2. Knowings

What are you made of? What is reality made of? What does intuition say about this? What does science say?

The deliverance of intuition on these matters is not unambiguous. Western science and philosophy begins with Thales of Miletus, who proclaimed "All is Water!". Other Greeks believed the primordial stuff to be "Air", or "Earth", or "Fire", and Empedocles settled on all four. On the other hand, Leucippus and Democritus thought everything was composed of tiny invisible, immutable atoms. Two millennia later, it looked like the two atomists had gotten it right: Isaac Newton built his sixteenth-century theory of the universe on the idea of enduring miniscule particles, and John Dalton's atomic hypothesis explained many facts of chemistry.

This notion that everything is composed of small bits of matter encountered, however, a serious difficulty. The earlier idea that "air" was a primary ingredient allowed soul or spirit to be construed as constructed out of one of the primitive substances. But it was hard to see how such a thing as a sensation of the color "red" or "green", or a feeling of "pain" or "joy" could be fully described in terms of a collection of tiny immutable bits of matter careening through space. Given even supreme knowledge and comprehension, how could the motions of billions of particles in a person's brain/body be understood to be the very same thing as a conscious sensation, or the *feeling* associated with the grasping of an idea? One can understand all manner of motions of objects, and of their changing shapes, in terms of the motions of their constituent parts, but there is a rationally unbridgeable gap between the purely geometrical concepts of motions of particles in space and the psychological realities of conscious sensations, feelings, and ideas.

Isaac Newton built his theory upon the ideas of the French philosopher Rene Descartes, who resolved this dilemma concerning the psychological realities by conceiving nature to be built out of two sorts of substances: "matter", which was located in and occupied space, and the "mental stuff" that our thoughts, sensations, and feelings are made of.

This shearing of nature worked well in science for more than two hundred years, but was abandoned by physicists during twentieth century. The old idea that the material part of nature is made out of tiny bits of reality whose changes are completely fixed by the prior state of the nearby physical stuff---independently of mind---was replaced by a very different picture. Once it became clear that the old notions could not account for the growing mountain of data concerning the properties of the atoms and their parts the focus shifted to what the experiments were actually telling us. This opened the door to a new approach that dealt directly with *what we could find out* about the systems being examined, rather than with the system itself. An incredibly beautiful and rationally coherent new kind mathematical structure eventually revealed itself, but this new mathematics was asserted to described not the physical system itself, but rather our knowledge of that system.

This original way of understanding and applying the quantum mathematics was created by a group of physics working closely with the Danish physicist Niels Bohr, and is called the "Copenhagen interpretation". This understanding was closely tied to the actual experimental procedures, which involve in the end the human experimenter who design the experiments with some purpose in mind, and later record and interpret the results of their investigations. This comprehension of the theory defines the way the quantum mathematics is used operationally, and it is the touchstone of all efforts to retain the practical utility of quantum theory while expanding its scope into the domains of cosmology and neuro-dynamics.

The foundations of all such efforts to increase the comprehensiveness of the theory is the work of the great Hungarian mathematician and logician John von Neumann. But before going on to describe von Neumann's formulation of quantum theory it will be helpful, and also fascinating, to appreciate the tremendous change in outlook instituted already by Werner Heisenberg, Niels Bohr, and the other founders. For these insights into the nature of the new theory are preserved in an altered form by von Neumann.

In the introduction to his book "Quantum theory and reality"
the philosopher of science Mario Bunge (1967) said:
"The physicist of the latest generation is operationalist all

right, but usually he does not know, and refuses to believe, that the original Copenhagen interpretation---which he thinks he supports---was squarely subjectivist, i.e., nonphysical."

Let there be no doubt about this point. The original form of quantum theory, which is still alive today, is subjective: it is about relationships among conscious human experiences, and it expressly recommends to scientists that they resist the temptation to try to understand the underlying processes of nature that are responsible for those connections between our experiences that the theory correctly describes. The following brief collection of quotations by the founders give a conspectus of the Copenhagen philosophy:

Heisenberg (1958a): "The conception of objective reality of the elementary particles has thus evaporated not into the cloud of some obscure new reality concept but into the transparent clarity of a mathematics that represents no longer the behavior of particles but rather our knowledge of this behavior."

Heisenberg (1958b): "...the act of registration of the result in the mind of the observer. The discontinuous change in the probability function…takes place with the act of registration, because it is the discontinuous change in our knowledge in the instant of registration that has its image in the discontinuous change of the probability function."

Heisenberg (1958b:) "When the old adage `Natura non facit saltus' is used as a basis of a criticism of quantum theory, we can reply that certainly our knowledge can change suddenly, and that this fact justifies the use of the term `quantum jump'. "

Wigner (1961): "the laws of quantum mechanics cannot be formulated...without recourse to the concept of consciousness."

Bohr (1934): "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 relations between the multifold aspects of our experience."

Bohr (1963): "Strictly speaking, the mathematical formalism of quantum mechanics merely offers rules of calculation for the deduction of expectations about observations obtained under well-defined classical concepts."

Bohr (1958): "...the appropriate physical interpretation of the symbolic quantum mechanical formalism amounts only to prediction of determinate or statistical character, pertaining to individual phenomena appearing under conditions defined by classical physics concepts."

The references to `"classical physics concepts" is explained in: Bohr (1958): "...it is imperative to realize that in every account of physical experience one must describe both experimental conditions and observations by the same means of communication as the one used in classical physics."

Bohr (1958) "...we must recognize above all that, even when phenomena transcend the scope of classical physical theories, the account of the experimental arrangement and the recording of observations must be given in plain language supplemented by technical physical terminology."

Bohr is saying that scientists do in fact use, and must use, the concepts of classical physics in communicating to fellow scientists and technicians the specifications on how the experiment is to be set up, and what will constitute a certain type of outcome. He in no way claims or admits that there is an actual reality out there that conforms to the precepts of classical physics.

In his book "The creation of quantum mechanics and the Bohr-Pauli dialogue" (Hendry, 1984) the historian John Hendry gives a detailed account of the fierce struggles by such eminent thinkers as Hilbert, Jordan, Weyl, von Neumann, Born, Einstein, Sommerfeld, Pauli, Heisenberg, Schroedinger, Dirac, Bohr and others, to come up with a rational way of comprehending the data from atomic experiments. Each man had his own bias and intuitions, but in spite of intense effort no rational comprehension was forthcoming. Finally, at the 1927 Solvay conference a group including Bohr, Heisenberg, Pauli, Dirac, and Born come into concordance on a solution that came to be called "The Copenhagen Interpretation", because of the central role of Bohr and those working with him at his institute in Denmark.

Hendry says: "Dirac, in discussion, insisted on the restriction of the theory's application to our knowledge of a system, and on its lack of ontological content." Hendry summarized the concordance by saying: "On this interpretation it was agreed that, as Dirac explained, the wave function represented our knowledge of the system, and the reduced wave packets our more precise knowledge after measurement."

Certainly this profound shift in physicists' conception of the basic nature of their endeavor, and the meanings of their formulas, was not a frivolous move: it was a last resort. The very idea that in order to comprehend atomic phenomena one must abandon physical ontology, and construe the mathematical formulas to be directly about the knowledge of human observers, rather than about the external real events themselves, is so seemingly preposterous that no group of eminent and renowned scientists would ever embrace it except as an extreme last measure. Consequently, it would be frivolous of us simply to ignore a conclusion so hard won and profound, and of such apparent direct bearing on our effort to understand the connection of our knowings to our bodies.

Einstein never accepted the Copenhagen interpretation. He said: "What does not satisfy me, from the standpoint of principle, is its attitude toward what seems to me to be the programmatic aim of all physics: the complete description of any (individual) real situation (as it supposedly exists irrespective of any act of observation or substantiation)." (Einstein, 1951, p.667: the parenthetical word and phrase are part of Einstein's statement.);

and "What I dislike in this kind of argumentation is the basic positivistic attitude, which from my view is untenable, and which seems to me to come to the same thing as Berkeley's principle, {\it esse est percipi}. (Einstein, 1951, p. 669). [Transl: To be is to be perceived]

Einstein struggled until the end of his life to get the observer's knowledge back out of physics. But he did not succeed! Rather he admitted that: "It is my opinion that the contemporary quantum theory constitutes an optimum formulation of the [statistical] connections." (ibid. p. 87).

He also referred to: "the most successful physical theory of our period, viz., the statistical quantum theory which, about twenty-five years ago took on a logically consistent form. This is the only theory at present which permits a unitary grasp of experiences concerning the quantum character of micro-mechanical events." (ibid p. 81).

One can adopt the cavalier attitude that these profound difficulties with the classical conception of nature are just some temporary retrograde aberration in the forward march of science: one can imagine, as some do, that a strange confusion has confounded our best minds for seven decades, and that the strange conclusions of physicists should be ignored because they do not fit our classical-physics-based intuitions. Or one can try to claim that these problems concern only atoms and molecules, but not the big things built out of them. In this connection Einstein said: "But the `macroscopic' and `microscopic' are so inter-related that it appears impracticable to give up this program [of basing physics on the `real'] in the `microscopic' domain alone." (ibid, p.674).

Philosophers have tried for three centuries to understand the role of mind in the workings of a brain conceived to function according to principles of classical physics. We now know no such brain actually exists: neither the brain nor the body nor anything else in the world of nature is composed of those bits of matter that Democritus and Newton imagined the universe to be made of. Hence it is not surprising that those endeavors of philosophers have been beset by enormous difficulties, which have led to such positions as that of the `eliminative materialists', who hold that our conscious thoughts do not exist; or of the `epiphenomenalists', who admit that human experiences do exist but claim that they play absolutely no role in how we behave; or of the `identity theorists', who claim that each conscious feeling is exactly the same thing as a motion of the particles that nineteenth century science thought brains and everything else to be made of. The difficulties in reconciling mental realities with pre-quantum physics is dramatized by the fact that for many years the mere mention of "consciousness" was considered evidence of backwardness and bad taste in most of academia, including, incredibly, even the philosophy of mind.

Given these difficulties with the earlier approach, coupled with the further fact that human experience now appears to be an important part of the causal process of nature, the question naturally arises: why not try to understand the role of mind in a physical world that conforms to the mathematical rules that work.

Success in this endeavour is augured by the fact that the mathematical structure uncovered by quantum physics, although highly counter-intuitive to minds indoctrinated in classical concepts has an amazing internal logical cohesion, as well as the capacity to correctly predict numbers that can be measured to accuracies of one part in a hundred million. This inner consistency combined with that incredible precision means that quantum theory must embody some deep truth about the structure of reality. And this truth brings human experiences into the description even of external atomic processes. Can one then expect to ignore it in the description of the organ of human experience itself?