Emergence of life and consciousness in a purposeful universe

Rodolfo Gambini
Instituto de Física, Facultad de Ciencias, Universidad de la República
Iguá 4225, Montevideo, Uruguay

Jorge Pullin
Department of Physics and Astronomy, Louisiana State University
Baton Rouge, LA 70803, USA

Abstract

Recent scientific developments provide evidence that we live in a world whose nature encourages the emergence of life and consciousness. We are not arguing that the world was created with that purpose, rather our view is that the world has a nature that is receptive towards life and consciousness and is open to organization imposed via top down causation by ever more complex organisms. We can see in this -at first unrecognized- tendency a universe whose purpose is to offer opportunities for life and expand the potential of the living organisms endowed with various degrees of consciousness. Such purpose is manifest in the laws that rule the world and in the nature of the fundamental entities whose regularities such laws describe. That is how we end up with individuals whose goal is the development of capabilities that are just a further manifestation of the fundamental nature of the world, and through them, a universe capable of observing itself.

Introduction

Modern scientific thinking, based on the physical sciences, was erected on a mechanistic notion of matter, lacking most of the properties usually associated with life. The Universe was viewed as an infinite space where masses described trajectories determined by forces ruled by immutable laws. In fact, it was considered a triumph of human intellect to make the remarkable effort of abstraction that eliminates vital aspects and feelings and sensations from the scientific description of the world. Insofar as life was concerned, the only remaining task was to explain it in mechanical term as just a system of masses and forces. That was the straitjacket that the ontology of classical physics imposed on the world-view.

The possibility of knowledge by a thinking conscious mind that, for instance, elaborates physical explanations, was completely excluded by the ontology emergent from classical physics. Philosophically, this led to the dead end of dualism. Mind and matter were conceived as independent and possessing different attributes. Since this conception was developed, the world divided into two camps: materialism and idealism. Each camp attempts to reduce the other to non-existence. If, as Descartes puts it, nature is *res extensa*, then the thinking conscious human being remains a world apart from the rest of existence. As Hans Jonas (2001) notes “his consciousness only makes him a foreigner in the world, and in every act of true reflection tells of this stark foreignness."

This worldview, when combined with 19th century evolutionism, led to nihilist positions. In evolutionism, life is devoid of any plan or purpose other than self-preservation. The development of life in the most diverse environments lacks any previous design. For example, orchids take many forms and colors without any other purpose than optimizing their ability to reproduce in the environments they live in (Darwin 1862/1977). In his "Collapse of Cosmological Values", Nietzche (1888/1968) talks about "extreme nihilism" in Europe. He associates nihilism with living in a world lacking any purpose. Nihilism appears when attempting to view the world with a purpose ends in disillusion. Humans can feel protagonists of a world that has a purpose, giving a goal and meaning to their lives. Mechanistic views strip from the description of the world any reference to aims and goals and therefore does not provide any justification for human purpose.

We would like to argue in this essay that, since the 20th century, a remarkable number of scientific developments take place that imply profound conceptual revolutions. These include in physics the general theory of relativity and quantum mechanics. In biology, the understanding of epigenetic processes. In complex systems theory, the notion of top-down causation. And in astrophysics the development of models for cosmology that get us close to the first instants after the Big Bang. We will see that these developments illuminate a world that is much more hospitable to life than that of the mechanist paradigm. These developments imply a shift in worldview away from the 300 years old tendency in which the ontology of science and the decay of traditional religious views all pointed towards a nihilist position. We will argue that they open the possibility for new vistas on the problem of consciousness and, through it, how a Universe ends up understanding itself.

We will review briefly the shifts in perception we mentioned and how they lead to a purposeful world. We will first start discussing the status of the nature of physical laws. We will see that a careful analysis of the role and meaning of physical laws is needed in order to accommodate life and purpose. We will then review the ontology that is suggested by several interpretations of quantum mechanics and how it lays out building blocks for reality dramatically different from those of the mechanist paradigm. In particular we will see that this ontology naturally leads to the understanding of emergence and top-down causation. We will conclude arguing that it opens the possibility for purpose in the world and that it fits very elegantly with the description of the Universe that modern science leads to.

The nature of physical laws

If one is to understand how a universe ruled by natural laws can harbor aim and intention, it is important to be precise about the nature of physical laws. Concerning this point, two positions have emerged: the regularist and the necessitarian. The former states that laws derive their truthfulness from the regularities of the world. Laws therefore only express what occurs. The necessitarian position is well summarized by Norman Swartz (2003/1985): "physical laws determine which connections can and cannot occur". Our view is that many philosophers who identify themselves as physicalist hold necessitarian views and this has limited their options at the time of elaborating a coherent worldview. We will avoid these constraints adopting a position we call regularist physicalism. For regularists, physical laws are descriptions of what happens in the world. Physical reality may well go beyond the laws, which only describe observed regularities. On the other hand, for necessitarians, laws determine what can and cannot occur. In that sense the laws have primacy over mere occurrences.

In modern physics an example of necessitarianism is Tegmark (2008), who states that our universe satisfies the Mathematical Universe Hypothesis (MUH): "Our external physical reality is a mathematical structure." He distinguishes between the "bird perspective" of a mathematician that studies the mathematical structures that emerge, from the "frog perspective" of an observer living in the universe. The formal mathematical structure precedes and determines how to compute the "frog" view from the "bird" one. This is a radical vision that claims that languages, feelings, concepts and cultural heritage are "baggage" to be dismissed and lacking any fundamental status. Only the mathematical laws are fundamental.

Einstein (1917) seems to have held a regularist point of view. For instance, he says "If two different people pursue physics independently of one another, they will create systems that certainly agree as regards the impressions (`elements' in Mach's sense). The mental constructions that the two devise for connecting these `elements' can be vastly different." Theories are under-determined by the "impressions", even though physicists are unaware of this.

Summarizing, the position we advocate is that we can only understand aim, purpose and intention in the world if we understand what physical laws refer to. In other words, if we can figure out the ontology underlying the two main theoretical frameworks of physics: general relativity and quantum mechanics.

The ontology of quantum mechanics

Ontology studies the fundamental entities that constitute our world. There is a long history of basing ontology on events and it was just reinforced by the appearance of general relativity and quantum mechanics. In relativity events are ordered, if a given event is in the future of another a signal may be sent from the latter to the former. Since the maximum speed is the speed of light, there exist events that cannot be influenced by a given event since no signal could ever reach them without having to travel faster than light. One can say that relativity is the theory that establishes the rules for the causal organization of events in space-time.

In quantum mechanics the theory is built on primitive concepts like system, state, events and the properties that characterize them. This suggests constructing an ontology of objects and events (Gambini and Pullin 2016). A system in quantum mechanics is described by a Hilbert space that contains the possible states and the events that may take place in the system. Objects and events can be considered the building blocks of reality. An object corresponds to a system in a given state. Events are the actual entities. States characterize the disposition of a system to produce certain events. In the mathematical framework of the theory an object called the projector is associated with each event and its properties. The fundamental objects have a precise mathematical description. For instance, the chemical element hydrogen is an example of quantum system. A particular hydrogen atom corresponds to such a system in a given state. We call this an object. Its disposition to produce events characterizes it. An example could be the detection of a photon by a photodectector. The "click" of the latter upon detection is the event.

Attempts to describe physical reality in terms of events go back to Russell (1927/2007). He put it this way: "the enduring thing or object of common sense and the old physics must be interpreted as a world-line, a causally related sequence of events, and ... it is events and not substances that we perceive." So for Russell an object is a set of causally connected events.

We think that this point of view does not go far enough to provide a foundation for a reality based on events. In this view an atom cannot be considered an object until it interacts and produces an event. Our definition, on the other hand, considers any system as an object since its state defines it predisposition to yield events. The reality we perceive through our senses is composed of events localized in space-time. This concept was already captured by Whitehead, (1925/1997) who stated: "the event is the ultimate unit of natural occurrence." The quantum theory provides probabilities for the occurrence of events and their associated properties. When an event takes place, typically many properties get actualized. For instance, if one looks at the double slit experiment, when a dot forms on the photographic plate, it might be of various shapes, darker in certain regions, etc. Objects in a quantum world should be thought of as systems in certain states. They do not have properties until they produce events, like for instance in a measurement.

The quantum theory also contemplates the possibility of non-local systems that are entangled. One can have groups of particles that have interacted in the past in such a way that the quantum state of each particle cannot be described independently anymore. A quantum state must be assigned to the whole system. Measurements of properties of entangled particles are correlated. In the case of two particles with total spin zero, measuring the spin of one in a given direction implies that the other will have the opposite spin. Notice that if we talk about non-local systems it is not possible to talk about a state at a given time as that is a notion that depends on the Lorentz frame chosen. On the other hand, if one defines the state by its disposition to produce events one can show in detail (Gambini and Porto 2001) that such aspect is uniquely defined and the state only changes when events take place. The concept of states in quantum systems is therefore necessarily holistic (Maudlin 2007).

To make a long story short, the measurement problem in quantum mechanics is that in its traditional formulation the theory is not complete without an observer involved. The theory does not say what happens when there are no measurements on the system. The ultimate goal in solving the problem is to provide a coherent vision of reality valid both for microscopic systems that we probe through specialized measuring devices and macroscopic systems like those in our everyday experience.

A realist interpretation of quantum mechanics given in terms of events is much more than an understanding of the measurement problem. It is a vehicle to understand how a world with given properties emerges from a world of quantum potentialities. One would end up with a world in which objects, understood as quantum systems in given states and the ensuing events are the building blocks of reality.

The event ontology we are talking about has the interesting feature of potentially eliminating the divide between the mental and the material. As Russell (1921/2011) said: "if we can construct a theory for the physical world which makes its events continuous to perception, we have improved the metaphysical status of physics." A possible scenario is that events in the external world are subject to a physical description whereas at least some events in our brain are accessible as perceptions. Both types of events have the same mathematical description. Their difference consists in how we access them. The mental has a first person access whereas we have a third person access for the physical. Due to the dispositional nature of states it is natural to associate to them a first person aspect in terms of moods, emotions and desires since they all define dispositions to act.

There are many interpretations that admit an ontology of events. They range from the different versions of the Ghirardi-Rimini-Weber theory (Ghirardi 2016), Modal Interpretations (Lombardi and Dieks 2016), Many Worlds Interpretations (Vaidman 2016) and the Montevideo interpretation (Gambini and Pullin 2015). We can also include interpretations that are not necessarily realist but that use the notion of event as for instance the Consistent Histories Interpretation.

An important point is that in order to have a truly quantum ontology,the interpretation of quantum mechanics considered should supply a self-consistent notion of event. Interpretations that define events via interactions with classical systems or observers are not suitable to construct a purely quantum ontology.

For realist interpretations with an event ontology, if one considers quantum systems interacting with a macroscopic environment, events will be plentiful. Events take place around us all the time, they are not confined to measuring devices. Measurements are the assignment of certain quantitative properties to events that occur in measuring devices. Notice that in this picture one has a completely quantum description of the universe, there is no need to invoke a classical world.

Emergence and top down causation

Emergent phenomena arise out of more basic ones but at the same time they exert a "top-down" control or limitation on the processes that sustain them. The emergent phenomena give rise to genuinely new features of the world. In classical physics the state of a system of particles is just given by the union of the states of all particles. In quantum mechanics, on the other hand, it is well known that the state of a system cannot in all cases be reduced to a union of the states of the components. As Maudlin (1998) puts it they cannot be reduced to: "those [states] of its parts together with their spatiotemporal relations, even when the parts inhabit distinct regions of space. " The point we would like to emphasize is that this holism of quantum mechanics implies that systems have ontologically new properties and exhibit downward causation where macro systems have effects on micro components (Gambini et al. 2015). Using Crane's (2001,2010) terminology our view can be characterized as non-reductive physicalism. We deny ontological reduction but admit explanatory reduction because we allow upper level properties to be explained in quantum mechanical terms.

Let us start by showing that ontological new properties can emerge in quantum systems. Entangled states have well defined properties that do not follow from either the those of their parts nor relations between them. In quantum mechanics most properties of systems do not have well defined values until measured. However, any quantum system in a pure state has some properties that are well defined. As an example, a particle with spin can have two possible values for its component along the z direction: up or down. If one performs repeated measurements of spinning particles with a Stern-Gerlach device one observes dots appear in the upper region with certain probability and dots in the lower region with complementary probability. When the particle is in a state that leads with certainty to the upper region, we say it is in the state |z, up>. One can assign the property "z up" to the state. One cannot assign other properties to the state due to the uncertainty principle. The measurement of any other component will not lead to a unique value, it will be sometimes up and sometimes down.

In systems of many particles one may also have some well-defined properties, but that refer to the system as a whole. In some cases there may not be any properties well defined for the constituent systems. Such systems are called entangled. More in general one calls entangled any system with well-defined properties that cannot be deduced from those of the constituents. An emblematic example of entangled system is one with two electrons with spin in the z direction in a state with total spin one and z component zero,

$$|\psi_0\rangle = \frac{1}{\sqrt{2}}|1, z, \mathrm{up}\rangle|2, z, \mathrm{down}\rangle + \frac{1}{\sqrt{2}}|1, z, \mathrm{down}\rangle|2, z, \mathrm{up}\rangle.$$

The states of the individual particles have no well-defined properties. If one measures any of their spin components, there will be probability ½ of "up" and ½ of "down". One can however show that the total spin of the composite system is 1 and its z component is zero. This type of holistic behavior is not exceptional but it is actually generic for composite systems after its constituents interact. Associated with this emergence of new properties is the fact that the growth of the number of states in quantum mechanics when one adds components to the system is exponential whereas in classical mechanics is linear.

A strong form of emergence involves downward causation: the emergence of new causal powers. A suitable notion of causality for the ontology we are considering was developed by Chakravartty (2007). He bases it on what he calls "causal properties". Since we associated properties with projectors we prefer to call the concept "causal powers" to avoid confusion. A causal power has the capacity to endow with dispositions the objects. Such dispositions lead them to behave in certain ways when in the presence or absence of other objects that have causal powers of their own. An object will exhibit downward causation if the parts have some behaviors dictated by the state of the whole that cannot be inferred from the states of the parts. The entangled spinning particles considered before, precisely exhibit this kind of behavior. For instance the spin measurements of both particles are correlated. Two experimenters attempting to measure the spin in the same direction would find that their results are opposite. They could have never had concluded this from studying the systems in isolation.

So any system in an entangled state exhibits downward causation. The states' roles in causation, their disposition to produce events, and their non-separatiblity when entangled are at the root of this phenomenon. More elaborate examples can be discussed. For instance in molecular behaviors where entanglement cannot be ignored or in quantum computers, where it plays a key role.

To conclude this point, emergence is not the exception but the rule in quantum systems that interact. Recent advances in the study of the role of quantum mechanics in biology (Vedral 2011) and the discussion of strong emergence with top-down causation lead to the expectation of understanding the effectiveness of mental phenomena in the determination of our actions in a unified view of objective reality based on the ontology of states and events we introduced.

Recent progress in the area of epigenetics, showing that organisms and not only genes are key in the evolutionary process, provides another example of top-down causation's central role in nature (Moss 2004). The creative process of activation/deactivation of potential capabilities in a genome resides in the organism and admits a countless number of possible combinations. A portion of the DNA acquires the function of a gene only if it is activated by the upper levels: the organism itself and its environment. This is a clear demonstration of downward causation. Genetic information cannot be characterized by its effects on the phenotype but by its participation in a "genetic toolkit" that the organism uses in different ways according to its needs.

A life-friendly universe

The regularist vision of the laws of science and the quantum ontology introduced make some room for purposeful actions that were not allowed by the mechanist framework. But going from something just allowed to something purposeful requires a last piece of the puzzle: the observation that our Universe is remarkably life-friendly.

It is quite clear that our space-time placement in the Universe is quite privileged. The existence of life requires many favorable conditions, temperature ranges, existence of certain substances in certain proportions, only to mention a few. It is clear that such conditions do not happen at an arbitrary point in space in the Universe nor at an arbitrary moment in time. The Copernican revolution argued that we lived in a "typical" corner of the Universe. But the development of life teaches us that this is not really so. Conditions are somewhat special in the corner of the Universe we inhabit. But more recent studies suggest that perhaps it is not so special. For instance it has been observed that the number of Earth-like planets orbiting stars similar to the Sun could be billions, just in the Milky Way (Cassan 2012). Also the values of many fundamental constants of physics have to be within a tight range of their current ones for the processes that give rise to the elements that are fundamental for life -like carbon- to be possible and well spread along the universe.

It has been argued that the characteristics especially friendly to life of our Universe could be explained via the multiverse hypothesis by considering the subset of habitable universes among the large range of possibilities of the landscape. A desirable outcome would be to show that a universe capable of harboring observers is a typical case without requiring fine tuning of the fundamental constants. An expectation would be that the parameters, which already are limited in ranges of values in order to allow for life, are not further finely tuned to have the optimal conditions for life. If a further fine-tuning were required to have close to optimal conditions for life the Anthropic Principle would be insufficient to account for our existence in the universe. The recently discovered life-friendly properties suggest that this is the situation we are in.

It does not appear possible to justify why these are the life-friendly laws of nature and not others. Under what axioms would one justify it? Attempts to do this end up in a vicious circle in which each explanation requires another one. It is reminiscent of the anecdote of the Universe and the turtle that Paul Davies (2006) mentions in his book: "There is a famous story [attributed by some to Bertrand Russell, by others to the nineteenth-century American philosopher William James about a lecture on the nature of the universe. Partway through the talk a woman at the back stands up and denounces the lecturer, claiming that she knows how the universe is put together: the Earth rests on the back of a giant elephant that stands on the back of a giant turtle. The bewildered lecturer responds by asking what the turtle is standing on. "You may be very clever, young man," the woman shoots back, "but you can't fool me. It's turtles all the way down!""

Putting it in more serious terms we should recall the so called Leibnitz' Modal Argument: “the existence of a contingent reality can only be ultimately explained through a cause whose existence is in itself necessary. However, something whose existence is in itself necessary is something whose existence cannot depend upon anything else but itself, its own nature."

Given the lack of answers to the inexplicable life-friendliness of the Universe and its physical laws and fundamental constants, to elevate to a logical principle this insatiable need for explanation leads to the feeling that we live in an absurd universe where things do not have a rational explanation. Our view is that the Universe does not appear as absurd if one questions such need of sufficient reason. Absurdity arises when we fail in our search for assigning meaning and purpose to the Universe.

Explaining why the Universe is life-friendly does not depend only on the values of certain parameters. It also depends on the elegance and creative potential of the physical laws. It depends on quantum mechanics being as it is, and on the geometric and dynamical nature of space-time. As Einstein put it: “Everything is determined, the beginning as well as the end, by forces over which we have no control. It is determined for the insect, as well as for the star. Human beings, vegetables, or cosmic dust, we all dance to a mysterious tune, intoned in the distance by an invisible piper.” Although it is not emphasized frequently, the life-friendliness of the Universe also depends on the ontology that lies behind of the laws of nature. *Ultimately it is the laws of nature and their ontology who are bio friendly.*

Purpose

The thought that we live in a world whose only goal or destiny is the mere existence is what led to nihilism. To have purpose in the world is to make it compatible with human concerns and that provides motive and guidance to our behavior. It is, ultimately, to find a foundation for an ethics.

As we argued, we seem to live in a world that is hospitable to life. Laws of nature appear fine tuned to make life possible. This is seen in the particular values of the fundamental constants of physics as well in emergent structures that exhibit top-down causation. As the universe is structured it not only favors the existence of life. It also favors the development of high degrees of mental integration, where the latter expresses itself in changes of behavior. We have also argued that nature described by quantum mechanics is about dispositions and events with a phenomenal internal aspect. Dispositions and events are concepts that are close to those of our conscious experience. This is what Russell (1921/2011) wanted: “an ultimate scientific account of what goes on in the world, if it were ascertainable, would resemble psychology rather than physics... such an account would not be content to speak, even formally, as though matter, which is a logical fiction, were the ultimate reality.”

Why do humans act with definite purposes, something that according to our subjective experience clearly occurs, if they are mere material entities? Wouldn’t the laws of physics clash with any action that has a purpose? If we take into account the quantum ontology we discussed, based on behaviors of systems and their disposition to act with actions determined probabilistically, there suddenly appears room to avoid the clash. Putting together the subjective experience with some form of physicalism requires the notion of matter to allow for purposeful actions. Our experience indicates that superior animals organize their perceptions with a certain degree of subjectivity. This should persist to a certain extent even if one goes down the evolutionary ladder. The new physics is not incompatible with the primitive forms of subjectivity that the Darwinist evolutionary process allows to assert.

The purpose of the Universe should appear in the laws that favor the emergence of systems with high degree of complexity. Such laws allow and promote the processes necessary for the generation of life. They also imply that they distinctions between material and spiritual blur. We hold the regularist position that states that the laws of nature just describe certain regularities of a reality that transcends them. From a first person perspective the world has a phenomenal nature which we perceive from our conscious mind but it also satisfies certain regularities that science –in particular physics- describes.

If the Universe had no beginning as in the eternal inflationary scenario, one cannot discuss the purpose of its creation. But in a Universe that is life-friendly and phenomenic in character one can always find purpose in its inhabitants. We live in a world receptive towards life and consciousness and open to the organization imposed via top down causation by ever more complex organisms. We can see in this -at first unrecognized- tendency, a universe whose purpose is to offer opportunities for life and expand the capabilities of the living organisms endowed with various degrees of consciousness. That is how we end up with individuals whose purpose is the development of capabilities that are just a further manifestation of the fundamental nature of the world, and through them, *of a universe capable of observing itself.*

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