Chapter 5

Quantum Mechanics and the Application of Quantum Mechanical Ideas to the Mind-Body Prodlem

To set the stage for an overview of guantum Mechanics, this anecdote is provided by the Quantum physicist John wheeler. A group of scientists gathered at the home of Lothar Nordheim for a friendly dinner. John Wheeler was among them. After dinner they started what is usually played as the 20-question game. However, there was an interesting modification to the one they played.

> According to Wheeler, he was sent from the room for what seened an inordinate length of time. Returning to the room he saw a smile one everyone's face--a sure sign that some sort of mischief was a foot. He then started his questioning with the customary sweeping queries: "Is it animal?" No. "Is it alive?" No. But as the questioning went on, Wheeler noted that the answers were slower and slower in coming, with the person being questioned thinking for a long time before responding with a simple yes or no. Finally Wheeler felt he had narrowed the possibilities down to the point where he was ready to take the plunge. "Is the word 'cloud'?" he asked. At which point everyone broke out laughing and told him he was correct. It seemed that while he'd been out of the

> room the others had agreed that they would not select any word, but rather would let some word emerge as a consequence of Wheeler's questioning. The agreement was that the parties being questioned could respond with either a yes or a no, the only constraint being that whichever response they gave, they would have to have a definite word in mind that would be consistent with all the preceding responses. So the game was at least as difficult for the others as it was for Wheeler[1][*]

The lesson inherent in this story is the distinction between Newtonian reality consisting in the objective existence of things and their properties and a different kind of reality very much defined by the participation of observers of that reality. As Wheeler's game was played, there was no definite word agreed upon by those in the room and awaiting discovery by the questioner. In fact there was no word but only the potentiality for a word. What that word becomes, rather than what that word is, has been determined not by any pre-arrangement but by the spontaneous questions and answers of the participants.

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[1] John L. Casti, *Paradigms Lost* (Abacus, London, 1990), p. 416

[*] A more detailed account of Wheelers 20-question game is found in P.C.W. Davies & J.R. Brown, *The Ghost in the Atom* (Cambridge U. Press, London, 1986), p. 22-24.

It might be said that the word evolves out of the probing in the game. This competing versions of reality lies at the heart of what is problematic about Quantum Mechanics.

In order to appreciate the participatory kind of reality which Quantum Mechanics seems to have made inevitable, a few words must be said about Newtonian reality. This is the kind of reality which can be described by the phrase "really there". If such definite reality is scaled down to the micro-world, Newtonian reality is exhaustively described in terms of a world of particles and forces. The particles are real things, little billiard balls, if you will. At any given moment, each of these reality-consitituting entity maintains its definite physical presence as determined by its static attributes and its dynamic attributes. The static attributes refer to properties such as its mass which do not change over a period of time while the dynamic attributes are those which change in the course of time such as position and velocity. In Newton's world, each and every constituents of reality together with its attributes exist at each moment in time and continue toexist from moment to moment. The image of Newton's micro-world is just a replication of the picture that we have regarding tables and chairs, that is, regarding our everyday world. An observed table and an unobserved table both share the benefit of having definite attributes. Even when unobserved, a table either has three legs or it has four legs, for example. It would be difficult to understand someone who says that such an unobserved table has neither three nor four legs because when unobserved it is meaningless to ask how many legs it has. In both the common-sense and the micro-world of Newtonian physics, to observe an object is to discover its attributes and not to create them. The world is really there, ready-made, and independent of observers.

If the picture of the particles as constituents of Newtonian reality is clear, the other basic ingredient--the forces--remains somewhat mysterious. This mystery has to do with the nature of these forces rather than with describing them and their interactions with the particles. Newton's Second Law is expressible as a=F/m, meaning that the rate of change of the velocity of a particle or, in short, its acceleration, equals the force imposed upon it divided by the particle's mass.[2] Once the imposed forces, the initial position and velocity of each particles are known,it is in principle correct to say that all physical events can be described, predicted and retrodicted in terms of the interactions between the particles and the forces. Yet,what the forces essentially are had not been made clear by Newton. On the contrary, in regards to the nature of gravity, Newton said "Hypotheses non fingo--I make no hypotheses".[3]

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[2] Ibod.,, p. 417-418.

[3] Ibid., p. 418.

Newton's forces have been later understood in terms of fields. A classical field is a distribution of forces in space. The range of a field is how far its force extends, the force falling off as the distance squared. There are two fields of forces in classical physics--the electromagnetic field and the gravitational field. The three classical forces are, of course, electric, magnetic and gravitational. Together with his laws of motion, Newton discovered the inverse square behavior of the gravity field.[4] It was James Clerk Maxwell who put down the laws governing the electric field and the magnetic field, showing that the two fields are not separate but different aspects of a single electromagnetic field.[5] These field laws together with the laws of motion are sufficient to describe the workings of the universe of classical physics. Moreover, these laws are deterministic because each outcome is uniquely dependent on a given initial condition. It is such a determinism that would come into conflict with the implications of Quantum Mechanics.

The clockwork regularity of the Newtonian world rests on the definiteness of the reality-constituting objects and the fixed laws governing such objects. It has often been emphasized in

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[4] Nick Herbert, Quantum Reality (Anchor Books, New York, 1985), p. 33.

[5] Ibid., p.33.

layman's terms that Quantum Mechanics represent something indeterminate, uncertain and mysterious. Such as observation should be taken with a pinch of salt, for while it may be said that these descriptions figure in the interpretations of Quantum Mechanics,the mathematical formalism descriptive of Quantum Mechanics is very preicse and underlies the deterministic paths of sub-atomic objects. Probabilities plays no role at the quantum level but only at the crossroads where quantum objects meet the everyday objects of classical physics.But it should be noted that if there is anything indeterminate, uncertain and mysterious about Quantum Mechanics, then it is not in the ways that physicists can describe the quantum world. What emerges as problems about quantum reality has more to do with explaining what such descriptions mean and imply. As a background for the problematic, at least a brief sketch of quantum descriptions is in order.

A physicist describing some quantum event would construct a mathematical model of the event which would represent various aspects that are the focus of his descriptions. There are at least three different descriptions of quantum reality which, as it turned out, are ultimately mathematically equivalent.[6] Each of

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[6] Nick Herbert, <u>Quantum Reality</u>. p.42.

these description is a quantum theory, and, depending on how one chooses to view them, it can be said that because they are all mathematically equivalent, they all constitute one Quantum Theory or the three descriptions can be taken as constituting a group of Quantum theories. Whichever way seems unimportant to our project. But it is important to be clear about what Quantum Mechanics is.

Quantum Mechanics, used as a collective name for a group of theories,is a mathematical representation of the workings of subatomic entities such such as electrons, photons, and other more exotic particles, namely, quarks, hadrons, etc.:

> Quantum theory is a method of representing quantumstuff Mathematically: a model of the world executed in symbols. Whatever the math does on paper, the quantumstuff does in the outside world. Quantum theory must contain at least: 1. some mathematical quantity that stands for quantumstuff; 2. a law that describes how this quantity goes through its changes; 3. a rule of correspondence that tells how to translate the theory's symbols into activities in the world.[7]

In terms of mathematics, Quantum Mechanics is continuous with classical physics in incorporating physical facts in the economy of

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[7] Ibid., p. 41.

mathematical formulas. What the mathematical symbols do on paper is always correlated with actual facts as though there is some connections between the symbolic notations and the workings of nature. This mysterious contact has been described by Eugene Wigner as "The unreasonable effectiveness of mathematics in the natural sciences".[๘] As an intellectual system of mathematical symbolism, Quantum Mechanics is no different from classical physics. To have a clear picture of Quantum Mechanics, it is necessary to sketch even only briefly how its roots emerged out of the shortcomings of classical mechanics.

The word "quantum" arose in connection with Max Planc's assumption that enery comes only in particular-sized chunks, like coins of various denominations.[๙] According to classical physics, particles can have any energy range. One consequence of this view is the prediction that black objects should glow bright blue at all temperature, which contradicts the empirical fact that they do glow bright red. Only if electromagnetic radiation comes in packets of energy, or quanta, can theory be made to accomodate the facts. The finite unit of energy or radiation signified by the quanta reveals

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[๘] Ibid., p. 2.

[๙] Ibid., p. 36.

that fact that the inhabitants of the sub-atomic world do not obey Newtonian laws. In fact, electrons and the likes of them do not even obey a classical kind of law, that is, a kind of law which governs the world of ordinary objects.[10]

Further undermining of classical mechanics came from Einstein's first 1905 paper.[11] Using Max Plank's quantum of energy, Einstein demonstrated that light's ability to knock electrons out of metal means that light behaves also as particles, as opposed to the received view that light has wave-like characteristics. Einstein's theory of the photoelectric effect ironically revives the Newtonian idea that light consists of corpuscles. But more significantly, it underlines the wave-particle duality which characterizes the behavior of quantum objects. Departing from the established theory that light behaves like a wave, the idea that the nature of light also has something to do with being particles has an iconoclastic implication which can be brought out clearly by considering how contradictory it is for something to be both a particle and a wave. First, a wave can spread out sweeping an ever widening area, but a particle is localized to a very small area. Second, a wave can be split in an infinite variety

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[10] Ibid., p. 34.

[11] Ibid., p. 35-36.

of ways, each way tracing an a different path, but a particle's path is constrained to a single direction. Waves can produce interference patterns, either reinforcing or cancelling each other, but two particles in contact would only crash. Einstein's understanding of the nature of light as consisting of two contradictory aspects not only showed that Newtonian physics is incomplete, but also that to complete it, we have to be prepared to deal with something as much paradoxical as it is alien to common-sensical descriptions.

The "black body puzzle" and the strange interaction between light and electrons in metal encapsulated in the theory of the photoelectric effect exemplify the inability of Newtonian physics to explain sub-atomic phenomena. This by no means imply that classical mechanics is obsolete. On the contrary, Newton's laws remains useful in the world of common-sense objects stradling between the very large and the very small. Quantum Mechanics took root in the realm below the surface phenomena of things with well-defined attributes which answer to the governance of Newtonian formulas. In response to the need for ways to describe and predict the contradictory behavior of sub-atomic particles, three quantum theories were proposed by Werner Heisenberg, Erwin schrodinger, and Paul Dirac. To give a flavor of what these theories consist in, a rough sketch of each follows:

1) Heisenberg's theory is called matrix mechanics because he represent the quantum world by set of matrices. A matrix is a square array of numbers like a mileage table on a road map which

lists the distances between various cities. In Heisenberg's equation, each matrix stands for a particular attribute of the particle such as position, spin, energy, etc. The evolution of these matrices follows a particular law of motion which resembles Newton's law in form but contains peculiar differences. One big difference is that unlike numbers, maatrices do not commute. This means that the order of matrix multiplication makes a difference. In particular, when p and x are square arrays, p times x is not equal x times p.[12]

2) Schrodinger represents quantum objects as a wave form. More precisely, he represents the state of a quantum entity such as an electron by mathematically visualizing it as having wavelike properties. What this means is that the quantum entity being described can show the type of interference phenomena associated with waves. According to Schrodinger's law of quantum motion, before measurement the sub-atomicparticlesevolve as waves. When the measurement is made, the wave nature of each entity disappears, resulting in the exact localization of the entity. This is called "collapse of the wave-function" and has been interpreted loosely as the cross-road where quantum probability becomes common-sence reality.[13]

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[12] Ibid., p. 41-42.

[13] Ibid., p. 42.

3) In Dirac's equation, quantum objects are represented by rotating arrows. The motion of each quantum entity corresponds to the rotation of the arrow. Describing quantum motion, according to Dirac, has to do with understanding the rotating arrow in relation to the prescribed set of coordinates. Mathematically, Dirac's arrow can be conceived as either a group of matrices or a wave, so that it can be shown that both Heisenberg's and Schrodinger's theories are special cases of Dirac's description.[14]

For our purposes, the technical details are of peripheral importance. The mathematics of quantum theories does not concern the problem being handled in this paper. What is at issue is the question concerning what sort of reality encompasses the quantum world, for it is the intention of this paper to show that some features of the quantum reality make it possible to describe interaction between an immaterial mind and a material body. The nature of the underlying quantum reality is certainly relevant to quantum physicists. But it is also equally certain that physicists do not need to answer this question in order to carry on with their work. In fact, it could be said that a majority of physicists use quantum theories as a tool to manipulate the world rather than as windows into deep reality. But it is necessary for our project that the nature of quantum reality be brought out. It will be seen that various views are

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[14] Ibid., p. 42-43.

offered as descriptions of the deep structure of the world, these views representing different ontologies based on results obtained when quantum theories are tested against events in the actual world. There are at least seven versions of quantum reality:

1) There is no deep reality. This is one version of the orthodox Copenhagen interpretation of what the quantum theories mean in terms of the underlying ontology. According to Niels Bohr, there is no quantum world. Because of the paradoxical behavior of sub-atomic particles, the underlying reality constituted by them is anything but real in the classical sense. Heisenberg says that atoms are not things, the connotation of the image of ghostly particles suggesting that what we think of as concrete reality has no substantial essence.[15]

2) The world considered to be concrete reality is created by acts of observation. This is the second version of the Copenhagen interpretation and may be viewed as an extension from the first version. Compounding what is already arcane in the first version, namely, the quantum existence, this second version suggests that the world spoken of as objective reality is in fact observer-created, leaving open what is to qualify as an observation. This view does not collapse into idealism; for an observed phenomenon does not necessarily have to be a mental observation. Any recording instrument

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[15] Ibid., p. 158-164.

counts as an observer, which, of course, means that the mind can be an observer as well, but acts of observation are not limited to those belonging to the mental category.[16]

3) Reality is seamless. Despite the appearance of diversity of existents, the underlying reality is not constituted by various categorical boundaries dividing things into kinds of things. The universe is interconnectedly linked as one piece of cloth. The emphasis on the seamless aspect of a piece of cloth is significant, for it serves to point out that the quantum wholeness is not a matter of things being linked together in the manner in which, for example, they are gravitationally connected. On the contrary, quantum wholeness implies a nonlocal connection in which the interconnectedness is undiminished by spatial and temporal separation, no matter how vast. A non-local interaction is unmediated, a certain cause originating at one end of the universe instantaneously producing an effect at the other end. Magic such as a voodoo curse employs the concept of non-locality. A curse is uttered here and the victim of the curse immediately receives its content a thousand miles away.[17]

4) Reality consists of a multiplying number of parellel universes. For any situation in which several outcomes are possible,

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[16] Ibid., p. 164-168.

[17] Ibid., p. 168-172.

such as flipping a coin, this version of quantum reality, known as the many-worlds interpretation, suggests that all possible outcomes actually happen. When a coin is flipped, it either comes up heads or tails. According to the many-worlds reality, one universe contains a coin that comes up heads, and another universe takes shape to accomodate the other possibility of the coin being tails. In more complex situations, more universes are required to accomdate the outcomes,and the number of these additional worlds are not limited. The number of possible outcomes in a given situation matches the number of the accomodating universe which are identical in every detail except for the outcomes which trigger their coming into being.[18]

5) Reality must be understood with a non-Boolean kind of logic. This version is almost ontologically silent, for it makes no attempt at the description of deep reality, focusing instead on how we are to make sense of the paradoxical data of quantum experiments. To give a flavor of what the quantum logicians are getting at,consider the two views of gravity offered by Newton and Einstein. Newton explained gravity in terms of a force which is never verified by sensation.Newton's laws provide approximately accurate descriptions of the interaction between the force of gravity and matter. Such approximate descriptions become evident when Mercury's anomalies are inexplicable in terms of the Newtonian laws. On the Other hand,

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[18] Ibid., p. 172-175.

Einstein chose to explain gravity by the concept of the curvature of space-time. According to Einstein gravity is not a force but a curvature of space-time. From Einstein's perspective, observing the effect of gravity on the movement of the planets is like standing on top of a mountain on a dark night and observing some night travellers, each holding a torch, following a circular path around and up the mountain. Like each traveller, each planet is just following a path in space-time without being compelled by any external force.[19] In the words of leading quantum logician, David Finkelstein:

> Einstein threw out the classical concept of time; Bohr throws out the classical concept of truth... Our classical ideas of logic are simply wrong in a basic practical way. The next step is to learn to think in the right way, to learn to think quantum-logically.[20]

6) Reality is created by consciousness. This version has some affinity with the second Copenhagen view alluded to above. In the second Copenhagen version, an act of observation creates reality in the sense that it collapses the wave function by converting the probabilities of a quantum attribute taking on a certain value into the actuality of that attribute taking on a definite value. In this view, however,no specification has been given as to what is to qualify

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[19] Ibid., p. 177-185.

[20] Quoted in Herbert, Ibid., p. 21.

as an observer, with the implication that any measuring apparatus can count as such. On the other hand, if reality is created by consciousess, and if the act of observation is necessary to collapse the wave function, then only a conscious apparatus qualifies as a observer.

7) Reality consists in the two worlds of potentialities and actualities. This is Heisenberg's own version of quantum interpretation. Heisenberg subscribes to the Copenhagen view that there is no deep underlying reality. However, Heisenberg qualifies such a lack by postulating a quantum world of potentialities or possibilities. According to his duplex world view:[21]

> The probability wave... means a tendency for something. It's a quantitative version of the old concept of "potentia" in Aristotle's philosophy. It introduces something standing in the middle between the idea of an event and the actual event, a strange kind of physical reality just in the middle between possibility and reality.[22]

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[21] Ibid., p. 193-197.

[22] Quoted in Herbert, Ibid., p. 27.

Heisenberg's world of potentia is both less real and more real than our own. It is less real because its inhabitants enjoy a ghostly quantum existence consisting of mere tendencies, not actualities. On the other hand, the unmeasured world is more real because it contains a wealth of coexistent possibilities. In such a world, a flipped coin can show heads and tails at the same time. It is only when an act of measurement takes place that the world of possibilities collapse into the world of factual realities.

The seven quantum realities briefly sketched above represent seven speculative ontologies consistent with thequantum theories. As already mentioned, all quantum theories, or at least the three we have looked at,are experimentally competent in the sense that their mathematics fit the facts. So from the philosophical point of view, it seems a matter of taste what reality one subscribes to, for all are experimentally indistinguishable, underlining once again the underdetermination of theory by data. But it is important for the problem at hand to understand one crucial aspect of Quantum Mechanics that gave rise to these competing versions of deep realities.

This crucial feature shared by all quantum theories is the emphasis on measurement. First of all, we must note that despite their differences in mathematical formalism, all quantum descriptions proceed from the common assumption that prior to measurement, noting definite can be said of quantum objects: quantum objects are described only by a probabilistic quantity specifying the relative likelihood of some attributes taking on certain valued when measured. The emphasis on measurement results in two important questions about measurement: 1) "At exactly what point in the measurement of the electron's spin does the probability set collapse? 2) How does the act of observing the electron's spin collapse the set of likelihoods?"[23] In answering the second question about quantum measurement, we will have also explained how is it that an immaterial mind interacts with a material body.

The significance of quantum measurement brings out in essence what has been considered "strange" or "paradoxical" about Quantum Mechanics. According to everyday common-sense, the point at which a measurement takes place is usually unproblematic. For example, when a measurement is taken on a piece of land, the point of measurement coincides with the laying down of the yardstick or some similar measuring tools. However, when it comes to measuring some sub-atomic attributes,the situation is not so cut-and-dried. Questions like these, which would seem comical when applied to common-sense situation, are part of the quantum measurement problems: Does the measurement of an attribute of a quantum object occur when the experiment is planned. Or does it occur when a dark spot appears on a phosphor screen. Or does the measurement take place when our

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[23] Casti, op. cit., p. 432-433.

consciousness registers some observable results. Or, to take the problem to the limit, does it occur when the experimenter first decides to perform the experiment. The problem seems to be compounded by the fact that no agreement is forthcoming from the community of physicists.[24]

As for the second question concerning the mechanism involved in the collapsing of the wave function, the major problem here lies in explaining how is it that an observer, which in principle may be just a recording machine, could act upon the quantum wave function, which is a mathematical object composed of pure information.Collapsing a wave function means determining a definite quantum attribute. When a quantum attribute is fixed, physical reality ensues. A dark spot on a phosphor screen is a physical event as this is understood in our everyday world. The dark spot implies that at least one attribute--the position--of a sub-atomic particle has been fixed. However, prior to this marcro-world event, the particle cannot be said to *be* in any position. According to Quantum Mechanics, the particle in question occupies no particular region of space, being in one sense everywhere and nowhere at the same time. Prior to measurement, a quantum object only "exist" in the probabilistic wave function which, as its name suggests, represents the particle's possible whereabouts with the image of an ever-widening spherical wavefront. How is it, then, that a measuring device, which is a macro-world object, act upon this mathematical wave function to bring about the "collapse". Further, it is also unclear what this "collapse" means other than what is implied by its mathematical formalism.

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[24] Herbert, op. cit, p. 145-149.