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SCIENTIFIC THOUGHT AND ABSOLUTES

for an image of the sciences, between computing and biology

Giuseppe Longo

Abstract

We propose a reflection on the construction of scientific knowledge and in so doing an image of this knowledge. This will allow us to develop a comparative analysis of some of the main principles underpinning the constitution of the different sciences. We will highlight the role of critical thought in science, or even “negative results,” which pose limits and hence open new trajectories. In particular, we will address a misleading point of view, based on some informal concepts taken from computer science, which dominates the biological imaginary. An “ethics of knowledge” will follow, as a critical and open perspective, capable of taking on the well-intentioned responsibility of proposing universal, though not absolute, principles of knowledge.

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1 introduction

More and more often we hear echoes of a new metaphysical tension between ethics and science: on the one hand, transcendence and absolutes of a religious and ethical kind claim to permeate scientific research (the infinite kindness of divine intelligent design, for instance, in theories of evolution), while on the other hand, scientific answers propose yet again a new universality of knowledge, instead of an absolute, and the ethical values thereof. To a great extent, this tension and the problems in resolving it have to do with the new order presented by new dogma holders. Some thinkers propose a counterattack that evidences, with intellectual vigor, the distinct values of anti-dogmatic propositions that too often come with “relativistic” accents. It is this relativism that seems to us inadequate in responding to dogmatic absolutes. We will discuss this in the first part, with the aim of underscoring the difference between universality and the dynamic generality of scientific thought, on the one hand, and the thinking of absolutes on the other. In the second part, we will try to highlight the role of critical reflection, as well as its complex interplay in relation to the universality of concepts and scientific intelligibility, so often motivated by negative results. The “ethics of knowledge” that guides scientific research provides renewed motivations today for the analysis of the foundations of the various sciences, and makes it the point of departure for any thoughtful critique of their constitutive principles, a “relativizing” rather than a “relativistic”

one. The interplay between computing and biology will allow us to provide some examples and reflect on the image that a certain “common sense” suggests for the scientific analysis of life.

2 relativism and scientific universals

A first fundamental observation against “relativist slippery slopes,” whether they be propositions or accusations, needs to underscore that scientific thought is not relativistic: it would be false to say that “everything is fine” with a few minor constraints of coherence or efficacy. Religious fundamentalists (comprising those we have been able to moderate with the force of scientific and philosophical thought, if not with the violence of politics, for example) base their accusations on the loss of (absolute) “values” and on “relativism” that, according to them, cover the whole of ethics and the modern sciences. Because of the limits of my own scientific experience, I will only address the second accusation, the question of relativism, and a single yet important aspect of ethics in science, hoping however to arrive at some reflections on the first.

Science of the twentieth century is “relativizing” and not “relativist.” Because of this, it can provide a very general example of knowledge construction. Let me explain with particular reference to Einstein’s theory of relativity. My goal is to help us understand how scientific thought possesses “bearing axes,” some strong knowledge propositions by which we make “choices” and propose “universals,” but not absolutes.

The great mathematician of relativity theory, Hermann Weyl, who was very close to Einstein, illustrates quite well the crucial contribution that Einstein’s theory makes to epistemology. In a very general manner, relativity teaches us that scientific theorization must be considered “objective knowledge” if it makes explicit the “frame of reference and measure” and the (mathematical) “conceptual invariants,” as well as the transformations of the frame of reference, that preserve them; it is from this explicitness that the construction of knowledge takes effect (Weyl). In other words, when doing scientific research, we must try to make explicit where we start, what hypothesis we are making, in which conceptual frame we are evolving, which frame of reference (Cartesian axes or more general, conceptual) we are choosing, and what is stable (invariant) in relation to the transformations of this base (these frames of reference) of knowledge. The expert will recognize the epistemological heart of Einstein’s theories, as well as Weyl’s “gauge theory,” the mathematical theory of “capacity” that relativizes and puts in relation inertial and non-inertial systems. It is in relation to these frames of reference, in the larger sense, that we obtain scientific objectivity, precisely because it is these frames that are subject to an evaluation, a critique and a measure, in terms of not only theoretical coherence and experimental “friction” with the real, but also, and most importantly, the “extension” of knowledge. But let’s apply Weyl’s discourse to a better-known example: the link between the Ptolemico-thomist epicycle theory and the theory of Copernicus–Kepler (reread in light of modern physics).

Let’s first observe that any number of points on an ellipse around the sun can be interpolated by enough epicycles around the earth – it is a question of series summation with a good frame of reference. Therefore, in itself, the system is coherent. At a certain moment in history, some audacious thinkers (the aforementioned two are the most well known and the greatest) dare to say: the criterion of intelligibility (the frame of conceptual reference, the measure) must be “simplicity” or geometric “regularity” of the planetary orbits – as suggested by Greek figures and polyhedrons; in modern terms, this was to be transformed in the principle of optimality, if

not of minimization of energetic variations (the principle of least action) – that of which will produce somewhat different orbits.

Far beyond this first approach to optimality as elegance, Newton, Lagrange, and Hamilton would demonstrate that from Newton's equations one can derive Kepler's orbits and more generally the trajectories of bodies in any physical conservative vector field; we will come back to this, since the proofs are based on principles of optimality (geodesic). Their predecessors, Saint Thomas for instance, used different criteria to construct knowledge: God created man, and him only, in his image, and put him on earth; then he sent him his only son in order to complete the history of Redemption. So the earth must be the center of the Universe; what counts is our absolute criterion and referent of knowledge, namely, the divine creation of the Universe. Some dissidents ended up at the stake for not accepting this basic principle of reasoning, which in itself is coherent. Obviously, Copernicus, Kepler, Giordano Bruno, and Galileo did not have the Hamiltonian or Lagrangian approaches in mind, that is, the modern criterion of optimality, the mathematical geodesics – optimal curves – that marked the physics of the last two centuries. However, we can say that they explicitly referenced the “simplicity” of the trajectories, which contradicts Ptolemaic epicycle theory's recourse to intricate geometrical tracings to explain the movement of the stars.

In short, it is erroneous to think that in scientific work “everything goes well as long as it is coherent (and that it works)”: once the frame of reference, the criterion of judgment and measurement, are made explicit, different intelligibilities must confront each other. In principle, on the basis of the “relativizing” principles of Einstein–Weyl, it is absolutely legitimate to propose the earth as the origin of a frame of reference to analyze the movement of the planets and the sun. With the planetary epicycles, perfectly coherent from a geometrical and logical point of view, we do not, however, understand much of the sudden back and forth, if not the route inversion, the knots, and interlacing of celestial trajectories. The principle of inertia (the conservation of momentum) makes them impossible: neither Galilean nor Einsteinian transformations allow a passage from a Ptolemaic system to another (inertial). And, equally important, we are obliged, each time, to add hypotheses and ad hoc corrections, epicycles on epicycles; the researcher can measure the quantity of hypotheses and epicycles that, planet after planet, must be added to the model to make it plausible. With the “geodesic principle” (the criteria of optimality and simplicity), which guides the birth of modern scientific thought and which, progressively over time, was to be fully mathematized as we say (Newton, Maupertuis, Lagrange, Laplace, Hamilton, etc.), we understand in a coherent way a great quantity of the universe's fragments: in particular, by Hamilton's variational method, the geodesic principle could be derived from conservation properties (inertia or momentum conservation and energy conservation). A single grand instrument of intelligibility allows, in a unitary manner, an accounting of phenomena ranging from gravitational movement on the earth (the apple that falls) to the celestial movement of the stars, all the way to thermodynamics. In fact, the latter can also be analyzed in terms of optimal trajectories of gas particles described in statistical physics (to the infinite limit, a mathematical integral). And even in quantum physics, the passage to objectivity is obtained by the “gauge invariants” of Weyl; these are invariants with respect to the passage from one frame of reference or measure to another and are defined on the basis of modern extensions of the great geodesic or conservation principles.

2.1 “relativizing” objectivity

The knot is precisely here: the passage from the absolute-subjective (look at the sky and say: “I am at the centre of the Universe, son and creature of God, the stars are revolving around me”) to the relativizing-objective directly implies the choice to make explicit a frame of reference, of measure, and of (mathematical) invariants with the transformations that preserve them (principles of conservation, energy, and momentum, as we said); and before this, the capacity of the observation of nature, curiosity about the world, all of which are foreign to religious fundamentalisms. Having arrived at this point, I can now affirm: the two theories (epicycles vs. the geodesics of Kepler–Hamilton) are not “equivalent”; we cannot put everything in the same boat. The criterion of intelligibility, the power of explication, the type of unity they presuppose, the criterion of measurability (also modifiable, if not falsifiable), tell me the modern theory is clearly better, far more important for the human and her knowledge. It does not resort at any moment, for every planet and every star, to trajectory adjustments, to divine will, to new hypotheses and ad hoc corrections. It is not only – I would even say not at all! – a matter of simple experimental evidence (is it not evident that it is the sun that revolves around the earth?) but rather an audacious proposition, counterintuitive (it is clear that the earth is flat and immobile [...]), but capable of organizing events on the basis of “universal” and not absolute knowledge criteria – criteria that are there for all humans, yet also categories that can be revised, if necessary, a dynamic with a history. Galileo did not believe in the influences and effects of the attraction between the earth and the moon and did not understand tide dynamics; and from Copernicus to Laplace or Einstein, a long journey was to be travelled, but the commonly adopted principles present themselves as objective propositions, to revise, if necessary, in relation to these very same criteria, of relativizing invariance as we said, and thus they are not relativistic (“everything is fine”).

2.2 explicitness and universality of theoretical principles

Let’s take another example: Buffon, a fervent naturalist, affirmed that the earth and living beings, Nature, have a history, that they were not created all at once the way they are today. Misfortune followed: accusations from theologians, in a majority at the Sorbonne in 1751, humiliating retraction, the burning of books. After him, Lamarck, by meticulously studying mollusks and, thanks to the new liberty of thinking made possible by the French Revolution (which gave rise to a flowering of scientific debates and schools, despite the murderous fervor of the Terror), explicated the “progress” of living species – and that, from the height of one of the twelve chairs created by the Convention in the first public Natural History museum. He was to make a mistake in his criterion of progress (*adaptation*, as he explicitly framed it as a true scientific principle); then, Darwin was to propose a frame of intelligibility of great scope for the evolution of the living, based on reproduction with variation and natural selection. Even today, the selective theories of the immune system (Edelman and Gally) and of the neural system (Changeux; Edelman) confirm the extraordinary generality (universality) of the Darwinian conceptual frame; it renders intelligible phylogenesis, and a part of ontogenesis (at least for neural and immune systems – we are working in this direction to understand ontogenesis in general (Soto, Longo, and Noble)²). We can then compare such a theory with absolutist theories (creationism) in relation to the scope of the intelligibility they propose and observe that the former is significantly better. We can also say that our proposition is fed by universal criteria, ready to be revised, modified, updated, as has been the case in the past. However, with the theory of evolution, we have realized the construction of a scientific objectivity, mixed with empirical evidence (Lamarck’s shellfish, Darwin’s turtles); and precisely because we are analyzing the constitutive principles of such a science, we introduce them into debate and measure their scope of application. Creationist theories require divine intervention case by case: there is no universality of either method or criteria, but only faith in

an omnipotent God, who created species and biological functions one by one, each with their own characteristics. Generality is in God, not in the method of knowledge.

We can say the same of the modern version of creationist absolutism: “intelligent design” theory, which is having great success with the American public. Tapping the molecular alphabet on the genetic keyboard, God would program DNA mutations for his own supreme ends.³ But then, paleontological evidence tells us that approximately 99 percent of species that were formed on earth have disappeared, and that, especially in the five greatest known extinctions, massacres and death have ravaged our planet. That all of this has taken place to conserve us, as well as the 1 percent of species that have survived, does not seem to be very productive, or particularly intelligent. Hence, we invoke the impenetrability of divine design, of the Absolute Programmer, as the face of the tens of millions of deaths caused by the mutation of the flu virus (the “Spanish flu” of 1918 for example). Whenever we see fit, this “intelligent design” becomes impenetrable (unintelligible), the criteria change, and we invoke faith. It was even worse when we added epicycle on epicycle to justify, one by one, the zigzags of the stars in the sky over the immobile earth. Custom-made criteria, a shaky and limited intelligibility: science says no, this is not knowledge construction. We are looking to propose criteria that are dynamic in their generality, revisable with time and with the expansion of the field of applicability, but nonetheless universal, particularly in the sense that they do not need to be modified at birth in their own original field, with pseudo-theoretical and ad hoc adjustments.⁴

For these reasons, it will be difficult to dispense with the great frames of intelligibility that are physics’ geodesics and Darwin’s theory of evolution. The former is the basis of numerous profound results from the twentieth century and are correlated to conservation phenomena (energy, momentum, etc.), which are themselves linked to symmetries (by Noether Theorems, see Longo and Bailly), the mathematico-philosophical pilasters of Greek geometry. And this correlation passes through equational negotiations, that is, through the distant heritage of the “algebraization” of geometry, the great marriage (cultural “métissage”) of the Greek tradition and the Arab algebra, that is Descartes’ geometry. Similarly, Darwinian evolution marks a resolute turning point in the intelligibility of the living. It will be difficult, like I said, to remove ourselves from such historical and conceptual depths, but not impossible: it is not a matter of absolutes here. Besides, these two frames are for now far from each other, in physics and in biology, despite the efforts of some in “dynamical evolutionary physics.” To link both will perhaps require “reorganizing” them, possibly modifying one or enriching both (we are currently trying to do so with a tentative enriching of the history of evolution in terms of “historicized invariants,” a complex interplay between stability and variation (Longo, “How Future Depends”). Here, potential negative results (Longo, “On the Relevance”; “Interfaces of Incompleteness”) are equally theoretical and empirical, but also suggest alternate frameworks as deep and vast, helping us modify, partially or totally, these different manners of understanding nature.

This has already happened in part in quantum physics, for which the unity I have indicated with classical optimality is only indirect; it must not be extended to common, everyday bodies and space-times. Observations at the microphysical level forced us to revise the causal structure (the field) of the very nature of physical “objects” and their “trajectories” beyond classical (and relativist) frameworks. We arrived in fact at saying that quanta do not follow trajectories in space-time, and this after 2,500 years of “trajectory” physics – Schrödinger’s equation describes the trajectory of a law (amplitude) of probability, not of a quantum. Once again, the scientific universal has its own motivated and gradual dynamic that is recomposed

by the discussions and proofs around new axes of thought, new experiences; it is not an absolute.

2.3 science vs. ethics

Can the distinction between *universal* and *absolute* scientific propositions help us say something about ethics or politics? I have in mind the Kantian distinction between science and ethics, and I realize that the search for universals, with all their historical weight, is already complex in a scientific framework, and even more complex in ethics. But if we do not want to leave the latter facing alone the insoluble conflicts of dogmas against dogmas, knowledge paradigms might help us say something about living together (and vice versa).

In *La Nascita della Filosofia*, a book on Greek thought, Giorgio Colli observes:

how can we explicate, then, the passage from this religious background to the elaboration of abstract, rational, and discursive thought? [...] [W]ith dialectics [...] the art of discussion between two living persons [...] the vision of the Greek world becomes more nuanced [*mite*]. The bitter backdrop of the enigma, the cruelty of the gods fades away, being replaced by a purely human confrontation [*agonismo*] [...] the one who will lose will not lose life, as it happened with Homer.⁵ (73–80)

The scientific universal, as we know it, is thus the result of a dialogical process; this is what the Greek heritage consists of. It gave its origin to an *ethics of knowledge*, which demands a continuous reflection on what we mean by *better, just, knowledge, “critical thinking,”* etc. Today, beyond Kant, a renewed pragmatism proposes the notion of “teleological gesture” as a new frame for an ethics and knowledge of the living: an intentional gesture governs human action, for knowledge as well as for the social (Maddalena).

Once again we must continue to interrogate the principles of knowledge and the conceptual categories through which we make the world intelligible and livable, each time stepping aside to see and evaluate our own work as we progress, always interrogating the reasons for the very principles by which we research, measure, inquire, operate, in science and also in society. Such a process is necessary in order to make choices, while also assuming other responsibilities, by saying: “this theory is better than the other” (even: “there are no teaching positions in physics for a Ptolemist, nor in biology for a creationist, even if there are many publications on both perspectives in *The Watchtower Announcing Jehovah’s Kingdom*”⁶ or in similar journals). So, the center of scientific thinking, and of each of its *praxes*, must be firm in its choices, and not “relativist.” And this, in spite of the immense difficulty of choice, when we know the universal is what potentially concerns everything by reason, even if *it cannot* be imposed, while the absolute *can only* be imposed by subordination to a leader – (“ab-solute,” detached from any bonds and Constitutions), as an act of faith or as the result of war or holy war (as there were many in history) – who imposes his own values and principles of absolute repute.

Both the universal *Déclaration des Droits de l’homme et du Citoyen de 1789* [Declaration of the Rights of Man and of the Citizen] of the French Revolution, as well as the United Nations’ *Universal Declaration of Human Rights* of 1948, have a similar sense to what I have sketched out here in relation to the opposition *universality/absolute* in the sciences: we determine forms of living together that can be presented as better, the unit of measure being analyzable, criticizable, and always in evolution. Without imposing absolutes, some men *propose to all*

other men certain values to share, a common history; such are the bases of a human construction of our societies, of our living together. These propositions are dynamic, subject to justified revisions, just as in the case of scientific work, where great changes make history. They put forth relatively few necessary values, essential but extremely important, in contrast to the modes of living together and the political structures dictated for centuries by the great religions. These propositions are perhaps even based on a single absolute principle, which we absolutely cannot question, a sort of secular dogma of science, that has never featured in the sacred books of any monotheist religion: the possibility to think over everything in order to construct with others – the *absence of dogmas* (except this one).

3 analysis of the foundations and ethics of knowledge, on “dogmas” in biology

We have discussed above an “ethics of knowledge,” which always occupies itself with thinking over what was presupposed, the evidence of common sense, and the very principles of any constituted knowledge, even scientific, particularly if those principles are implicit. Too often in science, the researcher lives in the midst of a technicity that loses the sense of its roots and succumbs to the blinding force of mainstream concepts. This can leave the researcher imbued with a “common sense” regarding the critical capacity of her own knowledge, and can make her pass from rational/universal propositions, that will need to be relativized (as we say), to forms of absolutes. For example, I am thinking of the “central dogma in molecular biology,” perhaps originally dubbed so with irony and lightness, but which has since become a new absolute of biological intelligibility. And this to such a point that certain dissidents, in recent decades, have been called (I quote) “rascals” or “mad” by their technically competent colleagues who are nonetheless locked in a scientific present influenced by information society and incapable of seizing elements of interest other than the ones of the dominant vision – elements that are even more influential today, unfortunately.

Here is what this dogma says about the heart of the genetic *program*'s functioning:

- – *information* (which information? Classic? *À la* Kolmogorof, or following Von Neumann? In the sense of quantum mechanics? Or is it, rather, negentropies of dynamic systems, *à la* Brillouin? (see Longo et al.; Perret and Longo, for an analysis of the confusion around the concept of information that dominates molecular biology, even in articles of reference)). Information, we learn, is:
- – *deterministic* (in the strict sense of Laplace, or in the larger sense of Poincaré? Or is it a quantic indetermination, of probability, of classic or quantum statistics? See, in this case, Buiatti and Longo for the phenotypical consequences of quantic effects in the cell; ah, so uncertain is this genetic information in these last cases!) and is:
- – *transmitted and elaborated* by replicas, based on enzymes and by mRNA *transcriptions*, messengers that emerge from the nucleus (eukaryote) thanks to exact correspondences (stereospecific: a correspondence of the type, “key-lock”), but sufficiently elaborated so that ribosomes can:
- – *read and translate* it (again: letters, the alphabet, transcription, a reader, and a book are invoked,⁷ but what is the phoneme that produces sense, as when we are reading, how is it alphabetized? Or, where is the operating system or compiler, if we are talking computing?).

And all of this is done in an entirely *unidirectional* manner. As in the Holy Scriptures, the metaphors of everyday life describe the nature of God's action: shape man out of clay, like a Neolithic pot, today with writing and reading, or better, with quotidian computing, the one of common sense. The term "dogma" is thus a good choice here, in the era of information society with its computers; the common usages dictate, without critical analysis, the sense of the words, of the "metaphors" we use, without scientific content. Therefore, as in any dogma proposing an absolute, the present subject places herself at the center of the universe and, enveloped in her topical social affairs with her contingent technologies, she holds them as absolute – that is, intrinsic to a natural process: DNA is a complete program for ontogenesis. And once again, everything would be inscribed in *alphabetico-formal notation*, as Aristotle was saying already of thought and Hilbert of mathematics: the Greek alphabet, or one of a formal language, or the DNA's alphabet, would form the intrinsic or complete signs of thought, complete descriptions of the world, of mathematics, or of hereditary biology and the organism, its functions, if not its behaviors.⁸

Of course, scientific passion can lead to such attitudes, but we must always strive toward secularism in scientific thought and always be ready to listen to the critique of dominant frames, especially if these are imbued with common sense.⁹ As we were saying earlier, this implies the engagement of an explicit and motivated theoretical choice, comparative, and sustained by observations and empirical analysis. In this case, critical reflection on foundations is at the center of all scientific activity and fosters, might we add, positive scientific propositions that should not be confused with the search of "absolute foundations," which are proper to other foundational approaches, such as logicism and Platonism. In opposing the latter, the non-logicist mathematician – the one who does not look for foundations in the definitive and pre-human (better: a-human) rules of logic – can in fact view with interest approaches towards knowledge that claim an "absence of foundations." We can say the same of the physicist who appreciates the relativizing analysis of Einsteinian space-time, as well as the construction of knowledge and the very object of knowledge proper to quantum physics, entirely permeated with a relativizing subject-object polarity. In these analyses, and even more in quantum physics, the object is co-constituted, between the "real" and a knowing subject, in experimental and theoretical activity; it is the result of a "friction" between subject and world, whose objectivity needs to be encompassed by making explicit the methods of experimental and theoretical construction – by making explicit the frame of reference and of measurement.

In this optic, the Wittgensteinian school of thought, amongst others, has rightly picked up on a problematic in "the second Wittgenstein" by developing a very stimulating reflection on "knowledge without foundations" (Gargani). This is a true breath of fresh air against the obsessive search for "unshakable certainties" specific to formalism (as Hilbert wrote in a letter to Brouwer), but above all specific to Platonic logicism: the ideal that rules of logic that are external to the world, or that precede the world, would be the norms of mathematics (and of the world). But then, why insist on the problems with "foundations"; why insist on distinctions – like the ones presented in Longo and Bailly's book *Mathematics and the Natural Sciences: The Physical Singularity of Life* – between "principles of construction" and "proof principles," that are at the heart of a foundational proposition in mathematics or in physics?

In the case of this book, the argument is epistemological, not logical: it is above all a search for *épistème*, for historical and conceptual paths, that are constitutive of forms of knowledge. It revisits, as much as possible, the practices of scientific knowledge so as to retrace their

dynamics, but more so, their constitutive principles. In other words, the question is finding the *sense* of axiomatic and logical propositions, finding views that are concerned with certain purely empirical practices that mold between each other the different sciences. And this must be done, not to bring to light “unshakable certainties,” nor to propose absolute or definitive bases: on the contrary, the goal is almost the inverse. I’ll explain.

The individuation of the principles of order or symmetry in mathematics, or the identification of the omnipresent role of the geodesic principle in physics, must be accomplished with the goal of gathering “what lies behind” the theoretical choices, the principles, explicit or not, the constitution of their signification or “origin,” usually in more a conceptual sense than a historical one, but historical as well. This is done to *put into discussion* these principles, if necessary, and if this can render intelligible other fragments of the world.

For these reasons, on the one hand, the fact of understanding that, from Euclid to Riemann and Connes, some *common* principles of construction *do* found the geometrical organization of physical space and our relation to it on the basis of access to space and its measure is subtended to the following three great moments of geometry that “found” themselves on *instruments of access*, of measures of space: the rule and compass of Euclid, the rigid bodies of Riemann, and the non-commutative algebra of Heisenberg for quantum measurement employed by Connes. This is at the origin and conveys the sense of each corresponding theory, while taking into account the radical change of views that each of these approaches proposed. Likewise, the fact that the geodesic principle can make intelligible a historical path from Copernicus and Kepler to Schrödinger’s equations (derivable from the Hamiltonian, just like Newton’s equations) allows us to glimpse the power of the theoretical proposition in modern physics, in its successive stages. On the other hand, the “foundational” operation that also counts for us here is a reflection on the principle of each science: “stepping aside,” as we said, to look at them from a perspective, to think them over, especially when considering other scientific domains. That is what we do when we observe in the aforementioned book that the phylogenetic (and in part ontogenetic) “trajectories” of living beings must not be understood anymore as “specific” (geodesic) but as “generic” (possibilities of evolution); it is rather the individual being that is “specific,” historical, individuated. Or to put it differently, in physics, the (experimental) object is generic (a grave, a photon, can be replaced by any other) and follows “specific” trajectories (critical, geodesics in a good phase space), contrary to what happens in biology. The latter is thus in a duality with physics that allows a seizing of the necessity of a theory specific to living beings that *enriches* the underlying physical principles – which also participate in the intelligibility of the living. It is a foundational analysis that, once conducted, allows for a highlighting of the force and limits of the theoretical physico-mathematical framework, its non-absolute character, and the boundaries of its universality, particularly when trying to apply it to biology (Longo, “Information and Causality”) – a framework that is to be revised entirely, outside its historical domains of construction and the blissful rapport between physics and mathematics.

To conclude, the goal of foundational analysis today is not the same as the one of the founding fathers: the quest for certitudes, understandable in an epoch of great crisis of the foundations – I think especially of the collapsing of the absolute Euclidean space-time of Newton, of the catastrophe of common sense due to the intrinsic indetermination of quantum measurement. This quest for certitude in and by foundations has been rightly questioned by many, including the second Wittgenstein. Our goal today is rather to give a place to the ethics of knowledge I discussed earlier: the duty of each researcher to make explicit the great *organizational or founding principles* of his own knowledge, to reflect critically in order to

work better, and above all to turn to other scientific domains in an open manner, where these principles might be insufficient to understanding, or where they can be thought over, even radically rethought, as was the case both in relativity and in quantum physics (which is what I have tried to also do in the passage from physics to biology (see below the volumes with Bailly, Montévil, and Soto)). Here is a possible image of science that is always in construction, that expresses a universal dynamic, the relativizing proper to scientific knowledge, and that is far away from any forms of the absolute and of relativism.

disclosure statement

No potential conflict of interest was reported by the author.

Notes

1 Note on the translation(s) – Pensée laïque et absolus: les paradigmes des sciences.

2 We refer to articles listed in the bibliography for a too vast bibliography necessary to this rather quick overview.

3 During a recent colloquium on biology in Paris, I have heard with dread *all* American colleagues, but fortunately only them (for the moment), lost 20 percent of their time and brain power combat intelligent design theory, so much the stakes have become drastically central, even for the financing of research, in this country.

4 To give new ammunitions, even unintentionally, to the absolutes of ad hoc writing and of the unicity of the “center,” the genocentered theories of genetic programming come to tell us, in rather prestigious publications, to have identified the gene of “monogamy” (Young et al.). That is how is mingled, in a pre-modern melange, the Protestant idea of predestination and the notion of genetic program: every phenotype would be pre-written in a gene, all the way to behavior. With the aim of inscribing everything in the DNA, the very beautiful discovery of a few regulator genes of genetic expression (Jacob, Monod, Lwoff, Nobel Price of 1965) has been for too long extended to all genes: their expression would always be regulated by other genes, regulator gene on regulator gene, epicycles on epicycles (Longo and Tendero), excluding by principle all epigenetic control (Fox Keller, *The Century of the Gene; A Feeling for the Organism*).

5

[...] come si spiega allora il passaggio da questo sfondo religioso all’elaborazione di un pensiero astratto, razionale, discorsivo? [...] con dialettica [...] di arte della discussione [...] tra due o più persone viventi, [...] dialettica interviene quando la visione del mondo del Greco diventa più mite. Lo sfondo aspro dell’enigma, la crudeltà del dio verso l’uomo vanno attenuandosi, vengono sostituiti da un agonismo soltanto umano [...] se sarà sconfitto non perderà la vita, come era accaduto invece a Omero. (73–80)

6 In some southern states of the United States, Republican representatives have proposed “democratically balanced” hires in state universities: as many Darwinian teachers as creationists.

7 [“La surprise, c’est que la spécificité génétique soit écrite, non avec des idéogrammes comme en chinois, mais avec un alphabet comme en français [...]”] (“The surprise, is that genetic specificity is written, not with ideograms as in Chinese, but with an alphabet as in French [...]”) (Jacob pr. 34).

8 See the interview by Craig Venter, on the human genome’s “decoder” in 2001, published in *Die Spiegel* on 29 July 2010: “We Have Learned Nothing from the Genome” (Von Bredow and Grolle) where he gets to call “phonies” his colleagues who iterated, in 2001, the promise of soon understanding everything, in biology of organisms, thanks to DNA decoding. We should also read the severe autocritique of great import, for forty years, of all genetics in cancer biology: in 2014, he recognizes the limits, if not the dramatic errors proper to this approach (Weinberg). No one doubts the extraordinary importance of this incredible physico-chemical trace of evolution: DNA (Longo, “How Future Depends”); we are criticizing here the myths of its descriptive completeness, common image of the biological, that, while being pre-scientific (coded Aristotelian homunculus) and having in turn penetrated common sense, is difficult to exceed, from wherever it comes from.

9

[Nous croyons, en effet, que le progrès scientifique manifeste toujours une rupture, de perpétuelles ruptures, entre connaissance commune et connaissance scientifique, dès qu’on aborde une science évoluée, une science qui, du fait même de ces ruptures, porte la marque de la modernité.] (We believe, in fact, that scientific progress always manifests a rupture, perpetual ruptures, between common knowledge and scientific knowledge, as soon as we tackle an advanced science, a science that, by the very fact of these ruptures, bears the mark of modernity.) (Bachelard 207)

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