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Triadic conceptual structure of the maximum entropy approach to evolution

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ABSTRACT

Many problems in evolutionary theory are cast in dyadic terms, such as the polar oppositions of organism and environment. We argue that a triadic conceptual structure offers an alternative perspective under which the information generating role of evolution as a physical process can be analyzed, and propose a new diagrammatic approach. Peirce's natural philosophy was deeply influenced by his reception of both Darwin's theory and thermodynamics. Thus, we elaborate on a new synthesis which puts together his theory of signs and modern Maximum Entropy approaches to evolution in a process discourse. Following recent contributions to the naturalization of Peircean semiosis, pointing towards 'physiosemiosis' or 'pansemiosis', we show that triadic structures involve the conjunction of three different kinds of causality, efficient, formal and final. In this, we accommodate the state-centered thermodynamic framework to a process approach. We apply this on Ulanowicz's analysis of autocatalytic cycles as primordial patterns of life. This paves the way for a semiotic view of thermodynamics which is built on the idea that Peircean interpretants are systems of physical inference devices evolving under natural selection. In this view, the principles of Maximum Entropy, Maximum Power, and Maximum Entropy Production work together to drive the emergence of information carrying structures, which at the same time maximize information capacity as well as the gradients of energy flows, such that ultimately, contrary to Schrödinger's seminal contribution, the evolutionary process is seen to be a physical expression of the Second Law.

1. Introduction

In this paper, which is 'physical' in its approach to semiosis, we intend to bring semiosis beyond biology, into the realm of physiosemiosis (Deely, 2001), taking, therefore, a pansemiotic perspective (Salthe, 2007b). Our viewpoint is evolutionary, on the principle that any property of an evolved system must have been built upon precursor situations. We show how the process of semiosis must be guided by attractor states that have been demonstrated in thermodynamics discourse. Thus we assimilate thermodynamics into a process discourse because in a material world entropy production is the most basic physical demand, which needs to be acknowledge for its power in guiding action and behavior.

2. From Dyadic to Triadic Conceptual Structure

Evolutionary theory is haunted by a number of problems which emerged in its defining stages, and have persisted to the present time, such as the relation between ontogeny and phylogeny, the relations between genotype and phenotype, and the relation between organism and environment. In their research strategies, evolutionary theorists have tended to vacillate between polar approaches, for example, gradualism versus saltationism in the broadest sense. In many respects, as in Robert Wilson's terminology (Wilson, 2004: 68ff.), these oppositions can be interpreted using the 'internal richness' and 'external minimalism' format. Different approaches to evolution differ in whether they adopt an 'internal richness' position, such as in the gene-biased position, which sees genetic information as carrying the exclusive determinants of development, minimizing the role of external factors, or whether they reject one or both extremes, such as in the developmental systems approach (Oyama, 2001), which continues to maintain the internal richness view, but rejects external minimalism, thus positing that biological information is contextual, that is, embodied in the larger structures of cells, organisms and even local biomes.

The conceptual trouble with dualisms is that they vacillate between privileging the epistemological positions of externalism, focusing on constraints, and internalism, focusing on generativity, depending on the aspect of evolution that is in focus. They may even fail to distinguish between the epistemological and ontological dimensions of an issue, uncritically assuming, for example, that

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the scientific observer is able to position herself in an external position such that possible internal positions become irrelevant, thus effectively eliminating the distinction between internal and the external. This also obscures the material fact of their own position as mediating observers by assuming a direct mapping between reality and concepts. For example, with reference to development, the NeoDarwinian view focuses internally on the locus of biological information in the ontological dimension, but at the same time is externalist with reference to the process of selection in the epistemological dimension, so that the forces of evolutionary change are seen to be located outside of the genome even though change must materially originate internally (Reid, 2007). This reflects a failure to distinguish between ontological and epistemological internalism vs. externalism in the treatment of the notion of information—that is, the question of the location of operative information and the question as to which stance of the observer the information refers. In order to keep our subsequent argument within the confines of a paper, we avoid even more fundamental issues that would arise if we were to consider that even the distinction between epistemological and ontological dimensions is itself a problem pointing toward more radical approaches, such as anchoring both dimensions internally in the observer (Matsuno and Salthe, 2002).

In the present paper, we propose that the difficulties with these questions have resulted from the fundamentally dualist oppositions in which the discussions have been framed. Ontological dualisms permeate the field, as with 'genetic cause and phenotypic effect', or 'genetic sender and phenotypic receiver'. This is related to the belief that biological phenomena can be fully explained as efficient–causal, that is, as mechanistic processes (Ulanowicz, 1997: Chapter 2). In the mechanistic worldview, there is no need to distinguish between different possible positions of observers in the treatment of information. This has, however, produced perennial debates about foundational issues such as the distinctions between units of selection, units of heredity and units of evolution.

Neither polar opposition is entirely satisfactory, and so we need some 'meta' perspective to dissolve them. Herein we propose a triadic structure to evolutionary change, in which polar oppositions are revealed to be two modes of approach to the same fundamental reality, somewhat like the wave-particle dualism in physics during 19th century debates. Correspondingly, biologists debate the nature of biological information, whether it is 'particularistic,' i.e. manifested ontologically in genes, or whether it is more holistic, i.e., ontologically manifest in complex living systems, of which genes are only one part (Godfrey-Smith and Sterelny, 2008). In a triadic approach, this debate is found to be a dual perspective view. The required triadic structure can be based on the theory of signs developed by Charles Sanders Peirce (for an accessible collection of his most important works, see Peirce, 1992, 1998). We will link as well his broader views on the stochastic nature of reality, and on the roles of final, as opposed to efficient causation in evolution. In referring to Peirce's views, we mainly build on the synthesis offered by Stone (2007), who puts these views into the more explicit context of modern analytical philosophy.

In Fig. 1, we show the polar oppositions resolved into two modes in the fundamental triadic structure of reality envisaged by Peirce: This structure is a static snapshot of an evolutionary process in which information about an object, while not directly accessible epistemically, is generated within a system of interpretance (Salthe, 2009) via sequences of interpretants informed by an evolving sign (sometimes referred to as 'representamen' in Peirce's later works, a notation that has been accepted by many semioticians, using instead 'sign vehicle', but rejected by Stone (2007: 19, 55) whose usage we follow in the present paper, if only for reasons of consistency and expediency). However, the triadic structure of object, sign and interpretant could be interpreted in two different ways, ending up in those polar dyadic discursive oppositions (for a related

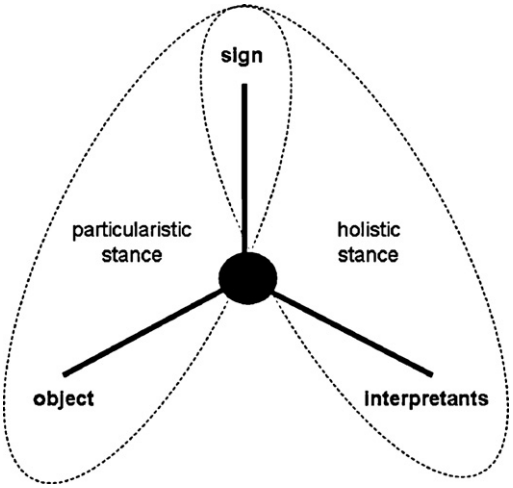

Fig. 1. The two modes in the Peircean triadic structure of semiosis.

analysis of the apparent opposition of Thompson and Uexküll, see Cannizzaro, 2010):

- One way is to conflate sign and object, thus assuming a direct accessibility of objects by the reactive system of interpretants. In this 'particularistic mode' efficient causality is the framework of explanation, and this perspective also tends to adopt atomistic ontologies which gravitate towards the presumption that causal processes relate to certain fundamental entities, such as elementary particles or genes (for programmatic statements, see Wilson, 1998: 53ff., 297, or von Baeyer, 2003: 11ff.). In this view, the distinction between different observational standpoints becomes irrelevant, because if sign and object are conflated, it appears to be possible for observers to get direct access to 'reality,' independently of the epistemological position from which the object is approached. Interestingly, and perhaps unexpectedly, this truncation of the triadic structure has resulted in serious epistemological problems in foundational physics, where the distinction between the observer's states of knowledge and the physical object has been blurred, resulting in endless debates over the Copenhagen view on quantum mechanics, where the ontological status of 'randomness' still awaits final clarification (Jaynes, 2003: 327ff.; Penrose, 2006: 782ff.; Faye, 2008).
- The other way is to conflate sign and interpretant, thus positing that objects are only accessible from the perspectives of particular systems of interpretance, such that there is no way to conceive of objects independent from context. This view neglects the fact that the sign is co-produced by both the system of interpretance *and* the object. This is a holistic mode, as, for example, in theories about the co-evolution of organisms and environment, which, again interestingly and unexpectedly perhaps, might also be formulated in a mechanistic fashion, because the conjunction of different causalities can only emerge in the triadic structure (see, for example, the theory of 'niche construction,' Odling Smee et al., 2003). However, in this view, all potential positions of observers are equally valid, so that there is no way to arrive at a canonical unified picture of 'reality' – a Peircean desideratum – such as in the aforementioned example, when trying to overcome the principled distance between the epistemic reconstruction of a niche by the external observer and the internal position of the evolving biological systems that results in niche construction (Brier, 2008: 169ff., referring to Reventlow's ethological theory).

In modern science, the co-existence of the two modes was suppressed by the social construction of the 'experiment,' in which