
CONFLATED EPISTEMOLOGY OR HOW TO LOSE THE ORGANISM (AGAIN)

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Like following life through creatures you dissect,
You lose it in the moment you detect.
A. Pope (1688-1744), *Moral Essays*, epistle i, line 20.

INTRODUCTION

There is much that we agree with in Linde Medina's paper ¹ (the author and the paper are henceforth indistinctly referred as LM). What we try to do in these comments, however, is to parse her view on internalism in what we think is a more fruitful way. At the end of this paper, a different model to analyze biological form as well as some guidelines for future research on the understanding of the organism are suggested.

LM's abstract states: "Do we need an extended evolutionary synthesis? This question will be analyzed here". LM's question is sharp and legitimate in the context of a dominant interpretation of evolutionary theory in terms of the Modern Synthesis. In fact, while the development of new research programs in the last decades has motivated several calls for expansion of the current evolutionary understanding (Carroll 2000; Kutschera and Niklas 2004; Love 2003; Müller and Newman 2005; Pigliucci 2009; Rose and Oakley 2007), it seems unclear what the requirements are for a new synthesis to be able to meet these demands.

LM addresses the question of the nature of an extended evolutionary synthesis by means of a laudable and ambitious strategy. Drawing on the history of biology, LM proposes an interpretative framework to biological form and its implications for the contemporary theory of evolution. Though critical of LM's account, we sympathize with her project and her methodological starting points. There is much to be done to unveil the

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epistemological commitments in both historical and current approaches to biological form. In exploring this issue, any vantage perspective should appeal to history and philosophy as supplementary discursive sources in a Kantian spirit: "Philosophy without history is empty and history without philosophy is blind". Furthermore, a close perspective of current research in biology is absolutely essential for understanding the dynamics of scientific discourses like evolutionary theory.

However, when one focuses on LM's argumentative development, it soon becomes clear that it does not accurately represent the topic announced in the abstract. What LM actually deals with is the history of the dichotomy internalism/externalism over the past few centuries. LM claims that this development has led to a progressive reductionism in explaining the origin of biological form in terms of external causes. In exploring her hypothesis, LM traces a number of dichotomies in biology since the second half of the eighteenth century in order to link externalism with Darwinism and reductionism. Certainly, the dominant interpretation of Darwinist Modern Synthesis is marked by two crucial assumptions: natural selection as the privileged creative force and gene-reductionism concerning phenogenesis. LM emphasizes throughout that this externalist-reductionist approach deprives internal matter of any active causal role.

Anyhow, the actual issue of a purported extended evolutionary synthesis is tackled only in a small portion of the paper and this is done in a succinct manner. LM defends, in the last three pages of the paper, that advances in the knowledge of physical mechanisms involved in self-organization may provide for a new paradigm in explaining form in a non-reductive internalist way.

While there are certainly reasons to be dissatisfied with the reductionist approach to biological form, the belief that this position is exclusive of externalism is misguided. In fact, we argue that LM's position is another version of strong reductionism grounded in a new *physicalization* of internalism in biology.

Our critique intends to clarify some misconceptions that result from an analysis based on a small number of works, usually general overviews. The actual authors referred to have rarely been consulted first hand. This is perfectly acceptable for papers that do not focus exclusively on philosophical but also historical analysis. However, LM's account renders the analyses of different debates rather superficial, which results in an oversimplified discourse on biological form. We address the drawbacks of LM's account in mainly three aspects: the conflation of (i) reductionism and eliminativism, (ii) externalism and reductionism and (iii) diachronic and synchronic approaches.

Finally, the first author of this paper outlines a methodology to understand biological form based on the analysis of three related theoretical

dimensions and a working hypothesis to grasp the essence of the organism in biology. A further development of this approach may contribute to understand both historical and current approaches to biological form.

CONFLATING DEBATES

The present section is devoted to show that LM's position conflates externalism with reductionism, which is, in its turn, conflated with eliminativism. Correspondingly, internalism is wrongly identified with non-reductionist doctrines. We wish to draw the attention to explicit associations among different conceptual frameworks and omissions or ambiguities regarding the main thesis on LM's dichotomy internalism/externalism.

LM states her position quite early. The abstract's first sentence claims: "There are two approaches in the study of organic form: the externalist and the internalist perspective". The first paragraph of the paper describes contemporary theory of evolution as an externalist theory depending "on the idea that living matter is a passive and non-intrinsically ordered agent" (p. 25). LM argues that contemporary evolutionary theory is externalist as a result of the grafting of a "Newtonian framework into the study of organisms" (p. 25). In contrast, research on embryology—especially the branch of epigenesis—is described as a tradition profoundly opposed to reductionist-mechanistic approaches. Epigenesists defended some non-mechanical inner force driving the development of the embryo. This position was frequently dismissed as some sort of mysticism. On the contrary, preformationists thought that morphogenesis was a process of mere mechanic unfolding of pre-existing elements. Preformationism was, according to LM, much more popular among Newtonian scientists because it did not appeal to any extra force participating in morphogenesis. While it is not clear whether LM considers preformationism as an externalist or internalist doctrine, she associates preformationism with Newtonian physics and, later on, with a Darwinian-externalist perspective.

In the section "The controversy begins," Cuvier and Geoffroy's theories are portrayed as battling for the preeminence of function or form². It is not evident what the relation is with the previous debate. Whereas LM's association of Geoffroy with Goethe's interest on inner activity of living organisms seems to put Geoffroy on the side of internalism, it is not made explicit what position LM attributes to Cuvier. LM refers that Cuvier's functionalism stressed "the *internal* relationships between organs" (p. 29; emphasis added). But if both Geoffroy and Cuvier were internalists, which controversy began during this debate? What exactly is the debate about? Is Cuvier's position an unconfessed sort of externalism? Is Geoffroy's notion of the Unit of Composition more internalist than the four basic embranchments defended by Cuvier? Additionally, nothing is said about

Cuvier and Geoffroy's respective positions on reductionism, mechanisms, epigenesis or preformationism. LM's interpretation of this important debate with respect to externalism/internalism is not clear, to say the least.

Shifting the battle arena in an acrobatic jump, LM introduces a dichotomy between substance and pattern. She quotes Webster and Goodwin (1996, p. 3; LM incorrectly attributes the quote only to Webster) to suggest a relation between Aristotle's material cause and a general notion of substance, on the one hand, and Aristotle's formal cause and a general notion of pattern, on the other (p. 30). According to LM, "Darwinism is a theory of substance (composition)" (p. 31) based on a preformationist view: "The form of the organism is completely determined (preformed) by hereditary particles carried in its germ plasm" (p. 35). In conclusion, LM implies that the Neo-Darwinism-preformationism³ nexus became a sort of coordinated substantialist theory in the Modern Synthesis privileging the notion of heredity in terms of the transmission of pre-existing substantial determinants (germ cells or ultimately genes), and a "mechanistic conception of living matter as a passive agent" (p. 35).

Furthermore, LM concludes that whenever substance is emphasized over pattern, eliminativism is just around the corner: "pattern is not conceived as a real entity demanding an explanation"⁴ (p. 30). If pattern is not conceived as a real entity, then pattern and form are eliminated and ontologically reduced to substantial entities from a lower level: "it is assumed that pattern can be reduced to substance" (p. 31). What follows "is a gradual *elimination* of any agency (generative capacity) in the living matter [...] the *loss* of its dynamical component, the *denial* of the existence of organizing principles, the *loss* of structure as a real entity...the *loss* of organism" (p. 31; emphasis added).

According to LM, much of the twentieth century history of biology was devoted to the elimination of the organism from biology by means of locating and identifying genetic determinants in a progressively reductionist endeavor. The *lac operon*, the Human Genome Project, the gene regulatory networks approach, the theory of positional information, the Hox genes and, in general, the genetic program for development have pursued the causes of biological form exclusively in a genetic and, whenever possible, molecular basis. It should be noted that across LM's narrative, nothing is explicitly said about the internal or external character of the genetic program for development. However, the Modern Synthesis understood developmental mechanisms as products of gene configurations molded by natural selection. This enforced the gene-centered reductionist view in understanding morphogenesis and evolution. It can be inferred that, according to LM, the genetic program for development was naturally incorporated into the externalist view of the Modern Synthesis.

In the last part of the paper, LM performs a crusade for theories of self-organization as an internalist alternative to the externalist Modern Synthesis. LM contends that self-organization may recover not only the causal agency of organic matter, but also the organism, lost during the nightmare of Darwinian reductionism: “organisms are active agents capable of can self-organize [*sic*] intrinsically without the intervention of an external organizing principle” (p. 45). Additionally, LM points out that the recent advances on the research of the physical mechanisms of self-organization, in particular the Developmental Patterning Modules (DPMs), provide a generative language to biological form profoundly based on a non-reductionist internalism.

In conclusion, LM associates externalism with a group of doctrines marked by an eliminativist reductionism, depriving organic matter of any causal role. In contrast, internalism is associated with non-reductive doctrines attributing causal relevance to organic matter ⁵ (see table 1).

Externalism-Passive Matter	Internalism-Active Matter
Preformationism	Epigenesis
Mechanism	Mysticism
Rationalist science	Empiricist science
Substance/Composition	Pattern/Structure
Material cause	Formal cause
Natural selection is creative	Matter is (creatively) self-organized
Reductionist (only substance)	Holistic (pattern and substance)

TABLE 1

Dichotomies traced in LM’s account across the argumentative line of externalism-passive matter *versus* internalism-active matter.

DEFLATING REDUCTIONISM

Reductionism is one of the most relevant doctrines in the history of biology and of science in general. While there is little philosophical consensus about the nature of reductionism, it is safe to say that reductionism gathers together a large and heterogeneous group of explanatory practices. We argue below that LM’s account overlooks this variety, leading to severe epistemological problems.

One of the best expositions of reductionism was offered by Shimony (1987). He claims reductionism has two dimensions. On the one hand, reductionism appeals to an ontological notion of additivity: the properties of a composite system (*explanandum*) are fully determined by determining

the properties of the components (*explanans*). The whole is the sum of the parts ⁶. On the other hand, this possibility raises the epistemological question of the conditions in which phenomena from upper levels can be derived (and explained) by lower level laws considered as more fundamental.

In exploring these conditions, Sarkar (1998) uses fundamentalism and hierarchical containment (see next section) as criteria to distinguish five different kinds of reductionist explanations. Some of them are stronger than others depending on which criteria are completely satisfied ⁷. It seems strange that LM refers indirectly to Sarkar in arguing for Neo-Darwinism as a genetic reductionism (p. 47), for there is nothing less imprecise than interpreting Sarkar's categories in eliminativist terms. LM assumes that Neo-Darwinism eliminates pattern, form and even the organism in favor of substantial genetic causes. On the contrary, Sarkar's account on reductionism refuses both ontological and epistemological eliminativism as dubious and unviable positions in understanding reductionist explanations in genetics (see Sarkar 1998, pp. 60-65). Actually, Sarkar's genetic reduction or "abstract hierarchical reduction" is a category of non-strong reductionist explanations conceptually quite far from LM's eliminativism. In contrast to strong reductions, Sarkar's genetic reductionist explanations do not demand the physical containment of the components (alleles, genes, linkage groups) in the organism (e.g., segregation analysis is based on statistical models assuming Mendelian inheritance, but it says nothing about the physical containment of the alleles in the organism ⁸).

Though it seems clear that reductionism is one of the main features of Neo-Darwinism (and Modern Synthesis), it exhibits a wider variety of reductionist explanations than those assumed by LM. In addition to the already mentioned genetic reduction, studies of natural selection frequently explain the evolution of continuous characters by appealing to standard analyses of heritability ⁹. This is the case Sarkar uses to exemplify weak reduction, a kind of reduction that does not make any claim about any particular structure of the genotype (see Sarkar 1998, ch. 4). Yet Modern Synthesis appeals to stronger reductions. The genetic program for development, for example, is largely devoted to formulate reductionist explanations by identifying genetic determinants spatially contained in the organism. Sarkar calls this kind of explanations, associated with molecular biology, strong or physical reductions ¹⁰. It seems possible that LM chose these cases as paradigmatic examples to reduce all reductionist explanations to her poorly defined picture. Nonetheless, not even Sarkar's strong reduction implies some sort of eliminativism: Sarkar's account dissects reductionism to appreciate different explanatory strategies; LM, on the contrary, chooses to put all eggs in one basket.

One of the main drawbacks of conflating reductionism with substantialist eliminativism is that it hinders the understanding of the *explanandum*

and *explanans* involved in reductionist explanations. Ernst Mayr, for instance, defends the reduction of teleological form in biology to adaptation (Gould 1980, p. 120; Mayr, 2001, pp. 492-493), but he categorically refuses to reduce biological form to physics (Mayr 1982, pp. 59-67; 1985) or even to isolated genes or molecular biology (Mayr 1988, pp. 423-438; 2000, p. 896). How can we understand positions such as this one if all reductionism collapses into substantialist eliminativism? If Neo-Darwinism supposedly eliminates biological form in favor of substances, why does Mayr refuse to eliminate biological form in favor of substantial physical molecules? Moreover, if Mayr's adaptationism reduces teleological form to adaptation, then which kind of substance is an adaptation? What are the substances involved in Mayr's position: atoms, macromolecules or adaptations?

It appears possible that the problem here has to do not only with LM's conflation of reductionism and eliminativism, but also with her unclear use of the notion of substance. As mentioned above, LM associates substance with a materialist, even chemical reductionist theory of composition of matter (pp. 30-31). In such a case, the opposition between the approaches featuring pattern (anti-reductionism) vs. those focusing on substance (reductionism) (p. 30) is plainly wrong. Three related arguments undermine this approach.

a. Materialist-*substantialist* approaches are neither necessarily eliminativist nor reductionist.

LM's identification of Neo-Darwinian reductionism with substantialism is imported from an analogy between the way substance may be divided into atoms and the Neo-Darwinian notion of form as an assembly produced by a sequence of steps—"atoms of change"—molded by natural selection¹¹ (Emmeche and Hoffmeyer 1991). Nonetheless, this analogy only works when substance and matter are considered in a reductive way. Non-reductive materialism can be understood as a position which, on the one hand, allows for the emergence of structural properties of biological pattern, but which, on the other hand, claims that these properties are derivative from or dependent on material physical properties. The latter does not mean that the properties of form can be ontologically reduced to the properties of lower level elements (atoms, macromolecules or genes) or that the behavior of form can be epistemologically deduced from physical laws¹². We agree with LM when she defends theories of self-organization and other approaches featuring pattern as non-reductionist approaches. But these approaches are, in the sense of materialism explained here, not less *substantialist* than reductionist Neo-Darwinism. In the light of non-reductive materialism, LM's use of this analogy seems fallacious.

b. Neo-Darwinism and Modern Synthesis are not theories of *composition*.

Darwinism and Modern Synthesis study living entities *composed*—all of them—of matter. But this does not make these approaches theories of composition. The main idea of a theory of composition is that the features or behavior of a certain class of objects are explained by the presence of a peculiar component (e.g., physical or chemical substances) which does not occur in other classes of objects¹³. Neither Neo-Darwinism nor pattern-focused approaches advocate that the behavior of life organization is caused by some peculiar physical or chemical component not occurring in inert matter¹⁴. Even more important, in describing Neo-Darwinism or Moderns Synthesis in terms of substantialist theories of *composition*, LM fails in capturing the functionalist nature of Neo-Darwinism. In fact, Neo-Darwinism does not defend that adaptation can be accounted for by substantial composition *per se*. Wings are not adaptations because they are composed by such and such percentages of proteins, oxygen, lipids, carbon, carbohydrates or nucleic acids (even when a chemical composition can be considered an adaptation in a specific *functional* context).

c. Finally, if substantial *composition* is intended as a formal concept of structure or organization, then substance and composition are quite close to pattern, and the opposition pattern (anti-reductionism) vs. substance (reductionism) is even less viable. A proper opposition between reductionist and anti-reductionist approaches would deal with the essential difference between two ways of understanding structure and pattern: on the one hand, a decomposable pattern that is nothing more than the sum of the properties of its parts and, on the other hand, a pattern that cannot be fully accounted for by the sole reference to the parts. Denying that the first case offers a notion of structure or pattern would entail denying that mechanical Newtonian systems have any structure. Even in the Newtonian picture, the solar system has a structural configuration, even though it can be described in additive terms.

In our view, conflating reductionism with substantial eliminativism contributes to LM's misinterpretation of internalism¹⁵. Furthermore, LM's physicalism seems to be a kind of strong reductionism quite similar to Sarkar's physical reduction. But before we analyze the latter conjecture, we have to deflate the spurious nexus of internalism/antireductionism and externalism/reductionism.

DEFLATING INDEPENDENT DEBATES:

INTERNALISM/ANTIREDUCTIONISM AND EXTERNALISM/REDUCTIONISM

Debates on reductionism/antireductionism and internalism/externalism cannot be conflated because the first debate is much broader in scope than the second¹⁶. Though we previously identified ontological and epistemo-

logical dimensions in the debate reductionism/anti-reductionism, there is no such clear ontological aspect in the debate internalism/externalism. There are no ontological claims involved in defining internal and external, but epistemological claims about internal or external explanatory patterns concerning specific systems.

Even if we exclusively consider the epistemological aspects, LM is mistaken. Perhaps the best way of clarifying the difference between these debates is by means of an analogy. As mentioned above, according to Sarkar, reductionist explanations are based on fundamentalism and a criterion of hierarchical containment (either abstract or spatial):

- a. Fundamentalism: lower realm elements (*explanans*) and their operations are considered as more fundamental in explanatory terms than the principles in the upper realm.
- b. Abstract hierarchy: a multilevel arrangement is assumed and the explanation proceeds by abstractly subsuming the *explanandum* in the upper realm under the elements from the lower realm (*explanans*).
- c. Spatial hierarchy: the upper realm phenomena (*explanandum*) physically contains the elements of the lower realm (*explanans*).

The important point to be made here is that the debate reductionism/antireductionism is on the *verticality* of explanation: it implies a directional explanatory process along a vertical hierarchy. In contrast, internalism/externalism is a debate on the *horizontality* of explanation: it describes the interactions between a system and its environment, but it does not imply a hierarchical arrangement of explanatory levels¹⁷. Although fundamentalism in Sarkar's sense is present in both debates, the geometrical explanatory directions are orthogonal. Consequently, all epistemological combinations are possible: internalism-reductionism, internalism-antireductionism, externalism-reductionism, externalism-antireductionism. LM's conflated epistemology misinterprets several research programs because she does not recognize the independence of these debates. For example, LM portrays the genetic program for development as an emblematic example of genetic reductionism associated with the externalist Neo-Darwinism and, cogently, depriving matter of any causal internal agency. While it is true that Neo-Darwinism explains every trait (genetic or phenotypic) appealing to the ultimate action of natural selection; the genetic program for development explains the development of traits in proximal terms (for a distinction between ultimate and proximate causes see Mayr 1961; Ariew 2003). In doing so, this program almost always ignores or dismisses any possible environmental influence. Model organisms are explained by focusing on internal genetic determinants as if organisms were isolated from the environment. The genetic program for development is a highly reductionist *internalist* program with respect to the

ontogenic origin of phenotypes. In fact, this program conceives of genes not only as *internal* and *material*, but also as the only *causally active* entities, hence the “loss of the organism”¹⁸.

Another drawback of LM’s account is that she neglects the inherent relativity in the debate internalism/externalism. The main assumption behind all debates on internalism/externalism is that it is possible to distinguish unambiguously the system from its background. However, this distinction depends on the conceptual, methodological and epistemological elements in a specific field. Since there is not always agreement on how to draw the border, epistemological attribution of externalism/internalism is tremendously dependent on the specific explanatory context. This precludes the application of a uniform criterion for labeling an explanatory pattern as externalist or internalist. A good example for illustrating this point is the debate empiricism/rationalism: in general terms, it is possible to identify classical empiricism as an epistemological doctrine privileging the causal channel from the outside (objects) to the subject’s inner perception¹⁹. On the contrary, for rationalism, any idea or thought is impossible without some internal process in the subject. This difference may be useful in understanding the Cuvier-Geoffroy debate, for these issues were part of the discussion: while Cuvier vigorously defended a sort of empiricism (Appel 1987 p. 46-53), Geoffroy endorsed a kind of idealism (Appel 1987 p. 69, 88.) According to this view, we may interpret Cuvier as an externalist and Geoffroy as an internalist. But this criterion is only useful in contexts in which epistemological assumptions or the derived scientific methodologies are at stake. This is obvious even when talking about the same persons, e.g., regarding the vitalist/mechanist debate, Cuvier believed that life consisted of an internal vital movement, a *tourbillon*, “which opposed itself to the forces of physics and chemistry” (Appel 1987, p. 50); on his part, Geoffroy endorsed a form of physicalism diametrically opposed to vitalists and much more sympathetic to an externalist mechanicism. He was willing to apply a Cartesian mechanicism and the Newtonian laws to the study of phenomena like hibernation, muscular contraction, respiration or the nervous impulse (Appel 1987, pp 75-80). Another nice example of this relativity is seen in Darwin himself. While most of Darwin’s interpreters have stressed almost exclusively the role of natural selection on determining biological form, Darwin acknowledged the relevance of morphogenetic internal rules having nothing to do with external natural selection (Asma 1996a). Stephen Jay Gould, author of one of the clearest accounts exploring internalism/externalism in paleontology (1977), endorses a similar position: micro-evolutionary processes are explained mostly by means of externalist forces, but macro-evolutionary transformation of form is influenced much more by internal dynamics (Godfrey-Smith 1998, p. 45).

In conclusion, internalist and externalist models can be compared concerning a specific issue, but there is no fact of the matter about the preeminence of any approach in an entire general domain (see Godfrey-Smith 1998, ch. 3). LM's eliminativist interpretation of any externalist approach stripping matter of any causal agency is a very rigid and general concept useless in understanding the debate externalism/internalism on form. As a matter of fact, most externalist positions in no way ignore the order of inner matter or internal causal mechanisms; externalism only denies significance to internal factors as primary causes of biological form. Furthermore, attributing a purely external or internal explanatory schema to such and such view is, most of the times, an oversimplification tending to conflate epistemological principles. Modern Synthesis, Neo-Darwinism, Cuvier, Mayr and others, rather than a coarse externalist-reductionist view, exhibit a more sophisticated combination between external and internal perspectives. Any attempt to understand the debate on internalism/externalism to form has to be highly sensitive to these differences.

SYNCHRONIC AND DIACHRONIC APPROACHES: A DEEPER EPISTEMOLOGICAL DICHOTOMY

Besides the failures concerning reductionism, a major difficulty in LM's account is the lack of a proper distinction between synchronic and diachronic approaches to biological form, which leads to an implicit conflation of both dimensions. Nevertheless, this fundamental dichotomy sets up specific epistemological demands and defines methodological needs across all biological inquiry (Piaget 1971a).

Diachronic approaches are etiological approaches²⁰, they seek to explain the existence of biological form in terms of its *origin* and the *processes* involved in bringing it about. They account for the temporal transformation of form, the emergence of form from a modification of a temporally previous form. Diachronic processes have two dimensions of time-dependent transformation. On one hand, the processes of differentiation of sub-structures. On the other, the unification of differentiated sub-structures into totalities.

Two main modes of diachronic approaches can be recognized. On the one hand, ontogenic theories like epigenesis explain biological form in terms of the origin and the processes carried out during the development and constitution of organisms²¹. They ignore or play genealogical history down. On the other hand, evolutionary approaches like Modern Synthesis or Lamarckism are diachronic accounts of transformation: biological form is explained appealing to history, genealogy and generative processes along phylogenetic lineages.

In contrast, synchronic approaches²² consider the relations, *at a given time*, among the parts of a system (Rueger 2000) or among systems. They correspond to the investigation on physiology (Piaget 1971a, p. 71) and much of anatomy, morphology, biochemistry and other disciplines²³. Rather than appealing to the origin or history, synchronic approaches abstract formal, timeless relations from states of relative equilibrium. Though all synchronic approaches emphasize the system's organization as a key concept in grasping life, there are several positions in the way organization may be accounted for. Some synchronic reductionist approaches explicitly endorse the principle of additivity or decomposability of the system (e.g., systemic accounts on functional forms²⁴). Others emphasize a non-reductionist account of living organization²⁵ (Rosen 1991; Cornish-Bowden & Cárdenas 2007). In the latter case, the part-whole relations are assumed to be circular. In contrast to efficient causality, circular causality does not explain a sequence of production of phenomena, but a set of timeless conditions required for accounting for a phenomenon (e.g., life organization). The first author in this paper defends that this is only possible if circular causality is assumed to be a constant or at least invariable relational structure unified in the organism (see last section and Ramirez Trejo, forthcoming).

Internalism/externalism and reductionism/antireductionism debates are primarily concerned with setting up the borders of a system and the causal relations among components either in a vertical or horizontal direction, without considering historic-temporal transformations²⁶. In contrast, the debate synchronic/diachronic is not only concerned with the determination and possible reduction of the system, but also with its historical transformation and the genealogical relations of both parts and whole.

PROBLEMS FROM CONFLATION:
SOLUTIONS FROM DEFLATION

In what follows we will exemplify some of the problems in applying LM's account to specific historic episodes and current investigations on form. Subsequently, we will show how LM's account leads to a new sort of reductionism. Finally, we will sketch a comprehensive model for understanding different approaches to form.

LM is interested in understanding the *origin* of biological form, that is, she is interested in diachronic mechanisms. She starts her discussion by criticizing the theory of evolution and appraising that "the first theories of form were based on development" (p. 26). Strictly speaking, classification of living organisms antecedes any modern embryological or evolutionary theory: taxonomy appeared before the debates on preformationism and epigenesis had taken place²⁷. It is possible that LM shares the view that

taxonomical accounts are not really scientific *theories* because they do not address the causal origin of form. It is not the business of the present article to define what exactly a scientific theory is, but the relevance of taxonomical approaches in the understanding of form should not be neglected.

The historical development of taxonomy resulted in the adoption of species “fixism” in the mid-eighteenth century. Fixism ruled out several notions of abrupt species transformation broadly accepted for centuries, for instance, inter-species crossbreeding resulting in new species, transmutation from one species to another, non-gradual large-scale mutations, and pervasive spontaneous generation (Amundson 2005, pp. 34-39). Fixism made it possible to construct a system of stable relations among species in which comparative anatomy and morphology could confidently explore synchronic affinities and correspondences among different biological forms. In fact, Cuvier and Geoffroy’s relational approaches depended on such a system of invariances: despite their different interpretations of living structure, they both focused on synchronic relations among the different parts of an organism, and among the parts of different organisms, without thereby committing themselves to any kind of genealogy or evolutionary change²⁸. In turn, essential Darwinian notions, like the species of the “Natural System” related by ancestry and the gradual transmutation of species limited by phylogeny, could not have been built without such fixist synchronic relational accounts.

LM’s simplistic internalist/externalist division ignores the importance of synchronic accounts in bringing about diachronic approaches. Furthermore, she oversimplifies the synchronic aspects in the Cuvier/Geoffroy debate. We do not mean to suggest that LM should provide a complete interpretation of these figures, nor do we claim to fully account for the epistemological difference between Cuvier and Geoffroy²⁹. We do, however, wish to point out some of the difficulties that may derive from the application of LM’s conflated epistemology in understanding historic episodes.

Geoffroy’s “philosophical anatomy” understands “analogies” as “essentially equal parts occurring in different animals [species], regardless of their variance in shape or function” (Kleisner 2007, p. 320). In modern terms these structural correspondences are understood as “homologies” and, according to Geoffroy, they converge in an abstract “archetype” stemming from internal morphological laws determining the structure of organisms (Asma 1996b, ch. 3; Scholtz 2010, p. 48). In fact, natural laws generate structure, a material pattern, constraining the possible functions of the parts of the organism: “So, function is the result of structure and structure is the result of natural laws” (Asma 1996b, p. 59). Geoffroy overemphasizes internal morphological laws and dismisses the role of the environment and functional relations. According to LM’s epistemology,

Geoffroy's perspective is a paradigmatic example for the internalist-antireductionist view.

Closer examination reveals that, on the contrary, Geoffroy's complex system resists this characterization. While it is true that Geoffroy concedes preeminence to diachronic internal morphological laws in generating form (Rieppel 1990), it does not follow that this is an internalist approach, at least not in terms of LM's "active matter." Stephen Asma nicely illustrates this point in comparing Geoffroy's structuralism and Goethe's idea of form (Asma 1996b, pp. 43-60). Goethe combines the traditional formal and efficient causes in a notion of form that is more similar to an active force involved in its own materialization. In contrast, Geoffroy's structuralism is much more congenial with a doctrine in which material laws mold passive organic structure. If internalism would mean LM's "active matter," Geoffroy should be an externalist-reductionist. However, Geoffroy's account exhibits concepts, metaphysical assumptions and methodologies that are worthy of deeper analysis. Only some points will be suggested here.

A central element in Geoffroy's system is, indeed, the synchronic notion of "archetype." Geoffroy's "archetype" has a dubious ontology, but it is best understood as an abstract plan of organization constituted by a series of topological *relations* (Asma 1996b, p.179; Rieppel 1994). Geoffroy considered his archetype as an abstraction, a "shorthand" stemming from the convergence of material causes but without any causal power in itself (Asma 1996, p. 56).

Anyhow, the relational character of the archetype had strong methodological implications, for it was inconceivable for Geoffroy to study any structural element without appealing to its connection with other elements in the structure. Geoffroy's guiding principles, the "principle of connection" and the "principle of balance-of-organs," assume that "there must be homology within the *overall* structure" (Panchen 2001, p. 43, emphasis added) of organisms. The first principle takes into consideration the number and relative positions of the components in biological structures. The second principle asserts that the changes in the components are due to transformations: if there is an enlargement of a component, there is a shortening somewhere else.

In fact, it seems Geoffroy's archetype relies on an implicit notion of circular dependency: the whole topological structure depends on the connections of the components; the specific disposition and distribution of the components depend on the topological structure. This circular dependency between whole and parts does not mean any functional dependency like in Cuvier's schema, but only a circular dependency similar to other non-teleological approaches to complex systems (Lewis 2000; Seifritz 2005). In any case, it seems improbable that Geoffroy's

structure implies a reduction to its components, for the notion of connectivity appeals to the relations between components in the structure and there cannot be compensation of magnitude between parts if it is not assumed that the parts are interconnected in a structural unity. Whether Geoffroy believed that the qualities of the organic structure (archetypical or material) can be ultimately reduced to quantitative relations is not clear (Asma 1996b, p. 57). However, like Asma suggested (1996b, ch. 8), it seems more probable that Geoffroy's structuralism is related to non-reductive materialist approaches like Kauffman's self-organization theory.

For his part, Cuvier thought that the affinity among parts of different organisms were the result of having the same function: function was necessary and sufficient for structural comparison. Structures, according to Cuvier, are immutable and harmoniously unified to fulfill their functions with respect to the demands of the organism's style of life:

Since nothing can exist that does not fulfill the *conditions* which render its *existence* possible, the different parts of each being must be co-ordinated in such a way as to render possible the existence of the being as a whole, not only in itself, but also in its relations *with other beings*, and the analysis of these conditions often leads to general laws which are as certain as those which are derived from calculation or from experiment (Cuvier 1817, i., p.6—translation from Russell 1916, p. 34; emphasis added).

Cuvier's reference to "other beings" and to the fact that "the parts of an animal were necessarily correlated to assure internal harmony as well as harmony with its environment" (Appel 1987, p. 46) has suggested to some authors that Cuvier's "conditions of existence" entail a strong commitment with respect to the external environment (Mayr 1982 p. 461; Scholtz 2010, p. 48). This conjecture on Cuvier's externalism may be enforced because he assumed functional organs to be probes of the Creator's skills in adjusting every detail of the organism to the environment (see Appel 1987, ch. 3; Asma 1996b, p. 13; Coleman 1971, pp. 18-19). Like Rieppel (1990, p. 301) says, for Cuvier "every organ was designed (*causa formalis*) by the creator to serve a specific purpose or function (*causa finalis*)."

If we acknowledge this interpretation, according to LM's conflation of externalism and reductionism, Cuvier should be labeled as an externalist and even as a reductionist. Yet things seem to be much more complicated. Though it is true that, in contrast to Geoffroy's approach, Cuvier considered the relation organism-environment as essential, he did not consider this relation as involved in the causal *origin* of form in the style of an ecological approach. Cuvier's organism and its environment are concerned, above all, with the "conditions of existence," that is, the synchronic *pre-requisites* establishing the plausibility of the organism as an integrated entity capable of dealing with the demands of its life style (Grene & Depew

2004, p. 129). Furthermore, Cuvier's approach is based on a deeply internalist notion of teleology flowed from Kant's *Critique of Judgment* (Asma 1996b, pp. 36-37). Cuvier's "conditions of existence" hold a strong commitment with the synchronic conditions making "an animal system work qua system" (Asma 1996b, p. 36). Accordingly, while Cuvier advocated an analytical and empirical methodology, he claimed that the organism cannot be understood by decomposing it in its parts. His "principle of correlation" assumes that the parts of the organism are unified into a synchronic functional whole in a Kantian vein.

In conclusion, Cuvier and Geoffroy conceived of biological form from a mainly synchronic non-reductionist perspective, Cuvier's "conditions of existence" and Geoffroy's "archetype" stress the necessary dependence among the parts³⁰. The whole system is not reduced or eliminated. On the contrary, either the actual organism (Cuvier) or the general structure (Geoffroy) is permanently assumed as a privileged epistemological formal stance in understanding living form and organization.

But conflated epistemology leads LM not only to a misguided perspective on the history of inquiry on biological form. Blinded by her epistemology, LM is also unable to make out the shape of her enemy. Besides any consideration on externalism, two things certainly differentiate Darwinism and derived views. On the one hand, the emphasis of form in diachronic evolutionary terms and, on the other hand, the decoupling and reduction of the organism into an aggregate of morphological, physiological or ultimately genetic optimized traits. LM is right when she says that Darwinism is reductionist, materialist (substantialist) and externalist. Anyhow, Darwinism is not reductionist *because* it is externalist or substantialist; for we have seen that reductionism can be internalist and there are materialist non-reductive approaches. What makes Darwinism and all its descendants (Neo-Darwinism and Modern Synthesis) reductionist approaches is an ontological conception of living organisms as decomposable systems, and the derived mechanistic methodology, that lead Darwinists to inappropriately atomize the organism (Gould and Lewontin 1979). This is strong reductionism in Sarkar's terms, it reduces the organism to the sum of the spatially contained traits and is diametrically opposed to the notions of parts dependency and the preeminence of the unified entity present in Cuvier and Geoffroy. This is the enemy LM fails to target.

An important turn is unveiled when LM enthusiastically jumps over epistemological issues regarding the scientific status of biology and its generalizations: "As such, it [natural selection] does not express any essential aspect of nature (a material law) [...] Devoid of generative principles, evolutionary biology is a historical narrative, guided by contingent fluctuations" (p. 46). But what does LM mean with "essential aspects of nature

(material law)?” We suspect she thinks that temporal-independent physical laws (or the like) are the *truly essential aspects* in the origin of form. This kind of physicalism seems to be at odds with other passages in which she expresses a more moderate position: “While genes and their products *also have an essential role* in this framework [origin of form by self-organization], they are not sufficient to explain biological organization” (p. 47, emphasis added). However, LM emphasizes that “form is the result of the laws that govern self-organization. Thus, organisms are coherent wholes reflecting the order immanent in the laws of nature” (p. 47). Ruled by such essential laws, the evolutionary origin of form would emancipate from *non-essential* historical contingency. In supporting this interpretation, she argues in a temperate tone that “Life is not *exclusively* an historical phenomenon, isolated from the inanimate, but is part of the wave of creativity that expands through the universe from its origination in the Big Bang” (p. 47-48, emphasis added). Nonetheless, LM states in an almost moralizing flavor that “biology would be a better science if these principles were acknowledged” (p. 48) by quoting Goodwin:

Biology would begin to look a little more like physics in having a theory of organisms as dynamically robust entities that are natural kinds, not simply historical accidents that survived for a period of time. This would transform biology from a purely historical science to one with a logical, dynamic foundation [...] (Goodwin 1994, p.103).

It seems ironical that, while LM devotes so much effort in showing how grafting Newtonian physics as a model of science into Darwinian biology precluded the pursuing of general principles, she seems so uncritically fascinated by a neo-*physicalization* of biology.

For LM, the origin of biological form is determined by internal essential synchronic laws acting in the building materials of organisms. Consequently, history is not anymore an explanatory source of biological form unless it (paradoxically) refers to what Kauffman called “ahistorical universals”: constitutive properties of the building materials resulting from universal timeless self-organization laws (Kauffman 1993, p. 487). In this view, LM attributes the constancy and diversity of biological form to *essential* a-temporal laws and condemns history and contingency to a minimal and irrelevant role: given the original state of matter, evolution could not have been otherwise. Darwinists were seduced by the capacity of Newtonian physics to describe natural phenomena in terms of unrestricted temporal laws; LM simply fell in love with the same clothing.

It is debatable whether what LM understands as a natural law is as uniform and consistent as she seems to assume. The notion of law has been criticized, refused and/or reformed in physics itself (Cartwright 1983) and especially when used to compare physical and biological principles

(Beatty 1995; Brandon 1997; Mayr 1985; Mitchell 2000). Further, LM's disdain towards history seems to be motivated by what Hull described as an "overly doctrinaire" attitude regarding scientific explanation:

There is one and only way of explaining a particular natural phenomenon or regularity and that is to derive it from one or more laws of nature and, when necessary, relevant particular circumstances. On this view, historical narratives are explanatory only to the extent that they contain explicit or implicit reference to scientific laws. If these laws turn out to be weak, then the explanatory content of the correspondent narrative is weak. If there are no such laws, then the historical narrative is not explanatory at all (Hull 1989, p. 200).

LM's fascination with internal a-temporal laws expunges history of any explanatory virtue and reflects what Piaget called "structuralism without genesis": "the implicit hope of anti-historical and anti-genetic structuralist theories is that structure might in the end be given a non-temporal mathematical or logical foundation" (Piaget 1971b, p. 12). Riepel is even more emphatic in describing this essentialist attitude towards laws. For him, it expresses a reversal to the essentialist idea of Linnaeus that classification reflects the rationality imposed on nature by the creator; likewise, "The process of embryogenesis, the unfolding of structures, follows time-independent laws and this is of rational rather than of a merely contingent nature" (Riepel 1990, p. 314).

The problem here is that while this kind of structuralism seeks to fix the diachronic origin of form to generative laws, the question of where generative laws come from in the first place is avoided; for it must be admitted that the generative laws are synchronic and "preexist in the manner of *time-independent laws* or essences" (Riepel 1990, p. 314, emphasis added). Nonetheless, a more relevant concept of historical time is needed; otherwise generative laws and biological form ultimately remain ungenerated (Asma 1996b, p. 159).

In contrast, the explanation of the origin of biological form is essentially linked to epigenetic processes in which form is a modification of a *temporally* previous form in ontogenetic or evolutionary terms: the historical sequence of events or forms is extremely relevant in explaining the origin and transformation of biological form (Asma 1996b, pp.158-161). In dismissing the epigenetic nature of time, LM denies history itself and collapses the diachronic dimension of form *into* a synchronic timeless group of organizational laws. On the contrary, any "generative structuralism" should conceptualize the structural viewpoint in an epigenetic time-dependent manner (Riepel 1990, p. 318). Time, in this historical sense, is essential to organic form rather than accidental (Asma 1996b, p. 159); for there is no form without history; no synchrony without diachrony; no being without becoming.

In addition, LM defends the conception of organisms as “coherent wholes” and holistic approaches to biological form, but there is nothing in her account that explains what exactly a “coherent whole” is, or how organisms reach “coherence” and “wholeness”. If either a cat or inert turbulent plasma (Hasegawa 2009) exhibit self-organizational properties, what is the difference between their respective “coherent wholeness”? It seems that LM is largely oblivious of the fact that the problem of coherence of organisms has to do with the problem of a specific kind of an internal functional structure that permanently interacts with the external environment. In fact, the conservation of the inner stability in the organism and the construction of the niche of the organism cannot be understood by ignoring or subordinating the role of the environment to internal laws. This kind of internalism gives no clue for understanding the multiple dialectical combinations of internal and external causes that participate in the stability (coherent wholeness) and origin of organisms. Wholeness, in this functional and dialectical sense, is essential for the understanding of the historical origin and transformation of organisms; for there is no history without stable organism; no diachrony without synchrony; no becoming without being.

Additionally, without a clear idea of how to understand organisms as “coherent wholes,” there is no way to distinguish living structures and mere aggregates of matter (Piaget 1971b, pp. 6-10). Consequently, it is not clear what precludes that LM’s physicalism would end up in a kind of reductionism. If biological form would be determined by physical laws acting on internal mechanisms like DPMS, what precludes the reduction of form to DPMS and similar mechanisms? Even more, what prevents us from thinking that the DPMS would become the new *homunculus* in some kind of fashionable preformationism? After all, when organic form is entirely attributed to antecedent structures or its potentialities, the paradox of preformationism begins to emerge (Asma 1996b, pp. 151). There is nothing in LM’s account that explains how organisms reach coherent unification and, therefore, there is nothing in her perspective that precludes to lose the organism again.

Fortunately, it seems that Newman, Müller and other ‘evo-devo’ scientists are much more aware of the need of a pluralist approach to different causal sources on the origin of form and, we suspect, on biology in general: “Conceptually, understanding the laws of form for complex materials, such as living tissues, requires, *in addition to genetic information*, an understanding of chemical dynamics, including oscillations, pattern forming processes, and chaotic causes” (Newman 2003; emphasis added). Furthermore, plurality of causes and epigenetics is an essential part of their program:

The epigenetic approach investigates the generic properties of developmental systems in the origination of novelty, explicitly addressing the non-programmed aspects of development (Newman and Müller 2000).

This includes the physical properties of biological materials, the self-organizational capacities of cell and tissue assemblies, the dynamics of developmental interactions, the role of geometry and tissue architecture, the influence of external and environmental parameters, and all other factors that affect the development of organismal form—regardless of whether their role in generating novelty is associated with concurrent changes in the genetic hardwiring or not (Müller and Newman 2005, p. 496).

Notwithstanding, LM's overemphasis of internal mechanisms, the DPM hypothesis does not exclude natural selection as a cause of biological form, but it assigns to it the role of refining form: "I suggest that the ancient and continuing role of certain physical mechanisms in the molding and patterning of multicellular aggregates has provided a fount of complex forms that could be selected and *refined* over the course of evolution" (Newman 2010, p. 282; emphasis added). It has to be noted that structuralist approaches like evo-devo and self-organization have the virtue to specify the range of possible phenotypes (Riepel 1990, p. 292), but that does not mean that they can explain all the diversity of biological form. Perhaps self-organization sets up the necessary conditions for understanding the origin of the main characteristics of form, but the sufficient conditions for understanding variability are provided by history and a panoply of causes acting in the origin of form (natural selection, genetic drift, phylogenetic constraints among others). While it is true that depending on the level of inquiry we can be interested in the main types or in the variability of biological form, to subordinate the origin of variability to the origin of the main types means to underdetermine the diversity of form (Asma 1996b, p. 152). In the end, pluralism has a strong voice in the DPM hypothesis and in the origin of form in general.

Strictly speaking, it does not seem that the investigation of self-organization would imply reducing biological form to *essential* physical laws. Even the mere DPM's definition vigorously resists reductionist interpretations in terms of *either* physical laws or the molecules produced by the genetic tool kit: "functional modules in which one or more of the tool kit products mobilize physical processes on this scale [meso-scale: > 100 μm] so as to mediate the formation of new patterns and forms" (Newman 2010, p. 285). That is to say, the DPM hypothesis includes genetic causes, but is not gene reductionist; it implies physical processes, but they are relevant only in the context and characteristic scales of the emergence of multicellular living tissues: "The relevant physical determinants [...] were not new to the physical world, but rather became newly relevant to living systems in conjunction with a change in their spatial scale and cell proximity"

(Newman 2010, p. 282). More importantly, Newman and Bath themselves appeal to history in describing the relevant molecular events during the rapid morphological diversification that occurred in the “Cambrian explosion” about 550-530 million years ago. They explain the specific historical context in which the relations between the developmental transcription factors (DTFs) and DPMS were established. While DPMS were tied to the morphogenetic and patterning effects they mediated, DTFs established conserved relations with specific developmental pathways that for Newman and Bath significantly represent “[historical] frozen accidents” (Newman and Bath 2009, p. 694). It seems improbable that any evo-devo approach would brush away the role of history in the origin of form. Newman explicitly acknowledges the importance of time in discussing different biological systems:

Each of these biological systems, and all others, has an *evolutionary history*, in which not only its particular internal character, but its relationship to other systems, has undergone change. This *adds* a further complexity: relationships between the same systems in different organisms will not always be the same (Newman 2003, p. 9).

In conclusion, the DPM’s hypothesis relies on an ontological non-reductionist epigenetic assumption of the emergence of novelty. This emergence results from the irreducible functional behavior of collective matter in specific temporal-dependent historic points. While it has always been problematic to know whether something is an *essential aspect* of nature, it seems that the origin of biological form cannot be grasped exclusively on the grounds of physical laws.

LM’s disproportionate enthusiasm is an expression of fundamentalism in Sarkar’s terms. She believes that physical principles (laws) are more fundamental and better than biological principles. LM’s fundamentalism may suggest an interpretation of self-organizational mechanisms deprived of their contextual and anti-reductionistic nature: causal components of a lower realm contained in the organism and ruled exclusively by a-temporal physical laws. In this view, evo-devo would be a new episode of strong reductionism. LM critically assesses the story of a progressive reduction in accounting for form, the last section of this story, “The genetic program version 3.0”, features homeotic genes and the regulatory networks approach as the final stage leading to the loss of the organism. We sympathize with such a critical view. Even so, following LM’s spirit, there is still a missing episode in this reductionist tendency: “The DPM’s program version 1.0. How to reduce the organism and by the way all of biology forever.”

TOWARDS A COMPREHENSIVE ACCOUNT OF BIOLOGICAL FORM

Throughout these comments we have pointed out the poverty of LM's approach in accounting for biological form. The roots of the problems in LM's epistemology rely on the fact that she uses the dichotomy externalism/internalism to justify her own commitment with a kind of internalism defined exclusively in terms of self-organized active matter. Consequently, she subordinates and conflates other relevant explanatory dimensions to defend internalist self-organizational mechanisms as *the* legitimate way of explaining the origin of biological form from a non-reductionist viewpoint.

As noted by Asma in discussing the dichotomy function/structure (1996b, ch. 8), Kant clearly grasps the problems of similar approaches from an epistemological viewpoint. For him the problem consists in taking subjective principles of our reason (maxims) as objective principles of the reality. According to Kant, the maxims reflect the alternative and equally valid interests of our reason on "unity" and "diversity."

When principles which are really regulative are regarded as constitutive, and employed as objective principles, contradictions must arise; but if they are considered as mere maxims, there is no room for contradictions of any kind, as they then merely indicate the different interests of reason, which occasion differences in the mode of thought [...] This reasoner has at heart the interest of diversity—in accordance with the principle of specification; another, the interest of unity—in accordance with the principle of aggregation. Each believes that his judgement rests upon a thorough insight into the subject he is examining, and yet it has been influenced solely by a greater or less degree of adherence to some one of the two principles, neither of which are objective (Kant, *Critique of Pure Reason*, A666 B694).

LM and similar internalist approaches are examples of the interest of our Reason in "unity" regarding biological form. Neo-Darwinism and adaptationism follow the interest of our Reason in "diversity" of adaptation to environmental demands. However, according to Kant, the interpretation of these two ways of seeing reality as mutually exclusive perspectives is misleading, for considering the maxims on unity and diversity as objective and antagonistic facts of reality ultimately obstructs the advancement of knowledge:

Both have, in reality, been struggling for the twofold interest of reason; the one maintaining the one interest, the other the other. But this difference between the maxims [subjective principles] of diversity and unity may easily *be reconciled and adjusted*; although, so long as they are regarded as objective principles, they must occasion not only contradictions and polemic, *but place hindrances in the way of the advancement of truth*, until some means is discovered of reconciling these conflicting interests, and bringing reason into union and harmony with itself (Kant, *Critique of Pure Reason*, A667 B695; emphasis added).

We do not need to agree with the particular division of Kant between subjective and objective principles or the purported harmonization of interests of our Reason to recognize that biological form can be fruitfully understood from different vantage points. In fact, Levins and Lewontin (1985, pp. 277-278) illustrate the same critique from a different epistemological stance that stresses the dynamic, heterogenic and dialectical ontology of organisms:

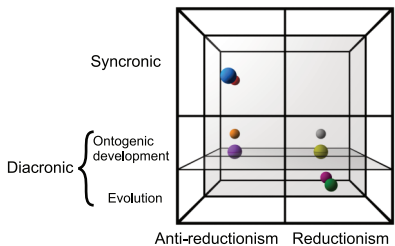
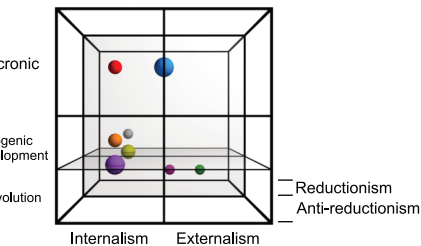
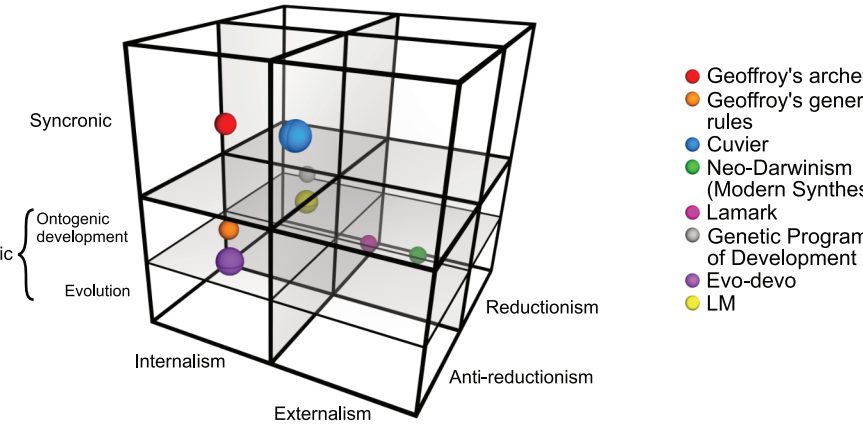
The change that is characteristic of systems arises from both internal and external relations. The internal heterogeneity of a system may produce a dynamic instability that results in internal development. At the same time the system as a whole is developing in relation to the external world, which influences and is influenced by that development. Thus internal and external forces affect each other and the object, which is the nexus of those forces. Classical biology, which is to say alienated biology, *has always separated the external and internal forces* operating in organisms, holding one constant while considering the other (Levins and Lewontin 1985, pp. 277-278; emphasis added).

Although Kant and Levins and Lewontin depart from entirely different epistemological contexts, they are examples of how different views are important in understanding the plurality of external and internal causes involved in phenomena like the origin of form. Likewise, the use of dichotomies like diachronic/synchronic, reductionism/antireductionism, structure/function is misleading when they are not conceived of as equally relevant, dynamical, related, and inter-defining discourses, for they reflect mutually irreducible dimensions of the inquiry on biological form.

In an attempt to understand the different approaches to form from a relational perspective, a working hypothesis is suggested here, inspired by the inherent richness of the concepts, methodologies as well as epistemological and ontological assumptions intermingled in *every specific* explanatory pattern. This “geometrical model”, rather than taking advantage of one dimension of analysis, intends to explore the relations of the conceptual frameworks outlined above: diachronic/synchronic, externalism/internalism, reductionism/antireductionism (see figure 1). Nevertheless, this model does not pretend to limit the exploration of the inquiry of biological form to these axes; additional dimensions can be added depending of the explanatory contexts to be analyzed. The main idea is that mapping a view on form along these axes may be useful in exploring the relations of the referred dimensions in specific approaches. Even current research programs, like evo-devo, can be analyzed in an attempt to clarify aspects that are perhaps not completely determined. Furthermore, this approach may help to address the implications, possibilities, limitations and inconsistencies of current investigation on form. Since more historical and theoretical

analyses are not available at the moment, it remains to be seen what the potentiality of this proposal may be.

However, some points discussed above can be used to sight the potential of this model. We pointed out above that the diachronic dimension had little influence in Cuvier's investigation; in contrast, Geoffroy supported internal ontogenetic diachronic laws of generation. Yet, the most interesting points have to do with Geoffroy's "archetype" and Cuvier's "conditions of existence". Both of them are better understood as synchronic and anti-reductionist approaches. Even so, the difference between both naturalists becomes evident in pointing out the subtle difference in terms of their synchronical positions with regard to the environment. Whereas Geoffroy dismisses the role of the environment in his structuralist approach, Cuvier's position should be considered as an epistemological view considering external and internal elements as pre-conditions in understanding biological form. On a diametrically opposed epistemological view, Neo-Darwinism should be regarded as a diachronic, externalist and reductionist approach. Lamarck's emphasis on the *sentiment intérieur* and acquired adaptations is, perhaps, better understood as a position which is diachronic, reductionist and close to a middle point between externalism and internalism. As we have seen, the genetic program for development is clearly an ontogenic-diachronic, reductionist and internalist approach. Evo-devo is a fascinating example of different practices and methodologies that can endorse more than one characterization. In principle, the original physicalist evo-devo version—stripped of LM's fundamentalist interpretation—is an internalist, anti-reductionist approach, with potential impact on ontogenic and evolutionary diachronic dimensions.



	Synchronic	Diacronic		Internalism	Externalism	Reductionism	red
		Ontogenic development	Evolution				
Geoffroy's archetype	●			●			
Geoffroy's generative rules		●		●			
Cuvier	●				●		
Neo-Darwinism (Modern Synthesis)			●		●	●	
Lamarck			●		●	●	
Genetic Program of Development		●		●		●	
Evo-devo			●	●			
LM			●	●		●	

FIGURE 1

Geometrical approach to biological form. The axes do not mean to measure the referred categories in a quantitative way, but to help to analyze and compare

As a final remark, it is worth mentioning that whereas it seems that physicalist evo-devo advocates an antireductionist position, it is not always evident what is the notion of organism this program departs from. A truly antireductionist perspective trying to account for the organism in a compelling way should include, explicitly or implicitly, a synchronic, formal understanding of the organism emphasizing the irreducible dependence of the parts in the structure. Additionally, any attempt to recover the form from an antireductionist view should not only recognize the ordered structure of the internal dynamics in functional and purposive terms, but also its dialectical relation with the environment. In the section “Synchronic and diachronic epistemologies: a deeper dichotomy”, we mentioned that Kant’s circular causality, Piaget’s transcausality or Locke’s purpose may be useful approaches for this sort of causal dependency. Some insights on these approaches have already been advanced by some authors ³¹. In conclusion, any approach lacking in a formal, non-reductionist and dialectical stance with regard to form is condemned to reduce biological form to a collection of mechanisms.

NOTES

- 1 Linde-Medina (2010), "Natural selection and self-organization: a deep dichotomy in the study of organic form," *Ludus Vitalis* XIX (34) 25–56.
- 2 LM rightly captures the empirical convictions of Cuvier and the rationalist tone of Geoffroy's approach. This could mark an epistemological division: externalist empiricism *vs.* internalist rationalism (see table 1). However, LM does not explore this possibility.
- 3 Neo-Darwinism has been conveniently used in referring to the radicalization of Darwinism by Wallace and Weismann (see Gayon 1995. The influence of Weismann on Darwin's doctrine resulted in an approach focusing on the transmission of germ cells and Natural Selection as the sole evolutionary force. Neo-Darwinism led to the understanding of heredity exclusively in terms of the transmission of genetic factors (see Amundson 2005; pp. 148-152). LM, Amundson and other authors point out that Morgan played a major role in excluding development from research on genetics and heredity during the first half of the twentieth century.
- 4 Correspondingly, LM claims that the investigation featuring pattern considers both substance and pattern in a holistic way (p. 30).
- 5 As an accessorial argument on LM's identification of externalism with reductionism, she refers that Driesch, departing from the perspective of transcendentalism, defended a non-mechanical inner force he called 'entelechy'. As expected, LM points out that Driesch opposed Neo-Darwinism from a non-reductionist anti-mechanistic stance.
- 6 Shymoni refers to reduction in terms of properties of composite systems and its components. However, as Sarkar (1998, p. 21) correctly remarked, there is no reason for limiting this view. The same reasoning can be applied to more general reductions (e.g. reduction of theories to other theories). Sarkar suggests, and his view is adopted here, that this can be done by replacing the system and its components with two theoretical realms on different levels.
- 7 Sarkar's categories of reductionist explanations from the weakest to the strongest are: weak reduction, approximate abstract hierarchical reduction, abstract hierarchical reduction, approximate strong reduction and strong reduction.
- 8 Of course, biologists think that alleles are located in a physical space in the organism. However, this fact is irrelevant in the explanation itself: the alleles involved in the genetic explanation are conceived of as a representation of the genome in an abstract lower level with respect to phenotypes (see Sarkar 1998, ch. 5).
- 9 For an excellent overview of evolutionary models concerning continuous characters and heritability, see Falconer and Mackay (1996).
- 10 The *physical* level referred to here can be better described as the level of macromolecular physics, hence the otherwise misguided term *physical* reduction (see Sarkar 1998, ch. 6). One of the main features of these reductions is that, rather than being based on statistical or mathematical models, they draw on the description of detailed mechanistic causes. This emphasis on mechanisms has been arguably recognized as the most important change in evolutionary theory in the last decades (Pigliucci and Müller 2010, p. 12).
- 11 Unlike LM, the original authors make explicit the ontological reductionist notion of substance they depart from and the semantic use of the analogy.
- 12 For an excellent discussion on non-reductive materialism see Beckerman, et al. (1992).

- 13 A classical comparison between theories of composition vs. theories of structural emergence can be found in Broad (1925, p. 55-81).
- 14 Broad calls the approach that studies life from a genuinely *compositional* view “substantial vitalism.” This approach explains pattern or form by means of a non-material but substantial component such as Driesch’s entelechy. We doubt LM wishes to describe Neo-Darwinism as a theory of composition in this sense.
- 15 Mayr makes the same point in discussing “constitutive reductionism”: “The difference between inorganic matter and living organism does not consist in the *substance* of which they are *composed* but in the organization of the biological systems” (Mayr 1982, p 60; emphasis added).
- 16 For an enlightening account on the orthogonality of these debates, see Godfrey-Smith (1998, ch. 2).
- 17 Bechtel and Richardson (1993, pp. 27-28) use a similar analogy in considering the conditions of decomposition of a system in mechanical explanations. Whereas the interactions between parts of the same level are described as horizontal mereological processes, the combination of parts in larger units are described in vertical terms. Their analogy comes quite close to an epistemological approach to reduction, but they do not take into account the internalism/externalism dimension.
- 18 More examples of reductionist internalist programs, specifically in metabolism and physiology, can be found in Bechtel and Richardson (1993, ch. 3, 4).
- 19 Yet most classical empiricists attribute some internal role to perceptual mechanisms. Godfrey-Smith (1994, ch. 3) features Spencer as a paradigmatic extreme externalist combining Darwinian adaptationism and a strong empiricism.
- 20 The term “etiological” as used here resembles the way it is used in the debate on function: it appeals to the historical causes in explaining something. However, we do not endorse the very common adaptationist assumption privileging natural selection as the sole historical cause of form, structure or function (Millikan, 1989; Neander 1991a, 1991b; Godfrey Smith 1994).
- 21 For Piaget (1971a), every diachronic approach accounts for the development of matter. He uses the concept of development in the most general sense: the temporal transformation of structures and their integration into totalities (Piaget 1971a, p 71). Anyhow, we use development to refer to the ontogenic transformation of matter and evolution to refer to the transformation of organisms across generations.
- 22 The notion of the synchronic approach was introduced by de Saussure in linguistics. De Saussure’s epistemological implications contributed to the development of structuralism and constructivism. Piaget (1971a) uses this distinction in comparing diachronic and synchronic approaches in biology and mental development. The version we defend here draws on Piagets’ work and Ramírez-Trejo’s interpretation of the parallel debate between etiological and systemic approaches to functions (Ramírez Trejo 2010 and forthcoming; for a review on the debate on functions see Ariew, Cummins and Perlman 2002; McLaughlin 2001; Perlman 2004; Walsh, 1996; Wouters 2003, 2005a, 2005b). Ramírez -Trejo advocates that the debate etiological-systemic functions is a subset of the debate on biological form.
- 23 Several authors have recently called for the legitimacy of different non-evolutionary explanatory approaches in several sub-disciplines (Griffiths 2009; Weber 2005; Wouters, 2005a, 2005b, 2007). Some of these accounts clearly

- argue for non-evolutionary approaches in the same sense we defend here synchronic approaches (see specially Amundson and Lauder 1994).
- 24 See Cummins (1975), Bechtel and Richardson (1993), Craver (2001, 2007a, 2007b), Machamer, Darden and Craver (2000) and Glennan (1996).
 - 25 For some theorists like Kant, this stance involves a limitation in objectively knowing the organism. Kant understood organisms as natural purposes demanding a subtle regulative role of teleological judgment. In such a view, living beings are synchronic self-organized entities that cannot be reduced to mechanical processes. Here, circular causality is a necessary heuristic idea without which the analysis of the organism is impossible. Rather than pretending to get knowledge of the totality, we have to presuppose it in getting any knowledge of the parts. For others like Locke or Schelling, purposiveness is an inherent characteristic of life that does not deserve any special epistemological status in understanding the organism. Piaget's idea of "transcausality" plays a similar role in understanding the organism, but only in the first stage of his genetic epistemology. It is, however, an immature notion of psychomorphic origin that has to be overcome through a stage of mechanical atomization leading ultimately to integrative knowledge (Piaget 1971a, p. 95).
 - 26 Actually, it is safe to say that a good deal of synchronic investigations in biology are characterized by (i) the determination of the system by appealing to a more or less clear criterion that sets up the border between the internal system and the milieu and (ii) the reduction of the system to its lower level causes.
 - 27 While it is possible to trace back investigations on epigenesis and classification to Aristotle, modern debates on preformationism vs. epigenesis date mainly from the XVIII century (Van Speybroeck et al. 2002, pp. 13-23; Pinto-Correia 1997, pp. 16-20). The modern history of classification of plants may have started as early as the XVI century with the herbalists in Germany and Andrea Cesalpino in Italy (1519-1603) among others (see Mayr, 1982 ch. 4).
 - 28 At the end of his career, Geoffroy became an evolutionist. However, this had almost no influence on his approach to comparative anatomy, which was primarily devoted to establishing a pure science of morphology (see Panchen 2001).
 - 29 Appel (1987) and Asma (1996b) provide insightful analyses on the historical and epistemological dimensions of Cuvier and Geoffroy.
 - 30 As noted by Grene and Depew (2004), the level of generalization differs between Geoffroy and Cuvier. Cuvier focuses on the integration of the actual organism in relation with its allotted environment. Geoffroy pursues a much more general structural idea. However, both of them conceived of a hardly decomposable system.
 - 31 For a recent account on the epistemological understanding of the organism that includes an extensive bibliography, see Weber and Varela (2002).

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