Quantum Mechanics and Consciousness

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Abstract

Quantum mechanics is a groundbreaking theory: not only it is extraordinarily empirically adequate but also it is claimed to having shattered the classical paradigm of understanding the observer-observed distinction as well as the part-whole relation. This, together with other quantum features, has been taken to suggest that quantum theory can help us understand the mind-body relation in a unique way, in particular to solve the hard problem of consciousness along the lines of panpsychism. In this paper, after having briefly presented panpsychism, I discuss the main features of quantum theories and the way in which the main quantum theories of consciousness use them to account for conscious experience.

Keywords: panpsychism, dual-aspect theories; the hard problem of consciousness, orthodox quantum theory; quantum theories without observers; quantum theories of consciousness.

1. Introduction

Arguably, the image of the world given by our theories has grown distant, one step after another, from the one of our everyday experience. Think of atomic theory, for instance: contrary to experience, matter is discontinuous and the world is mostly empty. Nonetheless, it was a cumulative progress, a slow refinement of our everyday concepts by our scientific understanding. This was true up to the advent of quantum mechanics, which is one of the most mind-boggling physical theories ever. It is taken by many to have provided a true paradigm shift in our understanding of the world: for instance, the observer affects the properties of the observed; the observer and the observed are governed by different laws, which now are probabilistic rather than deterministic; the properties of certain systems can no longer be accounted for in terms of properties of their parts; there is nonlocal 'spooky action at a distance.'

On another front, while physics has been extremely successful in describing the behavior of matter since Newton, one prominent open problem was how we, as conscious beings, fit in this description. A first view, roughly identifiable with physicalism and supported by Newtonian physics, is that we are fundamentally material beings who obey the laws of physics just like every other physical object. However, it was still unclear to many why complicated machines like us would feel something at all. A prominent response to this question, panpsychism, is that every physical object has consciousness at different levels. This seems a variety of the traditional Platonic idea that the universe is conscious, the idea of the World-soul, which is here invoked for explanatory purposes. Nonetheless, this view directly clashes with Newtonian physics, which excludes consciousness. Quantum mechanics then arrived to change all that: it is often claimed that consciousness itself is needed to account of measurements; that the intrinsic randomness of the theory helps with the tension between free will and determinism; that some versions of quantum theory are non-algorithmic and so is consciousness; that quantum collapse and nonlocality can explain some psychophysical phenomena and shed light on the nature of consciousness.

The aim of this chapter is to provide a brief summary of the theories people have suggested about the relation between quantum mechanics and consciousness along the lines of the traditional World-soul theories. I will start in the next section by presenting the hard problem of consciousness and the non-physicalist responses, prominently panpsychism. Then in the third section I will move to quantum theory, discussing the commonly accepted version as well as the theories which go beyond it. In Section 4 I will present and analyze the various proposals of quantum theories of consciousness, and then I will conclude.

2. Non-Physicalist Approaches

Arguably, one of the philosophical problems that has been with us since the times of the ancient Greeks is the mind-body problem.[1] Our bodies appear to have physical properties, like size, weight, shape, location and state of motion, and are well described by Newtonian physics. In addition, people have other kinds of properties, which seem to be fundamentally different from physical properties. For instance, I have desires, which do not appear to be located anywhere in space, and to have a shape or a size or a weight. They instead are experienced and felt by me, and influence my actions. More generally, these mental properties involve consciousness (the ability of having some sort of experience, including perceptual and emotional experience), intentionality (the feature of being about something else than themselves, like beliefs and desires are about something outside themselves), and they are possessed by me, a subject. Thus, the mind-body problem is the problem of understanding the relation between these two kinds of properties. One answer is to endorse dualism, the view that mind and matter are fundamentally different substances interacting with one another. However, whoever hopes to construct a more unitary view of nature comes to face the following dilemma: either mental properties are properties of the fundamental particles (which also constitute our bodies), or they somehow arise from them. If the latter, which we

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[1] For a contrary view, see Wallace I. Matson, "Why Isn't the Mind-Body Problem Ancient?" in *Mind, Matter and Method*, ed. Paul K. Feyerabend & Grover Maxwell (Minneapolis: University of Minnesota Press, 1966), 92-102.

can loosely identify it with physicalism, one needs to explain how we are composed of the fundamental building blocks of nature, which do not possess mental properties even if we do; if the former, which we can identify with *panpsychism* broadly construed, one has to explain how these fundamental entities do not appear to have these features even if they do.

Panpsychism strictly speaking is the view that there is one fundamental substance with mental properties. Other theories closely related to panpsychism include dual aspect monism, according to which reality possesses phenomenal as well as physical properties. Another possibility is that this substance is neither mental nor physical, and thus it has been dubbed neutral monism. Be that as it may, physicalism and panpsychism broadly construed, had an alternating fate throughout history. In the 17th century, physicalism and the mechanistic view of the world initiated by Democritus (c. 460-370 BC)[2] culminated with the scientific revolution boosted by the triumphs of Newtonian mechanics. As noticed, this framework leaves no room for mental or conscious experiences: everything is made of matter, including us, and so we are merely complicated machines. Moreover, since the physical world is causally closed and thus a scientific investigation of consciousness is not needed for the development of physics, physics simply took off in its successful development isolating the mind in its own domain. Regardless, panpsychist views have always been present in philosophy during and after the scientific revolution, starting from Baruch Spinoza (1632-77) and Gottfried Wilhelm Leibniz (1646-1716). For a variety of reasons, panpsychism and its cousins became dominant views in 19th century metaphysics, featuring proponents such as William James (1842-1910), and Charles Sanders Peirce (1839-1914) among others.[3] Aside from its influence in metaphysics, however, panpsychism did not have much impact on science itself, which continued its successful development. Indeed, the gap between science and philosophy presumably had a big influence on the growth of positivism in the philosophy of science. In fact starting in the 1930s an increasing number of people wanted a philosophy informed by science, and ultimately discredited panpsychism in philosophy of science first, and later in the general philosophical community as well. Thus, panpsychism lost much of its attractiveness in this respect in the eyes of a growing community of philosophers, since it seemed to preclude any integration of the mind within the accepted and successful scientific picture. For most of the 20th century philosophers of mind, therefore, the mind-body problem was the

[2] Jonathan Barnes, *The Presocratic Philosophers: The Arguments of the Philosophers* (London and New York: Routledge, 1982). David Skrbina (ed.) *Mind that Abides, Panpsychism in the New Millennium* (Advances in Consciousness Research, John Benjamins Publishing Company 2009).

[3] For more on the history of panpsychism see D. S. Clark, *Panpsychism: Past and Recent Selected Readings* (Albany: State University of New York Press, 2004), David Skrbina, *Panpsychism in the West* (Cambridge, MA: MIT Press, 2005) and David Skrbina (ed.) *Mind that Abides, Panpsychism in the New Millennium* (Advances in Consciousness Research, John Benjamins Publishing Company 2009).

problem of 'scientific integration of the mental,' and physicalism looked like the best choice.

In the 1970s, when the positivist school began to lose its influence over philosophy, a series of anti-physicalist arguments started being published, initially by Thomas Nagel[4] and Frank Jackson[5] and followed by much other work, notably the arguments of Galen Strawson.[6] The main problem, now dubbed the hard problem of consciousness,[7] is that science, being objective, cannot explain why a person has subjective experience. The panpsychist proposes that consciousness is explained in terms of more basic forms of consciousness, postulated as properties of the fundamental constituents of the material world. Another argument against physicalism, which can be tracked back to Bertrand Russell (1897-1970)[8] and Alfred North Whitehead (1861-1947)[9], is based on the skepticism that physics is able to capture the true nature of reality, consciousness included. The idea is that physics can only get us to structural, mathematical properties of nature, while its intrinsic, categorical properties are hidden from us. Panpsychism proposes that while physics only tells us how an electron behaves, the electron is essentially a thing that instantiates consciousness. Panpsychists also urge that since we know that matter constituting the brain is conscious, by simplicity we should assume that the rest of matter is conscious too.[10] Another motivation for panpsychism comes from the fact that it avoids one of the main objections to dualism. In fact, if dualism is correct, then consciousness exists outside the physical world, so it is a mystery how it could interact with material entities. However, if, as the panpsychist believes, consciousness is everywhere in the physical world, the mystery disappears.

Moving to the objections, the most common is that it seems deeply counterintuitive to say that fundamental physical entities such as electrons are conscious. In response, panpsychists point out how many scientific theories lead us to a counterintuitive picture of the world, but we take them seriously nonetheless: atomic theory says that matter is mostly empty and discontinuous, string theory says that the universe is eleven-dimensional, relativity theory says that simultaneous events do not exist. In addition, evidence for panpsychism is more secure than evidence for any physical theory as we know for sure consciousness exists because we directly experience it, in contrast with electrons, of which we have merely indirect evidence.[11] Aside from this,

[4] Thomas Nagel, "Panpsychism," in *Mortal Questions* (Cambridge: Cambridge University Press 1979), 181.
[5] Frank Jackson, "Epiphenomenal Qualia," *The Philosophical Quarterly*, vol. 32, no. 127 (1982): 127–136.
[6] Galen Strawson, "Realistic Materialism: Why Physicalism Entails Panpsychism", *Journal of Consciousness Studies*, vol. 13 no. 10–11 (2006): 3.
[7] David Chalmers, *The Conscious Mind* (Oxford: University of Oxford Press, 1996).
[8] Bertrand Russell, *The Analysis of Matter* (London: George Allen and Unwin, 1927).
[9] Alfred North Whitehead, *Adventures of Ideas* (New York: Macmillan, 1933).
[10] Philip Goff, *Consciousness and Fundamental Reality* (New York: Oxford University Press, 2017), 7.
[11] Philip Goff, *Consciousness and Fundamental Reality*, 7.

the hardest challenge appears to be the one posed by the so-called the 'combination problem'[12], which is especially severe for the varieties of panpsychism like the so-called 'constitutive micropsychism.' This is the most common form of panpsychism, according to which the consciousness of the microscopic entities grounds the consciousness of living beings composed by them. The combination problem is that it is unclear how the combination of distinct conscious subjects can form a single conscious mind. Indeed, it seems to be possible that many conscious microscopic entities exist without them forming a conscious macroscopic entity at all. If this is the case, panpsychism faces the same kind of problem of physicalism, namely that it is possible that there are 'philosophical zombies' with the same material constitution as we have, but without any conscious experience.[13] If so, it is hard to see how panpsychism is supposed to be an improvement over physicalism. Varieties of panpsychism which are not constitutive arguably do not suffer from the combination problem.[14]

The advent of quantum theory, having features compatible with panpsychism, contributed to promote the plausibility of the view also from a scientific point of view. It has been argued that, while in the framework of Newtonian physics there was no room of consciousness, the situation has changed in the new quantum paradigm, which is said instead to require consciousness. To clarify, in the next section I will present the main features of the traditionally accepted quantum theory as well as the ones of the theories which go beyond the orthodoxy.

3. Quantum Theories

The so-called classical world was described by two theories: one, Newtonian mechanics, describes matter as made of particles with definite position and velocity; the other, classical electrodynamics, describes light as the wave constituted by the vibrating electromagnetic fields. Waves and particles have fundamentally incompatible properties: particles always have an exact location and move along one direction, while waves are vibrations which propagate in all directions. Accordingly, in contrast with particles, waves can interfere.[15] This dual ontology remained the orthodoxy for a long

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[12] William E. Seager,"Consciousness, Information, and Panpsychism", *Journal of Consciousness Studies*, vol. 2 no. 3 (1995): 272; William James, *Principles of Psychology*, vol. 1.

[13] David Chalmers, "Panpsychism and Panprotopsychism." In *Consciousness in the Physical World: Perspectives on Russellian Monism*, ed. Torin Alter & Yujin Nagasawa (New York: Oxford University Press, 2015), 246–276.

[14] See Harald Atmaspacher, *20th Century Variants of Dual-Aspect Thinking*, Mind &Matter vol. 12 no. 2 (2014): 245-288.

[15] To understand, imagine to throw a rock in a lake and observe the behavior of the surface of the water when it reaches a screen with two narrow slits on it. When two crests cross each other the amplitudes combine (interfere) to form taller waves. Instead, when a crest crosses a trough the amplitudes subtract, so that there is a wave where there was not one earlier. There is a sense in which, therefore, the wave has travelled through both slits, while a fish (as a particle) would only travel through one.

time until at the beginning of the 20th century some well-known intractable experimental results could no longer be ignored, and Max Planck (1858-1947) and Albert Einstein (1879-1955) started exploring new avenues.[16] A little later, Niels Bohr (1885-1962) proposed a new atomic structure which relied on the idea that light, understood as a wave, sometimes behaves like a particle. Conversely, Louis de Broglie (1892-1987) proposed that sometimes matter, so far understood as particle-like, behaves like a wave. These ideas needed a new framework, which started its development in the 1920s, and was dubbed 'quantum mechanics.' From here on out the theory flourished, and in 1932 John von Neumann (1902-1957) put it in the form in which it is still taught now.[17]

Quantum mechanics is difficult to describe as it is not a unique theory. The theory presented in physics books often goes by the name of 'orthodox quantum mechanics,' as it is the one which is standardly taught in school. I will present this view in the next section. Starting the 1950s, new quantum theories, in response to well-known problems, started to develop beyond the orthodoxy. I will discuss these theories in Section 3.2.

3.1. Orthodox Quantum Theory

Orthodox quantum theory marks a radical departure from the Newtonian understanding of the world. While classically physical objects are either made of particles or of waves, the new theory implies that both matter and light sometimes behave particle-like, and sometimes wave-like. Thus, matter shows a wave-particle duality or complementarity: when we see the particle, we do not see the wave, and the other way around. The proponents of this theory therefore concluded that such 'classical' categories as waves and particles are obsolete and inadequate. Consequently, it is claimed, we are forced to abandon our traditional understanding and construct a new paradigm. The result is that orthodox quantum theory can only discuss measurement results, which inform us of the values that physical 'observables' (position, velocity and energy, for instance) have when an experiment is performed. The fundamental equation of the theory is the Schrödinger equation, which describes the temporal evolution of an object called the wavefunction. However, in a measurement situation, for mathematical reasons, the Schrödinger evolution would not yield a single measurement outcome, but a combination (called 'superposition') of all the possible results. So, it is claimed, before the measurements the properties of a system are

[16] In 1900, Planck accounted for the experimental frequency distribution of the light emitted by a black body assuming that light is made of particles which can exchange energy only in discrete amounts (the quanta), in contrast with the accepted understanding of light as a wave with continuous energy. Five years later, Einstein explained the photoelectric effect, namely the emission of particles when a material is hit by light, using Planck's hypothesis.

[17] For more on the history of quantum mechanics, see Joseph P. McEvoy, *Introducing Quantum Theory* (Totem Books, 1996).

undefined, and they become definite when a measurement is performed. Therefore, it is the act of measuring, or observing, which suitably gives reality to the quantum realm. Mathematically, this is implemented by postulating that, when a measurement is performed, the wavefunction randomly and instantaneously 'collapses' from the superposition state to the state describing the measured outcome. So, in contrast with Newtonian mechanics, the theory is intrinsically probabilistic, and it has the distinctive feature that the observer appears in the very definition of the theory. As discussed later, this is one of the places in which it has been argued, consciousness is needed: to complete the quantum framework.

Moreover, one feature of quantum mechanics which made people think of connecting the theory with consciousness is entanglement. It is the phenomenon in which certain systems which compose more complex systems cannot be described independently with one another, but have to be described as a whole. Formally, a system is entangled if its wavefunction is not the product of the wavefunction of its subsystems. So, given A and B two entangled objects propagating towards the opposite sides of the galaxy, any interaction with A will instantly affect B, regardless of their spatial distance. Einstein, Boris Podolsky (1896-1966), and Nathan Rosen (1909-1995), often abbreviated as EPR in their joint article,[18] noted that this violated a locality condition: what happens in a given spatial region cannot instantaneously influence what happens in a spatially separated region. Since EPR thought that this condition had to be true (because suggested by relativity theory according to which nothing travels faster than light), they concluded that quantum theory had to be false. However, later John Stuart Bell (1928-1990) proved that *any* theory which reproduces the predictions of quantum theory has to violate the locality condition, therefore invalidating EPR's rebuttal of quantum theory, and showing that quantum theory has to be nonlocal.[19]

Orthodox quantum mechanics has later developed into more complete theories which aimed to include relativity theory, called quantum theories of fields. Their development began in the 1920s with the description of interactions between light and electrons, culminating in the first quantum field theory, quantum electrodynamics, which describes many-particle systems, their mutual interactions, and their interactions with the electromagnetic fields. In this framework, one relevant notion is 'collective

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[18] Albert Einstein, Boris Podolsky, and Nathan Rosen, "Can Quantum-Mechanical Description of Physical Reality be Considered Complete?" *Physical Review,* vol. 47, no. 10 (1935): 777–780.

[19] John S. Bell, "On the Einstein-Podolsky-Rosen Paradox," *Physics*, vol. 1 (1964): 195–200. However, see Myrvold, Wayne, Genovese, Marco and Shimony, Abner, "Bell's Theorem", The Stanford Encyclopedia of Philosophy (Spring 2019 Edition), Edward N. Zalta (ed.), URL = https://plato.stanford.edu/archives/spr2019/entries/bell-theorem/ for a review of how this conclusion has been disputed.

excitation.'[20] Formally, it can be shown that the formation of collective excitations is an example of spontaneous symmetry breaking (the symmetry of the fermions is broken by the bosons), which is a mechanism often present in quantum field theory. As we will see in Section 4.1, these collective states have been invoked to explain specific mental features, in particular some features of memory.

3.2. Beyond the Orthodoxy

Aside from nonlocality which is a genuine feature of the quantum world, independent of the quantum theory considered, complementarity and the definitional role of the observer are distinct features of the orthodox approach, which are not shared by the other quantum theories. Even if in the 1920s many were reluctant, the orthodox theory later became the accepted view for a variety of reasons. Starting from the 1950s, however, there was a new wave of alternative proposals which rejected both complementarity (at least in the original sense) and the privileged role of the observer. Two of them, which I will discuss below, have been taken as inspirations of some quantum theories of consciousness, as discussed in Section 4.2.

The first one was proposed by David Bohm (1917-1992)[21] and later dubbed the pilot-wave theory. In this theory, which is a rediscovery and an expansion of the original proposal by de Broglie, the motion of particles is guided by the wavefunction, so that both particles and waves in a sense really exist rather than being merely complementary aspects of the same reality. In this theory, which is deterministic, the properties of every system are always well defined, so one does not need an observer to complete the description. In Section 4.1 we will discuss Bohm's approach to consciousness, as inspired by his theory.

In the 1980s, GianCarlo Ghirardi (1935-2018), Albert Rimini, and Tullio Weber proposed that the collapse of the wavefunction during the measurement happens as a matter of law of nature, rather than being triggered by an observer. For this reason in their theory, called spontaneous collapse theory, there is a stochastic equation that would unify the Schrödinger evolution and the collapse of the wavefunction. While in the spontaneous collapse theory no mechanism to trigger the collapse is specified,

[20] For instance in superconductors, which display zero electric resistance below a given temperature, there is a particular interaction between the electrons and the vibrations of the atomic crystal of the material, which are collective excitations called phonons, which creates electron pairs, dubbed Cooper pair. These pairs behave very differently from electrons: while electrons are fermions and so cannot all have the same energy, these pairs behave as bosons, and are not subject to this restriction. This phenomenon, in which all Cooper pairs occupy the same state and thus experience no resistance from the crystal, is called boson condensate, and realizes one of the few macroscopic quantum objects.
[21] David Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of "Hidden Variables" I & II, *Physical Review*, vol. 85 no. 2 (1952): 166–179 & 180–193.

Roger Penrose[22] has proposed that it is induced by gravity, as we will see in Section 4.2, as he thinks it is going to help with the mind-body problem.

4. Quantum Approaches to Consciousness

All of the distinctive features of quantum theory reported above (wave-particle duality, the privileged role of the observer, indeterminism and nonlocality) have been used to claim that quantum mechanics can be of help with a scientific understanding of consciousness. However, different quantum theories offer different possibilities, and so I will divide this section into the approaches that are directly built from orthodox quantum theory, and the ones that require going beyond the traditionally accepted theory.[23]

4.1. Approaches Based on Orthodox Quantum Theory

First, the need of an observer in the definition of orthodox quantum theory suggested that this theory is leaving room for consciousness. Eugene Wigner (1902-1995)[24] proposed that only a conscious observer can trigger the collapse. In the 1980s Henry Stapp[25] began developing Wigner's idea by distinguishing between actuality and potentiality, as hinted in some of Heisenberg's work on the meaning of complementarity.[26] Before anyone observes the system, it has several potentialities, or propensities. For instance, an electron facing a screen with two slits has the potentiality of going through the first and the second slit. Instead when the system is observed, it actualizes one of the potentialities. That is, when someone measures where the electron has passed, they only find one answer: it passed, say, through the first slit. This is a distinct departure from the traditional ontology of substances, towards some process ontology in the tradition of Whitehead, where the focus is on change rather than on being. The deterministic Schrödinger evolution does not control the actual things, but controls these propensities. The wavefunction collapses are Heisenberg's actual events. Stapp identifies conscious events with certain specific kinds of brain events, rather than synaptic events or more microscopic ones. This is in contrast with the approach

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[22] Roger Penrose, *The Emperor's New Mind* (Oxford: Oxford University Press, 1989); Roger Penrose, "On Gravity's role in Quantum State Reduction," *General Relativity and Gravitation*, vol. 28 no. 5 (1996): 581–600.

[23] See also J. Acacio de Barros and Carlos Montemayor, eds., *Quanta and Mind: Essays on the Connection between Quantum Mechanics and Consciousness*, Springer (2019) and references therein.

[24] Eugene P. Wigner, "Remarks on the Mind-Body Question," in *Symmetries and Reflections* (Bloomington: Indiana University Press, 1967): 171–184.

[25] Henry P. Stapp, "A Quantum Theory of the Mind-brain Interface," in *Mind, Matter, and Quantum Mechanics* (Berlin: Springer, 1993): 145–172.

[26] Werner Heisenberg, *Physics and Philosophy* (New York: Harper and Row, 1958).

developed by Friedrich Beck (1927-2008) and John Eccles (1903-1997),[27] later refined by Beck[28], according to which consciousness enters at the level of the synaptic cleft. These proposals also emphasize that both nonlocality and indeterminism help to bridge the gap between physics and consciousness. For instance, Stapp argues that nonlocality is at the root of the holistic character of the stream of consciousness, while indeterminism helps with making sense of the freedom of the will.[29] This view seems reminiscent of panpsychism in the sense that a particle is a set of objective tendencies, or propensities, for certain kinds of actual events to occur, and "these events are things of a new and entirely different kind".[30]

A different but still orthodox-based approach is the one put forward by Wolfgang Pauli (1900-1958) and Carl Jung (1875-1961).[31] The idea, also deriving from the privileged role of the observer in orthodox quantum mechanics but mostly suggested by wave-particle complementarity, is that the observer and the observed are fundamentally distinct but also connected and dependent on one another. That is, mind and matter, just like particles and wave, stand in complementary relations. They conjecture that the epistemic/ontic distinction in the quantum domain respectively between the measurement results and the superposition systems translates into the mental domain as the distinction between the conscious and the unconscious. In Jung's psychology the conscious and the unconscious are connected by a process of emergence analogous to the physical measurement.[32] The holism deriving from quantum nonlocality matches well with Jung's idea that reality is an unfragmented whole (the *unus munus*) rather than composed by parts, which consists in the so-called archetypes.[33] Thus, this view can naturally be read as a dual aspect strategy where the mental and the material are aspects of one underlying neutral reality. In particular, it is non-compositional, for the whole is not reducible to the sum of its parts. Mind and

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[27] Friedrich Beck, and John Eccles, "Quantum Aspects of Brain Activity and the Role of Consciousness," *Proceedings of the National Academy of Sciences of the USA*, vol. 89 (1992): 11357–11361.

[28]Friedrich Beck, "Quantum Brain Dynamics and Consciousness," in *The Physical Nature of Consciousness*, Philip van Loocke, ed. (Amsterdam: Benjamins, 2001): 83–116.

[29] Henry P. Stapp, "Neuroscience, Atomic Physics, and the Human Person," in *Mind, Matter, and Quantum Mechanics* (Berlin: Springer, 1993): 203-236.

[30] Henry P. Stapp, *Mind, Matter, and Quantum Mechanics* (Berlin: Springer, 1993): 41

[31] Carl G. Jung, and Wolfgang Pauli, *The Interpretation of Nature and the Psyche* (New York: Pantheon, 1955). Translated by P. Silz. German original *Naturerklärung und Psyche* (Zürich: Rascher, 1952); Carl A. Meier, ed. *Atom and Archetype: The Pauli/Jung Letters 1932–1958* (Princeton: Princeton University Press, 2001).

[32] Harald Atmanspacher and Hans Primas, "Epistemic and Ontic Quantum Realities," L. Castell L., O. Ischebeck, eds, *Time, Quantum and Information* (Berlin, Heidelberg: Springer, 2003): 301-321.

[33] For more details, see Harald Atmanspacher and Hans Primas, eds., *Recasting Reality: Wolfgang Pauli's Philosophical Ideas and Contemporary Science* (Berlin: Springer, 2009); Harald Atmanspacher, and Christopher Fuchs, eds , *The Pauli-Jung Conjecture and Its Impact Today* (Exeter: Imprint Academic, 2014), and references therein.

matter display mutual correlations as a remnant of the holism of the whole.[34] These correlations are called synchronistic: they are mind-matter acausal connections which show meaning to the person experiencing them.[35] Harald Atmanspacher and Wofgang Fach provide a general classification of coincidences, and those experiences which seem exceptional, in terms of their deviation from the 'norm,' and argue that synchronicity is a special kind of deviation.[36] Hans Primas has proposed a formal framework in which he relates the mind-matter distinction to the tensed-tenseless distinction: as symmetry breaks at the fundamental level, tensed time, including the 'now,' arises in the mental domain, and tenseless time, as an external parameter, on the physical level.[37]

Other approaches have been proposed to explain specific mental features within the orthodox approach. Karl Lashey (1890-1958)[38] has provided evidence that the 'macroscopic' activity of a large assembly of neurons appears to be spatially coherent and highly structured. This is an example of what physicists call a 'collective behavior,' when a large collection of spatially distributed entities behave as if they are one. Inspired by this, Karl Pribram (1919-2015)[39] proposed his 'holographic' model of the brain. He argued that brain processes involve electric oscillations in the brain's dendritic webs. They can be described by waves which can interfere, and arguably they can be used to store memories. Pribram noticed some similarities with holograms: as any part of the hologram contains the whole information about the whole hologram each part of the dendritic network contains all the information stored over the entire network. Hiroomi Umezawa (1924-1995) and his collaborators[40] have refined this view with the

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[34] Harald Atmaspacher, *20th Century Variants of Dual-Aspect Thinking*, Mind &Matter vol. 12 no. 2 (2014): 245-288.

[35] Jung's paradigmatic example of a synchronicity concerns one of his patients. As the patient was reminiscing a dream which involved a scarab beetle-shaped piece of jewelry, Jung heard a sound at the window and it was a small gold-colored beetle. The connection between the patient recalling the dream and the insect at the window is obviously non-causal, however there is a connection through meaning for the patient.

[36] Harald Atmanspacher, and Wolfgang Fach, "A Structural-phenomenological Typology of Mind-matter Correlations," *Journal of Analytical Psychology* vol. 58 (2013): 218–243.

[37] Hans Primas, "Time-entanglement Between Mind and Matter," *Mind and Matter*, vol. 1 (2003): 81–119; Hans Primas, "Complementarity of Mind and Matter," in Hans Atmanspacher and Hans Primas, eds., *Recasting Reality* (Berlin: Springer, 2009): 171–209.

[38] Karl S. Lashley, "In Search of the Engram," In *The Neuropsychology of Lashley*, Beach, F.A., Hebb, D.O., Morgan, C.T., Nissen, H.W., Eds. (New York, McGraw-Hill, 1960): 478–505.

[39] Karl H. Pribram, "Some Dimensions of Remembering: Steps towards a Neurophysiological Theory of Memory," In *Macromolecules and Behavior*, John Gaito, ed. (New York, NY: Academic Press, 1966): 165-187.

[40] Luigi M. Ricciardi, Hiroomi Umezawa "Brain and Physics of Many-Body Problems," Kybernetik. 4 (1967): 44–48; C.I.J. Stuart, Yasuchi Takahashi, and Hiroomi Umezawa, "On the Stability and Nonlocal Properties of Memory," *Journal of Theoretical Biology*, 71 (1978): 605-618; C.I.J. Stuart, Yasushi Takahashi, and Hiroomi Umezawa, "Mixed-system Brain Dynamics: Neural Memory as a Macroscopic Ordered State," *Foundations of Physics* 9 (1979): 301-327.

aim of describing memory storing and recalling. The mathematical formalism in which the model is formulated is the one of quantum electrodynamics, and in general quantum field theory for many-body systems. The basic elements of their approach are the neurons. They can form assemblies, which can be activated by external stimuli, and those which are activated are taken to be conscious. These activated states are parallel to the collective excitations in quantum field theory. Mari Jibu and Kiro Yasue[41] have developed these ideas into what they dubbed a 'unified quantum theory of brain dynamics,' where a crucial role is played by water's collective excitations states called corticons. Some further research, mainly by Giuseppe Vitiello and Walter Freeman (1927-2016), has provided a more realistic picture which includes phenomena such as dissipation and chaos.[42]

These are the main approaches to consciousness based on orthodox quantum theory. However, as already mentioned, a growing number of people have expressed dissatisfaction with orthodox quantum theory. For one, the theory claims that the world exists only when observed, without specifying what the observer is. Stapp's response is that whoever is conscious can be an observer and collapse the wavefunction, and that it is consciousness which gives reality to the quantum realm. However, while Stapp's view may open the scientific route to panpsychism, it seems questionable whether it truly helps in understanding consciousness. In fact, the theory is merely postulating that consciousness exists (without saying what it is), that some physical objects possess it (without specifying which), and that it acts on the wavefunction by collapsing it (without specifying how). Indeed, one could claim that things get worse: while without quantum theory we had the mystery of consciousness confined to conscious beings as the physical world was causally closed, now this mystery also infects physics: no only we do not know what consciousness is, but also we do not know how the rest of the physical bodies behave because we need consciousness to account for them. The Jung-Pauli conjecture suffers from similar problems as well.

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[41] Mari Jibu, and Kiro Yasue, Quantum Brain Dynamics and Consciousness (Amsterdam and Philadelphia: John Benjamins, 1995).

[42]Giuseppe Vitiello, "Dissipation and Memory Capacity in the Quantum Brain Model," *International Journal of Modern Physics* B, 9 (1995): 973–989; Giuseppe Vitiello, *My Double Unveiled (*Amsterdam: Benjamins, 2001); Giuseppe Vitiello, "Dissipative Quantum Brain Dynamics," in *No Matter, Never Mind*, K. Yasue, M. Jibu, and T. Della Senta, eds. (Amsterdam: Benjamins, 2002): 43–61, and references therein. See also Walter J. Freeman, and Giusepe Vitiello, "Nonlinear Brain Dynamics as Macroscopic Manifestation of Underlying Many-body Field Dynamics," *Physics of Life Reviews*, vol. 3, no. 2 (2006): 93–118; Walter J. Freeman, and Giusepe Vitiello, "Dissipation and Spontaneous Symmetry Breaking in Brain Dynamics," Journal of Physics A, 41 (2008): 304042. Walter J. Freeman, and Giusepe Vitiello, "Nonlinear Brain Dynamics as Macroscopic Manifestation of Underlying Many-body Field Dynamics," Physics of Life Reviews, vol. 3, no. 2 (2006): 93–118; Walter J. Freeman, and Giusepe Vitiello, "Dissipation and Spontaneous Symmetry Breaking in Brain Dynamics," Journal of Physics A, 41 (2008): 304042.

Different considerations can be made for the quantum electrodynamic approach. While this treatment of the brain dynamics appears to successfully reproduce the available empirical evidence, it does not address the hard problem of consciousness. This is a theory of brain states, which can be suitably treated as classical states, and as such is perfectly compatible with physicalism. In this approach, as in the one of Hameroff and Penrose that we will discuss in the next section, it is unclear how the collective neuronal dynamics should have anything to do with the subjective character of experience. To be fair, Freeman and Vitiello agree that the model "describes the brain, not mental states."[43]

4.2. *Approaches Going Beyond the Orthodoxy*

Given that none of the theories which go beyond the orthodoxy requires an observer, the connection with consciousness relies on other considerations. Roger Penrose proposed a non-orthodox quantum theory in which the collapse is triggered by gravity, since he believes that some characteristics of this theory may help us understand some of the features of consciousness.[44] His motivation comes from his conviction that consciousness is fundamentally non-algorithmic, or non-computable: it does not function following a finite set of rules. Penrose thinks that, since a stochastic theory like the spontaneous collapse theory briefly mentioned in Section 3.2 is algorithmic, it cannot describe consciousness. However, he thinks that Heisenberg's uncertainty principle applied to a future theory of gravity could help. The principle states that the more determined a position of a particle is, the less velocity it has, which is another way of stating quantum complementarity. Another version of the principle, relevant for Penrose's purposes, relates time and energy: the greater the energy difference between two states, the less time it takes for a system to go from one state to the other. In the orthodox theory, as we saw, a quantum object can be in a superposition of different states of affairs, and Penrose wants to say that if the energy difference between two terms exceeds a certain amount then the superposition will collapse into one of its terms, in a way suitably implemented by a future theory of gravity, and in a time given by the Heisenberg uncertainty principle. Anesthesiologist Stuart Hameroff suggested to Penrose that microtubules in the neurons are the right structures for the gravitational collapse to occur in. In fact the tubulin, which constitutes the microtubule's surface, can exist in two slightly different configurations, and Hameroff noticed that some anesthetics were acting on consciousness as well as on the ability to switch between the two configurations. Together, Penrose and Hameroff propose a model, dubbed 'Orch-

[43] Walter J. Freeman, and Giusepe Vitiello, "Dissipation and Spontaneous Symmetry Breaking in Brain Dynamics," Journal of Physics A, 41 (2008): 304042.

[44] Roger Penrose, *Shadows of the Mind: A Search for the Missing Science of Consciousness* (Oxford: Oxford University Press, 1994).

OR' for 'Orchestrated Objective Reduction,' which they suggest could link microtubules to consciousness.[45]

One prominent criticism of this approach concerns the argument to show that consciousness in non-computable, which is based on Gödel's incompleteness theorem.[46] Regardless, from a technical point of view, it has been argued that the types of states needed in this approach could not be physically realized in microtubules, because they could not stay isolated from their environment for the required amount of time.[47] More important, I think, is the problem that this approach does not seem to solve the hard problem, as the Penrose and Hameroff account appears to be perfectly compatible with physicalism.[48] Everything seems to rests on the non-computability of consciousness, as if it is not computable, then it is not describable objectively. However, even granting that, it seems unclear what this has to do with subjectivity, since one can imagine something being non-algorithmic without describing someone's subjective point of view. While Hameroff seems optimistic about the ability of his approach to describe consciousness, as he argues that Orch-OR can accommodate for free will,[49] Penrose is instead quite tentative in his speculation, asserting that he wants "to search, within scientific explanation, for some place where subjective experience might find a physical home" and admitting that he has not found it yet.[50]

Another quantum approach to consciousness was developed by Bohm. As discussed in Section 3.2, in the pilot-wave theory proposed by Bohm the motion of particles is guided by the wavefunction. One would think therefore that the wavefunction is a physical wave. However, the consequence of this is that in many-particle systems this wave lives in a $3N$-dimensional space, where N is the number of particles in the system, and thus the world itself is high dimensional. This, together with quantum nonlocality, was one of the factors which led Bohm to the idea that particles should be taken as

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[45] Stuart Hameroff, and Roger Penrose, "Orchestrated Reduction of Quantum Coherence in Brain Microtubules: a Model for Consciousness," Journal of Consciousness Studies 3 (1996): 36-53.

[46] Penrose's argument was anticipated by John S. Lucas "Mind, Machines and Gödel," *Philosophy*, XXXVI (1961): 112-127; and has been criticized by David K. Lewis "*Lucas against Mechanism*," Philosophy vol. 44 (1969): 231–233 and by Hilary Putnam (1926-2016), "Review of Roger Penrose, Shadows of the Mind," *New York Times Book Review*, November 20, (1994): 7 among others.

[47] Max Tegmark, "Importance of Quantum Decoherence in Brain Process," *Physical Review* E61 (2000): 4194-4206. See Scott Hagen, Stuart, Hameroff, Jack Adam Tuszynski, (2002), "Quantum Computation in Brain Microtules: Decoherence and Biological Feasibility," *Physical Review* E65 (2002): 061901-1 – 061901-11 for a reply which challenges Tegmark's assumptions.

[48] See also Jeremy Butterfield, "Quantum Curiosities of Psychophysics," In *Consciousness and Human Identity*, John Cornwell, ed. (Oxford: Oxford University Press, 1997).

[49] Stuart Hameroff, "How Quantum Brain Biology Can Rescue Conscious Free Will." *Frontiers in Integrative Neuroscience*, 6 (2012): 1-17.

[50] Roger Penrose *Shadow of the Mind*, p. 406

three-dimensional 'projections' of a 3N-dimensional, deeper, reality.[51] He distinguishes between an implicate and an explicate order. The explicate order is what we perceive, while the implicate order is the inaccessible ontic level. As in his reading of the pilot-wave theory particles and waves are the manifestation of a deeper order, the physical and the mental aspects of reality belong to the explicate order and they emerge (by explication, or unfoldment) from an undivided neutral implicate (or enfolded) order.[52] The totality of the movement of enfoldment and unfoldment is a process called 'holomovement,' to refer to the idea that information is nonlocally distributed, like in a hologram. This view seems compatible with a dual aspect approach[53] which, in contrast with the Pauli-Jung conjecture, is fundamentally dynamical in a Whiteheadian sense. Basil Hiley further developed Bohm's approach in a formal way, using algebraic structures to model a pre-space and a pre-time of the implicate order.[54]

This view suffers from problems similar to the ones of the approaches based on the orthodox theory, as it breaks the causal closure of physics. Moreover, this view also relies on a particular reading of the pilot-wave theory in which the wavefunction is a physical entity. However, there are proposals that maintain that it is not necessary (or advisable, according to the proponents of this view) to take the wavefunction as physically real.[55] Be that as it may, there are other approaches with a physical wavefunction in which no holomovement or implicate order is required.[56] If so, the evidence for Bohm's proposal seems to disappear.

5. Conclusion

As we have seen, the arguments against physicalism suggested that we needed to revolutionize physics to accommodate consciousness, as it does not have any place in Newtonian mechanics. Quantum theory, with its paradigm shift which revolutionized

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[51] David Bohm, *Wholeness and the Implicate Order* (London: Routledge, 1980).

[52] David Bohm, "A New Theory of the Relationship of Mind and Matter," *Philosophical Psychology*, 3 (q990): 271–286; David Bohm and Basil Hiley, *The Undivided Universe* (London: Routledge, 1993.

[53] However, Bohm makes clear reference to panpsychism when he writes:" A rudimentary mind-like quality is present even at the level of particle physics." (David Bohm, "A New Theory of the Relationship of Mind and Matter," Philosophical Psychology, vol. 3 (1990): 271-286).

[54] Basil Hiley "Non-commutative Geometry, The Bohm Interpretation and the Mind-matter Relationship," by D. Dubois, ed., In *Computing Anticipatory Systems – CASYS 2000* (Berlin: Springer, 2001): 77-88.

[55] See Detelf Dürr, Sheldon Goldstein and Nino Zanghi, "Quantum Equilibrium and the Origin of Absolute Uncertainty," *Journal of Statistical Physics*, vol. 67 no. 5-6 (1992) 843–907; Valia Allori, Sheldon Goldstein, Roderich Tumulka and Nino Zanghí, "On the Common Structure of Bohmian Mechanics and the Ghirardi-Rimini-Weber Theory," *The British Journal for the Philosophy of Science*, vol. 59 no. 3 (2008), 353-389.

[56] See (e.g. Alyssa Ney, *Finding the World in the Wavefunction*(Oxford University Press, forthcoming); David Z. Albert, "Elementary Quantum Metaphysics," in James T. Cushing, Arthur Fine and Sheldon Goldstein, eds., *Bohmian Mechanics and Quantum Theory: An Appraisal* (Kluwer Academic Publishers, 1996), 277-284.

the traditional scientific understanding as well as the traditional distinctions between observer and observed and between parts and whole, was naturally taken as the right place to try to accommodate consciousness in a scientific framework. As we have seen, various features of the theory were used as inspirations. First, the wavefunction collapse was used by Stapp to argue that, while Newtonian mechanics does not leave room for consciousness, quantum mechanics requires it. From a different perspective, Penrose suggested that a collapse caused by gravity could account for the non-computability of knowledge. Moreover, the randomness of the theory was taken by Stapp and also by Hameroff to help accommodate free will. Entanglement and nonlocaltity played a crucial role in the understanding the holistic character of consciousness as well as other mental states involving memories in the approach of Umezawa and collaborators, Bohm, and Pauli and Jung. The collective behavior described by quantum collective excitations has been connected to memories by Vitiello and Freeman. Pauli and Jung were inspired by the wave-particle complementarity, while Bohm was influenced by the high dimensionality of the wavefunction.

While all these approaches can be seen as following the tradition of a World-soul, and they provide new excited venues in constructing a unified theory of mind and matter, at the same time they face the problem that now physics is no longer complete, and thus, no longer successful. One could maintain that we would have to accept these theories if they were unavoidable: if it were not possible in principle to formulate a quantum theory independent of consciousness, then one presumably would have no choice but to consider a unified theory of mind and matter. However, in the quantum theories discussed in Section 3.2 consciousness remains separated from physics, and this allows physics to progress independently. *Divide et impera* strategies suggest that it is more efficient to face problems divided rather than united: consider quantum mechanics and solve its problems first, then move on to consciousness. Nonetheless, presumably a World-soul theories and a panpsychist would reply that this physicalist approach has no hope of solving the hard problem, for the reasons we saw, and that it was indeed the insistence of Newtonian mechanics on eliminating the mind from science that led to the current impasse, which can be overcome only if we completely rethink what science is.[57] Accordingly, I think that the quantum approaches to consciousness discussed in this chapter should be further explored, even if they currently are speculative and seem to put scientific progress momentarily on hold, as they provide the only route to advance further our understanding of nature in its entirety. In this way, one can say that the concept of World-soul, with qualifications, is not only viable but also scientifically supported.

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[57] Philip Goff, *Consciousness and Fundamental Reality* (Oxford University Press, 2017); Philip Goff, *Galileo's Error: Foundations for a New Science of Consciousness* (Pantheon, 2019).