Project: **Laws of the Gods, Men and Nature**

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Introduction

In the course of Giuseppe Longo's 2013/2014 residency at the IEA, two interdisciplinary meetings on this theme were held. More specifically, GL arranged two informal sessions for IEA fellows around Alain Supiot's work *Homo Juridicus*, bringing together French, Chinese, Indian and Turkish scientists, jurists and historians. These meetings provided the opportunity to consider the problem of how the notion of law is variously interpreted in time and world space, as well as to discuss the diversity of the links of these interpretations to different forms of knowledge, both scientific and humanist.

This project is above all a questioning with a long-term, fundamental objective: to discuss the meaning that the notion of law in biology has, or should have, taking as the departure point the Theory of Evolution and up to the sense given to it by modern and contemporary physics. In view of the role of paradigm which other disciplines attribute to the mathematized laws of physics, the economy of the equilibria of financial dynamics, not to mention the quantification of many social areas, it would seem that a reflection which stems from within natural sciences might also contribute to a better evaluation of the strengths and limits of these transfers.

A first theory: the notion of the physical law, which has dominated all references to "the laws of nature" for at least four centuries is profoundly impregnated with religious metaphysics and juridical references which have not only shaped it, but given it legitimacy. Whilst anticipating an objective which could be falsified, we believe that the historical and metaphysical bias that is normally implicit and which weighs upon the notion of the law of nature and mainly, if not exclusively, involves the ("well-deserved") hegemony of physico-mathematical theorization, currently presents an obstacle to original thinking on the dynamics of the living. We will therefore attempt to carry out a thorough questioning on intelligibility and normativity within the framework of life sciences, going beyond the preconceived metaphysical notions which govern physico-mathematical intelligibility. From this perspective, we also hope to contribute to the debate taking place within the human sciences, particularly as regards their relationship to "laws" such as those put forward by natural sciences.

Law, space and equations

A now classic tradition ascribes the success of the scientific revolution in Europe to the correlation which the revolutionary scientists of the 16th and 17th centuries were able to

establish between the regularities of observed phenomena and the notion of law pertaining to their religious culture, even their juridical context. In different ways, Cassirer, Needham and many others took up the texts of Leonardo da Vinci, Kepler, Giordano Bruno, Galileo, etc., which indeed went in this direction. Certain authors, such as Needham to whom Supiot refers, also perceive the contribution of generality and the particular strength of the law in the new centralized states, unified in the person of the King, as compared to feudal regimes which are always local and specific.

However, this vision of a direct and causal relationship between the concepts of divine law, the law of men and the law of nature has been called into question more recently. Indeed, the term itself only came into use gradually and in a way which was not uniform, sometimes within the works of a single author. Roux observes, for example, that neither Galileo nor Boyle and Mariotte talk of the "law of falling bodies" or "the law of gases". It was only during the 18th century that scientific use of this term started to become relatively uniform and generalized.

We therefore put forward a first "sub-theory" to examine in this project. The "law of nature" notion was to become a precise and uniformly understood concept, in physics and especially from Newton onwards, only once its precise expression was found in the form of equations. Equations (of motion, for instance) are what definitively describe the law (of motion). Yet, as Kant says, this is only possible due to the "condition of possibility" if there is to be physical intelligibility; the prerequisite of space (and time) within which the equations take place. In our opinion, the framing of the law within a pre-given space is what confers its general, rigorous, in fact wholly mathematical nature.

Yet this historical and epistemological passage was only possible after the mathematization of space, an issue which was preceded firstly by centuries of theological reflection, and then by artistic practices.

In fact, the "invention of space" is the result of the intermingling of a long philosophical debate on the Infinite and pictorial construction. Euclid only mathematized potential infinity, as a limitless "apeiron", although "he practices" actual infinity (a delicate question). For example, he explicitly considers the ascending, limitless, sequence of prime numbers, to which *numbers can always be added*, to be a potential infinity, but he does not consider as being infinitary (and actual) the notion of the breadthless line at the heart of all his constructions.

In fact, from at least Aristotle onwards, there have been discussions on the legitimacy and meaning of the concept of actual infinity, given in its entirety, essence, or existence of a whole *to which nothing can be added.* The Christian God poses the problem of the perfect infinity which was definitively attributed to Him by, among others, St Thomas and the Templars in the 13th century. As Zellini explains, the question of the grace of Mary is also hotly debated: can a woman, by nature finite, receive the full and infinite grace without which the Son of God could not be conceived? Italian painting would answer this question: yes, there can be "the incommensurable within the measurable", according to St Bernardino's sermons of the early 15th century, which pointed out those annunciations where the infinite lies within the finite, as the projective point or line, actual infinite limits, visually and visibly organize pictorial space. Ambrogio Lorenzetti, priest and theologian, in his 1344 annunciation, seems to have been the first to have changed how we organise the way in which look at space according to Italian perspective. The long-distance debate between Panofski and Arasse (see also S. Longo)

clarifies this question, which will need to be discussed in the framework of this project, to gain a better grasp of the passage which takes place with Descartes and Desargues towards the new mathematics of space. Because, according to these two authors, it is possible to set out the *conditions of possibility* of physico-mathematical knowledge: Newtonian space-time. (Differential) equations thus explicate *laws* which finally find their mathematically stable description and legitimacy.

The space of phases and phenotypes

In the 19th century, Kantian space in physics extended to *the space of phases*, in other words, the space of parameters and relevant observables, where Hamilton frames, by variational methods, the geodesic principle. To space, impulsion is added, and to time, energy. Towards the end of the century Boltzmann and Poincaré made revolutionary use of this change: quantum physics considers these parameters and observables as "conjugated" and establishes by this means the indetermination proper to their simultaneous measure, the difference of which cannot go below the h of Planck (1900). The framework of legality widens and ultimately structures itself, even in quantum: from the work of Hamilton is also derived Schrödinger's equation (1925), a law which determines the dynamic of an amplitude of probability (and the indeterminist character of quantum is thereby preserved and … legalized). The space of phases becomes in this case very abstract: Hilbert space where observables are bounded operators (linear and symmetric), a mathematical space which can also have an infinite number of dimensions. In the same period, Noether and H. Weyl unified the laws of physics in terms of symmetries: the principles of conservation, which enable the hamiltonian of each non-dissipative system to be written, are only symmetries in the equations, of which the relevant groups give the ultimate intelligibility not only of classic and relativist physics, but of quantum. The unity and strength of physico-mathematics thus reaches a peak of rigour and generality among the forms of human knowledge.

A contemporary of Hamilton, but outside of, or independently of, the triumphal march which heralds physical determination, Darwin puts forward two principles to analyse the evolution of organisms, of which the first at least is a principle of "non-conservation": "descent with modification", to which is applied selection, his second principle. Phenotypes are changed in every circumstance, by each reproduction, even if to a lesser extent. We ask the question: can these principles be framed on the same *a priori* as intelligibility in physics, a pre-given space of biological observables? Are they "laws' in the same sense of the word as physics established in the past?

In our opinion, there is no way of (mathematically) predetermining the space of possible evolutions, the space of the "phases" of living things. In short, since Ambroglio Lorenzetti and Piero della Francesca, since Descartes, Desargues, Newton and Hilbert, we have known how to produce mathematical infinites, and in particular infinite spaces. And even the randomness of casting a dice or flipping a coin, or again, of a quantum event, operates in a predefined space of all the possible dynamics. Symmetries (invariants and mathematical transformations) enable these spaces (phases, possibles: spaces of the laws of physics) to be geometrically and formally defined, even infinite dimensions.

On the other hand, there is no method of predetermining the space of phenotypes (biological forms) possible in the course of evolution – and phenotypes, indeed organisms, are the biologically relevant observables. Phenotypes and ecosystems co-constitute each other and jointly produce the space of possibilities. And the slightest fluctuations in these interactions, within, or even between the different levels of organization, change not only the "trajectories" in spaces of pre-given phases, as in physical dynamics, but modify these spaces themselves.

What can therefore be said about "laws" in biology, if our "sub-theory" is relevant? In other words, if the "laws of nature" have only acquired a rigorous, mathematical meaning by being set out as equations in the spaces of pre-given phases, what meaning do they then have in biology? The relentless search for geodesics, or even hamiltonians of the evolution of species has only led to *a posteriori* descriptions, very incomplete or even erroneous, or fragments thereof. The informational turning point has only worsened the situation, by obscuring the issues: descriptive laws, organizing physical intelligibility like those of conservation (of energy or impulsion), have been replaced in biology by instructions, a normative programme, in other words, by the computer coding of a homunculus (or animalculus) in DNA, the only target of selection.

The phylogenetic and ontogenetic trajectories, which we analyse in terms of "cascades of symmetry breakings" (Longo, Montévil) require new analyses of determination, and in consequence, of randomness (Buiatti, Longo), where the notion itself of scientific law, held in physics, is called into question. We think that this can only be possible after an epistemological and historical analysis.

The coming together of cultures: the programme

The dialogue outlined at the IAS during winter 2014 was the opportunity to grasp the considerable difference of viewpoint of other peoples with regard to the laws of gods, men and nature.

The author of this paper was able to appreciate the sense of balance between the organic unity of bodies and state regulation which is peculiar to certain Chinese lines of thought, and which is very different from the normativity of our divine and human laws. For certain African people, law is almost exclusively an interdiction and rarely a recommendation. What can we say about these harmonic legislations of Chinese organicity relating to what we call the structures of coherence, ever changing, ever reconstructed, of an organism in biology? And our notion of "enablement" which permits without being normative (Longo, Montévil)- what is its position faced with the interdiction of what is incompatible with the ecosystem, according to Darwinian selection?

The aim is not to replace one vision by another coming from another culture, but to put certain knowledge into perspective, reconstruct histories which lead all too often to an absolute, and find meaning to help us go forward. Chinese culture does not seem to conceive of a pre-given empty space, the mathematical preconception at the core of the path of physics from Galileo and Descartes through to Newton, and in fact also reaches the (dimensions of) the Riemannian varieties used by Einstein.

What can this tell us about our vision of an impredictability of the space itself of biological phases (and phenotypes)? Indeed, these perspectives of the law which are found in China and Africa, derive or propose an approach to others and to space, even to the ecosystem, profoundly different from our own. What can the jurist or anthropologist learn from the very particular transfer which was made between the law of gods, men and of nature and its space, in the construction of our sciences and *its opposite*, very in vogue at this time of quantification in human sciences?

This cross-disciplinary and cross-cultural thinking is at the heart of this project. It should take place in parallel to the ongoing work at the ENS in Paris of GL's CIM team in theoretical biology and aim for a comparative analysis of various "contexts of meanings", historical, juridical, anthropological, etc., concerning the construction of the notion of law in human and natural sciences, focussing particularly on physical and biological knowledge. Only such a "pluri-" research institute as Nantes IAS can enable this type of analysis.

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