Epistemology of the Inert and Epistemology of the Living

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ABSTRACT

The intellectual act of imposing borders to contain and delimit objects has been a constituent factor in physics since its origins, and is also fundamental for philosophical reflection. However, the characteristics of the conceptual universe thus constructed (tendency towards the ideal limit, invariance in variation, a conception of matter as residue, etc.) seem inadequate in biology. The essential characteristic of the living thing is, in fact, that of having a history: that is, of being the concrete trace of a memory. Making an epistemology of the living thing (and not of the inert) means identifying new categories which, being radically antithetical to disembodied notions like that of program and information, take account of the unpredictability and creativity which time introduces. This essay aims to bring some of these fundamental categories into focus.

1. The Line and the Idea

In mathematics the notion of "structure" is central. Consider for example the notion of line. The line, as length without thickness (Euclid's definition beta), and the sign-point are the "structures" at the historical origin of geometry, the

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originating objects of Western mathematics in its relation to space; limited objects, outside the world, but which at the same time organise, shape and measure the world. The sign (semeion), marks a position on a line, is at the extremities of a segment (definition gamma). Its spatial interpretation (that which does not have parts, definition alpha) comes later and turns out to be derivable: it is the intersection of two lines without thickness (theorem 1, chapter 1). The line without thickness is remote from any sensible experience, even though, in the act of tracing the line, its contiguity with that experience is implicit: it highlights the sense of movement, of trajectory, of an "edge" or mathematical "border" (Longo 2016).

In fact, the notion of line produces and results from that of border. All the figures of Greek geometry are constructed from continuous lines which intersect one another: they are therefore given by their borders alone, which allows the calculation of surfaces – if the border has a thickness, what then would the surface be? It is the correlation with philosophy, and especially with the Platonic Ideas, which allows this miracle: the invention of mathematics as a science of limits, a geometry of pure outlines, of lengths and borders, which can be numerically irrational, or rather beyond the arithmetical logos. As asymptotic notions, π and the square root of 2 have meaning only in a geometry of lines without thickness. Mathematics is not exclusively the discovery of proof, but also a practice of structures remote from the sensible world. These gestures, these abstract diagrams, organise the world *more geometrico*, giving it a new meaning, subjecting it to a rigorous conceptualisation.[1]

In an audacious analogy to Euclid's, Galileo proposes the principle of inertia, a fundamental principle of conservation of the quantity of motion in physics: a uniform movement of a material point on a Euclidean straight line, physically unachievable, the external limit of all movements, since no perfect inertial movement exists. But precisely because he places himself outside all real movements, Galileo succeeds in making them all intelligible at a stroke, identifying what they have in common at the limit, and at the same time what modifies this limiting state – gravitation, friction – in the experiences with falling objects or on the inclined plane (*ibid.*).

[1] A meaning, the origin of which can be traced in the figures drawn only with outlines at the dawn of our figurative humanity, in the caves of Lascaux.

Galileo's principle is therefore "at the limit", asymptotic, and was further made possible by that naturalisation of infinity that was characteristic of the Italian Renaissance (Arasse 1999; S. Longo 2010; G. Longo 2011). It is a mathematical principle, in the sense in which mathematics and physics, making use of limiting principles ad infinitum, render geometric forms and movements of finite and material bodies intelligible. From Aristotle to Galileo, in physics, trajectories were studied "per se", without a mathematical space which might conceptually precede them. Only after Descartes, and then Newton, was a geometry of space gradually constructed. This perfectly empty space pre-exists trajectories. From the epistemological point of view, the intellectual potency of mathematics, from Greek myth to today, its interweaving with Myth, theology and the formation of scientific thought, is beyond doubt. The various forms of Platonism still fashionable in the philosophy of mathematics, which claim to be secular, on the contrary remain immersed in theology, refusing to make that critical and historical "sidestep" that is necessary for epistemological reflection. The intellectual potency of mathematics, its positioning of itself as a science *at* and *of* the limit, initiates bold steps which organise the world, rendering it thus, in their own way, intelligible. Borders without thickness impose themselves on objects; the thickness of bodies (the pictorial perspective with its vanishing point tending towards infinity) becomes visible on flat surfaces, framing movement by means of non-existent inertial trajectories, subsequently immersed in an absolute, Newtonian, pre-given space.

But what is the relationship between the idea of a border without thickness and the concreteness of the thing manifested in experience? Let us try to rediscover its meaning by following a thread among the ideas of Husserl. Line and limit also play a crucial role in a philosophy of experience that is radical and at the same time rational, such as Husserl's, in which the two concepts prove to be profoundly and inextricably connected. It is the line that allows the object to have a perimeter, making possible the manifestation of that which is given. It is always the line which, indicating the limits to extension, allows the object to be detached from the background and fragmented. Line, the priority of extension, and determination (this last linked to localisation) constitute a cluster of reciprocally sustaining notions. Determination, phenomenologically conceived as an invariant in variation, is what enables the establishment of distinct properties in objects. On the other hand, conceiving of determination as invariant entails the attribution of ontological primacy to extension at the expense of qualitative "filling". Extension, thanks to the homogeneity which it imposes, is what enables things to appear: indeed, without extension the phenomenon would be destined to lose its own boundaries or borders, thereby nullifying its own phenomenological status. Moreover, extension is what enables the object to be sub-divided into parts.

> There belongs to the essence of extension the ideal possibility of fragmentation. It is then evident that every fragmentation of the extension fragments the thing itself–i.e., splits it into pieces, each of which once again has the full thingly character, that of material thingness. Conversely, every partition of the thing into things, every fragmentation, as such, of the thing, also fragments the extension of the thing (Husserl, 1912-29/1989: 33).

It is a distinguishing characteristic of extension to point towards an ideal limit. This possibility constitutes one of the central points in the argument about the indirect mathematization of the *plena* which Husserl proposes in *Krisis* (Husserl 1937/1970). According to this argument, the *plena* – in essence inexact, vague, morphological – cannot be directly geometrised or mathematised. The reason consists in the fact that there is no possibility of a *plenum* tending towards an ideal limit: unlike form (and therefore extension) which can in themselves be idealized (the sliding scale of the more or less straight, the more or less flat, the more or less circular implies the possibility of rendering the straight still straighter in a tendency towards the infinite). In reducing the sensible thing to mere extension, Galileo (who "is at once a discovering and a concealing genius *[entdeckender und verdeckender Genius]*" (1937/1970: 51) hides the effective nature of the thing experienced, a nature which Husserl calls morphological, vague, fluid, more suited to the description of botany than of geometry. Indeed, botany refers to its own object of study "in the empirically vague sense in which, in ordinary life, one speaks of sharp points and corners as opposed to blunt or ever rounded ones. Plainly the essential forms of all intuitive data are not in principle to be brought under 'exact' or 'ideal' notions, such as we have in mathematics" (Husserl 1900-1/ 2001: 15)

The concepts which come closest to the sensible thing are concepts with rough outlines.

> The most perfect geometry and the most perfect practical mastery of it cannot enable the descriptive natural scientist to express (in exact geometrical concepts) what he expresses in such a simple, understandable, and completely

> appropriate manner by the words "notches", "scalloped", "lens-shaped", "umbrelliform", and the like - all to them concepts which are *essentially, rather than accidentally, inexact* and *consequently* also non-mathematical (Husserl 1913/1983: 166).

Galileo's ploy consists in disembodying and emptying one of the disembodied parts, and finally declaring its independence, creating that ideal clothing which the object will finally put on, in view of a physicalization of ontology, in which the colours, sounds, weight, and heat radiation of a body that warms nearby bodies are transformed into luminous, sonic, calorific vibrations: that is, into *forms*. Nevertheless, there is a crucial aspect which Husserl shares with Galileo: considering extension as the essential characteristic of the material object, as opposed to the inessentiality of sensible qualification. It is extension which permits the object to be "something"; it is onto extension that the *plena* spread themselves. Movement itself, inseparable from the moved body, becomes an additional, or integrating, component of an extension (it is impossible to form "abstract ideas", to separate the idea, e.g. of a movement, from that of a moving body (Husserl 2001:6).

Therefore, phenomenology, as an inexact science, is not a geometry of phenomena. The presence of the *plena*, and the impossibility of their tending towards an ideal limit, renders phenomenology fluid, morphological, vague. The comparison between phenomenology and botany is, as we have seen, sanctioned by Husserl himself. Nevertheless, *inexactness d*oes not exclude *determination* but, on the contrary, in certain respects guarantees it. Determination, invariant in variation, in fact implies the ontological primacy (although not the exhaustiveness) of extension.

If exactness is the domain of geometry, which proceeds through idealizations and the perfect deducibility of each singularity from general assumptions; *determination* (although not *pre-determination*) is the essential feature of phenomenology. For Husserl, experience is essentially and before all else experience of *things*, and being a thing means being determined: that is, delimited, delineated. In considering the sensible *plena* as residual, line and surface are foregrounded, giving priority to the static and spatial dimension at the expense of the dynamic and temporal dimension (Lanfredini 2015).

1.2. Time and history

The bold and constitutive gesture of imposing borders to contain and delimit objects, is complemented by a conception of matter as a residue, a conception which arises from the privileging of the formal dimension over the material, a positioning that is so general as to take on the guise of a paradigmatic system. This is a *logic of the residue* (Lanfredini 2016a) of which there are many illustrations: for example, the distinction between quanta and qualia in philosophy of mind; between form and content in philosophy of knowledge, and as an exemplary case, the notion of information, with its claim to have freed itself entirely from the material substratum.

Moreover, interesting analyses of the visual centres in the cerebral cortex show how the brain extracts borders from, or rather *imposes* them on, objects (Sarti et al. 2008): the primary cortex seems to be activated along outlines and borders. Retention and protention of a trajectory, the primary gestures of action, further contribute to organizing the world in continuous lines, in Gestalts which structure vision, at least in animals with a fovea and brain similar to ours (Longo, Montévil 2014). These are structures which, in setting up the concepts of line and border as foundational, enable us to think of conditions in which knowledge is possible. The cerebral traces relating to outlines are concerned with the original frictions between us and the world, those same frictions which ensure that our mathematical propositions, language, writing are not arbitrary. These are organizing principles of the real, instruments for the praxis of knowledge, which have shamed our scientific method, and with it our universe, permitting us to look at it from the limit of the world of things. Only at the mathematical limit, outside the physical world, can a theory of surfaces or space be made, capturing the inert with such unequalled expressive and cognitive power. But these passages to the limit, stretching to its extreme the a-historical invariance of the inert (the principles of energy and momentum, for example), collide when they have to capture the historicity and variability of the living thing. The immaterial and mathematically invariant characteristics of the conceptual universe thus constructed, which are of great, but reasonable, force and efficacy in mathematics and physics (strong even from their mythical and theological origins), are inadequate in biology.

As if to supply the inadequacy of this asymptotic character of the mathematical forms of the inert, biologists have turned to a different environment in search of foundations and instruments of intelligibility, albeit one that is mathematical in origin: the instructive theories of arithmetical calculus and numerical algorithms. The notion of information has seemed sufficiently capable of enriching the mathematics of physics, supplementing its notions with a limit of energy and quantity of motion (inertia) or of entropy and "field": these are limits because either they delimit conservation – the first two – or because they are syntheses of asymptotic transitions, like entropy in the statistical physics of Boltzmann or the field originating with Maxwell (their properties, the irreversibility of entropy and the coherence of the field, are given at the limit).

So, in biology, the myth of the computational alphanumeric datum has become the alternative theoretical heart to the geometrical reign of mathematics, giving rise to particularly serious distortions. This century has been marked by a vision of DNA as "instructive", as data and instructions which completely regulate ontogeny, genes which propagate such data in the course of the evolution of species independently of the materiality of the cell and the organisms, which are regarded as mere "avatars" of the digital information (Gouyon, Henry and Arnaud, 2002). Since the 1950s, genetics has been dominated by alphabetical, intrinsically linear (one-dimensional) scripts such as every digital code, lists of complete (and egotistical) instructions for ontogeny (and phylogeny) and, for both the living thing and for mankind, the sense of one's body and one's own space. In biology the notions of information and of program are metaphors which limit the complexity of the living thing (Longo et al., 2012; Soto, Longo, 2016). Program and information enjoy an independence from coding, from (Cartesian) dimensions, and from the material (hardware), in that this independence is based on properties of rigorous mathematical invariance, on a radical, formal dualism. The evolutionary dynamic of genetic information is independent of the biological body, which is only a contingent material realisation of it (an avatar). In other words, the biological body becomes a mere material and theoretically irrelevant vehicle (hardware), like hardware in information theory (Gouyon, Henry and Arnaud 2002); whereas in biology there is only the concrete and historical materiality of this DNA, these membranes, these bodies, in their dimensions and no others. Therefore, in genetics the notions of information and program can only remain "soft", vague, lacking in rigour, even if they have extremely potent consequences. Indeed, the living thing only exists in this material – DNA, RNA, membranes – and nothing else: no informational invariant can be extracted from it for use in another physical material. So mathematical notions of invariance cannot be rigorously used in relation to codification, to realization in matter (hardware) that are at the heart of both the theory of the *elaboration* of information (Turing) and the theory of the *transmission* of information (Shannon). So, with vague reference to notions of common sense drawn from information and programming, highly potent biological properties are derived, first among them the so-called "stereospecificity" of biological macromolecules: these dovetail together exactly into each other through exact physico-chemical correspondences, like the correspondence between key and lock. Or rather:

> Necessarily stereospecific molecular interactions explain the structure of the code ... a boolean algebra, like in computers ... The cell is ...[and] the molecular processes are a Cartesian Mechanism, autonomous, exact, independent from external influences ... (Monod, 1970)

> biological specificity ... is entirely ... in complementary combining regions on the interacting molecules (Pauling, 1987)

So, in biology, far beyond the dynamics of the inert, a conceptual universe of the calculable has been forged – linear and decidable, apart from occasional "noise": "Evolution originates in noise, imperfections ..." (Monod, 1970).

Following (Longo, Montévil, Kauffman, 2012), we on the contrary see in biology the necessity to break the *a priori* framing of all dynamic possibilities within a pre-given space-time or, more generally, in a pre-established space of observables and parameters (a "space of phases"), as is done in any theory of physics. The living thing has a history, and not only a time of dynamics and processes, even if these are irreversible, in a pre-given mathematical space. Historical time is marked by the change in the observables (phenotypes, organisms) and in the relevant parameters and by "rare events" (Longo, 2017) This places biological unpredictability, and its time, far beyond that of physics (which is the unpredictability of a trajectory in a pre-given space), situating it at the level of the necessary space of possibilities. In short, in evolutionary time, but also in ontogenetic time, the species and the organism co-construct their own dynamic and the ecosystem. They construct ("create") organs and ecological niches, new species. Speciation, for example, is often due to the rare occurrence of a "hopeful monster" which finds or constructs a niche which makes it possible (Longo et al., 2012). The grave failure to appreciate this essential biological unpredictability (creativity) consists in having neglected a fundamental factor for the materiality of the living thing: its historicity (Longo, 2017).

2. How the Future Depends on Past Histories

An epistemology based on the inert has the following among its meta-theoretical assumptions:

1. Privileging fixity over movement (and thereby finding ideas, universals, essences in fixity)

In that it is assigned the role of preparing and directing our action on things, intelligence divides, breaks, allocates. In the predominant culture, intelligence is most easily applied to fixed points; consequently, fixity and immobility are what our intelligence seeks. This operation of parcelling out is customarily also applied to time, which is transformed from duration (the essence of which is to pass, in the sense that none of its parts is present at the arrival of the next) into succession, intervals, or moments: that is, virtual arrests of time. What emerges from this is a special conception of time in which the concept of "juxtaposition" is replaced by that of "succession". Intelligence wants always to be concerned with immobilities, real or possible. Space-time is nothing but a practical surrogate of time and movement, useful insofar as it is able to bend itself to the demands of language and calculation. In reality, movement is not a series of positions, nor the mutating of a series of states. Time is not a succession like the sequence of images in a film: real evolution, however slightly it is accelerated or slowed, is a radical modification. We could even say that it is precisely in acceleration or slowing that time consists.

1) It is therefore possible to replace assumption 1) with the following:

Time is not *lack* of stability and fixity (of the idea, of the universal, of essence, etc.). Time is *effective* – that is, *creative* (we will try to say what we mean by this).

There is a second meta-theoretical assumption which, in an epistemology of the inert, stands beside and completes the first.

2) Privileging the given over duration

«Time - says Bergson - is what hinders everything from being given at once. It retards, or rather is retardation» (1938/1946: 108). The fact that time prevents everything being given at once leads us to replace the idea of the *created* (the already given) with that of a unceasing *creation*. This also justifies the cryptic nature of the second sentence: time delays, or rather is delay.

Because time, understood as duration and not as spatialized time (or, if we wish, as time of the living thing and not as time of the inorganic), is principally a virtual projection of the present into the past [al contrario?], as we shall shortly see. Assumption 2) can therefore be replaced by the following:

2) Time is not given, but ongoing

The past is not understood as a reservoir or warehouse on which memory can draw, fishing here and there for events, experiences, data, etc. Duration is, on the contrary, the incessant progress of the past which undermines the future and which increases as it progresses, conserving itself indefinitely, thus making "an avalanche of itself" (ibid).

Having recourse to the notion of duration gets us back in touch with the dynamic, temporal structure of the flux of phenomenological consciousness, articulated in three motions: retention of the past, the actual present, and protention towards the future. For Husserl, there is no reality that is not temporal, which introduces the essential factor of memory and of the relationship between memory and perception. For Husserl (as for Bergson) memory is not a simple placing of past data in some "drawer" or "ledger" of our consciousness, and perception is not a purely instantaneous state, a source of data which, then slipping into memory, are gradually eclipsed by the horizon of the consciousness. Perception is not mere instantaneousness, not purely present consciousness, but an act which entails a certain duration. This means that every present "now" is ceaselessly transformed into a retention, thus producing a continuum in which each successive moment is retention of each preceding moment: a sort of comet whose tail consists of the "wake" or indistinct halo of the retentions (Husserl 1893-1917/1991: 89). The comet's tail is what provides the original impression (the present) with its necessary adumbrations (*Abschattungen*): every actuality that has duration is thus perceived distinctly in its original impression, to pour out later into retention until it blurs and finally collapses into the past. However, there are two ways of reading this temporal articulation, a difference which can be attributed to a difference of emphasis. In the first, that of Husserl, the emphasis is placed on the present, according to the following schema:

retention □ present □ protention

For Husserl, "consciousness is nothing without impression" (ibid, Appendix I: 163) and so-called adequate perception is the continuous passing, in consciousness, of the present into retention; a passing which, in the perception of the now (the head of the comet), finds that absolute "source" which enables continuous, unitary and indivisible progress, made possible by the restraining action of the retentional consciousness. If it is true that in lived time every now-point always and necessarily becomes mediated by its own retentional wake, it is also true that there is no retention that is not rooted in a now, exactly as every tail can only be the wake from the head of a comet.

The original impression, the present, the now, are the necessary fulcrum without which duration cannot unfold. By doing this, Husserl once again identifies *form*, in this case a temporal form, a *linear* or *horizontal* continuity between retention, original impression and protention, which ideally (and metaphorically) unfolds itself into a "surface", a swimmer in the temporal current, passing through its entire extension exactly as a swimmer would do.

In the second, that of Bergson, the emphasis is placed instead on the past, according to the schema:

retention → present □ protention

In Husserl we can speak of the primacy of the impressional consciousness, or of the given. The now holds back its own past. But for Bergson the primacy belongs to retention. It is not the present that restrains, but the past which flows onto the present. The former approach privileges the life of consciousness (presence); the second privileges the life of the organism (the phylo- and onto-genetic horizon), in respect of which consciousness is only one possible derivation.

The two ways of understanding time also imply two ways of conceiving the relations between perception and memory: in the first case, there is only a difference of degree between perception and memory (memory as a trace of the perception, without which it could not subsist); in the second case, there is a difference not of degree but of kind between memory and perception (independence of memory from perception and consciousness). In the first case the present is constitutive; in the second it is history that is constitutive.

History is irrelevant in most theories of physics, whereas it is central to biology. If the understanding of physical dynamics, or the determination of the system under examination, even for the purposes of prediction (albeit purely in probabilistic terms), is given by the present situation, the understanding of a biological dynamic is given by its history. The past and the sense of the future play a crucial role in living systems, contributing to their intrinsic unpredictability.

Mathematical determination does not mean foreseeability. This outcome has been well known since Poincaré and was later reinforced by quantum mechanics. Nevertheless, in physico-mathematical systems, a pre-determined space of phases enables us to define the equations or the functions of evolution on the basis of the (relative) knowledge of the present. In order to write equations, it is necessary to set the relevant parameters and the observables: that is, the space of the phases. We could sum this up by saying that, faced with a superseding of foreseeability, determination continues to play a fundamental role in the physics of the inert, via the crucial notions of invariance and symmetry, or via principles of conservation in spaces of the pre-given phases. Instead, Darwin's first principle, "descent with modification", must be read as a principle of "non-conservation of the phenotype" in the hereditary processes of evolution (Soto, Longo, 2016). Or rather, evolution (and selection) are possible because in every reproduction, large or small, there is variation, a breaking, however slight, of symmetry (Longo, Montévil, 2014). The space of the phenotypes, organisms, species, which are the relevant observables, changes constantly, even if minutely, at each reproduction (sometimes in a radical way, when the "hopeful monster" becomes viable). This suggests the impossibility of transferring the physico-mathematical concept of laws to the dynamics of biology and, *a fortiori*, to those of cognition. This is a "negative result" (Longo 2010) which nevertheless opens the way to the positive (constructive, creative) role of history in the understanding of living systems. If, in physics, mathematical determination allows a probability to be assigned to future outcomes (probabilistic analysis is made possible by the fact that the trajectories, although unpredictable, nevertheless move within spaces of the given phases), the continual breaking of symmetry in biological dynamics (Longo, Montévil 2014) does not permit the application of a similar formalization. The impossibility of determining a space for the pre-defined phases is given by the efficacy of history: the unpredictability is no longer within a pre-determined space of the phases, but applies to the very constitution of the space of the phases, which constantly changes on the basis of the (often unknown and inaccessible) contexts of the past. This puts at risk not only predictability or pre-determination, but also determination of a physico-mathematical kind, and does in fact make it the case that causality in biology cannot, in general, be associated with, or replaced by, a measure of probability.

(Relative) invariance as viable stability of living organisms and their (relative) autonomy is therefore not static but dynamic, indeed evolutionary, founded on an incessant reconstruction of components (Montévil, Mossio

2015; Mossio et al., 2016) and on the adaptation of the organism to its environment. Hence it seems possible to identify two senses of invariance: a static invariance in variation, in which the notions of datum, determination and categorization play a fundamental role, and an invariance in transformation, evolutionary and relational, *path-dependent* and for this reason endowed with historical time. Only the second type of invariance describes the living thing's variability and flexibility, its resilience: that is, the peculiar type of changing structural stability which characterises biology, differentiating it from physics and mathematics. In mathematics an invariant is completely known or defined when the class of transformations and spaces on which these act is completely defined and known (eg. a straight line can be defined as an axis of rotation – that is, as the invariant of a group of symmetries; principles of conservation, or rather symmetries, which permit the definition of each physical trajectory, even those of quantum mechanics: Schrödinger's equation derives from a form of the Hamiltonian, an expression of a principle of conservation of energy). Instead the invariant in biology is relational, depends on the context, and is based on retentions (restraining the past) and protentions (openness to the future, ever-mutable reactivation of a continuously reinterpreted past). Moreover, in mathematics and physics the invariant is attributable to a perfectly stable (formal) definition, since its objects are *generic*; in biology, on the contrary, the structural stability of an organism (or of an organ, or a population) concerns specific objects and, as such, is not formal.[2] Stability in biology is closely connected to memory (whether understood as a physico-chemical trace of the past – DNA for example – or, in cognition, as unconscious retention or conscious memory) and to its capacity for selecting what is relevant and forgetting, losing track of, what is irrelevant for the purposes of action[3]. Retention (present in the most elementary animal movement) is what permits the constitution of an invariant (biological or

[2] Physics operates with generic objects (interchangeable, invariant objects of theory and experience) which nevertheless move along specific (geodetic) trajectories. By contrast biological objects (organisms) are not generic but specific (historical and individuated) and their trajectories are generic (possible evolutionary and ontogenetic paths): see (Bailly, Longo, 2006/2011; Longo, Montévil, 2014).

[3] DNA can be considered a fundamental chemico-physical trace of an organism's evolutionary history, used by each cell in the course of ontogenesis. Like any other component of life, the functions of DNA can be understood only in a way that relates them to a context or an ecosystem. DNA does not by any means contain the complete determination of an organism. It is only the relatively stable invariant which is formed and maintained over time through various different contexts.

cognitive) that is preserved in the contextual transformations: the restraining of what is relevant for action permits the action to be reiterated in modified contexts, even if they are partly similar. In this sense, memory is interpretation, as the use of DNA by a cell is contextual, hence "interpretative".

In short, biological systems can be considered "systems determined by the state" like those of physics, since the course of history which results in the present state plays an essential role in the determination of the future (Longo, 2017). Biological determination therefore produces unforeseeable dynamics which cannot be ascribed to equations or to the assigning of probabilities in spaces of possible pre-givens. Evolutionary paths are by no means analysable as geodetic trajectories in a predefined space of phases, and hence become "creative" or "inventive". The relatively invariant traces of the past are at the same time the product and producer of the permanent reconstruction of a relatively stable and locally invariant structure. Protention, founded on retention, is an always mutable form of reactivation of a continually reinterpreted past that is often inaccessible to our consciousness.

These key concepts of the trajectory of life that we propose are: *enablement* (the continual variations suggest what is to be eliminated or made possible in a co-constituted environment – Longo, Montévil, Kauffman, 2012); *evolutionary heredity with con variations* (the phylogenetic and ontogenetic pathways are the permanent constitution of organic unity as a structure whose coherence is maintained during and thanks to change); extended criticality – Bailly, Longo, 2006/2011; Longo, Montévil 2014 – (extending the physicists' notion of critical transition of phase to the permanent reconstruction, through duration, of a coherence of structure with new symmetries). Variability, adaptation and diversity are all elements which contribute to biological stability understood as *relative invariant*.[4] In biology, invariance is neither exact nor permanent, and conceptual and historical

[4] Not that Gould's *exaptation* (Gould 1982) and Jacob's *bricolage* (Jacob 1981) are only comprehensible if we distance ourselves from the myth of evolution as optimalization (Goldenfeld, Woese 2011), emphasizing Gould's exaptation (ex-post adaptation) and the functional "overloading" of organs (Longo, 2017). The human brain and hand are typical examples of this. Hands are good, but not "optimal", for grasping tree branches (the thumb is not perfectly opposable), but this is precisely why hands can also be used for giving caresses and for playing the piano. If an organ had been planned to be "optimal" in an activity (optimality would contribute to "fitness"), it would be difficult to make use of it for other purposes. We could even go so far as to maintain that an "optimal" (perfect) organism is dead. Only a crystal or a diamond can be perfect.

instability is essential for relative stability by means of the variation of organisms and species, adaptation and the emergence of new diversities. It thus becomes impossible to determine completely the structure and the function of an organism or of one of its components, in that they arise not only from current relationships but also from the history of past ones, with a view to the constitution of future meanings.

4. Rethinking the living thing with new categories

In order to place such key categories in a unified framework, we need new categories. We have said, for example, that between memory and perception there is a difference of kind and not of degree, and that memory is independent of perception and consciousness. But what does difference of kind mean? If the notion of degree, or of gradation, is connected to the two concepts of *distinction* and *identity* (we take gradation to be the same thing as distinct intensity), the difference in kind is not concerned with the same thing, but precisely with different things. Difference of kind and difference of degree correspond respectively – at least in part – to discrete multiplicity on the one hand, and continuous multiplicity on the other (Riemann). The latter resemble duration to the extent that, as Deleuze affirms, they are that which can only be divided by changing its nature, which lets itself be measured by varying the principle of measurement at every stage of its division, whereas discrete multiplicities contain the principle of their measurement. Furthermore, discrete multiplicity foresees the intervention of the void (whose power of negation is essential in order to be able to make distinctions), and which is something that does not arise through continuous multiplicity. Lastly, in continuous multiplicity any form of *reduction* (understood in a general sense as the re-attribution of certain orders of phenomena back to the laws of another order of phenomena) is impracticable.

The discrete multiple is concerned with exteriority, simultaneity, juxtaposition, order, quantitative difference or difference of degree, distinction, discontinuity, actuality, making space for a homogeneous multiplicity. The qualitative multiple is concerned with interiority, with what is divided only by changing its nature and for this very reason does not produce movement, but *is* movement, fusion, heterogeneity, qualitative discrimination, virtual or continuous multiplicity irreducible to number (*ibid.*). But what "continuum"? The phenomenal continuum, that of intuition, or a specific mathematical construction?

In *Das Kontinuum* (1918), H. Weyl underlined the inadequacy of the construction of a continuum made of points, as proposed by Cantor and Dedekind for the mathematization of time. He acknowledged that we have no better one and resigned himself to working with it; but during those years he in fact contributed to the relativistic mathematics of space-time, in which the unity between space and time was not only given by the common use of the Cantorian continuum, but also by the fact that the Lorentz-Poincaré transformations, which leave the laws of physics unvaried in response to a change in the system of reference, apply in a similar way to space and to time. Nevertheless, he insisted that this mathematization of time is wholly inadequate, because no "present point" exists: when we try to isolate it, it is no longer there, but is instead *en route* between past and future, in the coexistence of Husserl's arrows which correlate the present to the past and to the future.[5]

So we must think of two forms of continuum, spatial and temporal, while also maintaining the distinction between temporal and spatial order, as well as in the play between discrete and continuous. The first form is concerned with space and the second with time, understood as duration. In duration no reduction is possible (there is no biunivocal correspondence which may allow reduction to its own sub-grouping), nor is there any reiterability or reversibility. The two multiplicities lead to two profoundly different conceptions of matter: the first (the discrete) describes matter susceptible to being partitioned, objectified, potentially capable of being subdivided and reconstituted ad infinitum, but lacking virtuality, in which everything is characterized as actual. Matter, understood as *objective* matter, is both that which is divided and that which being divided does not change its own nature. Then there is a second meaning of matter, not objective but *qualitative*, not divisible into parts and capable of reconstitution, endowed with a thrust which

[5] Today there exist continuous spaces "without points", in highly abstract *topoi* with which some people are trying to do physics, following Grothendieck′s approach. It is difficult to say if the difficulties that are being encountered are only due to the conceptual force of the Cantorian continuum, to the immensity of the mathematics done in it and the difficulty of "exporting" them, or to the inadequacy of these ideas in the representation of time, see (Longo, 2015) for references.

leads it to be differentiated indefinitely; matter linked to duration more than to the object, to time more than to space, understood as extended space; matter that is not only actual, but virtual, in which the virtual becomes foundational and the actual an abstraction of the virtual. Indeed, the virtual is the difference of kind which becomes actual, only once fixed as difference of degree. Identity and distinction are therefore abstractions, particular cases of that difference of kind which, if "stopped" present themselves as differences of degree. Thus, identity and distinction are nothing but difference at zero degrees.

Qualitative multiplicity proceeds from the virtual to its actualization, along lines of differentiation which, before "precipitating" in an actual that is given from time to time (distinct, objective, decomposable), proceed temporally in a way that is continuous, heterogeneous and simple (that is, not divisible). Space thus becomes a particular instance of time: not absence of movement, but presence of movement in its form of stasis, actualization, *repetition*.[6]

The articulation which emerges as central is that between *virtual* and *actual*. It outlines an ontology of a temporal character, contrary to the distinction between *possible* and *real*, which implies an ontology of a spatial type. The possible is that which is realized (or not realized), the virtual is that which is actualized. The process of realization is subject to the two fundamental rules of *likeness* and *limitation* (or elimination). Since the possible is what has not occurred but which could occur, possible and real stand on the same logical plane or, put another way, from the point of view of the concept, there is not difference between real and possible. In this sense the real is realized as an image and likeness of the possible: in fact, all it possesses *in addition* are existence and reality. Furthermore, since not all possibles are realized, realization implies a limitation which "repels" or "prevents" certain possibles, making others "pass" into the real. The virtual does not proceed through limitation or elimination in order to actualize itself, but through *creation*; not through likeness, but through *difference* (or *divergence*). If the real is realized as an image and likeness of the possible, constituting a prolongation of it, in

[6] This radically modifies the principle of causality, converting it into what Bergson calls "the retrograde movement of the true". Its causes are always obtained retroactively by starting from the product. The principle of causality, and the rule that the same events always follow the same causes, is furthermore founded on divisibility, reversibility and reiterability of events, and hence on the collapse of differences of kind into differences of degee. Real duration is nevertheless neither reiterable nor reversible.

the sense of projection, the actual does not at all resemble the virtuality which it incarnates, constituting a prolongation of it in the sense of creation. In this sense, contrary to the relationship between possible and real, in the virtual there is full coexistence of past and present: the evolution of life is the continuous explication of the vital impulse, Darwin's "reproduction with variations", more "motility" as the "default state" of the living thing (Soto, Sonnenschein 2016), starting from the gigantic virtual memory, from that dark temporal depth which corresponds to phylogenetic development and precedes the ontogenetic (Bergson 1911/1944). Beneath the solidified crust of extension, thought is thus able to grasp the value of *tendency* as impulse, as qualitative unfolding.

What the qualitative conception of matter urges to do is to have faith not so much in what is "given", so much as in the underlying force or impulse. Things are not so much the effects of causes as expressions of tendencies. In the passage from discrete to continuous, moreover, the idea of boundaries falls profoundly silent: the boundaries of an entity in fact coincide with the boundaries from which the next entity begins, which makes impossible an exact subdivision of objects into their parts.

Virtual vs actual, difference, tendency, impulse, friction, creation, qualitative unfolding, etc. are some expressions for a new philosophical dictionary, aimed at rethinking the living thing and, more generally, the relationship between science and philosophy.

The intention is not so much to destroy the quantitative scientific paradigm, as to integrate it with new categories of thought.

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