peirce works, in this case, with a merging of firstness and thirdness. It is in this latter sense that we understand potentialities at the micro-semiotic level here, as a particular set of potential Signs, Objects, and Interpretants which have been established due to the fact that the micro-semiotic level is embedded in a hierarchical system which includes levels showing the nature of secondness and thirdness (focal and macro-semiotic levels, respectively). These potentialities show, thus, the nature of a generality, being closer to a merging of firstness and thirdness, than to pure firstness. Such a treatment seems to be compatible with Peirce's categoreal scheme, since, as Potter (1997, p. 94) stresses, "the categoreal structure which Peirce uses is […] highly subtle and complex, admitting of various combinations".

[iv] Notice that by characterizing a semiotic system as an embodiment of semiotic processes, we are blurring the distinction between entities and processes. This can be justified on the grounds of an understanding of entities as relatively stable bunches of processes. It is not the case that a process philosophy should necessarily claim that the idea of entities or things has to be abandoned. It can rather claim that processes should be treated, in a dynamic world, as more fundamental than things, since "… substantial things emerge in and from the world's course of changes…" (Rescher 1996, p. 28). This is a suitable basis for process philosophy as a tendency to address philosophical issues which is committed to the idea that reality is best understood in terms of processes. In this framework, substances are conceptually and ontologically subordinated to processes. The fact that we give privilege to processes entails that, when we talk about things, we should bear in mind all the time that they emerge from processes, change all the time through processes, and subsequently vanish into processes.

[v] At first, it may seem that qualisigns refute this idea, since they consist in qualities which are Signs, but may not be physically instantiated. But a qualisign only functions as a Sign if physically instantiated in a sinsign (see CP 2.244). It is important to take in due account that we assumed above that physical instantiation is necessary for the active mode of being of a Sign. It is the case, then, that a qualisign can only be active when it is physically instantiated in a sinsign. The idea of a "potential Sign", i.e., that an entity or a process is a Sign if it is potentially capable of producing Interpretants, does not create difficulties for this view too, since a system should be physically embodied even to potentially show semiosis. According to the model developed above, if a semiotic system has the potentiality of showing a given semiotic process, it can only have this potentiality if it is a physically realized system which can establish boundary conditions for the actualization of that potential semiotic process. If we claim that a Sign can exist as a potential entity or process, we should be committed to the idea that, given a set of conditions {*a*, *b*, *c*,…,*n*}, that Sign would be capable of engaging in semiosis, producing Interpretants. It remains potential while those conditions are not fulfilled. Whenever those conditions are fulfilled, that Sign will turn from potentiality to actuality. As this can only happen, according to the model presented here, when boundary conditions guide the actualization of the Sign, and boundary conditions, in turn, are established in physically embodied systems, then, even as potentiality, the action of Signs presupposes physically extended systems.

[vi] Notice that, even if one assumes that there can be semiosis before the emergence of semiotic systems, the Sign processes at stake would still have to be physically instantiated or realized in one way or another, since Sign processes are relationally extended within the spatiotemporal dimension no matter if they involve semiotic systems or not.

[vii] For further discussions about synechism, see Parker (1998), Potter (1997), Murphey (1993).

[viii] See Morgan (1923), Blitz (1992). The theses were named by Blitz.

[ix] We would rather say 'variational evolution'.

[x] To understand our argument in a clear way, it is very important to avoid conflating synchronic with diachronic determination. We claim here that a Peircean framework accommodates a thesis of synchronic determination, while denying any claim of diachronic determination.

[xi] Notice that while discussing the logical relations between elements and triads, we are working in the domain of Speculative Grammar, the study of the "general conditions of signs being signs" (CP 1.444). For Houser (1997: 9), "the logician who concentrates on speculative grammar investigates representation relations (signs), seeks to work out the necessary and sufficient conditions for representing, and classifies the different possible kinds of representation."

[xii] The distinction between material and formal properties was clearly established by Peirce after 1885 (see Kent 1997, p. 448).

[xiii] For an introduction on phenomenology, normative sciences, and metaphysics, see De Waal (2001), Parker (1998).

[xiv] About the demonstration of the irreducibility of a triadic relation, see Ketner (1986); Brunning (1997); Burch (1991, 1997).