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Biological Autonomy

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We argue that genuine biological autonomy, or described at human level as free will, requires taking into account quantum vacuum processes in the context of biological teleology. One faces at least three basic problems of *genuine* biological autonomy: (1) if biological autonomy is not physical, where does it come from? (2) Is there a room for biological causes? And (3) how to obtain a workable model of biological teleology? It is shown here that the solution of all these three problems is related to the quantum vacuum. We present a short review of how this basic aspect of the fundamentals of quantum theory, although it had not been addressed for nearly 100 years, actually it was suggested by Bohr, Heisenberg, and others. Realizing that the quantum mechanical measurement problem associated with the "collapse" of the wave function is related, in the Copenhagen Interpretation of quantum mechanics, to a process between self-consciousness and the external physical environment, we are extending the issue for an explanation of the different processes occurring between living organisms and their internal environment. Definitions of genuine biological autonomy, biological aim, and biological spontaneity are presented. We propose to improve the popular two-stage model of decisions with a biological model suitable to obtain a deeper look at the nature of the mind-body problem. In the newly emerging picture biological autonomy emerges as a new, fundamental and inevitable element of the scientific worldview.

Keywords: spontaneity, teleology, biological aim, vacuum processes, quantum indeterminacy, consciousness

1. Introduction

Today's dominant paradigm holds that everything is physical (Stoljar 2009). If this entails physical determinism, it involves that a genuine biological autonomy, by which we mean the ability of living organisms to decide about their acts themselves in a way that is not determined completely by physical or biological laws and previous conditions (this is our definition of genuine biological autonomy), "*ab ovo*" cannot exist. At the same time, we point out that the main reason to physicalize biological autonomy is that it has so far proven impossible to uncover *a workable model of teleological causation* (Skewes and Hooker 2009). In this paper, we attempt to make a first step towards developing such a model.

We are motivated by the consideration that in the practical life of living organisms numerous tasks arise

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that cannot be solved on the basis of evolution and physical laws alone. For example, when a fish is thrown back into the river, nature's command is short: survive! This command does not inform the fish in terms of physical details and spatial coordinates what to do, such as to turn left or right. Organisms commonly have alternative means of performing the same function (Beckner 1969), therefore, they must decide between biologically equivalent alternatives, the differences of which would not depend on evolution. Since biological functions are defined here as processes serving biological aims, ultimately survival and flourish, the fact that the same functions can be performed by alternative means and from highly different initial states within widely different conditions means a *biological equifinality*, the presence of a common aim beyond different physical processes. Moreover, living organisms interact with a complex environment that is indefinitely rich in unexpected changes. Therefore, organisms must continuously solve newly encountered tasks in their daily lives. Organisms must have certain intelligence since they can solve problems that no specific individual in the evolutionary history of the species has solved before (M. Heisenberg 2009). Accordingly, numerical estimations indicate that a significant part of the thermodynamic potential of cells is utilized to generate novel information (Grandpierre 2008). Ross W. Ashby's pioneering work (1960) showed that adaptive behavior, corresponding to the origin of intelligence, should be understood dynamically through the homeostatic maintenance of essential variables under viability constraints through environmental interactions. Our point here is that the development of intelligence and adaptive plasticity are mere capabilities; their realization requires an ingredient that is based on the organism's autonomous decisions, which we label as "biological autonomy."

We cannot understand the nature of *genuine* biological autonomy, namely, that it is not determined completely by physics but caused by biological autonomy, without considering where such biological causes can come from (this is the "problem of biological causes"). When looking after possible answers, we can keep in our mind that nature is one unified system, while physics and biology are only human conceptualizations that we project onto nature, expressing two basic aspects of nature that is in reality a unified system. Therefore, physics and biology (as an autonomous science) must have a common natural basis. In general, the development of science has two basic directions; it proceeds towards a deeper and wider picture of nature. Regarding depth, today's science, physics, recognized that "the vacuum holds the key to a full understanding of the forces of nature" (Davies 1985, 104; 2005, S40; Milonni 1994, xiii). The theoretical structure of quantum field theory as specified by mathematics is dictated by the basic ontological commitment to a violently fluctuating vacuum (Cao 2010, 208). Regarding breadth, physics nowadays develops towards biology (e.g., F. Kafatos and Eisner 2004) and with increasing depth, the breadth of science increases. Therefore, one can expect that the vacuum must play a fundamental role in biology.

The development of science in the last decades underpins this argument. A popular idea in modern physics is that all the material of the Universe has been created from quantum vacuum fluctuations by the physical laws (e.g., Tryon 1973; Hawking 1988, 142; Davies 1992, 73). Cosmic evolution, the idea that the universe and its constituent parts are constantly evolving, has become widely accepted only in the last 50 years (Dick 2009).

In the last decades, it became increasingly clear that biological (and cultural) evolution has been an important part of cosmic evolution on Earth, and perhaps on many other planets (Davies 2009a; Dick and Lupisella 2009). Indeed, Paul Davies (2009b, 383) presents arguments showing that the long-held prevailing view claiming that living systems had no particular significance in the cosmic scheme of things is "profoundly wrong." Biological organisms are products of a very basic organizational principle, replication with variation plus selection, a principle that applies anywhere in the cosmos. Moreover, the ability of living organisms to construct a computational representation of the universe makes them capable of manipulating their environment on a large scale. Therefore, "life ... and mind is a key part of the evolution of the universe" (Davies 2009b, 383). This means that the problem of biological causes led us to the quantum vacuum.

2. Biological Causes without Collapse of the Wave Function

The ability of human mind to decide about different options exists in a fundamental way in quantum physics. The most detailed quantum description of measurement actions and nature's responses to such action is currently a modified version of the Copenhagen Interpretation, namely the von Neumann (as described by Stapp 2007; see also M. Kafatos and Nadeau 2000) model. In it, the self-conscious mind freely selects what kind of experiment to construct. The first step is related to formulating questions that can be answered by yes or no answers (Stapp 2007, 24); this is the process of human "choice": the observer must first specify what aspect of the system he intends to measure or probe, and then put in place an instrument that will probe that aspect. The next step is nature's "choice," which is a choice between the alternatives specified by human "choice."

We point out here that regarding genuine biological autonomy, the situation is basically different. Formulating yes or no questions seems to require human-type self-consciousness. While human beings are self-conscious, arguably living organisms in general are not self-conscious but nevertheless are aware of their environment, they are conscious. It seems plausible that living organisms in their life activities act internally, within their organism, i.e., not on inanimate matter, but on their own living matter. As we argue here, this makes a difference. In the quantum physical description of self-conscious decisions, the creation of a physical force by muscle contraction is roughly proportional to the number of bits per second of the limited central processing capacity that is devoted to the task (Stapp 2007, 42-43). We point out that the rate of self-conscious information processing of the human brain as a whole, when measured in bits/sec, is around 1-100 bits/sec (Elsasser 1958, 70-71; Lehr and Fischer 1988). Since our brain consists of ca. 10^{11}-10^{13} neurons, this yields an average rate for the self-conscious information processing as 10^{-11} *bits/sec/neuron*. In comparison, von Neumann estimated that the rate of neural activity is less than 10 activations/sec/neuron (von Neumann 1958, 63-64). Accordingly, the rate of information processing in the visual system is ca. 3 bits/sec/neuron (Anderson, Van Essen, and Olshausen 2005). The global activity level of the cell, corresponding to global activations or "spikes," must be distinguished from the cellular activity occurring at the molecular level. In the average cell of the human body 4×10^7 ATP molecules are produced per cell per second. This means that the number of molecular reactions in an average cell must be by order of magnitude around 10^8/sec/cell. The corresponding rate of information processing characterizing the intrinsic activity of the cells at the molecular level is estimated to be roughly 10^8 *bits/sec/cell* (Grandpierre 2008). This means that *there is something like 19 orders of magnitude difference between the rate of information processing of human self-consciousness and that of molecular-level cellular activity*. It is already known that self-consciousness represents only an infinitesimal fraction of our ability to process information (Norretranders 1998, 124-56). We add that elementary biological processes corresponding to elementary cellular decisions in driving biochemical reactions are much more direct and effective than in the case of the quantum measurement problem.

Recently, Margulis and Sagan (2010) noted that Samuel Butler (1835-1902) presented sentient life as making numberless tiny decisions—and thus responsible in part for its own evolution. For Butler, amoebas too have their little wants, their little "tool-boxes" with which they materially change their environments, pursue their little goals. We think that Butler's cited views can be substantiated by the developments of quantum electrodynamics.

In exploring the working mechanism of biological autonomy we need something more elementary and fundamental than self-conscious decisions and standard “collapses” of the wave function. In this paper, we explore the central role of spontaneity. Bauer, the founder of the still uniquely exact theoretical biology, pointed out that spontaneity is one of the basic properties of all living organisms (Bauer 1967). Recently, Björn Brembs (2011) argued that spontaneity is one of the basic ingredients of biophysical autonomy. Yet his usage of the term “spontaneity” seems to refer to a physical process. We think that it is necessary to distinguish between physical (i.e., completely random) and biological (not completely random) types of spontaneity. As such, spontaneity should be related to vacuum processes, specifically the quantum vacuum.

3. Is there a Room for Biological Causes to Act on Matter?

The normal laws of physics operating at the micro-level are supposed to be sufficient to completely determine the behavior of the system, and so leave “no room at the bottom” for additional biotonic laws or organizing principles to exercise downward causation on the parts (Davies 2004b). Nevertheless, a type of physical spontaneity corresponds to incomplete physical determination: the type of quantum fluctuations of the vacuum. Indeterminacy means that there is not sufficient cause fully explaining an individual event, they escape a complete and full description (Zeilinger 1996). Such quantum fluctuations can be thought of as forcing spontaneous emission (this formulation is somewhat simplified; for details, see Milonni 1994, 142-43, 151). In quantum physics there is no spontaneous emission without its pair process, absorption. Single quantum fluctuations are not completely determined by previous physical conditions working with the physical laws; this is why single quantum fluctuations are termed spontaneous. We refer to such events with the term “quantum spontaneity.”

Here we propose that *biological spontaneity utilizes quantum spontaneity*. Quantum electrodynamics rests on the idea that charged particles (e.g., electrons and positrons) interact by emitting and absorbing photons, the particles that transmit electromagnetic forces. These photons are “virtual”; that is, they cannot be seen or detected in any way because their existence violates the conservation of energy and momentum. The photon exchange is merely the “force” of the interaction, because interacting particles change their speed and direction of travel as they release or absorb the energy of a photon. The picture of electromagnetic interactions as the exchange of virtual particles has been carried over to the theories of the other fundamental interactions of matter, the strong force, the weak force, and the gravitational force (“quantum electrodynamics,” Enc. Brit. 2012). The fundamental uncertainty relation of Werner Heisenberg allows a discrepancy in energy, ΔE, to exist for a time, Δt, provided that the product of ΔE and Δt is very small—equal to the value of Planck’s constant divided by 2π, or 1.05×10^{-34} joule seconds. The energy of the exchanged photon can thus be thought of as “borrowed,” within the limits of the uncertainty principle (i.e., the more energy borrowed, the shorter the time of the loan) and used to excite a molecule in a process of spontaneous excitation.

Not only spontaneous excitation can occur via virtual interactions, but long-range transfer of excitation energy in molecular systems as well (Andrews 1989; Scholes 2003; Andrews and Bradshaw 2004). Del Giudice et al. (2010) pointed out that in living organisms, most biological reactions are redox reactions, which demand a supply of electrons. However, both biomolecules and isolated water molecules are not electron donors, since electrons are tightly bound to parent molecules with binding energies of several electron volts. One (virtual) photon, getting out from the quantum vacuum because of Werner Heisenberg quantum fluctuations, could excite an atom. The excited atom would decay after its typical decay time, giving back the photon, which could alternatively be reabsorbed by the vacuum or excite another atom; each excitation corresponds to quasi-free electrons (Del Giudice et al. 2010). Spontaneous donor-acceptor interactions are the manifestations of virtual quantum effects and play a central role in chemistry. The subtle virtual effects modify the electron distributions of the donor and acceptor, and the modified electron distributions determine the behavior of the molecules (Andrews 1989). Recently, it became clear that proteins shape the energy landscape and they mediate an efficient energy transfer despite thermal fluctuations (Panitchayangkoon et al. 2010). The conformational changes of proteins are related to changes in van der Waals forces as the manifestations of vacuum processes (Fukuyama and Wagner 2000, 55). Additionally, it seems that the activity of DNA is triggered by quantum processes defining a kind of virtual world (Pitkanen 2011). Also, evidence shows that mental activation occurs in quantum processes (Pop-Jordanov and Pop-Jordanova 2010). It is also proposed that highly ordered virtual photons encode for conscious processes (Romijn 2002). We think it is plausible to allow that spontaneous virtual processes are useful tools of biological autonomy.

Let us consider a specific example: It is shown that the wavelike characteristic of the energy transfer within the photosynthetic complex can explain its extreme efficiency in that it allows the complexes to sample vast areas of phase space to find the most efficient path (Engel et al. 2007). Instead of following a single trajectory like the electrons on a silicon chip, the energy in photosynthesis explores all of its options and collapses the quantum process only after the fact, retroactively "deciding" upon the most efficient pathway (Garfield 2009). These data prove that the wave-like energy transfer process is directly relevant to biological function (Panitchayangkoon et al. 2010). We point out that the extreme biological efficiency is possible only if the energy landscape formed by protein conformational states corresponds to the realization of biological aims. The first stage of this process is the decision selecting the next biological aim to be realized. The selection of the biological aim occurs on the basis of the greatest action principle (Grandpierre 2007), organizing the protein shapes accordingly, building up a new energy landscape on which the wavelike energy collapses to the already most efficient pathway. Once the endpoint is selected on biological grounds, the process works as the endpoint for the least action principle of physics. The "collapse" of wavelike energy corresponds to the second stage of the process, to the realization of the biological function within the biologically regulated new physical conditions. The systematic biological modification of the input conditions to physical laws at each time step by our proposal corresponds to quantum processes of the vacuum.

We have to add here a note regarding vacuum fluctuations. Spontaneous vacuum fluctuations in physics are random. Such random vacuum fluctuations are generated by the least action principle of physics as in the Feynman path integral method (Feynman 1942; Barrow and Tipler 1986, 132). We propose that biologically initiated vacuum processes (see the Appendix, "Fifth difficulty," in more details) can, similarly, initiate physical processes when they interact with physical matter. Now if the biological principle of the greatest action can be regarded as the extension of the physical principle of least action (Grandpierre 2007), then the biological principle offers the same (already established) mechanism to produce spontaneous vacuum processes, namely to serve the basic biological aims by quantum vacuum processes. Actually, the realization of the greatest action corresponds to the selection of the endpoint of the given process. We note that biological autonomy must contribute to *endpoint selection*, as in the example of a bird dropped from the Pisa tower in a biologically extended Galileo experiment. The principle of greatest action (see the Appendix) tells the bird to regain its original height with a minimal energy investment, but the bird itself must decide which direction to fly. Yet these biologically initiated vacuum processes are not random since they are initiated by biological autonomy (see the Appendix in more details) to manifest a spontaneous decision. The chain of biological causality is the following: biological autonomy generates biological aims that create vacuum processes and become transformed into physical forces. This means that we can distinguish between physically and biologically spontaneous processes in the following way: physically spontaneous vacuum fluctuations are random, while biologically spontaneous vacuum processes are not random but serving biological aims, therefore, we term them vacuum "processes" instead of vacuum "fluctuations."

We do not find the term "choice" appropriate to describe how biological autonomy acts since at a "choice" the spectrum of vacuum fluctuations remains random. In the case of decisions serving a certain biological aim, the spectrum itself becomes modified by the biological aim. In biology, such spontaneous changes realizing aims from the organismal down to the microscopic level of elementary biochemical processes are ubiquitous: raising arms, moving the body or its parts—all are processes necessarily involving spontaneity, and, therefore, biological autonomy. Since the physically not-completely-determined possibilities are found at the quantum level to be related to virtual particles exploring all paths in the Feynman interpretation of the least action principle, in our attempt to find room for biological causes we are led to the quantum vacuum. Not only the problem of the common basis of physics and biology, but also the problem of biological causes indicates that the solution of these basic problems is related to the quantum vacuum.

4. How is it Possible to Obtain a Workable Model of Teleological Biological Aims?

A biological aim is defined here as a specific biological tool determining the outcome of a set of biological events and their physical aspects, observable structures and processes, directing and teleologically organizing them into a functional unit fulfilling the relevant aim. For example, the chemical structure and conformational state of a protein can be described in physical terms; at the same time, its biological aim or function (e.g., defense of the cell against germs) is left out of the physical description working in terms of coordinates, mass, energy, charge, spin, etc..

We point out that the basic and distinguishing characteristics of biology is teleology (Green 2012; Toepfer 2012). That the merely possible should influence the actual progressively into the future is still a paradox from the mechanistic point of view (Short 1983). We arrive at a fundamental and yet unsolved problem (Skewes and Hooker 2009): how can a decision (in general, teleology) be physically effective? Descriptions of final causation as "backwards causation" are mistaken (Nagel 1979, 278). As Ernest Nagel argues, a final cause is not a future actuality: it is a present possibility in the mind of the subject. How to transcend the linear sequence of physical determinations while remaining within the realm of exact science? This seems to be a fundamental and yet unsolved problem. We point out that there is a well-known scientific fact capable to solve this fundamental problem. A decision event can be effective in a teleological perspective only if it transcends the linear sequence of physical determinations occurring at the level described by the differential equations of physics (like the Euler-Lagrange equations, Maxwell equations, Schrödinger equation, etc.).

By our proposal, this teleological perspective corresponds to an integral aspect. Beyond the level of nature described by differential equations, a deeper level also exists, and this deeper level of nature can be described by integral principles, written in terms of integral equations. The "possible future" becomes active through the biological aim exerting its influence *on the present*. We note that although the least action principle is capable to offer a kind of teleological perspective, it cannot solve the problem of *biological teleology*. The endpoint of the least action principle in physics is given by the initial and boundary conditions. For example, the endpoint of a falling stone is given by its initial position, velocity, and the boundary conditions (when the drag of the air is negligible, the boundary condition determining the endpoint of the falling stone is the position and shape of the ground). In biology, the endpoint of the action principle cannot be determined by the initial state and the physical boundary conditions, since it must be determined by biological aims. This means that it is necessary to generalize the least action principle to make it suitable for describing biological teleology. The generalization of the least action principle to the action principle in biology is realized recently (Grandpierre 2007). As a first step towards working out a model of teleological causation we suggest to consider the endpoint selection for the greatest action principle and taking into account autonomous decisions. In our attempt to find a scientifically acceptable place for biological teleology we are led again to vacuum processes, to the least action principle and to its biological generalization, the greatest action principle (about the greatest action principle, see the Appendix). This means that the solution of all the three basic problems of biological autonomy points toward the quantum vacuum.

It is shown that biological teleology corresponds not to a minimal, but a maximum principle (Grandpierre 2007). Indeed, all life phenomena—metabolism, regeneration, growth, homeostasis, and response to stimuli—occur for the sake of maintaining and extending life as far as possible. In biology, the endpoint for the action principle is to be chosen on the basis of the greatest action principle, which requires the active contribution of the organism. The problem of how the decision event can be physically effective translates now into the problem of how a decision of a living organism can fix the endpoint for the action principle. If biological organization can occur through the specification of the endpoint for the greatest action principle, living organisms must be able to realize biologically useful endpoints. We suggest that genuine biological autonomy is realized by endpoint selection mediated by spontaneous quantum vacuum processes.

Living organisms harness the physical-chemical processes on which the organism relies (Polanyi 1968). What remains constant in these kinds of systems is their "organization," i.e., the causal pattern of interdependence of parts with certain effects of each part being relevant for the working of the system (Toepfer 2012). It is this fundamental teleological structure that determines the physical processes within living organisms (see the Appendix in more details). Vacuum processes of biological origin are not the agents but the tools of biological autonomy. One can speculate that biological principle cannot exist, and so the spectra of quantum fluctuations must always be physically determined, random, and biological autonomy, itself also considered as basically physical, merely utilizes somehow (how?) these physically originated, random fluctuations. Yet this option leads to physicalism, which leaves the problem of biological autonomy obscure, and is in conflict with the basic facts of nature pointed here.

We emphasize that the existence of biological aims is actually a basic and elementary fact of nature. Fundamental biological aims like self-preservation, self-defense, obtaining, processing, and utilizing matter, energy and information for the sake of biological aims are all inevitable for the existence of living organisms. Indeed, a living organism is capable to achieve "at once the pursuit and fulfillment of its own purpose" (Monod 1972, 80). Moreover, it is generally accepted that there are ultimate biological aims that have immense explanatory power—such as the aim of survival, as can be seen in the case of Darwinism. We note that it is possible to view living organisms as being merely "survival machines." Yet if genuine biological autonomy exists, then living organisms are not machines at all.

The physical efficiency of consciousness is widely suspected in the process of wave function "collapse" occurring at measurements. Our proposal is that quantum processes within living organisms assisting biological decisions must occur not by "collapses of wave functions" but in a fundamentally simpler manner that escaped attention until now: living organisms must be able to *decide* about their own behavior. This means that the statistical, random character of physical spontaneity plays a relatively little role at the biological initiation of biophysical quantum processes. Within a living organism, the organism itself can decide about the initiation of biophysical processes, effectuating a decision that characteristically prevails without being smeared out into a random distribution of probabilities by the intervention of random stochastic processes. It is the organism that must decide about most of the details of what processes should be realized, where and when—at the molecular level, where the quantum indeterminacy of physics prevails. Since the task of a conscious agent is to decide what to do, when, where, and how, this means that biological autonomy and consciousness are closely related. The relation between "consciousness" and biological autonomy is that while "consciousness" is a metaphysical, philosophical, and scientific concept without a generally accepted definition, heavily laden by history, having many different meanings, biological autonomy is defined here in a strict scientific context. We consider that biological autonomy is the first exact definition of the operation of consciousness in living systems.

5. The Nature of Biology according to the Founders of Quantum Theory and Recent Developments

Already Bohr realized that biological teleology transgresses the conceptual framework of quantum physics. The familiar deployment of teleological concepts in the life sciences was a source of controversy because they seemed incompatible with a strictly physico-chemical approach (McKaughan 2005). For example, Bohr in 1927 claimed that there are well-known biological relations that we do not describe on the basis of physical causality, but rather with respect to their biological ends. We have only to think of the healing process in an injured organism (cited in W. Heisenberg 1971, 91-92). Bohr's view was that teleological and mechanistic descriptions are mutually exclusive yet jointly necessary for an exhaustive understanding of life. In fact, this is a prime example of complementarity applied to biological systems, which Bohr himself espoused. Bohr's hope was that at least some aspects of life are not reducible to physico-chemical terms (McKaughan 2005). Bohr clearly thought that teleological or finalistic concepts transcend the domain of physics and chemistry (McKaughan 2005, 517).

Similarly, Werner Heisenberg considered that non-random, intentional, and, therefore, teleological elements may be present in the process of evolution (1965, 242) and within bacteria. Recent evidences seem to underpin Heisenberg's idea about the presence of non-random, teleological elements in the process of evolution (Matsuno 1992; McFadden and Al-Khalili 1999; McFadden 2002; Davies 2004a; Speybroeck 2008; Damiani 2009; Ogryzko 2009; Perez 2010). Underlying the conventional view of genome evolution was the idea that the genome is a stable structure that changes rarely and accidentally by random chemical fluctuations (Watson and Crick 1953) or replication errors. This view has changed in response to the realization that maintenance of genome stability is an active cellular function, and to the discovery of numerous dedicated biochemical systems for restructuring DNA molecules (Shapiro 1983; 1992; 2009; 2011; McClintock 1984; Craig et al. 2002).

More and more evidence has been accumulating indicating that it is possible to act on the states of a particular organism by the subjectively accessible tools of biological autonomy (aims, beliefs, expectations, emotions, thoughts) that are not effective in the external world; and which are not restricted to the production of slight deviations from the physically expected changes. It is known that beliefs and expectations (e.g., the well-known placebo effect) can markedly modulate neurophysiological and neurochemical activity (Beauregard 2009; Meissner, Kohls, and Colloca 2011; Miller 2011; Pollo, Carlino, and Benedetti 2011). Neural correlates of emotional states like sadness or depression have already been identified (Fortier et al. 2010), as well as measurable skin-conductance, heart rate, and event-related potential changes (Balconi, Falbo, and Conte 2012). It has been shown that emotions can induce secretion of hormones and influence external behavior (Marin, Pilgrim, and Lupien 2010; Martins et al. 2010). Rossi and Pourtois (2012) demonstrated that converging electrophysiological and brain-imaging results indicate that sensory processing can be modulated by attention. We think these facts demonstrate that living organisms have a biological autonomy that is effective—through the occurrence of biologically initiated spontaneous vacuum processes—in producing physically measurable outcomes. If such subjective tools are experimentally, even if indirectly demonstrated to be effective in acting upon matter, and there are experimental evidences for the material efficiency of free will, too (Cerf and MacKay 2011), then autonomous decisions of living organisms can also be effective in a similar manner.

Recent developments in psychological experiments carried out by Bem (2011) and others indicate that subjects can anticipate future random events. Henry Stapp (2011) and M. Kafatos and Nassikas (2011) propose that an additional principle operates beyond the pure randomness of quantum phenomena. Although their proposed solutions in the case of the Bem experiments if confirmed would differ in detail, both teams postulate the operation of the principle of sufficient reason. The principle of sufficient reason provides the reasons behind all phenomena in nature we seek to explain, telling that all phenomena must be determined. Therefore, if a phenomenon is actually determined in nature, but theoretically it seems to be "acausal," i.e., physically non-determined, spontaneous, then it must be determined by biological or other natural conditions.

It is important to become aware that there are three basic conceptual frameworks and corresponding mental toolkits to consider the problems of determinism, "acausality," autonomy, and "free will." In the first and narrowest one, corresponding to strict physical determinism, only physically determined processes are available as tools of explanation. In such a narrow context, the spontaneous quantum processes must arise acausally since there are no physically determined processes to determine phenomena like spontaneous radioactive decay. In a somewhat wider context including vacuum processes, radioactive decay can be explained by spontaneous vacuum processes. In that second context the apparent "acausality" (indeterminacy) is shifted from radioactive decay to vacuum "fluctuations." In this paper, we attempt to outline a novel, third, wider context, in which vacuum processes can be initiated by biological autonomy, since in this wider context biologically initiated vacuum processes are also available as tools of explanation. In this widest, biological context the apparent "acausality" is shifted from vacuum processes to biological autonomy. Indeed, apparent "acausality," or, more precisely, physical and biological indeterminacy is the characteristic property of biological autonomy, leading to a natural conceptual framework of "free will." Indeed, "acausal" decision of living organisms is physically and biologically not completely determined, i.e., at least to a certain extent, free. We point out that understanding of biological autonomy and consciousness requires a mental shift from the narrowest first mental toolkit to the widest third context of actual reality. Physical "acausality" is the natural precondition of biological autonomy and free will.

Moreover (M. Kafatos, Tanzi, and Chopra 2011), building on Kafatos' previous works (M. Kafatos and Nadeau 2000; M. Kafatos and Draganescu 2003) we propose that universal principles such as complementarity, non-locality, and sufficient reason operate at all levels. We believe that these ideas would indeed make biological autonomy better understood: Quantum randomness assists biological autonomy but in tandem with other deep principles such as sufficient reason. Autonomy occurs because of “good reasons,” to allow biological aims to be realized. In this way, nature would not be capricious, as Einstein himself often emphasized. While one side of the coin is physical “acausality,” the other side is the determinative power of biological autonomy and free will.

6. Autonomy and Physical Determinism

Many scientists claim (Smart 1963; see Kane 2002, 118) that although single quantum spontaneity exists in principle, it really only points to the negligible problem of indeterminism or “acausality” (accepting the thesis of “adequate determinism”; Doyle 2011). It is, after all, only a microscopic phenomenon; and since it averages out in the macroscopic realm, one can ignore it. Defending such views, David Papineau (2007) argued that since the chances of physically undetermined processes are fully fixed by prior physical circumstances, “this alone is enough to rule out sui generis non-physical causes.” What we have developed indicates why David Papineau is wrong in that claim; vacuum fluctuations must average out only in physical systems, since they are initiated by the physical principle. In contrast, biologically initiated vacuum processes are *ab ovo* not random, since they are initiated not by physically “acausal” randomness but teleological, autonomously determined biological aims.

One might object that spontaneous processes must represent energy, and, therefore, their occurrence violates the law of energy conservation (Papineau 2001). Certainly, vacuum processes involve energy. They occur within the constraints of the uncertainty relation. Quantum uncertainty allows the apparent violation of energy conservation as given by the W. Heisenberg principle. Moreover, a single quantum process like spontaneous emission occurs practically simultaneously (within one time step) with its coupled process (for example, a spontaneous emission coupled with a spontaneous absorption), and such a pair of coupled processes already obeys the law of energy conservation.

Papineau’s claim that physical processes can have only physical causes (Papineau 1990) has been shown here to be false. We pointed out that biological spontaneity mediated by vacuum processes makes biological teleology physically efficient.

7. Discussion and Conclusions

Nowadays a two-stage model of free will is very popular (M. Heisenberg 2009; Doyle 2010). In the two-stage model, one stage generates behavioral options, randomly, and the other one decides which of those actions will be initiated. According to this popular view, the first stage is physical, random, “free” and the second stage is “chosen,” or “willed.” Apparently, any decision can result from such a two-stage process, therefore, the capability of such a model seems to be universal. Moreover, it may seem that such a two-stage model is compatible with physicalism as well as with the freedom of decision. But if we consider it a bit more closely, it becomes clear that this popular model suffers from a basic difficulty. Actually, the process of “choosing” or “willing” remains not only unspecified but also inconsistent. In realizing such a process, any “choosing” requires a physical process; when I choose from among ten bottle of wine, I have to use my arm to choose one of them. But what kind of “arm” selects from the allegedly infinite number of options produced by physics? If this “arm” has a physical nature, as it seems it has to be, then, except the timing of single spontaneous physical processes, it must be governed by physical laws, therefore it cannot be free. And if the initiating “arm” remains in the realm of Cartesian “mental” distinct from physical nature, then, allegedly, it cannot be physically effective.

We propose that this problem can be solved with the help of spontaneous vacuum processes. If only random, i.e., physically initiated vacuum fluctuations would occur, than the “choosing” were random, too, in contrast to basic biological facts. Therefore, it is necessary to expand the horizon of explanation and include biological causes that can initiate non-random vacuum processes directly serving biological aims. In this way we obtained one of our main results: we are led to the discovery of biological causes capable to initiate biologically useful vacuum processes. In this chain of events biological causes precede and initiate quantum vacuum processes. For the first time in science, we discovered natural processes occurring beyond the realm of quantum physics. Our result indicates that biological autonomy, even if beyond the physical realm, can be physically effective. This achievement makes our proposal effective in solving the mind-body problem, offering vacuum processes to bridge the gap between the realms of mind and matter. Moreover, in living organisms biological processes are not completely random already at the quantum level. In contrast, they are characteristically teleological. Therefore, we suggest completing the two-stage model of free will with a biological step initiated by biological autonomy with the help of biologically initiated quantum vacuum processes.

Indeed, spontaneous vacuum emissions in physical systems are in accordance with quantum mechanics, but only regarding the averages. Quantum mechanics is unable to predict when and where the “next” radioactive decay will occur within a mass of radioactive material. Quantum mechanics is unable to predict the timing of spontaneous biological reactions. The situation is similar to the difference between the role of mathematics and physics in the description of tossing a coin a large number of times. Spontaneous tossing of a coin is in accordance with mathematics, therefore, it may seem that there is no need for a deeper level description. Nevertheless, mathematics is unable to predict when the next “head” will occur, even if it correctly describes the probabilities of this process. Similarly, although it may seem that quantum mechanics describes correctly spontaneous biological processes, a different, deeper branch of science is required to describe when and how the spontaneous biological processes occur, and this deeper branch of science must be biology.

We confirmed in a quantum context the recognition of Bauer (1967, 32-38) that one of the basic properties of biological organisms is spontaneity. We succeeded to clarify that biological spontaneity has a physical aspect: it initiates quantum processes for the sake of biological aims. Life can “decide” for physically non-deterministic quantum fluctuations as a means for biological determinations of suitable paths of action. Quantum processes assisting biological aims are not completely random. In fact, following the principle of sufficient reason, the randomness that would be applicable for strictly quantum physical processes is now modified for the sake of biological aims. When the decision in accordance with sufficient reason selects an endpoint for the action principle, these two tools, the decision and the teleological perspective offered by the maximum action principle, together become powerful in realizing biological aims.

We found that the difference between the behavior of physical and biological entities is that while physical objects follow the physical principle and random fluctuations, biological organisms follow the biological principle and non-random vacuum processes initiated by autonomous decisions. The biological principle produces biologically initiated vacuum processes, according to ultimate biological aims like survival and flourishing. The biological organisms actively contribute to the biological principle by autonomous decisions themselves producing all the other biological aims either during the history of evolution or during their lifespan.

The proposal made in the present work can have a fundamental importance not only in biology, but also in solving one of the biggest problems of science, the mind-body problem. Biological autonomy can be regarded as an exact, scientific formulation of "consciousness" (note that consciousness here is to be distinguished from self-consciousness, which is thought to be characteristic of self-aware humans), opening an unexpected, new avenue in consciousness research and quantum biology.

As the complementarity principle states (M. Kafatos and Nadeau 2000), parts and wholes cannot exist independently of each other, and the whole serves as the ground for the existence of the parts. This is confirmed in the context of cellular functions, too (Kawade 1992). Cells act on microscopic, quantum states, e.g., initiate spontaneous emissions and couple them to spontaneous absorptions useful for biological aims.

Although quantum limits set extremely small ranges for initiating single and elementary biological actions at the cellular level, living organisms are built in a way that their activity is, in many respects, unconstrained by present-day physical laws and conditions. This fact may indicate that a more complete theory beyond quantum physics is needed which will account for the existence and behavior of living observers. This more complete theory must allow teleology in order to make it possible to describe genuine biological behavior. It is necessary to work out in more details how the extremely small quantum limits of virtual processes add up into observable biological behavior. One of our first results in this direction (Grandpierre 2013) indicate that living systems capable to move their body must have a lower limit in size that corresponds to the minimal size of the living cells. On the other hand, there is an increasing need towards an exact theoretical biology, formulating the biological principle in a mathematical form, and clarifying the related conceptual issues. In our next paper we attempt to introduce the Bauer-principle into contemporary biology (Grandpierre and M. Kafatos 2013).

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Appendix: Attempt to Clarify the Basic Concepts of Teleology, Biological Autonomy, Biological Cause, Function, Physical, Biological, and Life

1. About the Method of Explanation

A methodological remark is necessary. We attempt here to avoid *ad hoc* philosophical positions and argue as close to the requirements of rigorous scientific methods as possible for us, involving philosophical aspects only if we find it inevitable. This method, we hope, allows us to stay on the valid grounds of physics as long as possible as well as to open new avenues towards a new biology that builds up on genuine biological concepts and laws. Regarding that today physics plays an outstanding role in natural sciences, and that we attempt to clarify some biological concepts, attention is required to not over-physicalize biology.

2. Tools of Explanation and Domains of Explanations

The tools of explanations in physics are the physical equations (physical forces), the physical conditions (input data to physical equations), and, admittedly, randomness (random fluctuations). In philosophy of physics, physical causes are called efficient causes (physical forces).

It will be useful to keep in mind some caveats. Nobody has seen physical forces as such or physical laws directly with her outer senses. When Newton introduced the concept of physical forces, some rejected it on the grounds that only empirically observable entities can be accepted in physics. Moreover, when Newton discovered the law of gravitation, many rejected it on the grounds that only direct, local, bodily interactions are allowed, and so action in distance, like the gravitational force, must be rejected. Additionally, the nature of physical laws themselves is unclear; it is general to regard them as merely mental tools. Actually, we point out that while physical equations are mental tools, their corresponding physical laws acting in nature are not; yet their material or non-material nature is not yet clarified. Nevertheless, despite all such insufficiencies, these physical terms are well established, and serve as extremely useful tools of explanations.

Now let us consider what kinds of difficulties are met on the road towards clarifying biological teleology, biological aim, biological autonomy, vacuum, and spontaneity.

3. Biological Teleology

Basically we meet two kinds of causes in experiencing natural phenomena. One kind of causes is the effective, external cause of motion; the other is internal motivation. The cause of motion of physical objects is physical force. As Newton’s law tells, no change occurs in the state of motion in the absence of force acting upon the considered object. Yet the state of motion of living organisms systematically changes also in the absence of any external force. Motivation is present only in living organisms. Basic biological motivations (aims) are self-preservation and flourishing. All other biological motivations or aims are useful to these basic biological aims. By their very nature, biological aims are teleological.

Teleology is, by the Encyclopedia Britannica, explanation by reference to some purpose or end; also described as final causality, in contrast with explanation by efficient causes only.

4. The First Difficulty: Can Any Cause besides Efficient Ones Act on Matter? (Causal Closure of the Physical?)

We are led to the *first difficulty* in considering the problems of biological autonomy: can a final cause act, if apparently, physical forces govern all physical objects, from the level of elementary particles? Indeed, since living organisms consist from physical elementary particles, if any causes act besides the efficient physical one, they must somehow influence the behavior of elementary particles. Considering that physics knows only four fundamental interactions acting on elementary particles, there is no scientific basis for assuming a “fifth force” to serve biological aims. The possibility for physical causes to act lies in the circumstance that efficient causes do not determine completely every detail of (at least some) natural phenomena. Quantum indeterminism is a phenomenon due to the fact that quantum physics allows the spontaneous creation of particle-antiparticle pairs, within the limits given by the uncertainty relation. In physics, such vacuum processes are referred to as “fluctuations,” expressing the fact that these processes have a random character. Therefore, although they are not completely determined, their random character presents a further difficulty for the idea that final causes utilize physically not completely determined processes.

5. The Second Difficulty: Can Physical Indeterminacy be Useful for Final Causation?

How can living organisms utilize quantum indeterminacy? Let us consider a thought experiment. We have two birds that are considered identical in all details except one is dead and the other is alive. Certainly, there are some accompanying subtle physical differences between them, but we are considering the case in which these differences are infinitesimal or physically negligible, in a way in which the two birds have the same gross properties (mass, structure, chemical composition, etc.).

The only important difference between them is that in the living bird all the biochemical reactions are organized in a way that the extremely high number of elementary biochemical reactions are "not only strictly coordinated in time and space, not merely cooperating harmoniously in a single sequence of self-renewal, but the whole of this sequence is directed towards the continual self-preservation and self-reproduction of the living body as a whole" (Oparin 2010, 74), in the dead one biological organization is broken, the causal closure towards continual self-preservation is missing. We propose that such an orchestrated behavior can arise only if within living organisms the quantum indeterminacies corresponding to biomolecules are all utilized in a maximal manner, selecting the options within quantum limits that are the most favorable for life, add them up in the whole of the living organism collectively and systematically from time step to time step. If so, living organisms can harness physical indeterminacies, utilizing quantum vacuum processes for biological aims.

6. Third Difficulty: How can Final Causation Act on Matter?

There is a general belief that teleology is scientifically bankrupt, and that history shows it always has been. Barrow and Tipler (1986) had shown that on the contrary, teleology has on occasion led to significant scientific advances. Indeed, the success of the least action principle became increasingly clear (Zee 1986, 109; Taylor 2003; Moore 2004; Romano, Barretta, and Barretta 2009; Gray 2012). "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). Variational principles, such as Fermat's, are the contemporary descendants of final causes (Lemons 1997, x). Moreover, the least action principle offers some significant advantages over the differential equations of physics. It has a higher conceptual depth and accompanying explanatory power. It offers a panoramic view instead of the local picture. It is more elegant, compact, and invariant. Many physicists have contended that the action principle formulation of mechanics is more fundamental than the mechanistic formulation. It allows a drastic reduction in the data set. Moreover, our point here is that the action principle offers a natural way towards biology. Extending the action principle with one minimal step, allowing the biological selection of its endpoint offers a strict scientific basis for teleology.

This idea is coherent with Bohr's, W. Heisenberg's, Wigner's, Bertalanffy's and Szent-Györgyi's ideas; for example: "We must realize that the description and comprehension of the closed quantum phenomena exhibit no feature indicating that an organization of atoms is able to adapt itself to the surroundings in the way we witness in the maintenance and evolution of living organisms … it is evident that the attitudes termed mechanistic and finalistic [that is, purposeful] do not present contradictory views on biological problems, but rather stress the mutually exclusive character of observational conditions equally indispensable in our search for an ever richer description of life" (Bohr 1958, 10).

As Barrow and Tipler noted (1986, 152), it is this teleological way of thinking about the motion of charged particles that led Richard P. Feynman to develop his sum-over-histories formulation of quantum mechanics (Feynman 1948), which is a method of expressing quantum mechanics in terms of an action principle. Remarkably, this most fundamental principle of physics acts with vacuum processes. The path integral method, worked out by Feynman (1942; 1964; 1994) offers a kind of explanation in terms of quantum superposition as to why the least action principle works so similarly yet differently than the way we humans do. The system (for example, a photon in the two-slit experiment) explores every possible path to any possible endpoint with the help of virtual particles that are freely created from the quantum vacuum, and the path integral simply calculates the sum of the probability amplitudes for each of them. Interference effects guarantee that only the contributions from the stationary points of the action give histories with appreciable probabilities, and the most probable path corresponds, remarkably, just to the least action. The system does not have to know its endpoint in advance, as a human being has to know where to go, since it does not have to decide about its path; the physical path arises without the active contribution of the system. Therefore, the least action is the result of a simple and mechanical summation of the probabilities of all paths. Yet these probabilities themselves were calculated on the basis of the least action principle (or with the help of equations derivable from it). Definitely, the process in which the end state of the quanta in the two-slit experiment becomes determined is similar to a human decision process in which the first phase corresponds to exploring all the possibilities, and the second to sum them up, weighed up by our own principles. With this addition, Feynman's argument sheds light to the circumstance why and exactly in what respect physical teleology is different from the human one. Physical "teleology"—although the reference to the end is explicit—is automatic, mechanical; the endpoint is determined not by the system (as in the case of a human being) but by the initial (and boundary) conditions on the basis of the least action principle.

Recently, Edwin F. Taylor (2003) argued that even the simple case when a stone is dropped from a height and falls freely obeys the least action principle because while all its elementary particles explore all paths, as the mass of a stone increases, the set of paths between the initial point *A* and endpoint *B* that contribute significantly to the probability of detection at *B* shrinks to a narrow pencil around the trajectory of least action. Now we have the physical basis to consider what is the difference between a dead and a living, practically identical birds, when dropped from the same height? Why do they follow such a characteristically different trajectory, the dead one falling freely on a vertical path to the ground, while the living one in a curved path regains its original height nearby? The factual difference in the initial state, that is responsible for the factual difference of the paths, is the state of living. In the living bird, intrinsic motivations exist which are missing in the dead one. These biological motivations are the biological causes that become transformed into physical causes (forces) that are able to deteriorate the living bird from the path of free fall. The living bird's elementary particles also explore all paths, yet the bird is able to select an endpoint to the action principle that fits with its factual biological motivation to regain its original height. Once the endpoint is decided about, the rest occurs according to the least action principle. The bird travels to the selected endpoint with the minimal action. In contrast to forces that act instantaneously, determined on the basis of previous physical conditions and differential equations, the integral, panoramic perspective of the action principle offers the possibility of a genuine final causation for the bird to select the future endpoint of its path already at start.

How does the bird select the endpoint? First of all, as a living being it has the motivation to avoid the possibly lethal path of free fall. Moreover, it has the instinct, a suitable genome, and learned knowledge how to fly. Therefore, already at start it knows how to move its tail and wings in order to follow the path selected. The selection occurs already at start also in case when the bird flies from one tree to another. The presence of teleology in the trajectory of the bird is a basic condition. Similarly to a function that can be realized in many different ways, the same endpoint can be realized in different but biologically quasi-equivalent trajectories. Since the equifinality of biological functions cannot be realized on the basis of physical conditions inserted to physical laws, it becomes evident that in living organisms the biological determination, the determination of the endpoint of the trajectory or function occurs first, and the physical determinations comes only after that. Now since the biological determination is that of the endpoint, it is by its very nature teleological. Therefore, our argument shows that in living organisms final causation is the primary, and effective causation is the secondary; biology harnesses physics. It can be tempting to interpret such processes within the already familiar physical context, with the help of the already established physical tools of explanation: physical conditions, laws of physics, randomness. Nevertheless, since the presence of teleology is a fundamental explanatory tool of biology, such an attempt presents an obstacle in understanding the nature of biology. We emphasize that it is inevitable to allow in such contexts not only physical, but biological tools of explanation as well.

7. The Nature of Action and the Greatest Action Principle

The action principle of physics is claimed to be, regarding its form and content, to come nearest to the ideal final aim of theoretical research to condense all natural phenomena into one simple principle, that allows the computation of past and future processes (Yourgrau and Mandelstam 1955, 126). It is a truism that the physical meaning of each symbol contained in any principles of physics has to be specified before the theory can be applied in practice (1955, 139). Actually, it seems that the physical meaning of what action is remains obscure, just because of its teleological and biological connotations that seem to be alien in physics. At the same time, action is the central concept of physics; therefore, the clarification of its nature and meaning is of primary importance.

Action is an integral (sum) of all energy changes during the corresponding time intervals, constituting a cost function formulating a mathematical optimization problem. Although the physical meaning of such a quantity is not clear, its biological meaning is highly plausible in such a context of an optimization problem. The sum of all energy changes of the consecutive time intervals in the whole period of the given process is the energy investment. In the quantity of action the elementary energy investments in each time interval are weighed with the lengths of the corresponding time intervals. Therefore, action is, roughly, the product of energy investment and time investment. Such an interpretation, although alien in physics, makes sense in biology. We can define vitality as the distance of the living organism above the thermodynamic equilibrium (death) and can measure it in units of energy. Since living organisms have the ultimate biological aim to preserve their life, secured by their vitality, they have a natural attitude to maintain their vitality as high as possible and as long as possible. Indeed, as recently Mark A. Bedau (2010, 393) formulated: living organisms have intrinsic goals and purposes, where those goals and purposes are minimally to survive and, more generally, to flourish. If so, they naturally maximize action. Roughly, this fact is formulated mathematically in the principle of greatest action (Grandpierre 2007). It is also shown (Grandpierre 2007) that the greatest action principle is mathematically equivalent with Bauer's principle (Bauer 1967). It is worth knowing that Ervin Bauer, the Hungarian biologist formulated the universal law of biology in the following form: "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 initial conditions of the system on the basis of the physic-chemical laws" (1967, 51). Bauer was able to derive all the fundamental life phenomena, growth, metabolism, and reproduction from his principle. Therefore, we can call it as the first principle of biology (Grandpierre 2011a; 2011b).

In the 21st century we are living in the century of biology. This means that we live in the era of the most fundamental paradigm shift since the origin of modern science. The Kuhnian revolution in which we are now embedded is all about the special qualities of living matter and of discoveries, now underway, and still to come, of the very special boundary conditions that harness the material forces (quantum mechanical-obeying forces) to the purposeful pursuits of organisms (Strohman 1997). Our proposal is that the very special boundary conditions that harness the material forces are regulated on the basis of Bauer's principle utilizing quantum uncertainties. Bauer's principle prescribes that in each time step the boundary conditions jump quantum—mechanically from the one, which is the output of the previous time—step on the basis of the physical laws. In each time step a biological jump occurs away from equilibrium, therefore, in the next time step the input conditions of the physical equations are not the ones that are the output of the previous step, but changed by the amount allowed by the uncertainty relation and prescribed by Bauer's biological principle.

8. Fourth Difficulty: Difference between Biological and Human Teleology

One of the biggest obstacles on the road towards understanding biological teleology is human teleology (free will) that is so familiar to us in our everyday life. By the term "purpose" we most frequently mean human purpose. Since the Cartesian view claiming that plants and animals are merely machines without a soul, we are accustomed to think that only humans can have purposes. Yet humans are self-conscious, while animals and plants seem not to manifest self-consciousness. At the same time, even bacteria are able to process the information flow they receive through their outer senses in a manner that corresponds to actual situations in a biologically reasonable manner. On the grounds that the information flow received by our outer senses mediates much higher rate of information than human self-consciousness, we can estimate that even microorganisms have to process a much higher information flux than human self-consciousness does. They are able to process the received information properly and decide themselves about their actions in an autonomous manner that is not determined by previous physical or biological conditions and laws. Therefore, it is reasonable to consider that the genuine biological autonomy of non-human terrestrial living beings is natural consciousness (instead of self-awareness or self-consciousness in which autonomy, instead of cooperating with natural consciousness, becomes itself an agent separating itself from natural consciousness and controlling it).

It is important to note here that recently the existence of free will became experimentally demonstrated. In two novel experiments Cerf and Mackay (2011) had shown that subjects are capable of overriding external sensory input with internal imagery, and can directly control the firing rate of individual neurons in the medial temporal lobe.

9. Fifth Difficulty: How can a Living Organism Initiate or Elicit a Biological Cause, and Call Forth a Virtual Particle from the Vacuum?

We emphasize once more that it is not possible to understand the genuine *biological* nature of biological teleology, autonomy, and spontaneity, as it is usual, on the basis of the explanatory tools of physics. In biology, we must admit as basic explanatory tools a special, non-human type of teleology as well as the existence of biologically available energies corresponding to biological aims. In the main body of our paper, we presented experimental evidences that subjective tools of mind like expectations, emotions, like sadness and depression can markedly modulate neurophysiological and neurochemical activity, induce secretion of hormones and influence behavior. Our proposal tells that such experimentally evidenced facts can yield a physically interpretable background in the context of vacuum processes, and these vacuum processes are initiated by biologically accessible mental energies corresponding to autonomous decisions of the organism itself. We found a logical chain between these basic biological concepts: biological autonomy—biological aim, teleology—spontaneous vacuum processes—macroscopic changes, efficient causes, physical forces.

10. Definitions

Genuine biological autonomy is meant as the capability to decide about the generation and execution of biological aims in a way that is physically and biologically is not pre-determined on the basis of conditions and laws. Biological autonomy is an element of nature having a similar fundamental role to that of laws of nature.

Biological aim is defined as a basic biological phenomenon, namely the teleological, causally efficient aspect of living organisms.

Biological cause is a biological process in which the biologically autonomous living organism interacts with the quantum vacuum initiating virtual processes that are effective in eliciting processes serving biological aims.

Biological function is a system of biophysical processes serving a biological aim.

What is physical? In a narrow context, a process is physical if it is determined by physical conditions on the basis of physical laws. In a wider context, a process is physical if it is determined by physical conditions on the basis of physical laws, and when random fluctuations are allowed.

What is biological? A process is biological if it is determined by biological conditions on the basis of the biological principle and autonomy.

What is life? Life is a phenomenon in which organisms manifest collective and systematic, spontaneous, self-initiated changes serving teleological processes acting against physico-chemical equilibration. See the above-cited definition of living organisms by Bauer (1967, 51) and the claim of Hans Jonas (1966, 74) that life means spontaneous and teleological motion.