## 4. THE OBSERVER

The decisive move of the founders of quantum mechanics was to bring conscious human observers into the basic theory of physics in a fundamental way. This was a revolutionary step, because it revoked the root cause of the successes of the classical approach that had stemmed from the work of Isaac Newton. The spectacular achievements of that earlier method were due primarily to the exclusion from physics of things such as thoughts and feelings in favor of mathematically described properties attached to points in space-time. The resulting simple conception of the universe as a collection of microscopic properties governed by microscopic laws was dynamically complete: it allowed all physical realities to be determined solely by interactions between tiny neighboring mechanical elements. This meant that our conscious experiences, insofar as they had any influence at all on physical events, were completely fixed by a self-determining micro-local process. Consequently, those experiential aspects of nature could be denied fundamental status in basic physical theory.

The reversal by quantum theorists of the precept of micro-local completeness was due principally to the non-local aspect of nature discussed in the preceding chapter: faster-than-light action at a distance is strictly incompatible with the precepts of classical physics, in the form demanded by Einstein's theory of relativity. On the other hand, our nearby actions can quickly affect *our knowledge* about a faraway physical reality.

For example, if you know that two particles started together at some known faraway point and have moved away from that point in opposite directions at the same speed, with one moving roughly in your direction, then *what you choose to* *find out* about the location of the partner that eventually comes into your neighborhood does influence *what you can know* about its faraway mate. Thus if you find out that one of the two particles is currently in the nearby region R then you can determine by simple arithmetic that its partner is in a corresponding faraway region R'. There is nothing mysterious about that quick change in our knowledge *here* about something faraway! But it does mean that "our knowledge" has a faster-than-light feature that superficially resembles the non-locality property described in chapter three.

This trivial observation about sudden changes in "our knowledge" of a faraway reality cannot account for the faster-than-light influences described in chapter 3, unless "our knowledge" is in some sense reality itself. In that case an observation here, by instantly affecting our knowledge of the faraway system, would be instantly affecting faraway reality. However, that literal idealism is not what the founders espoused: their position was more subtle than that.

Yet in a certain way this notion that knowledge is the basic reality is tantamount to what they proposed, which is that we should neither think about nor inquire about the nature of a possible reality lying *behind our experiences*, but should focus our attention instead on the rules that we use to make successful predictions about connections among our experiences. This pragmatic view of science, as a theory exclusively about connections between human experiences, is rationally justified by the observation that, in the final analysis, science is both validated by, and derives its utility from, the success of such rules. What is "actually happening behind the scenes" is irrelevant to science, insofar as science is simply a practical tool for coping with the evolving world of human experience. Yet if the formulas of quantum theory are just rules connecting the experiences of an entire community of communicating observers then the theory is, in effect, a model in which the reality is knowledge, since the growing collective knowledge of the community is the reality that the theory describes.

Thus the founders of quantum theory did not need to endorse literal idealism. They retreated instead to the more defensible position that science is about *what we can know*, and that all that we really can know is our experiences, and how well our theories account for those experiences. This viewpoint that science is about "our knowledge" allows instantaneous action at a distance to be incorporated into scientific practice in a rationally coherent way, without saying anything at all about what is going on "behind the scenes."

This evasive tactic 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 hugely successful practical formulation of what is the basic existing physical theory.

This pragmatic view of science brought the consciousness of the human observers into basic physics in two important ways. The first is as the passive receptacles of the *descriptions* that constitute the database of science. The second is as active participants whose free choices can influence the course of physical events. This second role is the one that this book is about. But to understand this vital second role one must understand the first.

"The observer" that enters the original "Copenhagen" formulation of quantum theory differs from the one of ordinary speech. 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 extend out to and include the measuring devices that he uses to probe "the observed system", which, however, is not actually seen. This way of splitting things up is unusual: normally one regards the human observer as confined to his body, and what he is observing, in this measurement situation, to be the measuring apparatus, not the unseen atomic system that this device is probing. Yet what is important in quantum physics --- as in all of science --- is that the actual practice involves two different kinds of descriptions. On the one hand, there are descriptions of our conscious experiences, which we can record, remember, and communicate to our colleagues, and which form the empirical database. On the other hand, there is a theoretical structure that we invent for the purpose of extending the range of our experience and reducing it to order. [cf. N. Bohr. Atomic Physics and Human knowledge, p.1]

Copenhagen quantum theory regards the devices as part of the observer because the devices are described not in terms of their atomic constituents but rather in terms of our conscious experiences. 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)

Notice that the human observers enter here not as passive receiving "witnesses" but rather as active probing agents, and purveyors of the communicable descriptions of the conscious experiences that result from their probings. This way of viewing science is quintessentially realistic. It takes science to be what it actually is, namely a human endeavor that is a key component of our interaction with nature, not some pristine abstraction of the real thing that leaves its creators, its beneficiaries, and its foundations in human experience and human actions out. Human experiences and human actions are the foundations of actual scientific practice.

It might seem that since the key realities in quantum physics are descriptions of experiences pertaining to devices we ought to eliminate the observer and consider instead the devices themselves, regarded as objectively existing realities, and dispense with all the mumbo jumbo about observers. That is not the tack taken by Bohr and his colleagues, for that approach would oblige them to explain how these macroscopic devices could be built out of the atomic entities that obeyed the rules of quantum theory. This theory has well defined rules for building up systems that are conglomerations of the atomic systems that it describes. The problem is that the "devices" constructed in accordance with these rules do not behave like the devices we observe.

For example, the paradigmatic quantum measuring device is the so-called Stern-Gerlach apparatus. It deflects an ion into either an upper or lower detector according to whether the spin of the ion is pointing up or down. However, the straightforward solution of the quantum-mechanical equation of motion for the whole system of measured particle plus deflecting device plus detector specifies, under certain conditions, that the state of this entire system consists of two nearly equal parts that could , if the detectors were removed, be brought back together and interfere, like the light passing through the two slits of the famous double-slit experiment. This interference effect demonstrate that the particle has a wave-like character, with both of the two parts of the divided beam being physically present in some sense. But if the two detectors are suddenly shifted into place, just before the pulses arrive, then either one detector fires or the other, not both. Only one part of the divided beam or the other will produce an effect visible to you or me. Some gross disconnect has occurred between the quantum mathematical description of the physical system as a collection of atomic particles and fields and the description the system in terms of our actual human observations the large conglomerations of atomic particle that we can see. This huge failure of the mathematical laws that work so well at the level of several atomic particles, and even millions of millions of them, to work for the conglomerations that constitute visible devices, is a key problem that the founders of quantum theory had to face.

How can one cope with this blatant contradiction between the theory and the facts? The straightforward approach would be to say that these mathematical rules are not exactly correct, but fail for systems involving huge numbers of atoms, and fail in such a way as to produce the behaviors we observe. That tack must, however, overcome several obstacles. In the first place, the quantum rules have an amazing internal logical cohesion that fits perfectly with the idea of an informational system that is interacting with a collection of communicating probing agents. This beautiful cohesive structure tends to be disrupted by any tinkering with the rules. In the second place, the quantum rules have been tested for systems involving millions of millions of atoms, and no indication of any failure has been observed. In the third place, any such purely physical explanation of the observed facts would require physically real faster than light action at a distance.

This third "obstacle" is a purely psychological one: most physicist abhor the idea physically real faster-than-light action. Rather than accepting that unpalatable option the founders of quantum theory chose to change philosophies by shifting to the more realistic conception of science as a human activity that seeks to identify and describe regularities in our streams of conscious experiences. In Bohr's words:

"In our description of nature the purpose is not to disclose the real essence of phenomena but only to track down as far as possible the relations between the multifold aspects of our experience. " (Atomic Physics and Human Knowledge, p.18)

This pragmatic view of the scientific enterprise accommodates any theoretical construction that works in practice. It does not prejudge the nature of the unseen reality, and refuses to take seriously any properties of the theoretical structure outside their ramifications in the realm of human experience.