Up until about the turn of the century, 1900 that is, scientists were rather comfortable with their mastery of our world. Their physical laws had explained every experienced phenomenon for hundreds of years. In the early 1900's this comfort would turn into a panic that would last almost the whole 20th century. The belief that “we only know what we can measure” got scientists in and out (and back in, etc.) of a lot of trouble. Not only would the classical laws of physics be disproved, but our entire view of reality would be challenged and eventually vanquished by the new set of laws, Quantum Mechanics. Unfortunately, there has yet to be an adequate interpretation of Quantum Mechanics which has been found to work in all experiments so far. Scientists are stuck with a set of laws, the Quantum Theory’s postulates, but no view of reality that works with them. This has, of course, been very unsettling for many in the world of science and has left some of the best logical minds of our time speechlessly reverting to the concept of a deity to explain what their experiments keep telling them: Quantum Theory works.

Other minds have offered radically new and different interpretations of our reality that “fit” with Quantum Mechanics. No interpretation has risen to the forefront, yet, leaving science still in a state of relative chaos. An understanding of this chaos might best be started by examining how it came about: the breakdown of classical physics.

Ever since Newton codified the Aristotelian view of the world, things have been cool. In this view, the world can be easily examined by agreeing on a reference point, or origin and applying an orderly coordinate system to the events in the world. Any event’s position can be measured in reference to everything else in the three spatial dimensions. Theoretically (I mean that literally), this is accomplished by placing an observer at every point in this coordinate system, and asking all of them, “Who saw the event?” The observers at whose position the event was seen can answer with certainty that they saw it there. This certainty of position is the first important detail of classical physics. The second piece necessary to examine the world is time. To Newton and Galileo (and everyone else until the 1900’s) time was absolute. No matter where
the observers were placed or if one observer was moving in reference to another, they could agree on time. With absolute time and certainty of position, one could describe any possible experimental scenario. In this view of the world, Newtonian physics works. Every possible event in the universe could be explained and linked to a cause. In this way, this view of reality was completely deterministic. Although it theoretically eliminated free will, Newton’s Laws worked so well that they dominated physics for centuries.

Around 1900, though, some experimental results were beginning to challenge Newton’s reign. The first blow was not a fatal one. The velocity of light was experimentally shown to be a constant, c. This gave Newtonian physics a maximum possible velocity (nothing can travel faster than light), equations were adjusted, and everything was still fine. Then, the Newtonian concept of time was threatened by Einstein’s Special Relativity. Several new concepts were adopted, such as the time dilation and length contraction (outgrowths of the new relativity of time), and once again, classical physics still worked after some adjustments.

Then, some experiments with blackbody (an all-absorptive and reradiative object) radiation gave some results that did not fit the classical view that energy was a continuous quantity. An explanation was offered by Planck, who theorized that maybe energy was not continuous, but rather, quantized in very small discrete amounts. He called these amounts “quanta.” This meant that no matter what the frequency of a certain beam of light, its energy could only be an integer amount of these quanta. These theories culminated in Einstein’s Photoelectric Effect in which the particle nature of these quanta was demonstrated in the instantaniosity of the jump of electrons in the photoelectric surface no matter what the intensity of the light was. These particles were called photons. Classical physics could not explain this quantization of energy, or this experimentally shown wave-particle nature of light. In other experiments, single photons were shot at screen, but in between the gun and the screen was placed a wall with two slits. When a continuous beam of light is shown through the slits, a pattern is made of the screen which attests to the wave nature of light (as shown in class). When a large number of photons are fired one at a time in this set up, the pattern is still made, showing that light still maintains its wave nature even when reduced to only one particle. This resulting concept of light’s wave-particle duality, and Bohr’s model, which included electrons being able to jump between states without having to have been anywhere in between, were the final nails in the coffin of classical physics. Science needed some new theories...
One of the first and most basic quantum ideas was the concept that we cannot look at anything in the microworld (I'll call them all "electrons") without disturbing its natural state. To look at something, light (at least one photon) must be bounced off it in order for the eye to see it. While bouncing a photon (having about $10^{-19}$ the amount of energy of a macroworld object) off of an object in the macroworld (you, me, Aunt Bea) will not effect the energy level of the object, bouncing a photon off an electron (whose energy is roughly the same as a photon) will greatly effect the state of the electron. This means that if we measure some quantity of an electron, we disturb the state of the electron, possibly changing the results. Since we only know what we can measure and we do not want to disturb the natural state of what we are trying to measure, we can only talk about an electron's state in probabilities. This is also stated in Heisenberg's Uncertainty Principle which says that we cannot know, with certainty, both the position and velocity (and therefore, momentum) of an electron. One quantity may be known, but that means that we have to talk about the other quantity as the probabilities that it might be somewhere in a range of values, albeit a narrow range. Since we have to measure to "know," being forced to talk in probabilities is disturbing.

One of the fundamental mysteries of the Quantum Theory is the concept of being in a superposition. This concept is, perhaps, best approached through the examination of experiments that demonstrate its curious effects. These experiments deal with some measurable properties of an electron. We will call these properties hardness with the possibility of being either hard or soft and color with the possibility of being either green or magenta. Say hardness is being measured. This is done by sending an electron through what we will call a hardness box. The electron will then emerge from either the hard aperture or the soft aperture of the box. Which aperture it exits through corresponds, of course, to the results of the properties measured. In short, a soft electron being sent into a hardness box will come out of the soft aperture. We also have a box to measure color. If we send a large number of electrons through one of these boxes (say a hardness box), we get a even 50-50 split between the two apertures (say 50% soft, 50% hard). If we send the resulting beam of just hard electrons into a color box, we get another 50-50 split between green and magenta. All of these electrons should still, theoretically be hard, but if we send say, the green beam into a hardness box, we get another 50-50 split of hard and soft. The hardness property of the electrons was somehow changed (randomized) by measuring their color. The results are the same no matter how the experiment is configured (it does not matter which property you measure first, etc.)
A second experiment makes this all-the-more curious. If we send a 100% magenta beam into a hardness box (resulting in a 50-50 split of hard and soft beams), recombine the beam without changing any of their properties, and then measure color, we get 100% magenta. According to the results of the first experiment, the color of the electrons should have been randomized by measuring their hardness. In that case we should have gotten only 50% magenta in the end. We don't. If we go through the recombining process but somehow block the soft beam from being recombined, we expect to get 50% magenta (from the randomizing) in the hard beam. We only get 25% magenta. The results are the same if we block the hard beam and measure the soft. With both beams we get 100% magenta. In each beam, however, we only have 25% magenta. Several other experiments and configurations produce similarly curious results that seriously challenge how we have been looking at reality up to this point. In the situation above, we say that a given electron is in a superposition of color states. What this really means is that the electron is in a state where talking about its color does not make any sense. This state was produced by measuring its hardness. But we will get into more detail about that later.

Quantum Theory has five postulates that are the core assumptions of this new physics. The first postulate states that each physical entity or physical system in the world (universe) can be represented (is represented) by normalized vectors that describe its state. These vectors are called the system's “state vectors.” This implies that different states can be manipulated mathematically as vectors and that these states must obey the restrictions of vector math.

The second postulate states that if a physical system has a state vector that is an eigenvector with eigenvalue $x$ of an operator of the state vector’s measurable property, then the system has a value $x$ for that measurable property. When two physical states are involved, this postulate can result in a combination of vectors that reflects a state of superposition. After the vector math involved in, say, trying to determine hardness and color, we have a state in which we get a definite value for color but a superposition of hardness states and a state in which we get a definite value for hardness and a superposition of color states. The superposition happens because the operators that determine hardness and color are (vector- mathematically) incompatible. This is why color talk makes no sense when measuring hardness and vice versa.

The third postulate deals with the dynamics of state vectors. It defines a “time evolution” operator as the governing operator that determines how a state vector
changes dynamically, that is, through time. These changes are necessarily changes of
direction because state vectors are, by definition, normalized (length = 1) The time
evolution operator is just a mathematical representation of the dynamical laws which
are actually changing the state vector in question. These laws are defined in
Schrödinger’s equation.

The fourth postulate states that if a system’s state vector of a certain property is
not an eigenvector of the associated operator, than the experimentally determined
value of the property is governed by the laws of probability. The probability that a
system in this situation will have a value \( x \) for the measurable property is the square of
the product of the system’s state vector and an eigenvector of the operator in question
with an eigenvalue \( x \). This implies that the laws of probability as they apply to vectors,
are really in control of non-eigenvector state vectors. A certain outcome in some
physical system is not caused by something physical, but rather, by probability laws’
effect on the system’s vector math.

The fifth postulate deals with the concept of collapse. In the discussion of the
fourth postulate, a situation was presented in which the state vector of a system was
not an eigenvector of the necessary operator. The outcome of the measurement was
then determined by a probability equation that used an eigenvector with an eigenvalue
\( x \) in the calculations. The fifth postulate states that the instant the measurement
happens, the original state vector is collapsed to be an eigenvector of the original
operator. This collapse is instantaneous. The eigenvector the state vector collapses to
is a matter of chance, because it depends on the outcome of the measurement which, as
mentioned before, is a matter of probability.

These postulates have shed some light on that fuzzy concept of superposition.
We can see, by postulate two, that when speaking about measurable properties as
vectors, we can only measure one at a time. If we try to determine, say, two measurable
properties, then the system will be in a superposition of one of the properties, while
the other may be measured. This explains the strange results of the color and hardness
box experiments. When we were measuring hardness, weird things would happen to
the color results. This is because, being in a superposition of color states, color talk did
not mean anything; it was meaning less to say, “There are 50% magenta electrons in
this beam.” This superposition happens because at the instant the hardness of an
electron (or the whole beam) was measured, the state of the electron collapsed into an
eigenvector of the hardness operator. Therefore, the color state vector lost its meaning.
To measure color, then, we would have to collapse the state vector to an eigenvector of
the color operator. This is done by simply measuring for color. The electron would then be thrust into a superposition of hardness states.

These postulates merely represent the workings of Quantum Mechanics, how we have been able to explain our experimental results. They do not tell us why Quantum Mechanics works. This is the subject of much debate and a handful of important theories have surfaced. One theory was the brain child of a brain trust. Einstein, Podolsky, and Rosen's (EPR) theory was based on the assumption that systems could actually have elements of reality, that is, that if a system was measured to have a certain value for a certain property, that that property was an element of the system's reality. They stated that even if we do not measure a system, that its value for a certain property exists; it's just information that is "sitting" there, undisturbed by measurement. Their main thrust has been how to get to that information without disturbing the system. When two electrons are involved and we try to determine their states, vector mathematics tells us that whatever the state of the first electron is, the second one will be the opposite. If the first one is measured to be green, the other one will be magenta. The assumption that EPR make is that there is a possible way to set up the experiment so that the two electrons could not possibly have any effect on each other. They figure that if you separate the two measurements by enough distance and keep them close enough time-wise that not even light could make it from one to the other before you made the second measurement, that no information could possibly be conveyed between the two. The assumption that one electron's measurement could have an effect on the other one's depending upon how close they are together is principle of Locality. By mathematically proving that the two constraints implicit in EPR's view, the constraint of vector math on a two particle system that the second measurement's value must be the opposite of the first's and the statistical probability of different observables in two electrons, are incompatible, Bell crushed EPR's theory.

Two methods of exploring Quantum Theory to try to come up with some sort of theory to explain it would be to examine the contradiction between the collapse postulate and the dynamic equations of Quantum Mechanics. The postulate works when we measure something, but everything seems to behave according to the dynamic equations when left alone. Some insight might be found by exploring the deeper nature of what it means to measure. There are a lot of steps involved when something is measured. Say the color of an electron was indicated by a pointer on a new and improved color box. Then, the variable aspects of measuring something can be eliminated one by one, eventually leading us to the point where the only variable is
in our consciousness. It comes down to a question of what the measurer believes the color of the electron to be. This is a fuzzy area, and does not clear up the aforementioned contradiction.

If we could figure out exactly where the collapse takes place, we might be able to resolve the conflict and figure out the principles of reality that make Quantum Mechanics work. Many theories, from looking for the collapse in the pointer like the one on the aforementioned color box to eliminating every possible place of collapse except for the leap to conscious thought, have failed to paint a reliable picture of the collapse being the important factor to Quantum Mechanic's success. Others have tried to ignore the collapse and say that the dynamic equations are right. Everett and DeWitt suggested that when a superposition happens, there is no collapse, but that the universe splits into two universes, identical except for the outcome of the measurement that produced the superposition. According to this theory the universe(s) has been splitting since the big bang, resulting in countless universes at this instant in time. Also according to this theory, those going through this split (the measurer and really everybody) cannot notice it. This theory is, therefore, very hard to disprove. It is also a little hard to swallow.

The inherent contradictions in Quantum Mechanics still have scientists-philosophers baffled. No one can argue with the fact that it works. Everyone seems to want to argue why. Some scientists have even crossed their secular picket lines boycotting God to shrug in ignorance and say, "It might just be the hand of God." Most scientists who believe this to be a possibility, see this God as more of a being which is one with nature, not necessarily and entity with a personality/consciousness. This idea of God is close to the Taoists' view of the Tao.

"The importance of the Tao is not, of course, its mere presence, but rather, the fact that it binds everything together and gives the universe harmony. It is the force that unifies everything on a spiritual and metaphysical level. The Tao also gives an entity the particular energy that determines its nature, and place in the universe. It gives the universe a natural order." (Buttram, p.7)

This view of a natural order could very well apply to Quantum Mechanics. I think that another Taoist principle could be well used in the conundrum of Quantum Theory. The Taoists are only interested in the true nature of things, what role they serve in the world. When presented with Quantum Mechanics, they would say, "Cool. It works,
and you can accurately predict all of your experimental results.” When confronted with the deeper question of why, the Taoist is likely to answer, “Why ask why? It works doesn’t it? You don’t need to know why it works to use it, now do you?” I would have to agree with this view. Reality is what we see, what we think, what we think we know, the things that effect us... you know, practical everyday living. Phenomena which are not part of our everyday experience are exactly that- not part of our experience. Why should these things affect our own view of reality?
Bibliography

Buttram, Will. "The Taoist View of Reality."
