Introducing Phenomenology to QBism and Vice Versa: Phenomenological Approaches to Quantum Mechanics

Abstract

This is the first volume that focuses specifically on phenomenological approaches to quantum mechanics. It is also the first volume focusing on the philosophical implications of QBism. This coincidence is not accidental. Phenomenology's rich potential for our understanding of quantum mechanics has long been overlooked by analytic philosophers and phenomenologists alike. The experience-first approach of phenomenology, its descriptive methodology, and Husserl's critique of mathematization do not sit well with "mainstream" analytic philosophy of physics. But as this volume will demonstrate, it sits nicely with the basic tenets of QBism. Conversely, QBism constitutes the most consistent and best-developed interpretation of quantum mechanics that fully embraces the Bohrian idea that "the primitive concept of *experience* is fundamental to an understanding of science" (Fuchs et al. 2014, 749). However, since its inception in the early 2000s, QBism has struggled to connect with the philosophical community. Not only are the underlying intuitions shaping and dominating contemporary philosophy of quantum mechanics—namely, that a scientific theory must be purged of all subjective and operational notions such as "experience" or "measurement" and that, consequently, a successful approach to quantum mechanics must be formulated as a "quantum theory without observers"—at odds with QBism. It seems that sometimes the incommensurability already starts at the level of the basic conceptual framework which, in the case of mainstream analytic philosophy, is not very well suited to express some of QBism's main tenets. Considering this situation, the main hypothesis of this volume is that phenomenology and QBism are natural bedfellows, and that both can profit from mutual exchange. In order to make this exchange as profitable as possible, the aim of this introductory chapter is to identify, clarify, and motivate some of the cornerstones of phenomenological approaches to quantum mechanics, to shed light on the main ideas and virtues of QBism, and to discuss points of contact and points of possible conflict between these two projects.

1. Introduction

Books on philosophical implications of quantum mechanics typically start by pointing out that although quantum mechanics is the most successful theory in the history of science, we still do not (agree on how to) understand it. As paradoxical as this might seem, this is undoubtedly true. In terms of accuracy and range of applications, quantum mechanics is unrivaled. And yet, there has never been a widely accepted scientific theory that has caused so much perplexity and disagreement. What does quantum mechanics tell us about the nature of reality? Although disputes about interpretational issues are as old as the theory itself, the situation is still that over a dozen different interpretations give diverging answers to this question. For some, quantum mechanics implies that there exist infinitely many worlds and that every time a quantum event is observed, reality branches. Others have argued that quantum mechanics must be seen against the backdrop of a strict mind-body dualism, and that consciousness causes the wave function to collapse. Quite generally, said wave function, a central notion in quantum mechanics, is a particular bone of contention. Many philosophers in the analytic tradition tend to consider the wave function a physically real entity, suggesting that the mathematical space it populates is real and ontologically fundamental. Physicists, by contrast, typically relegate the wave function to the status of a mere mathematical tool. And although the collapse postulate is accepted since the 1930ies, most working physicists prefer to ignore the question of what it exactly means or why the process of measuring seems to bring about the collapse in the first place. For philosophers, on the other hand, questions surrounding the apparent collapse of the wave function—and the infamous measurement problem more generally—lie at the heart of any serious philosophical attempt to come to terms with modern physics.

There are two main reasons why the present volume occupies a special place in the vast philosophical literature on quantum mechanics. First, being the first collection that explicitly focuses on the relationship between phenomenology and quantum physics, it advances the somewhat unusual thesis that the phenomenological tradition has much to offer to advance our understanding of the latter. Section 2 of this introductory chapter thus aims at identifying, clarifying, and motivating some of the cornerstones of phenomenological approaches to quantum mechanics. Here we will already see that phenomenology shares crucial systematic similarities with a recent interpretation of quantum mechanics that goes by name of QBism. This, then, is the second unique feature of this volume: Being the first collection on the philosophical implications of QBism, it advances the thesis that phenomenology and QBism offer rich potentials for mutual enlightenment. While phenomenology provides several building blocks that could support QBists in their attempts to explicate the philosophical underpinnings of their own position, QBism is attractive for phenomenologists because it renders quantum mechanics close in spirit to some of the main characteristics of phenomenological philosophy.

There are several additional points of contact between QBism and phenomenology: For one thing, both projects consider the sphere of *lived experience* the ineluctable starting point and epistemological foundation of any scientific investigation. In the eyes of many, this emphasis on experience has put QBism and phenomenology on a direct collision course with the picture of science that is still dominant in large parts of contemporary philosophy of science. For instance, "mainstream" philosophers of science have accused QBism of rendering quantum physics explanatorily impotent because the reduction to experience and subjective degrees of belief seem to cut all ties to the external world which, according to the critics, is the only explanandum in physics (Hagar 2003; Timpson 2008; Brown 2019; Earman 2019). However, instead of rejecting QBism because of its incompatibility with the received view about science, one could also consider the radical alternative: What if quantum mechanics can be consistently interpreted as revealing that our picture of science and reality, as inherited from classical mechanics, is fundamentally ill-headed? And what if, furthermore, QBists are right that the mathematical formalism of quantum theory is no representational vehicle, but rather a tool for embodied agents to manage their expectations about future experiences? Since, arguably, phenomenology is the most thoroughly developed experience-first approach in modern philosophy, it would not be altogether surprising under these assumptions that the phenomenological tradition—and not "mainstream" analytic philosophy of science—offers the most suitable framework for the understanding and interpretation of science in general and quantum mechanics in particular.

Conversely, interpretational disputes about the nature of quantum physics could also have an impact on the reception of phenomenology within the wider scientific arena: It is a common criticism that phenomenology's emphasis on first-person experience puts it at odds with a purely objective third-person methodology that is usually associated with the sciences. In the face of this charge, phenomenologists typically concede, insisting that philosophy and science are indeed very different projects. But if QBism is successful in showing that a third-person methodology is by no means a universal characteristic of science, this would have obvious consequences for questions regarding the "scientificality" of phenomenology. We will come back to these and similar other points in Section 3.

2. Phenomenological approaches to quantum mechanics

Phenomenology, the philosophical tradition that has been inaugurated by Edmund Husserl at the beginning of the 20th century, is a movement that requires the experiencing subject to focus on how she experiences the world. Its basic objective is to unveil the structures of consciousness. What does it mean to undergo an experience? What distinguishes, for instance, perceptual experiences from other types of experiences such as introspective experiences, mathematical intuitions, evaluative experiences, etc.? On a more basic level: What distinguishes mental states that in a sense to be specified "present" their objects (such as when a perceptual experience presents a tree as bodily present) from mental states that do not possess this kind of presentiveness or givenness (such as beliefs)? Regarding methodology, phenomenology constitutes a *descriptive* and *eidetic* approach to investigating consciousness. It is descriptive in the sense that it is a first-person analysis. The aim is to clarify what it is like for the subject to undergo a specific experience, not, for instance, how the brain behaves when having the experience. The ambition, however, is not simply to describe how it feels to undergo a specific experience, but to specify necessary phenomenal features that distinguish different types of experiences and mental states. In this sense, phenomenology pursues an eidetic methodology, using tools like conceptual analysis to unveil structural moments of consciousness. One such structural moment typically identified by phenomenologists as a mark of the mental is *intentionality*. Here intentionality denotes the "aboutness" or "directedness" of mental states. Experiences, wishes, or desires are essentially characterized by their being directed at something *beyond themselves*. Importantly, intentionality comes in many different flavors. One can be intentionally directed towards the same object in many different ways, such as when one first believes that one's bike is in the office, and then sees that one's bike is in the office. For Husserl, these different modes of "givenness" are of utmost *epistemological* importance. Experiences in which the object is given in a presentive manner are contrasted with empty (or signitive) acts in which what is given is not the object in its actual presence, but the object as something that is only meant. While believing that one's bike is in the office is an empty act, the presentive act of seeing the bike *fulfills* the empty act of believing. For many phenomenologists, fulfillment, i.e., the congruence between the object as it is emptily intended and the object as it is given in a presentive experience, is what distinguishes knowledge from mere belief (see, e.g., Hopp 2020, Section 5.1). Phenomenology, in Husserl's tradition, also has the ambition to be the First Philosophy, i.e., the most basic science. This is precisely due to the central epistemic role that phenomenology ascribes to experience: Every science, every piece of knowledge, can be traced back to epistemically foundational experiences (see Berghofer 2022). Since experiences are our basic justifiers, and since phenomenology can be viewed as the study of experience that clarifies how experiences justify, phenomenology enjoys epistemological priority over the individual sciences. In what follows, we focus on features, methods, and teachings of phenomenology that we consider important when it comes to developing phenomenological approaches to quantum mechanics. For more details on phenomenological key concepts and how they are relevant to (philosophy of) physics, see Berghofer & Wiltsche 2020.

2.1. Life-world first! (against wave function realism)

Of all works of classical phenomenology, we consider Husserl's last major publication, *The Crisis of European Sciences and Transcendental Phenomenology*, particularly relevant for phenomenological interpretations of science. In our view, there are two key concepts that deserve special attention: First, the notion of the *life-world* which is not only crucial for a more general understanding of Husserl's late philosophy but which was also highly influential in areas such as sociology or anthropology. Second, the *Crisis* is the locus classicus for Husserl's critique of the *mathematization of nature*. In this subsection we briefly discuss both notions and focus specifically on their relevance for the interpretation of quantum mechanics.

As mentioned above, in phenomenology experiences play the central epistemological role. Phenomenology considers experience to be the ineluctable starting point and epistemological foundation of any scientific investigation. The life-world, in turn, can be understood as the world of our everyday experiences. It is the world of ordinary objects, the world of tables and chairs, the world as it is immediately perceivable and familiar to us. However, the life-world is not only the pre-scientific world in which we all live. According to Husserl, it is also the "meaning-fundament of natural science" (Husserl 1970, 48) and the "realm of original evidences" to which "[a]ll conceivable verification leads back" (Husserl, 1970, 127 f.; translation slightly modified). This is to say that the life-world is both the meaning fundament and the epistemic basis of all scientific endeavors.

In light of this initial characterization, it becomes immediately clear that the life-world thesis puts certain restrictions on our understanding of science and scientific theories. Most importantly, once the thesis of the priority of the life-world is accepted, all interpretations that relegate the life-world to the status of a mere illusion are ruled out from the outset. Such a view was popularized, for instance, by Wilfrid Sellars:

> [S]*peaking as a philosopher*, I am quite prepared to say that the common sense world of physical objects in Space and Time is unreal-that is, that there are no such things. Or, to put it less paradoxically, that in the dimension of describing and explaining the world, science is the measure of all things, of what is that it is, and of what is not that it is not. (Sellars 1963, 173)

The view expressed here is still common in contemporary analytic philosophy of science (see, e.g., Ladyman & Ross 2007). From our phenomenological vantage point, however, any attempt to demote the life-world to the status of an illusion amounts to an empirically incoherent, self-defeating line of reasoning. To put it crudely, declaring our experiences to be illusory is like sawing off the branch on which we are sitting. This is, of course, because our perceptual experiences and the life-world are the *epistemic foundation* of the sciences. As Husserl puts it: “Straightforward experience, in which the life-world is given, is the ultimate foundation of all objective knowledge” (Husserl 1970, 226). If the sciences reveal the illusory character of our experiences, they cast doubt on their own epistemic foundation. Following Jeffrey Barrett (1999, 116), Huggett and Wüthrich define “a theory to be *empirically incoherent* in case the truth of the theory undermines our empirical justification for believing it to be true” (Huggett & Wüthrich 2013, 277). Hence, if our everyday experiences and the life-world are the epistemic foundation of modern physics, but modern physics is interpreted as revealing that the life-world is mere illusion, this interpretation of physics is in danger of being empirically incoherent.[1] One strategy for reconciling the life-world and the world of science could be to regard ordinary experiences and mathematical models as two distinct ways of being intentionally directed towards one and the same world.

This discussion regarding the life-world/science relationship brings us directly to Husserl's critique of the mathematization of nature which, in slogan form, amounts to the warning that we must not “take for *true being* what is actually a *method*” (Husserl 1970, 51). Quite generally, the Husserlian term “mathematization” refers to the cognitive process through which nature is turned into a mathematical manifold. What this means, concretely, is best understood through Husserl's interpretation of the works of the “father of modern science,” Galileo Galilei. On Husserl's view, Galileo marks a watershed in the history of physics not primarily because of any of his individual theoretical or experimental accomplishments. What sets Galileo apart from the tradition before him is rather the larger methodological vision “that trying to deal with physical problems without geometry is attempting the impossible” (Galilei 1967, 203). On Husserl's reading, however, the purpose of Galileo's introduction of mathematical models into physics was not merely to “save the appearances” in individual sub-segments or reality. Rather, Galileo linked his methodological innovation to the much more radical ontological thesis that his mathematical-geometrical models are direct representations of the one true reality *which is mathematical in nature*. It is this metaphysical view that forms the background of Galileo's famous book-metaphor:

1 For similar discussions in the philosophy of quantum gravity of what it would mean for the very endeavor of physics if it turned out that space and time are not fundamental, cf. Huggett & Wüthrich 2013 and Oriti 2014. We must not forget that “[a] central concern of philosophy of science is understanding how the theoretical connects to the empirical, the nature and significance of ‘saving the phenomena’” (Huggett & Wüthrich 2013, 276). Cf. for a phenomenological rendering of this argument, Wiltsche (forthcoming).

> [T]his all-encompassing book that is constantly open before our eyes, that is the universe, […] cannot be understood unless one first learns to understand the language and knows the characters in which it is written. It is written in mathematical language, and its characters are triangles, circles, and other geometrical figures; without these it is humanly impossible to understand a word of it, and one wanders around pointlessly in a dark labyrinth. (Galilei 2008, 183)

Following Husserl's account, then, Galileo's contribution to the history of modern science cannot be reduced to the insight that mathematical models are highly suitable tools for the representation of empirical reality. On Husserl's reading, Galileo's radicality lends itself to the much more radical view that reality literally consists of and is exhausted by geometrical-mathematical structures and entities. "[T]hrough Galileo's *mathematization of nature*, *nature itself* is idealized under the guidance of the new mathematics; nature itself becomes […] a mathematical manifold" (Husserl 1970, 23). Accordingly, concerning the formal and technical apparatus of the mathematical sciences, Husserl warns us not to be "misled into taking these formulae and their formula-meaning for the true being of nature itself" (Husserl 1970, 44).

We note that Galileo, according to this reading, is even more radical than Sellars. Both demote the world of our everyday experiences to some form of illusion but while Sellars holds that reality consists of the objects of our fundamental physical theories, Galileo believes that reality *is* a mathematical manifold. Of course, this appears highly counter-intuitive at first glance, and one might argue that while Husserl's criticism of Galileo is sound, it is only of historical interest. But views very similar to Galileo's are prominently championed in contemporary philosophy of quantum mechanics. This brings us to the doctrine of *wave function realism*.

In quantum mechanics, the quantum state is represented by the so-called wave function. Mathematically speaking, *wave functions are vectors in a Hilbert space*. This is often expressed by saying that "[w]ave functions live in Hilbert space" (Griffiths 2018, 94). A Hilbert space is an abstract mathematical concept, namely a complete vector space on which an inner product is defined. But if one thinks of the wave function as something real, doesn't this mean that the mathematical Hilbert space must be granted physical existence too? This question is directly connected to the more general issue regarding the relationship between abstract mathematical spaces and the space we actually live in. In light of this issue, one possible reaction would consist in the straightforward reification of Hilbert space. And indeed, one can find prominent voices championing Hilbert space realism (e.g. Carroll & Singh 2019). However, most consider this an implausible and unwarranted hypostatization of mathematical objects and it has been pointed out that only "[v]ery few people are willing to defend Hilbert space realism in print" (Wallace 2013, 216).

A similar but more subtle form of mathematization takes place in configuration space realism, i.e., the project of reifying the $3N$-dimensional configuration space, N being the number of the particles in the universe. The main proponent of this view is David Albert.

> [I]t has been essential […] to the project of quantum-mechanical *realism* to learn to think of wave functions as physical objects *in and of themselves.* And of course the space those sorts of objects *live* in, and (therefore) the space *we* live in, the space in which any realistic understanding of quantum mechanics is necessarily going to depict the history of the world as *playing itself out* (if space is the right name for it – of which more later) is *configuration-space.* And whatever impression we have to the contrary (whatever impression we have, say, of living in a three-dimensional space, or in a four-dimensional space-time) is somehow flatly illusory. (Albert 1996, 277)

This configuration space realism, often referred to as wave-function realism,[2] has been quite popular and has sparked much controversy (see particularly the contributions in Albert & Ney 2013). In fact, "[t]his view of the ontology of (no hidden variable) quantum mechanics has probably been the most commonly assumed in the recent literature" (Wallace 2013, 217). Note that Albert explicitly says that our impression to live in a three-dimensional space is "flatly illusory." Obviously, from a Husserlian perspective, such a claim is highly suspect, to say the least. Accordingly, many objections to this claim have a phenomenological touch.[3]

David Wallace objects that configuration space realism "makes the same unmotivated conceptual move as Hilbert space realism: it reifies a mathematical space without any particular justification" (Wallace 2013, 217). Bradley Monton argues "that our everyday commonsense constant experience is such that we're living in three spatial dimensions, and nothing from our experience provides powerful enough reason to give up that prima facie obvious epistemic starting point" (Monton 2013, 154). Peter Lewis has even argued "for the converse of Albert's initial position; the world really is three-dimensional, and the $3N$-dimensional appearance of quantum phenomena is the theoretical analog of an illusion" (Lewis 2013, 124).

It would go beyond the scope of this introductory chapter to discuss these arguments in detail, but we note the Husserlian idea that no matter how abstract our scientific theories are, their justification, ultimately, lies in ordinary experiences, in what is immediately given. In Husserl's

2 It should be noted that this common terminology is misleading since there are other positions that can be viewed as realist positions concerning the wave function that do not subscribe to configurations space realism (see Chen 2019).

3 For an early anticipation of and objection to this kind of wave function realism, see the comments of the phenomenologically minded physicist Hermann Weyl in (Weyl 2009, 147f.).

words, “the inductive scientific judging” of the “exact objective sciences that by going beyond the immediately experienced infers the non-experienced is always dependent on its ultimate legitimizing basis, on the immediate data of experience” (Husserl 1973, 121; our translation). For phenomenologists, arguing based on scientific theories that the life-world is mere illusion is empirically incoherent (Wiltsche forthcoming), and, indeed, this worry has been raised against Albert’s configuration space realism (Chen 2019, 6).

In sum, since the wave function is the central concept of quantum mechanics, reifying the wave function is the natural move for interpretations that are in the spirit of standard scientific realism. It is rather unsurprising, then, that wave function realism is widely held in contemporary philosophy of quantum mechanics.[4] Reifying the wave function, however, is similar to the reification of geometrical concepts that Husserl ascribed to Galileo. It runs the risk of constituting a counter-intuitive mathematization of nature that confuses reality with what is a method to describe or represent reality. Phenomenologists should thus be cautious to subscribe to any interpretation that is in danger of implying such a mathematization. Here phenomenologists are in agreement with the QBist worry that in standard realist interpretations “the strategy has been to reify or objectify all the mathematical symbols of the theory and then explore whatever comes of the move” (Fuchs & Stacey 2019, 136). As a critical reaction to this argumentative strategy, an idea that has recently emerged in the foundations of quantum mechanics is that the whole project of interpreting quantum mechanics is problematic—if this project is understood as taking the quantum formalism as a given and attempting to read off the nature of physical reality from the mathematical structure of the formalism. Instead, it has been argued that one first needs to identify intuitive physical principles from which the formalism can be *reconstructed*. What is then interpreted are the physical principles and not the mathematical formalism. We return to this project of reconstruction below when discussing Philip Goyal’s contribution to this volume.

2.2. Physics first! (against modificatory interpretations)

4 However, while the most common realist interpretations of quantum mechanics—the many-worlds interpretation, Bohmian mechanics, and Ghirardi-Rimini-Weber theory—are all in danger of leading to a problematic mathematization of nature, not all proponents of these interpretations argue for reifying the wave function. Even the main proponents of the respective interpretation do not agree on the ontological status of the wave function. In the case of the many-worlds interpretation, one of its main proponents, David Wallace, is also one of the strongest critics of wave function realism (Wallace 2021). In Bohmian mechanics, we find versions of wave function realism that consider ordinary three-dimensional space as illusory (Albert 1996), or emergent and non-fundamental (Ney 2013), as well as the idea that there is a fundamental three-dimensional ontology and that the wave function might not be physically real like particles or fields but ontologically sui generis (Maudlin 2013).

Quite generally, a driving motivation for phenomenology is a deep respect for the phenomena. This is to say that phenomenologists strive to be attentive to how intentional objects are given to them, aiming at a study of the given that is as unprejudiced as possible. This idea has been expressed by Husserl in various ways, most prominently in his call to "go back to the 'things themselves'" and his verdict that phenomenologists "are the genuine positivists" (Husserl, 1982, 39). One implication of this is, according to Husserl, that logical truths should not be reduced to psychological facts. Logical truths are given to us as being independent of our encountering them, which is why we should be cautious in our naturalist ambitions to reduce them to psychological or physical laws. In this spirit, Mirja Hartimo has recently argued that Husserl's phenomenological approach to mathematics can be described as a mathematics-first approach.

> While philosophers' and mathematicians' activities are complementary, each should also respect the others' autonomy. [...] In general, his approach is 'mathematics first.' [Husserl] *does not develop a philosophical view of what mathematics should be like, but aims rather to describe mathematics as it is for mathematicians* [our emphasis]. (Hartimo 2021, 27)

The relationship between mathematics and philosophy of mathematics is summarized by Hartimo as follows: "For Husserl mathematics comes first – in accordance to the slogan 'back to the phenomena themselves' – yet at the same time, philosophy comes first in the sense that it seeks to give reflective foundations to the other disciplines" (Hartimo 2021, 31). Edith Stein clarifies the foundational role of phenomenology as follows:

> Being a foundational science, indeed, does not mean that phenomenology generates presuppositional statements for all other sciences, from which the latter would be able to logically derive their own theorems. Rather, by removing the 'self-forgetfulness' of the dogmatic scientist, phenomenology reveals the dimension of unclarity that attaches to *every* dogmatic science, and transforms 'naive' science, which does not inquire into the meaning and justification of its methodology, into a science that has been clarified by critical reason (Stein 2018, 312; Husserl 1987, 263f.).

On our view, these comments can be summarized as follows: Phenomenology aspires to be the most basic science not because it claims to deliver the axioms or theorems of every or even any individual science, but because it addresses the epistemic foundation of any given individual science, identifies justification-conferring experiences as foundational justifiers, and seeks to clarify how we legitimately get from these experiences to scientific theories.

Regarding physics, one of our main interests as phenomenologists lies in the question of how the respective theory and mathematical formalism *emerges from its experiential and life-worldly foundation*. It should be noted, however, that phenomenologists should be *very* cautious to demand modifications of the formalism on philosophical grounds.[5] One should be particularly cautious if the urge for modification is based on ontological principles or intuitions (that might turn out to be ontological prejudices). Consider, for instance, Bohmian mechanics. In contemporary philosophy of quantum mechanics, Bohmian mechanics is a highly popular choice. In the physics community, however, it remains disliked and largely ignored. This is because Bohmian mechanics actually *changes* the formalism of quantum mechanics, adding so-called hidden variables that are, in principle, unobservable. Importantly, it remains technically challenging to square Bohmian mechanics with special relativity and, as of yet, we do not have a relativistic extension of Bohmian mechanics that rivals the predictive scope of well-established relativistic extensions of textbook quantum mechanics (see Goldstein 2021, Section 1.4 and Kofler & Zeilinger 2010, Wallace 2022). Bohmian mechanics, strictly speaking, is thus not an interpretation of our most successful scientific theory (i.e., quantum mechanics), but a *rival* theory that is clearly inferior in its predictive power. But why, then, is Bohmian mechanics so popular in philosophy? One main reason is that Bohmian mechanics promises a *clear ontology*. This desideratum has been expressed as follows:

> In fact, the lack of a clear ontology in orthodox quantum mechanics is the real root of the measurement problem (and many other problems). If the ontology is clear—if it is clear what the fundamental entities in nature are that the theory seeks to describe—there can't be any paradoxes. (Dürr & Lazarovici 2020, 47)

In Bohmian mechanics, the fundamental objects of the theory are point particles that have a definite position at each time, their dynamics being governed by deterministic equations. Accordingly, Bohmian mechanics is the interpretation whose ontology is closest to classical mechanics. Of course, there are some important dissimilarities between classical and Bohmian mechanics. Although both theories are deterministic, it is impossible in Bohmian mechanics to know all initial conditions. As a consequence, Bohmian mechanics—just like textbook quantum mechanics—is limited to predictions that are probabilistic in nature. Furthermore, in Bohmian mechanics the wave function plays an important role in determining the dynamics of the point particles. Accordingly, one might argue that its ontology is not as clear as its proponents would like it to be since the

5 However, there are noteworthy exceptions: Following Ryckman's interpretation (2005), the motivation for Weyl's criticism of Einstein's choice of Riemannian geometry as the mathematical backbone of General Relativity Theory was philosophical and not scientific in nature.

ontological status of the wave function remains contentious. As mentioned above, Bohmians disagree on whether the wave function is physically real, or more like a nature of law, or a new kind of entity that is ontologically sui generis. Also, it should be mentioned that Bohmian mechanics implies non-locality which has often been understood, most notably by Einstein, as a counter-intuitive "spooky action at a distance."

However, the main worry addressed in this section is that Bohmian mechanics is not in accordance with the "physics first" idea. As we have seen, this is because Bohmian mechanics does not interpret the formalism that is actually used by the majority of quantum physicists, but *modifies* the quantum formalism and thereby introduces a rival theory. This is true for Bohmian mechanics as well as for objective collapse theories such as the Ghirardi-Rimini-Weber theory (GRW). Proponents of the many-worlds interpretation (MWI) typically regard this as a major advantage of their interpretation, arguing that on their account no modification of the quantum formalism is required (Wallace 2022). Although we do not contest this claim, we wish to note that the ontological status of the wave function is a problem for MWI as well, as is the postulation of infinitely many, in principle unobservable worlds. We shall turn to the topic of observability in the next subsection.

The "physics-first" idea can be broken down to the following guideline which should be taken seriously by every phenomenological approach to quantum mechanics: We should be cautious to modify the formalism of our most successful scientific theory, particularly if the rival modified theory is (i) predictively less successful and (ii) less parsimonious due to surplus mathematical structure. Furthermore, as will become clearer in the course of this chapter, we may add the following guideline: We should not consider the properties of classical mechanics as properties that must be preserved in quantum theory. This is to say that if quantum phenomena—such as the phenomenon that quantum objects apparently do not have pre-determined and pre-existing values—suggest a worldview that is different from our classical intuitions, we should be open to that possibility, respecting the quantum phenomena.

2.3. Experience first! (against objectivist interpretations)

Phenomenology is an "experience-first" project in an epistemological and a methodological sense. Epistemologically, because it acknowledges that all epistemic justification, every piece of knowledge, and any successful scientific endeavor can be traced back to epistemically foundational experiences. One of its aims, then, is to analyze which experiences are involved and which role they play in the practice and reasoning of the respective science (Berghofer 2022). In a methodological sense, phenomenology qualifies as an "experience-first" project because it relies on a descriptive first-person analysis of consciousness. Applied to phenomenological approaches to science, this latter aspect leads to questions such as whether we should accept the existence of scientific entities that are in principle unobservable, whether science can successfully abstract away from the subject and her experiences, or whether, to the contrary, science should actively seek to incorporate the first-person perspective into science. In Section 2.3.1, we briefly discuss the criterion of *observability* which took center stage in the reasoning of various phenomenologists and physicists. If scientific theories must conform to this criterion, this alone would be enough to undermine the idea that science can be purged of all subjective or operational notions. In Section 2.3.2, we move on to the stronger claim that physics needs to incorporate the physicist and that quantum mechanics in particular should be understood in exactly this way. Interestingly enough, this is a claim that unites classical phenomenologists such as Merleau-Ponty and contemporary QBists. Finally, in Section 2.3.3, we discuss a concrete interpretation of quantum mechanics that exemplifies such a phenomenological approach.

An additional goal in this section is to make explicit the tensions between some of the basic tenets of phenomenology on the one hand and objectivist interpretations of quantum mechanics on the other. In our terminology, interpretations qualify as "objectivist" if they (i) reify the wave function, i.e. assign it the status of a physically real entity, and/or (ii) claim to deliver a purely objective third-person perspective that does not contain any irreducibly subjective or perspectival moments. While (i) was in the center of attention in Section 2.1, the focus in this section is on (ii).

2.3.1. Observability

For Husserl, the most fundamental question in epistemology is how subjectivity can be the source of objective knowledge (see Melle in Husserl 1984, page XXXI). In his view, the kind of acts that play the role of justifiers for all sorts of beliefs are a particular type of experiences, namely *originary presentive intuitions*. What makes this particular category of acts special is the fact that they present their objects as "bodily present," "actually present," or simply "self-given" (Husserl 1997, 12). Since all mediate justification leads back to immediate justification, and since originary presentive intuitions are the source of this kind of justification, originary presentive intuitions also play the role of *ultimate* (albeit fallible) justifiers. The epistemic significance of these acts is most firmly stated in the famous *principle of all principles*:

> No conceivable theory can make us err with respect to the *principle of all principles: that every originary presentive intuition is a legitimizing source of cognition*, that *everything originarily* (so to speak, in its "personal" actuality) *offered* to us *in* '*intuition*' *is to be accepted simply as what it is presented as being*, but also *only within the limits in which it is presented there*. (Husserl 1983, 44)

Particularly the last part of this principle is sometimes interpreted as suggesting that one cannot be justified in believing in the existence of an entity that cannot, in principle, be originally given. This, of course, would have far-reaching consequences for the interpretation of scientific theories. For instance, Wiltsche argued for a phenomenologically motivated anti-realism about unobservable scientific entities (Wiltsche 2012). On an exegetical level, this anti-realism can be backed up by passages in which Husserl explicitly demands that being a physical object implies being perceptually experienceable (Husserl 2003, 74). Although it remains controversial whether phenomenologists should feel committed to such a form of anti-realism (see the response to Wiltsche in Berghofer 2018, Hardy 2020, and also Wiltsche forthcoming), we note that from a phenomenological perspective it is prima facie suspect if a scientific theory implies the existence of entities that are in principle unobservable.

Another way for the concept of observability to enter the discussion is the idea that "a theory shouldn't make distinctions that it cannot empirically honor" (Carrier 2012, 28; our translation). To put it differently, if A and B are two distinct physical states, it must at least in principle be possible to empirically distinguish between them, there must be an observable difference. This was the driving idea behind Einstein's development of relativity theory as well as Heisenberg's quantum mechanics (see, e.g., Carrier 2012, Rovelli 2021). Consider how Heisenberg opens his 1925 article that marks the beginning of modern quantum mechanics:

> "The objective of this work is to lay the foundations for a theory of quantum mechanics based exclusively on relations between quantities that are in principle observable" (Heisenberg, as cited in Rovelli 2021, 20).

Arguably, hidden-variable theories like Bohmian mechanics violate this idea, as does the many-worlds interpretation.

2.3.2. Incorporating the first-person perspective into science

Considering Husserl's aforementioned critique of Galileo, it cannot be emphasized enough that Husserl nowhere questions the tremendous success of Galileo's amalgamation of mathematics and physics. In fact, the technological and predictive success of modern mathematized science is so tremendous that it poses questions on its own: One can wonder, as Eugene Wigner famously did (1960), why mathematical models can be so successfully used to represent reality at all. In answering this question, phenomenologists typically do not follow mathematical monists such as Galileo or Max Tegmark in claiming that "our successful theories are […] mathematics approximating mathematics" (Tegmark 2008, 125). Instead, phenomenologists like to point out that the application of mathematical models involves a *process of idealization* such that our mathematical framework is not applied to nature itself but an idealization, a model of nature (see Islami & Wiltsche 2020).

The success of mathematical physics has indirectly led also to some further problems. For instance, it has been argued that the undeniable success of quantum physics in general and of relativistic quantum field theory in particular has shrouded and overshadowed a lack of conceptual clarity in physics (Berghofer et al. forthcoming). It seems that a new generation of physicists is learning how to apply certain concepts, methods, and theories in order to solve suitable problems, but that the meaning of these concepts, their historical embeddedness, and their relationship to our real world is more and more lost. One can suspect that this alienation between physical theory and physical reality is not only a philosophical problem but actually hinders progress in physics. This problem has been explicitly mentioned by Einstein:

> Concepts that have proven useful in ordering things easily achieve such an authority over us that we forget their earthly origins and accept them as unalterable givens. Thus they come to be stamped as 'necessities of thought,' 'a priori givens,' etc. The path of scientific advance is often made impassable for a long time through such errors. For that reason, it is by no means an idle game if we become practiced in analyzing the long commonplace concepts and exhibiting those circumstances upon which their justification and usefulness depend, *how they have grown up*, *individually*, *out of the givens of experience* [our emphasis]. By this means, their all-too-great authority will be broken. (Einstein 1916, 102; cited in Howard 2014, 358)

A similar point has been made by Husserl:

> And it is precisely for this reason that a theoretical task and achievement like that of a natural science [...] can only be and remain meaningful in a true and original sense *if* the scientist has developed in himself the ability to *inquire back* into the *original meaning* of all his meaning-structures and methods, i.e., into the *historical meaning of their primal establishment*, and

especially into the meaning of all the *inherited meanings* taken over unnoticed in this primal establishment, as well as those taken over later on. (Husserl 1970, 56)

A further problem that indirectly arose from the success of mathematical physics is the naturalistic attitude according to which a third-person mathematical description can describe everything there is. In this context Stein said: "What physics [...] reveals pertains to the real nature but it never *exhausts* nature. And what evades the web of mathematical formulas is not less 'real' than what is captured by mathematics" (Stein 2004, 62). Here we find two motifs that are typical for a phenomenology of physics. First, although phenomenology does not, of course, dispute the success of physics or object to the implementation of mathematics, a claim often seen in phenomenology is that the mathematical picture delivered by physics only constitutes one perspective on nature, and that what we gain from the successful application of mathematical tools can never be an exhaustive picture of nature. "We have seen that the methods of the exact natural sciences do not capture reality in its totality, instead they are only concerned with certain sides of nature" (Stein 2004, 73).[6] Second, and closely connected, most phenomenologists reject the view according to which mathematizability is a criterion for existence. Typically, this not only holds true in the case of physical existence but also for entities such as values, essences, or consciousness. Ultimately, this amounts to the overall view that, although mathematics can be an extremely useful tool in many areas of science, we must not mistake mathematizability for scientificality.

It is a commonplace in phenomenology that a purely objective third-person perspective is unreachable (see, e.g., Berghofer 2020 and Khalili 2022). Here is how Zahavi puts it: "There is no pure third-person perspective, just as there is no view from nowhere. This is, of course, not to say that there is no third-person perspective, but merely that such a perspective is, precisely, a perspective from somewhere. It is a view that *we* can adopt on the world" (Zahavi 2019, 54). However, instead of merely discussing whether the natural sciences can reach a pure third-person perspective, some phenomenologists went a step further and considered the considerably *stronger* view that the natural sciences should actively try to incorporate the *first-person* perspective. Merleau-Ponty is perhaps the most prominent phenomenologist who explicitly championed this claim.

But a physics that has learned to situate the physicist physically, a psychology that has learned to situate the psychologist in the socio-historical world, have lost the illusion of the absolute view

6 "Phenomenology is not out to dispute the value of science and is not denying that scientific investigations can lead to new insights and expand our understanding of reality. But phenomenologists do reject the idea that natural science can provide an exhaustive account of reality. Importantly, this does not entail that phenomenology is, as such, opposed to quantitative methods and studies. The latter are excellent, but only when addressing quantitative questions" (Zahavi 2019, 52).

> from above: they do not only tolerate, they enjoin a radical examination of our belongingness to the world before all science. (Merleau-Ponty 1968, 27)

The upshot here is that physics in its most sophisticated form not only abandons the project of delivering a completely objective picture of the world but instead actively incorporates the cognizing subject and thus accounts for the fact that the life-world predates all scientific endeavors. It is only by doing so that we can hope to unveil the most fundamental relation, namely the one between the observer and the observed.[7] According to the late Merleau-Ponty, quantum mechanics represents the closest approximation to such a new kind of physics, which—unlike classical physics—not only "posits nature as an object spread out in front of us, [but rather] places its own object *and its relation to this object in question*" (Merleau-Ponty, 2003, 85; our emphasis). Adopting the terminology from the French physicist and logician Paulette Destouches-Février, Merleau-Ponty calls the worldview that emerges from quantum mechanics a "participationist conception" and the kind of realism he subscribes to a "partial realism" (Merleau-Ponty 2003, 97f.). As we will see below, this is a striking similarity both in content and in terminology to the QBist notion of a "participatory realism" (Fuchs 2017).

It should also be noted that Merleau-Ponty's understanding of quantum mechanics was influenced by the interpretation offered by Fritz London and Edmond Bauer in their *La Théorie de l'Observation en Mécanique Quantique* (1939). The London & Bauer interpretation constitutes the first genuinely phenomenological approach to quantum mechanics. One of its main ideas is that quantum mechanics should be interpreted from the perspective of a phenomenological theory of knowledge that seeks to clarify the relationship between the observer and the observed. We return to this below. First, we briefly point out what it is that makes quantum mechanics so interesting for phenomenology and how this connects to the main question of this sub-section, namely whether physics can or should incorporate the first-person perspective.

In textbook quantum mechanics "measurement" is a central and irreducible notion. This finds expression in the so-called collapse postulate. According to this postulate, when a measurement takes place, the wave function collapses such that the quantum state is not in a state of superposition anymore, which in turn results in us observing a definite value. This raises the question, of course,

7 Consider in this context also Weyl's *Mind and Nature* where it is argued that "the structure of our scientific cognition of the world is decisively determined by the fact that this world does not exist in itself, but is merely encountered by us as an object in the correlative variance of subject and object. The world exists only as that met with by an ego, as one appearing to a consciousness; the consciousness in this function does not belong to the world, but stands out against the being as the sphere of vision, of meaning, of image, or however else one may call it." (Weyl 2009, 83)

as to why it actually is that the wave function collapses upon measurement. Yet even more importantly, one distinctive feature of (textbook) quantum mechanics is that it includes the subjective-operational term "measurement" as a primitive notion. It is "primitive" in the sense that it cannot be reduced to mathematical terms, which also explains why—according to several scholars—the way quantum mechanics is taught and understood in some physics textbooks is not only misleading but plainly unscientific. The background of this verdict is the conviction that the aim of a sensible approach to quantum mechanics must be to "develop an objective description of nature in which 'measurements' are subject to the same laws of nature as all other physical processes," thus resulting in a situation in which "any form of interpretation […] is superfluous" (Dürr & Lazarovici 2020, viii). The intention behind such purely objectivistic interpretations—which tend to be referred to as "quantum theories without observers" (Dürr & Lazarovici 2020, viii; Goldstein 1998)—is to purge scientific theories of all subjective, experiential, and operational notions such as "consciousness," "experience," or "measurement." In the words of Tim Maudlin: "A precisely defined physical theory […] would never use terms like 'observation,' 'measurement,' 'system,' or 'apparatus' in its fundamental postulates. It would instead say precisely *what exists and how it behaves*" (Maudlin 2019, 5). As the reader will find, the mindset underlying this volume goes in the opposite direction. Virtually all authors agree that we should welcome the operational flavor of quantum mechanics, and that we should consider the central, irreducible role of measurement or experience as a virtue instead of a vice. One way to cash this out is to view the wave function not as a physically real entity but as a mathematical tool that encodes the subject's probabilistic expectations about her future experiences. The notorious "collapse" of the wave function, then, is not a physical process but simply corresponds to the updating of the subject's information that results from the measurement process. As we shall see in more detail in Section 3, this is precisely how QBists approach the infamous measurement problem in quantum mechanics.

2.3.3. Phenomenological Approaches to the measurement problem

As mentioned in the previous subsection, the notion of measurement plays a central and irreducible role in quantum mechanics. According to textbook presentations, a unique feature of the theory is that the wave function always collapses upon measurement. But why? Understanding the apparent collapse of the wave function is the central theme of the infamous measurement problem. An early "solution" to this problem was to argue that consciousness causes the wave function to collapse. In fact, this view goes back to none other than John von Neumann, who provided quantum mechanics with its rigorous mathematical foundation. In his monumental *The Mathematical Foundations of*

Quantum Mechanics von Neumann approached the process of quantum measurement by making the following distinction: "[L]et us divide the world into three parts: I, II, III. Let I be the system actually observed, II the measuring instrument, and III the actual observer" (von Neumann 2018, 273). Now, the distinctive feature of III is that, in contrast to I and II, "III itself remains outside of the calculation" (von Neumann 2018, 273). This was usually taken to amount to the view that non-material consciousness is responsible for the collapse of the wave function, a view that is of course diametrically opposed to the objectivist interpretations mentioned before. Although the "consciousness causes collapse" idea has also been endorsed by other prominent physicists such as Eugene Wigner, it plays virtually no role in current debates. This has to do with what is considered to be its main defect, its inability to make clear how non-material consciousness could have a causal physical effect on material reality (Shimony 1963; Putnam 1979).

As Steven French has pointed out in a series of papers and a forthcoming book (French 2002, 2020, forthcoming), there exists an alternative to the von Neumann/Wigner approach which is relevant in our context for at least three reasons: first, it avoids the main problems usually associated with the "consciousness causes collapse" idea; second, it restores the intuition that consciousness is crucial to our understanding of quantum mechanics; third and last, it explicitly relies on the framework of Husserlian phenomenology. The account we are referring to is laid out in Fritz London's and Edmond Bauer's short 1939 monograph *La Theorie de l'Observation en Mecanique Quantique.* In essence, the book had two aims, namely to provide a "concise and simple" (London & Bauer 1983, 219) account of the measurement problem in the spirit of von Neumann's groundbreaking work and to shed more light on the relationship between the observed and the observer. Although London and Bauer's book was generally well-known in the community, its genuinely phenomenological dimensions had been overlooked. This is unfortunate because, arguably, if "interpreted correctly, it offers a much more sophisticated account of measurement which, being grounded in the tradition of Husserlian phenomenology, is capable of responding to" the objections that have been raised against the von Neumann-Wigner interpretation that consciousness causes collapse (French 2020, 208).[8]

8 From a phenomenological perspective, it is Fritz London who deserves particular historical attention: The fact that London was nominated four times for the Nobel Prize in chemistry and one time for the Nobel Prize in physics speaks volumes about the breadth and significance of his oeuvre. However, London's academic career had started in philosophy where he completed his first doctoral dissertation *Über die Bedingungen der Möglichkeit einer deduktiven Theorie* under the supervision of the Munich phenomenologist Alexander Pfänder. London's dissertation, which appeared in Husserl's *Jahrbuch für Philosophie und Phänomenologische Forschung* in 1923, was described as „a set theoretic concretization of Husserl's largely programmatic account of a *macrological philosophy of science*" (Mormann 1991, 70). After graduating in philosophy at the age of 21, London's focus shifted towards quantum physics where he worked under the likes of Arnold Sommerfeld and Erwin Schrödinger. However, as we will see, London's phenomenological training remained the background of his approach to quantum mechanics.

Considering the specifics of the London and Bauer approach, the first thing to note is that, in their view, "a measurement is achieved only when the" outcome "has been *observed*" (London & Bauer 1983, 251).[9] This is to say, according to them, a measurement is only complete when the observer has observed the outcome of the measurement procedure. What is more, London and Bauer "consider the ensemble of three systems, (*object* x) + (*apparatus* y) + (*observer* z), as a combined and unique system" that is described "by a global wave function" (London & Bauer 1983, 251). Here object x is the quantum system upon which a measurement is conducted, apparatus y is the measuring apparatus, and the observer z observes the measurement outcome. The global wave function is expressed as follows: $\mathbf{\Psi}(x, y, z) = \sum \mathit{\Psi}_k u_k(x) v_k(y) w_k(z)$. In their unusual terminology, $\mathit{\Psi}_k$ are the coefficients. The states of the quantum system are represented by u_k, v_k represent the states of the apparatus, and w_k the states of the observer.

What this all means, in essence, is that the consciousness of the observer is not something non-physical that impinges on the quantum system from the outside, magically causing the wave function to collapse. Instead, the wave function represents an *interrelated* system of object, apparatus, and observer. According to London and Bauer, however, there is something special about an observer who relates back to her own consciousness. Such an observer

> possesses a characteristic and quite familiar faculty which we can call the 'faculty of introspection.' He can keep track from moment to moment of his own state. By virtue of this 'immanent knowledge' he attributes to himself the right to create his own objectivity – that is, to cut the chain of statistical correlations summarized in $\sum \mathit{\Psi}_k u_k(x) v_k(y) w_k(z)$ by declaring, 'I am in the state w_k' or more simply, 'I see $G = g_k$.' (London & Bauer 1983, 252)

It is through the faculty of introspection that conscious observers have privileged access to their own states. This is what makes the observer special, and what distinguishes her from the object and the apparatus. By introspecting her own state, "the observer establishes his own framework of objectivity and acquires a new piece of information about the object in question" (London & Bauer 1983, 252). Consequently, we should not think of the relationship between consciousness and the wave function in terms of consciousness causing the wave function to collapse but rather in terms of a conscious observer who is able to *separate* herself from the wave function.

> Thus it is not a mysterious interaction between the apparatus and the object that produces a new $\mathit{\Psi}$ for the system during the measurement. It is only the consciousness of an 'I' who can separate himself from the former function $\Psi(x, y, z)$ and, by virtue of his observation, *set up a new*

9 Compare this with the central QBist thesis: "This experiment has no outcome until I experience one" (Fuchs et al. 2014, 751).

> *objectivity* in attributing to the object henceforward a new function $\Psi(x) = u_k(x)$. (London & Bauer 1983, 252)

As Steven French rightly points out, many of the concepts employed by London and Bauer "clearly demand a phenomenological reading" (French 2002, 484). French also emphasizes that, furthermore, the original term for what is here translated as "set up" is the French "constituer." So, basically, what London and Bauer are saying here is that the consciousness of an I *constitutes* objectivity, which, again, prompts a phenomenological reading. Hence, according to French, London and Bauer's view of the "separation" between the ego and the wave function can be understood "not […] in terms of consciousness 'causing', in whatever sense, the wave function to collapse, but rather in Husserlian terms, as that of a *mutual separation* of both an Ego-pole and an object-pole through a characteristic act of reflection" (French 2002, 484).

Another clear testament of London and Bauer's commitment to Husserlian phenomenology can be found towards the end of their booklet.[10] Here, London and Bauer point out that the discussion surrounding the concept of a quantum measurement relates to a broader philosophical problem, namely "the determination of the necessary and sufficient conditions for an object of thought to possess objectivity and to be an object of science" (London & Bauer 1983, 259). They continue by adding that "[m]ore recently Husserl […] has systematically studied such questions and has thus created a new method of investigation called 'Phenomenology'" (London & Bauer 1983, 259). Summarizing the philosophical implications of their understanding of the quantum formalism, London and Bauer write:

> [T]he discussion of this formalism taught us that the apparent philosophical point of departure of the theory, the idea of an observable world, totally independent of the observer was a vacuous idea. Without intending to set up a theory of knowledge, although they were guided by a rather questionable philosophy, physicists were so to speak trapped in spite of themselves into discovering that the formalism of quantum mechanics already implies a well-defined theory of the relationship between the object and the observer, a relation quite different from that implicit in naïve realism, which had seemed, until then, one of the indispensable foundation stones of every science. (London & Bauer 1983, 220)

Similar ideas have been articulated by several of the founding figures of quantum mechanics, most notably by Niels Bohr who believed quantum mechanics to reveal that "physics is to be regarded not so much as the study of something *a priori* given, but rather as the development of methods for

10 However, it should be noted that French's phenomenological reading of the London and Bauer approach has recently been challenged by Otávio Bueno (2019).

ordering and surveying human experience" (Bohr 1963, 10). Or, to put it differently: The main lesson of quantum mechanics is that science, at a fundamental level, is not supposed to provide "a description of *reality in itself* [but] a description of *reality as experienced by an agent*" (Goyal 2012, 584).[11]

In sharp contradistinction to the many-worlds interpretation—according to which the quantum formalism provides us with an objective description of the deterministic evolution of the universal wave function—and the Bohmian interpretation—according to which the formalism is about the deterministic evolution of point particles—, London and Bauer take the quantum formalism to be a "well-defined theory of the relationship between the object and the observer." One consequence of this view is that, on London and Bauer's reading, quantum mechanics is clearly at odds with naïve realism. In fact, London and Bauer go so far as to say that "the idea of an observable world, totally independent of the observer was a vacuous idea" (London & Bauer 1983, 220). Yet, despite this anti-realist flavor, it would still be wrong to see in London and Bauer straightforward instrumentalists according to whom quantum mechanics does not tell us anything about reality. It tells us something very important namely precisely that naïve realism is wrong and that, in the words of the QBists, "reality is *more* than any third-person perspective can capture" (Fuchs 2017, 113).

3. QBism

The distinctive idea of QBism is to apply a personalist Bayesian account of probability, as it has been developed by Bruno de Finetti, to quantum probabilities (Fuchs et al. 2014). This means that probabilities in quantum mechanics are interpreted not as objective but as subjective probabilities. Another way to put this is that, according to QBism, quantum states do not represent objective reality but instead *represent an agent's subjective degrees of beliefs about her future experiences*. Consequently, instead of being construed as (the representation) of something physically real, the wave function is considered to be a mathematical tool that encodes one's expectations about one's future experiences. In short, QBism argues that quantum states do "not represent an element of physical reality but an agent's personal probability assignments, reflecting his subjective degrees of belief about the future content of his experience" (Fuchs & Schack 2015, 1). A measurement is

11 Consider in this context also Weyl's claim that modern physics reveals that science "does not state and describe states of affairs—'Things are so and so'—but that it constructs symbols by means of which it 'represents' the world of appearances." (Weyl 2009, 83)

understood as an act of the subject on the world and the outcome of a measurement is the very experience that results from this process (see DeBrota & Stacey 2019). Instead of subscribing to a worldview according to which the world is objectively "out there," waiting to be discovered, QBists think of the relationship between world and subject in terms of a reciprocal one. Building on the insight that "reality is *more* than any third-person perspective can capture" (Fuchs 2017, 113), they propose a kind of realism that has been aptly labeled a "participatory realism" (Fuchs 2017). Accordingly, one of the QBists' objectives is to put the scientist back into science (Mermin 2014). In this section, we highlight some of the similarities between QBism and phenomenology and discuss possible tensions. The overall objective is to bring both into a fruitful dialogue, expecting a better understanding of quantum mechanics to emerge from this engagement.

3.1. QBism & phenomenology: Points of contact

Perhaps the most obvious and systematically most significant similarity between QBism and phenomenology is their commitment to an experience-first approach. In phenomenology, this commitment finds its expression in the thesis that all epistemic justification and every piece of knowledge can be traced back to epistemically foundational experiences. In QBism, it manifests itself in the interpretation of quantum mechanics as a tool that allows the experiencing subject to predict future experiences, and in the construal of measurement outcomes as the very experiences of the subject. Furthermore, both QBism and phenomenology agree that experiences constitute our main points of contact with the world and that a purely objective third-person perspective that abstracts away from the subject and her experiences is in principle impossible. Accordingly, in their contribution to this volume, Michel Bitbol and Laura de la Tremblaye write:

> "And since Phenomenology is the only contemporary philosophical research program that does not turn lived experience into some ghostly epiphenomenon, and that takes instead experience as its absolute starting point, we claim it is the only unified framework suitable for making sense of QBism."

This, of course, is in stark opposition to the received view in "mainstream" analytic philosophy of science according to which scientific theories purport to describe a reality that is assumed to be completely independent from the observer. Here, the underlying picture is that physical objects have a number of intrinsic properties (such as position and momentum), that the states of these properties are objectively fixed, and that the aim of science is to offer an exhaustive third-person description of what these states are. To be sure, our point is not to deny that this picture has some initial plausibility and that it is in agreement with a straightforward interpretation of many successful scientific theories. This is true, in particular, of classical mechanics which has crucially shaped the way we think about the nature of science and reality.[12]j Yet, its tremendous successes notwithstanding, the fact of the matter is that classical mechanics is dead. It now has been dead for over a century and it is not coming back. To put it provocatively, then, the impression is that while physicists tend to accept the classical picture to be undermined by quantum mechanics, large parts of the philosophical community do not seem ready to move on. The three main interpretations in contemporary philosophy of quantum mechanics—Bohmian mechanics, the many-worlds interpretation, and objective collapse theories—still cling to the idea that physics is in the business of providing a description that is completely free from all irreducibly perspectival or subjective moments. But the price to be paid is either a modification of the quantum formalism or the introduction of a rather baroque ontology of infinitely many unobservable worlds.

Although there is no universal agreement regarding phenomenology's stance in the metaphysical realism debate, it seems safe to say that phenomenologists tent to be more open than standard analytic philosophers to some of the stronger implications of QBism. For instance, when QBists insist that "there is no such thing as the universe in any completed and waiting-to-be-discovered sense" and that "nature is being hammered out as we speak" (Fuchs in Schlosshauer, 2011, 285), this is indeed reminiscent of Husserl's description of the constituting role of transcendental subjectivity.

> Every imaginable sense, every imaginable being, whether the latter is called immanent or transcendent, falls within the domain of transcendental subjectivity, as the subjectivity that constitutes sense and being. The attempt to conceive the universe of true being as something lying outside the universe of possible consciousness, possible knowledge, possible evidence, the two being related to one another merely externally by a rigid law, is nonsensical. They belong together essentially; and, as belonging together essentially, they are also concretely one, one in the only absolute concretion: transcendental subjectivity. If transcendental subjectivity is the universe of possible sense, then an outside is precisely – nonsense. (Husserl 1960, 84)

In light of this, it does not come as a surprise that phenomenologists typically embrace the idea that "[t]he reality of the object is not hidden behind the phenomenon, but unfolds itself in the phenomenon" (Zahavi 2003, 16). There are obvious similarities here with John Archibald Wheeler's position which, employing Bohr's concept "phenomenon," comes to expression when he asks "what other kind of universe can we expect to see than one built as 'phenomenon' is built, upon

12 See, e.g., Rovelli 2006. Husserl would describe this as a process of historical sedimentation in which we (unwittingly) inherit meanings from previous generations.

query of observation and reply of chance, a *participatory* universe?" (Wheeler 1980, 359). Wheeler elaborates on the crucial role of the participator in the following way:

> More generally, we would seem forced to say that no phenomenon is a phenomenon until – by observation, or some proper combination of theory and observation – it is an observed phenomenon. The universe does not 'exist, out there,' independent of all acts of observation. Instead, it is in some strange sense a participatory universe. (Wheeler 1978, 41)

The terminological similarity between Wheeler's "participatory universe" and the QBist "participatory realism" is no coincidence. Wheeler was the main inspiration for this terminology and had a crucial impact on Fuchs' intellectual development (see Fuchs 2017 and Crease & Sares 2021). Wheeler not only articulated ideas that resemble phenomenological teachings but was in fact influenced by phenomenological thinkers (see Berghofer 2022, Section 15.4.).

We also note that Wheeler's slogan "no phenomenon is a phenomenon until it is an observed phenomenon" is similar to the QBist principle that "[an] experiment has no outcome until I experience one" (Fuchs et al. 2014, 751). This is the QBist personalized version of Asher Peres' saying that "[u]nperformed experiments have no results" (Peres 1978). As noted in the previous section, this resembles London and Bauer's claim that "a measurement is achieved only when the [respective outcome] has been *observed*" (London & Bauer 1983, 251). As trivial as these statements may initially sound, they encapsulate one of the central tenets of QBism because they directly connect to the question "of whether quantum measurements reveal some pre-existing value for something that's unkown, or whether in some sense they go toward creating that very value, from the process of measurement" (Fuchs & Stacey 2016, 289). QBists, of course, subscribe to the latter view, claiming that measurements do *not* reveal pre-existing values.

> This leads us down the path of participatory realism in which experiences are as real and as fundamental as what we hope to uncover behind the normative part of quantum theory. When I said that for participatory realism, reality is more than any third-person perspective can capture, I view that as a positive statement—that we grasp some feature of reality that says it resists representation. Experience becomes a fundamental and irreducible element in the universe. The world is such that we cannot give a block universe representation of it. There is no view from nowhere, and I view that as an ontological statement. (Fuchs in Crease & Sares 2021, 555)

The claim that measurements do not reveal pre-existing values but that the very act of measurement is responsible for the object in question having the observed value is in agreement with the "orthodox position" of textbook quantum mechanics. According to orthodoxy, *before* the measurement takes place, "[t]he particle wasn't really anywhere. It was the act of measurement that forced it to 'take a stand'" (Griffiths, 2018, 17). It is needless to say that this is hard to reconcile with the prevailing objectivist interpretations commonly found in contemporary philosophy of quantum mechanics.

What distinguishes QBism from textbook quantum mechanics is that QBism constitutes a consistent approach that specifies the role of the experiencing subject, the nature of the wave function, the nature of measurement, and crucial implications for the nature of reality. Textbooks and the original Copenhagen approaches are either silent on (some of) these topics or inconsistent, for instance when it comes to the nature of the wave function. Also, sometimes the main objectives of science are spelled out in terms of the subject's experience (Bohr, 1963, 10), other times in terms of factive notions such as knowledge (Heisenberg 1958, 15) or information (Zeilinger 1999). QBism, by contrast, is the best-developed interpretation in which experience plays a fundamental role. Phenomenology, analogously, is the most thoroughly developed experience-first project in philosophy. In light of this similarity, bringing QBism and phenomenology into mutual dialogue is the obvious move. The question is not whether QBists and phenomenologists should attempt to join forces but what has taken us so long. Here is a list of exemplary ways in which, on our view, phenomenologists and QBists can benefit from each other.

What phenomenology offers QBism

1. Even opponents of QBism tend to agree that QBism delivers a consistent interpretation of quantum mechanics that avoids problems surrounding the apparent collapse of the wave function and non-locality (Vaidman 2014, 17f.). However, the main objection is that there is a lack of a clear philosophical foundation (Timpson 2008, 580). One of the main objectives of this project of engaging QBism and phenomenology is to introduce phenomenology as a suitable philosophical-conceptual framework for QBism.

2. QBists argue that (quantum) measurement outcomes are the very experiences of the observing subject. However, QBists are physicists with no formal training in phenomenology or epistemology. So when asked what precisely the experience looks like that is supposed to correspond, for instance, to the outcome of a spin-up/spin-down measurement or how exactly an instrument-mediated experience gains its justificatory force, answers remain vague. It is precisely here that phenomenologists could come to the rescue.

What QBism offers phenomenology

1. Phenomenology specifies experiences as our ultimate evidence/justifiers, but, of course, it would go beyond the scope of phenomenology to provide an answer to the question: Based on my *actual* experiences, what should I believe (to experience next)? According to QBism, quantum mechanics should be understood as delivering this formalism. This would imply an intimate connection between philosophy and science.

2. Contemporary analytic epistemology is dominated by anti-phenomenological externalist accounts according to which evidence is not constituted by our experiences but by facts and the epistemic status of our beliefs is not determined by what is internally accessible to us but by external factors such as reliability. A crucial rationale for externalism is the idea that philosophy should strive to be methodologically similar to the natural sciences. Here the natural sciences are typically understood as adopting a third-person perspective that successfully abstracts away from the subject and her personal experiences. If it turns out that this requirement does not even work for the most fundamental physical theory, this motivation vanishes. This would open the door for a phenomenological experience-first epistemology according to which epistemology clarifies how experiences justify and science clarifies what a subject should believe (to experience next) based on her actual experiences.

Summarizing the above, here are some of the main claims that unite phenomenologists and QBists.

QP1: We must be careful with the project of mathematizing nature and should abstain from reifying mathematical quantities such as the wave function. Since such reifications/objectifications “take for *true being* what is actually a *method*” (Husserl 1970, 51), we should be highly critical of “the strategy […] to reify or objectify all the mathematical symbols of the theory and then explore whatever comes of the move” (Fuchs & Stacey 2019, 136).

QP2: We should not modify the quantum formalism—the formalism of the most successful theory in the history of humanity—simply to make our fundamental scientific theory a better fit for our ontological intuitions. Instead, we must acknowledge that these intuitions and our scientific worldview have historically sedimented inherited meanings. If theory A (classical mechanics) dominates for hundreds of years, significantly shaping our view of science and reality, but then turns out to be empirically unacceptable and is superseded by B (quantum theory), it is problematic to require of B to fit with the intuitions we inherited from A. Instead, we should take the quantum phenomena seriously as well as the implications that “[q]uantum theory itself threw [...] before us!” (Fuchs 2017, 115).

QP3: The notion of experience is an irreducible primitive that is the ineluctable starting point of any encounter with and knowledge of the external world.

QP4: The life-world is the “meaning-fundament of natural science” and thus we should not expect science to deliver a purely objective view on the world. “There is no pure third-person perspective, just as there is no view from nowhere” (Zahavi 2019, 54). Accordingly, we should not be surprised if quantum mechanics can be understood as suggesting that “reality is *more* than any third-person perspective can capture” (Fuchs 2017, 113).

QP5: Instead of striving for the unreachable goal of a purely objective science that offers a comprehensive third-person description of reality, we may look for “a physics that has learned to situate the physicist physically” and has “lost the illusion of the absolute view from above” (Merleau-Ponty 1968, 27). Accordingly, it should be appreciated if “QBism puts the scientist back into science” (Mermin 2014).

QP6: “[A] measurement is achieved only when the [respective outcome] has been *observed*” (London & Bauer 1983, 251). Or in the QBist version: “This experiment has no outcome until I experience one” (Fuchs et al. 2014, 751). This is to say that the quantum formalism does not offer an objective description of the evolution of some external entities such as wave functions or point particles. Instead, it tells us something about the interaction between the observed and the observer.

QP7: The most fundamental aim of science is to deliver the formalism that allows the experiencing subject to predict what she should expect to experience next.

We believe that QP1-7 should be universally accepted by all QBists. Concerning the phenomenological tradition, QP1-4 should be uncontroversial among Husserlian phenomenologists. QP5 is a stronger claim endorsed by Merleau-Ponty, probably anticipated by Husserl. QP6 has been endorsed by the phenomenologically minded physicist Fritz London, regarding Husserlian phenomenology as providing the broader philosophical framework to address the problems that arise in the context of quantum measurements. Obviously, if this were true, this would be good news for the phenomenological movement. QP7 is true if the QBist interpretation of quantum mechanics is correct and if quantum mechanics truly is fundamental. Phenomenologists could regard QP7 as revealing the close connection between philosophy and science.

3.2. QBism & phenomenology: Possible points of conflict

Although we do believe that phenomenology and QBism are natural bedfellows, we also want to address some possible points of conflict. As we have repeatedly noted, the core claim of phenomenological epistemology is that all knowledge/justification leads back to epistemically foundational experiences. If this is true, it would be of great significance to develop a formalism that allows the experiencing subject to answer the question of what, based on her previous actual experiences, she should expect to experience next. Assuming that quantum mechanics is a good candidate in this regard, QBism is the currently best-developed interpretation that embraces the idea that "*experience* is fundamental to an understanding of science" in the sense that "quantum mechanics is a tool anyone can use to evaluate, on the basis of one's past experience, one's probabilistic expectations for one's subsequent experience" (Fuchs et al. 2014, 749). More precisely, in QBism quantum states are doxastically interpreted as representing the subject's beliefs about her future experiences (DeBrota & Stacey 2019, 10). QBists rightly emphasize that this is a *doxastic* and not an *epistemic* interpretation of the quantum state/wave function. This is because knowledge is a factive notion. If one knows that *p*, then *p* is the case. Belief is non-factive. From a phenomenological perspective, it is a clear advantage of QBism to be formulated in non-factive terms such as experience and belief. Importantly, this is also why QBism avoids the PBR no-go theorem (Pusey et al. 2012). According to QBism, the wave function neither represents an underlying ontic state, nor is it about our knowledge/uncertainty of an underlying ontic state. In the terminology introduced by Harrigan and Spekkens (2010), it is neither *ψ-ontic* nor *ψ-epistemic*. While the PBR theorem rules out *ψ-epistemic* interpretations, it is silent on the QBist claim that wave functions represent degrees of beliefs about one's future experiences (DeBrota & Stacey 2019, Glick 2021, Hance et al. 2022).[13]

Importantly, however, QBists explicitly deny that the quantum state represents what the subject *should* believe.[14] For QBists, the quantum state is a set of probability assignments. These probabilities are personalist Bayesian probabilities. As long as your assignments are consistent, you

13 Unfortunately, in the literature the PBR theorem is often misunderstood as ruling out any interpretation that is not *ψ-ontic* (e.g. Maudlin 2019, 83-89). This means that large parts of the community falsely believe that a successful approach to quantum mechanics must be *ψ-ontic* and are ignorant of how the QBist escapes the PBR theorem. In fact, the implications of PBR should be understood as revealing that QBism is one of the main alternatives to *ψ-ontic* interpretations.

14 Personal email conversation between Chris Fuchs, Jacques Pienaar, and Philipp Berghofer.

cannot be wrong about them. This is to say that for an event X, the probability P(X) represents the subject's degree of belief that X will occur. But perhaps epistemologically minded phenomenologists should disagree. Maybe quantum mechanics has a more straightforward epistemically normative dimension in the sense that quantum states represent what a subject *should* believe to experience next. And perhaps it would even be more accurate to say that quantum states assign *degrees of justification* to beliefs about possible future experiences.[15] This is to say that for the phenomenologist it remains to be seen whether QBism succeeds in developing the methodology of taking experience as the starting point of science or whether we need an approach in which quantum states tell us what we objectively should believe. If the latter is the way to go, then phenomenological approaches to quantum mechanics might share crucial similarities with Richard Healey's pragmatist interpretation according to which quantum mechanics "is a source of objectively good advice about *how* to describe the world and what to believe about it as so described. This advice is tailored to meet the needs of physically situated, and hence informationally-deprived, agents like us" (Healey 2022, Section 4.3).

A further potential point of conflict concerns the QBist account of scientific instrumentation. As we have seen, QBists identify the outcome of (quantum) measurements with the *experiences* of the measuring subject. However, this is understood by the QBists as implying that the instruments used in quantum mechanical measurements must be regarded as *bodily extensions* of the measuring subject such that the respective objects (e.g., electrons) can be observed *directly* (Pienaar 2020). In his contribution to this volume, Pienaar puts this in the following way:

> "Prolongation Thesis: Those measuring instruments which the agent regards as being the source of their experiences (i.e. of their measurement outcomes) are to be regarded as prolongations of the agent's body, and thus having the same metaphysical status as the bodily sense organs of the agent."

As Pienaar elaborates, the prolongation thesis goes back to a remark of Wolfgang Pauli, but while it remains unclear what role this idea played in Pauli's considerations, the QBists take it "deadly seriously" (Fuchs 2017). This raises at least two questions. First, does the prolongation thesis really follow from the QBist postulate that measurement outcomes are experiences? This is the question of whether and to what degree QBists are committed to the prolongation thesis. Secondly, is the prolongation thesis plausible, particularly from a phenomenological perspective? Concerning the latter question, one thing to note is that phenomenologists typically do employ a broader notion of

15 In more technical terms, this relates to the question of whether quantum probabilities should be understood as subjective Bayesian probabilities along the lines of Bruno de Finetti or rather as objective Bayesian probabilities in the Coxian sense according to which probabilities represent reasonable expectations (Cox 1946). For a discussion from the QBist perspective, see DeBrota & Stacey 2019.

perception (more precisely: originary presentive intuition). For Husserl, not only bodily objects can be originally given in perceptual experiences but also eidetic truths in eidetic intuitions, one's own mental states in introspective experiences, and perhaps even values in evaluative experiences (see Husserl 1996, 286, 290).

Most notably, the prolongation thesis seems to resonate well with Merleau-Ponty's famous example of the blind man's stick.

> "The blind man's stick has ceased to be an object for him, and is no longer perceived for itself; its point has become an area of sensitivity, extending the scope and active radius of touch, and providing a parallel to sight." (Merleau-Ponty 2002, 165)

However, while the prolongation thesis seems to make sense in this example, it is far from clear that it also holds with respect to quantum measurements. Merleau-Ponty seems to reject the thesis in the latter context. Contrasting the role of the measuring apparatus in classical physics and quantum mechanics, Merleau-Ponty states that while classically "the apparatus is the prolongation of our senses" in quantum mechanics "[t]he apparatus does not present the object to us." Instead, "[i]t realizes a sampling of this phenomenon as well as a fixation. […] Known nature is artificial nature" (Merleau-Ponty 2003, 93). Although, unfortunately, Merleau-Ponty does not offer a detailed analysis of what is "artificial" about quantum measurements, it is prima facie plausible to assume that indeed there is a fundamental difference between looking through telescopes or microscopes on the one hand and using measuring devices in modern particle physics on the other hand. In the case of telescopes and microscopes, there is a rather straightforward sense in which we directly observe the object in question. But it would be quite a stretch to say that we directly observe particles when looking at the *photographs* gained by cloud chambers and bubble chambers that visualize the *tracks* of charged particles. What is more, while cloud chambers and bubble chambers have a photographic readout, the devices that are now common, such as particle colliders like the LHC, have a purely electronic readout. What we gain from LHC experiments is data – big data. "Data pours out of the LHC detectors at a blistering rate. Even after filtering out 99% of it, in 2018 we gathered 88 petabytes of data."[16] To say, for instance, that the Higgs boson can be originally given in LHC experiments is highly implausible to us.

This discussion, of course, concerns the question of whether we should believe in the existence of so-called "unobservable" scientific entities such as atoms and electrons. As mentioned in Section 2.3.1, this is hotly debated in analytic philosophy as well as in phenomenology. Here, we only note

16 https://wlcg-public.web.cern.ch/about. Retrieved on February 13, 2020. In this context, see, e.g., Karaca 2017, 344.

that Husserl's conception of *horizontal intentionality* may prove useful in this context. It is commonly accepted in phenomenology that we can distinguish between what is originally given in experience and what is co-given in the horizon of the experience. When you look at the table in front of you, what is originally given to you is the frontside of the table, while its backside is co-given. This table-experience is rich in anticipations of what the table looks like from different angles. Importantly, co-givenness is *not* just another term for background beliefs. Co-givenness—just like originary givenness—is a name for how experiences present (parts of) their objects/contents. This means it denotes a distinctive kind of phenomenal character. Joel Smith has convincingly argued that the phenomenal character of co-givenness is "belief independent" (Smith 2010, 736). We understand this as implying that if an object is co-given in the horizon of an experience, the object can be regarded as experienced (although not as originally given). Perhaps QBists might want to soften their claim, saying that in quantum measurements scientific entities like atoms and electrons are co-given in instrumentally mediated experiences.

4. Contributions

This volume is structured in three parts. Roughly speaking, Part I constitutes the QBist perspective on phenomenology, Part II the phenomenologist perspective on QBism, and Part III sheds light on complementary ideas and supplementary approaches.

Part I comprises four chapters, authored by leading QBists. Blake Stacey gets the ball rolling by addressing the history of QBism and by elaborating on some of the ideas that have been dropped and renounced over the years. This is a service of extreme value to the readers of this volume because QBism must not be understood as a project that saw the light of day in a completed fashion. Instead, it is an ongoing research program whose history "is a series of hard-fought battles for self-consistency" (Stacey, this volume). This is to say that some views that are still often ascribed to QBists have already been dismissed, and that instead of trying to synthesize older and newer QBist texts, one should rather turn to the latter. In fact, Stacey suggests that "nothing posted on the arXiv before 2009 should be cited as an example of QBism." Stacey depicts the QBist struggle for consistency as a process "of becoming consistently Jamesian." When addressing the future of QBism, Stacey points out that William James' pragmatism and Husserl's phenomenology are evolutionary cousins. Building on this insight, Stacey sketches "ways in which phenomenological turns may be inspirational for future developments in the QBist project." In Stacey's view, one particular avenue for phenomenologists who wish to contribute to the development of QBism is the ongoing project of reconstructing quantum theory. This project of theoretical reconstruction is discussed in detail in Philip Goyal's contribution, marking the final chapter of this volume.

Chris Fuchs' chapter "QBism, Where Next?" complements Stacey's foregoing contribution. While Stacey focused on the historical development of QBism, Fuchs discusses the present and future of QBism. Fuchs' chapter stands out as the most comprehensive and conceptually/philosophically clearest depiction of the QBist research program to date. Fuchs begins by introducing two concepts central to QBism, "agent" and "user of quantum mechanics," and proceeds by clarifying eight key tenets of QBism. Fuchs refers to this as "QBism's eightfold path." What is still missing is the "noble truth" to which this eightfold path is supposed to lead. In Fuchs' words: "What is the precise ontology that compels the eightfold path?" As the reader will see in the course of this volume, which ontological conclusions to draw from the theory is one of the most pressing open questions QBists have to face. As Fuchs notes, this is also a consequence of the QBist mindset that we must be careful not to read our ontological preconceptions into the quantum formalism. Instead, "it became clear that the pertinent way to move forward was to get the 'epistemics' of the theory right before anything else: Getting reality right would follow for those who had patience enough to pass the marshmallow test." From a phenomenological perspective, this seems the most reasonable way to proceed, although one might be cautious regarding the optimism expressed here. Concerning the quest of uncovering the ontological implications of quantum theory, Fuchs speculates that the best way to move forward is by analyzing the famous Wigner's friend thought experiment precisely in view of the tenets constituting QBism's eightfold path. Accordingly, the penultimate section of Fuchs' contribution is devoted to Wigner's friend, pointing out that both agents – Wigner and his friend – are agent as well as system and thus must be treated symmetrically. Fuchs concludes his chapter by elaborating on parallels between the QBist approach to Wigner's friend and how Merleau-Ponty illustrates his ontology of chiasm and flesh by discussing the example of a person touching one hand with the other.

In Chapter 3, Rüdiger Schack sheds light on points of contact between QBism and Merleau-Ponty. More precisely, he discusses the QBist claim that "[t]he world does not admit a third-person description and is fundamentally indeterministic" in the context of Merleau-Ponty's essay "The intertwining—The chiasm." Schack's chapter begins with an excellent exposition of the normative character of QBism. According to QBists, quantum states represent an agent's degrees of beliefs and the Born rule is a *normative* constraint that "functions as a consistency criterion which puts constraints on the agent's decision-theoretic beliefs." Schack stresses that measurement outcomes do not reveal pre-existing properties. Instead, they are viewed as "personal consequences for the agent taking the measurement action and come into existence only through the measurement action itself." In this QBist picture, the measurement apparatus is a bodily extension of the measuring subject that gives direct access to the physical system. While this constitutes a consistent interpretation of quantum mechanics that, as mentioned above, avoids the PBR theorem and other no-go theorems, it leads to several philosophical challenges. Here is how Schack approaches one such challenge:

> "What remains a big challenge is to develop an explicit ontology for QBism, an ontology that [is] based on first-person experience but which accounts for a real world beyond any particular agent's experience and thus avoids the trap of idealism. It turns out that there is a significant overlap between the project of finding such a QBist ontology and the philosophy of Maurice Merleau-Ponty and other phenomenologists."

In this context, Schack discusses the "Copernican principle" of QBism according to which we human beings are both experiencing agents *and* physical systems. This is contrasted with Merleau-Ponty's notion of the flesh and his remarks about the relationship between the seeing subject and the visible world. Throughout his chapter Schack hints at discussions surrounding the issue of free will, concluding that the scientific world view of QBism is the one best suited for free agents.

In his chapter "Unobservable Entities in QBism and Phenomenology," Jacques Pienaar also addresses the issue "that reality in QBism must be somehow founded upon an agent's subjective experiences." Contrasting and comparing QBist and phenomenological approaches, Pienaar discusses the view according to which in-principle observability is a criterion for physical existence. What implications does this criterion have for atoms, fields, quantum states, and probabilities? In this context, Pienaar introduces the above-mentioned prolongation thesis, stating that certain measurement instruments in modern physics "are to be regarded as prolongations of the agent's body, and thus having the same metaphysical status as the bodily sense organs of the agent." Making a distinction between probability-like entities on the one hand and system-like entities, such as atoms and fields, on the other hand, Pienaar seeks to establish a QBist approach as a middle-position between two phenomenological proposals:

> "We found that QBism distinguishes between system-like entities and probability-like entities, and adheres to the Prolongation Thesis, which renders unobservable system-like entities potentially observable, contrary to Wiltsche's objection (Wiltsche, 2012). On the other hand, in

> order to maintain its claim that probability-like entities cannot be said to physically exist, QBism should embrace Wiltsche's 'Originality Thesis of Justification' over Berghofer's counter-proposed 'Criterion of Justification', as the latter opens the door to the possible physical existence of quantum states and hidden variables."

Hans Christian von Baeyer's contribution marks the beginning of Part II. The chapter begins by assessing that the field of interpreting quantum mechanics is about to enter a new epoch, one that centers on the notion and fundamental role of *perception*. Due to this focus, von Baeyer elaborates, it is natural to assume that phenomenology is the ideal philosophical framework researchers working on quantum foundations should consult. This is illustrated by building upon the phenomenological work of the little-known American philosopher Samuel Todes. Von Baeyer is particularly interested in Todes' claim that the active human body must not be reduced to passive matter but should be recognized as the "material thing whose capacity to move itself generates and defines the whole world of human experience in which any material thing, including itself, can be found" (Todes 2001, 88). This brings us back to the question of whether science should be viewed as a completely de-humanized endeavor. Von Baeyer stresses similarities between Todes and the QBist David Mermin. Mermin has recently addressed the "problem of the now," i.e., the issue that worried Einstein so deeply, namely the fact that physics seems to be unable to single out the present moment as something special. Why is there such a gap between how we experience time and how time is treated in physics? Von Baeyer writes:

> "Mermin showed that the principal difficulty was not the relativity of simultaneity, but the compulsive exclusion of subjectivity from science. […] With the emphasis of both QBism and phenomenology on a first-person perspective, the problem of the NOW melts away. NOW, according to both Mermin and Todes, is simply the moment in time at which the anticipation and prediction of a future event turns into memory of the past experience of that event. Since each of us is capable of distinguishing between those two modes of cognition, that moment is not only well defined, but surely of surpassing importance."

Above we mentioned that the descriptive methodology of phenomenology is typically considered to be in tension with the third-person approach of science. However, if von Baeyer and Mermin are on the right track, science and phenomenology may turn out to be just two sides of the same coin.

Like several other contributions to this volume, Thomas Ryckman's chapter, entitled "QBism: Realism about What?", focusses on one of the most apparent worries regarding QBism, namely its relationship to realism and anti-realism. While several critics have expressed the worry "that lurking under QBism's philosophical hood is an ogre of solipsism," QBists themselves have traditionally been busy distancing themselves from subjectivism and instrumentalism, and—following Wheeler—to present "participatory realism" as a counterproposal. However, even if one deems the QBists' distancing from all sorts of anti-realism as successful, the question still remains what participatory realism actually amounts to and how it relates to other positions in the field. Ryckman addresses this issue by discussing a historical figure whose philosophical outlook has been intensely discussed in the literature and who is considered by QBists as a "*sine qua non*" of their own position, Niels Bohr. Following Ryckman's reading, what makes Bohr's thought attractive to QBists is fruitful connection between two ideas that are seen as incompatible by many, epistemological anti-representationalism on the one hand and a rather minimal empirical realism about the quantum world on the other. In this context, Ryckman summarizes one of his central insights as follows:

> "[Bohr's] rejection of representationalism stems entirely from the implications of the quantum postulate for the subject-object relation concerning the objective description of quantum phenomena. Many interpreters of Bohr regard this non-representationalism to imply an anti-realist or instrumentalist stance towards quantum theory. This is not correct. Non-representationalism, occasionally termed 'renunciation of visualization', is a necessary epistemological step when fashioning objective description of the physical world beyond the objectifying methods employed in classical physics. Such knowledge as we have of the microphysical world is empirically based and fallible, it can only be projected from the interpretation of our experiences and is therefore indeterminate, but it is nonetheless knowledge of the real."

Engaging QBism with phenomenology is a field of research that originated in the contributions of Michel Bitbol and Laura de la Tremblaye in (Wiltsche & Berghofer 2020). Their joint paper "QBism: An Eco-Phenomenology of Quantum Physics" published in the present volume may turn out to be similarly groundbreaking. Here they focus on a tension within QBism that has been worrying many researchers sympathetic to this program, namely the "discrepancy between the instrumentalist and realist inclinations of QBism." On the one hand, QBism is anti-realist regarding the wave function and views quantum mechanics as a tool anyone can use to make better predictions about one's future experiences. This is the instrumentalist dimension of QBism. On the other hand, QBists view themselves as being part of a realist program that seeks to uncover the deep structure of reality. But what can quantum mechanics tell us about reality if it is only a tool? The typical move of QBists is to argue that the simple fact that the quantum formalism is so successful tells us much about reality. The idea is that by analyzing the tool we use to systematize our experiences, we learn significant lessons about the world we experience. Still, it remains a widespread suspicion that the QBists can't have it both ways and that their "realism" does not deserve this label. In their contribution, Bitbol and de la Tremblaye resolve this discrepancy by "unambiguously choosing the first-person standpoint as a radical origin of knowledge, and by ascending from the situated lived experience of a knowing and acting subject, to the structure and use of the quantum formalism." In this context, they suggest to replace "the concept of a somehow extrinsic relation between subject and world, with the immersive experience of a subject partaking of the world." This leads them to the proposal that QBists should replace their "participatory realism" with a form of "*radical participatory empiricism*." We have seen that QBism has a history of becoming more consistent by sacrificing views that are sacred to standard realists. The proposal of Bitbol and de la Tremblaye might be the next step in this evolution.

Part III begins with Steven French's chapter "Putting Some Flesh on the Participant in Participatory Realism." One apparent feature of French's contribution is that it resonates nicely with topics that are also in the center of several other chapters, most notably those by Ryckman, Boge and Bitbol and de la Tremblaye. Most importantly, French focuses on the question of whether QBism is successful in its attempts to navigate between the extremes of subjectivist idealism and naïve realism. In line with the general topic of this volume, French considers whether phenomenology provides a suitable middle ground and thus can serve as a useful philosophical framework for QBism. In particular, French takes a closer look at a recent suggestion by Laura de la Tremblaye who has argued that QBism's insistence on subjective expectations squares nicely with Husserl's understanding of perception as based on a horizontal structure of intentionality. In a nutshell, de la Tremblaye's proposal is that the Husserlian perceptual horizon corresponds to the QBist's quantum state, the content of the perceptual act parallels the measurement outcome, and the modification of the horizon corresponds to the post-measurement modification of the state vector. However, French sees several problems with this comparison. Apart from circularity concerns, French pays special attention to the dangers of drawing parallels between everyday perception and quantum cases. As French argues, one way to overcome these problems is to move beyond the strictures of Husserlian phenomenology and to consider the later works of Merleau-Ponty, and the notion of the *flesh* in particular. According to French, however, Merleau-Ponty's later philosophy is harder to mesh with QBism than it might initially appear:

> "It is [the] perspectival aspect of Merleau-Ponty's thought that encourages a positive comparison with QBism. However, […] he also drew on London and Bauer's analysis, with its explicit incorporation of a correlationist aspect, both phenomenologically and physically, as manifested via quantum entanglement. This is anathema to the QBist, of course, as is Merleau-Ponty's centering of the relations represented by the theory more generally. If, then, the QBist wants to draw on phenomenology to philosophically underpin her position, she is going to have to either modify the latter or exclude the correlationist understanding of the former."

Florian Boge's chapter "Back to Kant! QBism, Phenomenology, and Reality of Invariants!" can be read as a continuation but also a significant refinement of some of the main objections that were levelled against QBism in the philosophy of physics literature. Among these criticisms, QBism's alleged inability to distance itself from extreme forms of subjectivism and solipsism as well as problems associated with its anti-representationalism appear particularly relevant. While some of the earlier critics were arguably guilty of misconstruing the basic tenets of QBism (Earman 2019; see, for a rejoinder, Fuchs and Stacey 2020), Boge is very cautious in critically engaging with the actual QBists and not with a strawman version of their views. After formulating what he sees as the main problems with QBism, Boge goes a step further and considers the question whether phenomenology could help QBism to overcome its philosophical shortcomings. The assumption that it could is not only in line with the overall topic of this volume. Since subjectivism, solipsism, and anti-representationalism are topics that are traditionally high on the phenomenological agenda, the suspicion that phenomenological arguments might be of use for QBists is indeed not unreasonable. But ultimately, Boge's conclusion is negative. Accordingly, the rest of Boge's chapter is devoted to show that

> "[…] QBism […] could profit from a Neo-Kantian philosophy of science. The reason is that this allows for a solid, comprehensible abduction-basis and a solid framework for a non-reductionist semantics, thus doing justice to actual physical practice. The suggestion should actually not come as a big surprise, since a connection has been made before […], and since not only phenomenology, the philosophy currently 'flirted with' by QBism, has its roots in Kant, but also QBism's 'old love' *pragmatism*."

The volume concludes with Philip Goyal's contribution which elucidates the virtues and prospects of the quantum reconstruction program. The program of reconstruction constitutes a novel field of research that already enjoys popularity among physicists working on quantum foundations but remains largely ignored in the philosophy community. Goyal's chapter is perhaps the philosophically richest and conceptually most stringent account of reconstruction that exists to date. The main idea of reconstruction is introduced as follows:

> "The methodology of quantum reconstruction seeks to remove the interpretative bottleneck by systematically deriving the quantum formalism in an operational framework from postulates that are, ideally, physically well-motivated, thereby *distilling* the full mathematical content of the theory into precise natural-language statements that—unlike the abstract mathematical postulates of quantum theory—are amenable to philosophical reflection."

Goyal specifies the method of reconstruction as a two-step procedure: Reconstruct the quantum formalism, and then interpret the reconstruction. This is to say that we should not treat the quantum formalism as a given but instead derive it from precise physical principles and then interpret these principles. The project of reconstruction emerged at the turn of the millennium as a consequence of the booming interest in quantum information. By now, there exist several successful reconstructions. As Goyal elaborates, typically they are formulated in an *operational* framework, deriving the quantum formalism from *information-theoretic* principles. In our view, the operational dimension coheres perfectly with phenomenological and QBist ideas. This is because in operational frameworks the notion of a measuring subject is considered an irreducible part of the theory. Since "information" is a factive concept, it is less clear to us how the informational dimension squares with phenomenological and QBist approaches. Perhaps future reconstructions can be spelled out in terms of non-factive mental states such as experience and belief. Goyal's thorough and rigorous chapter will play an important role in advancing the project of reconstruction and increasing its popularity among philosophers.

Acknowledgments: The majority of the chapters in this volume were presented at the conference "Phenomenological Approaches to Physics: QBism and Phenomenology, Compared and Contrasted" which finally, after two pandemic-related postponements, took place at Linköping University, Sweden, in June 2022. We would like to thank our co-organizer Jan-Åke Larsson as well as all participants who helped to make this conference a memorable event. Financial support for organizing this conference was provided by the Faculty of Arts and Science at Linköping University and Riksbankens Jubileumsfond (project number F19-1529:1). Many thanks to Chris Fuchs and Mahdi Khalili for their feedback on earlier versions of this chapter. Furthermore, we would like to thank our families for emotional support, and the Austrian Science Fund for a generous grant to carry out research on the intersection between physics and phenomenology (project number: P31758). Philipp Berghofer's research was funded in part by the research project "Quantum Mechanics and Phenomenology: Specifying the Philosophical Foundations of QBism" granted by the Styrian Government. Finally, parts of this publication were made possible through the support of Grant 62424 from the John Templeton Foundation. The opinions expressed in this publication are those of the author(s) and do not necessarily reflect the views of the John Templeton Foundation.

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