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Semiosis and Information: Meeting the Challenge of Information Science to Post-reductionist Biosemiotics

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Abstract: The concept of information and its relation to biosemiotics is a major area of contention among biosemioticians. Biosemioticians influenced by von Uexküll, Sebeok, Bateson and Peirce are critical of the way the concept as developed in information science has been applied to biology, while others believe that for biosemiotics to gain acceptance it will have to embrace information science and distance biosemiotics from Peirce's philosophical work. Here I will defend the influence of Peirce on biosemiotics, arguing that information science and biosemiotics as these were originally formulated are radically opposed research traditions. Failure to appreciate this will undermine the challenge of biosemiotics and other anti-reductionist traditions to mainstream science with its reductionist ambition to explain everything through physics. However, for this challenge to be successful, it will be necessary to respond to criticisms of Peircian ideas, jettisoning ideas that are no longer defensible and integrating ideas allied to his anti-reductionist agenda. Here I will argue that the natural philosophy of Gilbert Simondon, offering a searching critique of the application of the new concept of information and cybernetics to the life and human sciences, provides the means to defend and advance Peirce's core ideas and thereby defend post-reductionist biosemiotics.

Keywords: Biosemiotics; Information; C.S. Peirce; Jesper Hoffmeyer; Howard Pattee; Gilbert Simondon

There is a problematic relationship between biosemiotics and the concept of information, along with information science generally. Jesper Hoffmeyer in *Signs of Meaning in the Universe,* essentially a manifesto for biosemiotics based on Peirce's philosophy, pointed out that 'form' for the Romans was a mangled version of the Greek 'morf' (or 'morph'), and 'information' meant being formed mentally. Atomistic thinking in the Twentieth Century led 'information' to be understood as isolated chunks of knowledge and this was taken over by the physicists, who then characterized it as something in the world, independent of anyone, and then tried to impose this inverted, desiccated concept of information on all other disciplines. In his later book *Biosemiotics,* he wrote that 'up-to-date biology must acknowledge that the biochemical concept of information is just too impoverished to be of any explanatory use' (p.61). In the lead article to a special issue of *Biosemiotics* published in 2013 devoted to information in biosemiotics, 'Epistemic, Evolutionary, and Physical Conditions for Biological Information', Howard Pattee took exception to Hoffmeyer's denigration of the concept of information. As he put it, 'On the contrary, as a physicist I believe information is a fundamental primitive concept and all semiotic concepts are forms of information' (p.11). More specifically, Pattee rejected Hoffmeyer's allegiance to Peirce's cosmology. 'In my opinion' he wrote, 'if biosemiotics should follow his advice and replace the principles of modern science with Peircian cosmology, it will become a fringe subject ignored by both biology and physics. … Scientists and mathematicians recognize Peirce as a great logician, not as great cosmologist' (p.18). Most of this paper was devoted to defending more orthodox biologists and their achievements, including his own work, along with their use of the notion of information. He denied that biosemiotics utilizing Peirce's work had contributed anything significant to biology. Referring to Hoffmeyer and Emmeche's paper on dual coding, arguing for the importance of analog coding as well as digital coding he wrote: 'I see no difference in Hoffmeyer and Emmeche's view of digital and analog codes from von Neumann's logical requirement for descriptions and constructions. I also see nothing in their "code duality" that differs conceptually or goes beyond my two codes' (p.19).[1] The most important contributions to biosemiotics, he claimed, had been made by orthodox biologists who had noticed the parallel between the genetic code and the codes of language. Different views were defended by the remainder of the papers, some aligned with Hoffmeyer's views, some more sympathetic to information theory. There was no consensus, although subsequently there appears to be a move away from semiotics as characterized by Peirce in order to reconcile biosemiotics with information science and to accord more place to codes (Auletta 2016).

In fact, Hoffmeyer did not reject the notion of information entirely. He accepted Gregory Bateson's characterization of information as 'a difference that makes a difference'. This implies that there is no information outside living beings interacting with their environments. Hoffmeyer also took seriously Stan Salthe's notion of information as characterized in his version of infodynamics (influenced by the work of the ecologist Robert Ulanowicz) and along with this, information constraints (Hoffmeyer 2008a: 112f.). The notion of constraints was influenced by Pattee; however, Salthe (1993) was also strongly influenced by Peirce and formulated his conception of these constraints to accord with Peircian semiotics. Furthermore, Peirce himself gave a central place to information in his philosophy, although conceiving it very differently than the later information scientists. His conception of information evolved with his philosophy, from incorporating it into his work in logic to his characterization of logic as semiotics, and then his generalization of semiotics beyond humans and into a cosmology.

To begin with, Peirce characterized information as a logical quantity, the amount of comprehension a symbol has over and above its extension (Liszka 1990; Nöth 2013). However, right from the beginning of his work in symbolic logic, which was able to deal with relations and not merely the attributes of substances (as in Aristotelian logic), Peirce took seriously the ontological implications of this logic, taking relations to be real components of the world, including the relation of the knower to the known. Hence he referred to his work in logic as the 'logic of relatives'. With the reformulation of logic as semiotics, information was identified with all the knowledge acquired through experience incorporated into signs as interpretants, and this was applied to signs in general, not only verbal signs. Conveying information requires a synthesis of icons and indexes in a dicent symbol, that is, a proposition, but a weathercock also could convey information in this sense. With the extension of semiotics into a philosophy of nature (metaphysics), signs were seen as developing in nature as well as being instituted, growing in complexity with semiosis and the creative evolution of interpretants. The greater the quantity of information, the more adequate the interpretant, with signs acquiring further implications in the course of their history. Information is the knowledge we accumulate, pass on and develop through this history to be better informed. This analysis of semiosis was then generalized to the non-human world.

Biosemioticians closely aligned with Hoffmeyer have set out to develop Peirce's notion of information to overcome the limitations of its current use by geneticists, exemplified by Ernst Mayr, J. Maynard Smith and E. Szathmáry (El-Hani et al. 2008: 92ff.). From this Peircian perspective, information is semiosis, the 'triadic dependent process through which a form embodied in the Object

[1] Pattee appeared to be unaware that Hoffmeyer and Emmeche's notion of dual coding came from Gregory Bateson, that this was acknowledged by them, and that in defending analog coding Bateson was continuing a debate between cyberneticians from the 1950s over the status of analogue coding (see Dupuy, 2009: 114).

in regular way is communicated to an interpretant through the mediation of a Sign' (p. 96). Here, the form is not a 'thing' but is embodied in the object as a habit and as a real potential or permanence of some relation which allows it to be interpreted as indicative of a particular class of entities, processes or phenomena, and allows a system to respond to it in a regular way (p.93). Since 'information' is a noun of process, Peirce's appropriation and development of this concept and his characterization of it as a process accords with its original meaning. These authors argued that Bateson's notion of information, while different and not immediately emphasising the processual aspect of information, is consistent with this Peircian notion and can be integrated with it (p.10ff.). They also showed in detail how Salthe's hierarchical structuralism was influenced by Peirce and accorded with Peirce's philosophy (p.141ff). Infodynamics as conceived and defended by Salthe was a development of this hierarchical structuralism. So, the opposition by Hoffmeyer and his colleagues to the notion of information should be understood as opposition to what they claimed was a fundamentally defective conception of it, not an outright rejection of the concept.

Biosemioticians as a group have not embraced this commitment to Peirce's notion of information, or even Salthe's integration of Pattee's work with Peirce's semiotics, however. While some biosemioticians have ignored the challenge of reductionist science or, as in the case of Jaime Cárdenas-García (2020a), explicitly defended Bateson's notion of information, other biosemioticians, for instance, Gennaro Auletta (2011), have embraced information science. Others, by using the word 'information' unreflectively, are simply absorbing the terminology and ways of thinking of mainstream information science. This is blurring the boundaries between information science applied to biology and post-reductionist biosemiotics as distinct and opposing research programs. When the development of information theory is investigated, it becomes evident why Hoffmeyer was hostile to the role information theory was playing in biology.

The Origins and Rise of Information Science

There is now a huge amount written on various aspects of information, with a number of subdisciplines emerging, and despite books being written trying to provide a coherent overview of the whole field, it is difficult to find and pin down a consensual set of assumptions on which the information sciences are based. However, information theory as such had its origins in the Macy Conferences on Cybernetics held between 1946 and 1953 (Heims 1980; Heims 1991: 11; Hayles 1999: 50ff.; Dupuy 2009) with the integration of Claude Shannon's mathematical treatment of the concepts, parameters and rules governing the transmission of messages through telephone cables (embraced and generalized by Warren Weaver) with Norbert Wiener's work on cybernetics as a general theory of regulation (Shannon 1948; Shannon & Weaver 1949; Wiener 1948). This integration was effected by John von Neuman and Wiener, and Wiener related all this to thermodynamics by endorsing Leo Szilard's argument from 1929 that information is a measure of negentropic organization, the opposite of entropy, which is the measure of disorganization (Wiener 1961: 11). From this perspective, information is an objective component of the physical world, along with matter and energy. The work of Warren McCulloch and Walter Pitts on the functioning of neurons and the formation of neural nets, able to carry out Boolean algebra calculations, held out the promise of explaining (or explaining away) mind and consciousness through this form of information theory, justifying the view that there is no essential difference between humans and machines (Heims 1991: 38). These are the ideas that later were incorporated into cognitive science (Dupuy, 2009: ix).

With the discovery of the prominent role of DNA in heredity in 1953 and its interpretation as the genetic code, this suggested that 'information' provided the key to understanding biology. Physicists later interpreted quantum theory through information theory, beginning with efforts to resolve the measurement problem (Bub 2004; Floridi 2011: 66). These developments seemed to overcome the limitations of past science and suggested the whole of reality could now be understood through the categories of physics. Cognitive scientists believed they now had the concepts required to 'mechanize the mind', showing that organisms, including humans, are nothing but complex information processing machines (Dupuy 2009). By adding information to matter and energy, and even privileging information, many scientists believed they had the basis for a metaphysical monism. For these ontological reductionists, the universe's essential nature is digital, composed of bits of information (Zurek 1990; Floridi 2011: 91). Material objects could be and were interpreted as complex, secondary manifestations of information, with John Wheeler summing up this metaphysics in three words: 'it from bit' (Wheeler 1990). The whole universe could be seen as an information processing mechanism. This reductionist metaphysics, first put forward by Konrad Zuse and advanced by E. Fredkin, S. Wolfram and Gregory Chaitin, among others, was defended as a coherent naturalist metaphysics. A less extreme (and more plausible) form of this has been defended by James Ladyman and Don Ross (2007) as 'information-theoretic structural realism' (p.238ff.) and Luciano Floridi (2011, Chap.15) as 'informational structural realism.' Ladyman and Ross as philosophers were defending this metaphysics as part of 'scientism', the view that only science can produce genuine knowledge of reality, claiming their philosophy to be based on the most advanced science.

Not all scientists saw these developments as the triumph of reductionist science, however. While McCulloch vigorously promoted the reductionist agenda, claiming that his and Pitts' work on neural nets showed that the brain is nothing but a computer and human thought nothing but computing as characterized by Turing, Shannon and Wiener were cautious in their claims for the mathematical theory of information and the applicability of cybernetics to biology and society. Shannon went so far as to write a critique of the generalization of his notion of information beyond its initial very limited domain (Shannon 1956, 3) and Wiener retreated from his earlier claims. Others, however, saw the incorporation of the notion of information into science as the required breakthrough for creating a more humanistic form of science. This was all seen as part of the unity of science project begun in the 1930s. While Shannon and Weaver's notion of information was purely syntactic, which they themselves acknowledged, efforts were made to supplement this with theories of the semantics and pragmatics of information as these had been characterized by logical positivists, according a place to truth and meaning, and beyond that, to meaningful action (Barr-Hillel & Carnap 1953; Floridi 2011: 196; Hayles 1999: 54ff.), a notion of meaning which precludes ascribing meaning to life or literature.

Cybernetics was taken up but also challenged by Heinz von Foerster, Margaret Mead and Gregory Bateson, giving a place to what von Foerster called 'second order cybernetics' in which cybernetics is applied recursively to itself (Clarke and Hansen 2009). Von Foerster (1995) referred to second order cybernetics as the cybernetics of 'observing systems', where first order cybernetics is the cybernetics of 'observed systems', or as the control of control and the communication of communication. Information was then defined in relation to the observing system rather than being an objective component of the physical world. This is the basis of Bateson's definition of information as a 'difference that makes a difference' (Cárdenas-García 2020a). Inspired by second order cybernetics, Humberto Maturana and Fransciso Varela developed their theory of autopoiesis as self-organising autonomous networks which produce and recursively sustain themselves, thereby preserving systemic cohesion (Varela et.al. 1993). Cárdenas-García (2020b) argued that information can only be understood in relation to such autopoiesis where it can be seen to have a functional role, thereby supporting a notion of information commensurate with that of the Peircians. So, while drawing on work in cybernetics and information science, proponents of second-order cybernetics were not merely critical but were deeply suspicious of efforts to mechanize the mind, with von Foerster noting that 'cybernetics' is already an anthropomorphic characterization of machines (Dupuy 2009: xix).

Pattee's own work developed along a different path. It could be seen as furthering the reduction of biology to physics, although his work has also been used to oppose such thinking. Beginning with an analysis of measurement in quantum theory, where, as von Neumann argued, an epistemic cut is required between the observer and the object observed and the setting up of constraints to make such an observation, Pattee pointed out the dynamics revealed in such observations presuppose the establishment of both initial and boundary conditions. The existence of boundary conditions as constraints allows for the possibility of hierarchical ordering through new levels of constraint, facilitating specific control of lower level organization by higher level organization. He promoted this idea strongly in the 1970s and it has subsequently been enormously influential (Pattee 1973; Pattee 2012). Emergence occurs through new enabling constraints. This idea was developed by Salthe and accepted by Hoffmeyer, although Hoffmeyer disliked the notion of the epistemic cut. It is clear, however, that Pattee did not view these ideas on hierarchical ordering as incompatible with developments in mainstream information science, providing information science acknowledged a place for semantic and pragmatic aspects of information as well as Shannon's syntactic information, and could accommodate hierarchical ordering. Characterizing genetics, he wrote 'the genetic code is translation (syntax), the protein folding is the first level of reading (semantics) where the degeneracy of the information is removed, and the specific enzymatic catalysis (with all the RNA machines) is the first level of execution (pragmatics) of the stored information' (Pattee 2008: 22). The presence of all three is required for semantic closure where the transmission or catalytic code is itself coded in stored information.

The Crux of the Matter

Resolving the opposition between biosemioticians upholding Peirce's more complex but more traditional notion of information along with Bateson's notion of information and biosemioticians happy to build on developments in mainstream information theory is clearly much more complex than it seems. One way of settling the dispute is to focus on specific areas of research to show that one or the other approach is defective. For instance, it has been argued by a number of theorists that Shannon's notion of information is inadequate to understand biotic processes (Logan 2012; Perrett and Longo 2016), while Søren Brier (2008) argued that it is inadequate to understand either biotic or cultural processes. Through a careful study of the problems in characterizing the functioning of genes through syntactic, semantic, and pragmatic theories of information, and the superior potential of Peirce's notion of information as semiosis for accounting for epigenesis, El-Hani et.al. (2008) argued for the potential fruitfulness and thereby provided a good defence biosemiotics utilizing Peirce's philosophy as a viable research program (p.222). In doing so, they still argued convincingly that 'we don't have an established notion of biological information up to this point' (p.222). This certainly is a viable way to proceed. However, what their work points to is a more fundamental difference in orientation, between those who begin with current physics and attempt to make it more complex to deal with life and mind, and those who take as their starting point the reality of mind and demand that physics be developed in a way that is consistent with the evolution of and reality of life and mind. This difference and its significance were well characterized by Tommi Vehkavaara (2008). As he put it,

> … the recognition of an analogy between mind and living nature has produced two kinds of approaches or research strategies, both risky in their own peculiar way. The *naturalized models of mind* focusses on mind and tries to naturalize it. … They tend to commit naturalistic fallacies by using too simple and distorted picture of the complexity of mental phenomena. […] [T]he other kinds of approaches, the *mental models of life* – to which biosemiotics belongs – pursue typically a holistic

> strategy. They focus on natural phenomena and try to model them on concepts that originally referred only to the human mental or social sphere. Consequently, they fall easily into *anthropomorphic fallacies* by predicating properties or qualities exclusive to humans to non-human natural phenomena. (p.258)

While there are difficulties with both forms of naturalism, it can be shown historically that the holistic strategy has been more fruitful and is more coherent. This is evident in the failures of those proposing naturalised models of the mind with their associated conceptions of life. As Robert Rosen (1999) pointed out, this approach is based on the idea that in 'serially endowing a machine with more and more of the simulacra of life, we would cross a threshold beyond which the machine would become an organism' (p.269). From the clockwork models of Descartes' times to the thermodynamic machines of the energeticists to the chemical models of molecular biologists to Turing machines, the same strategy has been pursued. As Rosen observed, 'The manipulation of meaningless symbols by fixed external rules is, it should be noted, exactly analogous to the Newtonian view of material nature, expressed in terms of manipulation of configurations of structureless particles by impressed forces' (p.266). What has been left out of such models, as Nicholas Rashevsky, Rosen's mentor and the first person to develop neural nets, argued, is life itself. Rashevsky abandoned his work on neural nets because he concluded that through them it was still not possible to comprehend life itself. In examining the work of the biochemists, Rosen claimed that not only had they failed to account through chemistry how genes could generate form; in terms of their own assumptions it is impossible. As he put it, 'the chasm is the distinction between chemistry and geometry, and, from a purely reductionistic viewpoint, it is simply unbridgeable' (p.227). Rosen worked with Pattee for some time, and fully accepted the argument that it is impossible to account for the agency associated with making measurement within the initial and boundary conditions presupposed by post-Newtonian science, but became dissatisfied with Pattee's solution. He concluded that it is first necessary to characterize life itself, and that the physical sciences will then have to be revived to accord with the insights generated by biology. That is, from Vehkavaara's perspective, Rosen resolutely embraced the agenda of the holists.

In doing so, Rosen was aligning himself with a tradition of thought going back to Schelling, and it is in relation to this whole Schellingian tradition that the superiority of agenda of the holists becomes fully apparent. Schelling accepted Kant's argument that science requires a set of metaphysical presuppositions about the structure of the world that are not merely analytically true nor empirically derived but are the condition for there being science; however, he argued that it is possible to replace prevailing metaphysical presuppositions. As a Kantian transcendentalist he was first of all concerned with mind and the categories required for scientific knowledge to be possible, but evolved into a naturalist, 'naturalizing the transcendental' and focussing on how nature must be understood if it is to make intelligible the emergence of life, with organisms seen as maintaining their form by defining their environments in relation to themselves as their worlds, and humanity seen to be capable of comprehending itself as a part of nature. He called for new physics and new mathematics to achieve this. What has largely written out of history until relatively recently has been recognition of the prescience of Schelling and the success of the research program he inspired, not only in the human sciences and biology, but in physics, chemistry and mathematics (Heusser-Kessler 1986; Gare 2013). This includes the development of the dynamic conception of matter culminating in field theories in physics, the notion of the conservation of energy, the notion of valency in chemistry, the notion that organisms define their environments as worlds, the notion that nature as a whole and its components are self-organizing systems or processes, and Hermann Grassmann's extension theory in mathematics that underpins most of the mathematics now used in physics.

The original biosemioticians were clearly continuing this tradition. Jacob von Uexküll who was a major source of inspiration and point of departure for the biosemioticians, was strongly influenced by Kant and echoed and further developed Schelling's conception of organisms. Peirce, whose philosophy was embraced to rigorously defend and extend von Uexküll's work, preserving his phenomenology of life while abandoning his Platonic Idealist belief in eternal Bauplans, claimed to be 'a Schellingian of some stripe' (Peirce: 6.605). However, there are other philosophers and scientists contributing to this Schellingian tradition. One group of these are the philosophers and scientists attempting to naturalize phenomenology. This project was largely inspired by Varela, who was an originator of the notion of autopoiesis based on second-order cybernetics, but went on to embrace and further advance the late work of Maurice Merleau-Ponty (Varela et.al. 1993). From the beginning of his career Merleau-Ponty had been trying to overcome the focus of phenomenology on the subject and the Cartesian dualism it led to by focussing on embodiment, but came to the conclusion that his solution to the problem was inadequate, and turned to natural philosophy in his last lectures. In doing so, he revived interest in Schelling's philosophy and the work of von Uexküll to naturalize phenomenology (Merleau-Ponty 2003).

Merleau-Ponty's former student, Gilbert Simondon, had taken this naturalistic direction further, asserting that nature comes before experience, and set out to develop a natural philosophy that could unify the sciences and give a place to experience (Simondon et.al. 2019: 579). This was presented in his Ph.D. dissertation published in book form as *L'individuation à individuation à la lumière des notions de forme et d'information* in 1964 and republished in 2013, and then in English translation as *Individuation in Light of Notions of Form and Information* in 2020. Simondon was more influenced by Bergson than Schelling, but then Bergson himself was part of a French Schellingian tradition of philosophy. In the tradition of Schelling, Rosen was concerned to develop mathematical models adequate to life itself. However, he acknowledged that mathematics is necessarily abstract. It must be complemented by non-mathematical ways of knowing. Simondon was concerned with the realm of ontogenesis or becoming that cannot be understood through mathematics but explains how aspects of reality that can be grasped through mathematics, emerge. Here I will argue that Simondon's work, complementing Rosen's, can be used to justify and further develop Peircian philosophy and thereby biosemiotics influenced by it, including the Peircian conception of information. That is, as Wendy Wheeler has argued and been defended in a review of her work by Theirry Bardini (2017), through Simondon's philosophy a place can be given to both semiotics and information.

Simondon's Natural Philosophy

Simondon can be seen as a major figure in the Schellingian tradition grappling with far more advanced science than was Peirce (Barthélémy & Iliadis 2015: 106f.). In a letter to William James, Peirce wrote: 'If you were to call my philosophy Schellingianism transformed in the light of modern physics, I should not take it hard' (Esposito 1977: 203). Just as Peirce could claim that he was a Schellingian but dealing with much more advanced science, Simondon if he had referred to Peirce could claim that he was a Peircian transformed in the light of more recent physics, and essentially this is how he has been interpreted by Alberto Toscano (2006: 123-156). One of Simondon's major concerns was to challenge and reformulate the notion of information as it had been developed by Shannon, Weaver and Wiener, and along with this, the notion of cybernetics and the way it had been used as an analogy for living processes. Some of the ideas associated with this challenge were developed at a conference in Paris in July 1962, organized by Simondon, in which Wiener was a major participant (Bardin 2015: 31). Simondon's work on information was part of a broader project of natural philosophy focussed on 'individuation' from the 'preindividual' characterized by excess potentiality, in terms of which Simondon was also concerned to interpret recent developments in science.

Simondon embraced the development of information science and cybernetics, seeing them as a creative hybrid of advances in logic and technology, but argued that the source of these ideas in technologies of communication leads to the exclusion of what is most important when it comes to understanding information. To begin with, Simondon challenged Wiener's equation of information with negative entropy and for dissociating information from *signification*. He pointed out that to avoid signal degradation one can increase the signal energy or reduce the background noise. If the latter, a reduction of energy increases order, so there cannot be a constant mathematical relationship between the energy input and the quantity of information transmitted (Bardin 2015: 29). He then pointed out the problems with the assumptions on which information science was developing. It presupposed an individual sending a message, an individual bit of information or signal and a code through which it is encoded and an individual receiving the message by decoding it. In Peircian language, each of these are dyadic relations. But such dyadic relations presuppose the individuation of all the individuals involved in this, including the message. To reveal what is wrong with this scenario, Simondon provided examples where this characterization of communication fails. One is the communication within the central nervous system associated with seeing images recorded from slightly different (but not too different) positions being unified in stereoscopic vision. He also described a situation of coupled electronic oscillators of slightly different frequencies arranged so that their magnetic fields overlap. Under these circumstances, the interaction will produce composite field which modifies of the oscillators themselves until a single frequency is arrived at, producing a new metastable equilibrium. What is important here is that there is communication but no logical identification of a sender and receiver since the two systems perform both functions. What we have is a macrosystem composed of the two systems and their interactions forming a macro-system or macro-field modifying itself from within (Bardin 2015: 25). What this example reveals is the problematic nature of the implicit dualisms of information science, between the active and the passive, the internal and the external, and information and relation. For Simondon, information itself as he characterizes it, constitutes the system of sender, receiver and message.

The points raised by this example of the oscillators concur with the points raised by Mikhail Bakhtin in his critique of Roman Jacobson's model of communication based on a code. Bakhtin pointed out that an utterance is not encoded and decoded, but is produced by both the speaker and the listener in dialogue using language, where the inherited language is not a fixed code but is maintained and modified as people engage in dialogue and struggle to achieve a common understanding. In doing so, participants in these dialogues are formed as individuals through this dialogic relationship and the utterances evoked in the dialogue; they do not pre-exist as unchanging individuals before, during and after dialogue and their utterances, but are individuated (although never completely) through dialogue, and as individuals, are always related to their context, including the shared language and other conditions of the dialogue. (Todorov 1984: 54f.)

These conditions constitute what Simondon refers to as the preindividual from which, through the process of individuation, individuals emerge. They do not emerge in isolation. As Jean-Hughs Barthélémy (2012) noted, 'individuation as genesis founds and encompasses the differentiation between individuals' (p.214). Simondon referred to preindividual being as a field or milieu of potentialities and set out to characterize the ontogenesis of individuals from this preindividual being. He took the figure emerging against a background from a perceptual field as studied by Gestalt psychology as an example of such individuation from the preindividual, although Simondon was critical of Gestalt theorists for characterizing this process as deterministic and failing to take into account tensions in the field allowing for possibility of further individuations. There could be no principles to grasp ontogenesis, since principles already assume an isolated, extricable, thus already individuated factors. As Simondon (2009) put it, '[c]oncepts are adequate only to individuated reality' (p. 7). Ontogenesis can only be understood by means of analogy through which we can grasp an identity of operative relations between the genesis of beings and the thought of this genesis (Barthélémy 2012: 204f.; Combes 2013: 9). It is only where individuation has taken place and there are individuals that mathematical modelling can be used. However, what is modelled in this way is always dependent upon the preindividual realm and the individuating process, and 'individuals' are always related to the preindividual realm, field or milieu from which they have individuated and are never completely individuated from this realm. These relations were held by Simondon to be real (p.16ff.), as are relations in Peircian semiosis (Fernandez 2010; Gare 2019: 61).

Simondon used examples from physics to illustrate these points in his quest to develop a natural philosophy adequate to life and human existence able to explain both the possibility of, and then the limitations of science. A major development within science, the importance of which had eluded most scientists and philosophers, was the appreciation of metastable systems. Metastable systems are not at their lowest energy levels but contain an excess of potentiality. They are 'more than unity and more than identity' (Simondon 2009: 6). Examples are supersaturated solutions or supercooled liquids. An internal resonance maintains these systems, with tensions between opposing potentialities balanced but not eliminated. A small perturbation either external to the system or completely internal to it will set off a rapid crystallization or freezing. For instance, a crystal, beginning with a very small seed, grows in all directions in which 'each molecular layer already constituted serves as a structuring base for the layer in the process of forming' (p. 6). Such dramatic changes are characterized by phase shifts in which one or some of a great many potentialities are realized to the exclusion of others. Simondon (2009) argued that quantum phenomena should be understood in terms of preindividual metastable systems with excess potentialities (p. 6f.). The realization of some potentialities precludes the realization of other potentialities, with the observed scientific object being individuated while at the same time the observer is constituted as an observer.

Simondon developed his ideas before Ilya Prigogine developed his notion of dissipative structures and later complexity theorists developed the notion of 'edge of chaos'. These developments illustrate and help to clarify Simondon's notion of metastable systems and individuation (although Simondon's notions are broader and cannot be identified with these scientific concepts, which were developed through mathematical modelling (Mills 2016: 49f., 59 & 63ff.)).[2] As Asra Atamer (2011) argued:

> Simondon's criticism of equilibrium and his theory of the physical and the vital individuations attain their methodological and onto-scientific underpinnings in Ilya Prigogine's theory of dissipative structures. […] Conversely, Prigogine's concept of dissipative structures finds its onto-scientific and onto-genetic relay in Simondon's non hylomorphic materiality (p.58).

Dissipative structures develop in far from thermodynamic equilibrium conditions in the process of transforming negative entropy into entropy (Prigogine 1978: 779). Based on Prigogine's work, it can also be conjectured that the universe originated from a metastable state. As Prigogine et.al. (1988) suggested: 'It appears that the usual initial singularity associated with the big bang is structurally

[2] It is noteworthy that both Prigogine and Stuart Kauffman (who developed the notion of 'edge of chaos'), argued that mathematics is limited, consistent with Simondon's claims. Kauffman, a mathematician, argued that stories are more fundamental than mathematics for comprehending reality.

unstable with respect to irreversible matter creation. The corresponding cosmological history therefore starts from an instability of the vacuum rather than from a singularity' (p.7428).

Living beings are more complexly organized dissipative structures characterized by hierarchical order in which conditions are actively maintained that prevent the system reaching thermodynamic equilibrium. Far-from-equilibrium conditions are locally maintained as part of these systems. These are a special kind of metastable system. In Simondonian terminology, they are characterized by internal resonance between multiple individuations communicating with each other over multiple orders of magnitude to maintain their metastabilty as the condition for individuation. As Simondon (2009) put it, '*the living conserves within itself a permanent activity of individuation'* (p.7). He characterized this activity of individuation as 'transduction', defining this as:

> an operation … by which an activity propagates itself from one element to the next, within a given domain, and founds this propagation on a structuration of the domain that is realized from place to place: each area of the constituted structure serves as the principle and the model for the next area, as a primer for its constitution, to the extent that the modification expands progressively at the same time as the structuring operation (p.11).

This is clearly consistent with and illuminated by C.H. Waddington's characterization of epigenesis in the development of embryos into differentiated organs, a process he characterized as individuation, and Piaget's characterization of cognitive development.

The focus on metastable systems and the ontogenesis of individuals as a process of individuation provides the basis not only for rethinking the notion of information and the place accorded to the engineering version of this, including its use in cybernetics, but also for updating Peirce's cosmological speculations and thereby defending his work on semiotics. Pattee (2013) was dismissive of this aspect of Peirce's work, notably the speculation that the universe began (citing Peirce) as 'a chaos of unpersonalized feeling' (p. 19, from Peirce 1931-58: 6.33). Elsewhere, Peirce (1931-58) characterized the beginning of the universe as 'the germinal nothing, in which the whole universe is involved or foreshadowed. As such, it is absolutely undefined and unlimited possibility -- boundless possibility. There is no compulsion and no law. It is boundless freedom.' (6.217) Peirce continued from the passage quoted by Pattee: 'This feeling, sporting here and there in pure arbitrariness, would have started the germ of a generalizing tendency. … Thus, the tendency to habit would be started; and from this, with the other principles of evolution, all the regularities of the universe would be evolved' (6.33). Matter was seen to have emerged through this tendency to take on habits which then by an iterative process, reinforced themselves.

We can now replace this characterization of cosmogenesis in a way that supports Peirce's claims for the place of possibilities in cosmology with that of a preindividual metastable state of the vacuum characterized by excess of potentiality laden with tension, where 'dissipative processes … start from empty conditions and gradually build up matter and entropy' (Prigogine and Géhéniau 1987: 6245). Fluctuations play a central role in this, and there is an indeterminacy in which fluctuations and thereby which potentialities will prevail. There is, in Simondon's sense, a process of individuation or ontogenesis where 'individuals' always remain related to the preindividual realm from which they are individuating, and this is a realm of possibilities. While removing some of the excessive anthropomorphism from Peirce's cosmology, this cosmology, according a central place to metastability, is not greatly different from that proposed by Peirce, the original metastable state consisting of endless possibilities with the amplification of fluctuations introduced by Prigogine corresponding to Peirce's characterization of original order emerging through self-reinforcing habits.

While the basic laws of physics would not be seen as the product of habits, Lee Smolin (2019) has argued that these laws could be different and could be evolving. What is more important is that a set of metaphysical presuppositions supporting post-reductionist biosemiotics is strongly supported in physics.

While characterizing metastable systems and individuation generally, Simondon attempted to distinguish between different domains of existence, or 'regimes of individuation': the physical, the vital and the psychosocial. He distinguished a primary individuation of inert systems and a secondary individuation of living systems not in terms of their being different substances, but different rhythms of becoming. He wrote of the living:

> the living individual has [...] true interiority, because individuation takes place within it; the interior is constituting in the living individual, while only the limit is constituting in the physical individual, and what is topologically interior is genetically anterior. The living individual is contemporary to itself in all its elements, while the physical individual is not, comprising a past that is radically past, even when it is still in the process of growing (2013:.28, as cited in Combes 2013: 23).

Simondon (2009: 8) argued that such a living individual has within itself 'a nexus of informative communication,' containing within itself a mediation between two orders of magnitude. It is 'a system within a system.'

Biological individuation does not add new determinations to an already existing physical being, as one would expect, but, as Karatay et. al. (2016) noted, 'by suspending [physical individuation] before the preindividual metastability is completely exhausted' (p.422). As Simondon (2009) himself put it, *'the living conserves within itself a permanent activity of individuation* …. it is the theatre of individuation' (p.7). Similarly, the animal is an inchoate plant, dilated at the very beginning of its becoming. And as Simondon (2013) wrote elsewhere, animal individuation 'finds sustenance at the most primitive phase of plant individuation, retaining something prior to the development into an adult plant, and in particular the capacity of receiving information over a long period of time' (p.152, as cited in Combes 2013: 22). Effectively, these are forms of neoteny, the retention in adults of characteristics of juveniles, exemplified by humans which as compared to the great apes, have the characteristics as adults of their young, including mental creativity. While Simondon's claims might appear to contradict Hoffmeyer's ascription of 'semiotic emergence' to membranes and the complex communication and control these make possible (Hoffmeyer 2008b, 28ff.), it should be noted that neoteny is only possible within the context of more complex organizations. Membranes can be seen as the more complex organization that enables the organism to maintain and exploit the indeterminate states of its components, as plants are able to exploit quantum indeterminacy in photosynthesis.

Simondon's work on biology is compatible with and supports most of the work of the major opponents of reductionism. Along with Waddington's work on embryology, Prigogine's work in thermodynamics and Kauffman's version of complexity theory, it supports Salthe's work synthesising hierarchy theory, non-linear thermodynamics and Peircian semiotics, characterizing emergence as interpolation of new constraints (Salthe 1993: 279), and Rosen's work on life itself, showing how living beings consist of multiple processes which are the components of each other without being reducible to each other, and according a place to final causes and anticipation of the future. What Simondon adds to these, or at least clarifies, is the place of invention in response to tensions in the existing milieu, leading to new metastability with the possibility for further structuration, involving further invention, breaking radically with Newtonian assumptions that have dominated science for over three centuries. In focussing on individuation, which is never complete, Simondon was giving a place to and making intelligible the process of creative emergence.

Peirce and Simondon on Information

While each in the tradition of Schellingian thought demanded of the sciences that their understanding of nature accord a place to philosophers and scientists able to know it and themselves as part of it, Peirce and Simondon developed their ideas from opposite directions. Characterizing science, they set out to characterize nature in such a way that science as they portrayed it could be seen to be possible. Peirce began as a logician and then developed a natural philosophy, developing his notion of information in the process, while Simondon first developed his natural philosophy and then developed his social philosophy giving a central place to technology, through this, putting forward his ideas on information. While superficially very different, close inspection reveals their work (including the work of biosemioticians aligned with Hoffmeyer), and their ideas on information, to be complementary.[3] In both cases there is a rejection of dyadic thinking which allows bits of information to be conceived as atomic, self-contained substances stored and moved around, only contingently related to those informed by information, and less obviously, to what information is about.

The opposing directions and complementarity of Peirce and Simondon are evident in Peirce's notion of abduction and Simondon's notion of transduction. Both concepts were defined in relation to deduction and induction. To develop his account of reason, Peirce began with the abstract problem faced by Kepler in interpreting the recorded observations of Tycho Brahe, with the conjecture that planets have elliptical orbits. This provided greater quantity of information about planets. However, with the semiotic reinterpretation of abduction, a place was provided for major transformations in ways of understanding nature challenging prevailing metaphysical assumptions. Newton's work did not merely deal with empirical observations; he effected a major reconceptualization of physical existence, replacing the then prevailing Aristotelian metaphysics with its assumption that everything moves to its natural place. Doing so required ampliative semiosis, utilizing metaphors. The extension of semiotics to action allows abduction a place in solving practical problems, which could then be extended to animals, and then to the way organisms grow, that is, to vegetative semiosis, or to the behaviour of single celled organisms. It is this extension of semiotics by biosemioticians that led to the charge of anthropocentricism.

Simondon by contrast began by conceiving transduction in relation to metastable systems with internal differentiation, individuation, and resonance, maintaining unity over durations, as the process of resolving and rebalancing various problematic tensions, then characterized life and then human reasoning as special cases of this. As Simondon (2009) put it,

> … transduction is that by which a structure appears in the domain of a problematic, that is, as that which provides the resolution of the posed problems. However, transduction, as opposed to *deduction*, does not search elsewhere for a principle to resolve the problem of a domain: it extracts the resolving structure from the tensions of the domain themselves, just as a supersaturated solution crystallizes using its own potentials and according to the chemical species it contains, not using some foreign form added from the outside. (p. 10)

[3] A similar argument, grappling with much the same problem, has been made by Karatay et.al. (2016). Although having a different focus, my interpretation of Simondon has been influenced by this paper.

For Simondon, thinking the relationship between a living being and its milieu was at the same time a theory of knowledge (Barthélémy 2015: 22), with transduction being central to cognitive development. Simondon regarded analogy as an aspect of transduction whereby a relation is established between the genesis of beings outside thought and the thought of this genesis. This echoes Schelling's philosophy and parallels Peirce's deployment of human semiosis as an analogy for all natural processes, this itself being a form of abduction.

Despite appearances, there is the same complementary relationship between Peirce and biosemioticians influenced by him and Simondon's views in their notions of information, each approaching it from different directions, in both cases, treating relations as real, and giving a place to creativity in nature, while opposing the atomistic, substantialist notion of information being promoted as universal by information scientists and philosophers aligned with them. As noted, Peirce began with what looked like a view of information much like the current view, as what is quantifiable in knowledge. That Peirce was arguing something different became evident with the evolution of his notion of information, but also in his defence of the reality of relations and his characterization of semiosis through these relations. Once knowledge was characterized through semiotics and thereby situated within nature, and interpretants were identified as signs with the most important interpretants arrived at through abduction using metaphors - which then redefine what are taken to be objects, a huge difference with empiricist logicians became apparent. This can be seen by using Peirce's logic to characterize the evolution of scientists' view of the atom. As an 'immediate' object of inquiry, it evolved through semiosis from an inert object occupying space, to a planetary system, to complex fields of dynamic forces only explicable through quantum theory. Utilizing Peirce's mature philosophy, biosemioticians influenced by Peirce treated information as the process of informing the interpretant, which could be developing the form of an organism or the mind of a person. Information from this perspective can only be understood in terms of the triadic nature of semiosis as a process, and in fact, as El-Hani et.al. (2008) argued, is semiosis. With semiosis, the sign, the object and the interpretant cannot be identified except as components of this triadic process, and this is why the conception of information as self-subsistent, atomic ' bits' as characterized by the information scientists and those who have embraced their work, must be seen as defective.

Conversely, for Simondon (2009),

> […] information […] is the signification that will emerge when an operation of individuation will discover the dimension according to which two disparate realities may become a system. Information is therefore a primer for individuation; it is a demand for individuation, for the passage from a metastable system to a stable system; it is never a given thing (p.9f.).

Information is 'becoming informed' as part of a process of individuation made possible by the metastable state of the receiver of a message (Barthélémy 2015, 35f.). It is only then, when the signal resonates with this process while being different from it that a signal from another individual becomes a signification. As a signification it relates disparate realities in the common process of 'in-forming', leading to individuation.

On the surface of it, this does not seem to have much in common with the way information was conceived in Peircian biosemiotics as portrayed by El-Hani et.al. As we saw, these theorists wrote of information as the 'triadic dependent process through which a form embodied in the Object in regular way is communicated to an interpretant through the mediation of a Sign' (p.96), while Simondon characterized information as emerging to unify two disparate realities into a unified system. However, this apparent difference ignores the importance accorded to triadicity by Peirce and Peircians and their realist view of relations. The sign-object-interpretant triad does not allow these to be treated as independent existents but as only existing as such through their relations to each other. The object is the 'immediate' object, not the dynamical object, although it is partially caused by the dynamical object and has a real relation to it. The immediate object is the object signified and then defined as such in the formation of a new interpretant, which in vegetative semiosis can be the form taken by the organism, where the communicated form is what 'produces upon the interpretant an effect similar to that which the Object itself would under favourable circumstances' (Peirce 1993: 544).

While being complementary, this interpretation of the Peircian characterization of semiosis to accord with Simondon's ontology does modify it, overcoming some limitations in Peirce's work. The dynamical object and previous semiosis that produced the sign that is now generating this new interpretant is essentially what Simondon referred to as the preindividual milieu or field, and the whole process is a process of individuation involving information as signification in which components (signs, 'objects' and interpretants) are individuated as disparate realities related within a system. As Karatay (2016: 429) pointed out, such a characterization of semiosis allows that it can be more than one sign that produces an interpretant. Simondon accords a place to a not fully definable complex context in each individuation (the preindividual milieu), so semiosis can involve a multiplicity of signs over different orders of magnitude. Also, Simondon gave a genuine role to individuated beings as individuals. The individual as the product of individuation is to some extent an emergent immanent cause of itself acting back on the conditions of its existence, an aspect of causation that Peirce failed to recognize. 'Form' must always be understood as 'informing', an immanent aspect of the operation of individuation by which individuals emerge with some autonomy from their context.

Knowledge for Peirce, as for Simondon, can be appreciated as a real component of nature because relations are recognized as real, including relations between relations, with subject and object emerging from these relations rather than knowledge being a nominal relation between a transcendental subject and objects in the world (Toscano 2006: 127f.; Fernandez 2010). As Muriel Combes (1995) characterized Simondon's conception of knowledge, 'knowledge, insofar as it is a "relation between two relations," "is itself a relation," which is to say, knowledge *exists in the same mode as the beings that it links together, considered from the point of view of that which contributes their reality*' (p. 17f.). What is communicated and the communication itself are all part of the individuation (or individuations) of a metastable system interacting with its environment maintaining its unity over time. Individuated components are related to each other and their pasts along with the preindividual realm from which they emerged, with the whole system continuing in a metastable state characterized by resonance, facilitating a relatively stable balance between these individuated components with competing potentialities. That is, as Simondon put it, 'information' is an aspect of a complex process of individuation. Information is not in bits. Information conceived in this way unifies the sign, the object and the interpretant as understood by Peirce while individuating them as components of individuals and preparing them for further operations of ontogenesis, or further semiosis.

Conclusion

With this confluence of biosemiotics influenced by Peirce and Simondon's natural philosophy, Hoffmeyer's scepticism towards information science can be clarified and further defended. Information science, including cybernetics in their original formulation, were developed as advanced forms of technology, that is, as the science of automatons. Using automatons as analogies to comprehend nervous, living and social systems might seem to be justified by the place accorded to analogies by Simondon; however, from the perspective of Simondon's understanding of analogy, bringing together the logical structure of control systems in living processes without studying their ontogenesis, that is, their concrete individuation, must lead to the identification of life with automatons capable only of adaptive behaviour. As Combes summed up Simondon's claims, 'structures must be known by the operations that energize them and not the inverse' (p.16). As Robert Rosen would put it, using machines as analogies for living processes, no matter how advanced the machines, will leave out life itself.

This does not mean that information science and the technology that it is associated with are not enormously important, and as with earlier, less complex machines, using analogies from this is bound to reveal and make intelligible some aspects of the mechanisms that have evolved with life. In these circumstances, it can be pragmatically useful to ignore the ontogenesis of functional components of these mechanisms. As in the past, such essentially reductionist research programs are likely to be fruitful and useful, to a certain extent. However, this analogy should be recognized for what it is, an abstraction from living processes in which the ontogenesis of the individuated components of these mechanisms is simply assumed. Progress can be made, but as Søren Brier put it in *Cybersemiotics: Why Information is not Enough* (2008), information as it is understood in information science, even giving a place to the semantics and pragmatics of information as well as syntax, or utilizing second order cybernetics, fails to do justice to life as it was characterized by von Uexküll (p.100ff., 336), and it is likely to be misleading. The most obvious place where it has proved misleading is the promotion of impoverished characterizations of living beings, human cognition and culture, but it has been equally misleading in genetics in the supposed great achievement of the molecular biologists in characterizing DNA as the genetic code associated with the synthetic theory of evolution. This culminated in sociobiology with Richard Dawkins' claiming that we are nothing but gene machines, that is, machines for reproducing DNA.

If 'genes' function as anything like 'bits of information' along with a code it is because they have been individuated as such from theatres of individuation from a pre-individual field whereby the whole organism is 'informed', that is, has taken and maintained its form as an interpretant of preindividual conditions, including the theatre of individuating components resonating with each other in a metastable state, responding to both internal changes and the individuated 'objects' in its environment (its world), and capable under stress of radically re-individuating along different trajectories, redefining what are taken to be these 'bits of information'. There is bound to be ambiguity in these codes, even if through evolution there has been a tendency to eliminate such ambiguity (Barbieri 2019), making organisms more machine-like. As Lenny Moss (2003) concluded his review of failed efforts to explain life through DNA: 'After the (conflated) gene, it's the living organism, an active agent of its own adaptive ontogeny and evolvability, that is once again poised to move back into the ontological driver's seat' (p.198). Mechanisms are only intelligible as products of and as serving living processes from which their telos derives, and the point being made by proponents of the Schellingian tradition of natural philosophy, including Peirce, Bergson, von Uexküll, Whitehead, Waddington, Bateson, Hoffmeyer, Rosen and Simondon, is that life cannot be understood as nothing but its mechanisms. It is also necessary to appreciate the reality of life itself.

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