10 Non-Orthodox Versions of Quantum Theory and the Need for Process 1

Eugene Wigner introduced the term 'orthodox' to describe von Neumann's formulation of quantum theory. I use the term more broadly to include, *at the pragmatic level*, also the Copenhagen formulation. But at the *ontological* level I mean the von Neumann–Tomonaga–Schwinger description that includes the entire physical universe in the physically described quantum world, and that accepts the occurrence of the process 1 interventions in the process 2 evolution of the physically described state of the universe.

This conventional formulation of quantum theory – with experimenter-induced interventions – is the one used in practice by experimental physicists who need to compare the predictions of the theory to empirical data. It is consequently the form of the theory that is actually supported by the empirical facts.

It might seem odd, therefore, that any quantum physicist would want to promote an alternative formulation. It seems particularly strange that there could be physicists who now seek to remove the effects of consciousness from the basic dynamics; physicists who want to reverse the great twentieth century achievement of rescuing consciousness from the passive limbo to which it had been consigned by classical physical principles. It seems strange that there could be physicists who seek to retreat from the idea of giving consciousness a causal role that: 1) accords with our deep intuitions; 2) meshes neatly with empirical practice; 3) explains naturally the effortful learning of new tasks; and that 4) allows consciousness to evolve by natural selection, by virtue of its capacity to aid our bodily survival. Yet theoretical physicists who favor such a reversion do in fact exist.

The feature of quantum theory that precipitates the disagreements among physicists is that it is exceedingly difficult to detect directly by physical measurements whether a large physical system that is strongly interacting with its environment is, or is not, acting as a quantum agent: it is virtually impossible to determine, directly by measurements, whether reduction events are occurring in such a sys-

tem. Given such empirical latitude it is natural that theorists should tend to build alternative theories. And from the perspective of a theoretical physicist it is of course desirable to have a causal structure that is completely fixed in terms of the purely physical descriptions with which he or she is familiar, in spite of the deep problems that such a restriction eventually generates, both mathematically and philosophically.

There are three main non-orthodox approaches to the problem of imbedding pragmatically validated quantum theory in some coherent conception of reality itself. These are the many-worlds approach initiated by Everett (1957), the pilot-wave approach of Bohm (1952, 1993) and the spontaneous-reductions approach of Ghirardi, Rimini, and Weber (1986).

The many-worlds approach is the most radical and sweeping. It asserts that the quantum state of the physical universe exists and evolves *always* under the exclusive control of the local deterministic process 2. In this scheme no reduction events occur at the level of objective reality itself. The fact that we *seem* to choose particular experiments that *seem* to have outcomes that conform to the predictions of quantum theory then needs to be explained as essentially some kind of persisting subjective illusion that produces coherent long-term streams of human *conscious* events that somehow conform over long times to the statistical predictions of the orthodox theory, even though the *physical reduction events that logically entail these properties in the orthodox approach are now asserted not to occur*. The *consciously perceived* experiences that conform to the statistical rules of pragmatic quantum theory then need to be explained as intricate properties of the purely mental by-products of a continuous physical process that eschews the interventions and reductions that provide the mathematical foundation of the orthodox understanding of the empirical facts.

The pilot-wave approach claims that there really is *both* a world of the kind specified in classical physics – a world that determines the content of our human streams of conscious experience – and *also* a real state of the universe of the kind specified in quantum theory. It asserts that this latter world always evolves via process 2, with no collapses or interventions, and that the real classical world is buffeted around by the real quantum world in a way that accounts for the validity of the empirical predictions of pragmatic quantum theory.

The spontaneous-reductions approach maintains that the evolution via the local mechanical process 2 is interrupted from time to time by a sudden spontaneous and random reduction event that keeps the