

A Peircean Approach to 'Information' and its Relationship with Bateson's and Jablonka's Ideas

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Abstract: The Peircean semiotic approach to information that we developed in previous papers raises several new questions, and shows both similarities and differences with regard to other accounts of information. We do not intend to present here any exhaustive discussion about the relationships between our account and other approaches to information. Rather, our interest is mainly to address its relationship to ideas about information put forward by Gregory Bateson and Eva Jablonka. We conclude that all these authors offer quite broad concepts of information, but we argue that they are just as broad as they should be, since information is in itself a sweeping concept. Furthermore, all of them suggest a processual approach to information, which departs from the treatment of information as something that is contained in some structure (e.g., in sequences of nucleotides) and moves us towards an understanding of information as a *process* — in the terms of our account, a semiotic process, i.e., *semiosis*.

I. Introduction

C. S. Peirce's formal science of signs provides an analytic framework in which information can be modeled as a triadic dependent process that irreducibly connects signs, objects, and interpretants (i.e., effects

on interpreters). According to the model we have developed in previous papers (Queiroz et al. 2005; El-Hani et al 2006; El-Hani et al. 2007; Queiroz and El-Hani 2007) and briefly present in this paper, information is treated as *semiosis*, i.e., as the communication of a form or habit *from* an object *to* an interpretant *through* a sign so as to constrain the interpretant as a sign (in general) or an interpreter's behaviour (in semiotic systems). Here, we intend to discuss the relationships between this Peircean semiotic approach to information and a number of ideas put forward by Gregory Bateson and Eva Jablonka. But, first, we need to say some words about the most influential approach to information in the twentieth century, namely Shannon and Weaver's mathematical theory of communication, so as to establish in what sense our account of information departs from it.

2. Information Theory

Shannon and Weaver's mathematical theory of communication¹ defines a measure of the amount of "information" in terms of the unexpectedness of a sequence of signals, [written $H = \sum p_i \log(1/p_i)$] — where p_i is the probability of the i th form of a signal. As is well known, this probabilistic measure of "information" is acknowledgely *non-semantic* — and, even though it is useful in biological research for several purposes (see note 1), it is not clear whether it can be *sufficient* for understanding *biological* information, and, moreover, there are arguments against the very possibility of this prospect (see, e.g., Jablonka 2002; El-Hani et al. 2006).

An important point to highlight, then, is that the Peircean account of information we have developed shows an obvious difference from Shannon and Weaver's approach, since it incorporates both semantic and pragmatic dimensions of information, as well as its syntactic and probabilistic dimensions. In a Peircean approach to biological information, the focus is naturally on the *meaning* of signs to a given living system, and on the variations shown

1. Shannon and Weaver's mathematical theory of communication, developed in their 1949 book, *The Mathematical Theory of Communication*, has since become almost synonymous with 'information theory'. The theory developed in the 1949 book is based upon Claude E. Shannon's paper 'A Mathematical Theory of Communication' originally published in the *Bell System Technical Journal* in July and October of 1948. Other important ideas preceded it (see the articles 'History of information theory' and 'Timeline on information theory' in the internet encyclopedia Wikipedia) and other kinds of mathematical or algorithmic approaches to information have been developed later. For a biological application of algorithmic information theory, see Küppers (1990). For its biological applications, see Yockey (1992), Adami (2004), Scherrer and Jost (2007), and the work of Schneider's lab (e.g., Schneider and Stephens 1990; Schneider 1994). In the humanities, 'communication theory' is sometimes referred to as denoting the interdisciplinary field of human communication, including pragmatics, sociolinguistics, rhetorics, etc.

by meanings in different (pragmatic) contexts of interpretation. Thus, we can argue that a major advantage of this approach when applied to living systems, as compared to the mathematical theory of communication, is that it allows one to coin a semantic/pragmatic concept of information, addressing, thus, an open problem in the philosophy of biology (see, e.g., Küppers 1990; Jablonka 2002; Jablonka and Lamb 2005).

Obviously, this does not mean that Shannon and Weaver's approach is not useful in the domain of biology; rather, it is clear that it brings its contributions to the treatment of certain issues in which the "meaning" of signs and the "contexts" of interpretation are not particularly relevant (Yockey 1992; Adami 2004). But, in the case of other research questions, ones in which sign-meaning is a fundamental feature of information systems, networks and pathways, a richer conceptual framework — one which takes into due account semantics and pragmatics — is needed. Therefore, it is not a case of simply advocating one approach rather than the other, but of at least delimiting the domains of problems in which each can be successful and of attempting an integration of the approaches in order to develop a coherent syntactic, semantic, and pragmatic approach to biological information.

This does not mean, however, that the Peircean approach to the analysis of, e.g., sequence information in fields such as molecular biology, bioinformatics, and systems biology, addresses a totally *different* set of problems. Rather, as we see it, the largely qualitative Peircean approach to what is 'biologically meaningful' has not been developed to the extent that we can properly examine whether or not it can be fruitfully integrated with more quantitative accounts.

3. The Sign as a Medium for the Communication of Forms

Peirce's concept of semiotics as the 'formal science of signs', and the pragmatic notion of meaning as the 'action of signs' (semiosis) have had a deep impact in philosophy, psychology, theoretical biology, computational semiotics, and cognitive science (Thom 1975; Freeman 1983; Prigogine and Stengers 1983; Fetzer 1988; Colapietro 1989; Tiercelin 1995; Hoffmeyer 1996; Brunning and Porter 1997; Deacon 1997; Houser et al. 1997; Freadman 2004; Hookway 2002, 2004; Queiroz and Merrell 2005). And since it deeply informs our own analysis, we need, thus, to present a brief overview of Peirce's semiotic here.

First and foremost, Peirce's semiotics is grounded on a list of categories — Firstness, Secondness, Thirdness — which corresponds to an exhaustive system of hierarchically organised classes of relations (Houser et al 1997). This system makes up the formal foundation of his philosophy and of his model of semiotic action (Murphey 1993: 303–306). In brief, the categories can be

defined as: (1) Firstness: what is such as it is, without reference to anything else; (2) Secondness: what is such as it is, in relation with something else, but without relation with any third entity; and (3) Thirdness: what is such as it is, insofar as it is capable of bringing a second entity into relation with a first one in the same way that it brings itself into relation with the first and the second entities.

Thus, Firstness is the category of vagueness, freedom and originality: “firstness is the mode of being which consists in its subject’s being positively such as it is regardless of anything else. That can only be a possibility” (CP 1.25). Secondness is the category of reaction, opposition, differentiation: “generally speaking genuine secondness consists in one thing acting upon another, — brute action ... I consider the idea of any dyadic relation not involving any third as an idea of secondness” (CP 8.330). Thirdness is the category of mediation, habit, generality and conceptualization or cognition (CP 1.340).²

As it is well known, Peirce defined semiosis as an irreducible triadic relation between a Sign, its Object and its Interpretant.³ That is, according to Peirce, any description of semiosis involves a relation constituted by three irreducibly connected terms, which are its minimal constitutive elements (MS 318:81; CP 2.242).⁴ Considering the difference between dyadic and triadic models, Colapietro (1989: 4) argues: ‘Peircean definition adds a dimension the classical formula lacks, namely, reference to mind: A sign not only stands for something, it stands to someone — to some mind. The implication of this is that the sign is a more complex phenomenon than the classical definition indicates.’ In Peirce’s words:

My definition of a sign is: A Sign is a Cognizable that, on the one hand, is so determined (i.e., specialized, *bestimmt*) by something other than itself, called its Object, while, on the other hand, it so determines some actual or potential Mind, the determination whereof I term the Interpretant created by the Sign, that that Interpreting Mind is therein determined mediately by the Object. (CP 8.177)

Importantly, Peirce also defined a sign as a medium for the communication of a form or a habit embodied in the object to the interpretant, so as to determine

2. For more on categories, see Hookway 1985; Murphey 1993.

3. We shall hereafter refer to this triad as S-O-I.

4. We shall follow the practice of citing from the *Collected Papers of Charles Sanders Peirce* (Peirce, 1931–1935, 1958) by volume number and paragraph number, preceded by CP; the *Essential Peirce*, by volume number and page number, preceded by EP. References to the *Annotated Catalogue of the Papers of Charles S. Peirce* (1967) will be indicated by MS, followed by the manuscript number and pages.

the interpretant as a sign, or to determine the interpreter's behavior (see De Tienne 2003):

a Sign may be defined as a Medium for the communication of a Form. ... As a medium, the Sign is essentially in a triadic relation, to its Object which determines it, and to its Interpretant which it determines. ... That which is communicated from the Object through the Sign to the Interpretant is a Form; that is to say, it is nothing like an existent, but is a power, is the fact that something would happen under certain conditions. (MS 793:1-3. See EP 2.544, n.22, for a slightly different version)

In short, a sign is, for Peirce, both "a Medium for the communication of a Form" and "a triadic relation, to its Object which determines it, and to its Interpretant which it determines". If we consider both definitions, we can say then that *semiosis is a triadic process of communication of a form from the object to the interpretant through sign mediation*.

Figure 1 represents the basic idea that the transfer of a form or pattern from the object to the interpretant cannot be reduced to a direct physical, dyadic reaction of one entity or process acting physically upon another; rather, it is an indirect process that is mediated by the form, in which general form-aspects of the pattern are conserved in the process of transference. Thus, in addition to involving particular direct and physical processes, this form-transfer is a mediated transfer and a conservation of form as a transfer of general patterns of a certain type, i.e., an instance of communication.

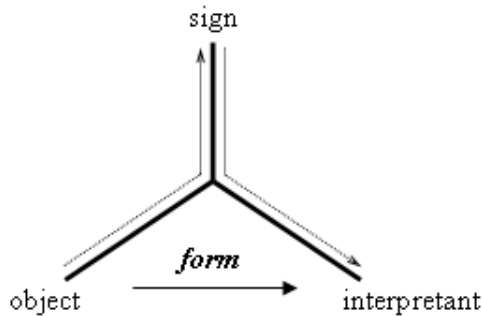


Figure 1: Semiosis as the communication of a form from the object to the interpretant through sign mediation.

In Peirce's works, *form* is defined as having the "being of predicate" (EP 2.544) and it is also pragmatically formulated as a "conditional proposition" stating that certain things would happen under specific circumstances (EP 2.388). Form is

something that is embodied in the object (EP 2.544, n. 22) as a habit,⁵ a “rule of action” (CP 5.397, CP 2.643), a “disposition” (CP 5.495, CP 2.170), a “real potential” (EP 2.388) or, simply, a “permanence of some relation” (CP 1.415). Form can also be defined as potentiality (‘real potential’, EP 2.388). We can say that Peirce follows a *via media* in which “form” has both the characters of firstness and thirdness. This is in accordance with Bergman’s (2000: 236) understanding of communicated form as a *First* of a *Third*. Thus, from the Peircean framework discussed in this section, we have derived the basic background for our account of *information* as *semiosis*. We will now expand upon that account.

4. Meaning, Information, and Semiosis

The notions of meaning, ‘information’, and ‘semiosis’ intersect in different ways (Johansen 1993). Debrock (1996) comments that Peirce defined ‘information’ at least ordinarily (CP 2.418), metaphysically as a connection between form and matter (CP 2.418), and logically, as the product of the extension and intension of a concept (W 1.276). We have argued in previous papers that the definitions of *sign* discussed in the preceding section lead to a conception of information as the communication of a *form* from O to I through S (Queiroz et al. 2005; El-Hani et al. 2006; Queiroz and El-Hani 2007). This process amounts to the communication of a habit or regularity embodied in the object to the interpretant, so as to constrain (in general terms) the interpretant as a sign or (in semiotic systems) to constrain the interpreter’s behaviour.

An alternative way of saying this is that the production of an effect of the sign on the interpreter results from the communication of the form embodied in the object (as a regularity), *via* the sign, to the interpretant. According to this approach, ‘information’ can be strongly associated with the concepts of ‘meaning’ and ‘semiosis’. Moreover, it is important to emphasize that the form communicated from the object to the interpretant through the sign is a *regularity*, a “habit” that allows a given semiotic system to *interpret* that form as indicative of a class of entities, processes, phenomena, and thus, to “answer to it” in a regular way. Otherwise, the semiotic system would not be really capable of interpreting the object by means of its effect on it (i.e., its interpretant), as mediated by a sign.

5. It is well known among Peirce scholars that ‘habit’ occupies a central position in Peirce’s pragmatism (for a summary, see Almeder 1980; Hookway 1985). Peirce’s habit entails a disposition to act in a certain way under certain circumstances, especially when the carrier of the habit is stimulated, animated, or guided by certain motives (CP 5.480). The *meaning* of a Peircean sign is most adequately understood through the habits of action, reaction, and thought they provoke, sustain, and modify (in the event that the habit carrier wishes to bring about a change of the customary response to a given sign).

Peirce's (CP 8.177) idea that a sign determines an interpretant in some 'actual' or 'potential' Mind (in other passages, a 'quasi-mind'; see CP 4.536) also plays an important role in our arguments. On the grounds of this idea, we differentiate between *potential* and *effective semiosis*. We understand *potential semiosis* as a triadically-structured process that could take place, but that is not effectively taking place at a given time *t*. *Effective semiosis*, in turn, concerns a sign in effective action — i.e., a sign that, by its being actualized, has an actual effect on the interpreter. Following the distinction between potential and effective semiosis, we can define *potential* and *effective information*, as well.

According to our interpretation of Peirce's ideas, "information" has a processual nature: it is a *process* of communicating a form to the interpretant that operates as a constraining influence on possible patterns of behaviour of the semiotic system (i.e., the interpreter). When applying this general semiotic approach to semiotic systems, information will most often be an *interpreter-dependent objective* process. It thus cannot be dissociated from the notion of a situated agent. It is, moreover, interpreter-dependent in the sense that it is only as a result of a process of interpretation that information *triadically* connects representation (sign), object, and an effect (interpretant) for an interpreter (which can be an organism or a part of an organism). In turn, the form — as a regularity embodied in the object — constrains the interpreter's behaviour through the mediation of a sign. In sum, information in a semiotic system depends on both the interpreter and the object (in which the *form* communicated in information is embodied as a constraining factor of the interpretative process).

A framework for conceiving of information as a process, can be constructed in Peircean terms by employing the following definitions:

[Information \approx semiosis] A triadic-dependent process through which a form embodied in the object in a regular way is communicated to an interpretant through the mediation of a sign.

[Potential information \approx potential semiosis] A process of communicating a form from an object to an interpretant through the mediation of a sign that could take place in a given moment.

[Effective information \approx effective semiosis] The process by which a sign effectively produces an effect (interpretant) on some semiotic system (an interpreter) by making the interpretant stand in a similar relation to something else (the object of the sign) as that in which the sign itself stands. Thus, the sign *mediates the relation* between object and interpretant. The sign thus effectively communicates, in this way, a form from the object to the interpretant, changing the state of the interpreter.

This account of information raises several important questions and shows both similarities and differences with regard to other approaches. Nevertheless, we

do not intend to present here an exhaustive discussion about the relationships between our account and all other approaches to information. Rather, our focus will rest upon a treatment of the relationships of this account to ideas about ‘information’ that have been put forward by systems theorist Gregory Bateson and evolutionary biologist Eva Jablonka.

5. Bateson: Information as a Difference Which Makes a Difference

It has been proposed that Bateson’s (1972) account of “information” can be fruitfully used as an alternative to the treatment of biological information as just sequence information in nucleic acids and polypeptides (Emmeche 1990; Hoffmeyer and Emmeche 1991; Hoffmeyer 1996; Bruni 2003). Bateson (1972: 453) conceives ‘information’ (or, as he stressed, the “elementary unit of information”) as “a difference which makes a difference”. As we think that Bateson’s definition of information involves the idea that, for something to be ‘information’, it is necessary some interpreting system that, by interpreting it, suffers its effects; we would add that a difference can only make a difference to ‘somebody’ — or, more generally speaking, to an interpretative system.⁶

The relevant question then becomes: What is a “difference”? Bateson asks where are the differences between two objects and answers that they are not in any of the objects, nor in the space between them, nor in the time between them. He comes to the conclusion, then, that a difference is an ‘abstract matter’ (Bateson 1972: 452). Bateson stresses the contrast between the world as seen from the perspective of the physical sciences — a world in which effects are caused by rather concrete conditions or events, impacts, forces, etc., a world he calls “pleroma — and a ‘world of communication’ or ‘organization’, i.e., the ‘psychological’⁷ world (which he calls ‘creatura’), in which effects, if such a word can still be used, are brought about by differences (ibid.).⁸

6. This is not the first time that Bateson has been interpreted this way (see, e.g., Wilden, 1980). For an explicit connection of the expression ‘makes a difference’ to the notion of ‘somebody’ or an organism, see also Emmeche (1990: 53; 2000) and Hoffmeyer (1998).

7. Bateson’s understanding of what is a ‘psychological’ world obviously depends on the broad concept of *mind* that he assumes. It would be an interesting task to compare Bateson’s and Peirce’s concepts of ‘mind’, but it is beyond the scope of this work to discuss this issue.

8. Notice that Bateson’s distinction here is not between a ‘physical world’ and a ‘mental world’, but, rather, to the world *seen as* ‘physical’ or as ‘mental’. This distinction is indispensable, for reasons of consistency with Bateson’s notion of ‘mind’ and his general critique of the separation of mind and body. Symptomatically, he writes that the world in which effects are brought about by differences (‘creatura’) is ‘the world seen as mind, wherever such a view is appropriate’ (Bateson 1972: 457).

In an effort to clarify the abstract concept of 'difference', Bateson argues that the word *idea*, in its most elementary sense, is synonymous with *difference*. In any thing, say, a piece of chalk, there are an infinite number of 'differences' around and within it, differences between the chalk and any other thing in the universe, as well as differences 'within the piece of chalk, there is for every molecule an infinite number of differences between its location and the locations in which it *might* have been' (Bateson 1972: 453). It is precisely because of this infinitude, Bateson argues, that a piece of chalk, or any other thing, cannot enter into communication or mental processes as *Ding an sich*. He observes that we (or, generally speaking, any interpreter) 'select' and 'filter out' a 'very limited' number of differences around and within the piece of chalk, which 'become *information*' (ibid.).

Note that in the preceding section, we defined 'information' as a triadic-dependent process through which a form embodied in an object in a regular way is communicated to an interpretant through the mediation of a sign. We can notice, then, an important difference between this Peircean account of information and Bateson's treatment of information. When Bateson argues that information is *a difference which makes a difference*, he seems to be focusing on the *form* communicated (the 'difference'), rather than on the *process* of communicating the form. The latter would be rather conceptualized, in Bateson's account, as the process *through which* a difference (information) 'makes a difference'. Thus, even though both accounts can be seen as committed to an interpretation of information as having the nature of a process, this nature is, in our view, more evident in (and perhaps more central to) the Peircean account than in the Batesonian approach to information.

Nevertheless, we see these accounts as intersecting and not in conflict, even though they certainly diverge in important respects. In our view, Bateson's notion can be interpreted as triadic-dependent, and the important aspects of both notions are processual and relational. From the point of view of a Batesonian 'ecology of mind' (or, as some would prefer, 'second-order cybernetics'),⁹ a living system likewise *entails* ongoing semiosis, or the action of signs, whereby any sign is a first that stands in such a relation to a second, its object, so as to determine

9. The very fact that second order cybernetics emphasizes the role of the observer in investigating cybernetic systems makes this approach more prone to being integrated with a semiotic approach (see also Brier 1996). Yet it is disputed whether or not there is a clear 'break' between first and second order cybernetics. According to Heylighen and Joslyn (2001), 'if we look more closely at the history of the field, we see a continuous development towards a stronger focus on autonomy and the role of the observer, rather than a clean break between generations or approaches'; furthermore, 'the second order perspective is now firmly ingrained in the foundations of cybernetics overall' (ibid.).

a third, its interpretant, to take the same relation to that object (that the sign takes) and thereby effecting that interpretant so that this effect is (potentially or actually) meaningful to an interpreter-organism, *precisely* in the sense that it is “a difference that makes a difference” to that interpreter.

The interpreter must, in this Batesonian perspective, be an organism-environment unit of survival (or a part of an organism, or an organism-like entity, within such a unit), and the effects on that organism’s parts, to be *meaningful* (i.e., ‘to make a difference’), cannot be merely physical, because by definition, the difference, if any, that they make, is of potential or actual purport or relevance to the organism in question; which means that they concern the organism’s chances of finding food or other sources of energy and matter, or that they ultimately concern its chances of surviving and reproducing. It is important to note, however, that we are not advocating a synthesis of Peirce’s and Bateson’s framework *in toto*. Our main point of reference is the Peircean framework, and, from this standpoint, we think it is both useful and inspiring to look for points of convergence, similarity, compatibility, or even possibilities of synthesis of some notions in the works of authors otherwise quite different.

6. Jablonka’s Concept of Semantic Information

Eva Jablonka (2002) has proposed a semantic definition of biological information. She suggests a list of requirements that can be used to identify a ‘common denominator’ among informational phenomena of different types (e.g., alarm calls, DNA sequences, pieces of software, etc). These types include *environmental cues, man-made instructions, evolved biological signals, and hereditary material*.

The “common attributes” of these phenomena are: (i) a special type of *reaction* between receiver and source, this reaction in all cases affecting the potential or actual actions of the receiver; (ii) that the receiver’s response leads to a complex, regulated chain of events in the receiver, and depends on the *organization* of the source rather than on its energy content or chemical constitution; (iii) that the reaction to the source contributes to a type of response by the receiver that is *beneficial* over evolutionary time; (iv) that *variation* in the *form* of the source leads to a corresponding variation in the *form* of the response.

On the basis of these attributes, Jablonka proposes a definition framed by a functional-evolutionary perspective that emphasizes the prominent role of the interpretative system of the receiver in evolutionary terms. This definition has, in her view, the following advantages: (i) it accommodates environmental cues and potential informational sources; (ii) it makes it easy to think about non-genetic information. The definition is as follows:

A source — an entity or a process — can be said to have information when a receiver system reacts to this source in a special way. The reaction of the receiver to the source has to be such that the reaction can actually or potentially change the state of the receiver in a (usually) functional manner. Moreover, there must be a consistent relation between variations in the form of the source and the corresponding changes in the receiver. (Jablonka 2002: 582)

According to this model, a 'source' has *information* when the modification of a receiver-system is "functionally coupled" to the variation of the source of the form. But for a source to be regarded as informational it must elicit an *adaptive response* — i.e., a functional reaction in the evolutionary sense. Jablonka explains that 'functional' is used in her definition to mean the 'consistent causal role that a part plays within an encompassing man-designed or natural-selection-designed system, a role that usually contributes to the goal-oriented behavior of this system'. This is related to her definition of the function of a part or a process as something that 'has to be analyzed in terms of its causal role in the receiver system, which now or in the past contributed to the designed (by natural selection or by human intelligence) goal-oriented behavior of the encompassing whole' (Jablonka 2002: 584).

It is worth considering some further definitions of terms as put forward by Jablonka. She explains *form* as the organization of a source's features or actions, in particular, those related to the actual or potential responsiveness of a receiver (Jablonka 2002: 582). The 'input', or 'information cue', is the *source* eliciting a specific, functional, and regular response of the receiver. A *signal* is an evolved informational input. And finally, the processes resulting in a regular and functional response by the receiver are called by her *interpretation*.

We can clearly map semiotic concepts onto Jablonka's definitions: A 'source' can be defined in Peircean terms as an *object*. A receiver-system, in turn, can be understood as an *interpreter*, which has, according to Jablonka, an interpretative system that plays a central role. She compares her definition of *biological information* with that of Maynard Smith (2000), claiming that, although both are based on evolutionary considerations, Maynard Smith requires that both the input and the final response (output) must have evolved by natural selection, while she requires instead that the *interpretation and evaluation processes of the receiver* are products of natural selection (Jablonka 2002: 582).

Furthermore, these processes develop in a context-sensitive manner. As a consequence, her definition does *not* require that the form of an input evolves through natural selection; for instance, the responsiveness of a given living system to black clouds is a product of natural selection, obviously not the 'blackness' of the clouds. Instead, the perceptual and cognitive processes of the *receiver* evolved to be *responsive* to the form of the source's variation.

According to Peirce's model, however, such 'blackness' embodied in the object would be a necessary requisite for the selection, and a regular spatiotemporal correlation 'blackness – rain', a necessary requisite for the interpretative process. The regularity of this spatiotemporal *co-occurrence* ('blackness – rain') is the *form* communicated from the source to the interpreter eliciting a specific adaptive response. As Jablonka (2002: 583) argues, 'in order for external, non-evolved cues like a black cloudy sky to be interpreted adaptively, the interpretation system of the receiver must be able to respond to the cloudy sky, a recurrent environmental agent, by specifically altering its internal state.' That is, a *quality* (e.g., blackness) embodied in the object in a regular way is a requisite for the interpretative process. The emphasis on 'form variation' has interesting consequences when compared to Bateson's interpretation of information as 'a difference that makes a difference' to some system.

As shown above, Jablonka explains the 'form' of the source as the organization of its features and/or actions, focusing specifically on those aspects of the organization to which the receiver reacts in a (usually) functional way. This is consistent, in our view, with the conceptualization of information as a *process* through which a 'form' is communicated from the object to the interpretant through the sign. If so, however, it would be contradictory to argue, as Jablonka does, that an entity or a process can 'have information'. Rather, in our account of information, an entity or process is said to possess a 'form' to which an interpreter reacts when a sign mediates a relationship between that entity or process and an effect on the interpreter. Therefore, a consistent relationship between variations in the form of the object and corresponding *effects* upon *the interpreter* (i.e., interpretants) results from the mediation of a sign. However, the functional role of the *sign* is not explicitly articulated in Jablonka's account.

The relationship between variations in the form of a process or entity and the corresponding effects on an interpreter is crucial in Jablonka's account. The specific 'reaction' of a receiver-system to the source (or, in more precise terms, the effect of the source on the interpreter) corresponds, in Peircean terms, to the *interpretant*. In a way reminiscent of Bateson's distinction between *creatura* and *pleroma*, Jablonka argues that, for a source to be an information input rather than merely a source of energy or material, its *form*, or variations in its form, rather than any other attribute, should affect the interpreter's response in a consistent, regular way (Jablonka 2002: 585). That is, only when an entity or process is a difference which makes a difference to an interpreter, can we argue that information enters the scene. The relationship between the form of the object and the interpretant (in Peircean terms) involves, in living systems, complex and regulated chains of events, and, as Jablonka stresses: 'in all cases

this chain of events depends on the way the source is organized rather than on its energy content or its precise chemical constitution' (ibid.: 580).¹⁰

Jablonka's definition of the form of a source can be related to Peirce's notion of form as a 'habit' or a 'rule of action'. Nevertheless, when we compare Jablonka's account of information with the Peircean approach discussed here, we can detect some important points of disagreement. Her model, as described in her 2002 paper, seems to be dyadic, i.e., she seems to lose from sight the idea of the sign as the agent *mediating* the relation between object and interpretant — consequently, she does not explicitly recognize that the form of the object is communicated to the interpreter through the mediation of the sign.

Too, while analyzing Jablonka's definition of information, we should ask how the form of the source is *communicated* to the interpreter. In the Peircean approach to information discussed here, the answer is that signs mediate the relation between objects and interpretants, and, thus, bring about a consistent relation between variations in the form of the object and corresponding effects on the interpreter (interpretants) — and that this can happen in many different ways, depending on the types of signs, objects and interpretants involved.

Consider: when Jablonka argues for the generality of her definition, as applying to all types of information, she writes:

a source *S* (allele, alarm call, cloudy sky, etc.) carries information about a state *E* for a receiver *R* (an organism or organism-based product), if the receiver has an interpretation system that reacts to *S* in a way that usually ends up adapting *R* (or its designer, if *R* is humanly designed) to *E*. (Jablonka 2002: 585)

A comparison between the ideas contained in this passage and the definition of 'information' quoted earlier (Jablonka 2002: 582) shows how a more semiotic treatment can make an important contribution to Jablonka's approach. Mapping semiotic concepts onto this passage, we obtain a picture which is significantly different from that resulting from the previous definition in her paper: As a 'source' is now explained as 'carrying the information', it might be defined in Peircean terms as a *sign*, introducing the missing element in her definition. The *object* is, in the latter case, a state *E* to which the receiver is adapted. As above, the receiver's interpretation system is the interpreter, and the 'reaction' of a receiver system to the source, the *interpretant*.

Finally, in the conclusions of her paper, Jablonka writes:

10. For interesting comparisons between *informational processes*, dependent on the organization of the source (object), and *non-informational processes*, involving material and energy transfer, and, accordingly, dependent on energy content or chemical constitution, and also between sources of information and sources of material and energy, see Jablonka's original paper (Jablonka 2002).

a source becomes an informational input when an interpreting receiver can react to the form of the source (and variations in this form) in a functional manner. (Jablonka 2002: 602)

In this statement, it seems that object and sign are differentiated, through the usage of the concept of ‘input’, which may be read in Peircean terms as a sign, while the source would be the object. Furthermore, the same element first plays the role of object (source) and subsequently of sign (informational input) when the interpreter enters the scene. Jablonka’s scheme is entirely interpreter-dependent, as she herself emphasizes (Jablonka 2002: 582), but a crucial idea in a Peircean framework is not clear in it, namely, that *semiosis* (and, in the terms of our arguments, *information*) is irreducibly triadic — i.e., its three elements are necessarily and always interdependent.

In other words, a Peircean account of information leads to an emphasis on the very prominent role of the *interpretative system* of the receiver. But because the entire process is highly distributed, one cannot assign prominence to any one of its components. In a Peircean model, *sign*, *object*, and *interpretant* are *triadically coupled* in a dynamically *irreducible* process. In other words, ‘information’ requires a *triadic pattern of determinative relationships involving S-O-I*.

But why does one need to appeal to a Peircean view in order to analyze Jablonka’s approach? It is our contention here that the employment of Peirce’s conceptual toolbox would help us avoid the vacillation we observe in the way that Jablonka explains the elements in her concept of information, with the *sign* being sometimes “left outside the picture”, and, when it is introduced, being sometimes conflated or even merged with the *object*. In our view, these are consequences of the lack of a sign-theoretical framework in her account of information in biology. Peirce’s theory of signs, we argue, would offer precisely such a framework.

Similarly, another potential problem in Jablonka’s account that a Peircean understanding of signs may help alleviate lies in her claim that ‘information’ is conferred *only by a receiver* (Jablonka 2002: 586). After all, there is a real aspect in the environment which is necessary for information to take place. This is yet another point in which Peirce’s account is helpful. It is an important assumption in a Peircean framework that the ‘blackness’ of the sky, for instance, is a form embodied in an object in a regular way. The regular property of blackness and the ‘blackness – rain’ correlation compose the “form” communicated from the source to the interpreter, eliciting a specific response. In this case, we treat *information* as the communication of a regular spatiotemporal correlation ‘blackness – rain’ from O to I. The communication of such a form is the transference of this *correlation* to the interpreter *so as to produce* a specific response (an effect on the interpreter) constraining its behaviour.

This brings about a constrained set of effects of the object on the interpreter *through* the mediation of the sign.

Finally, even though Jablonka's understanding of information is in several respects consistent with our conceptualization of information as a process through which a form is communicated from the object to the interpretant through the mediation of a sign, there are also aspects of the Peircean view presented here that disagree with her argument that information is something that an entity (or process) can autonomously possess, 'have'.

7. Concluding Remarks

Both Bateson's and Jablonka's concepts of "information" (and perhaps even the Peircean account discussed in this paper, as well) may seem "too broad" — but we think they are just as broad as they should be, since "information" is in itself a sweeping concept. Information can encompass a variety of processes, involving, for example, genes, molecules, computers, the media, and everyday things such as recipes or instructions in a manual. Furthermore, information can be acquired, communicated, reconstructed, processed, translated, shared, and so on, in a variety of ways. Therefore, we can say that, in an adequate manner, such accounts as Bateson's, Jablonka's, and a Peircean one are as broad as the phenomena they intend to grasp. A wide variety of entities and processes can be "differences that make a difference" to an interpreter or can "make a receiver-system react to them in such a way that the reaction can actually or potentially change the state of the receiver in a (usually) functional manner", or can "embody a regular form which may be communicated to an interpretant through the mediation of a sign".

Symptomatically, Jablonka (2002) presents arguments to the effect that one of the advantages of her definition *is*, in fact, its broad nature — allowing it to accommodate 'information' as related to both environmental cues, and evolved signals. Furthermore, she argues that her definition can be used as a basis for a comparative analysis of different types of information systems in living beings. And the same is true of the Peircean account of information. Both accounts also avoid the attribution of a theoretically privileged informational status to "genes" — which are just *one* of the types of informational sources contributing to the development and functioning of organisms.

Another important aspect to be noted is that Jablonka restricts information to living systems (and systems designed by living beings, such as man-made devices): "according to my definition, information is something that can exist only when there are living (or more generally, designed) systems. Only living systems make a source into an informational input" (Jablonka 2002: 588). We

are also sympathetic to the idea that living systems, historically, have been the first genuine semiotic systems.¹¹ In our view, systems such as the first cell-like entities were the first true semiotic systems, in that they had a boundary separating an internal environment from an external environment, thus requiring that the system interpreted external entities and processes as meaning something more than just being external events, as a part of cosmos with no pragmatic significance, but rather, as being potentially useful (or the opposite) for the maintenance and reproduction of the system — i.e., being relevant *signs*. These systems furthermore, internalized such meanings, producing another sign inside the system, which, in turn, stood for the object as the external sign itself stood — i.e., an *interpretant* (see also El-Hani et al. 2007).

In closing, Bateson's and Jablonka's remarks on "information" suggest, in agreement with the Peircean account that we have developed, a *process interpretation* of that concept. Thus, even though it may not seem so clear in Bateson that information is a process, his arguments indeed focus on a dynamical process by which a difference makes a difference to a system which interprets it. Similarly, Jablonka does not make it explicit that information should be conceived as a process, but she stresses that the source is made into an information input when the receiver functionally reacts to it — and this highlights, in turn, the processes mediated by the interpretative systems of living beings which functionally correlate the variation of the form of the source to the variation in the response of the receiver.

Our Peircean account, in turn, makes *explicit* the conceptualization of information as a process — namely, the process of communicating a form from the object to the interpretant through the sign. In short, we believe it is possible to employ the Peircean account of information discussed here as the basis for building a *synthetic account*, incorporating several aspects of both Bateson's and Jablonka's approaches. This is a challenge that we hope to expand upon in future works.

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11. We will not enter here into the debate about borderline cases or the famous question of the semiotic threshold below which processes cannot be characterized as depending on triadic relations or Thirdness. On this issue, see Stjernfelt (2006), Nöth (2001) and the special issue of *Sign Systems Studies*, vol. 29, issue 1, 2001, as a whole.

References

- ADAMI, Cristoph.
2004. "Information Theory in Molecular Biology" *Physics of Life Reviews* 1, 3–22.
- BATESON, Gregory.
1972. *Steps to an Ecology of Mind* (New York: Ballantine).
- BERGMAN, Mads.
2000. "Reflections on the Role of the Communicative Sign in Semeiotic". *Transactions of the Charles S. Peirce Society: A Quarterly Journal in American Philosophy* Spring, XXXVI (2), 225–254.
- BRIER, Søren.
1996. "From Second-order Cybernetics to Cybersemiotics: A Semiotic Re-entry into the Second-order Cybernetics of Heinz von Foerster". *Systems Research* 13, 229–244.
- BRUNI, Luis.
2003. "A Sign-theoretic Approach to Biotechnology". Unpublished Ph.D. dissertation. Institute of Molecular Biology, University of Copenhagen.
- COLAPIETRO, Vincent.
1989. *Peirce's Approach to the Self: A Semiotic Perspective on Human Subjectivity* (New York: State University of New York Press).
- DEACON, Terrence .
1997. *The Symbolic Species: The Co-evolution of Language and the Brain* (New York: W.W. Norton & Company).
- DETIENNE, André.
2003. "Learning *Qua* Semiosis". *S.E.E.D. Journal (Semiotics, Evolution, Energy, and Development)* 3.3, 37–53.
- DEBROCK, Guy.
1996. "Information and the Metaphysical Status of the Sign", in *Peirce's Doctrine of Signs — Theory, Applications, and Connections*, ed. V. Colapietro and T. Olszewsky (Berlin, New York: Mouton de Gruyter), 80–89.
- EL-HANI, Charbel Niño, João QUEIROZ, and Claus EMMECHE.
2006. "A Semiotic Analysis of the Genetic Information System". *Semiotica* 160.1/4, 1–68.
- EL-HANI, Charbel Niño, Argyris ARNELLOS, and João QUEIROZ.
2007. "Modeling a Semiotic Process in the Immune System: Signal Transduction in B-cell Activation". *TripleC — Cognition, Communication, Co-operation* 5.2, 24–36.
- EMMECHE, Claus.
1990. *Det Biologiske Informationsbegreb*. Aarhus: Forlaget Kimære. Ph.D. dissertation; [*The Concept of Information in Biology*]; in Danish.

2000. "Closure, Function, Emergence, Semiosis and Life: The Same Idea? Reflections on the Concrete and the Abstract in Theoretical Biology", in *Closure: Emergent Organizations and Their Dynamics*. (Annals of the New York Academy of Sciences, volume 901), ed. J. L. R. Chandler and G. Van de Vijver, 187–197 (New York: The New York Academy of Sciences).
- FETZER, James.
 1988. "Signs and Minds: An introduction to the Theory of Semiotic Systems", in *Aspects of Artificial Intelligence*, ed. Fetzer, James (Dordrecht: Kluwer Academic Publishers), 133–161.
- FREEMAN, Eugene (ed.).
 1983. *The Relevance of Charles Peirce* (La Salle: Monist Library of Philosophy).
- FREEDMAN, Anne.
 2004. *The Machinery of Talk: Charles Peirce and the Sign Hypothesis* (Stanford: Stanford University Press).
- HOUSER, Nathan, Don D. ROBERTS, and James van EVRA (eds.).
 1997. *Studies in the Logic of Charles Sanders Peirce* (Bloomington: Indiana University Press).
- HEYLIGHEN, Francis, and Clifford JOSLYN.
 2001. "Cybernetics and Second Order Cybernetics", in *Encyclopedia of Physical Science and Technology* vol. 4, ed. A. J. Meyer, 155–170 (New York: Academic Press).
- HOFFMEYER, Jesper.
 1996. *Signs of Meaning in the Universe*. (Bloomington: Indiana University Press).
 1998. "The Unfolding Semiosphere", in *Evolutionary Systems. Biological and Epistemological Perspectives on Selection and Self-Organization*, ed. G. Van De Vijver, S. Salthe, and M. Delpos (Dordrecht: Kluwer), 281–294.
- HOFFMEYER, Jesper, and Claus EMMECHE.
 1991. "Code-duality and the Semiotics of Nature", in *On Semiotic Modeling*, ed. M. Anderson F. and Merrell (Berlin/New York: Mouton de Gruyter), 117–166. [Reprinted 2005 in *Journal of Biosemiotics* 1.1, 27–64].
- HOOKWAY, Christopher .
 1985. *Peirce* (London: Routledge and Kegan Paul).
 2002. *Truth, Rationality, and Pragmatism : Themes from Peirce* (Oxford: Oxford University Press).
- JABLONKA, Eva.
 1994. "Inheritance Systems and the Evolution of New Levels of Individuality". *Journal of Theoretical Biology* 170, 301–309.

2002. "Information: Its Interpretation, Its Inheritance, and Its Sharing". *Philosophy of Science* 69, 578–605.
- JABLONKA, Eva, and Eors SZATHMÁRY.
1995. "The Evolution of Information Storage and Heredity". *Trends in Ecology and Evolution* 10, 206–211.
- JABLONKA, Eva, and Marion J. LAMB.
2005. *Evolution in Four Dimensions* (Cambridge, MA: MIT Press).
- JABLONKA, Eva, Marion LAMB, and Eytan AVITAL.
1998. "Lamarckian' Mechanisms in Darwinian Evolution". *Trends in Ecology and Evolution* 13, 206–210.
- JOHANSEN, Jørgen Dienes.
1993. *Dialogic Semiosis* (Bloomington and Indianapolis: Indiana University Press).
- KÜPPERS, Bernd-Olaf.
1990. *Information and the Origin of Life* (Cambridge, MA: MIT Press).
- MAYNARD SMITH, John.
2000. "The Concept of Information in Biology". *Philosophy of Science* 67.2, 177–194.
- MURPHEY, Murray.
1993. *The Development of Peirce's Philosophy* (Indianapolis: Hackett).
- PEIRCE, Charles Sanders.
1867–1913. *The Collected Papers of Charles Sanders Peirce*, ed. C. Hartshorne and P. Weiss (Cambridge, MA: Harvard University Press, 1931–1935). Vols. VII–VIII ed. A. W. Burks (Cambridge, MA: Harvard University Press, 1958). Electronic edition reproducing Vols. I–VI (Charlottesville: Intelix Corporation). [Here referred as CP, followed by volume and paragraph number.]
1967. *Annotated Catalogue of the papers of Charles S. Peirce*, ed. R. Robin (Amherst, MA: University of Massachusetts). [References to manuscripts and letters by Charles S. Peirce — MS and L — are in accordance with this catalogue.]
1998. *The Essential Peirce: Selected Philosophical Writings*. Vol. II, ed. Peirce Edition Project. (Bloomington and Indianapolis: Indiana University Press). [Herein referred as EP 2, followed by the number of the page.]
2000. *Writings of Charles S. Peirce: a Chronological Edition*. Vol. 2, ed. Peirce Edition Project (Bloomington: Indiana University). [Quoted as W, followed by page number].
- PRIGOGINE, Ilya, and Isabelle STENGERS.
1983. *Order Out of Chaos: Man's New Dialogue with Nature* (New York: Bantam).

- QUEIROZ, João, and Charbel Niño EL-HANI.
 2007. "On Peirce's Notion of Information: Remarks on De Tienne's Position". *Cognitio* 8.2, 289–298.
 2006. "Towards a Multi-level Approach to the Emergence of Meaning Processes in Living Systems". *Acta Biotheoretica* 54.3, 174–206.
- QUEIROZ, João, Claus EMMECHE, and Charbel Niño EL-HANI.
 2005. "Information and Semiosis in Living Systems: A Biosemiotic Approach". *S.E.E.D. Journal (Semiotics, Evolution, Energy, and Development)* 5.1, 60–90.
- QUEIROZ, João, and Floyd MERRELL (guest eds.).
 2005. "Abduction — Between Subjectivity and Objectivity". (special issue on abductive inference) *Semiotica* 153.1/4.
- SCHERRER, Klaus, and Jürgen OST.
 2007. "Gene and Genon Concept: Coding Versus Regulation". *Theory in Biosciences* 126, 65–113.
- SCHNEIDER, Thomas D.
 1994. "Sequence Logos, Machine/Channel Capacity, Maxwell's Demon, and Molecular Computers: A Review of the Theory of Molecular Machines". *Nanotechnology* 5, 1–18.
- SCHNEIDER, Thomas D., and R. Michael STEPHENS.
 1990. "Sequence Logos: A New Way to Display Consensus Sequences". *Nucleic Acids Research* 18, 6097–6100.
- SHANNON, Claude E., and Warren WEAVER.
 1949. *The Mathematical Theory of Communication* (Urbana, IL: University of Illinois Press).
- THOM, René.
 1975. *Structural Stability and Morphogenesis*, trans. W.M. Brooks and D. Rand (West Sussex: Ellis Horwood).
- TIERCELIN, Claudine .
 1995. "The Relevance of Peirce's Semiotic for Contemporary Issues in Cognitive Science", in *Mind and Cognition: Philosophical Perspectives on Cognitive Science and Artificial Intelligence*, ed. Leila Haaparanta and Sara Heinämaa *Acta Philosophica Fennica* 58, 37–74.
- WILDEN, Anthony.
 1980. *System and Structure. Essays in Communication and Exchange* 2. rev. ed. [1. ed. 1972] (New York: Tavistock Publications).
- YOCKEY, Hubert P.
 1992. *Information Theory and Molecular Biology* (Cambridge: Cambridge University Press).