Panel

[Teilhard de Chardin and the necessity of life in the universe]

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We identify and discuss here some elements of convergence between the computational view of the universe, as recently formulated and divulged by Wolfram, and the ideas about the cosmos and its evolution proposed, about half a century earlier, by Teilhard de Chardin.

In particular, we illustrate some interesting emergent properties of computational universes based on variants of mobile automata on graphs, a model originally proposed by Wolfram, and we discuss possible evolutionary steps for artificial universes of this kind, that appear as prerequisites for achieving the level of complexity observed in the biosphere.

The phenomenon of emergence, in the context of the spontaneous behaviour of simple models of computation, is surprisingly creative and versatile, and seems to suggest that, if the fabric of the universe is fundamentally computational, it would be unlikely to see life emerge in only one way and one place.

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Teleology always involves a conscious mind – or, more in general, an anticipatory system – able to build a model of reality and act on it by means of inferences to produce representations of future scenarios, chose one, activate behaviours suitable to drive the context towards that scenario. The fact that a system's evolution brings about unlikely configurations is not a sufficient condition for teleology (as wrongly assumed by neocreationists). This is why modern science has given teleology up as an interpretative paradigm of natural history. In recent decades nevertheless, progress in complexity science has shed new light on the possibility of finalistic aspects in material reality. There are clues (mainly from the works of Stuart Kauffman at the Santa Fè Institute) that in complex systems information isn't generated by mere statistical fluctuation, in case hooked by an evolutionary mechanisms. Instead, such a process may be the outcome of peculiar dynamics irreducible to lower ontological levels. In these dynamics (as emphasized in particular by Robert Rosen) the relation between structure and function commonly accepted in physics and biology is turned upside-down and, because of that, they don't fit the usual notion of computability. Contrary to Newtonian paradigm, ontology (i.e. how a system come to its concrete existence) is here more important than epistemology (i.e. its abstract model).

Leonardo Angeloni, Università di Firenze

The union, as a result of the correlative interactions of different entities, has been shown as a driving force of the evolutionary process that led to the current state of the universe, from elementary particles up to clusters of galaxies.

The emergence of life is an important chapter that is part of this universal process that occurs as a continuous succession of stationary states and qualitative leaps characterized by the emergence of higher entities through the interaction of massive elementary entities (law of complexity / consciousness).

In the report we try to highlight the role of the processes of confinement (niche effect) both chemical and biological and social in the creative process of up-conversion that occurs as emergency of the pseudo-stationary equilibrium.

The mechanism of universal evolution is extended to the socio-cultural field to propose a Teilhardian solution of the current global crisis .

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The ecological perspective is distinguishable from the other scientific perspectives because of its transdisciplinary and systemic character. The ecological perspective is based on a representation of reality which stems from four epistemological foundations: hierarchy, emergence, communication and control. The ecological perspective is able to distinguish three levels of organization and integration of the phenomenon life: the cell, the organism, and the ecosystem. The human phenomenon , i.e. the evolution climax according to the Teilhard's law of complexity-conscience, is able to feedback upon both macro- and microsystems (ecosystems and cells) because of its increasing demographic, technological and psychological pressure, and therefore raises doubts, insecurity and risks for the evolution of life as a whole. An emergent eco-theological perspective can help channel the development of life on the Earth , where the process of “ominization” is completed while the process of “humanization” is still running.

Ludovico Galleni, Università di Pisa

Teilhard de Chardin proposed the investigations of the general laws of Biosphere evolution. Biosphere was considered as a complex evolving object and these general laws could be a tool also for the investigations of life outside the solar system.
In Teilhard scientific research program there is the description of the complexity consciousness law: matter was moving towards complexity and life towards an increasing of brain and in animals
towards consciousness. The recent discovery of the bacterial nano brain could be considered one of the experimental confirm of this law.
The moving towards complexity and consciousness was described also thank to a careful investigations of parallelism in animal life and thank to the proposal of the continental evolution as a different approach in respect to the population’s approach of the modern synthesis. Recent discoveries in Mammals evolution are a confirm of the value of continental investigations.
Finally the evolution of the Biosphere, thanks to its recent developments, is due to the necessity of maintaining the stability of the parameters allowing the survival of life itself.
These parameters are maintained far from the thermodynamic equilibriums. Is Evolution the way used by the Biosphere in order to maintain its stability? It will possible to ascertain if the atmosphere of the extra solar planets are outside the thermodynamic equilibriums and so far it will be possible to deduce the presence of an evolving Biosphere?

The search for life in the Universe and the extra solar planets.. (PowerPointPresentation Omitted)

Valfredo Zolesi, Kayser Italia Livorno

First of all some definitions: exobiology is the science studying the behaviour of terrestrial biological objects in space conditions.
Astro biology is the science looking for the possibilities to find life outside our Earth.
The search was first of all limited to the solar system, but at present many more extra solar planets are discovered.
For this reason now the question is: how it is possible to get information about the possibility of the presence of life in planets outside the solar system?

THE FABRIC OF THE COMPUTATIONAL COSMOS: FROM TEILHARD TO WOLFRAM

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Abstract

We identify a few elements of possible convergence between the computational universe conjecture, made popular by the recent work of Stephen Wolfram, and the visions on cosmic evolution proposed, about half a century before, by Pierre Teilhard de Chardin.

1 Introduction

Ten years have passed since the publication of 'A New Kind of Science' (NKS)[9], the monumental work by the British physicist and computer scientist Stephen Wolfram, that has provided perhaps the strongest contribution to the divulgation of the 'computational universe conjecture'.

According to this conjecture, the complexity we observe in the physical universe is to be understood as the manifestation of the emergent properties of a computation taking place at the tiniest space-time scale. The arguments in support of this idea are, currently, still of a metaphorical value, more than rigorously scientific, and consist in a huge repertoire of simple computer programs that produce, via self-organization and emergence, patterns similar to those observed in nature.

The original idea of a natural universe fundamentally based on computation is usually attributed to Konrad Zuse [10, 11], but several other scientists, mostly from theoretical physics or computer science (e.g. J. A. Wheeler, R. Feynman, E. Fredkin, G. 't Hooft, S. Lloyd, J. Schmidhuber, M. Tegmark) have been involved, in a variety of ways, in its elaboration.

Our purpose here is to identify analogies and elements of possible convergence between the computational universe conjecture, with specific reference to the approach by Wolfram, and the visions on the cosmos and its evolution proposed by the French philosopher and paleontologist Pierre Teilhard de Chardin in his book

’The Human Phenomenon’ [5], published in 1955 soon after his death. [1] In this short note we focus on the first two chapters of the book – ’The Stuff of the Universe’ and ’The Inside of Things’ – which already offer plenty of stimulating hints for our investigation.

A preliminary legitimation of the planned comparison comes from the fact that at the roots of both approaches we find the same questions on the same object of study: what is the fabric of the cosmos, what are its properties, how does it evolve? This is the incipit of Teilhard’s book:

> Moving an object back into the past is equivalent to reducing it to its simplest elements. Followed as far as possible in the direction of their origins, the last fibers of the human composite are going to merge in our sight with the very stuff of the universe.

2 Space

What are the fundamental properties attributed by Teilhard to the fabric of the universe?

> the stuff of tangible things reveals itself to us with increasing insistence as radically particulate, yet basically connected, and finally, prodigiously active. Plurality, unity and energy are the three aspects of matter.

Referring to plurality:

> each smaller material unit tends under the analysis of our physicists to be reduced to something more finely granulated than itself. [...] Beyond a certain degree of depth and dilution, the most familiar properties of our body (light, color, heat, impenetrability...) become meaningless.

The substratum of the tangible universe is also defined as a swarm, dizzling in number and smallness, and it is clear that Teilhard does not mean to stop this decomposition at the representations of the atom as envisaged by the (provisional) physical theories of his times, but pushes it downwards, towards a texture of increasingly abstract nature.

And, referring to unity:

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[1] Unless otherwise stated, all quotes appearing in the paper in italics are from ’The Human Phenomenon’, in the english translation by Sarah Appleton-Weber [6].

> Whatever their degree of magnitude and whatever their name, these minuscule entities [...] seem to be remarkably calibrated – and monotonous [...] As if the stuff of all stuff is reduced to one simple and unique form of substance. There is a unity of homogeneity, therefore.

The best way to approach the description of this increasingly abstract texture, while preserving scientific rigor, is to resort to the abstract constructs of pure mathematics. For example, we could model a swarm of featureless entities as a set of points. However, the swarm manifests also collective unity :

> the innumerable centers [...] are not independent from each other. Something binds them together that makes them mutually interdependent.

And, finally, unity of domain :

> However narrowly circonscribed is the ”heart’ of an atom, its domain is at least virtually coextensive with that of any other kind of atom.

The simplest mathematical structure that describes a set of elements and their inter-relations is the undirected graph G(N, E), where N is the set of nodes, and E is the set of edges that link them pairwise. Edges are undirected, meaning that the binary relation that they define for the nodes is symmetric.

The computational universe conjecture requires, by definition, that space be modeled as a formal, mathematical structure – one that can be animated algorithmically. Then, how is space conceived by Wolfram? In [9] he writes:

> if the ultimate model of physics is to be as simple as possible, then one should expect that all the features of our universe must at some level emerge purely from properties of space. But what should space be like? [...] for the richest properties to emerge there should in a sense be as little rigid underlying structure built in as possible. [...] I believe that what is by far the most likely is that at the lowest level space is in effect a giant network of nodes.

An example of finite trivalent graph – one in which each node is exactly connected to three other nodes – is provided in Figure 1, on the left. It can be easily shown that these graphs are highly flexible and can ’implement’ any other type of graph, as well as discrete versions of spaces of any dimensionality – 1D, 2D, 3D and beyond. A graph (or ’network’) may then represent a first, firm element of convergence between the views by Teilhard and by Wolfram.

The unity of domain could itself be implemented, in a way, by the edges of the graph. However one might interpret this property otherwise, for example as an

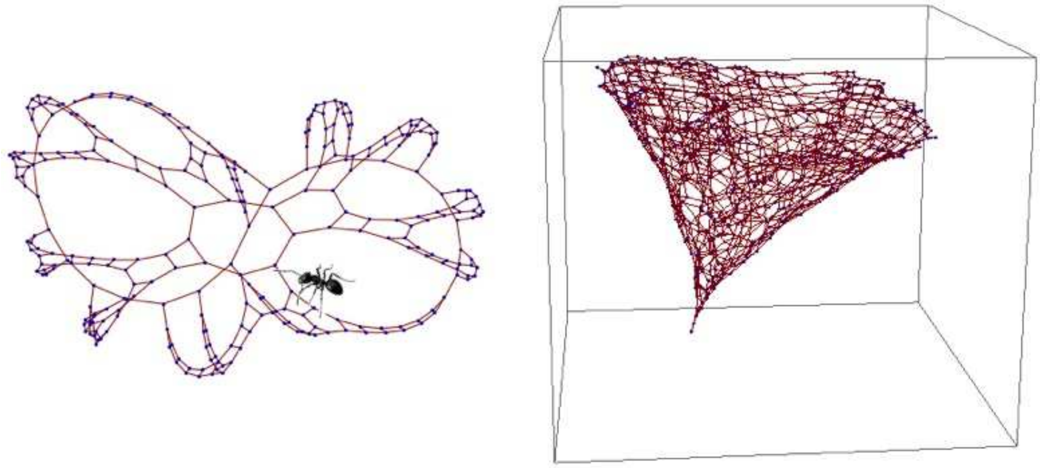

Figure 1: Left – a trivalent graph and a control unit, depicted as an ant, are the components of a network mobile automaton; this graph is built by the ant in 1000 steps, starting from a tiny initial trivalent graph with two nodes and three edges (some steps create a new node, others simply change the local interconnection pattern). Right – the causal set obtained from the 1000 steps of the ant; each step corresponds to a node [2].

ability of particles to freely move anywhere in space. And, of course, we still need to address the third fundamental property of the stuff of the universe – energy, that Teilhard characterizes as follows:

> Under this word [...] physics has introduced the precise formulation of a capacity for action, or more exactly, for interaction.

These two remarks lead us to address the dimension of time, that makes a very early appearance both in Teilhard's and in Wolfram's elaborations. In doing so, we shift the focus from a static space to the dynamic entity of spacetime.

3 Spacetime

The formal model of computation most frequently considered in the context of the computational universe conjecture, from Zuse to Fredkin and Wolfram, is the cellular automaton. Figure 2 shows a computation of Wolfram's most celebrated elementary cellular automaton 'Rule 110' [9]. Its emergent localized structures and interacting trajectories have often suggested analogies with scattering diagrams of particle physics. The fabric of spacetime, in this simple artificial universe, consists of a regular square array of binary cells, black or white, and is therefore quite rigid. Space extends horizontally, time flows downwards.

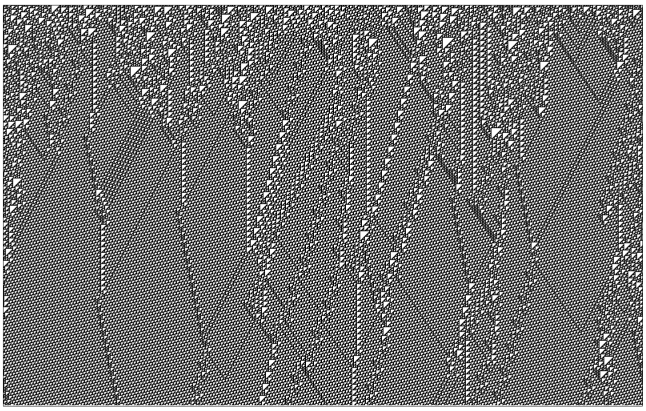

Figure 2: A 500-step sequence of Wolfram's cellular automaton Rule 110.

In spite of the attractive emergent properties of cellular automata, Wolfram writes [9]:

> At first it may seem bizarre, but one possibility that I believe is ultimately not too far from correct is that the universe might work not like a cellular automaton in which all cells get updated at once, but instead like a mobile automaton or Turing machine, in which just a single cell gets updated at each step.

An interesting variant of the above mentioned automaton is the network mobile automaton, a model of computation in which a control unit (depicted in Figure 1 as an ant) moves on a possibly trivalent graph while modifying locally its topology, at each step, by applying some simple graph rewrite rule.

At first, one might imagine the graph to represent space, a dynamic structure that evolves in time due to the action of the ant. However, Relativity theory dictates that space and time be merged into the unique mathematical structure of spacetime. Fortunately, it is possible, and even rather straightforward, to derive discrete versions of a spacetime-like structure from the computations performed by a Turing machine, or by an ant on a trivalent graph; and the result is a causal network [9], also called causal set [4].

A causal set is a directed, acyclic graph in which nodes represent spacetime events, and edges (which are now directional) define causal dependencies among them, in the same way as lightcones define the causal structure of continuous spacetime. Several examples of causal sets, derived from Turing machines and a few other models of computation, are introduced in [9, 1]. Other examples, in particular from network mobile automata, are provided in [2]; one of them, of roughly conical shape, is shown in Figure 1, on the right.

With trivalent graphs and algorithmic causal sets we have obtained mathematical objects whose simplicity, level of abstraction, and flexibility appear to satisfactorily match some of the key properties attributed by Teilhard to the stuff of the universe. These algorithmic structures must now be confronted with the challenge of self-organization: can they escape the repetitive monotony of "a crystal, or arabesque, where the same law is valid for filling up the entire space, but already entirely contained within a single mesh"? Can they reproduce the layers of emergent complexity that we observe in the natural universe, where "matter never repeats itself in its combinations at different orders of magnitude"?

4 A layered architecture of emergence

> the evolution of matter reduces, in current theory, to the gradual building up, by increasing complication, of the various elements recognized by physicochemistry. [...] This fundamental discovery, that all bodies derive, by arrangement, from one initial corpuscolar type is the flash that lights up the history of the universe [...] From the beginning, matter has, in its own way, obeyed the great biological law of "complexification".

The chances of the computational universe conjecture to provide a scientifically sound, formalized counterpart to Teilhard's inspired visions largely depend on how far can the algorithmic paradigm go in building up complexity and manifesting 'creativity' across the layers of the hierarchical cosmos. Some important features have already emerged from the experiments and simulations made in the last few decades.

Pseudo-randomness. In spite of the deterministic nature of the used algorithms, in some cases one obtains very irregular, (pseudo-)random patterns – e.g. with Wolfram's Rule 30 [9] – or interesting mixtures of order and disorder.

N-dimensional flat and curved spacetime. While most of the causal sets obtained from computations represent totally unrealistic discrete models of spacetime, some yield lattice structures that support the analysis of properties of physical significance, such as flatness/curvature and realistic dimensionality [1, 2, 3].

Fractals. Self-similar patterns, from snowflakes to cauliflowers, from shells to galaxy clusters, are frequently observed in nature, and a theory has been proposed [8] that attributes a fractal structure to spacetime itself. Fractals are easily obtained also in the computational universe. A similar remark applies to Fibonacci sequences.

Particles. Not only do these localized, periodic structures create trajectories across artificial spacetime (Figure 2), reminiscent of particle worldlines in real spacetime; they also play an important role in transmitting information and carrying out themselves actual computations [7].

Self-reproduction. Cellular automata have been indeed first devised by John von Neumann and Stanislaw Ulam, in 1951-53, as an abstract model for self-reproduction in biology. Several automata have been found, since those initial attempts, that can reproduce undefinitely a given initial pattern.

Some of the listed items are of course key ingredients for sustaining an evolutionary biosphere.

However, Teilhard identifies a further, crucial factor for cosmic evolution – the inside of things:

> matter at its origins is something more than the particulate swarming so marvelously analyzed by modern physics. Beneath this initial mechanical sheet we must conceive the existence of a "biological" sheet, thin in the extreme, but absolutely necessary to explain the state of the cosmos in the times that follow. Inside, consciousness, and spontaneity are three expressions of one and the same thing.

The appearance, in the natural universe, of 'agents' – entities able to act freely and to spontaneously take initiative ('agency') – dramatically boosts complexity, and provides the potential for an immensely rich and 'creative' cosmic evolution. Is it conceivable to obtain such advanced features in a computational universe, purely by emergence? Could this all be obtained by, say, the tireless work an ant operating at the bottom of the computational, layered architecture, in the same way as we get interacting particles from the simple rules of a cellular automaton?

Teilhard himself attributed a central role to the general notion of emergence, and the remarkable advances in the sciences of complexity and self-organization that took place decades after his death fully confirm his intuition. Experiments, by Wolfram and many others, have provided strong evidence for the surprising 'creative' force of emergence in computation, and although the evolution in the very long run of some of these 'artificial' universes, and their possible final fate, are still to be fully explored, in our opinion it would be unwise to rule out a priori the above possibility – that consciousness might emerge computationally.

Then, how far can we push the similarity between Wolfram's computational universe and Teilhard's evolutionary cosmos? One difference might be in the way the universe is conceived to be held together.

In the computational, ant-based picture, agency would all be concentrated exclusively in the ant; all features in the upper layers, no matter how complex, would only be apparent: stop the ant, and everything above it would freeze. The driving force, the energy, is all concentrated at the bottom. Similarly, in an elementary cellular automaton, all energy can be imagined to be spent at the bottom level, for computing the boolean function that decides the next state of each binary cell; no additional energy is required for explicitly animating the interacting particles at the upper level. This is what Teilhard calls tangential energy, which supports particle aggregation and self-organization; and it seems to be the only energy necessary for a computational universe to evolve. Wolfram's computational universe would hold together from below.

Apparently, Teilhard's viewpoint is different:

> A more complete observation of the movements of the world will gradually oblige us to turn this perspective around; I mean, to discover that if things hold, and are held together, it is only by reason of complexity, from above.

Is the conflict terminological or substantial? If the emergence of complexity – the way it can provably occur in the computational universe – were the only reason for claiming that the universe is 'held together from above', then Wolfram's and Teilhard's visions would appear compatible, beyond some terminological mismatch. If, on the other hand, the emergence of complexity is understood as requiring the combined action of a tangential and a radial energy, as Teilhard suggests, then the difference might be more substantial.

In the latter case, keeping in mind Teilhard's declared aim to produce, with 'The Human Phenomenon', a scientific study, not a metaphysical or theological work, we are left with the arduous challenges to understand the exact nature of the radial energy, to formalize its interplay with the tangential energy, to possibly revise the notion of emergence in light of the two energies, and to strengthen as much as possible the scientific foundation of a cosmos conceived as held together from above.

In either case, much more effort is needed, with more simulations and experiments, for exploring the actual limits of the computational universe hypothesis.

Acknowledgments

I wish to express my gratitude to Don Enrico Rossi, for convincing a teenager to read 'The Human Phenomenon', to Ludovico Galleni, for stimulating this work, and to Stephen Wolfram, for inspiring discussions on the computational universe.

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FINALISM CLUES IN MODERN SCIENCE

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Abstract
Teleology always involves a conscious mind – or, more in general, an anticipatory system – able to build a model of reality and to act on it by means of inferences to produce representations of future scenarios, to chose one of them, to activate behaviours suitable to drive the context towards that scenario. The fact that a system's evolution brings about unlikely configurations is not a sufficient condition for teleology (as wrongly assumed by neo-creationists). This is why modern science has given teleology up as an interpretative paradigm of natural history. In recent decades nevertheless, progress in complexity science has shed new light on the possibility of finalistic aspects in material reality. There are clues that in complex systems information isn't generated by mere statistical fluctuation, in case hooked by an evolutionary mechanisms. Instead, such a process may be the outcome of peculiar dynamics irreducible to lower ontological levels. In these dynamics the relation between structure and function commonly accepted in physics and biology is turned upside-down and, because of that, they don't fit the usual notion of computability. Contrary to Newtonian paradigm, ontology (i.e. how a system come to its concrete existence) is here more important than epistemology (i.e. its abstract formalized model).

Introduction: teleology and modern science
Since ancient times, the observation of regularities in nature has suggested the action and intention of a cosmic designer behind them. That is indeed plausible, but entailing the presence of a God creator from the order in the universe is a blatant logical mistake. In fact, any purpose-built process moves from an anticipatory system able to create models of reality which constitute the base for foreseeing probable evolution of the environment. Then, according to some choice criteria, a particular option is selected and eventually effected. So, an unlikely and complex configuration might well be the consequence of an intentional act but, as it is well known from elementary logic, implications cannot be inverted.
With the adoption of modern science's method, finalistic view has been given up. The Newtonian paradigm, in fact, provides explanations of natural phenomena based on simple mathematical relations. Moreover, Darwin's theory of evolution is a quite sensible framework for the interpretation of the richness and complexity of the living world. So, according to the celebrated principle known as "Ockham's razor[1]", one can dismiss a cumbersome and epistemologically weak explanation if a simpler one is available. The worldview implied by this paradigm is reductionism.
Nevertheless, in the last decades outstanding scientific results both in physics and biology have partly shadowed this view. It seems in fact that the Newtonian description of reality is far from being complete and the evolutionary mechanism alone is unable to explain the rising of complex structures (in particular living beings) from the outset. Even so, the view of a deterministic and aimless universe, implied by Newtonian science, can be maintained if one adopts a milder form of reductionism. The Nobel laureate Stephen Weimberg recently said that[2] «*...he did not care about the capacity of physical laws to predict all in the universe, rather he cared that all that happened in the universe was "entailed" by the laws of physics...* ». We may, however, ask ourselves if reductionism is a tenable epistemological position, even in its weaker form and, if not, which are the conse-

[1] *Frustra fit per plura quod fieri potest per pauciora*, as William of Ockham (Franciscan friar and philosopher who lived in 14th century) himself stated his famous principle.
[2] Personal communication reported by Stuart A. Kauffman in the foreword of the volume: *A Third Window. Natural Life beyond Newton and Darwin*, by Robert E. Ulanowicz.

quences for the issue of finalism. There are, in fact, a number of severe objections that can be raised against it.

The universe is not deterministic

The first objection to reductionism is that quantum mechanics laws – which rule the atomic and subatomic world – are not deterministic. This not necessarily implies a lack of causality, for one can assume that every phenomenon in the universe is entailed by probabilistic quantum laws instead of the deterministic ones of classical physics, but such a causality doesn't fit very well reductionism's claims. In fact the observer plays a crucial role in quantum mechanical processes, so that we cannot speak of an independent reality, but rather of an empirical one[3]. In other words, without determinism we have to give up realism too. It is evident that the claim that every phenomenon is describable in terms of elementary interactions between particles hardly accords with the fact that those very interactions are strongly affected by the observer who describes them.

This is the reason why a number of scientists, refusing the idea of a non-deterministic universe, proposed realistic interpretations of quantum mechanics. Einstein, in particular, never accepted quantum indeterminism as an essential feature of physical reality. Together with Boris Podolsky and Nathan Rosen he conceived a famous *Gedankenexperiment*[4] (the so called EPR paradox, after the initials of the three scientists) which, according to the authors, should have shown that quantum indeterminism is not a true feature of physical reality, being a consequence of an incomplete knowledge of the relevant parameters instead.

To illustrate the essentials of the EPR paradox, let's consider a couple of particles produced in a decay, so that they have properties related to one another. For example, if the initial state has zero magnetic moment, and the moment of one of the particles turns out to be north-oriented after measure, the other one must have a south-oriented moment. Were the first particle's state really indeterminate until the measure is performed, an instant influence on the other one would take place, a fact wholly at variance with the usual notion of causality. So, conclude EPR, the parameters of the particles must be determined from the very beginning by some still unknown hidden variables. Quantum mechanics is therefore an incomplete theory. When we eventually succeed in coping with hidden variables, physics will fully recover the Newtonian determinism. On the opposite side, the group which gathered around Niels Bohr at Copenhagen university – the so called Copenhagen school – claimed the completeness of quantum mechanics and, as a consequence, reality's intrinsic indeterminism.

In the early sixties of the last century, Irish physicist John Bell provided[5] a set of inequalities which would be satisfied in an EPR-like experiment only whether hidden variables actually existed. The road was open to the ultimate answer to the determinism problem. The experiment was performed[6] a few years later and its results left no room for doubt: the correct interpretation is the Copenhagen one and physical reality is intrinsically indeterminate.

The limitations of natural law

A second and more severe objection against reductionism concerns the Galilean axiom that all that unfolds in the universe is describable by natural law. In fact, as we have already seen, reductionism claims that all that happens in the universe is entailed by the law of physics, i.e. relations involving elementary constituents of matter, expressed in a mathematical form. Such a claim is not only quite far to be actually verified, but it is also questionable in several ways.

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Stuart Kauffman, among others, has repeatedly pointed out[7] that our universe is strongly non-ergodic. We briefly recall that *ergodicity* is the property that a closed system has to occupy all the available phase-space states during its evolution. As a matter of fact, universe is so a huge system that the time required to systematically explore even a tiny fraction of its phase-space would be lots of orders of magnitude greater than its entire lifespan. So, it is hard to believe that complex systems arise by means of statistical fluctuations in the configuration space of elementary particles. Consider for example the random generation of a given protein two hundred amino acids long. It can be estimated[8] to occur only once in 10^{39} repetitions of the entire history of the universe, were the 10^{80} particles of the universe all engaged in assembling proteins two hundred amino acids long at a rate of a trial every Planck time (10^{-43} seconds). Let alone the random building of a simple bacterium such as *Escherichia Coli* which requires 2000 different functionally interwoven enzymes, each of them about two hundred amino acids long[9]. On the other hand, in a canonical reductionism-like view the outset of a complex system can occur only by means of a statistical fluctuation "hooked" and stabilized by a Darwinian evolutionary mechanism[10]: a quite poor explanation indeed. Why? The question is subtle. We are not saying that a complex system can't be described in terms of elementary parts interacting with each other. If one arranges a set of elementary particles according to proper boundary conditions the subsequent evolution of the system shows the features of complexity and no further epistemological tool is needed. But how is it possible to get the proper initial conditions without the intervention of an experimenter? In other words, the problem lies in the ontology of complex systems. It is worth noticing that Newtonian paradigm takes into account only the epistemology of systems (i.e. their structure described in terms of mathematical relations) and totally neglects their ontology (i.e. the way they come into existence), but such an approach is unsuitable for complex systems[11].

If this is the case, if the fluctuation-based mechanism is unable to justify the outset of complex systems, there must be some still unknown laws or principles which account for the self-organization of physical systems up to a threshold in complexity suitable for Darwinian selection to begin acting. The hypothesis that complex systems (in particular biological objects) should follow proper laws not in contrast with – but neither reducible to – physics ones, was first suggested by Schrödinger[12]. More recently, Stuart Kauffman has gone over the issue with a number simulations on model systems as well as observations from biochemistry and economy. He has come to a viewpoint which encompasses the possibility of a fourth law of thermodynamics, in order to explain the apparent tendency of the cosmos to build itself as a system of ever-increasing complexity[13].

A more radical perspective on the problem is the one of the theoretical ecologist Robert Ulanowicz[14], who argues for the existence of real lawless islands in the sea of physical phenomena or – as he calls them – *causal holes in the fabric of space/time*. Ulanowicz's argument steps form the claim of Russell and Whitehead that natural law must be based on homogeneous classes (such as the class of all identical electrons), and the observation of the physicist Walter Elsasser that – due to non-ergodicity of universe – each organism can occur only once in the history of the universe. So, Galileo's postulate that everything in the universe is describable by means of quantitative relations (the celebrated metaphor of Nature's big book written in mathematical characters) has to be

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[7] See for instance: STUART A. KAUFFMAN, *Reinventing the Sacred. A New View of Science, Reason, and Religion*, Basic Books, New York 2008.

[8] *Ibidem*, p. 122.

[9] ROBERT SHAPIRO, *Origins: A Skeptic's Guide to the Creation of Life on Earth*, Summit Books, New York 1986.

[10] JAQUES MONOD, *Le Hasard et la Nécessité*, Editions du Seuil, Paris 1970.

[11] ROBERT ROSEN, *Life Itself. A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*, Columbia University Press, New York 1991.

[12] ERWIN SCHRÖDINGER, *What is Life? The Physical Aspect of the Living Cell*, Cambridge University Press, Cambridge 1944.

[13] STUART A. KAUFFMAN, *Inverstigations*, Oxford University Press, New York 2000.

[14] ROBERT E. ULANOWICZ, *A Third Window. Natural Life beyond Newton and Darwin*, Templeton Foundation Press, West Conshohocken, Pennsylvania 2009.

relaxed. At least for life phenomena, strict physical causality must be replaced with the wider and more general concept of propensity, originally developed by Popper. Propensities seem to be the base for a more reliable description of the biological world, a highly non-deterministic description into which raw chance plays an important role.
Both Kauffman's and Ulanowicz's positions take into account the non-ergodicity of the universe and claim the impossibility to foresee the outset and evolution of complex systems. Moreover, the very existence of self-organized complexity cannot be accounted for within the paradigm of reductionism. In a worldview alternative to reductionism, complexity arises from a primordial soup following paths deeply contingent upon the details of the ontology, loosely guided by propensities or some high-level laws.

No common language for all phenomena, or causality's arrow

According to reductionism the whole universe is nothing but elementary particles interacting with each other. If this were the case, there would be a common language able to describe every phenomenon, even the most complex, i.e. the language of particle physics. As a matter of fact, such a goal has not been accomplished yet, and there are strong clues that it will be never.
In the canonical view of physical reductionism reality is mainly composed by linear simple systems, which perfectly fit the Newtonian paradigm. Nonlinearity is seen as a perturbation, and no difference exists between "complex" and "complicated" (in the sense that no new meaning comes out by increasing the number of parts and relations in a system, only its behaviour becomes richer and richer). But if we forget the models and turn to reality, we immediately see that complex non-linear systems are the overwhelming majority, while linear simple systems are a small fraction, obtained by the former under very particular conditions. In a certain sense, Newtonian approach is turned upside-down: complex systems are the rule in the universe while the linear and simple ones are rare and artificial special cases. So, it's a gross epistemological mistake considering complex and non-linear systems as perturbations of linear ones. In a complex system one can recognize peculiar *functions* which bring about a set of new meanings, perhaps describable but no way explicable in terms of the underlying ontological level. Let's consider as an example the outset of the heart in biosphere's evolution[15]. Heart is a complex object, but it not breaks the laws of physics. That is, given Heart's properties – in particular pumping blood – one can deduce them by the laws of physics (at least in principle). Nevertheless, a low-level description can't account for the functional aspects of pumping blood, let alone the Darwin's point that heart came into existence in the universe as a complex organ and set of processes precisely because it pumped blood. In other words, pumping blood as the relevant function of heart is not a matter of mutually interacting elementary particles. Rather it can be outlined only by means of high-level concepts such as breathing, metabolic exchanges, etc. To make this point clearer, let's consider computational experiments where a number of interacting elementary agents simulate a complex situation[16]. Raw data from the simulation contain the maximum amount of information from the model system. But this low-level piece of information is completely useless, unless the experimenter – who knows what he/she is looking for – applies to it a proper filter to get processed data, which can be interpreted within a framework of high-level meanings.
The features of a complex system which cannot be reduced to the properties of its constituents are called *emergent properties*. A trivial example of emergence is liquidity: water is a liquid, but nothing "liquid" exists in a water's molecule or in the interaction between water molecules. A far less trivial example is consciousness: every mental process corresponds to a physical process in my brain, but none of my neurons or group of interacting neurons feels or thinks or experiences the self. So, if emergent properties are real (and not a mere way to express some features of low-level dy-

[15] STUART A. KAUFFMAN, foreword of the volume: *A Third Window...*, by Robert E. Ulanowicz, *cit.*
[16] See for example the artificial life simulation presented in: ALESSANDRO CORDELLI, PAOLA CERRAI & LUDOVICO GALLENI, *Artificial Life and Speciation, a Case Study: Heterocormatin and Speciation in the Microtus Savii Group (Rodentia – Arvicolinae)*; Rivista di Biologia/Biology Forum, **96**, pp. 87-104 (2003).

namics) it can be argued that changes in the high-level functions of a system affect also the constituents. In other words, in complex systems a top-down causation occurs. It means that explanatory arrow goes from the complex to the simple, from the whole to the parts[17]. So, it is evident that the very concept of a top-down causation is totally at variance with reductionism and its epistemology based on the Newtonian paradigm.

Conclusions: clues of finalism

The universe is full of complexity, the universe itself is complex, and reductionism is a poor and useless paradigm to understand complexity. If reductionism were the correct paradigm to describe reality, there would be very little complexity in the universe. But this is not the case. Matter shows a spontaneous tendency to build structures of increasing complexity, self-sustaining systems capable of producing and processing meaningful information. A tendency driven by some still unknown physical principle (maybe Popper's propensities or Kauffman's fourth law of thermodynamics), but anyway not a mere fruit of raw chance. In other words, the tendency to complexity seems to be deeply inscribed in the laws of nature, so that the universe itself moves towards structures of ever-increasing complexity. The concept of "moving towards" is a fundamental point in the thought of the French philosopher and anthropologist Pierre Teilhard de Chardin, who recognized various stages in cosmic evolution: from inanimate matter, to life, to human mind[18]. It is worth noticing that such an interpretation of finalism is quite different from those which require a direct intervention of God in order to shape the otherwise senseless natural history. Indeed it is in full compliance with the laws of nature, because the push towards structures of enough complexity to give rise to spiritual activity comes from these very same laws.

The interpretation of finality as "moving towards" does not prove the existence of a design beyond natural history, but is consistent with it. Rather it is completely at variance with reductionism. Be intentional or not, there is a tendency of cosmic evolution towards complexity, and human brain is the most complex thing known in the universe. If we ask ourselves what might be the further evolution of universe along the coordinate of complexity, we are presented with a number of possibilities. Maybe the proliferation of more and more advanced forms of individual consciousness localized in the hospitable spots in the universe. Or perhaps the overcoming of the "age of individuals" with the outset of a cosmic consciousness. This is a hypothesis already envisaged by ancient philosophers: we can find the idea of the entire universe as a unique organism in Stoicism[19] as well as in platonic and neo-platonic philosophy (Plotinus explicitly writes about *Anima Mundi*, or the soul of universe). In addition to these hypotheses, taking into account particular features of the cosmological models, a far worse scenario can be outlined[20]. In fact, due to the everlasting expansion of universe and the irreversible consumption of nuclear fuel into stars' cores, the physical conditions which allow of complexity and processing information soon or later will come to an end everywhere. We are talking of a very long time on a cosmological scale, but however finite. If this were the case, the destiny of consciousness in the universe would be falling into primordial not-be, or the *Nirvana* of eastern philosophies.

As a matter of fact almost nothing can be stated with any certainty about the far future of consciousness in the universe but, as far as past and present are concerned, the tendency towards complexity, self-organization and generation of information seem really to be a feature deeply inscribed into the very laws of Nature.

[17] ROBERT ROSEN, *Essays on Life Itself*, Columbia University Press, New York 2000.
[18] PIERRE TEILHARD DE CHARDIN, *Le phénomène humain*, Seuil, Paris 1955.
[19] See in particular Marcus Aurelius' literary masterwork, *Meditations*, a real handbook of Stoicism.
[20] FREEMAN J. DYSON, *Disturbing the Universe*, Harper & Row, New York 1979.

THE UNION AS A UNIVERSAL PARADIGM OF CONTINUOUS CREATION: THE ORIGIN OF LIFE.

Leonardo Angeloni, University of Florence

Introduction

The "creative evolution" is the fundamental idea that summarizes all the work of Teilhard de Chardin both as a scientist and as a mystic, this idea combines two terms deriving from two worlds considered still too often irreconcilable, that is science and religion.

The theory of biological evolution has been identified in his Darwinian formulation, with a materialistic view of reality in which chance and natural selection are the only agents that have led to the appearance of various species up to the human being, on the contrary the word "creative" evokes the presence of an external agent, identified with God, responsible for the multiplicity of forms and substances originated at the beginning of time.

The synthesis found by Teilhard does not oppose science and religion, that is, reason and faith, or empirical research and ecclesiastical dogma but it overcome partially distorted visions in science and theology determined by a still partial and incomplete knowledge.

The paradigm of the Teilhardian evolution is the union, because this is the process that science shows us to be the only mechanism responsible for the multiplicity of forms and substances from the hydrogen atoms in the early universe up to the birth of life and the human being. The Teilhardian evolution is a continuous series of unifying acts that occur under conditions of confinement or in ecological niches, alternating with long periods of stasis in which the transformations are stabilized and spread.

The primordial particles are united in a real synthesis process to give rise to a new subject indivisible (individual) with new properties and superior to those of the individual components to which is due but not reducible to those.

The old creation myth handed down from the holy Scriptures is replaced by a creative act that unfolds in space and time and which is perceived by us as a continuous creation representing the largest event of the "divine presence" in the universe.

The union is inevitably accompanied and characterized by increasing complexity and is the true act of ontological foundation of the essence of things, plants, animals, and man himself. The evolution of the universe unfolds according to what Teilhard called the law of "complexity/ consciousness" that begins in the matter by the appearance of what are called emergent properties but goes beyond the material to reach the spirit and the consciousness that are the typical manifestations of the human species.

As we speak of the divine presence, we do not refer to an anthropomorphic representation of the deity, the legacy in some sense of a naive vision of divinity, daughter of naive Creationism as well as a naive atheism opposed to it, but rather we refer to the ontological basis of the being which recognizes in God the own vocation of the existence that extends beyond the immanent and beyond the contingent.

The evolution of the universe

Surprisingly the two words have the same root in fact evolution comes from "ex-volvo" and the universe comes from "uni-versus" that is turned toward unity; Teilhard de Chardin has grasped the profound meaning of this coincidence which is not the result of chance, but has a precise scientific connotation and is a philosophical and theological fundament.
The gradual increase of complexity that is observed in the transition from elementary particles (hydrogen atoms) in the early universe until the emergence of life and human life on the planet earth or the formation of clusters of galaxies that we see today is the fruit and the representation of the union which take place as a result of progressive correlative interactions between the individual and various entities (individuals).
Science gives us the opportunity today to affirm the validity of the insights of Teilhard through the identification of the forces and mechanisms involved in this huge evolutionary process that involves not only our bodies and the environment in which we live but also our souls in a unified view in which matter and spirit are two successive stages of an evolution that sees distinct but not separate.

Genesis.

With the union of the electromagnetic force to the weak nuclear force (responsible for beta decay) in the electroweak theory, the three fundamental forces that operate in the universe from the first moments of its formation are: the electromagnetic force that determines the balance within of atoms and molecules, the strong nuclear force that binds protons and neutrons in the atomic nucleus and the gravitational-inertial force that is responsible for the balance between the planetary and stellar masses in galaxies and between galaxies in which the centrifugal force counteracts the gravitational pull.
The 98.1 percent of the matter in the universe is formed by hydrogen atoms and molecules of helium which are the two simplest elements of the periodic table and constitute the real brick which built the remaining 1.9 percent of incoherent mass scattered among the stars, planets and satellites.
These protons, neutrons and electrons would have formed in the earliest moments of the universe as a result of a great explosion called the Big Bang in which energy would be transformed into mass.
As in any process of violent expansion of gases even in this case would have place a cooling of matter with the onset of phenomena of condensation that would give rise, through the gravitational attraction, to the first nuclei of star formation causing a de facto stop of the expansion in a state which can be defined as a pseudo stationary. In fact, if we do a little of accounts using the Hubble constant, we see that due to the expansion, a distant star one light-year from the earth would be achieved by a laser pulse launched from the earth after a year and 2.2 milliseconds with an expansion coefficient of $dr/r = 0.7\ 10^{-10}$ which is much smaller than the measurement error of the distances.
The formation of heavy atoms is the result of the first processes of union that is a real nuclear fusion occurred within the first stars in the conditions of confinement at high temperatures and pressures. These elements were then distributed in space following the explosion of these protostars creating the conditions for the formation of planetary systems and satellite; however planets constitute a small fraction of the stellar mass, for example in the solar system, 99.9% of the mass is constituted by the sun.

The distribution of elements in the universe and the solar system.

In the solar system planets are very different from one another in composition, size, temperature and other characteristics. The terrestrial planets (Mercury, Venus, Earth and Mars) all have a small mass, high density (5 times that of water) none or very few satellites and low speed of rotation, while the Jupiter like planets (Jupiter, Saturn, Uranus, Neptune) have great mass density 2.1 times that of water, several satellites and high speed of rotation.

	Milky Way	Oceans	Atmosphere	Human Body		
Element	**% mass**	**% mass**	**% Volume**	**% mass**		
hydrogen	73,9 00	10.82	<1 (H_2O)	10		
helium	24,0 00					
oxygen	1,0 70	85.84	20.9	65		
carbon	0,4 60	0.0028	<1(CO_2)	18		
neon	0,1 34					
iron	0,1 09			<0.05		
nitrogen	0,095		78.1	3		
silicon	0,065					
magnesium	0,058					
sulfur	0,044	0.091	<<1	0.2		
calcium		0.04		1.5		
chlorine		1.94		0.2		
potassium		0.04		0.2		
sodium		1.08		0.1		
bromine		0.0067				
magnesium		0.1292		0.05		
argon			0.96			
phosphorus				1.2		
remainder	0,065					

The table shows the abundances of chemical elements present in the Milky Way (and therefore practically in the universe) in the hydrosphere, atmosphere and in the human body.

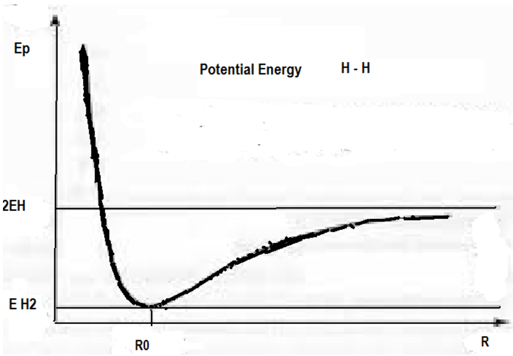
As can be seen, if we neglect the helium gas that is a chemically inert, the most abundant elements in our galaxy are hydrogen and oxygen in the form of water that constitute up to 80% of the human body together with the carbon and nitrogen (which with oxygen is the major constituent of the atmosphere), these elements constitute the large majority of the weight of organic matter and living organisms.

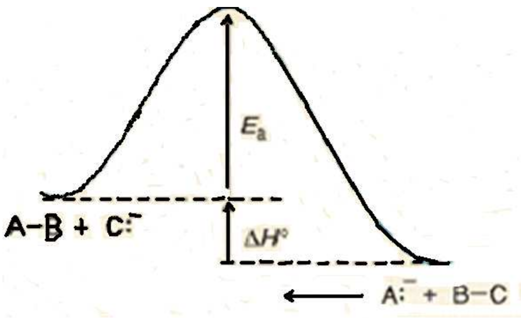
In probabilistic terms therefore the life, both vegetable and animal, originates from the interaction of atoms and molecules that are the most abundant elements on the Earth's surface at the boundary between lithosphere and atmosphere in what is commonly called Biosphere and which constitutes a real area of confinement protected from ultraviolet rays coming from the sun, and extreme temperature changes that occur in other solar planets.

The birth of life has occurred then in delimited areas where the temperature stabilization has allowed the establishment of a series of chemical reactions that have created the preconditions. The first stage was the formation of organic molecules mainly consisting of hydrogen atoms and of chains of carbon atoms linked to each other, when these organic molecules react with small amounts of other atoms such as oxygen and nitrogen or other still acquire a positive or negative polarity determined by these atoms acquiring the ability to interact with polar molecules, such as water, through a part of the molecule that is called hydrophilic or with nonpolar molecules, for example other organic molecules, with the hydrophobic part.

The chemical bond

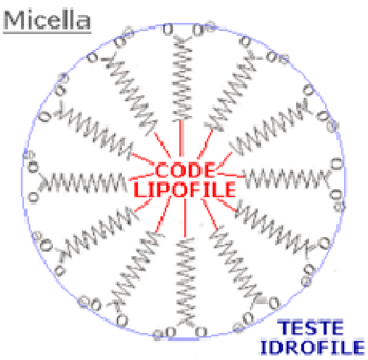
After the nucleosynthesis, responsible for the formation of the elements, the second stage of the merge process is the chemical bonding that occurs in a reaction environment in which there is a high concentration of reactants and a temperature and pressure adequate for the reaction.
For two atoms from an infinite distance approaching until the formation of a bond we have the following scheme





The potential energy difference between the two levels E_{H2} and $2E_H$ is what Teilhard de Chardin called "radial energy" and is the energy that is converted into heat due to the formation of the bond that brings the system to a greater stability.
All chemical reactions have an activation energy E_A that is a threshold which must be exceeded to switch from reactants to products and which serves to overcome the forces of repulsion between the nuclei of the atoms. This threshold may be higher or lower depending on the reaction conditions and can be lowered using the catalysts or, for biological reactions, of enzymes.

In addition to the bonds between atoms in a molecule may be links between molecules, these interactions involve much lower energies of the chemical bonds and the processes of nucleosynthesis.



The fatty acids that have a hydrophilic head and a hydrophobic tail, placed in a polar environment eg. water tend to form micelles, they are the prototype of both plant and animal cell membranes that constitute and define the cell as a living element first appeared on earth and as the fundamental building block used to manufacture higher organisms. Unlike the micelle, the cell has a double phospholipids membrane (organic molecules that also have their polar part and a nonpolar part) in which the hydrophobic part of the first one is facing the hydrophobic part of the other allowing to expose the hydrophilic part outside and inside the cell allowing to delimit a volume of aqueous solution in which to place other organelles.

The cell is a space of confinement, bounded by the cell membrane, where occur a long series of chemical reactions that characterize the function but does not alter the essence of indivisible element. It is an indivisible element which cannot be reduced to its constituent elements, is able to feed, to move and to reproduce and multiply.

The eukaryotic cell

As we have seen all evolutionary processes involve the union of two or more elements in a creative synthesis that gives rise to a new entity, namely a new individual, this is also what happened to the eukaryotic cell that has in addition to the other constituent bodies also a nucleus in which the DNA is preserved. This nucleus was originated by inclusion in a prokaryotic cell of another cell prokaryote stripped of all the other functions and specialized in the storage and replication of biological memory organism, ie the DNA that governs the synthesis through protein messenger RNA.

All higher organisms are constituted by multicellular beings in which all cells while being organized into organs, ie with different shape and function, however, retain their individuality essential, ie the ability to grow and reproduce and finally to become extinct. The evolution arises then the union of several individuals in a higher entity but does not sacrifice the individuality of the constituent elements.

Biological Memory that manifests as chemical memory is transmitted to the next generation with the life and allows each organism to transmit to future generations the changes he undergoes in the course of his life by creating a real synergy not only horizontally, that is, between individuals of the same species (and often different species) living in the same space at the same time, but also between individuals living in a different time and perhaps even in different spaces.

Interaction with the environment.

The evolution constructive contrary to the selective evolution is determined not only by the interaction between individuals of the same species or different species but also and above all by the interaction of individuals with the environment which forms with them a unique ecosystem. Also in this case it is necessary a condition of isolation (ecological niche) that allow the achievement of an evolutionary pressure such as to cause and consolidate morphological changes on individuals of the species. This creates a new species capable of spreading and proliferation.

This explains why evolution does not proceed in a continuous manner, as suggested by Darwin, but through discrete jumps, as noted by S. J. Gould had postulated the theory of punctuated equilibrium, ie long periods of equilibrium pseudostazionario that are experiencing the spread of new species alternating with short periods of strong evolutionary pressure under contained conditions in which other new species are formed.

And this is also what happened with regard to the human race for which we have evidence now quite evident that it is developed in the Rift Valley in Africa which has migrated in successive waves in other continents and is also what has happened and is still to culture that has developed in conditions of partial or total confinement before spreading in different continents, as evidenced by the Egyptian civilization protected geographically and economically from the desert surrounding the Nile Valley, civilization or Greek or Roman or Renaissance in terms of which economic and social evolution have led to a high tension in terms of art and philosophy.

THE ECOLOGICAL PERSPECTIVE OF THE PHENOMENON LIFE

F. Caporali, University of Tuscia

1. Introduction

The organizers of this meeting are confident that advocating a systems knowledge can promote a systems practice and set up a first step towards sustainability capacity building.

The big challenge for humanity as a whole is how to start a process of *cultural conversion* leading to a change from the Anthropocene – the present Era of human dominion on the biosphere regarded as a limitedness commodity- to the Ecozoic Era – an Era of sustainability for the biosphere regarded as a limited community to be kept in balance within its context of life (Crutzen et al., 2002). An epistemological failure, which is known as "mental apartheid", is likely to be at the origin of the dominant ill-informed human behaviour that is far from ecological principles and outcomes (Wackernagel and Rees, 1997). As a consequence, "to understand better in order to do better" is a kind of moral principle to be shared and implemented by the whole human community. Scientists have a major responsibility in fulfilling this commitment because they are "privileged today to be able to indulge their passion for science and simultaneously to provide something useful to society… Because the environment is so broad a topic, research across all disciplines is needed to provide the requisite knowledge base" (Lubchenco, 1998). In accordance with Norgaard and Baer (2005), we have to recognise that : " the modern world is characterized by an unprecedented fragmentation and specialisation of knowledge, including scientific knowledge", while to solve the problems "scientists must bring together the dispersed knowledge to inform collective deliberation". Transdisciplinarity in human knowledge and action should provide the inescapable connections for achieving sustainable development patterns, in a way that unity of knowledge, unity of judgement and coherent action can proceed in tune. The science of ecology can help in this connecting process as clearly stated by Keller and Golley (2000) in the following passage:

"From ecology to ethics: the step is inevitable. When the issue of human behaviour arises, it is difficult – and may be impossible – not to ask: Is there any difference between how humans are acting, and how humans should act? Now, at the end of the second millennium, we live on a planet where the activities of one species have an impact on all processes of the biosphere. The hegemony of *Homo sapiens* constricts the freedom of all organisms…. Ecologists cannot, and ought not, refrain from making moral judgments. Yes, ecology is political"

Agroecology is a recent example of a transdisciplinary field of enquiry that has served to connect the theory and practice of sustainable development in a human activity system, such as that of agriculture, which involves the use of land for human sustenance since thousands of years (Caporali, 2010).

2. Ecological Understanding

Picket et al. (1994.) present a framework of ecological understanding (table1) where, science, faith and art represent "three important and contrasting ways in which human make sense of the diversity of experience". But, *is it logically admittable to have separate fields of knowledge and understanding while we need a unity of knowledge in order to make synthetic judgments and develop coherent action?* This is a big epistemological question which deserves to be put forward even it may not receive an adequate response.

Table 1. Modes of understanding and their characteristics (modified from Picket et al.,1994)

Modes of Understanding	Features	Outcome
Science	Rational approach (verification through experimentation)	Conclusion
Religion	Emotional involvement (verification through affirmation)	Belief
Art	Proactive attitude (verification through exposition)	Expression

An astonishing comparison between two famous pieces of art (figure 1 and 2) reveals how meaningful an iconographic message deployed as a picture can be, communicating not only art but a whole “world vision”, which includes religion and science as well .They represent a description of contrasting human values and behaviour (selfishness vs. common good) at two different dates of human history, with the first representation that fits properly into the state-of –the-art of the current time and the second one that remind us the moral obligation to change human behaviour towards more social and environmental justice.

Bosch Hieronymus “***The Haywain Triptych***”
from the Flemish proverb, "The world is a haystack, and each man plucks from it what he can." [1485-1490]

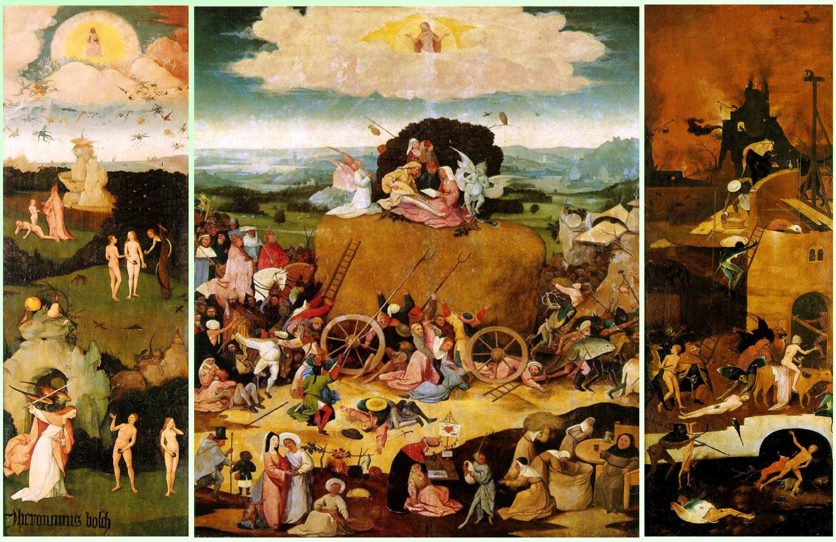


Figure 1. The “haywain triptych” (Prado, Madrid) represents past (left wing), present (center) and future (right wing) of humanity. After creation and sin, with Adam and Eve being cast from Eden, human beings are fighting for a share of hay (earthly richness) with all their might, until demons pull them into hell.

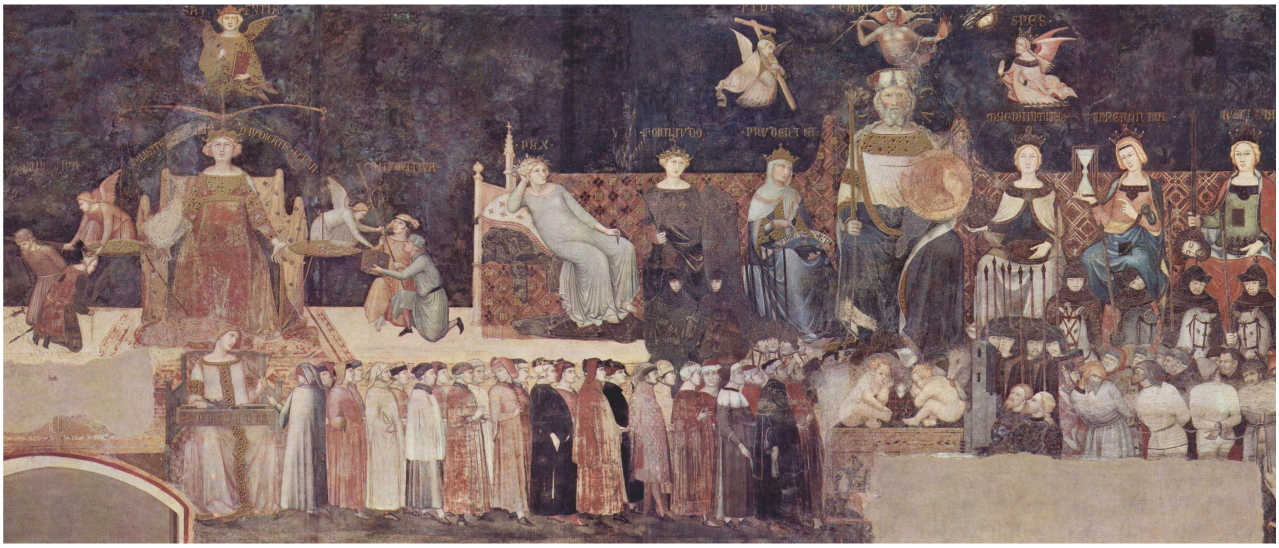
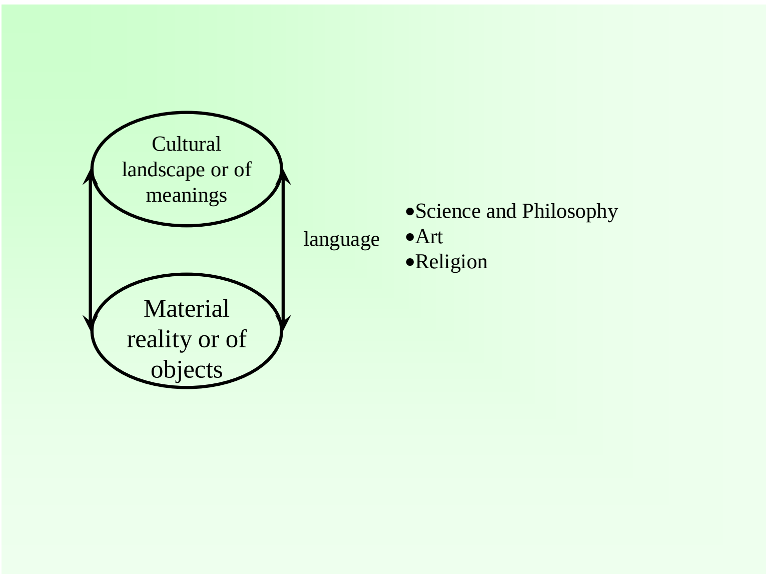


Figure 2 - The Allegory of Good Government (Ambrogio Lorenzetti, 1340, Palazzo Pubblico, Siena, Italy).Two central ethical and political themes are represented: Justice descends from divine Wisdom and creates Concord on the one end, and on the other end, the subordination of private interest to the Common Good, an authoritative noble figure holding a shield and a sceptre and bearing a crown. A Good Government for the Common Good like that of the medieval “polis” Siena is now required for the biosphere, the real “polis” of the whole contemporary humanity.

2.1 How we construct knowledge

We know by experience that each individual needs a map of his/her/its own context of life in order to survive. We can therefore state that the act of mapping is an ontological need. Mapping is the first requirement for survival and has the characteristics of a learning process, where to learn means establishing conscious connections with the context of life or external environment, in order to get food and shelter, to socialise and mate. Living requires knowing and acting at the same time. As human beings, we have developed sophisticated means for mapping our context of life, in order fu fulfil both material and immaterial (spiritual) needs. This process of mapping consists of transforming the material reality in which we are involved into cultural landscapes (or meaningful images) through the use of appropriate *languages* evolutionary developed, such as science and philosophy, art and religion (figure 3).

Figure 3.Codification of reality by means of specialised human languages

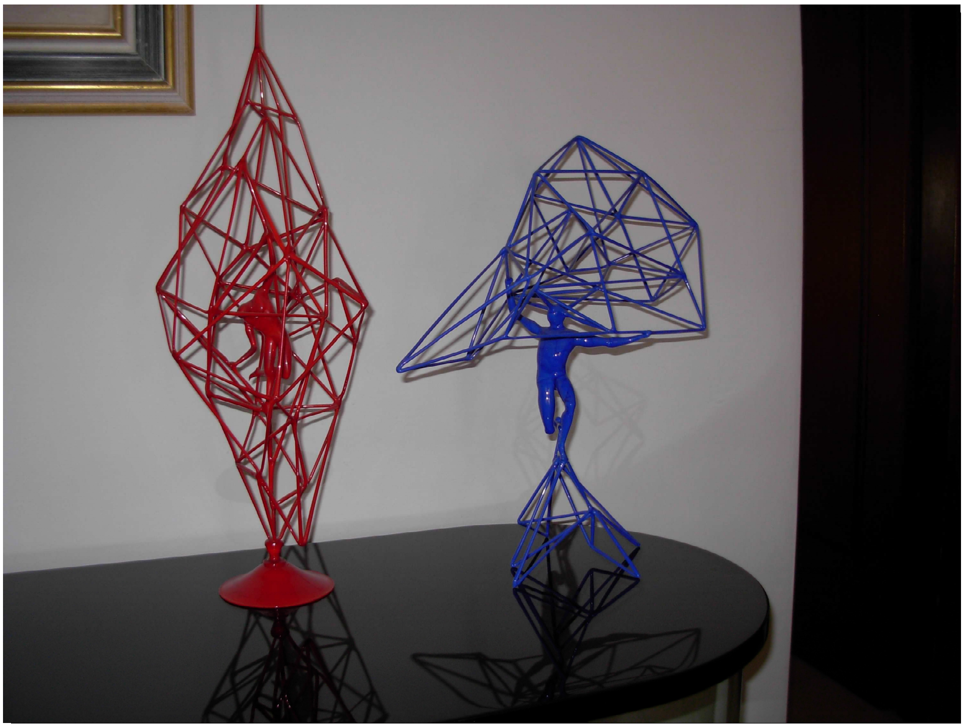


The cultural landscapes themselves institutionally established in families, schools, laws, buildings, etc. , such as a kind of collective memory operationally alive in all human activity systems (agriculture, industry, urbanisation etc.), change the composition of the material reality which in turn creates new meanings and cultural landscapes. The whole process is recursive and creative in its essence, a truly autopoietic learning and living process developing at both local and global level.

2.2 Individuals as "network structures"

In order to define the human condition and try to outline an individual identity, which personally each human being expresses, I would like to use the metaphor of the "spider man", as shown in figure 4 by the two pieces of ornament that belong to my home. Here, two men with contrasting attitude, energetic vs. depressed, are represented as involved in a web of links. Even if it is not so simple referring to the meanings that belong to a piece of art, I would like to suggest that the web represents the whole set of material and immaterial requirements that link each individual with her/his own external environment.

Figure 4. Individuals as "network structures"



The metaphor of the "spider man" refers to man's ability to construct both physiological (material) and psychological (immaterial) links in order to survive and develop human activities more or less successfully in the context of life. Looking at man as a network structure, i.e. an open entity in its environment, is more truthful than looking at man as an entity delimited by skin's boundary. Indeed, art's intuitions may help in developing knowledge. Human dependence by external factors, such as water, air, food and information is well known but paradoxically neglected considering how negatively today's human activities affect the renewal of the above mentioned resources.

2.3 Life as a "drama of dependence"

That life is a "drama of dependence" should be held as a guiding landmark for human behaviour. Indeed, life ought to be regarded as an interactive process that pertains both to the whole planetary system and to the single living beings. *Units of life can be detected at different levels of organisation, from the cell to the ecosystem, with the integration of different sources of energy, materials and information*. Even if each unit of life fluctuates in a spatiotemporal dimension and has an identifiable physical boundary, a form and a detectable functioning, the open hierarchy of organisation imposes constraints with *downward causation for control* originating from the higher levels and *upward causation for composition* originating from the lower levels (Rowe, 1962). *Life is a natural principle of organisation/integration of resources (energy, materials and information)*, that manifests itself with a network dynamics (Rowe, 1996). Each level of integration shows internal coherence among its components and external correspondence, in such a way that the whole system of life is self-sustainable and creative through renewal, change and continuing adaptation of its components (sub-systems) – a truly self-catalyzing and autopoietic system.

Ulanowicz (2009) puts emphasis on the fact that each living being is a unity which shows capacity of attracting and mastering resources and cites Russel's famous statement that " each living being acts as an imperialist" in collecting resources. Ulanowicz (2009) labels as *centripetality* the capacity by which materials and free energy are carried to a given living system. The concept of "centripetality" *sensu Ulanowicz* is at the roots of the science of ecology, as shown by the pioneering Lotka's book "Elements of physical biology"(1925), where the term Physical Biology has been employed to denote "the broad application of physical principles and methods in the contemplation of biological systems". In this book the very character of ecology is put forward by linking the separate worlds of the organic and the inorganic within a system's approach. It is very instructive to look at the book's contents in order to find out the scientific base of ecology. Firstly, general principles are provided in order to explain reality as a "General Mechanics of Evolution", where the mechanics of systems undergoing irreversible changes in the distribution of matter among the several components of such systems is investigated. Evolution is defined as the history of a system in the course of irreversible transformation and is conceived as a redistribution of matter among those components of which the system is build up. In this big framework of reference, a truly bio-geo-chemistry approach emerges at planetary level and astonishing insights into the most important element cycles are provided. A section on energetics – or "dynamics of the world engine" -follows, where nature is regarded as the evolution of a system of energy transformers ("anabions and catabions") doing cyclic working with output and efficiency performances. Finally, the flow of knowledge in the system as a relation of consciousness to physical conditions is investigated, speculating on both a) the function of consciousness in directing the course of events; b) the origin of consciousness as a tool to secure adaptive behaviour in the organism. As a conclusion, emphasis is put on the information –action unitary process:

"Nevertheless a connection is established between knowledge and will, through the fact that the Knower and the Willer are united in one physical body, so that physical reactions do occur between knowing and willing"(pag.423)

and on the emergence of the planetary and cosmic human responsibility:

"Thus, in the light of modern knowledge, man is beginning to discern more clearly what wise men of all ages have intuitively felt – his essential unity with the Universe… A race with desires all opposed to Nature could not long endure; he that survives must, for that very fact, be in some measure a collaborator with Nature. With extending knowledge must come awakening consciousness of active partnership with the Cosmos"(pag. 433).

Lotka's inspiring ecology has part of its roots in the science of chemistry developed in the 19th century. An important contribution to the bio-geo-chemistry approach was made by Justus von Liebig as early as 1847, in his book "Chemistry in its application to Agriculture and Physiology", as shown by this passage:

“ An inquiry into the conditions on which the life and growth of living beings depend, involves the study of those substances which serve them as nutriment, as well as the investigation of the sources whence these substances are derived, and the changes which they undergo in the process of assimilation. A beautiful connection subsists between the organic and inorganic kingdoms of nature. Inorganic matter affords food to plants, and they, on the other end, yield the means of subsistence to animals” (pag.9).
These fundamental ecological insights were due to Liebig’s commitment to investigating the agricultural activity with a transdisciplinary attitude , where “the power and knowledge of the physiologist, of the agriculturalist and chemist, must be united for the solution of problems”(pag.49).

3.4 Pierre Teilhard de Chardin’s contribution

In the history of human beings, the most important example in attempting to bridge the gap between science and faith is that offered by Pier Teilhard de Chardin (1881-1955) (TdC), a famous paleontologist and Jesuit priest . Systems thought is operating in each of his writings in the following recognizable patterns of the functional integration principle:

1) Ontological integration of opposites in view of a unitary vision of both material and immaterial reality in a way that satisfies the need of wholeness in knowledge and sense;
2) Ontological integration of the evolution steps in the history of both cosmos and humanity as a coherent process of unitary development leading to a focus point (Omega point) driven by a divine attractor;
3) Epistemological-ontological integration between a spatiotemporal scale with a process scale of increasing information according to the law of complexity-conscience;
4) Epistemological integration of disciplinary contents into a transdisciplinary framework .

In recent Italian collections of his writings, such as “L’Avvenire dell’Uomo” (Teilhard de Chardin, 2011) e “L’Uomo, l’Universo e Cristo” (Teilhard de Chardin, 2012), it is possible to grasp the seminal aspects of his prospective vision, that is characterized by the faith in both human beings and their capacity to integrate their needs towards a shared goal , under the increasing pressure of the two leading forces of “moralization” and “mystique”. For TdC, *Integration, Harmony* and *Love* are key -word and show an itinerary of hope, if they will be accepted as value elements for action. The process of planetary “hominization”, that is already at its climax, ought to be now followed by the process of “humanization”, that is instead at its very beginning. A spiritual evolution phase should complete the entire process of life evolution on the Earth, with a “noospheric” convergence brought about by both demographic pressure in a confined planetary space and a spirit of creative belonging in a cosmic project.

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LOOKING FOR BIOSPHERES?
TEILHARD DE CHARDIN AND THE THEORY OF AN EVOLVING BIOSPHERE

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A new look to Teilhard de Chardin's scientific papers

In 1995 I proposed a revision of Teilhard de Chardin's technical papers in order to investigate the presence of original contributions to evolution theories[21] (Galleni, 1995). In the following years other papers were published and the *moving towards* concept was considered the main contribution of Teilhard de Chardin to the present day theories of evolution: as a general rule, matter was moving towards complexity and life towards complexity and cerebralization.

Teilhard de Chardin defined this observation as the complexity consciousness law, and this law revised using tools of Lakatos epistemology, it is the central core of a true Scientific Research Program (SRP) and it is an example of the fecundity of the reciprocal influence of science and theology[22].

Now this meeting on astrobiology is a useful start point to discuss Teilhard de Chardin scientific perspectives.

The question posed by this meeting is:

"*Is the origin of life and its evolution the lucky event among many others equal probable possibilities or is it the necessary results of mechanisms described by the present day knowledge about evolutionary mechanisms?"*

Of course the possibility to develop astrobiology is strongly related to the answer to this question.

If life is a lucky event it is a non senses to investigate its possibilities on a near planet such as Mars.

On the contrary if it is the necessary or anyway the high probable result of describable laws of evolution than it makes sense to investigate its presence.

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[21] L. Galleni, *How does the teilhardian vision of evolution compare with contemporary theories?* Zygon 30 1995, pp.: 25-45

[22] L. Galleni and M.-C. Groessens-Van Dyck, *A Model on Interaction Between Science and Theology Based on the Scientific Papers of Pierre Teilhard de Chardin*, in: W. Sweet and R. Feist edtrs. , Religion and the Challenges of Science, Ashgate, Aldrshot, 2007, pp.: 55-71.

Hazard or necessity: a look to Teilhard Scientific Research Program

In his doctoral thesis Teilhard described the mammals of the deposits of Quercy and other French deposits and at the very beginning of his experience as a trained scientist he used the distinction between convergence and parallelisms.

Among the Primates he described fossils of the genus *Plesiadapis* (OS, I: 273-277) and from two genera of the Tarsidae family: *Pseudoloris* and *Tarsius* (OS, I: 223-245).

Plesiadapis represents their first morphological adaptation, called sciuroid stage, because of morphological similarities with squirrels; *Pseudoloris* and *Tarsius* on the contrary, are clearly along the phyletic line arriving at monkeys, apes and Hominidae.

Teilhard de Chardin described *Plesiadapis* as a convergence with the squirrel morphology. On the contrary *Tarsius* developed a line of evolution parallel to those of the other Primates: the evolution towards a more wide brain, presented in the line of *Tarsidae*, was independently developed in the phyletic branch of the other monkeys and in that bringing to humankind's progenitors. *Tarsidae* parallelism showed evolution as a *moving towards* cerebralization![23]

Very early during his scientific career Teilhard made a clear distinction between parallelisms and convergence. For this reason his choice of following the researches on parallelisms represented the acquisition of an experimental tool.

Parallelisms were one of the main items discussed from the very beginnings of evolutionary theories. The discussion was concerning the explicative capability of natural selection and parallelisms were considered to be a proof of the action of mechanisms different from natural selection.

The argument was proposed by St. George J. Mivart, an English zoologist collaborator of Darwin and T. Huxley. In 1871 he published in London a where the evolution was considered an accepted fact, but many events appeared difficult to interpret in term of natural selection[24]. It is a fascinating book because most of the difficulties of natural selection discussed in the last one hundred and fifty years are already presented. And parallelal evolution was among them.

At the beginning of the twenties a Russian botanist and genetist: N. I. Vavilov developed (quite in parallel with Teilhard) a proposal for parallelisms. His idea was more related to those of Mivart, and to a more deterministic model of evolution. His ambition was to be considered as the Mendeleyev of evolutionary biology. Mendeleyev, thanks to the deterministic rules of chemistry, was able to describe the chemical physical characteristics of the elements of a line, knowing the characteristics of the upper line. Vavilov proposal was that, thanks to the knowledge of the morphologi-

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[23] P. Teilhard de Chardin, L'oeuvre scientifique, N. et K. Schnitz Moormann edtrs, Walter-Verlag, Olten und Freiburg im Breisgau, 1971, pp. : 215-246

[24] St. J. Mivart, *On the genesis of species*, MacMillan, London, 1871.

cal and genetics characteristics of the species of a genus, it was possible the description of the morphology of the species of the parallel genus[25].

Evolution was not a continuing divergence of phyletic branches due to the free action of mutation and selection, but was canalized: when a morphological step was reached the following steps were strongly determined. The result was the emergence of similar traits in separated group.

Teilhard de Chardin, in his first papers on parallelism, used this concept in a different way. His interest is mainly in the description of events compatible with the hypothesis of evolution as a *moving towards* and basically as a *moving towards* complexity and consciousness. He looked for the description of events rather than for a search of mechanisms. In his SRP looking for parallelisms was to look for the experimental proofs of the *moving towards.*

After the first word war Teilhard started his Chinese period because of the collaboration between the Huango .- Paio Museum in Tien Tsin and his director and founder, the Jesuit Emil Licent and the Paris Museum of Natural History and M. Boule[26]. At the very beginning of his Chinese experience Teilhard de Chardin wrote about the necessity that geology and palaeontology passed quickly from the analysis of this or that layer or of this or that fossil to a more general and global methods of investigation.

Then he proposed the science of continental evolution: Geobiology. The geobiological method stated that, following the evolution of a peculiar animal group on a large geographical (continental) and temporal (millions of years) scale it was possible to describe mechanisms and events which were not acting at a lesser scale. Biology defined as the science studying the infinitely complex asked for new and different mechanisms when investigation passed from the population level to a larger scale, such as continental evolution. Thanks to the methods of continental evolution he found the best example of parallelism: that of the mole rats of the Chinese Pleistocene.

This is the proof that Teilhard used a true scientific research program based on the Galileian method.

First of all we meet the observations on Tarsidea and a research program based on the general idea of evolution as a *moving towards*; then we find the definition of a general law: the complexity consciousness law proved by the findings of parallelisms; finally we arrive at the confirmation of the law through the definition of the continental approach and then the finding and description of parallelisms in mole rats.

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[25] N.I. Vavilov, *The law of homologous series in variation*, J. of genetics, 12, 1922, pp.: 46-89

[26] L. Galleni and M.-C. Groessens-Van Dyck,, Lettres d'un Paléontologue, Neuf lettres inédites de Pierre Teilhard de Chardin a Marcellin Boule, Revue des Questions scientifique, 172, 2001, pp.: 3-104.

In mole rats (the *Siphneidae*) the basal group of divided into three branches following independent evolutionary lines but in all the three branches, independently, appeared similar traits: an increase in size, inception of continuous growth of molars and a fusion of the cervical vertebrae.

Teilhard de Chardin conclusions were that changes appeared independently in just separated phyletic branches and this observation provided examples of directionality in evolution. To these examples he applied the term orthogenesis , intended such as the appearance of similar tracts in branches just separated and this definition was free from any teleological or not scientific meaning, because based on the findings of fossil records.

In Teilhard's research program, the mole-rats example is also a way of demonstrating that the use of the continental scale suggests the existence of new elements in evolution: biology as the science of living complexity showed the emergence of different mechanism working at different scales.[27]

The moving towards at a more general levels: the distinction between aggregation and organization.

The interactions between objects happen in two different ways.

First of all the aggregation, as for instance, the origin of stars or of a crystal, where interstellar dusts (stars) or molecules (crystals) combine giving larger objects. They present internal regular structure and the possibility of increasing in dimension only from outside and without a precise boundary. Moreover they enlarge but they remain ontologically themselves.

The organization is completely different. Apparently the processes are the same, because they are interactions among objects of the same hierarchical level, but in the organization there is the origin of an object ontologically different. The interactions among molecules give rise to objects with different characteristics, based on new and not predictable relationships among the parts.

The origin of life (organization) is a completely different process from the origin of a crystal (aggregation) [28]

The new objects originated from organization processes have well defined boundaries and the relations among the parts develop a precise *telos*: that of the survival of the object and of the peculiar categories of objects: i.e. the survival of the single and the reproduction. The possibilities of an increase in dimension are not related to the apposition from the outside of new quantities of the same components such as in crystal. On the contrary from the outside there is a selective passage of

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[27] L. Galleni and M.-C. Groessens-Van Dyck, *A Model on Interaction Between Science and Theology Based on the Scientific Papers of Pierre Teilhard de Chardin*, op. cit. , pp.: 55-71.

[28] P. Teilhar de Chardin, *Le singolarità della specie umana*, a cura di L. Galleni, Jaca book, Milano, 2013.

molecules through the boundary and then the material is incorporated inside the objects. As a matter of fact they become components of the object and they acquire its *telos*.

The great novelty in evolution is the emergence of complex objects, or new systems, according to Van Bertallanfy's definition. These new objects cannot increase in dimension for appositions of new elements but only interacting and giving rise to new ontological objects: from the protobionts to the primitive cells, from the primitive cells to prokaryotic cells, from prokaryotic cells to eukaryotic cells , to pluricellular organisms, to species, ecosystems and so on.

There is an emergence of new ontological entities and qualities which makes the difference between aggregation and organization and the origin of complex objects.

However, working on evolution, there is also the necessity to find the final object to be investigated using the techniques of complexity. Teilhard proposed a way to measure complexity in order to find the proof of the *moving towards* but also to look for an asymptotic value where the curve of complexity is moving. The value corresponds to the Biosphere: this is the final complex object to be investigated in order to find the general laws of evolution: those laws which characterise the rising of complex objects thanks to organization all over the universe: life, is not any more an epiphenomenon but the essence of the phenomenon: it is the result of the general laws of evolution .[29]

The theory of the Biosphere is the next passage after the idea of continental evolution and a tool to give an empirical definition to the idea of complexity.

The Biosphere is the final complex object in order to describe the general laws of evolution. As a system, Biosphere is made up of parts and relations among the parts; and it is delimited by boundaries, actually not so sharply defined as those of a cell or of an organism, but still present and active. See for instance the greenhouse effect of the upper atmospheric layers.

Geobiology is, in the Teilhard scientific program, the general science of the evolution of the Biosphere and continental evolution is only a tool to study the evolving Biosphere at a lesser scale but without distortions.

Geobiological research was carried out at the Institute of Geobiology in Peking and the results of the geobiological methods were published in many papers and then in a Journal: *Geobiologia.*

In the foreword of the first issue of *Geobiologia*, Teilhard stated that Geobiology is the science reuniting all the other sciences of evolution such as palaeontology, ecology and biogeography thanks to its method: a more general and planetary method of investigation. Defined as the "science of the biosphere" it is a development of the previous definition of Geobiology: the science of continental evolution, is now extended to the whole Biosphere considered as a system, because it is

[29] L. Galleni, Darwin, Teilhard de Chardin e gli altri…le tre teorie dell'evoluzione, Felici, Pisa, 2012^2.

closed (see again the presence of a boundary: the upper active layers of the atmosphere) and it is characterized by the interactions among parts in order to maintain stability.

A very innovative approach to evolution!

Teilhard was not an isolated researcher in the Chinese subcontinent with few friends in the small Institute of Geobiology but the founder of a true palaeontology school , the latin school of evolution, where concepts such as symbiotic relationships and the maintenance of the ecosystem equilibriums were considered as a tool to explain directionality in evolution.[30]

Recent confirmations on the Teilhard research program.

We have just discussed the perspective of Teilhard de Chardin's SRP and its development : here we give a short summary about the more general perspective related to the *moving towards* concept.

Stability of the Biosphere was revised from Lovelock in a perspective related to the concept of the system of Van Bertallanfy and to its application on biology and sociology made by Waddington. The concept of Biosphere stability goes back to the very beginning of the Latin school thanks to the Italian geologist Antonio Stoppani: in his geological theories in the second half of the XIX century he investigated life at a planetary level and its interactions with physical and chemical parameters, giving as a result, the stability of the main parameters of the Biosphere allowing the survival of life on Earth[31] .

From this point of view we suggest a new and decisive heuristic perspective in the Teilhard research program. Could the maintenance of biosphere equilibriums be the true motor of evolution and of the *moving towards* complexity and consciousness? In the light of continuously changing parameters, the increase in diversity and in complexity is the suitable tool for stability maintenance.

Moreover mathematical models of Biosphere evolution gave new suggestions. The presence of catastrophic events such as mass extinctions are fundamental because they create new ecological niches and give the opportunity for new adaptive radiations. These events are related to the mechanism itself of Biosphere evolution and are not correlated to external accidental events[32]

These models are clearly in contrast with the S.J. Gould hazardous mechanisms of external impacts: the search for the general laws in Biosphere evolution, clearly related to the Teilhard de Chardin research program give us some information regarding the presence of less casual models than those proposed Gould. Also some of the present day novelties in evolution could be related

[30] L. Galleni, *Teilhard de Chardin and the latin school of evolution: complexity, moving towards and equilibriums of nature*, Pensamineto, 67 (ne 5) 2011, pp.: 689-708.

[31] L. Galleni, *Teilhard de Chardin and the science of the Biosphere*, in K. Duffy ed., Rediscovery Teilhard's fire, Philadelphia, Saint Joseph's University Press, 2010, pp.: 197-206.

[32] V. Benci and L. Galleni, *Stability and Instability in Evolution*, J. of theoretical biology, 194, 541-549.

to Teilhard de Chardin, first of all the links between the evo-devo theory and palaeontology. Metamery is determined in very different animal groups by the same genes which are present at the very beginning of animal evolution or at least when head tail directionality is developed. From this moment it was easy to reach the metameric organization, and it emerged two or three times in animal evolution. The origin of metamery is the best example of the importance of parallelisms. These topics were recently developed, again in the perspective of parallelisms by Conway Morris in his discussion about the Burgess Shale fossil deposits Conway Morris[33].

A second confirm is related to the new revision of Placental evolution. In this case the new phyletic tree based on the results of molecular and chromosome investigations clearly showed that Placental could be divided in four taxonomic entities based on the four continental regions recently separated. The continental approach which gives us new information about animal evolution.

However the final confirmation of the *moving towards* cerebralization and of the complexity consciousness law is the discover of the Bacterial nano brain. In this case we have a group of molecules just adjacent to the part of the bacterial membrane opposite to the flagellum and in the direction of the movement. These molecules are able to discriminate the presence of an attractive or repellent substance, to calculate its gradient and then to send a message to the flagellum in order to maintain or to change the direction of movement. The nano brain is able to receive information from the extern, to elaborate the information and then to send a message to the locomotors organelles. These is exactly the function of the brain in the primitive Metazoan.

It is the confirmation of the heuristic values of the *moving towards* complexity and consciousness as a general Galilean law. The bacteria are no longer the example of limited evolutionary possibilities, but on the contrary the example that evolution is everywhere exploring the possibility of *moving towards* cerebralization and the *moving towards* as a general empirical law finds one of its best confirmations here..

Finally the theory of the Biospheres gives us perspective in astrobiology investigations. Presently many planets outside the solar system are discovered. If and when it will be possible to study some parameters of their atmospheric composition, then the theory of an evolving Biosphere will give us some information about the possibilities of the presence of an evolving life (but is it possible to think of a not evolving life?). If the atmosphere equilibriums are not the thermodynamics equilibriums, the hypothesis could be make that they are actively maintained by livings such as it happens, in our Solar system, for atmosphere of Earth in respect f.i. to Mars and Venus.

[33] Cfr. L. Galleni, *Darwin, Teilhard de Chardin e gli altri*, op. cit.