Extended Criticality and Structural Stability: ‘architectures’ of biological individuation.

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> *« C’est pour donner cette profondeur au corps humain, cette archéologie, ce passé natal, cette référence phylogénétique, c’est pour Ie restituer dans un tissu d’être pré-objectif, enveloppant, d’où il émerge et que nous rappelle à chaque instant son identité comme sentant et sensible, que nous avons donné une si grande place à la théorie de l’évolution ».*
> Merleau-Ponty, *La Nature* (éd.1995)

1. *Introduction and objectives*

In recent decades, the architect Yona Friedman (b. 1923) proposed the concept of “mobile architecture”, hinting to a composition in which each structural element is connected both to individual users and to a superior order, corresponding with an ideal “grid of pillars or slabs” underlying the structure itself. In this way, Friedman opposes the static modernism, by presenting a new paradigm of composition (i.e. the mobile architecture) that emphasizes the “mobile relationships” occurring between an individual user and the (social) environment. Although in our paper we will not explicitly tackle Friedman’s tenet, life’s ever – changing dynamics will be the core of our analysis of its structural stability and its peculiar form of individuation.

As remarked by David Hull (1978: 335-360; 1992) and, more recently, by Thomas Pradeu (2010: 247-268), the question of biological individuation is “theory-dependent”. In our study, the reconceptualization of the biological individuation that we propose is largely based on the theoretical perspectives on organisms presented by Longo and Montévil (2014)[3], who provide an organ-

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[1] http://www.di.ens.fr/users/longo. . This author’s work is part of the project “Les lois des dieux, des hommes et de la nature” (http://www.di.ens.fr/users/longo/CIM/ProjetLongo2014-17.pdf), at IEA – Nantes., http://www.iea-nantes.fr/

[2] Post doc at the. https://ufjf.academia.edu/elenapagni.

[3] Henceforth, LM = Longo and Montévil.

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ismal approach to biological dynamics in ontogenesis and phylogenesis. Nevertheless, in this paper, we shall not go into the details of the developments of LM's work (2014): this would require a greater conceptual effort that we intend to take on elsewhere. We rather restrict ourselves here to general reflections on these perspectives on organisms and the related conceptual framework.

Generally, we consider ontogenesis as a form of quite plastic dynamics at each stage of the biological development of a living organism. Depending on the level of evolution, these stages include a large number of biological processes – biochemical, molecular, genetic, morphogenetic, anatomical and metabolic (processes) – as well as their mutual interactions in connection with the environmental exchanges.

On the side of phylogenesis, we have learnt that most, but not all, significant changes in the evolution of phenotypes of different species are related to modifications of the developmental genes expression (e.g. the gene FoxP2; see Prochiantz 2012:91 and 2008-2009: 303), which either lead to mutations of regulatory DNA sequences or induce modifications in the regulation of metabolic exchanges, size and shape of cells[4]. Some authors, such as Francisco J. Ayala, even claim that the analysis of proteins and DNA sequences would provide a "molecular clock" of evolution (Ayala 2009: 63). Actually, this may be true in an a posteriori analysis (corresponding to the phylogenetic history of a biolon – a biological entity such as a cell or a multicellular organism), but it is not true a priori, as a form of predictability of phenotypes' evolution. Moreover, the multidimensionality of heredity opens the way door to a richer understanding of evolution (Jablonka and Lamb 2006).

Our approach to biological individuation is neither metaphysical (we do not question which kind of biological entities we should consider as biological individuals, and which not…) nor epistemological (we do not wonder under which conceptual framework – physiology, genetics, developmental biology, evolutionary ecology … – we have to collocate biological individuality). Rather, we propose a review of biological individuation in the light of the theoretical attempt expressed by LM book, in order to provide a new foundation for a science of living systems.

Bailly and Longo (2011)[5] and LM (2014)'s analyses are opposed to the reductionist models of biological intelligibility, since they offer a different kind of paradigm, aimed at a theoretical understanding of living beings and their processes, with respect to their global evolutionary (onto-phylogenetic) dynamics. Their ap-

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[4] "Genes are the entities which are passed on in reproduction and which control the ontogenetic development of the organism" (Hull 1978: 336).

[5] Henceforth, BL = Bailly and Longo.

proach consists in making biological organisms (and processes) intelligible as natural objects, possibly within their physico/mathematical constructions or by conceptual dualities with respect to physico/mathematical theorizing.

In order to discuss what seems new, as a comparison, we could mention the work by D'Arcy Thompson (1917), who also tried to outline a mathematical/physical theory of morphogenesis. However, as Prochiantz notices, D'Arcy Thompson's analysis of morphogenesis is carried out under the astonishing absence of any evolutionary perspective[6].

We argue that the recent contributions by BL (2011) and LM (2014) aim to fill this gap, providing a theory of biological organization and of the organism thought of as co-builder of a specific (individual) history resulting from *spatio-temporally localized processes* (reproduction, DNA replication, adaptation, biological organization…)[7]. Indeed, as they state, even if, for the maintenance of its phenotypic functionality and efficiency, a biological system has to comply with specific physical constraints or laws (thermodynamic reactions, gravity…), it should be considered as a system characterized by a specific spatio-temporality, as also expressed by its duration (history) through time, in the sense meant by Bergson (1941). Thus, in opposition to the genericity of physical objects (they are interchangeable and anhistorical) and the specificity of their geodesic trajectories, biological organisms are specific, i.e. historical, individualized and developed along generic trajectories (that is, possible evolutionary paths), underlying permanent variables and changes occurring at any level of biological development (cell divisions, molecular and metabolic reactions, genetic expressions).

In particular, BL and LM propose to enrich the theory of evolution, based on "descent with modification" (the first Darwinian principle) and natural selection (the second principle), with the analysis of phenotype determination, especially focusing on new observables derived from or related to Darwinian evolution as well as on the notion of "enablement".

As a matter of fact, Darwinian Theory (TENS, theory of evolution by descent with modification and natural selection) lacks a theory of organism. For such reason, TENS cannot be a sufficient framework to detect, along ontogenesis, what "biological individuation" of phenotypes is.

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[6] Alain Prochiantz: "En effet, les organismes de D'Arcy Thompson sont des objets dont la vie a été exclue. Le geste qui'il exécute trace les lignes de force d'une morphogenèse d'objets sans dimension évolutive ou physiologique […]", preface to D'Arcy Thompson 1994: 16.

[7] "Both replication and reproduction are spatiotemporally localized processes. There is no replication nor reproduction at a distance. Spatiotemporal continuity through time is required" (Hull 1978: 8).

> Darwin's theory, and neo-Darwinian approaches even more so, basically avoid as much as possible the problem raised by the organism. Darwin uses the duality between life and death as selection to understand why, between given biological forms, some are observed and others are not. That is, he gave us a remarkable theoretical frame for phylogenesis, without confronting the issue of what a theory of organisms could be.
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> [...] Selection, acting at the level of the evolving organism in its environment, selects organisms on functions (thus on and by organs in an organism) as interacting with an ecosystem. The phenotype, in this sense constitutes the observables we focus on (LM 2014: 4).

By this, as already mentioned, BL and LM's examinations aim at extending the theory of evolution through the analysis of phenotype determination during ontogenesis, especially focusing on new observables derived from or related to Darwinian evolution. Thus, the general aim is to propose a mathematical understanding of different aspects of the biological organization, "*from the point of view of time and rhythms*" (biological temporal organization), "*of the interplay of global stability vs. instability*" (extended criticality) and "*of the formation and maintenance of organization*" (anti-entropy), which are the three main themes in LM.

In particular, we will use BL and LM 's theoretical framework as a tool to outline an explanation of biological individuation both as a natural phenomenon and as a historic fact.

We will clarify this issue later. For the moment, consider that: firstly, biological individuation embodies a natural fact, because it deals with the laws of evolution through natural selection. Secondly, biological individuation is also a historical fact expressed over its specific duration (lifespan), which emerges within the intersection among several and interdependent microevolutionary and macroevolutionary pathways. An organism occurs over time, by developing as a specific, individual and non-interchangeable entity. Each phenotype determination corresponds to a new evolutionary trajectory, which, like a furrow, takes place within the history of the natural evolution. As LM affirm, in biology "*time* [duration] *corresponds to the historicity of biological objects and to the process of biological individuation, both ontogenetic and phylogenetic*" (2014: 17) and they develop a detailed analysis by distinguishing between evolutionary time and processual time.

In this paper, we will focus on the following objectives:

1. Firstly, we aim to outline an account of biological individuation by focusing on a list of new biological observables – as established in BL and LM's work; this should make possible a clearer understanding of the dynamics based on the physical singularity (individuation) and the structural stability (organization) of life phenomena during ontogenesis. The mentioned observ-

ables refer to three deeply intertwined phases (or loops) occurring at each stage of phenotype determination. As we will see, their analysis allows us to broaden our perspective over the dynamics underlying biological individuation. Our analysis will focus on:

I. *Integration/Regulation*
II. *Biological protention/anticipation*
III. *Extended criticality*

As we argue, biological individuation may be expressed through the propensity of a biological system to permanently reconstruct its own structural organization in a meaningful (coherent) way, which includes several forms of adaptation, but without reducing living systems to mere adaptive systems: organisms are much more than adaptive systems.

2. Secondly, we will briefly explore the interplay between some considerations related to the theory of biological organism, proposed in BL and LM, and the analysis of the behaviour of organisms outlined by Merleau-Ponty. Thus, we will show that BL and LM's explanations of biological individuation match with the approach to biological phenomena proposed by Merleau-Ponty. For this reason we argue that Merleau-Ponty‘s analysis may be included in the general proposal aimed at analyzing biological individuation and be considered as a part of the construction of (a new type of) scientific objectivity (intelligibility) in biology[8].

2. *New perspectives in the intelligibility of life. An overview*

Over the last decades, a large number of theories have been put forward on the subject of the ontogenesis and the development of phenotypes, which would require a more detailed and deeper examination. Nevertheless, this overview restricts the range to a few current insights that we consider sufficient to answer to the question raised by Merleau-Ponty (1995: 266-267; 269-270) concerning the problem of how a natural being can become subject (*Leib*: as we mean, a historical entity) and still be part of nature (*Körper*: as we mean, physical/natural object). From the 1950s onwards, a greater research program advanced by cognitive sciences (especially cognitivism and connectionism) engages in explaining mind processes in terms of informational or computational

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[8] "Le recours à la science n'a pas besoin d'être justifié [...]. L'être se fraye passage à travers la science comme à travers toute vie individuelle. A interroger la science, la philosophie gagnera de rencontrer certaines articulations de l'être qu'il lui serait plus difficile de déceler autrement" (Merleau-Ponty 1995: 367-368).

(discrete) networks. It may seem to be a general insight, but the metaphor of mind as a "digital/discret" system encoding "information" dates back to the mathematical theories of information developed by Turing (1936) and Shannon (1949). Similar metaphors still dominate molecular biology.

The extraordinary merit of Turing and Shannon's mathematical theories of information consists in the assumption that the transmission of information (and coding) is based on discrete data types and is independent from the physical support, so that it does not directly depend on form/spatial sizes nor on the material out of which it is made (Longo *et al.* 2012: 108-114). However, as BL and LM claim, shifting from mathematics or physics to biology requires a radical change of theoretical frameworks. In particular, in biology explanations referring to discrete structures may be applied to a few levels of biological organization, but excluding whatever, in a living being, works in a non-discrete way, such as the role of continuous deformation extensively analysed in morphogenesis since Turing's work. Moreover, the radical contingency and materiality of life does not allow to split software from hardware, since only *these* DNA, RNA, membranes … and material organisms as such are actually living. In other words, there is no biological event nor mind process that can be conceived as independent from the physical matter in which it happens and ranks. This does not mean that "*biological events, states, and processes are 'nothing but' physical ones*" (this is the reductionistic thesis; Rosenberg 2007: 148), but only that any biological event (even a cognitive process) – from the lowest up to the highest level of biological organization – cannot be explained escaping from the history (evolution) that encompasses the event itself and its material, concrete organisation.

Definitively, the physical singularity of the living state of matter cannot be understood without referring to the whole field of complex interactions taking place at each level of an organism's development, among the different and several levels of biological organization.

Alongside cognitive dynamics, Edelman's proposal, known as *Neural Darwinism* or the *Theory of Neuronal Group Selection* (TNGS), tries to provide evidences for Darwinian evolution of brain and mind processes. According to Edelman, brain development and neural networks result from the same dynamics underlying the evolution by proliferation with variation and natural selection, progressing through permanence and change, selection and adaptativity (Edelman 1992). For such reason, explanations of mind processes (or networks) considered in terms of molecular interactions and transmissions of information can be only partially accepted. Specifically as to *sapiens*, the development of brain system shows, from the embryogenesis up to the adult neurogenesis, a high level of plasticity and adaptivity with respect to environmental changes and stimuli. Furthermore, we know that 'plasticity' and 'adaptivity' are typical features of the living matter for the *evolvability* of phenotypes), which do not pertain to *inert* things.

As recently remarked by Antonine Nicoglou, the concept of plasticity, in biology, refers to two meanings. Actively, it deals with "*le pouvoir de former*" and refers to the egg cell, which is able to generate a multicellular organism; passively, it deals with "*une susceptibilité à prendre un nombre indéfini de formes, avec l'exemple en biologie évolutive de la « plasticité phénotypique à partir d'un même génotype*", depending on (and as a function of) the environmental conditions (Nicoglou 2007: 489-532).

For a a reconceptualization of genome, Evelyn Fox Keller recently defined genome as a "*sensitive reactive system*", emphasising the need of abandoning

> dichotomies between genetics and environment, and between nature and culture. [...] interactions between genetics and environment, between biology and culture, are crucial to making us what we are (Fox Keller 2015: ???-???).

Evelyn F. Keller's contribution to "post-genomic biology" consists in providing an understanding of organism in a wider perspective that considers the evolutionary individual through different levels of biological organization – DNA, networks of proteins, cell/tissue interactions (Pagni 2015). In this sense, it is clear that in biology the paradigm of causation as one-way oriented (DNAà phenotype) turns out to be meaningless[9]. Along with Keller, we could also mention other important biologists engaged in overcoming the reductionist paradigm offered by the Modern Synthesis and its attempt to explain phenotypes as a mere reproduction of genotype. As among the others Antonine Nicoglou highlighted, Mary J. W. Eberhard's project aims to offer many alternative pathways able to explain evolution and phenotype determination (behaviour and social wasps, environmental induction...; West-Eberhard 2003; see also Nicoglou 2003: 1-2).

The mentioned remarks could maybe be a sufficient answer the question raised by Merleau-Ponty, that is how a natural being can become a subject and still be a part of nature. Particularly, according to Merleau-Ponty's Nature lectures given in the late 1950s, biological development is a process leading to the co-emergency of a "lived space", conceived as "*a meaningful relation formed between the body and its environment*" (Toadvine 2009: 97). Anyway, for a long time, biology has proposed an explanation of biological processes

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[9] Foreword by Denis Noble to LM 2014: ix: "The Central Dogma of Molecular biology, for example, for which causation was one way (genes to phenotypes) has failed: even the environment can influence gene expression levels."

through "solipsistic" views represented by isolated paradigms (molecular biology, physiology, embryology), avoiding the possibility of a "*unified biological understanding*" (LM 2014: 9) of the phenotype's complexity.

In order to fill such a gap, this paper aims to hint at a new conceptual paradigm able to detect biological individuation by focusing on those mechanisms – extended critical situations, protention, regulation/integration processes and temporal organization – which allow phenotypes to develop as systems able to provide meaningful relations with the surrounding environment. Ultimately, organisms evolve through the interaction with their environment. As a result of this interaction, organisms acquire a stronger cognition and knowledge of the environment, what produces an ecosystem of signs (meaning)[10].

3. *Contingent Finality, Causality and Anticipation*

We can describe the establishment of a *biolon* (a cell, a multicellular organism or, possibly, a species) as consisting of two phases: its development mostly characterized by the process of autopoiesis and organizational closure as well as by the manifestation of differentiated and functional parts as part of something whole that integrates and regulates them; the second stage is its maturity, during which the whole entity has already become quite stable in terms of structure and function, so that it is essentially the core of the processes of homeostasis (homeorhesis) which are made possible by these integrations and regulations, while it is also connected with its environment, which is now dominant.

These two constitutive phases of living organisms are subject to two main loops (auto-reference), albeit with different dominances: a rather internal loop (related to the phenomena of integration/regulation) useful for the preservation of the organism's unity, autonomy and subsistence, and a rather outward-oriented loop (related to the phenomena of perception/action) which shows the relationship of the organism with its environment, that it takes into account, to which it adapts trying even to transform itself as a result of it. Note that these "loops" are to be thought of as "spiraling", since biological iteration is never the same: whether it is molecular changes (DNA, proteome …) or cell membrane and structural organization of the organism, each iteration provides some (possibly minor) change. Variability is at the core of life , because it

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[10] On this issue: Hoffmeyer, J., 1996 (1993^1), *Signs of meaning in the universe*, Indiana University Press, ; Hoffmeyer, J., 2008, "Biosemiotics. An examination into the signs of life and the life of signs", in John Deely (Ed.), *Approaches to postmodernity 2*, Scranton, Scranton University Press; Bains, P., 2006, *The Primacy of Semiosis: An Ontology of Relations*, Toronto, University of Toronto Press; M. Barbieri, M., 2007, ed., *Introduction to Biosemiotics: The New Biological Synthesis*, Berlin, Springer.

causes adaptation and diversity, which both contribute to structural stability at every level of the biological organization.

It is possible to remark that these loops are not characterized exactly by the same features in their relationship to temporality. The first takes place, during development, within a physical temporality which is clearly oriented (towards the constitution of the organism) and then, once it is completely set, it shifts towards a form of atemporality: despite the presence of phenomena such as aging, for example, it is related to the iteration of internal rhythms, since biological clocks have become stable. The second does not definitively collocate itself within a characterized physical temporality that sometimes may however show a paradoxical aspect with respect to the arrow of time itself. In our opinion, it is precisely in this latter case that the memory/anticipation relationship becomes essential, even if we can of course see the manifestation of some of its aspects during its development (but in a rather different perspective that we will later specify).

Integration	*Regulation*	*Exchanges between organs*
flows control	gradients	matter/energy
apparent finality	homeorhesis	

3.1. The First Loop: Integration/Regulation

According to BL (2011) approach, contingent finality mainly concerns the relationships between a *whole* and its *parts*. The "efficient causality" related to the parts has for "finality" the (epistemic) complexification and maintenance of the whole: the aspect of finality can first be founded in the functionality of organs (made for…), as a conceptual schema for the intelligibility of the phenomenon.

In the internal loop occurring in the relationship between *integration* (of the parts with their functions *within* the whole) and *regulation* (of the parts *by* the whole), the apparent aspect of finality (in view of the maintenance of the whole) is essentially to be detected in the integrational aspect of the parts in a whole. The regulatory aspect rather is characterized by the tendency to homeostasis (homeorhesis), with the aim to maintain this internal autopoietic loop. At this issue there is an important nuance on the issue of information that we will tackle later. Indeed, this is probably due to the fact that integration processes mainly mobilize the fluxes of matter and/or energy (allowing the whole to develop, by constantly complexifying, and to subsist), whereas the regulation processes apparently mobilize mostly gradients of energy or matter that can be, more or less consistently, considered by many people as information fluxes. These gradients receive from the parts responses in terms of matter and energy supply.

In this perspective, another and complementary aspect of the analysis arises: the starting situation of an organism (the fertilized egg) constitutes a whole in a biological sense. Audaciously employing a mathematical terminology, we could say that this "whole", as any cell, corresponds to an infinite objective complexity albeit yet 'elementary', since the cell is biologically elementary and specifically characterizes biology, while no physical analysis can provide a complete description of its complexity[11]. In terms of extended criticality, BL and LM's approach confirms this intuitive terminology, given that, in physics, critical transitions correspond to the divergence of some observables. In this perspective, through a cascade (extended in time) of critical transitions, such as cell reproductions, embryogenesis and development provide a process of partition of the whole into different parts which are connected to each other by mutual relations (what contributes to the increase of epistemic complexity). Therefore the whole at issue precedes, temporally and conceptually, the constitution of these parts as well as the establishment of their functional relationships. It is from this standpoint, presumably, that finality for the whole and "inverted" temporality may be somehow confused (because the whole, conceptually, "precedes" the parts which must constitute it). In short, contingent finality manifests itself firstly in the integration/regulation causal loop, which constitutes a new symmetry, difficult to explain in the terms of physics' causal asymmetries ("this causes that", in an appropriately oriented direction). Autopoiesis, as a process generating the components that produce the process, could be understood as the dynamic effect of this first loop.

Therefore, the schema, the metric-topological diagram of this circularity allowing us to propose a sort of axiomatic definition of contingent finality, appears at a level as atemporal (abstract whole/parts relationships) and at another level as temporally oriented (energy/flux information represented namely by the arrows), but without the issue of this "finalization" being reduced to it.

3.2. The Second Loop: Action/Perception. Inverted time.

In contrast, as we mentioned earlier, the question of anticipation seems to actuate mainly the properties of temporal orientation (corresponding to the characteristics specific to what we have called "objective causality"). In this sense, everything occurs as if the organism, as elementary as it may be, was

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[11] Analyses of cells, organisms etc… as far from equilibrium systems, for example, nicely capture the role of flows of energy and matter. But these systems are a (self-)organization of flows, whereas a cell *constraints* and *uses* flows, it is not just their physical, thus optimal, (self-)organization, like flames, Benard's cells etc., see Montévil and Mossio 2015.

capable of "protention" (or, in the cases of superior organisms, of "representation" or even of "intentionality"), relatively with respect to a future inner or environmental situation such as to govern its behavioral dynamic in its present (see BL and LM chapters on Protention and retention in biological systems).

We might probably somehow interpret this aspect as "retrograde causality", as an expectation of future that may govern the present action. If so, it would be appropriate to emphasize the fact that this apparent "temporal inversion" is exclusively related to a specific form of information (excluding the propagation of a physical signal) and not to matter-energy. In other words, the protensive action, which co-constitutes ongoing behaviors, is related to the invariants established by retention (there is no protention without retention); or better, retention constructs informational invariants (stabilizes fragments of the world in order to iterate a possible action), for the purposes of protention as a key component of action. In this sense, the future, or the expected event (the protentional gamble) contributes to the "determination" of the present action.

For this reason, even if we admit an inverse causality as a tool for the intelligibility of action, the causal laws of physics related to the energetic, and hence effective, transmission of the signal, are preserved and are, as usual, temporally oriented (the transferal of matter-energy requires time). The situation in this respect evokes somehow that of the quantum non-separability, where the state of a quanton, considered as independent, is modified by the change of state of another involved quanton, without any possibility of transmission of a physical signal between them. In LM such a situation is modeled by the introduction of a second dimension of compactified time with a non-nul radius [resulting temporal topology: $\mathbf{RxS}_1$, which we know to break certain classical causal aspects (Bailly, Longo and Montévil 2011); but this second compactified dimension would then be exclusively relative to the flux of this very special component of "information" related to this protention (the compactification "radius" remaining null with respect to matter-energy)].

How should we consider the existence of such protentional possibilities, if they exist? As said above, one could consider that any organism has a propensity (more or less accentuated depending on the level of evolution, the presence or not of a nervous system, of a brain, etc…) to simply prolong a situation (a sort of inertial principle of life phenomena, what we call biological inertia) or to adapt to a situation in function of memory – or retention (biochemical, immune, neural, cerebral…) which it may have preserved from comparable situations (the result of learning). The presence of a such a state (of the organism or environmental) would be likely to activate this 'memory', to therefore make "plausible" some consequences and to generate behavior. In short, retension constitutes invariants of action, needed for further protensive actions: an animal tries to cope with a changing environment by stabilizing/recalling some possible invariances of its interaction with the ecosystem.

From this point of view, what about the role that we can attribute to the genome, in order to not reduce its action to that of a completely encoded computational memory? The genome could be considered as the main component of the "retention" specific to a species, or a chemical trace of a history. In this sense, it would play a role of a *constraint* or even inhibition with respect to the immense range of possibilities of life phenomena rather than a role of activator with respect to the development of such or such an organism belonging to a given species.

This constraint would "canalize" the developmental possibilities in function of the constraints related to the retentive heritage, that is, to the whole biochemical history of the species. The eventual "explosions" associated with the rupture of punctuated equilibriums (c.f. the Burgess fauna as analyzed, for instance, by S.J. Gould [quotation needed]) would then correspond to the lifting of all the classes of inhibition of potential DNA expressions: while generally it is largely prevented or strictly canalized, suddenly its random genetic expression may be extensively enabled, by the novel interactions with the organism and the ecosystem, so that it results in lifting constraints. This representation would then be conform to that perspective according to which life phenomena, far from selecting singular and specific geodesic trajectories as in physics, would evolve in a very generic framework of possibilities among which some (many) of them would not become actual because of either internal (genome) or external (environment) constraints. The second loop (action/perception) would then be another of the major symmetries which constitutes life phenomena. Of course, both loops interact causally: the interaction with the environment (specific to the action/perception loop) can affect regulation as well as integration – typically, organ functions. In fact, their looping, a third causal circular (super-)structure, constitutes the unity and autonomy of life phenomena, from the simple level of the cell to the most complex of metazoans.

To summarize, we consider that contingent finality intervenes in the two types of loops (auto-reference) that are specific of the biological field: the internal loop between integration and regulation, which manifests the relationship between the whole and its parts, and the external loop between perception and action through which, among other things, the property of anticipation arises. Anticipation itself (protension, if preconscious) is associated to memory and enables the organism to react by putting itself in a possible future situation due to the property of biological inertia (Longo and Montévil 2011; Longo and Perret 2013). The latter may be considered as a conservation of autopoiesis (integration/regulation loop), as a tendency to the conservation of the living being itself and at the same time as behavioral conservation (by learning and by memorized experience, perception/action loop), while changing.

As a matter of fact, heterogeneous factors (internal or external: mutations, environmental changes, accidental isolation of populations) continually require and select different forms and behaviors. We can remark that, according to this point of view, the concepts of "pathology" or "ecological crisis" are meaningful in biology, while completely extraneous to the theoretical field of physics: they are the result of a more or less integrated and regulated dynamics, that can be understood as a more or less severe failure in the maintenance of the two ever changing loops. In terms of symmetry, we could consider the effects of the interactions of the two loops with the environment as symmetry breakings related to the three loops: often sustainable micro-breakings, with respect to the structural stability of the loops, and sometimes unsustainable.

According to this perspective, it is therefore clear that a main biological invariant – which takes the form of these properties and propensities towards such conservation – is to be detected in the maintenance of the whole and of its relative autonomy, regardless of the different forms of the processes. These may be rather oriented either internally or externally; both are activated in order to enable the preservation of the organism through the dynamic stabilization of the two main types of loops that we have described. The challenging analysis of the role of time in dynamically constrained biological organization is proposed in Montévil and Mossio (2015), by an extensive use of the notion of characteristic times and scales in an autopoietic perspective.

The "projection" of the totality at a given level of organization (for analytical purposes, for example, or for in vitro experiments) entails the loss of most of these loops and, consequently, of this invariant (somewhat similar to the way the Cantorian encoding of the plane on a straight line causes the loss of connectivity and the topological invariant which dimension constitutes).

4. *Extended Critical Situations: from Mathematics and Physics to Biology*

The development of a biological system consists of on-going transformations, underlying a permanent (re)construction of a global coherent, adaptive structure. Therefore, we may explain phenotype determination as a process able to "canalize" the biological variability through a coherent, meaningful structural organization. In this sense, we say that variability is at the core of life, insofar it yields adaptation and diversity which contribute to structural stability at every level of the biological organization.

How can we strictly express the fact that, in biology, biolonic life (organisms, species, …) seems to conserve all *compatible* trajectories through its own endurance as well as some variations of its environment (albeit with a loss or replacement of some of its organic parts), whereas in physics, dynamics select *the* "optimal" trajectory, a geodetic one in the intended (phase) space? Following BL (2011) and LM (2014), it may be appropriate, first of all, to emphasize here two aspects of *criticality* that are quite distinct from each another: one related to a state of equilibrium (and the geodesic is indeed a critical trajectory at equilibrium) and one related to a situation far from equilibrium – a sort of self-organized unstable criticality which can nevertheless give rise in some conditions to a global structural stability. In the first case, we are led to consider that the evolution of the system from a situation of non-equilibrium towards equilibrium leads it to the loss of relevance of its initial conditions (since the final situation is that of equilibrium regardless of these initial conditions, in a quite large interval of existence), whereas in the second case, conversely, the system seems to retain the memory of these initial conditions, since its final situation depends on it.

In mathematics, from a complementary albeit somehow different point of view, the critical points on a curve (maxima and minima, for example) can be said to be *specific* as long as they are mostly much less numerous (in most cases, being a set of isolated points) than the continuum of the *generic* points. Likewise, Euclidean geometry can be said to be specific (or "critical") with respect to other geometries (Riemannian), because in Euclidean perspective the local radius of curvature (the scope of "mathematical correlations") is always infinite. This means that, in Euclidian geometry, there is no "natural" scale of length, unlike other geometries in which the natural scale of length is provided by the radius of curvature: this shows the particular role that can be played by homotheties, or in other terms, by changes of scale (Euclidean geometry can be said to be invariant under a change of scale). Please note that in this case, mathematics expresses criticality (of a geometry) by scale invariance: this is a quite general signature of critical transitions, also in the physics of criticality.

In physics, quite generally, the set of "conceivable" trajectories is generic, but, as we saw, the effective trajectory is defined by the geodesic principle and, therefore, it is specific (critical, stable, that is, dependent, minimal for Lagrangian action or, in the particular case of optics, minimal for the optical path). In other words, *effective physical phenomenality is specific*. This provides physical theories with a great mathematical force as well as the possibility, by means of abstraction, to characterize physical objects by very general properties, despite the singularity of each particular experience whose conditions may not always be reproduced. As for an issue of our concern, in physical criticality, renormalization methods make it possible to account for the passage from the local to the global at the critical point. They are thus restricted to a point-value of the parameter, a singularity, in which the critical transition takes place; in other words, renormalization depends only on a single value of this parameter, the critical value.

On the contrary, it seems that, in biology, the cells of an organism, the organisms of a species and the species of an environment (meaning, essentially, biolons) are concerned by certain generic "trajectories": all those which remain *compatible* with their subsistence, or even with their transformations (mutations, changes at various levels of organization); in other words, we find ourselves in a situation of constrained genericity (namely within the field of biological inertia we evoked earlier), which would allow to account for biological variability and for its internal and external plasticity. The reduction of this genericity to specificity is what makes the analysis lose its biological nature, in favor of a reduction to the physical level. In this sense, as shown by the number of examples of organisms and of behaviors, in living phenomena the constraint of optimality would actually be sterile and would impede the exploratory and adaptive variability that is specific of life.

In this sense, it would be possible to understand the extended critical situation as the domain of existence of this genericity in contrast with the localized critical transition of physics (localized in the parameter space and in time, in spite of incessant fluctuations). A further aspect, definitely essential in our opinion, is that this genericity touches not only the behavior of "trajectories" in a given phase space (set of relevant parameters and observables), but can manifest also by the modification, of this phase space itself through life phenomena (modification of the environment, mutations, appearance or disappearance of certain organs – or, more generally, of certain organs).

The biological invariants, in turn, should no longer be defined within a given "phase space", but *over the set of "phase spaces" which are compatible with this genericity*, since each specificity is able to modify an element of this set without disappearing. This is what may explain the major (though approximated), invariants that concern large sets of organisms (rhythms in mammals, oxygen metabolisms in the animal kingdom, etc.). Each of these invariants is compatible, at a given moment, with a certain "phase space", but is capable of passing in time to another. And, furthermore, if there is "biological renormalization" with respect to this extended critical situation, it would doubtless prove to be much more complicated than the renormalization in physics, due to this extension of the critical situation as well as to the concomitant fact that the conditions of such renormalization should then depend simultaneously on all the accessible critical values, except in the case of a return to the specificity of a properly physical trajectory.

5. *Biological Indetermination and its Phase Spaces*

From a highly speculative standpoint, what could be called the biological domain of existence of a biolon (in order to distinguish it from the phase space of physics) – grouping all those conditions that are proved to be not lethal for the biolon in question – can be represented as a space constituted by a set of so many layers as possible conditions of life (niche and ecosystem, more generally), given that each layer represents the existence of the biolon in a given set of internal and external conditions. As stated above, one of the major challenges for biology is precisely that this set of layers is not given beforehand, as occurs with the phase space of physical analyses, but it is co-constituted through their interaction. This relation between organisms and the environment may be seen at the core of ontogenetic and evolutionary "enablement" we mentioned (see LM).

A conceptual particularity of this "field of existence" is due to the fact that this set of layers can be used as such in an a posteriori analysis (corresponding to what we could call a history of the biolon), but not in a complete a priori predictability, even if there are some elements that may allow some predictability, such as, for example, the fundamental chemical trace of a history – the DNA – of a species or metabolic – also biochemical – reactions shared between several species.

In dynamic terms and in a first approximation, one could grasp this (apparent?) indeterminacy through the amplification of micro-interactions (below the threshold of observability) amplified by these loops: they would then be reducible to an unpredictability comparable to that of physical dynamic (deterministic) systems – and this interpretation could also stem from certain analyses in terms of co-evolutive dynamic systems. Moreover, one has to add to this unpredictability of a deterministic nature, the one deriving from the many quantum events that occurs in biology. As a matter of fact, there is increasing evidence of quantum phenomena present at the molecular level, yet "amplified" by molecular (classical) dynamics with consequences at the phenotypic level, see Buiatti and Longo (2013). Although this aspect could be part of the intelligibility that we propose, we believe that what is in question here is an essential indeterminacy that, in the physical perspective, is comparable to that of Quantum Mechanics (but quite different from it): the causal symmetry breaking which would intervene in one of the two aforementioned loops or in their looping, and its recomposition into a new layer, during the passage from one layer to another, would be physically undetermined (and undeterminable, in the terms of existing physical theories, quantum physics in particular).

In fact, any physical measurement (and analysis) would in turn break one of the loops, by introducing an oriented physical cause, and a consequent analysis may at most attempt to recompose it in a new space, in terms of physical geodesics (hence specific geodesics, see above); however, a physical geodesic and its causal intelligibility would require a given phase space, whereas the biological issues would lie in the circular determination of a new space (layer) as well as of the biological entity. The physical indetermination of the biological field would therefore consist in the evolving oscillations of three dynamic loops (internal, external, interaction of the these two loops).

Sometimes these loops amplify, sometimes they reduce (the stabilization of pathologies, the conservative maintenance of biological inertia) the effect of the interactions within each systems and with the environment. Especially note that the genericity of biological trajectories refers precisely to the passage to a new ecosystem, i. e. a compatibility with what is being formed by these looping interactions. Through evolution, this produces an ecosystem and a biolon (a cell, an organism, a species) which did not exist and which will be constituted by new loops and causal symmetries.

In conclusion, the extended critical situation specific to life phenomena, that is implausible or unintelligible for existing physical theories, is dynamically stabilized by the loops that characterize it; it is at the origin of an interaction with the ecosystem in which any physical action, causally oriented (exchange of energy-matter or of information, as gradients of energy or matter), perturbs a causal symmetry (one or several loops) which could generate new loops in new phase spaces (layers), because it is modified by the reaction of the biolon in question. As LM affirm: "*the permanent state of transition is maintained, at each level of organization, by the integration/regulation activities of the organism, that is by its global coherent structure*"(2014: 19).

The passage from a layer to another also imposes an irreversibility of time, much more pronounced than that of critical physical systems (dynamic and thermodynamic). This irreversibility would be intrinsic as it should be, in our opinion, in any theory of ontogenesis and phylogenesis: in a sound theory, their reversibility should be simply unconceivable

Furthermore, we could maybe consider that the genome itself and genes have an equally fundamental function in preventing, among all possibilities, a development which would not belong to the species (which could for example take the form of inter-species sterility). That is, we do not see DNA as *activating* developmental processes in general, but as a fundamental chemio-physical structure constraining and canalizing intracellular activity. Mutations and environmental effects could modify these constraining and inhibition capacities in the same respect as activation capacities. This view radically changes the perspective and stresses the role of DNA as *constraint*, in the wider sense that we should consider constraints in biology as fundamental, not just as "border conditions" like in physics, since they guide or canalize the default state of life, which is activity (Longo *et al.* 2015).

6. *Biology and cognition. The active bodily presence in the world.*

The above paragraphs 3, 3.1, 3.2, 4 and 5 allow us to reconsider the living organism as a system characterised by an essential physical indeterminacy (at least, "as for existing physical theories"). As shown above, the construction of phenotypes (within an environment) requires adaptive, plastic and higher protensive skills at all level of biological organization. The subsistence of life depends on a multiplicity of outcomes (integration/regulation, action/perception), which in turn interact each other, and arise from internal/external constraints and environmental factors that provide essential tools in the process of phenotype development. This also provide sufficient issues to reject an explanation of individual organisms as grounded on self/non-self distinction. Moreover, as suggested by recent accounts on symbiogenesis, life evolves through symbiotic associations: singular or reciprocal exchange of nutrients and/or protection between symbionts. In this sense, in our view, an analysis of cognition (in itself) does not provide an adequate yardstick to mark the boundaries between organisms and the outside (assuming that any boundary may exist….).

As even Merleau-Ponty states, the essential characteristic of a lived body consists in its possession of a hybrid identiy ["*sentant*" (perceiving) et " *sensible*" (perceived)], meaning that the organism must be considered as 'indivisible' and 'undivided' with respect to the rest of the world.

From this point of view, Bergson and 20th Century Phenomenology contributed a great deal to outline a unified understanding of biological organisms, through a reconceptualization of the apparatus and methodology of science, including the cognitive apparatus. Merleau-Ponty (1908-1961) and Ian Patočka (1907-1977), among others, have shed light on the intelligibility of biological organisms, on their unity, and emphasized the role of human cognition (perception and affectivity) in the modification and change of our perspectives on the intelligibility of the world. Their considerations on scientific theories of time, space and movement went through a very insightful reconceptualization of the role of human body and cognition within the construction of the scientific intelligibility. It may be appropriate to consider them as the precursors of the 20th and 21st centuries theories of embodiment and enactivism developed by some branches of cognitive science, which emphasize the role of the sensorimotor structure of the body in shaping mind. As further remarkable example we can mention the philosopher Gilbert Simondon (1924-1989), who emphasized the intrinsic value that should exist between the technical objects and the perceptual life of the scientist, so that the discovery of the scientific object or theory may change the perspective on the world. This concept is similar to LM's idea according to which scientific practice requires an "*active bodily presence in the world*" (2014: 6). In this sense, it is important Arthur Araúio's remarks about Uexküll's theories of meaning. In Uexkull (1864-1944) view: "*meaning corresponds to a functional relationship between an organism and its environment, e.g., if something has value for an organism, it is because of the particular way in which this organism perceives and acts in the world […]*" (Araúio 2014).

Ultimately, we could say that, from Galileo onward, every new mathematical construction in Physics corresponded to a change of perspective on the world, including a reconceptualization of theoretical frameworks. Nevertheless, the "*constructive objectivization of phenomena*" is very different if we shift from Physics to Biology. Indeed, in Physics the mathematical analysis is aimed at constituting the largest genericity of the object and the physical entities tend to preserve symmetries during transformations. This allows us to access the invariance or conservation properties and to define trajectories as geodetics in suitable phase spaces. In biology, the analysis of the organisms as objects of physics, possibly in their mathematical construction, encounters a difficulty, which is also related to a challenge. As we observed, a biolon's domain of existence (which has to be distinguished from the phase *space* of physics) is not given beforehand, but it is co-constituted through the interaction of the living entity with the ecosystem to which it also contributes by determining the entity. In this sense, we insist, the passage from one layer to another presents a specifically biological *indeterminacy*, related to the fact that this set of layers can be adopted as such in an *a posteriori* analsysis (corresponding to what we call a *history* of the biolon), but not in a completely *a priori* predictability of its specific developmental trajectory.

Definitively, the biological individuation (corresponding to singularity and specificity of each phenotype) develops as a coherent structure in a continual (extended) critical transition. As proposed by BL (2011) and LM (2014), living organisms are the result of onto/phylogenetic trajectories, as cascades of changes and extended symmetry breakings connected to stochastic and irreversible events that occur during ontogenesis (and, a fortiori, phylogenesis).

A further contribution to the analysis of individuation is provided by the great number of approaches to immune system that stress its phylogenetic and ontogenetic role in shaping or "setting the border" of individual organisms. In particular, Pradeu's explanation (2011: 759-784) of biological individuation is based on the *criterion of immunogenicity*, which he considers able to show us "*what makes the organism a unit constituted of different entities through time*". Pradeu's analysis offers a possible account "*of how organismic individuation works*" (2010), emphasizing the contribution provided by the immune system within the biological development. As Pradeu writes : "*Le système immunitaire est ainsi ce qui assure l'unité de l'organisme, son individualité véritable*" (2011: 78). Unquestionably, the criterion of immunogenicity proposed by Pradeu contributes to detect a possible evolutionary criterion of individuation by the side of physiology (Pradeu, 2010).

Likewise, in his book *La sculpture du vivant* (2003), Jean C. Ameisen consecrated many chapters to support the view according to which the immune system plays a key role in phenotypes determination, making a very significant contribution to the final architectural form of a living being, implementing processes of memory, shaping organismal identity and complexity.

Nevertheless, in our view, neither the physiological theory based on the criterion of immunogenicity – although including the analysis of biochemical, local, interactions to understand the functional integration of an organism – nor Ameisen's analysis offer sufficient criteria for the explanation of what biological individuation is.

In particular, those perspectives do not take into account two main aspects of biological individuation:

1. The first is that biological individuation must be understood as a *historic* fact ("*émergence d'une histoire*", Merleau-Ponty 1995: 369) – where *history* includes but it is not synonym of evolution (which acts on an overall set of physical natural objects: organisms, stones, planets, ecosystem…). Unlike the physical objects, however, biological temporal organization encounters a duration (life span). As Merleau-Ponty affirms, "*vie, matière, vie terrestre, vie marine, nature, animalité, humanité, sont liées à un certain tempo de présentation, sont des modes de temporalisation, sont solidaires de l'existence d'un certain champ temporal*" (2011: 117); "*Nous sommes des horloges, des machines à marquer le temps. Et pas seulement à le marquer: à le fonder*" (2011: 190). According to LM, the living being manifests a double temporality. On one hand, we see phenomena of integration/regulation (dealing with a physical linearity) concerning the transferal of matter-energy and targeted to the constitution of the organism. The regulatory activities are based on rhythms that scan biological time (hearth, respiration, hormonal cascades …) and may be represented in the orthogonal

axis of a two-dimensional representation of time (see LM). On the other hand, the organism also manifests a characteristic temporal inversion (retrograde causality) dealing with the perceptual phenomena of anticipation or protention (as preconscious form of anticipation) of behaviour, based on a reconstructive form of retention as a re-interpreted pre-conscious memory, as we suggested above. The implementation of this temporal inversion is required to produce compatible answers with respect to the environment and its changes (LM 2014). By this double activity (rhythms and retention/protention), the biological organism may be considered a real organizer of time.

2. The establishment of a biolon (especially as for higher multicellular organisms) consists in the attempt to give rise to "*a mutual construction of sense*" (Berthoz 2009), that is "*a meaningful relation*" between itself and the surrounding world (Toadvine 2009; Abrantes 2011). It is even more interesting to remark, as David Hull does, that organisms "*can pass on this knowledge. They can learn from one another*" (Hull 2001: 14). Thus, organisms evolve as adaptive and meaning interactive systems, capable to give a huge multiplicity of sense to their domain of existence and to pass on this knowledge (to their fellows). Even by way of their propensity to learning (that is not reducible to heritable mechanisms), indeed, organisms evolve as individualized entities belonging to meaningful ecosystems/niches. Concerning the relationships between living beings and the natural world, Merleau-Ponty refers to the world in terms of what "*opens up at the place where behavior appears*" (1942: 25) (experienced space).

To sum up, we agree that the immune system plays a pivotal role in establishing the limits of the physical/somatic 'identity' of a biolon, as well as in maintaining biological control and functional integration (Benasayag, 2010: 117). However, we think that the biolonic attitude to explore possibilities and to deal with the "*environmental complexity*" comes to play a more prominent role in the development of the individual, especially with respect to some mammals, like humans, provided with a very complex brain as well as with extraordinary plasticity and evolvability[12]. Definitively, at a higher level of biological evolution, the physical world is grasped as *world-of-perception*, *world-of-action* ("*le cerveau sert à bouger et met en relation le monde sensoriel et le monde moteur*", Prochiantz 2012: 85). This sense, the construction of niches as "lived

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[12] "[…] évolvabilité définie par la capacité de répondre à une modification de l'environnement par la création de formes (au sens large) nouvelles présentant un avantage sélectif" (Prochiantz 2008-2009).

spaces" depends on both adaptive mechanisms (dealing with natural selection) and higher protensive skills.

Furthermore, as remarked by Frezza & Longo (2010), "*the core of living matter dynamics, at all levels, from evolution to human action, is exploring possibilities*", where these possibilities are co-constructed by the dynamics. By this, Frezza and Longo describe living phenomena as processes essentially dealing with an "active protention", that is, the ability (ubiquitous in unicellular and multicellular organisms) to respond to the environment, on the grounds of traces of the past (all forms of retention), and to natural selection, by "*exploring possibilities*" (Frezza and Longo 2010: 8). Likewise, Mary Jane West-Eberhard defines phenotypic plasticity "*the ability of a single genotype to produce more than one alternative form of morphology, physiological state, and/or behavior in response to environmental conditions*" (West-Eberhard 1989: 249).

As we observed, any organism has a protention to simply prolong a situation or to adapt to a situation in view of "memory" – or "retention" – which it may have preserved from comparable anterior situations (the result of learning) [see 3.2].

We have to point out that here the meaning of 'protention' is different from what phenomenology calls 'intentionality'. In our opinion, biological protention (at a preconscious level) grounds on a biolon's structure and does not deal with a transcendental meaning (e.g. Husserl's idea of intentionality). In this sense, our concept of orientation (claims and) recalls a new model for the description of natural world, based on the immanence of organization and meaning[13].

From now on, we will consider that an organism develops as both a «natural» object, by reproduction with variation and intervention of the natural selection, and a «historic» object, namely, a specific and not interchangeable entity, ensuing from evolution and characterized by temporal irreversibility and self-organization.[14]

In this sense, Alain Prochiantz's book *Qu'est-ce que le vivant* (2012) is important, since it emphasizes both the natural and historical conceptualization of biological individuation. Especially in *sapiens*, individuation corresponds to their development as historical and cultural subjects, thanks to the evolutionary mechanisms that encompass memory and language, with the acquired experience of transmission of their own history.

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[13] R. Simanke, *Merleau-Ponty, Nature, and the project for naturalizing phenomenology*, manuscript draft.

[14] According to Prochiantz, biological individuation corresponds to the whole set of epigenetic mutations occurring during ontogenesis. These changes modify phenotypes irreversibly, by enabling the development of an organism as a single prototype of the species it belongs to. See Prochiantz, 2010: 24, 25, 33, 37.

7. *Merleau-Ponty‘s reconceptualization of the structure of behavior*

A careful reader has probably noted the presence, in the previous paragraphs 3, 3.1, 3.2, 4 and 5, of many perspectives in step with Merleau-Ponty‘s attempt to explain the behavior of living beings within their turn to natural sciences, particularly to biology.

In particular, the scientific paradigm proposed by Longo *et al.* complies with Merleau-Ponty‘s attempt to consider the explanations of “*biological behaviour*” and “*biological structural organization* [shape]” in the light of new ontological categories. Merleau-Ponty (1942) explicitly tries to reconsider the properly biological categories as constitutive of the organism –such as *coherent orientation*, *dynamic order*, *vital interest* (which is not vitalism), *meaningful unity* – in opposition to the mechanistic physiology of 20th century. In other words, BL and LM‘s methodologically physico-mathematical analysis of organisms responds to the Merleau-Ponty‘s effort to analyse “biological life” properly, i.e. scientifically, maintaining the consideration of the organism as a whole, of its specificity, along with the contingency and the irreversibility underlying biological dynamics, without reducing them to physical objects as such.

After all, Merleau-Ponty‘s reconceptualization of the living organism deals with the difficulty of achieving the “*transition from partes extra partes to unity*” (Merleau-Ponty, 1942: 227). In our opinion, BL and LM‘s view contributes to fill this gap, reconsidering organisms in the light of their inherent propensity to develop as a coherent, oriented, meaningful system, and to evolve as historic entity (Merleau-Ponty mentions an *archeology* of the body in 1995: 340). Moreover, according to Merleau-Ponty, the unity (identity) of the organism is that of its meaning, signification (1942): “*the body itself is – that is, a concrete unity capable of entering into a multiplicity of relations without losing itself* (1942: 118); “*The unity of physical systems is a unity of correlation, that of organisms a unity of signification*” (1942: 155-156).

We would like to focus our attention on the following two considerations, the former by Merleau-Ponty (1942) and the second latter by Longo (2014):

> [*in biology*] the discussions concerning mechanism and vitalism remain open. The reason for this is probably that <u>analysis of the physico-mathematical type progresses very slowly in this area and, consequently, that our picture of the organism is still for the most part that of a material mass partes extra partes</u> (Merleau-Ponty 1942: 3).

Une des immenses difficultés en biologie est en fait de saisir la matérialité radicale du vivant, sa spécificité et sa contingence (sa corporalité, dirait Merleau-Ponty) et proposer toutefois, dans son étude, la généralité propre à l'analyse scientifique (Longo and Perret xxxx: x)[15].

In the *Structure of behaviour* (1942) Merleau-Ponty accounts for an explanation of the form of organisms able to explain and to produce their behaviors. As Merleau-Ponty asserts, the form of an organism (as organised structure) represents a (changeable) measurement of adaptation, by means of which the organism may coherently act on the surrounding things. Definitively, the form is the "measurement" for/of being, knowing and acting in the world (Merleau-Ponty,1942: 148).

Although, in The Structure of Behaviour Merleau-Ponty maintains a too rigid distinction between animal and human behavior, by attributing to animals mere instinctive actions (1942: 120: "*In animal behavior signs always remain signals and never become symbols*"), we think that his explanation of animal behaviour (either in humans or non-humans) clearly refers to a biological process that expresses the co-emergence of meaningful relations.

In a certain sense, our explanation of biological individuation aims at extending the functional concept of biological organization (form) to new observables, expressing the 'relational' protensive skills of organisms (arising during ontogenesis). What we mean is that the organism is able to direct that form (in turn subject to important physical, environmental and genetic constraints), by creating new horizons of meaning, building its identity as relational. It is able to signify, to produce sounds expressing symbols, within the environment where it evolves. In this perspective, we outline the idea of organism as a relational, meaningful – and not only interacting (as a physical natural system, it impacts on the environment) – structure.

Ultimately, we may consider phylogenesis as a pivotal point of view for the analysis of the historical reconstruction of this "meaning" underlying the development of a specific biological form belonging to each organism.

Here below we try to sum up some considerations that we have detected in Merleau-Ponty, (1942; 1968; 1995, 2011) and BL and LM's works. We think that these remarks are expected to bring a significant contribution to our perspectives about organisms.

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[15] G. Longo, N. Perret, *Information in Biology*, waiting for publication.

BL (2011) LM (2014)	MP (1942; 1968; 1995, 2011)
Biological protention/anticipation	*Body shape and sensorimotor organization*
1) protention (anticipation) would express the role of an active causal influence on upcoming events. It is grounded on retention, as a changing continuation of an activity.	1) "*biological meaning of behavior*" (MP, 1942: 21, 25) as depending upon the vital significance of situations (1942: 161). It is still necessary to understand how, among all these systems of possible liaisons, only those which have a biological value are ordinarily realized … (1942:49)
2) *Active bodily presence in the world***:** living organisms as builders and organizers of a "sense construction", a "meaningful organization" of their surroundings. The *meaning* of a friction with the ecosystem lies in the way it affects a protensive action.	2) *The perceiving organism as measurer and active organizer of the natural world (things and events)*: …the orientation of the organism toward modes of behavior which have a biological meaning, toward natural situations, that is, an *a priori* of the organism. Thus there is a norm inscribed in the facts themselves (1942: 123). …the organism itself measures the action of things upon it and itself delimits its milieu by a circular process which is without analogy in the physical world. (1942: 148). Le corps humain est expressif en ceci qu'il porte dans chacun de ses gestes *Umweltintentionalität*, il dessine et déploie un "Umwelt" et {même} un "monde". L'identité de la chose est l'équivalence des gestes divers qui y conduisent." (2011: 58)
Integration/Regulation loops	*Biological praxis & organism/environment co-emergency:*
The coherent structures proper to extended criticality express the global regulative and integrative coherence of an organism. Its continual transition towards a new coherence rep-	Thus one should anticipate finding a *regulation* in the behavior of the simplest organisms which is different from that in physical systems" (1942: 149)

resents the symmetries' changes thatcharacterize variability, adaptation and, thus, diversity, as crucial components of biological stability	Si l'on veut, l'homme est mécanisme, mais c'est un mécanisme dans les limites de sa constitution et de son milieu: il est, dirait Coghill, créateur de lui-même et se met en fonction de lui-même (1995 : 194) …a propos de l'homme, il s'agit de le prendre a son point d'émergence dans la Nature" (1995 : 269). corps comme corps qui se meut, et se retourne [sur] le monde pour le signifier, le designer, organe de mimique." (2011: 64). A l'égard même du monde culturel (et pas seulement du monde naturel) considérer la praxis comme constituante. […] La praxis est l‘élaboration des conditions elles – mêmes [habitat, nourriture, conservation, reproduction], préadaptations, projection initiale de conditions internes d‘équilibre, *a priori* de l‘organisme (2011: 65). Le corps est une telle puissance d'invention, mais assujettie à conditions de nature… (2011: 82: 86).
– physical causality Vs. biological relational structure Biological relational dynamics stress even further the modern understanding of physics, since the rise of Relativity Theory. In this latter theory, the tissue of space-time correlations co-constitutes the object;	*– physical causality Vs. (biological) relational space* (biological) relational space ["espace relationnel", 2011: 75] L'organisme n'est pas échec à la physicochimie, il est dans l'entremonde, en filigrane, réalité de

the object deforms the tissue of correlations. In biology, one also has an oriented causality that is enriched by relational and stochastic structures, stabilized by interactions between different levels of organization (regulation and integration).	masse, il n’oppose pas causalité à causalité, il ne dépasse la causalité que par le détour d’une réinterprétation, d’une nouvelle dimensionnalité, par intégration et différenciations qualitatives (1995 : 276).– Notion de schéma corporel: – [*l‘unite du corps est schéma au sens que*] n‘est pas celle d‘une somme de parties […] totalité qui prescrit leur sens aux parties […] rapport à un espace extérieur qui fait système avec lui (2011: 128-129). – [*le monde perçu*]….suppose déjà la fonction expressive (2011: 45)-

Conclusion by an opening

In the difficult path towards knowledge construction, one may wonder why the issue of biological individuation, as an historical and organizational issue, has been so relevant not only in Life Sciences (especially for biology), but also in Humanities (especially for philosophy). Our tentative answer is the following.

In general and firstly, we believe in the attempt of philosophy to make the conceptual framework of science more definite, by providing interrogations and proposing ways of dealing with problems. Vice versa, we believe in a philosophy that, while relating to science, may be closer to the dynamics of life. In either case and as for individuation, the constitution of our historical individuality appears in close connection with the formation of the biological organism: the historicity and specificity of the latter precedes and strictly parallels the way we experience animality and humanity‘s organization and behaviour.

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