

Biosemiotics and development: metaphors and facts

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ABSTRACT

As a field of scientific expertise, semiotics has the interesting property of being a relevant tool for understanding how scientists represent any domain of research, including the semiotic domain itself. This feature is particularly expressive in the case of biology, as it appears to be the case that a certain range of biological phenomena are of a semiotic character. However, it is not consensual the extent to which semiotics pervades biology. This paper deals with this issue for the particular case of developmental biology, stressing the role of semiotics-as-a-discipline in delimiting the extent of semiotics-as-a-natural-phenomenon and, specifically, in disentangling semiotic mechanisms from semiotic metaphors aimed at clarifying non-semiotic developmental mechanisms.

KEYWORDS

Biosemiotics, Developmental Biology, Cognitive metaphors, Hypoicons, Blueprints, Information

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1 *Weaknesses of insight and deficiencies of language stand in the way*
2 *inexorably. Words and phrases must be stretched towards a generality*
3 *foreign to their ordinary usage; and however such elements of language be*
4 *stabilized as technicalities, they remain metaphors mutely appealing for an*
5 *imaginative leap.*

6 Alfred North Whitehead, *Process and Reality*, p. 4

7 *Literary license is not license to mislead, and when metaphor is employed in*
8 *the service of scientific understanding, it should be accurate and helpful as*
9 *well as vivid and evocative*

10 Susan Oyama, *The Ontogeny of Information*, p. 129

11

12 **1 Introduction**

13 This paper deals with biosemiotic concerns at two different levels of analysis. The first one is
14 epistemological, for the paper has to do with the semiotic means that are used in order to make sense
15 of the biological realm; the second one is ontological, as the paper is also concerned with the putative
16 semiotic aspects of biological phenomena that we struggle to understand by those semiotic means.
17 My discussion will focus specifically on the developmental history of organisms – or ontogeny.
18 Ontogenetic explanations have traditionally been carried out with the help of different metaphors,
19 prominent among which is the the main subject matter of this paper, namely, the blueprint or plan
20 metaphor – henceforth, BPM. According to this metaphor, which is pervasive in the literature and
21 taken almost at face value by many of its users, sequences of DNA encrypt representations of special-
22 typical traits of organisms in their adult forms. The BPM is customarily accompanied by other varying
23 assumptions regarding the executive powers of the genes themselves and of other extra-genetic
24 contributors to developmental processes.

25 The BPM has been subjected to different kinds of criticisms, which have mostly had to do
26 with the extent to which the target domain of the metaphor (individual development) fits the source
27 one (architectural blueprints or plans). As I clarify in section 2, the least problematic aspect of the
28 BPM is its being a metaphor – or a collection thereof. I agree with the mainstream opinion that
29 metaphors render genuine heuristic services to the advancement of science. A brief semiotic
30 introduction to the phenomenon of cognitive metaphors is offered in that section. In section 3, I review
31 some of the aforementioned critical approaches and settle what I believe to be the only interpretations
32 of the BPM that can survive such scrutiny. Subsequently, I add a personal note to these critical stances
33 in section 4, which, unlike them, is not directly concerned with the projectability of the architectural
34 domain onto the biological one, but with what I believe to be an even deeper weakness of the BPM;
35 in a nutshell, that it is not even based on an accurate characterization of the original technical domain
36 that it is purported to project onto the organic realm. The claim is dramatically illustrated by the fact
37 that the very same architectural processes that inspire the BPM are in themselves frequently the target

38 of biological metaphors. Section 5 is then devoted to an examination of the two surviving redoubts
39 for a semiotic accommodation of BPM-related metaphors not dealt with in section 3, namely, the
40 patterning role of proteins in between DNA and cells, and the idea of a flow of developmental
41 information on ontogeny. My conclusion in this section is that whilst epistemically promising, the
42 corresponding semiotic metaphors are not ultimately accommodable into bona fide developmental
43 explanations. Therefore, they do not offer the grounds for extending the biosemiotic realm to the
44 corresponding areas of developmental biology. A general Concluding Remarks section closes the
45 paper.

46

47 **2 Metaphors in Science: A Brief Semiotic Take**

48 The epistemic role of a certain kind of metaphors in scientific affairs has long been acknowledged.
49 According to Richard Boyd (1979), metaphors are in fact necessary when the scientist's task goes
50 beyond that of unveiling natural kinds – which ultimately correspond to internal essences compatible
51 with definitional characterizations – and it has instead to do with the uncovering of more complex
52 entities that comprise nets of mutually influencing units, with no definite limits or varying extensions
53 from one case to the next (Boyd, 1979). Boyd refers to these entities as “homeostatic property cluster
54 kinds” (henceforth, HPCCK) and he claims that new HPCCKs require the special kind of epistemic
55 access that can be offered by metaphors provided by better understood domains. Thus, images
56 provided by a given source domain (S) may be projected onto a given target domain (T) on the basis
57 of some intuitively felt affinity, then extended to a broader range of parallels, and eventually pave the
58 way for research programs that definitively fix the shared and diverging grounds of the domains
59 concerned. In Boyd's own terms, metaphors thus provide the means for “epistemologically
60 accessing” particularly recalcitrant fields of research, while research proper “accommodates” these
61 images, if they prove to be successful, to the ultimate joints of the fields concerned. In the end, the
62 suitability of the metaphorical projection of S onto T is thus not merely constrained by the intuitively
63 felt parallels at the onset, but, above all, by their capacity for provide more accurate and, eventually,
64 more reductive explanations of T. Otherwise, if nothing more is achieved than to drive the field of
65 expertise in charge of T into explanatory cul-de-sacs, the best route to take is to abandon the
66 metaphors before they start to pay lip service to the field – which, regrettably, appears to be very
67 commonly the case.

68 Considering this introductory paragraph, which stresses the epistemological value of
69 metaphors in science, it may come as a surprise that Charles S. Peirce, whose main focus of attention
70 was the logic of the science-forming capacity, did not put too much emphasis on the role of metaphors

71 in science, prioritizing the related, but different category of “analogies” instead (Anderson, 1984).¹
72 In any event, as I shall try to show here, it is perhaps the case that Peirce was not far away from a
73 view like that of Richard Boyd above. To be as succinct as possible, my thesis regarding this issue is
74 that, taken together, “metaphor” and “analogy” may compound in Peirce’s system a duplet
75 comparable to the “epistemic access” plus “accommodation” cycle in the case of Boyd’s system. Let
76 me explain.

77 In Peirce’s system, analogies and metaphors belong to the overarching class of (hypo)icons,
78 which represent in virtue of some kind of resemblance/likeness. However, analogies represent objects
79 diagrammatically, i.e. owing to their sharing a certain structural isomorphism with those objects; in
80 contrast, metaphors stand for objects with which they share certain properties, which may be vague
81 both in number and quality. Peirce regarded metaphors as belonging to creative rather than to
82 discovery affairs. For instance, he pinpointed metaphors as the most frequent source of lexical
83 innovations, wherein particular properties of an originally open set of connotations first becomes
84 restrained and then uniformly linked to an object all across the language community (Wilson, 2011).
85 As claimed by Douglas Anderson:

86 Some frozen metaphors, interestingly, *are* analogies; or, put the other way around, some
87 analogies arise out of metaphors [...] In this way an isomorphism, a univocal link, is established
88 between the constituents [i.e. S and T; my addition]. (Anderson, 1984: 464)

89 Thus, a kind of cycle appears to exist in the life of creative metaphors which resembles the
90 “access-accommodation” cycle of cognitive metaphors, as in both cases what is pointed is to the
91 fixation of a literal denotation – i.e. a theoretical concept or a lexical meaning, respectively.

92 It is certainly an intriguing detail, which appears to have been left undeveloped in Peirce’s
93 works (Anderson 1984), that he did not credit metaphors with an epistemic role in science. For him,
94 metaphors appeared to be deprived of the capacity to enter into the kind of cycle which leads, first,
95 to a denotation apt to indicate the dynamical object that constitutes the subject matter of a scientific
96 enterprise (i.e. epistemic access) and, ultimately, to the kinds of “collateral experiences” (Peirce’s
97 words) that may eventually lead to exploring the dynamical object’s nature (i.e. accommodation). It
98 is as if for Peirce, metaphors were doomed to remain in an immediate, as opposed to dynamic, relation
99 with their object as represented but no with the real object. Perhaps, as argued by Douglas Anderson,
100 this attitude regarding metaphors was due to the kind of fuzziness and indeterminacy that Peirce
101 associated with them. In any event, I believe that there is still space in the interpretation of Peirce’s
102 take on metaphors for the thesis that once frozen – i.e. centered around a particular set of properties,

¹ For some relevant loci of Peirce’s reflections on metaphors, see CP 1.367, CP 2.222, CP 2.276/7, CP 2.280, CP 2.290, CP 2.302, CP 2.306, CP 2.255, CP 2.258, CP 6.196/7. CP = Peirce, C.S. (1931–1966); reference to Peirce’s fragments is designated by CP followed by volume and paragraph number.

103 or even a single one – metaphors may then be apt for the job, as a sort of new schema that, similarly
104 to other analogies, may facilitate epistemic access to a certain domain of inquiry and give rise, through
105 an accommodation process, to relevant discoveries (Sørensen & Thellesfen, 2010; Wilson, 2011;
106 Feodorov, 2018; for similar approaches). This idea is congenial to the one stressed by Priscila Farias
107 and João Queiroz, who claim that metaphors, in order to become instantiated as icons of laws,
108 “depend on a certain internal coherence;” so in the end, “diagrams [i.e. analogies] may function as
109 metaphors once their use becomes a *habir*” (Farias & Queiroz, 2006: 287-307).

110 Be that as it may, the issue can remain open without interfering with my own concerns in this
111 paper. For one thing, the study that I present here is concerned with a type of metaphoric
112 representamen, the BPM, which is itself an analogy. Blueprints/plans (“e.g. an architect’s drawing of
113 a house;” Houser, 1991: 437) are certainly paradigmatic of the analogies/diagrams subclass within
114 the general family of Peircean (hypo)icons (Farias & Queiroz, 2006: 291). Consequently, whether a
115 metaphor or an analogy is at the onset of the BPM becomes a fuzzy, perhaps even a superfluous
116 question. One way of expressing it is to say that the BPM is based on a metaphoric intuition that takes
117 as its object an analogical kind of sign; or, in other words, it is based on the metaphorical use of an
118 analogy. I do not dwell on this further. Suffice it to say that the most relevant question that I wish to
119 raise is whether the (somewhat ambiguous) kind of epistemic access that the BPM makes available
120 to developmental studies is one that further processes of accommodation might confirm as fruitful.

121

122 **3 The Blueprint/Plan Metaphor: The Model and Its Critics**

123 Let me start by referring to a particular, highly influential and explicit instantiation of the BPM,
124 namely, that of the Nobel Prize-winning ethologist Konrad Lorenz:

125 What rules ontogeny, in bodily as well as in behavioral development, is obviously the hereditary
126 blueprint contained in the genome and not the environmental circumstances indispensable to its
127 realization. It is not the bricks and the mortar which rule the building of a cathedral but a plan
128 which has been conceived by an architect and which, of course also depends on the solid
129 causality of bricks and mortar for its realization. This plan must allow for a certain amount of
130 adaptation that may become necessary during building [...] Any such adaptive regulations,
131 however, presuppose at the very least as much information contained in the genetical blueprint
132 as any elements of little or no modifiability do. In other words, the apparatus which makes
133 adaptive modifiability possible is genetically blueprinted itself [...] (Lorenz, 1965: 42-43)

134 Thus formulated, the BPM introduces, above all, a (conventional) division of the labor model
135 of development, as Susan Oyama aptly makes explicit in the following passage:

136 Though a plan implies action, it does not itself act, so if the genes are a blueprint, something
137 else is the contractor-construction worker. Though blueprints are usually contrasted with
138 building materials, the genes are quite easily conceptualized as templates for building tools and

139 materials; once so utilized, of course, they enter the developmental process and influence its
140 course. (Oyama, 2000: 54-55)

141 The basic parallels that the metaphor suggests are thus the following: (1) genes are relative to
142 the development of an organism as the blueprint/plan is to the construction of a building; and (2)
143 factors other than genes contribute to the developmental process as the construction team does,
144 providing manpower, tools and materials to the execution of the plan.

145 Before going into a thorough examination, let me stress that the BPM is not as simplistic an
146 image as some critics appear to suggest. As introduced by Lorenz – as well as in Oyama’s well-
147 balanced presentation – the metaphor does not really intend the genes to contain something
148 comparable to a flat, a miniaturized version of the ultimate attainable design, whilst also abstracting
149 away, apart from size, other aspects that might freely vary without compromising the expected
150 outcome. The BPM is not a revamped instantiation of the old homuncular kind of preformationism
151 (Maienschein, 2017) for two reasons. On the one hand, as Lorenz himself strives to explain, it is not
152 the job of the blueprint to merely abstract what is essential from what is not, but also to constrain the
153 kinds of suitable locations and materials, the order of events in the realization of the organism, and
154 so on. On the other hand, at least in Lorenz’s version, the BPM does not appear to be committed to
155 the kind of isomorphic correspondences that homunculum, in contrast, entails. A blueprint may be a
156 non-isomorphic one – it may be propositional or language-like,² whilst remaining a blueprint. Thus,
157 blueprints are not necessarily mere miniature isomorphic representations of the expected scaled-up
158 end results – the reason for which I believe that psychologist and ethologist Daniel Lehrman’s (1970)
159 criticism of Lorenz (1965) is not accurate (in this particular regard).³

160 That said, it is true that the BPM raises fra-from-trivial issues regarding explanation,
161 intentionality and agency, as aptly synthesized by Susan Oyama:

162 The point of the blueprint analogy, though, does not seem to be to *illuminate* developmental
163 processes, but rather to assume them and, in celebrating their regularity, to impute cognitive
164 functions to the genes. How these functions are exercised is left unclear in this type of metaphor,
165 except that the genetic plan is seen in some peculiar way to carry itself out, generating all the
166 necessary steps in the necessary sequence. (Oyama, 2000: 55)

² This brings to mind Ruth Millikan’s (1984) conception of propositions as “iconic” signals for state of affairs, in the wake of Bertrand Russell/Ludwig Wittgenstein’s pictorial theory of propositional meanings (Russell, 1910; Wittgenstein, 1921)

³ “It seems to me that there is a fundamental fallacy in the use of the analogy relationship between a blueprint and the structure represented by it to represent the relationship between the genome at the zygote stage and the phenotypic adult. A blueprint is isomorphic with the structure that it represents. The ratios of lengths and widths in the blueprint are the same as those in the structure; the topographical relationships among the parts of the structure are the same as those among the corresponding parts of the blueprint; each part of the structure is represented by a separate part of the blueprint, and each part of the blueprint refers only to a specific part of the structure. It will be immediately obvious that this is profoundly different from the relationship between the genome and the phenotype of the higher animal.” (Lehrman, 1970: 34)

167 Oyama's criticism boils down to the objection that the BPM is a descriptive restatement of
168 developmental processes devoid of any clear explanatory contribution. Indeed, the main two
169 strategies aimed at putting the explanation seal on the metaphor are problematic in that they
170 ineluctably point to the genes showing one or another mark of the cognitive:

171 (1) On the one hand, one might opt for the idea that genes display executive powers – as in
172 the most literal interpretation of Lorenz's BPM, in that they orchestrate all the doings of the remaining
173 extra-genetic contributors. In that case, the genome is ultimately regarded as an "agentive" entity.

174 (2) On the other hand, one might defer those executive powers to the extra-genetic
175 developmental contributors – perhaps a more charitable reading of Lorenz. However, in that case, the
176 genome is regarded as an "intentional" entity (Maynard Smith, 2000), the states of which, to be read
177 and executed by said contributors, are "about" some expected kind of full-fledged organism.

178 Be that as it may, it appears to be clear that the BPM is only apt to come close to an explanatory
179 position at the price of regarding the genes as showing some core marks of the cognitive – see
180 Griffiths & Stotz (2013).

181 Such strong commitments of the BPM appear to be somewhat relaxed if one adopts a
182 information-based approach and envisions the genome as a representational vehicle, wherein
183 differences stand for differences at different levels (Bateson, 1972; Dretske, 1981). Such a solution
184 locates the genes in a semiotic terrain, with its own mode of existence – "among the most impotent
185 and useless materials imaginable," as Mary Jane West-Eberhard rhetorically emphasizes the urgency
186 of downsizing the kind of agentive/cognitive attributions above (West-Eberhard, 2003: 93).

187 However, an information-based reading of the BPM is not without its critics. Two families
188 thereof deserve particular attention:

189 1. On the one hand, informationally speaking, there appears to exist no particular justification
190 for singling out the genes from other developmental contributors, including those provided by
191 environment. Inasmuch as genetic and extra-genetic factors co-act and support each other in bringing
192 about phenotypic outcomes, the former are to be regarded as equals in terms of covariation with the
193 latter. According to this criticism, information spreads beyond the genome – or, in terms of the BPM,
194 the blueprint extends beyond the chromosomal context.

195 2. On the other hand, another well-known objection to the information-based interpretation of
196 the BPM stresses the fact that if they contain a blueprint at all, the genes cannot represent anything
197 other than proteins. As lucidly expressed by Nobel Prize-winning microbiologist Salvador Luria:

198 [...] the information represented in the sequence of amino acids is not available to translation;
199 it only serves to generate the shape of the protein and therefore its function. Informationally,
200 proteins are dead-end molecules. (Luria, 1973: 46)

201 Of course, the information-based model of development may survive this criticism if it is
202 understood that the dead-end character of proteins is such relative to the genes that shape them;
203 nevertheless, the proteins themselves, along with other intra and extra-organismic concurrent factors,
204 can be said to code for differences that make differences at subsequent states of phenotypic
205 organization. If so, however, two significant conclusions follow: firstly, the genome is definitely not
206 a blueprint of the expected kind of fully achieved phenotype since, secondly, the blueprint (if a place
207 is still there for it) is sparsely scattered at different locations throughout the process (Johnston, 1987;
208 Gray, 1992; Griffiths & Gray, 1994; Oyama, 2000). In the words of Oyama, information follows –
209 rather than guides – ontogenetic paths (Oyama, 2000: 129-157).⁴ Thus, according to the information-
210 style version of the BPM, development is informed by successive blueprints/plans at different stages,
211 each blueprint/plan informed by a prior one down to the genomic blueprint for the construction of
212 functional proteins.

213 In the next section, I aim a different kind of criticism at the BPM, namely, one based on the
214 idea that the BPM does not even properly fit the technical domain from which it is taken. As a
215 consequence, the projection of the metaphor onto the organic realm appears to be fatally flawed and
216 perhaps useless.

217

218 **4 The Bidirectionality of the BPM: Further Reasons for Questioning the Model**

219 As said, thinking metaphorically entails the projection of entities and relations that articulate a certain
220 domain (S) onto another, more poorly understood one (T). Such a cognitive strategy is a legitimate
221 one provided that those partially known parts of T somehow match aspects of S, prompting the
222 conjecture that a larger match that may exist which would facilitate a better understanding of T. This
223 succinct characterization of “cognitive metaphors” – in the sense of Kuhn (1979) – makes it clear that
224 one of the conditions for a successful application of this kind of education is that knowledge about S
225 is solid enough to allow it to facilitate understanding of T. For this reason, unlike other kinds of
226 metaphors, cognitive metaphors in the service of scientific understanding must necessarily exhibit

⁴ “[...] plans and information [...] have contingent developmental histories. The cognitive-causal models [...] have tended to present these controls as ahistorical (or, rather, as having a phylogenetic history but not an ontogenetic one), which provide no satisfactory way of explaining either species-typical development (maturation) or the manifest flexibility and multiplicity of many developmental phenomena, save the declaration that all contingencies were somehow anticipated, or at least hypothesized, by the DNA. Fate is constructed, amended, and reconstructed, partly by the emerging organism itself. It is not known to anyone, not even the genes.” (Oyama, 2000: 137)

227 the following kind of asymmetry of asymmetry: from the outset, knowledge about S must outstrip
228 that about T. Otherwise, metaphors may rather be a misleading and disadvantageous path to follow.

229 Considering this desideratum, it appears to be clear that the more symmetrical the domains,
230 the less clarifying the metaphor. As a case in point, one might consider metaphors that can function
231 in both directions – i.e. domains that may assume the S and T roles interchangeably, given that the
232 amount and clarity of knowledge about the corresponding domains is symmetric – or close to
233 symmetric. Susan Oyama – who refers to Campbell (1982) – points out that this was historically the
234 case of the interbreeding of analytical models and nomenclature between developmental genetics and
235 cybernetics in the 1940s. According to this historic narrative, by regarding genes to have a controlling
236 role in the cellular machinery to construct bodies on the basis of pure intuition or images of undeclared
237 provenance, genetics paved the way for the development of systematic models of information
238 processing by cybernetics, which, in time, has in turn provided developmental genetics with all kinds
239 of metaphors. Whilst this could be seen as a case of productive disciplinary interbreeding, it is also
240 indicative of the fact that a sort of explanatory emptiness exists at the heart of these metaphors. As I
241 try to show in the following paragraph, the BPM falls within the same pattern.

242 Curiously enough, at the same time that architecture provides the BPM to biology (Karatani,
243 1995), biology is a common source of metaphors for architectural commentators and theorists
244 (Steadman, 2008). The so-called bionic approach to architecture provides a suitable illustration (Costa
245 Cruceiro, 2009, 2010). In bionic architecture, for example, it is claimed that designs are not conceived
246 in the architect's mind exactly as they are later reflected in the blueprints. Of course, the architect
247 must entertain some initial ideas, but what happens, crucially, is that the designer's project grows as
248 a consequence of analogies between her thoughts and all kinds of surrounding information. From
249 these kinds of creative interactions, there emerge three dimensional geometries that are difficult to
250 conceive and construct completely without computerized aid. With the help of the visual outputs
251 resulting from such technical scaffolding, the architect is then able to proceed with her undertaking.
252 Throughout, solutions are chosen according to their calculated structural fitness. Note that, according
253 to this picture, even if the ultimate outcome of such a sequence of creative processes are plotted on a
254 single drawing or plan – a “structure model” (McLachlan, 1999) – the impression that the actual
255 process of construction follows on from a preformed version of the expected final result, reflected in
256 a blueprint, is obviously deceiving. If anything, what the blueprint depicts is a specific stage, and not
257 a particularly early one at that, of the architect's musings, together with all kinds of interactions that
258 she may have while entertaining them. In other words, the blueprint is a retrospective technical
259 account of what has been going on during the creative process up to a certain time, rather than the
260 initial stage of the entire project. The blueprint, of course, will influence the future sequence of events,

261 but this is so in the trivial, yet commonly neglected sense that every stage attained in a developmental
262 process constrains its subsequent unfolding (Oyama, 2000: 131).

263 Interestingly, the current penetration of biological metaphors in architecture provides another
264 lesson regarding the limited accurateness of the BPM in illuminating the understanding of organic
265 development, now in relation with the idea of “point of termination” or “steady state” that the
266 blueprint/plan analogy entails. Indeed, the conceptualization of development by use of the BPM
267 suggests not merely of a preordained course of event, but a fixed ultimate outcome. This is again
268 deceptive. As a case in point, Pritzker Architecture Prize-winning Arata Isozaki claims that an
269 ultimate image of a building frozen from change, which occupies a central position in architectural
270 design, is clearly misleading (Isozaki, 2009: 22-23). In his opinion, from inception to completion –
271 two open or fuzzy categories, a building is something that shifts and grows from state to state, its uses
272 may change over time, it may encroach or degrade, its capacities may become exhausted, etc.
273 Buildings are thus (like) organic entities – Isozaki concludes, for “totally unchangeable architecture
274 can only exist in the imagination” (Isozaki, 2009: 22). Like organisms, buildings grow, are responsive
275 to aggressions, and require care, repair, and renovation, while needing to keep functioning at the same
276 time. Thus, according to Isozaki, all things point to the conclusion that the living vitality of buildings
277 is incompatible with a preordained plan conception of architecture – i.e. a frozen, static, or synchronic
278 concept of design, and prefers to defend a powerful idea of “process,” which includes an absence of
279 clear points of termination.

280 The idea that organic development does not entail points of termination is also common in
281 current developmental and evolutionary biology (Minelli 2011), as well as in cognitive branches of
282 biology (Thelen & Smith, 1994; Balari & Lorenzo, 2015; Lorenzo & Longa, 2019). As developmental
283 biologist Alessandro Minelli stresses, if one is to maintain that development corresponds to a
284 particular “segment” of an organism’s life, then one must be prepared to admit that the kind of
285 segment concerned is an “open-ended” one (Minelli, 2011). The idea is not a completely new one –
286 but perhaps the increasing credit given to it is, as witnessed by the following pioneering claim of
287 biologist and philosopher Conrad Hal Waddington in the mid-twentieth century:

288 “To speak of the adult condition as a steady state is to some extent an oversimplification, since
289 developmental change continues at a slow rate throughout adult life, leading eventually to
290 senescence” (Waddington, 1957: 33).

291 In the end, it seems likely that “development” and “life” are two concepts ultimately doomed
292 to conflate into one, without explanatory loss (Minelli, 2003; Lorenzo & Longa, 2019). Interestingly,
293 in some kinds of organisms (e.g. Cnidaria) there are no clear-cut boundaries between the life cycles
294 of successive generations (Minelli, 2011). All in all, it appears to be the case not just that the concepts
295 of “initial state” and “steady state” are at least unclear, and maybe simply useless, in developmental

296 biology, but that those of “inception” and “termination” are blurred in many cases as well. All these
297 kinds of conceptual improvements in the field of developmental biology provide metaphors that are
298 inspiring current bionic or bio-logic approaches to the conceptualization and practice of architecture,
299 which inevitably leads us to question of the true role of blueprints and closed plans in this technical
300 domain.⁵

301 Before closing this section, let me insist that the use of metaphors is heuristically legitimate
302 and useful in science. The point of this section is to warn about the risk of indeterminacy that may
303 follow from the fact that two domains may be serving as the source of metaphors for each other, as
304 is the case of the ones dealt with in this paper: the technical domain of architecture has been
305 approached by developmental genetics in its search for illuminating analogies, whilst developmental
306 biology in a broader sense (encompassing genetics, but not limited to it) has been focused on by
307 architects for the same aim. Not surprisingly, with conflicting results.

308 Technical or scientific domains, like architecture or developmental biology, are lively areas
309 of research, more dynamic and long-lived than the images that relevant achievements in these areas
310 may have empowered and, eventually, become emblematic points of reference for other domains.
311 However, the longevity of an image may be tantamount to a sort of afterlife in its original domain. It
312 is true that blueprints continue to be used instrumentally in construction affairs, but it appears to be
313 clear now that they do not provide a correct conceptualization of the real dynamic process leading
314 from the architect’s creative activity to the moment when the building is occupied. Looking for
315 illuminating metaphors to help understand their own field, some architects have focused on the flesh
316 and blood or organic developmental processes as being currently conceptualized by some off-
317 mainstream developmental biologists, freed from the constraining impact of the BPM. For the former,
318 the complex, unbounded and ever-changing kinds of processes inspected by the latter, with abundant
319 contingencies yet confidently leading to robust states of organization, offered a good alternative
320 image to one which was too much centered on static blueprints. Meanwhile, a broad sphere of
321 mainstream developmental biology – mostly, developmental geneticists – remains anchored in the
322 old BPM idealization, taking for granted not merely its heuristic value, but its truth (Robert, 2004).

323

324 **5 The Biosemiotics of Development**

325 The discussion thus far should have made it clear that the BPM is neither accurate nor helpful in order
326 to deepen an overall understanding of the development of living beings. However, it might be the

⁵ A questioning that may perhaps be extended to the very role of the architect. For an illuminating starting point of reflection, see Rudofsky (1964).

327 case that a small, yet crucial portion of development, namely, that leading from DNA to the
328 “informational dead end” of proteins is based on a sort of semiotic link, for which the BPM may still
329 be both accurate and helpful. Furthermore, the idea that the stages of a single developmental process
330 might be read as informing each next successive stage might also be felt to be a way of rescuing the
331 heuristic and conceptual value of the BPM. The next two subsections discuss these stances in turn.

332

333 5.1 *Do Proteins Mark the Boundary Between the Semiotics and the Physics of Development?*

334 An affirmative answer to the question above is defended by Dan Faltynek and Ludmila Lacková, who
335 claim that the BPM is a correct conceptualization of the role of proteins as the building blocks of the
336 organic:

337 The function of proteins can be described metaphorically as blueprinting/modelling of the
338 amorphous unsegmented physical world. Proteins handle their specific physical conditions by
339 shaping them: the physical interaction of the protein is mediated by its shape (and not by
340 stereochemical interactions) which means that it is not completely physically direct. This is the
341 reason we treat proteins as signs. (Faltynek & Lacková, 2020: 14)

342 From the fact that the primary structure of proteins, in turn, “comes from a linear string which
343 is coded by a genetic code and stored in DNA,” they further conclude that DNA/proteins comprise
344 “the semiotic part” of a developing organism (Faltynek & Lacková, 2020: same page). I do not believe
345 that Faltynek and Lacková’s thesis is as straightforward as it may appear to be, so allow me to put
346 forward my arguments.

347 An important step in Faltynek and Lacková’s argumentation is the attribution of a “proto-
348 icon” status to proteins, where the “proto” specification signals that proteins relate with their objects
349 in the absence of any Thirdness (i.e. interpreter/interpretant entities). In this, they follow suit with
350 Eco (1999) and Sharon and Vehkavaara (2014), among others. Being icons, the proteins’ status as
351 signs must be anchored to their Firstness – i.e. their own physical properties. However, this is not
352 enough to grant a semiotic, rather than physical, character to their putative role as signs. Thus,
353 following the Peircean orthodoxy, Faltynek and Lacková (2020: 8) acknowledge that semiotically
354 speaking, Firstness is derivative (“cannot exist independently”) of Secondness (“the monad arises
355 only from being separated from the dyad”). In other words, it is only as a consequence of their relation
356 with their objects (i.e. certain shaped physical segments; see above) that proteins can be deemed
357 primary or proto-icons. Summing up their position, proteins blueprint/model certain organic segments
358 – thus, proteins are *icons*, and they do so on the grounds of their physical properties alone (proteins
359 are *proto-icons*), without the need need for semiotic intermediaries or interpretants. Let me show now
360 why I find this argument flawed.

361 To start with, it is important to stress that even if the relation between proteins and body
362 segments is not an interpretant-mediated one, nor it is an immediate one. Thus, if the reason for
363 declaring it not properly semiotic is the lack of the relevant type of intermediaries, my claim is that
364 in order to decide what kind of relation it belongs to, one must focus on the actual kind of mediation
365 that exists between proteins and body segments. If anything, the “proto” or “primary” qualifications
366 are tentative ways of labelling this search for a correct conceptualization. However, the addition of
367 “semiotic” to those morphs is misleading and, perhaps, based on an unmotivated preconception, for
368 a dynamic process does actually unfold between the primary structure of a protein (its amino acid
369 sequence) and its interaction with an as yet amorphous physical segment (as in cell specialization),
370 which is through and through based on stereochemical interactions. Note the following three crucial
371 facts:

372 (1) It is the chemistry of amino acid side chains that has a critical impact on the protein’s
373 unique three-dimensional shape due to their bonding properties.

374 (2) The ultimately, though not completely unmodifiable, shape that a protein attains after some
375 other alternative configurations have been tested is normally the most energetically favorable one.
376 Interestingly, this appears to resemble the evolutionary aspect of interpretation as defended by Peirce,
377 eventually leading to (relatively) fixed or frozen interpretants. Nevertheless, the process is again due
378 to stereochemical interactions, such as the influence of thousands of not covalent bonds and chemical
379 forces between the protein and its environment.

380 (3) Proteins need to protect themselves from the intromission of other macromolecules
381 dispersed in the cytoplasm capable of interacting with them. For this important defensive mission,
382 proteins benefit from the help of other proteins (chaperon proteins), which surround and sequester
383 them until folding is over.

384 Taking all this into consideration, it appears to be clear that the proteins/cells relation is neither
385 an immediate one (as should be the case of primary or proto- iconicity, according to its supporters)
386 nor one mediated by interpretive chains (as in the case of iconicity proper). It is one based on
387 stereochemical interactions;⁶ i.e. not one that functions as if guided by a mental interpreter (as in the
388 case of icons), nor one which functions according to a “key and hole” principle (as in the case of
389 putative proto-icons). Proteins, routinely referred to as the basic “building blocks” of life, are not
390 “biosemiotic” building blocks.

⁶ *Mutatis mutandis*, the argument also runs for the case of the patterning role of DNA relative to proteins. As stressed by Paul Griffiths, “the proximal effects of DNA are uniquely determined by physical laws” (Griffiths, 2001: 402).

391 In order to avoid this objection, one may resort to Marcello Barbieri's contention that proteins
392 are nevertheless signs ("representanda"), attending to the intermediation of a "code/codemaker"
393 between the protein sequence and the cell answer (Barbieri, 2009). In this way, Barbieri claims to be
394 avoiding the inconveniences associated with the "mental" connotations of the idea of interpretation.
395 In a nutshell, Barbieri thinks that the triplet-based matching system between codons and specific
396 sequences of amino acids is not due to "*objective* chemical properties," but to "codemaker-dependent
397 properties," as a "different codemaker would arrange the amino acids in different ways, which shows
398 that the sequence of a protein is only one of the possible 'meanings' that could be given to a string of
399 nucleotides" (Barbieri, 2009: 22):

400 Different code makers could scan it [codons] in different ways. If the nucleotides were scanned
401 two-by-two, for example, the sequence of codons would be totally different. (Barbieri, 2009:
402 same page)

403 As a matter of logical possibility, the claim that "codes" different from the three-by-three
404 scanning system exist is perhaps correct. Nevertheless, as an empirical matter, the triplet-based
405 system is universal – Barbieri (2009: 28) is not unaware of this fact – and, arguably, for good
406 physiochemical reasons, rather than for convention. For example, Pavel Baranov and coworkers
407 conclude that "the length of codons in the genetic code is optimal, as three is the minimal nucleotide
408 combination that can encode the twenty standard amino acids" (Baranov et al., 2009: 1). Thus, it is
409 the conspiracy of the actual amino acids available and an principle of economy that appears to solve
410 the case, which I consequently regard as an "objective" chemical problem solved by "objective"
411 physiochemical laws. Moreover, generally speaking, it is not even clear that the logical possibility of
412 alternatives accounts for the code-derived, meaningful character of some kinds of relation: e.g. does
413 allelic variation within genetic pools, for example, turn differential reproduction into a case of
414 semiosis?⁷ Indeed, according to Barbieri's point of view, such an attribution would regard it as a
415 meaningful phenomenon – without any explanatory gain for the theory of natural selection. I believe,
416 in contrast, that such a conclusion would probably but contribute to the confounding idea of Natural
417 Selection as a kind of mind-governed phenomenon (Fodor & Piattelli-Palmarini, 2010).

418 Note that Barbieri's claims have to do with the production of proteins from messenger RNAs
419 as a case of what he refers to as "manufacturing semiosis" (semiosis which brings into existence a
420 new thing), which, once accomplished, paves the way for further processes of "signaling semiosis"
421 (semiosis which reorganizes pre-existent things), ultimately responsible of different kinds of cellular
422 specializations. My counterargument is, in a nutshell, that the kind of "contingent" quality that

⁷ Indeed, John Maynard Smith appears to have entertained such an idea in one of his moods. Nevertheless, the idea is but one among his ever-changing musings in his efforts to endow genes with some kind of prominence in development and evolution (Maynard Smith, 2000).

423 Barbieri appears to deem the mark of the “code/codemaker” category is not one capable of
424 introducing an ontological divide between chemistry and semiosis, and that the processes that he
425 describes are physiochemical through and through.

426 Let me also stress that even if one is willing to accept that between proteins and physical
427 segments there exists a sort of key/hole, not interpreter/interpretant-mediated physical relation, or
428 even non code/code-maker one, regarding which “shape” happens to be the relevant parameter or
429 magnitude, this is not enough to guarantee has the relation has a (proto) semiotic character. The reason
430 is quite straightforward: the relation does not obey to Secondness, to start with, inasmuch as, say, a
431 specifically shaped kind of cell is “one entity” with the proteins concerned. In other words, there is
432 not a dyadic relation between proteins as representanda, on the one hand, and shaped functional cells
433 as objects, on the other hand, but rather they are part and parcel of a single dynamic object – i.e. a
434 unique, indivisible Firstness. In other words, it makes as little sense to ascribe an iconic status to
435 proteins as to the structural frame of a building. Perhaps one can read them as blueprints of cells or
436 buildings, respectively, but they are component parts thereof – i.e. not parts of the map, but parts of
437 the territory itself.

438 In order to conceptualize these kinds of cases, Ruth Millikan’s “natural sign” category could
439 maybe fit the bill, but it is worth stressing that the distinctive feature of this “kind of thing” is that
440 they “could be used” by an interpreter in a way that parallels how she/it would use an established
441 “intentional icon” (Millikan, 1984: 118-120; on natural signs, see also Deely, 2016; Favareau, 2007).
442 It is thus a category that covers almost everything around and, consequently, of little conceptual value.
443 Alternatively, one may be tempted to conceptualize proteins as Millikan’s “intentional signals,”
444 which constitute a primitive approximation to fully articulated “intentional icons” in her biosemiotic
445 framework (Millikan, 1984: 116-118). According to Millikan, icons proper relate with other familial
446 iconic devices, which vary in certain aspects whilst sharing others, this allowing them to capture and
447 match relevant differences of their objects. However, she is open to attributing a primitive kind of
448 natural intentionality to certain signals, which she exemplifies with the flowing of adrenaline and
449 other chemical messengers, which occurs at a particular time or at a place, or both. Thus, she explains,
450 they function as a whole (i.e. independently of any clear-cut variable/invariable internal divide) as
451 signals to ready other parts of the body for strenuous activity (Millikan, 1984: 116). According to
452 Millikan’s view, the substance as a whole may be equated to the invariant part of an icon proper, and
453 the specific time/place to the variant part. Proteins might fit into this category of intentional signals,
454 were one to feel tempted to see parallel between its primary structure and an invariable chemical unit
455 that occurs at a particular position/time – namely, the one that instigate transcription, so cells
456 specialize accordingly. However, such a parallel is not accurate, inasmuch as the proteins’ role is not

457 merely informative, but formative. They do not announce what is to be done next, but rather
458 instantiate it directly.

459 Going back to the kind of approach endorsed by Faltynek and Lacková, it might perhaps fit
460 Peirce’s efforts towards establishing a line of evolutionary continuity between the brute Secondness
461 of pure physical interactions and the full-fledged Thirdness of semiotic phenomena, via a kind of
462 Thirdness *in propecto* or *in futuro*, which he conveyed to those physical interactions whose outcomes
463 were not immediately interpretable, yet not exclusively physical – e.g. for exhibiting the marks of life
464 (Deely, 2016). One may contend that proteins belong to such a kind of evolutionary chain. However,
465 this does not grant them semiotic character – I would say that, on the contrary, it stresses their “pre”,
466 rather than “proto,” semiotic nature.

467

468 *5.2 Development and the Flow of Information*

469 Whilst Faltynek and Lacková appear to feel comfortable with the molecular dead-end of semiosis in
470 development, many authors support the idea that development is a thorough semiotic process, wherein
471 information is captured, processed and put into developmental work on a sequential basis. Prominent
472 among the supporters of the pivotal role of information in developmental processes are supporters of
473 “developmental systems theory.” One of the core contentions of this theory is that development is to
474 be conceptualized as the ontogenetic unfolding of the successive informational stages that lead to
475 organic forms apt to carry on cyclic iterations of the same kind of process (Oyama, 2000; Oyama et
476 al. 2001; Griffiths & Hochman, 2015). Roughly speaking, the concept of “information” that is
477 entailed in this theoretical framework boils down to the idea that relevant differences in a given state
478 of organization are accessible to a certain receiver, which processes them according to intrinsic
479 parameters to give rise to a new organized state, in which new differences match the original ones.⁸
480 Differences make difference – approximately paraphrasing Gregory Bateson (Bateson, 1972). While
481 the idea of a continuous flowing of information appears to be straightforward as a schematic
482 approximation of developmental processes, a closer inspection reveals that it is not so clear that the
483 the insights offered by these kinds of systematic approaches centered around the concept of
484 “information” go deep enough into the flesh and blood of organic development.

485 It is important to bear in mind that “information,” in the context of the present paper, is itself
486 a metaphor which comes to the rescue of the BPM. Actually, as observed by Mark Pharoah, the idea
487 of an “information system” is twice a metaphor, for not only “is information” used metaphorically in

⁸ Paul Griffiths observes that “information,” as applied in developmental studies, “is a way to talk about correlation” (Griffiths, 2001: 395).

488 biology (Griffiths, 2001; Levy, 2011; Longo et al., 2012; Sarkar, 1996), but so is “system” is, which
489 metaphorically introduces the idea of an organized or meaningful kind of complexity (Pharoah, 2020:
490 314). Be that as it may, the theoretical value of metaphors is not what is at stake; not even whether
491 one may resort to new metaphors in order to reinforce old ones. The real concern of this section is
492 whether the image of bits of information flowing through successive stages of developmental
493 organization, somehow injecting a sort of developmental memory into each newly attained stage and
494 impelling the resulting wholes to further organizational accomplishments, is a theoretically
495 reinvigorated persona of the BPM. In line with such a restatement, the BMP acquires an extra
496 (temporal) dimension, which may be captured by transitions like those of a state diagram that depict
497 the relevant inter-stage mappings. States may in turn be thought of as static maps (or blueprints/plans),
498 which stand for the more or less transient/lasting conditions of steadiness that a living entity goes
499 through. In the words of John McLachlan, the flow of information metaphor may be thought of as an
500 improved version of the BPM – at the onset, a kind of “structure model” – by means of an enhanced
501 “process model” (McLachlan, 1999).

502 A remarkable virtue of this extended metaphoric approach to the BPM is that the furtherance
503 of development is now captured by the specific kinds of transition which follow from the
504 accomplishment of a certain state of affairs. Moreover, inasmuch as it is assumed that
505 diagrammatizations function as generalizations, which range over an indeterminate number of
506 variable factual conditions, the specifics of which may have a far from trivial impact on outcomes,
507 the BMP can be said not to be bound to a deterministic interpretation of development. Thus, the
508 multiplicity and non-linearity of causes make development a process which is, in a way, non-
509 deterministic yet, at the same time, reliable and largely predictable. This is an aspect of development
510 which requires factoring in and incorporating elements of reinforcement, overlapping, redundancy,
511 non-deleterious bifurcations, etc., into diagrammatizations.

512 All that said, the flow of information metaphor is not without its own weaknesses. It is
513 important to evaluate whether these weaknesses are merely indicative of the point at which the
514 epistemic role of metaphors comes to an end and hardcore research must lead the way in conceptual
515 accommodation, or whether they point to some intrinsic shortcomings of the metaphor as such, as in
516 the case of the plain BPM. I shall briefly concentrate here on two particular issues, which I shall refer
517 to as the “stage problem” and the “realization problem.”

518 As for the first issue, I shall simply emphasize some claims of developmental biologist
519 Alessandro Minelli in the wake of seminal observations made by C.S. Hickman, himself an expert in
520 the study of larvae. According to the latter, stages are in the eye of the beholder – the biologist, in this
521 case – for stages are ultimately conventional demarcation points to facilitate the expert’s task – thus,

522 artefacts (Hickman, 1999: 7). In agreement with this view, Minelli argues that “the basic continuity
523 of development makes all such distinctions arbitrary” (Minelli, 2003: 57), and he stresses that “the
524 boundaries separating developmental stages along the temporal axis are generally less clear-cut than
525 the boundaries between organs in an animal’s body architecture” (Minelli, 2003: 60). When one
526 considers phases of relative stability in an animal’s life history, it is important to bear in mind that
527 even stability is, in such cases, but the lasting effect of sets of *synchronous* factors. In the end, Minelli
528 proclaims “the primacy of time,” as the axis to be privileged in developmental explanations, whilst
529 allowing for the heuristic participation of categories referring to discrete segments therein, with the
530 proviso that they are accompanied by corresponding “operational definitions” (Minelli, 2003: 56-57).

531 Thus, while the plain BPM is obviously barred by these kinds of considerations, the metaphor
532 of a flow of information, which maps prior stages onto subsequent ones is not, and consequently may
533 provide bona fide epistemic access to developmental inquiries. Obviously enough, one cannot lose
534 sight of the heuristic role of discrete slides chosen by a given system of periodization. This is an
535 aspect of the metaphor that should be ultimately overcome by a further accommodation of the
536 explananda to the unbounded continuity of development.⁹

537 As for the “realization problem,” let me simply stress that the kinds of functional
538 diagrammatization that the flow of information metaphor inspires belong to those that have
539 historically offered support to the thesis of autonomy for the special sciences (Fodor, 1974). In a
540 nutshell, diagrams point to a kind of formal causality which appears to be compatible with alternative
541 material bases of realization (Polger & Shapiro, 2010). In this regard, biology may be seen as a
542 transitional case between what is routinely considered “hard science” (e.g. physics) and what is
543 considered “special science” (e.g. economy): on the one hand, the biologist’s jargon largely overlaps
544 with or easily translates into that of chemists and physicists; yet, at the same time, biology also
545 appears to have an ineliminable/unreducible historical component (Gould, 1989; Mayr, 2004). In this
546 context, it may be tempting, particularly for those who take the kinds of metaphors thus far reviewed
547 at face value, to conclude that the “specialness” of biology extends beyond its partly historical
548 character to its partly semiotic nature. This is a difficult issue that would deserve a monographic

⁹ This is a matter with far-reaching philosophical consequences. To refer to just one of its multiple ramifications, Hume observed that secular debates on nativism have a lot to do with taking too literally an arbitrary boundary between prenatal and postnatal life. In his own words:

For what is meant by ‘innate’? If ‘innate’ be equivalent to ‘natural’, then all perceptions and ideas of the mind must be allowed innate or natural, in whatever sense we take the latter word, whether in opposition to what is uncommon, artificial, or miraculous. If by innate be meant ‘contemporary with our birth’ the dispute seems to be frivolous; nor is worth while to enquire at what time thinking begins, whether before, at, or after our birth (Hume, 1748/2000: 12, note).

549 treatment. Nevertheless, I will try to compress into a few words my own view on the matter, in line
550 with the ideas that I have defended in the rest of this paper.

551 My claim, in a nutshell, is that the flow of information is an apt metaphor in order to gain
552 adequate epistemic access to the complexities of development. In this sense, I believe that it continues
553 to be worth pursuing. However, I also believe that the thesis of multiple realizability, which appears
554 to be part and parcel of it, is not a price that should be paid for embracing the metaphor. Generally
555 speaking, one should never pay such a price for illuminating metaphors, the face value of which fades
556 away as soon as they have fulfilled their specific epistemic role – i.e. epistemic access. Having
557 reached that point, some entailments of the metaphor – e.g. the multiple realizability of functional
558 schematizations – become a ballast that researchers can (must) safely rid themselves of. In my my
559 view, this is clearly the case of the flow of information metaphor in relation to developmental biology:
560 once the metaphor has facilitated access, accommodation cannot refer but to the flesh and blood of
561 actual living entities. As Fred Dretske strived to clarify: “the informational relationships between r
562 and s must be distinguished from the system of causal relationships existing between these points”
563 (Dretske, 1981: 26). I consider that it is indisputably the case that these latter kinds of relationship
564 constitute the ultimate aim of developmental biology.

565 Sure enough, developmental processes and their outcomes are conceivably replicable – even
566 factually, in some cases – by using alternative materials, even synthetic or inorganic ones. However,
567 far from proving the specialness of the theories of development – or the primary semiotic character
568 of the flow of developmental information, the picture is rather one that confirms that the aims of
569 biological explanations must directly target the actual material bases of organic causation, even if
570 inspired by the goal of discovering alternative succedanea, which obviously entails the former.

571

572 **5 Concluding Remarks**

573 The conceptual repertoire of semiotics is undeniably an intellectual treasure. Historically, its richness
574 has not only served to clarify/explain concerns proper of its own subject matter, but to inspire
575 solutions in other fields of scientific specialization, carrying out the important role of facilitating
576 epistemic access to otherwise intractable or recalcitrant issues. When fulfilling such an epistemic role,
577 semiotic concepts must carefully respect the following premises:

578 (1) semiotic metaphors should not distort their target domains from the start; and

579 (2) they should not remain inadvertently active once their heuristic role has been fulfilled –
580 not, at any rate, without a deliberate effort to take into account their potentially distorting effects.

581 In this paper, I have evaluated some metaphors coming from the semiotics of architecture and
582 information/communication theory as applied to the theory of organic development, namely, the
583 blueprint/plan metaphor and the flow of information metaphor. My conclusion is that they exemplify
584 situations in which premise (1) and premise (2), respectively, are not respected as they should be in
585 a framework of metaphoric conceptualization.

586 The conceptual interbreeding between semiotics and biology demands special care, for the
587 duties of these disciplines partially overlap. Indeed, these are the very foundations of the field of
588 specialization currently known as biosemiotics. There exist general consensus regarding the
589 attribution to biosemiotics of those areas of the behavior and functioning of living entities that rely
590 on interpretive processes mediated by nervous systems is rather consensual. In contrast, it is not so
591 consensual that organic processes conducted at lower levels of analysis may be so regarded in the
592 same way. In this paper, I have claimed that some biological processes that routinely – sometimes,
593 rather uncritically – receive this kind of treatment actually rely upon the misuse of semiotic metaphors
594 along the lines of (1) or (2) above.

595 Nevertheless, it is my conviction that, far from a loss for biosemiotics, the conclusions reached
596 in this paper are but good news for the field, for clearly discerning what constitutes a biosemiotic
597 process from what does not is a crucial step, in my opinion, towards avoiding the ghost of
598 panbiosemioticism and to securing the credibility of the discipline. As aptly put by Felice Kruse,
599 commenting on Peirce's own panbiosemioticist metaphysical musings:

600 In order for the concept of sign to be at all intelligible, we must make recourse to elements that
601 are at least relatively extrasemiotic. [...] There must be, then, respects in which things are signs
602 and respects in which they are not, and an unqualified pansemiotic position would not be able
603 to account for this. (Kruse 1990: 220)

604

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606 To be inserted

607

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