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Genuine Biological Autonomy: How can the Spooky Finger of Mind play on the Physical Keyboard of the Brain?

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Abstract

Although biological autonomy is widely discussed, its description in scientific terms remains elusive. I present here a series of recent evidences on the existence of genuine biological autonomy. Nevertheless, nowadays it seems that the only acceptable ground to account for any natural phenomena, including biological autonomy, is physics. But if this were the case, then arguably there would be no way to account for genuine biological autonomy. The way out of such a situation is to build up an exact theoretical biology, and one of the first steps is to clarify the basic concepts of biology, among them biological aim, function and autonomy. We found a physical mechanism to realize biological autonomy, namely, biologically initiated vacuum processes. In the newly emerging picture, biological autonomy shows up as a new, fundamental and inevitable element in our scientific world picture. It offers new perspectives for solving problems regarding the origin and nature of life, connecting ancient Greek philosophy with modern science. Namely, our proposal sheds light in what sense can the God as conceived by Xenophanes can move the material objects of the Universe by its thoughts without toil.

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I. Introduction

We are motivated by the consideration that in the practical life of living organisms numerous phenomena arise that cannot be explained by evolution and physical laws alone. For example, the same group of men being in the same environment can form in the same spatial arrangement a football team, a chorus, or a group of friends, depending on their internal focus of attention. Moreover, a forward in a football team cannot be driven by physical forces of a crane governed by a computer program. Similarly, a protein having the function to defend the cell from germs cannot be governed by physico-chemical forces on the basis of static genomic information. *The difficulty of biological processes' physical government is the extreme and unforeseeable, time-variable complexity*.

It becomes more and more clear that even unicellular organisms can solve mazes and certain optimization problems, and can demonstrate both anticipatory and contemplative behavior (Tanaka and Nakagaki 2011). Bacteria are shown to be able to solve newly encountered problems, assessing the given problem via collective sensing, recallable stored information of past experience, and solving optimization problems that are beyond even what individual human beings can readily solve (Ben-Jacob 2009). Cells can perceive self and group identity and act accordingly to self and group aims (Ben-Jacob, Becker, Shapira and Levine 2004), sense their external and internal environment (Ben-Jacob, Shapira and Tauber 2006, 514), and monitor their internal states (Shapiro 2009, 9). Cells demonstrate the capability of collecting and integrating a variety of physically different and unforeseeable signals as the basis of problem-solving decisions (Albrecht-Buehler 2009). The chemical forms are utilized as symbols that allow the cell to form a virtual representation of its functional status and its surroundings (Shapiro 2009). It seems that genuine biological autonomy is present already at the level of cells.

In contrast, machines are not autonomous, they fulfil their tasks in a well-determined series of steps, each step being determined by the previous step on the basis of physical laws. At variance with machines, the same living organism in the same situation can behave in many different ways. In biological behavior we find a one-many situation; the next steps can be selected from a multitude of options, and an innumerably large set of series of states can develop from one and the same initial state without being completely determined by the physical conditions of the preceding state on the basis of physical laws. Similarly to the fact that an innumerably large set of mathematical curves $f(x, y)$ can be drawn starting from one and the same point (x_0, y_0), a living organism can evolve from the same initial state towards an innumerably large set of later or final states. Mathematical curves exist in higher dimensions than one-dimensional points. One point of a curve (x_0, y_0) does not determine the future trajectory $f(x, y)$ of the mathematical curve. Similarly, living organisms live in higher dimensions than the physical states of machines and the physical state of a living organism does not determine completely its future biological behavior on the basis of physical laws. Until decisions about the biological behavior did not occur, physical structure does not determine function on the basis of physical laws. Living organisms has a fundamental property that does not exist in physics: freedom to decide about their future states. The basic ability to associate many possible future biological states to the given initial state is similar to the one-many relation present in mathematics between points and curves starting from them. We call this remarkable biological condition as genuine *biological autonomy*: one initial state in biology can evolve towards many different future states. Definitely, biological autonomy must be distinguished from human-type free will including responsible action. Nevertheless, the basic condition of biology is that living organisms contribute actively to their behavior. 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. Such details must be decided by the organism itself.

Besides biological autonomy, which includes a *divergence* from a given initial state, the other basic biological phenomenon is *convergence* towards a prescribed final state. Organisms commonly have alternative means of performing the same function (Beckner 1969, 155), therefore, they must decide between biologically equivalent alternatives, the differences of which would not depend on evolution. Biological functions are defined here as processes serving biological aims, ultimately survival and flourish. Therefore, 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 aim-orientedness*, in short, biological *teleology*, the presence of a common aim beyond sets of different physical processes.

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). It is known that beliefs and expectations (e.g., the well-known placebo effect) can markedly modulate neurophysiological and neurochemical activity (Beauregard 2009; Miller 2011, Pollo, Carlino and Benedetti 2011; Meissner, Kohls and Colloca 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; Martin et al. 2010). Rossi and Pourtois (2012) demonstrated that converging electrophysiological and brain-imaging results indicate that sensory processing in V1 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 already demonstrated to be effective in acting upon matter, and there are experimental evidences for the material effectivity of free will, too (Cerf and MacKay 2011), than autonomous decisions of living organisms can also be effective in a similar manner.

We argue that the existence of biological aims is actually a basic and elementary fact of nature. Indeed, a living organism is capable to achieve "at once the pursuit and fulfillment of its own purpose" (Monod 1972, 80). Living organisms are not viable if their proteins, cells, organelles, organs cease to function.

II. On the nature of genuine biological autonomy

We define an organism as autonomous if it is able to make spontaneous decisions. A biologically spontaneous decision, as we define it here, is not completely determined from preceding conditions on the basis of physical and biological laws, and by phenomena like adaptation or evolution. We consider that *a process is biologically autonomous if its physical and biological determinations are not complete*, *and is completed by the active contribution of the individual living organism itself*. An example can be helpful. In a living organism, a biological aim initiates a spontaneous quantum fluctuation (Milonni 1994, 151, 78-80, 142), due to which a certain molecule emits a photon that is absorbed by another molecule (e.g. an enzyme) so that a biologically useful process will occur contributing to the realization of the biological aim. Certainly, this process is not determined completely by physics, because single spontaneous emission and absorption cannot be determined from previous input data to physical laws. The process, although still compatible with physics, is initiated biologically, and we regard it as autonomous only if it is not completely determined by prior (physical or biological) conditions attached to physical or biological laws.

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. Therefore, a biological aim cannot be described by physics or chemistry. For example, the chemical structure and conformational state of a protein can be described in physical terms; at the same time, its biological aim (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. In fact, if one accepts the chemical characterizations as new definitions of biological terms, it would involve a change not only in meaning or intension, but also in conceptual extension, and, correspondingly, in the domain of explanation. But such chemical definitions do not purport to express the meaning of the biological terms (Hempel 1966, 103-104). This means that biological aims are additional biological properties beyond the physico-chemical ones, non-reducible to physical terms.

In this paper, we suggest that spontaneous decisions of living organisms correspond to single, biologically useful vacuum processes occurring within living organisms. Indeed, "little occurs in the cell on the basis of chance" (Agutter, Malone, and Wheatley 2000); therefore, biological processes cannot be completely statistical, and so the corresponding „fluctuations" cannot be completely random as in physics (Heisenberg 1958, 102-104).

In physics, all the fundamental laws can be derived from the least action principle (e.g. Zee 1986, 109; Feynman 1994; Taylor 2003). According to the best explanation of the least action principle (Feynman 1942; Feynman 1964; Barrow and Tipler 1986, 132), the physical path arises as the sum of the quantum amplitudes of virtual particles. Therefore, if the physical principle can be regarded as generating virtual particles leading to physical processes corresponding to the least action, the biological principle can be regarded as generating virtual particles leading to spontaneous biological processes corresponding to the greatest action and biological autonomy (Grandpierre 2007; see below in more details). If this is the case, the generation of virtual particles by this biological principle should not average out to the physical path; instead, they contribute to the initiation of biologically useful changes.

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 (flourish) and as long as possible (survive). Indeed, as recently 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, living organisms naturally maximize action. This fact is formulated mathematically in the principle of greatest action (Grandpierre 2007). It is also shown that the greatest action principle is mathematically equivalent with Bauer's principle (Bauer 1967). It is worth to know 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 physico-chemical laws" (Bauer, 1967, 51). Bauer was able to derive all the fundamental life phenomena, growth, metabolism, reproduction from his principle. Therefore we can call it as the first principle of biology (Grandpierre 2011a, b). Our proposal is that Bauer's principle prescribes that in each time step the boundary conditions change ("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.

III. Different domains of explanation and biology

It is important to become aware that there are three basic domains of explanation and corresponding mental toolkits to consider the problem of determinism, and related problems of 'acausality', spontaneity and 'free will'. In the first and narrowest domain, corresponding to strict physical determinism, only physically determined processes are available as tools of explanation. In such a narrow domain, 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 domain including vacuum processes, radioactive decay can be explained by spontaneous vacuum processes. In that second domain the apparent 'acausality' (indeterminacy) is shifted from radioactive decay to vacuum "fluctuations". In this paper, we attempt to outline a novel, third, wider domain, in which vacuum processes can be initiated biologically, and so biologically initiated vacuum processes becomes also available as tools of explanation. In this widest, biological domain the apparent *'acausality' is shifted from vacuum processes to biological autonomy*. Indeed, 'acausality', or, more precisely, physical and biological indeterminacy is the characteristic property of biological autonomy, *leading to a natural explanation of biological autonomy* (and, later on, to human-type 'free will'). We point out that understanding of biological autonomy and consciousness requires a mental shift from the narrowest first mental toolkit to the widest third domain of nature.

Fundamental biological concepts like biological aim or functions serving such aims are not derivable from physical concepts. If one restricts herself to thinking about biological aims and functions exclusively in the narrow domain of physics, it would be an unassured move as it would render biology incomplete and leave out fundamental biological features. The understanding of biological aims requires a fundamental conceptual shift from that of physics, a different method of classifying the elements of a system on the basis of their biological properties (Beckner 1969, 164). Functional or aim-oriented ascriptions presuppose conceptual schemes of a certain logical character. The ascription "biological aim" is pointless, nonsensical, or involves a category error, if such a scheme is missing (ibid., 157). Physicists have not found it useful to construct a theory that defines physical bodies in terms of their contribution to the activities of their more inclusive systems. Physicists do not identify the parts of the solar system, or any of its activities, in terms of the contribution they make to the activities of the whole solar system (ibid, 160). Similarly, physics does not have a conceptual scheme to identify biological aims on the basis of their role securing fundamental biological purposes, such as the survival of the more inclusive system, the organism. Therefore, the conceptual toolkits of physics is inappropriate to handle fundamental biological concepts like biological aim. For in biology it is the hierarchy of biological aims and their corresponding functions extending from the molecular to the organismal level that constitutes the determinative factor of biological events. Notwithstanding, it is the organism that determines the system of physical conditions necessary for the physical implementation of a given biological aim. For example, if a protein has a function to defend the cell against harmful germs, it is the task of the cell to assist its unfolding, reaching the suitable conformational state; to assist at generating the physical conditions that guide the protein in its task to defend against germs, etc. If the cell acts in many time steps assisting the protein's working, then the protein's actions can significantly differ from the ones that would arise if the cell were different or dead. Definitely, biological aims have observable physical consequences. We note that this is why biology belongs to the natural sciences.

We found not only that biology has fundamental concepts that cannot be translated to physical terms, but also that the type of relation between biological concepts is not interpretable by the conceptual scheme of physics. Because of biological freedom and teleology, ultimate biological aims like „self-maintenance" and „flourish" do not translate to physical terms, neither to physical conditions, nor to deterministic physical or biological laws. The organism itself must contribute to determine its behavior.

With the help of an example: a living bird dropped from a height of the Pisa tower will not follow the vertical path prescribed for unaided physical objects (machines planned teleologically by humans are not considered here), corresponding to the least action. *In any physical situation, only one endpoint corresponds to the trajectory of least action*; there are no alternatives. For the living bird, the case is different. The biological principle prescribes the living bird to survive and flourish. The optimal trajectory is the one corresponding to the endpoint offering the same biological advantage, in that case, to regain its original height, with the constraint of minimal energy consumption. The bird falling down vertically can decide to turn to east or west, north or south, practically to any directions, with a minimal energy investment. Remarkably, like in the case of fish thrown back to the river, there are an innumerably large set of biologically equivalent endpoints and optimal trajectories. It is this biological equivalence of a large set of accessible endpoints that is a new phenomenon in biology in comparison to physics. *In any biological situation, with the given constraints, the greatest action prescribed by the biological principle can be satisfied by a large set of biologially equivalent endpoints*. Therefore, a biological trajectory can be realized only by the active contribution of the organism selecting from the suitable set of endpoints. It is this novel circumstance that indicates the role of biological autonomy in nature and its significance comparable to that of the most fundamental laws of nature. The active contribution of the organism to determine its own behavior is realized by the organism's spontaneous, autonomous decisions that represent a kind of biological motivational power mobilizing biological free energy. This biological motivating power is what initiates vacuum processes, and these vacuum processes act accordingly, influencing matter within the quantum limits in a way that corresponds to the given biological aim.

IV. Xenophanes on God and the Universe is explained

It seems that the root of the idea we outlined above is present already in ancient Greece. The famous saying of Xenophanes tells (Lesher 1992):

> „One god is greatest among gods and men,

Not at all like mortals either in body or in thought. (B 23)

Whole he sees, whole he thinks, and whole he hears. (B 24)

But completely without toil he shakes all things by the thought of his mind" (B 25).

Xenophanes claims that God moves all the material of the Universe „by the thought of his mind". But how is it possible to move physical matter by thought? As we argued here, such a possibility is accessible within living organisms. Indeed, when I bend my little finger, I do not perceive any mental effort. I move my finger completely without mental toil. Therefore, if the Universe is a living being itself, as the Presocratics and Plato thought, than the invisible governing power of the Universe, corresponding to the invisible laws of Nature and the invisible biological autonomy of such a living Universe, similarly, can move everything within its organism, apparently, completely without toil. Namely, the God of Xenophanes has two basic tools to move objects in its internal world: the laws of Nature and its own divine autonomy. These two tools are, in contrast to non-scientific interpretations, not only consistent with each other, but cooperative.

V. Discussion and conclusions

Our proposal that biological autonomy works by initiating vacuum processes 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. Consciousness is defined here as the basic biological entity capable to make autonomous decisions about future changes of the organism. Such autonomous decisions are capable to initiate suitable processes in the quantum vacuum which are able to realize the decision in the form of corresponding physical processes.

If we regard biological autonomy as a "ghost", our proposal suggest a way how such a "ghost" can govern the "machine" of the living organism. The "ghost" of biological autonomy, like all spooky ghosts, cannot act on any machine, and cannot act on any physical matter. But, at variance with fictive "ghosts", biological autonomy can act on quantum vacuum with the help of a living organism it belongs to. We do not enter here into the debate that can such "ghosts" exist without embodied living organsisms or not. But we mention that if so, such elementary actions on the quantum vacuum cannot be systematically added up into macroscopic amplitudes. It is biological organization that makes it possible to couple these elementary, biologically initiated vacuum processes and amplify them into observable amplitudes that deviate characteristically and, in respect of the quantity of action, lawfully (when the occasionally negative effects of autonomy on the ultimate biological aim of flourishing are negligible). Since biological organization extends to the molecular level, and changing in time, creating new and new functions, therefore living organisms in a strict sense are not machines at all.

Cellular functions are not determined by parts like single genes, but by the cell as the whole (Kawade 1992). But how can a whole - as a whole - act on a physical part? The only way we are able to conceive is, as we outlined above, through the vacuum. The vacuum as a whole can be regarded as a cosmic life form (Grandpierre 2008), but through vacuum processes it can act on its parts. 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.

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