Of Quiffs, Quarks, and God

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SCIENCE IS FULL OF STRANGE TWISTS and unexpected developments — so many, in fact, that we are rarely surprised anymore by its most recent revelations. But one of the biggest scientific surprises of the twentieth century has yet to attract the attention it deserves. That surprise is the formulation of quantum physics, an event which, according to physicist Paul Davies, "has gone largely unnoticed by the public, not because its implications are uninteresting, but because they are so shattering as to be almost beyond belief" (1980, 11).

Quantum physics is a description of nature radically opposed to one of classical science's most fundamental premises — the premise of objectivity. Scientists have traditionally assumed that nature operated independently of their observations and measurements, or at least that their interaction with nature was so slight as to be for all practical purposes negligible. Furthermore, they believed that "in science, right is right and wrong is wrong, and that what is right is true and what is wrong is false, absolutely so" (Bocher 1966, 73). Thus, scientists up until the twentieth century assumed that it was clearly possible — at least in principle, if not in practice — to frame an absolutely final, nonprejudicial statement about the nature of reality.

The development of quantum physics in the first three decades of this century has forced us to completely rethink this assumption. The concept which lies at the heart of quantum physics and which stymies our hope of achieving an absolute understanding of reality is Werner Heisenberg's principle of uncertainty. The principle proposes that the properties of subatomic particles are only partially accessible to our probings. This is not because we lack the instrumental resolution to accurately measure these properties, but because some properties are by nature incompatible — at least to a degree that makes a major difference in particle physics.

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Two such incompatible properties are position and momentum (mass times velocity). If we wish to measure a particle's position with absolute certainty, we must forego any hope of knowing its momentum. Conversely, if we measure the momentum of a particle with perfect accuracy we sacrifice all knowledge of its position. It is as if by measuring a particle we rotate it along an axis of observation which corresponds exclusively to the variable we wish to measure. At the same time, however, we occlude the measured variable's counterpart and thus lose the means of gaining a complete picture of the particle. The only way we measure both properties simultaneously is by designing the experiment to yield only approximate values of measurement for both properties. The loss of certainty, however, still persists; it has just been strewn across two properties rather than resting completely on one. This state of things denies us any hope of formulating a perfectly detailed description of reality. Rather, there seems to be an inherent slipperiness in nature that defeats our best efforts of precision observation.

It is difficult to understand why position and momentum — two seemingly unrelated properties — would exclude one another in the subatomic realm of reality. The fact is, however, that the same thing happens in ordinary reality but to such an infinitesimal degree as to be unnoticeable. Zeno of Elea argued 2500 years ago that a flying arrow could not simultaneously move through space and occupy a given position in space. Aristotle overcame Zeno's paradox by claiming that motion can be thought of as the successive passage of an object through an infinite number of overlapping points or positions in space.

The idea that space is infinitely divisible and therefore continuous prevailed in Western thought until 1900 when physicist Max Planck proposed that energy is emitted in discrete packets which subsequently became known as light quanta or photons. These quanta are, in fact, abrupt discontinuities of nature — fixed chunks of light which come into being only after certain energy threshholds are reached — and were soon found to be characteristic of the entire microworld. Heisenberg recognized in his uncertainty principle that we cannot analyze nature *ad infinitum*, that eventually we encounter discontinuities which render the simultaneous measurement of motion (momentum) and position impossible.

This basic incompatibility of position and momentum has revolutionized our understanding of subatomic reality. Classical physicists thought of subatomic particles as incredibly tiny bits of matter moving at immense speeds. But in quantum physics, because subatomic particles cannot simultaneously move through space and occupy a definite position in space, their precise nature is much more problematic. While in motion, a particle loses its position by mathematically dispersing itself through space. According to Heisenberg this does not mean that the particle itself is dispersed or diffused through space; rather, the mathematical probability of finding the particle is thus diffused. Having lost its position, the particle "vanishes" into a probability wave which reflects an entire gamut of possible particle locations.

With the probability wave, we get our first glimpse of the paradox which plagues quantum physics. The wave is a recasting in modern scientific terms of Aristotle's belief that being is linked to nonbeing by an intermediate reality expressing all possible outcomes. The wave thus becomes a teeming manifold of particle-possibilities, all mutually exclusive from our perspective, but all in the process of happening just below the threshold of macroworld reality. Incredibly, nature, when left alone, operates as a schizophrenic probability wave rather than a well-defined particle. Particles emerge from possibility only as we look for them. Our nosiness transforms the hazy multiplicity of the wave into a distinct singularity. In other words, our curiosity about the world causes the wave to collapse upon and give macroworld reality to just one of its infinitely many particle-possibilities.

Just why does the probability wave collapse when we go poking around for a particle? By looking for a particle we arrest the motion of the wave and give it a sense of position. We cannot "see" the particle unless we erect some sort of barrier to register its existence, just as we cannot see ordinary objects without "getting in their way" and intercepting their light reflections. Position implies a point in space and time and so one particle-possibility makes a quantum jump into our world while its many alternatives abruptly fail. The wave vanishes and a particle appears.

This reconciliation between the wave and particle aspects of subatomic reality has been one of the great achievements of quantum physics. But the cost to classical science has been high. Not only has the formulation of this new vision displaced the premise of scientific objectivity, it has also erased the related assumption of a clockwork universe comprised of independent parts. Moreover, the damage to classical science has not been confined to the musings of armchair theorists; experimental physicists have also found traditional explanations inadequate.

For example, in 1803, Thomas Young demonstrated the wavelike nature of light by showing that two interacting light beams create interference patterns exactly like those of interacting water waves. But in 1905, Albert Einstein argued persuasively that a shaft of light is comprised of myriads of tiny particles of light, or photons. (This proposal eventually won him a Nobel Prize.) The dichotomy was brought to a sharp focus several years later in a series of experiments initiated by Clinton Davisson. While bombarding nickel crystals with electrons, Davisson noted that the electrons rebounded off the crystals in wave-like patterns. Subsequent experiments showed that individually fired electrons scattered to form the same interference patterns that Young had observed over 100 years earlier. Evidently, it makes no difference whether electrons are fired one by one or in vast intermingling quantities — the same interference pattern results. Moreover, when we arrange for a number of different laboratories to each fire just one electron and then we superimpose the individual hits, the interference pattern still emerges!

"These results," says Davies, "are so astonishing that it is hard to digest their significance. How does any individual electron know what other electrons, maybe in other parts of the world, are going to do?" (1980, 66). Part of the answer to Davies's question lies in understanding that an electron moves as a probability wave whose very definition — an infinitely faceted polyphony of possibilities — implies an almost unreal sensitivity to outside influence. This observation, however, fails to account for the interaction or mutual interference of electrons over wide intervals of space and time. According to physicist Henry Stapp, this apparently instantaneous communication among particles is "the central mystery of quantum theory. . . . How does information get around so quick?" he asks. "How does information about what is happening everywhere else [and everywhen else] get collected to determine what is likely to happen here?" (in Zukav 1979, 87–88).

Over fifty years have passed since these questions were raised by such heavyweights as Einstein and Niels Bohr, and physicists still hotly debate whether information can get around instantaneously and what that concept even means in a macroworld where nothing travels faster than the speed of light. What is beyond serious dispute, however, is that "we never, even in principle, observe *things*, only the interaction between things" (Davies 1980, 57). That interaction always involves us in a most profound way. It is our observation of nature, our propensity to know and understand, that reduces the schizophrenic multiplicity of the microworld to a single, definite outcome in the macroworld. Moreover, quantum physics has shown that we influence what that outcome will be by the preconceived notions we carry with us. Those notions are categories or values that we impose upon the microworld which act to channel its collapse into the macroworld.

In experimental physics this means that subatomic reality encodes information about our experiments so as to generate properties anticipated by those experiments. A particle's axis of spin, for example, invariably coincides with the angle of reference chosen by the observer, no matter how often or how quickly the observer changes his angle. The uncanny ability of the microworld to encode and cast our observational biases back at us tends to give reality paths of least resistance along which to flow.

An analogy to this outlook is a rain-soaked canvas tent which does not leak until we reach up and touch it. Once we do this, we reduce the overall potentiality of the tent for leaking by giving it a point to leak from. There are obvious limitations to this analogy but it illustrates in a rough sort of way that not only does our observation of nature bring about the quantum collapse (we touch the tent and cause the leak), but that we also contribute to the precise character of the leak (we choose *where* to touch the tent). And to carry the analogy a bit further, nature leaks most easily from those places at which we poke it with our sharp, little ideas.

Implicit in this new outlook is the understanding that we are participating with reality as it unfolds, not steering its course deterministically. The microworld is simply too fluid and too all-involving to do anything but mirror a far-flung dynamic of influences. Our position is unique; we provide the image that the mirror reflects. Without our observation of nature and the specific values which we inject into that observation, the multifoliate microworld would never collapse and reality as we know it would never come into existence. We thus come face-to-face with the daring thought that we are in some deep sense architects of our own reality, that our predispositions bias the way we experience the world by acting as shaping forces upon reality in its highly fluid subatomic state. Such an outlook ultimately implies that "many of the features of the universe which we observe cannot be separated from the fact that we are alive to observe them" (Davies 1980, 14). Physicist Fred Wolf illustrates the revolutionary character of this new view of nature by referring to an old conundrum:

> A photon emitted many years ago from a distant star makes its way to my eye. Does it exist if my eye is not there to see it? The question is reminiscent of the age-old puzzle, "If a tree falls in the forest and no one is there to hear it, does it make any noise?" The answer appears so obvious: of course it exists. The photon must be there, like the sound waves, whether or not anyone experiences it. At least, that's the answer if you believe in classical physics.
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> But, alas, quantum mechanics does not seem to agree. Accordingly, the photon comes into existence as a spot on my retina only when I see it. Physicists have been more or less "forced" to accept this mystical position because of the uncertainty principle, which denies existence to objects having both well-defined spatial locations and well-defined paths of motion simultaneously (1981, 200).

There is no doubt that quantum physics offers us a *Gedankenwelt* very different from the mechanistic world view of classical physics. Science ever since the seventeenth century has viewed the universe as a great clockwork of separate, interacting parts. Now physics, the hardest of all hard sciences and the one, according to conventional wisdom, least likely to get mixed up with metaphysics, is telling us that some of our most fundamental assumptions about the world (largely inherited from classical science) are badly out of focus. First, the idea of anything having an independent, self-contained existence breaks down. Second, the universe, far from being a slow-moving clockwork of separate parts, appears to be incredibly dynamic and faultlessly sensitive to change and influence. Finally, rather than being passive observers of the world of nature, we seem to be active participants in an unfolding reality.

By casting these considerations into the philosophical arena, we come up with some interesting perspectives on some very old problems. First of all, we encounter the proposition familiar to process theology and early Mormon theology of a God limited by and in some sense dependent upon the universe he lives in. God's foreknowledge, for instance, may be limited by the fact of an unfinished universe forever pulling itself up by its own bootstraps. If this is the case, his omniscience would not be the static fund of knowledge we have traditionally esteemed it to be, but rather a dynamic intelligence in which all things participate. We, in turn, would not be marionettes hanging by the strings of some already determined future, but active agents in an open-ended cosmos.

This perspective additionally suggests that our thoughts and acts really may have eternal consequences, not because they will come back on judgement day to damn or exalt us, but because right now they are resonating throughout the universe. Our destiny, in short, may be interwoven with God's, all of us participating in a real adventure, a "creative advance into novelty" (Whitehead 1929, 407) that can only grow richer and more exhilarating as we learn to love each other — or poorer and less stimulating as we become more egocentric.

I hasten to add that none of these ideas *necessarily* follow from the principles of quantum physics. The philosophical implications of quantum physics are a subject of intense controversy and, like most philosophical issues, pretty much a matter of private interpretation. Einstein, whose insights into the nature of matter and energy laid much of the foundation for quantum theory, never did accept Heisenberg's claim that subatomic particles are intrinsically uncertain because it violated his belief in an orderly, fully understandable universe. Bohr, on the other hand, argued that nature at its deepest level is fluid and ambiguous beyond all visualization. Poetry, he told Heisenberg, is the only effective medium for describing atoms because it is "not nearly so concerned with describing facts as with creating images" (Heisenberg 1971, 41). Bohr was not a mystic; he was merely frustrated at having to communicate the mindwrenching insights of quantum physics within the narrowness of ordinary language. Aristotle's proposition that something is necessarily either true or false had to be rejected because subatomic reality held forth "other possibilities which are in a strange way mixtures of being and nonbeing, truth and falsity" (Heisenberg 1958, 182).

However, Bohr's interpretation of quantum phenomena, for all its paradox and sabotage of common sense, has been criticized by other scientists who argue that it stops short of what quantum physics ultimately implies — a truly holistic universe. David Bohm, for example, whose thinking on the subject was stimulated in part by conversations with Einstein while the two were at Princeton, contends that Bohr and Heisenberg erred in favor of the classical model of a fragmentary universe when they argued that our observation of nature brings the macroworld into existence. What really occurs, Bohm claims, is an interweaving of observer and observed. Each causes the other. There is no ultimate pivot around which reality revolves because all is totally involved in all else.

Bohm's holistic philosophy is truly heady wine and not at all the exclusive property of mystics and romanticists. Alfred North Whitehead, a philosopher and mathematician who was *au courant* with both quantum and Einsteinian physics, built an entire metaphysics around the idea that "all things are in all places at the same time" (1925, 87). In recent years, Ilya Prigogine (Nobel laureate in chemistry), Karl Pribram (neurophysiology), Erich Jantsch (biology), Rupert Sheldrake (biology), Thomas Kuhn (history of science), and Douglas Hofstadter (computer science and mathematics) have all advanced ideas which similarly suggest a universe of infinite depth, wholeness, and fluidity.

I confess that I find this scenario disconcerting in some ways. The concept of a holistic cosmos points beyond the idea of a separate moral weight for each of us to a communal weight for all of us and snatches away the standards against which I have long weighed and measured people to calculate their individual worth. The universe, it appears, is shot through with a primal sense of oneness that echoes and reechoes to all our "individual" actions. Our responsibility for self-improvement, therefore, is a mere shadow of the responsibility which each of us bears (whether we like it or not) for the unfolding destiny of a shared universe. But inherent in that responsibility is a tremendous freedom — the freedom to intervene in the ontological constitution of the cosmos. "Everything possible to be believ'd," wrote Blake, "is an image of truth" (1972, 254). That is, given the interrelatedness and infinite potentiality of reality, any idea to which we pledge our faith tends to work itself into existence. We literally deposit our thoughts, beliefs, and passions into what Joseph Pearce calls the "womb of eternity" (1971, 170), that world of endless potentiality where terrible numbers of possibilities await an actualizing influence. This outlook recalls Santayana's statement that "Essences are infinite in number. . . . So nature resprouts in us. Essences spring up inexhaustibly. They surprise even an omniscient God" (in Van Wesep 1960, 288).

Whether we stop short of a holistic model of the cosmos or go all the way with those who argue that we live in a universe "as free from ultimate interpretation as a Bach cantata" (Briggs and Peat 1984, 200), or as Thoreau put it, a universe "that will not wait to be explained" (in Eiseley 1978, 190), it is clear that quantum physics has given us a new thinking cap with which to explore the nature of reality. If nothing else, it has shown us that our way of seeing the world is largely a function of our language and culture. Classical science has given us certain ruts to think along and we are just now beginning to realize that those ruts are merely indentations in a much larger scheme of possibility.

Given that expanded scheme of possibility, three virtues present themselves as indispensable to our good fortune. Foremost is love which perhaps is in a last, irreducible sense the creative energy of the cosmos. Lack of love among any of us muffles and enervates the experience of life for all of us. My own belief is that the universe is rinsed in God's perfect, unrefusing love, a fact that mitigates much of our meanness and egotism but does not, of course, excuse our folly. The only acceptable response, it seems to me, is to respond to that universe with love. The other virtues are imagination and faith. Imagination is tied up with the capacity to wonder and create, to essay toward new combinations of increasing beauty. And as imagination fills our pool of wonder with dreams of a better, brighter world, faith empowers those dreams to become reality.

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