For a special edition of the *Theory, Culture and Society Annual Review,* 39: 7-8, 2022 (R. Bishop, ed.). Section "Bernard Stiegler and the Internation Project: Computational Practices and Circumscribed Futures".

Comparing artificial, animal and scientific intelligence

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a dialogue

Abstract The most recent tool for acting on the world, the *exosomatisation* of cognitive activities, is often considered an autonomous and objective replacement of knowledge construction. We show the intrinsic limits of the mechanistic myths in AI, from classical to Deep Learning techniques, and its relation to the human construction of sense. Human activities in a changing ecosystem – in their somatic and sensible dimensionalities proper to any living experiences – are at the core of our analysis. By this, we stress the key role of the knowing subject, far away from any allegedly objective Big collections of Data. The production of organized structures of physics, biology and in societal analysis will be compared and distinguished by trying to set on more robust grounds the constructive as well as the disruptive roles of *entropic, negentropic, anti-entropic* dynamics that are different concepts in different domains, to be handled with care. The use of machine learning and optimization methods are investigated as tools and models to analyse and manage human activities in view of their scientific and political ideology of technoscientific governance. They suppose that which they try to produce is objective, that is standardized and controllable behaviours. We stress a mirror symmetry between the lack of theoretical interpretation of scientific data and the lack of democracy in this fiction of neutrality. Moreover, bad analogies constitute an obstacle to grasp the anteriority of biological and ecological constraints which enable and limit all artificial products of human intelligence. We will thus stress biological specificity, the role of normativity and constraints in evolution, of labour in structuring the human historical construction of sense by common activities.

1. **Artificial correlations vs intelligence of causes.**

Andrea Angelini Q1. Many decades has passed since Husserl's *Krisis* (Husserl, 1936) announced the risks of an objectivism incapable of understanding the generative conditions in which every scientific *process of objectification* acquires meaning. And yet, many of his reflections are still relevant even after the great epistemological upheavals and new areas of research that developed during the 20th century, which continue to be exposed to the risk of scientific activity becoming meaningless. Or perhaps we should say, more precisely, that the social and

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technological conditions that currently mediate the work of the scientist are leading to a proliferation of scientific ideologies or obtuse scientisms that debase the great potential that belongs to the open, intransigent and anti-dogmatic character of true scientific research. Although it is illusory and idealistic to attribute to science a neutrality and an independence from its social conditions of production, it certainly has, at least in part, an aptitude for democratic confrontation and an awareness of its own limits of knowledge and relevance. But these limits are systematically disregarded by current technocratic tendencies. The scientist often has no choice but to play a role subordinate to research programmes dictated by specific political orientations and major economic interests, obliged to play the part of the innovator-inventor without actually being allowed to do anything other than implement technological apparatuses and private interests, beyond any question of scientific meaning or human and ethical sense.

In the prolonged dialogue you conducted, together with Maël Montévil, with Bernard Stiegler, you dealt a great deal with the progressive emptying out of meaning of the activity of the scientist (Stiegler 2017), the progressive demolition of his role of critical thinking, that Stiegler sees as the proletarianisation of scientific work (Stiegler 2020) within the new economic and technological arrangements of capitalist societies. In particular, it seems to me that it is very important for you to challenge a series of confusions generated by the bad analogies still widespread among Artificial Intelligence theorists. Starting from a whole series of erroneous epistemological assumptions, it is in fact believed possible to replace the role of theoretical construction, the result of patient work and collective confrontation, the role of interpretation and the production of meaning, with a mere accumulation of data made possible by the new digital technologies. This difficult and creative theoretical work is believed to be replaced, illusorily but with serious concrete effects, by rule-based thinking grounded on logical deduction mechanisms that can be processed anonymously, formalised and automated, thus allegedly objective. You insist, in particular, on attempts to take scientific invention away from the human being, by also giving these follies a mathematical response. How can you articulate a defence of scientific intelligence against the claims of so much Artificial Intelligence?

Giuseppe Longo A1. Let's start with a "classic" example. According to H. A. Simon (1977), one of the founders of Artificial Intelligence, a computer could have discovered Kepler's laws from the data of Tycho Brahe. Are we on the verge of replacing scientific intelligence with artificial intelligence? Let's go back to the source…

In the golden age of Arabic astronomy (the 9th to 12th century), scientists already had an enormous amount of data on visible planetary dynamics. Among them, Ibn Yunus (Egypt, late 10th c.) had observed the positions of all the known planets by producing vast quantities of astronomical data, used later in the Alfonsine tables (Catholic Spain, 1483), a fundamental tool for the explorations of the oceans. The theoretical framework of the era was geocentric (Ptolemy), which, from the mathematical point of view, is perfectly justifiable; specifically, *any finite set of points on an ellipse around the Sun can be interpolated by enough epicycles centered on the Earth*, all turning around one another. In modern terms, it is a question of a sum of suitably centered series. So, whatever is the amount of data on celestial bodies' relative positions, a computer can wonderfully interpolate them by enough epicycles. Predictions? Mathematically, this is hellish, even impossible - except for the moon, of course; to understand the future position, they could only base themselves on the past, and even then, this was far from obvious. Astrology was also one of the skills of the astronomers of the era, (Blake 2016), and the certainty of predictions of human destiny gave rise to very lively debate (Livingston 1971). And what about computers? Do they prefer epicycles or ellipses? Dare they do astrology?

Decades *after* Copernicus (1473-1543), Tycho Brahe (1546-1601) certainly contributed, via his data, to the birth of the new astronomy, but this data is not sufficient, it was said, to change perspective. The scientific issue is that the to-and-from motions of the planets ("retrograde motion") in epicycles are incompatible with a fundamental principle of the physics revolution, the *inertia principle* of Galileo (1564-1642). Copernicus had little knowledge of Arabic astronomy and did not have this principle – instead, an important source of inspiration for him was the perspective, invented by Italian painting (van Frassen 1970), a geometrical construct capable of explaining and modifying the point of view of the observer, including the astronomer's view-point. The end of geocentrism was first of all a deep, historical, metaphysical and theoretical change, a change of "perspective", for which many paid the price, as it was also rich of theological sense – the birth of a plurality of Christian religions. In this way the fusing of the point of view of Copernicus, the principle of Galileo, the data of Brahe and the properties of Kepler made possible a different understanding of planetary motion, even the most familiar. Their framework of intelligibility had totally changed: it was based on properties both physical (inertial motion) and geometrical (Kepler's laws) which were incompatible with the geocentric approach. Over time, the fall of apples, the movements of celestial bodies and their causes in terms of newtonian mechanics and, later, of relativistic space-time curvature would be successfully unified.

That's the unity and strength of scientific thought: the emergent patterns of Big Data, already so voluminous at the time of the Arabic astronomers, would never have produced this metaphysical change of system. Why should one decide, against lived experience and all received wisdom, to take "the Sun's point of view"? To think of inertia, this rectilinear and uniform motion that cannot be observed anywhere, as the "default state" of matter (Galileo)? To invent equations without physical meaning (Newton), to then manage to give them a meaning thanks to a new geometry of continuous deformations of space-time (Einstein)? Even the imposition of an optimality principle would not be enough without these decisions and these principles.

Only the insensitivity to history of certain scientists can lead us to forget the immensely rich historical process of construction of human knowledge. To this we must also add an ignorance of the interpolative power of mathematics, which can project epicycles, or even patterns, everywhere, even in the realm of the random – an issue to be discussed below (sect. 10): in any very large set of data, even generated at random, a computer will find regularities – and thus derive nonsense.

2 - Intentionality vs Program : The memory of *prégnant* lines

Andrea Q2. These remarks recall your insistence on the need to distinguish two realities that are often obtusely superimposed: on the one hand, the semiotic processes that characterise the "interpreted information" of living beings, which is always constructed from a sensible world, to quote Merleau-Ponty; and on the other hand, every attempt, however sophisticated, to artificially reproduce these processes, in which information is ultimately translated into an anonymous transmission of data.

Overlapping these dimensions means losing sight of the specific materiality of morphogenetic – or rather "heterogenetic" – dynamics, to quote Alessandro Sarti's work, which is dear to you, as often happened in the proliferation of cybernetic models in every disciplinary field in the second half of the 20th century.

Information received from experienced intentionality is quite different from mere information processing, which can be formalised and translated into automatable mechanisms. As Viktor von Weizsäcker wrote, biology and phenomenology are linked by a 'mutual factual affiliation' (Weizsäcker 1926). If phenomenology is concerned with the sensory experience, the latter is what specifically characterises living forms and the 'pathic' dimension of their existence. This means that the "interpretation" concerning the relationship between living beings and the environment is inseparable from the affective, emotional, desiring field of their experience, from the concrete spatiality and temporality in which their behaviour acquires its own always singular, creative, imaginative meaning. In your research you have often returned to the problem of the specific dynamics of living activity, combining your computer and mathematical skills within a much broader theoretical framework that includes physics, biology (in its many branches), semiotics, ethology and neuroscience. How can we understand, from your point of view, the extraordinary progress in the recognition of images, sounds, speech ...?

Giuseppe A2. You probably remember Plantu's caricature of Jacques Chirac: just a line, a profile. Anyone who was old enough before 2007 can recognize the former President in it. In fact, in this line, the "*prégnance*s" of a face are recognized. What does this word mean?[3]

When we meet a friend we haven't seen for thirty years - a friend from our college years, our first girlfriend - everything about their face has changed, they've got so old! Nonetheless, we can make out their smile, a crinkle under the eyes, their gaze. We no longer recognize the features, the "*saillances*" ("salient forms") of this face, still less their details, but we find again what was important for us, the *prégnance*s: those expressions and movements of the face that were dear to us, that were *meaningful*. Because the smile, the accompanying crinkles under the eyes, the gaze that recognized us, are all movements of the face. And they were significant for us, they were *prégnance*s, accompanying their emotion and our emotion. That is how the artist capture in a single line the "*prégnant*" movements that speak to us of the Presidential face, his expression.

Beware of those hypermnesics studied in old Russian psychology: pathological cases of people who remembered all the details of a face - not long after, they were incapable of recognizing a previously familiar face. In fact, an essential component of animal memory is forgetting. At the time the memory is formed, we select what matters. The child must learn to neglect, or even forget, the colour of the ball thrown to him if he is to learn to catch a ball in flight. He must form the invariant of a trajectory and learn to *precede* it with a saccade, independently of many details. Via the gaze, he will anticipate where the ball will be found to precede it with his arm. In fact, by trial and failure, he will learn to plot with his gaze the "curve of pursuit" that is essential to catch the ball; this curve intersects the one that the ball will take. The predator in us has developed a complex system of preconscious predictions, embodied in saccades which precede the prey, anticipate its trajectory (Berthoz 1997). Every tennis player is well aware of this; she must integrate in a rapid cerebral and

3 We follow here the *prégnance*s/*saillance*s distinction in (Thom 1988), these notions are though redefined following ideas in (Sarti & Barbieri 2017).

corporal circuit the vision, prediction and action that allow her to extend her arm to the right place before the ball arrives. Flight also requires a prediction of the predator's trajectory: to run away in time it must be anticipated.

The brain does not do this in isolation, as if in a jam jar - or in the metal box of a computer. Only strong integration in the body allows these protensive gestures (i.e. gestures that "orient and precede", that "go towards"), essential to any movement, in any situation, independently of changes that are insignificant to the action being performed. Muscles will also keep a memory: they must integrate brain activity as well as they can by lived experience which is constructed, practiced, cerebral and corporal at the same time, which entails, for example and at the highest possible level, the very hard training of the athlete. The synaptic reinforcement of a violin player is strongly correlated with those of the muscles of the playing hand and arm (Maffei 1998).

The forgetting of details is therefore essential to the constitution of an animal memory, a memory that exists first and foremost to allow the appropriate future action, without getting lost in memories of contingent details. And, when the new protensive activity occurs, the brain, in its body, subsequently selects that which serves the action in progress. Memory reconstructs the traces of the past according to the needs of the present; it does not use, and even subsequently forgets, what is no longer of service. And the choice of what to continue to remember is imbued with lived emotions, even when learning to hunt, for the young animal. It is highly unfortunate that the same word "memory" is used for the electrical storage of sequences of 0s and 1s, integer numbers, in exact databases. I will further develop these themes in a book (Longo 2023).

3 - Neurosciences and Artificial Intelligence: the question of meaning

Andrea Q3. Can you explain in more detail how this distinction between "saillance" and "prégnance" – which you, inspired by Sarti, take up and re-elaborate starting from the work of Réné Thom – and the different criteria of formalization and mathematization to which they can give access, concern the field of neurosciences, often invaded by research on Artificial Intelligence and where we frequently find the further abuse of neo-mechanist computer models?

Giuseppe A3. The great turning-point of Artificial Intelligence, AI, has its origin in the revitalization of an old *model* of the brain. It had been recognized that synaptic reinforcement is an essential component of cerebral activity since the famous research by Hebb (1949): a motor, or even cognitive, activity, reinforces the connections between neurons. Soon, especially from the Perceptron (Rosenblatt 1958) onwards, attempts were made to model this phenomenon by a (mathematical) network of artificial neurons, with (continuous) variations in connectivity.

This area of research struggled to survive in a scientific context dominated by the "imitators" of the brain. Let's explain what we mean by this. In a famous article from 1950, Alan Turing, inventor of the Logical Computing Machine (1936), the mathematical foundations of the modern digital computer, proposes a game, the *imitation game*. A computer is programmed to pretend to an interlocutor that it is a woman; the interlocutor interrogates the computer and a woman via teletype, to detect its nature. Turing argues that, in 2000, a computer would have been able to win in 30% of cases, if the interrogation does not last for more than five minutes. Later, working on a very different subject, biological morphogenesis (1952), he would propose a *model* for the generation of physical forms in living beings. I have already written on the subject of this fine distinction in several articles and even in a personal letter to Turing (2018): in short, the model attempts to grasp, by mathematical description, what matters in a dynamic, what makes it intelligible (for example, the interplay of forces in morphogenesis: action, reaction, diffusion (Turing 1952)); the aim of imitation is to "pretend" that one thing is the other, without the intelligibility of the phenomenon being involved (Turing 1950). Classic AI has been focused, from the 1950 article onwards, on imitation, considering that the artificial neuron model is no more "expressive". In fact, a finding from 1969 by Minsky and Papert had demonstrated the very obvious thing that neural networks do not compute more number-theoretic functions than the Turing machine and that they even have difficulties with *exclusive disjunction* ("one or the other, not both"), analogous to those which are found for the "parallel or" in lambda calculus (Church 1932)[4]. And for a long time this condemned to almost complete silence those modelers of the brain using artificial neural networks.

Very fortunately, based on the research of Hinton and LeCun, in the '80s and '90s, the use of several layers of Rosenblatt's networks, originally two-dimensional, relaunched this approach to AI, (Deep Learning - "deep" as in three-dimensions). "Inverse propagation" techniques thus make it possible to correct and adjust the weights of connections faced with a stimulus, in fact data in increasingly large amounts.

More generally, by methods of increasing complexity from the mathematical point of view, by interweaving, filtering and convolution, "wavelets", statistical regression and renormalization techniques, (Mallat 2016, Shuo-Hui 2018), a powerful mathematical universe for many activities of image, language recognition etc. has been built. The two-dimensional model of the brain has thus been transformed into a new, and much more powerful, imitation: the more the layers are increased and the mathematics are enriched, the further one gets away, structurally and functionally, from a model of the animal brain – the brain is truly three-dimensional, with connections in all directions, better described by very complex Riemannian geometries (Petitot, 2017). Moreover, the artificial multi-layer networks are "generic", in the sense that the same structure can be used for the recognition of voices, faces etc. The brain, instead, so little-known when it comes to details, appears to have very different organizational methods depending on the function; in short, the parts of the cortex dedicated to vision or hearing, or even to smell, have structures made of specific networks, strongly and differently connected in all three dimensions - they cannot be considered as layers of two-dimensional networks, still less generic. The great plasticity of this organ, however, allows it to perform very significant vicariance activities: one part can take on the functions of another, or even restructure itself to take on the role (Berthoz 2013).

That said, this new imitation of the brain has opened up a remarkable path to a radical renaissance of AI. The analysis of thousands, or even millions of labelled images (this one is a cat, this other one is a chair etc.) allows the machine to form invariants from *saillance*s, i.e. to identify shapes common to all objects of the same type – in no way trivial imitations of the animal memory's invariant formation. The

4 In fact it suffices to limit any process to the computation of the functions on integer numbers, so that, once formalized in the manner of Hilbert, it can at best compute the computable Turing functions - this has been known since the 30s. Neural Networks do much more than "computing input-output number-theoretic functions": they constitute invariants of vision, for example.

labels are affixed by humans, thousands of (low-paid) workers in India, China, but also Latin America and Africa, who classify the universe of all things, faces, situations etc….the greatest endeavor of classification in human history - and so we, too, are stored in categories (black, white, Hispanic etc. for example).

In summary, filtering methods applied to thousands of images select a finite number of points of each image, reconstruct invariants by interpolations/convolutions under certain transformations (by approximating continuous mathematics, in some approaches). The computer thus constructs invariants from the iterated image of the same object in different postures or situations. Gradients give local optima and a recognizable shape appears or is recognized by the machine. In vision and sounds, or even voices, the machine, which has been shown thousands, millions of examples, stores in its memory the links between a collection of these examples, images, phonemes, and labels: this is a car - it has all the *saillance*s of a car. Of course, this process of constructing invariants for associating images of the world with a given classification, independently of specific details, is only a pale imitation of the role of forgetting in the animal memory. It selects only visual, auditory etc. *saillances*, and organizes them into classes which are invariant with respect to a few small changes - not all, just those that have been shown to it.

4 - Pregnancy and embodied intelligence

Andrea Q4. As you said elsewhere, some have long considered the Turing Machine itself a model of the brain ("strong" AI), an organ in a box that would only do ‘‘0/1 - erase/write - left/right’’, in opposition to what Turing writes (1950 and 1952), and you nicely commented on this opinion by saying that most of these colleagues were probably working based on introspection. Despite the growing complexity, in these attempts to technically reproduce of behavior – which confuses the situated and sensible experience of the *Umwelt* with the storage and immediate recognition of reiterated forms in a generic space – we still have the same fundamental error. We have again a disembodied and de-historised consideration of living perceptual "inherence" and "motivation" – to once more use some of Merleau-Ponty's concepts (Merleau-Ponty 1945).

Giuseppe A4. Right. No emotion, no *prégnance*, no meaning helps the machine to select "what matters." However, in animals, including humans naturally, it is the *prégnance*s that help to stabilize the relevant invariant: the eagle recognizes a mouse running to hide behind a bush from 200 meters away, but ignores a photo of it shown from a meter away. The interest in the target object, hunting, or flight motivate the choice of details to be forgotten, the selection of the *prégnant* invariants for action, just like the meaning of a gesture, the "chin thrust" allows us to recognize Chirac in one line. And a child learns to catch the ball in a beloved game all the better if it is his mother who throws it to him, or someone dear or well-known to him. As hinted in (Sarti, 2018), *prégnances* contribute to the sensitivity of and shape even the primary cortex. More generally: "These [brain] morphologies do not only depend on external stimuli, but are modulated by an embodied evaluation process, linked to the signified of the very stimuli given by the situated organism. These simple but fundamental cerebral systems are to be considered as *prégnant* forms, i.e. forms which, in the vocabulary of the mathematician René Thom, already contain elements of meaning. It is therefore a question of proto-semiotic forms that form the brain as a system to produce meaning rather than the processing of information" (Sarti & Monier 2018). Husserl's intentionality is the ultimate, conscious component of this very deep and evolutionary ancient process.

Many examples show errors in AI, sometimes catastrophic (fatal accidents in self-driving cars, see below), due to tiny details of no importance that have not been ignored by the machine and have confused the image (Marcus 2018). How can they be excluded from the artificial process of recognition of an image, with a goal chosen by the programmer – the driving of a car, for example? The vast mass of examples with which the computer has been fed at best makes it possible to exclude details as noise in relation to *saillances* previously established or constituted in a process without interpretation, without meaning: only a meaningless computation guides the selection of what details to exclude. We continually use judgments of *prégnance* to exclude details.
The reference to the difficulty in establishing a "formal hierarchy" in the determining of details, which is often made in AI, attempts to empty the question of meaning by a Chomsky-style approach (Williams 2017), also applied outside language processing. In short, there is a recognition of the difficulty that the machine, an implementation of a formalism without semantics[5], has in making hierarchies between what matters and what matters less, or even has no importance, for the purposes of the action to be performed. This search for a solution a la Chomsky still falls, however, within the framework of a formalist approach, to language in particular: the construction, then, of a hierarchy of "what matters" would only be a deductive calculation, engendered by meaningless generative grammars. On the contrary, these hierarchies are not a "formal" question, the results of an algorithm to be refined in the construction of the invariants of *saillances*, but are constituted by a practice of what is *prégnant* for the animal *that is acting with a goal*: the animal organizes the world in relation to this goal and the ensuing action, in the spaces of life of its material body; on this basis it forces priorities, hierarchies of meaning. If one is not hungry one does not learn to hunt, or scream or cry for food, or, also, an animal can learn to hunt, a human to ask for food, by playing or imitating others in the group. Many mammals, when they follow the group or their progenitor in the hunt, are motivated by attachment, love: social or filial affectivity recognizes, in the imitation of similar bodies, strong *prégnance*s, or even what matters in a shared action. In general, the mother is the very first semiotic mediator between the child and the world - her emotions, to which the child is extremely sensitive, her singular gestures and gaze, teach the child what matters (Violi 2009).

5 – Interpretation and Information: recognizing a cat from the imitation of a cat

> **Andrea** Q5. We are still faced with the problem of the irreducibility between lived experience, linked to the concrete dimensionality and historicity of the relationship between body and environment, inseparable from the affectivity of the intersubjective relationship, with respect to any artificial reproduction of it. The contingency of the situation "in vivo", always played in improvisation, in the active relationship of meaning, cannot be reproduced by a system programmed *a priori* storing a casuistry of stimulus-response relationships pre-established. Kurt Goldstein's famous polemic against the mechanistic theory of reflex comes to mind: "If the life of the organism consisted merely of an interplay of elementary factors that kept each other in check, how could any movement, any dynamics, enter into the situation to give direction to

5 In the case of a formal system, the difference between semantics in the strict sense, as "meaning" by a geometrical interpretation for example, and so-called operational semantics, which remains a formal calculation, is summarized in (Longo 2019). A classical example of the first is the geometrical meaning of the imaginary number "i", a meaningless (and audacious) sign operationally used to solve equations, since Cardano (1501 – 1576), as a coordinate in a two dimensional space (Argand-Gauss, late XVII century).

behaviour? And direction is what we actually find as the outstanding characteristic in the performances of an organism" (Goldstein 1934). This relationship of situated, projective meaning escapes the classical criteria of measurability, and requires the elaboration of new mathematics. This question is at the heart of the work you are conducting – together with Nicolas Bouleau, Maël Montévil and Alessandro Sarti – within the Cardano group (https://cardano.visions-des-sciences.eu/).

Giuseppe A5. The digitized images of one cat, two cats….a million cats, in many possible contexts and positions: here we have a database for machine learning. If the cats have been labeled with their contexts (millions of images are associated with names), the learning is *supervised*, otherwise the machine identifies and memorizes common relationships between elements in the database and classifies them using general criteria, pre-programmed in various ways (*unsupervised* learning). Yet, this pre-programming leaves some margins to the machine that cannot be considered totally programmed. Newly recognized saillances, in particular in unsupervised learning, may force new rules. In both cases, this makes it possible to associate inputs with outputs and these associations feed databases of correlations, and thus new data that improve the performance of the machine over time. The recognition of language and images has thus made enormous progress, so breathtaking and in such a short time that "over-attribution", which is practiced with animals (my cat knows that…, the ant thinks that…), is also common when dealing with one's favourite machine. However, formal invariances thus constructed lead to equally surprising errors, due to the absence of meaning. Tiny perturbations to an image, such as the change in a coordinate of no importance, have led to serious errors (Kansky et al. 2017); in mathematics, the teaching of the identity between even numbers is not extended to uneven numbers (Marcus 2018). All this shows the absence of meaning, the only guarantee of robustness of action and animal intelligence: in the latter case, the simplistic induction performed by the machine has nothing to do with the gesture of the mathematician who interpolates and plots in thought or draws and therefore *interprets* the relationship between numbers *mentally seen* on a straight line - then identity visually extends to all numbers.
Similarly, millions of images were not enough to distinguish between meaningless black and yellow stripes and a school bus (Nguyen et al. 2015) – the contrary would have produced a typical accident case for a self-driving car; in fact, a traffic signal for aligned parking spaces is recognized as a well- filled refrigerator (Evtimov et al., 2017), (Vinyals et al. 2015). In both these cases, comprehension of the contexts of meaning would have dispelled any ambiguity.
When we are told that it is a question of improving the algorithms, or even increasing the databases, on the one hand a relevant remark is indeed being made, but on the other, by envisioning the possible "completeness" of computer systems (machines will one day be able to do everything), a frightening vision of the world, of nature is being unveiled. The world is not a collection of labeled images and sounds and numbers. The labels and numbers are not "already there" in nature. We associate names and numbers with processes by the difficult operations of *segmentation* ("découpage") and *classification*, then possibly *measurement* by associating numbers to the segmented and classified fragment of reality. The first two are protensive actions rich in emotion, at the core of human activity in the world, that we *qualify* by a historical formation of sense of the world. Measurement via the senses, or even scientific measurement, is a further, difficult business: it is necessary to choose an observable, a metric to a quantitatively segmented reality and then

determine a possible approximation in order to associate a number with it. It has been known since Poincaré (1892) that the slightest fluctuation below the best of the measurements of a classical dynamics can produce, over time, an enormous change in a process that is somewhat sensitive to initial conditions. Quantum physics (1900) and relativity (1905) have given measurement a central role, which is indeterminate or gives rise to surprising space-time correlations. In fact, there are whole libraries dealing with the question of measurement in physics, the association of a number with an observable that one decides to measure in a well-segmented and mathematically classified process. The situation is even more complex in historical sciences such as biology (Longo 2017; Montévil 2019) and hence in historical human sciences in which the segmentation and classification of what is relevant, and the choice of observables and metrics, are also political and social issues.

Similarly, human language is not the association of labels with things, an unrecognizable caricature of the man in his relationship to the world that is found in many constructs of the artificial realm. Human language begins when humans talk about *what isn't there*, when they give names to ancestors, gods, the laws they invent to live together (Lassègue 2007). Language is at the heart of a process of objectivation of the real of enormous symbolic richness and jointly forms our humanity, in its diversity and history (Lassègue 2015). A child does not label a mug with its name after inspecting many of them, but she learns to go and get a mug, and drink from a mug. She does not learn the name "cat" *in abstracto*, but when, full of fear, she dares to approach a cat with her body and stroke it. The emotion is such that only a single time is needed to learn many characteristics of this animal, for ever – and understand why her parents call her "my little cat".

The problem of artificial intelligence is not only that of better understanding what these computers and these absolutely terrific programming systems that we are currently making do, and what can be done with them, but also that of the view of humans and nature that too many technicians with no sense of history, both natural and human, transmit to one another and impose on us. These distortions of knowledge sometimes have the support of fashionable philosophers, who tell us that everything is computation, everything is information, without even having the technical skills, who do not even know what is meant by a computable function, the association of a number to a process and its limits, so well explained since Gödel (Kreisel 1982), (Longo 2018).

Very fortunately, the use of refined mathematical methods (wavelets, renormalization, eigenvalues etc.) have enormously enriched the practices and theory of AI: it might even be hoped that this could help to invent a new concept of computation and new machines, beyond the computations installed in this conventional machinery, discrete-state and therefore Laplacian, which only provides an identical iteration of the digital computer (Longo 2018t). The new rigour and power of this mathematics, often in continua, goes well beyond the arithmetic formalism at the roots of Turing's Logical Computing Machine, on which one is forced to implement it, and already makes it possible to demonstrate its limits, by a non-obvious mathematical result: the existence of an optimum in machine learning has just been proven independent of (unprovable from) the classic axiomatic frameworks (Zermelo-Fraenkel), as it is equivalent to the Continuum Hypothesis in Set Theory (Shai Ben-David et al. 2019). One cannot therefore have a *uniform* and *effective* method for computing optima essential to the construction of invariants of computations: for each type of problem a human will inevitably step in to define a suitable optimality method, depending on the (Set Theoretic/mathematical) context. Like any negative result in the history of mathematics, this imposes limits on knowledge projects and, at the same time as it defines them, can open up new paths to knowledge (Longo 2018).

6 - Labour between technology and a biological philosophy of technics: the effects of announcement and the meaning of actions

Andrea Q6. One part of the dialogue you and Maël conducted with Stiegler concerns the concept of negentropy (Montévil et al. 2020). As you and Maël have shown in a number of papers, there are several theoretical abuses in the application of this concept in order to understand living activity, its organisation and its co-evolutionary historicity. In spite of this necessary clarification, I think you will agree that through this issue Stiegler primarily wanted to rehabilitate the concept of work, as *labour*, which he sees as negentropic activity *par excellence*, with respect to Simondon's theoretical approach. From Simondon's perspective, in fact (Simondon 1958), the role of work was strongly minimized in order to understand the specific normativity of the technical object - an issue on which another famous student of Canguilhem, Yves Schwartz, focused his criticism of Simondon (Schwartz 1988). Stiegler was well aware of the risks of this perspective, which if taken uncritically could legitimise the well-known theses on the "end of work" (Stiegler 2015)[6]. The technological revolution, with which capitalist industrialisation reorganised production activity and introduced machines, promoted a fundamentally new mediation of social labour. This would be progressively replaced by an increasingly complex technological apparatus, managed by immaterial work of a predominantly intellectual order. It is certainly not possible here to summarise the complex debate on 'cognitive work', the problems and doubts it raises and the positive contributions it has made to our understanding of the transformations of the logic of production and the social figures involved. What I would like to focus on at this point is how this new *couplage* between man and machine, the way in which a whole new series of technological devices have progressively permeated large swathes of contemporary societies, has given rise to a whole series of 'hybrid' conceptions of the human and to the proliferation of new analogies that employ the operating criteria of artificial machines as the key to understanding living as well as social activity. Everywhere, from the social to the economic space, from the neurological to the micro-cellular, we would have systems of communication, information transmission, and programmes, with all the consequences that this entails in the illusion of being able to measure, control, and predict an extremely heterogeneous set of phenomena brought back to the probabilistic regularity of a uniform matter.

Certainly Simondon too, in the wake of Canguilhem, carefully distinguished the functioning of the machine from that of the organism (Simondon 1958, 2013). But it was Canguilhem (Canguilhem 1962), and after him Schwartz (Schwartz 1988), who insisted on the "necessary anteriority" of the organism – and therefore of the body, and therefore of work – with respect to the machine as its irreducibly prior "condition of existence", both as its enabling and binding conditions, as well as its "surplus" condition. The activity of bodies, in their constitutive and cooperative relation as well as in their differences and singularities, provides the living work which supports and vehicles all technological transformations. Through this "biological philosophy of

6 Elsewhere, Stiegler levelled further interesting critics of Simondon regarding the political limits of his enthusiasm for the digital transformation of labour in the second part of 20th century (Stiegler 2006).

technique", Canguilhem affirmed the need for a reversal of the relationship between life and technique, against the subordination of the organism to the machine that had been imposed by industrialisation and against the condition imposed on the worker by capitalist relations of production. In this sense, as Canguilhem argued, it is a question of "putting the mechanism back in its place in life, for life" (Canguilhem 1947), of recognising its function as an instrument in relation to a vital dimension that precedes it, rather than making it the model for understanding living things. This goes hand in hand with the recovery of the relationship of meaning between technology and work, against all illusory autonomy of technology based on the bad analogies between the living and the machine. Do you find these reflections still relevant? How would you articulate them among the many promises, myths and real effects on human labour?

Giuseppe A6. Before focusing on the delicate issue of entropy and its thematic variations, let's discuss the main motivation, as you suggest, for introducing this technical notion from physics in the analysis of human activities, work or labour in particular. Do you remember Google Glass? Where is it now, four years after its announcement? And the universal assistant M by Facebook, launched in 2015, and since dropped?[7] The self-driving car resurfaces from time to time, with a big moment in 2014-15. And where now are the huge programs of replacing human drivers? All taxis in Pittsburgh, PA? Some cities, in France, also invested in this. All gone. Volvo has just postponed its grand projects by four years[8]. The Uber programs have lost a good deal of ambition: an "employee" now accompanies the car - a number of fatal accidents in California and Arizona have caused the flood of promises to dwindle away[9]. All this in spite of global financial commitments touching on 3 billions dollars in 2017 (Marcus 2017). However, the threats to replace drivers (this has been said in France, with reference to the 700,000 professional drivers in this country), or even human labor altogether, are now permanently hanging over the workers. This is probably the most important role of all these promises – see these examples and many others in (Audétat 2015). Perhaps by putting both human and self-driving cars on electronic rails, like airplanes, this can be done, but then we should include pedestrians and ... dogs (why not?) by a close 5G - GPS control. I would love to sit in a car and be safely driven along rails, but the aim may be achieved only by a global guidance of everything and everybody, from the pedestrians to our way of walking and behaving, along rails – if this ever works, it is just frightening.

As for self-driving cars, though, we drive a car as if we were going on a hunt: we precede/anticipate with the gaze any moving object. More generally, animal intelligence is not (only) the formal elaboration of information, of "data" that come and go, but (also) the "imagination of configuration of meaning" (Sarti & Monier 2018) and the result of emotions, which shape memory and protensive action.

These configurations, these *prégnant* emotions guide and result from the activity of living, in a body, in a historical life situation. The brain, in particular, is not an input-output machine. It is so active that, in complete isolation, without the bodily and ecosystemic restrictions that marshal its activity owing to the action of the body in space, one becomes insane following the chaotic dynamics into which the neurons are plunged. The biological, ecosystemic, historical contexts *constrain* brain activity,

7 https://www.wired.com/2015/08/how-facebook-m-works/

8 https://www.wired.com/story/self-driving-cars-challenges/

9 An overly white truck against a white sky that was making a U-turn, a woman with an overly large skirt who was crossing the street pushing a bicycle – can one ever do such a non standard move?

while constructing sense out of this friction. The primary gestures that are canalized, come into friction with and correlate us with the world are the expression of "motricity (which is) the original intentionality" (Merleau-Ponty 1945), from the amoeba to us. This is how "the gesture, which starts with motor action, roots significance between us and the world, at the interface of the two. The chemical, thermal signal, which affects amoeba and cell, is "significant" for the living, regarding its current internal change, its action and its protensive movement". (Bailly & Longo 2006, p. 71).

There is of course a chasm between protensive activity in the amoeba and that in the ever-active and very strongly correlated neurons in the brain of an animal acting in the world with its body: the result of a stimulus is not the linear composition of those happening at monocellular level - everything changes in the non-linearity of the interaction. The signals that affect neurons mold the shapes of their exchanges, their networks, by superimposing vision and emotion, sound and fears, smell and desire.

Going back to what you said about Simondon, we certainly need to review some of his positions about the role of work. However, following the example of Bernard Stiegler, it is possible to maintain a critical distance while at the same time capturing in his work several useful instruments of reflection. For example, Simondon wrote: "*The machine may be out of order and present the operating characteristics similar to a mad behaviour in a living being. But it cannot revolt. The revolt indeed implies a profound transformation of the finalized behaviour, and not a malfunction of the conduct*" (Simondon 1989, p.272). Scientific research is always a revolt, however slight. A new idea transforms scientific behaviour, a direction of research, however small this change may be. Even within a community, it has its origin in a disagreement: no, it is not thus - this or that must be seen in a different way… Original thought is always critical, it requires a sidestep in relation to the very principles of knowledge, the availability to modify them. Discussion and debate are at the core of the construction of knowledge; the possibility of disagreement and the formation of a small space of thought for a minority exploring a new direction are essential. This is the contribution of science to the democratic method: its need and its practice of diversity, reasoned and freely compared. The loss of this "ethics" and role of science is the main consequence, in my view, of what Bernard calls a proletarianisation of scientific work.

Computer networks give us extraordinary tools to bring us into contact with distant colleagues, different experiences, to compare divergent visions, access rare texts, forge unexpected collaborations, construct immense data bases accessible to everybody, then interpreted from different viewpoints. They can however be used for the opposite, to "normalize" us. Automated bibliometrics (citation counts) has this effect: it forces us all to adapt to the thought of the majority, channels all minds towards the strongest school of thought, or even towards banality, common sense, fashion (Longo 2014). In France, we have perhaps won the battle and, at least formally, evaluations should be based on scientific content and no longer on machine ranking, "majority" votes (citations of colleagues across the surface of the Earth). Majority thinking makes it very difficult to form new thought, which is of necessity minority thought. In many countries, however, the battle is not yet over and, as is the case in Italy, budget cuts to Universities and Research have been accompanied for the last two decades by evaluations largely devoid of meaning. Other countries, like France, are quickly following. One might ask if and how this attack on such an important type of critical thought, scientific thought, might not participate in a crisis of democracy, of diversity in debate, including on the economic and social level.

Scientific research is increasingly reliant on computation and computer modelling, often a wonderful enrichment of tools for thought. In physics and biology, by modelling that assists in the intelligibility of phenomena, fundamental milestones have been passed. Even in pure mathematics the use of computers as "proof assistance" gives wings to the imagination of the mathematician; he can isolate the purely formal lemma, which requires insane amounts of computation, hand it over to the machine and…concentrate on the invention of original concepts and structures. The same goes for the physicist who finds herself thinking even more freely, exploring simulations without practical limits. Caution is needed, however. Overly expensive physics experiments are paving the way to purely computational "on-screen physics", at almost no cost, which can distort the intuition of young physicists and their view of nature. In biology, the crisis in certain fields, (Ioannidis 2005), (Nuzzo 2014), suggests that "with enough data" enormous clusters of computers will extract from Big Data instructions on how to prognosticate and heal … without understanding or even renouncing to understand, as some propose for cancer (Longo 2018c) - although mathematics says that this will not work (Calude & Longo 2017).

This caution must even extend to those fields in which scientific research has derived the most benefit from the use of computers. If in mathematics and physics the emphasis, i.e. funding and recruitment, is shifted towards "more computing" and less thinking, there is a risk of distorting scientific construction. In short, if preference is mostly, or always, given to the project or mathematician who promises to crack an old problem with largely computationally heroic proofs over the one who works on new worlds of thought, to the physics modeller over the inventor of new theories or directions of research, there is a risk of research work losing its way, affecting the perspective on nature as well as the mathematical inventions so often associated with it. Scientific activity can seem atypical, and probably is, but similar paradigms can affect other aspects of human work.

7 - Entropy, negative entropy and anti-entropy. From physics to biology and ecology.

Andrea Q7. Returning to the question of the problems linked to the concepts of entropy and negentropy, on which you worked with Francis Bailly and Maël Montévil (Bailly, Longo 2009; Longo Montévil 2014), could you summarise what are the epistemological obstacles that prevent it from being fully taken up as a relevant interpretative key to biological and social phenomena? You seem to recognize some inspiring value to their introduction in human affairs, yet, you insist on the specificity of the terms and on the needed caution when transferred from physics. Moreover, the concept of entropy, despite its limits, has been at the center of a series of debates on political ecology, as we can see in the theory of Georgescu-Roegen about the destructive effect of production in capitalistic economy. We need to rethink these problems with better conceptual apparatus, merging ecological reflexivity with his elective epistemological criteria, ie in a biological framework.

Giuseppe A7. I am always very critical of the abuses and transfer of words from a discipline to another, where each relevant word has a specific conceptual history. Indeed, sometimes, a metaphor may suggest a new way of thinking, yet in other cases, such as the use of "information" or "program" in biology, one *implicitly* brings into a discipline an entire universe of principles that may mislead research and knowledge, (Longo 2018c; Longo 2019). Entropy, a delicate concept in a difficult branch of physics, thermodynamics, must be handled with care, yet Stiegler was using it in a creative way that opened a very relevant debate. I can only hint here to my understanding in an area that is controversial even in physics – typically, Prigogine's work in physics is still now open to debate, in spite of the Nobel award, in 1977, see a technical synthesis of it in (Prigogine, Nicolis 1977).

In physics, energy is conserved by principle; the increase of entropy means that however energy may become less usable to perform macroscopic tasks: when transformed, it disperses, degrades into forms of energy less and less "free" to do work, over time. Entropy can only increase in isolated systems, that is in systems which are not traversed by flows of energy and matter - which is the second principle of thermodynamics. But it is also produced by systems that are open to flows of energy and matter: it is produced every time there is a transformation of energy. It therefore also participates in the construction of the organization, because this too needs to transform energy. But more will be said about the "constructive" character of entropy. We will make it short here: remarkable surveys, in our perspective and with a full understanding of the major physical challenge, yet in a debate with Bernard, may be found in (Montévil et al. 2020; Montévil 2021; Montévil 2021a). For statistical physics, the increase of entropy in a physical system is the process of moving from less probable macroscopic states to more probable macroscopic states: the perfume, placed on purpose in a flake, will disperses in a room, by a random "spontaneous" diffusion, towards a more probable situation for a smell. It follows that the increase in entropy is the disappearance of unlikely initial characteristics, and their replacement by more probable characteristics. Like the perfume, a drop of ink disperses in water until it reaches a uniform situation, thus erasing the initial position of the drop: the probability that the perfume will return to the flake or the ink will reform a drop are minimal, but ... beware, not zero. This framework imposes a direction to time and challenges the reversibility of classical mechanics - the latter having no objectified time arrow - and leads to the cosmological perspective of the thermal death of the universe. In fact, entropy is associated with all irreversible processes, including the biological processes, as we argue below, e.g. one of the more constructive: embryogenesis.

Stiegler transfers one meaningful aspect of the word entropy in physics to many applications in human organization, for example, from the loss of organized and organizing knowledge to a "denoetization" caused by the destructive capture of attention. Knowledge and attention are organized states of human beings in their environment: knowledge structures us, correlates us, just as attention towards something, towards the others; denoetization disperses/destroys this organisation. In this sense entropy becomes a property of configurations, and more precisely, of the evolution of these configurations towards a loss of structure, of meaning as due to our communicating, structured, historical community. And this distinguishes entropy, in Stiegler's sense, from the question of the physical quantities in closed or opened systems, open to flows of matter or energy. It is directly linked to a loss of capacity to weave a dialogue between humans in a society. This is a new use of the concept, in a human/historical context; yet, we must be careful with hidden puns.

8 – Information *vs.* Organization

Andrea Q8. Indeed, although you share Stiegler's intent to criticize the disruptive "economy of attention" imposed by contemporary capitalist techno-power and her consequences on social individuation (Stiegler 2006a, 2008, 2014), you (with Bailly and Montévil) support the necessity to distinguish the pertinent employ of these categories. In particular, you explained the frequent abuse of the word entropy with a negation: negentropy. Can you clarify this problem?

Giuseppe A8. Reference is often, and justly, made to Schrödinger for having (first?) used the concept of "negative entropy" (What is life? 1944). This is entropy with a negative sign, so if "entropy = K logD", says he, where "D is a quantitative measure of the atomistic disorder of the body in question", he writes, "negative entropy = - K logD = K log(1/D)" and "If D is a measure of disorder, its reciprocal, l/D, can be regarded as a direct measure of order" (K is Boltzmann's constant). Organisms absorb order from the environment, he insists, including, fundamentally, the (very) organized energy of the Sun (photons coming from the Sun have an entropy much lower than those leaving the Earth, which are also colder). Next, an abuse was committed and a wordplay crept in: since Shannon defines information by a "p log p", where p are probabilities of a series of signs (a given, ordered series of signs, a book by Balzac for example, is not very probable), then negative entropy (now become negentropy) and information have been considered the same thing. Brillouin contributed to this, but with a bit of humour, in my opinion conscious of the word play in reference to a then highly discussed magic ‘‘demon" that would reverse entropy growth, (Longo, 2019). In fact, there is between the notions of negentropy and information a dimensional constant, the K of Boltzmann, which is not nothing in physics (the dimension! what distinguishes 1 meter from 1 second!). Schrödinger (and Stiegler) did not make this mistake. Schrödinger added in a note: by negative entropy one should understand free energy (available to do work). For Stiegler, negentropy opposes social and cultural disintegration, by human activity (work). It therefore opposes a specific aspect of entropy, which however, I was saying above, is also produced by the "putting in place of organization" (evolution and embryogenesis, typically, but also a … tornado), it can even be functional in its analysis. In short, a cyclone is an organization of a flow which contributes to a fast dispersion of energy: the setting up of organization and entropy go together, cannot be opposed. Conversely, a major glaciation would decrease the entropy of the earth (by releasing it inversely as heat into the rest of the universe), but it would also destroy living and social organisations - then decrease Stiegler's negentropy as well. Thus, both philosophers and physicists need to be careful and make explicit reference to which level of organisation or interacting levels they are interested, which are the pertinent observables, the intended theory. For more, see the papers by Montévil quoted above, in particular, in a clarifying debate with Stiegler, (Montévil et al. 2020). Let's follow a parallel path of explanation.

To avoid confusion, Francis Bailly and I (2009), then with Mael Montévil, as summarized in chap. 9 of (Longo, Montévil 2014), we called anti-entropy a measurement of biological complexity which is neither information nor negentropy. The choice of the word anti-entropy is due to an analogy with the notion of anti-matter as well as a differentiation from that of negentropy by Schrödinger and Brillouin. Typically, since entropy and negentropy have the same dimension and just the opposite sign, they sum arithmetically - and give 0 when they meet in equal amounts. Instead, when matter and anti-matter meet, they do not give 'zero', but produce gamma radiation, energetically double with respect to the amount of matter observed - a physical singularity that can be measured (this is how anti-matter was 'discovered'). Analogously, entropy and anti-entropy production co-exist in an organism, a biological singularity - an 'extended critical state' (Longo, Montévil

2014). Bailly and I proposed anti-entropy, in 2009, in the aim of a specific application - a somewhat technical modelling of Gould's analysis of evolutionary complexity: anti-entropy supplies a measurement of it - (see Longo, Montévil 2014). It depends on spatial dimensions - which is absolutely not the case for the digital information, of Turing or Shannon, strictly one-dimensional, sequences of 0 and 1: in its first version, anti-entropy "counts" the folds, the fractal dimensions and structures, the number of tissues, the nodes in networks (neural etc.) of an organism. The increase of complexity of organisms, as anti-entropy, is described by a random diffusion of bio-mass over anti- entropy, a simple mathematisation of the analysis in (Gould, 1996). Maël highlighted the crucial role of symmetries and their changes in the production of anti-entropy.

In this context, I am some reservations regarding on a "purely destructive" role that is sometimes attributed to the (physical) notion of entropy: it is possible to specify another meaning of it and this according to the scientific context. Typically, entropy in the sense inspired by physics, is produced by all irreversible processes, including processes that produce anti-entropy such as embryogenesis. What's more, in our 2009 work, we were analyzing the evolutionary complexification of the living world as an "asymmetrical random diffusion", as recalled – and who says random diffusion, says entropy production…. In particular, at any instant of the ontogenesis of a multicellular organism there is a further, constructive role of entropy production, beyond the one due to the transformation of energy.

At each cell reproduction, two slightly different cells are generated: slightly different proteomes, membranes, DNA ... at least by random effects. This slight production of disorder goes together with an increase of order (two cells instead of one, in particular in embryogenesis). But this disorder is *functional* to differentiation and, even in an adult, to stability by plasticity. Both in phylogenesis and in ontogenesis, entropy production is also a component of the production of diversity, thus adaptability, thus biological stability (organismal and eco-systemic).

9 – Normativity and constraints

Andrea Q9. This remembers the concept of "normativity" used by Canguilhem to define the activity of living beings concerning both its ontogenetic and phylogenetic dimension. By merging in a unified theoretical solution the principle of organismic autoregulation, derived from the German morphological tradition, and the "random" variation taken from the Darwinian frame, "normativity" means at same time organization and differentiation; it indicates the capacity of the living beings to preserve its functional integrated form, but also its transformative and unpredictable relation with the environment (Canguilhem 1962, 1966). Normativity is a creative adaptation and irregular production of contingent stability, always charged and opened by an unaccomplished virtuality and oriented by its singular agency. This heterogenetic dynamic of living beings, which is situated in a network of historical constraints but doesn't obey to any pregiven rule, cannot be compared to inert matter, but neither to its energetic (but still physical) opposite. Despite the fact that Canguilhem – at least for a few years and following Jacob's works (e.g. Canguilhem 1971)[10] – accepted the terms "negentropy" and "information" in the biological field, he proposed some sort of "anti-entropic" conception (if I may dare to say so) of living

10 This complex problem, a challenge for several interpreters of Canguilhem's work, would require a specific attention.

beings. Anyway, his views seem very close to your perspective and this concerns as well socio-economic phenomena.

Giuseppe A9. Fantastic: I love to rediscover traces of what we are trying to work out in major predecessors, like Canguilhem. In our perspective, we explicitly stress that, in biology, entropy and anti-entropy production co-exist are not opposed or not in a trivial way. In summary, one may see entropy produced by evolution, embryogenesis etc. as an essential and constructive component of the installation of biological organization, that, in co-existence with entropy, we called anti-entropy and for which we have proposed a measure. Negentropy, whether identified with "information" as it is mostly done in physics, in particular in order to interpret Shannon, or not, is insufficient: it is unidimensional or with the same dimension as entropy (up to the abuse of forgetting Boltzmann's K!), it does not help in analyzing "organization".

This does not prevent us from emphasizing the "dispersion", or scattering aspect of entropy which is certainly an inherent and fundamental aspect of the concept: it is different, yet it superposes the constructive component, anti-entropy, they are interlinked. Yet, the correlation entropy/anti-entropy may be unbalanced and then the "negative" or disruptive connotation of entropy may come out. Typically, Georgescu-Roegen, to whom Stiegler extensively refers, stressed the destructive role of entropy production by an economic system, in particular in its relation to the ecosystem. Moreover, he was very right (and a long time ago!) in saying to economists: what a load of rubbish, all analyses based on dynamics at, or close to, equilibrium, in economy, inspired from classical mechanics – well before Boltzmann's physics. If you wish to draw inspiration from physics, you have to "at least" consider processes of thermodynamic type and, therefore, entropy that they make it possible to analyze: an economic system is surely open to a flow of energy and/or matter, take it as a country or the entire Earth – it transforms energy and matter extracted from physical or biological Earth, by work (possibly indirectly, from other countries), thus from the Sun, *en dernière instance*. I am adding "at least" here, since in the analysis of a historical science such as economics and biology, you have to go beyond physics, including thermodynamics, which is intrinsically insufficient … historicity does not allow us to give a pre-definite phase space, like in all physical theories (Koppl et al., 2015; Longo 2017; Montévil 2020). Yet, the critique proposed by Georgescu-Roegen and developed by Stiegler is fundamental: when considering economy as an equilibrium system, which transforms physical energy and matter, (neo-)liberal economists believe that equilibrium will always be found, in spite of perturbations due, for example, to the frictions with the ecosystem. So, no problem - go ahead with free economy, do not care: whatever happens in the relation to the ecosystem, free economy will lead to a new equilibrium. The market will produce an economic or techno-fix – indeed, say the younger neoliberals: the ecosystemic disruptions are a "business opportunity".

Thus, I welcome the arrival in social matters of the reference to activities that disrupt organization or, on the contrary, that oppose to its disruption, even by a somewhat abusive use of entropy and negentropy, which are rich of a complex and ambivalent meaning in physics. Yet, I think that anti-entropy is more relevant to that which is organized (living organisms, perhaps social structures etc.), although requiring more development – as Maël observed once, Bernard Stiegler had in mind a notion closer to our anti-entropy when referring to negentropy. Note though that our early use of it for measuring complexity, in the 2009 paper, was limited to the anatomy of the dead animal – no functions, even less societal relations etc, it was a very specific and technical application (to a huge phenomenon, evolution). In the "closure of constraints" by Maël and Matteo Mossio there is a much more precise specification of what biological organization can mean – it is the organism with its functions, alive. In this direction one can, I think, enrich the concept of anti-entropy, as a measurement, by including functional activities, that is the structure of diagrams which describe functions in (Montévil, Mossio, 2015). The dynamics of norms in organisms and evolution, in the sense of Canguilhem's normativity, corresponds then to changing constraints. In summary, there are no norms in biology, but normativity, no rules but a dynamic structure of evolutionary constraints – within it, a few physico-chemical norms, the macromolecular interactions, retain most of the attention, while forgetting that these interactions are stochastic, must be given in probabilities and these probabilities depend on the context, they are actually constrained, canalized by the context (Montévil et al, 2016). Thus, in view of Darwin's first principle of "reproduction with variation", it is not change that needs to be explained, this is a priori, but stability in spite of change, that is the structure of biological constraints that force stability and enable viable change. Evolutionary, ecosystemic and organismal constraints need to be analyzed; selection, as exclusion of the incompatible, is a consequence of this dynamics of constraints – and some widespread pathologies may be due to the disruption of constraints (see (Longo 2018c) for an application). An even further specification is required when addressing the complexity and impact of human symbolic communities and their technics in an ecosystem, on the network of its constraints. Maël goes in this direction in (Montévil 2021a).

10 - Randomness and spurious correlations: confusing *a priori* and *a posteriori* from biopolitics to large databases.

Andrea Q10. I would like to return once again to the important legacy of Stiegler's work, in which his ability to address meaningful critiques of contemporary society was accompanied by great originality in interpreting the major contemporary philosophers (Stiegler 2015, 2018). In this sense, having dealt extensively with Michel Foucault, I find that one of Stiegler's merits - I refer in particular to his *La société automatique* - is that of having underlined the technological dimension of biopolitics. Foucault in fact defined biopolitics as the development of a set of "political technologies of social regulation" aimed not only, like disciplinary technologies, at the training and the enhancement of the individual body, but also and more specifically at the management, control and planning of social activity understood as the set of productive and reproductive functions of a "population" endowed with specific biological characteristics and regularities (Foucault 1976, 2004, 2004b).

In this sense, biopolitics, in tune with the unprecedented use of demographic statistics, introduces a vicious circle between the political activity of social *regulation* and a *regularity* of social phenomena as a whole. A regularity that is both assumed and induced by these regulatory and 'normalising' policies. What is constituted through the new biopolitical technologies of power is a very paradoxical naturalism, centred on the 'naturalness' and 'regularity' of a spectrum of social phenomena. These are in fact already the result and the objective of a several repeated series of technological deployments and political practices aimed at constructing the new artificial environment of industrial society. The problem is then that of transferring into the 'naturalness' of the social a set of intrinsic normative principles in which government action would find its own justification, presenting itself as the neutral accompaniment of “natural” phenomena. The regularity of the population is therefore a product of the technologies of regulation that is assumed retrospectively as its presupposition, an a *priori* constructed a *posteriori* according to a recursive, self-founding, self-fulfilling circularity[11].

In your work it seems to me that it emerges how this vicious circle is still present in the statistical use of *big data* in order to base production and its political organisation on regularities derived from an incompetent use of statistics. These new technologies of 'cyber-capital' once again end up presupposing an *a priori* regularity that is rather the result of an organisation of production and communication, of advertising and political propaganda. This political regulation claims to be based on the deduction of needs, consumption and social values produced through the abstraction of algorithms that function precisely by inciting and inducing a specific regularisation and normalisation of behaviour. Once again, an a *posteriori* is taken as an *a priori*, confusing projections derived from the operation of artificial machines with intrinsic properties of social “nature”.

Giuseppe A10**.** I can propose a scientific “negative” answer to the issues you beautifully raised: even from the point of view of mathematics, the mechanical use of Big Data to predict and act cannot work, as we argued in (Calude Longo 2017). In a sense, one *a priori* forces a bias in the construction of data, by the choice of observables, of metrics etc. Then one derives predictions by forcing *a posteriori* behaviors, based on data – that are claimed to be objective. Some even dare to propose this techno-political practice as a replacement of knowledge construction in science.

As a matter of fact, the claim that the construction of scientific knowledge can be replaced by a sufficient quantity of data has gone very far over the last few years. “Correlation supersedes causation… with enough data, the numbers speak for themselves…. No semantic or causal analysis is required” (Anderson 2008): the more data there is, the more actions will be made possible by correlations, which only a machine can find - no need for understanding. But that’s not how it works….

Firstly - and statisticians are very aware of this - “if you *torture data long enough* it will confess”; secondly, “if you *have enough* data you can find any correlation”. These intuitions are worth analyzing more closely. The most frequent “torture” consists in enforcing a bias in the choice of observables, measurement etc. A biased perspective and measurement allow any phenomena to be interpreted as one likes: one may choose to measure (how?) certain observables and not others (skin color for example in “predictive justice” (Garapon Lassègue 2018)). As for correlations, mathematics tells us that, when we have “enough” numbers, they are found, *always.* In short, in (Calude Longo 2017), classic Combinatory Number Theory results are used to demonstrate that *whatever* the correlation between numbers one sets oneself, one may calculate a number, let’s say *m*, such that *any database* having at least *m* elements contains the given correlation. It is therefore only a question of size, as *any* “database” (set of numbers) that is *large enough* (with at least *m* elements), even produced at random (dice throws), contains patterns with the required characteristics - in an enormous amount of numbers “anything” can be

11 A self-founding circularity that for Foucault concerns the entire modern anthropological episteme and that characterizes man in particular as an "empirical-transcendental allotrope" (Foucault 1966).

found, or even better: one can find in it “whatever you want, *a priori*”. The number *m* is very often too vast to stay within our Universe and many mathematician know of Ramsey Theory only for this power of generation of “immensely fast growing sequences”. However, the specific results of Ramsey’s theory used in (Calude Longo 2017) produce them in the order of magnitude of the Big Data stored in our giant computer clusters.

Despite these negative results, faith in Big Data also contaminates certain sectors of medicine (Issa et al. 2014). For example, contrary to the recommendations of the etiology of cancer based on the Central Dogma of Molecular Biology (the “cancer phenotype” has somatic mutations as its primary cause), we can observe the unpredictable diversity of the “myriad mutations afflicting individual cancer cell genomes” (Weinberg 2014) and equally “tumors without mutations” (Versteg, 2014), or even “cancer cells [that] display…a mutational burden similar to and perhaps even lower than that of adjacent normal cells” (Gatenby, 2017). Consequently, it is not possible to propose diagnoses, prognoses or therapies based on the DNA of cancer cells, contrary to what had been promised, and in the immediate future, at the time of the decoding of the human genome (2001!), see (Longo 2018c). But, since “generating large data sets became an almost-addictive undertaking”, data is being collected from all the “omics … genomes, transcriptomes, proteomes, epigenomes, methylomes, glycomes…” (Weinberg 2014). AI will make it possible to detect patterns and propose diagnoses, prognoses and therapies without knowing more about the etiology of this disease, the incidence of which has doubled in 40 years. When the ‘‘omics’’ concern tens of millions of patients, a project in progress, we’re approaching the amount of data required by the results we used in (Calude, Longo 2017) of Ramsey’s theory and…“*anything*” can be deduced from it, any correlation can be found in these data.

Can automated predictions of behaviour, from consumers to those facing legal trial, at least be given? Yes, if they manage, as was sometimes the case in the astrology of the ancients, to *channel* and *standardize* this behaviour: when the most purchased books are recommended or the most high-risk social groups are incriminated as a matter of priority, it is easy to compute what books or criminals should be predicted. The myth of an all-powerful AI then reveals its true face: an “instructive” vision and an imposed praxis of life and history. Humans must follow the “formal rule”, without meaning: human-machine interaction and automated predictions will then be fully effective – if *we* adjust to machines.

It is only by breaking away from this vision, which subordinates humans to the mechanizable, that the best use can be made of these formidable digital machines that are changing the world: it is up to us to insert them into history in a way that enriches our sociality, instead of reducing its diversity.

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