Excerpts from Chapter 3 in:

The Universe in a Single Atom.

The Convergence of Science and Spirituality

By H.H. The Dalai Lama, Morgan Road Books, New York, 2005

Chapter 3: Emptiness, Relativity and Quantum Physics

My grasp of quantum theory is, I confess, not all that good - though I have tried very hard! I am told that one of the greatest of all quantum theorists, Richard Feynman, wrote, "I think I can safely say that nobody understands quantum mechanics," so at least I feel I am in good company. But even for someone like myself who cannot follow the complex mathematical details of the theory - in fact, mathematics is one area of modern science to which I seem to have no karmic connection at all - it is apparent that we cannot speak of subatomic particles as determinate, independent, or mutually exclusive entities. Elementary constituents of matter and photons (which is to say, the basic substances, respectively, of matter and of light) can be either particles or waves or both. (In fact, the man who won the Nobel Prize for showing that the electron is a wave, George Thomson, was the son of the man who won the same prize for showing that the electron is a particle, J. J. Thomson.) Whether one perceives electrons as particles or waves, I am told, is dependent on the action of the observer and his or her choice of apparatus or measurement.

Although I had long heard of this paradoxical nature of light, only in 1997 - when the experimental physicist Anton Zeilinger explained it to me with detailed illustrations - did I feel I had finally managed to grasp the issue. Anton showed how it is the experiment itself that determines whether an electron behaves as a particle or as a wave. In the famous double-slit experiment, electrons are fired one at a time through an interference barrier with two slits and are registered on material such as a photographic plate behind the barrier. If one slit is open, each electron makes an imprint on the photographic plate in the manner of a particle. However, if both slits are open, when a large number of electrons are fired, the imprint left on the photographic plate indicates that they have passed through both slits at the same time, leaving a wavelike pattern.

Anton brought an apparatus that could repeat this experiment on a smaller scale, so all the participants had great fun. Anton likes to remain very close to the empirical aspects of quantum mechanics, grounding all his understanding in what we can directly learn from experiments. This was quite a different approach from that of

David Bohm, who was primarily interested in the theoretical and philosophical implications of quantum mechanics. I later learned that Anton was and remains a strong advocate of what is called the Copenhagen interpretation of quantum mechanics, while David Bohm was one of its strongest critics.

I must admit I am still not quite sure what the full conceptual and philosophical implications of this paradox of wave-particle duality might be. I have no problem in accepting the basic philosophical implication, that at the subatomic level the very notion of reality cannot be divorced from the system of measurements used by an observer, and cannot therefore be said to be completely objective. However, this paradox also seems to suggest that - unless one accords some kind of intelligence to

electrons at the subatomic level two of the most important principles of logic, the law

of contradiction and the law of the excluded middle, appear to break down. In normal experience, we would expect that what is a wave cannot be a particle, yet at the quantum level, light appears to be a contradiction because it behaves as both. Similarly, in the double-slit experiment, it appears that some of the photons pass through both slits at the same time, thus breaking the law of the excluded middle, which expects them to pass through either one slit or the other.

Regarding the conceptual implications of the results of the double-slit experiment, I think there is still considerable debate. Heisenberg's famous uncertainty principle states that the more precise one's measurement of an electron's position the more uncertain is one's knowledge of its momentum, and the more precise

one's measurement of its momentum the more uncertain one is of its position. One can know at anyone time where an electron is but not what it is doing, or what it is doing but not where it is. Again this shows that the observer is fundamental: in choosing to learn an electron's momentum, we exclude learning its position; in choosing to learn its position, we exclude learning its momentum. The observer, then, is effectively a participant in the reality being observed. I realize that this issue of the observer's role is one of the thorniest questions in quantum mechanics. Indeed, at the Mind and Life conference in 1997, the various scientific participants held differently nuanced views. Some would argue that the observer's role is limited to the choice of measuring apparatus, while others accord greater importance to the observer's role as a constitutive element in the reality being observed.

This issue has long been a focus of discussion in Buddhist thought. On one extreme are the Buddhist "realists," who believe that the material world is composed of indivisible particles which have an objective reality independent of the mind. On the other extreme are the "idealists," the so-called Mind-only school, who reject any degree of objective reality in the external world. They perceive the external material world to be, in the final analysis, an extension of the observing mind. There is, however, a third standpoint, which is the position of the Prasangika school, a perspective held in the highest esteem by the Tibetan tradition. In this view, although the reality of the external world is not denied, it is understood to be relative. It is contingent upon our language, social conventions, and shared concepts. The notion of a pre-given, observer-independent reality is untenable. As in the new physics, matter cannot be objectively perceived or described apart from the observer - matter and mind are co-dependent.

This recognition of the fundamentally dependent nature of reality-called "dependent origination" in Buddhism - lies at the very heart of the Buddhist understanding of the world and the nature of our human existence. In brief, the principle of dependent origination can be understood in the following three ways. First, all conditioned things and events in the world come into being only as a result of the interaction of causes and conditions. They don't just arise from nowhere, fully formed. Second, there is mutual dependence between parts and the whole; without parts there can be no whole, without a whole it makes no sense to speak of parts. This interdependence of parts and the whole applies in both spatial and temporal terms. Third, anything that exists and has an identity does so only within the total network of everything that has a possible or potential relation to it. No phenomenon exists with an

independent or intrinsic identity.

And the world is made up of a network of complex interrelations. We cannot speak of the reality of a discrete entity outside the context of its range of interrelations with its environment and other phenomena, including language, concepts, and other conventions. Thus, there are no subjects without the objects by which they are defined, there are no objects without subjects to apprehend them, there are no doers without things done. There is no chair without legs, a seat, a back, wood, nails, the floor on which it rests, the walls that define the room it's in, the people who constructed it, and the individuals who agree to call it a chair and recognize it as something to sit on. Not only is the existence of things and events utterly contingent but, according to this principle, their very identities are thoroughly dependent upon others.

In physics, the deeply interdependent nature of reality has been brought into sharp focus by the so-called EPR paradox - named after its creators, Albert Einstein, Boris Podolsky, and Nathan Rosen - which was originally formulated to challenge quantum mechanics. Say a pair of particles is created and then separates, moving away from each other in opposite directions - perhaps to greatly distant locations, for example, Dharamsala, where I live, and say, New York. One of the properties of this pair of particles is that their spin must be in opposite directions - so that one is measured as "up" and the other will be found to be "down." According to quantum mechanics, the correlation of measurements (for example, when one is up, then the other is down) must exist even though the individual attributes are not determined until the experimenters measure one of the particles, let us say in New York. At that point, the one in New York will acquire a value - let us say "up" - in which case the other particle must simultaneously become "down". These determinations of up and down are instantaneous, even for the particle at Dharamsala, which has not itself been measured. Despite their separation, the two particles appear as an entangled entity. There seems, according to quantum mechanics, to be a startling and profound interconnectedness at the heart of physics.

Once at a public talk in Germany, I drew attention to the growing trend among serious scientists of taking the insights of the world's contemplative traditions into account. I spoke about the meeting ground between my own Buddhist tradition and modern science-especially in the Buddhist arguments for the relativity of time and for rejecting any notion of essentialism. Then I noticed von Weizsäcker in the audience, and when I described my debt to him for what little understanding of quantum physics I possess, he graciously commented that if his own teacher Werner Heisenberg had been present, he would have been excited to hear of the clear, resonant parallels between Buddhist philosophy and his scientific insights.

Another significant set of issues in quantum mechanics concerns the question of measurement. I gather that, in fact, there is an entire area of research dedicated to this matter. Many scientists say that the act of measurement causes the "collapse" of either the wave or the particle function, depending upon the system of measurement used in the experiment; only upon measurement does the potential become actual. Yet we live in a world of everyday objects. So the question is, How, from the point of view of physics, do we reconcile our commonsense notions of an everyday world of

objects and their properties on the one hand and the bizarre world of quantum mechanics on the other? Can these two perspectives be reconciled at all? Are we con-

demned to live with what is apparently a schizophrenic view of the world?

At a two-day retreat on the epistemological issues pertaining to the foundations of quantum mechanics and Buddhist Middle Way philosophy at Innsbruck, where Anton Zeilinger, Arthur Zajonc, and I met for a dialogue, Anton told me that a well-known colleague of his once remarked that most quantum physicists relate to their field in a schizophrenic manner. When they are in the laboratory and play around with things, they are realists. They talk about photons and electrons going here and there. However, the moment you switch into philosophical discussion and ask them about the foundation of quantum mechanics, most would say that nothing really exists without the apparatus defining it.

Somewhat parallel problems arose in Buddhist philosophy in relation to the disparity between our commonsense view of the world and the perspective suggested by Nagarjuna's philosophy of emptiness. Nagarjuna invoked the notion of two truths, the "conventional" and the "ultimate," relating respectively to the everyday world of experience and to things and events in their ultimate mode of being, that is, on the level of emptiness. On the conventional level, we can speak of a pluralistic world of things and events with distinct identities and causation. This is the realm where we can also expect the laws of cause and effect, and the laws of logic - such as the principles of identity, contradiction, and the law of the excluded middle - to operate without violation. This world of empirical experience is not an illusion, nor is it unreal. It is real in that we experience it. A grain of barley does produce a barley sprout, which can eventually yield a barley crop. Taking a poison can cause one's death and, similarly, taking a medication can cure an illness. However, from the perspective of the ultimate truth, things and events do not possess discrete, independent realities. Their ultimate ontological status is "empty" in that nothing possesses any kind of essence or intrinsic being.

I can envision something similar to this principle of two truths applying in physics. For instance, we can say that the Newtonian model is an excellent one for the commonsense world as we know it, while Einsteinian relativity - based on radically different presuppositions- represents in addition an excellent model for a different or more inclusive domain. The Einsteinian model describes aspects of reality for which the states of relative motion are crucial but does not really affect our commonsense picture under most circumstances. Likewise, the quantum physics models of reality represent the workings of a different domain - the mostly "inferred" reality of particles, especially in the arena of the microscopic. Each of these pictures is excellent in its own right and for the purposes for which it was designed, but if we believe any of these models to be constituted by intrinsically real things, we are bound to be disappointed.

Here I find it helpful to reflect on a critical distinction drawn by Chandrakirti (seventh century C.E.) in relation to the domains of discourse that pertain to the conventional and the ultimate truths of things. Chandrakirti argues that, when formulating one's understanding of reality, one must be sensitive to the scope and parameters of the specific mode of inquiry. For example, he argues that to reject distinct identity, causation, and origination within the everyday world, as some interpreters of the philosophy of emptiness had suggested, simply because these notions are untenable from the perspective of ultimate reality, constitutes a methodological error.

On a conventional level, we see cause and effect all the time. When we're trying to find who's at fault in an accident, we are not delving into the deeper nature of reali-

ty, where an infinite chain of events would make it impossible to place blame. When we accord such characteristics as cause and effect to the empirical world, we are not working on the basis of a metaphysical analysis that probes the ultimate ontological status of things and their properties. We do so within the boundaries of everyday convention, language, and logic. In contrast, Chandrakirti argues, the metaphysical postulates of philosophical schools, such as the concept of the Creator or the eternal soul, can be negated through the analysis of their ultimate ontological status. This is because these entities are posited on the basis of an exploration into the ultimate mode of being of things.

In essence, Nagarjuna and Chandrakirti are suggesting this: when we relate to the empirical world of experience, as long as we do not invest things with independent, intrinsic existence, notions of causation, identity, and difference, the principles of logic will continue to remain tenable. However, their validity is limited to the relative framework of conventional truth. Seeking to ground notions such as identity, existence, and causation in an objective, independent existence is transgressing the bounds of logic, language, and convention. We do not need to postulate the objective, independent existence of things, since we can accord robust, non-arbitrary reality to things and events that not only support everyday functions but also provide a firm basis for ethics and spiritual activity. The world, according to the philosophy of emptiness, is constituted by a web of dependently originating and interconnected realities, within which dependently originated causes give rise to dependently originated consequences according to dependently originating laws of causality. What we do and think in our own lives, then, becomes of extreme importance as it affects everything we're connected to.

The paradoxical nature of reality revealed in both the Buddhist philosophy of emptiness and modern physics represents a profound challenge to the limits of human knowledge. The essence of the problem is epistemological: How do we conceptualize and understand reality coherently? Not only have Buddhist philosophers of emptiness developed an entire understanding of the world based on the rejection of the deeply ingrained temptation to treat reality as if it were composed of intrinsically real objective entities but they have also striven to live these insights in their day-to-day r lives. The Buddhist solution to this seeming epistemological contradiction involves understanding reality in terms of the theory of two truths. Physics needs to develop an epistemology that will help resolve the seemingly unbridgeable gulf between the picture of reality in classical physics and everyday experience and that in their quantum mechanics counterpart. As for what an application of the two truths in physics might look like, I simply have no idea. At its root, the philosophical problem confronting physics in the wake of quantum mechanics is whether the very notion of reality - defined in terms of essentially real constituents of matter- is tenable. What the Buddhist philosophy of emptiness can offer is a coherent model of understanding reality that is non-essentialist. Whether this could prove useful only time will tell.