

#### **4. THE OBSERVER.**

From the time of Isaac Newton to the beginning of the twentieth century science relegated consciousness to the status of passive viewer: our thoughts were excluded from the action. The decisive counter move of the founders of quantum mechanics was to recognize that "in the drama of existence we ourselves are both actors and spectators." [Bohr, Essays 1958/1962 on Atomic Physics and Human Knowledge]. After two hundred years of neglect, our thoughts were suddenly thrust into the limelight. This was an astonishing reversal of precedent because the successes of the prior physics had been deemed due in large measure to the policy of keeping idea-like qualities out.

What sort of upheaval could have forced scientists to this wholesale revision of their idea of the role of mind in Nature? The answer in brief is "quantum jumps!" These events are sudden shifts in our best mathematical description of the size, shape, and structure of a physical system. At one moment the form may extend over miles, but an instant later be reduced to the size of a speck. How can we understand such precipitous leaps in our scientific description of the physical world? The resolution proposed by Heisenberg, Bohr, Pauli, and the other founders of quantum theory was a bold one: bring our thoughts, unshackled, into the basic theory of nature.

Einstein described a simple situation that illuminates the puzzling character of these quantum jumps. Suppose a radioactive atom is placed in a detecting device that responds to the decay of this atom by sending an electrical pulse to a graphical recording instrument that draws a line on a moving scroll. A blip in this line will indicate the time at which the electrical signal arrives. Next, suppose some

scientists are observing the instrument and reporting to each other where the blip is located on the scroll. What we know is that these observers will more or less agree amongst themselves as to the position of the blip. But quantum theory has stringent laws that govern in principle the behavior of all physical systems. If one applies these rules to the entire system under consideration here, which consists of the radioactive atom, the detecting device, the electrical pulse, the graphical recording instrument, the bodies and brains of the human observers, and all other physical systems that interact with them, then one arrives at a contradiction. What we know is that the blip seen by the observers occurs at a fairly definite location. But according to the mathematical laws the full physical system will be a smeared out blur encompassing equally all of the alternative possible locations of the blip. In particular, for each one of the infinity of possible locations of the blip on the scroll there will be an entire world, of the familiar kind, in which all of the observers report seeing the blip occurring at that particular location. Thus the quantum law, or rule, that governs the behavior of matter generates a whole continuum of possible worlds of the kind that appear in our streams of conscious experiences. The empirical world of experienced facts is just one tiny slice of the full world generated by the mathematical equations of quantum theory.

This clash, which lies at the heart of quantum theory, is a discord between the two distinct parts of science, the theoretical and the empirical: it is a sharp contradiction between theory and fact. These two interrelated aspects of science are extremely different in character. Each *fact* comes as a chunk of somebody's experience. But these individual chunks are related to each other. At one moment you see a chair, then look away. Upon looking back you see a chair that resembles the one you saw before. You were

alone in the room, hence no continuous human experience bridges the gap between these experiential moments. Yet the two experiences are obviously linked together by something.

To explain the connections between the disconnected perceptual facts we concoct *theories*. We create ideas about persisting realities that exist even when no one is watching them, and that bind the disjoint facts together. Our physical theories are conceptual frameworks that we create for the purpose not only of organizing our perceptual experiences, but also of permitting us even to have understandable and describable experiences. As Niels Bohr succinctly puts it: "The task of science is both to extend the range of our experience and reduce it to order." [N. Bohr. Atomic Physics and Human knowledge, p.1 ].

Contemporary science teaches us that the enduring reality that provides the fabric into which our experiences are woven, is composed of both moving atomic particles and changing physical fields. Laws governing the behavior of these physical realities were proposed by Isaac Newton, James Clerk Maxwell, and Albert Einstein. Those "classical" laws work well in cases where the detailed nature of the elementary components is unimportant, but fail absolutely in other cases. Specifically, they fail in cases where the "quantum of action" becomes important. This quantity was discovered and measured by Max Planck in 1900, and its numerical value is called *Planck's constant*. This value is very small on the scale of normal human activity, but becomes significant when we come to the behavior of the atomic particles and fields out of which our bodies and brains, and all other physical objects, are made. Planck's constant enters, in particular, into Heisenberg's uncertainty principle, which says that atomic particles can never reveal

themselves to be the tiny moving objects that they had been imagined to be since the time of Isaac Newton. Nor is there any reason to believe that such tiny objects exist at all. Each "particle", insofar as we can ever know it, may be associated with a particular mass (e.g., the mass of an electron) and a particular charge (e.g., the charge of the electron), but there is no evidence that it has a particular location. All the empirical evidence is most parsimoniously represented by taking each atomic particle to be a cloud-like structure that has a strong proclivity to spread out over ever-larger regions.

The important and amazing thing is that the older classical laws, built on the notion of miniscule objects, become automatically converted into unique new quantum laws when the empirically measured value of Planck's constant is consistently introduced. This "quantization" procedure automatically converts the notion of a particle as a minute entity into the notion of a "particle" as an extended cloud-like structure. Physicists had, for more than two hundred years, imagined Nature to be composed, at least in part, out of entities resembling miniature planets. But Nature, at least as she reveals herself to us through our observations, and through our mathematics, appears to be made out of a very different kind of stuff.

The unique quantum laws produced by the quantization procedure make predictions that are accurate to as much as one part in a hundred million, and they correctly describe various features of the behavior of systems of billions of particles. But Einstein's example shows that these quantum laws of motion lead also to smeared out physical states that are grossly discordant with the more narrowly defined character of our actual experiences.

You might immediately think that this huge disparity between the mathematical theory and the empirical facts would render the theory false and useless. However, the creators of quantum theory found that *all* of the successes of classical physics and a great deal more could be explained, without any contradiction ever arising, by adopting the following dictum: assume that the natural quantum laws do indeed hold, but if they lead to a physical state that disagrees with your empirical observation then simply discard the part of that (mathematically computed) state that disagrees with your observations, and keep the rest. This sudden resetting of the physical state is the "quantum jump." By itself it would yield nothing. But it is accompanied by a statistical law --- to be described later --- that produces all of the wondrous results.

You, like all of us, are continually creating, on the basis of the best information and ideas available to you a theoretical image of the physical world around you: you have an idea about the status of all sorts of things that you are not currently experiencing. But every time you gain more information you revise that picture to fit the new facts.

Quantum theory instructs the scientist to do the same. That simple dictum (revise your theoretical picture of the world to fit the empirical facts), together with its statistical partner, produces not only incredibly accurate predictions, but every successful result of the earlier classical physics, and all of the thousands of successes of quantum theory where classical physics fails. These impressive results are achieved by simply allowing the beautiful, internally consistent, and unique natural generalization of the old classical laws to hold whenever we are not actually acquiring knowledge about a physical system, but incorporating promptly any knowledge we acquire. The close connection

maintained in this way between what the mathematical description represents and what we empirically know underlies Heisenberg's assertion that the quantum mathematics ``represents no longer the behavior of particles but rather our knowledge of this behavior."

The shocker, however, is that Bohr and the other founders have argued persuasively that *no other description of nature in terms of its atomic constituents can be more complete than this one*, in the scientific sense of telling us more about relationships between human experiences. That is, this theory built on the unique adequate generalization of the older classical laws seems to tell us everything that a basic physical theory could ever tell us about relationships between human experiences.

This claim was strongly disputed by Einstein, who tried repeatedly to devise a counter-example. In the end he admitted that he had failed. Thus it does indeed seem to be true that this fantastically coherent quantization of the older laws generates *everything that is knowable about reality*: any attempt to add something more may please some philosophers, but carries us outside of science, regarded as a tool for "expanding our experience and reducing it to order."

This apparent scientific completeness of quantum theory, together with the fact that the "quantization" procedure totally *eliminates* the classically conceived "realities," and replaces them by cloud-like forms, make plausible the conclusion that there simply are no *classical-type or quasi-classical-type* realities lying behind our thoughts, and that searching for them is a futile endeavor. The presumption that such realities exist is therefore a gross philosophical blunder. There is absolutely no empirical evidence that rationally

supports the notion that there is a physical reality out there that is better defined than what quantum theory provides. Assuming that such a quasi-classical type reality exists is not justified by the scientific evidence, and is likely to produce a conception of both nature and human beings that is fundamentally incorrect.

Let us, however, be clear about one thing. Although quantum theory is built upon human experience, it does not assert that thought is the only reality, and matter naught but an invention of mind: the founders did not espouse the philosophy of idealism. Their position was the more conservative one that science is about what we can know, and that our theories must be judged not by concordance with intuition, but rather by rational coherence and capacity to order the empirical facts. This view liberates theoretical creativity: it allows science, unfettered by ancient prejudice and fallible intuition, to build its idea of reality upon the empirical evidence.

This philosophical retrenching did not satisfy everyone, Einstein and Schroedinger being the most notable hold-outs. But it did allow the scientists who accepted it to get on with the business of developing, testing, and using this practically useful and immensely successful theory.

Quantum theory brings your consciousness into physics in two distinctly different ways. The first is as a passive stream of conscious thoughts that constitutes a growing reservoir of knowledge. Each waking moment adds something new to what you knew before. The second way is as an active agent endowed with a free will that can influence both how your body moves and how your thoughts unfold. It is this second role that gives you your moral dimension. But to understand

yourself as active participant you must first appreciate yourself as an expanding collection of knowings.

"The observer" as understood in the original "Copenhagen" formulation of quantum theory differs from what one would normally mean by this term. For one thing, it involves an extension of the human observer outside his physical body. Bohr mentioned several times the example of a man with a cane: if he holds the cane loosely he feels himself to extend only to his hand. But if he holds the cane firmly then the outer world seems to begin at the tip of his probing cane.

In analogy, the quantum "observer" is considered to include not only the human experimenter himself, but also the measuring devices that he uses to probe what is outside his extended self. Thus the world is imagined to be cleaved into two parts, which are described in different ways. The outer "observed system" is described in terms of the quantum mathematics, whereas the inner "observing system" is described as a collection of empirical (i.e., phenomenal or experiential) facts. This way of dividing the world reflects the point, stressed already above, that quantum physics --- like all of science --- rests on two disparate kinds of descriptions, the first being of conscious experiences that we can record, remember, and communicate to our colleagues, and which form the empirical database, and the second being of a theoretical structure that we have invented for the purpose of comprehending the structure of our experience.

Copenhagen quantum theory regards the measuring instruments as part of the observer because these devices are described not in terms of their atomic constituents but rather in terms of our conscious knowings. Bohr repeatedly points to this key feature of quantum theory, in statements such as:

"The decisive point is that the description of the experimental arrangement and the recording of the observations must be given in plain language, suitably refined by the usual terminology. This is a simple logical demand, since by the word `experiment' we can only mean a procedure regarding which we are able to communicate to others what we have done and what we have learnt." (Essays 1958/1962....p.3)

You might think that since the key realities in quantum physics are descriptions of experiences pertaining to measuring instruments, we ought to disregard the observer and describe instead these devices themselves, regarded as objectively existing realities, and thereby dispense with all the mumbo jumbo about observers. But then the quantum jumps, which are now neatly placed at the interface between the two parts of science, which must always be linked by some sort of rule, get shifted into the physical world, which is supposed to be enduring, and continuously evolving. Such a move would bring in a host of questions as to how, when, and why the natural quantum generalization of the classical laws of physics should fail in the *physical* world. The most simple, natural, and parsimonious assumption is to retain the physical laws in the entire physical universe, but rescind the banishment of mind from the workings of nature.