CHAPTER FOUR

GENERALIZATION OF QUANTUM THEORY INTO BIOLOGY

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Introduction

It is high time to become aware of science's next milestone in its enterprise of exploring deeper and deeper realms of nature. Outstanding figures like Bohr, Heisenberg, Wigner and Whitehead assert the incompleteness of physics, claiming that biology transcends the framework of physics. Perhaps the biggest obstacle on the road of the evolution of science is the belief that physics is a complete science of nature. In order to clarify the issue at hand, the first task seems to be answering the question: what is physics? The answer to this is obtained with the help of the principle of least action, from which all the fundamental laws of physics can be derived. Then I consider the fundamental problems of quantum physics such as the violation of the principle of causality and the law of conservation of energy; the missing meaning of the central concept of physics, 'action'; and the problem of apparent teleology of the principle of least action. I show that all these are the signs of physics' fundamental incompleteness. To obtain a more complete approach, I propose a simple and elegant solution generalizing the principle of least action to biology by one minimal but powerful step.

The more general principle is shown, in this chapter, to be suitable to solve the problem of biological causation, the mind-body problem, it restores the universal validity of the principle of causation and the law of energy conservation, giving plausible meaning to 'action', and offers an exact mathematical formulation to represent teleology that is fully consistent with physics and physical causality. This generalized principle can be termed as the principle of greatest action for life. It can be regarded as the fundamental principle of biology, from which all the fundamental equations of biology can be derived and which explains fundamental life phenomena. This result demonstrates that the principle of least action of physics originates from the fundamental principle of biology. I indicate how the oeuvre of Whitehead is helpful in understanding biological causation and clarifying the relation between physical, biological and mental causes.

On the absence of new milestones since the discovery of quantum physics

The evolution of modern science is hallmarked by its great leaps forward like that of Galilei (1632), Newton (1687), Franklin (1752), Lagrange (1788), Faraday (1821), Maxwell (1865), Einstein (1905) and Heisenberg (1926). Since the discovery of quantum physics a century ago, modern science has proven to be unable to make the next step on the road of scientific development in exploring deeper and deeper into the realms of nature. This failure is made more remarkable because it happened despite the fact that the founders of quantum physics—Bohr (1933, 458a; 1955, 813; McKaughan 2005, 516), Heisenberg (1965, 242; 1971, 91-92), Wigner (1969; 1970)—repeatedly asserted the insufficiency of a physical or chemical explanation of the function which is peculiar to life. Similarly, one of the most profound philosophers of the Western world, Whitehead, was presupposing the organic theory of nature, which could serve as a basis for a thoroughgoing objectivism (Whitehead 1927, 121). In *Nature and Life*, Whitehead argued for a cosmology to be construed on the basis of the doctrine of life in nature (Whitehead 1938, 152). As Whitehead formulated, "[t]he doctrine that I am maintaining is that neither physical nature nor life can be understood unless we fuse them together as essential factors in the composition of 'really real' things whose interconnections and individual characters constitute the universe" (ibid. 150). Whitehead expressed his view that there is a need for a systematic cosmology based on the idea of life. Unfortunately for the evolution of modern science, Whitehead's oeuvre has been also largely ignored. In the following, I indicate how these insights can be supported by general biology, that could become the next great leap forward.

Signs showing that the method of physics is worn out

In his book *The Function of Reason* (Whitehead 1929[2018], 12), Whitehead critiqued the modern doctrine, claiming that in the transformations of matter and energy which constitute the activities of an animal body, no principles can be discerned other than those which govern the activities of inorganic matter. Whitehead points out that there is active interest restraining science within the scope of physics and ignore all other problems (ibid. 17). The doctrine constraining the science of all nature to physics is the doctrine of physicalism. The fact that the methodology of physicalism is worn out is shown by the fact that progress within it no longer deals with main issues: “There is a final epoch of endless wrangling over minor questions” (ibid. 18). If physics is the science of inorganic matter, then physicalism ignores the major issue of working out the science of life on exact ground, preserving the best traditions of physics and extending its formalism to become suitable for giving an account of life’s own universal and independent laws.

Physics in its full light: the first principle of physics

Due to the hegemony of physics, it is a popular view to consider that everything is physical. But what is the exact answer to the question “what is physics” from the viewpoint of physics itself? This point is crucial because as long as we do not understand what physics is, we do not understand what the scope of physics is. Seeing nature through the lens of physics may offer fundamental insights but may result in unwanted limitations.

In the search for how we can obtain scientific criteria to answer the question ‘what is physics?’ it is important to realize that the most powerful tools of science are its fundamental laws, and, even more importantly, their first principles. The fundamental laws of physics are the laws of classical mechanics, hydrodynamics, electromagnetism, thermodynamics, gravitation and quantum physics. These fundamental laws can be best described by differential equations, for example, the Euler-Lagrange equations of mechanics, the Maxwell equations of electromagnetism or the Schrödinger equation of quantum physics. The point here is that all these fundamental laws of physics can be derived from the principle of least action.

The ancient idea of the first principle is defined as the deepest law of nature from which all the fundamental laws of the given ontological domain can be derived. This is why the principle of least action can be regarded as the first principle of physics. The principle of least action is the highest achievement of modern physics and its most powerful tool. Because of its unusual profundity, the meaning of the least action principle itself is not understood, its physical content is obscure, and its origin is not clarified. In this paper I shed light to these fundamental questions. Let us consider now in a few words what is the principle of least action (PLA).

A few introductory words about the Principle of Least Action

The principle of least action (PLA) determines the path of a particle, or the way in which a physical process becomes realized, between a given initial point or state and its endpoint or final state. It tells that a certain mathematically defined quantity called as ‘action’ should be minimal. Although the physical meaning of ‘action’ is not known, it is measured in the units of energy and time, measuring the two at the same time, similarly to a taximeter measuring the consumption of oil and time at the same time. The PLA, in a simplified way, formulates the fact that within a given initial and final state, the physical trajectory that connects these two endpoints is usually the one—among all such possible paths—that corresponds to the minimum of the sum of actions calculated for all consecutive elementary time intervals.

We can illustrate the meaning of the PLA by a free falling stone dropped from a height, or an apple falling down from the tree. The stone falls down on a straight line to the ground. If it would behave differently in the same situation, it would use more energy and time. All deviations from the path of least action would require more ‘action’, roughly, energy and time investment. Once the difference between the stone’s potential energy between its initial and end-state could be equilibrated, it equilibrates. The result is the stone on the ground, in equilibrium. The PLA tells that the path taken by the stone is the one that is characterized by the minimum of action; in nature the two most important costs are energy and time, and in case of physical objects, this cost is minimal. This is why the PLA has been regarded as the principle of parsimony.

Similarly, it is the PLA that tells the wind to flow from regions of higher pressure to lower ones diminishing pressure differences. A similar phenomenon characterizes thermodynamic behavior, namely, the equilibration of temperature or concentration differences. When pouring hot water into a cold one, we find that their temperature difference will soon decrease and vanish in equilibrium. We point out to the meaningful connection between the second law of thermodynamics and the PLA. Similarly to the PLA, the second law tells that all macroscopic systems evolve towards diminishing all the differences between their equilibrating parameters like temperature, concentration etc. when left to themselves. In the end-state, these differences (in scientific terms, the general thermodynamic forces) are minimal. It was shown that the second law can be formulated in a general form including all other energy forms like electromagnetic or gravitational energies (Martinás and Grandpierre 2007; Grandpierre

2012a).

Similar to the behaviour of the free-falling stone, or the blowing wind, lightning is a naturally occurring event wherein there is an instantaneous electric discharge of high voltage produced by electric differences. The motion of planets follows the same law of nature as the apple falling from the tree. Electromagnetism and the theory of gravitation can be derived elegantly from the PLA. The power that makes the stars bright is nuclear energy that has been explained by quantum physics. Importantly, even quantum physics, the science describing nature from a more fundamental viewpoint than classical physics can be derived from the PLA. I argue that the PLA is the all-comprehensive principle of physics.

On the significance of the Principle of Least Action

The classical view was that all natural laws originate from a small set of fundamental principles. The fundamental principles like the PLA have served as the theoretical basis of the axiomatic method which can be regarded as the leitmotif of science. Indeed, without the notion that nature works by a small set of fundamental laws comprehensible for human beings, there is no science.

For at least 2,000 years, the Principle of Least Action runs like a red thread through the monumental achievements of mathematics and physics. The first variational principle in physics was articulated by Euclid of Alexandria (around 300 BC) in his Catoptrica. It says that, for the path of light reflecting from a mirror, the angle of incidence equals the angle of reflection. Hero of Alexandria (ca. 10 B.C.–ca. 70 A.D.) later showed that this path gave the shortest length and the least time. Studying the refraction of light, Fermat showed in 1643 that the light reaches its destination by following the fastest path (principle of least time). It was Pierre Louis Maupertuis who can be regarded as the first modern scientist formulating the PLA. The PLA is not just the culmination of Maupertuis's work in several areas of physics, he had seen it as his most important achievement in philosophy too, giving an incontrovertible, exact scientific proof of God, the famous Loi d'Epargne (the Principle of Parsimony).

In the Middle Ages, the PLA had been regarded as the best expression of final cause as it is manifested in nature. "There is absolutely no doubt that every effect in the universe can be explained as satisfactorily from final causes, by the aid of the method of maxima and minima, as it can from the effective causes" (Euler 1744, in Lemons 1997, x). In 1912, Pierre Jourdain wrote:

> The least action principle achieves the long sought after theoretical framework in which a rich variety of consequences flow from simple hypotheses. The Loi d'Epargne evidently tended to make unity of all the forces of the universe, the keynote or the goal of philosophical inquiry.

The Nobel laureate Max Planck wrote in 1915:

> Amid the more or less general laws which mark the achievements of physical science during the course of the last centuries, the principle of least action is perhaps that which, as regards form and content, may claim to come nearest to that final aim of theoretical research (Yourgrau and Mandelstam 1960, 144).

The significance of the first principles of science has survived even into the twentieth century. In his book *Science and First Principles*, F. S. C. Northrop summarized elegantly the ancient view of the first principles of science:

> Science proceeds in two opposite directions from its many technical discoveries. It moves forward with the aid of exact mathematical formulation to new applications, and backward with the aid of careful logical analysis to first principles. The fruit of the first movement is applied science, that of the second theoretical science. *When this movement toward theoretical science is carried through for all branches of science we come to first principles and have philosophy* (Northrop 1931, 1).

In their monograph written about the PLA, Yourgrau and Mandelstam noted:

> The action principle of physics is claimed to come nearest, in its form and content, to the ideal final aim of theoretical research: to condense all natural phenomena into one simple principle that facilitates the computation of past and future processes (Yourgrau and Mandelstam 1960, 126).

> 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).

The PLA was presumably more fundamental than differential equations upon which the physical concept of causality has been built. Over the centuries, no other principle of classical physics has to a larger extent nourished exalted hopes into a universal theory than the Principle of Least

Action (Stöltzner 2003).

> The principle of least action is simple, potent, and fundamental. It spans classical and contemporary physics and introduces deep concepts to current research (Taylor 2003, 424).

Regarding the fact that the PLA has the widest scope, extending to all the fundamental branches of physics, and that it simultaneously has the deepest explanatory power, it can thus offer the utmost range of information and simplicity when we make it the focus of our picture of the physical world (Grandpierre 2011). The PLA "is universal. It provides a framework that can be extended to all other laws of physics, and reveals a deep relationship between classical mechanics and quantum mechanics. This is the real reason why it's so important" (Baumann 2017, 2).

We can regard the PLA as a fundamental principle of the Universe, thus, the PLA is one of the most important things to know and understand in physics and philosophy.

On the rejection of the significance of the Principle of Least Action

The ancient idea of first principles seems to have been rejected by mainstream science in the twentieth century. Let us mention one argument that is decisive in this respect. The authors of the apparently most important monograph written about this problem, Yourgrau and Mandelstam, present the main counter-argument against the classical metaphysical claim by the following argument. They suggest 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". They 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. (Yourgrau and Mandelstam 1960, 155).

Let us note, first, that such a single argument, even if it was correct, seems to be hardly enough to reject the classical claim which has served as the very basis of modern science. Second, the action principle in its 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; this means that, at the initial state, the initial velocity is not given but considered as a free variable. Therefore, in reality, where in cases that the velocity is given at the initial state, together its direction, the conclusion of Yourgrau and Mandelstam does not apply at all (Grandpierre 2011). It is a simple thing to see that a particle with any given initial velocity cannot start in the direction opposite to its initial velocity, therefore there is no such case "when the particle may move between two points on the ellipse in either of two paths", as it is implicitly assumed by Yourgrau and Mandelstam (ibid.). If this were the crucial argument for rejecting teleology in physics (being reffered to as the "lethal question for teleology") (Stöltzner 1994), then it does not follow that teleology must be exiled from science.

The reasons for rejecting teleology from science had other sources as well. "Ever since the scientific revolution, however, teleology has become exiled from science" (Buller 2002, 393). This attitude seems to be based on the doctrine of physicalism. Teleology seems to be a disturbing element in physics because the explanatory tools of physics–namely, initial conditions, randomness and fundamental equations of physics–are inconsistent with it. The only exception that perhaps could bring back teleology into physics is found at a deeper level, that is the principle of least action.

The PLA is the ideal tool for teleology because it connects the initial state directly with the final state. The results show that PLA is ideally suitable to serve reasons, purposes and goals, because if decisions are able to determine the endpoint of the action integral, then these goals will be realized by the PLA in the most economical way (Grandpierre, 2007). In addition to the anti-religious and historical reasons, this aspect of the PLA seems to be the reason why physicists and philosophers of science have found it necessary to qualify the teleology of the principle of least effort as apparent. Due to the hegemony of physics, even biological autonomy has been regarded as to be physicalized. Perhaps "the main reason to physicalize biological autonomy seems to be that it has so far proven impossible to uncover a workable model of teleological causation" (Skewes and Hooker 2009). In this paper, I offer a workable model that is suitable to preserve the intact, genuine nature of biological autonomy and, at the same time, is consistent with all physics, restores the logical consistency of quantum physics and capable to explain teleology in an exact mathematical form.

The exact definition of physics by the Principle of Least Action

Since the fundamental laws of physics can be derived from this principle, we propose that the principle of least action is the essential, distinguishing characteristic of physics. In the case of macroscopic bodies, their behaviour will be judged as physical if and only if they follow their inertial path. With the help of the PLA, all fundamental branches of physics can be rewritten in their most elegant form. One can regard the PLA as physics in a nutshell. If we define physics by its most fundamental and comprehensive principle, the nature of physics will immediately appear in its true light. The active nature of living organisms is consistent with everyday experience, in the same rate as the passive nature of physical objects. I will show that typically biological and psychological phenomena involve genuine activities that initiate systematic, lawful deviations from the inert, incapable or passive behaviour. If we recognize the fact that not every phenomenon follows the inertial principle of least action, it will be clear that physics is not the science of all of nature. In this way, with the help of the exact definition of physics, it may be possible to prove that physics is not a complete science of nature because biological behaviour follows different laws of nature. If so, even quantum physics is fundamentally incomplete, and its incompleteness arises from the fact that it does not involve genuine biological phenomena.

On the completeness of quantum physics

It has been indicated already that quantum physics is not the ultimate theory of nature. Dirac (1927) remarked that the ‘freewill’ of the observer seems to play a crucial role at the beginning, in preparing the measurement (Bacciagaluppi and Valentini 2010, 188, 493). Although the fundamental equations of quantum physics, like the Schrödinger equation, are deterministic differential equations, as in classical physics, a fundamentally new type of determination enters into the picture, corresponding to the uncertainty relation, measurement and indeterminism. As von Neumann had shown (1955, 351), this fundamentally new type of determination is due to observers; it corresponds to the physically arbitrary changes introduced in the process of quantum measurements. I propose that the observer could become free from physical determinism by utilizing the quantum indeterminacies of the elementary particles corresponding to its decision to establish its own, biological self-determination. This means that there must be a fundamental type of determination in nature beyond the quantum level, and this new fundamental type of determination is genuine biological self-determination. This means that quantum physics is causally incomplete, and the observer problem leads us toward biology.

We argue that because the observer problem is central in quantum physics, quantum theory can be complete only if it becomes generalized and capable of involving the general theory of observers. Considering that all living beings are 'observers' in a general sense, i.e., sensing their bodies and their world, such an extension of quantum theory requires its extension to biology.

Besides the observer problem, the problem of biological action also indicates that quantum physics is not complete. It is important to mention here the violation of causality and the violation of the law of energy conservation (see below), the missing meaning of action, and the problem of apparent teleology in physics.

The problem of biological action

Science is nomothetic (Kim 1993, 194, 199), so if biology cannot provide laws, it is not a science. The additional principles beyond physical and chemical laws must be biological laws or principles. But is it possible to obtain a biological principle in the same manner as physics has its own fundamental laws?

My proposed solution to the problem of biological causation (Grandpierre 2007, 2012b; Grandpierre and Kafatos 2012) is simple and plausible, in complete agreement with physical laws, common sense and Whitehead. I propose that biological causes generate virtual particle pairs, a process possible below the quantum limits of Heisenberg's uncertainty relation. Virtual particles can act upon matter and complete the action, since all fundamental interactions of physics are realized by exchanges of virtual particles.

Biological causation solves the mind-body problem and restores the logical consistency of quantum physics

Quantum indeterminacy, the most fundamental characteristic of quantum physics violates two universal laws simultaneously, namely, (i) the universal principle of causality, and (ii) the law of energy conservation. The development of physics has reached the deepest level of physical reality, namely the quantum vacuum. Due to quantum physics, it has become obvious that cosmic space, the vacuum, is not empty because quantum theory allows virtual elementary particle pairs with extraordinarily short lives come into existence unceasingly. These ‘virtual’ particles are assumed to be born ‘spontaneously’. As it is stated in the Oxford English Dictionary ‘spontaneous’ means that it occurs without any external stimulus. Within the conceptual framework of physics, this means that it occurs without any physical cause. This is why quantum physicists state that the creation of these virtual particles appear to violate the principle of causation (Bohr [1931] 1999, Greenstein and Zajonc 1997, 51). If so, this process would violate one of the most fundamental notions of science, namely, causality. Such a violation is considered to be in conflict with the logical consistency of quantum physics, as well as with the nature of science since it is based on the universal validity of the principle of causality.

Quantum physics suffers from another fundamental fault by also violating the law of conservation of energy (Kane 2007; Josset, Perez and Sudarsky 2017). Actually, the spontaneous production of virtual particle pairs requires energy, since both the virtual particle and its antiparticle have a positive energy. Considering that the uncertainty relation allows the production of virtual particle pairs without constraining their number, these violations have an aspect of unlimitedness, and this circumstance adds to its significance considerably.

Let us realize that these two profound inconsistencies of quantum physics are present in one and the same process: the spontaneous creation of virtual particle pairs. Recently it has become clear that vacuum fluctuation, namely the spontaneous generation of virtual particle pairs, exists regardless of whether it is measured or not (Wilson et al. 2011). This means that virtual particles must be regarded as real entities. Therefore, the violation of the principle of causality and the law of energy conservation has to be seriously taken into account.

I propose a scientific solution for the twofold inconsistency of quantum physics. It requires expanding our horizon beyond the one limited by physics. If physical causes cannot offer a solution, and we want to remain within the context of science, the only thing we can do is to utilize the natural science next to physics, namely, biology. Fortunately, there exists already a biological theory suitable for that problem: the theory of biological autonomy (Grandpierre 2012b, Grandpierre and Kafatos 2012, 2013), that is based on the exact biology of Ervin Bauer (1967). This chapter uses a refreshed version of Bauer’s theoretical biology, bringing it into the context of theoretical physics (Grandpierre 2007, 2011; Grandpierre, Chopra and Kafatos, 2014).

Biological action is initiated by biological, that is, non-physical but real causes utilizing biologically governable energies. Introducing biological causes determining quantum indeterminacies solves the problem of biological action and, at the same time, automatically restores the validity of these two fundamental principles. Biological causes restore the universal validity of causality because they can mobilize biologically governable energies for the suitable production of virtual particle pairs. This means that, ultimately, biological causes are responsible for the production of physically undetermined production of virtual particles. This solution automatically restores the general validity of energy conservation as well. I think that such a solution solving three fundamental unexplained problems of science at the same time indicates its plausibility.

It is useful to point out that if biological causes are able to initiate the generation of virtual particles that are suitable to realize biological aims, they correspond to the next, more fundamental ontological level of the Universe beyond that of matter. We are led to recognize that biological causes act beyond the quantum level, governing and organizing the generation of virtual particles.

I have indicated that the first principle of biology acts through virtual interactions that determine the material processes. Now if virtual interactions are ultimately controlled by biological interactions, then the vacuum has to have a fundamentally biological nature. I suggest, in this sense, that the quantum-vacuum qualifies as the 'body' of a more subtle cosmic living organism extending to the entire Universe in its subquantum level.

On the meaning of 'action'

Pascual Jordan remarks that "although the concept of action is less obvious to man's physical intuition than that of energy, it is of even greater significance, as it appears also in connection with the quantum laws" (Jordan 1988). Actually, it seems that the physical meaning of action remains obscure. The saying "I don't know what action is" is attributed to Feynman (Toffoli 2003). Yourgrau and Mandelstam also acknowledge that "with the development of the older form of quantum theory the persuasion that the action had some deeper meaning gained renewed impetus" (Yourgrau and Mandelstam 1960, 146). Nevertheless, they exclude any possible physical meaning: "The action function can be fully and satisfactorily defined in terms of the other constructs and laws of dynamics, and it is thus rather an invaluable mathematical aid than a means of interpretation" (ibid. 158). In this way, we find that the situation at the very foundations of physics is paradoxical. Although it is a very central concept, action is formulated mathematically; its physical meaning has remained obscure. At the same time, physical meaning has central importance in the progress of physics.

Let us take into account that all living organisms are active. In order to manifest activity, the two requisite is energy and time. Physical objects can be characterized as their capability to act is minimal. In contrast, living organisms can be characterized as their capability to act, that is, their disposing power, is maximal. The first step of biological action is determining the final state of action in accordance with the principle of greatest action (PGA). This first step occurs by mobilizing biologically governable energies, modifying the energy landscape in a way that the physically most probable process will lead directly from the initial to the biologically determined final state. The second step is that the PLA realizes this final state in the most economical manner.

All actions require energy and time. If we want to measure the capability to act, it is proportional to the available amount of energy and time. Correspondingly, 'action' can be regarded as measuring the capability to act. In this approach, the least action principle expresses the fact that physical objects have the least capability to act. Their observable behaviour is passive, manifesting incapacity. Definitely, incapacity is not a concept within the conceptual framework of physics. On this basis, it is no wonder that action's physical meaning has remained unclear. But such a concept has a clear biological meaning as incapacity is considered the minimum degree of capacity to act. This means that 'action' is ultimately a biological concept.

On the problem of apparent teleology in physics

Feynman showed that the most elegant formulation of quantum physics can be obtained from the PLA. The most profound interpretation of the PLA, given by Feynman, tells that quantum physical objects "sniff around" all the possible pathways, and the resulting path is the sum of the quantum physical probabilities of all the pathways. Systems appear to "select" their paths between a selected initial and final state corresponding to the minimum (or stationary) action. We can consider that the PLA exerts its effects or becomes realized by virtual particles. Nevertheless, the real problem is not whether the system 'knows' its final state in advance, but another one, namely, why the sum corresponds to the least action. In other words, the real problem is the origin of the least action principle. Until now, the problem of the origin of the PLA has not been attacked. In this paper, I present a proposal suitable to offer a scientific and exact answer to this fundamental problem.

In the case of an inanimate, physical object, the "selection" of the paths between the initial and final state cannot be attributed to the physical object itself. The system does not know where it is going, the selection of the path corresponding to the least action just occurs with it. It is not the elementary particle that selects the path of the least action. Instead, it is given by nature. The apparent teleology of the least action principle could be a real teleology at the cosmic level if serious reasons are found showing that the PLA is indeed a tool for the actions of the Universe. In the following, I present arguments indicating that this is the case.

Teleology is the fundamental characteristics of biology

Ludwig von Bertalanffy, the Hungarian-born founder of theoretical biology has suggested "to extend principles like that of least action [into biology]" (Bertalanffy 1952, 201), to formulate a generalized principle of least action (Bertalanffy 1969, 101-2). It is also necessary, since genuine biological behaviour characteristically deviates from passive physical behaviour.

> The living creature has a will of its own or a mind of its own; it works persistently along lines which are not those of least resistance, towards a result which is not immediately attained (Thomson 1921, 4859).

Remarkably, even one of the leading figures of positivism, Moritz Schlick, in his "Philosophy of Organic Life" pointed out that biological teleology cannot be refuted:

> It is not likely that we shall be able to do without the assumption that organisms possess a special tendency and capacity for the development of teleological features which brings about adaptation to the environment in a more direct fashion than by the long way over various chance variations and subsequent selection of the fittest (Schlick 1953, 536).

In other words, it is likely that organisms possess a special tendency and capacity for the development of teleological features. If so, life is significantly more than physics; life involves a new, non-physical type of causality, teleology. The status of teleology today is much more promising than in the twentieth century (Toepfer 2012; Grandpierre 2012b, 2014; Nicholson 2013).

Bauer's principle—the first principle of biology

Ervin Bauer (1890–1938) was a far-seeing Hungarian biologist who wrote his fundamental works in 1920 and 1935 (Bauer [1935] 1967) before being killed by Stalinists in 1938. His work was banned in the Soviet Union on ideological grounds. Due to historical reasons and the dominance of physicalism, Bauer's work is not well known and misunderstood. Today Bauer is often presented in the Russian and Hungarian literature as a scientist who was much ahead of his time; he is regarded now as one of the founders of theoretical biology (Müller, 2005), which aims to achieve something like Einstein's great goal, to unify all of physics in one grand equation. "In our view, Bauer succeeded in solving a greater problem than Einstein faced, the unification of all fundamental biological phenomena in one equation" (Grandpierre, Chopra and Kafatos 2014, 367). Bauer sought to prove that all basic life phenomena are the consequence of the same underlying universal principle that characterizes living matter (Bauer 1967, 18). Bauer's principle shows that:

> The living and only the living systems are never in equilibrium; they unceasingly invest work to the debit of their budget of free energy against the equilibration which might occur for the given initial conditions of the system on the basis of physico-chemical laws; the source of deviations from physical behaviour is internal (Bauer 1967, 51–52, 12).

The initial state of the living organism is characterized by its potential differences and free energies (differences in pressure, concentration, electric fields, etc.). If the living organism was isothermally isolated, it would lose all these differences and free energies due to the equilibration that would inevitably occur as the second law of thermodynamics tells us. In contrast to a similar but dead organism, the living organism will act against equilibration and mobilize all its potentials and energies against the deadly equilibrium. This internally initiated work against the equilibration is the characteristic and universal property of living organisms and the crucial feature that distinguishes them from inanimate bodies.

From this principle, which he formulated also in a mathematical form, Bauer was able to derive the fundamental equations of metabolism, reproduction, and growth, as well as all the fundamental phenomena of life, metabolism, reproduction, growth and responsiveness. He also derived from his principle the law of the increasing potential of living matter as the law of evolution (Bauer 1967, 184; 195). On the basis of these outstanding achievements, it seems that Bauer's principle may be regarded as the first principle of biology (Grandpierre, Chopra and Kafatos

2014). The first principles are defined as one of the three deepest and most comprehensive principles of nature, mathematically formulated as a variational principle in an integral form, from which all the fundamental laws and phenomena of either physics, or biology or psychology can be derived.

How to extend the action principle to biology?

In contrast to physical objects manifesting a passive behaviour as governed by the principle of least action, a living organism's distinguishing characteristic is that it can act. Necessarily, living organisms, having a physical body, are in a situation wherein the PLA works on all their physical constituents. According to the equilibration tendency of the PLA, living organisms must compensate the physical equilibration tendency by their activities, and this can only be done successfully by a similarly powerful and fundamental principle, the principle of biological activity. Biological activities must be directed towards regenerating their capability to act, to do work. Yet their physical constituents seem to be governed by the principle of least action. We found that the only possibility to avoid the power of the PLA and become active beings capable for self-determination is to generalize the principle of least action allowing living organisms to act (Grandpierre 2007, 2011).

Action is an ideal tool of choice to describe biological phenomena since it can act between a given initial state and a biologically anticipated final state. Living organisms must be able to select the endpoint of the action principle according to the requirements of life, according to their biological aims. The only option to take into account biological teleology in the context of the most powerful tool of modern physics, the PLA, is to generalize it by admitting the basic fact of life that the endpoint of the action principle is selected suitably to realize biological ends (Grandpierre 2007). Such a final causation is not only compatible with the explanation by efficient causation, but it is the only means to explain biological behavior at the global level of the living organism (Grandpierre 2011; Grandpierre, Chopra and Kafatos 2014). Finally, biological causation is not in contradiction with the linear, consecutive character of effective, physical causation. As Nagel (1979, 278) pointed out, the agent's want for a goal acts contemporaneously with the initiation of biological behavior; therefore, it does not represent "backwards causation". Indeed, biological aims are present in the initial state, and these biological aims are directed towards life, towards end-states favourable and closely optimal for life.

The fundamental principle of biology—the Principle of Greatest Action as the extension of Feynman's Least Action Principle

Theoretical biologist Robert Rosen pointed out that the 'action' in the PLA is a cost function (Rosen 1967, 4; 155). If so, the PLA can be regarded as an optimality principle, indicating that physical processes are the ones with the lowest cost, in terms of action. Let us illustrate this argument by the example of a stone and a living bird dropped from the Pisa tower. The stone falls down vertically, following the physical path. Its consumption of nature's currency, action, is minimal. In contrast, the path of a living bird is unpredictable, being always different, because the endpoint is selected by the bird itself. Moreover, the final state may be reached from very different initial conditions and in different ways. This observational fact can be taken into account mathematically in the PLA by *allowing the endpoint as a free variable to be selected by the bird itself*. Necessarily, the living bird should select its ends according to biological aims. It is plausible to assume that normally all the activities of the living bird are selected in harmony with biological aims. This generalized principle can be used maximally for biological aims when biological actions are maximizing the capability of living organisms to act. This means that living organism's biological activities contribute maximally to regenerate their free energy content, their ability to do work. In this manner it is possible to obtain the principle of greatest action (PGA, Grandpierre 2007). The point is that when allowing teleology to serve biological aims maximally, a mathematical formulation of the PGA is obtained that is almost identical to the mathematical form of Bauer's principle which is the universal principle of all living organisms (Bauer 1967; Grandpierre, Chopra and Kafatos 2014). The difference between the PGA and Bauer's principle is that, in the latter, the amount of mobilized energy is maximized, while in the PGA the sum cost is of energy and time together.

The PLA is formulated in an exact mathematical form as being an integral of action between the initial and final state. When its endpoint was allowed to be variable and selected by the living organism itself according to its biological aims, a more general principle was obtained. In this more general principle, the free variable to be determined by the living organism is the mathematical expression of teleology, namely, endpoint selection. In this way, a precise mathematical expression that offers a possibility to integrate teleology into the present mathematical formalism of theoretical physics was obtained. By working out the scientific theory of biological autonomy on the basis of the independent fundamental principle of biology, it was discovered that biological autonomy can generate virtual particles through decision making representing biologically governable energy. In the case of human beings, such a biologically autonomous and governable energy corresponds to our will (Baumeister 2012). Taking into account the fact that Feynman's interpretation of the PLA shows that it operates through virtual particles, it is possible to suggest that such a biological autonomy that is capable to select spatio-temporal endpoints by creating suitable pairs of virtual particles seems to be ideally suitable to work with the least action principle which itself works also with the help of virtual particles.

Biology beyond the quantum level

Keeping in mind that the chain of physical causes is closed within classical physics, and the causal chain of quantum physics is open only in the quantum realm, where virtual particles are produced randomly, there is only room for biologically organised causes beyond the quantum level. Biological actions act in a causally deeper level of nature, being capable to determine the production of virtual particles. Now because all quanta have a physically indeterminate quantum range for biological actions, biological actions may have all the powers necessary to govern the behaviour of elementary particles.

Biology is more fundamental than physics

Now let us make the following step. If the biological action principle is more general than the physical principle, this means that biology is more fundamental than physics. Accordingly, life in nature is more fundamental than the existence of matter. This conjecture is unexpectedly profound. Therefore, it is important to keep in mind that Eugene Wigner came up with the idea that biology is a more general science that includes in itself physics as a special subclass:

> Since it is rather clear, in retrospect, that physics in the past always dealt with situations which turned out later to have been limited cases… It may well be suggested, therefore, that present-day physics represents also a limiting case—valid for inanimate objects (Wigner 1969, 98–99).

Wigner (1970, 44) considered inanimate matter "as a limiting case in which the phenomena of life and consciousness play as little a role as the non-gravitational forces play in planetary motion." Now if the physical principle (PLA) can be derived from the biological principle (PGA), this means that physical activity as it is expressed by the quantum physical laws are merely aspects of the fundamental biological activity of the Universe (Grandpierre 2018).

The PGA is a more fundamental principle than the PLA. It permeates the entire Universe from beyond the quantum vacuum, generating and organizing the virtual processes. It is necessary to point out that Laplacean cosmological models of physical cosmology correspond only to a surface layer of a more fundamental astrobiological or biofriendly cosmology that we are now discovering. The nature of the vacuum fluctuations that generated the Big Bang appears to be finely tuned for life's flourishing. After the first cause, which generated the Big Bang in an extremely special state suitable to host life, further causes act as well. Physicists think that all matter today, from galaxies to living things, originated from these primordial quantum fluctuations. Quantum fluctuations acting on the evolution of the observable universe have a far-reaching hand: from initiating the Big Bang to the formation of the suitable density irregularities leading to galaxies and stars, the formation of the Solar System, the Earth-Moon system, to the origin and evolution of the terrestrial biosphere, and to our existence here. Such quantum fluctuations are input elements for the Laplacean models of physical cosmology and are left unexplained by them. We, therefore, consider seriously the idea of a fundamental, universal and continuous biological cosmic activity as manifested through the quantum vacuum everywhere (Grandpierre 2018). In a sense, the quantum-vacuum is the body of the living quantum-vacuum.

Biology and Whitehead's organic cosmology

The fundamental, universal and permanent biological activity of the Universe has a decisive importance by giving a scientific foundation to Whitehead's suggestion to construct a cosmology in terms of biology. Indeed, as Whitehead wrote in *Nature and Life*, "[t]he doctrine that I am maintaining is that neither physical nature nor life can be understood unless we fuse them together as essential factors in the composition of 'really real' things whose interconnections and individual characters constitute the universe" (Whitehead 1938, 150).

> The status of life in Nature […] is the modern problem of philosophy and of science (ibid. 148).

> The object of these lectures is to indicate those elements in our experience in terms of which such a cosmology should be constructed (ibid. 168).

Whitehead also indicated that the physical approach omits those aspects of the universe as experienced, and of our modes of experiencing, which jointly lead to the more penetrating ways of understanding (ibid. 135).

On the causal completeness of physics and the relation between biology and physics

Physicalism claims that physics is complete, that is, no additional principles can be admitted in science. "The question is 'why does a frog jump?'" and, as the Nobel-laureate Feynman writes, "the physicist cannot answer. If they tell him what a frog is, that there are so many molecules, there is a nerve here, etc., that is different. In order for physical theory to be of any use, we must know where the atoms are located" (Feynman 1964, p. 9 of ch. 3). But here we find a real problem. Even if all the data of all atoms would be given, the physicist would not have any idea how to model the frog and its behaviour. It seems Feynman assumes that the only thing required for the physicist is the input data for the Schrödinger equation. As he continues, "[t]oday we cannot see whether Schrödinger's equation contains frogs, musical composers, or morality—or whether it does not" (ibid. p. 12 of ch. 41). Similarly, in one chapter titled "Why did the frog jump?" neuroscientist Steven Rose, a professor at the Open University states that the frog jumps because the muscles in its legs contract; in turn, the muscles contract because of impulses in the motor nerves arriving at the muscles from the frog's brain; these impulses originate in the brain because previous impulses, arriving at the brain from the frog's retina, have signaled the presence of a predatory snake (Rose 1998, 11). In Rose's picture, the frog does not intervene at all. The frog's jump, if Rose's argument is correct, simply occurs independently of the frog's internal mental or emotional states.

According to Whitehead, life implies the absolute, individual self-enjoyment arising out of the process of appropriating—replacing by this term his previous term 'prehension'—the many data provided by the antecedent functioning of the universe into a unity of existence (Whitehead 1938, 151).

> I hold that these unities of existence, these occasions of experience, are the really real things which in their collective unity compose the evolving universe, ever plunging into the creative advance (ibid.).

We can observe the sharp contrast between the physicalism of Feynman and Rose, and the organic doctrine of Whitehead. Indeed, life's fundamental nature is not being extremely submitted to the mercy of the circumstances, but freedom, wellness and abundance. The universal principle of biology urges all living organisms to mobilize all their efforts to live the most vital and satisfying life possible within the given conditions. Because biology is more fundamental than physics, their efforts are fundamentally successful. Life's natural main road is wellness, happiness and joy. In a normal case, the dominant factor is life's universal urge to improve self-enjoyment and maintain vitality for as long as possible—to improve the quality of life.

On the relation between biological, mental and physical causes

Now let us pose a somewhat different question. How could we move our body, for example, bend our finger? The argument follows a similar line to that of the frog's jump. We bend our finger by our muscles that becomes contracted by action potentials elicited in the brain by our mental decisions. As Whitehead has pointed out, the function of Reason is to promote the art of life (Whitehad 1929[2018], 4). Accordingly, mental decisions are fundamentally motivated by biological aims. We find that the relation between the physical, biological and mental causes is normally the following: biological causes motivate our mind for a task. The result is that our mind makes a suitable decision that results in the generation of virtual particle pairs that generate the action potential due to which the muscles become contracted. Of course, the human mind has its own autonomy that can be used for or against our fundamental biological aims. But until abnormal motivations harmful for our life are absent, our reasoning activities are in harmony with our natural, biological motivations to do what is best for life.

On the relation between the physical and biological principle

Now let us evaluate the relationship between matter and life on the basis of the action principle's two versions: the biological, maximal and the physical, minimal. The biological cause is the fundamental biological motivation to do anything, to act or to think. This primary motivation urges us to act, and this needs a decision what to act and how. The decision-making requires mental activity to determine or select the endpoint for the biological principle. Once the endpoint is determined by biological and mental causation, the activity of our bodies occurs with the help of the physical principle of least action, that is, in the most economic manner. We bend our finger with an utmost ease because all the details of how to move the elementary particles in our body are arranged by the least action principle. We can recognize that the PLA is the ideal tool for the principle of greatest action because realizing our aims with an utmost ease like the djinn in Aladdin's lamp, makes it possible to use our life energies to become maximally effective. The relationship between biological and physical causes can thus be compared to the relationship between a driver and a car—the driver steers the car in line with their aims, while physics controls the car's behaviour at a lower level and delivers it to its destination.

We found that these two principles—the PGA and the principle of matter, the PLA—are in a surprisingly close relation. Living organisms can only sustain themselves in the long term when they can reach their concrete endpoints with the least possible action. These endpoints must be selected in the spatio-temporal world. They are selected by the living organism on the basis of the principle of greatest action for life. And so, living organisms can only realize the PGA if, at a physical level, they use the physical principle as their tool. The principle of life utilizes the principle of matter on behalf of its own interest. The physical principle is the executive tool of the biological principle. Amazingly, I found that the principle of matter, as effectuating the most economical processes, is the ideal tool for the PGA.

Let us use a metaphor to illustrate the relationship between biology and physics. A company that builds bridges would like to build the greatest possible number of bridges each year. This corresponds to the principle of greatest action. Here, selecting endpoints means that the company would finalize the plans for constructing the bridges with the aim to maximize its output. If the company has already decided where and what kind of bridges it wants to build, the company must build each bridge economically, so as not to waste its time and energy. It can build the greatest possible number of bridges if and only if it builds each specific bridge in the most economical way possible. The management of the company must apply the principle of least costs for every bridge; only then can the company succeed in building the greatest possible number of bridges and fulfil the aim producing the maximum output in the year. From this perspective, there is a biological reason beyond the economical character of the least action principle. The reason for such economy is rooted in the nature of life attempting to maximize its potential.

I conclude that teleology is nature's fundamental feature. The very central quantity of physics, "action", has indeed a biological origin. Ultimately, I indicate that the least action principle of physics has its origin in the PGA. The biological extension of quantum theory led us to a scientific picture substantiating Whitehead's organic cosmology.

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