ACTIVE MATTER, ORGANISMS AND THEIR OTHERS[1]

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Marta Linde Medina's target paper criticizes the widespread confidence placed in that organic form results from processes of adaptation of populations' traits to the conditions of the environment. Like Pere Alberch (1989) and others, she holds that the "logical structure of the contemporary theory of evolution" is *externalist*, and in its place she favors an *internalist* approach, philosophically compatible with views of matter as intrinsically active, as well as scientifically engaged in modeling and experimenting how developmental systems spontaneously generate the forms they display. But, what is 'active matter'? Conceptions of hylomorphism, or of the relations of form and matter in ordinary objects and in living systems have been widely discussed in philosophy and science [2]. The paper maintains (as authors like Newman or Salthe, among others, have done before) that the notion of matter in the Newtonian framework is passive or inert, so it needs to be thought of as moved by external events or agents. Likewise, the Darwinian framework explains organic form as independent from the properties of matter and shaped by external pressures. Therefore, a different perspective in which matter may be conceived and modeled as active is demanded, i.e., able to pay attention to the intrinsic properties of living material systems, especially to their self-organization.

Even if these days 'externalism', as it appears in the paper, has been progressively losing support in current evolutionary biology [3], the issues raised in this paper are very relevant. I will not refer here to the various narratives on the historical aspects of developmental biology used to defend her points, but will focus on the author's appeal to matter's activity in relation to the internalism vs. externalism debate (the latter hotly discussed in current philosophical literature, particularly in philosophy of mind). To show some limitations of this dichotomy, a third character is introduced to the debate: *interactionism*, i.e., the view that organismal traits are the result of a continuous interaction of developmental systems with

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the environment, including other organisms. Interactionist views seriously defy the externalism criticized by the target paper, but they may also challenge other forms of internalism, in addition to the genetic.

INTERNALISM AND INTERACTIONISM

Since the last decades of the twentieth century, there have been two main styles of criticisms to the genetic determinism, stemming from the role attributed to genes in the theory of evolution and molecular biology. One of them argues that genes are conceived as *external* elements, connected with the environment via natural selection but unrelated to the metabolic and developmental dynamics of organisms, and vindicates the need to take into account the internal dynamics of living systems. The second one blames those mainstream approaches of ignoring the ongoing interactions of living entities with their environments, and claims that living entities are largely developed and constituted by them. Whereas the former concurs with the internalism defended in the target paper, the latter may raise some questions.

a) How internalists criticize "externalism"

For *internalists*, sometimes also called structuralists (Alberch 1989; Goodwin 1984), the processes of material self-construction that generate a multicellular organism in development are internal because they arise from an *inherent* self-organizing dynamics that cannot be altered by natural selection (Müller 2008). According to these authors, organisms are complex dynamical systems that self-organize to maintain their stability in spite of perturbations, and the "power" attributed to natural selection to produce adaptation overlooks those generative mechanisms. Generative phenomena can be studied through formal mathematical and/or experimental models (Alberch and Gale 1985; Kauffman 1993; Etxeberria and Nuño de la Rosa 2008; Nuño de la Rosa and Etxeberria 2010, 2012).

In principle, this approach is more interested in explaining the existence of similarities and regularities, by confronting the difficulties of how to generate 'the same', facing the mainstream approach, which is more concerned with the differences responsible for evolution and diversity. Relevant similarities emerge as "rules of organization" (Alberch 1989) or "developmental plasticity" (West-Eberhard 2003), in sum as a coherent system. As this underlies regular forms as well as variants, the explanation of variation cannot rely on random mutations only. If the transforming force were only external, then models would be right in considering that variation is random, isotropic and gradual (Gould 2004), but if form emerges out of coherent self-organizing processes, then it cannot be *specified* by genetic or environmental factors, which can only perturb,

and/or perhaps damage it in ways ultimately dependent on the system itself. This is the ultimate rationale for *internalism*. In their search for the coherent dynamics underlying development, internalists reclaim the notions of *organization* and *organism*, theoretically neglected by the mainstream theory of evolution (as MLM explains in her paper) to explain the regulatory and integrative phenomena responsible for how organic parts accommodate to each other (Alberch 1982, West-Eberhard 2003).

In contrast, genes are elements prone to a different kind of logic: modulated by environmental selective pressures, able to *specify* or determine form. The kind of explanation of form and morphology that this framework provides is functional and non-materialistic.

The main internalist claims can be thus summarized:

— *Development is a process of material transformation*. It is not the unfolding of a program (preformationism), but a dynamic process going from genes to phenotypes and governed by inherent rules or norms of construction (Alberch 1991). From this material perspective gene expression does not only cause morphogenetic processes, but is also an effect, i.e., genomes may be reactive.

— *Developmental processes are canalized* (Waddington 1957). They remain stable even in the presence of perturbations, genetic and environmental. The canalization of development entails that evolution is constrained or harnessed to go in some directions and not others (developmental constraints), developmental systems cannot be altered in any direction.

— *Possible variation depends on the mechanical properties of plastic developmental systems*. Natural selection cannot produce anything, internalists stress that the *morphospace* (the space of all the forms that can be produced as combinations of a given set of initial parameters) does not comprise all conceivable forms, as only some material variants are possible (yet, more than the existing forms).

Internalists demand a mechanistic biology which can be connected with the underlying physics and chemistry; the genes of the standard theory of evolution are for them too idealized entities that fail to help discover mechanisms. This last topic is central in MLM's argument: genes seem to appeal to a magic capacity to self-assembly, and not to the material forces of self-organization.

b) How interactionists criticize "internalism"

The main referents for the interactionist approach are the biologist Richard Lewontin and the psychologist Susan Oyama. The legacy of their work, together with other influences, gave place to the *Developmental Systems Theory* or DST (Griffiths and Gray 1994; Oyama, et al. 2001), and more

recently to eco-evo-devo (Gilbert and Epel 2009). Other important influences have occurred in the more recent years that are also congruent with this field, such as new work on epigenetics and systems of inheritance (Jablonka and Lamb 2006), the niche construction theory (Laland, et al. 2008), and new philosophical work on biological individuals (Pradeu 2010).

The *interactionist* kind of criticism to the standard view in evolution is that when genes are considered as determinant factors governing the construction of the organism, environmental influences are ignored, and living entities appear to be only objects, and not subjects, of evolution (Lewontin 1983). In their view, however, natural selection is not a consequence of how well the organism "solves" a set of fixed "problems" posed by the environment. Thus, development takes place in a conversation among many factors, including environmental ones (Oyama 1985).

Interactionists demand more attention to the proximate effects of environmental contributions, unlike *externalists* who consider the environment as an ultimate cause shaping all organic traits, its effects being the selected characters of organisms, the interactionist perspective considers that all organic processes take place in a continuous "dialogue" with the environment (Mayr 1961, but see Laland, et al. 2011).

However, interactionists do not concur with *internalism* either, for them it is too focused in the internal determination of organic processes (Van der Weele 1999). In recent times, philosophical discussions in this line have questioned the common sense notion of what a biological individual is, as morphological, physiological or evolutionary criteria seem to provide different intuitions.

The main interactionist claims can be thus summarized:

— *Environmental and genetic (or other internal) processes equally influence developmental systems.* There cannot be a rule because biology is full of exceptions, and the determinant factor needs to be examined case by case. Inheritance has to be extended to many factors that are not genetic. The idea that genes contain biological information is questioned: proponents of the DST have defended a *parity thesis*, according to which "any sense in which it is said that genes encode phenotypic traits or a developmental program, or contain information can be equally well applied to other factors needed for development" (Griffiths and Gray 2001, p. 195).

— *Phenotypes are plastic*. They are not determined by genes or the environment. Norms of reaction model the phenotypic variability accessible by a given genotype depending on the environment. This plasticity can affect genotypes themselves: through "genetic assimilation" by which a phenotypic character initially produced only in response to some environmental influence may be incorporated by

the genotype, through a process of selection, so that it is formed even in the absence of the environmental influence that at first had been necessary (Hall 2001).

— *Organisms are life cycles.* The metaphor of development as guided by a program to obtain adult phenotypes from genes is criticized; the organism is a historical process that goes on from the moment of conception until the moment of death (Oyama, et al. 2001).

Both internalism and interactionism pose important and challenging tasks to biology and its philosophy. For interactionists there is a risk in sharply identifying the internal with that belonging to the self, and the external with that belonging to others, and they warn against the simplistic thinking that living entities are enclosed in strict boundaries that separate the internal from the external.

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These two kinds of criticisms do not conflict with each other, and they may be independently maintained, yet dichotomies produce categories difficult to use. There is friction between the stability and constraints highlighted by internalists, and the variability and co-dependence supported by interactionists.

Internalism and interactionism complain about similar issues within the modern synthesis theory of evolution. Both criticize the notion of development as the unfolding of a genetic program: internalists aim to enhance the idea that development is a self-organizing process, whereas interactionists stress that development always takes place in a continuous interaction with the environment. Similarly, they reject that adaptation needs to be seen as the adjustment of organic processes to an independent or external environment (via natural selection). Here again are differences in the criticism: while internalists say that the forms organic processes can take on to adapt follow certain rules or intrinsic dynamics enforce by the material processes involved, interactionists stress that the environment is co-dependent with the organism, thus these need not adapt to the environment and often it is the environment what is changed to meet the needs of organic systems.

Internalism conflicts with the strong reliance of the theory of evolution upon selectionist accounts (Gould 1983) in detriment of mechanistic explanations. Interactionism is more interested in underlining that genes (or the innate or the internal) cannot explain all living phenomenology, since the environment and becoming are also required. For them, living entities need to be conceived as ephemeral, in permanent change. In sum, inter-

nalists struggle to explain the complexity of the material organization and interactionists the complexity of the many interactions taking place.

MLM's does not take into account that activity of matter may produce form and organization in an interactive rather than a constitutive way, as living systems continuously interact with other entities including ancestors and other others. The difficulties posed by interactionism to the genetic or any other internalist program for biology highlight that the complexities produced by the historical-genealogical and the interactive-ecological phenomena nature need to be considered to examine the active materiality of life.

Complexity studies occupied with self-organizing capacities of material systems has been one of the main developments of science since the twentieth century. The inanimate self-organizing system studied by physics and chemistry, does not fully grasp the notion of life or the biological, which involve parts having organized to fulfill functions. To understand systems as alive, not as mere collections of components or their processes, biology appeals to a functional understanding of their activities (as contributions to metabolism, reproduction, etc.), unlike physicists and computer scientists, who tend to favor research lines based on self-organizing dynamics starting from simple inert matter. Finding ways from the physics of self-organizing patterns to the biology of organisms, that is to say, to systems hierarchically organized in parts with functions contributing to the 'living state' of the whole is still a main issue for biology.

The problem of living organization was a central topic in the theoretical biology of von Bertalanffy and others in the early twentieth century, attached to areas like cybernetics and systems biology, and was peripheral within discussions on the relation of evolution and development in evo-devo (Etxeberria and Umerez 2006). Some proposals like the theory of autopoiesis have tried to develop a biological approach based on the notion of organization. The autopoietic organization provides a definition of minimal life as a close network of interactions among components that encloses itself within a membrane, thus defining an identity (self) in the domain of components and in the interaction of such unit with the environment. Anyhow, morphology and functional parts are absent in this definition. This approach has problems to extrapolate this minimal account of organization to multicellulars, since at that level it is very difficult to characterize how autonomy can define the identity of a system by means of a boundary that distinguishes the internal from the external. Cooperative phenomena and symbiosis are involved in many organic processes.

How to define the autonomous self that characterizes living entities without appealing to the slippery distinction of the internal versus the

external, and how to explain the biological emergence of functions in self-organizing systems remain two of the biggest challenges for an approach based in active matter. As suggested before, the ultimate rationale for *internalism* is that organic properties emerge from regimes of dynamic organizational closure. Interactionism cannot dispute this. But if an active matter perspective in biology is so difficult it is because it has to consider the nature of material organized entities emerging in spatial and temporal interaction with others: past, current, and becoming.

NOTES

1 A comment on Marta Linde Medina's "Natural selection and self-organization: A deep dichotomy in the study of organic form," *Ludus Vitalis* XVIII (34): 25-56.

2 A philosophical interpretation of hylomorphism that enhances the active potentiality of matter was provided by Bloch (1966) who said that left-wing Aristotelians somehow repudiated the form-matter duality by considering that the active matter did not require divine creative powers to be informed.

3 For example, Pigliucci and Müller (2010) constitutes a very widely acknowledged vindication of the need for an extended evolutionary synthesis, although Linde Medina (2010) has elsewhere commented that it mainly defends a version of evo-devo compatible with externalism.

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