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BIOSEMIOTICS AND SELF-REFERENCE FROM PEIRCE TO ROSEN

Eliseo Fernández
Linda Hall Library of Science and Technology
5109 Cherry St.
Kansas City, MO 64110, USA
fernande@lindahall.org

ABSTRACT

This paper continues and extends previous work on the functions of **self-referential** relational structures and processes in the articulation of semiotic ideas and hypotheses within biological theory. The inquiry explores the various ways in which self-referential loops are tacitly embedded in the interplay of some of the most basic and foundational notions of biosemiotics — notions ordinarily conveyed through the informal use of such terms as **signification**, **information** and **purpose**.

The examination proceeds by proposing a new way of understanding Peirce's account of the triadic nature of semiosis. The manifold correlations that link representamens to their objects and interpretants are clarified through the disclosure and articulation of the implicit function of self-referential relations in semiotic action. These ideas are initially discussed at the level of human language and are subsequently generalized to the level of biosemiotics. This generalization is reached by considering how the disclosed correlations can be partially extended to the sphere of those basic semiotic transactions that obtain within and between organisms and among organic systems in general.

In a separate section there follows a brief account of the explicit role of self-referential processes in Robert Rosen's modeling of organisms in terms of non-formalizable circularity, as clarified and expanded in a recent revival of his ideas through the work of several authors. The triadic structures within semiotic transactions and those arising in Rosen's (M,R)-systems are compared.

Finally some realizations springing from the preceding discussions are pointed out. One is the need to integrate the conceptual restructuration sought by biosemiotics into a wider conception of natural philosophy – into a view that is receptive to new epistemic insights disclosed by current physics and mathematics. Another advances a heuristic strategy for reaching that goal.

INTRODUCTION

My presentation is a draft for a future article and a provisional report of work in progress on the theme of self-reference and biosemiotics. It offers a continuation and extension of ideas communicated at the 2007 Gatherings conference. That contribution, with a few improvements and expansions, will appear in print as *Signs and Instruments: The Convergence of Aristotelian and Kantian Intuitions in Biosemiotics,* in a forthcoming issue of the journal *Biosemiotic*s. In order to make this presentation self-contained I will briefly summarize some of the tenets advanced in that paper, in so far as they serve as an introduction to ideas I will be elaborating thereafter.

Self-reference. Self-referential loops are often met in contemporary biosemiotic works and in theoretical biology generally. Terms used to describe them are usually marked by the presence of the prefixes *auto-* and *self-* (e.g. autonomy, autopoiesis, autocatalysis, self-organization, self-replication, etc.). It is my contention that in Peircean semiotics self-reference must be considered intrinsic to sign action (semiosis), given that every sign must simultaneously represent its object and the very relation of representation that ties it to that object. The triadic relation of representamen, object and interpretant must therefore include a self-referential loop in its constitution. We are thus led to explore the possibility that semiosis may be constitutive of the ubiquitous self-referential structures encountered in biosemiotics.

Similarities between biosemiotics and quantum physics. There are striking parallels in the historical rise and epistemic novelties of quantum physics and biosemiotics, which are due in part to their common acknowledgement of the role of self-referential loops in gaining epistemic access to their respective objects. In both cases the need for a sweeping overhaul of the established ("classical") conceptual framework was reluctantly recognized and carried out only after repeated failures to accommodate within it some new and unexpected empirical discoveries. In quantum physics phenomena such as the "ultraviolet catastrophe" and the photoelectric effect necessitated the introduction of Planck's

quantum of action. This subsequently ushered in a general reformulation and generalization of the classical conceptions.
In biosemiotics the discovery of the organic codes at midcentury necessitated the non-eliminable introduction of semiotic terminology into biology, beginning with the term “code” itself. This unintended change in terminology led to the recognition of the central role of semiotic transactions in biological phenomena. We will later explore the common roots in self-reference for this historical parallel.

Reincorporation and updating of suppressed Aristotelian notions. Some concepts used to articulate basic biological intuitions in the Aristotelian tradition were sacrificed to satisfy the needs for idealization and mathematical manipulation at the inception of classical physics. There is now a need to reincorporate some of these notions (e.g. forms, non-efficient types of causation, etc.) in new versions compatible with current scientific views. Some connections between this proposed revival and the issue of self-reference will be mentioned later in relation to the work of Robert Rosen.

FROM ANTHROPOSEMIOTICS TO BIOSEMIOTICS AND BACK AGAIN

Among the many things we owe to Thomas Sebeok is a clear distinction of the nested domains of biosemiotics, zoosemiotics and anthroposemiotics. In an obvious, extensional sense this is a list of diminishing generality corresponding to the concepts of organism, animal and human. In another, intensional sense, the levels of generality are reversed—for instance, in analogy to the hierarchy of the natural, rational and real numbers. The extensional sense corresponds to the chronological order of evolution and increasing complexity. The intensional sense corresponds to the increasing conceptual depth associated with the need for incorporating the novelties arising at each consecutive evolutionary transition. Consequently, the meaning of the term “organism” becomes increasingly richer and our understanding of bacteria benefits from ideas originally forged to deal with complex organisms and vice versa.

Our investigations must start by force at the level at which we find ourselves situated in the scale of things. As physicists we started with the bulky aggregates of atoms (classical objects) which we are naturally endowed to experience and conceptualize. Only later, armed with concepts and theories designed to deal with these familiar objects, through a tortuous intellectual process, were we able to transform and generalize those very ideas so as to deal with the cognitively remote and counterintuitive properties of atoms and quanta.

Likewise, as semioticians we start from our situation as anthroposemiotic organisms naturally endowed with the means to communicate with other humans and to model the surrounding world by means of those complex symbolic structures we call language and culture. These structures, arguably the most complex and recent forms of reality known to us, are the source of our basic intuitions regarding signs and communication. We have to start with words and gestures just as the physicists had to start with cannon balls and planets. Semiotic transactions within and between bacteria may prove as remote from anthroposemiotics as are photons and electrons from classical physics. The task of going from one to the other may be equally arduous. But the outstanding success of our physicist colleagues should reassure us that such a journey is feasible and within our present or future powers.

The journey from anthroposemiotics to biosemiotics was initiated by Peirce. In a 1908 letter to Lady Welby, towards the end of his intellectual career, Peirce tried one more time to convey a clear definition of the term “sign”:

> "I define a Sign as anything which is so determined by something else, called its Object, and so determines an effect upon a person, which effect I call its Interpretant, that the latter is thereby mediately determined by the former. My insertion of "upon a person" is a sop to Cerberus, because I despair of making my own broader conception understood." (Hardwick 2001, 80-81.)

A manuscript written two years earlier declares:

> "For the purposes of this inquiry a *Sign* may be defined as a Medium for the communication of a Form. It is not logically necessary that anything possessing

> consciousness, that is, feeling of the peculiar common quality of all our feeling should be concerned. But it is necessary that there should be two, if not three *quasi-minds*, meaning things capable of varied determination as to forms of the kind communicated." (MS 793:1 in Peirce 1998, p.544)

These are clear indications that Peirce was struggling to generalize the notion of sign by removing unnecessary anthroposemiotic shackles. We need to travel much further to locate those quasi-minds or "things capable of varied determination as to forms of the kind communicated." I suggest that we do so by embarking on a program for articulating clearly Peirce's inchoate allusions to "forms" and self-reference. To achieve this goal I believe we must place and develop his ideas within the context of some new discoveries— unknown to him—in biology, physics and mathematics of the 20th century.

SELF-REFERENCE: GOING BEYOND PEIRCE

We can attempt to gain some new insights into the functions of self-reference by returning briefly to the parallels between the conceptual restructurations demanded by biosemiotics and those elicited by quantum physics. The results of measurements in classical physics were considered independent both of the cognitive operations involved in obtaining them and of the instrumental context through which those operations are performed. In contrast, the conceptual core of quantum physics is shaped by the dual contextual constraints of Bohr's complementarity:

> "...evidence obtained under different experimental conditions cannot be comprehended within a single picture, but must be regarded as *complementary* in the sense that only the totality of the phenomena exhausts the possible information about the objects."
>
> … "However far the phenomena transcend the scope of classical physical explanation, the account of all evidence must be expressed in classical terms." (Bohr 1949: 209.)

These contextual dualities, one epistemic and the other semiotic, arise through the necessity of applying the physical theory not just to the objects under investigation but also to the very artifacts used to carry out the investigation. These are the instruments used to supply the theory's input data and test its predictions. The self-referential loop issues from the fact that we have no possible access to the quantum entities themselves except as they reveal their properties through the effects of their energetic interactions with the instruments — whose design and reliability are based on the classical conceptions. The strong analogies between these constraints and the limitations induced by self-reference on the descriptive, inferential and computational powers of logical and mathematical formalisms was studied by Maria Luisa Dalla Chiara in the 1970's (see e.g. Dalla Chiara 1977) and are central to some interpretations of quantum mechanics arising at present, including Carlo Rovelli's relational interpretation (Laudisa F., Rovelli C. 2008).

Both in the case of physics and that of mathematics these realizations—which first appeared as purely negative and limiting results—turned out to be the key to reaching extraordinary new insights and for opening unsuspected new realms of investigation in physics, mathematics and computer science. Linguists and ordinary semioticians are engaged, just as much as meta-mathematicians are, in the study of sign structures. Moreover, they must think and communicate about them by means of the very signs which are the object of their research. Biosemioticians, on the other hand, are organisms facing an even more demanding self-referential task. We must use the super-specialized signs (e.g., symbols, diagrams) of human manufacture to model the most basic and biologically universal semiotic structures and transactions. These in turn, through the agencies of biological and cultural evolution, are the roots of the protracted processes that eventually gave rise to human language and culture. I think it is reasonable to assume as a working hypothesis that the study of the successful solutions to their self-referential conundrums by physicists and mathematicians could reveal logical pathways leading to analogous success in our discipline. I

hope to explore and report in future work the results of pursuing further these analogies in biosemiotics.

BRINGING TOGETHER PEIRCE AND ROSEN

Robert Rosen's work in theoretical biology, mostly ignored until recently, seems to be having a revival through the work of many current authors, such as Letelier, Cornish-Bowden, Mikulecky, Louie, and others. Recently an entire issue of the Journal *Chemistry and Biodiversity* was dedicated to Rosen's work[1].

Since it appears that Rosen was not influenced directly by Peirce in any way, it seems quite remarkable that they both share and pursue some of the same unpopular views. Among these views we find the need to rehabilitate some Aristotelian intuitions about causality, the drive to find inspiration in mathematical ideas to solve problems across all disciplines (including biology) and the rejection of the taboo of impredicativity.
Because of its relations to the paradoxes of set theory, the type of self-reference called impredicativity was the *bête noir* of logicians and mathematicians in the first half of the last century. Impredicative definitions, in particular, were to be avoided at all costs. These are definitions in which the *definiendum* appears again in the *definiens*. Later on it was realized that they are unavoidable in mathematics. Computer scientists are presently busy putting impredicative structures to good practical use.

Peirce's definitions of the sign are all impredicative, as signs are defined in terms of other signs. It will be very interesting to uncover the relations between impredicativity and triadicity.

Since some of Rosen's basic insights refer to the effects of self-referential circularity in cellular metabolism and maintenance, it may prove enlightening to try to connect them to our reflections. Perhaps the most far reaching of these is

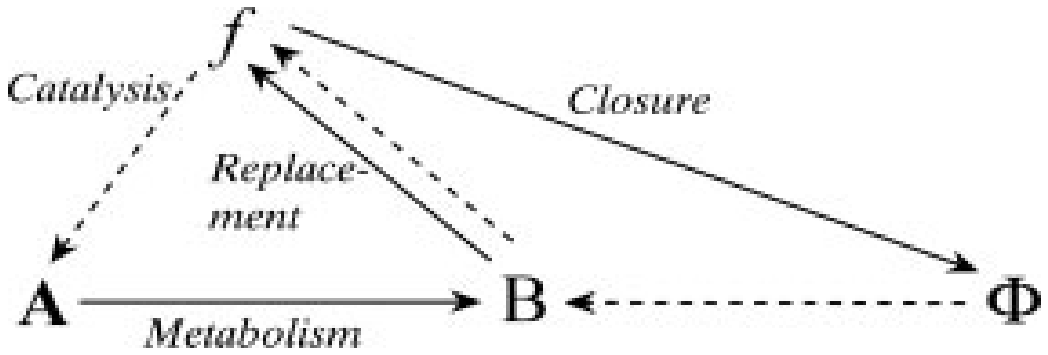
his conception of the organism as a system closed to efficient causation. The gist of the matter has been cogently stated by Arno Goudsmit (Goudsmit 2007):

> Rosen's most impressive achievement is his description of the living organization as one in which all relations of efficient causation are produced internally. Unlike a machine, there is no way to decompose an organism into disjoint physical parts that match with the system's functional units. Rather, in a living system, there is an entanglement of processes and processes that regulate other processes, such that a single physical process may function at various logical levels simultaneously. Such entanglement, when described in formal terms, boils down to an impredicativity: there is eventually no way to keep a distinct track of logical levels. That is: any hierarchical relation between these levels is merely local. More globally seen, these logical levels are not arranged hierarchically, but circularly. Thus, an arrangement is envisaged between component parts, yielding a closed loop of mutual specifications.

Goudmit's rendering of Rosen's central idea, with its accent on local hierarchy and mutual specification, suggests a remarkable parallel to the equally remarkable Kantian intuition of organisms as "natural ends": self-organized structures driven by circular and reciprocal causation:

> …In such a product of nature each part is conceived as if it exists only through all the others, thus as if existing for the sake of the others and on account of the whole, i.e., as an instrument (organ) […] it must be thought of as an organ that produces the other parts (consequently each produces the others reciprocally) […] only then and on that account can such a product, as an organized and self-organizing being, be called a natural end. (Kant 2000, §65, 245.)

Using geometrical diagrams and graphs, algebraic notation and concepts from category theory, Rosen strove to disclose the relational structures that characterize living systems. One such characterization has recently received considerable attention, improvement and development: the schema of metabolism-replacement or (M, R)-systems.



(Adapted from Cornish-Boden *et al*. 2007, p. 842)

The diagram demonstrates how enzymes that catalyze metabolism *are themselves products of metabolism* and that the self-referential closure may be represented by the expression:

$$\beta (f) = \Phi$$

Here **β** stands for the action of the metabolites **B** on the enzymes **f,** and **Φ** is the replacement (repair) mapping. Using mathematical symbolism in a sort of metaphorical way (not allowed by standard mathematical syntax) Letelier *et al*. (2006) rewrite this formula as:

$$\mathbf{f\,(f) = f}$$

In this expression self-referential circularity is represented by a function (mapping) that maps an instance of itself onto another instance of itself.

A comparison of Peirce's sign systems with Rosen's (M,R) systems yields the following communalities: 1) they are both systems of triadic relations, 2)

they irreducibly involve self-referential loops, 3) some of the relata are themselves relations, and 4) some of the relata are not things but temporal processes unrepresentable in purely spatial terms.
There is also an important dissimilarity. The effect of self-reference in one case is recursivity, through the production of an open-ended chain in which each interpretant becomes a sign for another future interpretant. In the other case the effect is circularity, in which each process is simultaneously at the beginning and the end of a cycle. In future work I intend to analyze these relational structures with the hope of revealing how semiotic transactions become embedded in the autocatalytic cycles that appear to subtend all living processes.

INSTEAD OF CONCLUSIONS

The preceding reflections are much more like a list of programmatic injunctions than results gained though the investigation of the issues considered. Nevertheless, in harmony with the *leiv motiv* running through them, some meta-results are in order.

Firstly, besides self-reference there is another common thread woven across these considerations: the need to connect past conceptions to present issues and problems across the institutional and ideological barriers that presently separate disciplines insulated from each other. If biosemiotics is to realize its promise of ushering in a new integration of biological knowledge by means of semiotic ideas it must simultaneously integrate that knowledge within a renewed natural philosophy rooted in the discoveries and preoccupations of all basic disciplines, including mathematics. The specter of reductionist imperialism from the mathematically developed sciences makes many biologists wary of this kind of *rapprochement*. But recent and current developments in those disciplines give us precisely the means for achieving **unification without reduction**. For a clear and insightful treatment of these complicated issues I would like

to bring to your attention a recent book by two sympathetic outsiders to the science of biology*: Mathématiques et sciences de la nature. La singularité physique du vivant* (Mathematics and the sciences of nature. The physical singularity of the living), by Francis Bailly and Giuseppe Longo[2].

Finally, the consideration of the issues reviewed here suggests a heuristic strategy for advancing biosemiotics. We can ask ourselves how thinkers with the perspectives of a Peirce or a Rosen (or an Aristotle or a Kant) would modify or expand their ideas, had they known what we know today. The history of science and philosophy teaches that such counterfactual, *gedanken*-musings have being very fruitful in the past — so I think, it is a good idea to apply them to our future.

NOTES

[1] This special issue of *Chemistry and Biodiversity* (**4** (10), pages 2269 – 2491, October 2007) includes 16 research articles by some of the best known experts and continuators of Rosen's thinking.

[2]This book, which appeared in 2006, has not been translated into English up to now. See Bailly, F. and Longo, G. 2006

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