



## Review Article

# Integration of thermodynamic, quantum and hierarchical theories of information in the context of Peircean semiosis – A review



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## ABSTRACT

I claim that Peirce's notion of information and sign iteration as an intermediation between potentialities that are actualized and actualities that are potentiated provides a suitable framework for interpretation of Zurek' Information gathering and using systems (IGUS). Moreover, this model can be extended to address the problem of quantum measurement (QM) since it allows exploring an alternative view based on IGUS understood as agents of internal measurement, beyond Copenhagen interpretation (CI) that invokes a classical observer that performs measurements and the "many worlds interpretation" (MWI) that rejects all sort of observers and measurements. This integrative view allows figuring out a hierarchy of IGUS-like systems of interpretation that explore new possibilities in the upper level analog boundary and consolidate actualized information in the lower level digital boundary.

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## 1. Introduction

I aim to justify an integrative theory of information that supports the understanding of living systems as information processing agents. I have divided the argument in four headings. 1. To start with I introduce Peirce's notion of information and *thirdness*. The mediatory activity between potentialities and actualities is explained as information transfer (the communication of a form) from the sign to the interpretant. In this case the content of the message is the object as internalized by the sign a reason why it is important to distinguishing between the external dynamical object ( $O_d$ ) and

the immediate internal object ( $O_i$ ). Thus, sign iteration results in growing informative breadth and depth that actualizes in the real world as a hierarchy of interpretation systems. 2. The process of sign iteration can be modeled after Zurek's IGUS that by means of measurements generate correlations between micro-states (genotype) and macro-states (phenotype), and between macro-states (phenotype) and environment. 3. I discuss the transitions from quantum potentialities to classical actualities as the outcome of the mediatory activity of IGUS-like agents that are being individuated, determined and specified as the interactive network that they establish gets tightly intertwined, while coherent preferred states fitted to local environmental conditions are preserved. In this way the interpretation of quantum measurement (QM) can be made congruent with the arguments posited in the previous sections, opening up an alternative way beyond both Copenhagen and

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the “many worlds” interpretations. 4. To end up I will depict the resultant hierarchical architecture fully congruent with Salthe’s infodynamic perspective in which the IGUS explore new instances of continuity (analog information) in the upper level boundary, while information is actualized in a digital mode in the interface with the lower levels. To conclude information can be thought of as a specification of Peirce’ category of *thirdness* that acts through a network of observers or agents of internal measurement that choose between really attainable structural adjustments and that by acting upon the environment bias in an unpredictable way the world of possibilities toward the actualization of forms that are to be put to the test of natural selection.

## 2. Peirce’s notion of information

In order to establish the general framework of interpretation that allows to attempting an integration of thermodynamic, quantum and hierarchical theories of information I will review the notion of information proposed by Peirce. Peirce considered that Aristotle’s *entelechy* anticipated his category of *thirdness* (Peirce, CP 1.22), and thought of it as a principle of continuity that leads to the logical foundation of an evolutionary thought that undermines the mechanistic and deterministic foundations of the Newtonian system (Peirce, CP 1.176, CP 1.179). Accordingly the word information should be understood as intermediation between potentialities – unbound or unconstrained energy or informed matter (Taborsky, 2002) – and actualities – matter-form –. Aristotle (Aristóteles, 1998) named this activity *entelechy* (ἐντελέχεια in-end-having) in his discussion over the relations between matter and form in the attempt to understand morphogenesis along embryo development. For him there is an activity that mediates between the potential intrinsic to a formless matter and the actualization of a definite matter-form (*hyle-morphysm*), whereas most of the possibilities are left un-actualized. This activity works as a continuous, permanent and sustained action that is directed to the full achievement or manifestation of a given potential. In other words *entelechy* is the intrinsic inclination of any system that strives to actualize a form and to renovate potentialities (Sachs, 1999).

For Driesch the *entelechy* is a non-spatial, intensive and qualitative morphogenetic field that has the ability to influence at any time every one of the subordinated parts. The teleological character of embryonic development and reproduction is then, explained by the ability to repair, influence and constraint at any time every single part of the living machine. But *entelechy* can occasionally lift up restrictions and so allows the living machine to run freely on its own in the exploration of new possible configurations (Driesch, 1929, in Sander 1987). Muller (1996) argued that Driesch *entelechy* can be understood as all kind of endogenous sources of information (genetic, cytoplasmic factors, chemical signaling, maternal inheritance, growth and induction factors, receptors, hormones, etc.) and cellular positional information (triggered by cell to cell interactions through physical contact, tensions, pressure, etc.) (Driesch [1894] in Sander 1987). Recently Oyama (2000) has stated that information emerges all along ontogeny by the confluence of a diversity of formative external and internal factors that include not only genetically encoded proteins, but chemical signals, hormones, nutritional, behavioral, environmental, social, and cultural factors that contribute to the morphogenetic process. Therefore, *entelechy* would be not only the genetic program but rather the coincidences in space and time of all formative external and internal factors.

Kauffman (2008) sees information as the propagation of organization by the actualization of forms whenever a constraint acts on an amorphous matter that tends to expand and vary isotropically, since among all imaginable forms only a minor fraction are in fact really possible and attainable in a precise moment of life

history. The set of all real possibilities that can be reached in one evolutionary step is dubbed “adjacent possible” and it tends to growth with the increase of diversity of actually existing entities (Kauffman, 2000). Along the same guide lines Aranda (2011) has proposed that there exist constraints that act upon the mathematical morpho-space of all possible forms, so that only a reduced number of forms can be really actualized at a given time along evolutionary history. In consequence the morpho-space of possible forms has structure and is real though in a potential mode, yet to be actualized. I agree that in order to develop evolutionary theories with higher breadth and depth, the ontological status of a real potentiality and *entelechy* as the mediatory agency between potentialities and actualities must be considered.

Peirce in 1865 defined the information that can be grasped by a human intellect as the multiplication of two logical quantities, “depth, connotation, comprehension” and “breadth, denotation, extension”, in recognition of the fact that information (I) was a higher-order logical quantity (De Tienne, 2006), then we have equation (1):

$$I_{\text{total}} = I_{\text{breadth}} \times I_{\text{depth}} \quad (1)$$

The informative “breadth” of a sign estimates the amount of objects and/or events (and possible states of them) that the sign represent with certainty (Peirce, CP 2.407), so to say the extent to which the external world is referred by the said sign. On the other hand informative “depth” associated also to coherence and rigor embraces the totality of characteristic properties that can be attributed or predicated to a particular object and/or event – the grammatical subject – that the sign truly represents (Peirce, W 1.276; Peirce, CP 2.408).

However, this epistemic notion of information was not free from ontological implications since it was claimed that total information validates the correlations between subjects and predicates that have proven to be functionally successful in nature and thus preserves this congruency as a potential for the establishment of future correlations. This ontological turn was further specified by Peirce in 1906 when information was defined as the totality of actions and processes that shape the natural world and enable the generation of new possible forms by means of the emergence of ever more complex systems of interpretation including the human intellect (De Tienne, 2006). As a result of the actualization of information, new information is potentiated so that nature from a reduced number of things and/or events, that can be described with a reduced number of predicates, has brought forth along evolution a great diversity of forms (beings, things, objects, events, systems, . . .) that require a greater number of predicates for their description (Peirce, CP 2.418, 2.419). Logically, information at a global scale grows because the development of the sign leads to increases in breadth and depth of the actualized or manifested information (Peirce, CP 3.608). In this sense information embraces under the same logic ontology and epistemology.

Information processing by sign iteration shows aspects of *firstness*, *secondness* and *thirdness*. *Firstness* understood as potency, qualitative possibility, absence of constraints, immediate present; *Secondness* thought as actuality, existing brute facts, constraints, past; and *Thirdness* as mediation, continuity, constraining actions, permanent activity and openness to future. In the natural world information transfer is the communication of form or stable patterns, regularities, rules of action, propensities, leanings and real potential (Peirce 1906, MS 793). These logical categories applied both to the epistemic and ontic domains given that humans in order to describe external objects need to employ predicates or attributes, and in turn as these objects are further specified along evolution and development, more predicates are needed for their comprehension.

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