# An attempt to reconcile quantum mechanical interpretations

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Abstract for academic philosophers: *The first five chapters can be skipped by academic philosophers, if they wish to do so. In a nutshell, they provide arguments for physicists to consider philosophical idealism [1] more earnestly. In proper philosophical terms and in layman language (think of OLP or "Oxford philosophy" [2]), I want to argue in terms of Immanuel Kant's Transcendental Idealism [3] as follows: By positing that nature conforms to physicalism [4] or materialism [5], physicists make a synthetic* a priori *statement without proof. I would like to take a step back and start with no metaphysical* a priori *assumptions about nature at all. This allows for the reconsideration of scientific idealism, starting with our own existence (think of "*cogito, ergo sum*", or Johann Fichte's* "the I posits itself*" from his* 'Wissenschaftslehre' [6]*). From there, I will attempt a philosophical re-examination of our existing knowledge of physics and other sciences. In the spirit of a natural scientist and in line with the neo-Kantian Marburg school [7], I take the scientific method and experimental findings (i.e. empiricism [8]) more strongly into account than most branches of philosophy do.*

## Chapter 1 – The infinitely far and infinitely small

The current gridlock in physics is largely due to the open question of how to reconcile quantum mechanics with gravity or general relativity. Additionally, we still do not know how to accurately describe the microcosm below the Planck Scale, with theories like String theory or Loop Quantum Gravity all having their own inadequacies and perhaps never testable. In the past few decades we made gradual progress on our journey towards the infinitely far (e.g. black holes) and the infinitely small (e.g. Higgs boson), but it feels like we're getting diminishing returns. This is akin to Zeno's paradox of travelling a path of length 1. At first we travel the distance ½, then the distance ¼, then $^1/_8$, $^1/_{16}$, and so on. What if incremental scientific discoveries towards the infinitely far and the infinitely small work in the same way as Zeno's paradox, namely that the impact of each new scientific discovery gradually diminishes, and we will never fully reach the goal?[1] This would be akin to the physicists of the late 19th century realizing that for too long they believed in the hypothesis of a luminiferous aether, until the Michelson-Morley experiment convinced them to let go of this Fata Morgana. We should therefore at least consider the possibility that the infinitely far (how to ever know what lies beyond the observable universe?) and the infinitely small (weird, inaccessible wonderland physics below the Planck Scale) are also some kind of mirages that we should shackle off, and instead try to think of something else.

| Interpre-tation | Year pub-lished | Author(s) | Determ-inistic? | Ontic wave-function? | Unique history? | Hidden variables? | Collapsing wave-functions? | Observer role? | Local dyna-mics? | Counter-factually definite? | Extant universal wave-function? |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ensemble interpretation | 1926 | Max Born | Agnostic | No | Yes | Agnostic | No | No | No | No | No |
| Copenhagen interpretation | 1927 | Niels Bohr, Werner Heisenberg | No | Some[60] | Yes | No | Some[61] | No[62][63] | Yes | No | No |
| De Broglie–Bohm theory | 1927–1952 | Louis de Broglie, David Bohm | Yes | Yes[a] | Yes[b] | Yes | Phenomen-ological | No | No | Yes | Yes |
| Quantum logic | 1936 | Garrett Birkhoff | Agnostic | Agnostic | Yes[c] | No | No | Interpre-tational[d] | Agnostic | No | No |
| Time-symmetric theories | 1955 | Satosi Watanabe | Yes | No | Yes | Yes | No | No | No[64] | No | Yes |
| Many-worlds interpretation | 1957 | Hugh Everett | Yes | Yes | No | No | No | No | Yes | Ill-posed | Yes |
| Consciousness causes collapse | 1961–1993 | Eugene Wigner, Henry Stapp | No | Yes | Yes | No | Yes | Causal | No | No | Yes |
| Many-minds interpretation | 1970 | H. Dieter Zeh | Yes | Yes | No | No | No | Interpre-tational[e] | Yes | Ill-posed | Yes |
| Consistent histories | 1984 | Robert B. Griffiths | No | No | No | No | No[f] | No[g] | Yes | No | Yes |
| Transactional interpretation | 1986 | John G. Cramer | No | Yes | Yes | No | Yes[h] | No | No[i] | Yes | No |
| Objective-collapse theories | 1986–1989 | Giancarlo Ghirardi, Alberto Rimini, Tullio Weber, Roger Penrose | No | Yes | Yes | No | Yes | No | No | No | No |
| Relational interpretation | 1994 | Carlo Rovelli | No[65] | No | Agnostic[j] | No | Yes[k] | Intrinsic[l] | Possibly[m] | No | No |
| QBism | 2010 | Christopher Fuchs, Rüdiger Schack | No | No[n] | Agnostic[o] | No | Yes[p] | Intrinsic[q] | Yes | No | No |

Figure 1: Overview of quantum-mechanical interpretations [11]

1 This could be imagined as repeatedly turning on and off a light switch with each new discovery ad infinitum, as succinctly described by David Deutsch in a recent video interview (around time mark 9:15 of [9]). From this he concludes that you need something that defines the limit. Deutsch even mentions the possibility that "there may be a better understanding that tells us it [infinity] doesn't make sense." (time mark 5:40 of [9]). Eliminating infinity is also what Werner Heisenberg did when introducing modern quantum mechanics in his 1925 paper. [10] The old, heuristic quantum theory (1900-1925) relied on infinite, convergent series to calculate observable quantities. [10]

Since quantum mechanics is our most accurate and best experimentally verified physical theory, we focus our attention on it.[2] A main topic in this essay will be the attempt to reconcile the vast zoo of wildly differing interpretations of quantum mechanics[3]. Each interpretation provides valid viewpoints, even though they vastly differ in their view on certain fundamental questions such as wavefunction collapse, determinism, hidden variables, and so on, cf. Figure 1. We propose that they are equally valid ways to look at a whole, a bit like how the Heisenberg picture and Schrödinger picture are equally valid views at a whole. In this essay we will not consider every single interpretation, but instead limit ourselves to the more popular ones and the ones that are the most helpful to explain our framework.

## Chapter 2 – Revisiting the anthropic principle

One possible avenue to steer away from the infinitely far and infinitely small is to revisit the anthropic principle, [13] which (in a nutshell) tells us there is something exceptional about our human existence in a universe of very low probability. If we were to ever understand quantum mechanics, wouldn't it be nice if we would also get a better understanding of the human condition? For all we know, there might not even be any theory that can explain all the physical phenomena in our world without taking the human observer into account as well. Many attempts to find a path to such a theory have been made before, for example the Many-Minds Interpretation of quantum mechanics [15] or the belief of Roger Penrose that subtle physical processes on the nanometer scale at the frontier between classical physics and quantum mechanics lead to a highly developed nervous system, which we commonly call consciousness. [16] Such theories are frequently dismissed in the scientific community, despite an ever growing body of evidence that certain mesoscopic quantum states can be surprisingly robust and stable, even in far-from ideal environments. After all, there's an entire research field of Quantum Biology, explaining phenomena such as enzyme catalysis or magnetoreception of birds in terms of quantum entanglement. [17] [18] Would it be that far-fetched to assume that a small part of the human brain is capable of controlling targeted quantum effects as well, leading to a better understanding of our mind, consciousness or free will? Very recent research even indicates that quantum-like dynamical effects demonstrated in human brain activity could be the computational backbone of human cognition.[4] [19] The quantum-like effects are robust and do not exhibit the fragility of decoherence, which could point towards the emergence of macroscopic quantum computing. [19] In an even more recent book, two of the authors suggest that this could solve a deep conundrum at the heart of human cognition, namely, how the surprisingly slow information transfer between neurons (with typical latencies of around 10−20 ms) is able to solve the time-critical computational problems ensuring survival. [20] Could Penrose's theory of a quantum mind still be vindicated three decades after being originally proposed?[5]

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2 As Feynman said - to the effect - at the beginning of his famous Lectures, philosophising is all good and well, but in the end "*the sole test of the validity of any idea is experiment*". [12]

3 Fundamentally, interpretations of quantum mechanics attempt to match the mathematical formalism of quantum theory with experienced reality. [11] This "match" (or lack thereof) with physical reality is what makes quantum mechanics so unsatisfactory from a philosophical viewpoint.

4 Not yet peer-reviewed, but authored by prestigious scientists, including Oxford Professor Morten Kringelbach. From a LinkedIn summary of one of the co-authors [14]: "A QL (quantum-like) system is a complex network of coupled oscillators, whose spectral properties are strikingly similar to those of quantum systems. *This is interesting because we can then use quantum mechanics to model these classical systems.* An advantage of this is e.g. the ultra fast information transfer at a distance encoded in entanglement. For a system like the human brain, which uses almost 1,000,000 times less power than the most advanced computing systems, the QL model provides an intriguing solution to how a system can transmit information so efficiently. We show that functional connectivity of the human cortex is most precisely given by a QL model. *In other words, it is likely probable that our brain regions talk to each other the same way as a group of entangled electrons."*

5 In this introductory Part 1 of the essay we only introduce the most striking arguments for quantum effects in our brains. Further arguments will be summarised in Chapter 8 of Part 2.

Surprisingly, only a tiny part of the human brain would need to be able to perform basic quantum computational tasks, while the vast remainder of the brain only performs classical information processing, and still we would reap the fruits of a profound computational speed-up! This is due to computational complexity theory, specifically the complexity class PP (probabilistic polynomial-time), the class of decision problems solvable by a classical, probabilistic Turing machine in polynomial time with an error probability less than ½. [22] The complexity class PP is widely considered to be much more powerful than the purely deterministic class P (polynomial-time) that governs classical information processing (cf. Figure 2), but from the viewpoint of theoretical computer science it is not straightforward to add probabilistic behaviour to a Turing machine. For us quantum physicists, however, there is a workaround: by performing quantum measurements, which leads to probabilistic outcomes based on genuine randomness on a physical level.[6] If the small "quantum part" of our brain acts as an observer and performs inherently probabilistic quantum measurements, then together with the large "classical part" of our brain, we could in principle solve problems that lie in PP.

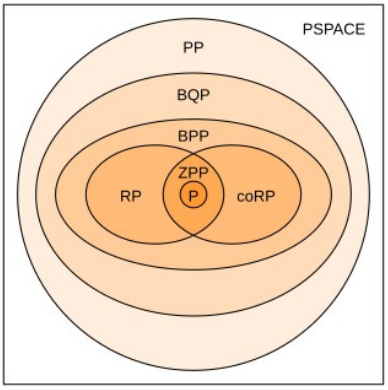



Figure 2: Hierarchy of different computational complexity classes [22]

What is more, Scott Aaronson proved that PP = PostBQP (Postselected Bounded-Error Quantum Polynomial-Time), the latter being the class of problems efficiently solvable by a quantum computer equipped with the ability to postselect on the outcomes of measurements.[7] [25] This provides us with an operational interpretation to imagine what is happening inside the tiny "quantum part" of our brain: Our mind or (sub-)consciousness is a simple quantum processing device (not necessarily full quantum Turing machine), and what we consider our free will is the ability – to a certain degree – to postselect the desired measurement outcome. So, if we make a resolution in our mind, for example to go out for a walk in the park, then our "quantum brain" would pick those measurement outcomes that gradually steer us towards getting dressed, get out of the house, walk to the park, and so on.[8] As unorthodox as this sounds, this would allow us to integrate two pivotal interpretations of quantum mechanics: the Copenhagen interpretation and the Many-Worlds interpretation (MWI). The Copenhagen interpretation suffers from the unexplainable special status of a classical, external observer, whereas the MWI suffers from the unknown branching rules between universes. We propose the following combination of three concepts, namely free will, Copenhagen interpretation and the MWI: The measurement process of the Copenhagen interpretation takes place in the quantum part of our brain, perhaps in the form of a

6 In general, PP speed-up can also be achieved by a pseudorandom number generator, but depending on the complexity of the problem, the randomness must be sufficiently good to explore enough of the search space. Considering the incomprehensible complexity of the quantum universe, one could argue that in this case only quantum randomness suffices. A humorous quote of John von Neumann springs to mind: *"Anyone who considers arithmetical methods of producing random digits is, of course, in a state of sin."* [21]

7 Interestingly, Aaronson's motivation for this result came from the idea of "anthropic computing", namely arranging things so that we are more likely to exist if a computer produces a desired output. [25]

8 What could be happening inside our brain if we instead ponder on deeper scientific questions that go beyond the complexity class P: the conscious, classical (P) part of our brain is querying the subconscious, quantum (PP) part as a kind of biological oracle with a yes/no question, and the quantum part is returning the answer to the classical part of the brain, which could in rare events lead to a major discovery. In fact, this querying of an "oracle" can be described in the language of computational complexity theory, which also has the concept of an oracle: PP is closed under polynomial-time truth-table reductions, [25] which refers to a machine making non-adaptive queries to a PP oracle. [28] In other words, $PP = P^{PP}$, where $P^{PP}$ is the class of problems solvable by a P machine that can make a polynomial number of non-adaptive queries to a PP oracle.

"weak" measurement[9], and instead of a wavefunction collapse, the outcome decides our branching in the multiverse[10]. This would solve long-standing issues with the Copenhagen interpretation, the MWI, and whether humans have a free will.[11] Note that the idea of mind influencing matter by means of quantum processes is not new (see e.g. references in [29]), but to our knowledge this has not been linked to both the Copenhagen interpretation and the MWI before. We also note that Deutsch already pointed out this compatibility of free will with physics, thanks to the multiverse character of quantum reality, in his 1997 book "*The Fabric of Reality*".[12] [23]

We note that our framework is similar, but not equivalent to the "consciousness causes collapse" interpretation of quantum mechanics, as once advocated by Eugene Wigner. [30] Firstly, in our framework there isn't really a collapse of the wavefunction, but rather branching of the universal state, and secondly, our framework does not lead to the controversial self-centric philosophical idea of Solipsism [33], because not only one's own free will, but also the free will of all other people influences our branching in the multiverse.[13] Which leads us straight to the thought experiment of Wigner's Friend. [34] In our framework this *gedankenexperiment* does not lead to a paradox, because both Wigner and his friend independently perform weak measurements in their minds, and each measurement results in a branching of the world that affects them both. This is also very much in line with the Relational interpretation of quantum mechanics (RQM), where the notion of "state" is always relative to some observer and there is no privileged, "real" account. [35] The essential idea behind RQM is that different observers give different accounts. For example, to one observer, a system is in a single eigenstate, but to a second observer, the same system is in a superposition of two or more states and the first observer is in a correlated superposition of two or more states. [35] This example can be translated into our framework as the two observers having branched into two different universes.

Our hypothesis of a dual classical and quantum brain is also highly compatible with the long-standing dual process theory of neuroscience, [36] namely that there is intriguing behavioural evidence that the human mind consists of two competing fast and slow systems. [20] System 1 is fast, instinctive and emotional, whereas System 2 is much slower, more deliberative, and more logical. System 2 has limited access to System 1, which is the main source of impressions, intuitions, intentions and emotions. [20] A firm neurobiological foundation of these systems has not

9 Possibly, this "weak measurement" is the one theorised by Yakir Aharonov. Weak measurements are the experimental procedure of extracting minute amounts of information about a quantum system without collapsing its state. Weak values are the statistical outcomes - often unusual or seemingly impossible - that emerge when weak measurement is combined with postselection. [26] [27]

10 This "branching in the multiverse" should not be taken too literally, as if all the alternative universes are physically real and present. As we will see in Part 2 when doing proper philosophy, the MWI as well as all other interpretations of quantum mechanics should rather be seen as analogies or models, each of which captures different aspects of a metaphysical whole (related to what Immanuel Kant called 'synthetic *a priori* statements').

11 From the viewpoint of the philosophy of mind, our concept of how mind and matter interact with each other roughly matches the theory of interactionism. [24]

12 Specifically, on p. 338-339 and Table 13.I of [23]. There Deutsch describes how our free will manifests itself through the amount of copies of ourselves in the multiverse that have made the choice that we wish to make. Although this is not a direct integration of free will in the MWI (in the form of influencing our branching), free will does seem to enter through the back door: if not free will, then what else mediates the branching to reach those copies of ourselves where we made the choice we wished for?

13 How exactly the free will of other people affects our own branching is a more complex topic and will be explored in Part 2 of this essay. There, we will for example consider Arthur Schopenhauer's theory of of a blind will that is encompassing all humans, and Carl Jung's theory of the collective unconscious, encompassing the "soul of humanity at large", [31] [32] a concept that always struck me as highly unscientific, but which might have a scientific grounding in our framework.

yet been established, but we might be able to provide a clue: System 1 could be understood as the quantum computing part and System 2 as the classical information processing part![14]

Let's assume that not only humans, but also animals such as cats, have tiny, rudimentary quantum computing capabilities that allow them to influence their branching in the multiverse through their actions or desires. Then we could reformulate the Schrödinger cat *gedankenexperiment* as follows: If the cat is placed inside a box where the probability for the apparatus to kill it within a certain timespan is p = 0.5, then the cat might be able to minimally improve its likelihood to survive, say to p = 0.5001, simply by being a conscious observer with a will to live, cf. Figure 3. Such a change of probabilities sounds unscientific, but firstly we note that the increased survival rate applies to the cat's own branching in the multiverse, and thus cannot be directly experimentally verified by a second observer branching into a different universe. Secondly, the increased survival rate might express itself into reality by the cat instinctively feeling that something is very wrong indeed while being placed inside the box and frantically trying to escape.[15] This would be strikingly reminiscent of the intriguing, or rather instinctive animal trait of getting alarmed of natural disasters long before humans. Kudos the famous expression of rats leaving the sinking ship, but also well-documented events during the 2004 Thailand tsunami, where e.g. elephants sensed the pending danger long before humans and fled for higher grounds (see e.g. [37] [38]). This incident of a "sixth sense" is generally attributed to elephants being able to feel the seismic vibrations of the earthquake or the infrasound of the nearing tsunami, but such explanations do not sound very convincing to me. Even if elephants were such highly sensitive laboratory apparatuses on four feet, then how come they can correctly interpret the sensations as omens of an impending natural disaster, rather than e.g. an industrial vacuum cleaner in operation nearby? After all, from a purely intellectual viewpoint, elephants are considered less intelligent than humans. Within our framework Occam's razor [39] would suggest that the quantum part of elephants' brains provides a stronger survival instinct than humans, resulting in a more pronounced universal branching in case of life-threatening situations, resulting in them to subconsciously flee before disaster hits.

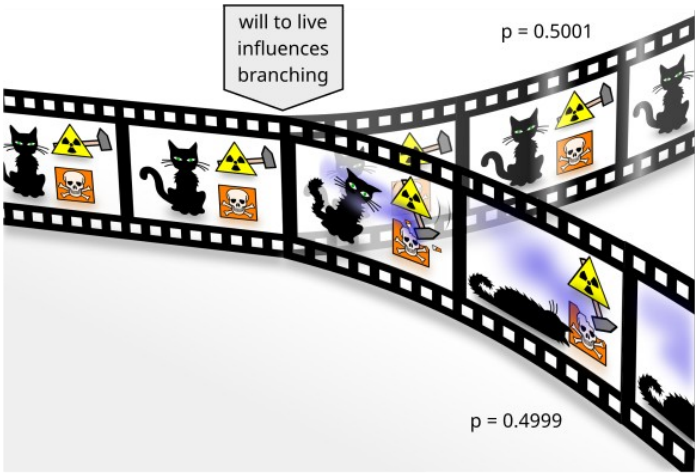



Figure 3: through its will to live the Schrödinger cat subtly alters its fate (simplified visualisation)

14 With regard to learning new skills such as how to drive a car, the activity in our brain could be described as follows: While learning how to drive in driving school, we have to consciously and deliberatively think about each individual step (such as staying in lane or shifting gears) with our classical System 2, which is slow, arduous and takes a lot of effort. Once we have mastered the basics, car driving becomes much easier and intuitive for us, as we can rely on our much faster, subconscious quantum System 1. This is also very much in line with what Marvin Minsky, the MIT professor who built the world's first neural network machine, once said about intelligence: "In general, we are least aware of what our minds do best." With this quote, Minsky refers to the fact, that things we do with apparent ease, such a reading a face, walking through a crowded room, understanding a sentence, etc. are not simple at all. They are the products of staggeringly complex networks running so smoothly, so far below conscious access, that you experience them as effortless. The things that feel like work, the logical arguments, the deliberate choices, the careful plans, are actually the clumsy surface layer, the small fraction of mental activity you can observe at all. So in some sense we are taking credit for the wrong parts of our own intelligence.

15 An improved survival rate though the will to live could also be behind the well-documented and statistically significant phenomenon of the placebo effect in medicine. As scientific studies have shown, simply by believing that a placebo works the health outlook will be improved. Conversely, a nocebo or also a clinical depression can sometimes be crippling to a patient's health, something which is also acknowledged among medical practitioners.

But for now let’s return to more tangible physical concepts. Although our framework still lacks objective experimental validation, it could help getting a better understanding of a remarkably large number of open questions in quantum mechanics, quantum information theory, and some aspects of the human condition. We note that our framework is also compatible with the Consistent Histories interpretation of quantum mechanics, which allows to assign probabilities to various alternative histories of a system such that the probabilities for each history obey the rules of classical probability while being consistent with the Schrödinger equation. [40] This interpretation could also provide probability distributions for our branching in the multiverse between different histories that are counterfactual to each other[16], but from our viewpoint as the observer our own history always appears consistent.[17] Criticism of the Consistent Histories interpretation is based around the lack of a selection rule, [40] but this can be resolved in our framework through the aforementioned branching in the multiverse. So far we managed to reconcile quite a few concepts and interpretations of quantum mechanics that are frequently considered to be at odds with each other, just like the pieces of a very complicated puzzle finally coming together. An open problem in our framework, however, stems from the very beginning of our essay, namely that we still need to provide a moderately convincing physical explanation for why we can ignore the infinitely far and infinitely small. We will tackle this in the next chapter.

**Chapter 3 – The game of life**

In mathematics a set of simple rules and initial conditions can often lead to surprisingly complex systems. One well-known example is Conway's Game of Life from 1970, a cellular automaton set in an infinite two-dimensional orthogonal grid of square cells, each of which is in one of two possible states, live or dead. [41] A few very simple rules determine the evolution of the entire system, resulting in vastly different outcomes depending on the initial configuration, with live cells forming larger shapes such as “still lifes”, “oscillators” or “spaceships”. We also note that already Edward Fredkin and Konrad Zuse pioneered the idea of a computable universe, the former by writing a line in his book on how the world might be like a cellular automaton, and the latter having the idea that the universe is running on a grid of computers. [42] [43] More recently, Stephen Wolfram claimed in his 2002 book *“A New Kind of Science”* that simple computational systems are needed to model and understand complexity in nature. [42] He predicted that the realisation of this within scientific communities would have a revolutionary influence on physics, chemistry, biology, and most other scientific areas, hence the book's title. [44] He beliefs that complexity is not a special quality of systems, but simply a label for all systems whose computations are sophisticated, [44] something that shares parallels with our framework of a human mind experience that is dependent on quantum computing processes. Wolfram suggests that the theory of computational irreducibility may explain how free will is possible in a nominally deterministic universe. He posits that the computational process in the brain of the being with free will is so complex that it cannot be captured in a simpler computation, due to the principle of computational irreducibility. [44] In our opinion, however, a mistake that Wolfram makes is his assumption that quantum mechanics is only an approximation to an underlying classical theory (for a professional critique see page 416 of [45]), something that does not stand the test of Occam’s razor in our framework.

16 The field of counterfactual history rejects philosophical determinism, highlighting human choice instead. As a field of study, it however struggles for acceptance by academic historians.

17 At first glance it’s not clear if in our framework the branching in the multiverse is only permitted between so-called strongly consistent histories (Trace of class operator over density matrix = 0) or if branching is also permitted between weakly consistent histories (Trace of class operator over density matrix ≈ 0). [40] The latter may possibly be related to the weak measurements and thus the concept of free will in our framework.

Thus far we have established that in our framework our reality would be directly affected by quantum processes within our brain, yet we cannot fully grasp this with our senses, because we are predominantly classical-information processing lifeforms that process quantum information only in the subconsciousness. In other words, what we perceive as our reality could be imagined as an information-theoretical projection of an underlying, deeper quantum-information theoretical nature, a bit like living in Plato's cave. [46] A more modern allegory is the 1884 novella *"Flatland"* by Edwin A. Abbott, with a two-dimensional world that is inhabited by geometric figures such as triangles, squares, and so on. The main character, a Square, has a dream of visiting the one-dimensional world "Lineland", where only points and lines can exist and which are unable to see the visiting Square as anything other than a set of points on a line, or in other words a one-dimensional projection. The Square tries to convince the monarch of Lineland of a second dimension, but is unsuccessful to do so. After his return to Flatland, the Square is later visited himself by a Sphere from the third dimension. The Sphere tries to convince the Square of the existence of a third dimension through various means, but is unable to do so, because in Flatland the Sphere can only manifest itself as a two-dimensional projection. Only after the Square is taken by the Sphere to the third dimension, Spaceland, does the Square finally realize and accept the existence of higher dimensions. Why this digression with the story of "Flatland"? It serves as an illustration that even intelligent and educated minds can struggle with concepts that are so outlandish and novel, that the rational part of our mind is unwilling to believe them. The philosophical idea that we formulate next can be similarly perplexing even for physicists working on the foundations of quantum mechanics.

In his 1997 book "*The Fabric of Reality*" [23], Deutsch assumes that a "Theory of Everything" (TOE) would be emergentist rather than reductive, and that it would include multiversal, computational, epistemological and evolutionary principles. [50] I fully agree with Deutsch that bold conjectures that resist falsification need to be taken seriously, but I don't share his view of a purely realist[18] interpretation of scientific theories. [50] Yet again, I agree with Deutsch regarding the significance of constructor theory, [53] [54] and him predicting that constructor theory will supersede the entire structure of physical explanation, allowing the conjecturing of new laws (time mark 16:15 to 17:10 of [9]). Enter the constructor theory of life, as proposed by Chiara Marletto. [56] [57] This is an attempt to combine constructor theory and neo-Darwinian evolutionary theory, typically by considering our genetic code, such as DNA or RNA. Instead of considering classical information, however, I suggest that constructor theory could be connected to quantum information, specifically our quantum brain. We have already seen in Chapter 2 that our free will could be linked to our branching in the multiverse (cf. Figure 3). If the quantum processes in our brain can be linked to the constructor of life, then the reality that we perceive with our mind could be understood as being generated by constructor theory in accordance with our branching in the multiverse.[19] This would imply that most objects, phenomena and even natural laws are emergent rather than pre-

18 As opposed to philosophical idealism/antirealism [1], nowadays a minority belief among philosophers. [48] [49] Notably, in his '*Critique of Pure Reason*' Immanuel Kant argued for Transcendental Idealism, [3] which asserts that space and time do not have an independent existence outside of our human mind. It should also be noted that while this vision cuts sharply against Western thought, Indian and Chinese philosophy have explored for many centuries that nothing enjoys absolute metaphysical priority, not even the universe as a whole. (see e.g. [55])

19 Again, this should not be taken literally, for the same reason as in Footnote 10 (namely an analogy to describe a metaphysical concept). From a philosophical point of view, we have to consider this interpretation of constructor theory in our essay too, because it can provide a physical explanation for how the '*empirically real*' (Kant) reality could be physically generated, in case nature is best described by philosophical idealism (as chiefly initiated by George Berkeley and Immanuel Kant). An alternative analogy of our reality playing out through the mind is the following: As Feynman already noticed, a quantum computer can be used to efficiently simulate quantum systems. Hence, our quantum brain has in principle the potential to influence the quantum universe that we perceive as our reality – akin to a literal game of life. Max Planck already said in 1931: *"I regard consciousness as fundamental. I regard matter as derivative from consciousness."* [58]

existing, created by programmable constructors inside (and outside) our minds.[20] In this framework, "the universal constructor, a machine that can be programmed to perform not just all possible computations, but all physical transformations that are allowed by the laws of physics" [59] could be assumed to be intimately related to our own subconsciousness as well as that of other people.[21] Note that the phrase "allowed by the laws of physics" in the previous sentence may or may not have to be re-phrased as "allowed by the laws of physics *constructed so far*"[22]. Marletto speculates that there could be an era, far in the future, where this all-powerful 3D printer could be a part of our lives as computers are now. [59] I propose that it has been with us already, in our brains!

Bearing this extremely anthropocentric theory in mind, it's already fairly obvious that we need not concern ourselves too much with the infinitely far and infinitely small. The *ignorabimus* regarding what might lie beyond the observable universe (93 billion light-years in diameter) or what happens below the Planck scale ($1.616 \times 10^{-35}$ m) could be due to hitting construction-related dead ends. So why not rather try to get a better understanding in which way it may be possible to "revolutionise our civilisation"? [59]

**Outlook**

If we had to sum up our bold framework in one sentence, then it would be: "It's not so much quantum mechanics that is utterly bizarre, it's our own existence and reality." Or put in a different way: "We are trying to understand the hard sciences by trying to understand the hard problem", as the problem of conciousness is known in the philosophy of mind. This could allow us to gain a better understanding of quantum mechanics[23], the anthropic principle and free will. Regarding possible experimental validation, we point out an intriguing proposal that due to local activity in neuronal axon hillocks "weak violations" of the second law of thermodynamics (a statistical law, not a conservation law) may manifest themselves inside the quantum-part of the brain in the from of local temperature decreases of the order of $10^{-9}$ K, which could in principle be detected experimentally. [29] [62] A physical explanation for such statistically unlikely thermodynamical effects could be the previously mentioned weak measurements that often result in statistically unlikely outcomes.

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20 Note the connection to the "It from Bit" [47] (Wheeler) as well as the related "It from Qubit" (Deutsch et al.) paradigm. They essentially say that space, time and matter are not the fundamental building blocks of the universe, but emerge from quantum information. In fact, it has been noted that quantum information-centric interpretations of quantum mechanics often have an immaterialist or observer-centric character. [52] This is also evident in the popular science books of Deutsch and Vedral that often ponder on metaphysical or idealism-related questions.

21 Now it becomes clearer that the Many-Minds interpretation (MMI), also known as Many-Consciousness interpretation, is compatible with our framework too. [15] It describes that while the wavefunction follows deterministic evolution without collapse, the observer experiences a single, classical reality, because their mind (or rather, many copies of their mind) has branched to experience each outcome separately. The main critique of MMI is its reliance on a strict dualism - the separation of mind from the physical world - and the philosophical difficulty of defining exactly what constitutes a "mind", all aspects which – as we will see – our framework can overcome by providing reasonably plausible metaphysical explanations.

22 Regarding special relativity, it has been shown very recently that relativistic spacetime structure does emerge from intrinsic properties of quantum information, and the authors finish on the note that the formulation of an explicit mechanism for this emergence remains an open and profound challenge. [51]

23 We haven't looked at QBism and Bohmian mechanics in detail, but remark that in QBism the degrees of belief an agent has about the possible measurement outcomes could be linked to our concept of free will in conjunction with the transformations allowed by the universal constructor. [60] The "hidden variables" of Bohmian mechanics could be linked to the weak values resulting from weak measurements. This is in agreement with experimental findings: "Generalized particle trajectories can be extrapolated from numerous weak measurements on an ensemble of equally prepared systems, and such trajectories coincide with the de Broglie–Bohm trajectories." [61]

We conclude Part 1 of this essay with the anecdote that in his later life Feynman was pessimistic about the future progress of physics, due to the academic system increasingly forcing us to think in prescribed, standardised ways about physics (time mark 22:45 - 24:00 of [9]). Indeed, we are going against the grain of established beliefs in physics by questioning physicalism [4], and instead considering an idealist worldview where the frontiers of spacetime do not deserve preferential attention. If we can provide experimental results that are consistent with our framework, but cannot be reasonably explained from the viewpoint of scientific realism or physicalism, then the scientific method would imply that our theory is the better one.[24] We hope that Feynman would have enjoyed this essay, even if our framework should turn out to be critically flawed.

Part 2 of this essay will start with revisiting some pivotal experiments of the past 150 years of physics, in order to demonstrate the equivalent explanatory power of our framework. After this, the focus shifts from physics to philosophy, e.g. by revisiting the Free Will Theorem of Conway and Kochen. [64] Other academic fields such as psychology (e.g. the Pauli-Jung conjecture) will be investigated as well. Towards the end of Part 2 we will also discuss the possible application of our framework to improve scientific progress and especially our quality of life.

24 To quote Vlatko Vedral (p. 8-9 of [63]): *'Once we have a theory with too many things in it, we can try to winnow them down with some anthropocentric statement, such as "The laws are the way they are because we humans are here," or perhaps we throw up our hands and take the related view that all mathematical realities are actually represented and we just happen to be in one of them. Neither of these views is testable, and they completely lack explanatory power.'* – Yes, a bit like this, except that we could get a better understanding of quantum mechanics and free will, and it might be testable! Part 2 will deal with this in more detail when doing proper philosophy.

(*We consider Wikipedia and similar websites to be as trustworthy as peer-reviewed papers, because their non-profit authors are generally not interest-driven, whereas peer-reviewed research is generally interest-driven due to the "publish or perish"principle.)*

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