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On the biological origin of design in Nature

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Abstract. We consider first the most fundamental „design in Nature”, the explanatory structure of the Universe on the basis of the natural sciences, and the related problem of teleology in Nature. We point out that it is necessary to generalize the presently used explanatory scheme of physics. We derive here the first essentially complete scientific world picture, and obtain new insights answering to the problem of cosmic design. Considering some important objections against teleology, we present counter-arguments, give a new classification of the main classes of teleology and their quantitative complexity measures. Comparing the new classification of teleology with that of Mayr, we give useful examples and indicate why teleology is useful for natural science. As a result, we outline a general picture of the basic types of design in Nature and provide their scientific explanation.

1. Design and teleology

As the Oxford English Dictionary indicates, design is “a mental plan”, or a “purpose, aim, intention”. Therefore, design seems to be closely related to teleology. Perhaps the most transparent version of design is the type that is created by man, like the one that is manifest in machines. In a machine, design is manifest in its structure, namely, in its materially manifest "plan" or "working principle", which controls the function of the machine. Actually, the "working principle" can fulfill the prescribed function only by harnessing the physical laws; that is, machines manifest a dual control, one is exerted by their design, the other is by the physical laws. Certainly, the design of machines is teleological, since machines by their very nature are controlled by human purposes; a car is designed to be suitable for transport, a watch to show the time etc. What can we know about the nature and origin of the underlying control, the one realized by the physical laws? Physical laws in physics are regarded as the fundamental basis of physical reality. This means that physical laws play an important role in the ontological structure of the Universe. Therefore, understanding the origin of control by physical laws require the exploration of the ontological structure of the Universe. Indeed, it is required by the fact that in the concept "design in Nature" the teleological aspects of physical reality play a basic role.

We are interested here in the scientific aspects of natural phenomena or man-made facts that are usually referred with the term "design". At present, it seems that from the basic natural sciences, physics, biology and psychology, only physics is a mature and exact science. Regarding the general view that teleology is widely regarded as being "contrary to the whole orientation of theoretical physics" (Yourgrau and Mandelstam, 1960, 154), the scientific study of "design" in Nature seems to be problematical in the usual conceptual framework of physics. Yet our aim is to approach this problem with the most exact tools of science. As a preliminary step, let us consider the question: is there any scientific basis for the general belief in the "design" of the Universe?

"The belief in a purposive power functioning throughout the universe (…) is the inevitable consequence of the opinion that minimum principles with their distinctive properties are signposts towards a deeper understanding of nature and not simply alternative formulations of differential equations in mechanics (…)." (Yourgrau and Mandelstam 1960, 154) In the last decades, it is more and more recognized that the least action principle plays a central and comprehensive principle of all the fundamental branches of modern physics (Landau and Lifshitz, 2000, 2-3; Feynman, Leighton and Sands, 1964, Vol. 2, 19-4; Moore, 1996, 2004; Brown, 2005, x; Taylor, 2003). Actually, it is well known that all the fundamental physical laws (that is, the laws of classical mechanics, hydrodynamics, electromagnetism, thermodynamics, theory of gravitation, and quantum physics, including quantum field theories and string theory) are derivatives of one and only one deeper-level law — namely, the *least action principle.* It has been remarked (Taylor, 2003) that the least action principle lies at the foundation of contemporary theoretical physics. “The action principle turns out to be universally applicable in physics. All physical theories established since Newton may be formulated in terms of an action. The action formulation is also elegantly concise. The reader should understand that the entire physical world is described by one single action.” (Zee, 1986, 109).

Now if the action principle is so fundamental, and if its property of being a minimal principle is crucial for the deeper understanding of nature, as Yourgrau and Mandelstam claim, than why is it that teleology is regarded as being “contrary to the whole orientation of theoretical physics”? One point is the appearance that “the action is not always the least, like in the case when the particle may move between two points on the ellipse in either of two paths; the energy is the same in both cases, but both paths cannot have the *least* possible action”. On that basis, Yourgrau and Mandelstam were quick to conclude: “Hence the teleological approach in exact science can no longer be a controversial issue; it is not only contrary to the whole orientation of theoretical physics, but presupposes that the variational principles themselves have mathematical characteristics which they *de facto* do not possess. It would be almost absurd to imagine a system guided by a principle of purpose in such a manner that sometimes, not always, the action is a minimum.” (ibid., 155) Yet we point out that the action principle in its usual form considered by Yourgrau and Mandelstam is restricted to holonomic systems, i.e. systems whose geometrical constraints (if any) involve only the coordinates and *not the velocities*; therefore, the conclusion of Yourgrau and Mandelstam does not apply to the case they refer to. After all, it is a simple thing to see that a particle with any given initial velocity cannot start in the opposite direction, therefore there is no such case „when the particle may move between two points on the ellipse in either of two paths”, assumed by Yourgrau and Mandelstam (ibid.). If this is the crucial argument underlying the widespread opinion against teleology in physics, than it does not follow that teleology must be exiled from physics. Therefore, we have to reconsider the problem.

It is true that teleology is not visible at the level of observable phenomena or of physical laws. Indeed, the fundamental differential equations are time symmetric, and so they avoid teleology. Yet at the level of the action principle teleology is explicitly manifest. In the usual formulation of classical action principles, the initial and final states of the system are fixed, and are formulated as: Given that the particle begins at position x_1 at time t_1 and ends at position x_2 at time t_2, the physical trajectory that connects these two endpoints is the one that makes the action stationary. “The method does not mean anything unless you consider paths which all begin and end at the same two points. So the deviations have to be zero at each end. With that condition, we have specified our mathematical problem.” (Feynman, Leighton and Sands, 1964, Vol. 2, 19-4).

For our present purposes, it is enough to realize that teleology (see the entry „teleology” in the Encyclopedia Britannica) is defined as “explanation by reference to some purpose or end”. Definitely, the least action principle is based on a relation between some initial and final state; therefore, reference to some end (attention: not necessarily to a purpose)— namely, to a subsequent, final physical state — is already explicitly present. Variational principles are „the contemporary descendants of final cause” (Brown, 2005, x). We can observe that Yourgrau and Mandelstam misinterpreted physical teleology as “purpose” (these are widely different concepts!) and were wrong when claiming that the action principle does not possess teleology. Now if a kind of teleology is present already in physics, the general opinion that its companion, design, must be “naturalized” (explained in terms of physical forces as effective causes) in order to become scientifically acceptable is also based on a wrong premise.

1.1 MECHANISM AS A WORLDVIEW AND THE RELATED CAUSAL LEVELS OF NATURE

In the last centuries, science as well as philosophy of science has been dominated by the idea of *mechanism*. Apparently, the “mechanism worldview” was formulated as a bedrock of scientific method by Henry Oldenburg, the first secretary of the influential Royal Society, who claimed that all phenomena can be explained exhaustively by the mechanical operation of physico-chemical forces (Oldenburg, 1661; Henry, 1988). Physical forces can arise as effects of causes arising at two basic levels: (1) due to interactions between physical objects (which are, of course, mediated by physical laws), and (2) interactions between physical objects directly with the physical laws. A third element is also allowed: (3) “random”, “spontaneous” or “acausal” phenomena. Examples are collision of physical objects (1), free fall (2), and radioactive decay or spontaneous emission (3)[1].

Indeed, “almost all physicists who work on fundamental problems” accept that “the laws of physics stand at the base of a rational explanatory chain, in the same way that the axioms of Euclid stand at the base of the logical scheme we call geometry” (Davies, 2004). Yet to take into account the action principle in our explanatory scheme requires an extension of the above cited, two-levelled explanatory scheme, and to indicate whether the action principle offers us a deeper understanding of Nature or not.

1.2 DESIGN OF THE UNIVERSE, AND ITS APPARENTLY NECESSARY NATURALIZATION

A significant attempt of modern physics seeks answers to the origin of physical laws trying to “naturalize” the possible answers (Wheeler, 1989; Hartle, 1991; Davies, 2006), explaining them in terms of “randomness” (Davies, 2011) or by such a highly speculative idea as the “multiverse” (e.g. Hawking and Mlodinow, 2010). Now “a strong motivation for introducing the multiverse concept is to get rid of the need for design, this bid is only partially successful. Like the proverbial bump in the carpet, the popular multiverse models merely shift the problem elsewhere – up a level from universe to multiverse.” (Davies, 2011)

We point out that the aim of science, since at least Plato, is to find the minimal number of ultimate principles which are able explain observable phenomena. In this paper, we carry out this program, and explore this road in two steps, obtaining a new, more deeply penetrating and more completely comprehensive explanatory scheme than the one in which “the laws of physics stand at the base of a rational explanatory chain”. In our essentially complete explanatory scheme of Nature, the first principles of physics, biology and psychology stand at the base of a rational explanatory chain.

[1] In quantum electrodynamics, radioactive decay as well as spontaneous emission and similar processes are elicited by virtual interactions. In that way, class (3) causes become involved into class (1).

1.3 THE ESSENTIAL SURPLUS OF THE ACTION PRINCIPLE OVER THE PHYSICAL LAWS

It is a widespread opinion that the least action principle is strictly equivalent with the differential equations derivable from it (Yourgrau, Mandelstam, 1960, 156). At variance with this unsubstantiated claim, we point out that the at present best explanation of the least action principle, Feynman's sum over histories approach (Feynman, Leighton and Sands, 1964, Vol. 2, 19-4; Feynman and Hibbs 1965; Brown, 2005) contains definite surplus beyond the differential equations derivable from it. „There is quite a difference in the characteristic of a law which says a certain integral from one place to another is a minimum – which tells something about the whole path – and of a law which says that as you go along, there is a force that makes it accelerate. (Feynman, Leighton and Sands, 1964, Vol. 2, 19-8). "It isn't that the particle takes the path of the least action but that it smells all the paths in the neighborhood and chooses the one that has the least action by a method analogous to the one by which light chose the shortest time." (ibid., 19-9). The essential surplus elements are the following: One is the selection of the endpoint corresponding to the least action principle in the given situation, another is exploring all possible paths in the Universe[2] (Taylor, 2003), and the third one is the activity of summing up the probability amplitudes of each explored path.

It seems that reality is even more surprising, than the presence of an automatic, physical teleology: how is a quantum able to explore all paths in the Universe? And how is it able to select its endpoint from the gigantic zoo of all possibilities? And how is it able to execute any activity, especially such characteristically intellectual activity like summing up the obtained gigantic amount of information? The answers lead to infinite dimensional Hilbert spaces, where the wave functions exist, and to virtual particles of the quantum vacuum, the physical manifestations of the action principle (Grandpierre, 2007). In our more complete explanatory scheme a new class of possible physical causes seems to be also available: class (4), containing the first principles, namely the least action principle of physics, the Bauer principle of biology, and the first principle of psychology.

[2] In the double-slit experiment Feynman's ideas mean the particles take paths that go through only one slit or only the other; paths that thread through the first slit, back out through the second slit, and then through the first again; paths that visit the restaurant that serves that great curried shrimp, and then circle Jupiter a few times before heading home; even paths that go across the universe and back. Feynman's formulation has proved more useful than the original one. (Hawking, Mlodinow, 2010, 45-46.)

1.4 SCIENTIFIC EXPLANATION BY FIRST PRINCIPLES — THE ONTOLOGICAL STRUCTURE OF NATURE

We indicate here that the "mechanism" view gives a partial picture of Nature, and as such, it can be misleading. We present here the first essentially complete scientific picture of Nature, improving what has been considered till now as the "best model of human knowledge", built up on the basis of the Aristotelian model of scientific induction and empiricism by Kepler, Galilei, Bacon, and Newton (Hooker, 1996). Acknowledging about the fundamental significance of the first principle of physics, we allow it to represent a third, and ultimate explanatory level of physical reality. Instead of physical laws, as in the explanatory scheme of the mechanism view, we recognize the least action principle as the natural end of any physical explanation, since all the fundamental laws arise from it. In our new, broader picture, the Universe consists of three fundamental ontological layers: the levels of phenomena, of the laws of Nature, and of first principles, representing the surface, depth and core of Nature, respectively.

1.5 ON THE NECESSITY TO INTRODUCE THE BIOLOGICAL PRINCIPLE INTO SCIENCE

It is not generally known that the behavior of biological organisms is governed also by a „first principle", which is the Bauer principle (Bauer, 1967; Grandpierre, 2007). The Bauer principle is the first principle of biology, since it is mathematically formulated, giving quantitative account of all basic phenomena of life, including metabolism, regeneration, growth and death (Bauer, 1967, 119-132), reproduction (ibid., 133-158), adaptation and response to stimuli, substantiated by experimentally determined basic relations (ibid., 159-183) – as well as determining the basic law of evolution (ibid., 184-198). The Bauer principle tells that: "The living and only the living systems are never in equilibrium; they unceasingly invest work on the debit of their free energy budget against that equilibration which should occur for the given the initial conditions of the system on the basis of the physical and physico-chemical laws" (Bauer, 1967, 51; Grandpierre, 2008a). Its introduction is necessary since no physical theory explains the basic life phenomena as well as biological behavior at the level of the organism, including such observables as the gross behavior of a living bird dropped from a height (Grandpierre, 2007), or the simple action of bending a finger. The complexity of the living organisms, as it is widely acknowledged, is intractably large in the bottom-up approach of physics. A still bigger problem is that this complexity is not static. It changes from time step to time step. Such structural changes are regarded as random in thermodynamics. Yet in biology these structural changes are not random, but change systematically and consequently, and sum up in a complex way which is governed by the Bauer principle. It was shown that this fundamental biological principle can be formulated in terms of physics as the greatest action principle (Grandpierre, 2007). Therefore, biology shows the same explanatory structure as physics: phenomena can be explained by laws, and all basic biological laws can be derived from the first principle of biology. Based on the newly found fundamental explanatory structure of physics and biology, we postulate that the ontological structure of the Universe represents a hierarchical order: observable phenomena are governed by laws, and laws by first principles. If so, psychology must also have a first principle.

1.6 ON THE NECESSITY TO INTRODUCE PSYCHOLOGICAL PRINCIPLE INTO SCIENCE

Let us consider a simple example to shed light on the nature of physical, biological, and psychological causes of natural processes. Why did I jump into the air? Let us approach this problem in two steps. (i) A physicist can claim that I jumped into the air because a physical force had arisen between my foot and the ground. Yet this explanation indicates a further question: why did these physical forces arise? The answer can be given by the biologist: because biological processes like induction of biocurrents or neural voltage (excitations, action potentials, electric gradients) have been generated and form a system of stimuli extending from the neurons through the nerves to the muscles, making them contract. But then a further question arises: why did the neurons become excited? The answer a psychologist (a scientist of self-conscious decisions) would likely give is that the neurons were agitated because a willing, self-conscious agent made a decision — in this case, to jump in the air. Apparently, this simple example indicates that the physical explanation by mechanism does not exhaust the problem, nor does it exclude the need for a biological or psychological explanation.[3] (ii) Of course, the physicist can point out that the generation of the neural voltages and their propagation towards the muscles corresponds to material processes (like ion transfer) which are determined by physical laws. But this claim is only partially true; the generation and coordination of an immense number of elementary biocurrents into a biologically meaningful system of neural processes cannot be *explained* by physics, physical equations do not allow to *predict* them, simply because they serve a *biological* aim and that aim governs the whole process from its generation to its final manifestations. If so, how are the first neural voltages generated? This is a crucial problem: how can our allegedly immaterial, unobservable decisions elicit material, observable consequences?

1.7 SPONTANEOUS PROCESSES ARE TRIGGERED BY VACUUM FLUCTUATIONS

Answering that crucial problem, we note that we found apparently unnoticed loopholes in physical determinism regarding the significance of spontaneous processes. For example, in spontaneous radiactive decay, it is impossible to determine which atom will be the "next" to decay . By our best present understanding given by quantum field electrodynamics, spontaneous emission and similar processes are due to vacuum fluctuations, i.e. virtual interactions (Milonni, 1994), and are not determined at the level of differential equations. In our understanding, such virtual interactions act on a deeper level than the laws of Nature, at the generative, principal level of Nature, where the action principle acts, and it acts through virtual interactions.

We found that the biological principle, the natural extension of the least

[3] It is easy to observe that the different kinds of explanation of "why did the frog jump into the water?" given by Rose (1997, 10-13, 85-97) missed the target of obtaining a clear and complete picture regarding the nature of causation in Nature. At variance of his five types of explanations, all the three causes we indicated here are actual causes, and all of them correspond to a generative principle of reality, which form an essentially complete system of Nature.

action principle, works in a similar manner: by virtual interactions. These virtual interactions represent the interface between „nothing” and „matter”, they can trigger physically spontaneous, that is, physically undetermined phenomena, such as the spontaneous emission of photons, whereby photons activate biomolecules, triggering spontaneous couplings between endergonic and exergonic processes (Grandpierre, 2008a). Certainly, the biological principle can organize physical conditions, the input elements for physical laws, into suitable sequences for successfully fulfilling biological needs and ends. The suitably organized input conditions can lead with the help of physical laws to biologically useful output, like in the case when we bend our little finger. We are led to the insight that biology is the control theory of physics.

1.8 THE EXAMPLE OF THE DROPPED BIRD

Let us illustrate this point with the following example. A live bird dropped from the Pisa tower manifests a characteristically different trajectory than other physical objects dropped from the same location. It is customary to think that the reason for this difference lies in the extreme, intractable complexity of the living bird relative to that of the sorts of objects dropped by Galileo — stones, cannonballs, compacted feathers, etc. Such objects fall uniformly, in “free fall.”

Yet the case is different with the complex, living bird. For it can accomplish the feat of regaining its height to the point where it was originally dropped from the Pisa tower; and it can do so without changing its own vital, *specific complexity* during the process. Although all the vital aspects of the bird’s complexity prevail, some other aspects of the bird’s complexity must change, like the position and shape of its wings, or tail. This process unfolds in a highly specific, time-dependent manner. Though the bird is not changing its „vital complexity”, it invests work to change the position of its wings and tail in each instant in a way which, instead of being random or sporadic, is continuous and above all consequent. One change comes after another, in such a way that they quickly sum up to an increasing deterioration from the path expected on the basis of physical laws, given the same initial conditions. We must also take into consideration the given initial conditions of the bird: There is a biological principle generating and governing the internally initiated modifications of the physical conditions on which the physical laws exert their influence. The bird harnesses the physical laws, and evidently does so with the utmost ease.

The question is: How is this possible? To answer, we are led back to the first principles. How do the first principles exert their physical role? And how does the biological principle act, if all living organisms consist of material particles, and all of these are governed by the physical laws? It seems that “there is simply no ‘room at the bottom’ for the deployment of additional ‘downwardly mobile’ forces if the physical system is already causally closed. Thus a typical closed and isolated Newtonian system is already completely determined in its evolution once the initial conditions are specified. To start adding top-down forces would make the system over-determined. This causal straightjacket presupposes the orthodox idealized view of the nature of physical law, in which the dynamical evolution of a physical system is determined by a set of differential equations.” (Clayton and Davies, 2006, 46)

1.9 IS THERE A ROOM AT THE BOTTOM?

We indicate that the two-levelled mechanism view of the nature of physical world would not allow “room” even for the activity of the least action principle, which, as we suggest here, is the very bedrock of all fundamental physical laws themselves. In contrast, we point out that there exists an immense realm of physically not completely determined possibilities — for example, spontaneous emisission or absorption, fluctuations, instabilities, chaotic phenomena, or spontaneous energy focusing (Martinás and Grandpierre, 2007). We propose that these “holes” in physical determinism allow the generation of significant changes in the observable behavior of living organisms, which are extremely complex systems far from thermodynamic equilibrium. Extreme complexity is necessary in order that the “hole” in physical determinism be sufficiently large, so that spontaneous reactions can dominate the system. Being far from thermodynamic equilibrium is necessary in order for spontaneous processes to lead to macroscopic changes. In suitably organized, complex and far-from-equilibrium systems an immense number of couplings are possible between quantum states having a large non-equilibrium energy, by spontaneous emission and spontaneous absorption processes between an immense number of spontaneous exergonic (energy-liberating) and endergonic (energy-consuming) reactions; these latter ones require activational energy.

With the help of an illustrative example: Biological couplings are like the performance of acrobats in a circus. One *acrobat jumps down onto one end of a seesaw, another performer standing on the other end of the seesaw gets launched into the air*, and so the otherwise fast equilibration process of the exergonic process that should set up within the individually given initial conditions plus the physical laws will be postponed in the presence of the coupling. In a living organism, an immense number of “acrobats”, i.e. spontaneous processes triggered by virtual interactions, are coupled by an immense number of “seesaws” (seesaws are simple mechanical machines; living organisms can apply complex non-mechanical “machines” as well) to thermodynamically uphill, biologically useful processes, to realize biological endpoints.

Therefore, although the „bottom-up” view simply regards that biological behavior is „obscured” by the „untractable” complexity of living beings (Vogel and Angermann, 1992, 1), it is possible to shed more light to these depths of complexity. We found that this time-variable complexity is governed by the biological principle.

1.10 THE SOLUTION OF THE MIND-BODY PROBLEM AND THE NATURE OF BIOLOGICAL CAUSES

We note that quantum electrodynamics (QED) is able to give account of the generation of “matter” in quantum processes: QED is able to describe quantitatively the generation and annihilation of particles and antiparticles from the vacuum, which is a “sea” of spontaneously generated virtual particles (e.g. Davies, 1984, 104-106; Milonni, 1994, xv). Therefore, the solution of the mind-body problem — namely the generation of biocurrents by means of decisions — has a plausible solution: Biocurrents can be generated through virtual particles, through quantum-vacuum interactions (Grandpierre, 1995) that serve biological aims. This is not forbidden, but, instead, explicitly allowed by the physical laws. The term “spontaneous” means something not completely determined by physics.

We found not only that biology is an autonomous science having its own first principle, but also that this biological principle acts in the same way as the least action principle, namely, through virtual interactions mediating between the biological principle and the material world. Spontaneous processes provide scope for the biological principle to act upon physically not completely determined, spontaneously arising possibilities, so to serve biological ends such as well-being, happiness, survival, as well as routine tasks like biological functions.

1.11 HOLES IN DETERMINISM — CONCRETE EXAMPLES

Now let us offer some more concrete insights into the nature of "holes in determinism". For example, Jacob and Monod (1961) discovered that *there is no chemical necessity about which inducers regulate which genes* (Monod, 1974, 78). "The result — and this is the essential point — is that so far as regulation through allosteric interaction[4] is concerned, everything is possible. An allosteric protein should be seen as a specialized product of molecular "engineering" enabling an interaction, positive or negative, to take place between compounds without chemical affinity, and thereby eventually subordinating any reaction to the intervention of compounds that are chemically foreign and indifferent to this reaction. The way hence in which allosteric interactions work permits a complete freedom in the "choice" of controls (ibid., 78–79). On such a basis, it becomes possible for us to grasp how in a very real sense the organism effectively transcends physical laws - even while obeying them - thus achieving at once the pursuit and fulfillment of its own purpose" (ibid., 81). This means that the *functional* properties of proteins are determined by non-physical, i.e. *physically arbitrary* processes. It is this arbitrary nature of molecular biology that Monod calls "gratuity".

The basic importance of physically arbitrary processes is frequently acknowledged (e.g. Hunter, 1996; Barbieri, 2002; Yockey, 2005, 6). Maynard Smith (2000) emphasizes the profundity of Monod's idea. He proposes to call the terms for inducers and repressors "symbolic," since there is no physico-chemically necessary connection between their form (chemical composition) and meaning (genes switched on and off), just as in semiotics, where there is no necessary connection between the forms of the symbols and their meaning. For example, histidine is coded by the triplet CAC (C stand for cytosine) in the DNA. Maynard Smith calls attention to

[4] In biochemistry, allosteric regulation is the regulation of an enzyme or other protein by binding an effector molecule at the protein's allosteric site (that is, a site other than the protein's active site).

the fact that *there is no chemical reason* why CAC should not code for glycine instead of histidine. Maynard Smith argues that it is the symbolic nature of molecular biology that makes possible an indefinitely large number of biological forms.

We found that there is a room „at the bottom", and the biological principle can act on matter, making the existence of organismic order, teleology and design plausible. Now let us evaluate some relations between phenomena, laws and first principles.

1.12 RELATION BETWEEN PHENOMENA, LAWS AND FIRST PRINCIPLES

The whole presently observable universe is generated into material existence by deeper-level laws of Nature. "Given the laws of physics, the universe can create itself. Or, stated more correctly, the existence of a universe without an external first cause need no longer be regarded as conflicting with the laws of physics....This makes it seem as if the laws of physics act as the "ground of being" of the universe. Certainly, as far as most scientists are concerned, the bedrock of reality can be traced back to these laws." (Davies, 1992, 73). Such general views underpin our argument above, which states that all physical phenomena are rooted in laws and, ultimately, in first principles.

Now let us consider the relation between the physical and biological principle. Here we can only indicate that the greatest action principle of biology can fulfill its role only when, after selecting the endpoint according to the greatest action, this endpoint is realized by the least action principle. Illustrating it with an example: a bridge constructing company wanting to reach the maximum output in a year (corresponding to the greatest action principle), after deciding about the concrete bridges, must build them with the least cost (corresponding to the least action principle), in order that it can reach the maximal output. We can observe that there is a possibility to interpret the relation between the biological and physical one as being such that in a logical sense the biological principle precedes the physical one. If so, it can be the most ultimate principle of the Universe, from which the physical principle arises. „Bauer's dream of theoretical biology was similar to Einstein's goal in physics to create a single equation that encompasses the "Essence of Nature," from which all physical phenomena can be derived"

(Tokin, 1988). The above argument seems to underpin that Bauer's dream can be realized.

2. Natural classes of teleology

2.1 DIFFERENT CLASSES OF NATURAL TELEOLOGY

Teleology has played a significant role in the history of physics (Barrow and Tipler, 1986) and philosophy. Physico-teleology was considered by Leibniz and Kant. *Physical teleology is independent of physical objects*, not only because the endpoint of the trajectory is not selected by the physical object itself, but also because the physical object does not contribute actively to the selection of its trajectory. Indeed, mathematically, different trajectories can have the same endpoints. In biology, the endpoint is characteristically selected by the greatest action principle; therefore, at first sight it may seem that biological teleology is also independent of the system considered. Yet, even if this is true, living organisms actively participate in the realization of their trajectory. First of all, usually the endpoint is not unequivocally determinable, since an immense number of processes occur in a living organism in many time scales simultaneously. Therefore, it is necessary that the living organism itself selects the processes requiring endpoint selection. Moreover, the organism can select the time-scale on which the action should be maximized. Additionally, there is a possibility that the organism can select the context of maximization, with respect to its individual or communal life. Moreover, the commitment to the biological principle is not as strict as in physics. While all physical objects must obey the physical laws as secured by the coercive physical forces, there are no such coercive forces in biology. And so living organisms can manifest different degrees in their commitments to the biological principle. At the one end of scale, they can live their life with almost full vitality; at the other end, they can commit suicide like lemmings. Even in cases when the commitment to the biological principle is strong, as is usually the case, living organisms must contribute to the selection and realization of their trajectory, because in biology many different, biologically possible trajectories can lead to the same endpoint. For example, a bird dropped from a height has many degrees of freedom to select the direction and the form of its trajectory, even when the endpoint is already selected. The biological principle prescribes only one requirement:

"Regain your vitality!" All the other parameters, for example whether the dropped bird selects a trajectory towards north or south, are indifferent for the biological principle, and are determined by the organism itself. Therefore, considering biological behavior from different angles, we can find biological teleology either dependent or independent from the considered living organism. This circumstance goes far to explain why viewpoints regarding biological teleology are so controversial.

2.2 OBJECTIONS AGAINST TELEOLOGY

Now let us see somewhat more concretely the objections against teleology based on Mayr (1988, 40), who summed up the traditional objections against teleology in four reasons, namely (i) teleology is based on vitalism, which is an unverifiable theological or metaphysical doctrine in science. (ii) final causation is incompatible with the mechanistic explanation by physical laws, (iii) final causation represents a backwards causation, and (iv) teleology is a form of mentalism.

2.3 DEFENSE OF TELEOLOGY

Regarding (i), the argument against neo-vitalism is summed up by Hempel (1966, 72) in the following form. The doctrine of entelechy is not definite enough to permit the derivation of specific implications concerning the phenomena that the theory is to explain. It does not indicate under what circumstances entelechy will go into action and, specifically, in what way it will direct biological processes. This becomes clear when we contrast it with the explanation of the regularities of planetary and lunar motions by means of the Newtonian theory. Notwithstanding, instead of unscientific concepts like "entelechy" or mystic "God", we worked out exact scientific concepts like the greatest action principle, formulated it in mathematical form, and applied it to yet unexplained phenomena (Grandpierre, 2007). Regarding (ii), we have shown above that final causation is not only compatible with the mechanistic explanation, but is the only means to explain biological behavior at the whole organism level. Regarding (iii), already Nagel (1979, 278) pointed out that the agent's wanting a goal acts contemporaneously with the initiation of biological behavior; therefore it does not reperesent “backwards causation”. Regarding (iv), we argue in this paper that mentalism corresponds to a type of teleology that is not present in physics. This last point requires a suitable classification of teleologies occurring in Nature.

2.4 A NEW CLASSIFICATION OF TELEOLOGICAL TYPES BASED ON THE PHYSICAL APPROACH

Appreciating the achievements of physics in becoming the first exact natural science, and aspiring to a similar achievement regarding biology and teleology, we will categorize teleology on the basis of theoretical physics, but, as necessary, expanded by a minimal step allowing endoint selection corresponding to the greatest action principle. Therefore, as a starting point we consider the fact that the two fundamental factors governing physical processes are (a) the input (i.e. initial and boundary) conditions and (b) the physical laws. On this exact physical basis, natural behavior can be categorized into the following classes:

(A) The simplest case: The input data are few, fixed, corresponding only to the initial state $t=t_0$. This is the usual case in physical problems. Since the input conditions are simple, the relative complexity of the physical laws is large, and therefore the arising behavior is considered as determined by the physical laws (A1). (A2): The input data can be many and variable in time, but simple in a sense that they average out to the arising physical behavior. This is the statistical case.

(B) The input conditions are complex, but fixed and do not average out. The simplest case is (B1) in which the input conditions are built in into the physical object in a form of a pre-fixed scheme, like in the structure of machines or in programs of robots. The behavior of these machines is continuously determined by this basically fixed input (structure, blueprint, or design) plus the physical laws. Even learning robots are always governed by external inputs plus physical laws. Machines are artifacts representing a fixed human purpose to solve a task. Similarly, biological organisms regularly meet in their normal life with the same type of tasks to be solved, such as respiration, digestion, moving the body, etc. These routine biological tasks are solved by functions (B2) of lungs, stomach, muscle, etc. Biological functions significantly modified in their history by natural selection can contribute to the development of adapted features. Biological functions and adapted features represent natural design.

(C) The input conditions to the physical laws are not pre-fixed but variable in time and contribute to the arising non-physical behavior. The system continuously changes the internally generated input conditions of the physical laws in order that the output serving varying biological needs can change in a manner corresponding to the greatest action principle. Serving biological needs within changing conditions requires a capability to solve newly arisen problems; in other words, creativity. Type (C1) of biological behavior corresponds to the case when the endpoint of the trajectory is determined by the biological principle. In such cases, the distance of the organism as a whole from thermodynamic equilibrium, which decreases due to the continuously occuring physical processes, is regained, due to biological processes. In the prototype case of a dropped bird, (C1) corresponds to the fact that the bird regains its original height. Teleology of the class (C2) of biological behavior is an aspect of biological behavior which is determined by the autonomous decisions of living organisms. In the case of a dropped living bird, (C2) corresponds to parameters forming other points of the trajectory besides the endpoint, which are determined by the bird itself. Instead of one parameter, the distance of the endpoint of the given process from equilibrium, class (C2) corresponds to other degrees of freedom. The difference between (B2) and (C2) can be illustrated when one considers different aspects of the same biological behavior: the non-autonomous in case (B2) and the autonomous in case (C2). Class (C3) biological behavior corresponds to cases in which the organism can autonomously select, not only the special trajectory corresponding to the given endpoint, but also can contribute to decisions respecting the context and time scales in which its distance from equilibrium can be regained. That is, although the endpoint in a sense is determined by the biological principle (in our example, the dropped bird striving to regain its height above the equilibrium), living beings also have a certain autonomy in selecting the important processes and time scales involved in maximizing distance from equilibrium. Autonomous interpretation of the different contexts (short- and long-term, individual and communal) of the biological principle enables determination of the controllable aspects of autonomous behavior, which in turn can lead to the development of systematically self-conscious behavior, to self-conscious goals. The same biological behavior seen in the bending of a finger can be classified as (C2) if it occurs without self-conscious control, "instinctively" or consciously; but it belongs to (C3) if it is a result of a self-conscious decision. In the language of teleology, physical laws refer to "ends"; biological ones to "aims", and psychological ones to "goals". The common term comprehending all three together is "telos". Isolated from its system, the heart seems not to have a goal, nor an aim; yet as an integrated part of the whole system, it corresponds to an overarching, fundamental biological aim — its function, pumping blood, corresponds to a biological aim of the organism as a whole.

One can see that this new classification is logically systematic and extends to all types of possible behaviors: physical, biological, and psychological. If so, it can be regarded as the first complete scientific classification of behaviors and teleologies. Yet in science a suitable quantitative measure is inevitable.

2.5 THE MEASURE OF TELEOLOGY: ALGORITHMIC COMPLEXITY

Now let us look for a suitable measure of complexity on the basis of which one can distinguish easily between classes of teleology (A), (B) and (C). Behavior belonging to class (A) is usually regarded as simple, without notable complexity. Yet if we compare the complexity of the physical laws when they are the dominant factors in the governance of behavior, with the complexity of the simple input (i.e., initial conditions), we recognize the complexity of the physical laws can be assessed in terms of algorithmic complexity. Acknowledging the control of physical laws over natural phenomena, we noted above (Sect. 1.3) that in comparison to the mathematical laws, physical laws represent a measure of control; and now we add that this control represents a complexity that can be measured in terms of algorithmic complexity and expressed in measuring units of bits.

In general, the solution of a task requires two kinds of procedures: one leading towards the end step by step, involving a finite number of steps; and one which requires an infinite number of steps. In computable cases the problem can be formalized and solved in a finite number of steps. The minimum number of steps is a good measure of the complexity of the problem. Indeed, Kolmogorov (1965) and Chaitin (1966) suggested defining the information content of an object as the length of the shortest program computing a representation of it. *The algorithmic complexity* of a mathematically described entity is defined as the length of the shortest program computing a representation of this entity. Since algorithmic complexity is a measure of the complexity of solving a task, which is definitely an end-directed process, teleology is an ineliminable property of algorithmic complexity. Chaitin (1985) determined that the laws of physics have very low information content, since their algorithmic complexity can be characterized by a computer program less than a thousand characters long. His programs were solved numerically, taking into account Newton's laws, Maxwell's laws, the Schrödinger equation, and Einstein's field equations for curved space-time near a black hole. All were about half a page long — which is amazingly simple. Now we can estimate the complexity of a page as approximately 2×10^3 bits, since the average rate of information processing in reading is about 50 bits s^{-1}; and so at a reading rate of 1.5 pages per minute, the information content of a page is about 10^3 bits. Taking a page from Chaitin, we thus found that the algorithmic complexity of physical equations is surprisingly low, being around 10^3 bits.

The distinguishing mark of class (A) is a simple input without complexity; at the same time, physical behavior corresponds to the algorithmic complexity of the physical laws. Class (B) can be characterized by the algorithmic complexity present in the fixed input conditions of machines or adapted features. Remarkably, class (C) has a fundamentally different complexity measure, since it corresponds to the solution of continuously surfacing new problems. As a result, the complexity representing class (C) is measured not in bits, but in bits s^{-1}. It follows that this kind of complexity can be termed generative complexity (Grandpierre, 2008b). Since generative principles represent a deeper concept than laws of Nature, generative complexity represents a deeper level of complexity than algorithmic complexity. We obtained a useful result: the three different kinds of behavior correspond to three different kinds of teleology, design, and complexity; and these can be easily distinguished with the help of quantitative complexity measures.

2.6 COMPARISON OF THE NEW AND OLD CLASSIFICATIONS OF TELEOLOGY

As a test of our new classification of teleologies, we now compare it to that of Mayr (2004). He defined five classes: (1) teleomatic, (2) teleonomic, (3) purposive behavior, (4) adapted features, and (5) cosmic teleology. It is straightforward that Mayr's first teleomatic class (1) corresponds to cases when physical laws determine the output "automatically". His teleonomic class (2) corresponds to cases when the behavior is determined by programs.

"All teleonomic behavior is characterized by two components. It is guided by 'a program' and it depends on the existence of some endpoint, goal, or terminus that is 'foreseen' in the program that regulates the behavior or process. This endpoint might be a structure (in development), a physiological function, the attainment of a geographic position (in migration), or a 'consummatory act' in behavior." Mayr (2004, 51) He also includes the behavior of human artifacts like machines into this class. With the recognition that tortoises have short stocky legs adapted for a certain function (namely, climbing, crawling and walking), and as such represent behavioral programs, we can classify the legs of tortoises as corresponding to our class (B). It is easy to see that physiological functions like the heart pumping blood, migration of birds, or consummatory acts, as well as the complexity of machines, can be characterized by algorithmic complexity, which can be measured in bits, confirming the classification of teleonomic behavior into our class (B).

Mayr's category (3) is that of purposeful behavior. We classified purposeful behavior into class (C) and gave it a somewhat definite meaning. His fourth category "adapted features" is classified into our class (B). This classification is confirmed by the fact that the complexity of adapted features can be characterized by algorithmic complexity and can be measured in bits. Mayr refutes his own fifth class, (5) "cosmic teleology", with the following argument: "Natural selection provides a satisfactory explanation for the course of organic evolution and makes an invoking of supernatural teleological forces unnecessary. The removal of the mentioned four material processes from the formerly so heterogeneous category 'teleological' leaves no residue. This proves the nonexistence of cosmic teleology." (Mayr, 2004, 61). We note that in biology the universal principle of all biological behavior is more basic than the study of some historical aspects of one specific form of life, which is present on Earth. Moreover, instead of supernatural forces, in this paper we argued the case for cosmic teleology on the basis that biology has its own autonomous principle which is an exact analogue to the least action principle already established in physics; and so, similarly as the physical principle, it is valid in the whole Universe. This means that the biological principle permeates the quantum vacuum, and so it can govern virtual interactions. If so, then the quantum vacuum fulfills the criterion of life; and thus it represents a cosmic life form. Indeed, a detailed consideration of the criteria of life within cosmic conditions (Grandpierre, 2008a) has shown that different cosmic life forms extend to the whole of the Universe. This conclusion is confirmed by the simple quantitative fact that algorithmic complexity increases in the

Universe (e.g. in the protosolar cloud, in solar activity [quantitative study in Grandpierre, 2004 and 2008b]), and in the biosphere (Grandpierre, 2008b). Therefore, Nature can be characterized by generative complexity corresponding to our class (C). This means that Mayr's "cosmic teleology" actually exists in Nature and it belongs to our class (C). This completes our comparison.

2.7 SOME USEFUL EXAMPLES

Now let us look some other useful examples elucidating the differences between these types of natural design.

2.7.1 Homo Sapiens from cosmic cloud

Definitely, the contraction of the protosolar cloud, from the onset of contraction until the development of the Earth and Homo Sapiens on it is conceived today as describable by physical laws. Yet our results indicate (see also Ellis, 2005a) that this assumption contradicts the fact that Homo Sapiens appeared on the Earth, since the physical laws have a fixed and relatively low algorithmic complexity that is measured in bits (10^3 bits), while Homo Sapiens is a creative being having a much larger algorithmic complexity (10^{15}-10^{17} bits), and having also a generative complexity that is measured in bits s^{-1}.

2.7.2 Physical "self-organization" corresponds to phenomenological complexity

Physical "self-organizing" processes are frequently regarded as the basis of extremely complex, biological organization (e.g. Kurakin, 2010). Yet we point out that all physical "self-organizing" processes are, at least in comparison to biological organization, *very simple, having a relatively very low algorithmic complexity*. The crucial difference is that physical "self-organizing" processes are governed by the physical laws, and manifest characteristically physical behavior. Biological processes differ from physical ones with respect to their governance. Biological organization is governed by the biological principle, while physical self-organization is governed by the physical principle. This is why the latter is much simpler.

2.7.3 Control of physical laws: the dual control of organisms

Although physical laws prevail within organisms, their behavior is governed by a dual control, in which the biological control harnesses physics. Mayr (2004, 29) assumes that the dual control is due completely to the genes: "In contrast to purely physical processes, these biological ones are controlled not only by natural laws but also by genetic programs. This duality fully provides a clear demarcation between inanimate and living processes. The dual causality, however, … is perhaps the most important diagnostic characteristic of biology..." We point out that the relation between the two controls, the physical and the biological, is not symmetric, since it is the biological control that determines the characteristically biological behavior, and the physical control is subservient. It is the biological control that regulates the input of physical laws, and harnesses the physical laws, not vice versa. The crucial element of transcending physical laws is that virtual interactions are able to induce spontaneous, physically undetermined processes, couple them together in an extremely specific manner, in a way that the biological control can become manifest, observable, as in the trajectory of a living bird.

We add that genetic complexity corresponds to the sequence of the amino acids, and so, it is static and can be measured in bits. Since the solution of new tasks is an inevitable part of life, generation of algorithmic complexity is also inevitable. Generative complexity, measurable in bits/s is more fundamental than any algorithmic complexity which is already generated. Therefore if genetic programs play an important part in governing dynamic biological behavior, they must be suitable tools for the activity of the biological principle that continuously generates the algorithmic complexity of biological behavior.

Since man-made control is applied at the input of physical laws, it can harness the physical laws, it can "govern" the physical laws, similarly to a sailor who changes the inner condition of his ship by trimming its sails in a way to most efficiently harness the physical power of the wind. It is the control of behavior through the control of input of the physical laws that determines the observable gross behavior of organisms, and not the physical laws themselves.

2.7.4 The mathematical science of intentional behavior

Certainly, modifying systematically and time-variably the input of the physical laws in a way to obtain an outcome corresponding to certain kinds of goals, (C)-type behavior must generate especially complex conditions in order to be manifested. Such especially complex conditions can be made accessible with the help of especially complex internal structures having an especially sensitive and rich set of different internal conditions. The task to produce certain favorable time-dependent output with the help of a suitable selection of time-dependent input variables is investigated in control theory. Control theory is an interdisciplinary branch of engineering and science that deals with the behavior of dynamical systems. The desired output of a system can be generated by the suitable selection of changing input conditions. The description of this type of problem requires the introduction of an extra degree of freedom in problems such as, for example, creating the design of a rocket capable of reaching a target governed by a living being (Pontryagin maximum problem). Pontryagin (1978) found that the most important element of such a problem is that the governed system can change all its coordinates at any moment by exerting governmental forces. To take these governmental forces into account, one has to introduce additional degrees of freedom that the living bird has, which the dead bird no longer has. This means that life and its related governmental forces are what elicit the exerted physical forces, and these are the most important elements determining the bird’s trajectory. That being the case, one cannot ignore them without missing the main point of the whole problem. In mathematical psychology, the introduction of such an additional variable corresponds to the decisions made by a subject, which can be described with the help of the Reflexive-Intentional Model of the Subject (RIMS, Lefebvre, 2001). The RIMS is a mathematical model that predicts the probabilities of two alternatives a subject will choose, and *it allows us to deduce theoretically the main patterns of animal behavior* in experiments with two alternatives (Lefebvre, 2003).

2.8 THE POWER OF TELEOLOGICAL EXPLANATION

It is usual to assume that teleology is not useful in science. In contrast to this view, we argue here that such an anti-teleological assumption presents a conceptual obstacle to a more complete understanding of Nature. The biological principle allows us to introduce biological ends, which in turn represents natural teleology. Such an approach opens up vistas for a new scientific revolution, since it makes it possible to understand the behavior of whole organisms in mathematical details, elevating biology to the rank of a quantitative, exact science. At present, the situation is characterized by the following quotation: “Today, by contrast with descriptions of the physical world, the understanding of biological systems is most often represented by natural-language stories codified in natural-language papers and textbooks. This level of understanding is adequate for many purposes (including medicine and agriculture) and is being extended by contemporary biologists with great panache. But insofar as biologists wish to attain deeper understanding (for example, to predict the quantitative behaviour of biological systems), they will need to produce biological knowledge and operate on it in ways that natural language does not allow.” (Brent and Bruck, 2006, 416). Our results make observable biological behavior calculable at the level of the organism (Grandpierre, 2007).

3. Is there a design in Nature?

Contemporary attributions of function recognize two sources of design, one in the intention of agents and one in the action of natural selection (Kitcher, 1999). It is usual to deny the existence of the ontological „design” in the Universe. For example, Dawkins (2006, 157-158) acknowledged that (1) one of the greatest challenges to the human intellect, over the centuries, has been to explain how the complex, improbable appearance of design in the universe arises. The apparent design is so spectacular, that (2) the natural temptation is to attribute it to actual design itself. In the case of a man-made artifact such as a watch, the designer was an intelligent engineer. It is tempting to apply the same logic to an eye or a wing, a spider or a person. But, according to Dawkins, „the temptation is a false one, because the designer hypothesis immediately raises the larger problem of who designed the designer." If so, this „designer-problem" raised by Dawkins is solved here. In our picture, the Universe is a biologically governed system, governed by the biological principle. Regarding that the first principles exist in all time and space, life is eternal, and ultimate. Dawkins continues: „It is obviously no solution to postulate something even more improbable." In contrast, we were able to show that the nature of scientific explanation leads in two steps from phenomena to laws and, ultimately, to the first principles. The existence of these first principles is validated by all our empirical and theoretical knowledge, therefore they are not improbable, but, on the contrary, the most probable, actually, universally reliable facts from all facts science. (4) "Darwinian evolution by natural selection offers the greatest, most powerful explanatory scope so far discovered in the biological sciences." Dawkins quickly concludes: "We can now safely say that the illusion of design in living creatures is just that -- an illusion."

In contrast, we argued that the theory of Darwin is not fundamental, as it is clear from its contrast with the theoretical biology of Ervin Bauer, which is capable to give the mathematically formulated universal principle of biology. Indeed, Dawkins claims: "We don't yet have an equivalent well-grounded, explanatory model for physics. Some kind of multiverse theory could in principle do for physics the same explanatory work as Darwinism does for biology." In contrast, we think that Dawkins ignores the present situation of biology, as it is shown from reports like the one cited by us above (Brent and Bruck, 2006) indicating the basic fact that at present the only exact science is physics, and biology seem to suffer from missing the knowledge similarly exact laws and principles. Yet we argued that it is a false opinion, since there is an exact formulation of theoretical biology (Bauer, 1967; Grandpierre, 2007). Regarding the multiverse theory, it is based on a superficial understanding of physics, expressing the opinion that physical laws can be awkward. In contrast, we pointed out that the essence of physics is the least action principle, and all physical laws must obey this fundamental principle and should be derived from it. Therefore, a kind of "grand design" of Nature, which is revealed here in the three-leveled, "vertical" structure of the Universe: phenomena-laws-first principles, plus the "horizontal" structure characterized by physical-biological-psychological behavior, exists, and this ontological structure of the Universe is proved by a scientific analysis. The "grand design" we found is represented in the hierarchical architecture of the Universe, which has an ontological, explanatory, and causal significance as well.

Hawking and Mlodinow (2010) argued that the material universe can be explained by the M-theory, which predicts that a great many universes were created out of nothing. “Their creation does not require the intervention of some supernatural being or god. Rather, these multiple universes arise naturally from physical law. They are a prediction of science” (ibid., 12). They added: “The fact that we human beings…have been able to come this close to an understanding of the laws governing us and our universe is a great triumph...If the theory is confirmed by observation, it will be the successful conclusion of a search going back more than 3,000 years. We will have found the grand design.” (ibid., 102) We point out that the “prediction” of the M-theory, namely, the multiverse theory does not explain why do the laws of physics take their specific form we observe. Instead, it assumes that since an infinite variety of physical laws exist in the multiverse, therefore every improbable cases have a certain probability, and the specific form of physical laws that are so favorable for life, can occur as well with a finite probability. In contrast of this highly speculative and uneconomic assumption, we point out that the existence of physical laws is explained scientifically by the least action principle. Instead of the speculative assumption of the “multiverse”, we presented here a scientific explanation for the origin of the physical laws from an exact and already established physical principle: the least action principle.

We found that the Universe is permeated by a biological principle capable of controlling the physical principle. This indicates that we are living in a fundamentally living Universe, which allows the presence of „design” in Nature. Yet we note that the presence of „design” depends sensitively on what we mean on this term. If we mean „order” by the term „design”, than already the existence of the laws of physics presents a design in Nature. If we mean by „design” teleological behavior in general, we found such teleology present in Nature, in biological processes governed by biological aims. If one means by „design in Nature” purposeful planning, processes governed by human intentions show their existence.

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