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Foundations of Quantum Approaches to Consciousness

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Abstract

As generally accepted, consciousness or mind and material brain are closely related to each other; but how? Quantum mechanics is a new pathway to understand the hard problem of consciousness and its relation to the brain. Consciousness has specific properties such as unity, irreducibility, non-locality, etc. The completely different features of classical physics (locality, reducibility, determinacy, etc.) hindered the success of scientists to study consciousness. But quantum mechanics with its features (non-locality, irreducibility, indeterminacy, etc.) gave scientists hope to study consciousness. Several quantum approaches to consciousness have been proposed in recent decades; the most important point about these approaches is that each one has used its own philosophy to determine its viewpoint about the mind's nature and even its quantum approach. In general, all scientific theories are based on some metaphysical principles which come from the worldview of scientists. In this article four contemporary approaches are discussed: The Eccles-Beck, Stapp, Penrose-Hameroff, and Avicenna-Bohm theories; philosophical and scientific points are highlighted for each of them. Finally, the theory of Top-Down Causation is discussed because we think it can provide a fertile philosophical ground for theories of "mind-brain relation" and "quantum consciousness".

Keywords: Quantum Consciousness, Top-Down Causation, Mind-Brain Interaction, Eccles-Beck Theory, Stapp theory, Orch OR Theory, Avicenna-Bohm Theory

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1. Introduction

The interaction of philosophy and science is one of the most important issues, the neglect of which will lead to many misunderstandings and deviations. Although in the last century less attention was paid to the scope of these two categories and their interaction, in the last decade many papers have been published by eminent scholars about the relationship between philosophy and experimental sciences. Every scientific and physical theory is based on a set of principles; Many of these principles cannot be confirmed or rejected in science itself and through empirical methods; For example, in physics, we assume that physical laws are valid everywhere in the world and that the universe is comprehensible and can be described by mathematics; all of these general principles are metaphysical and not empirical. Worldview and philosophy enter the experimental sciences and scientific theories through many ways; a scientist's worldview is effective in designing experiments, interpreting laboratory data, constructing theories, and even in the question one seeks to answer (Golshani, 1998); an important point is that worldviews do not come from experience.

In ancient times we had scholars who were well expert in all the sciences of their time, and there was no challenge between philosophy and science, but in the last century sciences became so specialized that the scholars of one field were unaware of their fellow scholars' works in other fields; In addition, the empiricist schools of thought emerged; therefore the undeniable role of philosophy in the sciences was ignored. Fortunately, in recent decades interdisciplinary sciences have emerged, in which "philosophy" is explicitly one of the vertices of these sciences, or indirectly used.

One of these interdisciplinary sciences is "cognitive science", which studies the problem of human cognition (consciousness). This field was formed in an interaction between six areas of science: philosophy, neuroscience, linguistics, computer science, anthropology, and psychology (Miller, 2003). The role of philosophy in the cognitive sciences is undeniable. Cognitive science, with its claim to study consciousness, was formed in a special philosophical context, namely naturalism, but it was unable to study the issue of "consciousness", because consciousness is basically at a higher level than cognition. According to the prominent contemporary physicist Stapp:

> "In spite of this obviously extremely pertinent twentieth century revision of the relevant physical principles, contemporary neuroscience and philosophy of mind largely continue to base their quest to understand human consciousness on the inadequate nineteenth century classical mechanical conceptualization of reality, which contrary to standard quantum mechanics, leaves our consciousness completely out of the causal dynamics." (Stapp, 2017)

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Things like perception, feeling, self-awareness, awareness, etc. are fundamentally different from what is dealing with in the physical and experimental sciences, such as energy, force, ions, cells, etc.; The difference is firstly in their nature; Our perception of warmth and cold, of colors, of joy and sorrow, is basically different from what in the kinetic theory of gases about temperature and heat, in electromagnetism about light and wavelength, or in neuroscience about the release of hormones and the firing of neurons in the brain. Secondly, they are different in their characteristics: one speaks of unity and the other speaks of fragmentation and reduction. Therefore, dealing with the field of consciousness just by using the tools of experimental sciences has no result other than denying these identities; but how can these be denied, while we first contact the outside world through these perceptions to make sciences and theorize them! According to the eminent contemporary cosmologist Andre Linde:

"Let us remember, though, that our knowledge of the world begins with perceptions, not with matter. I know for sure that my "pain" exists, my "green" exists, and my "sweet" exists. I do not need any proof of their existence, because these events are a part of me; everything else is a theory. Later we find out that our perceptions obey some laws, which can be most conveniently formulated if we assume that there is some underlying reality beyond our perceptions. This model of the material world obeying laws of physics is so successful that we too readily forget our starting point and come to think that matter is the only reality, and that perceptions are only helpful for its description. … In fact, we are replacing the reality of our feelings with a successful theory of an independently existing material world. And the theory is so successful that we almost never think about its limitations until we are forced to address those deep issues which do not fit into our model of reality.

… Is it possible to introduce a "space of elements of consciousness," and investigate the possibility that consciousness may exist by itself, even in the absence of matter, just like gravitational waves, excitations of space, may exist in the absence of protons and electrons?" (Linde, 1998)

Due to intellectual developments in contemporary "experimental science (as an acquired knowledge)", many prominent contemporary physicists and biologists decided to study "consciousness (as an intuitive knowledge)" by using suitable tools and new theories, in the context of some philosophical theories to connect the two. This is possible; as human beings, on the one hand, work with physical tools such as the brain, heart, etc., and on the other hand, they are under the will and control of the soul and consciousness.

This new interdisciplinary field that has been formed from the interaction of physics, mathematics, neuroscience, psychology, and philosophy in the recent decades, is known as the field of "Quantum Consciousness". In this article, we have reviewed some presented theories in this field and have studied the philosophical principles that govern them in order to show the special place of philosophy in these

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theories. These theories consist of Penrose-Hameroff (Orch OR[1]) theory, Stapp (James-Heisenberg) theory, Eccles-Beck theory, and Avicenna-Bohm theory.

Finally, we study the philosophical theory of George Ellis separately and in more detail. Although this theory is not a codified theory of quantum consciousness, our main motivation for investigating this theory (the Top-Down Causation theory) was its provision of a fertile philosophical ground for the theories of mind-brain relation and quantum consciousness.

2. Introduction to the revolution of quantum and relativity theories in regard to Quantum Consciousness

While it seemed impossible to describe mental states and features of consciousness in terms of classical mechanics, after the physics' revolutions of the twentieth century and the emergence of new concepts in science, which changed our attitude towards reality, scientists became hopeful to be able to study consciousness or some of its features scientifically. Special and General Relativity changed our perception of time, space, energy, and matter. On the other hand, quantum mechanics has given us concepts such as the active role of the observer in physics, non-locality, unity, irreducibility, and indeterminability. In modern physics, concepts such as emergent properties, emergent laws, and emergent entities, and also irreducible complexities, such as interaction-free measurement(Elitzur & Vaidman, 1993), top-down causation, etc. have given scholars a wide range of ideas.

Consciousness and mental states contain characteristics such as unity and integrity, irreducibility, being related to the whole, having a causal effect on the lower levels, non-locality, etc. These did not correspond to the characteristics of classical physics such as atomic individuality, reducibility, locality, spatiotemporality, determinability, etc. After the aforementioned revolutions in physics and the emergence of features that were more compatible with the features related to consciousness, some first-level scholars started to study consciousness and its features in modern science, so a new field called quantum consciousness emerged.

One of the main features of modern physics in comparison to classical physics was that in classical physics the observer was outside the natural world, and its effect on physical systems could be neglected or calculated. With the advent of special relativity, the observer entered physics; however, it still didn't matter if the observer was conscious. But in the context of quantum theory, the conscious observer plays an active role and can no longer be considered merely an external observer. In the standard quantum theory, the conscious observer is a component of physics on which a part of physics depends.

One of the first challenges to quantum consciousness theories is the existence of quantum behaviors in the brain and nervous system. This issue is investigated in a new field called the "quantum brain". Although many quantum phenomena with macroscopic effects on the brain and nervous system are well known (such as

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quantum tunneling in olfaction, photosynthesis, quantum effects in bird-brain navigation, etc. (Brookes, 2017)), the relationship between quantum mechanics and cognitive phenomena in the brain is still being debated.

3. Review of some presented theories of "Quantum Consciousness" and some of their philosophical concepts

3.1. Eccles-Beck theory

This theory was proposed by John Eccles an Australian philosopher and neurophysiologist who is Nobel Laureate in Medicine (1963) and Friedrich Beck a German physicist, as one of the first theoreticians of Quantum Consciousness. In their theory, the soul, having an independent nature, can affect the electrical activity of neurons in certain areas of the brain. Eccles considers mental concepts and mental states, to be explicable by a quasi-computer process in the brain, and also associates intention with the dynamics of the cerebral cortex (Beck & Eccles, 1998; Eccles, 1994). They showed that the process of exocytosis in pyramidal neurons, which are mostly present in the cerebral cortex, is a quantum process based on quantum tunneling phenomenon, and can initiate a presynaptic process (which) leads to the release of neurotransmitters in synaptic space between neurons (Beck & Eccles, 1992). In other words, the chemical connection at the synapse of neurons, which occurs through the diffusion of neurotransmitters from the end of neurons (axon terminals) and their absorption by the dendrites of the next neuron (synapse), is a quantum event. They claimed that here is the room in which the mind can influence quantum probability via the mental units called psychon, and as a result, the role of conscious intention in initiating a dynamical brain process can be explained in this way (Beck & Eccles, 1998). In this theory, the mind-brain relation occurs through the interaction of psychons (as units of the soul) and dendrons (as key parts of neurons which behave under quantum mechanics) (Eccles, 1994).

A philosophical discussion

Eccles believes that consciousness and matter belong to two separate worlds. In his words:

"Following Popper (Popper, 1968) I can say: 'I wish to confess, however, at the very beginning, that I am a realist: I suggest somewhat like a naive realist that there is a physical world and a world of states of consciousness, and that these two interact'." (Eccles, 1994)

Eccles-Beck theory focuses on two main issues:

1. Demonstrating the existence of effective quantum processes in neural network dynamics.
2. Inserting the effect of consciousness through the influence of will and intention on the probabilities of the quantum processes in the brain.

There are also three main assumptions about mind or consciousness in this theory:

1. It is an incorporeal and immaterial entity that consists of many units, called "psychon".
2. These psychons have direct effects on the probabilities of quantum processes in the dendrons of the cerebral cortex's neurons.
3. These psychons and dendrons interact with each other.

In Eccles words:

> "In the fully developed hypothesis psychons act on dendrons in the whole world of conscious experiences and dendrons act on psychons in all perceptions and memories." (Eccles, 1990)

They consider quantum wave function reduction, brain dynamics, and consciousness as related issues. Although standard quantum mechanics is used in this theory, they have hypothesized beyond the standard quantum; that the occurrence probability of a quantum process could be due to an immaterial cause; a hypothesis that does not contradict quantum but is metaphysical; Similar to Max Born's probabilistic interpretation (Born's rule) which was merely a metaphysical assumption in the standard quantum theory. Eccles explains his metaphysical assumption's reasoning:

> "Since materialist solutions fail to account for our experienced uniqueness, I am constrained to attribute the uniqueness of the Self or Soul to a supernatural spiritual creation. To give the explanation in theological terms: each Soul is a new Divine creation which is implanted into the growing foetus at some time between conception and birth. ... I submit that no other explanation is tenable; neither the genetic uniqueness with its fantastically impossible lottery, nor the environmental differentiations which do not determine one's uniqueness, but merely modify it.
>
> This conclusion is of inestimable theological significance. It strongly reinforces our belief in the human Soul and in its miraculous origin in a Divine creation. There is recognition not only of the Transcendent God, the Creator of the Cosmos, the God in which Einstein believed, but also of the loving God to whom we owe our being." (Eccles, 2005)

One of the philosophical interpretations of Eccles-Beck theory is that consciousness at the beginning of the causal process in the dynamics of neurons plays an active role in the horizontal of other physical parameters. This theory has also a special philosophical context and attitude in the three issues of free will, the role of conscious intention, and the nature of the soul. It began with a philosophical idea, namely the immaterial assumption of consciousness and its mechanism of action on the brain, and then focuses on a subject in quantum mechanics which is challenging

and full of metaphysical arguments, namely "wave function reduction" and "measurement". They were aware of the science's limitations which is insufficient to describe various aspects of the mind; in Beck's words:

> "Science cannot, by its very nature, present any answer to the philosophical, ethical or religious questions related to the mind. It can, however, and it does by the quantum logic of microprocesses, provide the openness which is essential to make discussions beyond the limitations of science possible."(Beck, 2001)

Eccles-Beck theory requires further research and development in many cases, such as the effect of the brain on the soul, the description of cognitive phenomena (such as time passage perception, thinking, etc.), description of the Libet-type experiments, and so on.

3.2. Stapp (James-Heisenberg) theory

At a time when many scientists were reducing consciousness and mental states to classical physics and were considering it beyond science and scientific studies, the American psychologist James, before the physics revolutions of the last century, suggested that new physics should be developed to explain consciousness. A contemporary theoretical physicist, Henry Stapp, presented his theory of quantum consciousness, taking ideas from James's model of psychology (James, 2007), using Heisenberg's interpretation of quantum mechanics theory. In Heisenberg's interpretation of the quantum theory, there are potential and actual facts, similar to Aristotelian philosophy. Potential states evolve under the Schrödinger equation, and nature eventually actualizes one of these potential states by choosing Born's probabilistic rule. The key point of Stapp theory is in the process of actualization or wave function reduction. He shows that the interaction of neurons with each other follows quantum behavior, in such a way that potential multiple neuronal patterns evolve according to the corresponding Schrodinger equation until natural selection occurs .This natural selection contains two aspects, one is determining a physical state and a specific pattern in the brain and the other is creating a specific mental and conscious state. In fact, mental states and physical actualities are two coin sides of wave function reduction. So these two realities are equivalent to each other and there is no causal relationship between them (Stapp, 2009).

Although Stapp considers the feeling of free will as a phenomenon due to wave function reduction, like other mental states, the effect of conscious choice is subtly and indirectly placed in his theory. A quantum state can be written in different bases, and it is the measuring device that determines in what basis the reduction process in the quantum will occur. He sees the role of "conscious will" as determining the appropriate basis for brain states. Then, nature randomly chooses one of these different states, and this process is repeated so that what nature has chosen is in

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accordance with the conscious will of the mind; As a result, the feeling of free will occurs as a posterior feeling (Stapp, 2017). Although the nature of the mind is ambiguous in Stapp theory, his theory emphasizes explaining mental states. Using the quantum Zeno effect, he describes the time passage perception, mind attention process, and mental states in great detail. This detailed explanation distinguishes his theory from other previous theories.

i. A Philosophical discussion

Stapp's main premise is naturalism; he considers the mind and mental states beyond classical physics, and he counts them debatable in the context of future science or even quantum physics. He also considers mental states to be a reality, equivalent to physical realities. His philosophical choice in quantum theory is that of Heisenberg's, which supposes the existence of a potential Aristotelian world, and on the other hand, he considers the process of actualization to be the result of natural choices, which at the comprehensible level to us, seems quite by chance. Although Stapp acknowledges "causality" in his book, at this level he incorporates "chance" into his theory. In fact, Stapp presents a new interpretation for the quantum theory which is named "semi-orthodox" (Stapp, 2015).

He proposed an explanation to enlighten the difference between orthodox blind-chance and his own interpretation which leads to mental influences on quantum physical processes:

> "Nature's choices are not actually random, but are positively or negatively biased by the positive or negative values in the minds of the observers that are actualized by its (nature's) choices." (Stapp, 2015)

Stapp's very important assumption is the effect of consciousness on the choice of quantum bases so that consciousness acts as a measuring device in quantum theory. Of course, despite other theories such as Eccles-Beck theory, Stapp does not consider the mind and mental states as the cause of physical processes in the brain. Even in the case of free will, he considers its effect as an indirect effect and also considers the feeling of free will not as a result of the agent's agency but as an a posteriori feeling due to the wave function reduction. Therefore, the apparent interpretations from Libet-type experiments that consider free will as an illusion are completely consistent with Stapp theory. Similar to James' model, he considers the time passage perception as a result of the flow of memory and the order of events in it, but not as an original matter (Stapp, 2009).

3.3. Penrose-Hameroff (Orch OR) theory

Using Gödel's incompleteness theorem, Penrose showed that certain aspects of human consciousness, such as the mental quality of "understanding" cannot be explained on the basis of an algorithmic formalism. However, it can be derived from

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some "non-computable" effect; so that no computer or artificial intelligence can achieve consciousness (Penrose, 1989).

On the other hand, we have a phenomenon in quantum mechanics which is "non-computable" too, and interestingly, the conscious observer has an important role in it; i.e. the problem of "measurement". The main question in this problem is "When does quantum state reduction take place? And why?"; Penrose believed that these two problems (consciousness & measurement) have the same solution, and for that, he proposed to extend standard quantum mechanics by offering an objective form of quantum state reduction which is abbreviated as "OR" (objective reduction) (Penrose, 1994). Penrose's OR theory is closely related to Einstein's theory of relativity; in fact, Penrose believes that "gravity" has an important role in quantum state's reduction. Because of this, Penrose postpones the final solution of the hard problem of consciousness to the future, i.e. at a time when we reach the theory of quantum gravity (Penrose, 2000).

On the other hand, anesthesiologist Stuart Hameroff showed that clinically in the anesthesia process, consciousness depends on the function of microtubules (sub-structure of the neurons). Thus, he suggested microtubules as an option for where quantum state's reduction may take place (Hameroff, 1998). In fact, the theory of "Orchestrated Objective Reduction" ("Orch OR") proposes that there are series of objective reduction (OR) of superposition states in microtubules; if these OR events suitably "orchestrate" (Orch OR), consciousness will emerge (Hameroff & Penrose, 2017).

Using energy-time uncertainty relation, they calculated the time for the space-time reduction which relates to the spatiotemporal wave function of structure and quantum interaction of microtubules. They found this time to be of the order of conscious events' time interval. Penrose's uncertainty relation is:

$$\tau \approx \frac{\hbar}{E_G}$$

Here $\hbar$ $(= h/2\pi)$ which h is Planck's constant and E_G is the gravitational self-energy of the superposition of spatiotemporal packs, and τ expresses an average time of reduction (similar to a half-life in radioactive decay) (Hameroff & Penrose, 2017).

The main physical challenge against this theory was been the problem of quantum decoherence (Tegmark, 2000), which they have tried to answer it and to show there are compelling reasons for this event to be delayed in the warm, wet and noisy environment within the brain (Hagan, Hameroff, & Tuszyński, 2002).

Given the spatiotemporal non-local properties of the theory, which relate to the nature of quantum gravity, Hameroff gave a qualitative explanation of the Libet experiment on free will (Hameroff, 2012). He also tried to show the effect of microtubules' oscillation in the treatment of mental illness via ultrasonic stimulation of the brain (Hameroff et al., 2013).

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ii. A philosophical discussion

The metaphysical presupposition of this theory is that consciousness results from discrete physical events i.e. proto-conscious events for which we have no adequate physical laws to describe and understand it. But, we should hopefully try to achieve such physics i.e. theory of Quantum Gravity. Their philosophical viewpoint, as they said, is very close to the philosophy of Whitehead (Hameroff & Penrose, 2017).

Penrose's philosophical choice in the use of quantum theory is an extended version of standard quantum mechanics, which consists of a specific scheme of objective reduction (OR) (i.e. Diósi–Penrose). In addition, in the hypothesis of OR (objective reduction), they affirm that R is firstly real and secondly independent of any observer. They believe that OR can provide a "bridge" between the classical and quantum worlds; where spontaneous collapse leads quantum superposition to a classical alternative. This takes place in a time interval τ. For OR, this time can be determined by the amount of displacement between the two tiny quantum space-times (Hameroff & Penrose, 2017). These are the metaphysical ideas of the theory on which their theory of quantum consciousness is based.

One of the philosophical consequences of this theory is the existence of non-local effects of consciousness in the brain. They neither explain the nature of consciousness nor the mechanism by which it affects the brain nor vice versa, but they consider consciousness to be related to the quantum relationships of microtubules in the objective reduction of their spatiotemporal wave function. According to this theory, free will exists as an effective factor and although consciousness cannot be explained by current physics, future physics can provide better descriptions for understanding it.

There has been a lot of criticism of this theory, and they tried to answer them all. Perhaps there is no theory among quantum consciousness theories that has been criticized as much as this one, especially from various angles (physics, neuroscience, philosophy, etc.). Many of the criticisms and answers can be found in the article (Hameroff & Penrose, 2017). In our opinion, the high amount of criticisms of this theory confirms its importance and power. Even if it was a weak theory, its survival after nearly three decades of enduring scientific attacks has made it a strong theory.

3.4. Avicenna-Bohm theory

Avicenna-Bohm theory was proposed by a research team led by Prof. Golshani (Jamali, Golshani, & Jamali, 2019c); the main question of this theory is how the immaterial mind affects the material brain? Among theories related to consciousness, this theory is the only one that explains precisely and quantitatively how the mind affects matter. They have studied the issue by using Avicenna's psychology theory and have generalized it to study the effect of the mind on the brain and vice versa. In this theory, mind and consciousness are considered as incorporeal essences that "conscious will "by its choice in the space of possibilities[۲], allows some possibilities

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and prohibits the others. These constraints in the space of possibilities, by affecting the modified Bohmian equations, generate a new quantum potential at the level of particles and neurons that guides neuronal dynamics to the mind's will. These dynamics lead to some material constraints at the final time which are compatible with the constraints affected by the mind in the space of possibilities. In order to achieve this theory, they generalized Bohmian quantum theory to the level of quantum field theory, which leads to a new modified potential at the particle dynamic's level. The concepts used in this theory are:

Avicenna's theory: Ibn Sina, after describing the human brain and ascribing many human cognitive powers to different areas in the brain, used some arguments to show that consciousness cannot be reduced to the brain (Jamali, Golshani, & Jamali, 2019a). After proving the incorporeity of the mind, he considered it to affect the brain in a top-down process and being affected by the brain in a bottom-up process. In fact, the mind with imagination affects the form of the brain's matter (formal essence), and in a bottom-up effect, by exploring the states of the brain, it will be ready to receive an appropriate form from the incorporeal world (actual intellect) (Jamali et al., 2019a).

In Avicenna's theory, the mind is of an incorporeal and non-spatiotemporal nature, and its effect on the matter is also a non-local effect.

Bohmian quantum theory: In this theory, the two natures of wave and particle coexist objectively; the wave has an informational nature and non-local properties which generates a quantum force through a quantum potential. In fact, the quantum particle, in addition to the classical evolution, is affected by a quantum force that guides its trajectory. Bohmian quantum theory is a deterministic theory and a non-local theory in space. By generalizing Bohmian theory to the level of QFT (Jamali, Golshani, & Jamali, 2020), Golshani et al. obtained a new quantum potential that encompasses all effects which are related to the level of field theory; (Such modification leads to a superwave alongside the quantum wave and particle). This new quantum potential, gives rise to a causal and yet non-local theory in space-time, through the path integral formalism.

The space of possibilities: The space of possibilities is a quasi-Hilbert space that appears in Avicenna-Bohm theory as a connection between the mind and the matter; it is equivalent to the potential space in Avicenna's philosophy. In this space, which represents all the possibilities, on the one hand, it is influenced by the soul's conscious will, and on the other hand, it corresponds one to one with the material space and the physical world's constraints. The effect of the mind on this space is a non-spatiotemporal effect like the nature of the mind, and the effect of matter on this space is a spatiotemporal effect like the nature of matter. Changing the possibilities, by changing the boundary conditions of modified Bohmian equations, changes the quantum potential and affects the dynamics of material particles. The changing of the possibilities is possible in two ways(Jamali, Golshani, & Jamali, 2019b; Jamali et al., 2019c):

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1. The existence of constraints in material space;
2. The effect of the mind's will on the probability space.

iii. A Philosophical discussion:

Avicenna-Boehm theory has two important metaphysical assumptions:

1. Consciousness and mind have an incorporeal nature, so their effect on the matter is a non-local effect in space-time.
2. Humans have free will and authority, which leads to the acceptance of causality along with the unpredictability of human actions, based on the brain's physics.

Given this theory's emphasis on causality, they chose Bohmian quantum theory; Then, considered the non-local effect of the mind on the brain, as well as the inadequacy of classical causation, they modified the Bohmian quantum theory to the level of QFT, in a way that leads to the appearance of some terms in the equations of particle dynamics that cover all non-local effects of the mind on the brain. One of the philosophical consequences of this theory is the guidance role of the mind and its top-down effect on the brain and body, so that "conscious will" affects the brain in a hierarchical manner along with physical factors and without violating the physical laws.

This theory, by emphasizing the recent achievements in the field of delayed-choice experiments (Jamali et al., 2019b), has provided a suitable background for explaining Libet-type experiments(Jamali et al., 2019c). On the other hand, due to the non-spatiotemporal property of the mind, they consider the time passage perception as a result of the mind's interaction with matter and also the spatiotemporal effect of matter on the space of possibilities.

Unlike other theories of quantum consciousness, which often focus on the wave function reduction and the measurement problem, Avicenna-Bohm theory considers the effect of the mind on matter as a continuous, calm, and permanent effect by choosing a modified Bohmian quantum field theory.

One of the main philosophical aspects of this theory is the strong presence of the ultimate cause alongside and compatible with other physical causes; In fact, this theory has formulated how the ultimate causes affect. The ultimate cause as an effective cause affects the dynamics of physical particles through the top-down effect of a conscious will. AS one of the prominent contemporary Muslim philosophers Allamah Motahhari said:

> "Another type of development (navigation/motion) observed in objects is that the past and the actual causality, the material order, are not sufficient for explaining such development. That kind of development (motion) indicates a mysterious relationship between the object and its future and ultimate causality, that is, a kind of interest and attention to the end and purpose.

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> … but according to the ultimate principle, future events are also involved in some way, and it is as if they [future event] absorb these [present] events from the front." (Motahhari, 1985)

This newborn theory, despite its original and innovative idea, still has much room for research to mature.

4. Top-Down Causation (George Ellis)

"Top-down causation" has an important role in the Islamic worldview; Therefore, Muslim scholars have paid special attention to it and have discussed it under the title of "vertical causation"; For example, we can refer to the book "Al-Isharat wa al-Tanbihat" by Avicenna (980-1037), who was one of the scholars of the flourishing period of Islamic civilization (Avicenna, 1957). An important point about this kind of causation is its capability of providing a deep and fertile philosophical ground for theories of mind-brain relation and consciousness. Fortunately, some of the contemporary prominent scientists have proposed top-down causation as a mechanism for a better description of nature, especially for describing the hierarchy of causation and structure in living matters (Walker, 2012). Among them, George Ellis deals with the issue more completely and in more detail. Therefore, in the following, we shall investigate the issue of top-down causation from Ellis's viewpoint.

4.1. Bottom-up vs Top-Down causation

In nature, there are many levels of the hierarchical structure. These levels which extend from micro-scale to macro-scale are the subjects of the different branches of science. At each level, there are some concepts and essences, and also some laws that show the causal relationship between those essences. These different levels in nature are interrelated. As described in the following table, there are two directions of relation and effect between these levels: top-down relation and bottom-up relation:

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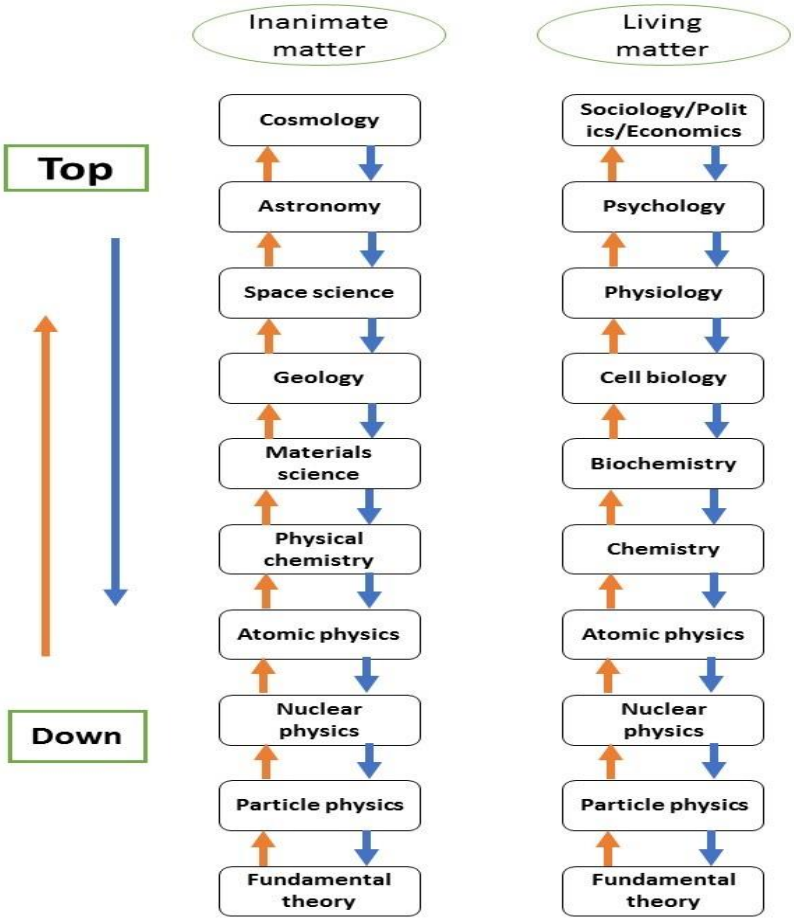
Table 1 The basic hierarchy of structure and causation



Bottom-up causation in the hierarchy of complexity is a key assumption in the physical thought; another assumption is that this is all which takes place! An important consequence of these two assumptions is that any higher-level issues can, in principle, be reduced into lower levels for example the level of particle physics (Ellis, 2015); This view is called reductionism. This attitude has many followers in science. Physicists who follow this idea believe that science can be classified according to hierarchy, and theoretical physics can be placed at its most basic level, so it should be possible to reduce all sciences to theoretical physics (Golshani, 2006).

George Ellis believes that each causal level is real. Ellis criticizes reductionists and says that they limit their view to their own specialty. Ellis quotes the famous Nobel Laureate in Medicine, Francis Crick:

> "You, your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact

> no more than the behavior of a vast assembly of nerve cells and their associated molecules." (Ellis, 2016)

Then Ellis asks Crick why he stops at the level of cells and molecules? While nerve cells and molecules themselves are made up of smaller creatures like neutrons, protons, and electrons, which are also themselves made of quarks and so on. In the other word, why not:

> "You, your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behavior of a vast assembly of quarks and electrons." (Ellis, 2016)

In fact, if we accept that one level (e.g. the level of cells) is real, then we should accept that all levels are real too; because there are no substantial differences between the levels. In addition, by accepting the reality of each level, Ellis considers them as independent of each other i.e. to understand higher levels, we don't have to understand lower levels. For example, a Botanist or a mechanical engineer doesn't have to know particle physics(Ellis, 2015).

The most important point on which Ellis emphasizes is that this one-way flow of causation (bottom-up causation) which is crucial, is not adequate to explain all issues in science. So he offers us to expand our viewpoint and be aware that for explaining the behavior of a special level's entities we need to know the effects of upper levels on this special level. For example:

- In neuroscience, there is a flourishing branch called "social neuroscience" which shows how human brains are influenced by the society in which they live and also adapt their minds with that society.
- In biology, there is an interesting branch called "epigenetic" which demonstrate that environment has a crucial influence on biological developments (Ellis, 2015).

4.2. More examples of Top-Down Causation

Ellis gives a variety of examples of top-down causation to illustrate his idea:

- About the brain; contrary to what may seem at first glance, **reading** is not just a bottom-up process. In fact, top-down causation also plays a key role in this continuous holistic process; as Ellis said:

  > "The brain predicts what should be seen, fills in what is missing, and interprets what is seen on the basis of what is already known and understood."(Ellis, 2015)

- **Vision** also works in the same way; especially about the resolution, Ellis believes:

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> "The resolution is top-down shaping of vision by the cortex, based in prediction of what we ought to see." (Ellis, 2015)

- In Classical physics, there are many examples of top-down causation. In fact, there is nothing new about them, just we haven't seen them before as a top-down effect. Look at the following example:

Suppose the **flow of electrons in a wire**; it is the shape of the wire that determines the direction of the electron's flow (Ellis, 2016).

And many more examples in quantum physics, cosmology, astronomy, microbiology, physiology, etc. (Ellis, 2015, 2016).

4.3. Room at the bottom? (mechanism of top-down causation)

There is a question here: Is there any room at lower levels so that upper levels influence them downwardly and top-down causation finds an opportunity to take place?

To answer this question, we should know that there are various ways that top-down causation can takes place without the violation of physical laws: (Ellis, 2015, 2016)

✓ Setting constraints on Lower Level Interactions; for example, by setting boundary conditions:
- This is true for most of the above examples, like "flow of electrons in a wire".

✓ Changing the nature of the underlying entities; for example:
- Hydrogen, as a free atom, has very different properties as compared with when it is bounded in a water molecule.
- The half-life of free neutrons in comparison with when it is bounded in the nucleus is respectively 11.5 minutes and billions of years!

✓ Creating the possibility of the existence of lower-level entities;

In some instances, the lower-level things cannot even exist outside their upper-level context; for example:

- The existence of phonons and Cooper pairs depends on some specific material's physical structure (Ellis, 2015, 2016).

An important point is when an environment acts on lower levels of the hierarchy of structure downwardly, there is no violation of physical laws. In fact, mechanisms mentioned above while respecting the laws of physics let the Top-Down Causation occur. Ellis invites those who still disappoints with his idea to a challenge:

> "If you believe this is wrong, please advise me of a physical law or process that unambiguously determines how a tea cup can be created in a purely bottom-up way. You will not be able to do so—it does not exist." (Ellis, 2015)

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4.4. Two philosophical concepts

Although most of the contents discussed in this chapter were Philosophical, we especially want to discuss here two concepts of causation and existence:

✓ **Causation**

Ellis has a pragmatic viewpoint about causation so he defines Causal Effect as follows:

> "If making a change in a quantity X results in a reliable demonstrable change in a quantity Y in a given context, then X has a causal effect on Y." (Ellis, 2015)

Example: I press the fire alarm button; the alarm sounds.

✓ **Existence**

Ellis interestingly defines the concept of existence on the basis of causation. First, he assumes that physical matter (comprised of electrons, protons, etc.) exists; then he offers a criterion for existence:

> "If Y is a physical entity made up of ordinary matter, and X is some kind of entity that has a demonstrable causal effect on Y, then we must acknowledge that X also exists (even if it is not made up of such matter)." (Ellis, 2015)

To summarize, the key messages of Ellis's theory are that firstly, the different levels of the hierarchical structure of nature are real; so the level of mind and consciousness are as real as the level of particles. Secondly, we shouldn't think that everything can be understood in a bottom-up way, but we must consider the top-down effects as well if we want to understand nature (especially the mind-brain relation) in a fruitful way (Ellis, 2019).

5. Conclusion

The desire to provide a deeper description of consciousness and the mind-brain interaction has prompted many great scientists over the past three decades. The Quantum consciousness theories, in an interdisciplinary field using contemporary physics, mathematics, philosophy, neuroscience, and psychology, have been the result of those efforts. The main philosophical choice in these theories, before any mathematical and physical theorizing and modeling, is to choose a philosophy about the mind and consciousness. This important philosophical assumption overshadows all aspects of theorizing in this area. Some theories, such as Stapp theory, consider the mental state as a fundamental and natural identity alongside the other electrochemical processes in the process of quantum reduction, and therefore will essentially have to eliminate the active and effective role of the mental states on the brain. The other three theories introduce the mind as something beyond the brain; Orch-OR theory considers consciousness as an emergent identity that arises from Orchestrated OR events, and has causal effects on the brain dynamics; it is beyond the contemporary

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physics and a more accurate understanding of it will be left to future science (Quantum Gravity). In the theories of Eccles-Beck and Avicenna-Bohm, the mind is considered as an incorporeal identity by which the management of the brain is done.

In the next step, according to the adopted psychological philosophies to describe mind-brain interaction qualitatively (a philosophy that has choices about the nature of the mind, the existence of a free will, the description of self-awareness, etc.), These theories choose one of the 14 interpretations that governs mathematics of quantum theory, which is a purely metaphysical choice in line with previously adopted philosophy. These interpretations do not differ experimentally, but different philosophical choices; and their different metaphysical descriptions of reality have made them distinct from each other.

In short, we can say:

- The Eccles-Beck theory uses the orthodox quantum theory in the brain but it assumes that the soul has an effect on the quantum probabilities. Eccles chose a theological philosophy about the incorporeity of the soul and its creation.
- The Stapp theory uses Heisenberg's interpretation of quantum with potential and actual facts and he was also inspired by James's psychological philosophy.
- The Penrose-Hameroff theory uses an objective reduction of the wave function under gravity while the philosophy that governs their theory is the same as Whitehead's.
- The Avicenna-Bohm theory while being inspired by Ibn Sina's philosophy of mind uses modified Bohmian quantum theory.

Apart from Stapp's theory, in which consciousness and the brain are not directly causally related, the other three theories can be compared within the framework of Ellis's theory of Top-Down causation:

- In Eccles-Beck theory, the soul is considered as an incorporeal entity that has a causal effect on the brain, but there is an ambiguity in the theory that whether this effect is a vertical effect or a horizontal effect along with other material causes. Therefore, examining its correspondence with Ellis' theory requires further explanation from the theory.
- In Penrose-Hameroff theory, the mechanism of the effect of consciousness on the brain is not clear, but since consciousness is considered as an emergent phenomenon and also it has a causal effect on the brain, so its effect must be considered as a top-down effect.
- In Avicenna-Bohm theory, consciousness is considered as an incorporeal entity that exists in upper level than matter; and controls the brain by applying constraints in possibilities space. Therefore, this theory has the most correspondence with Ellis's theory of top-down causation.

Each of these theories, in addition to descriptions, contains some predictions that can be empirically tested; But in addition, they contain important philosophical results

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on self-awareness, free will, psychological time, etc., which inherently, as well as in terms of application and effect of these results in other sciences (especially the humanities), can be very important and fundamental; and also be a criterion for selecting and judging between them in the absence of sufficient empirical data (either inherent or due to lack of technology).

Notes:

[1] Orchestrated Objective Reduction

[2] A common space which is a boundary between the incorporeal and the matter.

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