

# **Time and spaces from physics to biology: Ontogenesis, phylogenesis and the formation of “sense”**

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In this series of six or more lectures, I will survey some key steps in the construction of our mathematical relation to space and time. Both the invention of Greek geometry and of the space and time of the Scientific Revolution are grounded on strong metaphysical assumptions. Myths and theology contributed to shape the mathematics of what Kant considers the “a priori” of physical knowledge and produced an extremely fruitful and effective co-construction of mathematics and physics. More recently, the fundamental dualism separating space (and time) from the objects in them has been extended to another very effective dualism for the construction of machines, the mathematical and practical distinction between software and hardware. These mathematical “a priori” and the related forms of dualism seem to be inadequate for the understanding of biological phenomena by their historicity and radical materiality. Alternative proposals will be hinted, focusing on principles that stress first the autonomy of organismal dynamics and the role of historicity, variability and diversity both in phylogenesis and ontogenesis. In this perspective, the material, bodily presence of organisms produce, a posteriori, the space and time of possible life dynamics.

## TITLES

1. The mythical and theological origin of the physico-mathematical spaces; the geometrization of time
2. Biological time and the origin of sens: biological rhythms, retension and protension
3. Historicity and the systems of life: the dynamics of phase spaces and of rare events
4. From Kant to Darwin: changing the "a priori" – towards organization and variation
5. Modern geometry and the foundational crisis: the “physicalization” of geometry vs the absolute of the logic of numbers - the logical origin of the numerical machine
6. The current “crisis”: digital networks and the “mean field” problem vs. the diversity in ontophylogenesis and the historical formation of sens

## ABSTRACTS

### **1 – The mythical and theological origin of physico-mathematical spaces; the geometrization of time**

**Abstract** There is no mathematical plane nor space in Euclid's geometry. Lines are traced, extended, intersected on a plane, an “apeiron” (it has no boundary), which is “practiced” but not mathematized. These lines have no thickness, they intersect in a point, that is a sign (“semeion”); they are objects of a mythical, ideal realm. Infinity is only potential: lines in the plane or endless sequences of numbers can be extended with no limit. Actual infinity will be fully conceptualized

much later, in the theological debate of late middle age, as an attribute of God. How does actual infinity relate to or how can it be represented in the finite? The Renaissance Italian painters will show that this is possible: the projective limit of the newly invented linear perspective, first used in XIV century paintings of the Annonciation, shows the infinite in the finite and joins the infinity of God to the bodily, three dimensional presence of a human being, the Madonna. We will critically analyze paintings from Giotto to Piero della Francesca that show this joint invention of actual infinity and of mathematical spaces, which allows as well the expression of a new, corporeal humanity. Later, this theological invention will become the mathematics of Descartes' and Desargues' spaces, the science of Newton's infinities. In the XIX century, physics will extend this mystical creation of infinite space and time to the mathematical “phase space” of its new scientific rigor, based on an increasing mathematical unity of space and time.

Reference:

G. Longo. [Mathematical Infinity "in prospettiva" and the Spaces of Possibilities](#). In "**Visible**", a Semiotics Journal, n. 9, 2011.

<http://www.di.ens.fr/users/longo/files/PhilosophyAndCognition/InfinitySpaceEN.pdf>

## **2 - Biological time and the origin of sens: biological rhythms, retension and protension**

**Abstract** By protention and retention we refer to (possibly preconscious) intentionality and memory which anchor our beings to an environment and its timing. Action in space will be analyzed as the earliest protensive gesture of organisms, while acknowledging that there is no protension without retension, from eukaryote cells to humans. The construction of sense will be grounded on protensive actions and on retension. Moreover, sufficiently complex brains construct invariants of action by the double role of forgetfulness: when memory is constructed, the contextual relevance of an action selects the invariants to be memorized. While both memorizing and acting, “irrelevant” details are forgotten. Then, it will be argued that joint protentional and retentional activities produce an “extended present”, while biological rhythms scan the time of organisms and their processes. We will first explicitly “geometrize” biological times and rhythms, then hint to a critique of the common geometrization of time and the lack of historicity in the analysis of processual time in physics.

Preliminary References:

1 - Francis Bailly, Giuseppe Longo, Maël Montévil. [A 2-dimensional Geometry for Biological Time](#). In **Progress in Biophysics and Molecular Biology**: vol. 106, n. 3, pp. 474 – 484, 2011. <http://www.di.ens.fr/users/longo/files/CIM/2-dimTime.pdf>

2 - Giuseppe Longo, Maël Montévil. [Protention and retention in biological systems](#). In **Theory in Biosciences**: 130, 2, pp. 107-117, 2011. <http://www.di.ens.fr/users/longo/files/CIM/proret.pdf>

For a more comprehensive account, see chapters 3 and 4 of G. Longo, M. Montévil, [Perspectives on Organisms: Biological Time, Symmetries and Singularities](#), Springer, Berlin, 2014.

<http://www.di.ens.fr/users/longo/files/Longo-Montevil-book-forew-intro.pdf>

### 3 - Historicity and the systems of life: the dynamics of phase spaces and of rare events

**Abstract** The dependence on history of both present and future dynamics of life is a common intuition in biology and in humanities. Historicity will be understood in terms of changes of the space of possibilities (or of “phase space”) as well as by the role of diversity in life's structural stability and of rare events in history formation. We will hint to a rigorous analysis of “path dependence” in terms of invariants and invariance preserving transformations, as it may be found also in physics, while departing from the physico-mathematical analyses. The idea is that the (relative or historicized) invariant traces of the past under organismal or ecosystemic transformations contribute to the understanding (or the “theoretical determination”) of present and future states of affairs. This yields a peculiar form of unpredictability (or randomness) in biology, at the core of novelty formation: the changes of observables and pertinent parameters may depend also on past events. In particular, in relation to the properties of synchronic measurement in physics, the relevance of diachronic measurement in biology is highlighted. This analysis may a fortiori apply to cognitive and historical human dynamics, while allowing to investigate some general properties of historicity in biology.

References:

1 - Giuseppe Longo, Maël Montévil, Stuart Kauffman. [No entailing laws, but enablement in the evolution of the biosphere](http://www.di.ens.fr/users/longo/files/CIM/noentail.pdf). *Invited Paper*, **Genetic and Evolutionary Computation Conference**, GECCO'12, July 7-11, 2012, Philadelphia (PA, USA); proceedings, ACM 2012.  
<http://www.di.ens.fr/users/longo/files/CIM/noentail.pdf>

2 - Giuseppe Longo. [How Future Depends on Past Histories and Rare Events in Systems of Life](http://www.di.ens.fr/users/longo/files/biolog-observ-history-future.pdf), To appear in **Foundations of Science**, 2017.  
<http://www.di.ens.fr/users/longo/files/biolog-observ-history-future.pdf>

### 4 - From Kant to Darwin: changing the "a priori" – towards organization and variation

We adopt organization as a theoretical principle for biology. The analysis of organization as a new Kantian “a priori” frames the intelligibility of biological objects and will found our analysis of their relevant aspects. This approach radically departs from the condition of possibility for physical theories, today grounded on the notion of phase space. We then focus on how biological organization fosters an original approach to biological stability and on its interplay with variation. Darwin introduced the concept that random variation generates new living forms. We will compare the biological notion of randomness to randomness in physics and propose that biological variation should be given the status of a fundamental theoretical principle in biology. Our way to understand the qualitative and functional changes in biology will be based on the role of changes of phase space and of rare events proper to the historicity of life systems.

References: papers 6 and 7 in

A.M. Soto, G. Longo (Editors), "**From the century of the genome to the century of the organism: New theoretical approaches**", a *Special issue* of [Progress in Biophysics and Molecular Biology](#), Elsevier, (in print), 2016.

<http://www.di.ens.fr/users/longo/files/SotoLongoSpecialIssueContentsLongosPap2016.pdf>

## **5 - Modern geometry and the foundational crisis: the “physicalization” of geometry vs the absolute of the logic of numbers - the logical origin of the numerical machine**

In the leading foundational analysis of mathematics, our relation to phenomenal space has been largely disregarded, and with good motivations. The collapse of Euclidean certitudes, more than a century ago, excluded “geometric judgments” from certainty and contributed, by this, to isolate the foundation of Mathematics from other disciplines, where the relation to space is crucial. After the success of the logical approach, it is time to broaden our foundational tools and reconstruct, also in that respect, the interactions with other sciences. The way space (and time) organize knowledge is a cross-disciplinary issue that will be briefly examined in Mathematical Physics, Computer Science and Biology, in connection to the previous analysis of the “a priori”, in Physics and in Biology. Cognitive action and gesture in space and time organize and found them while departing from the purely linguistic foundation of knowledge.

Preliminary References:

1- Giuseppe Longo. [Space and Time in the Foundations of Mathematics, or some challenges in the interactions with other sciences](#). Invited lecture, **First AMS/SMF meeting**, Lyon, July, 2001.

<http://www.di.ens.fr/users/longo/files/PhilosophyAndCognition/space-time.pdf>

2 - Giuseppe Longo. [Theorems as Constructive Visions](#). *Invited Lecture*, Proceedings of **ICMI 19 conference on Proof and Proving**, Taipei, Taiwan, May 10 - 15, 2009, (Hanna, de Villiers eds.) Springer, 2010.

<http://www.di.ens.fr/users/longo/files/PhilosophyAndCognition/proof-visions.pdf>

For a more comprehensive account:

F. Bailly, G. Longo, [Mathematics and the Natural Sciences. The Physical Singularity of Life](#), Imperial College Press, London, 2011.

<http://www.di.ens.fr/users/longo/files/BaLoSingBook/english-introduction.pdf>

## **6 - The current “crisis”: digital networks and the “mean field” problem vs. the diversity in onto-phylogenesis and the historical formation of sens**

We will focus on the consequences on knowledge construction of the very “mathematical structures” the new technologies of information are based on. The claim is that the use of discrete state (digital) devices both as mathematical models and as a knowledge paradigm in science and humanities is far from neutral. In particular, these computational networks provide tools for knowledge as well as an image of the world; but, by their peculiar mathematical structure, the “causal relations” of phenomena, in all areas of knowledge, is often redesigned according to the relations proposed by the digital networks and their implicit causality. Their strong dualism (software vs. hardware) as well affects our views and activities. From the new role in “formatting” human behavior to Big Data, some key issues in our personal and scientific relation to the WWW and its dynamics will be discussed.

References:

1 – G. Longo, Letter to Turing, *to appear*, 2017.

<http://www.di.ens.fr/users/longo/files/Lettera-a-Turing.pdf>

2 – C. Calude, G. Longo. The Deluge of Spurious Correlations in Big Data. **Foundations of Science**, 1-18, March, 2016.

<http://www.di.ens.fr/users/longo/files/BigData-Calude-LongoAug21.pdf>

3 – G. Longo, (in French) Entretien "**Complexité, science et démocratie**", paru le 10-5-16, **Democrazia nella comunicazione**, traduit pour **Glass Bead**, le 23-11-16.

<http://www.di.ens.fr/users/longo/files/LongoEntretienDemocratScie.pdf>