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Does consciousness really collapse the wave function?: A possible objective biophysical resolution of the measurement problem

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Abstract

An analysis has been performed of the theories and postulates advanced by von Neumann, London and Bauer, and Wigner, concerning the role that consciousness might play in the collapse of the wave function, which has become known as the measurement problem. This reveals that an error may have been made by them in the area of biology and its interface with quantum mechanics when they called for the reduction of any superposition states in the brain through the mind or consciousness. Many years later Wigner changed his mind to reflect a simpler and more realistic objective position which appears to offer a way to resolve this issue. The argument is therefore made that the wave function of any superposed photon state or states is always objectively and stochastically changed within the complex architecture of the eye in a continuous linear process *initially* for most of the superposed photons, followed by a discontinuous nonlinear collapse process *later* for any remaining superposed photons, thereby guaranteeing that only final, measured information is presented to the brain, mind or consciousness. An experiment to be conducted in the near future may enable us to simultaneously resolve the measurement problem and also determine if the linear nature of quantum mechanics is violated by the perceptual process.

Introduction

What is the measurement problem and why is the act of measurement deemed so important in quantum mechanics that it has engendered such spirited discussion for over seven decades? The measurement problem can be approached in the following fashion. von Neumann (1932) advanced the theory that the possible states of a system can be characterized by state vectors, also known as wave functions, which change in two ways: continuously in a linear fashion as a result of a passage of time, as per Schrödinger's equation and, discontinuously if a measurement is carried out on the system (Wigner, 1961, Shimony, 1963). This second type of discontinuous change, called the reduction of the state vector or collapse of the wave function, is unacceptable to many physicists. The measurement problem can then be posed as how and when does the wave function collapse or, how does a state reduction to one of the eigenstates of the measured observable occur.

von Neumann (1932) was the first one to conceive this problem in terms of what is known as the 'von Neumann chain' (Esfeld, 1999). He starts with a quantum object, an observable of which is to be measured. However, based on the formalism of quantum theory and the Schrödinger dynamics in particular, as a result of the interaction between the object and the measuring instrument, the object is entangled with the instrument. von Neumann extends this chain up to an observer but, if we take an observer into consideration, we simply end up with a description according to which the body of the observer, including his or her brain, is entangled with the instrument and the object. The measurement problem can then be further refined as to how it is that a state reduction to one of the eigenstates of the measured observable can occur in this chain (Esfeld, 1999). von Neumann showed that as far as final results are concerned, you can cut the chain and insert a collapse anywhere you please (Herbert, 1985). He felt that the process by which a physical signal in the brain becomes an experience in the human mind or human consciousness, is the site of the wave function collapse.

London and Bauer (1939) have postulated that consciousness randomly selects one product state out of the superposition of product states, thereby effecting a state reduction. Wigner (1961) feels that consciousness or the mind, plays a more directly physical role, adding an extra term to the mathematical equations and hence, selecting one particular branch of the wave function and one particular result for the experiment, thus producing the effect that von Neumann called collapse. They feel therefore, that this is a subjective rather than an objective process. Like von Neumann and, London and Bauer before him, Wigner did not give many details to back up his idea (Whitaker, 1996, p. 201; Esfeld, 1999). Wigner readily concedes that we do not have at our disposal a description of how a state reduction is effected by consciousness. He goes on further to state, with remarkable candor that, “We are facing here the perennial question, whether we physicists do not go beyond our competence when searching for philosophical truth. I believe that we probably do” (Wigner, 1963).

He suggests that the dynamics of quantum theory has to be modified in such a way that events of state reduction by consciousness are taken into account (Wigner, 1963). And, he further feels that the equations of motion of quantum mechanics cease to be linear, in fact they are grossly nonlinear if conscious beings enter the picture.

Shimony (1963) feels that the conceptual problems of quantum mechanics will be resolved by discovering corrections to the physical theory itself, for example, by finding that the time-dependent Schrödinger equation is only an approximation to an exact nonlinear equation governing the evolution of the state of a system. If this proves to be true, then he advances the theory that the reduction of a superposition could perhaps occur when the microscopic system interacts with the macroscopic apparatus, and no appeal to the consciousness of an observer for this purpose would be required.

In his later years Wigner changed his position to an exactly opposite viewpoint, in order to avoid solipsism and the role that consciousness plays, closely mirroring that postulated by Shimony (Mehra, 1995, p. 593). Wigner considered it to be necessary to admit state reductions independently of an observer's consciousness, and makes a concrete suggestion for an amendment of the Schrödinger equation which is intended to describe a physical process of state reduction (Mehra, 1995, pp. 73, 230). A state reduction is now felt by Wigner to occur as an *objective* event in the physical realm before the von Neumann chain reaches the consciousness of an observer (Mehra, 1995, pp. 75–77, 242–243; Esfeld, 1999).

It is of historic interest to note here that Dirac (1930), who invented the idea of wave function collapse, said that it is *nature* that makes the choice of measuremental result; once made the choice is ‘irreversible and will affect the entire future state of the world’ (Kragh, 1990).

It is felt by the author that Shimony and Wigner are pointing us in a direction which may finally lead to a resolution of the measurement problem through a cooperative blending of certain philosophical, theoretical and empirical aspects in the realms of quantum mechanics and biology, with emphasis on the eye in the role of a *living* macroscopic measuring instrument, serving to terminate the von Neumann chain in an objective discontinuous nonlinear fashion.

The eye as a macroscopic apparatus and its possible role in resolving the measurement problem

One can more readily grasp the essentials of the measurement problem from a biological viewpoint by studying the diagram of the visual pathways in primates in Fig. 1 (Dowling, 1987). Visual information from the eyes in the form of retinal ganglion cell spike trains passes, via the optic nerve, to the lateral geniculate nucleus and is relayed from there via the optic radiation to the visual cortex. In primates the eyes face forward and the visual fields of each eye overlap. Information from the

Can *Euglena* collapse the wave function?

I would now like to address the issue as to whether humans alone can collapse the wave function, since there is such a wide range of both vertebrates and invertebrates, all of whom preceded us on this planet, possessing varying degrees and types of vision processes from which our eye evolved (Wolken, 1967). As regards their degree of consciousness or if they can be considered sentient, I have attempted to deal with this in a very limited fashion in a previous paper (Thaheld, 2004) and this

Proposed Ghirardi superposed photon-retinal tissue experiment

It is anticipated that sometime in the near future an experiment will be conducted at the Univ. of Milan utilizing retinal tissue mounted on a microelectrode array and, superposed single photon states to test Ghirardi's theory (Ghirardi, 1999), as to whether these states collapse in the visual cortex of an observer (Thaheld, 2000, Thaheld, 2003). This retinal tissue will have its outer elements such as the sclera, pigment epithelium and the inner limiting membrane removed (Meister et al., 1994

The “many worlds” interpretation of the measurement problem: can biophysics tell us something about quantum cosmology?

There is another approach to dealing with the measurement problem, popularly known as the “*many worlds interpretation*”. According to Everett, 1957, Shimony, 1963 the measurement problem can be solved at one stroke by simply assuming that *no collapse or state reduction ever takes place*. The whole issue of the transition from ‘possible’ to ‘actual’ is taken care of in his theory in a very simple way, *there is no such transition*. If there is no collapse this means that we do not need von Neumann's

Discussion

If the theory advanced in this paper is correct, we will have been successful in moving the previous site for wave function collapse out of the brain and mind or consciousness (what is known as the subjective), some 17 cm *back* from the visual cortex to the eye. It is at this point that we can consider two different types of objective wave function changes to take place in a sequential fashion, continuous and linear in the first phase and discontinuous and nonlinear in the second phase. The

Conclusion

It is interesting to note that von Neumann, London and Bauer, and Wigner were able to come up with such definite pronouncements on this subject of measurement, which is built upon what appears to be a shaky foundation of brain, mind and consciousness. One is also struck by the fact that none of these mathematicians or physicists had any real grounding in biology or psychology and yet, when they encountered this problem, they turned to the brain, mind and consciousness in an attempt to arrive at

Groundbreaking Study Affirms Quantum Basis for Consciousness: A Paradigm Shift in Understanding Human Nature

BY STACEY SCHMEIDEL, WELLESLEY COLLEGESEPTEMBER 14, 202440 COMMENTS3 MINS READ
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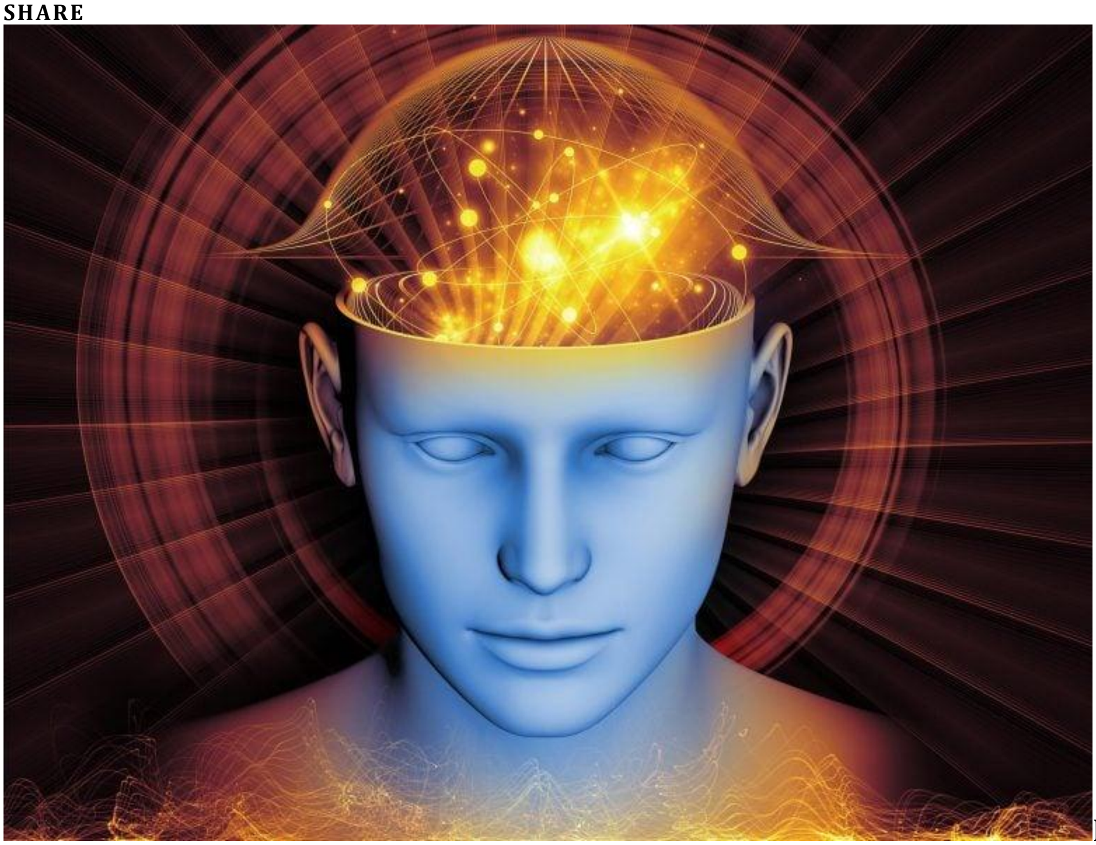

New research indicates that anesthesia's effectiveness via microtubule interaction supports a quantum theory of consciousness, potentially transforming neuroscientific approaches and treatments.

A groundbreaking study has provided experimental evidence suggesting a quantum basis for consciousness.

By demonstrating that drugs affecting microtubules within neurons delay the onset of unconsciousness caused by anesthetic gases, the study supports the quantum model over traditional classical physics theories. This quantum perspective could revolutionize our understanding of consciousness and its broader implications, potentially impacting the treatment of mental illnesses and our understanding of human connection to the universe.

Exploring the Quantum Basis of Consciousness

For decades, one of the most fundamental and vexing questions in neuroscience has been: what is the physical basis of consciousness in the brain? Most researchers favor classical models, based on classical physics, while a minority have argued that consciousness must be quantum in nature, and that its brain basis is a collective quantum vibration of "microtubule" proteins inside neurons.

New research by Wellesley College professor Mike Wiest and a group of Wellesley College undergraduate students has yielded important experimental results relevant to this debate, by examining how anesthesia affects the brain. Wiest and his research team found that when they gave rats a drug that binds to microtubules, it took the rats significantly longer to fall unconscious under an anesthetic gas. The research team's microtubule-binding drug interfered with the anesthetic action, thus supporting the idea that the anesthetic acts on microtubules to cause unconsciousness.

"Since we don't know of another (i.e,. classical) way that anesthetic binding to microtubules would generally reduce brain activity and cause unconsciousness," Wiest says, "this finding supports the quantum model of consciousness."

Implications for the Future of Neuroscience

It's hard to overstate the significance of the classical/quantum debate about consciousness, says Wiest, an associate professor of neuroscience at Wellesley. "When it becomes accepted that the mind is a quantum phenomenon, we will have entered a new era in our understanding of what we are," he says. The new approach "would lead to improved understanding of how anesthesia works, and it would shape our thinking about a wide variety of related questions, such as whether coma patients or non-human animals are conscious, how mysterious drugs like lithium modulate conscious experience to stabilize mood, how diseases like Alzheimer's or schizophrenia affect perception and memory, and so on."

More broadly, a quantum understanding of consciousness "gives us a world picture in which we can be connected to the universe in a more natural and holistic way," Wiest says.

Wiest plans to pursue future research in this field, and hopes to explain and explore the quantum consciousness theory in a book for a general audience.

Broader Research Impact

Wellesley students who co-authored the paper with Wiest are Sana Khan ’25, Yixiang Huang ’25, Derin Timucin ’27, Shantelle Bailey ’24, Sophia Lee ’23, Jessica Lopes ’26, Emeline Gaunce ’26, Jasmine Mosberger ’25, Michelle Zhan ’24, Bothina Abdelrahman ’26 and Xiran Zeng ’27. Published on September 1 in the journal *eNeuro*, the Wellesley study demonstrates that anesthesia works by binding to microtubules inside neurons, thus providing important evidence for a quantum theory of consciousness while reviving a focus on microtubules in anesthesia.

eNeuro is the Society for Neuroscience’s open-access journal.

Reference: “Microtubule-Stabilizer Epothilone B Delays Anesthetic-Induced Unconsciousness in Rats” by Sana Khan, Yixiang Huang, Derin Timuçin, Shantelle Bailey, Sophia Lee, Jessica Lopes, Emeline Gaunce, Jasmine Mosberger, Michelle Zhan, Bothina Abdelrahman, Xiran Zeng and Michael C. Wiest, 15 August 2024, *eNeuro*.
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CAN QUANTUM PHYSICS, NEUROSCIENCE MERGE AS QUANTUM CONSCIOUSNESS?

Physicist and astronomer Marcelo Gleiser offers some thoughts as to the light that quantum mechanics — as opposed to classical physics — can shed on consciousness. The problem, he thinks, is that both quantum mechanics and consciousness are mysteries. Adding two mysteries together doesn’t produce simple answers:
The truth is that despite the tremendous success of quantum physics when it comes to its applications — the digital and nuclear technologies that define much of modern life — its interpretation remains uncertain, a target of heated debate among physicists. We know how to use quantum physics, but we do not know what it is telling us about the nature of reality.
It’s the same with the brain and the mind:

In a nutshell, the issue here is that tagging neuronal activity is the easy part of the task. The hard part is understanding how active neurons conspire to create the sense of who we are — that is, translating bioelectrical activity and blood flow into self-awareness.
MARCELO GLEISER, "CAN QUANTUM MECHANICS EXPLAIN CONSCIOUSNESS?" AT *BIG THINK* (NOVEMBER 24, 2021)
Indeed. For example, in a recent discussion, neuropsychologist Mark Solms and neurosurgeon Michael Egnor agreed that, while neuroscientists tend to see the prefrontal cortex of the human brain as the seat of consciousness, clinical experience points to portions of the brain stem. But where does that leave us? Vertebrates of widely varying degrees of intelligence or self-awareness have brain stems.
Physicist (and Nobelist) Roger Penrose and anaesthesiologist Stuart Hameroff offer a model of consciousness from quantum mechanics: Gleiser poses it as a question, "Could thoughts exist in some sort of quantum superposition in an unconscious level only to become conscious when there is a specific selection — akin to a measurement of the electron's position?" (explained in detail here). They see the protein *tubulin,* which forms the microtubules that make up the skeleton of neurons as a enabling the entangled quantum states the force a choice.
He also hat tips Giulio Tononi and Christof Koch's Integrated Information Theory (IIT), which likewise incorporates "quantum vibrations in microtubules." Quantum entanglement between electrons in the neurons might mean that contact can be maintained over considerable distances because two entagled particle will act together even when separated.
Sharp criticism of these hypotheses, he notes, includes the concern that the brain is too "busy and warm" *(Max Tegmark)* for anything but classical physics.
That said, we can be fairly certain that classical physics doesn't account for consciousness either. Gleiser suggests that there co-operation between quantum and classical physics, depending on the level, may be part of the explanation. Then he closes with an interesting admission:
Whatever the resolution may be, we still do not know how to avoid the arguments from the Mysterians. The nature of consciousness could be one of those "unknowables" that many people will find very hard to live with. I, for one, embrace it. This unknowability may well be what will rescue what is left of our humanity from the unstoppable mechanization and objectification of modern existence.
MARCELO GLEISER, "CAN QUANTUM MECHANICS EXPLAIN CONSCIOUSNESS?" AT *BIG THINK* (NOVEMBER 24, 2021)
By the *Mysterians,* he means philosophers like Thomas Nagel (what is it like to be a bat?), Colin McGinn ("we are not equipped to understand the workings of conciousness, despite its objective naturalness") and David Chalmers (the Hard Problem of Consciousness). They argue that "although we know that the conscious

mind is nothing more than the brain, it is simply beyond the conceptual apparatus of human beings to understand how this can be the case." *(Britannica)*
Such an answer raises further questions: If "the conscious mind is nothing more than the brain," then we won't understand it. to understand it, we must look beneath it and there is nothing beneath it.
But how do we know that? We don't, actually. All we know is that efforts to understand the mind as merely what the brain does have not proven useful.
If we assume that the mind is *not* merely what the brain does, we have some reasonable hope of understanding it further. That's where quantum physics may shed some light. It may provide, for example, a point of intersection between mind and brain — but there is no reason to think that that's a full answer.

Wave function collapse

In quantum mechanics, **wave function collapse**, also called **reduction of the state vector**,[1] occurs when a wave function—initially in a superposition of several eigenstates—reduces to a single eigenstate due to interaction with the external world. This interaction is called an *observation* and is the essence of a measurement in quantum mechanics, which connects the wave function with classical observables such as position and momentum. Collapse is one of the two processes by which quantum systems evolve in time; the other is the continuous evolution governed by the Schrödinger equation.[2]

While standard quantum mechanics postulates wave function collapse to connect quantum to classical models, some extension theories propose physical processes that cause collapse. The in depth study of quantum decoherence has proposed that collapse is related to the interaction of a quantum system with its environment.

Historically, Werner Heisenberg was the first to use the idea of wave function reduction to explain quantum measurement.[3][4]

Mathematical description

For an explanation of the notation used, see Bra–ket notation. For details on this formalism, see Quantum state.

In quantum mechanics each measurable physical quantity of a quantum system is called an observable which, for example, could be the position and the momentum but also energy , components of spin ( ), and so on. The observable acts as a linear function on the states of the system; its eigenvectors correspond to the quantum state (i.e. eigenstate) and the eigenvalues to the possible values of the observable. The collection of eigenstates/eigenvalue pairs represent all possible values of the observable. Writing for an eigenstate and for the corresponding observed value, any arbitrary state of the quantum system can be

expressed as a vector using bra–ket notation: The kets specify the different available quantum "alternatives", i.e., particular quantum states.

The wave function is a specific representation of a quantum state. Wave functions can therefore always be expressed as eigenstates of an observable though the converse is not necessarily true.

Collapse

To account for the experimental result that repeated measurements of a quantum system give the same results, the theory postulates a "collapse" or "reduction of the state vector" upon observation,[5]:566 abruptly converting an arbitrary state into a single component eigenstate of the observable:

where the arrow represents a measurement of the observable corresponding to

the basis.[6] For any single event, only one eigenvalue is measured, chosen randomly from among the possible values.

Meaning of the expansion coefficients

The complex coefficients in the expansion of a quantum state in terms of

eigenstates , can be written as an (complex) overlap of the corresponding

eigenstate and the quantum state: They are called the probability amplitudes.

The square modulus is the probability that a measurement of the observable

yields the eigenstate . The sum of the probability over all possible outcomes must be one:[7]

As examples, individual counts in a double slit experiment with electrons appear at random locations on the detector; after many counts are summed the distribution shows a wave interference pattern.[8] In a Stern-Gerlach experiment with silver atoms, each particle appears in one of two areas unpredictably, but the final conclusion has equal numbers of events in each area.

This statistical aspect of quantum measurements differs fundamentally from classical mechanics. In quantum mechanics the only information we have about a system is its wave function and measurements of its wave function can only give statistical information.[5]:17

Terminology

The two terms "reduction of the state vector" (or "state reduction" for short) and "wave function collapse" are used to describe the same concept. A quantum state is a mathematical description of a quantum system; a quantum state vector uses Hilbert space vectors for the description.[9]:159 Reduction of the state vector replaces the full state vector with a single eigenstate of the observable.

The term "wave function" is typically used for a different mathematical representation of the quantum state, one that uses spatial coordinates also called the "position representation".[9]:324 When the wave function representation is used, the "reduction" is called "wave function collapse".

The measurement problem

The Schrödinger equation describes quantum systems but does not describe their measurement. Solution to the equations include all possible observable values for measurements, but measurements only result in one definite outcome. This difference is called the measurement problem of quantum mechanics. To predict measurement outcomes from quantum solutions, the orthodox interpretation of quantum theory postulates wave function collapse and uses the Born rule to compute the probable outcomes.[10] Despite the widespread quantitative success of these postulates scientists remain dissatisfied and have sought more detailed physical models. Rather than suspending the Schrödinger equation during the process of measurement, the measurement apparatus should be included and governed by the laws of quantum mechanics.[11]:127

Physical approaches to collapse

Quantum theory offers no dynamical description of the "collapse" of the wave function. Viewed as a statistical theory, no description is expected. As Fuchs and Peres put it, "collapse is something that happens in our description of the system, not to the system itself".[12]

Various interpretations of quantum mechanics attempt to provide a physical model for collapse.[13]:816 Three treatments of collapse can be found among the common interpretations. The first group includes hidden-variable theories like de Broglie–Bohm theory; here random outcomes only result from unknown values of hidden variables. Results from tests of Bell's theorem shows that these variables would need to be non-local. The second group models measurement as quantum entanglement between the quantum state and the measurement apparatus. This results in a simulation of classical statistics called quantum decoherence. This group includes the many-worlds interpretation and consistent histories models. The third group postulates additional, but as yet undetected, physical basis for the randomness; this group includes for example the objective-collapse interpretations. While models in all groups have contributed to better understanding of quantum theory, no alternative explanation for individual events has emerged as more useful than collapse followed by statistical prediction with the Born rule.[13]:819

The significance ascribed to the wave function varies from interpretation to interpretation and even within an interpretation (such as the Copenhagen interpretation). If the wave function merely encodes an observer's knowledge of the universe, then the wave function collapse corresponds to the receipt of new information. This is somewhat analogous to the situation in classical physics, except that the classical "wave function" does not necessarily obey a wave equation. If the wave function is physically real, in some sense and to some extent, then the collapse of the wave function is also seen as a real process, to the same extent.[*citation needed*]

Quantum decoherence

Main article: Quantum decoherence

Quantum decoherence explains why a system interacting with an environment transitions from being a pure state, exhibiting superpositions, to a mixed state, an incoherent combination of classical alternatives.[14] This transition is fundamentally reversible, as the combined state of system and environment is still pure, but for all practical purposes irreversible in the same sense as in the second law of thermodynamics: the environment is a very large and complex quantum system, and it is not feasible to reverse their interaction. Decoherence is thus very important for explaining the classical limit of quantum mechanics, but cannot explain wave function collapse, as all classical alternatives are still present in the mixed state, and wave function collapse selects only one of them.[15][16][14]

The form of decoherence known as environment-induced superselection proposes that when a quantum system interacts with the environment, the superpositions *apparently* reduce to mixtures of classical alternatives. The combined wave function of the system and environment continue to obey the Schrödinger equation throughout this *apparent* collapse.[17] More importantly, this is not enough to explain *actual* wave function collapse, as decoherence does not reduce it to a single eigenstate.[15][14]

History

The concept of wavefunction collapse was introduced by Werner Heisenberg in his 1927 paper on the uncertainty principle, "Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik", and incorporated into the mathematical formulation of quantum mechanics by John von Neumann, in his 1932 treatise *Mathematische Grundlagen der*

Quantenmechanik.[4] Heisenberg did not try to specify exactly what the collapse of the wavefunction meant. However, he emphasized that it should not be understood as a physical process.[18] Niels Bohr never mentions wave function collapse in his published work, but he repeatedly cautioned that we must give up a "pictorial representation". Despite the differences between Bohr and Heisenberg, their views are often grouped together as the "Copenhagen interpretation", of which wave function collapse is regarded as a key feature.[19]

John von Neumann's influential 1932 work *Mathematical Foundations of Quantum Mechanics* took a more formal approach, developing an "ideal" measurement scheme[20][21]: 1270 that postulated that there were two processes of wave function change:

1. The probabilistic, non-unitary, non-local, discontinuous change brought about by observation and measurement (state reduction or collapse).
2. The deterministic, unitary, continuous time evolution of an isolated system that obeys the Schrödinger equation.

In 1957 Hugh Everett III proposed a model of quantum mechanics that dropped von Neumann's first postulate. Everett observed that the measurement apparatus was also a quantum system and its quantum interaction with the system under observation should determine the results. He proposed that the discontinuous change is instead a splitting of a wave function representing the universe.[21]: 1288 While Everett's approach rekindled interest in foundational quantum mechanics, it left core issues unresolved. Two key issues relate to origin of the observed classical results: what causes quantum systems to appear classical and to resolve with the observed probabilities of the Born rule.[21]: 1290[20]: 5

Beginning in 1970 H. Dieter Zeh sought a detailed quantum decoherence model for the discontinuous change without postulating collapse. Further work by Wojciech H. Zurek in 1980 lead eventually to a large number of papers on many aspects of the concept.[22] Decoherence assumes that every quantum system interacts quantum mechanically with its environment and such interaction is not separable from the system, a concept called an "open system".[21]: 1273 Decoherence has been shown to work very quickly and within a minimal environment, but as yet it has not succeeded in a providing a detailed model replacing the collapse postulate of orthodox quantum mechanics.[21]: 1302

By explicitly dealing with the interaction of object and measuring instrument, von Neumann[2] described a quantum mechanical measurement scheme consistent with wave function collapse. However, he did not prove the *necessity* of such a collapse. Von Neumann's projection postulate was conceived based on experimental evidence available during the 1930s, in particular Compton scattering. Later work refined the notion of measurements into the more easily discussed *first kind*, that will give the same value when immediately repeated, and the *second kind* that give different values when repeated.[23][24][25]

Physicists explain how the brain might connect to the quantum realm

Down the rabbit hole ...
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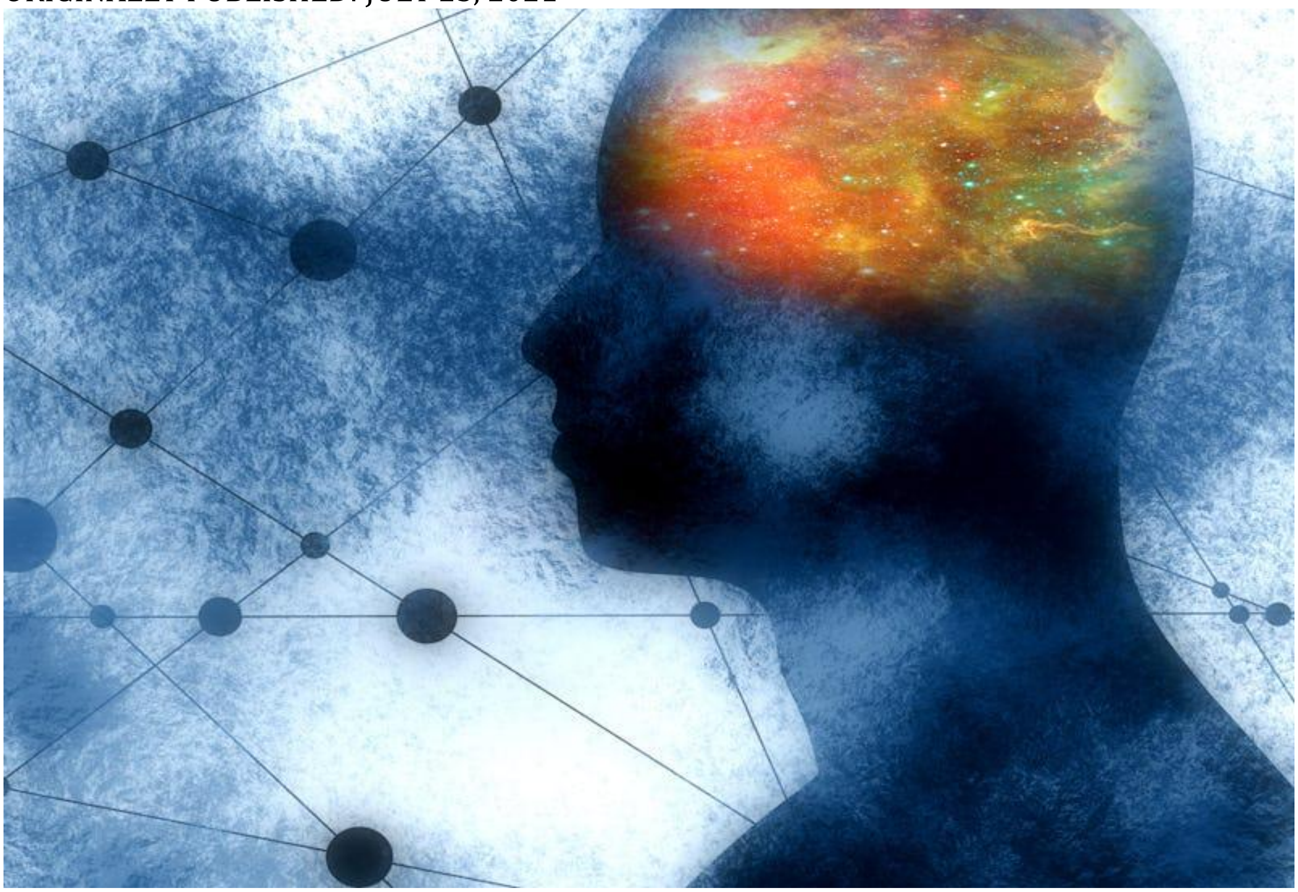

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One of the most important open questions in science is how our consciousness is established. In the 1990s, long before winning the 2020 Nobel Prize in Physics for his prediction of black holes, physicist Roger Penrose teamed up with anesthesiologist Stuart Hameroff to propose an ambitious answer.

They claimed that the brain's neuronal system forms an intricate network and that the consciousness this produces should obey the rules of quantum mechanics — the theory that determines how tiny particles like electrons move around. This, they argue, could explain the mysterious complexity of human consciousness.

Penrose and Hameroff were met with incredulity. Quantum mechanical laws are usually only found to apply at very low temperatures. Quantum computers, for example, currently operate at around -272°C. At higher temperatures, classical mechanics takes over.

Since our body works at room temperature, you would expect it to be governed by the classical laws of physics. For this reason, the quantum consciousness theory has been dismissed outright by many scientists — though others are persuaded supporters.

Instead of entering into this debate, I decided to join forces with colleagues from China, led by Professor Xian-Min Jin at Shanghai Jiaotong University, to test some of the principles underpinning the quantum theory of consciousness.

In our new paper, we've investigated how quantum particles could move in a complex structure like the brain – but in a lab setting. If our findings can one day be compared with activity measured in the brain, we may come one step closer to validating or dismissing Penrose and Hameroff's controversial theory.

Brains and fractals

Our brains are composed of cells called neurons, and their combined activity is believed to generate consciousness. Each neuron contains microtubules, which transport substances to different parts of the cell. The Penrose-Hameroff theory of quantum consciousness argues that microtubules are structured in a fractal pattern which would enable quantum processes to occur.

Fractals are structures that are neither two-dimensional nor three-dimensional but are instead some fractional value in between. In mathematics, fractals emerge as beautiful patterns that repeat themselves infinitely, generating what is seemingly impossible: a structure that has a finite area, but an infinite perimeter.

This might sound impossible to visualize, but fractals actually occur frequently in nature. If you look closely at the florets of cauliflower or the branches of ferns, you'll see that they're both made up of the same basic shape repeating itself over and over again, but at smaller and smaller scales. That's a key characteristic of fractals.

The same happens if you look inside your own body: the structure of your lungs, for instance, is fractal, as are the blood vessels in your circulatory system. Fractals also feature in the enchanting repeating artworks of MC Escher and Jackson Pollock, and they've been used for decades in technology, such as in the design of antennas.

These are all examples of classical fractals — fractals that abide by the laws of classical physics rather than quantum physics.

This extension of Escher's Circle Limit III shows its fractal, repeating nature.
VLADIMIR-BULATOV/DEVIANTART

It's easy to see why fractals have been used to explain the complexity of human consciousness. Because they're infinitely intricate, allowing complexity to emerge from simple repeated patterns, they could be the structures that support the mysterious depths of our minds.

But if this is the case, it could only be happening on the quantum level, with tiny particles moving in fractal patterns within the brain's neurons. That's why Penrose and Hameroff's proposal is called a theory of "quantum consciousness".

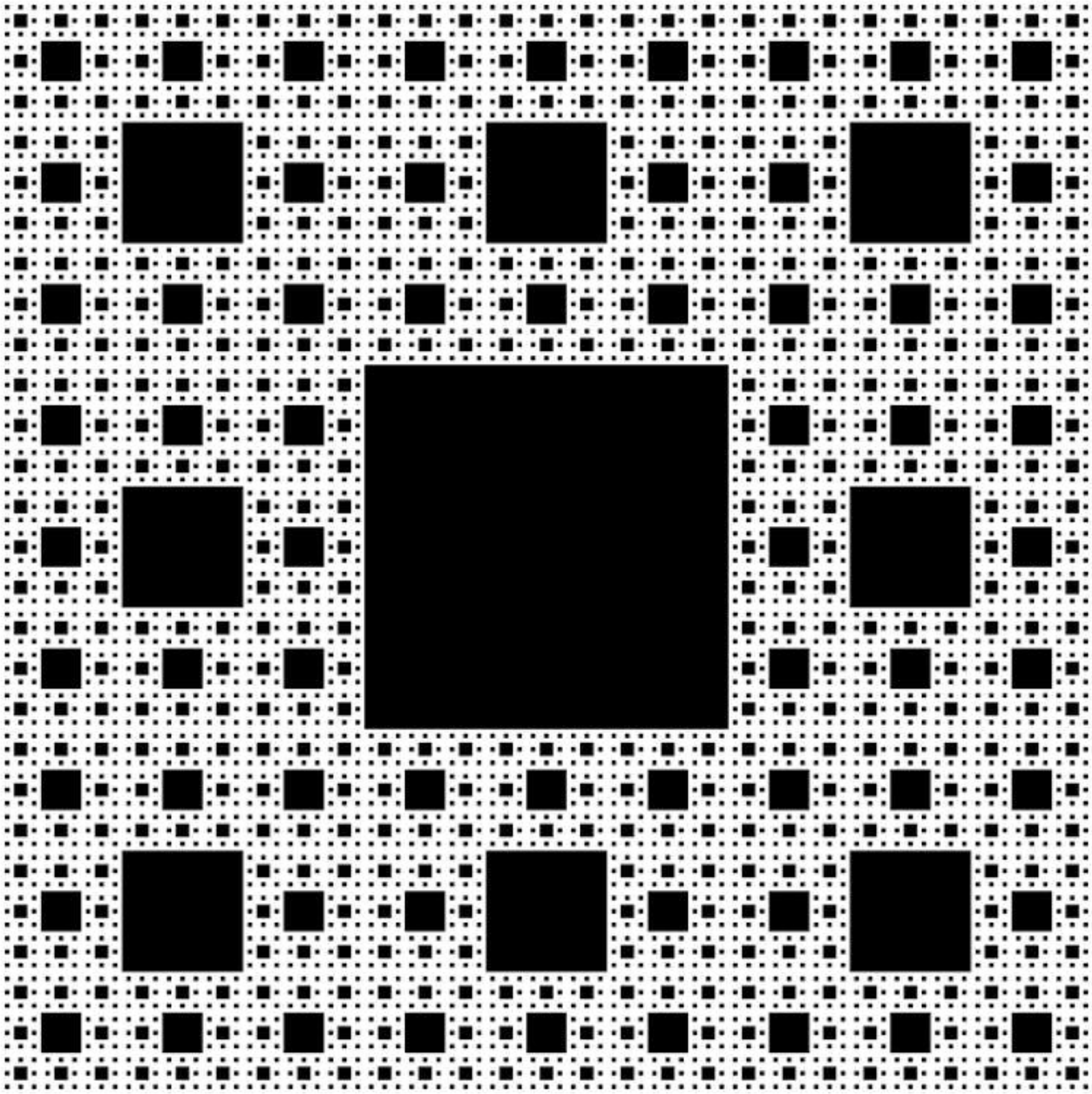
Quantum consciousness

We're not yet able to measure the behavior of quantum fractals in the brain — if they exist at all. But advanced technology means we can now measure quantum fractals in the lab. In recent research involving a scanning tunneling microscope (STM), my colleagues at Utrecht and I carefully arranged electrons in a fractal pattern, creating a quantum fractal.

When we then measured the wave function of the electrons, which describes their quantum state, we found that they too lived at the fractal dimension dictated by the physical pattern we'd made. In this case, the pattern we used on the quantum scale was the Sierpiński triangle, which is a shape that's somewhere between one-dimensional and two-dimensional.

This was an exciting finding, but STM techniques cannot probe how quantum particles move – which would tell us more about how quantum processes might occur in the brain. So in our latest research, my colleagues at Shanghai Jiaotong University and I went one step further. Using state-of-the-art photonics experiments, we were able to reveal the quantum motion that takes place within fractals in unprecedented detail.

We achieved this by injecting photons (particles of light) into an artificial chip that was painstakingly engineered into a tiny Sierpiński triangle. We injected photons at the tip of the triangle and watched how they spread throughout its fractal structure in a process called quantum transport. We then repeated this experiment on two different fractal structures, both shaped as squares rather than triangles. And in each of these structures, we conducted hundreds of experiments.


We also conducted experiments on a square-shaped fractal called the Sierpiński carpet.
JOHANNES RÖSSEL/WIKIMEDIA

Our observations from these experiments reveal that quantum fractals actually behave in a different way to classical ones. Specifically, we found that the spread of light across a fractal is governed by different laws in the quantum case compared to the classical case.

This new knowledge of quantum fractals could provide the foundations for scientists to experimentally test the theory of quantum consciousness. If quantum measurements are one day taken from the human brain, they could be compared against our results to definitely decide whether consciousness is a classical or a quantum phenomenon.

Our work could also have profound implications across scientific fields. By investigating quantum transport in our artificially designed fractal structures, we may have taken the first tiny steps towards the unification of physics, mathematics, and biology, which could greatly enrich our understanding of the world around us as well as the world that exists in our heads.

Quantum Approaches to Consciousness

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It is widely accepted that consciousness or, more generally, mental activity is in some way correlated to the behavior of the material brain. Since quantum theory is the most fundamental theory of matter that is currently available, it is a legitimate question to ask whether quantum theory can help us to understand consciousness. Several approaches answering this question affirmatively, proposed in recent decades, will be surveyed. There are three basic types of corresponding approaches: (1) consciousness is a manifestation of quantum processes in the brain, (2) quantum concepts are used to understand conscious mental activity without referring to brain activity, and (3) matter and consciousness are regarded as dual aspects of one underlying reality. Major contemporary variants of these quantum-inspired approaches will be discussed. It will be pointed out that they make different epistemological assumptions and use quantum theory in different ways. For each of the approaches discussed, both problematic and promising features will be highlighted.

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1. Introduction

The problem of how mind and matter are related to each other has many facets, and it can be approached from many different starting points. The historically leading disciplines in this respect are philosophy and psychology, which were later joined by behavioral science, cognitive science and neuroscience. In addition, the physics of complex systems and quantum physics have played stimulating roles in the discussion from their beginnings.

As regards the issue of complexity, this is evident: the brain is one of the most complex systems we know. The study of neural networks, their relation to the operation of single neurons and other important topics do and will profit a lot from complex systems approaches. As regards quantum physics, there can be no reasonable doubt that quantum events occur and are efficacious in the brain as elsewhere in the material world—including biological systems.[1] But it is controversial whether these events are efficacious and relevant for those aspects of brain activity that are correlated with mental activity.

The original motivation in the early 20th century for relating quantum theory to consciousness was essentially philosophical. It is fairly plausible that conscious free decisions ("free will") are problematic in a perfectly deterministic world,[2] so quantum randomness might indeed open up novel possibilities for free will. (On the other hand, randomness is problematic for goal-directed volition!)

Quantum theory introduced an element of randomness standing out against the previous deterministic worldview preceding it, in which randomness expresses our ignorance of a more detailed description (as in statistical mechanics). In sharp contrast to such epistemic randomness, quantum randomness in processes such as the spontaneous emission of light, radioactive decay, or other examples has been considered a fundamental feature of nature, independent of our ignorance or knowledge. To be precise, this feature refers to *individual* quantum events, whereas the behavior of *ensembles* of such events is *statistically* determined. The indeterminism of individual quantum events is constrained by statistical laws.

Other features of quantum theory, which became attractive in discussing issues of consciousness, were the concepts of complementarity and entanglement. Pioneers of quantum physics such as Planck, Bohr, Schrödinger, Pauli (and others) emphasized the various possible roles of quantum theory in reconsidering the old conflict between physical determinism and conscious free will. For informative overviews with different focal points see e.g., Squires (1990), Kane (1996), Butterfield (1998), Suarez and Adams (2013).

2. Philosophical Background Assumptions

Variants of the dichotomy between mind and matter range from their fundamental distinction at a primordial level of description to the emergence of mind (consciousness) from the brain as an extremely sophisticated and highly developed material system. Early overviews can be found in Popper and Eccles (1977), Chalmers (1996), and Pauen (2001).

One important aspect of all discussions about the relation between mind and matter is the distinction between *descriptive* and *explanatory* approaches. For instance, *correlation* is a descriptive term with empirical relevance, while *causation* is an explanatory term associated with theoretical attempts to understand correlations. Causation implies correlations between cause and effect, but this does not always apply the other way around: correlations between two systems can result from a common cause in their history rather than from a direct causal interaction. Moreover, correlations can be synchronic rather than diachronic, so the temporal distance that is presupposed by cause-effect relations is lacking altogether.

In the fundamental sciences, one typically speaks of causal relations in terms of interactions. In physics, for instance, there are four fundamental kinds of interactions (electromagnetic, weak, strong, gravitational) which serve to explain the correlations that are observed in physical systems. As regards the mind-matter problem, the situation is more difficult. Far from a theoretical understanding in this field, the existing body of knowledge essentially consists of empirical correlations between material and mental states. These correlations are synchronic, not diachronic; neither are mental states causally conditioned by brain states nor the other way around. It is (for some purposes) interesting to know *that* particular brain areas are activated during particular mental activities; but this does, of course, not explain *why* they are.

In many discussions of material [ma] brain states and mental [me] states of consciousness, the relations between them are conceived in a *direct* way (A):

[ma]←→[me][ma]⟵⟶[me]

The most popular approaches along these lines as far as quantum behavior of the brain is concerned will be discussed in Section 3, “Quantum Brain”.

The scheme (A) of direct relations between material and mental states sketches a minimal framework to study reduction, supervenience, or emergence relations (Kim 1998; Stephan 1999) which can yield both monistic and dualistic pictures. For instance, the idea of *strong* *reduction* assumes that all mental states and properties can be reduced to the material domain or even to physics. This point of view claims that it is both necessary and sufficient to explore and understand the material domain, e.g., the brain, in order to understand the mental domain, e.g., consciousness. It leads to a monistic picture, in which any need to discuss mental states is eliminated right away or at least considered as epiphenomenal. While mind-brain correlations are still legitimate though causally irrelevant from an epiphenomenalist point of view, eliminative materialism renders even correlations themselves irrelevant.

Counterarguments against the validity of such strongly reductive approaches are qualia arguments, emphasizing their impossibility to properly incorporate the quality of the subjective experience of a mental state, the “what it is like to be” (Nagel 1974) in that state. This leads to an explanatory gap between third-person and first-person accounts for which Chalmers (1995) has coined the notion of the “hard problem of consciousness”. Another, less discussed counterargument is that the physical domain itself is not causally closed. Any solution of fundamental equations of motion (be it experimentally, numerically, or analytically) requires to fix boundary conditions and initial conditions which are not given by the fundamental laws of nature (Primas 2002). This causal gap applies to classical physics as well as quantum physics, where a basic indeterminacy due to collapse makes it even more challenging. A third class of counterarguments refer to the difficulties to include notions of temporal present and nowness in a physical description (Franck 2004, 2008; Primas 2017).

However, relations between mental and material states can also be conceived in a non-reductive fashion, e.g. in terms of emergence relations (Stephan 1999). Mental states and/or properties can be considered as emergent if the material brain is not necessary or not sufficient to explore and understand them.[3] This leads to a dualistic picture (less radical and more plausible than Cartesian dualism) in which residua remain if one attempts to reduce the mental to the material. Within a dualistic scheme of thinking, it becomes inevitable to discuss the question of how mental and material states are related to one another. This topic has attracted growing interest under the notion of “downward causation” (Velmans 2002; Ellis *et al.* 2011). Since such causation would be synchronic rather than diachronic, a less controversial concept addressing this issue has been proposed in terms of “downward constraints” that mental states impose on brain states (Atmanspacher and beim Graben 2007).

It has been an old idea by Niels Bohr that central conceptual features of quantum theory, such as complementarity, are also of pivotal significance outside the domain of physics. In fact, Bohr became familiar with complementarity through the psychologist Edgar Rubin and, more indirectly, William James (Holton 1970) and immediately saw its potential for quantum physics. Although Bohr was convinced of the extraphysical relevance of complementarity, he never elaborated this idea in concrete detail, and for a long time after him no one else did so either. This situation has changed: there are now a number of research programs generalizing key notions of quantum theory in a way that makes them applicable beyond physics.

Of particular interest for consciousness studies are approaches that have been developed in order to pick up Bohr’s proposal with respect to psychology and cognitive science. The first steps in this direction were made by the group of Aerts in the early 1990s (Aerts *et al.* 1993), using non-distributive propositional lattices to address quantum-like behavior in non-classical systems. Alternative approaches have been initiated by Khrennikov (1999), focusing on non-classical probabilities, and Atmanspacher *et al.* (2002), outlining an algebraic framework with non-commuting operations. The recent development of ideas within this framework of thinking is addressed in Section 4, "Quantum Mind". Other lines of thinking are due to Primas (2007, 2017), addressing complementarity with partial Boolean algebras, and Filk and von Müller (2008), indicating links between basic conceptual categories in quantum physics and psychology.

As an alternative to (A), it is possible to conceive mind-matter relations *indirectly* **(B)**, via a third category:

[ma][me]↘↖↙↗[mame][ma][me]↘↖↙↗[mame]
This third category, here denoted [mame], is regarded as being neutral with respect to the distinction between [ma] and [me], i.e., psychophysically neutral. In scenario (B), issues of reduction and emergence concern the relation between the undivided "background reality" [mame] and the distinguished aspects [ma] and [me].

Such "dual-aspect" frameworks of thinking have received increasing attention in contemporary discussion. In occidental philosophy, they have a long tradition reaching back as far as to Spinoza (1677) and Schelling (1809). In the early days of psychophysics, Fechner (1861) and Wundt (1911) advocated related views. Whitehead, the modern pioneer of process philosophy, referred to mental and physical poles of "actual occasions", which themselves transcend their bipolar appearances (Whitehead 1978). Many approaches in the tradition of Feigl (1967) and Smart (1963), called "identity theories", conceive mental and material states as differentiated descendants of "central states". Other variants of this idea, focusing on quantum ideas, have been suggested by (a) Jung and Pauli (1955) [see also Meier (2001)], involving Jung's conception of a psychophysically neutral, archetypal order, by (b) approaches toward a neither-mental-nor-material base reality by Eddington (1946) and Wheeler (1994), and by (c) Bohm and Hiley (Bohm 1990; Bohm and Hiley 1993; Hiley 2001), referring to an implicate order which unfolds into the different explicate domains of the mental and the material. They will be discussed in more detail in Section 5, "Brain and Mind as Dual Aspects".

Velmans (2002, 2009) has developed a similar approach, backed up with empirical material from psychology, and Strawson (2003) has proposed a "real materialism" which uses a closely related scheme. Another proponent of dual-aspect thinking is Chalmers (1996), who considers the possibility that the underlying, psychophysically neutral level of description could be best characterized in terms of information.

Before proceeding further, it should be emphasized that many present-day approaches prefer to distinguish between first-person and third-person perspectives rather than mental and material states. This terminology serves to highlight the discrepancy between immediate conscious experiences ("qualia") and their description, be it behavioral, neural, or biophysical. The notion of the "hard problem" of consciousness research refers to bridging the gap between first-person experience and third-person accounts of it. In the present contribution, mental conscious states are implicitly assumed to be related to first-person experience. This does not mean, however, that the problem of how to define consciousness precisely is considered as resolved. Ultimately, it will be (at least) as difficult to define a mental state in rigorous terms as it is to define a material state rigorously.

3. Quantum Brain

In this section, some popular approaches for applying quantum theory to brain states will be surveyed and compared, most of them speculative, with varying degrees of elaboration and viability. Section 3.1 addresses three different neurophysiological levels of description, to which particular quantum approaches refer. Subsequently, the individual approaches themselves will be presented and discussed — Section 3.2: Stapp, Section 3.3: Vitiello and Freeman, Section 3.4: Beck and Eccles, Section 3.5: Penrose and Hameroff. For this purpose, the philosophical distinctions A/B (Section 2) and the neurophysiological distinctions addressed in Section 3.1 will serve as guidelines to classify the respective quantum approaches in a systematic way. However, some preliminary qualifications concerning different ways to use quantum theory are in order.

There are quite a number of accounts discussing quantum theory in relation to consciousness that adopt basic ideas of quantum theory in a purely *narrative* manner. Quantum theoretical terms such as entanglement, superposition, collapse, complementarity, and others are used without specific reference to how they are defined precisely and how they are applicable to specific situations. For instance, conscious acts are just *claimed* to be interpretable somehow similarly to physical acts of measurement, or correlations in psychological systems are just *claimed* to be interpretable somehow similarly to physical entanglement. Such accounts may provide fascinating science fiction, and they may even be important to inspire nuclei of ideas to be worked out in detail. But unless such detailed work leads beyond vague allusions and intimations, they do not yet represent scientific progress. Approaches falling into this category will not be further discussed in this contribution.

A second category includes approaches that use the *status quo* of present-day quantum theory to describe neurophysiological and/or neuropsychological processes. Among these approaches, the one with the longest history was initiated by von Neumann in the 1930s, later taken up by Wigner, and then championed by Stapp. It can be roughly characterized as the proposal to consider intentional conscious acts as intrinsically correlated with physical state reductions. Another fairly early idea dating back to Ricciardi and Umezawa in the 1960s is to treat mental states, particularly memory states, in terms of vacuum states of quantum fields. A prominent proponent of this approach is Vitiello. Finally, there is the idea suggested by Beck and Eccles in the 1990s, according to which quantum mechanical processes, relevant for the description of exocytosis at the synaptic cleft, can be influenced by mental intentions.

The third category refers to *further developments or generalizations* of present-day quantum theory. An obvious candidate in this respect is the proposal by Penrose to relate elementary conscious acts to gravitation-induced reductions of quantum states. Ultimately, this requires the framework of a future theory of quantum gravity which is far from having been developed. Together with Penrose, Hameroff has argued that microtubuli might be the right place to look for such state reductions.

3.1 Neurophysiological Levels of Description

A mental system can be in many different conscious (intentional, phenomenal) mental states. In a hypothetical state space, a sequence of such states forms a trajectory representing what is often called the stream of consciousness. Since different subsets of the state space are typically associated with different stability properties, a mental state can be assumed to be more or less stable, depending on its position in the state space. Stable states are distinguished by a residence time at that position longer than that of metastable or unstable states. If a mental state is stable with respect to perturbations, it "activates" a mental representation encoding a content that is consciously perceived.

Neural Assemblies

Moving from this purely psychological, or cognitive, description to its neurophysiological counterpart leads us to the question: What is the neural correlate of a mental representation? According to standard accounts (cf. Noë and Thompson (2004) for discussion), mental representations are correlated with the activity of neuronal assemblies, i.e., ensembles of several thousands of coupled neurons. The neural correlate of a mental representation can be characterized by the fact that the connectivities, or couplings, among those neurons form an assembly confined with respect to its environment, to which connectivities are weaker than within the assembly. The neural correlate of a mental representation is activated if the neurons forming the assembly operate more actively, e.g., produce higher firing rates, than in their default mode.

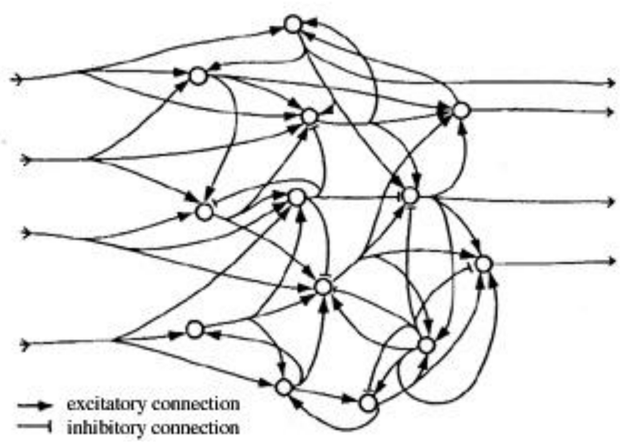

FIGURE 1. Balance between inhibitory and excitatory connections among neurons.

In order to achieve a stable operation of an activated neuronal assembly, there must be a subtle balance between inhibitory and excitatory connections among neurons (cf. Figure 1). If the transfer function of individual neurons is strictly monotonic, i.e., increasing input leads to increasing output, assemblies are difficult to stabilize. For this reason, results establishing a non-monotonic transfer function with a maximal output at intermediate input are of high significance for the modeling of neuronal assemblies (Kuhn *et al.* 2004). For instance, network models using lattices of coupled maps with quadratic maximum (Kaneko and Tsuda 2000) are paradigmatic examples of such behavior. These and other familiar models of neuronal assemblies (for an overview see Anderson and Rosenfeld 1988) are mostly formulated in a way *not* invoking well-defined elements of quantum theory. An explicit exception is the approach by Umezawa, Vitiello and others (see Section 3.3).

Single Neurons and Synapses

The fact that neuronal assemblies are mostly described in terms of classical behavior does not rule out that classically undescribable quantum effects may be significant if one focuses on individual constituents of assemblies, i.e., single neurons or interfaces between them. These interfaces, through which the signals between neurons propagate, are called synapses. There are electrical and chemical synapses, depending on whether they transmit a signal electrically or chemically.

At electrical synapses, the current generated by the action potential at the presynaptic neuron flows directly into the postsynaptic cell, which is physically connected to the presynaptic terminal by a so-called gap junction. At chemical synapses, there is a cleft between pre- and postsynaptic cell. In order to propagate a signal, a chemical transmitter (glutamate) is released at the presynaptic terminal. This release process is called exocytosis. The transmitter diffuses across the synaptic cleft and binds to receptors at the postsynaptic membrane, thus opening an ion channel (Kandel *et al.* 2000, part III; see Fig. 2). Chemical transmission is slower than electric transmission.

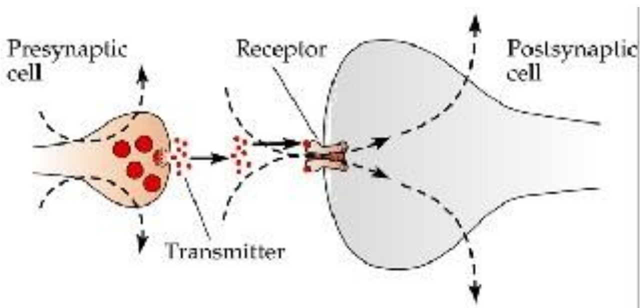

FIGURE 2. Release of neurotransmitters at the synaptic cleft (exocytosis).

A model developed by Beck and Eccles (and later refined by Fisher) applies concrete quantum mechanical features to describe details of the process of exocytosis. Their model proposes that quantum processes are relevant for exocytosis and, moreover, are tightly related to states of consciousness. This will be discussed in more detail in Section 3.4.

At this point, another approach developed by Flohr (2000) should be mentioned, for which chemical synapses with a specific type of receptors, so-called NMDA receptors,[4] are of paramount significance. Briefly, Flohr observes that the specific plasticity of NMDA receptors is a necessary condition for the formation of extended stable neuronal assemblies correlated to (higher-order) mental representations which he identifies with conscious states. Moreover, he indicates a number of mechanisms caused by anaesthetic agents, which block NMDA receptors and consequently lead to a loss of consciousness. Flohr's approach is physicalistic and reductive, and it is entirely independent of any specific quantum ideas.

Microtubuli

The lowest neurophysiological level, at which quantum processes have been proposed as a correlate to consciousness, is the level at which the interior of single neurons is involved: their cytoskeleton. It consists of protein networks essentially made up of two kinds of structures, neurofilaments and microtubuli (Fig. 3, left), which are essential for various transport processes within neurons (as well as other cells). Microtubuli are long polymers usually constructed of 13 longitudinal α and β-tubulin dimers arranged in a tubular array with an outside diameter of about 25 nm (Fig. 3, right). For more details see Kandel *et al.* (2000), Chap. II.4.

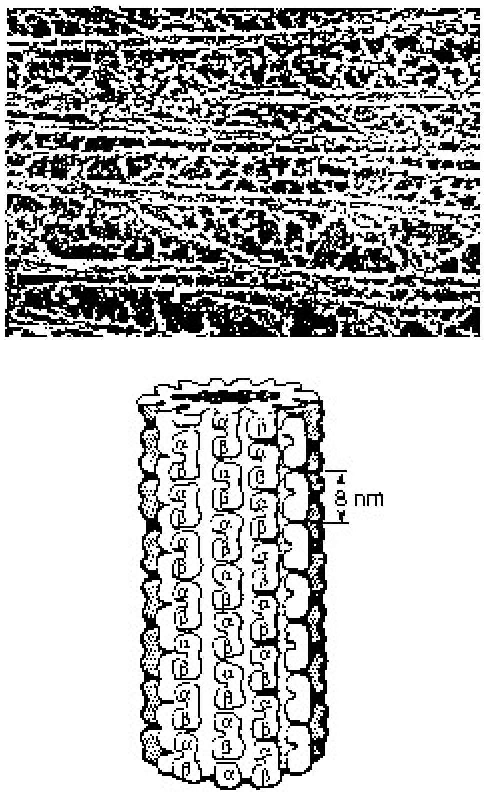

FIGURE 3. (left) microtubuli and neurofilaments, the width of the figure corresponds to approximately 700nm; (right) tubulin dimers, consisting of α- and β-monomers, constituting a microtubule.

The tubulins in microtubuli are the substrate which, in Hameroff's proposal, is used to embed Penrose's theoretical framework neurophysiologically. As will be discussed in more detail in Section 3.5, tubulin states are assumed to be quantum states, so that quantum coherence among different tubulins is possible. A crucial thesis in the scenario of Penrose and Hameroff is that the (gravitation-induced) collapse of such coherent tubulin states corresponds to elementary acts of consciousness.

3.2 Stapp: Quantum State Reductions and Conscious Acts

The act of measurement is a crucial aspect of quantum theory, that has been the subject of controversy for more than eight decades now. In his monograph on the mathematical foundations of quantum mechanics, von Neumann (1955, Chap. V.1) introduced, in an *ad hoc* manner, the projection postulate as a mathematical tool for describing measurement in terms of a discontinuous, non-causal, instantaneous (irreversible) act given by (1) the transition of a quantum state to an eigenstate b_j of the measured observable B (with a certain probability). This transition is often called the *collapse* or *reduction* of the quantum state (the "wavefunction"), as opposed to (2) the continuous, unitary (reversible) evolution of a system according to the Schrödinger equation.

In Chapter VI, von Neumann (1955) discussed the conceptual distinction between observed and observing system. In this context, he applied (1) and (2) to the general situation of a measured object system (I), a measuring instrument (II), and (the brain of) a human observer (III). His conclusion was that it makes no difference for the result of measurements on (I) whether the boundary between observed and observing system is posited between I and (II & III) or between (I & II) and III. As a consequence, it is inessential whether a detector or the human brain is ultimately referred to as the "observer".[5]

In contrast to von Neumann's fairly cautious stance, London and Bauer (1939) went further and proposed that it is indeed human *consciousness* which completes the quantum measurement process (see Jammer (1974, Sec. 11.3 or Shimony (1963) for a detailed account). In this way, they attributed a crucial role to consciousness in understanding quantum measurement in terms of an update of the observer's knowledge. In the 1960s, Wigner (1967) radicalized this proposal,[6] by suggesting an impact of consciousness on the physical state of the measured system, not only an impact on observer knowledge. In order to describe measurement as a real dynamical process generating irreversible facts, Wigner called for some nonlinear modification of (2) to replace von Neumann's projection (1).[7]

Since the 1980s, Stapp has developed his own point of view on the background of von Neumann and Wigner. In particular, he tries to understand specific features of consciousness in relation to quantum theory. Inspired by von Neumann, Stapp uses the freedom to place the interface between observed and observing system and locates it in the observer's brain. He does not suggest any formal modifications to present-day quantum theory (in particular, he stays essentially within the "orthodox" Hilbert space representation), but adds major interpretational extensions, in particular with respect to a detailed ontological framework.

In his earlier work, Stapp (1993) started with Heisenberg's distinction between the potential and the actual (Heisenberg 1958), thereby taking a decisive step beyond the operational Copenhagen interpretation of quantum mechanics. While Heisenberg's notion of the *actual* is related to a measured event in the sense of the Copenhagen interpretation, his notion of the *potential,* of a *tendency* or *disposition*, relates to the situation *before* measurement, which expresses the idea of a reality independent of measurement.[8]

Immediately after its actualization, each event holds the tendency for the impending actualization of another, subsequent actual event. Therefore, events are by definition ambiguous. With respect to their actualized aspect, Stapp's essential move is to "attach to each Heisenberg actual event an experiential aspect. The latter is called the *feel* of this event, and it can be considered to be the aspect of the actual event that gives it its status as an intrinsic actuality" (Stapp 1993, p. 149).

With respect to their tendency aspect, it is tempting to understand events in terms of scheme (B) of Section 2. This is related to Whitehead's ontology, in which mental and physical poles of so-called "actual occasions" are considered as mental and physical aspects of reality. The potential antecedents of actual occasions are psychophysically neutral and refer to a mode of existence at which mind and matter are unseparated. This is expressed, for instance, by Stapp's notion of a "hybrid ontology" with "both idea-like and matter-like qualities" (Stapp 1999, 159). Similarities with a dual-aspect approach (B) (cf. Section 5) are evident.

In an interview of 2006, Stapp (2006) specifies some ontological features of his approach with respect to Whitehead's process thinking, where actual occasions rather than matter or mind are fundamental elements of reality. They are conceived as based on a processual rather than a substantial ontology (see the entry on process philosophy). Stapp relates the fundamentally processual nature of actual occasions to both the physical act of state reduction and the correlated mental intentional act.

Another significant aspect of his approach is the possibility that "conscious intentions of a human being can influence the activities of his brain" (Stapp 1999, p. 153). Different from the possibly misleading notion of a direct interaction, suggesting an interpretation in terms of scheme (A) of Section 2, he describes this feature in a more subtle manner. The requirement that the mental and material outcomes of an actual occasion must match, i.e. be correlated, acts as a constraint on the way in which these outcomes are formed within the actual occasion (cf. Stapp 2006). The notion of interaction is thus replaced by the notion of a constraint set by mind-matter correlations (see also Stapp 2007).

At a level at which conscious mental states and material brain states are distinguished, each conscious experience, according to Stapp (1999, p. 153), has as its physical counterpart a quantum state reduction actualizing "the pattern of activity that is sometimes called the neural correlate of that conscious experience". This pattern of activity may encode an intention and, thus, represent a "template for action". An intentional decision for an action, preceding the action itself, is then the key for anything like "free agency" in this picture.

Stapp argues that the mental effort, i.e. attention devoted to such intentional acts, can protract the lifetime of the neuronal assemblies that represent the templates for action due to quantum Zeno-type effects. Concerning the neurophysiological implementation of this idea, intentional mental states are assumed to correspond to reductions of superposition states of neuronal assemblies. Additional commentary concerning the concepts of attention and intention in relation to James' idea of a holistic stream of consciousness (James 1950 [1890]) was given by Stapp (1999).

For further progress, it will be mandatory to develop a coherent formal framework for this approach and elaborate on concrete details. For instance, it is not yet worked out precisely how quantum superpositions and their collapses are supposed to occur in neural correlates of conscious events. Some indications are outlined by Schwartz *et al.* (2005). With these desiderata for future work, the overall conception is conservative insofar as the physical formalism remains unchanged.

This is why Stapp insisted for years that his approach does not change what he calls “orthodox” quantum mechanics, which is essentially encoded in the statistical formulation by von Neumann (1955). From the point of view of standard present-day quantum physics, however, it is certainly unorthodox to include the mental state of observers in the theory. Although it is true that quantum measurement is not yet finally understood in terms of physical theory, introducing mental states as the essential missing link is highly speculative from a contemporary perspective.

This link is a radical conceptual move. In what Stapp (2015) later denotes as a “semi-orthodox” approach, he proposes that the blind-chance kind of randomness of individual quantum events (“nature’s choices”) be reconceived as “not actually random but positively or negatively biased by the positive or negative values in the minds of the observers that are actualized by its (nature’s) choices” (p. 187). This hypothesis leads into mental influences on quantum physical processes which are widely unknown territory at present.

3.3 Vitiello and Freeman: Quantum Field Theory of Brain States

In the 1960s, Ricciardi and Umezawa (1967) suggested to utilize the formalism of quantum field theory to describe brain states, with particular emphasis on memory. The basic idea is to conceive of memory states in terms of states of many-particle systems, as inequivalent representations of vacuum states of quantum fields.[9] This proposal has gone through several refinements (e.g., Stuart *et al.* 1978, 1979; Jibu and Yasue 1995). Major progress has been achieved by including effects of dissipation, chaos, fractals and quantum noise (Vitiello 1995; Pessa and Vitiello 2003; Vitiello 2012). For readable nontechnical accounts of the approach in its present form, embedded in quantum field theory as of today, see Vitiello (2001, 2002).

Quantum field theory (see the entry on quantum field theory) deals with systems with infinitely many degrees of freedom. For such systems, the algebra of observables that results from imposing canonical commutation relations admits multiple representations that are not unitarily equivalent to each other. This differs from the case of standard quantum mechanics, which deals with systems with finitely many degrees of freedom. For such systems, the corresponding algebra of observables admits unitarily equivalent Hilbert-space representations.

The inequivalent representations of quantum field theory can be generated by spontaneous symmetry breaking (see the entry on symmetry and symmetry breaking), occurring when the ground state (or the vacuum state) of a system is not invariant under the full group of transformations providing the conservation laws for the system. If symmetry breaks down, collective modes are generated (so-called Nambu-Goldstone boson modes), which propagate over the system and introduce long-range correlations in it.

These correlations are responsible for the emergence of ordered patterns. Unlike in standard thermal systems, a large number of bosons can be condensed in an ordered state in a highly stable fashion. Roughly speaking, this provides a quantum field theoretical derivation of ordered states in many-body systems described in terms of statistical physics. In the proposal by Umezawa these dynamically ordered states represent coherent activity in neuronal assemblies.

The *activation* of a neuronal assembly is necessary to make the encoded content consciously accessible. This activation is considered to be initiated by external stimuli. Unless the assembly is activated, its content remains unconscious, unaccessed memory. According to Umezawa, coherent neuronal assemblies correlated to such memory states are regarded as vacuum states; their activation leads to excited states and enables a conscious recollection of the content encoded in the vacuum (ground) state. The stability of such states and the role of external stimuli have been investigated in detail by Stuart *et al.* (1978, 1979).

A decisive further step in developing the approach has been achieved by taking *dissipation* into account. Dissipation is possible when the interaction of a system with its environment is taken into account. Vitiello (1995) describes how the system-environment interaction causes a doubling of the collective modes of the system in its environment. This yields infinitely many differently coded vacuum states, offering the possibility of many memory contents without overprinting. Moreover, dissipation leads to finite lifetimes of the vacuum states, thus representing temporally limited rather than unlimited memory (Alfinito and Vitiello 2000; Alfinito *et al.* 2001). Finally, dissipation generates a genuine arrow of time for the system, and its interaction with the environment induces entanglement. Pessa and Vitiello (2003) have addressed additional effects of chaos and quantum noise.

Umezawa's proposal addresses the brain as a many-particle system as a whole, where the "particles" are more or less neurons. In the language of Section 3.1, this refers to the level of neuronal assemblies, which correlate *directly* with mental activity. Another merit of the quantum field theory approach is that it avoids the restrictions of standard quantum mechanics in a formally sound way. Conceptually speaking, many of the pioneering presentations of the proposal nevertheless confused mental and material states (and their properties). This has been clarified by Freeman and Vitiello (2008): the model "describes the brain, not mental states."

For a corresponding description of brain states, Freeman and Vitiello 2006, 2008, 2010) studied neurobiologically relevant observables such as electric and magnetic field amplitudes and neurotransmitter concentration. They found evidence for non-equilibrium analogs of phase transitions (Vitiello 2015) and power-law distributions of spectral energy densities of electrocorticograms (Freeman and Vitiello 2010, Freeman and Quian Quiroga 2013). All these observables are classical, so that neurons, glia cells, "and other physiological units are *not* quantum objects in the many-body model of brain" (Freeman and Vitiello 2008). However, Vitiello (2012) also points out that the emergence of (self-similar, fractal) power-law distributions in general is intimately related to dissipative quantum coherent states (see also recent developments of the Penrose-Hameroff scenario, Section 3.5).

The overall conclusion is that the application of quantum field theory describes why and how classical behavior emerges at the level of brain activity considered. The relevant brain states themselves are viewed as classical states. Similar to a classical thermodynamical description arising from quantum statistical mechanics, the idea is to identify different regimes of stable behavior (phases, attractors) and transitions between them. In this way, quantum field theory provides formal elements from which a standard classical description of brain activity can be inferred, and this is its main role in large parts of the model. Only in their last joint paper, Freeman and Vitiello (2016) envision a way in which the mental can be explicitly included. For a more recent review including technical background see Sabbadini and Vitiello (2019).

3.4 Beck and Eccles: Quantum Mechanics at the Synaptic Cleft

Probably the most concrete suggestion of how quantum mechanics in its present-day appearance can play a role in brain processes is due to Beck and Eccles (1992), later refined by Beck (2001). It refers to particular mechanisms of information transfer at the synaptic cleft, which is known to be affected by anesthetic drugs when they switch off consciousness (for review see Platholi and Hemmings 2022). However, ways in which these quantum processes might be relevant for mental activity, and in which their interactions with mental states are conceived, remain unclarified to the present day.[10]

As presented in Section 3.1, the information flow between neurons in chemical synapses is initiated by the release of transmitters in the presynaptic terminal. This process is called exocytosis, and it is triggered by an arriving nerve impulse with some small probability. In order to describe the trigger mechanism in a statistical way, thermodynamics or quantum mechanics can be invoked. A look at the corresponding energy regimes shows (Beck and Eccles 1992) that quantum processes are distinguishable from thermal processes for energies higher than 10^{-2} eV (at room temperature). Assuming a typical length scale for biological microsites of the order of several nanometers, an effective mass below 10 electron masses is sufficient to ensure that quantum processes prevail over thermal processes.

The upper limit of the time scale of such processes in the quantum regime is of the order of 10^{-12} sec. This is significantly shorter than the time scale of cellular processes, which is 10^{-9} sec and longer. The sensible difference between the two time scales makes it possible to treat the corresponding processes as decoupled from one another.

The trigger mechanism proposed by Beck and Eccles (1992) is based on the quantum concept of quasi-particles, reflecting the particle aspect of a collective mode. Skipping the details of the picture, the proposed trigger mechanism refers to tunneling processes of two-state quasi-particles, resulting in state collapses. It yields a probability of exocytosis in the range between 0 and 0.7, in agreement with empirical observations. Using a theoretical framework developed earlier (Marcus 1956; Jortner 1976), the quantum trigger can be concretely understood in terms of electron transfer between biomolecules. However, the question remains how the trigger may be relevant for conscious mental states. There are two aspects to this question.

The first one refers to Eccles’ intention to utilize quantum processes in the brain as an entry point for mental causation. The idea, as indicated in Section 1, is that the fundamentally indeterministic nature of individual quantum state collapses offers room for the influence of mental powers on brain states. In the present picture, this is conceived in such a way that “mental intention (volition) becomes neurally effective by *momentarily increasing the probability of exocytosis*” (Beck and Eccles 1992, 11360). Further justification of this assumption is not given.

The second aspect refers to the problem that processes at *single* synapses cannot be simply correlated to mental activity, whose neural correlates are coherent assemblies of neurons. Most plausibly, *prima facie* uncorrelated random processes at individual synapses would result in a stochastic network of neurons (Hepp 1999). Although Beck (2001) has indicated possibilities (such as quantum stochastic resonance) for achieving ordered patterns at the level of assemblies from fundamentally random synaptic processes, this remains an unsolved problem.

With the exception of Eccles’ idea of mental causation, the approach by Beck and Eccles essentially focuses on brain states and brain dynamics. In this respect, Beck (2001, 109f) states explicitly that “science cannot, by its very nature, present any answer to […] questions related to the mind”. Nevertheless, their biophysical approach may open the door to controlled speculation about mind-matter relations.

A more recent proposal targeting exocytosis processes at the synaptic cleft is due to Fisher (2015, 2017). Similar to the quasi-particles by Beck and Eccles, Fisher refers to so-called Posner molecules, in particular to calcium phosphate, $Ca^{9}9(PO^{4}4)^{6}6$. The nuclear spins of phosphate ions serve as entangled qubits within the molecules, which protect their coherent states against fast decoherence (resulting in extreme decoherence times in the range of hours or even days). If the Posner molecules are transported into presynaptic glutamatergic neurons, they will stimulate further glutamate release and amplify postsynaptic activity. Due to nonlocal quantum correlations this activity may be enhanced over multiple neurons (which would respond to Hepp’s concern).
This is a sophisticated mechanism, whose physics has been studied in detail by Yunger Halpern and Crosson (2019) and by Adams and Petruccione (2020). A posible empirical test would be to modify the phosphorus spin dynamics within the Posner molecules. For instance, replacing Ca by different Li isotopes with different nuclear spins gives rise to different decoherence times, affecting postsynaptic activity. Corresponding evidence has been shown in animals (Sechzer *et al.* 1986, Krug *et al.* 2019). In fact, lithium is known to be efficacious in tempering manic phases in patients with bipolar disorder.

3.5 Penrose and Hameroff: Quantum Gravity and Microtubuli

In the scenario developed by Penrose and neurophysiologically augmented by Hameroff, quantum theory is claimed to be effective for consciousness, but the way this happens is quite sophisticated. It is argued that elementary acts of consciousness are non-algorithmic, i.e., non-computable, and they are neurophysiologically realized as gravitation-induced reductions of coherent superposition states in microtubuli.

Unlike the approaches discussed so far, which are essentially based on (different features of) *status quo* quantum theory, the physical part of the scenario, proposed by Penrose, refers to future developments of quantum theory for a proper understanding of the physical process underlying quantum state reduction. The grander picture is that a full-blown theory of quantum gravity is required to ultimately understand quantum measurement (see the entry on quantum gravity).

This is a far-reaching assumption. Penrose's rationale for invoking state reduction is not that the corresponding randomness offers room for mental causation to become efficacious (although this is not excluded). His conceptual starting point, at length developed in two books (Penrose 1989, 1994), is that elementary conscious acts are not conceived of as algorithmic, hence cannot be computed. His background in this respect has a lot to do with the nature of creativity, mathematical insight, Gödel's incompleteness theorems, and the idea of a Platonic reality beyond mind and matter.

Penrose argues that a valid formulation of quantum state reduction replacing von Neumann's projection postulate must faithfully describe an *objective physical process* that he calls *objective reduction*. As such a physical process remains empirically unconfirmed so far, Penrose proposes that effects not currently covered by quantum theory could play a role in state reduction. Ideal candidates for him are gravitational effects since gravitation is the only fundamental interaction which is not integrated into quantum theory so far. Rather than modifying elements of the theory of gravitation (i.e., general relativity) to achieve such an integration, Penrose discusses the reverse: that novel features have to be incorporated in quantum theory for this purpose. In this way, he arrives at the proposal of *gravitation-induced objective state reduction*.

Why is such a version of state reduction non-computable? Initially one might think of objective state reduction in terms of a stochastic process, as most current proposals for such mechanisms indeed do (see the entry on collapse theories). This would certainly be indeterministic, but probabilistic and stochastic processes can be standardly implemented on a computer, hence they are definitely computable. Penrose (1994, Secs 7.8 and 7.10) sketches some ideas concerning genuinely non-computable, not only random, features of quantum gravity. In order for them to become viable candidates for explaining the non-computability of gravitation-induced state reduction, a long way still has to be gone.

With respect to the neurophysiological implementation of Penrose's proposal, his collaboration with Hameroff has been instrumental. With his background as an anaesthesiologist, Hameroff suggested to consider microtubules as an option for where reductions of quantum states can take place in an effective way, see e.g., Hameroff and Penrose (1996). The respective quantum states are assumed to be coherent superpositions of tubulin states, ultimately extending over many neurons. Their simultaneous gravitation-induced collapse is interpreted as an individual elementary act of consciousness. The proposed mechanism by which such superpositions are established includes a number of involved details that remain to be confirmed or disproven.

The idea of focusing on microtubuli is partly motivated by the argument that special locations are required to ensure that quantum states can live long enough to become reduced by gravitational influence rather than by interactions with the warm and wet environment within the brain. Speculative remarks about how the non-computable aspects of the expected new physics mentioned above could be significant in this scenario[11] are given in Penrose (1994, Sec. 7.7).

Influential criticism of the possibility that quantum states can in fact survive long enough in the thermal environment of the brain has been raised by Tegmark (2000). He estimates the decoherence time of tubulin superpositions due to interactions in the brain to be less than 10^{-12} sec. Compared to typical time scales of microtubular processes of the order of milliseconds and more, he concludes that the lifetime of tubulin superpositions is much too short to be significant for neurophysiological processes in the microtubuli. In a response to this criticism, Hagan *et al.* (2002) showed that a corrected version of Tegmark’s model provides decoherence times up to 10 to 100 μsec, and it has been argued that this can be extended up to the neurophysiologically relevant range of 10 to 100 msec under particular assumptions of the scenario by Penrose and Hameroff.

A few years later another option has entered this debate. Theoretical studies of interacting spins have shown that entangled states can be maintained in noisy open quantum systems at high temperature and far from thermal equilibrium. In these studies the effect of decoherence is counterbalanced by a simple “recoherence” mechanism (Hartmann *et al.* 2006, Li and Paraoanu 2009). This indicates that, under particular circumstances, entanglement may persist even in hot and noisy environments such as the brain.

However, decoherence is just one piece in the debate about the overall picture suggested by Penrose and Hameroff. From another perspective, their proposal of microtubules as quantum computing devices has received support from work of Bandyopadhyay’s lab at Japan, showing evidence for vibrational resonances and conductivity features in microtubules that should be expected if they are macroscopic quantum systems (Sahu *et al.* 2013). Bandyopadhyay’s results initiated considerable attention and commentary (see Hameroff and Penrose 2014). In a well-informed in-depth analysis, Pitkänen (2014) raised concerns to the effect that the reported results alone may not be sufficient to confirm the approach proposed by Hameroff and Penrose with all its ramifications.

In a different vein, Craddock *et al.* (2015, 2017) discussed in detail how microtubular processes (rather than, or in addition to, synaptic processes, see Flohr 2000) may be affected by anesthetics, and may also be responsible for neurodegenerative memory disorders. As the correlation between anesthetics and consciousness seems obvious at the phenomenological level, it is interesting to know the intricate mechanisms by which anesthetic drugs act on the cytoskeleton of neuronal cells,[12] and what role quantum mechanics plays in these mechanisms. Craddock *et al.* (2015, 2017) point out a number of possible quantum effects (including the power-law behavior addressed by Vitiello, cf. Section 3.3) which can be investigated using presently available technologies, see also Adams and Petruccione (2020) for competent and detailed review. More empirical results about potential quantum interactions of anesthetics in microtubuli are due to Li *et al.* (2018), Burdick *et al.* (2019), and Zadeh-Haghighi and Simon (2022).

From a philosophical perspective, the scenario of Penrose and Hameroff has occasionally stirred up heated debate, see e.g., Grush and Churchland (1995) and the reply by Penrose and Hameroff (1995). Indeed, their approach invokes several top level mysteries, among them the relation between mind and matter itself, the ultimate unification of all physical interactions, the origin of mathematical truth, and the understanding of brain dynamics across hierarchical levels. Combining such deep and fascinating issues certainly needs further work to be substantiated, and should neither be too quickly celebrated nor offhandedly dismissed. After more than three decades since its inception one thing can be safely asserted: the approach has fruitfully inspired important innovative work about quantum effects (from microtubuli to synaptic processes and large-scale brain areas) on consciousness across various research groups, both theoretical and empirical.

4. Quantum Mind

4.1 Applying Quantum Concepts to Mental Systems

Today there is accumulating evidence in the study of consciousness and cognition that quantum concepts like complementarity, contextuality, entanglement, dispersive states, and non-Boolean logic play significant roles in mental processes and have epistemological consequences (see, e.g., Bruza *et al.* 2023). Corresponding quantum-inspired approaches address purely mental (psychological) phenomena using formal features also employed in quantum physics, but without involving the full-fledged framework of quantum mechanics or quantum field theory. The term “quantum cognition” has been coined to refer to this new area of research. Perhaps a more precise characterization would be non-commutative structures in cognition.

On the surface, this seems to imply that the brain activity correlated with those mental processes is in fact governed by quantum physics. The quantum brain approaches discussed in Section 3 represent attempts that have been proposed along these lines. But is it necessarily true that quantum features in psychology imply quantum physics in the brain?

A formal move to incorporate quantum behavior in mental systems, without referring to quantum brain activity, is based on a state space description of mental systems. If mental states are defined on the basis of cells of a neural state space partition, then this partition needs to be well tailored to the neural dynamics in order to lead to robustly defined states. Especially for nonlinear neural dynamics, ad hoc chosen partitions are typically “misplaced” and will create incompatible mental descriptions (Atmanspacher and beim Graben 2007) and mental states may become entangled (beim Graben *et al.* 2013).

This implies that quantum brain dynamics is not the only possible explanation of quantum features in mental systems. Assuming that mental states arise from partitions of neural states in such a way that statistical neural states are co-extensive with individual mental states, the nature of mental processes depends strongly on the kind of partition chosen. If the partition is not properly constructed, it is likely that mental states and observables show features that resemble quantum behavior although the correlated brain activity may be entirely classical: *quantum mind without quantum brain*.

Intuitively, it is not difficult to understand why non-commuting operations or non-Boolean logic should be relevant, even inevitable, for mental systems that have nothing to do with any quantum physics of brain activity. Simply speaking, the non-commutativity of operations means nothing else than that the sequence, in which operations are applied, matters for the final result. And non-Boolean logic refers to propositions that may have unsharp truth values beyond yes or no, shades of plausibility or credibility as it were. Both versions obviously abound in psychology and cognitive science (and in everyday life). Pylkkänen (2015) has even suggested to use this intuitive accessibility of mental quantum features for a better conceptual grasp of quantum *physics*.

The particular strength of the idea of generalizing quantum theory beyond quantum physics is that it provides a formal framework which both yields a transparent well-defined link to conventional quantum physics and has been used to describe a number of concrete psychological applications with surprisingly detailed theoretical and empirical results. Corresponding approaches fall under the third category mentioned in Section 3: further developments or generalizations of quantum theory.

One rationale for the focus on psychological phenomena is that their detailed study is a necessary precondition for further questions as to their neural correlates. Therefore, the investigation of mental quantum features resists the temptation to reduce them (within scenario A) all-too quickly to neural activity. There are several kinds of psychological phenomena which have been addressed in the spirit of mental quantum features so far: (i) decision processes, (ii) order effects, (iii) bistable perception, (iv) learning, (v) semantic networks, (vi) quantum agency,and (vii) super-quantum entanglement correlations. These topics will be outlined in some more detail in the following Section 4.2.

It is a distinguishing aspect of these approaches that they have led to well-defined and specific theoretical models with empirical consequences and novel predictions. A second point worth mentioning is that by now there are a number of research groups worldwide (rather than solitary actors) studying quantum ideas in cognition, partly even in collaborative efforts. For about two decades there have been regular international conferences with proceedings for the exchange of new results and ideas. Target articles, special issues, and monographs have been devoted to basic frameworks and new developments (Khrennikov 1999, Atmanspacher *et al.* 2002, Busemeyer and Bruza 2012, Haven and Khrennikov 2013, Wendt 2015).

4.2 Concrete Applications

Decision Processes

An early precursor of work on decision processes is due to Aerts and Aerts (1994). However, the first detailed account appeared in a comprehensive publication by Busemeyer *et al.* (2006). The key idea is to define probabilities for decision outcomes and decision times in terms of quantum probability amplitudes. Busemeyer *et al.* found agreement of a suitable Hilbert space model (and disagreement of a classical alternative) with empirical data. Moreover, they were able to clarify the long-standing riddle of the so-called conjunction and disjunction effects (Tversky and Shafir 1992) in decision making (Pothos and Busemeyer 2009). Another application refers to the asymmetry of similarity judgments (Tversky 1977), which can be adequately understood by quantum approaches (see Aerts *et al.* 2011, Pothos *et al.* 2013). Moreover, Busemeyer *et al.* (2019) found evidence for quantum interference effects, which are absent in classical models, in the way confidence is dynamically building up during decision processes.

Order Effects

Order effects in polls, surveys, and questionnaires, recognized for a long time (Schwarz and Sudman 1992), have long been insufficiently understood. Their study as contextual quantum features (Aerts and Aerts 1994, Busemeyer *et al.* 2011) offers the potential to unveil a lot more about such effects than the well-known fact that responses can drastically alter if questions are swapped. Atmanspacher and Römer (2012) proposed a complete classification of possible order effects (including uncertainty relations, and independent of Hilbert space representations), and Wang *et al.* (2014) discovered a fundamental covariance condition (called the QQ equation) for a wide class of order effects.

An important issue for quantum mind approaches is the complexity or parsimony of Hilbert space models as compared to classical (Bayesian, Markov, etc.) models. Atmanspacher and Römer (2012) as well as Busemeyer and Wang (2018) addressed this issue for order effects, with the result that quantum approaches generally require less free variables than competing classical models and are, thus, more parsimonious and more stringent than those. Busemeyer and Wang (2017) studied how measuring incompatible observables sequentially induces uncertainties on the second measurement outcome.

Bistable Perception

The perception of a stimulus is bistable if the stimulus is ambiguous, such as the Necker cube. This bistable behavior has been modeled analagous to the physical quantum Zeno effect. (Note that this differs from the quantum Zeno effect as used in Section 3.2.) The resulting Necker-Zeno model predicts a quantitative relation between basic psychophysical time scales in bistable perception that has been confirmed experimentally (see Atmanspacher and Filk 2013 for review).

Moreover, Atmanspacher and Filk (2010) showed that the Necker-Zeno model violates temporal Bell inqualitities for particular distinguished states in bistable perception.[13] This theoretical prediction is yet to be tested experimentally and would be a litmus test for quantum behavior in mental systems; see recent work by Waddup *et al.* (2023). Such states have been denoted as *temporally nonlocal* in the sense that they are not sharply (pointwise) localized along the time axis but appear to be stretched over an extended time interval (an extended present). Within this interval, relations such as “earlier” or “later” are illegitimate designators and, accordingly, causal connections are ill-defined.

Learning Processes

Another quite obvious arena for non-commutative behavior is learning behavior. In theoretical studies, Atmanspacher and Filk (2006) showed that in simple supervised learning tasks small recurrent networks not only learn the prescribed input-output relation but also the sequence in which inputs have been presented. This entails that the recognition of inputs is impaired if the sequence of presentation is changed. In very few exceptional cases, with special characteristics that remain to be explored, this impairment is avoided.

Semantic Networks

The difficult issue of meaning in natural languages is often explored in terms of semantic networks. Gabora and Aerts (2002) described the way in which concepts are evoked, used, and combined to generate meaning depending on contexts. Their ideas about concept association in evolution were further developed by Gabora and Aerts (2009). A particularly thrilling application is due to Bruza *et al.* (2015), who challenged a long-standing dogma in linguistics by proposing that the meaning of concept combinations (such as “apple chip”) is not uniquely separable into the meanings of the combined concepts (“apple” and “chip”). Bruza *et al.* (2015) refer to meaning relations in terms of entanglement-style features in quantum representations of concepts and reported first empirical results in this direction.

Quantum Agency

A quantum approach for understanding issues related to agency, intention, and other controversial topics in the philosophy of mind has been proposed by Briegel and Müller (2015), see also Müller and Briegel (2018). This proposal is based on work on quantum algorithms for reinforcement learning in neural networks (“projective simulation”, Paparo *et al.* 2012), which can be regarded as a variant of quantum machine learning (Wittek 2014). The gist of the idea is how agents can develop agency as a kind of independence from their environment and the deterministic laws governing it (Briegel 2012). The behavior of the agent itself is simulated as a non-deterministic quantum random walk in its memory space.

Super-Quantum Correlations

Quantum entanglement implies correlations exceeding standard classical correlations (by violating Bell-type inequalitites) but obeying the so-called Tsirelson bound. However, this bound does not exhaust the range by which Bell-type correlations can be violated in principle. Popescu and Rohrlich (1994) found such correlations for particular simple models of quantum measurements, and the study of such super-quantum correlations has become a vivid field of contemporary research, as an early review by Popescu (2014) already shows.

One problem in identifying super-quantum correlations in mental systems is to delineate genuine (non-causal) quantum-type correlations from (causal) classical correlations that can be used for signaling. Dzhafarov and Kujala (2013) derived a compact way to do so and subtract classical context effects such as priming in mental systems so that true quantum correlations remain. See Cervantes and Dzhafarov (2018) for empirical applications, and Atmanspacher and Filk (2019) for further subtleties.

5. Mind and Matter as Dual Aspects

5.1 Compositional and Decompositional Approaches

Dual-aspect approaches consider mental and material domains of reality as aspects, or manifestations, of one underlying reality in which mind and matter are unseparated. In such a framework, the distinction between mind and matter results from the application of a basic tool for achieving epistemic access to, i.e., gather knowledge about, both the separated domains and the underlying reality.[14] Consequently, the status of the underlying, psychophysically neutral domain is considered as *ontic relative to* the mind-matter distinction.

As mentioned in Section 2, dual-aspect approaches have a long history, essentially beginning with Spinoza as its earliest explicit protagonist in occidental philosophy. Major directions in the 20th century have been described and compared to some detail by Atmanspacher (2014). An important distinction between two basic classes of dual-aspect thinking is the way in which the psychophysically neutral domain is related to the mental and the physical. For Russell and the neo-Russellians the *compositional* arrangements of psychophysically neutral elements decide how they differ with respect to mental or physical properties. As a consequence, the mental and the physical are reducible to the neutral domain. Chalmers' (1996, Chap. 8) ideas on "consciousness and information" fall into this class. Tononi's theoretical framework of "integrated information theory" (see Oizumi *et al.* 2014, Tononi 2015) can be seen as a concrete implementation of a number of features of Chalmers' proposal. No quantum structures are involved in this work.

The other class of dual-aspect models is *decompositional* rather than compositional. Here the basic metaphysics of the psychophysically neutral domain is holistic, and the mental and the physical (neither reducible to one another nor to the neutral) emerge by breaking the holistic symmetry or, in other words, by making distinctions. [15] The decompositional framework can be seen in analogy with quantum holism, where wholes that do not consist of parts in the first place (characterized by non-product entangled states) become disentangled into parts. This explains why the predominant versions of this picture are quantum theoretically inspired as, for instance, proposed by Pauli and Jung (Jung and Pauli 1955; Meier 2001), by Eddington (1946) and Wheeler (1994), and by Bohm and Hiley (Bohm 1990; Bohm and Hiley 1993; Hiley 2001). They are based on speculations that obviously exceed the scope of contemporary quantum theory. Details of these three lineages are comprehensively discussed by Atmanspacher and Rickles (2022).

Already in his *Fundamental Theory* of 1946 it is evident that Eddington is looking for a basis reality that he called the "spiritual world", which is free from the mind-matter distinction. He referred to this reality in terms of an algebraic structure with idempotents as operators distinguishing between existence versus non-existence. Over and above this basic level of reality Eddington proposed a tight link between physical objects and their phenomenal perception, treating physical observation as a subjective act (his "selective subjectivism"): a clearly non-mainstream attitude toward the measurement process in quantum theory, yet not to be confused with the approaches described in Section 3.

Wheeler followed up on this idea with his notion of observer-participancy (see e.g. Wheeler 1994), originally proposed already by Bohr. The idea that experiments are tools in which nature provides objective answers to questions it is asked is complemented by the subjective selection of the questions that nature does not prescribe. Wheeler's (1994) slogan *it from bit* is deeply misunderstood if it is only related to the yes-no alternative that is decided by a measurement. There are no bits in an unpartitioned state space: only the selection of a question entails a particular partition that allows the definition of (sequences of) bits.

The link between objective registration and subjective selection is neither part of the physical alone nor of the mental alone. It is relational between the two. In this spirit, Wheeler introduced the notion of a *meaning curcuit*, where meaning massively differs from syntactic information as measureable in bits. Meaning (not causation) is the appropriate concept to interpret correlations between the mental and the physical which — in the Eddington-Wheeler approach — connect the subjective with the objective. Quantum Bayesiansism (QBism) according to Fuchs (2002, 2017) offers a contemporary approach developing this further. Bohr's cartoon picture of a "smokey dragon", tangible at its teeth and tail but unseizable in between, illustrates how the psychophysically neutral reality defies being fixed in mental or physical terms.

In Bohm's and Hiley's approach, the notions of implicate and explicate order mirror the distinction between ontic and epistemic domains of reality. Mental and physical states emerge by explication, or unfoldment, from an ultimately undivided and psychophysically neutral implicate, enfolded order. This order is called *holomovement* because it is not static but rather dynamic, as in Whitehead's process philosophy. De Gosson and Hiley (2013) give a good introduction of how the holomovement can be addressed from a formal (algebraic) point of view, which Hiley actually developed inspired by Eddington's existence algebra.

At the level of the implicate order, the term *active information* expresses that this level is capable of "informing" the epistemically distinguished, explicate domains of mind and matter. It should be emphasized that the usual notion of information is obviously an epistemic term. Using information-based concepts in a non-epistemic manner appears inconsistent, or at least confusing, if the common (syntactic) significance of Shannon-type information is intended. This does not only apply to Wheeler's *it from bit* (if taken unreflected) but also to other information-based approaches.[16]

5.2 Pauli-Jung Conjecture

While the lineages of Eddington-Wheeler and Bohm-Hiley essentially sketch conceptual frameworks without further concrete empirical consequences, particularly concerning the mental domain, the Pauli-Jung conjecture (Atmanspacher and Fuchs 2014, Atmansapcher and Rickles 2022) offers some more material to discuss in this respect. An intuitively appealing first step into their approach considers the distinction between epistemic and ontic domains of *material* reality due to quantum theory in parallel with the distinction between epistemic and ontic *mental* domains.

On the physical side, the epistemic/ontic distinction refers to the distinction between a "local realism" of empirical facts obtained from classically conceived measuring instruments and a "holistic realism" of entangled systems (Atmanspacher and Primas 2003). Essentially, these domains are connected by the process of measurement. The corresponding picture on the mental side refers to a distinction between conscious and unconscious domains.[17] In Jung's depth psychological conceptions, these two domains are connected by the emergence of conscious mental states from the unconscious, analogous to physical measurement.

In Jung's depth psychology it is crucial that the unconscious has a *collective* component, unseparated between individuals and populated by so-called *archetypes*. They are regarded as constituting the psychophysically neutral reality into which the collective unconscious and the holistic reality of quantum theory converge. Archetypes operate as "ordering factors", being responsible for the arrangement of their mental and physical manifestations in the epistemically distinguished domains of mind and matter. More details of this picture can be found in Jung and Pauli (1955), Meier (2001), Atmanspacher and Primas (2009), Atmanspacher and Fach (2013), Atmanspacher and Fuchs (2014), and Atmanspachr and Rickles (2022).

The Pauli-Jung conjecture is clearly related to scenario (B) of Sec. 2, combining an epistemically dualistic with an ontically monistic approach. Correlations between the mental and the physical are conceived as non-causal with respect to one another, thus respecting the causal closure of the physical *against the mental* (and *vice versa*). However, there is another kind of "causal" relationship, in the sense of formal rather than efficient causation, between the psychophysically neutral, monistic level and the epistemically distinguished mental and material domains. In Pauli's and Jung's terms this kind of causation is expressed by the ordering operation of archetypal activity.

This scenario offers the possibility that the mental and material manifestations may inherit mutual correlations due to the fact that they are jointly caused by psychophysically neutral archetypes. One might say that such correlations reflect the lost holism of the underlying reality. They are *not* the result of any *direct* causal interaction between mental and material domains. Thus, they are *not* suitable for an explanation of *direct* efficient mental causation. And yet, dual-aspect monism according to scenario (B) is the only philosophical position that explains such correlations in a most natural way, rather than just positing them. Wheeler's observer-participancy with its mind-matter link can be seen as a special case of such correlations.

5.3 Mind-Matter Correlations and the Role of Meaning

In the Pauli-Jung conjecture, particularly striking ones among these correlations are called *synchronistic*, and Meier (1975) has generalized this concept to psychosomatic relations. A comprehensive taxonomy of mind-matter correlations following from Pauli's and Jung's dual-aspect monism was proposed by Atmanspacher and Fach (2013). They found that a large body of empirical material concerning more than 2000 cases of so-called "exceptional experiences" can be classified according to their deviation from the conventional reality model of a subject and from the conventional relations between its components (see Atmanspacher and Rickles 2022 for more details). Synchronistic events in the sense of Pauli and Jung appear as a special case of such relational deviations. See Atmanspacher and Rickles (2022) and Fach (2023) for extensive studies in clinical psychology, psychophysiology, and psychophysics supporting the taxonomy with empirical material.

An essential criterion required for synchronistic correlations is that they are *meaningful* for those who experience them. This re-emphasizes the significance of meaning that is found in Eddington-Wheeler's meaning circuit and Bohm-Hiley's active information. It is thus tempting to speculate about the concept of meaning as a basic ingredient in our overall view of reality *in toto*. Although this entails difficult problems concerning a clear-cut definition and operationalization, something akin to meaning, both explicitly and implicitly, might feature highly significantly in the framework of decompositional dual-aspect thinking. Along with the distinction of meaning as sense and meaning as reference due to Frege (1892), Atmanspacher and Rickles (2022) suggested to distinguish a surface structure of meaning between the mental and the physical from a deep structure that connects these two domains with their psychophysically neutral ground.

Primas (2003, 2009, 2017) proposed a dual-aspect approach where the distinction of mental and material domains originates from the distinction between two different modes of time: tensed (mental) time, including nowness, on the one hand and tenseless (physical) time, viewed as an external parameter, on the other (see the entries on time and on being and becoming in modern physics). Regarding these two concepts of time as implied by a symmetry breaking of a timeless level of reality that is psychophysically neutral, Primas conceives the tensed time of the mental domain as quantum-correlated with the parameter time of physics via "time-entanglement". This scenario has been formulated in a Hilbert space framework with appropriate time operators (Primas 2009, 2017), so it offers a formally elaborated dual-aspect quantum framework for basic aspects of the mind-matter problem. It shows some convergemce with the idea of temporally nonlocal mental states as addresed in Section 4.2.

As indicated in Section 3.2, the approach by Stapp contains elements of dual-aspect thinking as well, although this is not much emphasized by its author. The dual-aspect quantum approaches discussed in the present section focus on the issue of a generalized mind-matter relationship based on psychophysically neutral "non-product states" reminiscent of quantum entanglement, rather than on physical state reduction. The primary purpose here is to understand correlations between mental and material domains by their common ground, and not by direct causally efficacious interactions between them.

A final note in this section refers to the position of panpsychism or panexperientialism, respectively (see Skrbina 2003, Seager 2020, and the entry on panpsychism). Other than dual-aspect monism, panpsychism has no psychophysically neutral domain of reality characterized by non-product states. It is a plainly dualistic approach with mental and physical domains that are primordially coupled to one another (as in psychophysical parallelism). In such a situation it is important to understand "mentality" more generally than restricted to human "consciousness". Unconscious or proto-mental acts as opposed to conscious mental acts are notions sometimes used to underline this difference. The special case of human consciousness within the mental domain might be regarded as special as its material correlate, the brain, within the material domain.

6. Conclusions

The historical motivation for exploring quantum theory in trying to understand consciousness and its place in reality as a whole derived from the realization that collapse-type quantum events introduce an element of randomness, which is primary (ontic) rather than due to ignorance or missing information (epistemic). Approaches such as those of Stapp and of Beck and Eccles emphasize this (in different ways), insofar as the ontic randomness of quantum events is regarded to provide room for mental causation, i.e., the possibility that conscious mental acts can influence brain activity. The approach by Penrose and Hameroff also focuses on state collapse, but with a significant move from mental causation to the non-computability of (particular) conscious acts.

Any discussion of state collapse or state reduction (e.g. by measurement) refers, at least implicitly, to superposition states since those are the states that are reduced. Insofar as entangled systems remain in a quantum superposition as long as no measurement has occurred, entanglement is always co-addressed when state reduction is discussed. By contrast, dual-aspect quantum approaches refer to the topic of entanglement differently, and independently of state reduction in the first place. Inspired by entanglement-induced nonlocal correlations in quantum physics, the splitting of a holistic, psychophysically neutral domain of reality into mental and physical aspects is conceived as the origin of mind-matter correlations.

Each of the examples discussed in this overview has both promising and problematic aspects. The approach by Beck and Eccles, refined by Fisher, is most detailed and concrete with respect to the application of standard quantum mechanics to the process of exocytosis. However, it does not solve the problem of how the activity of single synapses enters the dynamics of neural assemblies, and it leaves the mental causation of quantum processes as a mere claim. Stapp's approach suggests a radically expanded ontological basis for both the mental domain and status-quo quantum theory as a theory of matter without essentially changing the formalism of quantum theory. Although related to inspiring philosophical and some psychological background, it still lacks empirical confirmation.

The approach initiated by Umezawa is embedded in the framework of quantum field theory, more broadly applicable and formally more sophisticated than standard quantum mechanics. It is used to describe the emergence of classical activity in neuronal assemblies on the basis of symmetry breakings in a quantum field theoretical framework. A clear conceptual distinction between brain states and mental states is often been missing in presentations of this approach. The proposal by Penrose and Hameroff exceeds the domain of present-day quantum theory and is the most speculative example among the quantum brain approaches discussed. Nevertheless it has initiated important empirical work on the function of anesthetics and the operation of microtubuli. At a conceptual level, a consistent framework for the interplay of mental and physical domains of reality with Penrose's mathematical Platonism has not yet been worked out.

The dual-aspect approaches of Pauli-Jung, Eddington-Wheeler, and Bohm-Hiley offer a tripartite picture of reality with a psychopysically neutral domain in addition to the mental and the physical. This extension implies additional options for understanding psychophysical correlations in a conceptually transparent fashion. With surprising coincidence, all these approaches emphasize the concept of meaning for the interpretation of correlations between the mental, the physical, and the psychophysically neutral domains of reality. Also, there is now a huge body of empirically documented (ordinary and exceptional) mind-matter correlations in clinical psychology, psychophysiology, and psychophysics that supports the Pauli-Jung conjecture in particular. Wheeler's approach has been formally developed in profoundly interesting ways by quantum Bayesianism (QBism) due to Fuchs. Hiley's work (based on old ideas by Eddington) offers an algebraic framework which also indicates theoretical progress. A dual-aspect quantum proposal by Primas, based on the distinction between tensed mental time and tenseless physical time, marks another potential step forward.

Maybe the best prognosis for short-term future success among the examples described in this overview, at least on foreseeable time scales, goes to the investigation of mental quantum features without focusing on associated brain activity in the first place. A number of corresponding approaches have been developed which include concrete models for concrete situations and have lead to concrete predictions and successful empirical tests. On the other hand, a coherent theory behind individual models and relating the different types of approaches is still to be settled in detail. With respect to scientific practice, a particularly promising aspect is the visible formation of a scientific community with conferences, mutual collaborations, and some perspicuous attraction for younger scientists to join the field.

The finer scale of consciousness: quantum theory

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Abstract

Consciousness is a multidisciplinary problem that has puzzled all human beings since the origin of human life. Being defined in various pointcuts by philosophers, biologists, physicists, and neuroscientists, the definitive explanation of consciousness is still suspending. The nature of consciousness has taken great evolution by centering on the behavioral and neuronal correlates of perception and cognition, for example, the theory of Neural Correlates of Consciousness, the Global Workspace Theory, the Integrated Information Theory. While tremendous progress has been achieved, they are not enough if we are to understand even basic facts—how and where does the consciousness emerge. The Quantum mechanics, a thriving branch of physics, has an inseparable relationship with consciousness (e.g., observer effect) since Planck created this subject and its derived quantum consciousness theory can perfectly fill this gap. In this review, we briefly introduce some consciousness hypotheses derived from quantum mechanics and focus on the framework of orchestrated objective reduction (Orch-OR), including its principal points and practicality.
Keywords: Consciousness, quantum mechanics, uncertainty principle, orchestrated objective reduction theory (Orch-OR theory), microtubule

Introduction

The nature of consciousness, once the exclusive realm of philosophers, has been gradually penetrated by neuroscientists, biologists, and physicists. Consciousness has always been defined as the Hard Problem in these subjects (1-4). With the emergence of unprecedented devices and the development of multidisciplinary experiments in different research fields, more details of this hard problem have been revealed, especially in quantum mechanics and neuroscientific fields. Since we decided to dive into the ocean of consciousness, many may think that the “water molecule” is our best beginning to disentangle this multidisciplinary conundrum. Thus, various interpretations of consciousness originated at the neuronal and molecular levels. The past 30 years have witnessed the tremendous and remarkable achievements of the neural correlates of consciousness (5,6). Nevertheless, there are many riddles that these “neuronal and molecular” models cannot explain (7). As a supplement to the theory of macroscopic physics (classical Newton’s mechanics), quantum mechanics has existed only for approximately one hundred years; however, some quantum mechanics terminologies have been ever prevalent, e.g., quantum entanglement, quantum coherence, wave-function collapse, and the most famous cat worldwide—Schrödinger’s cat. Quantum computers are considered the brightest new star in the quantum field and increasingly fascinate quantum physicists and information technology specialists. Advances in new materials and cryogenic physics have led to remarkable breakthroughs in quantum computing in recent years. Large commercial quantum computer systems that were invented by IBM (8-10) or the University of Science and Technology of China (11-13) could soon be operational within five years. Because quantum mechanics deals with the tiniest constituents of the material world, it seems capable of elucidating numerous unsolved and tough problems. Quantum theory, a branch from the finer scale of consciousness, has been accompanied by numerous controversies since its inception, but abundant proof demonstrated that this theoretical framework is capable of explaining the majority of consciousness problems that traditional neuroscience could not, especially the orchestrated objective reduction (Orch-OR) theory introduced by Penrose and Hameroff.

Origination

Consciousness was brought onto the scene that was ablaze with lights for more than 2,500 years since Socrates postulated that the cerebrum created consciousness, while Aristotle argued that mental qualities belonged to fundamental reality. More recently, Descartes proposed “Cogito ergo sum” in the Late Renaissance (14), and its definition and biological basis remain impasses such that no ultimate version has been reached, although there are various explanations based on its different aspects. Undoubtedly, any objective definition trying to explain this subjective problem seems feeble, which accounts for its official position—a hard problem. Compared with consciousness, quantum mechanics that was first invented approximately one hundred years ago is much younger. However, the latecomers have the upper hand. The last 100 years have witnessed the rapid development of quantum mechanics, and various significant breakthroughs have been accomplished by quantum physicists, while evolution in consciousness has progressed at a snail’s pace.

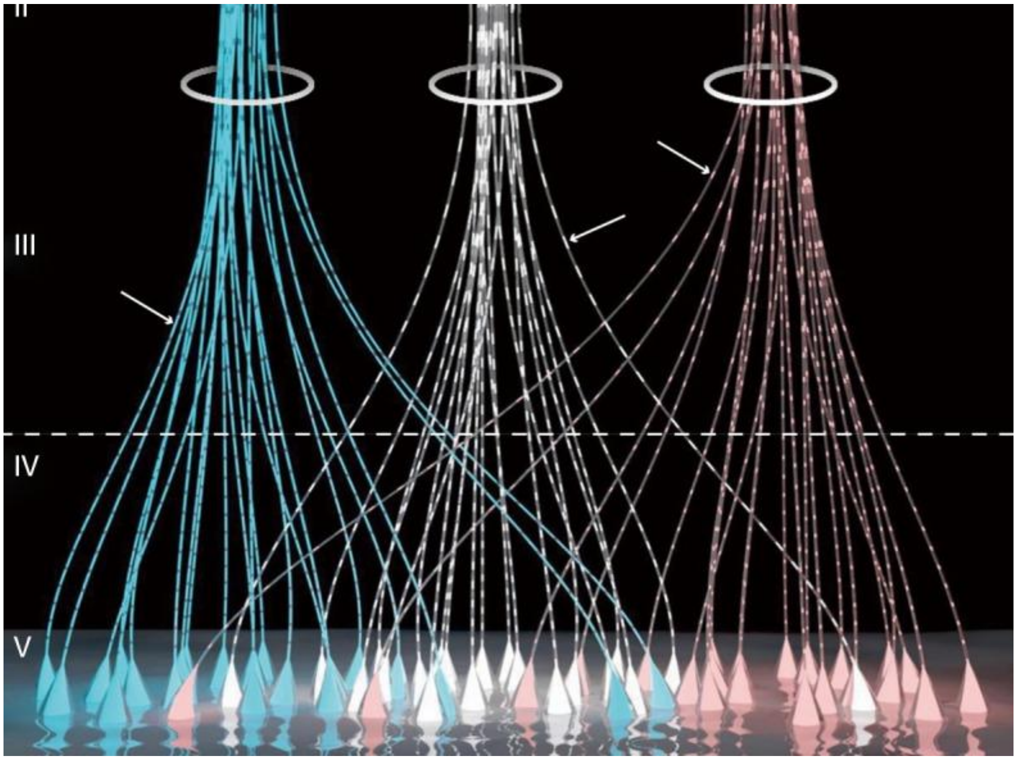
Initial exploration

In the 1930s, the Hungarian physicist Eugene Wigner considered it logical that the quantum description of an object is influenced by the mind that comes into our consciousness. In logic, solipsism may be consistent with current quantum mechanics (15). From the theory of the brain quantum field, Hiroomi Umezawa interpreted memory and other conscious phenomena as the result of the energy exchange of energy particles in the cerebral cortical field (16-19). Before long, Herbert Fröhlich proposed that the quantum field in the cell membrane condensed into the same state with quantum coherence during charge oscillation, namely, the Bose-Einstein condensate (20,21). Next, following Fröhlich, Marshall introduced that Bose-Einstein condensate produced from pumped phonons was the candidate for processing consciousness (22). John Wheeler, a noble American physicist, even suggested that the existence of life, including all life with “observation” ability, may have transformed many of the possible “quantum pasts” into real history. From this perspective, we have been participants since the beginning of the universe. Stunningly but perceptibly, we live in a “participating universe” (23). In the book of *Quantum Theory* (24), Bohm proposed that implicate order could apply to both the material world and consciousness, which was capable of explaining the relationship between them. In his opinion, mind and matter are projections into the explicate order from the underlying implicate order. By comparing optical holography with visual memory, Gabor attempted to explain the connection between human temporal recall and quantum mechanics (25). Stapp postulated a global collapse, a 'mind like' wave-function collapse that exploited certain aspects of the quantum Zeno effect within the synapses (26,27), distinct from the idea of Hameroff and Penrose (described in the "Orch-OR theory" section). Although his theory was based on synapses, a junction structure between neurons within the brain, unfortunately, he did not integrate his exhaustive quantum mechanical theory into an optimal interpretation with neurological or neuronal substrates. Jibu and Yasue believed that the movement of corticon and boson in the dipolar vibrational fields distributed along protein filaments of the cytoskeleton and extracellular matrices and surrounding water fields of the brain was the process of quantum information transmission, which ultimately led to the formation of quantum coherent states in the cortex (28-33). Disagreements and rebuttals were inevitable due to these ideas, and theories were simply overflowing from those physicists' minds, lacking factual neuroanatomical evidence and even systematic contexture (34-36).

Gradual systematization

Many biological scientists have tried to find a quantum-level substance that can be transmitted between neurons, such as a neurotransmitter, which conveys consciousness-related information (37). Based on "consciousness evolutionism", which emphasized that it is unlikely that consciousness came to higher creatures as a sudden leap, a finer world had been built. In this microgranular mental world, the "quantum-level substance" is the mental microunits called psychons, wandering around the mammalian neocortex (*Figure 1*). Each kind of psychon represents a unitary experience of consciousness-qualia. Like conventional neurotransmitters, psychons are transported along dendrons formed by apical dendrites (also their branches) of pyramidal cells in layers V, III, and II. During the period in which synapse structure was discovered, its foundational hypothesis had no reason to deviate from synaptic micro-property.

Figure 1.



Schematic diagram of dendrons and psychons of layer V pyramidal cells. Each triangle represents a pyramidal cell, and the ascending lines extending from the top of triangles are apical dendrites. Light spots (arrowhead), which are transported along apical dendrites with different colors, represent different kinds of psychons that could give rise to unique experiences. The dendrites cluster automatically while ascending to the superficial layer of cortex to configure dendrons (circle) according to the different psychons they transmit. Additionally, pyramidal cells are divided into different groups based on the distinct conscious experiences that they process (37).

Following the analogy of probabilistic fields of quantum mechanics and neural events arising from mental activity (38), as well as the hypothesis of dendrons and synaptic structure mentioned above, a more complete and systematic framework was constructed by Beck (37). More quantum mechanics mechanisms were also introduced. Exocytosis, as an intriguing discovery, was chosen as the indispensable and pivotal step. In the standby phase of the synaptic bouton, exocytosis was seen as a staged quantal event based on the quantum tunneling effect, resulting in momentarily increasing the probability of exocytosis (actually, it was named the selection of events in quantum mechanics). This selection mechanism augmented the likelihood for exocytosis and led to amplified excitatory postsynaptic potentials. Then, a coherent coupling of boutons in a dendron occurred. Because the dendrons in the cerebral cortex contain countless synaptic connections, there is an enormous amount of quantum transmission in the human brain, which inevitably leads to the randomness and freedom of mental phenomena-free will.

However, after more than twenty years, no subsequent development of this ancestral hypothesis occurred; additionally, the true identity of psychons was not discovered, despite countless works focused on cortical architecture (39). Various limitations persisted in these theories; however, they probably marked the beginning of the convergence of neuroscience and quantum mechanics for further understanding of consciousness.

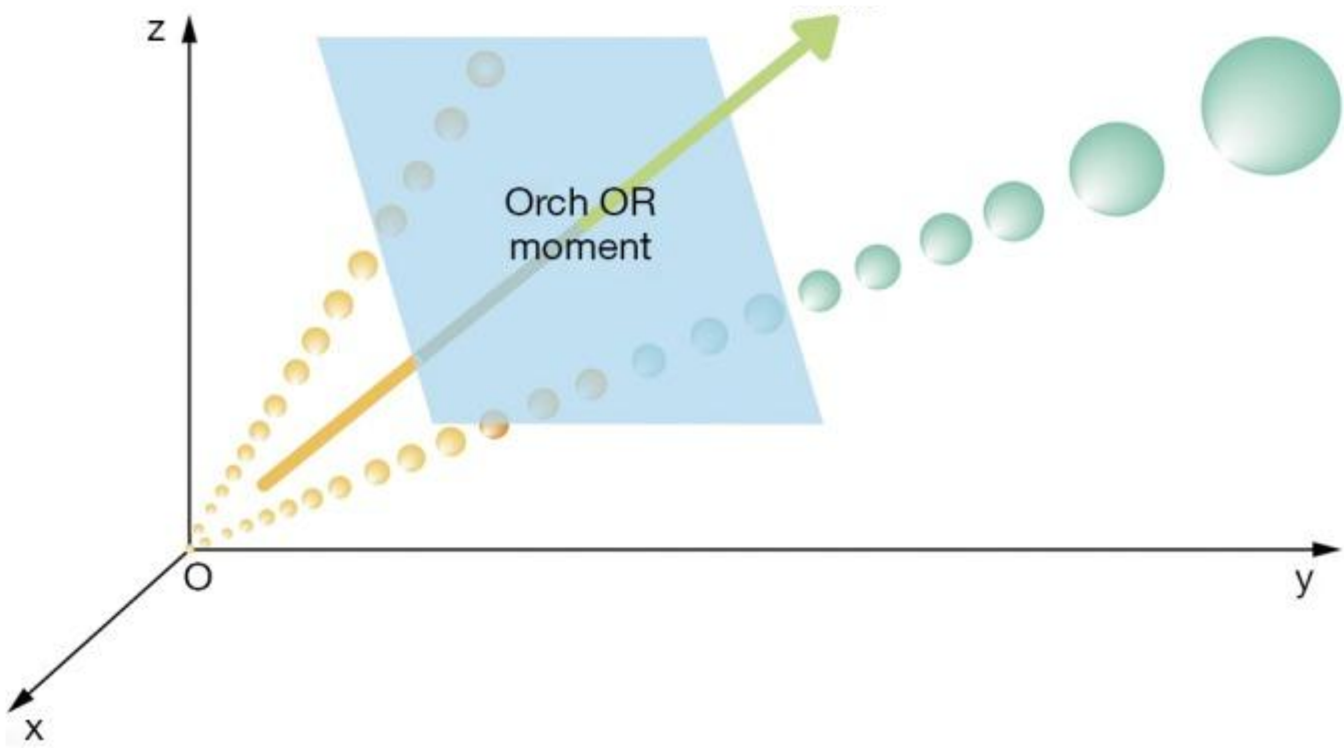
Orch-OR theory

It was widely accepted that most neuronal communication and information transmission initially occurred on receptors and ligands (especially among synapses in the central nervous system) on the cell membrane, followed by second messengers that broadcast or transfer the information to various parts of the interior cell. Almost all basic studies in neurobiology converge on the various receptors, ligands and signaling pathways. However, are we 100% certain about this prerequisite basis of neuroscience? Rather than the conventional receptors and ligands of the membrane, the principal cellular components of the Orch-OR theory are microtubules that are mostly considered pivotal structures for material transportation, cell movement, mitosis and establishment and maintenance of cell form and function.

To date, this theory has remained one of the most acceptable and continuous theories that covers in detail quantum physics, quantum gravity, quantum information theory, molecular biology, neuroscience, cognitive science, philosophy, and anesthesiology. Additionally, this theory was known to neurobiologists who were interested in the “Hard Problem” as well as physicists and philosophers.

Under the background of rapid development of world computer technology, Hameroff likened the flow of information in the brain to computers in which microtubules were to the brain what transistors were to the computer (40-43). Inspired by this fantastic analogy and Gödel’s incompleteness theorems, in *The Emperor’s New Mind* (44) published in 1989, Roger Penrose first attached the quantum effect in human cognition. For example, he considered whether consciousness can affect quantum mechanics or vice versa and that quantum mechanics itself might be included in consciousness. Penrose suggested that the “objective collapse”, that is, the collapse and superposition of quantum interference, is a real physical process, similar to the bursting of bubbles (44). Furthermore, consciousness was the product of quantum space-time structure (*Figure 2*), which was inextricably related to the universe, and the theory describing the relationship between consciousness and the universe was the Orch-OR theory (44). These quantum theories facilitated the emergence of later biological hypotheses of consciousness based on quantum mechanics.

Figure 2.

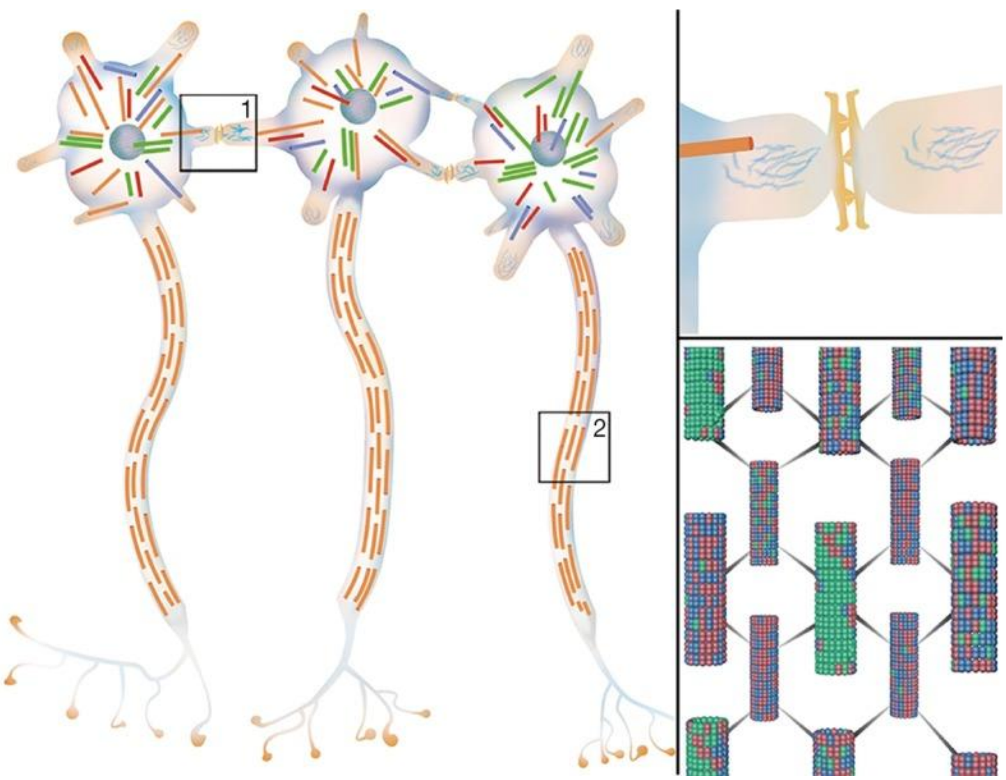


Conceptual graph of quantum space-time structure. The quantum particle vibrates from the start point O. Based on the uncertainty principle, the superposed condition of the particle determines that there are two possible tracks of particle progress in 3-dimensional xyz space. The orange and green large arrow indicates time, the fourth dimension. The initial variance between the two tracks is tiny (O point), but over time, the variance increases. One of its possible tracks would disappear after reaching the threshold at the moment of Orch-OR, leaving the other as certain and valid. The blue panel is the conscious moment of Orch-OR (44).

Originally, the cytoskeleton was proposed as the cell's nervous system and biological controller (nanocomputer), which had self-stabilizing logic algorithms introduced by Hameroff who was inspired by the subtle link between Fröhlich's coherent excitations and tubulin subunits in microtubules (40,42,45-47). He invoked that microtubules could be the fundamental units involving information processing in our enigmatic brain (48), e.g., visual identity (49,50), learning (42), cognition (42), and memory (49,51). An unprecedented collaboration heralded the advent of the Orch-OR theory. Illuminated by the structure of microtubules, Penrose posited that the microtubules composed of protein polymers played an essential role in the understanding of human consciousness from the perspective of quantum mechanics (52). Co-established by Hameroff and Penrose, the Orch-OR theory approached consciousness from various aspects and became richer and more profound with new discoveries in neuroscience and development of research methods and instruments.

Microtubules and tubulins, as the elaborate and dynamic three-dimensional network, are found in almost all eukaryotes (53,54) and some prokaryotes (55-57). Microtubules are stiff noncovalent polymers of α- and β-tubulin functioning as the cell cytoskeleton (58), the spindle during mitosis (59) and axonemes of cilia and flagella, playing dispensable roles in cell support, migration (60,61), development (62-64), gene regulation (65,66) and axoplasmic transport (67). Because of the particularity of neurons, e.g., nondividing properties and electrical signal conduction, microtubules have many specific characteristics. There are many more tubulins for microtubules within neurons than within somatic cells. The nondividing property determines its unique stability. Furthermore, each part of microtubules within neurons is also distinct. Microtubules in axons extend with the same orientation from the centrosome near the nucleus to the axon terminal. In contrast, microtubules in dendrites and cell bodies are disordered and multi-oriented (68,69) (*Figure 3*). The caps on dendritic and somatic microtubules could prevent treadmilling-like depolymerization that occurred in other somatic cells, which accounts for the steady and probable basis of information processing (70,71). Microtubule-associated proteins (MAPs), actin, and intermediate filaments are the key structures precipitating proper microtubule function (*Figure 3*). Microtubules are interconnected by MAPs; thus, their physiological activities are modulated by MAPs in different phosphorylation states (72). One of the most famous MAPs is the tau protein, which has been widely studied in Alzheimer's disease (73).

Figure 3.

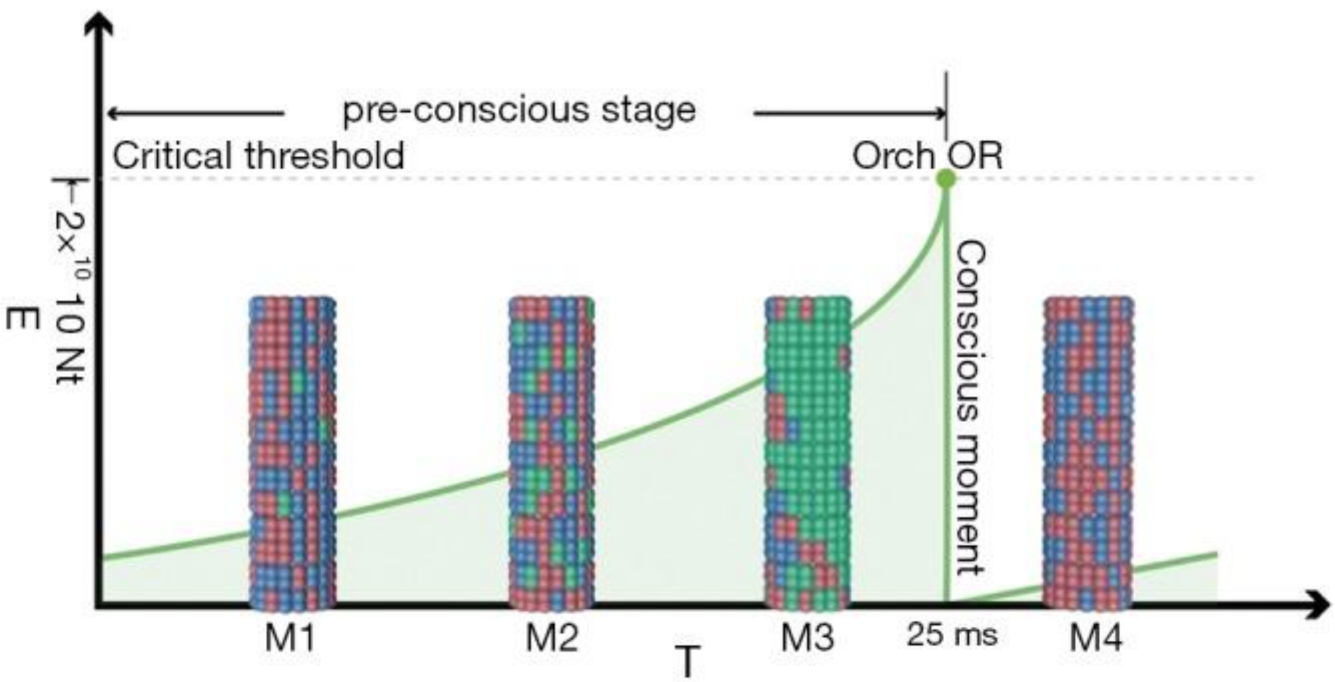


Neurons with gap junctions and microtubules. Left: schematic of the morphology of adjacent neurons. Microtubules in the soma and dendrites are clustered randomly and multi-oriented, while their counterparts in axons stretch from the axon hillock to the terminal in the same direction. Upper right: the magnified version of box 1 in the left graph. The gap junctions link nearby dendrites of different neurons, which make instantaneous interneuronal communication possible. Lower right: the magnified version of box 2 in the left graph. Microtubules in axons are regularly arranged in the same direction interconnected by microtubule-associated proteins (69).

Tubulins were deconstructed long ago. The study of tubulin amino acids was more advanced than the study of their α and β functional groups (74,75). In the Orch-OR theory, one of the most creative and prerequisite points is that tubulins are in a quantum superposition state according to the Heisenberg uncertainty principle; similar to qubits in quantum mechanics, they are 1 and 0 instead of 1 or 0 in computer computation.

Similar to the initiation of information transmission between neuronal synapses in traditional neurobiology, after the neurotransmitter binds to the receptor on the postsynaptic membrane, the activation of ion channel type receptors increases the intracellular calcium ion concentration. Alternatively, binding to a metabolic receptor activates a second messenger and subsequent signaling pathways. Conformational changes, e.g., phosphorylation and dephosphorylation, occur in microtubules and MAPs due to changes in calcium concentration and activation of various signaling pathways (71,76). These subtle changes caused by neurotransmitters from synaptic inputs could “orchestrate” tubulin states controlled by dipole couplings (one kind of intermolecular force), thus leading to microtubule simulation (50,77) (*Figure 4*). Tubulin quantum coherent superpositions and computations are increasingly combined to augment their superposed mass energy. Once the energy meets the critical threshold of quantum gravity, self-collapse occurs. That is, at this moment, the consciousness event occurs (according to Hameroff and Penrose, consciousness is discrete and independent rather than continuous) (*Figure 4*). Notably, under the “warm and noisy” brain, the information flow of neurotransmitters could prevent random environmental decoherence from overwhelming unitary evolution (derived from Schrödinger equation) quantum procedures. The whole orchestration and self-collapse process could be represented by a function schematic graph (*Figure 4*). From the equation $E = \hbar/T$ ($\hbar$ is Planck’s constant divided by 2π, T is time, E is the energy level that could be represented by the number of tubulins (Nt) in the Orch-OR theory), we could infer that only when an animal possesses enough microtubules (or a large enough brain) could it give rise to consciousness in a relatively short and realizable period of time. In the modern physical field, it was suggested that reality is composed of 3-dimensional space and 1-dimensional time. As *Figure 2* shows, from the beginning, particulates (microtubules) exist two alternative states in 3-dimensional space (just like Schrödinger’s cat in the uncertainty principle). Additionally, with the orchestration of synaptic inputs over time, once the threshold is met, objective reduction occurs, and their state is confirmed (69,79). Therefore, only one certain state continued, while the other disappeared. A neuron could accept numerous distinct neurotransmitters by its dendrites and soma, that is, there must be integration between different dendritic and somatic microtubules that precipitates dendritic and somatic microtubules within a neuron to meet this critical point congruously in case their quantum coherence and computation are chaotic. Gap junctions, which are not of much concern in ordinary neuroscience research, are considered to play an important role in quantum tunneling among dendrites in the macroscopic quantum coherent state, information exchange and mutual adjustment between neurons (49,80-82) (*Figure 3*). Then, the axon senses the instantaneous conscious events and fires to convey outputs to control advanced life intelligence activities and behaviors. In conclusion, dendritic and somatic microtubules' tubulins are initially in superposed states. Synaptic inputs orchestrate these tubulins such that their state tends to be unified, and total energy increases. Then, the threshold is met, followed by Orch-OR and a conscious event. Finally, all the tubulins and microtubes return to their original state, ready to accept the next synaptic input (*Figure 4*).

Figure 4.



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Orch-OR event. Minor tubulins begin with classical computing (green tubulins in M1), which leads to quantum coherent superposition and quantum computing (expanding of green tubulins in M2 and M3). When the critical threshold of coherence to quantum gravity is met, Orch-OR will occur; thus, the entire condition of the microtubule returns to the original pattern (M4). The conscious Orch-OR event occurs in the M3 to M4 transition. The area under the curve represents superposed mass energy E with self-collapse time T, which is consistent with the formula of $E = \hbar/T$. E may be described as Nt, the number of tubulins whose mass separation (and separation of underlying space time) for time T will self-collapse. Hameroff posited that T =25 ms (e.g., 40 Hz oscillations), Nt $=2\times10^{10}$ tubulins (69,78). M1, microtubule state 1; M2, microtubule state 2; M3, microtubule state 3; M4, microtubule state 4.

However, debates have become increasingly turbulent since the introduction of the Orch-OR theory. Some scientists, including philosophers, physicists and neuroscientists, support that their work heralded a new level of understanding of consciousness and was worthy of further development and experimentation (83-88). However, numerous rebuttals have emerged since the inception of the Orch-OR theory. These criticisms covered biological, gravitational and quantum fields to which Hameroff and Penrose responded one by one with detailed biological evidence, quantum mechanical equations and theoretical frameworks in “Consciousness in the universe: A review of the ‘Orch OR’ theory” (69). However, this review generated an even larger wave of criticism. Comments sprang up like mushrooms (84,89,90). One of the most noted retorts was proposed by Baars (89) in his article “Consciousness, biology and quantum hypotheses”, which caused this debate to reach the climax. Baars invoked some actual questions that many other critics mentioned. (I) All plant and animal cells are composed of microtubules, and some of their MAPs are similar. (II) Countless previous studies have proven that the cerebral cortex and thalamus are strongly implicated in conscious experience, while on a quantum basis, their specificity did not emerge. (III) More than half of the human brain region, especially the cerebellum, does not hold consciousness content; however, neurons in these regions also have identical microtubules. (IV) There is no known quantum-level proof to account for the difference between conscious versus unconscious brain events. (V) Consciousness must evolve with biological evolution. Hameroff replied with reasonable explanations that validated Orch-OR as an appropriate and qualified theory to surmise consciousness, despite the increasingly detailed development that should be interpreted (91). An inevitable situation was that arguments about Baars’s direct exclusion of “freshman” quantum theory burst into more debates in which critics stated that Baars should be more generous regarding quantum consciousness theory due to its practical basis, which could enrich our understanding of consciousness (92-95). In addition, more theories and rebuttals could bring more attention and science funding into the “puzzle game” of consciousness that has confused and captivated philosophers, neuroscientists, and physicists for ages.

Conclusion and perspective

Quantum mechanics has been inextricably linked with consciousness since its birth. Various proposals and theories have been put forward to lift the veil of consciousness. In this review, we summarized the main quantum theory of consciousness of which the theories based on neural structure were the principal parts. Undoubtedly, the Orch-OR theory co-established by theoretical physicist Penrose and neuroscientist Hameroff is currently the most convincing theory. Even more exciting, with the emergence of new drugs, new research methods, and new quantum technologies, this theory is constantly being enriched and perfected. Especially in the research of anesthesiology (96-100), memory (71), cognition (42,101-103), neural synchrony (104) and vision (49), mounting results and evidence indicated the Orch-OR theory could be self-explanatory and could be invoked to many different conscious backgrounds. More recently, Li *et al*. found that xenon’s (one kind of anesthetic) nuclear spin could impair its own anesthetic power, which involves a neural quantum process (105). Thus, the quantum theory of consciousness is increasingly gaining more supporters. With the dedication of these supporters, the quantum theory of consciousness will be gradually completed and will be able to explain the hard problem systematically and comprehensively. As the enigmatic riddle of consciousness has remained intractable, we need more theories and hypotheses to attract enough attention and maintain lively debate. This conflict is the only way for human beings to explore the truth. Since there is no conclusive scientific mechanism of consciousness, as one of the most systemic and convincing theories among various theories of consciousness, the Orch-OR theory deserves our deeper understanding and study. Let us not put Descartes before the horse (94). It is possible to disperse the fog of our ignorance and shed light on new knowledge regarding consciousness.

Why a 'genius' scientist thinks our consciousness originates at the quantum level

Do our minds have quantum structures that give rise to consciousness? Sir Roger Penrose, one of the world's most famous scientists, believes this and can explain how he thinks it works.

Human consciousness is one of the grand mysteries of our time on earth. How do you know that you are "you"? Does your sense of being aware of yourself come from your mind or is it your body that is creating it? What really happens when you enter an "altered" state of consciousness with the help of some chemical or plant? Are animals conscious? While you would think this basic enigma of our self-awareness would be at the forefront of scientific inquiry, science does not yet have strong answers to these questions.

One way to think of consciousness is to conceive of it as a byproduct of numerous computations that are happening in your brain.

The integrated information theory, created by neuroscientist Giulio Tononi of the University of Wisconsin-Madison, proposes that conscious experience is an integration of a great of amount of information that comes into our brain, and that this experience is irreducible. Your brain interweaves a sophisticated information web from sensory and cognitive inputs.

The global workspace theory of consciousness, developed by Bernard Baars, a neuroscientist at the Neurosciences Institute in La Jolla, California, says that maybe consciousness is simply the act of broadcasting information around the brain from a memory bank.

But there are some who think our attempts at understanding the nature of consciousness through neuroscience are doomed to fail unless quantum mechanics is involved. World-renowned Oxford University mathematical physicist Sir Roger Penrose, for one, thinks that consciousness has quantum origins.

Together with noted anesthesiologist Stuart Hammeroff, who teaches at the University of Arizona, Penrose came up with the Orchestrated Objective Reduction theory of the mind. The theory is somewhat outlandish, but cannot be easily dismissed considering that Roger Penrose is regarded by many as one of the world's most brilliant people for his contributions in cosmology and general relativity. He is known also for his prize-winning work with Stephen Hawking on black holes. Physicist Lee Smolin once remarked that Penrose is "one of the very few people I've met in my life who, without reservation, I call a genius."

Sir Roger Penrose in 2011.

Penrose believes that consciousness is not computational. Our awareness is not simply a mechanistic byproduct, like something you can make a machine do. And to understand consciousness, you need to revolutionize our understanding of the physical world. In particular, Penrose thinks the answer to consciousness may lie in a deeper knowledge of quantum mechanics.

In an interview with Nautilus's Steve Paulson, Penrose uses an example from quantum computing to explain that *qubits* of information remain in multiple states until coming together into an instantaneous calculation, called "quantum coherence," making a large number of things act together in one quantum state.

Here's where Penrose's theory draws upon the work of Hameroff by saying that this quantum coherence takes place in protein structures called "microtubules". These microtubules reside inside the neurons in our brains and can store and process information and memory. Penrose and Hameroff think that microtubules are quantum devices that are orchestrating our conscious awareness.

This theory is not appreciated by everyone in the scientific community, with many critics saying the brain is too "warm, wet, and noisy" and cannot sustain a quantum process. Another physicist, Max Tegmark, even calculated that the brain cannot possibly think as fast as this idea requires. Hawking is also not on board, suggesting Penrose should stick with his field of expertise.

Yet, a 2013 study by Japanese scientists added some proof to the theory by Penrose and Hameroff as researchers detected vibrations in the microtubules. Penrose and Hameroff then proposed that by focusing brain stimulation on these vibrations one could conceivably "benefit a host of mental, neurological, and cognitive conditions."

Still, this theory of consciousness is rather on the outs in a field that hasn't had much advancement in a while.

In 2017, Sir Roger Penrose launched the Penrose Institute to study human consciousness through physics and to differentiate it from any potential artificial intelligence.

Watch Sir Roger Penrose explain how he came to conceive of quantum structures in the brain:

Dynamic brain connectivity distinguishes conscious and unconscious states

Our brains are remarkably dynamic, constantly shifting between states of activity that reflect our thoughts, perceptions, and awareness. A new study published in *Communications Biology* suggests that this dynamism is key to distinguishing between consciousness and unconsciousness. Researchers found that the brain "explores" a diverse range of connectivity patterns when we are awake, but during states like deep sleep or anesthesia, the brain becomes more predictable and rigid, its functional activity corresponding more closely with its structural wiring.

Consciousness—our ability to experience, perceive, and respond to the world—has long been one of the most puzzling topics in neuroscience. Researchers have sought reliable, objective markers to distinguish between conscious and unconscious states, both to deepen our understanding of awareness and to improve clinical tools for diagnosing and managing conditions like comas or anesthesia.

Brain connectivity can be classified into two types: *structural* connectivity and *functional* connectivity. Structural connectivity refers to the physical wiring of the brain, the fixed networks of neurons and pathways that form its architecture. Functional connectivity, on the other hand, reflects the brain's activity patterns, showing how different regions work together dynamically at any given moment.

Previous research has shown that the brain's functional connectivity constantly shifts between different configurations, reflecting various cognitive processes. The new study aimed to address whether the shifting patterns of functional connectivity could reliably differentiate between conscious and unconscious states by focusing on brain dynamics in people who were awake, under general anesthesia, or in deep sleep.

"Consciousness remains one of the most intriguing topics in neuroscience—something deeply fundamental and yet not fully understood," explained study authors Alain Destexhe and Rodrigo Cofré, who are both affiliated with the Paris-Saclay Institute of Neuroscience.

“We are broadly interested in the whole spectrum of consciousness states, from the unconscious states to those induced by psychedelics. Our interest lies in unraveling the dynamic functional mechanisms that underlie conscious awareness and how they differ when consciousness is perturbed. Resting-state functional MRI (fMRI) gives us a unique way to observe the brain in action, allowing us to capture spontaneous activity and its transitions, which may reflect deeper processes related to consciousness.”

For their study, the researchers analyzed fMRI data from two datasets. The first involved 16 healthy participants scanned during three states: awake, under general anesthesia (using the intravenous drug propofol), and after recovery. The second dataset included 18 healthy participants scanned during wakefulness and deep sleep (N3 stage).

The analysis focused on “phase coherence,” which measures how synchronized different brain regions are at any given moment. This approach enabled the researchers to identify recurring patterns of brain activity and track their transitions over time. Using statistical clustering techniques, these patterns were grouped into distinct categories, or “states,” for each condition. The frequency and distribution of these states were then analyzed across conscious and unconscious conditions.

To characterize brain dynamics, the study employed two key measures. Shannon entropy quantified the diversity of brain activity patterns, with higher entropy indicating a broader repertoire of states. Structure-function coupling assessed how closely the brain’s functional activity aligned with its physical wiring, as determined by structural MRI. The researchers also used a Markov chain model to evaluate the likelihood of transitions between states, providing insights into the stability and flexibility of brain dynamics in various conditions.

The results revealed significant differences in brain dynamics between conscious and unconscious states. During wakefulness, the brain exhibited a diverse and flexible repertoire of activity patterns, reflected in high Shannon entropy. These patterns were less reliant on the brain’s structural connectivity, indicating that the conscious brain explores states independent of its physical wiring. Frequent transitions between states during wakefulness underscored the dynamic and adaptable nature of the conscious brain.

In contrast, unconscious states, such as those induced by general anesthesia or deep (N3) sleep, showed reduced diversity in brain activity patterns. Shannon entropy was significantly lower, indicating that the brain explored a narrower range of states. Additionally, functional activity in unconscious states closely aligned with the brain's structural connectivity, suggesting that the unconscious brain relies more on its anatomical wiring. Transitions between states were also less frequent, reflecting a more rigid and repetitive dynamic.

"In simple terms, our brain's activity patterns are far more dynamic when we're awake and conscious," Destexhe and Cofré told PsyPost. "These rich dynamical patterns of brain connectivity appear to be essential for awareness. Under anesthesia or deep sleep, however, the brain is still very active but relies on less dynamic patterns, closer to the anatomical connectivity, and shows fewer transitions. These findings bring us closer to identifying objective and reliable indicators of consciousness, which could one day help us better understand and even track awareness in clinical settings."

Interestingly, the researchers observed that certain activity patterns typically associated with unconsciousness occasionally appeared during wakefulness, and vice versa. This finding suggests that consciousness may exist on a spectrum, with overlapping features between states of awareness and unawareness. Despite these overlaps, the overall findings consistently demonstrated that rich and dynamic brain activity is a hallmark of consciousness.

"We were surprised by the robustness and generalizability of our results," the researchers said. "Additionally, we were surprised to find that certain connectivity patterns more associated with unconsciousness can appear in small bursts even when we're awake, and vice versa. This suggests that consciousness isn't necessarily an all-or-nothing state; rather, it may be a fluid spectrum with overlapping features, raising intriguing questions about the boundaries between states of awareness and unawareness."

As with all research, the study includes some limitations. The data came from two different research groups using distinct scanning and preprocessing methods, which may have introduced variability. Additionally, the study focused on one anesthetic, and the effects of other drugs on brain dynamics remain unexplored. Deep sleep, which involves more than just a loss of consciousness, may also introduce complexities not fully addressed in this study.

“While our method is robust and seems applicable across different states such as general anesthesia and deep sleep, there are still limitations in how data is collected and preprocessed in different studies,” Destexhe and Cofré explained. “For example, differences in data acquisition settings and preprocessing techniques can introduce subtle variability. Additionally, while we studied the effects of one anesthetic (propofol), other drugs may have different effects on brain dynamics.”

Future research could expand these findings by exploring other unconscious states, such as those induced by different anesthetics or psychedelics. Using alternative brain imaging techniques could also provide complementary insights. Ultimately, the goal is to develop universal markers of consciousness that can be applied in diverse clinical and research contexts.

“Long-term, we hope to develop generalizable markers of consciousness that could be used across various clinical scenarios, from general anesthesia monitoring to assessments of consciousness in patients with brain injuries,” Destexhe and Cofré said. “We’re also interested in exploring other imaging methods like EEG, which may offer additional insight into the brain’s conscious and unconscious states. We would also like to generalize our results further to psychedelic states.”

“This study underscores the centrality of the brain’s dynamic patterns to consciousness. A deeper understanding of these dynamics holds promise not only for advancing scientific knowledge but also for practical medical applications, such as assessing brain states in patients with traumatic brain injuries or comatose states, or for monitoring the depth of anesthesia and altered states under psychedelics. Ultimately, we hope this work inspires further research to extend these methods across additional species, alternative anesthetics, and diverse data acquisition techniques.”

The study, “Dynamical structure-function correlations provide robust and generalizable signatures of consciousness in humans,” was authored by Pablo Castro, Andrea Luppi, Enzo Tagliazucchi, Yonatan S. Perl, Lorina Naci, Adrian M. Owen, Jacobo D. Sitt, Alain Destexhe, and Rodrigo Cofré.

In a Declassified CIA Report, Scientists Tried to Move Consciousness Beyond the Physical Realm

- Declassified documents show that throughout the latter half of the 20th century, the CIA had some... interesting... ideas on how to obtain intelligence.
- One of the most dizzying reports comes from a 1983 document detailing the "Gateway Experience"—various means of altering the mind to create a kind of psychic spycraft.
- Although the document details some well-known techniques, such as hypnosis and transcendental meditation, the document veers into some unconventional territory and makes lofty claims about consciousness and the universe.

If you spend any amount of time pursuing declassified Central Intelligence Agency materials, you come across some pretty wacky stuff. There are dragonfly robots, cyborg cats, and an absolutely bonkers Soviet submarine heist. Recently, another chapter of the CIA's strange investigations surfaced on TikTok.

Through some creative extrapolation by TikTok user Sara Holocomb, the document purported to confirmed existence of reincarnation, which was further touted by sites like the Daily Mail. While this is not in fact true, the document *does* offer a bizarre look into the agency's efforts to develop some sort of a psychic spycraft.

The declassified document itself isn't new—originally drafted in 1983, the CIA declassified the 29-page report back in 2003. The agency is also well-known for its investigations into the inner workings of the human mind and how it could be manipulated for extracting information. The most famous of these investigations was the 20-year-long MKUltra top-secret project, which started back in the 1950s.

The document, written by U.S. Army Lieutenant Colonel Wayne M. McDonnell, explores a number of varying means of mind alteration, which McDonnell refers to collectively as "the Gateway experience."

“The ‘Gateway Experience’ is a training system designed to bring enhanced strength, focus, and coherence to the amplitude of brainwave output between the left and right hemispheres so as to alter consciousness, moving it outside the physical sphere so as to ultimately escape even the restrictions of space and time,” the report states. “The participant then gains to the various levels of intuitive knowledge which the universe offers.”

So… yeah. I’ll have what he’s having.

Some of these mind-altering techniques are relatively mainstream, such as hypnosis or transcendental meditation—a practice actively advocated for by film director David Lynch. Other ideas are a bit further afield, such as biofeedback (the ability for one hemisphere of the brain to gain control of parts of the other hemisphere) and an idea known as “The Consciousness Matrix,” which claims that “the human is also a hologram which attunes itself to the universal hologram by the medium of energy exchange thereby deducing meaning and achieving the state we call consciousness.”

In her series of TikTok videos, Holocomb zeroes in on page 19, which states how consciousness is timeless—as it exists outside of a space and time, it seemingly has “neither beginning or end.” Which… woah, if true.

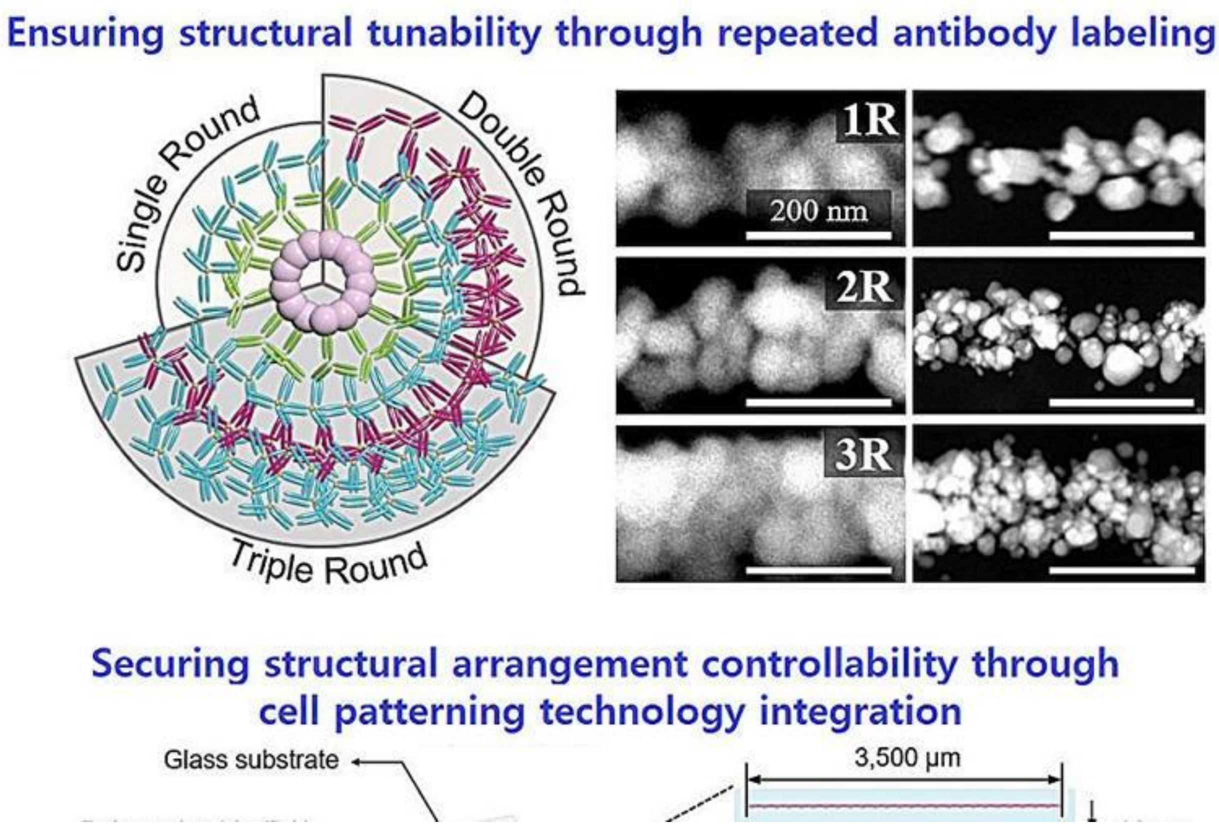
This line led Holcomb—and, by extension, the Daily Mail—to assert that the CIA believed in the existence of a reincarnation. However, the document describes this consciousness as a “pool of limitless, timeless perception,” which does not exactly match up with the tenets of reincarnation as described in some religions.

Regardless of these takeaways, the CIA memo is quite the trip, and is written with an impressive amount of unflagging certainty. Which is strange, considering that those working in the scientific field of consciousness still have no concrete idea as to how it’s generated in the animal mind—let alone that it’s a “differentiated aspect of the universal consciousness.”

Needless to say, the CIA never developed a corps of psychic spy agents.

To solve this problem, the research team studied a way to utilize various biological structures within the cells while retaining high malleability.

As a result of the research, the team developed the conversion to advanced materials via labeled Biostructure, shortened as CamBio, that can selectively synthesize nanostructures with various specificities and sizes from specific protein structures in biological samples composed of various proteins.



A method for securing tunability using CamBio at the cell level. An example of integrating the repetitive antibody labeling and cell patterning technology with CamBio to control the characteristics by integrating the tunability of the structure through biotemplating is shown. Credit: Advanced Science (2024). DOI: 10.1002/advs.202406492

The CamBio method secures high re-tunability of functional nanostructures that can be manufactured from biological samples by merging various manufacturing and biological technologies.

Through the technology of repeatedly attaching antibodies, arranging cells in a certain shape, and thinly slicing tissue, the functional nanostructures made with CamBio showed improved performance on the surface-enhanced Raman spectroscopy (SERS) substrate used for material detection.

"If combined with the latest biological technologies such as gene editing and 3D bioprinting and new material synthesis technologies, biostructures can be utilized in various fields of application."

More information: Dae-Hyeon Song et al, Highly Tunable, Nanomaterial-Functionalized Structural Templating of Intracellular Protein Structures Within Biological Species, *Advanced Science* (2024). DOI: 10.1002/advs.202406492

Provided by The Korea Advanced Institute of Science and Technology (KAIST)

Signs You're Experiencing A Higher Dimensional Shift

The spiritual path is unique to everyone and will be different depending on where your life is at, because of that this is largely uncharted territory. Experiencing a dimensional shift can be one of the most disorienting things anyone can go through.

It can seem as if you wake up one day and the world is upside down, and it can quite literally be like that! When I first experienced a dimension shift it felt like I had traveled to a new planet entirely, and yet I was in the exact same place.
The things around me hadn't changed…but the way I was looking at them had.
During the course of our life we can go through endless dimension shifts, however there are a few key signs to identify. This post is to help you find clarity in what is an extremely confusing time.

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What is a dimensional shift?

Before we get into the signs you're experiencing a shift, let's clear up what exactly that means and why it's important. On the most basic level a consciousness shift, dimension shift, exiting the matrix, whatever you want to call it, is about bringing awareness to your reality and seeing beyond just the physical.

When we engage in practices like meditation or mindfulness we tune into an energy that permeates all existence. In becoming aware of this energy we see how **everything is connected**. We see the lies we were taught about the nature of reality. We see that there is more than meets the (physical) eye.

As we shift into higher and higher dimensions our knowledge of reality gets increasingly expansive. We embody deeper levels of love, wisdom, peace and clarity.

When we talk about the dimensions in a spiritual context it's not that we're actually living in those spaces, nor is this how dimensions are discussed scientifically. We use dimensions to refer to layers of awareness beyond the physical and corresponding qualities of each.

A lot of people talk about these levels as if we will actually go there permanently, especially 5D. However in reality it isn't quite like this. We can move into and out of different levels of awareness, and we aren't going anywhere physically. Just as we can ascend, we can descend or regress.

We still exist in the third-dimension, however by opening our consciousness up we can gain a wider, fuller picture of ourselves and our place in the Universe.

What is 3D, 4D & 5D consciousness?

3D

This is our current dimension of physical existence. When we live 'in the third-dimension' this is a very physical-focused existence, where we are completely closed off from our spirit – our ego runs the show. I don't think anyone lives solely in the third dimension, even those we do not consider 'aware', we are all open to spirit in some sense.

4D

This is a level of consciousness where time and space become flexible. We notice how our thoughts influence physical reality, or how spirit comes through in our daily lives. When we live in 4th dimensional awareness we are less attached to timescales and routines. We understand how to let go and allow paths to unfold organically, rather than trying to control things.

5D

Next up is the fifth dimension. This is a level of consciousness that has been spoken about in much spiritual literature, in videos and blogs. There is also a lot of misinformation surrounding this level of consciousness, how it looks and what it means.

A one point 5D was described as a place that we would reach if we develop ourselves to a high enough level spiritually, there would be a split of consciousness between the 3D and 5D worlds, a physical rapture of sorts.

There was a lot of religious overtones to this theory. However 5D is more so a state of complete acceptance and present-moment awareness. We are not going anywhere physically, but our focus is purely on the NOW.

Living in the 4th dimension

For this post we're going to be talking mainly about **a fourth dimensional shift**, although some of these symptoms will apply to a number of different 'shifts'. In fact this is just the language we are using now to make it easier to understand this transition, although the experience itself is far more expansive than any one label. The fourth dimension is outside of linear space and time. It is the dimension we tune into when we apply the *law of attraction*, where we play with our internal energy/emotions/thoughts in order to shift the physical.

We often talk about the 3D or speak on a 5D shift, but there is very little information on 4D. 4D acts as the **bridge between 3D and 5D**, from linear time to non-linear to the NOW moment. To live in 5D we must first pass through 4D and so this is an incredible important discussion to have. Let's get right into it!

Dimensional shift symptoms

1. You experience 'glitches' in your reality

The first and most noticeable sign that you are currently experiencing a dimensional shift is the occurrence of glitches in your reality. These can take on the form of constant synchronicity, deja vu, **seeing energy in the air**, past life memories seeping into your daily life, and synchronistic encounters.

These glitches make you step back for a moment and question if reality is as you believed it to be. Even the smaller occurrences can stick with us for years, it can feel like we've taken a *peek behind the curtain.*

These glitches essentially act as subtle ways to make us more aware as we go about the day, notice how everything is interconnected, and come into contact with the energy that permeates all existence.

2. Dreams become vivid, waking life becomes dreamy

The second tell tale sign that you experiencing a shift is that your dream become exceptionally vivid. You are often waking up from dreams feeling intense emotions, feeling as if what you experienced was real somehow or knowing that it had a deeper meaning.

Along with this, it can feel as if we are living in a dream in our waking hours. As we go about our day we may experienced an increased *lucidity*, everything appears brighter and more pleasant. We randomly meet people who compliment us, or speak about things we were thinking about.

This occurs because as we raise our level of consciousness we begin to see how the dream world and waking world are linked. We see the realness of our dreams and the falseness or dream-like quality of our waking lives.

The gap in between the two closes. It's common to dream about things only for them to happen the next day, or have incredibly lucid dreams where we have insightful conversations with dream characters.

3. Time feels expansive

Another common symptom of a dimension shift is the sense that time has become more expansive. This can look like temporary memory loss, not being able to place the days and feeling like time has been condensed.

Of course when looking at symptoms like this it is incredibly important to put them in the right context, be careful not to characterize a mental health/physical problem as a spiritual one. As you navigate the awakening process keeping yourself grounded and your physical body and mind healthy is just as important.

Memory loss may come in the form of feeling as if you are simply a point of consciousness, that your physical memories in this one lifetime aren't all that you have. **Past life memories** can bubble to the surface and be triggered by mundane activities.

4. You feel a deep sense of oneness

I would say that the most telling sign that you've shifted to a higher state of consciousness is the sense that you are not alone, in that you feel your connection to every living being around you.

When you walk in nature you can feel how you are connected to the trees, birds, even bodies of water. You walk around and animals will happily approach you, people feel uplifted in your presence and babies will smile at you. It's your energy that they are perceiving and feeling at home with.

You will find that you are attracting random encounters with people who are on your wavelength, they mention things that you were thinking, meet you at your moment of need, or seem to communicate with you in a telepathic manner.

These people are what we refer to as **soul family**; they act as your support network in this physical incarnation.

5. You are drawn to help others

The final step is feeling drawn to help others! As we move along our spiritual path and become more aware it's natural to want to spread that knowledge with others. This doesn't mean we lecture or force our opinions on others but that we are more conscious with our interactions.

We may express what we are learning (or unlearning) through writing, art or music. As we awaken we become beacons of light that others are attracted to, with this we must be extremely conscious of how we exchange energy.

Just as beacons can attract those in need, they can also attract those with ill intentions. As you go about your day these energy sucking interactions will become increasingly obvious, they pinpoint where we can fill in our 'energy leakages' and become more stable in our awareness.

No doubt many or all of these signs sound familiar to you. Know that you are not alone, there are thousands if not millions of other people going through this same awakening journey. As will become clear, this journey includes becoming more sensitive to the light but also more sensitive to the shadow, and so you'll want to keep your wits about you.

What causes a dimensional shift?

Circling back a bit, I want to discuss some of the reasons we might experience this 'dimensional shift'.

So I dimensional shift is basically an increase in awareness; you are able to perceive yourself, others and the world around you in a multi-dimensional way. There is no longer a disconnection between the physical and spiritual aspects of your life.

This sort of awakening or transformation doesn't happen by chance, although it happen spontaneously, but based on the inner work we do.

A dimensional shift can happen when practicing shadow or ego work, meditation, mindfulness, a specific spiritual practice like yoga. There is usually a 'tipping point' where we suddenly see things differently, and start bridging the divide between the different aspects of our being.

Alongside the more abstract symptoms, we can also experience a very physical purging. You could call this an emotional or spiritual purge.

We are born with a very tuned in spiritual awakening that gradually gets dimmed over time. As we take on social programming and beliefs systems, the connection between the physical and spiritual is severed.

Through a spiritual practice we release density, which is another way of saying 'dense energy'. We feel lighter and brighter, and although we are having a physical experience we reconnect with our spiritual essence.

How to access higher dimensions of consciousness

It's one thing to know all of these levels of consciousness and another to practice accessing them.

A lot of spiritual literature is difficult to understand or perhaps contexualize in our daily lives because it is coming from a different *place* entirely. This is why some spiritual teachings can seem out-of-touch or inapplicable to our everyday problems. In practicing raising our consciousness we can better understand and apply this information.

Meditate

It doesn't have to be complicated. Meditation is simple in theory but it can be difficult to remain consistent. When we meditate we become aware of our habitual thought patterns (particularly the more subtle ones) and through practice we can go beyond this familiar chatter.

The difficulty comes in overcoming all of the usual doubts, fears and anxiety we carry around with us daily. Even getting seated can bring up an immense amount of resistance.

Get seated in a comfortable position, place your arms in your lap and breathe deeply from your stomach area. Simply pay attention to each breath in and out. If you become distracted, bring your focus back to the breath. Start with five minutes to begin and slowly work your way up to longer periods.

Mindfulness

There is some debate about the difference between meditation and mindfulness, some see them as the same thing and others make a delineation. In this context both mindfulness and meditation will work hand in hand for you.

This is another simple concept in theory but difficult in practice, this is the art of bringing awareness to each action.

Mindfulness can be incorporating into any activity we do throughout the day. Whether we are washing the dishes, walking to work or having a conversion, we can bring mindfulness to it.

The impact of meditation and mindfulness is not always obvious but builds up over time. With consistency we will notice moments where our awareness goes beyond the ego, beyond the physical, we start tuning into something *more*.

Affirmation

Affirmation and intention are another key part of shifting our reality and perspective. Everything is energy as the saying goes, this applies to our thoughts, words and actions.

It's one thing to have a meditation or mindfulness practice, and another to actually embody an uplifted perspective in all areas of our life.

What we are constantly thinking and speaking into existence is a huge part of the puzzle.

A lot of people struggle with affirmations because they approach them in the wrong way, or have too many expectations about the result they are looking to get with them.

To me affirmations are useful for creating consistent energy more than anything, rather than getting a specific physical result (although that comes too).
Reciting affirmations is a practice in trusting yourself, to open the mind up to different possibilities.

Some affirmations I enjoy:

- My vision is clarified, I look at things with new eyes
- I am endlessly supported
- I manage abundance well
- I trust myself to take this next step
- I am allowing ___ into my life

Ascension & spiritual bypassing

A lot of the time when there are discussion of dimensions like this there is a strong emphasis on the spiritual side of things. Especially when discussing 5D, the tendency to frame this as a race towards some spiritual *goal*. Where we might ascend and leave our physical lives or physical problems behind.

This focus can encourage a lot of spiritual bypassing. This is where we use spiritual concepts or ideas to avoid our physical emotions and duties. Our spiritual practice shouldn't be an escape from *regular* life, instead it should be something that enriches every aspect of it.

Many of us come to these spiritual teaching because we are deeply uncomfortable with the normal way of things. The eat, sleep, repeat cycle. The mindless entertainment & news industry that seems to have the world in its grasp. We are aware of how deeply broken the system is.

And so we must keep this in mind as we navigate our spiritual paths. Rather than trying to avoid the physical or maintain a high vibe all of the time, bringing a new awareness to old patterns.

We might also fall into the trap of always trying to surpass our ego, or even deny it exists. This leads to the formation of a 'spiritual ego'. Our ego is still present but we wrap it up in spiritual platitudes.

While the ego causes us many problems (it wouldn't be difficult to write up a list) it is also crucial to how we lead functioning lives. The ego let's us know where we end and someone else begins.

How to manage a higher dimensional shift

This stuff is no joke! Whatever term you use to refer to an experience like this, whether spiritual awakening or ascension, when our energy shifts in such a dramatic way for the better we also have to deal with the downsides.

The key here is balance. As we bring our consciousness up, learning how to ground ourselves aswell. As we reconnect with our spirit, getting to know our ego and the ways it manifests better too. We can honor both the physical form and spiritual being, dark and light, yin and yang.

Another important practice doing a shift or awakening is setting strong boundaries! This is something I come back to time and time again because the relationships in our lives affect our spiritual development immensely.

There is often a period of isolation after awakening. A time where we reassess our relationships, hobbies and interests, work life etc.

If we don't set the right boundaries after coming to an awakening we can easily slip back into old patterns, or lose this new and sharp awareness.

As difficult as it may be, we have to reconsider a lot of areas in our life and how aligned they actually are with our spirit.

Duality and Nonduality Explained: Key Insights from the Nondualists

December 27, 2024

OVERVIEW: This guide explores the meaning of duality and nonduality for beginners. It also provides specific precepts and practices from world-renowned nondualists Ramana Maharshi and Nisargadatta Maharaj.

What is the nature of duality?

What exactly does *nonduality* mean?

What's the difference between duality and nonduality? And why is it important?

Are there "nondual meditations" you can practice?

In this in-depth guide, we'll explore these questions and much more.

Let's dive in …

CONTENTS

What is Duality?

Every aspect of form is dualistic in nature. Every quality and trait of our three-dimensional world is a part of duality.

Duality is so all-encompassing that we might incorrectly assume that's all there is.

Everything within the manifest universe represents duality including:

- All physical objects
- Language/words
- Physical bodies
- Thoughts
- Nature
- Emotions
- The five senses
- Cosmos
- Time
- Space

With duality, we have differentiation: this or that, either/or, pleasure and pain, subject and object.

Duality represents separation. The dualistic manifest reality is the world we observe, perceive, and experience.

What is Nonduality?

Nonduality is an English translation of the Sanskrit term *Advaita* which technically means "not two."

Nonduality is challenging to define because it can only be perceived by what it is *not*.

For example, while duality is related to time, space, linearity, and limitation, nonduality is defined by the timeless, nonlocal, nonlinear, and infinite.

But that's not entirely accurate either. Since words are dualistic, how can you use duality to describe nonduality? You can't. Therefore, we can only approximate the meaning of nondualism with language.

While nonduality is sometimes considered a philosophy or even a religion associated with Hinduism and Buddhism, it's ultimately a principle understanding found throughout all the ancient wisdom traditions.

Duality and Nonduality Comparison Chart

Duality and Nonduality Definitions

Duality is easier to define. If you can perceive it, it's dual.

Why? Because there's an observer (you/subject) and the observed (object). By definition, this is duality.

Can you perceive …

- A toothbrush, a book, or a pot?
- Another person (body)?
- Yourself?
- Nature?
- Experience of time?

Simply put, anything *perceivable* is part of the manifest universe and is therefore dual.

Nonduality, however, is not as easy to define. The nondual is, by definition, non-perceptible by the five senses. It can not be divided into two; it has no subject-object relationship.

Said another way, the nondual is *indivisible* and *uncognizable*. Do you see the challenge here?

How can you define something indivisible that cannot be cognized?

You can only *approximate* a definition. You can only *point* to what the nondual is. And that's what the nondualists do.

Shankara, one of India's great nondualists explains:

The world is illusory,
Brahman [Spirit] alone is real,
Brahman is the world.

That's nonduality.

Let's proceed …

Duality and Nonduality: The Three Gunas

Guna is a Sanskrit term that means qualities or attributes. The three *gunas* are considered the qualities of consciousness.

The three gunas in the Yogic tradition are Tamas, Rajas, and Sattva.

Duality and Nonduality: The Three Gunas

Tamas

Tamas represents inertia, apathy, inactivity, and darkness. In a Tamasic state, one might feel lazy, depressed, helpless, hopeless, bored, or confused. Tamas manifests as ignorance and delusion.

Tamas leads the ego to *claim doership* ("I am the doer").

Rajas

Rajas is the quality of action, change, movement, and energy. In a Rajasic state, one might feel motivated, energized, and ready to work. Rajasic energy builds the world.

Rajas is the *dynamic quality* of consciousness.

Sattva

Sattva is the attribute of balance, clarity, harmony, peace, and purity. In the experience of a satvic state, tamas and rajas are reduced, enabling one to realize *moksha* (Self-liberation).

Sattva is the quality most closely associated with *consciousness itself*. (More on this topic below.)

Nirguna

From a nondual perspective, all three gunas or attributes of consciousness are aspects of duality. They each represent an expression of form in the manifest universe. Each guna expresses itself through a subject (person/being).

However, in a nondual state, one is considered *nirguna*—**without attributes**.

How can you adequately describe something that is *without attributes*?

Nonduality as the "Fourth State"

Another way to conceptualize nonduality is through the three-bodies doctrine in Hindu philosophy combined with nondualist Ramana Maharshi's "fourth state."

The three bodies are:

1. Gross body (Sthula sarira)
2. Subtle body (Sukshma sarira)
3. Causal body (Karana sarira)

This same three-state structure is used in Buddhism as well. These three bodies represent the three levels of relative consciousness:

Duality and Nonduality: The Three Relative States of Consciousness

The Gross Level

We are most familiar with the *gross world* as it represents our waking state (*visva*).

The gross level is the three-dimensional plane of existence or the manifest reality from which our physical bodies operate.

The Subtle Level

The subtle realm is the dreaming state (*taijasa*)—the dimension of our dreams, imagination, astral level, and psyche.

All primordial images (Jung's archetypes) reside within this level. The subtle level is beyond gross form, but it's still dualistic.

The Causal Level

The causal level is associated with deep sleep (prajñā). It is far more subtle than the prior two. The "causal" is the *unseen cause* of the waking and dreaming states of consciousness.

The causal level can be likened to quantum physicist David Bohm's enfolded universe.[1]

Note that all three of these states of consciousness—gross, subtle, and even causal—represent duality.

The "Fourth State"

Nondual sage Ramana Maharshi explained there was also *turīya*, a "fourth state."

He explained that the Self is that "which is the witness of these states, that it is called the fourth (turīya)."[2]

That is, the Self is the underlying reality supporting the appearance of the three relative states of consciousness.

In the context of nonduality, the three relative states are not ultimately "real." They are aspects of duality and therefore expressions of *Maya* (illusion).

Ramana Maharshi explains:[3]

There is only one state, that of consciousness or awareness or existence. The three states of waking, dreaming, and sleep cannot be real. They simply come and go. The real will always exist. The 'I' or existence that alone persists in all the three states is real.

Maharshi beautifully explains this penetrating nondual realization.

"The real will always exist." Why is this necessarily so?

Because anything subject to time is dualistic; that which *always* exists is not subject to time (timeless, eternal, unlimited).

The "fourth" is considered a substratum of *all that unfolds*—the **only real Truth of our Being**.

According to Maharshi, it is in transcending this so-called "fourth state" (*turiyatita*) that one realizes the Self.

Duality and Nonduality: The Sense of "I Am"

Now, let's take a quick step back because if you're new to this material, what's expressed above might sound too conceptual.

So let's clarify a few terms—*nondual-style*. (Note: You'll find a quick glossary at the bottom of this guide for reference.)

To understand the nondualists, we need a direct, first-hand understanding of *consciousness* itself, specifically how nondualists use this term.

The Body-Mind Identification Problem

The problem starts with the physical body—not the body itself but *one's exclusive identification with it*.

The identification with the body-mind organism forms the *illusory ego*. The ego is one's self-identity. It says, "I am [state your name]" and the body associated with that name.

Once the ego forms, one becomes entrenched with duality as to what's real. We experience separation. Samsara (suffering) begins. We are now divorced from the Self.

As nondualist Nisargadatta Maharaj explains:[4]

You are not able to give up your identity with the body. This is the great maya—the Illusion.

Simply put, the identification with the physical body-mind organism as "I" creates the experience of duality, obscuring the nature of consciousness and the nondual.

The Sense of "I Am"

You know you are. You know you exist.

How do you know this? What is the quality of "I-am-ness" that provides this sense of awareness or experience of existence?

As the nondualists explain, the physical body combined with vital energy (prana) and consciousness creates the sense of "I am."

The sense of "I Am," however, isn't personal. That's the illusion. Instead, this knowledge "I Am" is *impersonal;* it is *beingness* or *consciousness itself*.

However, through early conditioning in our first few years, the sense of "I Am" or *beingness* mistakenly identifies with the body.

Once this misidentification occurs, there's now a *subject* (you) experiencing an *object* (body). Hence, duality.

The *chit* or universal consciousness (consciousness of Self) silently slips into the background and the experiencer (*tamas*; ego doership) takes center stage.

Consequently, nondual masters like Nisargadatta Maharaj and Ramana Maharshi repeatedly drive home the point that you are **not** the body. That is, you are not the experiencer.

Consciousness as Beingness

So, if you're not the body-mind organism, what are you?

You are the universal consciousness through which experiencing is witnessed.

As the nondualists explain, *consciousness* or *beingness* is the outcome of the five elements (fire, water, earth, wind, and metal) and what they call the "food-essence body."

Nondualists direct you back to this consciousness because it is the only "capital" we have. But this consciousness or beingness is still representative of form. That is, there is still a witness of this consciousness.

Therefore, there is something that transcends consciousness…

Beingness and the Absolute (Nonduality)

Nisargadatta Maharaj explains:[5]

Now I have told you about the beingness, which is the outcome of the five-elemental play and the result of the food-essence body. But "You" as the Absolute are not the body, and not even the indwelling beingness.

That is, you are a principle that transcends form in *all its expression*.

The ***Absolute*** is often translated as *Parabrahman* (the Supreme) or *Paramataman* (the Supreme Self).

Nonduality Expressed in Taoism

To draw an analogy from Taoism, beingness represents *conscious knowledge* while the absolute is *real knowledge*.

Conscious knowledge stems from the conditioned mind (personal); real knowledge is unconditioned and derives from the Original Spirit (impersonal).

The Absolute as a Non-Being State

It's important to note that this Absolute state cannot be "achieved" by the beingness. Again from Maharaj:[6]

The Absolute state cannot be obtained. That is your state. To the Absolute state the witnessing of the consciousness happens.

He's explaining that you are already THAT. The Absolute is a non-being state representative of nonduality.

The Supreme Self (*Paramataman)* impersonally witnesses the manifest reality (but not as a subject-object). The Absolute transcends and includes the illusionary world of form.

Maharaj explains:[7]

The initial humming of the beingness as "I am, I am" is the duality. But who accepts the duality? The "non-beingness" accepts duality with the beingness. The Absolute "non-being" state, by assuming the being state, becomes dual in manifestation."

This is the essence of nondual teachings. You are the "I" as the Absolute, but ***not*** the personal, dualistic "I." Again from Maharaj:[8]

"I", the Absolute, am not the personal "I." The personal "I" cannot tolerate the impersonal beingness and is afraid of death. The factual, eternal "I," the Absolute, has no fear of death.

Illustrations for Understanding Nonduality

The nondualists provide clever and creative metaphors for explaining nonduality. Let's examine a few of these illustrations.

The Telescope Metaphor

One's consciousness or beingness is likened to a telescope.[9]

As an observer, you can view the stars, sun, and moon through a telescope.

But you (as the observer) are not the field of observation or the telescope itself.

Now, apply this understanding to one's consciousness.

What is witnessing the manifest universe?

According to nondual sages like Nisargadatta Maharaj, witnessing (observation through the telescope) doesn't result from one's beingness (consciousness).

Instead, witnessing happens to the Absolute—an eternal principle called *Parabrahman* (the supreme state of the Absolute).

This Absolute is neither the medium of witnessing nor the manifest universe being witnessed.

Illustration of the Self as a Projector (from Ramana Maharshi)

The Cinemas Metaphor

Ramana Maharshi illustrates the ego and the Self with an analogy of a film projector:[10]

The light from the lamp throws shadows through the lens causing pictures to appear on the screen.

Similarly, the phenomenal (manifest) world appears to the individual in the waking and dream states as long as latent mental impressions exist in the mind.

The projector's lens magnifies the specks on the film into a large size, throwing off many images within a second.

Similarly, the mind enlarges the "sproutlike tendencies into treelike thoughts" creating inumerable images and realities.

The light source within the projector is like the Self. The projector's light source is only visible when there is no film in the projector.

Similarly, the Self is realized only when the mind's tendencies drop away during the three relative states of consciousness.

Just as the light source illuminates the lens while remaining unaffected by it, the Self (nondual) illuminates the ego (dual) and its proclivities while remaining unaffected.

Western Psychology, Duality, and Nonduality

Since the guides on this website largely center around psychological insights from [depth psychology](#) (Jung), [humanistic psychology](#) (Maslow), and similar sources, let's quickly address how Western psychology relates to duality and nonduality.

The short answer is that virtually everything within Western psychology deals *exclusively* with duality.

Duality and the Personality

Virtually all of Western psychology is oriented around the personality. The personality is an aspect of duality.

From a nondual perspective, the personality is not real. It's part of the Maya (illusion).

The personality results from mental conditioning that starts when the I-Am emerges and mistakenly identifies with the body (usually around age two or three).

Western psychology, in contrast, seeks to develop the personality—to create what they call a "healthy ego." As such, it deals with mental illness and mental health.

Nonduality doesn't address the personality except to reaffirm that it's not real. *Nondual realizations transcend the ego*.

Jungian Psychology and the Self

Jungian psychology and a few modern adaptions like Internal Family Systems (IFS) use the concept of the Self.

However, the Self in these systems is still not the impersonal *Atman*. That is, the Self in these systems does not transcend the individual (as is the case with nondual teachings).

For example, Jung's individuation process seeks to make the person whole (a *complete individual*) while nonduality destroys the concept of the individual.

As Jung humbly noted in his foreword to *The Spiritual Teachings of Ramana Maharshi*,[11]

Psychology cannot contribute anything further to [the nondual insights of Maharshi and other nondualists], except the remark that it lies far beryond its scope to propose such a thing.

By this remark, Jung acknowledged that nonduality lies beyond the range of Western psychology.

Maslow and Self-Transcendence

Maslow also addressed the concept of self-transcendence.

Self-transcendence is a state of consciousness beyond the confines of the limited ego.

However, this conception is also still oriented toward the subtle and causal states of consciousness. Therefore, self-transcendence still represents duality—not nonduality.

The Self in Nonduality

While in Jungian psychology, the Self represents the organizing principle within the psyche, in nonduality, it has a more all-inclusive meaning.

Ramana Maharshi was asked to explain the nature of the Self:[12]

What exists in truth is the Self alone. The world, the individual soul, and God are appearances in it, like silver in mother-of-pearl; these three appear at the same time and disappear at the same time. The Self is that where there is absolutely no "I" thought. That is called Silence. The Self itself is the world; the Self itself is "I"; the Self itself is God; all is Shiva, the Self.

That is, the Self in psychological thought is still dualistic while the nondual Self (Atman)—especially *Paramatman* (Supreme Self)—is indivisible (nondual). The Self IS the totality.

Nondual practices guide you back to the Self, leaving behind one's false identification with the empirical self (body-mind organism).

Nisargadatta Maharaj explains:[13]

The body has importance only because the "I Amness," the consciousness, is dwelling therein. If the "I Amness" or consciousness is not there, the body will be disposed of as refuse. Call the knowledge "I Am" as your Self, don't call the body as knowledge.

Identification with the body-mind organism fosters separation and illusion; stabilizing consciousness in the Self clarifies the error.

Matter & Consciousness: Which Comes First?

Those working from a standard “scientific” understanding of the cosmos will be challenged to *appreceive* nonduality.

Material reductionism is the concept that everything can be reduced to its smallest form, assuming that the base material is matter itself.

Material reductionism is a rampant ideology that pervades much of modern science. This presumptive belief system makes understanding nondual principles virtually impossible. Let’s look at two quick examples.

The Official Narrative in Physics

In the “official narrative,” matter comes first. Life develops and evolves by random chance. Only then can consciousness enter the picture.

The “Big Bang” theory is the pinnacle expression of material reductionistic thought.

From the perspective of mystics and sages throughout recorded time, the official narrative has things *entirely backward*.

Consciousness comes first. Only then can matter manifest. This phenomenological, experiential insight is shared in all ancient cosmologies including Taoism, Hinduism, and Buddhism (as well as Western religions).

Of course, numerous physicists have transcended the “official” paradigm. For example, see physicist Amit Goswami’s *The Self-Aware Universe* or David Bohm’s *The Implicate Order*. There are countless others.

This distinction is important because only duality can exist if you believe that matter comes first. There’s no place for god, nonduality, or the Self in material reductionism.

(There’s a good reason why so many scientists are atheists. A non-spiritual perspective is baked into their prevailing ideology.)

The Official Narrative in Neuroscience

Current neuroscience suffers from the same ideological handicap.

Many neuroscientists believe that consciousness is just some chemical or molecule in the brain that can and will be isolated and replicated.

As such, they will be searching for this magical and mysterious molecule for a *very long time*! The nondual reality will remain elusive.

In this field, there are exceptions too. For example, neuroscientist Karl Pribram's theory of the holographic brain with nonlocal memory storage. (See Michael Talbot's *The Holographic Universe*.)

Chit, universal consciousness, exists before the formation of the body and then mistakenly identifies with the form as "I."

Common Traps Related to Nonduality

In the context of psychological development, nondual teachings can trigger certain common traps we should be mindful of. These psychological pitfalls include:

1. The spiritual bypass and
2. Disassociation

Let's address both of these traps.

Spiritual Bypass

Nonduality is akin to the Buddhist doctrine of *Anatta* or No Self.

This doctrine appeals to many "spiritual aspirants" who are, consciously or subconsciously, seeking an escape from their daily lives.

As such, the uninitiated can use nondual principles in an act of avoidance behavior, known as a "spiritual bypass."

With a spiritual bypass, individuals use spiritual ideas like nonduality to avoid addressing unresolved psychological wounds and emotional trauma.

Avoiding this trauma stalls one's psycho-spiritual development, leading to stagnation.

Subconsciously, many are drawn to nondual teachings because they offer a means of avoiding the discomfort of addressing our prior wounds and trauma.

In these cases, a person may give lip service to nonduality, but an aspect of their shadow is still in control.

When this occurs, nondual principles are restricted to "philosophy" and become yet another set of mental concepts.

Disassociation

Held only as a concept, nonduality can also foster dissociation.

The mind can use nondual principles as a new set of beliefs.

While nonduality is designed to take you *beyond body-mind identification*, it can be misapplied to *sever* one's connection to the small self (body-mind).

Philosopher Ken Wilber articulates this as "transcending and dissociating" versus "transcending and including."[14]

That is, you can *cut yourself off* from your body and/or mind OR one can *include it* and *move beyond* your body and mind.

The reality is that many people are *already* somewhat dissociated from their physical bodies due to past trauma and living in their minds. In these cases, nonduality can potentially strengthen this dissociation.

Yes, nondualists are saying you're not the body or the mind. But simply disassociating from the body-mind organism doesn't bring you to a higher state of consciousness or deeper Self-realization.

Nondual Meditations: How to “Practice” Nonduality

Nondual teachers provide various *sadhana* (spiritual practices/methods) to realize nonduality.

The goal of any nondual practice is to silence the mind first and then stabilize in the Self.

Self-Inquiry

The primary, over-arching approach to nonduality is ***self-inquiry***.

Self-inquiry is a form of nondual meditation that directs your attention to the source of your *beingness*.

Your awareness is placed on the sense that “I Am”—that quality of existence itself—leading to “nondual awareness” over time.

As Maharaj explains:[15]

You know you are. Because you know you are, everything is happening. Get to know that knowledge “I Am.” When you understand what that “I Amness” is, then the shell of the mystery is broken.

Whatever approach one takes to realizing nonduality, some form of self-inquiry is always at the root.

Neti-Neti

Neti-Neti translates to “not this; not this.” With this form of self-inquiry, you systematically negate everything you are not until you arrive at the Absolute (nondual).

For example:

I am not the physical body.
I am the five sense organs.
I am not any other bodily functions.

I am not the breath.
I am not the mind.
I am not the thoughts.

You continue to negate everything you are *not* until nothing cognizable remains. Then, you are THAT.

As Ramana Maharshi explains,[16]

After negating all of the above-mentioned as "not this, not this," that Awareness which alone remains—that I am.

Marharshi's Who Am I?

A famous form of self-inquiry from Ramana Maharshi is continuously contemplating the question, *"Who am I?"*

The goal here is the same as above: to bring you back to the Self.

The key is to contemplate this question ceaselessly and continuously. The intention must be genuine for the inquiry to take hold and override the conditioning of existing mental tendencies.

Maharaj's Abide in the Knowledge "I Am"

The knowledge (or sense of) "I Am" is the source of one's beingness or consciousness.

Instead of identifying with the body-mind organism, Nisargadatta Maharaj instructs you to abide in the I-am-ness that gives you the sense that you are. Remember that this consciousness isn't personal; instead, it is universal.

The *jnani* (sage) explains:[17]

If you accept individuality you will not make progress. You must identify with the manifest totality from the first moment of daybreak.

Focusing on the sense of "I Am" pulls your attention away from body-mind identification and towards the Self.

Again from Maharaj:[18]

This "I Amness" is a function of nature, a product of the five elemental food body. It knows itself, it loves to be. With the aid of this knowingness, get to know your Self.

That is, become one with the beingness *first*. Then, the Self takes you the rest of the way.

Suggested Reading on Nonduality

This guide focused on the insights of two nondual masters who lived in India over the last century: Ramana Maharshi and Nisargadatta Maharaj.

Thankfully, many of their talks were transcribed and translated into English.

Many readers may be familiar with Western spiritual teachers like Deepak Chopra, Eckhart Tolle, Wayne Dyer, David R. Hawkins, and Lester Levenson (The Sedona Method). It's worth noting that nondualists Ramana Maharshi and Nisargadatta Maharaj are the source material for *all* of them—and countless others.

So if you want to understand nonduality, why not go to the source?

An excellent starting point for Nisargadatta Maharaj is I AM THAT, translated by Maurice Frydman. This book is like a primer for Maharaj's later works translated by Dr. Robert Powell and Jean Dunn.

Powell's translations include *The Nectar of Immortality*, *The Experience of Nothingness*, and *The Ultimate Medicine*.

Dunn's translations include *The Seeds of Consciousness*, *Prior to Consciousness*, and *Consciousness and the Absolute*.

For Ramana Maharshi, The Spiritual Teachings of Ramana Maharshi is an excellent starting point. From there, you might go to *Be As You Are* (edited by David Godman)

Glossary: Duality and Nonduality

Below is a short-hand glossary in case you want to refer back to it later. Most of these definitions come from Robert Powell's translations.

Advaita: nonduality

Atman: Self; the true, spiritual Self (as opposed to the body-mind self)

Brahman: the Absolute Reality

Chit: consciousness; the universal consciousness, the Self

Gunas: qualities of consciousness

Jnana: spiritual knowledge

Jnani: realized sage

Maya: the cosmic illusion

Nirguna: attributeless, unconditioned, nonqualitative

Neti-Neti: not this, not this.

Para: the Supreme; the Absolute

Parabraham: the supreme state of the Absolute (without attributes); the Unborn eternal principle (beyond "I am")

Paramatman: the Supreme Self; the eternal Absolute state

Prana: the vital breath; life force

Sat-chid-ananda: Being-Consciousness-Bliss

Sattva: consciousness; seed-consciousness; clarity, purity, harmony

Can Consciousness Exist Outside of the Brain?

The brain may not create consciousness but "filter" it.

The prevailing consensus in neuroscience is that consciousness is an emergent property of the brain and its metabolism. When the brain dies, the mind and consciousness of the being to whom that brain belonged cease to exist. In other words, without a brain, there can be no consciousness.

But according to the decades-long research of Dr. Peter Fenwick, a highly regarded neuropsychiatrist who has been studying the human brain, consciousness, and the phenomenon of near-death experience (NDE) for 50 years, this view is incorrect. Despite initially being highly incredulous of NDEs and related phenomena, Fenwick now believes his extensive research suggests that consciousness persists after death. In fact, Fenwick believes that consciousness actually exists independently and outside of the brain as an inherent property of the universe itself like dark matter and dark energy or gravity.

Hence, in Fenwick's view, the brain does not create or produce consciousness; rather, it filters it. As odd as this idea might seem at first, there are some analogies that bring the concept into sharper focus. For example, the eye filters and interprets only a very small sliver of the electromagnetic spectrum, and the ear registers only a narrow range of sonic frequencies. Similarly, according to Fenwick, the brain filters and perceives only a tiny part of the cosmos' intrinsic "consciousness."

Indeed, the eye can see only the wavelengths of electromagnetic energy that correspond to visible light. But the entire EM spectrum is vast and extends from extremely low energy, long-wavelength radio waves to incredibly energetic, ultrashort-wavelength gamma rays. So, while we can't actually "see" much of the EM spectrum, we know things like X-rays, infrared radiation, and microwaves exist because we have instruments for detecting them.

Similarly, our ears can register only a narrow range of sonic frequencies but we know a huge amount of others imperceptible to the human ear exist nevertheless.

When the eye dies, the electromagnetic spectrum does not vanish or ceases to be; it's just that the eye is no longer viable and therefore can no longer filter, be stimulated by, and react to light energy. However, the energy it previously interacted with remains. And so too when the ear dies or stops transducing sound waves, the energies that the living ear normally responds to still exist. According to Fenwick, so it is with consciousness. Just because the organ that filters, perceives, and interprets it dies does not mean the phenomenon itself ceases to exist. It only ceases to be in the now-dead brain but continues to exist independently of the brain as an external property of the universe itself.

What's more, according to Fenwick, our consciousness tricks us into perceiving a false duality of self and other when in fact there is only unity. We are not separate from other aspects of the universe but an integral and inextricable part of them. And when we die, we transcend the human experience of consciousness, and its illusion of duality, and merge with the universe's entire and unified property of consciousness. So, ironically, only in death can we be fully conscious.

This is not to be taken as joining God or a creator because the cosmic consciousness that Fenwick describes did not create the universe but is simply a property of it. Obviously, despite his impressive body of research into this subject, there is no current way to empirically establish the validity of Fenwick's cosmic consciousness hypothesis. Ultimately, it aligns more with faith than science. Thus, it seems the answer to the question in this post's title is "No." There is no empirically established explanatory framework for understanding how consciousness can exist independently and outside of the brain.

Recall the old riddle, "If a tree falls in the woods and no one is there to hear it, does it still make a sound?" Well, it seems the answer is "No." Because sound is the conscious perception of sonic or acoustic stimuli that require a sense organ to experience. Without an ear to hear and a brain to interpret the stimulation there will be only molecular vibrations but no sound, per se. In the same vein, all of the energies and biophysical phenomena that the brain experiences as consciousness do indeed exist independently and outside of the brain (e.g., physics, chemistry, and quantum events). But the wondrous experience of consciousness itself seems to require a brain to give rise to it and a brain-based mind to perceive it.

Can Consciousness Exist Without a Brain? | Neuroba

Dec 29, 2024

The question of whether consciousness can exist without a brain has long intrigued philosophers, neuroscientists, and thinkers from various disciplines. Consciousness—the state of being aware of and able to think about one's own existence—has traditionally been understood as a product of the brain's complex neural networks. However, as research in neurotechnology and consciousness studies progresses, new perspectives are emerging, challenging conventional wisdom.

At Neuroba, we are committed to pushing the boundaries of human understanding in neurotechnology, consciousness, and the mind-body connection. This blog explores the scientific inquiry into whether consciousness can exist without the brain, examining alternative theories and the role of neurotechnology in uncovering these mysteries.

Traditional Views of Consciousness and the Brain

The Brain as the Seat of Consciousness

In mainstream neuroscience, consciousness has been widely accepted as a function of the brain. This view is grounded in the understanding that neural activity within the brain generates subjective experiences, thoughts, emotions, and self-awareness. Through methods like fMRI and EEG, scientists have observed how specific brain regions are activated during conscious thought and perception, reinforcing the idea that the brain is the central organ for consciousness.

Key areas of the brain involved in consciousness include:

1. **The Thalamus:** Often referred to as the brain's relay station, the thalamus plays a crucial role in processing sensory information and regulating conscious awareness.

2. **The Cortex:** The cerebral cortex, particularly the prefrontal cortex, is associated with higher cognitive functions like decision-making, reasoning, and self-reflection.

3. **The Reticular Activating System (RAS):** This network of neurons is responsible for regulating wakefulness and attention, contributing to the brain's ability to maintain consciousness.

The Neural Correlates of Consciousness (NCC)

The concept of Neural Correlates of Consciousness (NCC) refers to the specific brain structures and functions directly associated with conscious experience. This framework suggests that consciousness emerges from the dynamic interactions between neural networks and is inseparable from the brain's biological processes.

Theories Suggesting Consciousness Can Exist Without a Brain

The Role of Quantum Mechanics in Consciousness

One of the most speculative and controversial theories posits that consciousness may be a quantum phenomenon. Some proponents, like physicist Roger Penrose, suggest that consciousness arises from quantum computations occurring within the brain's microtubules. However, recent studies have raised the question: could quantum processes extend beyond the brain?

The possibility of consciousness existing outside the brain may involve quantum coherence—a state in which quantum particles behave in a synchronized manner across vast distances. In this view, consciousness could be a non-local phenomenon that transcends physical matter, potentially existing independently of the brain.

Non-Centralized Consciousness Models

Another theory proposes that consciousness could be more widespread and not strictly tied to a specific location, such as the brain. This view is based on observations of simple organisms like plants and single-celled organisms, which exhibit behaviors suggesting some form of awareness despite lacking a central nervous system.

Emerging models of distributed consciousness challenge the idea that the brain is the exclusive home of conscious awareness. For example, the theory of **panpsychism** suggests that consciousness is a fundamental property of the universe, present in all matter, from atoms to galaxies. According to this perspective, consciousness could exist independently of the brain, as an inherent feature of the cosmos.

Near-Death Experiences (NDEs) and Consciousness Beyond the Body

An intriguing area of research comes from the study of near-death experiences (NDEs). Individuals who have been clinically dead for brief periods and then revived often report vivid, conscious experiences, including a sense of leaving their bodies and traveling through tunnels toward a light. These experiences suggest that consciousness may not be entirely reliant on the brain and could persist beyond the body's physiological functions.

While these phenomena are not yet fully understood, they raise important questions about the nature of consciousness and its potential existence outside the brain.

Can Technology Help Unlock the Mystery?

The Role of Brain-Computer Interfaces (BCIs)

Neuroba is at the cutting edge of developing Brain-Computer Interface (BCI) technologies that allow for direct communication between the brain and external devices. While BCIs are primarily designed to enhance or restore brain function, they may also offer valuable insights into the nature of consciousness itself.

By exploring how neural activity can be translated into external actions, we may uncover how the brain generates consciousness. However, BCIs also prompt important questions: If we can interface directly with the brain's neural activity, could we manipulate or even create conscious experiences without relying solely on biological neural networks?

Advances in Neurotechnology and the Mind-Body Connection

At Neuroba, we are also exploring neurostimulation techniques, such as transcranial magnetic stimulation (TMS) and deep brain stimulation (DBS), which can alter brain activity and potentially influence conscious states. These technologies have been used to treat conditions like depression and Parkinson's disease, but they also open the door to understanding the precise mechanisms by which the brain generates awareness. Could similar techniques be used to investigate consciousness beyond the brain, perhaps in the context of artificial intelligence or non-human consciousness?

Ethical Considerations and Future Directions

Ethical Implications of Consciousness Beyond the Brain

As we explore the possibility of consciousness existing outside the brain, ethical questions inevitably arise. How would we define personhood or consciousness if it could exist in non-brain-based forms? What would this mean for our understanding of life, death, and identity? These questions challenge our current ethical frameworks and call for new models of consciousness and personhood.

The Potential for Mind-Body Integration

The future of consciousness studies may lie in the integration of biological and technological systems. At Neuroba, we believe that understanding consciousness requires a holistic approach that combines neuroscience, quantum physics, and advanced neurotechnologies. By bridging these disciplines, we can move closer to unraveling the deepest mysteries of consciousness—whether it originates solely from the brain or exists in a more complex, distributed form.

Conclusion

While the traditional view holds that consciousness is inextricably linked to the brain, alternative theories suggest that it may exist in forms beyond the brain, possibly as a quantum phenomenon or as a fundamental property of the universe. As neurotechnology continues to advance, particularly with developments in brain-computer interfaces, we may unlock new insights into the nature of consciousness and its potential existence without a brain.

At Neuroba, our commitment to pioneering neurotechnology is part of our ongoing quest to understand consciousness in all its forms. As we continue to explore the limits of human cognition and the brain's capabilities, we remain dedicated to expanding the horizons of consciousness research, ultimately connecting human minds and building a better future.

Neuroba: Pioneering Neurotechnology for Human Consciousness | Connecting Human Consciousness, Building a Better Future.

Does the Mind Really Exist? Exploring Consciousness Beyond the Brain

Oct 7, 2024

In the quest to understand ourselves and the universe around us, one of the most perplexing and hotly debated questions is: does the mind truly exist, or is it just an illusion created by the brain?

This question lies at the crossroads of philosophy, neuroscience, and even metaphysics, opening the door to some fascinating discussions.

Let's take a look at some popular opinions....

What Do We Mean by "Mind"?

First, let's define the "mind." When we talk about the mind, we're generally referring to consciousness, thoughts, feelings, and self-awareness—essentially, everything that makes you... you. It's the inner landscape where you experience dreams, emotions, and perceptions. But while we all experience having a mind, understanding what it actually is has proven to be much harder.

Some say the mind is a direct result of the brain's activity, like a movie that plays on a screen—the screen being our physical brain and the movie being our thoughts. Others believe the mind is more than that, something that exists beyond the neural wiring in our heads. These perspectives raise the critical question: does the mind exist independently of the brain, or is it just a product of complex biology?

1. The Mind as an Emergent Property of the Brain

One popular viewpoint, especially in the scientific community, is that the mind is an emergent property of the brain. In simple terms, the brain is like a supercomputer, and consciousness is the software it runs. Just like your computer needs hardware to function, your mind needs the brain. In this view, your thoughts, emotions, and even your sense of self are all products of the 100 billion neurons firing off inside your skull.

Proponents of this theory point to advances in neuroscience that show specific areas of the brain lighting up when we think or feel certain things. For example, when you're happy, there's measurable activity in the brain's reward centre. This all suggests that the mind doesn't exist independently of the brain but is, in fact, a byproduct of it.

2. The Mind as an Illusion

Taking this idea a step further, some scientists argue that the mind itself doesn't really exist at all. Rather, it's a convincing illusion created by the brain—a trick it plays on itself. In this view, there is no "you" watching the movie; there is only the movie itself. Consciousness, in this framework, is merely a side effect of the brain's intricate workings. It's like the glowing light from a lightbulb—once the lightbulb (the brain) is gone, so is the light (the mind).

This concept can be unsettling for many. After all, if the mind is just an illusion, what does that say about our sense of free will, identity, and everything we hold dear as human beings? It's a perspective that can provoke more questions than it answers.

3. The Mind as a Conceptual Framework

On the more philosophical end of the spectrum, some believe that the mind is less about what it is and more about how we use it to understand thought itself. In this view, the mind is a conceptual tool, a framework we've developed to make sense of human experience. It doesn't necessarily "exist" as a physical or even metaphysical entity. Instead, it's a way of organizing and interpreting the flow of thoughts, emotions, and perceptions that run through us.

This perspective suggests that we shouldn't get too caught up in whether the mind exists in a literal sense. Instead, we should focus on how the concept of the mind helps us navigate life, much like how we use maps to understand geography even though the map isn't the territory.

4. The Mind as Fundamental and Beyond the Brain

Now, let's venture into more metaphysical territory. Some philosophers and even quantum theorists propose that consciousness—the mind—might not be tied to the brain at all. They argue that the mind is a fundamental part of reality, something that exists beyond the material world, possibly even influencing it. This view leans into what is sometimes called "panpsychism," the idea that consciousness is a fundamental component of the universe, much like space and time.

If this is true, it could mean that our minds aren't just tied to our brains, but are part of a broader cosmic fabric. Consciousness, then, would not cease when the brain dies—it might exist independently, perhaps even surviving physical death. It's a perspective that invites us to rethink not only what the mind is but also what reality itself might be.

5. Is the Question Even Relevant?

Finally, there's another angle worth considering: maybe the distinction between the mind and the brain doesn't matter as much as we think. After all, whether the mind exists independently or is a product of the brain, the experience of consciousness—the feeling of being you—is very real. We may never fully understand how or why it works, but does that lessen its value or importance?

Some might argue that the philosophical and scientific debates, while fascinating, can miss the point: the mind, whatever its origins, shapes our lives and experiences in profound ways. Whether it's through introspection, creativity, or even lucid dreaming, what we call the mind gives us the ability to explore not just the world around us but also the world within.

So, Does the Mind Exist?

The truth is, we don't have a definitive answer—at least not yet. The mind might be an emergent property of the brain, an illusion, a concept, or something far more mysterious. And perhaps, like many of the most profound questions in life, it's not about finding the answer, but rather about exploring the possibilities.

As we continue to study the brain, consciousness, and the nature of reality, one thing is clear: the mind, however we define it, remains one of the most fascinating and essential aspects of the human experience. Whether we ever fully understand it or not, the journey to unravel its mysteries will always be worth taking.

MAY 13, 2024

Our brains trick us into thinking consciousness can reside outside the body, research argues

Psychology professor Iris Berent says perceiving minds and bodies as separate has evolutionary roots.

The origins of consciousness have been debated by philosophers for centuries. Each conscious person has a sense of "being me," which invariably gives rise to the question of where that sense originated—from within or outside the body, says Northeastern University psychology professor Iris Berent.

"How do human brains give rise to this experience? That's the big mystery, right?" she says.

Influential philosopher David Chalmers famously won a bet in 2023 for claiming consciousness exists beyond the merely physical, Berent says.

But she says the question of where consciousness exists is a false one—and she has a new paper that presents her position.

In an article published in the *Neuroscience of Consciousness*, she argues that the debate stems from the delusional—albeit natural—biases in the way humans think about the separation, or lack thereof, between body and mind.

"One of the biases is dualism, intuitive dualism—the fact that we perceive minds as separate from our bodies."

"The extent to which we look at consciousness and think that it is this really mysterious thing could very well arise from how we see it rather from what consciousness really is," Berent says.

"Consciousness isn't hard. Psychology is," she says.

Mary and the zombie

Berent points to an experiment in perception she conducted in her lab that used the well-known Mary and the zombie hypothetical exercise, but with a twist.

According to the experiment, when people are asked to think of a zombie twin of themselves, they describe a creature with their physical features but without their thoughts or feelings.

"They intuit that the mind, consciousness included, is really separate from the physical," Berent says.

In the other thought experiment, Mary is a neuroscientist who knows everything about color and how the brain perceives color, even though she lives in a black-and-white world.

When Mary sees a red rose for the first time, people participating in the experiment say she learns something outside the bounds of physical, scientific explanation.

Berent says she decided to challenge these conclusions with two additional questions.

"The first question is kind of a reality check question, which is do they think Mary's case is significant? Is it transformative? And everybody said, 'Sure, it's super transformative,'" Berent says.

"We also asked how likely is it that this experience will actually show up in her brain? If we scan her brain, will it light up? And it turns out that that's exactly what people said. It will significantly register in the brain."

"The point being, in the condition of the zombie people say, 'no,' (consciousness) is not physical," Berent says. "And in Mary's condition, people say it's physical."

"If people change their mind in this way, it can't possibly be that in reality consciousness has changed. It must be that there is something within the human psyche that colors how we see consciousness."

"For me, this means that we need to be really careful before we assume that there is any real mystery going on."

The evolutionary roots of dualism

Berent blames what she calls "delusional attitudes about bodies and minds" to "the same old psychological biases that I've been studying in my lab for years."

She calls the separation of mind and body dualism Previous research by Berent shows that autistic people are less dualistic than neurotypical people and that males are less dualistic than females.

Evolution is responsible for the fact people hold two different systems of perception in their mind, Berent says.

"Animals have an evolutionary advantage to be able to perceive objects, say, the bodies of their mothers," she says.

It's also important to be able to perceive objects that have agency as separate from other objects, Berent says. "You want to follow the mother and not a body that is inanimate" to receive nurturance and protection.

This type of dualism, she says, "primes us to think about people and their minds and bodies as separate from each other. That's one reason we think about consciousness as this ethereal thing separate from the body."

"The point is that our perception of consciousness changes depending on the situation. And if that's the case, there's no way that we can trust it to reflect what our consciousness really is. It must be that our brain plays tricks on us."

An intimate understanding of who we are

"Every psychology student that has ever come into my class asks if we're going to talk about consciousness," Berent says.

"This is considered to be super important. This is our intimate understanding of who we are."

Berent says the thought experiment outlined in her paper provides "the smoking gun" that intuitions about consciousness existing outside the body are manufactured by humans' dualistically inclined brains.

Consciousness likely comes down to electrochemical functions in the brain, she says. "It's hard for psychological reasons."

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Provided by Northeastern University

The Evidence for Non-Local Consciousness: Researchers Prove Consciousness Can Exist Outside of the Body & After Death

BY STANISLAV GROF, M.D., Ph.D.

non-local consciousness researchers have conclusively shown that consciousness exists independently of the brain and after death, based on hundreds of verified case studies that demonstrate this fact beyond a shadow of a doubt.

Some observations from the study of holotropic states (non-ordinary or altered states of consciousness) are so radical that they not only challenge the theory and practice of psychiatry, psychology, and psychotherapy, but also undermine some of the most fundamental metaphysical assumptions of Western science. None of these conceptual challenges are more

drastic and far-reaching than the new insights regarding the nature of non-local consciousness and its relationship to matter. According to Western neuroscience, consciousness is an epiphenomenon of matter, a by-product of the complex neurophysiological processes in the brain and thus an intrinsic and inseparable part of

the body. Modern consciousness research conducted in the last five decades has made this hypothesis highly questionable.
Very few people, including most scientists, realize that we have absolutely no proof that consciousness is actually produced in the brain and by the brain. There is no doubt that there exists vast clinical and experimental evidence showing significant interconnections and correlations between the anatomy, physiology, and biochemistry of the brain, on the one hand, and states of consciousness, on the other. However, it represents a major logical jump to infer from the available data that these correlations represent a proof that the brain is actually the source of consciousness, and, in fact, the data largely points to the fact that consciousness is non-local. Such a deduction would be tantamount to the conclusion that the TV program is generated in the TV set, because there is a close correlation between functioning or malfunctioning of its components and the quality of the sound and picture.

It should be obvious from this example that the close connection between cerebral activity and consciousness does not exclude the possibility that the brain mediates consciousness, but does not actually generate it. The research of holotropic states has amassed ample evidence for this alternative—that consciousness is non local to the body.

Lack of Evidence for Brain-Based Theories

There exist no scientific theories explaining how consciousness is generated by material processes, nor does anybody have even a remote idea how something like that could possibly happen. The gap between consciousness and matter is so formidable that it is impossible to imagine how it could be bridged. In spite of the lack of convincing evidence that consciousness is an epiphenomenon of the brain or matter, this basic metaphysical assumption remains one of the leading myths of Western materialistic science. While there exists no scientific proof for the fact that the brain generates consciousness, there are numerous observations indicating that consciousness can under certain circumstances function independently of the brain and of the world of matter. This philosophy is referred to as non-local consciousness.

In holotropic states (non-ordinary or altered states of consciousness), our consciousness can reach far beyond the boundaries of the body/ego and obtain accurate information about various aspects of the material world that we have not obtained in this lifetime through the mediation of our sensory organs, which would not be possible unless consciousness is non-local in nature. We have already mentioned reliving of birth, of prenatal memories, and of conception. In transpersonal experiences our non-local consciousness can identify with other people, with members of various species of the animal kingdom from primates to unicellular organisms, with plant life, and even with inorganic materials and processes. We can also transcend linear time and experience vivid ancestral, racial, karmic, and phylogenetic sequences, and episodes from the collective unconscious.

Transpersonal experiences can provide not only accurate new information about various aspects of the material world, including those that we are unfamiliar with, but also about various figures and realms of the archetypal domain of the collective unconscious. We can witness or even participate in mythological sequences from any culture of the world and any historical period accurately portrayed in every detail. It is absurd to attribute this rich array of experiences accurately portraying various present and past aspects of the material world and figures, realms, and themes from world mythology to some yet unknown pathology afflicting the brain, whereas we believe that it is in fact a byproduct of the abilities we have as a result of the inherent properties of non-local consciousness.

The Evidence for Non-Locality

The most convincing evidence that consciousness is not produced by the brain and can function independently of it comes from the young scientific discipline of thanatology, the study of death and dying. It is now an established fact, confirmed by many independent observations, that disembodied, non-local consciousness of people in near-death situations is able to accurately observe the environment and various near or remote locations and events.

Individuals, who are clinically dead (in a state of cardiac death and even brain death), are able to observe their bodies and the rescue procedures from above and "travel" freely to other parts of the same building or various remote places. Independent research has repeatedly confirmed the accuracy of observations made by disembodied, non local consciousness (Ring and Valarino 1998; Sabom 1982 and 1998).

Such non-local consciousness experiences are strikingly reminiscent of the descriptions of the bardo body found in the *Tibetan Book of the Dead (Bardo Thödol)*. This famous spiritual text states that, after having fainted from fear in the Chönyid Bardo, the dying person awakens in the Sidpa Bardo in a new form—the bardo body. This body differs from the gross body of everyday life. It is not composed of matter and has many remarkable qualities, such as the power of unimpeded motion, the ability to penetrate through solid objects, and the capacity to perceive the world without the mediation of the senses. Those who exist in the form of the bardo body can travel instantaneously to any place on earth and even to the sacred cosmic mountain Mount Meru. Only two places are not accessible to this form: the maternal womb and Bodh Gaya, clear references to leaving the bardo state at the time of conception or enlightenment (Evans-Wentz 1957).

An extensive study conducted by Ken Ring and his colleagues has added a fascinating dimension to these observations: people who are congenitally blind for organic reasons and have never been able to see anything in their entire lives can perceive the environment when their non-local consciousness detaches from their bodies during various life-threatening situations. The veracity of many of these visions has been confirmed by consensual validation; Ring refers to such visions as veridical OBEs (out-of-body experiences) (Ring and Valarino 1998; Ring and Cooper 1999). Various aspects of the environment accurately perceived by disembodied non-local consciousness of blind subjects ranged from details of electrical fixtures on the ceiling of the operating room to the surroundings of the hospital observed from bird's-eye view. Modern thanatological research has thus confirmed an important aspect of classical descriptions of OBEs, which can be found in spiritual literature and philosophical texts. Veridical OBEs are not limited to near-death situations. We have seen them repeatedly in people undergoing psychospiritual crises ("spiritual emergencies") and in participants in Holotropic Breathwork workshops.

Some of these individuals were able to observe the group from above and describe unusual behavior of some of its members, in spite of the fact that they themselves breathed with their eyes closed. The non-local consciousness of others left the building and observed the environment from above or traveled to some remote locations and observed the events there. On occasion, these bird's-eye views appeared in the mandalas.

These observations demonstrate without any reasonable doubt that consciousness is not a product of the brain and thus an epiphenomenon of matter—consciousness is non-local. It is more likely at least an equal partner of matter, or possibly superordinated to it. The matrices for many of the aforementioned experiences clearly are not contained in the brain, but are stored in some kinds of immaterial fields or in the field of non-local consciousness itself. The most promising developments in hard science offering models for transpersonal experience are David Bohm's idea of the implicate order (Bohm 1980), Rupert Sheldrake's concept of morphogenetic fields (Sheldrake 1981 and 1988) and Ervin Laszlo's hypothesis of the psi fi eld or Akashic field (Laszlo 1993 and 2004).

NOVEMBER 7, 2023

Understanding Consciousness Goes Beyond Exploring Brain Chemistry

We can account for the evolution of consciousness only if we crack the philosophy, as well as the physics, of the brain

Pobytov/Getty Images

Consciousness

Opinion

The science of consciousness has not lived up to expectations.

Over the summer, the neuroscientist Christof Koch conceded defeat on his 25-year bet with the philosopher David Chalmers, a lost wager that the science of consciousness would be all wrapped up by now. In September, over 100 consciousness researchers signed a public letter condemning one of the most popular theories of consciousness—the integrated information theory—as pseudoscience. This in turn prompted strong responses from other researchers in the field. Despite decades of research, there's little sign of consensus on consciousness, with several rival theories still in contention.

Your consciousness is what it's like to be you. It's your experiences of color and sound and smell; your feelings of pain, joy, excitement or tiredness. It's what makes you a thinking, sentient being rather than an unfeeling mechanism.

In my new book, entitled Why? The Purpose of the Universe, I take head-on the question of why it's so hard to make progress on consciousness. The core difficulty is that consciousness defies observation. You can't look inside someone's brain and see their feelings and experiences. Science does deal with things that can't be observed, such as fundamental particles, quantum wave functions, maybe even other universes. But consciousness poses an important difference: In all of these other cases, we theorize about things we can't observe in order to explain what we can observe. Uniquely with consciousness, the thing we are trying to explain cannot be publicly observed.

How then can we investigate consciousness? Although consciousness can't be directly observed, if you're dealing with another human being, you can ask them what they're feeling, or look for external indications of consciousness. And if you scan their brain at the same time, you can try to match up the brain activity, which you can observe, with the invisible consciousness, which you can't. The trouble is there are inevitably multiple ways of interpreting such data. This leads to wildly different theories as to where consciousness resides in the brain. Believe it or not, the debates we are currently having in the science of consciousness closely resemble debates that were raging in the 19th century.

There may be a way forward. I argue that we can account for the evolution of consciousness only if we reject reductionism about consciousness. Most consciousness researchers employ a reductionist view of the universe, where physics is running the show. Thus insofar as there are some future possibilities left open by the arrangements of particles in our brains, they are settled by nothing more than the random chanciness implicit in quantum mechanics.

Some challenges have lately emerged to this reductionist paradigm. The neuroscientist Kevin Mitchell has argued that the free will of conscious organisms plays a role in determining what will happen in the brain, over and above what is settled by the laws of physics. And the assembly theory of chemist Lee Cronin and physicist Sara Walker decisively rejects reduction to microscopic-level equations, arguing for a kind of memory inherent in nature that guides the construction of complex molecules.

Evolution offers one of the strongest challenges to reductionist approaches to consciousness. Natural selection only cares about behavior, as it's only behavior that matters for survival. Rapid progress in AI and robotics has made it clear, however, that extremely complex behaviour can exist in a system that entirely lacks conscious experience. Natural selection could have constructed *survival mechanisms*: complex biological robots able to track features of their environment and initiate survival-conducive behavioral responses, without having any kind of inner life. For any adaptive behaviour associated with consciousness, there could be a nonconscious mechanism that instigates the same behaviour. Given all this, it is a deep mystery why consciousness evolved at all.

Or rather, the evolution of consciousness is a deep mystery under the reductionist paradigm, according to which the behavior is determined at the micro level, making it irrelevant whether or not consciousness pops up at higher levels. But suppose instead that the emergence of biological consciousness brings into existence radically new forms of behavior, over and above what physics alone could produce. Perhaps organisms that have conscious awareness of the world around them, and thereby freely respond based on that awareness, behave very differently than mere mechanisms. Consequently, they survive much better. With these assumptions in place, we can make sense of natural selection's preference for conscious organisms.

If consciousness does defy reduction, this could revolutionize the science of consciousness. What it would essentially provide is a new empirical marker of consciousness. If the neural processes that correspond to consciousness have a novel causal profile, one that could not be predicted—even in principle—from underlying chemistry and physics, then this would amount to a giant "HERE IT IS!" in the brain.

Would we not have noticed already if there were processes in the brain that didn't reduce to underlying chemistry and physics? The truth is we know very little about how the brain works. We know a lot about the basic chemistry: how neurons fire, how chemical signals are transmitted. And we know a fair bit about the large functions of various brain regions. But we know almost nothing about how these large-scale functions are realized at the cellular level. To an extent, abstract theorizing has stood in for detailed neurophysiological investigation of what is actually going on in the brain.

As a philosopher, I'm not opposed to abstract theorizing. However, it's crucial to distinguish the scientific questions of consciousness from the philosophical questions. The scientific task is to work out *which* kinds of brain activity correspond to consciousness, and it's this task that detailed neurophysiological investigations—equipped to catch the HERE IT IS marker of consciousness—will help us make progress on. But what we ultimately want from a theory of consciousness is an explanation of *why* brain activity—of whatever form—is correlated with consciousness in the first place. Because consciousness is not an observable phenomenon, the "why" question is not one we can make progress on with experiments. In Why? I develop a radical form of panpsychism—the view that consciousness goes right down to the fundamental building blocks of reality—aimed at addressing the philosophical challenges of consciousness, as well as providing a framework for scientists to make progress on the scientific issues.

We're still not at first base in dealing with consciousness. It requires working on many fronts, exploiting many different areas of expertise. We need to let the philosophers do the philosophy and the scientists study the brain. Each provides a different piece of the puzzle. It is a pincer movement of science and philosophy that will, ultimately, crack the mystery of consciousness.

NOVEMBER 8, 2024

Consciousness Might Hide in Our Brain's Electric Fields

A mysterious electromagnetic mechanism may be more important than the firing of neurons in our brain to explain our awareness

Hiroshi Watanabe/Getty Images

Consciousness

Opinion

The neuron, the specialized cell type that makes up much of our brains, is at the center of today's neuroscience. Neuroscientists explain perception, memory, cognition and even consciousness itself as products of billions of these tiny neurons busily firing their tiny "spikes" of voltage inside our brain.

These energetic spikes not only convey things like pain and other sensory information to our conscious mind, but they are also in theory able to explain every detail of our complex consciousness.

At least in principle. The details of this "neural code" have yet to be worked out.

While neuroscientists have long focused on spikes travelling throughout brain cells, "ephaptic" field effects may really be the primary mechanism for consciousness and cognition. These effects, resulting from the electric fields produced by neurons rather than their synaptic firings, may play a leading role in our mind's workings.

In 1943 American scientists first described what is known today as the neural code, or spike code. They fleshed out a detailed map of how logical operations can be completed with the "all or none" nature of neural firing—similar to how today's computers work. Since then neuroscientists around the world have engaged in a vast endeavor to crack the neural code in order to understand the specifics of cognition and consciousness—to little avail.

"The most obvious chasm in our understanding is in all the things we did not meet on our journey from your eye to your hand," confessed neuroscientist Mark Humphries in 2020's *The Spike*, a deep dive into this journey: "All the things of the mind I've not been able to tell you about, because we know so little of what spikes do to make them."

Brain researchers have long acknowledged that there are a number of ways other than firing by which neurons could communicate, including the little-known mechanism known as ephaptic coupling. This coupling results from electromagnetic (EM) fields at the medium and large scales of the brain interacting, alongside much smaller scale fields accompanying synaptic spikes (which themselves result from a type of highly localized EM field activity) operating at nanometer scales.Retinal neurons, for example, operate without any neural firing. These cells employ a type of electrodiffusion, the diffusion of charged particles without synapses, the connection points between neurons. Electrodiffusion passes along a signal to the optic nerve at very fast rates and with high bandwidth. We couldn't see without this.

The "ephaptic" in ephaptic coupling simply means "touching." Though not well-known, ephaptic field effects result from the textbook electric and magnetic interactions that power our cells. Intriguing experimental results suggest these same forces play a bigger role in the brain than one suspected and perhaps even in consciousness.

Ephaptic field effects first came to my attention in a significant way with a remarkable 2019 paper from the Case Western Reserve University laboratory of Dominique Durand. That lab demonstrated that the mouse cortex was affected without synaptic connections—by definition, ephaptic field interactions. This remarkable effect was found by the Durand team after they cut a slice of mouse hippocampus in half and then measured the voltage potential going up and down the slice. There was almost no change in that measured voltage even after the slice was fully severed, demonstrating a strong influence from ephaptic fields.

The influence did, they found, wane after a certain distance, as we'd expect. Once the cut slices were separated by 400 microns or more, the ephaptic field effect mostly disappeared.

These results were considered so remarkable by peer reviewers that they required the Durand lab to replicate the results not once but twice before they approved publication of the paper. One scholar stated at the time of the paper's publication that the findings of Chiang and colleagues "should probably (and quite literally) electrify the field."

Another team compared the speed of ephaptic field effects in various tissues, finding that the speed of propagation of ephaptic fields in gray matter is about 5,000 times faster than neural firing.

This means that what would take normal spike pathways one second to span through the brain, could be traversed 5,000 times during that same time interval with ephaptic effects. If we cube this over the volume of the brain we get an information density up to a staggering 125 billion times more from ephaptic fields than from synaptic firing.

A key caveat to this statement is to stress that this is *potential* information density only, and it is not necessarily the case that this potential can actually be reached. More research will need to be done to see how much of this vast ephaptic potential is realized by our brains.

Abundant evidence shows that synaptic firing is essential for moving, hearing, touching and much else, but given the vastly greater information density in the ephaptic fields, and the pervasiveness of ephaptic field effects, it would be exceedingly strange if evolution hadn't grasped upon this effect for important brain functions. Indeed, it seems that she has, in sundry ways.

Walter Freeman, a legendary now-deceased neuroscientist from the University of California, Berkeley, stated in a 2006 paper that traditional synaptic firing speeds could not explain the speed of cognitive functions he had observed over the years in rabbits and cats.

Instead the recent spate of ephaptic effects findings suggest a solid mechanism to explain these speeds. Our recent theoretical paper, building on these findings, suggested that ephaptic field effects may in fact be the primary mechanism for consciousness and cognition, rather than neural firing.

Another recent paper including as authors the University of California, Los Angeles's Costas Anastassiou and former Caltech neuroscientist Christof Koch, provides strong support for the importance of ephaptic effects. They find that, indeed, ephaptic coupling can explain the "fast coordination" required for consciousness "even in the absence of very fast synapses." This single paper could take the field of ephaptic field science from the fringes of neuroscience to the forefront. Its findings regarding the speed and pervasiveness of ephaptic field effects may presage a fundamentally new understanding of how cognition and consciousness work.

JANUARY 14, 2020

Does Consciousness Pervade the Universe?

Philosopher Philip Goff answers questions about "panpsychism"

Getty Images

March 2020 Issue

Cognition

One of science's most challenging problems is a question that can be stated easily: Where does consciousness come from? In his most recent book, *Galileo's Error: Foundations for a New Science of Consciousness*, philosopher Philip Goff considers a radical perspective: What if consciousness is not something special that the brain does but instead is a quality inherent to all matter? It is a theory known as panpsychism. He answered questions from former longtime Mind Matters editor Gareth Cook.

Can you explain, in simple terms, what you mean by panpsychism?

In our standard view of things, consciousness exists only in the brains of highly evolved organisms, and hence it exists only in a tiny part of the universe and only in very recent history. According to panpsychism, consciousness pervades the universe and is a fundamental feature of it. This doesn't mean that literally everything is conscious. The basic commitment is that the fundamental constituents of reality—perhaps electrons and quarks—have incredibly simple forms of experience, and the very complex experience of the human or animal brain is somehow derived from the experience of the brain's most basic parts.

I should clarify that by "consciousness," I don't mean self-awareness or the capacity to reflect on one's own existence. I simply mean "experience": pleasure, pain, visual or auditory experience.

Human beings have a very rich and complex experience; horses less so, mice less so again. As we move to simpler forms of life, we find simpler forms of experience. Perhaps at some point the light switches off, and consciousness disappears. But it's at least coherent to suppose that this continuum of consciousness carries on into inorganic matter, with fundamental particles having unimaginably simple forms of experience.

What does panpsychism seek to bring to physics?

Philosophers of science have realized that physical science, for all its richness, is confined to telling us about the *behavior* of matter, what it does. Physics tells us, for example, that matter has mass and charge. These properties are completely defined in terms of behavior—things like attraction, repulsion, resistance to acceleration. Physics tells us absolutely nothing about what philosophers like to call the *intrinsic nature* of matter: what matter is in and of itself.

Consciousness, for the panpsychist, is the intrinsic nature of matter. There's nothing supernatural or spiritual, but matter can be described from two perspectives. Physical science describes matter from the outside in terms of its behavior. But matter from the "inside"—that is, in terms of its intrinsic nature—is constituted of forms of consciousness.

Do you foresee a scenario in which panpsychism can be tested?

You can't look inside an electron to see whether or not it is conscious, just as you can't look inside someone's head and see their feelings and experiences. We know that consciousness exists only because we are conscious.

Neuroscientists correlate certain kinds of brain activity with certain kinds of experience. We now know which kinds of brain activity are associated with feelings of hunger, pleasure, pain, and so on. This is really important information, but what we ultimately want from a science of consciousness is an explanation of those correlations. Why is a particular feeling correlated with a particular pattern of brain activity? As soon as you start to answer this question, you move beyond what can be, strictly speaking, tested, simply because consciousness is unobservable. We have to turn to philosophy.

Science gives us correlations between brain activity and experience. We then have to find the philosophical theory that best explains those correlations. In my view, the only theory that holds up to scrutiny is panpsychism.

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What if consciousness is not an emergent property of the brain? Observational and empirical challenges to materialistic models

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Abstract

The nature of consciousness is considered one of science's most perplexing and persistent mysteries. We all know the subjective experience of consciousness, but where does it arise? What is its purpose? What are its full capacities? The assumption within today's neuroscience is that all aspects of consciousness arise solely from interactions among neurons in the brain. However, the origin and mechanisms of *qualia* (i.e., subjective or phenomenological experience) are not understood. David Chalmers coined the term "the hard problem" to describe the difficulties in elucidating the origins of subjectivity from the point of view of reductive materialism. We propose that the hard problem arises because one or more assumptions within a materialistic worldview are either wrong or incomplete. If consciousness entails more than the activity of neurons, then we can contemplate new ways of thinking about the hard problem. This review examines phenomena that apparently contradict the notion that consciousness is exclusively dependent on brain activity, including phenomena where consciousness appears to extend beyond the physical brain and body in both space and time. The mechanisms underlying these "non-local" properties are vaguely suggestive of quantum entanglement in physics, but how such effects might manifest remains highly speculative. The existence of these non-local effects appears to support the proposal that post-materialistic models of consciousness may be required to break the conceptual impasse presented by the hard problem of consciousness.

Keywords: non-local consciousness, orch-OR, integrated information theory, global work-space theories, higher-order theories, re-entry and predictive processing, analytic idealism, interface theory of perception

What is consciousness?

The term "consciousness" means different things to different audiences. From a lay perspective, the fact of consciousness (here meaning *awareness*) is so self-evident that the only question that may arise is why anyone would consider consciousness to be mysterious in the first place, akin to asking a fish, "What is water?" From a scientific perspective, the unsolved mystery is how consciousness emerges from brain activity. How does a three-pound lump of tissue inside the skull give rise to a mind that is self-aware and enjoys subjective experience? In philosophy, which has debated the "mind-body problem" for millennia, many sets of assumptions have been proposed, ranging from materialism (i.e., all is dependent on or reducible to the physical) to idealism (i.e., ideas or thoughts make up fundamental reality). For mystics and others entranced by the esoteric traditions, the problem is not so much about the mind but how the physical world emerges from a non-physical "substance."

Over the past few decades, most scientifically oriented research on consciousness has studied consciousness as a controlled variable. They have reduced consciousness to simpler constructs, such as perception, and focused on comparisons in brain processes during conscious and unconscious conditions, the so-called "contrastive approach." In this approach, differences in brain activity are examined when the same stimulus is subjectively perceived versus when it is not (Baars, 2005). This search for the neural correlates of consciousness (NCC) is defined as the "minimum neuronal mechanisms jointly sufficient for any one specific conscious experience" (Koch et al., 2016). Experimental designs have used methods like stimulus masking (Shapiro et al., 1997; Simons and Chabris, 1999; Dehaene et al., 2001) or binocular rivalry (Leopold and Logothetis, 1999) to examine the brain activity associated with subliminal perception where information is not consciously perceived yet processed by the brain. Other approaches have relied on brain lesions (Hebb and Penfield, 1940), or, more recently, by artificially modulating brain activity in specific regions and networks intracranially, during neurosurgery, or non-invasively with transcranial magnetic/electric/ultrasound stimulation (Selimbeyoglu and Parvizi, 2010). Other authors have focused solely on states of unconsciousness during general anesthesia (Hudetz, 2012), epilepsy (Blumenfeld and Taylor, 2003), or sleep (Steriade et al., 2001). While a front line of research, the NCC approach has conceptual limitations. Mainly, the terms "consciousness" and "correlates" are enmeshed because brain events that co-vary with conscious experience can either be the experience's neural substrates, the prerequisites, or even the experience's neural consequences (Aru et al., 2012; de Graaf et al., 2012).

Several scientific theories of consciousness are primed to be tested experimentally instead of merely identifying correlations between conscious/unconscious events and brain activity. In the sections below, we briefly summarize the main neuroscience theories, referred to as physicalist or reductionist theories, most of which assume that consciousness emerges from the brain. While most physicalist theories aim to explain different aspects of consciousness, they often share similarities and have been recently grouped into four categories: higher-order theories (HOTs), global work-space theories (GWTs), integrated information theory (IIT), and re-entry and predictive processing theories (Seth and Bayne, 2022). Here, we follow this categorization and present a brief summary. However, a full review of each theory is beyond this article's scope (see Seth and Bayne, 2022, for a full review).

Physicalist theories of consciousness

Global work-space theories

Cognitive scientist Bernard J. Baars first proposed the GWT in 1983. GWT is a cognitive architecture inspired by artificial intelligence where a centralized resource is available through which specialized processors share and receive information (Baars, 2005; Baars et al., 2021). The theory is based on the observation that there are highly specialized brain regions that process information locally and unconsciously, such as the visual cortex. Conscious experience occurs once there is a distributed activity in other brain areas, that is, "broadcasting" to the system as a whole (Baars, 2005). The widespread access, operation, and coordination of specialized neural networks, which would otherwise operate autonomously, is coordinated by consciousness, involving mainly the frontoparietal network and high-frequency oscillatory rhythms (Baars, 2005).

Dehaene and colleagues have adjusted the GWT to account for new knowledge about the brain, the so-called "neuronal global work-space" (Dehaene et al., 2003). For example, global activity among work-space neurons is generated by excitatory neurons responding to sensory stimuli with long-range cortico-cortical connections. In turn, this global activity inhibits alternative activity patterns among the work-space neurons to prevent the conscious experience of other stimuli (e.g., attentional blink). This inhibition mechanism would allow the unified experience of consciousness (the composition and exclusion axioms in IIT). Supported by experimental findings in the context of the search for NCCs, this popular model suggests that (1) most of the brain's computations are performed in a non-conscious operation mode and that (2) conscious access must be distinguished from selective attention, (3) conscious perception may be characterized by a non-linear function that 'ignites' a network of distributed areas (a gradual increase in stimulus visibility accompanied by a sudden transition of the neuronal work-space into a pattern, i.e., the broadcasting), and (4) the selected information gains access to additional computations for conscious perception such as temporary maintenance, global sharing, flexible routing (Dehaene et al., 2014). The model predicts that measures of complexity, long-distance correlation, and integration of brain signals should provide reliable indices of conscious processing and has clinical applications (e.g., sleep, coma, anesthesia; Dehaene et al., 2014; Mashour et al., 2020). Some investigators have recently attempted to generalize the GWT to brain-inspired artificial architectures by implementing the GWT into deep learning algorithms (VanRullen and Kanai, 2021). GWT is promising as a model. However, it is unclear what determines when information is broadcasted to the whole (e.g., threshold) and what discriminates different types of subjective experiences within the GWT theory.

Higher-order theories

The HOTs family includes, for example, the self-organizing meta-representational account theory (SOMA; Cleeremans et al., 2020), the adversarial framework for probabilistic computation (Gershman, 2019), and the perceptual reality monitoring theory (Lau, 2019). In this view, consciousness is defined as a higher-order representation of lower-order representations. In other words, subjective experiences reflect higher brain orders like meta-representations, which have learned to describe and interpret the lower-order functions such as local modules specialized in processing specific information. In this sense, consciousness is the brain's unconscious, embodied, enactive, non-conceptual theory about itself (Cleeremans et al., 2020). While Gehrman's model interprets this view in terms of computations and algorithms, Lau's view is in terms of belief and epistemic justification on a subjective level. The NCCs for the HOTs generally consist in anterior regions of the brain, like the prefrontal cortex, reflecting their involvement in complex cognitive functions (Lau and Rosenthal, 2011).

The primary limitation of both GWTs and HOTs is that they do not account for the phenomenal differences between distinct subjective experiences (Seth and Bayne, 2022). Furthermore, neither GWTs nor HOTs have addressed the adaptative and evolutionary role of conscious experience (i.e., embodiment and environmental embeddedness; Seth and Bayne, 2022).

Integrated information theory

Integrated information theory is a mathematical approach based on phenomenology by first identifying the essential properties of consciousness, the so-called axioms: *intrinsic information* – each experience is specific, there is intrinsic information in the system that is associated with that experience that differs from alternative experiences, *information* – consciousness is composed of a specific set of specific phenomenal distinctions and is different from other possible experiences, *integration* – consciousness is unified with each experience being irreducible to non-interdependent components, and *exclusion* – consciousness is unique in content and spatio-temporal context (Tononi, 2015; Tononi et al., 2016). IIT infers the postulates or requirements for a physical system to be a physical substrate of consciousness from the axioms.

Integrated information refers to a system's constituents that are discriminated by their respective information. The whole cannot be reduced to the information of each part, called the "causal-effect power" (Oizumi et al., 2014). These irreducible maxima of additional integrated information generated by the system as a whole compared to its parts are termed and quantified as Φ ("phi") and affect the probability of its past and future states. The larger the Φ value, the more intrinsic cause-effect power the system has and the more conscious it is (Koch, 2018). Thus, any complex and interconnected physical system with these properties will have some level or quantity of consciousness, corresponding to the amount of intrinsic cause-effect power the substrate has. The content of a conscious experience is predicted to be structurally identical to the cause-effect structure of its physical substrate (Albantakis, 2020). So the more structurally complex the system is, the more structurally complex the experience is. IIT, therefore, provides a potential method to (1) assess whether a physical system constitutes a physical substrate of consciousness through its compliance with the postulates, (2) quantify the level of consciousness of that system, and (3) estimate its phenomenological structure in causal terms (Albantakis, 2020).

Unlike HOTs and GWT, progress has been made to assess the relevance of environmental embodiment for consciousness (i.e., consciously capturing the causal structure of a rich environment). For example, Haun and Tononi (2019) showed how this is useful for successfully navigating spacetime (Haun and Tononi, 2019). Albantakis et al. (2014) showed that this is an important driving force for organisms to develop highly integrated networks ("brains"), leading to an increase in their internal complexity (Albantakis et al., 2014). These concepts bring evolutionary context to the development of consciousness and the complexity of the brain.

Re-entry and predictive processing approaches

Re-entry theories were developed from the idea that "we are fooled into thinking that we know what we are conscious of" (Lamme, 2010, p. 204). Therefore, introspective or behavioral observations make understanding the mind-brain relationship impossible. Thus, this approach removes intuitive or psychological notions of conscious experience from the study of consciousness (Lamme, 2006). In the local recurrency theory, conscious perception corresponds to top-down signaling (Lamme and Roelfsema, 2000; Lamme, 2006; Seth and Bayne, 2022). Consciousness emerges from simple localized recurrent, top-down processing within perceptual cortices, and frontal and parietal regions would be crucial to perceptual experience content, reasoning, and decision making (Lamme and Roelfsema, 2000; Lamme, 2006, 2010). Local recurrency theory is similar to GWTs, except that we do not know what we are conscious of and that it is about perception. In contrast, GWT is about access (Lamme, 2010).

Predictive processing approaches in computational neuroscience, such as the hierarchical generative model, consider the brain as a machine that matches bottom-up inputs with top-down expectations through cortical processing, aiming to minimize the error in these predictions (Clark, 2013). In this bi-directional model, top-down connections from higher levels encode the predictions in the lower levels. This fully explains the bottom-up signal and leaves only residual prediction errors propagating information forward in the system to update the following predictions (Huang and Rao, 2011; Clark, 2013). This predictive control function is termed "active inference" (Seth and Bayne, 2022).

The adaptive resonance theory (ART) was developed by Stephen Grossberg and Gail Carpenter to address the "stability-plasticity dilemma," or how the brain learns so quickly and stably without forgetting past knowledge (Grossberg, 2013a). For ART, various brain processes are required, namely Consciousness, Learning, Expectation, Attention, Resonance, and Synchrony (the CLEARS processes). Top-down expectations (E) direct the focus of attention (A) across competitive features. When a match occurs between the expectation and what is perceived, a resonant synchronization (RS) occurs and generates attentional focus driving fast learning (L) of bottom-up, called "many-to-one maps," and top-down, called "one-to-many maps" representations. This whole process is called "adaptive resonance." Here, the focus of attention corresponds to the minimization of error in the prediction function. There is growing experimental data supporting these predictions, and some ART models are thought to explain and predict behavioral, anatomical, neurophysiological, and biochemical data (Grossberg, 2013b).

In brief, for this family of theories, perceptual experience is the brain's best guess of its cause (minimization of the prediction error) through the exchange of top-down predictions and bottom-up prediction errors (Rao and Ballard, 1999; Friston, 2010; Hohwy, 2013; Seth and Bayne, 2022). For example, subjective emotions are considered to emerge from cognitive evaluations of physiological changes in the body and their causes ("constructed emotion" and "interoceptive inference"; Seth, 2013; Barrett, 2016).

Summary of physicalist models

One common element across physicalist theories is the uncertainty reduction that results from allocating mechanisms to consciousness. The system must settle into one unified and highly informative representational state (Hohwy and Seth, 2020). This point of uncertainty reduction often corresponds to a threshold at which the contents become conscious (e.g., broadcasting for GWT, optimization of signal-to-noise ratio for HOTs, φ for IIT, information integration, and learning for re-entry and predictive theories). The second common element is the high importance of top-down signaling (e.g., a system with no top-down dimension has no φ in IIT; Oizumi et al., 2014).

The first disagreement between these theories regards the distinction between consciousness and cognition. Cognitive access relies on consciousness in GWT, consciousness is cognitively accessible in HOTs, whereas cognition is possible without consciousness for IIT and vice versa for predictive processing and re-entry theories. The second, more critical, disagreement between physicalist theories is in regards to the unity of consciousness, i.e., the subjective experience of awareness that fully captures what it is like to be an agent at any time. It is required by IIT and may be supported by the broadcast in GWTs but is ignored by HOTs, re-entry, and predictive theories that do not consider this concept necessary. These various theories may, in fact, address different aspects of consciousness.

In the well-known parable, "The Blind Men and the Elephant," each person attempts to describe the elephant but only touches one small part (Saxe, 2016). Thus, they arrive at very different conclusions about what an elephant is like: a tree, a fan, a rope, a spear. They commence arguing, each one convinced that they are correct in their conclusions. The story's moral is that we must step back to observe broader perspectives to describe and fully understand the elephant's nature. Similarly, these physicalist theories may describe some aspects of consciousness very well, but they likely do not describe it completely.

In conclusion, while extensive and rigorous efforts have attempted to find, test, and validate physicalist theories or NCCs (Reardon, 2019; Templeton World Charity Foundation, 2022), the field is far from consensus about which theories are valid and could potentially explain consciousness or neural differences between different phenomenological experiences. We suggest that the gaps in physicalist theories in explaining consciousness may arise because the debate is framed around how the brain *generates* consciousness. The theories discussed so far attempt to explain phenomenological experience or qualia through reductionist brain mechanisms or correlations, often equated to computational or information processing systems. Some of these theories (e.g., re-entry or predictive processing theories) even consider subjective reports and introspection to be unreliable. Consequently, none of these theories have completely and convincingly explained the nature of consciousness.

A different approach: Non-local consciousness theories

Alternative non-physicalist theories may inform other aspects of consciousness that are not completely explained by physicalist theories. Physicalist theories usually assume that consciousness is generated solely and purely from the brain and is only local to the brain. Alternatively, non-physicalist theories do not make these assumptions, even though both types of theories attempt to explain the underlying brain mechanisms of consciousness. Physicalist theories purport that consciousness originates from physical substrates like neurons that have evolved to be more and more complex over time through adaptation, leading to the emergence of consciousness. Non-physical models do not assume a physical substrate generates consciousness, and many even propose that consciousness is, in fact, more fundamental than matter and spacetime. In this view, that is the natural view for most ancient and eastern cultures, matter and spacetime arise from consciousness rather than the other way around. Perhaps a non-physicalist framework where consciousness is considered fundamental and has non-local properties (such as at the quantum scale) would better explain the full range of reported human phenomenology. For example, there are well-documented experiences of people perceiving information from distant locations, the future, and mental impressions from other people without the use of rationale or traditional means (Cardeña, 2018). In addition, there are verified cases of cognitive function when the neural substrate is severely degenerated, precluding normal brain function. These experiences, most of which are currently regarded as anomalous, will be described in the Section “Phenomena suggested by a model of nonlocal consciousness” as cases of what would be observed should non-physicalist theories of consciousness be valid.

These and other documented phenomenological experiences suggest a different nature of consciousness: one that may not be exclusively generated by neuronal activity and exhibits properties that transcend the conventional constraints of spacetime and, therefore, the physical body. The term “non-local consciousness” has been proposed to denote these purported transcendent properties of consciousness (Dossey, 1994). Physicalist scientists typically consider such experiences anomalous because they challenge prevailing assumptions about the nature and role of consciousness in physical reality. The term non-local is also referenced as a central idea within physics as an aspect of the physical world. For example, the brain operating, even to a small extent, in a quantum fashion might be a valid explanation for these non-local phenomena. However, this idea is not yet widely accepted because while there is evidence for quantum biology, quantum coherence in brain processing is so short-lived that it appears irrelevant to understanding consciousness. Neuroscience today says consciousness is generated by and localized in the brain because it emerges from brain activity. Alternatively, we propose that consciousness may not originate in the brain, although some aspects of human perception of consciousness may be dependent on the brain. We also suggest that awareness also extends beyond the brain. These non-physical, non-local properties of consciousness may be due to a non-local material effect, to consciousness being fundamental, or something else we have not yet discovered.

To begin an exploration of some of these non-physical theories, we present theoretical frameworks proposed by scientists from multiple disciplines, most of which include the idea that consciousness is fundamental, meaning that consciousness precedes the physical substrates (Chalmers, 1996; Currivan, 2017; Kastrup, 2017, 2021; Goff, 2019; Faggin, 2021a). Traditional materialists envision a world in which mathematics is more fundamental than physics, which is more fundamental than chemistry, which is, in turn, more fundamental than biology. Thus, in this way, physical processes are foundational to the generation of our biology. However, suppose we envision that consciousness is actually more foundational than physics. In that case, we can imagine that these other physical disciplines can arise from consciousness. In other words, if biology emerges from chemistry, chemistry from physics, and physics emerges from consciousness, then from this perspective, non-local consciousness phenomena would no longer be regarded as anomalous because consciousness can transcend some physical laws. Theories proposing this idea have been offered by Federico Faggin, Donald Hoffman, Bernardo Kastrup, Vernon Neppe, and numerous others. Most of these theories are speculative, while others are supported through mathematical arguments or empirical data (Hoffman et al., 2015; Neppe and Close, 2020; Faggin, 2021b). We briefly review a sample of non-local consciousness theories.

Operational probabilistic theory

Federico Faggin starts with the assumption that reality emerges from the free-will communications of a vast number of conscious entities (Faggin, 2021a). Faggin calls the totality of what potentially and actually exists, *One.* Any self-knowing within this *one* is a transformation from potential existence into actual existence, where potential existence is the “reservoir” of self-knowing that has not yet manifested. Each new self-knowing brings rise to a *consciousness unit (CU).* The CU reflects the whole of *One* and is also part of *One* because *One* is never complete in its self-knowing process. Thus there must be continued self-knowing and continual generation of CUs, which explains an apparently growing number of conscious entities (Faggin, 2021a, p. 294). Faggin describes the CUs characteristics and how they combine into *self*, in which an entity with identity, awareness, and agency is dynamic, holistic, and self-knowing. Faggin views the physical world as a virtual reality metaphor, in which sophisticated avatars controlled by conscious beings interact with each other, where the body that controls the avatar exists outside the computer and is not part of the program. Similarly, the conscious entities that control physical bodies exist beyond the physical world that contains the body (Faggin, 2021b, p. 286).

Interface theory of perception

Donald D. Hoffman proposes a model based on a mathematical structure called "conscious agents." Space and time emerge from conscious agents' exchanges (Hoffman, 2014). Hoffman proposes that our perceptions (i.e., the conscious agents) are not views of a grounded truth but are more like a personal computer's operating system and interface (Hoffman, 2014, 2019). Perceptions allow us to interact dynamically with the world and survive and evolve in this environment but not be aware of its actual structure. Space-time and physical objects do not represent a universal objective reality but are species-specific components that provide an evolutionary advantage. Hoffman highlights that evolutionarily, perception of spacetime and the physical world are shaped by natural selection in such a way that obfuscates the truth that we are experiencing an interface rather than a universal objective reality and thus influences adaptive behaviors. He further claims that the equations of quantum mechanics can be derived from formalized descriptions of the interactions between conscious agents (Hoffman et al., 2015).

Analytic idealism

Bernardo Kastrup proposes "analytic idealism" as a model for reality, in which the ground of existence is universal phenomenal consciousness (Kastrup, 2021). Analytic idealism is a metaphysics that postulates consciousness as Nature's sole fundamental ground and that all natural phenomena are ultimately reducible to universal consciousness. He describes phenomenal consciousness as a raw subjective experience of awareness that differs from cognition, meta-cognition, self-awareness, or other higher mental functions. Meta-cognition allows humans to know that they are having an experience and also supports cognitive properties like reasoning and planning. Experiential consciousness or pure awareness can also occur without meta-cognition, as reported in classical mystical states. Because there is only one universal consciousness, individuated living beings are described as dissociated mental complexes of the "fundamentally unitary universal mind" (Kastrup, 2021, p. 267). This dissociation creates a subjective private inner world that can perceive itself as interacting with the transpersonal world. Matter in this model is described as the outward appearance of the inner experience as observed from across the dissociative boundary. Put another way,

As experienced from the inside—that is, from the first-person perspective—each living being, plus the inanimate universe as a whole, is a conscious entity. But as experienced *from outside—that is, from a[n illusory] second- or third-person perspective—our respective inner lives present themselves in the form of what we call matter, or physicality…all matter—is merely the name we give to what conscious inner life looks like from across its dissociative boundary. (Kastrup, 2021, pp. 267–268)*

Triadic dimensional vortical paradigm

Vernon Neppe and Ed Close propose that the standard 4-dimensional model of physics (three dimensions of space and one of time) results in many contradictions or unexplained discrepancies (see Neppe and Close, 2020 for examples of apparent discrepancies). For example, using the Diophantine equation (a polynomial equation involving two or more unknowns and in which only integer solutions are allowed), Neppe states that the mass/energy of up-quarks and down-quarks produces an inequality that is unstable (Neppe and Close, 2015). To address these discrepancies, Neppe and Close describe a mathematical model in which we exist in a 9-dimensional finite, quantized, volumetric, spinning reality embedded in an infinite continuity (9D+). The model requires an extra component that they dub "gimmel," which is mass and energy less. Close expresses that "gimmel is the connection between consciousness, life, and the atomic structure and that the potential for conscious life existed in the mutable mass and energy of quarks even before they became the first protium atoms of physical reality" (Close, 2018). The model proposes that the 4D world we ordinarily experience is the physical component of this 9D+ existence. Neppe and Close believe that the model has been empirically demonstrated with correspondences to normalized data for the mass-energy equivalence volumetric data for measured particles. They also claim that their model is mathematically valid at the micro, macro, and cosmological scales.

Mathematically, gimmel necessarily has to exist in union with any particle in the universe for that particle to be stable. Without gimmel, the spinning (vortical) atoms would be unstable and asymmetrical about their axes and would, in effect, fly apart: Our world and the physical universe could not exist. (Neppe and Close, 2020, p. 4)

Zero-point field

Joachim Keppler (2018) proposes a theory where the energy of the vacuum is the basis for consciousness, the so-called "zero-point field" (Keppler, 2018). This is a theory of panpsychism where consciousness permeates the universe yet is only concentrated and apparent in certain circumstances. Unlike other panpsychism theories, it is not the "matter" that is conscious but empty space. However, the idea that matter is conscious may be incompatible with theoretical physics. If matter is conscious, particles may have the yet unknown property "consciousness." Mathematically, particles are elementary because they cannot be assigned additional parameters than those currently assigned (e.g., a charge, spin, mass). Therefore, the idea that they are conscious is challenging to reconcile with physics. The zero-point field does not have the same problem. Keppler hypothesizes that the human brain is one of the physical mediums which can interact directly with the zero-point field by concentrating on it and thus experiencing consciousness. The details of this putative interaction are not currently known. However, the interesting element of this theory is that it leads to testable predictions, e.g., interactions between the brain (maybe through quantum phenomena as in the Orch OR theory), and the zero-point field could possibly be observed and measured. For example, there might be specific types of photon exchanges that would reveal this interaction.

Orchestrated objective reduction theory

The Orch OR theory was developed by Stuart Hameroff and Sir Roger Penrose (Hameroff, 2021; Hameroff and Penrose, 2014). While the Copenhagen interpretation posits that the collapse of quantum states into a single state (the so-called “collapse of the wave function”) is determined by an observation (i.e., subjective reduction), Penrose’s objective reduction (OR) posits that it occurs when the energy difference (measured by spacetime curvature and mediated by gravity) of these states reaches an objective threshold (called the “Diósi–Penrose criterion”). Random proto-conscious moments of experience occur at each OR moment (Hameroff, 2021, p. 74). At the biological level, this OR would be orchestrated (Orch) by connective proteins (e.g., microtubule-associated proteins; MAPs) that influence this spacetime-separation of the qubits’ superimposed states. These quantum processes are performed by qubits formed on cellular microtubules by oscillating dipoles (the microtubule condensate), forming superposed resonance rings in helical pathways throughout the microtubule lattices. These oscillations are either electric or magnetic and are then amplified by neurons, leading to consciousness. This collective process corresponds to the orchestration of the objective reduction of quantum states in the brain (Orch-OR). The microtubules both influence and are influenced by the conventional synaptic activity of neurons. Hameroff later added that the condensates might travel across more considerable distances in the brain through dendritic-dendritic gap junctions (connections that allow much faster transfer of action potentials than synapses), generating gamma oscillations (high-frequency brain rhythms) associated with conscious perception, for example. This theory provides a straightforward mechanism that can be tested more easily than others. Experiments are underway to test the theory by evaluating if the proposed quantum interference is, in fact, present in microtubules and dampened by anesthesia (Kalra et al., 2020).

Schooler hypothesis of subjective time

Psychologist Jonathan Schooler proposes subjective time as a new dimension of physics that would allow us to have a causal effect on the world (Schooler, 2014). This model proposes that one could conceive of the possibility of alternative dimensions of meta-perspective where each of us could move across time and raises the possibility that consciousness itself could have some causal role. In his model, a hierarchical cascade of conscious elements would have synchronization happening essentially like carrier waves. The lower level of waves has a particular rhythm. They are also synchronized, or cross-coupled, with the higher levels. In the same way that you can have very high-frequency waves or vibrations synced in with lower-frequency ones, in a sort of cross-coupling manner, you could also have the rhythms of the lower-level ones connected up to the higher-level ones. Through cross-frequency coupling, there potentially exists both top-down and bottom-up paths, explaining consciousness at a macroscopical level.

Theory of double causality

Philippe Guillemant, a theoretical physicist, has proposed that trajectories between two spacetimes are not fixed within the block universe (Guillemant and Medale, 2019). The block universe is a model where the future is already realized and is implied by general relativity. Within this framework, Guillemant proposes a non-deterministic model of the block universe where consciousness and free will are mechanisms by which the exact path between two spacetime points is decided. He shows that this does not contradict the equations of physics. He also suggests that the irreversibility of time as we experience it might not be a fundamental property of the world but a statistical one. Statistically, time moves forward, but there might be rare instances where it could move backward. Similarly, he suggests that there might be future traces in the present. Although statistically, we will mostly see causal traces of the past, future traces may be experienced as observations of coordinated systems that past observations cannot explain. For example, one might observe an organized pattern that is not due to a specific causal effect in the past. In his model, he argues that the organization must come from the future as it has no causal past reason to exist. He states, “We can carry on doing physics, but we must be absolutely logical about it, considering our intentions as physical realities, with the added ingredient that they do not appear to depend solely on our brains but also on an information system outside spacetime” (Guillemant, 2016, p. 9).

Summary of non-local consciousness models

Most of these theories assume that consciousness is fundamental and primary to all else. Our subjective intersection with this fundamental consciousness is described in different ways, such as being an interface, a dissociative boundary, or a consciousness unit. Moreover, the mechanistic structure of our world with consciousness as fundamental is explained in various ways (e.g., dimensions, conscious agents, *gimmel).*

However, it is important to note that physicalist theories still have a place in this framework. Even if consciousness is fundamental, these theories will inform on the mechanisms for the embodiment of consciousness into this materialistic reality (e.g., how the interface works). If we can perceive non-local information (as observed at the quantum scale), we likely still need to filter out the noise from the environment through uncertainty reduction, broadcast, and top-down processes for that information to become conscious. Predictive processes and updating the error prediction might be a crucial process to allow the perception of non-local information.

Another important point is that the IIT model could be a tool to study both physicalist and non-local theories of consciousness by including non-local properties into the spacetime postulates. In Section “Physicalist theories of consciousness,” we placed IIT as a physicalist theory of consciousness in the sense that it excludes non-local spacetime properties into the spacetime boundaries required for a physical system to be conscious, and all models are based on the conventional assumptions of spacetime. However, since IIT is only about information and systems, one may be able to test IIT for non-local consciousness. Spacetime properties could be included in the postulates (i.e., requirements for a physical substrate to be conscious) for the calculation of φ (e.g., quantum links between past and future) to see how this addition affects φ's value. These non-local applications of ITT would allow for the non-local effects observed in quantum mechanics and the literature reviewed in Section "Phenomena suggested by a model of nonlocal consciousness."

Just like physicalist theories need rigorous testing to validate them, non-local consciousness theories also need testing and validating. The key to fully validating a theory of consciousness (physicalist or non-local) is to make a prediction that can be experimentally tested and quantified, thus, validating or invalidating the prediction. Theories that cannot meet the prediction can be rejected or adjusted. Unfortunately, many theoretical predictions are challenging to test experimentally, and sometimes prediction confirmation might depend on future technological innovations. Often, the theory is built with abstract terms that need further precision and elaboration. The more precise the theory and the prediction, the more it lends itself to testing. Also, the theory may be demonstrated with mathematics and yet not currently be experimentally validated.

One very small step to explore the applicability of the concept of non-local consciousness models and the motivation for developing these models in the first place is driven by phenomena that are not accounted for by physicalist theories, as described in the next section. One reason that non-local consciousness models may be useful is that they allow for the possibility of the subjective experiences that are usually considered impossible by physicalist models or simply ignored because of the basic assumptions on which they are built.'

Phenomena suggested by a model of non-local consciousness

In the next section, we propose specific phenomena that we would expect to see if non-local consciousness theories are correct.

Phenomenon #1: Perceiving information about distant locations

If consciousness were non-local, then an individual ought to be able to perceive information beyond the reach of the brain, body, and senses. For example, one might be able to gain information about a person, place, or object at a distant location. Such abilities are described as part of a classified US government program that ran from 1972 to 1995, which sought to use non-local consciousness for espionage (May and Marwaha, 2018). That program conducted over 500 operational missions, some of which are said to have resulted in actionable intelligence and also several hundred controlled experimental trials. The latter was evaluated by a professor of statistics and skeptical psychology professional. Both concluded that the evidence in those studies was statistically significant and could not be attributed to methodological flaws (Mumford et al., 1995; Utts, 2016). In a typical experimental session, a "viewer" would enter a relaxed state. An interviewer would give them a random number designating the desired target and then ask them to describe and/or draw any information they perceived about that target. Both viewer and interviewer were blind to the target. Multiple meta-analyses of public domain and declassified experiments of this type have been conducted, and the results showed highly positive evidence in favor of a genuine phenomenon (Milton, 1997; Dunne and Jahn, 2003; Baptista et al., 2015; Cardeña, 2018). This apparent ability is now used for other practical applications, such as predicting stock market movements (Harary and Targ, 1985; Kolodziejzyk, 2013; Smith et al., 2014), locating missing persons (Mcmoneagle and May, 2004), and finding previously unknown archaeological sites (Schwartz, 2005, 2019).

Phenomenon #2: Perceiving information from another person

If consciousness were non-local, an individual might be able to receive information about another, isolated person's mental activity from a distance. Numerous well-controlled laboratory studies have observed this apparent phenomenon using the *ganzfeld* protocol, one of the most-repeated non-local consciousness studies. Ganzfeld originates from a German word meaning "whole field," and Gestalt psychologists initially developed the protocol. First, a person is exposed to low-level, unpatterned sensory stimuli (e.g., red light diffused to the eyes and white noise played through headphones). Meanwhile, a second, isolated person attempts to mentally "send" a target image randomly selected out of a pool of four possible images, which was randomly selected out of a database of many such pools. The chance of the "receiving" person correctly selecting the actual image is thus 25%. Over 120 published experiments have used this protocol, comprising about 4,000 individual trials, and the overall hit rate was just over 30%. Multiple reviews and meta-analyses on this protocol have also been conducted (Storm et al., 2010; Baptista et al., 2015; Cardeña, 2018; Storm and Tressoldi, 2020). These results have been discussed and debated in one of the principal journals in academic psychology, *Psychological Bulletin* (Bem and Honorton, 1994; Hyman, 2010; Storm et al., 2010).

In a conceptually similar design, rather than testing whether one person could select a correct image sent by another isolated person, the person's unconscious physiological state was intentionally influenced by a second person who was asked to focus their attention on them. These studies have typically used measures such as electrodermal activity (Braud and Schlitz, 1983; Radin et al., 2008), electroencephalography (EEG) activity (Standish et al., 2004; Richards et al., 2005), and functional magnetic resonance imaging (Standish et al., 2003; Achterberg et al., 2005). To date, there have been three meta-analyses for this class of studies, with each reporting statistically significant outcomes (Schmidt et al., 2004; Schmidt, 2012, 2015). Using this experimental paradigm, researchers discovered that the prior beliefs of the investigators were an important element in the observed outcomes. That is, working with the same subject populations, protocol, equipment, and analyses, skeptical investigators obtained null results, but investigators more open to the possibility of an effect obtained significant results (Watt et al., 2002; Schlitz et al., 2006). These investigator-specific effects have been documented in psychology and are called "experimenter effects" (Palmer and Millar, 2015). Thus, it is challenging to ascertain if results are solely influenced by the experimenter effect (i.e., intentions of the investigator) or if there are intrinsic effects. Multiple-experimenter studies have been posed as a solution to solving this issue in psychological studies (Bierman and Jolij, 2020).

Phenomenon #3: Perceiving the future

If consciousness were non-local, one might be able to perceive information from non-inferable future events. Experiments testing this idea have shown that people's physiology has reacted to randomly selected future events (Radin and Pierce, 2015), including electrodermal (Radin, 1997) and electrocortical activity (Radin and Lobach, 2007; Radin and Borges, 2009; Radin et al., 2011), and heart rate (McCraty et al., 2004; Tressoldi et al., 2009). These laboratory studies apparently demonstrate that the body can react to randomly selected stimuli approximately 1–10 s in the future. Erotic and negative images produce more robust responses than emotionally neutral pictures, and pre-responses generally manifest in the same direction as the body would typically respond after exposure to a stimulus. Meta-analyses have evaluated multiple laboratory studies with positive effect sizes (Mossbridge et al., 2012, 2014; Storm et al., 2012; Mossbridge and Radin, 2018; Honorton et al., 2018). For example, Mossbridge et al. (2012) analyzed 26 studies where unpredictable stimuli were presented and physiological activity was collected before, during, and after the stimuli. There was a pre-stimulus effect demonstrating a physiological response prior to the unpredictable stimuli (fixed effect: overall effect size = 0.21, 95% CI = 0.15 – 0.27, $z = 6.9$, $p < 2.71 \times 10^{-12}$; Mossbridge et al., 2012).

Implicit bias tests with a retrocausal element provide similar findings. In one paradigm, a classic perceptual priming task was reversed, such that the prime occurred after the target images. For example, in one task, the prime “happy” might typically occur prior to the target picture of a flower. In a reverse priming task, the flower image would appear *before* the prime “happy.” These reverse priming tasks found slower response times when the prime/target pairs were incongruent (sad/flower) versus congruent (happy/flower), just as the classic task would, even though the prime occurred *prior* to the target. Some 90 independent replications of these experiments have provided evidence for a highly significant effect (overall effect size = 0.09, $z = 6.4$, $p = 1.2 \times 10^{-10}$; Bem et al., 2015).

Phenomenon #4: Apparent cognitive abilities beyond the experience/learning/skill of the person exhibiting them

If consciousness were non-local, then people might be able to gain cognitive skills without previous experience or training in those skills.

An example is the phenomenon of a person speaking a language unknown to, or xenoglossy. This phenomenon has been reported since ancient times. It refers to the ability of an individual to speak or write a language that they presumably did not know and could not have acquired by ordinary means. For example, in 400 BC, Plato mentions priestesses on the Island of Delos who spoke “in tongues.” There are also descriptions in the Bible (Corinthians 14:1-40 and Acts 2:4).

Another example is Indriði Indriðason (1883–1912), who apparently spoke multiple languages he did not know (Haraldsson, 2012). Similarly, Alec Harris spoke at length to witness Sir Alexander Cannon in Hindustani and Tibetan, two languages that Harris would have had no way of knowing, but Sir Alexander did know (Vandersande, 2008, p. 113). Other xenoglossy cases have also been documented by University of Virginia scientist Ian Stevenson (Stevenson and Pasricha, 1979, 1980). While anecdotal and subject to the known biases of experiential reports, these cases have been meticulously well-documented. Similar cases of “acquired” and “spontaneous savants” refer to individuals who, either through a traumatic event or with no apparent cause at all, suddenly gain exceptional musical or mathematical skills (Treffert, 2009).

Phenomenon #5: Non-local consciousness experiences are common

If consciousness were non-local, such experiences would be highly prevalent in all humans. And indeed, non-local experiences can be found throughout history, across all cultures, and at all educational levels. Formal prevalence studies have been conducted for almost 50 years, with rates ranging from 10% to 97%, depending on the population surveyed (Bourguignon, 1976; Palmer, 1979; Haraldsson, 1985, 2011; Greeley, 1987; Haraldsson and Houtkooper, 1991; Ross and Joshi, 1992; McClenon, 1993; Cohn, 1994; Castro et al., 2014; Wahbeh et al., 2018). Another survey of the general public, scientists, and engineers in the United States found that over 90% had experienced at least one of 25 of these experiences (Wahbeh et al., 2018). With prevalence rates being well-above 10% of most populations surveyed, it is evident that these phenomena, at least in their subjective reports, are more frequent than commonly supposed.

Phenomenon #6: Cognitive abilities can be retained when the brain is seriously compromised

We usually assume that the brain is the body's driver, and if the brain is not working well, the body should not work. Suppose this is wrong and consciousness is not entirely dependent on the physical function of the brain. In that case, cognition, perception, and memory may continue to operate normally even when the brain would not be considered functional. This is consistent with what we see in a phenomenon called *terminal lucidity*. Terminal lucidity is a label given to a phenomenon in which patients with terminal neurodegenerative conditions display apparently normal cognitive function and mental clarity during the period preceding death (hours to days). While such experiences would seem impossible based on known principles of neuroscience and neuroanatomy, they have been reported in the medical literature for over 250 years (Nahm et al., 2012).

Terminal lucidity, also called paradoxical lucidity, has occurred in conditions such as waking from a long-term coma, dementia due to advanced Alzheimer's disease, brain abscesses, tumors, strokes, and meningitis (Nahm et al., 2012). A recent study of terminal lucidity reviewed 124 cases in dementia patients and found that in "more than 80% of these cases, complete remission with the return of memory, orientation, and responsive verbal ability was reported by observers of the lucid episode" (Batthyány and Greyson, 2021). For example, one reported case involved a patient with cancer that had metastasized to the brain, with little functional brain tissue remaining. However, an hour before the patient died, he regained awareness and conversed with his family for about 5 min before passing away (Nahm et al., 2012). Most terminal lucidity cases are retrospective case reports (Kelly et al., 2007; Nahm and Greyson, 2009; Nahm et al., 2012; Mashour et al., 2019; Batthyány and Greyson, 2021), but a few are prospective. Macleod and colleagues prospectively observed terminal lucidity cases (Macleod, 2009), as did Fenwick and colleagues (Fenwick et al., 2010). In these cases, the patients demonstrated normal cognitive abilities just prior to death, contrary to what objective medical findings would have predicted (e.g., EEG, neuroimaging). These patients are operating in an anomalous manner that brings into question the idea that the body is a "puppet" controlled from the inside (the brain) and that perhaps it can function alternately in some instances. Perhaps there are aspects of consciousness that could be "outside" of the body controlling it. The lucid mental functioning associated with these patients' behavior is challenging to explain under the assumption that one's sense of identity, memory, and awareness solely depends on brain activity.

Summary

In sum, we presented six phenomena regarding aspects related to non-local consciousness. Reports of individuals perceiving information from distant locations, from another person, from the future, where people gain skills beyond their normal capacity, or when the brain is apparently non-functional, have been documented in anecdotal and experimental contexts. In addition, these phenomena are ubiquitous worldwide. Note that these examples are not meant to provide definitive evidence for non-local consciousness, nor provide a comprehensive list of such phenomena, but rather to highlight that certain commonly reported phenomena, and some rare effects, present clear challenges to prevailing physicalist models of consciousness.

Of course, given the significant theoretical importance of these phenomena, each example supporting these predictions has evoked critical responses. The critiques have tended to fall into two classes. First, the phenomena suggested by these examples are deemed impossible because they violate the basic limiting principles of science. Therefore, the only possible way to interpret experiments reporting positive results is that they most likely involve flaws, fraud, or both. Critical reactions to anecdotal reports have also tended to focus on their subjective nature and the many ways that such experiences can be misinterpreted as illusions, misperceptions, or distorted memories. Such critiques can be answered by pointing out that some of the anecdotal reports involved hundreds to thousands of documented case studies, and all the experiments mentioned involved controlled experimental paradigms that were repeated in multiple laboratories and dozens to over a hundred independent replications, with overall highly significant meta-analytic outcomes (Cardeña, 2018). In some of the earliest experiments, methodological flaws were discovered but later corrected with similar results, so insisting that flaws or fraud can be the only possible explanations is not supported by analysis of the data.

The second category of critique is that perhaps the results could be accounted for by one or more physicalist explanations that we do not understand yet, given the state of the science. For example, perhaps some material explanation will eventually arise for how someone with severe brain atrophy and neurofibrillary tangles, or who was in a deep coma for an extended period, could nevertheless suddenly become lucid and maintain a coherent conversation with loved ones shortly before death. Alternatively, perhaps if it is established that the brain has quantum biological properties, then that might provide a plausible substrate for perceptual non-locality. That is, a brain that is partially acting in a quantum manner could possibly account for all these anomalous phenomena. A quantum brain would have non-local properties, so our sensory system would be spread out in space and time, and it might also have observational properties. However, even if this was true, it would not tell us anything about the nature or source of our subjective awareness. That is, from the quantum brain perspective, these phenomena would be completely explained as a purely physical phenomena (albeit within the context of the not-quite-physical nature of the quantum world).

The scientific process and perspective in the face of a paradigm shift

Our call to test non-local consciousness theories is not a proposal to discard physicalist theories. There is no question that, as a set of assumptions, materialism has proven to be outstandingly successful in elucidating the nature of physical reality, and it will likely continue to be useful. However, the phenomena we have highlighted here bring some level of doubt to the ability of physicalist theories to explain *everything*, including the nature, origin, and capacities of consciousness. Here we propose that materialism be viewed as a special case of a more comprehensive metaphysic, one that includes consciousness in some fundamental way. This approach is akin to regarding classical physics as a special case, one that describes a limited domain of the physical world. Quantum mechanics, too, is probably a special case because, so far, it is not compatible with relativistic physics. These "modern" physical theories are more comprehensive than classical physics and are special cases.

Promoting the value of more comprehensive models of reality can be challenging. As Max Planck said, "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it" (Planck, 1950, p. 33). Researchers testing if this statement was true found that, indeed, acceptable scientific models and concepts became more varied after leaders in their field died (Azoulay et al., 2019).

A classic example of shifts in worldviews in science is the case of black holes. Imagine it is 1921, and we asked, "Do black holes exist?" In 1915, Karl Schwarzschild solved Einstein's equations of general relativity for the limited case of a single spherical non-rotating mass. In the process, he discovered the possibility that under extreme gravitational conditions, space could collapse upon itself. Einstein denied that these "black holes" could possibly form. In 1939, he published a paper arguing that a star collapsing would spin faster and faster, eventually spinning at the speed of light with infinite energy, well before the point that it would collapse into a singularity. It was not until the 1960s when Roger Penrose published more detailed models showing how black holes could form, that other physicists considered them viable. A half-century later, astronomers finally observed a black hole (The Event Horizon Telescope Collaboration). In fact, a team of Harvard scientists just released an image of Sagittarius A-star, a black hole at the center of our Milky Way galaxy (McDermott-Murphy, 2022).

We propose that today's understanding of the evidence for non-local consciousness is similar to what was understood about black holes in 1921. A jury of leading scientists in 1921 charged with deciding if black holes existed would have weighed the pros and cons of existing theory and data, they would have consulted with Einstein, and they would have almost certainly decided that black holes could not exist and therefore did not exist. As we know today, they would have been wrong.

Conclusion

Intriguing phenomena are alluding to consciousness being associated with – but not limited by – brain activity. We are in a position similar to those who were studying the possibility of black holes a century ago. Perhaps in 50 years, we will look back on the current transitional period between materialistic and post-materialistic paradigms in science and more clearly understand why we could not have possibly grasped the whole picture.

We can learn from the black hole example to release our desire to prove non-local consciousness and instead remain in a state of curiosity, focusing on methods and improved measures. Even if it were not possible to definitively demonstrate that consciousness is non-local but in the process of determining that, it was discovered that there were non-local aspects of consciousness that we learned more about and controlled to some extent, our world would be radically transformed with the shift in the understanding of our capacities and its practical applications. The systematic scientific study of consciousness is still in its infancy, and thus, we are at the very beginning of understanding the right questions to ask.

This review also calls for humility, open-mindedness, and collaboration in science. Is it possible to remain neutral about the various theories of consciousness? Perhaps physicalist theories will be tested and shown to be relevant in particular situations. Perhaps non-materialist theories will also be tested and shown to be valid in other situations. Could it be that multiple theories of consciousness are tested and found viable? If so, what would that mean about the nature of reality? Can these theories be evaluated for similarities and differences, perhaps combining some and ultimately testing them? Templeton World Charity Foundation Program 'Accelerating Research on Consciousness' has spearheaded such an initiative for physicalist theories. The same could be implemented for non-physicalist theories (Templeton World Charity Foundation, 2022). Is there an interaction between a non-local consciousness interfacing with the physical and/or quantum brain that is persuasively describable? Remaining open and flexible about these possibilities is essential in supporting the birth of new ideas. Remaining humble allows us to review other theories without prejudice.

To further assess the vast number of theories of consciousness, physicalist and non-local, we invite theorists to attempt to make their theories increasingly precise so that abstract terms become quantifiable predictions that can be confirmed or refuted. Furthermore, theorists could attempt to use similar language/terms to improve the clarity regarding the distinctions and commonalities across theories. Criteria could be developed, allowing researchers to easily determine the nature/aspect of consciousness discussed by the theory, the proposed processes that explain how non-local consciousness may interact with physical substrates, and the precise predictions to validate it. Physicalist theories might be closer to validating or invalidating their predictions if the assumption about the nature of consciousness being generated from the brain is correct. However, these predictions may never address the possibility that consciousness is a fundamental property of reality with non-local properties (i.e., they address physical mechanisms but not the nature of consciousness itself).

In conclusion, our reported phenomena of non-local consciousness present intriguing examples that should be addressed when evaluating whether consciousness may be more than an emergent property of brain activity. Despite sophisticated physicalist theories of consciousness dependent on brain function, these examples apparently demonstrate non-local aspects of consciousness, perceiving information in a way that is not limited by our conventional understanding of time and space and that is not dependent on the brain function. Many of these data have been observed with objective measures in the laboratory in a valid and reliable way or collected in the field with impeccable methods and exclusion of fraud. While materialism explains much in our world, it does not explain everything, including these phenomena. Non-materialist theories encompassing consciousness as fundamental and/or non-local may provide a pathway to understanding these phenomena. Perhaps holding the hypothetical assumption that consciousness *is* fundamental and focusing on what we can learn about the mechanism, mediators, moderators, and practical applications of non-local consciousness will reveal novel areas to explore.

Author contributions

HW contributed to the conceptualization, funding acquisition, project administration, and writing – original draft preparation, review, and editing. DR and AD contributed to the conceptualization, funding acquisition, and writing – original draft preparation, review, and editing. CC contributed to the conceptualization and writing – review and editing. All authors contributed to the article and approved the submitted version.

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WHY SOME SCIENTISTS THINK CONSCIOUSNESS PERSISTS AFTER DEATH

We should not assume that people who are near death do not know what we are saying

A very significant change that happened in the last century or so has been the ability of science professionals to see what happens when people are thinking, especially under traumatic conditions.

It was not a good moment for materialist theories. Here is one finding (there are many others): Death is a process, usually, not simply an event.

Consciousness can persists after clinical death. A more accurate way of putting things might be that the brain is able to host consciousness for a short period after clinical death. Some notes on recent findings:

The short answer is, probably, yes:

Recent studies have shown that animals experience a surge in brain activity in the minutes after death. And people in the first phase of death may still experience some form of consciousness, [Sam] Parnia said. Substantial anecdotal evidence reveals that people whose hearts stopped and then restarted were able to describe accurate, verified accounts of what was going on around them, he added.

"They'll describe watching doctors and nurses working; they'll describe having awareness of full conversations, of visual things that were going on, that would otherwise not be known to them," he explained. According to Parnia, these recollections were then verified by medical and nursing staff who were present at the time and were stunned to hear that their patients, who were technically dead, could remember all those details.

MINDY WEISBERGER, "ARE 'FLATLINERS' REALLY CONSCIOUS AFTER DEATH?" AT *LIVESCIENCE* (OCTOBER 4, 2017)

Death is probably, in most cases, a process rather than a single event:

Time of death is considered when a person has gone into cardiac arrest. This is the cessation of the electrical impulse that drive the heartbeat. As a result, the heart locks up. The moment the heart stops is considered time of death. But does death overtake our mind immediately afterward or does it slowly creep in?

Some scientists have studied near death experiences (NDEs) to try to gain insights into how death overcomes the brain. What they've found is remarkable, a surge of electricity enters the brain moments before brain death. One 2013 study out of the University of Michigan, which examined electrical signals inside the heads of rats, found they entered a hyper-alert state just before death.

PHILIP PERRY, "AFTER DEATH, YOU'RE AWARE THAT YOU'VE DIED, SAY SCIENTISTS" AT *BIGTHINK* (OCTOBER 24, 2017)

Despite claims, current science does not do a very good job of explaining human experience just before death:

Researchers have also explained near-death experiences via cerebral anoxia, a lack of oxygen to the brain. One researcher found air pilots who experienced unconsciousness during rapid acceleration described near-death experience-like features, such as tunnel vision. Lack of oxygen may also trigger temporal lobe seizures which causes hallucinations. These may be similar to a near-death experience.

But the most widespread explanation for near-death experiences is the dying brain hypothesis. This theory proposes that near-death experiences are hallucinations caused by activity in the brain as cells begin to die. As these occur during times of crisis, this would explain the stories survivors recount. The problem with this theory, though plausible, is that it fails to explain the full range of features that may occur during near-death experiences, such as why people have out-of-body experiences.

NEAL DAGNALL AND KEN DRINKWATER, "ARE NEAR-DEATH EXPERIENCES HALLUCINATIONS? EXPERTS EXPLAIN THE SCIENCE BEHIND THIS PUZZLING PHENOMENON" AT *THE CONVERSATION* (DECEMBER 4, 2018)

Such explanations are a classic case of adapting a materialist hypothesis to fit whatever has happened. They don't explain, for example, terminal lucidity, where many people suddenly gain clarity about life.

Research medic Sam Parnia found, for example, that, of 2000 patients with cardiac arrest,

Some died during the process. But of those who survived, up to 40 percent had a perception of having some form of awareness during the time when they were in a state of cardiac arrest. Yet they weren't able to specify more details.

CATHY CASSATA, "WE MAY STILL BE CONSCIOUS AFTER WE DIE" AT *HEALTHLINE* (SEPTEMBER 24, 2018)

THE PAPER REQUIRES A SUBSCRIPTION.

So we should not assume that people who are on the way out cannot understand us. Maybe they can — and would like to hear that they are still loved and will be missed.

Can consciousness continue after death? A Neuroscientific Perspective

What happens when we die? Unless we accept a religious explanation, the only remaining possibility seems to be the annihilation of consciousness. But another possibility is consistent with evidence from neuroscience. Our brains easily form predictive models of the behavior of close friends and loved ones, which emulate these other selves much as advanced computers can emulate other electronic devices. Whether these emulations are conscious is an open question, but there is preliminary evidence from several sources that the brain can host multiple independent spheres of consciousness. This opens up the possibility of survival through the medium of other brains.

What happens when we die? Some are lucky enough to have total conviction that a pleasant afterlife awaits — but most of us harbor doubts, which can curdle into profound terror. There are at least two reasons we might fear death. One is that it deprives us of being able to carry out our life's work, which can encompass everything from creating works of art to traveling the world to raising our children. This, at least, we can do something about: we can put plans in place to carry this work forward even after we're gone. But the second thing death takes from us is our capacity to experience, or to be conscious. There seems to be no hope that after we die, our consciousness will continue.

What to do? We can try to ignore death, but it has a way of forcing itself upon us. For me, my first real brush with death was watching my grandpa be swallowed up by Alzheimer's disease. This led me to pursue my PhD in neuroscience in hope of finding a cure. At the same time, I had an early-life crisis. I was struggling to find my place in the world and wanted to understand what it all meant. Since I wanted my beliefs to be based on evidence, I didn't find answers offered by traditional faiths satisfying.

But as I learned more about the brain, I came to a surprising conclusion. We are used to thinking about biological death — when the heart stops beating and the brain stops firing — as the end of us. But there are cases where these do not coincide. Alzheimer's, for example, wipes our memories and destroys our essential selves, even if our bodies linger on for a while.

But I also began to explore an even stranger possibility. The opposite might also be true: what if biological death is not the end of the self or of our conscious experiences? I reached this conclusion strictly through my understanding of how the mind works, without any metaphysical concepts: no souls required. In this article, I will make the case that a form of afterlife, which bears a strong resemblance to reincarnation, is compatible with a scientific worldview.

To readers who believe in the existence of the soul, this entire essay would seem like an exercise in futility. If you're religious, or open to the possibility, then the answer is simple: souls are attached to our bodies during life, survive after death, and carry us into the Great Beyond. But I don't think this is true: even if souls do exist, they are not *us* in the ways that matter most.

Believers in traditional afterlives think that they will continue to have conscious experiences after death via their souls; this means that the soul is conscious, or supports consciousness. It isn't enough that the soul exists after death and has experiences; for it to really be your afterlife, the soul has to *be you* and have *your* experiences. What this means is difficult to pin down, but I'd suggest that it has to have the same kind of mental life that you do. It has to think the way you do.[1]

Why does your soul have to share your mental life in order to really count as a continuation of you? Intuitively, we tend to think that the essence of a person is more closely tied to their mind and personality than to their body. Think of a body swap movie like *Freaky Friday*; in the story, the mother's mind swaps into her daughter's body, and vice-versa. We accept, as viewers, that after the swap the person who looks like the daughter is really the mom, because that's where her mind is.

To be *you* after death, the soul must have your mind. Ideally it would share your memories. Memories play a special role in making us who we are[2], because they are the raw ingredients we use to construct our life stories. If a soul entered into the afterlife with no memory of the life that had come before, whether that life would really be a continuation of yours would be in doubt; it would have the same connection to you that you have to the protagonist of an unremembered dream.

If a disembodied soul is to truly be a continuation of your life, it has to have experiences in common with yours, which should include your memories and ways of thinking and perceiving the world. The trouble is, all of those are mental phenomena, and the simplest explanation[3] of mental phenomena is that they are produced in your brain.

How do we know this? First, the activity of the brain is extremely well-correlated with mental events. Techniques like EEG and fMRI allow us to measure the activity of the brain, and we can see it buzzing with activity when study participants perform mental tasks, ranging from doing mental math, picturing objects in the imagination[4], recalling an emotional memory[5], or learning a new language[6]. Crucially, these patterns of activity are stable — thinking the same sort of thought will reliably be accompanied by predictable patterns of electrical activity in brain cells. The brain activity corresponds to the mental activity.

Correlation is not causation, but we also know that making physical changes to the brain leads, predictably, to changes in thought and experience. This is why humans enjoy taking drugs, from caffeine to alcohol to more exotic substances: introducing certain molecules to the brain changes how we think, feel, and see the world. Even mystical experiences, such as the sense that one is in the presence of a mysterious greater power, can be caused by consuming psychedelic drugs.[7]

All evidence points to memories being stored in the brain. Scientists have even transferred a memory from one mouse to another by teaching the first mouse a path through a maze, recording a pattern of brain cell activity as the mouse thinks about the task, and then replaying that pattern in another mouse's brain with electrical stimulation; the second mouse then "remembers" how to solve the maze, even though she has never seen it before.[8]

We also know that diminishing the activity of the brain, whether through injury or anesthesia, causes a dimunation and eventual loss of consciousness; and people who sustain injuries to certain parts of the brain can even lose whole categories of experience, such as the ability to perceive faces[9] or to notice objects to one's left.[10]

Taken together, we can conclude: conscious experiences happen in living, functioning brains; and functioning brains are required to produce conscious experiences.

When I, as a scientist, say that the simplest (and likeliest) explanation of consciousness is that it's produced by brain activity, I'm sometimes accused of being closed-minded. Since we don't know everything about how consciousness works, why am I so confident in dismissing the role that souls might play? If there are gaps in our understanding of how the brain works (as there certainly are), how can I rule out that consciousness might persist after death, via the soul?

It's true that we understand very little about how consciousness works. We can point to patterns of electrical activity in the brain that go on during thinking, but it isn't obvious why it feels the way it does to have those kinds of mental experiences. Why does it feel like anything at all when neurons send electrical signals to one another, while it (presumably) doesn't feel like something to the transistors in my iPhone? Why does a certain pattern of electrical activity cause all the experiences — pleasure, pain, sweet, bitter, blue, red, happy, sad — that create the feeling of life?

I'll be the first to admit that I don't know why a functioning brain produces the feeling of being alive. But we have good reason to believe that the brain is an essential ingredient, and no reason to think that consciousness can arise in other places. This could change as we develop more sophisticated artificial intelligence, which may become conscious if set up in the right way. And I also expect that there are fundamental things about the universe that we don't understand and have yet to discover. It may turn out that souls or other metaphysical things do exist and are involved in consciousness in some way: maybe, for example, the universe is pervaded by an invisible, unobservable mind field that has to interact with the brain to make it conscious. These things are not (currently) the simplest possible explanations, but as we learn more about the world around us, they may turn out to be right.

But that would still leave a soul-based afterlife in doubt. Remember, we have every reason to believe that consciousness requires a functioning brain or similar information-processing system: mental events have accompanying patterns of brain activity and changing the physical brain (with drugs or injury) causes changes in mental life. All that stops when you die, and there's no reason to think that *even if a soul exists*, it could sustain *you-ness* on its own. Memories can't even survive a night of heavy drinking — how plausible is it, really, that they could survive the complete destruction of your physical brain? A brain injury can change your personality — but death leaves it intact?

Some might object that near-death experiences (NDEs) prove that conscious experiences after death are possible, but there is no evidence that these NDEs are anything more than hallucinations in almost-but-not-quite-dead brains. NDEs can share some features across people[11] (with reports of bright lights, seeing loved ones, and so on), but this consistency is somewhat overstated and certainly not universal,[12] and anyway this does not disprove that NDEs are hallucinations — drugs like LSD cause similar hallucinations across many people, too.[13] Some researchers have tried to prove that the "out of body" experiences reported during NDEs are real perceptions by a soul that is literally separated from the body, by hiding objects in high places of operating rooms that would be out of sight for the body on the table, but visible to a soul that really was floating up above.[14] Unsurprisingly, these studies have failed; if one succeeds, I'll be happy to change my mind, but until then, I see no reason to believe that souls carry us into the Great Beyond. Everything that makes us who we are is in the brain; even if the soul exists, once it separates from your brain, it would no longer be you.

If a soul won't save us, are we doomed at death? Not necessarily. I think it's possible — even likely — that death will *not* be the end of experience.

As I've argued above, your mental life is the product of a particular pattern of electrical activity in your brain. It's an *activity* — something your brain does. The brain is like an enormous musical instrument, with trillions of tiny "strings" (the synapses, or connections between brain cells) buzzing at particular frequencies. The "music" produced by this staggeringly complex instrument is what makes you *you*. Your consciousness is a symphony of brain activity.

Music is a series of notes, along with temporal relationships between notes: the order the notes are played, the pauses between them, the length each is held, and so on. That's the information, or structured data, that defines music. And because music is information, it can be stored and transmitted in other forms. A live performance can be recorded on magnetic tape, digitized to 1s and 0s, and transcribed to sheet music; in all cases, as long as the recording is faithful, the song remains the same.

This is characteristic of information: it can be stored and transmitted in many different forms, while still containing the same essential data. Information is resilient. It needs some physical medium to be stored — whether paper or computer chips or human brains — but it can coexist in many different storage media at once, and even if some of those are lost or destroyed, the information exists as long as any of its copies do.

If conscious experience is informational, then it can be copied; and if it can be copied, then it can survive the death of its original vessel. It needs to be physically instantiated somewhere; it can't just exist as a ghostly soul. But its physical form doesn't need to be the original: the digital copy of "Macbeth" on a Kindle is the same as the one Shakespeare wrote in terms of its informational content, despite never having touched his quill.

Why is it plausible to believe that the mind is information, like music or language? First, the contents of the mind can be described in words and understood by others. This means that our mental states can be *transformed* into another form of information and transferred, just as the information in music can be expressed as vibrations in the air, notes on a page, or bits and bytes on a computer. Second, the things that go on in our mind represent events in the world; they encode data about what we're experiencing. Biting into an unfamiliar food and discovering that it tastes *sweet, and a bit peppery*, teaches you something about that food. And finally, these experiences are the result of information processing in the brain. Cells in the brain are arranged into circuits, and the computations these circuits perform are what produces the events we experience in our minds.

What does it mean to experience something in your mind — to hear a new song, for example, and to be aware of hearing that song? To have a conscious experience is just to recognize that your brain's circuitry is in a particular state. Hearing music is being aware that a certain pattern of vibrations in the air is causing a certain response in your eardrum, which leads to a certain pattern of electrical activity in the brain.[15]

Our intuitions also tell us that the self is a kind of information, which can be transferred, stored, and shared. We readily accept fictional stories in which one character's mental contents are transferred into another person's body or into a robot, and we expect that the recipient of this transfer is the "real" person.

The reason it is probably not obvious to most people that the self is a kind of information, just like music or language, is that we don't have the technology yet to copy and store selves. *Information theory*, the branch of science that studies and quantifies information and its properties, was invented only after electronic communication. Before messages could be sent over telegraph wires, it wasn't obvious to people that language and sound were both forms of *information*, having shared properties. "Information" didn't exist as a human concept until about 1920. I suspect that, if it becomes possible to store backup copies of the mind in a computer, that you and I are just another kind of information will suddenly become common sense.

If the mind is informational, then it can be copied, and these copies can outlive the original — not as imposters, but as the real deal. Every copy is as much the real thing as any other, as long as the relevant information is the same (for *Hamlet*, words; for us, mental events). But for this to give us any hope of an afterlife, we need to have some reason to believe that copies of our mind actually exist. Someday, technology may provide a solution, and I expect that it will become possible to copy the mind into a computer. Many of us reading this, including myself, were probably born too early for such technology to save us. But we are not doomed.

Each of us has the capacity to copy one another's minds, and we do it regularly. You just probably don't think about it as "copying"; you call it "getting to know each other" — or maybe "empathy" or "love".

Think of someone you know very intimately — a best friend, romantic partner, or close family member. You carry lots of memories of this person, and you can also easily anticipate their reaction to a new situation: "She wouldn't want her birthday to be a surprise — she hates surprises." You can probably hold an imaginary conversation with this person in your mind, because you know the contours of their personality: their humor, their insecurities, their sources of pride, their hopes for the future. You may have even had dreams where this person played a co-starring role and observed them in some truly fantastical scenarios that never happened in waking life.

What you're doing, in all of these cases, is predicting how this person would behave, based on the rich set of memories you have together. You're doing what scientists call *extrapolation*: drawing on past data to predict the future. This means that you have an internal model of their personality — or in other words, a copy of their mind. You just didn't know you were doing it. All the time you were hanging out, sharing laughs, and making memories, your brain was surreptitiously storing a copy of them away for later. Human brains even contain a special class of neurons, called mirror neurons, that are specialized for responding to the behavior to others and play a key role in empathy.[1]

It's an old cliche that when someone dies, they live on in the memories of their loved ones. Maybe this is not just a figure of speech. When our loved ones die, the mental model of them that we've carefully built up over years of careful study, doesn't go away. They continue to exist via neurological emulation. Just as *Hamlet* still exists, even if Shakespeare's original copy is lost, your loved ones exist so long as their copies do.

It may seem hard to believe that a mental copy of you could represent genuine survival from your perspective after your own death. So, let's consider a few possible objections.

First, to be genuine survival, the copy would have to be conscious; is this believable? We tend to think that each brain contains only one conscious self, which would make it impossible for these models of our loved ones to be conscious in their own right. But this way of looking at the brain is probably wrong. Evidence from "split-brain" patients — people who have the two halves of their brain surgically separated to prevent severe epilepsy — suggests that each half of the brain develops a separate sphere of consciousness, at least under some circumstances.[16] One half of the brain tends to control speech and the right side of the body, while the other half of the brain controls the right side; and in split-brain patients, these two sides can behave independently from (and sometimes in conflict with) each other. There is some evidence that the characters in dreams are independent spheres of consciousness: the side characters in your dreams can withhold information from you (or vice-versa), and they can behave in ways you don't expect, suggesting that they have a semi-independent mind despite sharing your brain.[17] Finally, practitioners report being able to deliberately create other conscious personalities through long-term meditation-like techniques.[18]

These sources of evidence are still preliminary, and we don't yet know enough about how consciousness works to be able to definitively say whether multiple truly independent minds can exist in a single brain, or whether this can happen under normal circumstances. We know, for example, that some parts of the brain contribute to conscious experience (the frontal cortex, for example) and that others do not (the cerebellum), but not why.[19] So it may turn out that the mental models we have of other people are not conscious, which would make my proposal wrong.

But I think it's reasonable to believe that they are — or at least as reasonable to believe this as not — for the simple reason that we know that our mental models of other people can participate in our own conscious experiences. When we hold an imaginary dialogue with a loved one, we are reconstructing the way they think, and being aware of it. They become part of us. It at least feels as if they are conscious, and with consciousness the feeling is the whole point.

Another objection to whether this is genuine survival is that, even if our models of other people are conscious, they might not be the original person's consciousness. They may be "just" a copy. In other words, if I die tomorrow, and my loved ones carry mental models of me, can I really expect to continue having experiences inside their brains? This can seem implausible; after all, those models of me exist right now, and I don't feel their experiences. So why would I start feeling them after my original body dies?

The philosopher Derek Parfit illustrates this dilemma vividly with his story about a teleporter[20] (a similar idea is explored in the movie *The Prestige*). Parfit's story is set in the near future, and teleporters are a common way to travel quickly. To use a teleporter you enter a special booth, and the booth scans and records your body (down to the position of every single atom). It then vaporizes you, destroying your original body; and simultaneously, a booth on the other side of the world receives the scan and reconstructs an exact copy of you. Parfit's story concerns a man who is initially hesitant to travel this way, fearing that teleporting is not really travel, but rather dying and being replaced by a clone. But he eventually decides to do it anyway, and to his amazement, when he steps out of the booth on the other side of the world, he still feels like himself. He begins to travel this way often. But then, one day, the machine malfunctions; he enters the booth, waits, and… nothing. The technician opens the door, and tells him some bad news: the teleporter malfunctioned. It did scan his body, and it *did* create a copy of him on the other side of the world. But the machine failed to destroy his original body, so now there are two of him. And even worse, the scan process involves a heavy dose of radiation, so the man's original self will die of cancer in one week. The man is horrified. He calls his clone on the other side of the world. The clone assures him that, even when the original dies, it won't really *be* death, because the clone is an exact copy that can carry on his life. But while the man accepts that his clone can play the *role* of him, doing his work and raising his kids, the clone won't really be him; in a week, he despairs, his life will be over.

Since mental copies of us exist right now in other people's brains, dying is exactly like what the man in Parfit's story faces. If the man is right that the clone isn't really him, then he (and we) are right to fear death; if the man is wrong, then death is really nothing to fear, since we should expect experiences to continue somewhere else. Both Parfit and I believe that the man is wrong. Parfit gets there via an elaborate argument about how personal identity is an illusion (so whether some future person is "you" is a meaningless question), but I think we can take a simpler route.

We are used to thinking of ourselves as physical things, where each individual is unique. Two cars may look alike — may even be the same model — but are not the same car. If I get into a car that merely *looks like* mine, I'm a thief. But information does not work this way. Two copies of *Hamlet* are both the *exact same* story. Even if one copy was printed first, the second copy is not an "imposter", as long as it has the same words.[21] If we believe that what really matters is our minds, and that our minds are information, then it doesn't matter that another version of your mind is "just" a copy. Any copy of a bit of information is the real thing.

This introduces one final problem: any mental copy we can make of another person is incomplete. No matter how well we think we know someone else, we can't know everything about them. So, while a full copy of your mind would be the real thing, a partial copy is just that — only partially you.

So maybe it's fairer to say that we do live on in other people, but only partly. That sounds just fine to me. In fact, it's exactly what would happen to you if you never died — given enough time. Compare yourself to how you were 10 years ago. Are you exactly the same? Of course not. Your personality has changed in ways big and small, deliberate and circumstantial. You've learned new things and forgotten others. You are only a partial copy of your older self; that person survives as you, *but only partly*. You probably don't find that especially troubling; quite the opposite, since we actively seek personal change. You will survive only partially in other people once you die, but you already survive only partially from one year to the next. In other words, *what happens when you die is remarkably similar to what happens when you continue to live*.

In this essay, I've argued that the self is a form of information that can be copied and shared; and that this actually does occur as a natural extension of our empathy for one another. Each of us carries around a whole host of characters in our brains, to varying degrees of fidelity. When we die, these copies of us continue to exist, and represent genuine (if partial) survival. All of this amounts to a kind of afterlife, albeit an unusual one. It does not involve any metaphysical concepts; it remains agnostic as to whether a soul exists. Even if you *do* have a soul that goes off to Heaven, it can't get rid of the copies that exist down here; it would just be one copy among many. This viewpoint also stays silent about how we got here, or what the purpose of all of this is (if any).

Traditional religions typically acknowledge the existence of an afterlife, but usually stay silent on what, exactly, we should expect once we get there. The Bible has little to say about Hell, and even less about Heaven. Can we say more about this strange afterlife that awaits us?

I don't know exactly what it will feel like to be distributed over many other brains, but I suspect it will feel a lot like living does now. Each of us carries around many other people in our heads; as we come to know others intimately, we don't just learn about them — we become more like them. We are a blend of the characteristics we picked up from other people. Even beloved fictional characters can leave their mark. Each of us is already something of an amalgam. We should expect more of that.

One disadvantage that this afterlife has over religious alternatives is that the vessel we transition to is fragile: other brains host us for a while, but they too will die. But just as they carried us, so will others carry them; and the ways that we informed our successors' lives will inform still others. Over time we become more diffuse, but do not vanish. Human existence flows on, one into the next, like a river.

In some ways, this vision of the afterlife has a lot in common with Buddhist or Hindu reincarnation. Unlike in Hinduism there is no soul that bridges the gap; and unlike Buddhism there is no escape, no final nirvana, no enlightenment to be gained. There is just more and more and more life: messy, imperfect, and beautiful.

The mechanism that keeps the great river of existence flowing is love. We don't need to do anything to preserve the people we care about, other than to do what we're already inclined to do: to care for one another. This afterlife imposes no judgements or cosmic laws on us. But it does suggest two bits of advice. We should live as authentically as we can — the more accurately others know us, the better they can preserve us. And we should do our best to really know the people we care about, so they can become part of us more fully.

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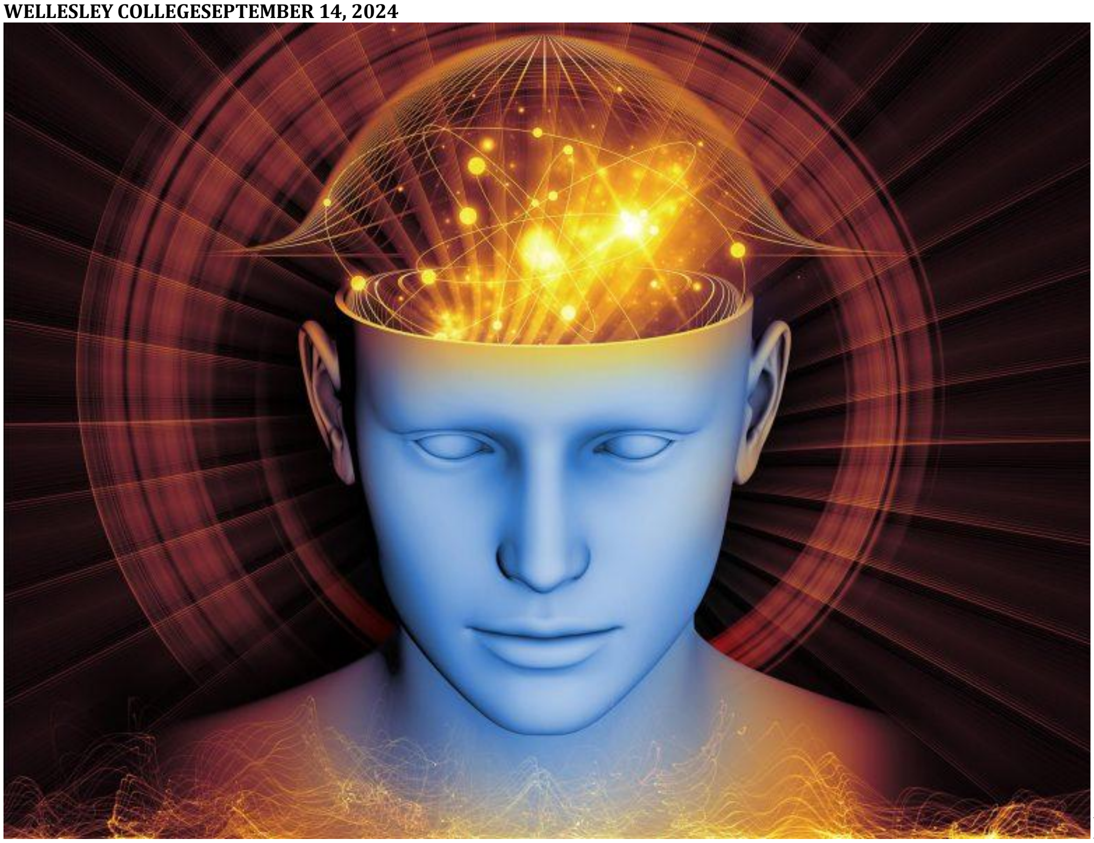
Groundbreaking Study Affirms Quantum Basis for Consciousness: A Paradigm Shift in Understanding Human Nature

WELLESLEY COLLEGESEPTEMBER 14, 2024



New research indicates that anesthesia's effectiveness via microtubule interaction supports a quantum theory of consciousness, potentially transforming neuroscientific approaches and treatments.

A groundbreaking study has provided experimental evidence suggesting a quantum basis for consciousness.

By demonstrating that drugs affecting microtubules within neurons delay the onset of unconsciousness caused by anesthetic gases, the study supports the quantum model over traditional classical physics theories. This quantum perspective could revolutionize our understanding of consciousness and its broader implications, potentially impacting the treatment of mental illnesses and our understanding of human connection to the universe.

Exploring the Quantum Basis of Consciousness

For decades, one of the most fundamental and vexing questions in neuroscience has been: what is the physical basis of consciousness in the brain? Most researchers favor classical models, based on classical physics, while a minority have argued that consciousness must be quantum in nature, and that its brain basis is a collective quantum vibration of "microtubule" proteins inside neurons.

New research by Wellesley College professor Mike Wiest and a group of Wellesley College undergraduate students has yielded important experimental results relevant to this debate, by examining how anesthesia affects the brain. Wiest and his research team found that when they gave rats a drug that binds to microtubules, it took the rats significantly longer to fall unconscious under an anesthetic gas. The research team's microtubule-binding drug interfered with the anesthetic action, thus supporting the idea that the anesthetic acts on microtubules to cause unconsciousness.

"Since we don't know of another (i.e,. classical) way that anesthetic binding to microtubules would generally reduce brain activity and cause unconsciousness," Wiest says, "this finding supports the quantum model of consciousness."

Implications for the Future of Neuroscience

It's hard to overstate the significance of the classical/quantum debate about consciousness, says Wiest, an associate professor of neuroscience at Wellesley. "When it becomes accepted that the mind is a quantum phenomenon, we will have entered a new era in our understanding of what we are," he says. The new approach "would lead to improved understanding of how anesthesia works, and it would shape our thinking about a wide variety of related questions, such as whether coma patients or non-human animals are conscious, how mysterious drugs like lithium modulate conscious experience to stabilize mood, how diseases like Alzheimer's or schizophrenia affect perception and memory, and so on."

More broadly, a quantum understanding of consciousness "gives us a world picture in which we can be connected to the universe in a more natural and holistic way," Wiest says. Wiest plans to pursue future research in this field, and hopes to explain and explore the quantum consciousness theory in a book for a general audience.

Broader Research Impact

Wellesley students who co-authored the paper with Wiest are Sana Khan '25, Yixiang Huang '25, Derin Timucin '27, Shantelle Bailey '24, Sophia Lee '23, Jessica Lopes '26, Emeline Gaunce '26, Jasmine Mosberger '25, Michelle Zhan '24, Bothina Abdelrahman '26 and Xiran Zeng '27. Published on September 1 in the journal *eNeuro*, the Wellesley study demonstrates that anesthesia works by binding to microtubules inside neurons, thus providing important evidence for a quantum theory of consciousness while reviving a focus on microtubules in anesthesia.

eNeuro is the Society for Neuroscience's open-access journal.

Reference: "Microtubule-Stabilizer Epothilone B Delays Anesthetic-Induced Unconsciousness in Rats" by Sana Khan, Yixiang Huang, Derin Timuçin, Shantelle Bailey, Sophia Lee, Jessica Lopes, Emeline Gaunce, Jasmine Mosberger, Michelle Zhan, Bothina Abdelrahman, Xiran Zeng and Michael C. Wiest, 15 August 2024, *eNeuro*.
DOI: 10.1523/ENEURO.0291-24.2024

Quantum Entanglement in Neurons May Actually Explain Consciousness

PHYSICS 09 August 2024

(PM Images/Getty Images)

A silent symphony is playing inside your brain right now as neurological pathways synchronize in an electromagnetic chorus that's thought to give rise to consciousness.

Yet how various circuits throughout the brain align their firing is an enduring mystery, one some theorists suggest might have a solution that involves quantum entanglement.

The proposal is a bold one, not least because quantum effects tend to blur into irrelevance on scales larger than atoms and molecules. Several recent findings are forcing researchers to put their doubts on hold and reconsider whether quantum chemistry might be at work inside our minds after all.

In their new published paper, Shanghai University physicists Zefei Liu and Yong-Cong Chen and biomedical engineer Ping Ao from Sichuan University in China explain how entangled photons emitted by carbon-hydrogen bonds in nerve cell insulation could synchronize activity within the brain.

Their findings come just months after another quantum phenomenon known as superradiance was identified in cellular frameworks, drawing attention to a highly speculative theory on consciousness called the Penrose-Hameroff 'orchestrated-objective reduction' model.

Proposed by the highly respected physicist Roger Penrose and the American anesthesiologist Stuart Hameroff, the model suggests networks of cytoskeleton tubules that lend structure to cells – in this case, our neurons – act as a kind of quantum computer that somehow shapes our thinking.

It's easy to see why there's an appeal in looking to quantum physics to explain consciousness. For one thing, both have a kind of 'weirdness' to them – a mix of predictability and randomness that's hard to pin down.

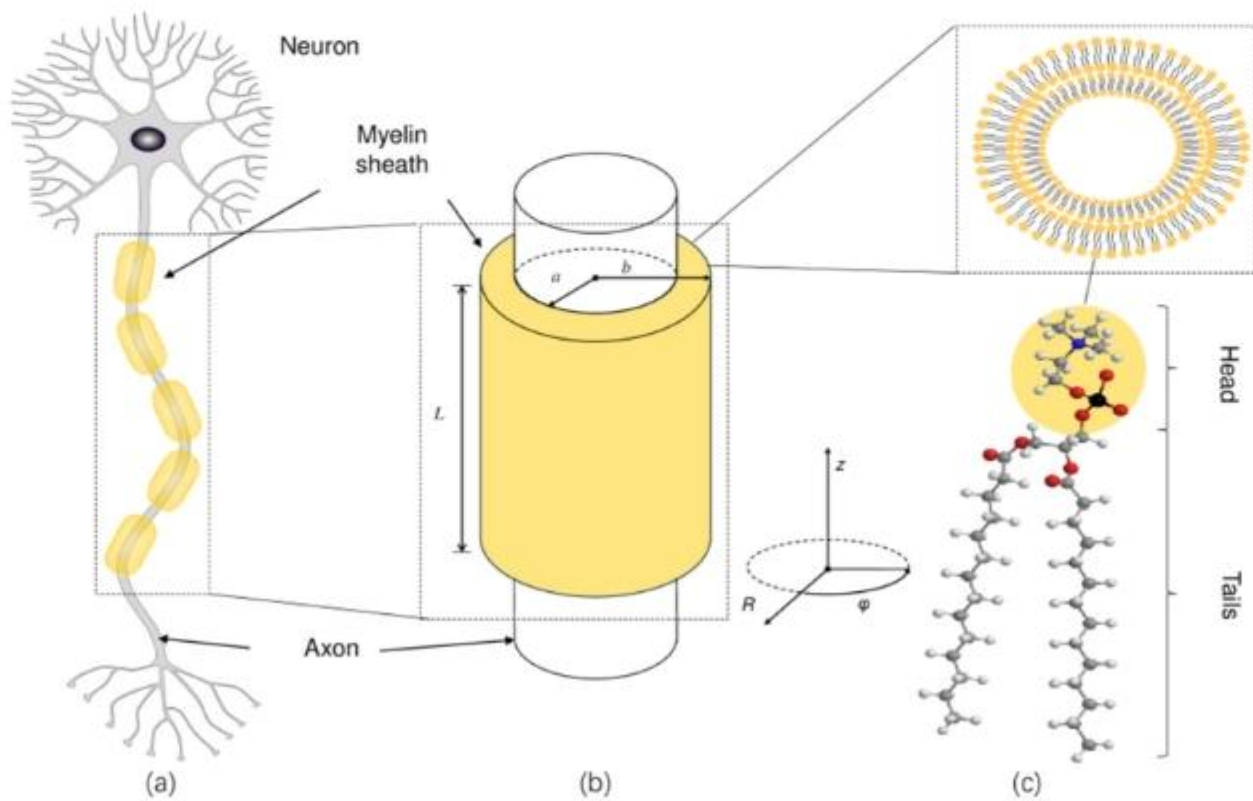
Then there is the perennial problem of what constitutes the pivotal observation that transforms quantum uncertainty into a classical absolute measurement. Could a quantum phenomenon in the brain be related to the collapse of a wave of probability?

On the other hand, weird plus weird doesn't equal scientific truth, no matter how incomprehensible each concept seems. Brains might not work like classical computers, but sprinkling with quantum magic is unlikely to lead to a comprehensive theory.

Scientists have had a whole other reason to staple their skeptic hat on tight when it comes to quantum theories of consciousness – the sloppy tides of biology have long been considered too chaotic, too noisy, and too 'big' for quantum mechanics to emerge in any significant way.

That part we might need to reconsider, especially if experiments can verify Liu, Chen, and Ao's prediction.

The trio notes the fatty coating called myelin around the nerve cell's axon 'tail' could conceivably serve as a suitable cylindrical cavity for the amplification of infrared photons generated elsewhere in the cell, causing carbon-hydrogen bonds to occasionally spit out pairs of photons that would have a high degree of correlation between their properties.



Gaps between segments of myelin sheaths (a) are small enough to consider the entire myelin-coated axon as a cylinder (b) with the axon's radius as a, the entire cylinder's radius as b, and the thickness of the myelin sheath as $d=b-a$. The length of the cylinder is denoted by L. (c) Phospholipid molecules in myelin have tails with a large number of carbon-hydrogen bonds. (Liu et al., *Physical Review E*, 2024)

Movements of these entangled photons through the ionic tides of the brain's biochemistry just might drive correlations between processes that play a central role in the organ's ability to synchronize.

The word 'might' is doing some tremendous heavy lifting here, of course. While there are plenty of empirical discoveries to support details of the hypothesis, evidence of entangled photons affecting large-scale biological processes is currently limited to photosynthesis.

That doesn't mean there are zero precedents for quantum biology in animals. Mounting evidence suggests the fuzzy superposition states of electron spins in proteins called cryptochromes can be influenced by magnetic fields in a way that helps explain long-distance navigation in some animals.

We're a fair way from demonstrating anything but classical chemistry is at work inside our heads, let alone confidently proclaiming the symphonies of our brain are united by a quantum composer.

But it might be time to press pause on reservations over quantum phenomena exerting an influence over at least some of our brain's basic functions.

This research has been published in *Physical Review E*.

Testing the Conjecture That Quantum Processes Create Conscious Experience

Hartmut Neven [1,*], Adam Zalcman [1], Peter Read [2], Kenneth S Kosik [3], Tjitse van der Molen [3], Dirk Bouwmeester [4,5], Eve Bodnia [4], Luca Turin [6], Christof Koch [7]
Editors: Andrei Khrennikov, Rosario Lo Franco
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Abstract

The question of what generates conscious experience has mesmerized thinkers since the dawn of humanity, yet its origins remain a mystery. The topic of consciousness has gained traction in recent years, thanks to the development of large language models that now arguably pass the Turing test, an operational test for intelligence. However, intelligence and consciousness are not related in obvious ways, as anyone who suffers from a bad toothache can attest—pain generates intense feelings and absorbs all our conscious awareness, yet nothing particularly intelligent is going on. In the hard sciences, this topic is frequently met with skepticism because, to date, no protocol to measure the content or intensity of conscious experiences in an observer-independent manner has been agreed upon. Here, we present a novel proposal: *Conscious experience arises whenever a quantum mechanical superposition forms.* Our proposal has several implications: First, it suggests that the structure of the superposition determines the qualia of the experience. Second, quantum entanglement naturally solves the binding problem, ensuring the unity of phenomenal experience. Finally, a moment of agency may coincide with the formation of a superposition state. We outline a research program to experimentally test our conjecture via a sequence of quantum biology experiments. Applying these ideas opens up the possibility of expanding human conscious experience through brain–quantum computer interfaces.
Keywords: physical substrate of consciousness, quantum biology, brain–computer interface, brain organoids, anesthesia, xenon

1. A Conjecture Inspired by Roger Penrose

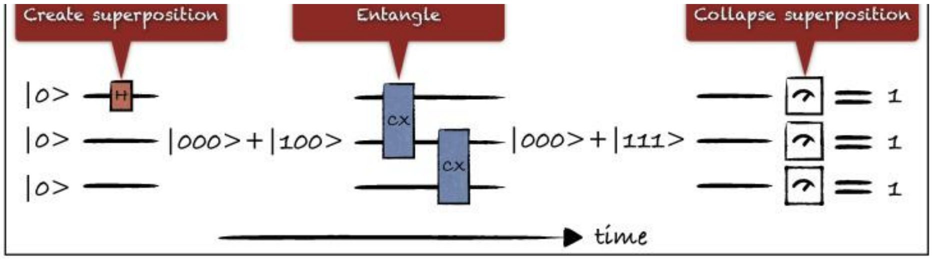
In 1989, in his seminal book “The Emperor’s New Mind”, Roger Penrose made an intriguing proposal [1]. He suggested that quantum processes are essential in forming the physical substrate of consciousness. This idea is attractive because the equations of quantum mechanics tell us that at any moment in time, an object, myself or the world at large, exists in a superposition of many configurations. Yet, in any given moment, we only experience one. To illustrate this, imagine a researcher who steps up to one of the quantum computers in Google’s Quantum AI lab to observe a quantum bit prepared in a superposition of two states $|0\rangle$ and $|1\rangle$. If the researcher sees the qubit in state $|0\rangle$, then the Schrödinger equation, which governs the time evolution of quantum systems, tells us that there is another version of the researcher that sees the qubit in state $|1\rangle$. This feature of quantum physics—that parallel worlds are spawning all the time—has perplexed physicists ever since quantum physics was invented. Hugh Everett, in his

1957 doctoral thesis, was the first to notice that the equations of quantum mechanics, if taken literally, describe a multiverse composed of co-existing parallel worlds [2]. In quantum physics, one refers to the world of our everyday experience as ‘classical’. If we accept a model of reality in which we are living in a multiverse, then an attractive explanation of consciousness becomes available: *Consciousness is how we experience the emergence of one unique classical reality from the many the multiverse is composed of.*

Penrose’s proposal was very definite. He suggested that a conscious moment occurs whenever gravity induces a quantum mechanical superposition to collapse, a process he named ‘objective reduction’. However, here, we argue that his original proposal is in need of refinement.

First, we want to remove the reference to gravity. Whether gravitational influences cause a collapse is testable, but so far, it has not been observed in a lab, and initial experiments looking for such an effect have come up short [3]. We prefer to stay with textbook quantum mechanics, which teaches that an ‘effective collapse’ occurs whenever a quantum system interacts with an external system with a large number of degrees of freedom, as, for instance, happens during a measurement of a quantum system by a macroscopic system, such as an instrument or a person. This interaction causes ‘environment-induced decoherence’, i.e., the quantum system of interest becomes entangled with the degrees of freedom of the external system, which, from the vantage point of the quantum system of interest, looks like an effective collapse of the superposition. This explains why we can predict classical probabilities for measurement outcomes in a specific basis, set by the coupling to the external system (the environment). Quantum superposition for the entire system (the system of interest plus the environment) still persists. The notion of collapse merely indicates that while the system of interest may still exist in a superposition of classical states, the superposition can no longer be observed via interference. In other words, the system of interest evolved from a pure quantum state into a mixture of classical states that coexist without knowing of each other’s existence.

Second, *we propose that a conscious moment occurs whenever a superposition forms, not when it collapses.* This modification is necessary to avoid the possibility of faster-than-light communication that Penrose’s original proposal entails when applied to multiple entangled qubits, as explained below. It also sidesteps the conceptual problem of having to define when exactly a measurement occurs, as all interactions are being treated alike. So our proposal is firmly rooted in Everett’s ‘many worlds’ formulation of quantum mechanics. Figure 1 depicts an example quantum circuit in which gate and measurement operations act on three qubits, each of which is initialized in the $|0\rangle$ state. A superposition is formed in the first qubit, then it spreads across all qubits via entangling operations and finally ‘effectively’ collapses, or, following Penrose, truly collapses by some real physical process, when one of the qubits is measured in the $|0\rangle$, $|1\rangle$ basis.



A generic quantum circuit consisting of gate and measurement operations acting on three qubits. All qubits are initialized in the $|0\rangle$ state. A Hadamard gate creates a superposition on the first qubit. Controlled X gates then entangle the first qubit with both the second and the third qubit, generating the superposition $|000\rangle+|111\rangle$. At the end of the circuit, each qubit is measured, effectively collapsing the superposition into $|111\rangle$. With which operation shall we identify the physical correlate of consciousness? We suggest a conscious moment occurs when a superposition forms.

In Roger Penrose's original proposal, a conscious moment occurs whenever a superposition collapses. However, if, as in this example, the superposition involves more than one qubit, then the question arises as to how the experience is distributed across the qubits when a first qubit is measured. There are two possible answers: (i) Only the qubit that is measured first, and causes the superposition to collapse, has an experience. (ii) All three qubits experience something. Answer (i) runs into difficulties because in a relativistic setting, the order in which the three qubits are measured depends on the reference frame. This leads to the unsatisfying conclusion that whichever qubit has a conscious experience also depends on the reference frame. (One could evade this difficulty by conjecturing that whenever a qubit is measured, a conscious moment arises, regardless of its quantum state. However, since this conjecture holds for classical states without superpositions as well, it amounts to saying that a conscious moment occurs whenever one particle bumps into another.) Answer (ii) is problematic as well because if all three qubits experience a conscious moment, then this could be used to construct a communication channel, for instance, by implementing a Morse code, which would enable the transmission of information faster than the speed of light. Recall that in standard quantum mechanics, it is well established that entanglement cannot be employed to achieve faster-than-light communication. It is the assumption that a collapse leads to a conscious experience across the spatially separated qubits that leads to the violation.

To avoid this violation, we posit that a moment of consciousness arises not when a superposition collapses, but when it forms. The structure of the evolving superposition and the paths the experiencing quantum system follows within it determine the qualities of the conscious experiences, "what it is like to be" that system in that state [4,5]. Our key tenet is that a system only ever experiences classical, *definite* states. These states form a basis of the Hilbert space the quantum system lives in. If a classical state evolves into a quantum superposition through a unitary transformation, as prescribed by the Schrödinger equation, then the experiencing system will evolve along multiple paths simultaneously. Each path, connecting basis states, is known as a 'Feynman path' and results in a distinct sequence of conscious moments. Hence, we posit that a quantum system may be composed of many experiencing minds, albeit often very simple ones [6,7]. As the system evolves from a basis state it just experienced, the population (probability mass), initially concentrated on this start state, will spread to other basis states within a light cone given by the prevailing interactions. The more the population decreases on the start state, the more likely a transition becomes. Eventually, depending on which Feynman path the state is moving along, the system will experience the transition to a different basis state. To illustrate how in our proposal the formation of a superposition creates a moment of consciousness, let us consider several examples (see Table 1).

Table 1.

We assert that at any given moment, a system can only experience definite classical states. Accordingly, when a superposition forms, the system consciously experiences only its constituent basis states. To illustrate this, we enumerate conscious experiences that arise when the classical $|000\rangle$ state undergoes quantum mechanical transitions to other states. Here, the assumption is that the computational basis, consisting of tensor products of $|0\rangle$s and $|1\rangle$s, single qubit states, is the preferred basis.

State Transition	**Associated Experience**
$|000\rangle \to |000\rangle$	No experience
$|000\rangle \to |111\rangle$	No experience
$|000\rangle \to \alpha|100\rangle + \beta|010\rangle + \gamma|001\rangle$	Experiences either 100 or 010 or 001. The modulus square of the probability amplitude determines the probability that the corresponding configuration is experienced.
$|000\rangle \to |0\rangle(\alpha|10\rangle + \beta|01\rangle)$	Experiences either 10 or 01 on the second and third qubit.
$|000\rangle \to (\alpha|0\rangle + \beta|1\rangle)(\gamma|10\rangle + \delta|01\rangle)$	Two separate, non-integrated experiences. The first is either 0 or 1 and the second is 10 or 01.
$|000\rangle \to (\alpha|0\rangle + \beta|1\rangle)(\gamma|0\rangle + \delta|1\rangle)(\epsilon|0\rangle + \zeta|1\rangle)$	Three separate, non-integrated experiences. Each consists of experiencing either 0 or 1.

Since quantum superposition is a basis dependent notion, we need to address the question of how a preferred basis is selected. Here, we can follow proposals made by David Deutsch or by Wojciech Zurek, who suggested that the interaction between subsystems selects a preferred basis, referred to alternatively as the 'interpretation basis' by Deutsch [8] or the 'pointer state basis' by Zurek [9]. See also Wallace for a monograph on this topic [10]. It may also be possible to apply a principle from Integrated Information Theory and choose the basis that maximizes the integrated information the system experiences [11,12,13].

In our proposal, entanglement solves the binding problem, that is, the unity of a phenomenal experience [14,15], in a natural manner and without any additional assumptions. The number of degrees of freedom involved in the entanglement bound the amount and content of consciousness [16]. To quantify the content of an experience in a principled manner, the Φ-measures proposed by a quantum mechanical instantiation of integrated information theory seem advantageous, such as Zanardi et al. in 2018 [11,12] or Albantakis et al. in 2023 [13]. The experimental tests described in the next section are capable of probing the various hypotheses inspired by Penrose's ideas, including his original one.

2. A Sequence of Quantum Biology Experiments

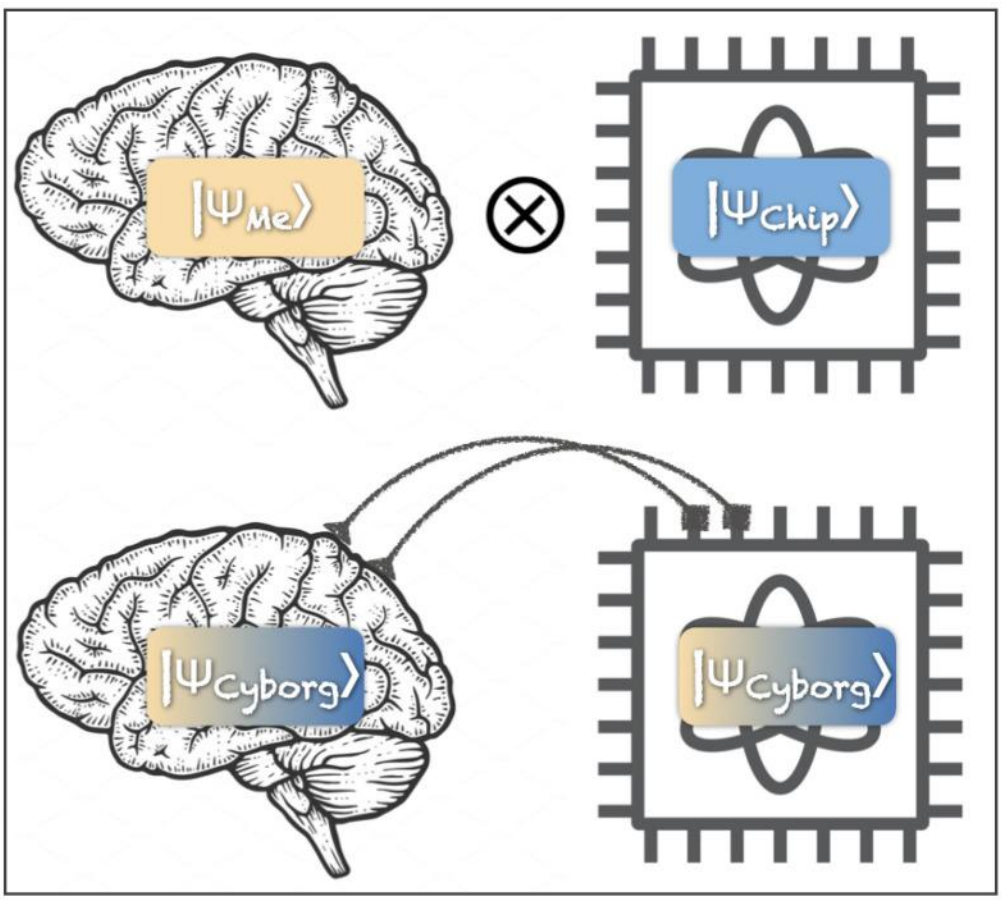
A key challenge when attempting to construct a scientific theory of consciousness is that conscious experience is not a traditional experimental observable with an associated objective, that is, subject-independent measurement protocol. Indeed, as famously argued by Descartes, my experience is the only thing I can be absolutely certain of [17]. Whether anything else is conscious, such as you, has to be inferred as the most likely explanation of all available information. It follows that I cannot conclusively demonstrate that anyone except myself is conscious. That is, epistemological solipsism, the position that I can only be certain of my own consciousness, is logically consistent [18]. Still, inferring consciousness in others is common and implicit—as in asking people what they see or how they feel. In neurologically impaired patients, such as in those with disorders of consciousness, speaking is replaced by command following (e.g., move your eyes). Without such communication, detecting consciousness becomes challenging [19].

To measure the position or velocity of an object like an airplane, any engineer knows what to do. But when tasked with answering to what degree the autopilot of the airplane, a large language model, such as Google's Gemini, or a brain organoid, is conscious, we do not agree on how to go about measuring this. Without either a well-accepted general theory of consciousness or an experimental test, any such claims remain vacuous. As some of us have argued in a recent article [20], consciousness does become an observable in the limit case that the observing system and the observed systems are exact copies of one another. But to the degree the system we are observing is dissimilar to ourselves, this protocol breaks down, hence the unresolved debate to what degree another person, a fish, a tree, a rock or a computer executing an LLM may be conscious. Here, we describe another approach that allows us to provide experimental evidence that a theory of consciousness is accurate. It relies on expanding one's own consciousness; hence, we will refer to this method as the *expansion protocol*. It sidesteps the challenge that has plagued consciousness research. In particular, it would allow us to test whether the creation of a superposition generates a conscious experience.

2.1. Expanding the Mind Using Quantum Processors

In an experimentum crucis, one would establish a physical link between a human brain and a quantum computer that would enable coherent interactions and mediate entanglement. If our conjecture is accurate, this should enable richer conscious experiences of the combined system, requiring more descriptive bits than the experiences the human reports without the link. Moreover, such a setup may enable dialing in specific qualia of an experience, as explained in the next paragraph. Figure 2 depicts coupling a system in a quantum mechanical superposition state residing in a subject's brain $|\psi_{Me}\rangle$ with a set of qubits in superposition inside a quantum computer $|\psi_{Chip}\rangle$. Before the systems are coupled, their respective states exist in separate state spaces, known as Hilbert spaces, of dimension *N* and *M*, respectively. After they are made to interact, the wave function describing the combined system $|\psi_{Cyborg}\rangle$ resides in an $N\times M$-dimensional Hilbert space. We conjecture that a superposition forming in this higher dimensional state space would be experienced by the subject as a richer experience as compared to a superposition state forming in the lower *N*-dimensional Hilbert space describing the isolated brain of the subject. A tantalizing conjecture is that this sort of expanded consciousness occurs during psychedelic, mystical, near-death and other types of extraordinary experiences [21] not by coupling to an external system, but by increasing the number of entangled qubits participating in superspositions forming in the brain.

Figure 2.



Conceptual depiction of a coherent coupling between a human brain and a quantum processor. If our conjecture is accurate, then we should be able to generate richer experiences by creating the superposition $|\psi_{Cyborg}\rangle$, which describes the combined system and which lives in a larger state space (Hilbert space) as compared to $|\psi_{Me}\rangle$ and $|\psi_{Chip}\rangle$, which describes the separate systems.

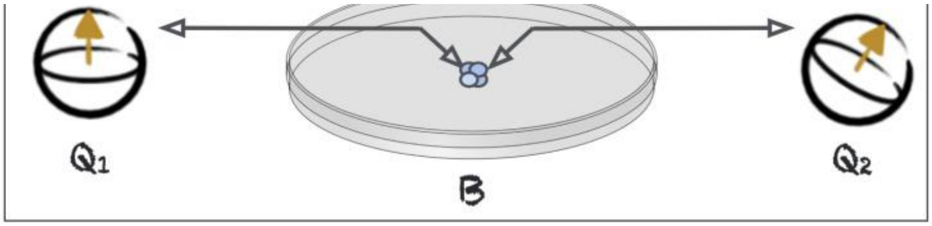
Likewise, if we were to stay with Roger Penrose's original proposal, it stands to reason that the collapse of a quantum mechanical superposition into a classical state requiring more bits to describe creates a richer experience than one collapsing into a classical state characterized by fewer bits.

While such experiments are possible in principle, they are technologically very challenging and may require invasive technologies. Today's technologies to establish brain– computer interfaces are not designed to support a coherent coupling (one that allows the spreading of entanglement) between structures in a brain and a quantum computer. Any such link would have to occur without perturbing the human brain sitting inside its protective skull and membranes.

But future quantum sensing technologies, such as nitrogen vacancy probes combined with optogenetic methods, may eventually allow for such protocols. A myriad of details would need to be engineered, i.e., which cell structures in which nerve cells in which parts of the brain are most suitable, and to which degrees of freedom in nervous tissue should one couple, and how. In short, we need to state what constitutes the neurobiological qubits. While various proposals have been made, such as nuclear spins (Fisher [22]), collective modes in microtubules (Penrose and Hameroff [23]) or aromatic rings (Hameroff [24]), we refrain from committing at this point and prefer to approach answering this question experimentally.

First, we suggest conducting a preparatory experiment. It consists of mediating entanglement between two room temperature qubits via a biological substrate. It is based on a theoretically well-founded approach to elucidate quantum mechanical properties of unknown systems. It considers three systems, two of which are well characterized and can be thought of as qubits or ensembles of qubits, referred to as $Q1$ and $Q2$. A system of interest, in our case a biological substrate B, is introduced. We then couple $Q1$ coherently to B, and likewise, $Q2$ is coherently coupled to B, taking care not to establish a direct link between $Q1$ and $Q2$. If we then find that it is possible to mediate entanglement between $Q1$ and $Q2$ via the system B, then we can conclude that B requires a quantum mechanical description [25,26]. This paradigm is rather flexible, as different coupling schemes and different substrates B can be investigated. For instance, B could be a microtubule, a receptor protein such as rhodopsin, a single nerve cell or even a brain organoid. This protocol is illustrated in Figure 3.

Figure 3.



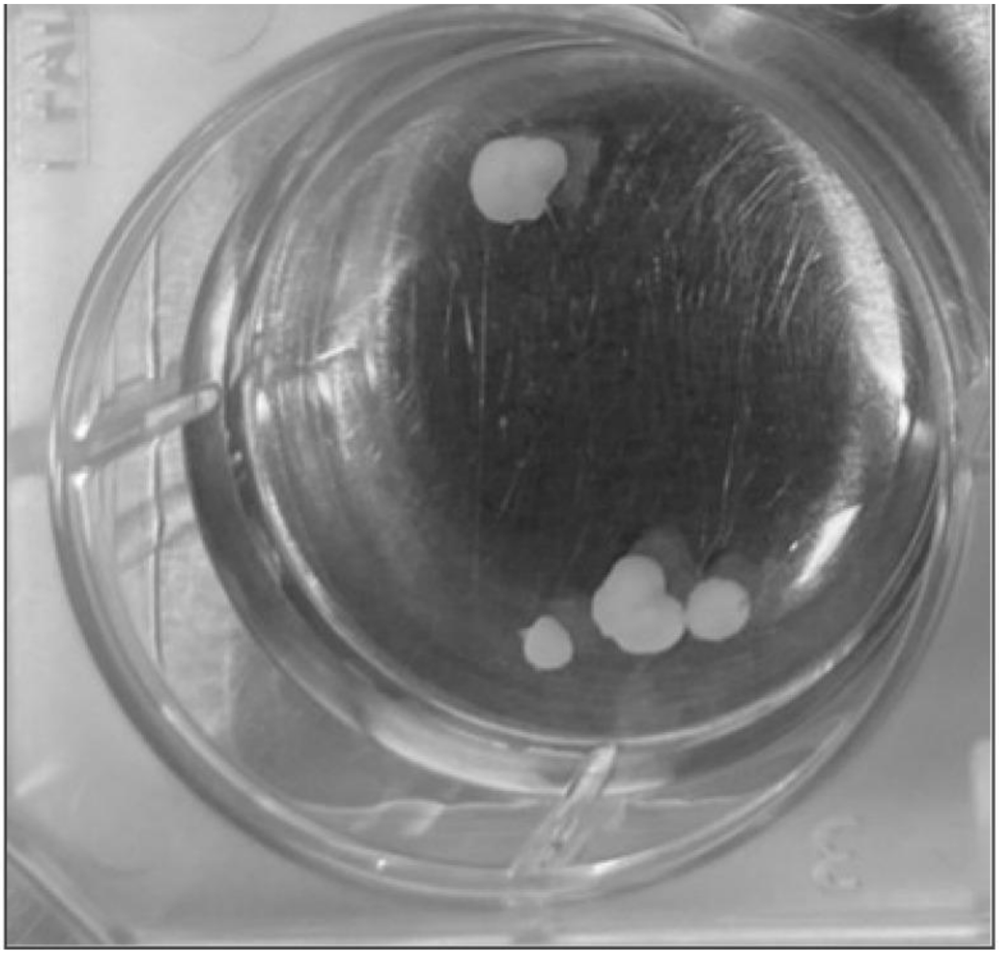
Two qubits, $Q1$ and $Q2$, linked coherently (as indicated by the horizontal arrows) via a biological substrate B. This setup allows us to learn whether B can act as a quantum channel and mediate entanglement between $Q1$ and $Q2$.

2.2. Turning the Mind off Using Isotopes of Xenon

In order to decide which biological structures are the most promising candidates to select as system B and how to implement the coherent coupling, we want to start with an even simpler experiment. In fact, this experiment, to some extent, has already been performed. In 2018, Li and co-workers exposed four groups of mice to four different isotopes of xenon that differ in the number of neutrons in their nucleus [27]. Xenon is an inert noble gas with anesthetic properties [28]. Indeed, xenon (with an atomic number of 54), has many properties that make it, in some sense, an ideal inhalation agent—it is odorless, nontoxic, nonexplosive, environmentally friendly and, due to its chemical stability, does not transform in the body [28]. Intriguingly, the work of Li et al. on the anesthetic effects of xenon isotopes shows that the potency of the two isotopes with half-integer nuclear spin (129Xe and 131Xe, spin of 1/2 and 3/2, respectively) is about 30% less than the potency of the two isotopes with zero nuclear spin (132Xe and 134Xe). This difference, if confirmed, cannot be explained by differences in the outer electron shells (there are none) and is unlikely to be caused by differences in atomic mass (<1% difference between 131Xe and 132Xe). If true, the results suggest that some of the effects of xenon on consciousness may be mediated by nuclear spins, quantum systems amenable to superposition. It is suggestive that the half-integer spin isotopes were the ones with reduced anesthetic potency. The non-zero spin may act as a qubit contributing to the formation of larger superpositions, which, according to our conjecture, would be correlated with a richer conscious experience counteracting the anesthetic effect.

Li et al. studied the ED50 of loss of the righting reflex of 80 mice treated with the different xenon isotopes (20 mice per isotope), which provides little information on the mode of action of xenon. Given that two out of three experiments in the biomedical sciences are not reproducible [29], it is important to replicate important experiments, in particular if they challenge widely held assumptions. Thus, we plan to repeat this experiment, but this time, we want to ‘anesthetize’ brain organoids, focusing on achieving results with high statistical confidence. Brain organoids, carefully instrumented to allow for high bandwidth measurements via high density electric or optical arrays, like those in the Kosik and Bouwmeester lab at UC Santa Barbara, have emerged as a potent platform to investigate living nervous tissue that share characteristics with human brain tissue (see Figure 4) [30].

Figure 4.



Cerebral organoids derived from human-induced pluripotent stem cells can model human brain development in anatomical organization, cellular composition and physiological signaling. Brain organoids, here about 2–3 mm in diameter, containing about 100,000 neurons, exhibit structured, non-random and fast electrical activity (including action potentials). As such, the organoid electrical activity represents a generic human brain. Photo courtesy of Kenneth Kosik.

As a complementary study to establish the veracity of behaviorally relevant xenon isotope effects, we also plan to administer the xenon isotopes to an invertebrate, the fruit fly, Drosophila Melanogaster, with about 100,000 neurons. Xenon does not fully anesthetize fruit flies at ambient pressure. We plan to measure the pressure at which its isotopes cause immobility. This will allow us to complement the organoid study with behavioral data with good statistics, as we can apply the anesthetic gasses to a sufficiently large number of flies to obtain statistically highly reliable results. The experiment can be conducted within an electronic spin spectrometer, and spin resonance will be employed to monitor spin signals. This part of the study will be conducted in the lab of Luca Turin at the University of Buckingham [31].

If we can replicate the findings by Li et al. in these two, quite different, model nervous systems, we are in a position to discover the underlying cellular processes. The electromagnetic field emanating from a nuclear spin is rather weak compared to the electromagnetic field generated by an electron. In brain tissue, there are plenty of overlapping electromagnetic fields generated by moving charges, electron, nuclear or orbital spins, or by external sources, such as the earth magnetic field or cell phone towers. We already have an indication from the Meyer–Overton law that anesthetics act in lipid, hydrophobic pockets [32]. (The Meyer–Overton rule states that the potency of an anesthetic can be predicted by its solubility in olive oil [33].) So a rather specific cellular environment is required for the weak isotopic spin effects to manifest. For instance, it has been proposed that this involves a radical pair mechanism, a quantum biological effect that is suspected to underlie bird magnetoreception [34] or lithium's effects on hyperactivity [35,36,37]. In conclusion, the necessary level of specificity may provide a clue as to which process relevant to sustaining the physical correlate of consciousness is interrupted during anesthesia, and in turn, this may suggest how to couple a qubit to implement the expansion protocol.

3. Dialing in Qualia with a Brain-Quantum Computer Interface

Our conjecture, if correct, suggests a novel approach to understand the relationship between states of matter and experience. If we would be successful in implementing the expansion protocol, we could more precisely investigate these correlations. Imagine asking a user with a brain linked to a quantum processor about their feelings and subsequently measuring the qubits' states. Then, one would look for correlations between the valence of the reported emotions and the bit string measured. This could reveal the qualia associated with different states of matter. Consequently, we may gain the ability to tailor experiences with unprecedented detail and precision.

Before achieving brain–quantum computer coupling, let us consider a simpler question: can volunteers given sub-anesthetic doses distinguish different xenon isotopes, say, by their differential psychedelic properties? While the answer remains unknown [38], there is evidence of isotope effects influencing human sensing and cognition. For instance, humans can differentiate the smell of odorants with hydrogen atoms replaced by deuterium [39], and they can taste heavy water, with hydrogen atoms replaced by deuterium, as sweeter than regular water [40]. Lithium 6 and lithium 7 exhibit different effects on mood [41]. Phosphorous nuclear spins have been proposed by Matthew Fisher as one of the most viable candidates for qubits in the brain that may confer quantum algorithmic advantages [22,42]. However, in none of these proposals have differential mass effects been ruled out. One reason xenon is attractive is that it is heavier than the isotopes used in the experiments cited, making it less likely that mass effects can account for the observed differences among isotopes. These observations suggest the potential significance of spin-dependent mechanisms in biology, opening up a new field we may call *biological spintronics*. In the coming years, we expect advancements in attaching spin markers to specific molecules within cellular tissues, granting us unprecedented control over biological processes at the molecular level in real-time [43].

In summary, we are proposing a fundamental research program to uncover whether quantum effects are underlying the physical substrate of consciousness. Central to this endeavor is the establishment of coherent coupling between quantum degrees of freedom in brain tissue and a quantum processor. Utilizing modern quantum biological methods, we aim to achieve this coupling in a non-invasive manner (i.e., without surgical intervention). If this program were to be successful, then it would allow for building technical aides that could expand human conscious experience in space, time and complexity (see Figure 5).

Figure 5.

Coherently linking a brain to an external quantum processor, ideally by employing non-invasive techniques, would allow for building technical aides that could expand human conscious experience in space, time and complexity. Rendering by DALL·E 2.

4. Formation of Quantum Superposition May Facilitate Agency

The formation of a superposition state may not only create a conscious experience, but may go hand-in-hand with a moment of agency. Maybe an organism can exercise some degree of choice in the libertarian sense over which classical configuration it is going to experience next. Whether Nature takes advantage of this possibility, we cannot yet say. What we can say for certain is that an external observer, in general, will not be able to predict the behavior of a living organism, not even probabilistically. If the number of quantum bits describing the evolution of a quantum system approaches about 100 (which is less than needed to accurately describe the electronic structure of a protein or the chromodynamics inside a proton), then, in general, it will be the case that the observer cannot even give probabilities anymore with which certain outcomes will occur. This is because computing the probabilities of the 2100 outcomes exceeds the capabilities of any computing machine that can be constructed [20]. This situation is referred to as *Knightian uncertainty* [44].

But why should we suspect that behind this veil of unpredictability moments of agency are hiding? Our argument rests on the following observation: *behaviors conducive to our well being, i.e., conducive to maintaining homeostasis, tend to be correlated with feelings of pleasure, while actions that threaten homeostasis feel unpleasant*. We call this the ‘homeostatic correlation’. If humans were adequately described as deterministic automata, then this homeostatic correlation is difficult to explain. If behaviors were predetermined, then evolution would not select for the homeostatic correlation, as it would not matter how an organism feels since its behaviors are determined anyway. Giving the automaton access to a source of randomness to select behaviors does not change the fundamental argument since, in this case, it does not matter either how the organism feels. It is instructive to consider two behaviors, both essential to the survival of a species, having sex and giving birth. The former is typically associated with pleasure, the latter with pain. Why is this so? We would argue that the former involves choice while the latter does not, at least during prehistoric times, when most of human evolution took place. So it seems to us that Nature uses feelings as a lure or a deterrent, but this only works if an organism can act to attain pleasant and avoid unpleasant states. A possible way to explain the correlation between pleasant sensations and behaviors conducive to an organism’s well-being is to postulate the existence of agency [12,45]. If an organism possesses the agency to freely choose a state, then presumably, it would choose emotionally rewarding over unrewarding ones. Evidence for this could be found by using the expansion protocol. We could measure $|\psi_{Cyborg}\rangle$ and ask the user about the valence of their emotions. If we observe a higher occurrence of pleasant than unpleasant states, this may indicate that the user has the agency to influence the outcome. Quantum operations, such as creating or collapsing superposition states, may give a system (experiencing a single classical reality at a given time) the freedom to exert agency and to express a preference. In this view, selecting a single classical configuration from the multitudes contained in a superposition implements conscious experience (of that classical configuration) and gives the system agency to select it.

In conclusion, we argue that the operations available to a quantum processor may be necessary to implement sentience and agency. Vice versa, today's AI systems running on semiconducting electronics are confined by the laws of classical information theory. Their computations can be abstracted by the operations of a probabilistic Turing machine. If the above arguments are correct, it follows that these operations are insufficient to implement consciousness and agency. Stated more pointedly, *Turing machines have become intelligent but may never become conscious*. For the latter, a quantum Turing machine is required.

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Quantum and Electromagnetic Fields in Our Universe and Brain: A New Perspective to Comprehend Brain Function

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Abstract

The concept of wholeness or oneness refers to not only humans, but also all of creation. Similarly, consciousness may not wholly exist inside the human brain. One consciousness could permeate the whole universe as limitless energy; thus, human consciousness can be regarded as limited or partial in character. According to the limited consciousness concept, humans perceive projected waves or wave-vortices as a waveless item. Therefore, human limited consciousness collapses the wave function or energy of particles; accordingly, we are only able to perceive them as particles. With this "limited concept", the wave-vortex or wave movement comes into review, which also seems to have a limited concept, i.e., the limited projected wave concept. Notably, this wave-vortex seems to embrace photonic light, as well as electricity and anything in between them, which gives a sense of dimension to our brain. These elements of limited projected wave-vortex and limitless energy (consciousness) may coexist inside our brain as electric (directional pilot wave) and quantum (diffused oneness of waves) brainwaves, respectively, with both of them giving rise to one brain field. Abnormality in either the electrical or the quantum field or their fusion may lead to abnormal brain function.

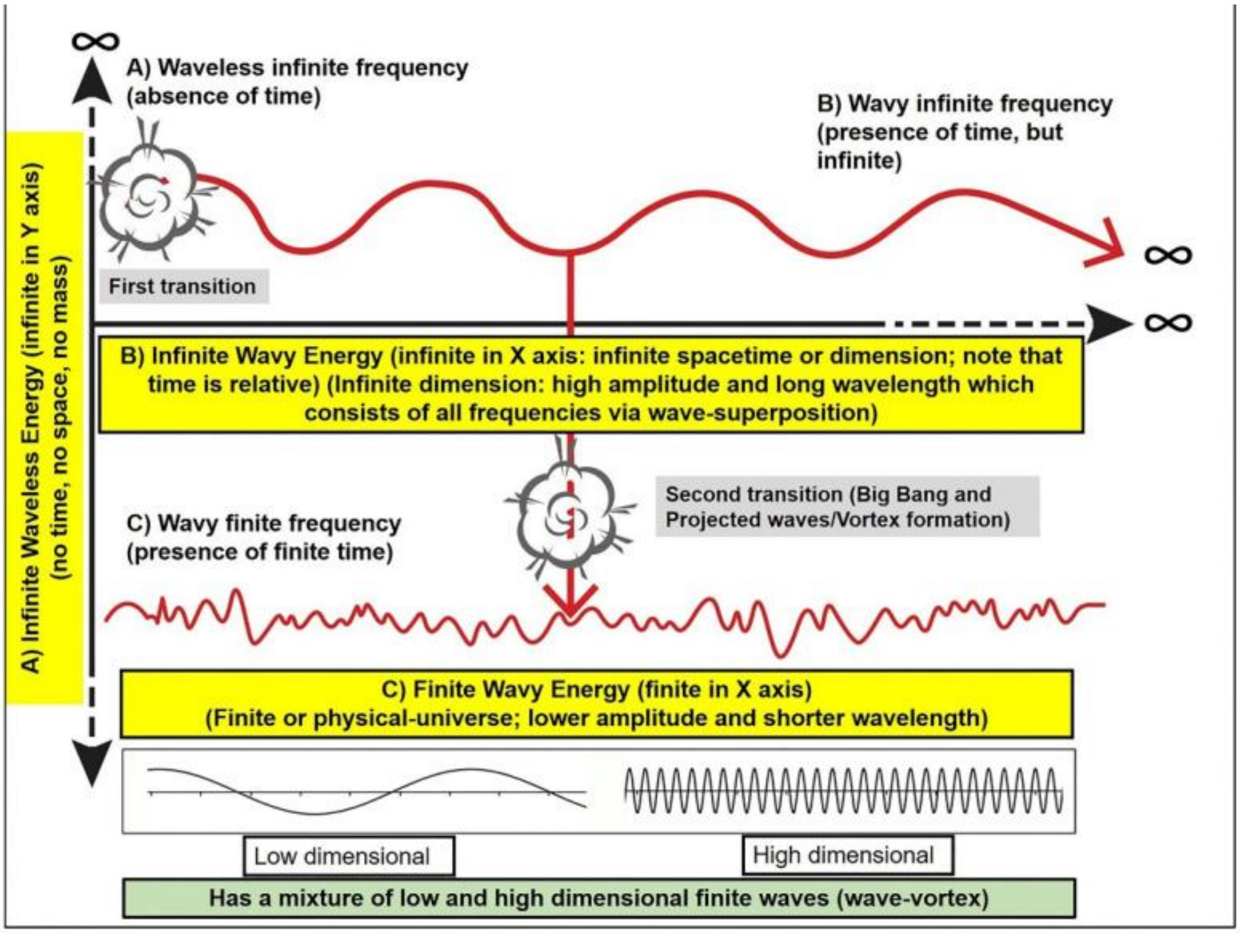
Keywords: brainwaves, electromagnetic field, quantum field, consciousness, quantum mechanics, Bohmian mechanics

1. Introduction

Our universe and brain obviously require energy. Energy is described in many ways and comprises chemical, metabolic, radiation, and many other types. In physics, energy has been noted as having one peculiar feature—ups and downs. This wavy form of energy is thought of as covering our entire universe, including our body and brain. This idea came about after realizing that an atom or light can exist in two forms, both as a particle and as a wave [1,2,3,4,5,6]. This is known as the duality of an atom or light. Therefore, we can also view all things in our universe as waves. In such a way, our brain can be viewed at the deepest level as either an ensemble of particles or a wavy brain. Hence, a picture of the wavy brain should at least have two components of waves: electromagnetic brainwaves and waves arising from all particles (the anatomical chemical component or mass itself is an energy). Many think that these whole waves are not only restricted to the brain, but that they easily diffuse out and form an interconnected wave network with our universe. This notion is accepted by some neuroscientists and physicists, which is associated with consciousness [7,8,9] or string theory [10,11].

In 2019, the present corresponding author published a manuscript that described waveless energy [12]. Waveless energy is regarded as infinite energy or infinite light. The reason for it being waveless is because of its dissociation from time and space (dimension) (thus having infinite frequency); therefore, it was thought of as something that has existed since before the formation of our universe or singularity (commonly known as the Big Bang). Here, in this manuscript, the authors expand this idea by introducing another infinite energy, which is wavy in nature and related to infinite time and space (infinite wavy energy). This hypothetical energy can be viewed as lying in between infinite waveless energy and finite wavy energy. In other words, the newly introduced infinite wavy energy of the cosmos in this manuscript is in fact equivalent to the cosmos quantum field (QF), which is well established in string theory. The authors use both terms in order to make the readers better understand the concept of oneness or one consciousness (related to QF) and interception of energy (projected waves). Figure 1 illustrates these points and the transitions that might occur among infinite waveless, infinite wavy, and finite wavy energy.

Figure 1.



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The two transitional points of the universe. The first transition is at the point between waveless (**A**) and wavy infinite energy (**B**). The second transition (the singularity or origin of our universe) is at the point between wavy infinite energy (**B**) and wavy finite energy (**C**), which has a mixture of various wave patterns—low, high, and intermediate dimensional waves. Thus, infinite energy, infinite light, or infinite frequency (the highest light and all light) may have already existed before the singularity, and the origin of lower light could have been from higher light.

According to the aforementioned concept of these three energies (infinite waveless, infinite wavy, and finite wavy energy), the authors discuss and explain (a) the possible relationship that might exist between waveless and wavy energy in our universe and brain, and (b) the projected wave concept (vortex), which could explain (1) the duality of an atom, (2) our borderless universe, (3) the absence of wave interference in our three-dimensional (3D) physical universe, (4) the infinite shape (geometric pattern that is technically repeatable or limitless) of materials in our brain and nature, and (5) the existence of two energy fields (electromagnetic and quantum fields) inside our universe, as well as inside our brain, which could explain the pathogenesis of neurological (particularly psychiatric) disorders. Through this perspective, the authors hope that future directions in research will focus on quantum field and quantum energy detectors for the brain, which may further enhance our understanding of brain function, thereby facilitating the cure of more diseases.

2. Infinite and Finite Field Energy

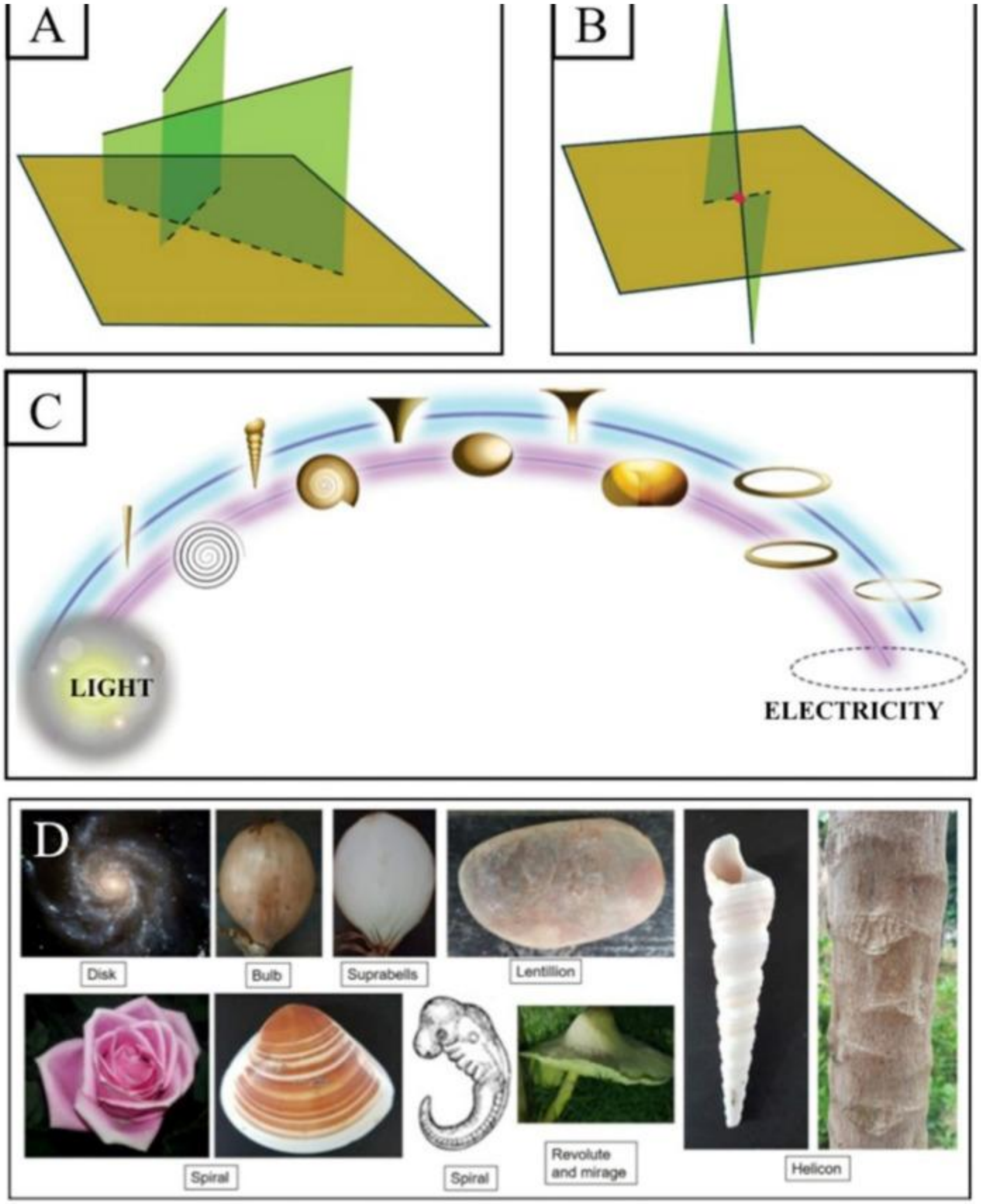
Energy conservation is a principle in physics. There is no loss of energy; it is only converted to different forms. From the time of singularity, the total energy has been maintained but in different forms. Previously, we explained the possible existence of infinite light, frequency, or energy prior to the Big Bang [12]. This light is infinite because it is not related to time or space, and it is waveless. Thus, this sort of energy is considered waveless energy, which is difficult or impossible to detect simply because it is waveless. On the contrary, our newly introduced infinite wavy energy (or the cosmos quantum field as stated in string theory) is detectable and can be studied. To understand the cosmos QF or infinite wavy energy, one must consider the view of an atom from the perspective of quantum physics. According to quantum theory, an atom can exist in duality, i.e., either in particle or in wave form. Therefore, one may also perceive all things as waves or as energy. Then, the important question related to this perception is the following: "Where did this wavy energy originate from?" Since our initial statement maintains that energy preservation is always valid, then a hypothesis could be that this finite wavy energy originated from infinite wavy or infinite waveless energy; hence, both (infinite wavy and infinite waveless energy) are indeed infinite in their features.

Figure 1 also depicts the conservation of energy concept, whereby the *Y*-axis describing infinite waveless energy (with the absence of spacetime: "zero" spacetime) gives rise to another source of infinite energy, i.e., the *X*-axis describing infinite wavy energy with the presence of "infinite" spacetime or infinite dimension. Therefore, these two infinite energies are inter-related, and the total energy is always preserved: one in the vertical or *Y*-direction (in fact, in any direction) with waveless, timeless, spaceless, and limitless energy, and the other in the horizontal or *X*-axis infinite direction with the presence of spacetime or dimension. In addition, one may notice at least two possible transitional points in Figure 1: (a) between infinite waveless energy and infinite wavy energy, and (b) between infinite wavy energy and finite wavy energy. In short, one may view such a connection as infinite waveless–infinite wavy–finite wavy energy or, from an analogous perspective, as infinite light–infinite waves–finite particles/waves (duality).

Then, another important question to answer is the following: "How was our physical universe formed?" To answer this, one should consider the second transitional point as illustrated in Figure 1 and return to the singularity. After the singularity, time (a new time period) began to exist (remember that time is only relative) and light was formed, followed by waves, particles, molecules, matter, and objects. The energy that was formed must again be wavy energy but finite along the *X*-axis (finite time and space). This wavy and finite energy formed our current 3D universe (finite dimensional universe). Thus, one may say that the wavy infinite energy which was initially derived from waveless infinite energy was the building stone for our physical or 3D universe.

From a broader perspective, electromagnetic photonic light (photonic light vortex/light immediately after the singularity) was initially thought of as arising from an implosion and explosion (the origin of our universe from a singularity can also mean a transition without an actual loud bang) of this infinite wavy energy (which could also be a kind of light); subsequently, our 3D universe came into complete existence via projected waves of infinite wavy energy that 'intersected' the initially formed electromagnetic photonic light to form electricity and matter (Figure 1, Figure 2 and Figure 3). The word "vortex" used in this manuscript refers to "projected wave movement" (normally, it is referred to as rotational fluid or air movement). Further details are provided in Section 4.

Figure 2.



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Limited projected waves and infinite shapes in the brain and nature. (**A**) Waves (green) in different dimensions. (**B**) Waves that really intersect our universe (a brown square) at the red point. (**C**) The intersected waves form wave-vortices that range from low- to high-dimensional waves (light to electricity vortices); matter and other vortices lie between these two vortices. (**D**) Limited projected waves give a sense of reality (which, in fact, describe the illusion of matter, collapsing its original wave or energy function), and their shapes (nature) are infinite shapes, denoting their infinite-wave origin. Interestingly, the brain also forms part of the projected waves and is indeed infinite in its shape; examples are the hippocampus as a logarithmic spiral, the caudate nucleus as a Dürer spiral, and the thalamus as a lemniscate.

Figure 3.

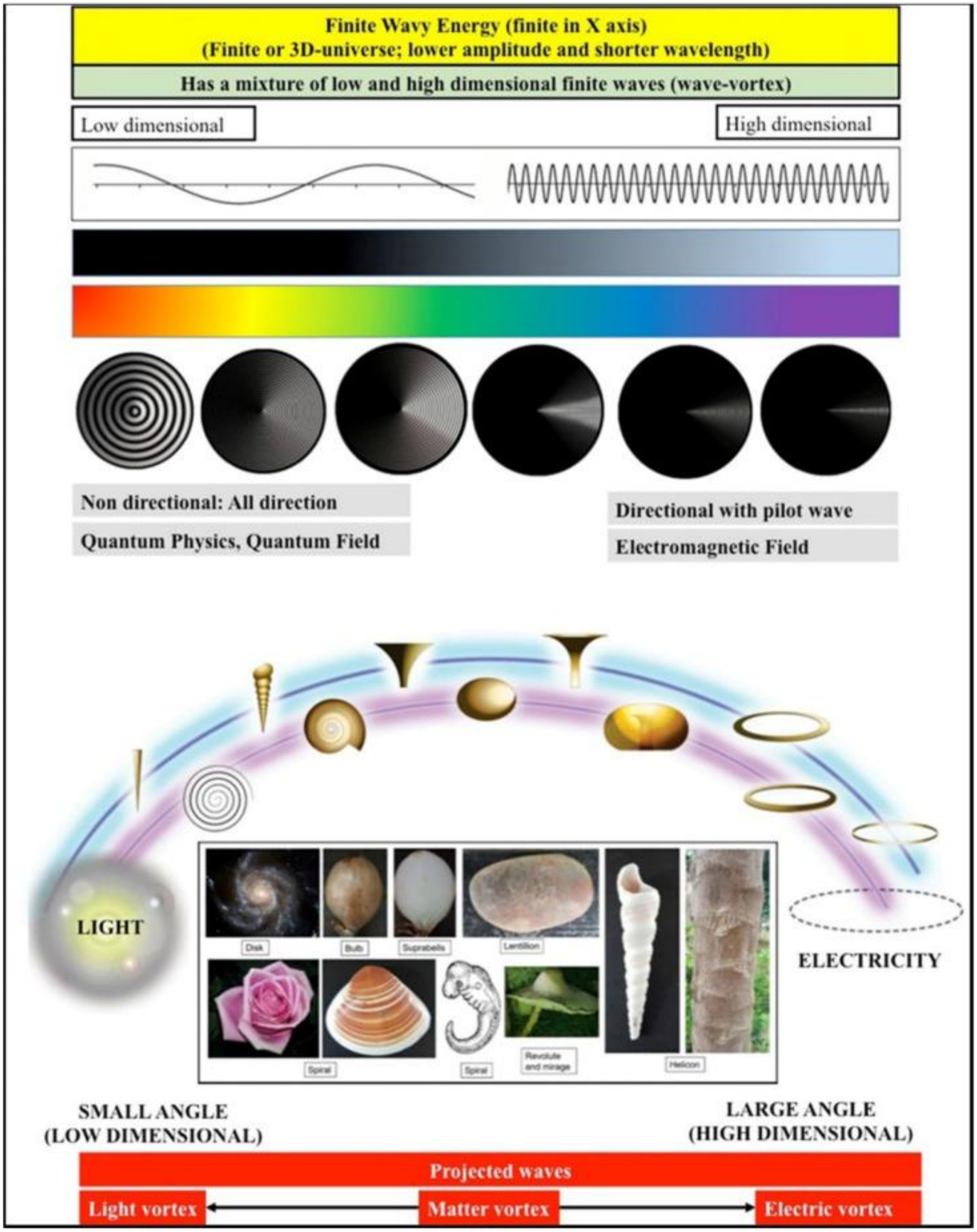

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Illustration of further details on the low- and high-dimensional fields of our finite universe. The intersection of higher and lower light creates light, electricity, and matter vortices. The light vortex is created by a small angle of interception, whereas electricity is created by a large angle of interception. Matter vortices are formed by the angles in between. Any light is regarded as low-dimensional and nondirectional, diffused, changing, or delocalized, whereas electricity is considered high-dimensional and directional with features of pilot waves, i.e., it is a locatable, deterministic, specific network that may follow Bohmian mechanics.

3. Physical Universe and Mind (Observer)

Before proceeding to a vortex or projected wave, perhaps it is better to briefly examine the mind (observer). One important question related to the mind is the following: "Does our physical universe really exist?" Because of the peculiar features of our brain, this sort of question is commonly asked by many scientists [13,14]. We acknowledge that all the individual features of the world are experienced through our body sense organs. The information that reaches us through these organs is converted into electrical signals in the brain. In summary, our brains constitute only electrical signals. This causes many to question the nature of the perceiver. The perceiver is thought of by some as the mind [15,16]. Despite the absence of an electrical converter inside the brain, the mind can interpret and make these electrical signals meaningful. Some authors regard the mind as a spirit or soul (infinite item, timeless, spaceless) [12,16]. It is worthy to note that, despite the absence of external stimuli, such as when a person is dreaming, undergoing hypnosis, or experiencing virtual reality, the brain's electrical signals (waves) are also activated. This is due to persistent biochemical activities, not only inside our brain but also inside the nerves around our body [17,18]. These represent possible proof that the brain does not necessarily require the material world to function. According to quantum theory and string theory, our physical world basically consists only of waves and vibrations. This is indeed in agreement with the quantum perspective of our brain, whereby only waves are present inside our brain and the acts of seeing, hearing, planning, etc., possibly happen via either entanglement or interconnected flow of wavy energy. This gives rise to yet another important question: "If so, why can the mind see matter, light, objects, etc., but not waves?" Indeed, waves and energy are subtle or abstract to the brain in that they cannot be seen by the normal brain. The reason for this might be related to the wave-vortex, the limited frequency for seeing, hearing, touching, etc., or the limitation of our human consciousness (i.e., having limited consciousness).

4. Wave and Consciousness as a Limitless (Infinite) and Limited (Finite) Entity

The aforementioned discussion stated that all things can apparently be described as waves (wavy energy), which originate from infinite wavy energy or, on a deeper level, from infinite waveless energy or an infinite light. This infinite wavy energy is limitless on a single *X*-axis (limitless or infinite in spacetime or dimension), whilst infinite waveless energy has infinite energy in any (infinite) direction. It is represented here as the *Y*-axis in Figure 1 due to the two-dimensional (2D) representation; thus, it has no time or space, but has infinite energy. Therefore, it appears that all things discussed here can be thought of as an infinite entity. This wholeness of waves, i.e., infinite waveless energy (infinite light) and infinite wavy energy (infinite waves, infinite dimension, energy, or all light), can be regarded as one consciousness, simply because they are interrelated and they give energy (life, existence, form) to all [14,19,20,21].

On the basis of the above argument, is it possible then that our 3D physical universe is not limitless, but instead a 'limited or finite physical universe'? The reason for saying this is because of the limited wave-projection concept (i.e., finite waves are formed from a portion of projected infinite waves, referred to as vortices in this manuscript). Since all things can be regarded as waves, then perhaps one should also wonder why all these wave signals do not bump into each other. The reason that these waves do not collide is that they only appear to us to across the same region of space or the same dimension (three dimensions for the physical universe), whereas, in reality, this is not the case. The medium in which these waves exist might consist of more than three dimensions (thought of as infinite dimension or spacetime, i.e., infinite or limitless wavy energy). However, humans have evolved to live with organs of vision that allow us to only view things in three dimensions. The next question then becomes the following: "How can a medium with more than three dimensions exist, while the universe that we observe through our eyes is only made up of three dimensions?" This is because what we observe as humans, using the sense organ that we know as our eye, is not a complete, correct representation of the environment. What we observe is a projected reality, projected energy, or 'limited part' of reality (waves/energy/dimension).

The limited projection of reality (energy) is due to the limited number of waves projected onto our physical universe [22]. Because of limited projection, these waves may appear as intersected (Figure 2A), whereas, in reality, they are not and instead lie in an extra dimension (limitless or infinite wavy energy that has infinite dimension or limitless spacetime). Its interesting element is one that really intersects our physical universe, which was initially formed by a sort of early light vortex (Figure 2B). In relation to this, the waves that intersect our finite early light vortices (or the lowest light) may appear as physical, material, or electrical vortices (a physical universe that follows the laws of physics) (Figure 2C). Therefore, the formed wave-vortices should cover the electromagnetic spectrum or the lowest light (low-dimensional, diffused, and faster vortex), electricity (high-dimensional, directional, and slower vortex), and anything in between with infinite shapes such as material vortices (vortex of matter), which are commonly observed in nature (Figure 2D). Figure 3 summarizes the wavy finite universe, which has a combination of low-dimensional (light) and high-dimensional (electromagnetic/electric/magnetic) wave fields (see later, where it is proposed that the brain might also have both fields or both low and high entropy).

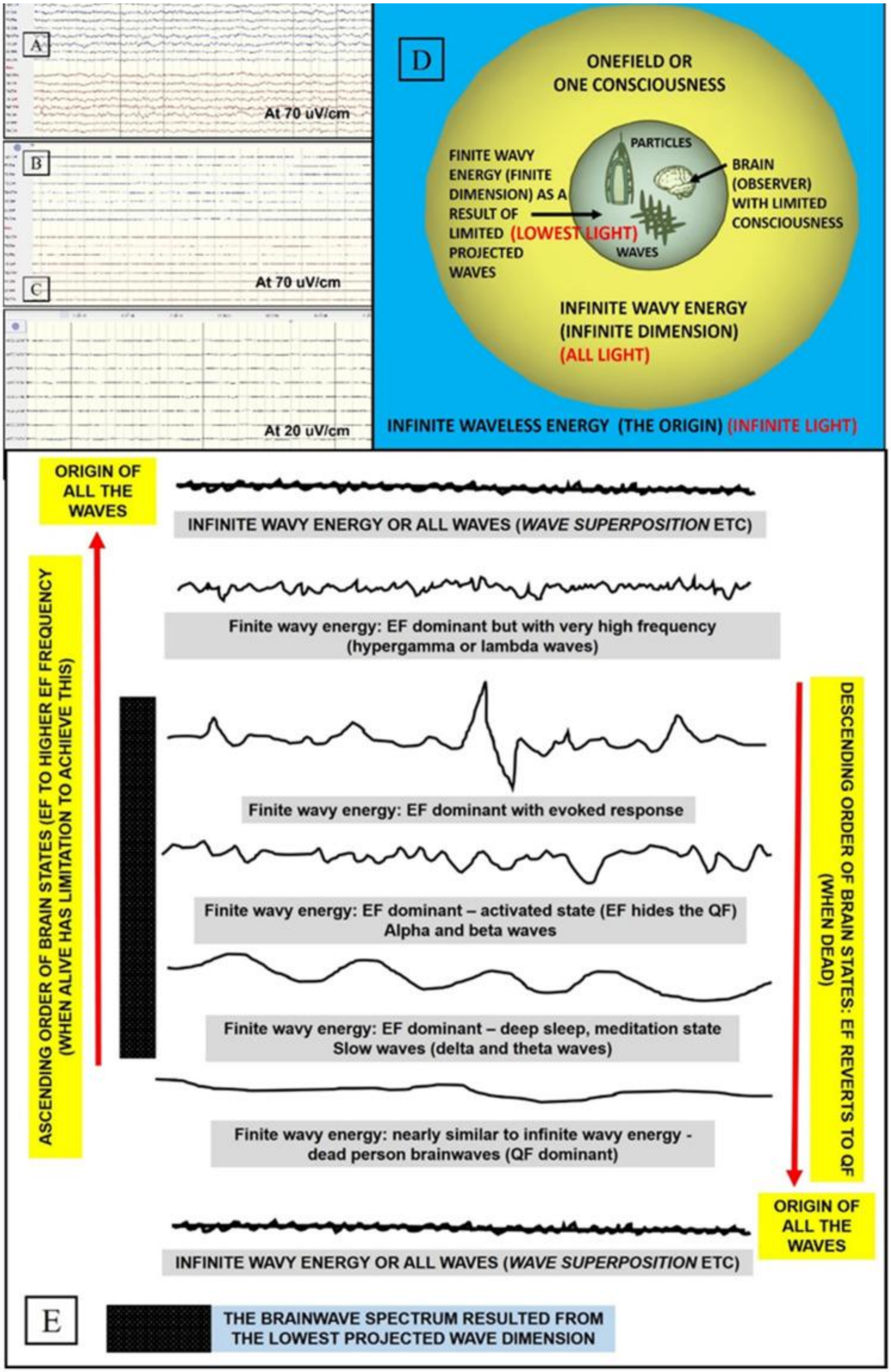
In summary, this intersection (i.e., infinite waves with finite waves or higher light with lower light) has apparently created an illusion of physical materials (hologram); they are actually waves (their reality or fundamental is energy) but appear as matter (vortex of matter), light, and electric vortices. This idea may explain why atoms or light existing in our physical universe can exist either in particle (matter is illusion) or wave form (reality or origin), i.e., a duality feature. Hence, one may conclude that an illusion of physical material is created by (a) the limited projection of waves and (b) the limited consciousness of the brain. As mentioned before, limitless consciousness exists as one entity, i.e., one consciousness (wholeness). Therefore, it also encompasses our brain consciousness. According to this argument, one may, hence, view our brain consciousness as not truly representing one whole consciousness. It is only partial or limited. Therefore, one may say that the human brain has limited consciousness. Similar to the 'limited projected waves' concept that was previously discussed, one may notice that the word 'limited' again appears in our discussion. Thus, with this limited consciousness concept that exists in our brain, we gain a glimpse of the original wave function of particles when collapsed. Thus, one cannot see the original waves (or energy); what we instead see are illusionary vortices of the limited projected waves. Since our interpretation of reality is represented by continuous waves or quantum energy (not particles or matter), our notion is that 'discreteness arises from continuousness when observed by the mind (brain)'.

5. Fusion of Electrical and Quantum Fields inside the Brain: Fusion of Bohmian and Quantum Mechanics and Their Algorithms

Since the brain is also encompassed by the oneness of consciousness (infinite wavy energy), one may presume that the brain features infinite waves. It is delocalized and in diffusion with external cosmos waves. In fact, it can be viewed as one medium of oneness, one field, wholeness, or one consciousness [14,19,20,21]. This indirectly compels us to realize that the brain, in fact, has quantum and multidimensional light features (nonlocal, quantum wave function, diffused, low-dimensional, tunneling, superposition, etc.). In other words, one may view these 'quantum–light waves of the brain' (i.e., energy of brain anatomy viewed on the smallest scale) as brain background waves interconnecting and permeating the whole universe, hidden underneath another wavy brain network, i.e., electrical (electromagnetic) brainwaves (functional brain energy). Thus, the brain has two types of energy: (a) anatomical energy (quantum view: anatomy or mass is also considered as energy), and (b) physiological energy (electromagnetic brainwaves). The quantum anatomical energy is hidden and has not yet been detected.

The electrical wave brain network (functional brain energy) is commonly studied and is easily evoked by physical stimuli. Projected waves (limited waves) or vortices which form physical stimuli cause evoked responses inside the brain, which is theorized here as having only limited consciousness (i.e., limited representation of true waves); furthermore, the brain itself is a part of the projected wave-vortices. Thus, one may say that the 'electrical wave brain network' represents a kind of mirror to 'limited projected waves' (finite physical universe items being compressed into the brain). With this view, i.e., considering the presence of limitations in both wave projection and consciousness, larger evoked electromagnetic fields are naturally observed for seeing, hearing, tasting, etc., of material objects [23,24]. At this juncture, we would like to consider the brainwaves of a dead person according to our clinical observation and our recently published manuscript [25]. It is commonly stated that the brainwaves of a dead person are isoelectric or flattened; however, in most circumstances, one might notice a slight wavy background, which may suggest that tiny background quantum–light waves (energy of the brain anatomy viewed on the smallest scale) could indeed be present. This wavy background is, however, only detectable using direct brain electrocorticography (ECoG) on the surface of the brain (Figure 4A–C). One of the scientific explanations in this regard might be related to our limited consciousness concept. The electrical field featuring very wavy electrical brainwaves, which is dominant when alive (i.e., the brain constantly reacts to the projected waves), has now reverted to one consciousness where the quantum–light field is dominant (substantially less wavy, nearly flattened, and diffused waves). In other words, the brainwaves are now similar to oneness or one-field waves (i.e., infinite wavy energy) (Figure 4D,E). These arguments may explain why the commonly regarded isoelectric brainwaves (when dead) (downward shift in Figure 4E) and the highest-frequency waves (when still alive) (upward shift in Figure 4E), such as gamma and lambda brainwaves, are both related to a heightened state of consciousness [26,27]. Simply put, these two states are related to the higher energy transition (a shift to the higher dimension or infinite wavy energy, i.e., beyond the ordinary range of the spectrum): one state when still alive and another when dead. Nonetheless, one must bear in mind that attaining and maintaining such high- or low-frequency waves when still alive (even through meditation) may not be an easy task for us. A final note on this part of the argument is that our current universe dimension is associated with the lowest brain frequency bands and, thus, can be regarded as the lowest dimension (Figure 4E).

Figure 4.


A
At 70 uV/cm
B
At 70 uV/cm
C
At 20 uV/cm
D
ONEFIELD OR
ONE CONSCIOUSNESS
PARTICLES
FINITE WAVY ENERGY (FINITE DIMENSION) AS A RESULT OF LIMITED (LOWEST LIGHT) PROJECTED WAVES
BRAIN (OBSERVER) WITH LIMITED CONSCIOUSNESS
WAVES
INFINITE WAVY ENERGY (INFINITE DIMENSION) (ALL LIGHT)
INFINITE WAVELESS ENERGY (THE ORIGIN) (INFINITE LIGHT)
ORIGIN OF ALL THE WAVES
INFINITE WAVY ENERGY OR ALL WAVES (WAVE SUPERPOSITION ETC)
ASCENDING ORDER OF BRAIN STATES (EF TO HIGHER EF FREQUENCY (WHEN ALIVE HAS LIMITATION TO ACHIEVE THIS)
Finite wavy energy: EF dominant but with very high frequency (hypergamma or lambda waves)
DESCENDING ORDER OF BRAIN STATES: EF REVERTS TO QF (WHEN DEAD)
Finite wavy energy: EF dominant with evoked response
Finite wavy energy: EF dominant – activated state (EF hides the QF) Alpha and beta waves
Finite wavy energy: EF dominant – deep sleep, meditation state Slow waves (delta and theta waves)
Finite wavy energy: nearly similar to infinite wavy energy - dead person brainwaves (QF dominant)
ORIGIN OF ALL THE WAVES
INFINITE WAVY ENERGY OR ALL WAVES (WAVE SUPERPOSITION ETC)
E
THE BRAINWAVE SPECTRUM RESULTED FROM THE LOWEST PROJECTED WAVE DIMENSION

Open in a new tab

Electromagnetic field, quantum field, and the two ends of the spectrum. (**A**) Scalp electroencephalography (EEG) brainwaves of a healthy person with wavy feature. (**B**) Scalp EEG brainwaves of a dead person at the same sensitivity (70 uV/cm), which now appear isoelectric (flattened). (**C**) Wavy background section of a dead person's brainwaves recorded directly on the brain surface and viewed at the highest scale (electrocorticography or ECoG at 20 uV/cm). (**D**) The relationship among infinite waveless energy (infinite light), infinite wavy energy (all light/first created light), and finite wavy energy (lowest light). (**E**) The descending order of brainwaves, from electromagnetic field (EF)-dominant to brain quantum field-dominant (dead person), and the ascending order of brainwaves, to the highest EF frequency (hypergamma and lambda) (alive person), may also come closer to infinite wavy energy, oneness, or one consciousness (heightened state of consciousness).

The subsequent question one might ponder is the following: "Is there any interaction between the electrical wave field (physiological energy) and quantum–light wave field (anatomical energy) inside the brain?" In our opinion, the interaction between these two fields is always present because they originate from the same infinite wavy field, which is diverted into two arms (projected waves/electrical wave field in the brain and quantum–light wave field/quantum level of brain anatomical waves or energy) and finally converges in the brain. This interaction may cause various states. The electrical wave field (evoked fields) dominates with respect to our five senses that are related to matter or projected fields (physical stimuli), whereas a possibly larger role is played by the quantum–light wave field in cognitive processes such as language, memory, attention, emotion, and anxiety (which are not directly related to material stimuli). A disturbed interaction, disharmony, or chaos (decoherence) between these two fields, as well as a reduction or increment in quantum neuroanatomical waves/energy (i.e., alteration in brain mass), may lead to various diseases, as seen in some psychiatric disorders where an 'exit from reality' or 'break in wholeness' (fragmented reality, fragmented energy, fragmented waves, or fragmented story/description) is commonly present [28,29,30,31,32]. The 'level of this interaction' may also explain why one healthy person has a higher anxiety level than another healthy person. Therefore, it is deemed appropriate to carry out electroencephalography (EEG) and magnetoencephalography (MEG) studies; in the future, with the availability of advanced technology (perhaps a sort of quantum wave detector technology, much more sensitive than MEG), one can include quantum field, quantum–light field, or quantum neuroanatomical energy measurements in these psychiatric or neurological patients. Furthermore, one may also want to use some sort of light (light therapy) and/or electromagnetic field (electroconvulsive therapy (ECT) or transcranial magnetic stimulation (TMS)) as a method of therapy for psychotic spectrum disorder or for cognitively impaired individuals.

In a nutshell, both electrical and quantum–light fields are needed to sufficiently study brain function. In other words, one may say that the brain has both an electromagnetic field (EMF) or electric field (EF) and a quantum field (QF) or quantum–light field (QLF);

	Feature	Electromagnetic or Electric Field (EMF)	Quantum Field (QF)
1	Origin	Projected waves (physiological waves)	Original waves (anatomic–chemical waves)
2	Wave pattern	Presence of pilot/directional wave	Diffused (delocalized) waves
3	Wave characteristics	High-frequency wave (limited frequency range when alive)	Low-frequency wave (unlimited and covers the whole frequency range via quantum wave superposition)
4	Wavelength	Short wavelength (presence or absence of wave superposition)	Long wavelength (with absolute presence of wave superposition)
5	Quantum concept	Deterministic (locatable)	Nondeterministic (unlocatable, changing)
6	Physics concept	Bohmian mechanics	(Truly) quantum mechanics
7	Dimension	High dimension (electric)	Low dimension (light)
8	System (energy) Note: The brain is like a mirror to the cosmos, with the brain and universe both having “low and high entropy”. Low entropy is formed from high entropy.	Concentrated organized system (energy) (low entropy) Low entropy is formed from the high-entropy state (EMF/EF originates from the projected and intersected QF waves)	Widespread diffused random system (energy) (high entropy) High entropy gives rise to the low-entropy state (the projected and intersected QF waves which form various vortices give rise to EMF/EF)
9	Brain network	Simple or specific network (few nodes)	Complex, changing, or nonspecific network
10	Symmetry	More asymmetry	More symmetry
11	Evoked response	Large evoked response with few stimuli or trials	Smaller evoked response, which needs a greater number of stimuli/trials and a quantum wave detector
12	Neuroplasticity (recovery once treated)	Less likely (because of limited field or focal/less diffused waves)	More likely (because of diffused waves and oneness)
13	Wholeness/oneness/one field concept	No (it is a response to the projected/limited field)	Yes (spreading, interconnecting, and permeating entire universe/field)
14	Related to psychiatry	Less relevant	More relevant (the brain QF is thought of as related to wholeness, reality, or the one consciousness concept)
15	Medical concept	Currently described by the Newtonian concept, whereby the brain is divided into anatomy/ensemble of particles and	Proposed as the medico-quantum physics concept, whereby an anatomic–chemical quantum brain field exists which remains hidden

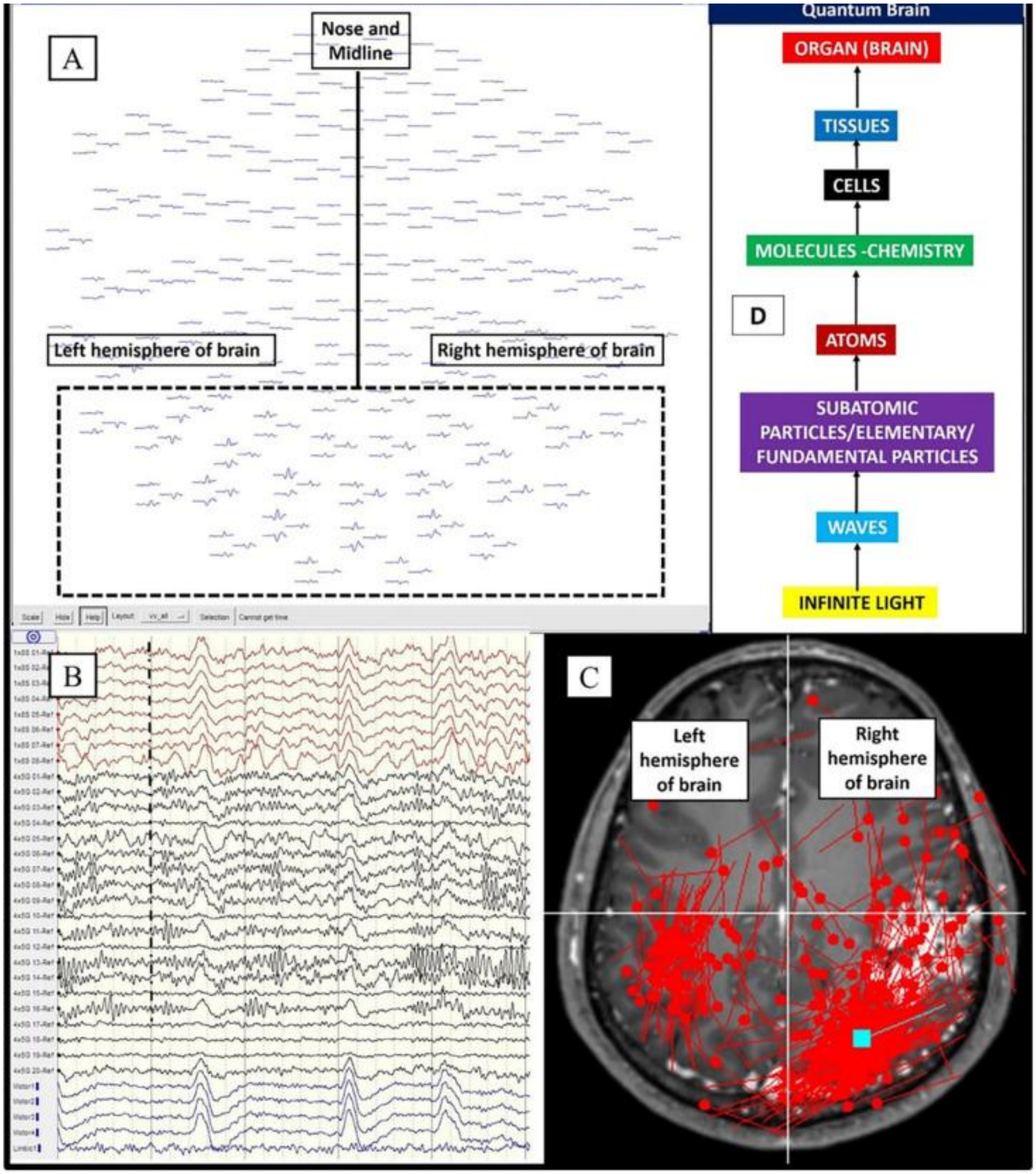
	Feature	Electromagnetic or Electric Field (EMF)	Quantum Field (QF)
		waves (physiological or electromagnetic brainwaves, i.e., the commonly studied waves)	(anatomy/particle is also regarded as energy quanta/waves or mass is also regarded as energy) When this diffused field combines with the brain electric field, we get the total brain field [#]
16	Why is only the brain involved in interacting meaningfully with these two fields? Is it related to the seat of human soul concept?	The brain is the only human structure where these two energy fields (pairs) "converge", Likely (because the center part of the brain is the origin for physiological brainwaves/EMF or all body functions (seat of soul))	The brain is the only human structure where these two energy fields (pairs) "converge" Likely, the cosmos QF can interact meaningfully *with only the brain*, which has a seat of soul concept, resulting in the *total brain field or mind field (see # above)*
	Brain Function	**Combination of EMF and QF (Total Brain Field or Two Brain Fields/Energy)**	
A	Brain function (motor, sensory, vision, sound, touch) and its impairment	Noncognitive impairment such as stroke affecting motor, sensory, vision, sound, touch. EMF is more affected than QF. It is measurable and associated with *degree of impairment*	
B	Brain function (language, emotion, memory, attention, planning, etc.) and its impairment	Cognitive impairment of language, emotion, memory, attention, planning, etc. QF is affected significantly, together with EMF. It is also measurable and associated with *degree of impairment*	
C	Brain function and psychosis	Psychotic manifestations such as auditory or visual hallucinations, thought insertions, and delusions QF is likely more affected than EMF (i.e., not related to projected waves or, in other words, no stimuli) or there is an abnormal total brain field or abnormal interaction between the two fields -Yes or no; *presence or absence, i.e., not associated with degree of impairment)*	

alternatively, it can be said that the brain has both high-EF and low-QF waves. Table 1 illustrates our points which differentiate the brain EF from brain QF, whilst Figure 5 shows the possible existence of quantum principles (entanglement, tunneling, and coherence) inside our brain. In physics, the concept of these two brain networks can be explained using Bohmian and quantum mechanics [33]. For quantum or background quantum–light brainwaves (difficult to locate and diffused), a nondeterministic algorithm should be used to study them, whereas, for electrical brainwaves (with features of a pilot wave, locatable, directional, and deterministic with a specific network), a Bohmian mechanics algorithm should be used to study them. For the fused brain field (EF + QF), a combined Bohmian and quantum algorithm may be the answer. As a final point, it is worth noting here that the brain is the only human anatomical structure (not bone, kidney, muscle, heart, etc.) which is seen as capable of interacting meaningfully with the cosmos quantum field. The total interaction of the brain QF (anatomical QF) with the cosmos QF, as well as with the brain electric field (EF), results in the formation of the ‘total brain field’, or perhaps an alternative name for it is “the mind field”. The reason for the brain being the only organ capable of interacting meaningfully with the cosmos QF may lie in ‘the seat of the soul’ brain concept (deep brain area that converges all waves), which has been debated since ancient times and was proposed by Leonardo da Vinci as being situated at the center of the brain. Thus, this deep and central part of the brain seems to be a mysterious and fascinating brain region that deals with everything from human consciousness to the determination of being alive or dead and awake or asleep, in addition to being associated with all brain–body functions [34,35]. In line with these arguments, the mushy brain should not be regarded as an organ and, thus, cannot be transplanted.

Table 1.

General features of the brain electromagnetic field (EF or EMF) and brain quantum field (QF) or brain quantum–light field (QLF).

Figure 5.

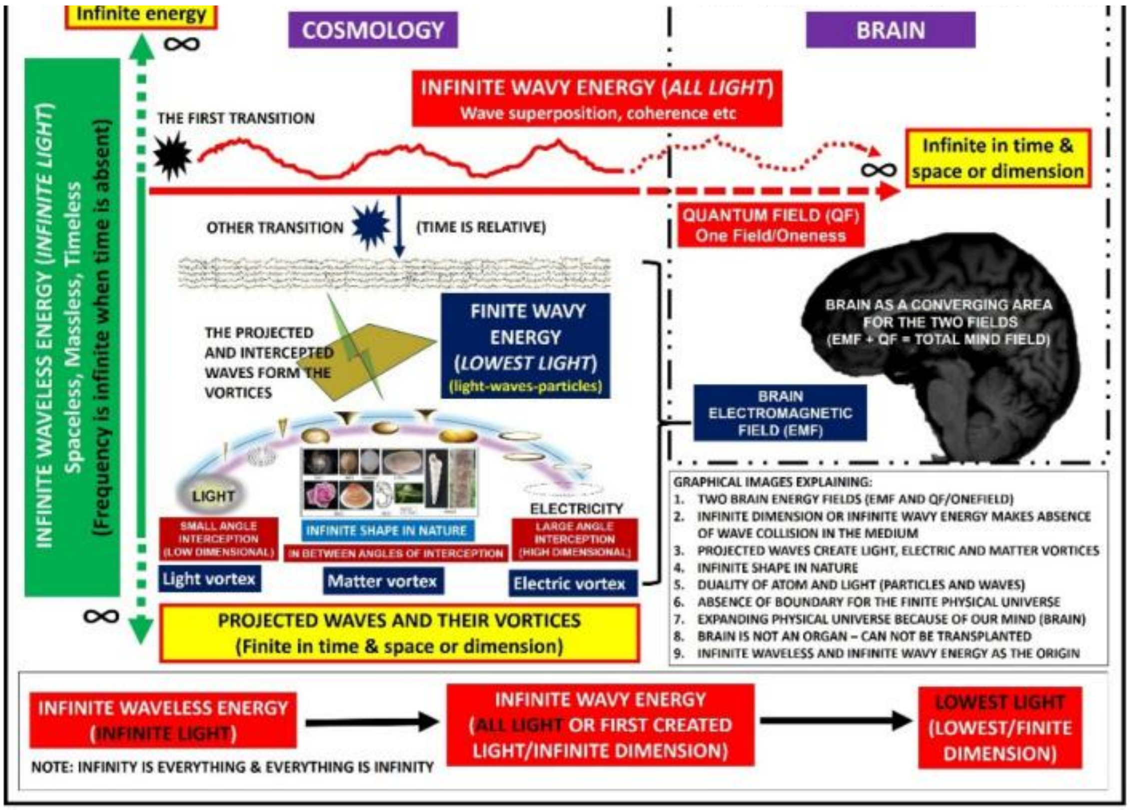


Quantum principles inside the brain. (**A**) The visually evoked magnetic field obtained through magnetoencephalography (MEG) as an example of an entangled electromagnetic field that has bihemispheric inversed potential responses. (**B**) Brainwaves obtained via ECoG (uppermost and middle, i.e., red and black waves) and EEG (bottom, blue waves): the normal areas of the brain (red and blue) have coherence or harmony waves, whilst the black (abnormal) areas exhibit decoherence (chaos/disharmony) in a psychotic epilepsy patient. (**C**) Despite the presence of a lesion in only the right hemisphere of the brain, epileptic spikes detected using MEG were noted in both hemispheres (may also be a sign of entanglement and/or tunneling; note that the slower detectable time response in the opposite brain hemisphere may be due to the measurement instrument used). (**D**) The brain and its anatomical hierarchy; the quantum part remains unexplored.

6. Conclusions

According to our new perspective on brain function, infinite waveless energy is an infinite frequency (energy) that is not related to time or space. It gave rise to another infinite energy, called infinite wavy energy, which is related to infinite space–time or dimension. Since time is only relative, new finite wavy energy (our universe) with a 'new period of time' can be formed via a second transition. The formation of new finite wavy energy/physical universe (started with the light) has resulted in the subsequent intersection of various waves coming from higher infinite wavy energy/waves/dimension. These intersections manifest themselves as various infinite-shape vortices that follow the laws of biology and physics. These vortices range from light to electricity. Matter and other vortices are included in between. Therefore, matter can be regarded as an illusion or can appear as either particles or waves (duality). This concept also explains our physical universe (finite wavy energy) as having no border. In reality, it is part of an infinite wavy energy/universe and, thus, the noted physical universe expansion could in fact be a consequence of our brain activity, which has partial consciousness (always sees waves or energy as particles). In essence, a person with limited brain consciousness cannot reach the border (no border or no question as to what substance the universe expanding into) of this illusionary universe (the brain itself is regarded as a projected vortex, which shall always notice the expansion of finite and angulated projected waves or the illusionary universe). According to these principles, our brain is thought of as having two types of brainwaves or energy: (1) quantum–light waves, which permeate and interact with the whole universe (one field/oneness/infinite wavy energy, related to macro and micro brain anatomical energy or brain particles which are viewed as waves, in tally with the string theory of the universe), and (2) the electromagnetic field or electric field (related more to brain physiological energy), which corresponds to a limited or finite projected wave (finite wavy energy) with a larger evoked response when stimulated. Thus, the brain can be regarded as an incomplete mirror to our cosmos (limited projected wave-vortices resulting in EMF and part of a more diffused QF). This manuscript ends with Figure 6 summarizing our whole perspective on this interesting aspect of brain function, which is closely related to cosmology.

Figure 6.



A graphical summary of our new perspective on brain function, which covers infinite waveless (infinite light), infinite wavy (all light), and finite wavy energy (comprises the lowest light), projected wave-vortices, quantum field, and electromagnetic field.

Author Contributions

Z.I., conceptualization, main content, and design of the manuscript; Z.I., R.O.C.H., and Z.Z. wrote the first draft of the manuscript. A.S.Y., D.N.F., A.R.I.G., J.M.A., W.M.N.W.H., M.H.H. and A.A.M.: manuscript revision. All authors have read and agreed to the published version of the manuscript.

Quantum effects in the brain

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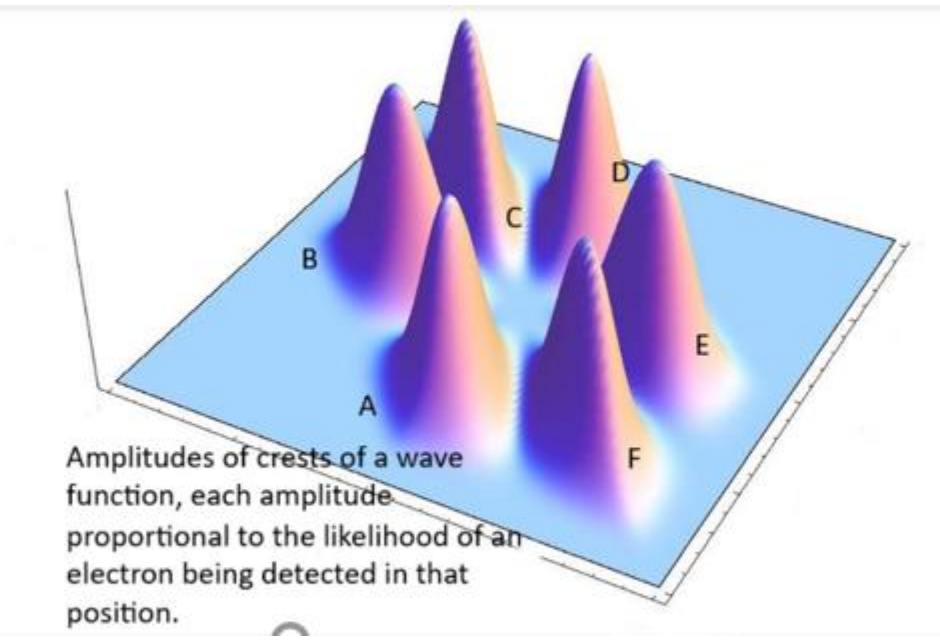
In the mid-1990s, it was proposed that quantum effects in proteins known as microtubules play a role in the nature of consciousness. The theory was largely dismissed due to the fact that quantum effects were thought unlikely to occur in biological systems, which are warm and wet and subject to decoherence. However, the development of quantum biology now suggests otherwise. Quantum effects have been implicated in photosynthesis, a process fundamental to life on earth. They are also possibly at play in other biological processes such as avian migration and olfaction. The microtubule mechanism of quantum consciousness has been joined by other theories of quantum cognition. It has been proposed that general anesthetic, which switches off consciousness, does this through quantum means, measured by changes in electron spin. The tunneling hypothesis developed in the context of olfaction has been applied to the action of neurotransmitters. A recent theory outlines how quantum entanglement between phosphorus nuclei might influence the firing of neurons. These, and other theories, have contributed to a growing field of research that investigates whether quantum effects might contribute to neural processing. This review aims to investigate the current state of this research and how fully the theory is supported by convincing experimental evidence. It also aims to clarify the biological sites of these proposed quantum effects and how progress made in the wider field of quantum biology might be relevant to the specific case of the brain.

What is wave function collapse? Is it a physical event?

In one view, a **wave function** is a piece of math, an equation. It's not a physical thing. So, it can't collapse in any physical sense. The collapse is metaphorical. This is one **interpretation of quantum mechanics**. It's the interpretation taught in most university classes, the **Copenhagen Interpretation**. However, physicists have not settled on a particular interpretation. For more nuance, see the later section "Caveat—Other Interpretations of Quantum Mechanics."

To continue on with the view that the **wave** function is a piece of math: a wave function is, first of all, a function—just like the functions in algebra—a very common type of equation. The reason that physicists call it a "wave function" is that it's an equation that when graphed, looks like waves. The accompanying image shows a graph of a particular wave function at a particular moment in time. It graphs as waves with six three-dimensional peaks:



Amplitudes of crests of a wave function, each amplitude proportional to the likelihood of an electron being detected in that position.

This wave function could describe an electron in a box, possibly imprisoned by magnetic fields. The graph tells us the likelihood of detecting the electron in any particular position in the box. It gives us a set of probabilities as to the likely position of the electron when detected. We'll need to square the amplitude (**wave height**) that we've calculated for each position to find out the probability of detecting the electron in that position.

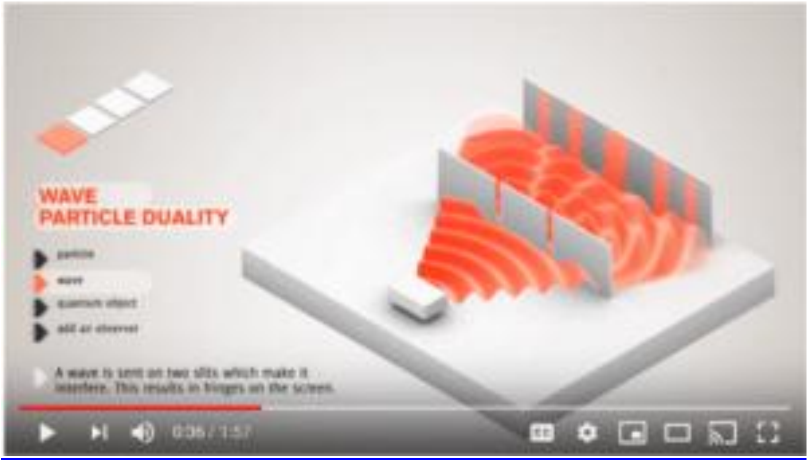
For this graph, the calculation of the wave function tells us that the electron has an equal probability of being detected in six different positions (A, B, C, D, E, or F) and a negligible probability of being detected elsewhere.

Collapse of the Wave Function

Upon detection of the electron, the probabilities calculated by the wave function instantaneously convert to a 100% probability for the position in which the electron is detected and 0% everywhere else. This is the "**collapse of the wave function**." All the probabilities collapse down to one position.

Double Slit Experiment, Ordinary object like a pebble

[Image source: Still from animation “Duality” **http://toutestquantique.fr/dualite/**



Double Slit Experiment, Ordinary wave like a water wave

[Image source: **http://toutestquantique.fr/dualite/**

The upcoming 2-minute video depicts this collapse in the Double Slit Experiment. First it shows in the “Particle” segment how an everyday object like a pebble would act (still image on left). Then it shows in the “Wave” segment how an ordinary wave like a water wave would act (still image on right)

Double Slit Experiment, Quantum object like an electron

[Image source: **http://toutestquantique.fr/dualite/**]Then, it shows in the third “Quantum Object” segment, **how an electron would act**. In this segment (still image on left), it shows the waviness of the electron prior to detection. Then, upon detection when the wavy electron hits the detection screen, it shows the collapse of the electron down to a localized **particle**. The detection screen might be a TV-type screen with phosphor pixels that glows when an electron hits.

Click on image for 2-minute animation of wave function collapse.

Click here to watch the 2-minute **video of the collapse of the wave function**.

So, a spread-out physical electron wave collapses down to a tiny physical particle? No, it doesn't.

The electron collapses down to a tiny physical particle, all right. But, according to the in the Copenhagen Interpretation, there was never any physical electron wave. The waviness of the electron prior to detection was never physical in the sense that tables and chairs are physical. If there is a wavy electron, it's no more physical than a mathematical expression.

But here's an alternative interpretation, it's a waviness is in an underlying sub-level of reality. That is, it's wavy in Quantumland where the rules of **quantum mechanics** apply. Not in our level of physical reality. This is the Transactional Interpretation as developed by Dr. Ruth Kastner (*Understanding Our Unseen Reality*).

Why isn't the waviness of the electron physical in the sense that tables and chairs are physical? Because the waviness described by the wave function is no more than probabilities that something will be detected. The wave function is **not** telling us where something is. It's telling us what's possible and how likely any particular possibility is. And there are other non-physical aspects of this waviness. Read the next section on this if you're familiar with the concept of imaginary numbers.

The Wave Function and Imaginary Numbers

(Skip this section if math isn't your thing. It isn't essential to the basic concept of this article.) Here's something else to consider. You know the **imaginary number** **i** and how it doesn't describe anything in the physical universe? You're never going to measure a table leg that is **i** inches tall. That's because **i** means the square root of negative **1**. What number squared equals **-1**? There is no such number. So, **-1** has no square root. But we go ahead and call it **i** and happily calculate with it. We're just never going to find a table leg or anything else that measures **i** inches long.

Well, here's the punchline. Many wave functions calculate wave amplitudes which are **i** big. The implication is that these wave functions are not describing anything in our physical reality. So, the waviness of the electron prior to detection can be described mathematically, but is not a physical thing in our physical universe. It's either just math or it's something in an underlying reality that I like to call "Quantumland."

Caveat — Other Interpretations of Quantum Mechanics

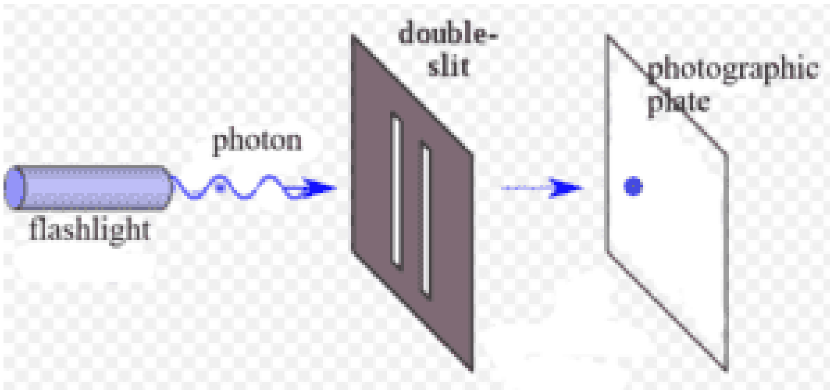
In the 1920's and '30's, the early days of **quantum** mechanics, a number of the founding fathers thought of the wave function as an actual wave. Erwin Shrodinger was in this camp. So, when reading the early literature on quantum mechanics, one will sometimes run across statements that the wave function describes a "**probability wave**," with the implication that it's a physical thing. However, few physicists today subscribe to this view. The interpretation that I've followed in this article is the current version of the Copenhagen Interpretation, the one usually taught in universities.

About 15 other interpretations of quantum mechanics have developed in the century since the Copenhagen Interpretation was first developed. Some of these do not include the concept of wave function collapse. Physicists who favor the De Broglie-Bohm Interpretation would say that there's always an electron wave and it's always guiding an electron particle: the wave does not suddenly collapse down to a particle. Physicists who favor the Many Worlds Interpretation would also say that there’s no wave function collapse.

* The probability densities are the squares of the wave amplitudes, as calculated by the wave function. The wave function yields the distribution of probability densities for detecting the electron in any particular position.

Collapse of the wave function

Collapse of the **wave function** is the transformation from a spread-out **wave** function to a localized **particle**. To understand this phenomenon, one must understand the meaning of "**wave function**," which is described in its own article.



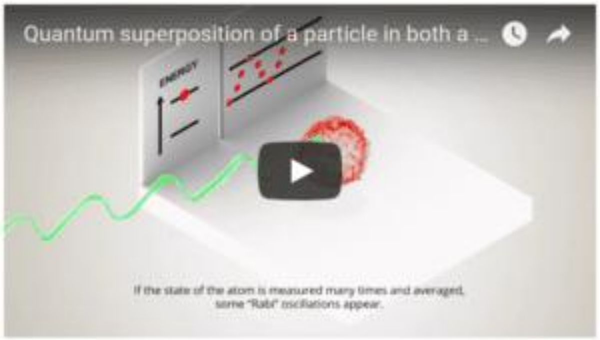
Double Slit Experiment shooting one photon at a time.

[Image source: modification of **https://en.wikipedia.org/wiki/Double-slit_experiment**]

Let's start with the example of the wave function for a photon that has been shot from a laser and aimed at a photographic plate. The photon must pass through a barrier with two slits before it hits the photographic plate. This is the famous Double Slit Experiment.

The wave function is the equation which describes the changing or "evolving" photon. It is an equation which derives from the Schrodinger Equation. Sometimes, scientists describe the wave function as if it were not only an equation but also a real physical object. However, this approach leads to difficulty in understanding the physical meaning of **quantum mechanics**. It's more straightforward to consider the wave function as no more than an equation.

In our example, the wave function describes the evolution of the photon. But it is not telling us the trajectory of the photon. Rather, it is telling us the evolving probabilities of where we would find it if the photon were to be detected. The wave function might tell us at any one moment that there's a 20% probability of the photon landing at this spot on the photographic plate, a 30% probability there, a 40% probability there, and a 10% probability there on the plate. The probabilities total 100% as this experiment has been set up so that there's a 100% chance that we'll find the photon somewhere on the photographic plate.



The wave function of an atom and wave function collapse.

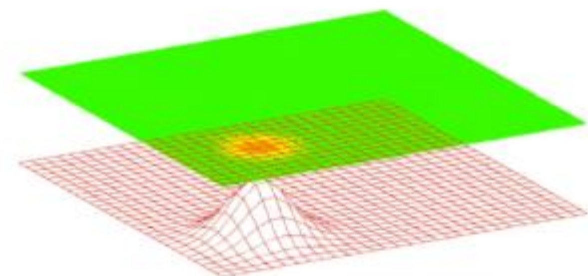
[Animation source: **http://www.QuantumMadeSimple.com**; Creative Commons Attribution-Share Alike 3.0 Unported license]

The possible trajectories are in a superposition. That is, at any moment in time, many trajectories are possible. Each possible trajectory contributes to determining the probabilities as to where we will detect the photon. Each possible trajectory has more influence than we are used to attributing to the idea of "a possibility." In the **quantum** world, each possibility influences what happens in the physical universe. It is as if there were an underlying Quantumland in which the possible trajectories are playing out and determining what happens in the physical universe.

The accompanying animation shows a different example of wave function collapse. An entire atom rather than a tiny photon is shown. The animation shows a superposition of two possible energy levels that the atom might adopt. These energy levels are shown as if they are real physical things. But they are possibilities described by the wave function and not part of our physical reality. The video gives substance to the possibilities described by the wave function in order to better communicate. When the atom interacts with an object (is "measured"), the wave function collapses. Upon collapse, the atom is measured as having one of the two possible energy levels. In this animation, the collapse of the wave function is called "decoherence." More about decoherence in a later section of this article.

Collapse of the Wave Function

Getting back to the photon shot from the laser gun. Soon enough, the photon is detected as a little dark dot on the photographic plate. Physicists would say that it has been "measured." "Measured" really means that the photon has had an interaction with something in the physical universe. This interaction allows us to detect the photon. In this case, the photon is absorbed by an electron in the photographic plate, which creates a dark spot on the plate. Upon measurement, that is, this interaction, the probabilities calculated by the wave function instantaneously convert to a 100% probability for the specific dark spot and 0% everywhere else. **The wave function has "collapsed."**



Red grid is a 3-D graph representing the wave function of the photon. Green film represents the photon as a particle, that is, as a collapsed wave function.

[Image source: stills from Fermilab video by Dr. Don Lincoln, "Quantum Field Theory" (in the public domain) Jan. 14, 2016; **https://www.youtube.com/watch?v=FBeALt3rxEA&feature=youtu.be**.]

The wave function does not calculate when the collapse will occur. To the contrary, the wave function tells us that the photon continues to evolve and will continue to evolve indefinitely. Nothing in the wave function gives us a hint that the evolution of the photon's trajectories will soon come to an abrupt halt. The wave function accurately describes the photon only so long as it remains free of interaction with the physical things.

Nor does the wave function calculate the position in which the photon will leave its mark. The selected position appears to be random. Physicists must "write in by hand" the detected position of the photon rather than being able to calculate it.

The failure of the wave function to describe what happens when the photon interacts with the physical universe and is detected is called the

"Measurement Problem." This is the problem that the Schrodinger Cat thought experiment (as described below) was designed to highlight. The Measurement Problem has additional aspects including an inability to rigorously define "measurement." In the Copenhagen Interpretation, the interpretation that this article focuses on, measurement is defined in a general way as the quantum particle interacting with a macroscopic object. The Copenhagen Interpretation, itself, provides no mathematical description of this interaction. However, other interpretations do. And the theory of decoherence when added to the Copenhagen Interpretation also provides a mathematical description of the interaction.

Wave Function Collapse and the Speed of Light

Yet another aspect of the Measurement Problem is that wave function collapse appears to violate the speed limit of the universe, the speed of light. Albert Einstein and two colleagues pointed this out in a famous paper, nicknamed "The EPR Paper" for the last names of the three authors. As noted above, when the wave function collapses, all positions except one instantaneously adopt a probability of 0%. One position, the position in which the photon is detected, adopts a probability of 100%. How can all the other positions described by the wave function instantaneously get the news that the photon has just been detected in one position? The conversion of the probabilities appears to be instantaneous, and "instantaneous" is faster than the speed of light. This violates the Special Theory of Relativity, a theory well-confirmed by empirical observations.

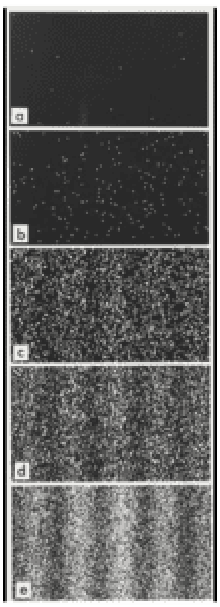
In this description of the wave function, it violates "locality." Locality is the principle that objects are affected only by those things which touch it. And anything that can touch something else must not exceed the speed of light. Even when we hear a radio broadcast of a symphony created half-way across the world, locality is preserved. The sound has traveled as vibrations of air molecules and as vibrations of electromagnetic radio waves. These are considered physical "things" which travel by touching things. At the end of the journey, vibrating air molecules touch our ear drums. At no point do any of these waves travel faster than the speed of light.

This is in contrast to wave **function** collapse. It appears that the quantum world, Quantumland, is not bound by the principle of **locality**. Experiments on entanglement and Bell's Theorem indicate that the quantum world is non-local.

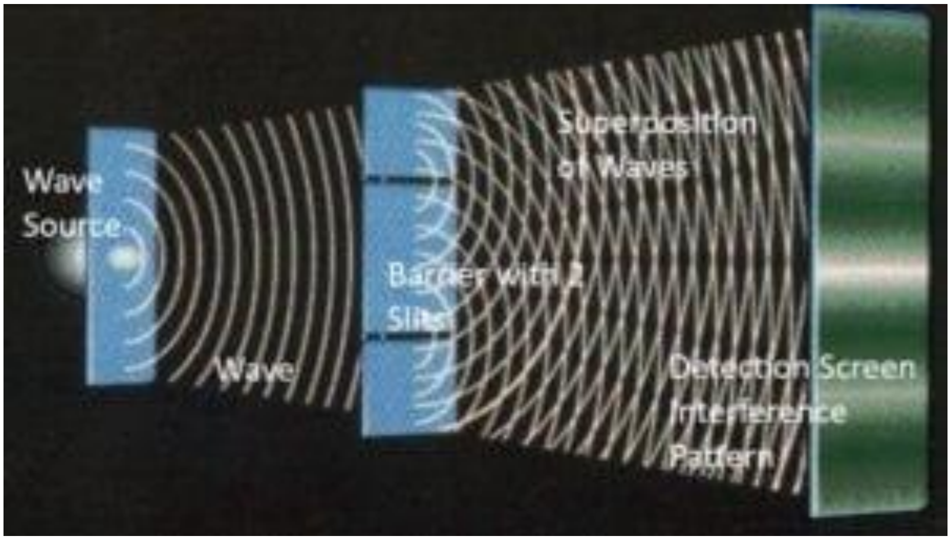
That is, quantum particles can act in a perfectly coordinated manner regardless of their distance from each other.

Non-locality can be absorbed by the **Copenhagen Interpretation**. It simply ignores the issue. The Copenhagen Interpretation does not address what quantum particles are doing prior to detection, and it argues that doing so would be unscientific. It argues that since what occurs in Quantumland cannot be detected, even in principle, it is not a proper subject for scientific investigation. Other **interpretations of quantum mechanics** explicitly address the issue of non-locality. The de Broglie-Bohm Interpretation is explicitly non-local as is the Transactional Interpretation. **Other interpretations** vary regarding locality.

Does the wave function really describe a wave?



Repeated runs of the Double Slit Experiment (using electrons) builds up an interference pattern on the detection screen.
[Image source: By user:Belsazar – Provided with kind permission of Dr. Tonomura, CC BY-SA 3.0, **https://en.wikipedia.org/wiki/Double-slit_experiment**]



Water waves pass through two slits and create a striped interference pattern (in green) on a detection screen.
[Image source: Dan Hooper, Fermilab **http://saturdaymorningphysics.fnal.gov/wp-content/uploads/2017/02/Hooper-II-2017.pdf** p. 36]

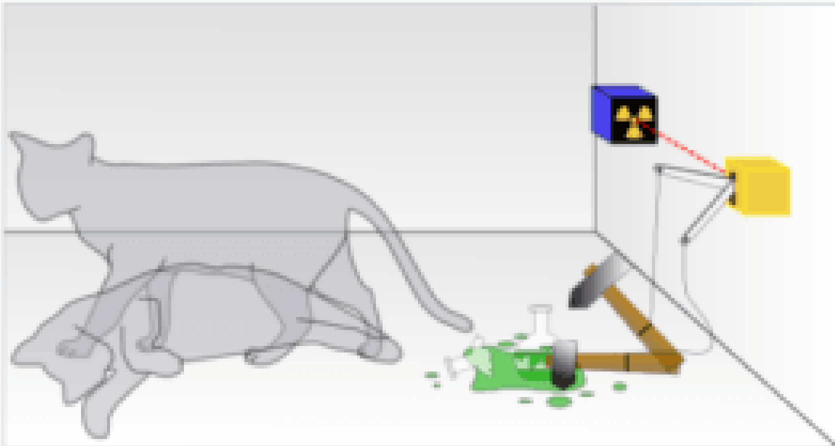
Let's return to the Double Slit Experiment. If we keep sending photons through the slits, more and more dots mark the photographic plate. The dots seem to land in **random** positions. But dot by dot, a pattern builds up. After thousands or millions of photons hit the plate, we see stripes of light and dark.

The accompanying photos (left) show this build-up of stripes. Gradually, frame by frame, the dots build up until in Frame (**e**), the stripes are clearly visible. (It should be noted that this series of photos was created by electrons rather than photons. As the electrons hit, light dots formed on a dark background. But were photons used, a striped pattern would also appear.)

This striped pattern is a signature pattern of waves meeting waves. Waves that meet superimpose themselves upon each other, creating a "superposition." The image above of two water waves meeting and interfering with each other shows a superposition of waves. Waves in superposition can form the familiar crisscross pattern of two boat wakes meeting or ripples from two pebbles thrown in a pond. The crisscrosses create a striped "interference pattern" on the detection screen.

The interference pattern formed by quantum particles in the Double Slit Experiment is the empirical clue that the photon acts as a superposition of waves prior to detection. The other evidence that the photon acts as a superposition of waves is that the probabilities of its detection are calculated by the wave function. This equation takes a form similar to those which calculate the behavior of water waves, sound waves, and other ordinary waves.

Wave Function Collapse and Schrodinger's Cat Experiment



Schrödinger's cat: a cat, a flask of poison, and a radioactive source are placed in a sealed box. If an internal monitor (e.g. Geiger counter) detects radioactivity (i.e. a single atom decaying), the flask is shattered, releasing the poison, which kills the cat. The Copenhagen interpretation of quantum mechanics implies that after a while, the cat is *simultaneously* alive *and* dead. Yet, when one looks in the box, one sees the cat *either* alive *or* dead, not both alive *and* dead. This poses the question of when exactly quantum superposition ends and reality collapses into one possibility or the other.

The Schrodinger Cat thought experiment. [Image source: By Dhatfield – Own work, CC BY-SA 3.0, **https://commons.wikimedia.org/w/index.php?curid=4279886**]

In the 1920's and 1930's physicists speculated about the collapse of the wave function. What was it about detecting the subatomic particle that ended the evolution of the wavelike behavior of the photon? What caused it to transform to a particle with a specific position? While the mathematics of the wave function was saying that the "photon wave" should continue to evolve, experiments showed that, instead, it adopted a specific position. Worse, it adopted a position that could not be predicted: In the same experimental setup, particles that were run through the experiment adopted different, apparently random, positions. The wave function calculates only the total distribution of particle positions.

In fact, the mathematics was saying even more. The wave function has a mathematical property called "linearity." This property means that when the photon superposition interacts with the photographic plate, the superposition should "infect" the photographic plate. The plate, itself, is composed of quantum particles. Mathematically, it appears that the particles in the plate should become correlated with the photon. The plate should go into a superposition like the photon, a superposition of all the positions in which the photon might land.

Instead, the wave function collapses down to a particle, making a single dot on the plate. Rather than going into a blurry superposition, the photographic plate stays solidly in place.

The Schrodinger Cat thought experiment highlights the problem of our ignorance of the cause of the collapse of the wave function. Here's the experiment: A radioactive atom is in a superposition of two states: 1) decay in which it emits an electron and 2) stability in which it doesn't. The atom is in a box with a hapless cat and a Geiger counter. If the atom decays and emits the electron, it triggers the Geiger counter, which releases a hammer, which breaks a vial, which releases a poison gas, which kills the cat.

The property of linearity of the wave function tells physicists that the superposition of the atom, both decayed and undecayed, would put the Geiger counter into a superposition of triggered and not triggered. The superposition of the Geiger counter would, in turn, infect the hammer, which would go into a superposition of smashing the vial and not smashing the vial. And so on, until the cat, itself, is in a superposition of being both dead and alive. But this does not describe the reality that we experience. What actually happens in the physical universe that saves us from zombie cats?

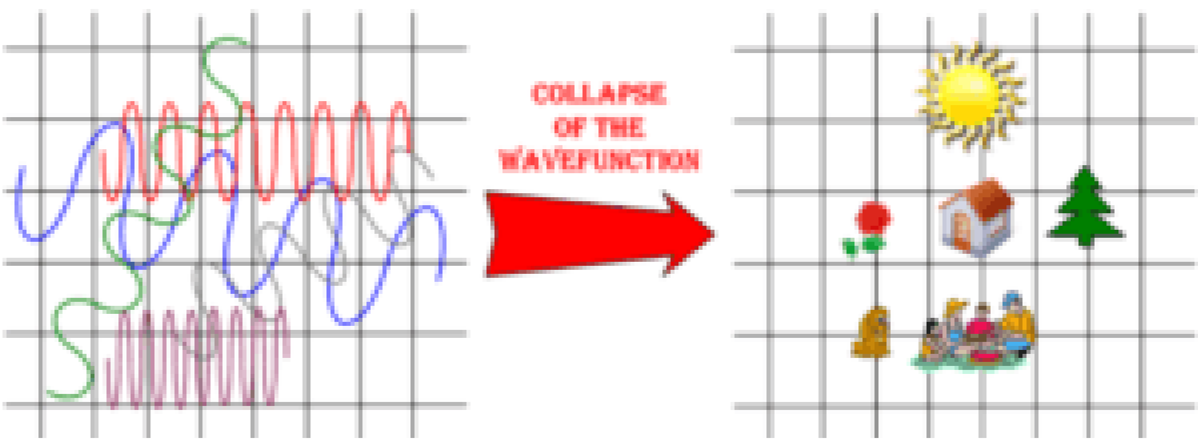
Early on, some physicists proposed that consciousness collapses the wave function. Upon the human experimenter looking at it, the entire cat-killing machine is solidified and the cat is found to be either dead or alive but not both. In later decades, the theory of decoherence was developed to explain wave function collapse. Both of these explanations are described below.

It should be noted that some interpretations of quantum mechanics do not hold that the wave function actually collapses. The Many Worlds Interpretation and the de Broglie-Bohm Interpretations are the most well-known of these.

Collapse of the Wave Function and Consciousness

In the 1920's and 1930's, some quantum physicists considered the possibility that consciousness collapses the wave function. This possibility is suggested by an odd aspect of the Double Slit Experiment. When the "which path" information is discovered about the quantum particle **in any manner whatsoever**, the wave function collapses. In other words, if we are able to determine either directly or indirectly the path of the quantum particle through the slits, the waviness of the particle disappears. It becomes a particle.

There's also a chain of reasoning that raises the possibility that consciousness could play a role in wave function collapse. This reasoning can be illustrated in regard to the **Schrodinger's Cat Experiment**: The box in the Schrodinger Cat Experiment might hold a cat which, infected by the superposition of the radioactive **atom**, is both dead and alive. But we know from experience that when the physicist opens the box and looks, she will see either a live cat or a dead cat, not a blurry superposition of both. Possibly, it is the physicist's looking, her consciousness, which causes the instantaneous collapse of the wave function to either a live cat or a dead cat.



Collapse of the Wave Function by Consciousness.
[Image source: David Chalmers and Kelvin McQueen, "Consciousness and the Collapse of the Wave Function" **http://consc.net/slides/collapse.pdf]**
All the objects in the box are composed of quantum particles. Due to the linear property of the wave function (see above section), the objects would be expected to enter into superpositions of states correlated with the undecayed atom and states correlated with the decayed atom. Given the tendency of the atom's superposition to infect everything composed of quantum particles that it interacts with, only something not composed of quantum particles could actually collapse the wave

function. Consciousness could be this thing. This is the **Von Neumann-Wigner Interpretation.**

Consciousness and Collapse of the Wave Function—Von Neumann-Wigner Interpretation

In 1932, John Von Neumann, one of the leading mathematicians of the 20th Century, wrote the first comprehensive presentation of the mathematics of quantum mechanics, *The Mathematical Foundations of Quantum Mechanics.* This became the standard textbook for quantum mechanics. In this volume, Von Neumann proposed that the wave function could collapse at any point in the causal chain from the measurement device to the human perception of the measurement. In the 1960's, Nobel Laureate Eugene Wigner, proposed that it is, specifically, human consciousness that collapses the wave function. However, in later years, he distanced himself from this proposal.

Noted physicist Henry Stapp, however, continued with the idea that consciousness collapses the wave function. He wrote:

"From the point of view of the mathematics of quantum theory it makes no sense to treat a measuring device as intrinsically different from the collection of atomic constituents that make it up. A device is just another part of the physical universe… Moreover, the conscious thoughts of a human **observer** ought to be causally connected *most directly and immediately* to what is happening in his brain, not to what is happening out at some measuring device… Our bodies and brains thus become … parts of the quantum mechanically described physical universe. Treating the entire physical universe in this unified way provides a conceptually simple and logically coherent theoretical foundation…."

The cartoon image above illustrates this view of collapse of the wave function. In this illustration, the universe is a collection of interacting waves which our consciousness collapses down to real solid particles that form houses, trees, the sun, and a family picnic. This view of the role of consciousness in collapsing the wave function is sometimes espoused by people who are into spirituality. They sometimes look back at statements along this line by early quantum physicists like Eugene Wigner and Werner Heisenberg, not realizing that this is no longer mainstream physics. However, some physicists are beginning to consider the possibility that consciousness gives physicality to our universe. Physicists interested in the possibility that we live in a virtual reality may be especially interested in the role of consciousness giving flesh to the equations which govern the universe. For a discussion, see the final section of this article.

Today, most physicists dismiss the idea that consciousness collapses the wave function. Of course, there is no theoretical understanding within physics of consciousness and the mechanics of how consciousness might collapse the wave function. Instead, today (2019), many physicists look to the mathematical theory of **decoherence** as the explanation or, at least part of the explanation, for the collapse of the wave function. (See next section.) Other physicists subscribe to interpretations of quantum mechanics, such as the Many Worlds and Bohmian Interpretations, which do not involve collapse of the wave function. This, in fact, is one of the main attractions of these two interpretations.

Experimental Results on Consciousness and Collapse of the Wave Function

While many physicists have moved away from considering consciousness as a possible cause of collapse of the wave function, a few physicists have done actual experiments. In addition to other possible causes of collapse, could conscious attention to the path of a quantum particle collapse the wave function? This possibility was investigated by physicists at Princeton University and York University in 1998. Participants were asked to observe with their mind's eye light traveling through a Double Slit Experimental set-up. The possibility of any physical contact with the set-up was eliminated.

Experimenters at Princeton University used subjects who were experienced with maintaining focused intention in these types of experiments. This experiment found a small but statistically significant effect of visualization on collapsing the wave function. The York University experiment, which used a random group of subjects, did not find a significant effect.

In 2012, a team of parapsychologists, led by Dean Radin, conducted a group of six experiments on consciousness and collapse of the wave function. These experiments found that the results depended heavily on the selection of the subjects. When experienced meditators were asked to see the path of quantum particles in their mind's eye, wave function collapse was slightly more likely. The results were statistically significant: odds against chance were 107,000 to 1. However, non-meditators were not effective in creating wave function collapse.

Results of these studies along with the earlier ones in 1998 were published in peer-reviewed physics journals.

This is an interesting area of research and, hopefully, more experiments will be conducted on the issue.

*M. Ibison and S. Jeffers, “A double slit diffraction experiment to investigate claims of consciousness-related anomalies;” *Journal of Scientific Exploration*; 1998; 12:543.

** D.I. Radin, L. Michel, K. Galdamez, P. Wendland, R. Rickenbach, A. Delorme, “Consciousness and the double-slit interference pattern: Six experiments;” *Physics Essays*. 2012:25(2):157-171.

Decoherence and Collapse of the Wave Function

So, what is decoherence? First, I must explain what coherence is. When a quantum particle is in a coherent state, we’re just saying that it’s in a superposition. It’s the wavelike state of the particle that the wave function describes. (Of course, it can be confusing to keep calling it a “particle” when it’s wavelike, but that’s the way physicists speak about it.)

To explain decoherence, let’s return again to the example of the photon moving towards the photographic plate. When it hits the plate, it’s absorbed by an electron in the plate. With this interaction, it’s position is definite. It’s no longer simply a set of possibilities. It has changed things in the physical universe. Information has been created and recorded by the photographic plate. This can’t be undone. The wave function has **decohered**. Decoherence has occurred.

Starting in the 1950’s, physicists began to realize that they needed to consider the environment that particles were functioning in. In ordinary environments, there are lots of macroscopic particles everywhere. At ordinary atmospheric pressure, so many air molecules float around that the photon need travel only the width of a human hair before bumping into a nearby air molecule. This means that many opportunities are provided quantum particles to decohere and leave the superposition state. For this reason, quantum particle experiments are often conducted within vacuums.

This tendency for a quantum particle to quickly leave its superposition (decohere) is the major barrier in developing useful quantum computers. Quantum computers depend upon the quantum nature of particles–their ability to exist in a superposition. Interactions with the environment bring a quick end to superpositions. Physicists must place quantum particles in containers that prevent the particles from touching the sides of the container. One way is to create magnetic fields which hold electrically-charged particles away from the sides of the container. The containers must also be emptied of air and kept at near-zero temperatures. All of these measures help to prevent decoherence.

This is an area of active research. Physicists are doing experiments and developing the math so as to better understand the interactions between quantum particles and the environment. A 2013 experiment on the interactions of photons with atoms is a good example. Both atoms and photons have the quantum property of **spin**. The spin of a photon can either be aligned with the spin of an atom that it encounters or not aligned. The experimenters found that if the spin of the photon is aligned with the spin of the atom, the two will not interact; the wave function of the photon will not collapse. It will remain in a superposition. However, if the spin of the photon and the atom are aligned, they will interact. The wave function will collapse, and the photon will have lost its superposition and been measured. It will experience decoherence.

The collapse of the wave function is a central problem which physicists continue to explore. It has become a problem with important implications due to its role as a major barrier to the development of quantum computing.

Another Role for Consciousness in Physics

Raining computer code, as in the film, "The Matrix"
[Image source: By Jamie Zawinski – screenshot, MIT, https://en.wikipedia.org/wiki/Matrix_digital_rain; retrieved Nov. 29, 2018]While today, consciousness is not generally thought by physicists to explain the collapse

of the wave function, it has emerged in another role. Some physicists propose that we live in a virtual reality. They see physical reality as fundamentally a set of interacting “wavinesses.” Upon interaction, the wave function collapses. But this is only a mathematical change. It is a change from one equation to another. If it’s a photon being absorbed by an electron, upon collapse of the wave fucntion, the wave function of the photon switches to an equation describing how photons and electrons interact. But how do we get from mathematical equations to physical reality? How does the math become a dark spot on a photographic plate? As Stephen Hawking put it: What “breathes fire” into the equations?

The entire universe might be seen as interacting equations, one equation’s output providing the input for another equation, and so on. Continuing the process of the photon being absorbed by an electron in the photographic plate, an entire chain of equations govern the interactions which end with equations for electromagnetic waves in the brain of the physicist who looks at the photographic plate. These electromagnetic waves describe a dark spot on the photographic plate. But how do we get get from these equations describing electromagnetic waves in the brain to the physicist having the **subjective experience of seeing** a dark spot? This is where consciousness comes in. The consciousness of the physicist decodes the equations and provides the **experience** of seeing a dark spot.

Rather than focusing on equations, we might see the universe as the “computer code” that the equations generate. This is the world that the enslaved humans in the movie “The Matrix” live in. They live in a virtual reality, essentially an interactive video game, created by computers which their brains are hooked into. However, this view of reality doesn’t necessarily imply that we are characters in a computer video game. Physicists like Amit Goswami have proposed instead that the coding is in one mind that we are all hooked into.

This Doctor Says He Knows How the Brain Creates Consciousness. New Evidence Suggests He's On to Something.

Stuart Hameroff has faced three decades of criticism for his quantum consciousness theory, but new studies show the idea may not be as fringe as once believed.

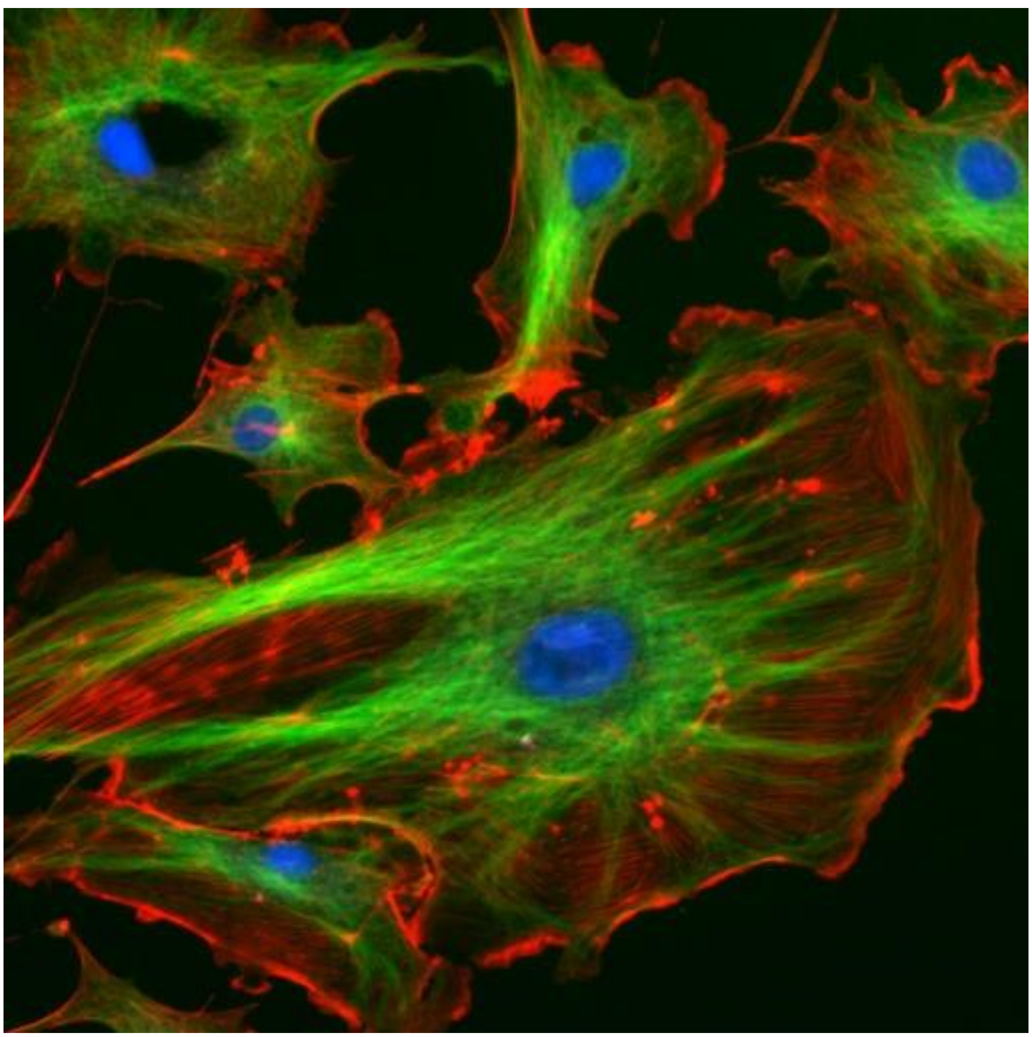
BY [DARREN ORF]PUBLISHED: DEC 18, 2024 5:13 PM EST

Save Article

For nearly his entire life, Dr. Stuart Hameroff has been fascinated with the bedeviling question of consciousness. But instead of studying neurology or another field commonly associated with the inner workings of the brain, it was Hameroff's familiarity with anesthetics, a family of drugs that famously induces the *opposite* of consciousness, that fueled his curiosity.

"I thought about neurology, psychology, and neurosurgery, but none of those . . . seemed to be dealing with the problem of **consciousness**," says Hameroff, a now-retired professor of anesthesiology from the University of Arizona. Hameroff recalls a particularly eye-opening moment when he first arrived at the university and met the chairman of the anesthesia department. "He says 'hey, if you want to understand consciousness, figure out how anesthesia works because we don't have a clue.'"

Hameroff's work in anesthesia showed that unconsciousness occurred due to some effect on microtubules and wondered if perhaps these structures somehow played a role in forming consciousness. So instead of using the neuron, or the brain's nerve cells, as the "base unit" of consciousness, Hameroff's ideas delved deeper and looked at the billions of individual tubulins inside **microtubules** themselves. He quickly became obsessed.



That is, until he had a chance encounter with an influential book by Nobel Prize laureate Sir Roger Penrose, Ph.D.

Within the pages of 1989's *The Emperor's New Mind*, Penrose argued that consciousness is actually quantum in nature—not computational as many theories of the mind had so far put forth. However, the famous physicist didn't have any biological mechanism for the possible collapse of the quantum wave function—when a multi-state quantum superposition collapses to a definitive classical state—that induces conscious experiences.

"Damn straight, Roger. It's freaking microtubules," Hameroff remembers saying. Soon after, Hameroff struck up a partnership with Penrose, and together they set off to create one of the most fascinating—and controversial—ideas in the field of consciousness study. This idea became known as **Orchestrated Objective Reduction** theory, or Orch OR, and it states that microtubules in neurons cause the quantum wave function to collapse, a process known as objective reduction, which gives rise to consciousness.

Hameroff readily admits that since its inception in the mid-90s, it's became a popular pastime in the field to **bash his idea**. But in recent years, a growing body of research has reported some **evidence** of quantum processes being possible in the brain. And while this in itself isn't confirmation of the Orch OR theory Hameroff and Penrose came up with, it's leading some scientists to reconsider the possibility that consciousness could be quantum in nature. Not only would this be a huge breakthrough in the understanding of human consciousness, it would mean that purely algorithmic—or computer-based—artificial intellligence could never truly be conscious.

• • •

In 1989, Roger Penrose was already a superstar in the world of mathematics and physics. By this time, he was already years removed from his groundbreaking work describing black hole formations (which eventually earned him the Nobel Prize in Physics in 2020), as well as his discovery of mathematical tilings, known as Penrose tilings, that are crucial to the study of quasicrystals—structures that are ordered but *not* periodic. With the publication of *The Emperor's New Mind*, Penrose dove headfirst into the theoretical realm of human consciousness.

In the book, Penrose leveraged Kurt Gödel's incompleteness theorem, which (in *very* simplified terms) argued that because the human mind can exceed existing systems to make new discoveries, then consciousness must be non-algorithmic. Instead, Penrose argues that human consciousness is fundamentally quantum in nature, and in *The Emperor's New Mind,* he lays out his case over hundreds of pages, detailing how the collapse of the wave function creates a moment of consciousness. However, similar to Hameroff's dilemma, Penrose admits in the closing pages that profound pieces of this quantum consciousness puzzle were still unknown:

> I hold also to the hope that it is through science and mathematics that some profound advances in the understanding of mind must eventually come to light. There is an apparent dilemma here, but I have tried to show that there is a genuine way out.

When Hammeroff first read the book in 1991, he believed he knew what Penrose was missing.

Hameroff dashed off a letter that included some of his research and offered to visit Penrose at Oxford during one of his conferences in England. Penrose agreed, and the two soon began probing the non-algorithmic problem of human consciousness. While the duo developed their quantum consciousness theory, Hameroff also brought together minds from across disciplines—including philosophy, neuroscience, cognitive science, math, and physics—to explore ideas surrounding consciousness in the form of a biannual Science of Consciousness Conference.

The University of Arizona Center for Consciousness Studies
Dr. Stuart Hameroff (left) and Sir Roger Penrose (right) giving a lecture on consciousness and the physics of the brain at the Sanford Consortium for Regenerative Medicine in La Jolla, California, January 2020.

And from its very inception, the conference broke new ground. In 1994, philosopher David Chalmers described how neuroscience was well-suited for figuring out how the brain controlled physical processes, but the "**hard problem**" was figuring out why humans (and all other living things) had subjective experiences.

Roughly two years after Chalmers gave this famous talk in a hospital auditorium in Tucson, Penrose and Hameroff revealed their own possible answer to this famous hard problem.

It wasn't well-received.

• • •

Penrose and Hameroff revealed their Orchestrated Objective Reduction theory in the April 1996 issue of *Mathematics and Computers in Simulation*. It **detailed** how microtubules orchestrate consciousness from "objective reduction," which describes (with complicated physics) Penrose's thoughts on quantum gravity interaction and how the collapse of the wave function produces consciousness.

The idea has since faced nearly 30 years of criticism.

Famous theoretical physicist Stephen Hawking once **wrote** that Penrose fell for a kind of Holmsian fallacy, stating that “his argument seemed to be that consciousness is a mystery and quantum gravity is another mystery so they must be related.” Another main criticism is that the brain’s warm and noisy environment is ill-suited for the existence of any kind of quantum interaction. Read any scientific literature about quantum computers, and lab conditions are always extra pristine and approaching-absolute-zero cold (–273.15 degrees Celsius).

“You know how long I’ve been hearing the brain is warm and noisy?” Hameroff says, dismissing the criticism of the brain as too warm and wet for quantum processes to flourish. “I think our theory is sound from the physics, biology, and anesthesia standpoint.”

In a 2022 interview with *New Scientist*, Penrose **admitted** that the original Orch OR theory was “rough around the edges,” but maintains all these decades later that consciousness lies beyond computation and perhaps even beyond our current understanding of quantum mechanics. “People used to say it is completely crazy,” Penrose told *New Scientist*, “but I think people take it seriously now.”

“I think our theory is sound from the physics, biology, and anesthesia standpoint.”

A lot of that slow acceptance comes from a steady tide of research showing that biological systems contain evidence of quantum interactions. Since the publication of Orch OR, scientists have found evidence of quantum mechanics at work during photosynthesis, for example, and just this year, a study from researchers at Howard University detailed quantum effects involving microtubules. This research doesn’t prove Orch OR directly; that’d be like discovering water on an exoplanet and declaring it’s home to intelligent life—not an impossibility, but very *far* from a certainty. The findings at least have some critics reconsidering the role quantum mechanics plays, if not in consciousness, then at least the inner workings of the brain more broadly.

However, the rise of quantum biology in the past few decades also coincided with the explosion of AI and large language models (LLMs), which has brought new urgency to the question of consciousness—both human and artificial. Hameroff believes that an influx of money for consciousness research involving AI has only biased the field further into the “consciousness is a computation” camp.

“People have thrown in the towel on the ‘hard problem’ in my view and sold out to AI,” Hameroff says. “These LLMs . . . haven’t reached their limit yet but that doesn’t mean they’ll be conscious.”

• • •

As the years—and eventually decades—passed, Hameroff relentlessly defended Orch OR in scientific papers, at consciousness conferences, and perhaps most energetically on his X (formerly Twitter) feed, where he regularly participates in microtubule-related debates. But when asked if he likes the arguments, he answers pretty bluntly.

“Apparently I do because I keep doing it,” Hameroff says. “I’ve always been the contrarian but it’s not on purpose—I just follow my nose.”

And that scientific sense has led Hameroff to explore potentially profound implications when you consider that consciousness doesn’t necessarily rely on the brain or even neurons. Earlier this year, Hameroff, along with colleagues at the University of Arizona and Japan’s National Institute for Materials Science, co-authored an non-peer-reviewed **article** asking the question of whether consciousness could possibly predate life itself.

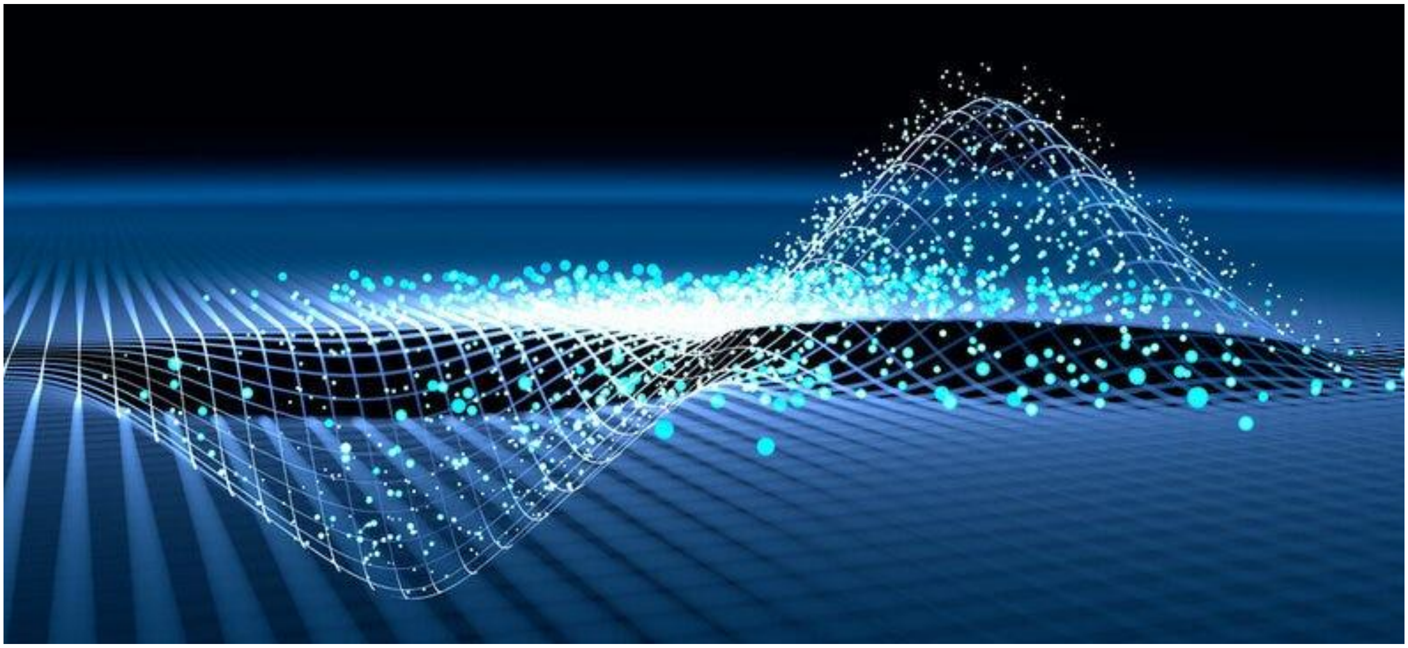
“It never made sense to me that life started and evolved for millions of years without genes—why would organisms develop cognitive machinery? What’s their motivation?” Hameroff says, admitting that theory traipses beyond the typical confines of science. “It’s kind of spiritual—my spiritual friends like this alot.”

Hameroff admits that some of his ideas are “out there,” and even stops himself short when describing some ideas involving UFOs, saying “I’m already out on enough limbs.” While most of his ideas may have taken up residence in the fringes of mainstream science, it’s a place where he seems comfortable—at least for now. “I don’t think everybody’s going to agree . . . but I think [Orch OR] is going to be considered seriously,” Hameroff says.

Hameroff retired from his decades-long career as an anesthesiologist at the University of Arizona, and now he has even more time to dedicate to his lifelong fascination.

“I had a great career, and now I have another great career,” he says. “Plus I don’t have to get up so damn early.”

Is the Collapse of Wave Function at the Heart of Reality?



The collapse of the wave function is a fundamental concept in quantum physics, signifying a shift from potential to actuality within a quantum system, such as a photon. This event, central to understanding quantum mechanics, encapsulates the transition from a superposition of many states to a single observable state upon measurement. The wave function itself, while not a physical entity, is a critical mathematical tool in quantum theory that provides probabilities for the location and momentum of particles. Its mysterious nature fuels ongoing discussions and research efforts, examining the very fabric of reality and challenging the norms of classical physics.

Unraveling this phenomenon takes us through a labyrinth of quantum experimental investigations and interpretations, from ‘Schrödinger’s cat’ to ‘quantum entanglement’, and from the Copenhagen interpretation to the many-worlds hypothesis. As this article surveys the complexities of wave function collapse and the resultant quantum state, it will guide through historical developments, competing theories like quantum decoherence and entanglement theory, and the perpetual quest to reconcile quantum mechanics with observable reality.

Understanding the Wave Function

The wave function is a cornerstone of quantum mechanics, providing a probabilistic framework for understanding the behavior of particles at the quantum level. Here is an exploration into the nature of the wave function:

Probabilistic Nature of the Wave Function: The wave function of a quantum system is not a direct depiction of the system’s properties but is instead a mathematical apparatus used for calculating the likelihood of various measurement outcomes. Upon performing a measurement, the wave function collapses, resulting in the particle acquiring definitive properties. This collapse translates into a 100% probability of finding the quantum system in the observed state post-measurement.

Mathematical Formulation and Interpretation:

$$\Psi = Ae^{i(kx - \omega t)}$$

Free Particle Wavefunction

A wave function, denoted as Ψ(x,t), is a complex function that assigns a complex number to each point in space, encapsulating the quantum state of an isolated system. According to the Born rule, the probability density for a particle's position is determined by the squared modulus of the wave function, $|\Psi(x,t)|^2$, which must integrate to one across all space to satisfy the normalization condition. The wave function can evolve over time following the deterministic Schrödinger equation, and although it shares qualitative similarities with classical waves, it represents a fundamentally different physical phenomenon.

$$\frac{-\hbar^2}{2m}\frac{\partial^2\Psi}{\partial x^2} = i\hbar\frac{\partial\Psi}{\partial t}$$

Schrodinger equation for free particle in one dimension.

Wave Function Representations and Transformations: The wave function can be expressed in terms of variables other than position, such as momentum, allowing for different representations of the quantum state. Transformations like the Fourier transform enable conversion between position-dependent and momentum-dependent wave functions, reflecting the particle's state in different degrees of freedom. For particles with intrinsic spin, such as electrons and photons, spin is incorporated as a discrete variable in their wave function, further elaborating on the complexity of quantum states.

$$\frac{\partial \Psi}{\partial x} = ik\Psi = \frac{ip}{\hbar}\Psi$$

The momentum connection

$$\frac{\partial \Psi}{\partial t} = -i\omega\Psi = \frac{-iE}{\hbar}\Psi$$

The energy connection

Relation to Momentum and Energy

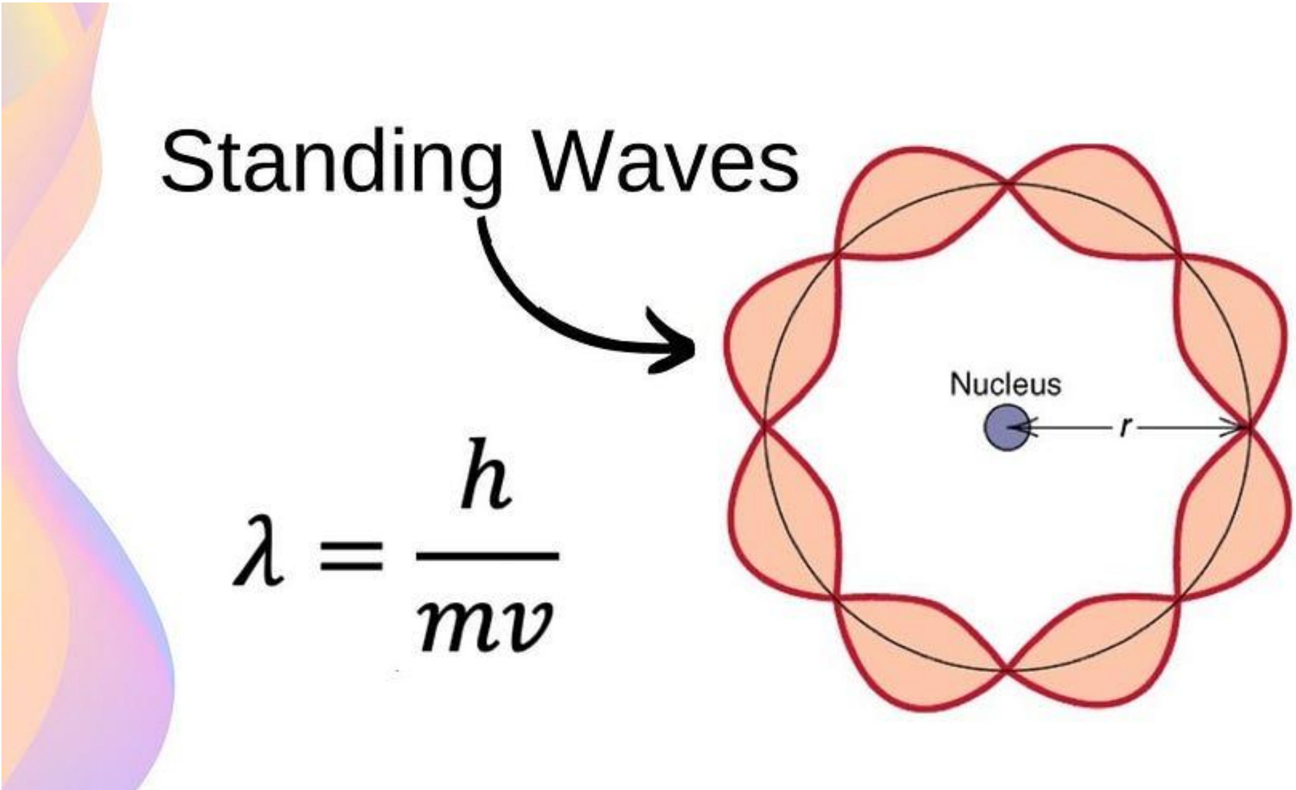
The Historical Context

Origins of Quantum Mechanics

Quantum mechanics emerged in the early 20th century, a revolutionary theory that utilized calculus and linear algebra to describe the behavior of atomic and subatomic particles. The theory marked a significant departure from classical physics, which could not account for the peculiarities observed at microscopic scales.

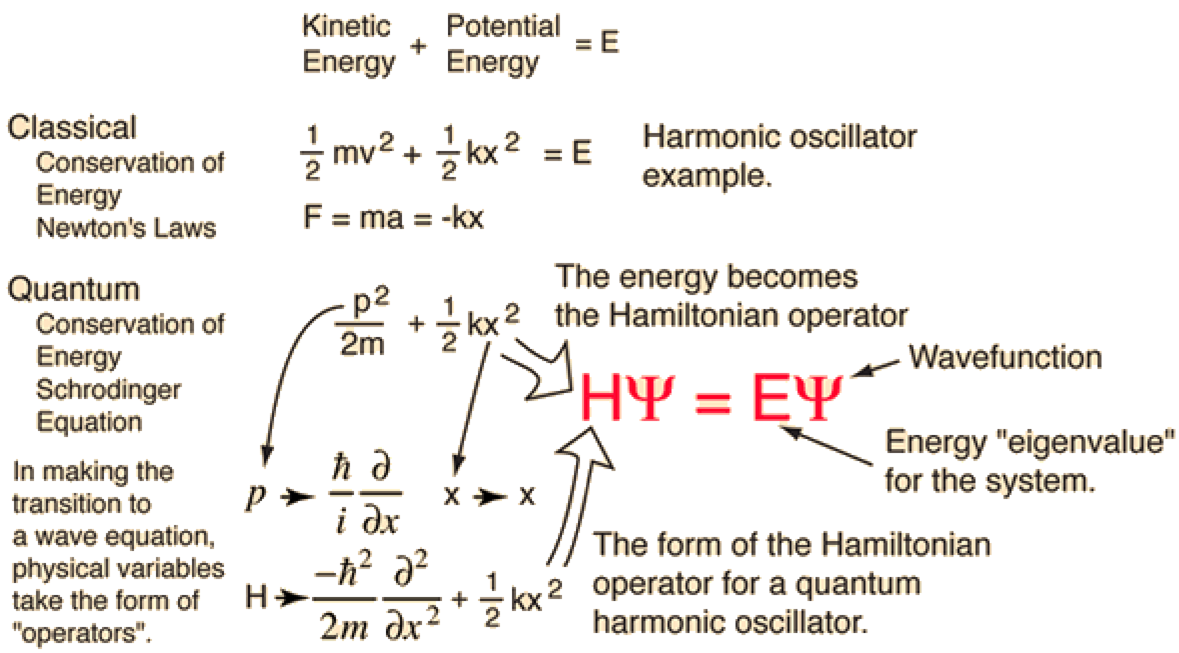
Key Milestones

Louis de Broglie's Hypothesis (1924): De Broglie postulated the wave-particle duality of matter, suggesting that particles could exhibit wave-like characteristics, laying the groundwork for the wave function concept .



Broglie's Equation

The Schrödinger Equation (1926): Erwin Schrödinger introduced his wave equation, a pivotal moment in quantum mechanics, describing the time evolution of the wave function.



Schrodinger equation, predicting the distribution of results

Born's Probability Interpretation (1926): Max Born proposed that the square of the wave function's magnitude represents the probability density for a particle's position, a fundamental aspect of quantum mechanics.

The Born interpretation

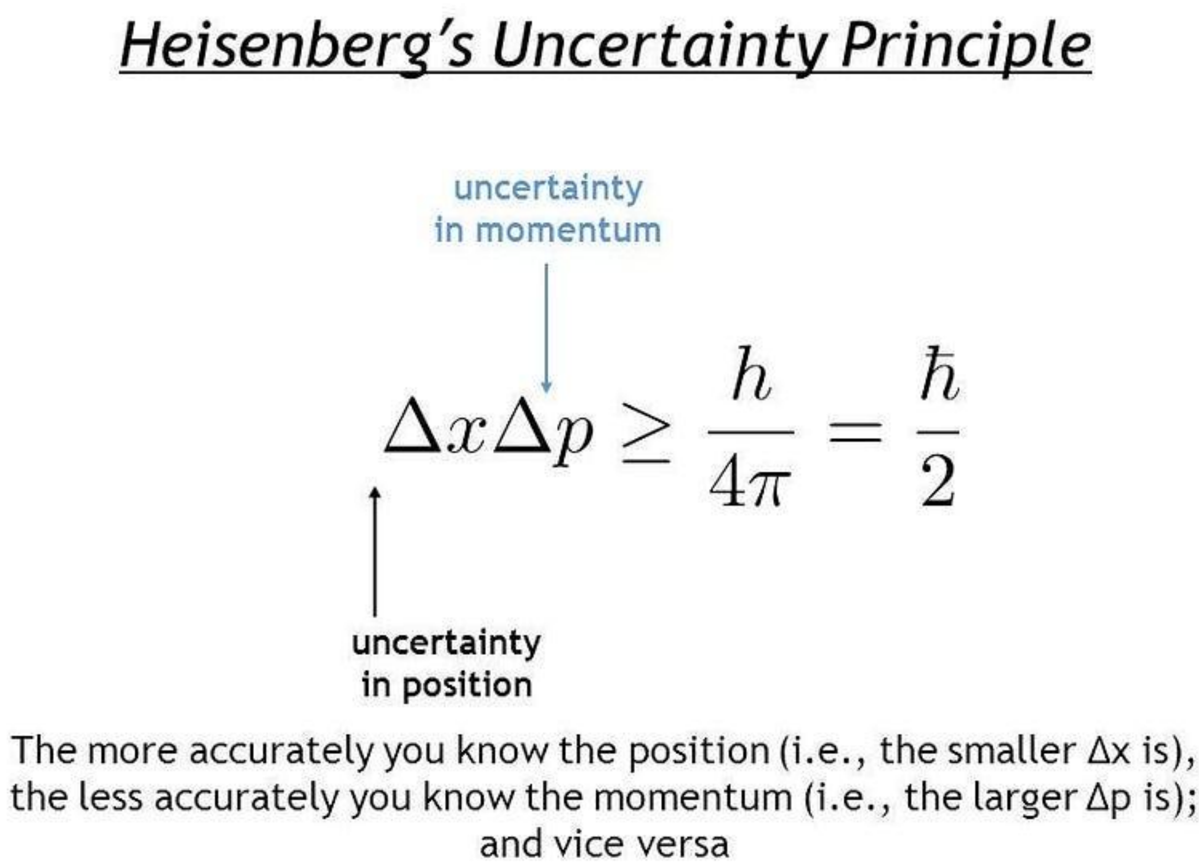
- The square of the wave function $|\Psi|^2$ at a point is proportional to the probability of finding the particle at that point.

$$\boxed{\left|\Psi\right|^2 = \Psi^* \Psi \geq 0}$$ Always real, non-negative

Complex conjugate of Ψ

$$\left|a+bi\right|^2 = (a+bi)^*(a+bi) = (a-bi)(a+bi)$$
$$= a^2 - b^2 i^2 = a^2 + b^2 \geq 0$$

Heisenberg's Uncertainty Principle (1927): Werner Heisenberg formulated the uncertainty principle, which implies that certain pairs of physical properties cannot be simultaneously known to arbitrary precision.



Conceptual Developments and Thought Experiments

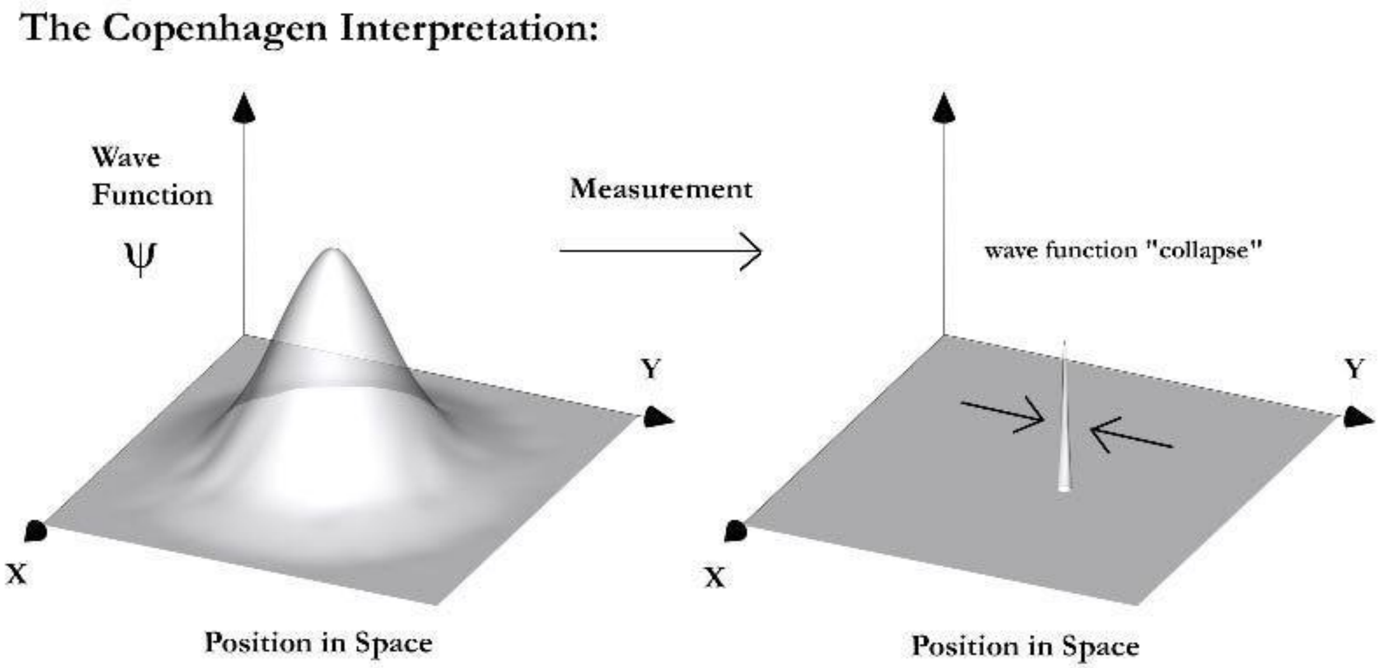
- The wave function's collapse was introduced by Heisenberg and mathematically formalized by John von Neumann, becoming an integral part of quantum mechanics.
- Albert Einstein, Boris Podolsky, and Nathan Rosen presented the EPR paradox in 1935, challenging the completeness of quantum mechanics and introducing the concept of quantum entanglement.

- Schrödinger’s Cat thought experiment, proposed by Schrödinger in the same year, highlighted the paradoxes of quantum measurement and the problematic nature of wave function collapse.
- Einstein’s discussions with Schrödinger reflected a broader scientific debate about the deterministic versus probabilistic nature of quantum theory.

These milestones and debates underscored the radical shift in understanding the fundamental nature of reality, with the wave function at the center of this transformation. The historical context of the wave function’s development reveals a tapestry of intellectual challenges and groundbreaking insights that continue to influence quantum physics today.

The Copenhagen Interpretation

The Copenhagen Interpretation, spearheaded by figures such as Niels Bohr and Werner Heisenberg, stands as a foundational framework in quantum mechanics, profoundly shaping the field’s understanding of the wave function and its collapse. This interpretation, developed in the 1920s, incorporates several distinctive principles that continue to influence quantum theory.



Probability and Measurement

- Central to the Copenhagen Interpretation is the notion that the squared magnitude of the wave function, as described in Schrödinger's equation, serves as a probability density function, indicating the likelihood of a particle's position.

- Observations and measurements play a pivotal role, as they are irreversible processes that define the properties of a quantum system. The act of measurement collapses the wave function, transitioning the system from a superposition of states to a definite state.

- According to this view, quantum systems do not possess definite properties prior to measurement. Instead, properties emerge as a consequence of the interaction between the observer and the system.

Principles of Complementarity and Correspondence

- The principle of complementarity posits that quantum entities exhibit dual aspects, such as particle-like and wave-like behaviors, which cannot be observed simultaneously but are equally real.

- The correspondence principle ensures continuity between quantum mechanics and classical physics, suggesting that quantum theory should mirror classical behavior under certain conditions or at a certain scale.

Critiques and Challenges

- Despite its widespread teaching and application, the Copenhagen Interpretation is not without its critics. One significant challenge is the need to introduce a “cut” between the quantum realm and the macroscopic world, which classical physics describes.

- Additionally, the interpretation’s indeterministic character, while integral to its framework, removes a direct explanation for the results of interference experiments and raises questions about the role of consciousness in measurement.

The Copenhagen Interpretation remains the most commonly taught perspective in quantum physics courses, emphasizing the role of the observer and the probabilistic nature of quantum events. It suggests that the very act of observation not only reveals but also produces the properties of quantum objects, a concept that has profound implications for our understanding of reality at the most fundamental level.

Wave Function Collapse

Nature of Wave Function Collapse

- The wave function collapse is an enigmatic process in quantum mechanics, representing a sudden transition from a quantum system's superposition to a single eigenstate upon interaction with the external world, such as during a measurement.

- Unlike the continuous, deterministic evolution described by the Schrödinger equation, collapse is a non-deterministic process, with the outcome's probability given by the Born rule.

Interpretations and Theories

- Various interpretations of quantum mechanics offer different perspectives on wave function collapse, with some viewing it as a physical process and others as a mathematical abstraction.

- Physical Collapse Theories suggest that the collapse is a real physical process, potentially influenced by a “noise field,” but recent experiments have not confirmed the simplest models of these theories.
- Decoherence, a process where a quantum system loses coherence due to interaction with its environment, has been proposed as a mechanism for collapse, aligning with the concept that quantum systems behave more classically when observed.

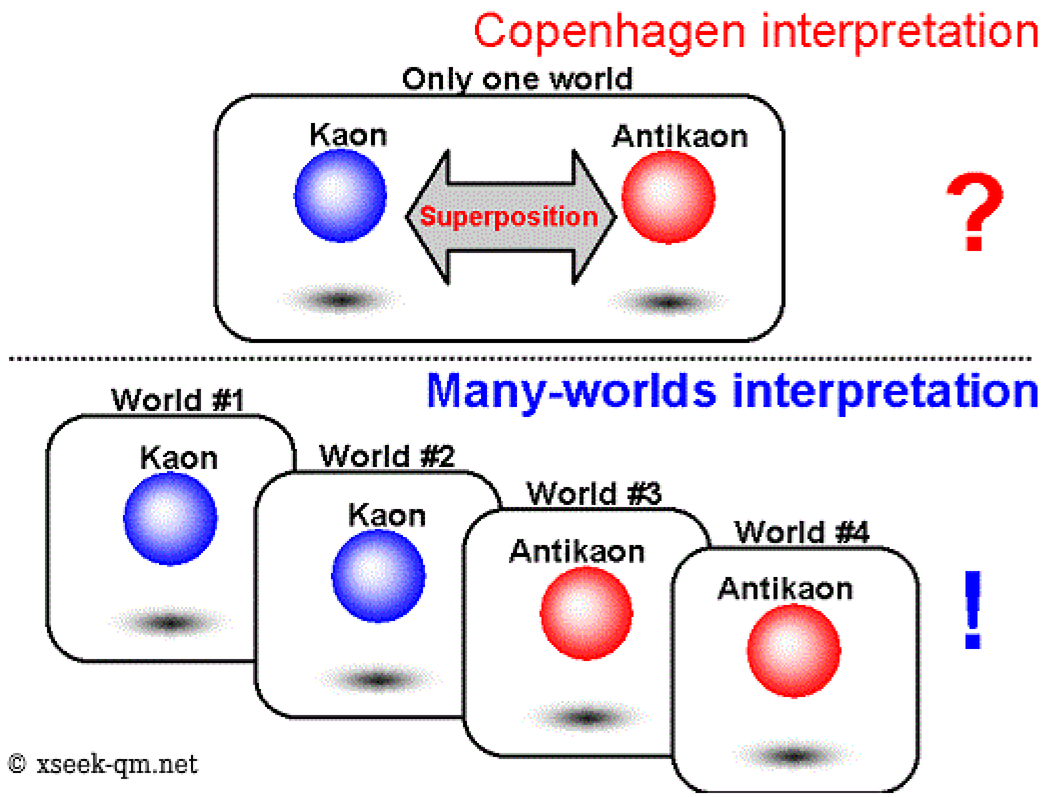
Measurement and Observation

- The act of measurement or observation is intimately connected with wave function collapse, wherein a wave function initially in a superposition of states reduces to a single state.
- The role of the observer in the collapse process has been a subject of controversy, with some interpretations suggesting that consciousness may play a role, while others, like the ‘Many Worlds’ interpretation, deny the collapse altogether.
- The measurement problem in quantum mechanics highlights the ambiguity around how or whether wave function collapse occurs, as this process is not directly observable, and measurements always yield a definite state.

Alternate Interpretations

In exploring the rich tapestry of interpretations that challenge the traditional view of wave function collapse, the academic community has put forth several compelling theories. These interpretations offer diverse perspectives on the nature of quantum reality:

Many-Worlds Interpretation by Hugh Everett:



Branching Universes: Everett's interpretation posits that with each measurement, the universe splits into a multitude of parallel branches, each representing a different outcome of the measurement process.

No Collapse: It contends that the wave function never collapses; rather, all possible outcomes outlined by the wave function are realized in their respective branches, effectively removing the traditional measurement problem from quantum mechanics.

Parallel Outcomes: This interpretation leads to the existence of multiple, non-communicating parallel universes, where each possible outcome of a quantum measurement is actualized.

Pilot-Wave Theory (de Broglie–Bohm theory):

Wave-Particle Duality: This theory upholds that quantum systems possess both particle and wave properties simultaneously, with the 'pilot wave' guiding the particles along specific trajectories.

Deterministic Evolution: Unlike the probabilistic nature of the wave function collapse, the pilot wave and the particle's position evolve in a deterministic manner, thus avoiding the need for a collapse.

Definite Properties: Particles are ascribed definite positions and velocities, offering a clear counterpoint to the indeterminacy inherent in other interpretations.

Transactional Interpretation of Quantum Mechanics:

Wave Interaction: This interpretation conceptualizes quantum interactions as a complex exchange involving both forward-in-time (retarded) and backward-in-time (advanced) waves.

Quantum Handshake: These waves engage in a 'handshake' across time, facilitating the transactional nature of quantum events without necessitating the collapse of the wave function.

Outcome Determination: The interplay between past and future waves is what determines the outcomes observed in quantum experiments, thus providing an alternative to the collapse mechanism.

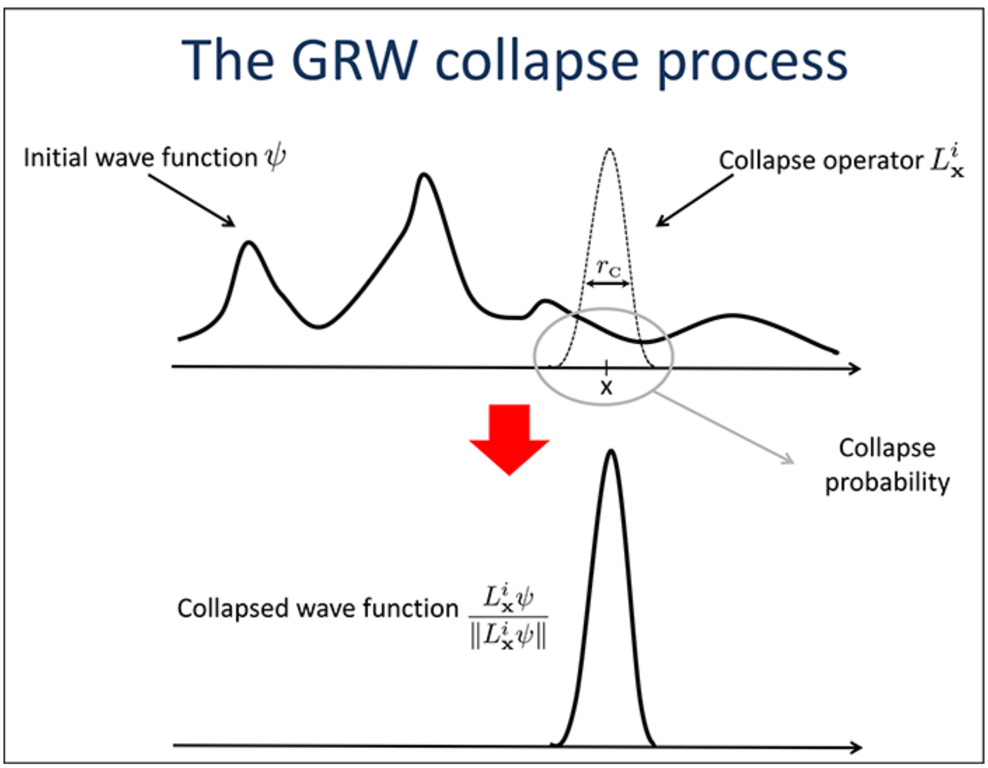
The debate surrounding these interpretations often touches upon the role of consciousness in the quantum realm. Some schools of thought speculate that consciousness may induce the collapse of the wave function, while others firmly reject this notion. Additionally, interpretations like Super-determinism introduce the concept of a predetermined universe, where all events are the result of an underlying force, preserving the notion of locality.

The Many-Worlds Interpretation, in particular, offers a unique perspective by suggesting that the universe's wave function persists in a superposition and that what we perceive as measurement is actually an entanglement between entities, leading to a universe-wide superposition that sidesteps the traditional measurement quandary. This perspectival theory, by postulating the continuous branching of wave functions, provides a framework where multiple realities coexist contemporaneously, thus circumventing the collapse-induced measurement problem.

Objective Collapse Theories

Objective collapse theories represent a group of models that modify the traditional quantum framework to account for the collapse of the wave function, a phenomenon that has perplexed physicists since the inception of quantum theory. These models aim to provide a physical mechanism for the wave function's reduction during a measurement, thereby addressing the measurement problem in quantum mechanics. Here, we explore some of the most notable objective collapse models and the experimental efforts to test their validity:

GRW and CSL Models



Spontaneous Localization: The Ghirardi-Rimini-Weber (GRW) model introduces the concept of spontaneous collapses in space, which occur randomly in time and space for each constituent of a physical system.

Continuous Spontaneous Localization (CSL): This model extends the GRW framework and incorporates a nonlinear, stochastic diffusion process driven by universal noise, which predicts spontaneous collapse for macroscopic objects.

Both GRW and CSL models make falsifiable predictions that differ from standard quantum mechanics, providing a clear avenue for experimental validation.

Diósi-Penrose Model

This model, proposed by Lajos Diósi and Roger Penrose, suggests that gravity may play a crucial role in the collapse of quantum mechanical vibrations, potentially linking the collapse with the emergence of consciousness. The model predicts that gravity-induced collapse would lead to a "permanent zigzagging of particles in space," a process that should generate detectable electromagnetic radiation known as bremsstrahlung.

Experimental Tests and Challenges

- **Testing Predictions**: Recent experiments have placed stringent bounds on the simplest forms of CSL models and have ruled out the most basic version of the Diósi-Penrose model.

- **The Legend Experiment**: Utilizing more massive and sensitive germanium detector arrays, this experiment seeks to push the limits on CSL models further and may provide crucial insights into the validity of objective collapse theories.
- **Relativistic Consistency**: Critics of objective collapse theories point out potential issues with energy conservation, compatibility with relativity, and the ‘tails problem’, where the wave function never fully collapses, leaving residual probabilities.

Objective collapse theories, by proposing a unified dynamics for both microscopic and macroscopic processes, offer a compelling resolution to the measurement problem. They suggest that interactions during measurement lead to wave packet reduction, thus ensuring that quantum measurements always result in definite outcomes.

Quantum Entanglement and Nonlocality

Quantum entanglement and nonlocality are two of the most intriguing concepts in quantum mechanics, challenging our classical understanding of space and causality. Here, we explore these phenomena and their implications:

Quantum Entanglement:

Correlated Particles: When particles interact, they may become entangled, meaning their states are so deeply connected that they cannot be described independently of each other. This entanglement persists even when the particles are separated by vast distances.

Loss of Individuality: Entangled particles effectively behave as a single entity. Their individual properties become indeterminate and instead are defined by the overall state of the system.

Model-Dependent Property: Entanglement is dependent on the theoretical framework used to describe it. While it is a key feature of quantum mechanics, its interpretation can vary across different models.

Nonlocality:

Instantaneous Coordination: Nonlocality describes how entangled particles seem to instantly coordinate their states, a phenomenon that has been repeatedly demonstrated in experiments such as the Bell test and the EPR experiment.

Challenging Locality: This instantaneous coordination conflicts with the principle of locality, which holds that an object is only directly influenced by its immediate surroundings. Nonlocality suggests that objects can have immediate influences on each other, regardless of distance.

Compatibility with Relativity: Despite its counterintuitive nature, quantum nonlocality does not allow for faster-than-light communication and thus remains compatible with the theory of special relativity.

Experimental Evidence and Challenges:

Bell Test and EPR Experiment: Experiments like the Bell test have confirmed that quantum mechanics' predictions regarding entanglement are correct, showcasing that entanglement is a real and fundamental aspect of the quantum world.

Nonlocal Correlations: Not all entangled states result in Bell nonlocal correlations, and not all Bell nonlocal states are maximally entangled, indicating that quantum correlations are restricted by the laws of quantum mechanics.

Foundational Discussions: These experimental confirmations of entanglement and nonlocality have led to ongoing foundational discussions about the nature of reality and how these phenomena fit within the broader framework of quantum theory.

Quantum entanglement and nonlocality not only challenge our classical intuitions about the world but also open up possibilities for new technologies and deepen our understanding of the universe. They highlight the interconnectedness of quantum systems and raise profound questions about the fundamental principles that govern the natural world.

The Problem of Measurement

The Correspondence Principle and the Measurement Problem:

- The Correspondence Principle, as articulated by Bohr, mandates that quantum mechanics must align with classical physics on a macroscopic scale, ensuring that the behaviors predicted by quantum theories do not conflict with classical observations when systems are large enough.
- However, the measurement problem introduces a significant challenge to this principle by questioning what constitutes a 'measurement' and how such an action influences quantum systems.

The Observer's Role:

The observer's role in the collapse of the wave function is a subject of intense debate, with theories ranging from the observer's consciousness impacting collapse to the mere act of measurement causing it. This debate is fueled by the lack of a clear definition within standard quantum mechanics of what 'measurement' entails, despite the theory's ability to predict the outcomes of measurements.

The Measurement Problem Explored:

Theoretical Challenges: The measurement problem presents a conundrum in quantum mechanics, questioning the connection between the act of measurement and the behavior of quantum systems. It raises concerns about our ability to associate quantum behavior with an underlying physical reality, suggesting that quantum theory may be more about perception or knowledge than about reality itself.

Approaches to Resolution: Consistent histories, or decoherent histories, provide a framework for a more classical description of quantum events, yet they fall short of resolving the measurement problem. Ormrod, Venkatesh, and Barrett propose a theorem that explores why certain theories, like quantum mechanics, face a measurement problem and how alternative theories might circumvent this issue.

Implications for Quantum Mechanics: The measurement problem has far-reaching implications for our understanding of reality, the interpretation of quantum mechanics, and the advancement of quantum technologies. It highlights the need for a more comprehensive understanding of the measurement process, questioning the completeness and consistency of quantum theory. Addressing the measurement problem could pave the way for groundbreaking developments in quantum foundations and the creation of innovative quantum technologies. The measurement problem remains a foundational issue within quantum mechanics, often overshadowed by the empirical success of the theory throughout the 20th century. It continues to be a central topic of discussion and research, with the potential to significantly alter our understanding of quantum phenomena and their applications.

Conclusion

The enigmatic quantum realm, as explored within this discourse, highlights the pertinacious connection between the collapse of the wave function and the very fabric of reality. In tracing the historical framework and debating the merits of various interpretations — from the Copenhagen to the many-worlds hypothesis — my article reaffirms that the wave function is the heart of reality.

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