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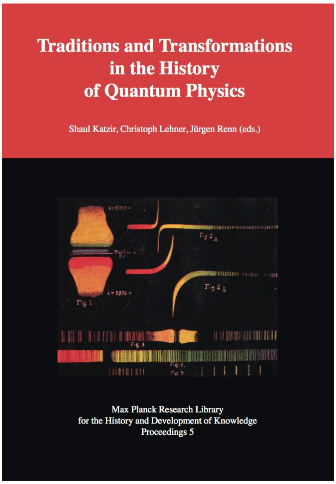
Olival Freire:

Orthodoxies on the Interpretation of Quantum Theory: The Case of the Consistent History Approach



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Chapter 12
Orthodoxies on the Interpretation of Quantum Theory: The Case of the Consistent History Approach

Olival Freire

Most of the historical narratives about the foundations of quantum theory center on the themes of orthodoxies and heterodoxies. Niels Bohr's and John von Neumann's early approaches were considered the orthodox views on the issue. In the 1950s, this research was marked by David Bohm's and Hugh Everett's heterodoxies, and according to such physicists who led the field in subsequent years as John Bell and John Clauser, its development faced the stigmas associated with this research. Since the blossoming of this research in the late twentieth century, warnings against the revival of old orthodoxies have been heard. A poignant alert was launched by Jeffrey Bub in *Interpreting the Quantum World*, published in 1997, when he dubbed the weaving of strands including decoherence, Everett's interpretation, and the consistent history approach the "new orthodoxy." Bub pointed to Roland Omnès writings as examples of this new orthodoxy.

Here, I analyze these claims, particularly the consistent history approach. I consider not only the rhetorical strategies adopted by its proponents and critics, such as Bub himself, but also the effective influence achieved by this approach. Bub's claim that the consistent history approach is a new orthodoxy is an overstatement. This paper presents a summary of the use of terms such as "orthodoxy" and "heterodoxy" in reference to quantum mechanics. In addition, it deals with the polysemic manner in which the concept of orthodoxy appears in Bub's book; and I present a synopsis of the consistent history approach, of its claims and rhetorical strategies. The final part is dedicated to the analysis of the effective influence of this approach on physicists. Further, I draw some conclusions from this history about the uses of the terms orthodoxy and heterodoxy in debates on the foundations of quantum mechanics.

12.1 Orthodoxies and Heterodoxies in Quantum Physics

Between 1925 and 1927, a polyphony of interpretations of the newly-born quantum theory emerged. This concurrence was narrowed in October 1927 when Bohr presented his complementarity principle at the Solvay Conference. Bohr's interpretation was not accepted by such physicists as Albert Einstein and Erwin Schrödinger. However, it was supported by a number of others, including Werner Heisenberg, Wolfgang Pauli, and Max Born. While the term orthodoxy was not commonly used at the time, its meaning hung in the air. Louis de Broglie, who arrived at the conference suggesting a causal interpretation of quantum mechanics which was at variance with the notion of complementarity, left disillusioned with his own proposal. When faced with the duties of teaching quantum mechanics in Paris, he "joined the ranks of the adherents to the orthodox interpretation which was accepted by the overwhelming majority of the participants at the Solvay meeting" (Jammer 1974, 114). In 1928, Einstein wrote to Schrödinger, both men in a clear-cut minority among the founding fathers of this physical theory, on complementarity: "The Heisenberg-Bohr tranquilizing philosophy—or religion?—is so delicately contrived that, for the time being, it provides a gentle pillow for the true believer from which he cannot very easily be aroused. So let him lie there."[1]

In the early 1930s, the mathematician von Neumann presented a fully consistent treatment of quantum theory in terms of Hilbert spaces. Together with complementarity, von Neumann's treatment conveyed the feeling that both the philosophical implications and the mathematical formalism of the theory were settled forever. Moreover, in the 1930s, physicists failed to exploit the differences between Bohr's and von Neumann's views regarding completeness and measurement problems.

In the 1950s, the manner in which physicists referred to the dominant view of the interpretation of quantum mechanics began to change. Critics of complementarity referred to it as the "usual" interpretation, as Bohm (1952), or "Copenhagen interpretation," as Everett (Osnaghi, Freitas, and Freire 2009, 105, footnote 111). Later, the historian of physics Max Jammer (1974, 250) dubbed the orthodoxy "the monocracy of the Copenhagen school." The term "Copenhagen interpretation," apparently created by Heisenberg, was not consensually accepted by adepts of Bohr's complementarity. Most importantly, it was used by critics of Bohr's views in general (Osnaghi, Freitas, and Freire 2009, 99). In the early 1960s, Eugene Wigner conspicuously called von Neumann's mathematical presentation of the measurement problem "the orthodox view" in quantum mechanics, only to say that either quantum mechanics was incomplete and could be complemented by a nonlinear modification or one should accept the mind's role during measurement processes (Wigner 1963). If Bohr were alive, it is unlikely that he would accept either of Wigner's choices. As I have argued elsewhere, Wigner indeed became a heterodox in the foundations of quantum mechanics and supported most

[1] Einstein to Schrödinger, 31 May 1928 (Jammer 1974, 130).

of the research in this field during the late 1960s (Freire 2007). From 1970 on, the term "Princeton school" was used to distinguish Wigner and von Neumann's views from Bohr's as well as to signal that the monolithic support behind what was once considered the orthodox view had waned or had been split (Freire 2007).

In the 1960s, a new meaning for orthodoxy was emerging among the new generations of physicists interested in the foundations of quantum mechanics. Bell, who would play a key role in subsequent years in this research, co-authored a paper with Michael Nauenberg in 1966 saying:

> [W]e emphasize not only that our view [that quantum mechanics is, at best, incomplete] is that of a minority but also that current interest in such questions is small. *The typical physicist feels that they* [issues on foundations of quantum mechanics] *have long been answered*, and that he will fully understand just how if ever he can spare twenty minutes to think about it. (Freire 2006, 583, emphasis added by OFJ)

The same sentiment was conveyed by Abner Shimony, in a later recollection:

> [T]he preponderance of the physics community at that time accepted some variant of the Copenhagen interpretation of quantum mechanics and believed that satisfactory solutions had already been given to the measurement problem, the problem of Einstein-Podolsky-Rosen, and other conceptual difficulties. (Shimony 1993, XII)

Thus, when research on the foundations of quantum mechanics began to appeal to a larger number of physicists in around 1970 (Freire 2004; 2009), orthodoxy was a polysemic term meaning Bohr's complementarity, von Neumann's mathematical presentation, and the vague but influential idea that problems in the foundations of quantum mechanics had already been solved by the founding fathers of the discipline.

A conclusion may be drawn from this short review. Orthodoxy is a term that was never used by the supporters of the complementarity view to refer to themselves. Often it is currently used without implicit assumptions, but mostly orthodoxy is used by critics of the complementarity view or Bohr's legacy. Such assessments suggest that Bohr and adepts of the complementarity view were closed-minded to the diversity of possible interpretations of quantum mechanics, and their authority helped suffocate debate on the subject. Heinz-Dieter Zeh sharply criticized the inappropriateness of authority's role: "I have always felt bitter about the way how Bohr's authority together with Pauli's sarcasm killed any discussion about the fundamental problems of the quantum."[2] The term orthodoxy has been

[2] Zeh to Wheeler, 30 October 1980, Wheeler Papers, Series II, Box Wo–Ze, folder Zeh. Cited in (Freire 2009, 282).

used in the controversy over the foundations of this physical theory as a rhetorical strategy, either by the critics of Bohr's views or von Neumann's mathematical formulation of this theory. It is a strategy used to open or keep open the debate about alternative interpretations or approaches to issues important to the foundations of quantum mechanics. Rhetorical strategies were also used by defenders of complementarity, a process the philosopher Mara Beller called "The Copenhagen Dogma: The Rhetoric of Finality and Inevitability" (Beller 1999). Léon Rosenfeld, for instance, criticized Heisenberg's use of the term Copenhagen interpretation because it conveys the idea that complementarity is just one among other possible interpretations (Osnaghi, Freitas, and Freire 2009, 99).

12.2 The Polysemic New Orthodoxy

Almost fifteen years ago, physicist and philosopher Bub warned about the appearance of a new orthodoxy as regards the interpretation of quantum mechanics. The term has since gained some currency among physicists and philosophers, as well as among historians of physics.[3] Bub opened his chapter dedicated to the new orthodoxy recalling a long-lasting attitude among physicists. According to Bub:

> For most physicists, the measurement problem of quantum mechanics would hardly rate as even a 'small cloud' on the horizon. The standard view is that Bohr had it more or less right, and that anyone willing to waste a little time on the subject could easily straighten out the sort of muddle philosophers might get themselves into. (Bub 1997, 212)

I have argued elsewhere that such an attitude has been blamed for hampering our understanding of foundational issues of quantum mechanics, as far as the hidden-variable issue and its related Bell's theorem are concerned. In fact, it was this kind of orthodoxy that Bell and Clauser referred to as the stigma against research on hidden variables (Freire 2006; 2009). However, those obstacles were eventually overcome, and the field is today generally considered a regular field of research, even reaping some of the fruits of the quantum information boom. Therefore, Bub's warning seems to alert us to past obstacles created by a prevailing orthodoxy encountered by physicists and philosophers who dealt with the foundations of quantum mechanics. Yet Bub was not only speaking of an already existing orthodoxy. According to him:

[3] See (Schlosshauer 2004; Hagar 2007; Ghirardi 2008; Camilleri 2009).

> There seems to be a growing consensus that a modern, definitive version of the Copenhagen interpretation has emerged, in terms of which the Bohr-Einstein debate can be seen as a rather old-fashioned way of dealing with issues that are now much more clearly understood. (Bub 1997, 212)

It is reasonable to question if this new consensus is producing a new orthodoxy, that is, creating new intellectual and professional obstacles, as in the past, thus hampering the development of quantum physics. To assess the reach of Bub's statement, we have to first examine what he meant by old and new orthodoxies. However, Bub used the term orthodoxy in a polysemic manner, which is not unusual in the literature on quantum physics, as already explored in the previous section. Indeed, Bub introduced the concept of orthodoxy in four different ways:

1. The first meaning is that transcribed at the beginning of this paper, which hinges on the founders of the discipline. In sum, the shared view that foundational issues were already solved by the founding fathers of the discipline and do not deserve attention from younger practitioners (Freire 2006, 583; Shimony 1993, XII).
2. Bub (1997, 221) also used orthodoxy with a second meaning, which he called "the orthodox (Dirac-von Neumann) interpretation principle (the 'eigenvalue-eigenstate link')."
3. Citing Zurek, Bub also included "Bohr's 'Copenhagen Interpretation'" as a third meaning for orthodoxy (Bub 1997, 223).
4. Lastly, in the boldest statement, Bub presented the new orthodoxy as a mix of several strands, such as the physical phenomenon of environment-induced decoherence, elements of Everett's relative state formulation and the notion of "consistent histories." And he singled out the French physicist Omnès as the spokesman of the new orthodoxy.

Bub recalled that:

> Omnès refers to '*the* interpretation of quantum mechanics, not *an* interpretation,' and characterizes the view as 'simply a modernized version of the interpretation first proposed by Bohr in the early days of quantum mechanics.'[4] (Bub 1997, 212, emphasis added by OFJ)

While the last three of Bub's concepts of orthodoxy, the orthodox interpretation principle, the Copenhagen interpretation, and Omnès's new orthodoxy, can be found in texts by various authors, the orthodoxy, the founder's orthodoxy, cannot be attributed to anyone in particular, as it is simply an unwritten belief held by

[4] Bub cites Omnès (1994, XIII and 498).

a professional group, physicists in this case. This founders' orthodoxy has no evident or single authorship, but it is a very effective, professionally-grounded attitude. It is not completely independent of Bub's second and third meanings, because the intellectual authority of some of the founding fathers contributed to its wide acceptance. However, hypothetically at least, the second and third meanings of orthodoxy could have existed independent of the founders' orthodoxy, and thus Bub's second and third meanings would not have hindered research on the foundations of quantum physics.

The belief that foundational issues had already been solved survived the founding fathers of the discipline; however, it was challenged by new generations, and eventually research on the foundations of quantum mechanics blossomed. The days of the supremacy of the authority of the founding fathers of the discipline are gone. Therefore, the issue of historical and practical interest seems to be: is the new orthodoxy, Bub's fourth meaning, resuscitating the founders' orthodoxy, his first meaning? If this is the case, such a symbiosis may be harmful to the development of research on the foundations of quantum mechanics. The issue deserves close scrutiny. However, instead of investigating Bub's new orthodoxy as a whole, which is of uncertain authorship, I choose to focus my analysis on the approach represented by Omnès, whom Bub singled out in his fourth meaning, the new orthodoxy. The analysis that follows is thus focused on the consistent history approach and whether it represents the new orthodoxy in quantum theory.

12.3 The Consistent History Approach and Its Rhetorical Resources

The consistent history approach developed between 1984 and 1990, and its founding fathers include Robert Griffiths, Omnès, Murray Gell-Mann and James Hartle. Griffiths is a prominent statistical physicist working at the Carnegie-Mellon University in Pittsburgh, who in the early 1980s turned his attention to research on the interpretation of quantum mechanics. In his seminal paper, "Consistent Histories and the Interpretation of Quantum Mechanics," published in 1984, Griffiths suggested mathematical criteria to use classical rules of probability to produce conditional probabilities for sequences of events at different times. He showed that such criteria could be applied to systems described by the usual quantum mechanical formalism (Griffiths 1984). He called these criteria a consistent history approach because they were able to identify sequences of events, now called consistent histories, which were meaningful in a quantum mechanical treatment. These criteria constitute a regulatory principle to adopt in quantum theory. For Griffiths (1984, 219), the main advantage of his approach was that it could be applied to closed (isolated) quantum systems between successive measurements, thus without taking measurement as a central process for quantum theory. Therefore, one could speak about the physical meaning of a quantum state even in the absence of measurement processes, which is an advantage for a philosophical approach to quantum physics in terms of realism. By the same token, the new approach solved the conceptual difficulties associated with measurement in other interpretations of standard quantum mechanics. Among them, Griffiths pointed to two interpretations. The first requires conscious observers, a reference to von Neumann, Fritz London and Edmond Bauer, and Wigner. The second approach includes classical apparatuses, an indirect reference to Bohr.

While his approach differed from these traditional interpretations, Griffiths did not see it as an alternative interpretation. Rather, he saw it "as an extension and [we hope] clarification of what is, by now, a 'standard' approach to quantum probabilities" (Griffiths 1984, 221). However, Griffiths did not present his paper as a reinforcement of any orthodoxy. He saw it as part of "an extended controversy which is far from being resolved" about the "physical interpretation to the solutions (including boundary and initial conditions)" of the Schrödinger equation (Griffiths 1984, 221). From the immense literature on quantum interpretation, he singled out papers by Kurt Gottfried, Marcelo Cini, Peter Moldauer and Everett for comment and criticism, in addition to the "orthodox views" by von Neumann and Wigner. It is remarkable that he did not reveal any special influence from Everett's interpretation (Griffiths 1984, 257–265).

Omnès is a theoretical physicist from the Université de Paris XI in Orsay. Before changing his focus to the foundations of quantum mechanics, he worked on particle and field physics. In his answer to a referee of the first major publication of his proposal, Omnès highlighted his own contribution to the consistent history approach. Asked about "what is common and what is different in [his] approach with Griffith's [sic] history description," he replied that "as far as mathematical techniques are concerned, Griffith's [sic] construction is used," and added "the conceptual foundations are different because what is proposed here is a revision of the logical foundation of quantum mechanics" (Omnès 1987, 172). Omnès revealed in this answer his intellectual heritage, that of the modern axiomatization which comes from the mathematician David Hilbert. Omnès acknowledges this influence through his debts to Henri Cartan's teachings (Omnès 1988a, 931). In three-paper follow up, he developed the logical and theoretical machinery that allowed him "to construct consistent Boolean logics describing the history of a system, following essentially Griffiths's proposal" (Omnès 1988a, 893).

While Omnès recognized discussions with other physicists interested in the foundations of quantum physics, such as Bell, Jean-Pierre Vigier, and mainly Bernard d'Espagnat, he did not relate his work to the ongoing controversy over quantum physics, except for Griffiths's contributions. In particular, he did not cite Everett's interpretation, a distance he would keep. Furthermore, while he admitted Bohr's shortcomings—"when singling out strict classical physics for expressing experimental data, Bohr was creating new, deep problems" (Omnès 1999, 52)—he tended to present the entire consistent history approach as "significant progress [...] towards a consistent and complete reformulation of the Copenhagen interpretation" (Omnès 1992, 339).

In contrast, Gell-Mann and Hartle came from very different backgrounds; it was the quantization of gravitation which led them to foundations of quantum physics, as they acknowledged in their first joint paper: "we will discuss the implications of quantum cosmology for one of the subjects of this conference—the interpretation of quantum mechanics" (Gell-Mann and Hartle 1989, 322). Previously, in 1983, Hartle, in collaboration with Stephen Hawking, had worked out what is now known as the Hartle-Hawking wave function of the universe, a solution of the Wheeler-DeWitt equation for quantizing gravitation. In the late 1980s, Hartle from the University of California, Santa Barbara, and his former PhD supervisor, the particle physics 1969 Nobel Prize winner Gell-Mann from the California Institute of Technology, approached the issue of interpreting quantum mechanics. The main merit of their contribution was to associate the attribution of classical probabilities in quantum systems as preached by Griffiths and Omnès with decoherence, a quantum feature whose understanding was just emerging. The connection was that "decoherence requires a sufficiently coarse-grained description of alternative histories of the universe" (Gell-Mann and Hartle 1989, 321; 1990, 425). According to Gell-Mann, "coarse graining typically means following only certain things at certain times and only to a certain level of detail" (Gell-Mann 1994, 144). While the first papers they jointly published were more programmatic, they eventually published a more technical work in which "the connections among decoherence, noise, dissipation, and the amount of coarse graining necessary to achieve classical predictability are investigated quantitatively" (Gell-Mann and Hartle 1993, 3345).

As for affiliations, Gell-Mann and Hartle departed from the point of view that all standard interpretations, Copenhagen included, which presuppose a classical domain or an external observer, are inadequate for cosmology because "measurements and observers cannot be fundamental notions in a theory that seeks to discuss the early universe when neither existed." They acknowledged Everett as the first to suggest "how to generalize the Copenhagen framework so as to apply quantum mechanics to cosmology." However, they considered Everett's work incomplete as Everett was not able to "adequately explain the origin of the classical domain or the meaning of the 'branching' that replaced the notion of measurement" (Gell-Mann and Hartle 1990, 429–430). Thus, Gell-Mann and Hartle considered the works of Wojciech Zurek, Erich Joos and Zeh with regard to decoherence as a "post-Everett" stage, and included this trend into their own proposal, along with Griffiths's and Omnès's (Gell-Mann and Hartle 1990). Later, in a book for a wider audience, Gell-Mann made a distinction between the interpretation of quantum mechanics by the founding fathers and the modern one. The former he considered marked by a "curiously restrictive and anthropocentric fashion," as it was based on the existence of observers and classical domains, while the latter was presented as an approach still under construction (Gell-Mann 1994, 136 and ch. 11–12).

As for the rhetoric of orthodoxy, these authors cannot be put in the same category. Certainly Griffiths did not frame his proposal in terms of a new orthodoxy. Instead, he explicitly considered it part of the ongoing quantum controversy, "which is far from being resolved" (Griffiths 1984, 220). Unlike Griffiths, Gell-Mann was seduced by the idea of a new orthodoxy. He presented his own approach as the "modern" interpretation, contrasting it with that of the founding fathers. Adopting the rhetorical strategy of presenting two interpretations, one old-fashioned and the other modern, Gell-Mann (1994, 136–173) implicitly conveyed the idea of a new orthodoxy. He christened the former "the approximate quantum mechanics of measured systems" and introduced it saying that "when first formulated by its discoverers, quantum mechanics was often presented in a curiously restrictive and anthropocentric fashion." He presented the latter saying "for describing the universe, a more general interpretation of quantum mechanics is clearly necessary, since no external experimenter or apparatus exists and there is no opportunity for repetition, for observing many copies of the universe," and added "that is one reason why what I call the modern interpretation of quantum mechanics has been developed over the last few decades" (Gell-Mann 1994, 136–173). By presenting his own approach as the "modern" interpretation emerging as part of the "post-Everett" stage, Gell-Mann is, indeed, excluding other possible interpretations and thus playing the game of the "new orthodoxy." The irony of history, a new orthodoxy barely fits with the idea of a "post-Everett" stage, as Everett's own ideas in their time were considered supreme heresy (Osnaghi, Freitas, and Freire 2009).

Omnès's rhetoric is rather close to the idea of a new orthodoxy. It may indeed have raised concerns about the claim to be a new definitive solution to the problems in the foundations of quantum theory. Omnès presented the new approach as bringing together three different achievements ("the decoherence effect," "the emergence of classical physics from quantum theory," and the "constitution of a universal language of interpretation by means of consistent histories") and went on to conclude that the consistent history approach is a method which "provides a logical structure for quantum mechanics and classical physics as well" (Omnès 1999, 69). He further states that:

> [W]hen these three ideas are put together, they provide a genuine theory of interpretation in which *everything is derived directly from the basic principles alone and the rules of measurement theory become so many theorems*. (Omnès 1999, 70, emphasis added by OFJ)

Thus, according to Omnès, the consistent history approach settles the main issues in the foundations of quantum theory. It is not by chance that Bub singled out Omnès's discourse as the target for his criticism.

12.4 The Reception of the Consistent History Approach

Rhetorical strategies, however, are not enough to explain the existence of a new orthodoxy. After all, heterodox interpretations, such as Bohm's hidden variables and Everett's relative states, were also presented with rhetorical strategies that promised to solve all the problems in the foundations of quantum mechanics (Freire 2005; Osnaghi, Freitas, and Freire 2009). As my colleague Joan Bromberg once remarked, the existence of an orthodoxy requires the existence of followers. Thus, answers to such questions as who are the followers of the consistent history approach and how influential are they, seem to be the litmus test for the existence of a new orthodoxy. In light of this, we now deal with more questions. How was the consistent history approach received by most physicists? Is there, indeed, a growing adhesion to the consistent history approach as the solution to the problems in the foundations of quantum theory?

To gain an insight into the reception of the consistent history approach, I bring into play scientometrics. We know how misleading this source may be if considered independently from other analytical resources (Freitas and Freire 2003). Given this, I have not only considered raw figures concerning citations but also some qualitative cues. I use as my example Griffiths's 1984 paper, not only because it was the first in this approach and introduced the term "consistent history approach," but also because it is the most cited among papers by Omnès, Gell-Mann, Hartle and Griffiths on this topic. According to the Web of Science, see fig. (12.1), it amassed 450 citations, which is very good for citations of a paper in physics. This first positive impression is slightly marred by the data in the following chart, which registers the number of citations per year from 1985 to 2009. Citations of Griffiths's paper took off after 1990, probably due to the connection made by Gell-Mann and Hartle between consistent histories and decoherence. After a decade of rising numbers of citations, however, citations began to decline then remained steady before declining again. These fluctuations can hardly be said to be evidence of a new orthodoxy.

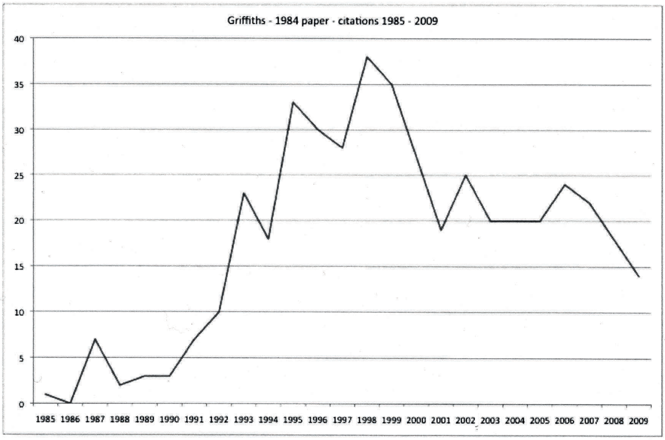

Figure 12.1: Citations of (Griffiths 1984). Data source: Web of Science, query, 4 June 2010, image by the author.

In addition, I checked publications citing Griffiths's paper. I was interested in particular in discovering any connections between this approach and the ever-growing experimental activities on the foundations of quantum mechanics. I sorted all the physicists who cite Griffiths's paper more than ten times. Their names and the number of times they cited Griffiths's paper are listed in the table below:

J. J. Haliwell – 29	R. Omnès – 21	B. L. Hu – 15
C. Anastopoulos – 22	R. B. Griffiths – 18	J. B. Hartle – 13

In addition to the expected cross-citations among the team who suggested such an approach, the other three physicists are also theoretical physicists, which suggests a weak connection between the consistent history approach and the blossoming experimental physics in this field. I also assessed the number of times Griffiths's paper was referred to by physicists working on experiments concerned with the foundations of quantum mechanics. I did not find any citations of Griffiths's paper by prominent experimentalist researchers in the foundations of quantum physics, such as Serge Haroche, Anton Zeilinger and Herbert Walther. It appears that the consistent history approach cannot be considered a relevant theoretical framework for the flourishing experimental research in this domain.

Leaving aside quantitative data, let me make a few qualitative comments. That the proponents of the consistent history approach have suggested a new approach to the foundations and interpretations of quantum physics is, in itself, evidence that they did not consider "the measurement problem of quantum […] a 'small cloud' on the horizon," or that "Bohr had it more or less right," as indicated in the founders' orthodoxy described by Bub (1997, 212). In addition, it is doubtful whether Griffiths, Omnès, or Gell-Mann and Hartle possess the kind of professional and intellectual authority that Bohr, Pauli and Heisenberg had in the golden days after the creation of quantum mechanics. In the introduction to his new book in 2002, Griffiths mentioned his "fellow consistent historians" naming Gell-Mann, Hartle and Omnès. He also identified some of the critics such as d'Espagnat, Giancarlo Ghirardi, Basil Hiley, Adrian Kent, Euan Squires, Angelo Bassi and Fay Dowker. This suggests that after more than a decade, the number of adherents remained the same.

12.5 Conclusion

Bub's fear of a new orthodoxy was not unfounded, as this field was handicapped in the 1950s and 1960s by the widespread idea that foundational issues had already been solved by Bohr and other founding fathers of quantum physics. Bub himself, as a graduate student of Bohm in the 1960s, probably experienced these adversities. However, in spite of having good reasons for fearing a new orthodoxy, my conclusion is that Bub, as far as the consistent history approach is concerned, overstated the existence of a new orthodoxy, at least in the first and fourth meanings described in this paper, namely, the founder's orthodoxy and the combined meaning represented by Omnès's approach. The consistent history approach seems to be simply one more candidate, albeit a strong one, in the plethora of possible interpretations for quantum theory. Thus, while following the steps of previous researchers in this field who criticized the rhetoric of orthodoxy in quantum mechanics, Bub appears to have used the same resource in a new and different context. The efficacy of using the same resources for different contexts is therefore doubtful.

It is possible that Bub missed the target while singling out the consistent history approach for the new orthodoxy and Omnès as its representative. Research on the foundations of quantum mechanics may face other kinds of obstacles at the time of this writing. Perhaps Bub was worried about the widespread feeling that decoherence is the solution to the quantum measurement problem. However, the relationship between decoherence and foundational issues is better addressed in terms of an ongoing controversy than in terms of orthodoxies, as Maximilian Schlosshauer's (2004) review on the subject may evidence. Others, such as Ghirardi (2006, 2913), are concerned with the uncertain idea that quantum physics is ultimately a physical theory of information, an idea that he called the "quantum information interpretation." Amit Hagar and Meir Hemmo (2006, 1295), along the same lines, state that "quantum information theory has by now become to a large extent a new orthodoxy in the foundations of quantum mechanics," but, as evidence that orthodoxy is a polysemantic word in quantum mechanics, Bub's approach, in terms of information, is itself the target of Hagar and Memmo's criticisms. However relevant these views may be to the unfolding research on quantum information, analyzing them is another and quite different story from that of the consistent history approach. At any rate, as the term orthodoxy has become so polysemous, with an increasing number of different orthodoxies, it has lost its rhetorical efficacy: it is pointless to speak either of many orthodoxies or of many heterodoxies.

Abbreviations and Archives

Wheeler Papers	American Philosophical Society, Philadelphia

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