First-Person Plural Quantum Mechanics

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Abstract

Doing justice to quantum mechanics calls for a deeper examination of the relations between our experience, its objects, and its subjects than either third-person interpretations or the first-person singular interpretation of the QBist permit. The metaphysical space opened by Bohr's employment of the "Kantian wedge" between the objective world, about which we can communicate, and the world "in itself" allows quantum mechanics to unfold its metaphysical potential. This in turn makes it possible to go a long way towards bridging the epistemological gap between the empirical and transcendental conceptions of reality.

1 Introduction

Interpretations of quantum mechanics come in a variety of flavors. There are third-person singular interpretations, which strive to make sense of the theory while taking for granted the existence a single, self-existent, mind-independent world. There are third-person plural interpretations, which posit many worlds or a "multiverse." There is the first-person singular interpretation of the QBist or Quantum Bayesian. And then there is the first-person plural interpretation of Niels Bohr, which drives a "Kantian wedge" between the objective world, about which we can communicate, and the world as it may be "in itself," out of relation to our experience.

The present paper aims to show that a metaphysical framework capable of doing justice to quantum mechanics may have to be considerably more complex and wide-ranging than we are generally prepared to envision. Doing justice to quantum mechanics calls for a deeper examination of the relations between our experience, its objects, and its subjects than either third-person interpretations or the first-person singular interpretation permit. Hence, this paper is an essay in first-person plural quantum mechanics. Doing justice to quantum mechanics does not seem possible without making full use of the metaphysical space opened by Bohr's employment of the "Kantian wedge." This space allows quantum mechanics to unfold its metaphysical potential, and this makes it possible to go a long way towards bridging the epistemological gap between "the world as we know it" and "the world in itself." Or so I shall argue.

2 Bohr and "experience"

> *Bohr's claim was that the* classical language is indispensable*. This has remained valid up to the present day. At the* individual *level of clicks in particle detectors and particle tracks on photographs, all measurement results have to be expressed in classical terms. Indeed, the use of the familiar physical quantities of length, time, mass, and momentum–energy at a subatomic scale is due to an extrapolation of the language of classical physics to the non-classical domain.* — Brigitte Falkenburg [1, p. 162]

No one, to my mind, has elucidated our epistemological situation more clearly than Immanuel Kant in the 18th Century and Niels Bohr again in the 20th. Kant taught us to distinguish between two concepts of reality, a transcendental reality and an empirical one, and Bohr stressed the need for this distinction when he reminded us that "in our description of nature the purpose is not to disclose the real essence of the phenomena but only to track down, so far as it is possible, relations between the manifold aspects of our experience" [2, pp. 17–18].

Bohr's reminder has been misconstrued nearly as often as it has been quoted. To give just one recent example, Mermin [3], in a comment published in *Nature*, maintains that Bohr "taught that physical science studies our experience." As far as Bohr is concerned, physical science studies not our experience *qua experience* but the *objectifiable aspects* of our experience. The reason Bohr refers to the *relations* between the manifold aspects of our experience is that it is these relations that make it possible to objectify certain aspects of our experience—to represent them as aspects of a cognizable reality from which we, the objectifying subjects, can abstract ourselves. The logical/grammatical relation between a subject and its predicates makes it possible for us to think of the manifold aspects of our experience as the properties of *substances* (i.e., self-existent objects). Applied to the successive (or timelike related) aspects of our experience, the conditional relation between propositions makes it possible for us to think of these aspects as properties related by *causality*. And applied to the simultaneous (or space-like related) aspects of our experience, the same relation makes it possible for us to think of these aspects as a self-existent system of objects related through *interaction*. The reason Bohr insisted on the use of classical language in describing experiments and reporting results was that he considered the categorial structure implicit in this language a *sine qua non* of empirical science. This structure is in all significant respects identical with the system of categories that Kant had shown to be a precondition of the possibility of empirical knowledge.

In a talk given three months after the publication of his *Nature* comment, Mermin [4] takes a stab at elucidating Bohr's meaning of "experience": "by 'experience' he almost certainly meant the objective readings of large classical instruments." Taken together, the two statements—that physical science studies our experience, and that experience stands for the objective readings of large classical instruments—imply that, according to Bohr, physical science studies the objective readings of large classical instruments, which is a crude statement of instrumentalism and an insult to Bohr.

To determine the import of Bohr's reminder, one has to take account of its context [2, p. 17–18]:

> Now, what gives to the quantum-theoretical description its peculiar characteristic is just this, that in order to evade the quantum of action we must use separate experimental arrangements to obtain accurate measurements of the different quantities, the simultaneous knowledge of which would be required for a complete description based upon the classical theories, and, further, that these experimental results cannot be supplemented by repeated measurements. . . . a subsequent measurement to a certain degree deprives the information given by a previous measurement of its significance for predicting the future course of the phenomena. Obviously, these facts not only set a limit to the *extent* of the information obtainable by measurements, but they also set a limit to the *meaning* which we may attribute to such information. We meet here in a new light the old truth that in our description of nature the purpose is not to disclose the real essence of the phenomena but only to track down, so far as it is possible, relations between the manifold aspects of our experience.

What Bohr concerned was "the task of bringing order into an entirely new field of experience" [5, p. 228], a field of experience that places limits on "the *extent* of the information obtainable by measurements" and on "the *meaning* which we may attribute to such information." When Bohr spoke of a "field of experience," when he insisted that it "lies in the nature of physical observation, that all experience must ultimately be expressed in terms of classical concepts" [2], or when he pointed out that "the requirement of communicability of the circumstances and results of experiments implies that we can speak of well defined experiences only within the framework of ordinary concepts" [6], what he meant by experience was its *objectifiable content*, i.e., an objective reality inevitably conditioned by how we experience it and how we describe it but not fundamentally dependent for its existence on how we experience and describe it nor on the fact that we experience and describe it.

The key to making sense of Bohr, and quite possibly the key to making sense of quantum mechanics itself, is the distinction between two concepts of reality:

(I) a *transcendental* reality undisclosed in experience, which for Kant was the intrinsically unknowable cause of experience, and

(II) the product of a mental synthesis—a synthesis based on the spatiotemporal structure of experience, achieved with the help of relational concepts that derive their meanings from this structure, and resulting in a knowable *empirical* reality from which the objectifying subject can abstract itself.

The reason Bohr insisted that it is not our purpose to "disclose the real essence of the phenomena" was this: while we can describe reality as we experience it, we cannot describe reality as it is in itself, regardless of how it presents itself to us.[1]

Nothing is more central to Bohr's views than the dual necessity (i) of defining observables in terms of the experimental arrangements by which they are measured and (ii) of describing these arrangements in classical terms. Because the limits placed on simultaneous measurements of incompatible observables imply "a complementarity of the possibilities of definition" [2, p. 78], observables can no longer be defined without reference to the "agency of observation" [2, pp. 54, 67] (i.e., the experimental apparatus), so that the "procedure of measurement has an essential influence on the conditions on which the very definition of the physical quantities in

[1]The necessity of making a clear-cut distinction between a transcendental or "veiled" reality and a knowable or "empirical" reality has also been stressed by d'Espagnat [7, 8, 9, 10].

question rests" [11]. The "distinction between object and agency of measurement" is therefore "inherent in our very idea of observation" [2, p. 68]. And since "[o]nly with the help of classical ideas is it possible to ascribe an unambiguous meaning to the results of observation" [2, p. 94], "it would be a misconception to believe that the difficulties of the atomic theory may be evaded by eventually replacing the concepts of classical physics by new conceptual forms" [2, p. 16]. For summaries of Bohr's mature views, which "remained more or less stable at least over the latter thirty years of Bohr's life" [12, p. 138], see Kaiser [13] and MacKinnon [14].

3 Bohr and Kant

> *In my opinion, those who really want to understand contemporary physics—i.e., not only to apply physics in practice but also to make it transparent—will find it useful, even indispensable at a certain stage, to think through Kant's theory of science.*
>
> — Carl Friedrich von Weizsäcker [15, p. 328]

Affinities between Bohr and Kant have been noted by a number of commentators [13, 14, 16, 17, 18, 19, 20, 21, 22, 23], including Cuffaro [24], who holds that any interpretation of Bohr should start with Kant. Kant owes his fame in large part to his successful navigation between the Scylla of transcendental realism (which eventually runs up against the impossible task of explaining the subject in terms of the object) and the Charybdis of a Berkeley-style idealism. What allowed him to steer clear of both horns of the dilemma was a dramatic change of strategy. Instead of trying to formulate a metaphysical picture of the world consistent with Newton's theory, as he had done during the pre-critical period of his philosophy, he inquired into the cognitive conditions that are (i) necessary for the possibility of empirical knowledge and (ii) sufficient for the objective status of Newtonian mechanics. He recognized, as Bitbol [19] has put it, "that the land sought by metaphysics can be foreign to us not due to the excessive distance we have with it, but rather due to its excessive proximity to us."

Kant's reading of classical mechanics dispelled many qualms that had been shared by thinkers at the end of the eighteenth century—qualms about the purely mathematical nature of Newtonian mechanics, about its partial lack of intelligibility (e.g., action at a distance), and about such unfamiliar features as Galileo's principle of relativity. The mathematical nature of Newton's theory was justified not by the Neo-Platonic belief that the book of nature was written in mathematical language but by being a precondition of empirical knowledge. What permits us to look upon the manifold aspects of our experience as the constituents of an objective world is the mathematical regularities that exist between them. They make it possible to synthesize these aspects into a system of interacting re-identifiable objects.

Similarly, Newton's refusal to explain gravitational action at a distance was due not to any incompleteness of his theory but to the fact that the only causality available to us consists in the same regular mathematical connection that permits us to objectify "relations between the manifold aspects of our experience," as Bohr put it a couple of centuries later. As for Galileo's principle of relativity, which asserts that motion is always relative, it is a direct consequence of the fact that regular mathematical connections only exists between particular aspects of experience, i.e., between successive events and between coexisting objects, but never between a particular aspect of experience and either of the general forms of experience, time and space.

In the course of the nineteenth century, most philosophers and apparently many of the scientists who cared to reflect on the nature of science came to adopt (or, in some cases, reinvent) Kant's epistemology. It alleviated the loss of transcendental realism by justifying the use of a universal objectivist language, which made it possible to think and behave *as if* transcendental realism were true. The advent of quantum mechanics dealt a severe blow to this comfortable attitude. Atoms respected neither Kant's apriorism, such as the assertion that the possibility of empirical knowledge requires the universal validity of the law of causality, nor his principle of thoroughgoing determination, which asserts that "among all possible predicates of things, insofar as they are compared with their opposites, one must apply to [each thing] as to its possibility" [25, p. 553]. Neither Kant's apriorism nor his principle of thoroughgoing determination, however, though significant elements of his thinking, are central to his theory of science. Hence, there are more ways to respond to this blow than relapsing into transcendental realism, embracing a Berkeley-style idealism, or resigning oneself to a metaphysically sterile instrumentalism. In Bohr's case, MacKinnon writes, the crisis

> precipitated something akin to a Gestalt shift, a shift in focal attention from the objects studied to the conceptual system used to study them. This effect was somewhat similar to the epoché advocated by Husserl. He stressed the need for philosophers to bracket the natural standpoint and consider it as a representational system, rather than the reality represented. Similarly, Bohr's realization of the essential failure of the pictures in space

> and time on which the description of natural phenomena have hitherto been based shifted the focus of attention from the phenomena represented to the system that served as a vehicle of representation. [14, p. 97]

Bohr's "epoché" mirrors the seminal change of strategy that had enabled Kant to navigate between the Scylla of realism and the Charybdis of idealism. Where Kant had famously stressed that "[t]houghts without content are empty, intuitions without concepts are blind" [25, p. 193], Bohr might have said that without measurements the formal apparatus of quantum mechanics is empty, while measurements without the formal apparatus of quantum mechanics are blind. What permits us to look beyond the directly experienced world, which is amenable to classical description, is the mutual exclusion of experimental procedures, but this also means that there is no quantum world that can be described independently of our experimental investigations: "it is only the mutual exclusion of any two experimental procedures, permitting the unambiguous definition of complementary physical quantities, which provides room for new physical laws, the co-existence of which might at first sight appear irreconcilable with the basic principles of science" [26, p. 61]. To look beyond the classically describable world, one needs the quantum-mechanical formalism, and one needs experimental arrangements situated in that world, "the specification of which is imperative for any well-defined application of the quantum-mechanical formalism" [26, p. 57].

For Bohr, as for Kant, there is an intimate connection between perception, which is conditioned by the spatiotemporal aspects of experience, and conception. For Kant, conception organizes the content of experience into an effectively subject-independent world of re-identifiable objects and causally connected events. For Bohr, conception provides the framework necessary for the formulation of unambiguous, communicable knowledge, which is required for a clear-cut separation of the subject from the object: "all subjectivity is avoided by proper attention to the circumstances required for the well-defined use of elementary physical concepts" [27, pp. 7]. Far from invalidating Kant's epistemological stance, quantum theory reminds us of the roles perception and conception play in the construction and constitution of the objective world. Bohr's departure from Kant is not a departure from Kant's epistemological stance but a consequence of quantum theory's departure from classical physics. By limiting the application of classical concepts, quantum theory *extends* the range of phenomena within our ken. It is an irony that Bohr, seeing Kant as arguing for the a priori necessity of classical concepts, regarded complementarity as an alternative to Kant's theory of science, thus drawing the battle lines in a way which put Kant and himself on opposing sides.

What allowed Bohr to go beyond Kant was his insight that empirical knowledge is not limited to what is accessible to our senses, and that it does not have to be a knowledge of interacting objects and causally connected events. It can reach beyond what is directly accessible to our senses. What it finds there, however, cannot be expected to be structured in the same way as what is directly accessible to our senses. We have no reason to expect that what is not directly accessible to our senses is subject to the spatiotemporal conditions of sensory experience, and we have no reason to expect that what is not subject to these conditions conforms to descriptions or explanations involving such spatiotemporal concepts as position and momentum, time and energy, causality and interaction. Since these are essentially all the descriptive and explanatory (or kinematical and dynamical) concepts at our disposal, it should have come as no surprise that what is not directly accessible to our senses can only be described in terms of correlations between events that are directly accessible to our senses. Bohr stands virtually alone with his insight that reality cannot be "squeezed" into Kant's "pure forms of experience," space and time. "It is my personal opinion," he wrote to the philosopher Harald Høffding [28], "that these difficulties are of such a nature that they hardly allow us to hope that we shall be able, within the world of the atom, to carry through a description in space and time that corresponds to our ordinary sensory perceptions."

I cannot but agree with Folse when he writes [22]: "It is often said that a work of genius resists categorization. If so, Bohr's philosophical viewpoint easily passes this criterion of greatness. Surely this is one of the reasons for the commonplace complaints over Bohr's 'obscurity'." Historically, Bohr's reply [29] to the EPR paper was taken as a definitive refutation by the physics community. By the time interpreting quantum mechanics became a growth industry, Bohr's perspective was lost. His epistemological reflections generally came to be treated on a par with a proliferating multitude of ontological interpretations of a mathematically formulated theory, and as such they could not but seem amateurish, outdated, ad hoc, bizarre, or downright irrational. This is how Jeffrey Bub [30, pp. 45–46] came to conclude that

> The careful phraseology of complementarity ... endows an unacceptable theory of measurement with mystery and apparent profundity, where clarity would reveal an unsolved problem,

how Abner Shimony [31] came to confess that

> after 25 years of attentive—and even reverent—reading of Bohr, I have not found a consistent and comprehensive framework for the interpretation of quantum mechanics,

and how Edwin Jaynes [32] came to see in "our present QM formalism"

> a peculiar mixture describing in part realities of Nature, in part incomplete human information about Nature—all scrambled up by Heisenberg and Bohr into an omelette that nobody has seen how to unscramble.

It would therefore seem appropriate to close this section with the following words by Hooker [12, pp. 132–133]:

> it is a remarkable commentary on the state of confusion and misunderstanding now existing in the field that Bohr's unique views are almost universally either overlooked completely or distorted beyond recognition—this by philosophers of science and scientists alike. Despite the fact that there are almost as many philosophies of quantum theory as there are major quantum theorists, the illusion somehow persists that they are all talking about the same thing and in essentially the same way. ... so many people can apparently read Bohr and not grasp the significance of what he was driving at.

4 The measurement problem

> *The most satisfying way to end a philosophical dispute is to find a false presupposition that underlies all the puzzles it involves.*
>
> — Bas C. Van Fraassen [33, p. 434]

What distinguishes Bohr's unique views from other quantum philosophies is his recognition of the objective middle-ground between the experiencing subject and the transcendental object—a knowable reality that, while being ontologically rooted in an epistemically inaccessible object, is epistemologically rooted in the experiencing and objectifying subject. Failure to distinguish the empirical (type-II) reality from the transcendental (type-I) reality leads to two fruitless lines of attack on the quantum measurement problem. This, as Mermin [34, p. 156] has pointed out, has two major components: "The first is how to account for an objective physical process called the collapse of the wave function, which supersedes the normal unitary time evolution of the quantum state in special physical processes known as measurements." The second concerns the question "whether there can be quantum interference between quantum states that describe macroscopically distinct physical conditions," including the challenge of elucidating the meaning of "macroscopically distinct."

The first fruitless line of attack is the way of the ψ-ontologists,[2] who believe in an objective physical process called the collapse of the wave function, and who take "objective" in the sense of referring to a mind-independently existing reality that, in and of itself, is just as the wave function describes it. That this line of attack is doomed to fail follows from insolubility proofs of the so-called objectification problem due to Mittelstaedt [36, Sect. 4.3b] and Busch *et al.* [37, Sect. III.6.2].

The peculiar meaning of "objectification" in the literature on the quantum measurement problem must not be confused with the regular sense of the word, which refers to the representation of a concept as a real or concrete object. This literature, which still follows the first rigorous formulations of the problem in the monographs of von Neumann [38] and Pauli [39], assumes that there is such a thing as a measurement process, and that this takes place in three steps: the system or state preparation, a continuous dynamical process called "premeasurement" (p), and the appearance of an outcome called "objectification" (o):

$$\sum_k c_k |A_0\rangle|q_k\rangle \xrightarrow{(p)} \sum_k c_k |A_k\rangle|q_k\rangle \xrightarrow{(o)} |A(q)\rangle|q\rangle.$$

The initial state assigns probability 1 to the outcome of a measurement which indicates that the apparatus is ready, and the final state assigns probability 1 to the outcome of a measurement which indicates that the apparatus indicates the outcome q. To make the initial state represent the *fact* that the apparatus is in the neutral state, and to make the final state represent the *fact* that the apparatus indicates the outcome q, one has to adopt the so-called eigenvalue-eigenstate link as an interpretive principle. Here is how it was formulated by Dirac [40, pp. 46–47]:

> The expression that an observable "has a particular value" for a particular state is permissible ... in the special case when a measurement of the observable is certain to lead to the particular value, so that the state is an eigenstate of the observable.

[2]Not to be confused with Scientologists. For the origin of this subtly suggestive term see Note 3 of Ref. [35].

So even if we had an explanation for the collapse transition from $\sum_k c_k|A_k\rangle|q_k\rangle$ to $|A(q)\rangle|q\rangle$, it would not explain the objectification transition from probability 1 to "is" or "has." Nor could it, for there can be no dynamical explanation for an interpretive principle like the eigenvalue-eigenstate link.

The second fruitless line of attack is the way of the QBists [35, 41, 42, 43]. QBists hold that quantum theory is an addition to Bayesian probability theory. It provides "users of science" with a calculus for gambling on their respective experiences. Because users' experiences generally differ, QBists believe that there are potentially as many quantum states for a given system as there are users of the theory. While they agree with Bohr that the events to which quantum mechanics assigns probabilities are measurement outcomes, they define "measurement" as an "action an agent takes to elicit a set of possible experiences," and they define a "measurement outcome" as "the particular experience of that agent elicited in this way" [44]. Because measurement outcomes are relative to individual users/agents, a QBist has to subject everything but her "own direct internal awareness of her own private experience" to the superposition principle, including reports of measurement outcomes she has yet to receive.

Missing the middle-ground between the experiencing subject and the transcendental object, QBists blame the trouble we face in our attempts to beat sense into the quantum theory on "our ingrained practice of divorcing the objects of our investigations from the subjective experiences they induce in us" [44]. In doing so, they conflate two distinct concepts of reality, identifying the type-II reality investigated by us with the type-I reality inducing experiences in us.[3] What is responsible for our interpretive predicament is not our practice of divorcing the objects of our investigations from our subjective experiences but our practice of *not* distinguishing between the objects of our investigations, which belong to the type-II reality objectified by us, and whatever it is that induces subjective experiences in us, which belongs to the epistemically inaccessible reality of type I.

One may wonder how Fuchs *et al.* [44] come to assert that "Instruments are the Copenhagen surrogate for experience," or how Mermin—"a QBist in the making" [46]—arrives at the conclusion that "All versions of Copenhagen

[3] This conflation is also responsible for the insolubility of the "hard problem of consciousness," which most philosophers of mind—including David Chalmers [45], who coined the phrase—take to be the problem of explaining how physical processes in a brain give rise to subjective experience. Since the empirically known brain with its empirically knowable processes is conditioned by the spatiotemporal structure of our experience, it cannot be what gives rise to our experience (including its spatiotemporal structure). See also Sect. 11.

objectify each of the diverse family of users of science into a single common piece of apparatus" [4]. The reasons for these seemingly bizarre claims can be discovered by comparing three different views on how subjects, instruments, and the quantum world are related—Bohr's view, the QBist view, and Bohr's view as misconstrued by QBists.

For Bohr, the possibility of drawing a line of separation between subject and object, in such a way as to be able to refer to objects without referring to our experiences, is a *sine qua non* of empirical science. This possibility calls for a language that is suitable for unambiguous communication, and only the language of interacting objects and causally connected events meets this demand. The need for this language has nothing to do with the particular field of experience to which it is applied. Because it remains the same whenever we stumble upon a new field of experience, "there is, strictly speaking, no new observational problem in atomic physics" [26, p. 89]. There is no new observational problem because in quantum physics we are doing what we have always done: setting up experiments and reporting their results, in a language suitable for unambiguous communication, which Bohr used to call "plain language," "classical language," or "the language of classical physics." (Bohr never asserted that quantum mechanics requires classical physics itself.)

What *is* new, and radically so, is that the properties of quantum systems are defined by the experimental conditions in which they are measured, and that they only exist if and when they are measured. Instead of being "the Copenhagen surrogate for experience," instruments open up a new and wholly unanticipated field of experience—a field of experience that does not permit itself to be conceived as an autonomous system of objects with causally connected intrinsic properties but, instead, evinces itself through statistical correlations between (classically describable) preparations and (classically describable) outcomes.

According to Bohr [27, p. 12], "the physical content of quantum mechanics is exhausted by its power to formulate statistical laws governing observations obtained under conditions specified in plain language".[4] The irreducible empirical core of quantum mechanics is a calculus of correlations, but so is the irreducible empirical core of classical mechanics, as was pointed out by Mermin [47]. What distinguishes the two is that the latter is trivial, in the sense that it only assigns the trivial probabilities 0 or 1. This allows us

[4]Having said that "QBism, like most varieties of Copenhagen, takes the quantum state of a system to be not an objective property of that system, but a mathematical tool for thinking about the system," Mermin [4] adds: "Bohr may well have believed it but never spelled it out as explicitly." Actually he did.

to think of the state of a classical system in the classical sense of “state”—a collection of possessed properties—and to believe that if the probability of finding a property of the system is 1, this is *because* the system has this property. In other words, we are free to interpret the classical correlation laws as causal laws.

When we come to quantum mechanics, the classically describable world does not wholly disappear, for it contains the correlata whose existence quantum mechanics presupposes and therefore has to take for granted. Nor do the quantum-mechanical correlations supplant all classical correlations, for without the latter it would not be possible to synthesize an objective world from which the objectifying subjects can abstract themselves. This disposes of both components of the measurement problem. The first component does not exist for Bohr because what happens between a system preparation and a measurement is a holistic phenomenon, which cannot be dissected into the unitary evolution of a quantum state and a subsequent “collapse”:

> all unambiguous interpretation of the quantum mechanical formalism involves the fixation of the external conditions, defining the initial state of the atomic system concerned and the character of the possible predictions as regards subsequent observable properties of that system. Any measurement in quantum theory can in fact only refer either to a fixation of the initial state or to the test of such predictions, and it is first the combination of measurements of both kinds which constitutes a well-defined phenomenon. [48]

Nor does the question whether there can be quantum interference between quantum states describing macroscopically distinct physical conditions arise for Bohr, since macroscopically distinct physical conditions are directly accessible to our senses, and what is directly accessible to our senses is subject to Kant’s principle of thoroughgoing determination.

Bohr’s view on how subjects, instruments, and the quantum world are related may thus be summarized like this: instruments exist in the world objectified by the community of rational subjects sharing the same spatiotemporal mode of perception, and so does the quantum world—the world described by whatever can be inferred from measurement outcomes and from the quantum correlations between them.

Having declared that “Instruments are the Copenhagen surrogate for experience,” Fuchs *et al.* go on to claim that “Being objective and independent of the agent using them, instruments miss the central point of QBism, giving rise to the notorious measurement problem, which has vexed physicists to this day" [44]. What actually gives rise to the measurement problem is, as Mermin himself has put it elsewhere, "our habit of inappropriately reifying our successful abstractions" [47], a habit of which Bohr would be the last person to be accused. When Bohr says that instruments are objective and independent of agents, QBists appear to hear him say that instruments are part of a reality that exists independently of how it presents itself to us and how we describe it. But this impression was explicitly repudiated by Bohr when he said, as quoted by Petersen [49], that "It is wrong to think that the task of physics is to find out how nature is. Physics concerns what we can say about nature." What exists independently of how it presents itself to us and how we describe it is epistemically inaccessible to us. Instruments are objective and independent of agents in the sense that some of their properties—in particular their outcome-indicating properties—are directly perceptible by suitably located subjects and therefore definite (i.e., subject to Kant's principle of thoroughgoing determination). They can consistently be represented as objective by those who are aware of them, and they can consistently be considered definite by those not aware of them. They are objective in the sense of belonging to an objectifiable nexus of interacting objects and causally related events from which the objectifying subjects can abstract themselves.

5 The QBist Agenda

> *That the world should violate Bell's theorem remains, even for QBism, the deepest statement ever drawn from quantum theory.*
>
> — Christopher A. Fuchs [35]

Two points appear to dominate the QBist agenda: the construal of quantum-mechanical probabilities as single-user Bayesian probabilities and the intention to put "the scientist back into science" [3]. (A third point will be addressed below.) The Bayesian understanding of probability as a degree of confidence or belief, however, is unsuited for an interpretation of quantum mechanics, for it denies the existence of external criteria—external to the *individual* subject—for declaring a probability judgment right or wrong, whereas in fact there are such criteria, to wit, the measurement outcomes on the basis of which probabilities are assigned with the help of the quantum-mechanical correlation laws. These criteria are external in the sense of belonging to the objectified, empirical reality of type II. The need to restore "the balance between subject and object" [3], on the other hand, arises only if the object is conceived as belonging to a reality that exists independently of how it presents itself to us and how we describe it.

In his essay "Nature and the Greeks" [50, pp. 95–97], Schrödinger deplores that "I actually do cut out my mind when I construct the real world around me":

> the scientific picture of the real world around me is very deficient. It ... is ghastly silent about all and sundry that is really near to our heart, that really matters to us. It cannot tell us a word about red and blue, bitter and sweet, physical pain and physical delight; it knows nothing of beautiful and ugly, good or bad, God and eternity.... And the reason for this disconcerting situation is just this, that, for the purpose of constructing the picture of the external world, we have used the greatly simplifying device or cutting our own personality out, removing it.

For Fuchs *et al.* [44] this is reason enough to claim that Schrödinger "takes a QBist view of science." It is true that Schrödinger takes a QBist view of science, but only insofar as he, too, takes the scientific picture of the real world around him to refer to a reality that exists independently of how it presents itself to us and how we describe it. But such a reality is epistemically inaccessible. The empirically accessible reality around us—the reality we perceive and describe—is our own creation, extracted from *our* experience, objectified and shared by subjects like ourselves. The reason we do not find in it the qualitative aspects of our experience is that our experience encompasses and exceeds it. That these aspects are missing from it—that they cannot be objectified—ought to worry only those who disregard this fundamental truth about our epistemological situation. (Unfortunately that's a lot of people.)

It deserves to be stressed that the qualitative aspects of our experience include the qualitative aspects of time and space. Weyl [51] made this point with respect to space, stressing "with what little right mathematics may claim to expose the intuitional nature of space":

> Geometry contains no trace of that which makes the space of intuition what it is in virtue of its own entirely distinctive qualities which are not shared by "states of addition-machines" and "gas-mixtures" and "systems of solutions of linear equations". It is left to metaphysics to make this "comprehensible" or indeed to show why and in what sense it is incomprehensible. We as

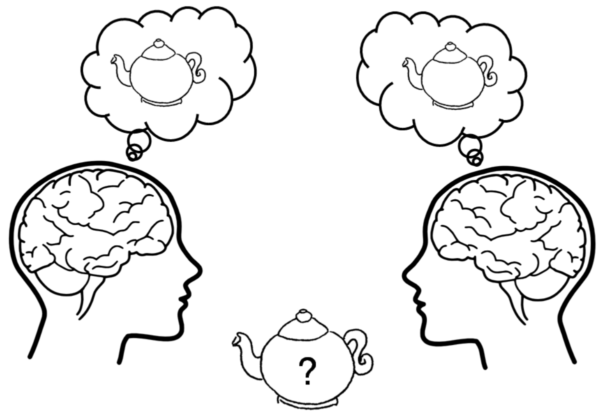

Figure 1: Do Alice and Bob see a teapot because there is a teapot, or is there a teapot because they each see one?

> mathematicians ... must recognise with humility that our conceptual theories enable us to grasp only one aspect of the nature of space, that which, moreover, is most formal and superficial.

Much the same applies to time. What we can objectify are the spatial relations between objects and the temporal or spatiotemporal relations between events. What we cannot objectify is the qualitative character of the warp and woof of our experience, phenomenal space and phenomenal time, including our subjective *here* and *now*. As I cannot objectify the particular point in space from which I surveys my surroundings—a fact that nobody seems to bemoan—so I cannot objectify my *now* as a particular point in time at which I remember my past and anticipate my future—a fact that Einstein famously regretted [52] and that Mermin [3, 53] believes QBism can redress.

The QBist view on how subjects, instruments, and the quantum world are related may now be summarized like this: Definite outcomes only exist in the individual user/agent's private experience, and so do definite properties in general and the outcome-indicating properties of instruments in particular. The quantum world is the "little more" [54] which requires outcome-indicating experiences to be correlated as codified by the laws of quantum mechanics. Thus if Alice and Bob both experience a teapot placed between them (Fig. 1), it is not because there is a real teapot out there, nor is it, as Kant and Bohr could have argued, because they can consistently represent the experienced teapot as being part of a shared objective world. A QBist would paraphrase either explanation by saying that it objectifies both Alice and Bob into a single common teapot. This is how Mermin comes to conclude that "All versions of Copenhagen objectify each of the diverse family of users of science into a single common piece of apparatus" [4].

The third point on the QBist agenda is a demonstration that quantum mechanics is "*explicitly* local" [44]. The demonstration consists in the claim that "space-like separated events ... cannot be experienced by any single agent," and that therefore quantum correlations "refer only to time-like separated events: the acquisition of experiences by any single agent." (In point of fact, spacelike separated events *can* be experienced by a single user, provided that both events are situated in or on that user's past light cone.) By giving "each quantum state a home ... localized in space and time—namely, the physical site of the agent who assigns it," QBism "expels once and for all the fear that quantum mechanics leads to 'spooky action at a distance'." [55]

It is true that each quantum state—in fact, every calculational tool of every physical theory—has a "home" in someone's mind, but if definite properties (including the property of being physically located somewhere) only exist in the minds of individual agents, this cannot mean that each quantum state exists at the physical location of the agent who assigns it. For QBists, to *be* is to be *measured*, and to be *measured* is to be *experienced*. Unexperienced properties do not exist. For Bob, Alice's location is her location as experienced/measured by him, and for Alice, Bob's location is his location as experienced/measured by her. The circularity implied by locating an agent's state of mind relatively to another agent's state of mind should be obvious.

It is not that easy to expel the fear that quantum mechanics leads to spooky action at a distance.[5] If Alice and Bob perform the test of Bell's theorem so beautifully designed by the earlier Mermin [56] (Fig. 2), Alice can use her outcome to predict with certainty the outcome that Bob obtains if he measures the same spin component as Alice (and vice versa). While her measurement changes nothing either in Bob's mind or at Bob's *absolute*

[5] In point of fact, the diachronic correlations between events in timelike relation are as spooky as the synchronic correlations between events in spacelike relation. While we know how to calculate either kind of correlation, and therefore know how to calculate the probabilities of possible events on the basis of actual events, we know as little of a physical process by which an event here and now contributes to determine the probability of a *later* event *here* as we know of a physical process by which an event here and now contributes to determine the probability of a *distant* event *now*.

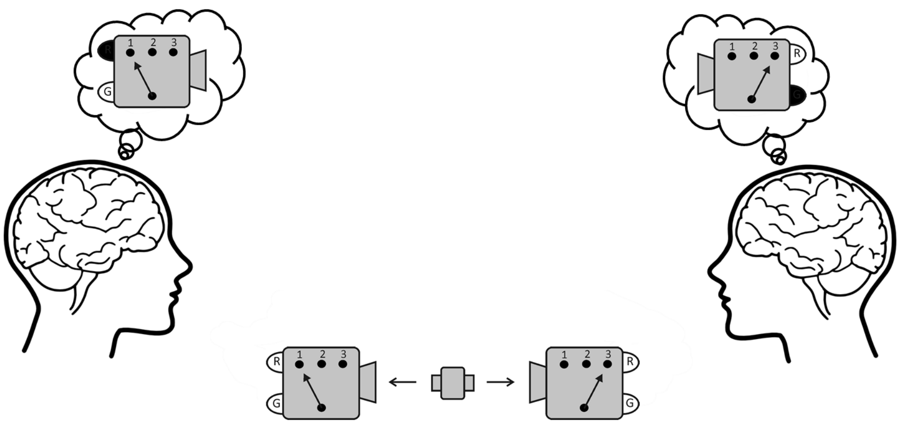

Figure 2: Can Alice predict Bob's outcome because it reveals something that is the case at Bob's *absolute* location, or is something the case at Bob's location *as it exists in Alice's mind* because Alice can predict Bob's outcome?

location, it does change something at Bob's location as it exists in Alice's mind: Alice can assign probabilities to the possible outcomes of each of Bob's possible measurements. QBists will argue that this violation of outcome-independence is an explicitly local effect, happening in Alice's mind, but the implication that there is no distance between Alice and Bob other than that existing in an individual user's mind makes their argument rather self-defeating.

6 Consistency

> *The measurement problem is a* consistency problem. *What we have to show is that the dynamics, which generally produces entanglement between two coupled systems, is consistent with the assumption that something definite or determinate happens in a measurement process. The basic question is whether it is consistent with the unitary dynamics to take the macroscopic measurement "pointer" or, in general, the macroworld as definite. The answer is "no," if we accept an interpretative principle sometimes referred to as the "eigenvalue-eigenstate link."*
>
> — Jeffrey Bub [57]

As long as we espouse the interpretive principle known as the eigenvalue–eigenstate link, we have a consistency problem. Bub [57] has claimed that the unitary quantum dynamics can be made consistent with the existence of measurement outcomes by stipulating instead that "the decoherence 'pointer' selected by environmental decoherence" is always definite. Decoherence then "guarantees the continued definiteness or persistent objectivity of the macroworld." Decoherence, however, merely displaces the coherence of the system composed of apparatus and object system into the degrees of freedom of the environment, causing the objectification problem to reappear as a statement about the system composed of environment, apparatus, and object system. Since the mixture obtained by tracing out the environment does not admit an ignorance interpretation, it can resolve the problem only FAPP ("for all practical purposes").

To demonstrate the consistency of the quantum-mechanical correlation laws with the existence of their correlata,[6] which really ought to be self-evident, we must desist from conceiving of the objective world as if it were directly accessible to our senses on all scales. The objective world is not the epistemically inaccessible (type-I) world—the world as it is in itself, unperceived and unconceived by us. Nor is it the world as we *perceive* it. The objective world is the world as we *conceive* it, and if we want our conception of it to be consistent with the quantum-mechanical correlations laws, we must not conceive of it as if it were spatially differentiated (or partitioned) "all the way down," which is what the insolubility proofs of the objectification problem implicitly assume.

The first part of the demonstration of consistency consists in showing that quantum mechanics itself implies the incompleteness of the world's spatiotemporal differentiation. The second part consists in deducing from this the existence of a non-empty class of objects whose positions are "smeared out" only relative to an imaginary spatiotemporal background that is more differentiated than the actual world [59, 60, 61, 62, 63].

Part 1. While quantum mechanics can tell us that the probability of finding a particle in a *given* region of space is 1, it is incapable of *giving* us a region of space. For this a detector is needed. A detector is needed not only to indicate the presence of a particle in a region but also—and in the first place—to realize a region, so as to make it possible to attribute to a particle the property of being inside. Speaking more generally, a measurement

[6] This is an example of what von Weizsäcker [58, p. 260] has called "semantic consistency": "Semantic consistency of a theory will mean that its preconceptions, how we interpret the mathematical structure physically, will themselves obey the laws of the theory."

apparatus is needed not only to indicate the possession of a property by a quantum system but also—and in the first place—to realize a set of properties so as to make them available for attribution to the system.[7] But if detectors are needed to realize regions of space, space cannot be intrinsically partitioned; it cannot be modeled as an actually existing manifold of points labeled by triplets of real numbers. If at all we conceive of it as partitioned, we can do so only as far as regions of space can be realized—i.e., to the extent that the requisite detectors are physically realizable. Because this extent is limited by the indeterminacy principle, the spatial differentiation of the objective (type-II) world is incomplete.

Part 2. In an incompletely differentiated world, there will be objects whose position distributions are and remain so narrow that there are no detectors with narrower position distributions. If anything truly deserves the label "macroscopic," it is these objects. While decoherence arguments can solve the objectification problem only FAPP, they quantitatively support the existence of macroscopic positions—positions whose indefiniteness is never revealed in the only way it could be revealed, i.e., through a departure from what the classical laws predict. The testable correlations between the outcomes of measurements of macroscopic positions are therefore consistent with *both* the classical *and* the quantum laws. This makes it possible to attribute to macroscopic positions a measurement-independent reality, and it enables them to define the obtainable values of observables and to indicate the outcomes of measurements.

7 Beyond consistency

> *The ever-popular* wavefunction formulation *is standard for problem solving, but leaves the conceptual misimpression that wavefunction is a physical entity rather than a mathematical tool. The* path integral formulation *is physically appealing and generalizes readily beyond the domain of nonrelativistic quantum mechanics, but is laborious in most standard applications.*
>
> — Daniel F. Styer *et al.* [64]

Having demonstrated the consistency of the quantum-mechanical correlation

[7] Just as (macroscopic) detectors are needed to realize attributable positions, so (macroscopic) clocks are needed to realize attributable times. This means that the wave function's dependence on time is *not* the continuous time-dependence of an evolving physical state. The t in $\psi(t)$ refers to the macroscopically realized and indicated time of the measurement to the possible outcomes of which $\psi(t)$ serves to assign probabilities.

laws with the existence of their correlata, our next order of business is to discern features of the quantum world—to infer them from the quantum-mechanical correlation laws. For this we need an interpretive principle to replace the untenable eigenvalue–eigenstate link.

An interpretive principle is intended to answer a question that arises in the context of a specific formulation of quantum mechanics. Both the wave function formulation and Feynman's [65] feature a pair of dynamical principles. In the former formulation they are unitary evolution and collapse, in the latter they are summation over amplitudes (followed by taking the absolute square of the sum) and summation over probabilities (preceded by taking the absolute square of each amplitude). From the wave-function point of view, unitary evolution is "normal" and hence not in need of explanation; what calls for explanation is collapse. From Feynman's point of view, adding probabilities is "normal," as it is what classical probability theory leads us to expect; what calls for explanation is why we have to add amplitudes whenever we are required to do so.

The reason the wave-function formulation forces us to postulate collapse, whose immediate consequence is probability 1 for a particular outcome, is the eigenvalue–eigenstate link, inasmuch as this equates probability 1 with the indisputable factuality of measurement outcomes. What could be the reason Feynman's formulation requires us to add amplitudes? This question is answered by the following interpretive principle [59, 60, 61, 62, 63]:

(I) *Whenever quantum mechanics requires us to add amplitudes, the distinctions we make between the alternatives correspond to nothing in the physical world.*

Thus while the wave-function formulation stumps us with the dual problem of collapse and objectification, Feynman's formulation presents us with a question to which there is a straightforward answer. We know why

> Any determination of the alternative taken by a process capable of following more than one alternative destroys the interference between alternatives [65].

By stating the indeterminacy principle in this way, Feynman does not mean to imply that the "destruction" is brought about by a physical process.

Applied to a two-way interferometer experiment, the replacement (I) for the eigenvalue–eigenstate link tells us that the distinction we make between "the particle went through the left arm" and "the particle went through the right arm" corresponds to nothing in the physical world. Since this distinction rests on a distinction between regions of space, it follows that space cannot be an intrinsically differentiated expanse. Its so-called parts need to be physically realized, and we have seen that the indeterminacy principle prevents them from being realized "all the way down."

8 Being

> *I received a telephone call one day at the graduate college at Princeton from Professor Wheeler, in which he said, "Feynman, I know why all electrons have the same charge and the same mass." "Why?" "Because, they are all the same electron!"*
>
> — Richard P. Feynman [66]

Applied to an elastic scattering event involving two particles of the same type (say, two incoming particles N and S, two outgoing particles E and W), the interpretive principle (I) tells us that the distinction we make between the alternative identifications

$$N \to E, S \to W \quad \text{and} \quad N \to W, S \to E$$

corresponds to nothing in the physical world. There is no answer to the question: "Which outgoing particle is identical with which incoming particle?" Now why would that be so? Here too there is a straightforward answer: because the incoming particles (and therefore the outgoing ones as well) are *one and the same entity*. What's more, there is no compelling reason to believe that this identity ceases when it ceases to have observable consequences owing to the presence of individuating properties. We are free to take the view that *intrinsically* each particle is numerically identical with every other particle. What presents itself here and now with these properties and what presents itself there and then with those properties is one and the same entity.[8] In what follows I shall call it "Being." (If you prefer any other name, be my guest.)

Perhaps the main reason it is so hard to make sense of the quantum theory is that it answers a question we are not in the habit of asking. Instead of asking what the ultimate constituents of matter are and how they interact and combine, we should ask: *how are forms manifested?* This question, too, has a straightforward answer [61, 62]: *The shapes of things are manifested*

[8] According to French [67], quantum mechanics is "compatible with two distinct metaphysical 'packages,' one in which the particles are regarded as individuals and one in which they are not." Esfeld [68] disagrees: it is not "a serious option to regard quantum objects as possessing a primitive thisness (haecceity) so that permuting these objects amounts to a real difference."

with the help of reflexive spatial relations. By entering into reflexive spatial relations, Being gives rise to (i) what *looks like* a multiplicity of relata if the reflexive quality of the relations is ignored and (ii) what *looks like* a substantial expanse if the spatial quality of the relations is reified. As Leibniz said, *omnibus ex nihilo ducendis sufficit unum*—one is enough to create everything from nothing. A single self-existent entity is enough to create both the relata we call particles and the expanse we call space.

The following brief reflection leads to the same conclusion. While the non-relativistic theory allows us to conceive of a physical system as being composed of a definite number of parts, and to conceive of its form as being composed of a definite number of spatial relations (to which values can be attributed only if and when they are measured), the relativistic theory requires us to treat the number of a system's parts as just another quantum observable, which has a definite value only if and when it is measured. There is therefore a clear sense in which a quantum system is always one, the number of its parts being just one of its properties and having a definite value only if and when measured.

To my mind, the most fruitful way to understand the necessary distinction between the classical or macroscopic domain (containing measurement-independent properties) and the non-classical or quantum domain (whose properties exist only if, when, and to the extent that they are measured) is that it is essentially a distinction between the *manifested world* and its *manifestation.* The curious mutual dependence of the two domains, pointed out by Landau and Lifshitz[9] and by Redhead,[10] is then readily understood. The manifestation of the world consists in a transition from a condition of complete indefiniteness and indistinguishability to a condition of complete or maximal definiteness and distinguishability, and what occurs in the course of this transition—what is not completely definite or distinguishable—can only be described in terms of probability distributions over what is completely definite and distinguishable. What is instrumental in the manifestation of the world can only be described in terms of its result, the manifested world.[11]

Quantum mechanics, this amounts to saying, presents us with a so far un-

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[9] "[Q]uantum mechanics ... contains classical mechanics as a limiting case, yet at the same time it requires this limiting case for its own formulation" [69, p. 3].

[10] "In a sense the reduction instead of descending linearly towards the elementary particles, moves in a circle, linking the reductive basis back to the higher levels" [70].

[11] It is worth noting here that the indeterminism of quantum mechanics is rooted in an underlying indeterminacy. Instead of consisting *fundamentally* in the existence of unpredictable changes disrupting a predictable evolution, it is a consequence of indeterminacies that *evince* themselves through unpredictable transitions in the values of outcome-indicating positions (Bub's "decoherence pointers").

recognized kind of causality—unrecognized, I believe, within the scientific literature albeit well-known to metaphysics, for the general philosophical pattern of a single world-essence manifesting itself as a multiplicity of physical individuals is found throughout the world.[12] This causality is associated with the atemporal process of manifestation, which effects the transition from complete indefiniteness and indistinguishability to complete or maximal definiteness and distinguishability. It must not be confused with its familiar temporal cousin, which links states or events across time or spacetime. The latter plays no role in the manifestation. Being part of the world drama, it does not take part in setting the stage for it.[13]

The causality associated with the process of manifestation casts new light on quantum theory's mysterious violation of outcome-independence. The reason why local explanations do not work may be the same as the reason why the manifestation of the spatiotemporal world cannot be explained by processes that connect events *within* the spacetime arena. The manifestation of the world is the nonlocal event *par excellence*. Instead of being an event *in* spacetime, it is *coextensive* with spacetime. Its atemporal causality supports the folk causality, which helps us make sense of the manifested world as well as of the cognate world of classical physics, but which throws no light on the process of manifestation nor on the quantum correlations that are instrumental in the process.

9 Match of fit?

> *I see our scientific theories as human inventions—nets designed by us to catch the world.... They are rational nets of our own making, and should not be mistaken for a complete representation of the real world in all its aspects....*
>
> — Karl R. Popper [75, p. 42]

An intrinsically undifferentiated (and therefore unqualifiable) Being manifesting the world by entering into reflexive relations—does not this refer to a transcendental (type-I) reality, rather than to a type-II reality experienced and conceived by us? Even if it did, we would not be in a position

[12] Some of its representatives in the Western hemisphere are the Neoplatonists, John Scottus Eriugena, and the German idealists. The quintessential Eastern example is the original (pre-illusionist) Vedanta of the Upanishads [71, 72, 73].

[13] Ladyman and Ross [74, pp. 258, 280] concur: "the idea of causation has similar status to those of cohesion, forces, and [individual] things. It is a concept that structures the notional worlds of observers.... There is no justification for the neo-scholastic projection of causation all the way down to fundamental physics and metaphysics."

to know this. As the Greek philosopher–poet Xenophanes pointed out some twenty-five centuries ago, even if our conceptions represented the world exactly as it is, we could never know that this is the case. But then there is this flipside: the fact that our models of reality are mental constructs does nothing to explain why most of our theoretical constructs turn out to be non-objectifiable. There has to be something about the (type-I) reality at the origin of our perceptions that licenses the objectification of only a very limited set of mental constructs. This cannot mean that the "world as we know it" faithfully represents the "world in itself"; something surely slips through the interstices of our nets designed to catch the world. But while we must not jump to the conclusion that the "world as we know it" *matches* the "world in itself," we *may* conclude that the former *fits* the latter.

The distinction between a match and a fit is due to von Glasersfeld [76]. He illustrated it by imagining a skipper who, in the dark of a stormy night, without navigational aids, passes a narrow strait whose contour he does not know. Epistemologically, we are in the skipper's position. If he reaches the open sea without mishap, he has found a course that *fits* the strait; if next time he takes the same course, he will again pass safely. What he has not obtained is a map that *matches* the coastline. To precisely locate at least one point of the coastline, he must come into contact with it—at the risk of wrecking his ship. My contention is that the ideas put forward here and in greater detail in Refs. [61, 62] *fit* the reality at the origin of our perceptions. No interpretation of quantum mechanics can achieve more than that.

We live in a world that allows itself to be understood in terms of interacting objects and causally connected events. Quantum mechanics allows us to conceive of this world as emergent, not from some mystical domain of potentiality, nor by a dynamical process, nor through environmental decoherence, but by a transition across a dimension that is neither temporal nor spatial, a transition from a condition of complete indefiniteness and indistinguishability to a condition of complete or maximal definiteness and distinguishability. The least definite stage of this transition, probed by high-energy physics, is known to us through correlations between the counterfactual clicks of nonexistent detectors, i.e., in terms of transition probabilities between in-states and out-states. At energies low enough for atoms to be stable, it becomes possible to conceive of objects with fixed numbers of components, and these we describe in terms of correlations between the possible outcomes of unperformed measurements.[14] Molecules, arising at the next stage, are the

[14]As always, we ought to keep in mind that saying that an atom is "in" a certain quantum state is the same as saying that certain measurements have been made, and

first objects with forms that can be visualized—their atomic configurations. But it is only the finished product—the manifested world, which allows itself to be understood in terms of interacting objects and causally connected events—that gives us the actual detector clicks and the actual measurement outcomes which allow us to study the correlations in terms of which quantum mechanics describes the various stages of the process of manifestation.

There is then a two-fold relation between the macroscopic world and the reality from which it emerges. On the one hand, as Falkenburg has so convincingly argued, "to our present knowledge subatomic reality is not a micro-world on its own but a part of empirical reality that exists relative to the macroscopic world, in given experimental arrangements and well-defined physical contexts outside the laboratory" [1, p. 340]. Subatomic reality is linked to the manifested world through a generalized correspondence principle—"a semantic principle of continuity which guarantees that the predicates for physical properties such as 'position', 'momentum', 'mass', 'energy', etc., can also be defined in the domain of quantum mechanics, and that one may interpret them operationally in accordance with classical measurement methods" [1, p. 191]. On the other hand, quantum mechanics allows us to infer an intrinsically undifferentiated (hence unqualifiable) Being, which manifests the macroscopic world by entering into reflexive relations, giving rise to increasingly definite and distinguishable structures—identical particles, non-visualizable atoms, and partly visualizable molecules—which are instrumental in the process of manifestation. Though this Being must not be identified with the transcendental (type-I) reality at the origin of our experience, it seems safe to consider it one of the fundamental, not further reducible ways in which that reality offers itself to our cognition.

10 Anthropic reasons

> *But the fact that we find ourselves in a quantum world where measurement is possible . . . will surely involve the same sort of explanation as the fact that we find ourselves in a world where we are able to exist as carbon-based life forms.*
>
> — Jeffrey Bub [77, p. 234]

Anthropic reasoning is the general line of argument that some features of the universe are prerequisites for the existence of X, Y, or Z, and so we

that their outcomes define algorithms that serve to assign probabilities to the possible outcomes of subsequent measurements. (Since unperformed measurements need not be capable of being performed, "possible" outcomes need not be capable of being obtained.)

should not seek to explain them from first principles: they are necessary consequences of the fact that there is X, Y, or Z. Typical candidates are intelligent observers, carbon-based life forms, or an "interesting" world, defined by Squires [78] as one that contains chemistry, and typical prerequisites for their existence are the specific values of certain dimensionless parameters not accounted for by the standard model and general relativity (SM+GR) or the cosmological initial conditions. But the range of anthropic arguments is much wider. When Kant inquired into the conditions of possibility of empirical knowledge, he engaged in anthropic reasoning. So, at bottom, did Bohr when he insisted on the necessity of using classical language to communicate "what we have done and what we have learned" (Refs. [26, pp. 39, 72, 89] and [27, pp. 3, 24]). More recently, von Weizsäcker [15, pp. 176–177] advanced the following hypothesis "as the formulation of a possibility of thought, as a challenge to prove or disprove it": the "fundamental postulates of the final closed theory of physics formulate nothing but the presuppositions for the possibility of experience in general".[15]

Instead of taking SM+GR (or some stringy substitute) for granted and ascertaining the ranges of adjustable parameters or the cosmological initial conditions necessary for the existence of X, Y, or Z, we might take for granted the manifestation of a world whose properties allow themselves to be sorted into causally evolving bundles of re-identifiable individual substances and ascertain the necessary minimal set of (effective) theories. If Being is to manifest such a world by entering into reflexive spatial relations, it stands to reason that these relations will have to obey a more or less specific set of laws. To find out why the empirically well-tested laws of physics have the form that they do, we might begin with the necessary existence of reasonably stable objects occupying finite volumes of space, and we might ask ourselves what it takes to create such objects out of nothing but spatial relations between relata that lack spatial extent. To this question the answer is: *quantum mechanics* [59, 63]. Quantum mechanics, however, presupposes the outcome-indicating events it serves to correlate. It is arguable that the existence of these events (or the existence of a world that conforms to the classical narrative mode) requires a sufficient variety of chemical elements, and that this in turn requires the validity of SM+GR, at least as effective

[15] By "experience" von Weizsäcker [15, p. 176] means that "we can learn from the past for the future," that "this learning can be formulated in terms of concepts," and that "there are therefore ... recurring events which we can recognize with recognizable words." Thus defined, "experience" refers to "the structures necessary for there to be individual experiences." An example of a closed theory is "a theory that cannot be improved upon by means of small changes" [15, p. 156].

theories [63, 79].

The standard objection to anthropic reasoning is that it is an abdication of scientists' responsibility to provide explanations, a cop-out in short. But this objection can only be raised by mathematical realists, who transmogrify their calculational tools into a mind-independent reality, nursing the pious hope that the latter will magically produce a macroscopic world complete with outcome-indicating events, agents, experience, and the variegated contents of experience. Apart from that, if an explanation can be provided for a fundamental physical theory, it cannot be provided by a "more fundamental" theory; the explanation can only be of an anthropic or else teleological nature.

11 The mystery of experience

> *Nobody has the slightest idea how anything material could be conscious. Nobody even knows what it would be like to have the slightest idea about how anything material could be conscious.*
>
> — Jerry A. Fodor [80]

If making sense of quantum physics is one of the biggest challenges in the philosophy of science today, consciousness and intentionality are among the biggest challenges in the philosophy of mind. Consciousness is the remarkable fact that things exist not only independently of us but also *for us*. This does not mean that the external world, or some part or aspect of it, is mirrored in our brains. It means that we perceive the external world via neural representations in our brains. Intentionality is the remarkable fact that instead of perceiving neural representations in our brains, we perceive things existing outside of our brains.

The so-called hard problem of consciousness [45] is generally understood to be the question how physical processes in a brain give rise to the various sensory qualities of the experienced world, complete with the impression of being an experiencing self or subject. Thus understood, the problem is misconceived.[16] To the extent we are in a position to know the physical or neural processes occurring in a brain, they belong to the empirical (type-II) reality constructed by us on the basis of our experience, rather than to the

[16]There is no mystery about how this problem becomes a mystery. We seize upon quantitative regularities we find in our experience, we think of them as the laws that govern a mind-independent world of interacting objects having purely quantitative properties, and then we marvel how such a world can contain the quality-rich experience we discarded when we modeled it as a system of interacting objects having purely quantitative properties.

transcendental (type-II) reality at the origin of our experience. If, on the other hand, by "physical processes" we mean processes that do give rise to conscious experience, we have no clue as to what they might be, belonging as they do to a reality that is epistemically inaccessible to us.

As the causality that relates objects and events across space and time throws no light on the process of manifestation, so it cannot explain how, by what magic, the manifested world comes to exist *for us*. Quantum mechanics throws light on the process of manifestation, but it too knows nothing of how the manifested world can exist *for us*.[17] Anthropic arguments go a long way towards explaining why the well-tested laws of physics have the form that they do, but insofar as they begin with *experience* and inquire into the preconditions of its possibility,[18] or begin with an intrinsically undifferentiated Being manifesting an *empirically knowable* world with *communicable* features by entering into reflexive spatial relations, they obviously cannot enlighten us as to the "wherefrom, wherein, and whereto of experience" [82].

The most promising alternative to materialist reductionism in the philosophy of mind is panpsychism, which has a growing number of advocates among contemporary philosophers [83, 84, 85, 86, 87]. Matter, von Weizsäcker once remarked [15, p. 234], can only be defined as "that which satisfies the laws of physics." As regards its intrinsic nature, we are clueless. Panpsychism holds that consciousness is, or is part of, the intrinsic nature of "that which satisfies the laws of physics." The cogency of this doctrine depends on what else is assumed. If we assume with Teilhard de Chardin that what satisfies the laws of physics is corpuscles, then we are, as he wrote, "logically forced to assume the existence in rudimentary form ... of some sort of psyche in every corpuscle" [88, p. 301]. William James reasoned along similar lines. Each atom of matter has an atom of consciousness linked with it, and "just as the material atoms have formed bodies and brains by massing themselves together," he wrote [89, pp. 148–149], "so the mental atoms ... have fused into those larger consciousnesses which we know in ourselves and suppose to exist in our fellow-animals." The difficulty with this version of panpsychism is that it is hard to see how our rich internal lives could

[17] While the "neural correlates of consciousness" are generally sought among the classically describable aspects of brains, some have sought them among non-classical constructs such as quantum-gravity induced collapses of wavefunctions in microtubules [81]. This, however, does nothing to explain how a merely quantitatively determined reality can give rise to sensory qualities, let alone to the conscious subject for whom they exist.

[18] Says Kant [25, p. 136]: "There is no doubt whatever that all our cognition begins with experience; for how else should the cognitive faculty be awakened ... to work up the raw material of sensible impressions into a cognition of objects that is called experience?"

emerge from the rudimentary psyches of material atoms.

Another line of reasoning leads to a similar conclusion. Beginning with Leibniz in the 17th Century, philosophers have argued that all physical properties are relational or extrinsic, and none are in a fundamental sense non-relational or intrinsic. This offers the possibility of situating consciousness among the intrinsic properties of the relata which bear the relational properties. This possibility was considered by Bertrand Russell [90] and more recently by Chalmers [45]. The problem with this possibility is that it is hard to imagine how the consciousnesses of a myriad of particles can constitute the unified consciousness that we enjoy. If, however, we take into account not only that all physical properties are relational but also that all relational properties are reflexive, so that the relata are identically the same Being, the idea that consciousness is an intrinsic aspect of the relata comes into its own, and so does the idea that consciousness is, or is part of, the intrinsic nature of "that which satisfies the laws of physics."

If Being is one of transcendental reality's fundamental, not further reducible aspects, Consciousness (with an equally deserved uppercase C) may well be another, complementary fundamental aspect of the same intrinsically unknowable reality. We have said that *Being*, by entering into reflexive spatial relations, manifests the world, but it may be more accurate to say that *transcendental reality* manifests the world *to itself*, and that in doing so it takes on the complementary aspects of Being (which manifests the world) and Consciousness (to which the world is manifested). To our cognition it features both as the single substance constituting the world and as the single consciousness containing the world. The only way knowledge and experience are possible—the only way the explanatory gap between object and subject [91] can be bridged—may well be that ultimately there is no gap because ultimately all knowledge is self-knowledge.

But then we have to explain how a single consciousness containing the world appears to fracture into a multitude of separate conscious subjects, a subjective process that mirrors the objective self-differentiation of Being into an apparent multitude of particles, achieved by Being's entering into reflexive spatial relations. What is to be explained, therefore, is not only how Being enters into reflexive spatial relations but also how Consciousness appears to fracture into separate conscious subjects. The good news is that there is a single story that furnishes both explanations: while we cannot get consciousness out of transcendental reality's objective aspect of Being, we can get both individual subjects and a multitude of particles out of transcendental reality's subjective aspect of Consciousness. That story, couched in the conceptual framework of the previously mentioned philosophy of the

Upanishads [71, 72, 73] (note 12), is the story of involution [92, 93]—the process which has set the stage for the adventure of evolution.

12 Involution

> *Matter, which we can now define only as that which satisfies the laws of physics, may be spirit insofar as the spirit can be objectified.* — Carl Friedrich von Weizsäcker [15, p. 234]

> *In a sense, the whole of creation may be said to be a movement between two involutions, Spirit in which all is involved and out of which all evolves downward to the other pole of Matter, Matter in which also all is involved and out of which all evolves upward to the other pole of Spirit.* — Sri Aurobindo [92, p. 137]

Here is how that story goes. Transcendental reality's intrinsic nature is *ānanda*, a Sanskrit term that transcends the subject–object dichotomy. While it is usually rendered in subjective terms, as an infinite Delight or Bliss, it can also be rendered in objective terms, as an infinite Quality or Value. Transcendental reality has the power to manifest its inherent Quality/Delight in finite forms, and the closest description of this manifestation available to us is that of a Consciousness creating its own content.

In the original creative poise, Being and Consciousness are undifferentiated. There is but one self or subject, which is coextensive with the content of its consciousness and identical with the substance that constitutes the content.

A first self-modification of this creative poise gives rise to a new poise of relation between Consciousness/Being and its manifestation. In this poise the self adopts a multitude of standpoints within the content of its consciousness. It views this content from a multitude of locations. It thereby takes on the aspect of a multitude of subjects that are objects for each other. There now exists a distance between the perceiver and the perceived, and each object is seen from outside, in perspective. It is here, in this secondary creative poise, that the dichotomy of subject and object becomes a reality. It is also in here that the familiar three dimensions of space—viewer-centered depth and lateral extent—come into existence.

The process that gives rise to a multitude of conscious beings may be described as a multiple concentration of consciousness. A further departure from the original creative poise ensues when this multiple concentration of consciousness becomes exclusive. Here, at last, is something with which we are familiar. For we all know the phenomenon of exclusive concentration, when our consciousness is focused on a single object or task, while other goings-on are registered subconsciously, if at all. A similar phenomenon reduces the single self, which creates and experiences the content of its consciousness from a multitude of locations, to individuals who have lost sight of their identity with that single self. One result of this loss of identity is that the individual self, confined to a particular standpoint, no longer commands the creative process in its entirety.

The creative process, objectively described, is the process by which infinite Quality manifests itself in finite forms. It takes place in two stages, the development of Quality into expressive ideas, and the spontaneous realization of each expressive idea by an inherent executive force. In the original creative poise, the entire process is conscious. Individuals who are no longer aware of being a single self interacting with itself from a multitude of locations, also are no longer aware of the infinite Quality/Delight at the heart of existence. While the characteristic activity of their consciousness remains the formation of expressive ideas, they receive the qualities their ideas serve to express from a source of which they are no longer conscious. Their consciousness is closer to the consciousness we are familiar with, but it does not suffer from the debilitating consequences of an evolutionary past.

A further modification of the relation between infinite Quality/Delight and its manifestation gives rise to individuals whose characteristic activity is the execution of ideas rather than their formation, individuals who receive even the ideas they execute from a subliminal source. And finally, when the multiple exclusive concentration of consciousness is carried to its logical conclusion, it results in individuals who also lack the power to execute ideas. And since this power is responsible for the existence of individual forms, the result is a multitude of formless individuals, which are none other than the particles studied by physicists. The stage for the adventure of evolution has been set. Welcome to the physical world!

13 Outlook

Contemporary evolutionary theorists portray mind as a reality simulator. It evolved because a faithful reality simulator contributes to an organism's fitness for survival, not to its ability to know "the truth." "Boiled down to essentials," Churchland [94] tells us,

> a nervous system enables the organism to succeed in the four F's: feeding, fleeing, fighting and reproducing. The principal chore

> of nervous systems is to get the body parts where they should be in order that the organism may survive.... Improvements in sensorimotor control confer an evolutionary advantage: a fancier style of representing is advantageous *so long as it is geared to the organisms way of life and enhances the organisms chances of survival.* Truth, whatever that is, definitely takes the hindmost.

While I do not believe for a moment that we owe the discovery of general relativity, quantum mechanics, and the standard model to improvements in sensorimotor control, I do agree with Nagel [95, p. 10] that

> too many hypotheses and systems of thought in philosophy and elsewhere are based on the bizarre view that we, at this point in history, are in possession of the basic forms of understanding needed to comprehend absolutely anything.

While the attitude chastised by Nagel is too presumptuous, Churchland's take is too presumptuously modest. We tend to think of the evolution of consciousness as the successive emergence of increasingly adequate ways of experiencing a world that exists in itself, out of relation to any kind of experience. But such a world may not exist. There may only be different ways in which transcendental reality presents itself to itself. A new way of experiencing the world would then be tantamount to the creation of a new world [96, 97].

Our very concepts of space, time, and matter are conditioned by the manner in which we, at this point in history, experience the world. If evolution consists *essentially* in the emergence of new ways of experiencing the world, then it is not matter that has created consciousness[19]; it is consciousness that has created matter, first by carrying its multiple exclusive concentration to the point of being involved in a multitude of formless particles, and again by evolving our present mode of experiencing the world, for this has given us the ability to integrate images into three-dimensional objects from which the experiencing subject can abstract itself.

There are earlier expressions of human consciousness which reveal how our present mode of consciousness differs from the earlier modes. Consider, for instance, the ancient notion that the world is contained in a sphere, which has the fixed stars attached to its boundary, the firmament. We

[19] The discussion by Hut *et al.* [98] of the math-matter-mind triangle is relevant in this context. The triangle suggests the circularity of the widespread view that mathematics is a creation of mind, mind arises out of matter, and matter is governed by mathematical laws.

cannot but ask: what is outside that sphere? Those who held this notion could not, because for them the third dimension of space—viewer-centered depth—did not at all have the reality that it has for us [97]. This is why they could not handle perspective in drawing or painting, and why they were unable to arrive at the subject-free stance which is a prerequisite of modern science—all this became possible only during the Renaissance.

It stands to reason that modes of experience will evolve that will differ from our present mode as much if not more than our present mode differs from earlier ones. Our present mode has enabled us to discover much that is relevant to understanding the evolutionary past, but its tendency to regard *its* experience of the world as the *definite* experience prevents us from envisioning a mode of experience that transcends our present time- and space-bound mode. As our present mode of experience has enriched the pre-scientific mode with a new experiential dimension, so will the next mode enrich our present mode, with the likely result that our present, scientific understanding of the world will come to seem as dated as the mythological understanding of the pre-scientific era seems today. And, conversely, just as the mythological understanding could not foresee the technological explosion made possible by science, so our scientific imagination is incapable of foreseeing the radical changes that could be wrought by the evolution of a new mode of experience.

The interpretation of the formal apparatus of a physical theory such a quantum mechanics does not take place in a conceptual vacuum. Just as science in general operates within a metaphysical framework that formulates the questions it seeks to answer, and that interprets the answers it obtains through experiment and observation, so every interpretation of quantum mechanics takes place in an already given metaphysical framework. My purpose in engaging in the above speculations was to show that a metaphysical framework capable of doing justice to quantum mechanics may be considerably more complex and wide-ranging than we are generally prepared to envision. Quantum mechanics may actually play a relatively minor role in such a framework. It may be no more than a necessary precondition of the Spirit's adventure of evolution.

The purpose of this paper was, *inter alia*, to demonstrate the sanity of making room for richer, more sophisticated, and I dare say more realistic relations between experience, its subjects, and its objects. An objectivist fundamentalism—be it the ψ-ontology of the quantum philosopher or the physicalism of the cognitive scientist—leaves the problems pertaining to these relations in a state of chronic insolubility. The subjectivist fundamentalism of the QBist fares not much better, reducing as it does the real object "out there" to the "little more" [54] that compels the correlations between experienced measurement outcomes to obey the laws of quantum mechanics. Neither the third-person singular quantum mechanics fixated on a self-existent, mind-independent world[20] nor the first-person singular quantum mechanics of the QBist treats the *objective* world with the respect it demands and deserves. This becomes possible only by (to begin with) driving a "Kantian wedge" between the objects of our investigations and whatever it is that induces experiences in us.

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