CHAPTER NINE

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

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Although biological autonomy has been widely discussed in the literature, its description in scientific terms remains elusive. We 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 fully account for genuine biological autonomy. The way out of this predicament 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 that we propose here, biological autonomy manifests as a new, and fundamental element in our scientific worldview. 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, or universal consciousness in modern terms, affect matter in the Universe through its willful action without toil.

Introduction

Biological autonomy is defined as the ability of biological organisms to decide and act at least partially independent of physical and biological preconditions and laws, utilizing these to achieve specific biological aims (Grandpierre and Kafatos 2012). In examining the issue of biological autonomy, the present situation can be characterized as conflicts between the following views. On the one hand, at present, the science of physics is the only exact science we have. Therefore, any serious researcher attempting to work on a scientific theory of autonomy would be required to work within physics alone. The result of such an approach is to end up accepting the popular view that physicalism is the only credible worldview we have, and the only way to preserve biological autonomy is to reduce it to the physical. If that were the case, genuine biological autonomy would then be an illusion, as it would just be determined by physics. For example, Varela (1979, p.55) considers that "autonomous systems" are machines: "Autonomous systems are mechanistic (dynamical) systems defined as a unity by their organization". "Our approach will be mechanistic: no forces or principles will be adduced which are not found in the physical universe" (Varela 1979, 6). Along this line of thinking, biological autonomy is usually physicalized (Maturana and Varela, 1972; Ruiz-Mirazo & Moreno, 2004; Boden, 2008; Barandiaran, Di Paolo and Rohde, 2009).

On the other hand, an increasing number of scientific arguments have been published, indicating the need to find extra-physical principles suitable to explain autonomy (von Neumann, 1955/1983; Koch 2009, 31). Recently, Kane (2002, 9) pointed out that due to the development of quantum physics, universal determinism has been under retreat in the physical sciences. At the same time, developments in sciences other than physics - in biology, neuroscience, psychology, psychiatry, social and behavior sciences - have been moving in the opposite direction, in some ways ignoring the foundations of quantum theory. Therefore, worries about determinism in human affairs persist with good reason in contemporary debates about free will (ibid.).

Recently Kather (2004) pointed out that one of the main characteristics of the scientific method as it has been developed above all in physics, is the exclusion of all experiences, which refer to the observer and subjective experience: Qualified sensations, aims and values are ignored as well as to the biographical identity of a person. But, Kather asks, if consciousness belongs to life, can we get a full definition of it, if we objectify it completely? It seems that it is not really sufficient to physicalize biological autonomy. "For autonomous beings...nothing is worse than to treat them as if they were not autonomous, but natural objects, played on by causal influences at the mercy of external stimuli" (Berlin 1997, p. 208).

In that situation, it seems that the real option is try to develop an exact theoretical biology that can offer a new scientific basis to treat biological autonomy as a genuine phenomenon. Indeed, as it is recently formulated, 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). The problem is acute since most biologists accept teleology in biology (see e.g. Ruse 2012). Voluntary actions are permanent features of our everyday life. For voluntary muscles, all contraction (excluding reflexes) occurs as a result of conscious effort originating in the brain (Tassinary and Cacioppo 2000). Voluntary muscle is considered to be a muscle that can be controlled by conscious effort, by one's free will (Shier, Butler, and Lewis 2004, 277). Biological teleology is such a basic fact of nature that, as it is formulated, "Nothing in biology makes sense, except in the light of teleology. This could be the first sentence in any textbook about the methodology of biology" (Toepfer 2012). Recently, it is argued that biological teleology cannot be considered on physical grounds alone (Grandpierre 2007, 2012). Froese and Ikegami (2012) argued that no formal theory of biological autonomy can properly do justice to the phenomenon, if it does not allow for the fact that life involves an essential uncertainty at its very core. As Adams and Suarez (2013, 273-290) formulated, consciousness and free will undoubtedly exist, and they must be fundamental ingredients of any sound explanation of the world. In this paper, we attempt to move a step ahead in the big challenge we are facing, working out a conceptual background for such a workable model of teleological causation.

Definitely, genuine biological autonomy can be approached only in a broader than physical framework, in which biology is an autonomous science having its own concepts and laws, that cannot be reduced to physics. In our best understanding genuine biological autonomy is 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 means that the decisions are somehow (and this is the big problem to be considered below: but how?) determined by the organisms themselves utilizing physical indeterminacy. Genuine decisions cannot be determined merely from physical conditions and laws alone, or on evolutionary, genetic or molecular biological grounds only. Since the only type of physical indeterminacy is quantum mechanical, genuine decisions must act on the level of the micro-world. Since at first sight the nature of such a non-physical determination may seem unclear, we recall that creation of virtual particle pairs in the quantum vacuum is a physically indeterministic process. Within the physical approach, causality is treated in terms of exclusively physical causes, and the result is the principle of causal closure of the "physical". Although the principle of causality is a backbone of the scientific method, the creation of virtual particle pairs is considered to be not only a completely random, but also an acausal process that violates the otherwise universal principle of causality. What is more, it simultaneously violates the otherwise universal principle of energy conservation, within the constraints of the Heisenberg uncertainty principle. Now we are working on a broader than physical approach, therefore our proposal is to introduce the principle of causal closure of the "natural", in which "natural" includes now not only physical, but also biological and psychological. Accepting this principle, it yields that if a phenomenon does not have a physical cause, it must have a biological or psychological cause. Therefore, if the creation of virtual particles is physically acausal, it must be biologically or psychologically causal. Considering that genuine biological decisions serve biological aims, they should represent an energy form under biological governance. This treatment allows us not only to introduce a suitable framework for genuine biological autonomy, but also to preserve the universal validity of the principle of causation and energy conservation at one blow.

One of the main reasons why the positions of determinism are strengthening nowadays in biology relates to the popular interpretations of Libet's experiment. According to Batthyany (2009), the claim that Libet's experimental results empirically support pre-determination of conscious decisions should be refuted. [...The subject was instructed "to let the urge appear on its own at any time without any pre-planning or concentration on when to act", i.e. to try to be "spontaneous" [...], this instruction was designed to elicit voluntary acts that were freely capricious in origin (Libet, Wright, and Carlson 1982: 324). Given these stipulations, it is obvious that the movement impulse is, as the instructions put it, an "urge", i.e. a passive event. Seen from this angle, Libet's results merely confirm that passive events are passive events, i.e. are not consciously brought about. More generally, the lesson we can draw is that it is highly problematic to study conscious causation in cases where the subjects themselves state that they did not consciously cause the act in question. One cannot, for example, passively wait for an urge to occur while at the same time being the one who is consciously bringing it about (Batthyany 2009, p.135ff). Libet's experiment that purported to show free will doesn't exist, is being challenged by many others (e.g. Ananthaswamy 2009, Trevena and Miller 2010). Conscious thoughts are far more than a steam whistle or epiphenomenon. Baumeister et al. (2011) argued that human conscious thought may be one of the most distinctive and remarkable phenomena on earth and one of the defining features of the human condition. Their results suggest that, despite recent skepticism, it may have considerable functional value after all.

Another difficulty of the genuine biological autonomy concept is that its main role is to *initiate* actions. Unfortunately, in which way can actions be initiated is the central unsolved problem in the philosophy of action. As general references, we mention Clarke (2003), O'Connor and Sandis (2010), and Pacherie (2012). One of the main difficulties of biological processes being governed by physical mechanisms is the extreme and unforeseeable, time-variable complexity. For example, a protein having the function to defend the cell as a whole from germs, cannot be governed by physico-chemical forces on the basis of static genomic information. The intention of the present paper is to offer a new solution to the old problem as close to our present state of knowledge in physics as possible.

It becomes more and more clear that even unicellular organisms can accommodate themselves to difficult situations, solve 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, assess given challenges via collective sensing, recallable stored information of past experiences, and solve 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 already present at the level of cells.

In contrast, machines are not autonomous, they fulfill 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. As long as decisions about the biological behavior do 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: 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.

Besides biological autonomy, which includes a *divergence* from a given initial state, the other basic biological phenomenon is *convergence* towards a prescribed final state. The phenomenon of concentration is present in focusing attention or will power, and the accompanying concentration of related biologically controlled energies acts to achieve biological aims despite the physical tendency of energy dispersion, as it is required by one of the most fundamental physical laws, the second law of thermodynamics. The power of persistently turning towards a particular end or goal, including the capacity to cope with an indefinitely large variety of obstacles on the road towards achieving their aims, manifested in growth and bodily movement, is one of the most characteristic features of the life of organisms. 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 do 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 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, physically 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.

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 quantum 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 tied to virtual particles leading to physical processes corresponding to the least action, the *biological* principle can be regarded as tied to 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, etc. 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 that 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.

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, spontaneous vacuum processes can explain radioactive decay. 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. 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.

We seek 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, 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 biologically 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.

Xenophanes on God and the Universe is explained

It seems that the root of the idea we outlined above was 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.

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 that 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 organisms 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 is 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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