From: L. Michael Hall
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THE STRANGE STORY OF QUANTUM MECHANICS AND WHAT IT MEANS FOR YOU

"Everybody knows that quantum mechanics is strange,
but ... very few people could tell you exactly in what way."
Leonard Susskind, *Quantum Mechanics*

The world that you know and experience with your senses everyday is the *natural* world. You see it when you see a beautiful sunrise in the early morning. You hear it when you sit on a beach and listen to the waves crashing on the rocks. You feel it when you climb a tree and feel the texture of the branches and the bark. You smell it when you pick strawberries in a strawberry patch. You taste it when you pluck an apple off a tree and bit into it.

Yet is this *natural* world the *real* world? If you take these elements and put them under a microscope— what is the world beneath the world of your senses? What we now find is another world— a deeper world. Is that the real world? A single drop of water from a river reveals a world of microscopic organisms swimming around in what seems like a self-contained world. Is that the real world?

If we then use some ever-more advanced instruments, an electronic microscope, what would we find? Far, far below the microscopic world (and I mean really far, far below it, a thousand times smaller), there is yet another level— the level of atoms. And atoms we are told are the building blocks of everything that exists. We are made out of atoms, so we are told.[1] So is our food, our cars, our computers. Yet no one has ever seen an atom even though with an electronic microscope, scientists have supposedly been able to write a word with atoms.[2]

Yet far, far below atoms scientists posit all sorts of sub-atomic particles, the fundamental particles that make up the universe— electrons, photons, quarks, the neutrino, exotic matter and antimatter, and in fact, hundreds of sub-atomic elements at work. So is this the real world? If it is, then we have some real problems. At least theoretically. In attempting to explore and study this world— the physicists who have led the way have hit upon all sorts of problems in understanding what they think they have found. In studying the electron— which is far, far too small to see— the studies, of course, are not direct, but indirect. The studies are via experiments, via thought-experiments, and via mathematical proofs from which the physicists then draw conclusions.

The great majority of physicists agree that consciousness is not within the discipline of physics. And while a few think that it is, it is only a very small minority. Physics is the study of natural phenomena that are successfully addressed using well-specified and testable models. About quantum physics, while the experience using macro-level apparatuses are agreed upon, the consensus about *what it means* is hotly debated. This is what is highly contentious. Because the experiments seem to say that "observation" creates the physical realm of the microscope world, this is the source of all of the controversy and debate.[3]

What is so hotly debated? *Reality!* The basic Copenhagen view of quantum physics says that *for all practical purposes,* a macroscopic measuring device, a Geiger counter, for example, counts as "observation." The extreme Copenhagen view goes much further, denying the very *existence of the microworld,* saying there are no atoms(!). One theory says there is no collapse of the superposition state of the wavefunction, only de-coherence. Another posits "many worlds," every observation creates multiple dimensions. All of them insist that "our reasonable, everyday worldview is fundamentally wrong." (2006, p. 168).

> "Useful as it is under everyday circumstances to say that the world exists 'out there' independent of us, that view can no longer be upheld. There is a strange sense in which this is a 'preparatory universe.'" (John Wheeler)

So, what is real? How is it that many in quantum physics interpret an electron, not as something physical, but as a mathematical function? And what does that mean? How can they say that electrons and atoms do not exist?

> "The big things we actually deal with in everyday life are real enough. Remember, you need to do an interference-type experiment to actually demonstrate the creation by observation." (Rosenblum, *Quantum Enigma,* 2008, p. 97).

Feynman in the first chapter of his Third Volume writes:

> "Quantum mechanics" is the description of the behavior of matter and light in all its details and, in particular, of the happenings on an atomic scale. Things on a very small scale behave like nothing that you have any direct experience about. They do not behave like waves, they do not behave like particles, they do not behave like clouds, or billiard balls, or weights on springs, or like anything that you have ever seen.
>
> Newton thought that light was made up of particles, but then it was discovered that it behaves like a wave. Later, however (in the beginning of the twentieth century), it was found that light did indeed sometimes behave like a particle. Historically, the electron, for example, was thought to behave like a particle, and then it was found that in many respects it behaved like a wave. So it really behaves like neither. Now we have given up. We say: "It is like neither."

Why this Paper?

I have written this paper to answer the question that continues to come up regarding quantum physics or mechanics. In the past couple years, nearly a dozen times Neuro-Semantic Trainers have asked if they could include a section or training on "Quantum Mechanics" in a training manual. I have always responded, "And what from Quantum Mechanics would you put into a training manual on NLP or Neuro-Semantics?" A few have been bamboozled by the Hollywood movies "What the Beep?" and "The Secret" and actually think that somehow, in some way, the discoveries about electrons and sub-atomic particles means that we can control reality. Others know better than that but think that they can use Quantum Mechanics as an example. Of what I still do not know.

The following took a long time to write. Admittedly, this is not my field or area of expertise, not by a long shot. Upon completing my first draft, I sent it to Dr. Pascal Gambardella who's doctorate was in this area and who continues to read extensively in this area and understands it hundred-fold better than I do. You will see some references to him, and many footnotes by him.

For years I have discouraged people trying to use Quantum Mechanics in NLP or Neuro-Semantics. After getting his corrections and updates to my first draft, I asked if he thought there was any use of Quantum Mechanics. He was especially succinct, "I don't think that there is any practical use of Quantum Mechanics in the usually teaching of NLP or Neuro-Semantics."

The Split Screen Experiment

What is commonly known regarding the paradox and contradiction in the field of quantum mechanics come from the famous two slit experiment. Light coming through a single narrow slit illuminates a screen more or less uniformly. Yet when we open a second slit, a pattern of dark bands appears whose spacing from each other depends on the separation of the two slits.[4]

> "At those dark places, wave crests from one slit arrive together with wave troughs from the other. Waves from one slit thus cancel waves from the other. Interference demonstrates that light is a spread-out wave. Nevertheless, Einstein held that the photoelectric effect showed light to be a stream of photons— tiny compact bullets. ... Choosing to demonstrate interference, something explicable *only* in terms of waves, you could *prove* light to be a widely spread-out wave. However, by choosing a photoelectric demonstration, where a single electron absorbed a whole light quantum, you could *prove* light to be a stream of tiny compact objects. .... The mystery is still with us one hundred years later. " (Rosenblum, p. 61)

About interference, Alstair Rae explains in his book, *Quantum Physics*[5]:

> "Direct evidence that a phenomenon, such as light, is a wave is obtained from studying 'interference.' Interference is commonly encountered when two waves of the same wavelength are added together. If two waves are in step (in phase), they add together to produce a combined wave that has twice the amplitude of either. If they are exactly out of step, they cancel each other out. If in an intermediate situation, the waves partially cancel and the combined amplitude has a value between the extremes. "Interference is crucial evidence for the wave properties of light and no other classical model can account for this effect." (Rae, p. 32)

So, what is light? This is a central problem in quantum mechanics. How shall we explain the wave–particle duality?

More than a century of experiments had show light to be a wave. Maxwell's successful theoretical description even identified what it was— the electromagnetic field–which was making the waves. Einstein demonstrated that when light interacts with metals it resembles a shower of particles. Taken together, light acts in certain situations as a wave, in others as particles. (Nick Herbert, p. 38) Particle and wave seem irrreconcilably different, but the nature of light is such that it is able to combine these contradictory attributes in a harmonious way.

> New quantum facts destroy the once sharp distinction between "matter" and "field." (40) What's at stake in the quantum reality is not the actual existence of electrons but *the manner in which electrons possess their major attributes.* (45). Attributes: static and dynamic. Static: mass, charge, spin. Dynamic: position, momentum. What attributes it seems to have depends on how you measure it.
>
> "Such an explanation probably does not exist. The phenomena that exhibit these quantum properties are not part of our everyday experience and cannot be described using classical categories such as wave or particle..." (Rae, p. 35).
>
> "In classical waves, there is always something that is 'waving.' In water waves the water surface moves up and down. In sound waves the air pressure oscillates. And in electromagnet waves the electric and magnetic fields vary. What is the equivalent quantity in the case of matter waves? ... There is no physical quantity that corresponds to this. So we use the term 'wavefunction' rather than wave. This emphasizes the point that it is a mathematical function rather than a physical object." (Rae, p. 37)

Without question, this is counter-intuitive. From the macro-level it is difficult not to believe that an object must always be somewhere. "When the particle is not being observed it is actually a wave. Yet this statement also attributes reality to something that is unobservable. (?? p. 163). The wave function should not be interpreted as a physical wave; it is a mathematical construction, which we use to predict the probabilities of possible experimental outcomes. Just how big does an object have to be in order to be classical?

Now strictly speaking, the reports on what electrons are doing is indirect rather than direct. What the quantum physicists are actually reporting on is the behavior that shows up on their laboratory apparatus. So even though the discussion is about microscopic objects, that is not what is seen. In fact, many of them don't even believe that atoms or elementary particles are real. Heisenberg said that "they form a world of potentialities and possibilities rather than one of things and facts." Nils Bohr, one of the key developers of quantum physics, wrote:

> "There is no quantum world. There is only an abstract quantum *description.* It is wrong to think that the task of physics is to find out how nature is. Physics concerns what we can *say* about nature."

Kenneth Ford has written that the remoteness of quantum phenomena from everyday experiences explains why the quantum theory is a scientific newcomer in human history and its part of the reason that quantum phenomena seem so strange (p. 221).

Of course, this is about the *meaning* of the wavefunction and goes far beyond the actual experimental results around the two-split experiment. What boggles the mind is saying that a physical thing can be in two places at the same time. The quantum mechanical term for this situation is to say that the atom is in a "superposition state" and is simultaneously in both boxes. The theory says that *"the method of looking* creates the present situation of the atom concentrated in a single box or spread out over two." (?? p. 79)

The Schrodinger's Cat Thought Experiment.
Then there is the Schrodinger's Cat thought experiment. Erwin Schrodinger, another founder of modern quantum theory, told his now-famous cat story to illustrate that, since the quantum theory applies to the large as well as the small, the theory is saying something 'absurd."

This experiment was actually a *thought* experiment. No actual cat was involved.

> "Suppose that before we send an atom, one of the boxes of the pair is not empty. It contains a Geiger counter desired to 'fire' if an atom enters its box. In firing, this Geiger counter moves a lever to pull the cork from a bottle of hydrogen cyanide. There's also a cat in the box. The cat will die if the poisonous cyanide escapes its bottle. The entire contents of the boxes, the atom, the Geiger counter, the cyanide, and the cat, is isolated and unobserved." (2006, p 117)

"Suppose the cat was placed in the box and the atom sent into the mirror system eight hours before you looked. The system evolves unobserved during those eight hours. If you find the cat alive, since it has gone eight hours without eating, you find a hungry cat. If you find a dead cat, an examination by a veterinary forensic pathologist would determine the cat to have died eight hours ago. Your observation not only creates a current reality *it also creates the history appropriate to that reality."* If you consider all of this absurd—that was precisely Schrodinger's point. Scrodinger's cat could be simultaneously dead and alive— until your observation *causes* it to be either dead or alive.

> "He concocted his cat story to argue that, taken to its logical conclusion, quantum theory was absurd. Therefore, he claimed, it must *not* be accepted as a description of what's really going on." (2006, p. 119)

Again, it has to be emphasized that the evidence provided by the quantum experiment is *circumstantial* evidence, not direct evidence. One fact (interference) is used to establish a second fact (namely, that the object had been in both boxes.

Ford —

> Quantum reality doesn't show up *directly* in the quantum facts: it comes indirectly out of the quantum theory, which perfectly mirrors these facts. (57). If the electron has any size at all, it is smaller than we can measure. Some physicists conjecture that the electron is a point particle whose intrinsic size is zero! (61). An electron seems to possess contradictory attributes. As a particle, it must be localized in space, cannot be split apart, and retains its identity in collisions with other particles. As a wave, it spreads over vast regions of space, is divisible in an infinity of ways, and merges completely with other waves it happens to meet. (64)

The Mathematics of Quantum Mechanics.
All of these ways of attempting to explore and understand the quantum level of reality has resulted in confusing, contradictory, paradoxical, and inconsistent theories. Ultimately these are *theories of human understanding* trying to make sense of what does not make sense to us on the natural level of existence.[6]

Now the mathematics of quantum mechanics has led to a great many practical uses. They have enabled people to create machines that utilize principles about atoms and electrons— so that we have numerous electronic equipment today giving us television, MRI machines in hospitals, etc. That is, the *facts* of quantum physics have been highly productive in many innovations. The facts have led to the most successful predictive scientific innovations in history which is due to its carefully constructed mathematical structure. Much of the mathematics involved in quantum theory at its foundational or ground-state level involves the manipulation of matrices, vectors and brackets. Among the practical applications of quantum mechanics is the laser, the transistor, the MRI (magnetic Resonance Imaging) machines, and many of the present day applications of electrons including your TV set.

In spite of all of these immensely practical usages, the theories (and there are many theories) about *what is happening* and *what it means* is a complete mess. The bottom line is that we do not know and we do not have any consistent unified theory about what is happening or what it means. IT is all guesswork and imagination and every theory has lots of problems.

The Delusion of Thinking You Understand

If you think you know and understand quantum mechanics, you are assuming a knowledge that goes far beyond what those who are experts in quantum physics. How do I know that? I know that because of what the pioneers and current quantum physicists say. That the quantum world is strange and weird and unexpected is acknowledged by all of the original developers as well as those involved in the ongoing research.

- Danish physicist and founder, Niels Bohr: "Anyone not shocked by quantum mechanics has not understood it." (Rosenblum, 2008, *Quantum Enigma,* p. 13).
- Richard Feynman who understood quantum mechanics as well as anyone ever did says, "Nobody understands quantum mechanics." (Rosenblum, p. 80).

If you ask, "Where does that put all of us who are non-experts in this field?" the answer is that it should completely eliminates dogmatism about quantum physics. *No one really knows!* The experts do not know and better yet, they know that they do not know. In terms of "knowledge" —it is all speculation, supposition, and belief. Whatever you think you know about this is a belief and not knowledge.

Bruce Rosenblum and Fred Kuttner, both Professors of Physics have written in their book, *Quntum Enigma* this:

> "When experts can't agree, you can choose your expert—or speculate on your own. 'What's going on?' is still an open question after eight decades. 'You know something's happening here, but you don't know what it is.'" (2008, p. 169)

In the field of quantum physics this sets an important frame: Even the experts do not understand this strange area of the quantum field and that's why a great many different interpretations have been posited. Albert Einstein strongly disagreed with Niels Bohr and the Copenhagen theory. He called it "spooky." He said that "God does not play dice with the Universe." They debated the issues for many years without ever came to an agreed-upon solution.

jump to a conclusion which disagrees with Einstein especially since he launched this field. This was his field of expertise. Rather than jumping onto "the quantum bandwagon" that our thoughts create external reality and that this is the great secret about the ultimate reality of the universe, let us walk more cautiously.

Welcome to the Strange World of Quantum Physics

What the experts theorize about the quantum world as they try to figure out what is there and what it means, it results in what everyone acknowledges as a weird, strange, unbelievable, impossible, contradictory, and spooky world. They use these words because if the conclusions which they draw are true, then everything we "know" of the natural world, even the microscopic world, and even below that level is somehow wrong, or false, or delusional.

> "To account for the demonstrated facts, quantum theory tells us that an observation of one object can instantaneously influence the behavior of another greatly distant object— *even if no physical force connects the two.* Einstein rejected such influence as 'spooky actions," but they have now been demonstrated to exist. Quantum theory also tells us that observing an object to be someplace *causes* it to be there." (Rosenblum, p. 12)

The Quantum World and NLP

By way of contrast, NLP (Neuro-Linguistic Programming) and Neuro-Semantics directly deals with the macro-world and the world of consciousness. Only derivatively do we deal with the field of *physics*. Yet while we do not explicitly study physics, we do deal with physics. Physics are involved, for example, every time it comes to encouraging people to take action and engage in some actual performance in the world. After all, there are the physical forces involved in the movements and actions of behavior. And there are physical factors involved in the environment and contexts in which the actions occur.

So the principles of macro-physics are involved and sometimes comprise a very important factor as we model excellence in sports, business, leadership, etc. Yet for the most part, we do not study or incorporate the Newtonian laws of physics into our studies, let alone quantum physics governing atoms and electrons. NLP and Neuro-Semantics is primarily about *mind* and *meaning,* not force, motion, momentum, space, etc. We focus on the mind-body-emotion system, the construct of meanings, and how we create frames that govern perception and response.

Given that, then why this article on quantum physics? The reason is because many NLP people have adopted what's called New Age thinking, or "spirituality," or philosophy, etc., and have attempted to wed NLP to Quantum Mechanics. They use such terminology as "quantum linguistics," "quantum psychology," "quantum states," etc. and while these words sound meaningful, they are not. The words refer, at best, to pseudo-knowledge.

Why would they try to combine NLP with atoms, electrons, and other subatomic particles? They do so because of a superficial correspondence. They hear that quantum mechanics posits that "observation creates reality" and that's all they need to hear to start inventing beliefs about the ability to create physical reality from their thoughts(!). Consequently they run with a flawed understanding of quantum physics and begin drawing all sorts of untenable conclusions.

In recent years, this has been popularized in movies such as, *What the Bleep? What the #X*! Do we Know!?* and *The Secret.* These movies encourage misleading conclusions and set people up to *believe* and *expect* things at the macro-level which are delusional. An editorial in *Time* magazine said this about the movie, *What the Bleep?*

> "[It is] an odd hybrid of science documentary and spiritual revelation featuring a Featuring a Greek chorus of Ph.D.'s and mystics talking about quantum physics."

They jump to the delusional conclusion that "Perception creates reality." Well, *your* perception may create *your perception of reality*, but it does not create the macro-realities in your environment. That kind of non-sense deceives people and sets them up for disillusionment. Thinking does not make it so.

The Weirdness of the Quantum World

From the beginning of the twentieth century when Albert Einstein published his two paradigm shifting papers in 1905, the things people began writing in the 1920s onward about quantum physics have left an impression that this is a strange, and rather arcane world. The impression is that it is in so many ways counter-intuitive to everyday reality. Kenneth W. Ford asks the questions about the weirdness in his book *The Quantum World.*

- Why is the subatomic world so strange? Why it is so weird and wonderful? Why do the laws governing the very small and the very swift defy common sense? (2004, p. 4)

What's weird and mind-boggling about the quantum theory? Here are some of the primary shocking things that some of the pioneers have said:

- Objects are created by our observation of it. This "creation by observation" is one of the most shocking and weird things that quantum theory postulates. "Quantum theory has atoms and molecules not existing someplace until observation creates them there." (2006, p. 115).
- In Quantum theory if atoms and molecules don't exist until observation creates them, then prior to that the atom is a wavefunction, a probability, a mathematical function.
- A few quantum *theories* assert that observing an object to be someplace *causes* it to be there. This means that an object can be in two or many places at once. Observing one object can instantaneously influence the behavior of another greatly distant object—even if no physical force connects the two. (Rosenblum, p. 12). Before observed, the atom was in a superpositional state— a state of all possibilities. In being observed, the wavefunction or the superpositional state *collapses* into reality.
- The wave–particle duality of light says that what light *is* on how you observe or measure it.
- The weirdness of measurement. Nick Herbert, in his book *Quantum Reality,* describes the problem in these words: "Quantum theory is peculiar in that it describes a *measured atom* in a very different manner than an *unmeasured atom.* The measured atom always has definite values for its attributes (such as position and momentum), but the unmeasured atom never does. Every atom in the world that's not actually being measured possesses (in the mathematical description at least) not one but all possible attribute values, somewhat like a broken TV set that displays all its channels at the same time."

(1987, p. xii)

- If quantum physicists view atoms as unreal, how can they accept objects made of atoms as real?

Now one thing that makes all of this strange is that we do not and have never actually seen these quantum dynamics when it comes to the operation of the macro-level objects of the empirical world. At the microscopic level they do not occur. At the macro-level they do not occur. They are asserted to only occur at the sub-atomic level. But here is a problem. If a big thing is a collection of atoms, and if an atom doesn't have physical reality, then how can a collection of them be real? That would mean that the big things also are not, and cannot be, real. Yet that is absurd to our everyday experiences. Now we have a problem.

> "It is not possible to demonstrate that a large object is in a superposition state." (Rosenblum and Kuttner, *Quantum Enigma,* 103).[7]

Some quantum theories deny the straightforward physical reality of atoms and then by extension seems to deny the straightforward physical reality of chairs which are made of atoms. This theory emerged in the 1920s (the extreme Copenhagen Theory) and the quantum enigma surfaced as the theory was seen to involve the act of observation, even conscious observation. Originally Quantum Theory was developed to explain the "mechanics"– the mechanism– governing the behavior of atoms.

> The energy of an atom was found to change only by a discrete quantity, a *quantum,* hence "quantum mechanics," a term that includes both the actual experimental observations and the quantum *theory* explaining them. (Rosenblum and Kuttner, *Quantum Enigma,* p. 11).

Everything in the world is pure quantumstuff, a physical union of particle and wave. The particle aspect of light waves is called photon, the particle aspect of gravity, graviton, of the strong nuclear force, gluon. (2006, p. 64). Rosenblum and Kuttner say that the quantum facts give us not one description but two– each one separately inadequate, and both together contradictory. Moreover the knot that connects these two descriptions is the act of observation; leave out observation and neither description makes sense. (p. 67).

It's a world that's wavelike when unobserved, particlelike upon observation; a world whose attributes come in pairs which jointly resist close examination. (69). For a quantum wave, the square of its amplitude represents not energy but probability— the probability that a particle will be observed if a detector is placed at location x. (95)

Now for the Theories that attempt to Explain the Quantum World

Professors of Physics, Bruce Rosenblum and Fred Kuttner, in their book *Quantum Enigma: Physics Encounters Consciousness* (2008/ 2015) describe the ten theories on the quantum enigma in their fourteenth chapter and conclude by quoting one of the key developers of quantum theory, John Wheeler:

> "Useful as it is under everyday circumstances to say that the world exists 'out there' independent of us, that view can no longer be upheld. There is a strange sense in which this is a 'participatory universe.' ... 'Consciousness' has nothing whatsoever to do with the quantum process. We are dealing with an event that makes itself known by an irreversible act of amplification, by an

> indelible record, an act of registration. .... [Meaning] is a separate part of the story, important but not to be confused with 'quantum phenomenon.'" (p. 168)

The best summary I have seen of the many different theories is that which Nick Herbert did in his book, *Quantum Reality: Beyond the New Physics* (1987). Here is his summary of the views of its foremost creators in the form of eight realities which represent eight major guesses as to what's really going on behind the scenes.

Quantum Reality #1: The Copenhagen Interpretation, Part I.

> There is no deep reality. Niels Bohr put forth one of quantum physics' most outrageous claims, namely, that there is no deep reality. He does not deny the evidence of his senses. The world we see around us is real enough, but it floats on a world that is not as real.
>
> > "There is no quantum world. There is only an abstract quantum description." Bohr. (p. 17)
>
> N. David Mermin, Cornell physicist summed up Bohr's anti-realist position in worlds that leave little room for misunderstanding,
>
> > "We now know that the moon is demonstrably not there when nobody looks." (17).

Niels Bohr and Werner Heisenberg developed what's known as the Copenhagen Interpretation. "An observation produces the property observed. The logical conclusion is that microscopic objects themselves are not real things.

> Heisenberg: "... the atoms or elementary particles themselves are not real; they form a world of potentialities or possibilities rather than one of things or facts." (Rosenblum and Kuttner, *Quantum Enigma,* p. 104).
>
> Bohr "There is no quantum world. There is only an abstract quantum description. It is wrong to think that the task of physics is to find out how nature is. Physics concerns what we can *say* about nature." (Emphasis added).

Quantum Reality #2: Copenhagen Interpretation, Part II.

> Reality is created by observation. Although the numerous physicists of Copenhagen school do not believe in deep reality, they do assert the existence of *phenomenal reality.* What we see is undoubtedly real, they say, but these phenomena are not really there in the absence of an observation. The Copenhagen interpretation properly consists of two distinct parts: 1. There is no reality in the absence of observation; 2. Observation creates reality.

Nick Herbert asks, "How is the world put together? What are the basic objects and how do they interact?" and then says that the Copenhagen interpretation holds that in a certain sense the unmeasured atom is not real; its attributes are created or realized in the act of measurement."

> Now if "observation" or "consciousness" creates reality, then what special feature of an observation endows it with the power to create reality? How does this work?

The enigma about the quantum phenomenon relates to consciousness. What is the relationship of "consciousness" to physics? Physicists tend to call this problem "the measurement problem."

> "When we come to quantum physics, we have to accept that there is no single map of the

> quantum world. Rather, quantum theory provides a number of maps; which we should use in a particular situation depends on the experimental context or even on the experimental outcome, and may change as the system evolves in time." (Rae, p. 164)
> In the quantum world, randomness and indeterminism are a fundamental property of nature. Although the individual events occur at random, the probability of their occurrence can be calculated. (Rae, p. 160). "Three principles— randomness of individual outcomes, alteration of state by measurement, and our ability to calculate probability— underpin the conventional interpretation of quantum physics." (161)
> In the Copenhagen interpretation, the attributes an object possesses depend on the context in which it is being observed." (163)

The measuring problem: the act of measuring one physical quantity destroys the knowledge we previously had about another. (Rae, p. 144). If we could say what actually goes on in *a measurement,* we would know what physical reality was all about. (Ford,? p. 47).

The theory itself violently conflicts with common sense. If light involves the wave–particle duality so that it can be viewed as either and both, then "The physical reality of an object depends on how you *choose* to look at it." (p. 67). Pascual Jordan, a developer of quantum theory said, "Observations not only *disturb* what is to be measured, they *produce* it." Somehow *observing* an atom being at a particular place created its being there.

> "All we know is that someplace on the scale between big molecules and humans there is this mysterious process of observation and collapse." (120).

Quantum Reality #3: Reality is an Undivided Wholeness.

This is the theory that comes from Walter Heitler. In spite of its obvious partitions and boundaries, the world in actuality is a seamless and inseparable whole— a conclusion which Fritjof Capra develops in *Tao of Physics.* Heitler accepts an observer-created reality, but adds that the act of observation also dissolves the boundary between observer and observed.

Quantum Reality #4: The Many-Worlds Interpretation.

Reality consists of a steadily increasing number of parallel universes. Myriads of universes are created upon the occasion of each measurement act. Some believe that all outcomes actually occur. This view has, of course, generated so many sci-fi movies over the decades.

Quantum Reality #5: Quantum logic.

This theory attempts to solve the problem by saying that the world obeys a non-human kind of reasoning. To cope with the quantum facts, we must scrap our very mode of reasoning, in favor of a new quantum logic. This view calls for a mutiny against the rules of logic.

Could the wave-particle problem be a semantic one? One colleague of Heisenberg thought so and suggested not calling them waves or particles, but "wavicles." (Rosenblum and Kuttner, *Quantum Enigma,* 105). Apparently, precision limits precision.

"Heisenberg's *uncertainty principle:* for some pairs of physical quantities, the measurement of one of the quantities to a certain precision puts a limit on how precisely the other quantity can be measure. Quantum mechanics imposes a limit on the ability to know." (213)

Quantum Reality #6: Neo-Realism.

The world is made of ordinary objects. Neo-realists accuse the orthodox majority of wallowing in empty formalism and obscuring the world's simplicity with needless mystification. Chief among the proponents of this theory was Albert Einstein, also Max Planck, Erwin Schrodinger, Prince Louis de Broglie, and David Bohr (p. 23).

> "I have thought a hundred times as much about the quantum problem as I have about general relativity theory. ... I cannot seriously believe in [quantum theory] because ... physics should represent a reality in time and space, free from spooky actions at a distance." Albert Einstein.

What Einstein explained to Bohr was that "in quantum mechanics, one can know everything about a system and nothing about its individual parts— but Bohr failed to appreciate this fact." (Susskind, p. xii)

"States and measurements are two different things, and the relationship between them is subtle and nonintuitive." (p. 3). "We are very adaptable creatures and we've been able to substitute abstract mathematics for the missing senses that might have allowed us to directly visualize quantum mechanics." (52) "States in quantum mechanics are mathematically described as vectors in a vector space."

Quantum Reality #7: Consciousness Creates Reality.

Assert that only an apparatus endowed with consciousness is privileged to create reality. The one observer that counts is a *conscious* observer. This was the theory that Denis Postle and Von Neumann held.

Von Neumann said that only a *conscious* observer, doing something that is not presently encompassed by physics, can collapse a wavefunction. Only a conscious observer can actually make an observation. (Rosenblum, p. 184). Yet this actually only raises more questions:

- Did the world not exist until humans arose?
- And how did the first humans arise in a world which didn't exist?

Among the theorists there are more questions:

- Do we have to have a conscious observer?
- If "observation" somehow creates the physical reality of the microscope world, then who or what counts as an observer?
- For that matter, what is consciousness anyway? Does merely a biological brain and neural activities count? How far down does consciousness extend? Cats and dogs? Earthworms, bacteria?

Quantum Reality #8: The Duplex World of Werner Heisenberg.

> The world is twofold, consisting of potentials and actualities. Only phenomena are real; the world beneath phenomena is not (p. 26).
>
> "When the province of physical theory was extended to encompass microscopic phenomena through the creation of quantum mechanics, the concept of consciousness came to the fore again. It was not possible to formulate the laws of quantum mechanics in a fully consistent way without reference to the consciousness." Eugene Wigner, Physics Nobel Laureate

This actually raises an equally problematic question, *What is consciousness?* If you go to the field of psychology, psychiatry, consciousness, AI, etc. there is no widely agreed upon definition of consciousness.

Bell's Theorem

> "Bell's theorem has been called 'the most profound discovery in science in the last half of the twentieth century.' It rubbed physics' nose in the weirdness of quantum mechanics." (2006, p. 139)

Bell said that Einstein's argument for reality *assumed* separability, and he denied separability. He claimed that what happened to one object could "influence" the behavior of another *instantaneously* even though no physical force connected them.

> Bell's Theorem: The quantum facts plus a bit of arithmetic require that reality be non-local. In a local reality, influences cannot travel faster than light. Bell's theorem says that in any reality of this sort, information does not get around fast enough to explain the quantum facts: reality must be non-local. (51)
>
> Bell's theorem proves that any model of reality, whether ordinary or contextual, must be connected by influences which do not respect the optical speed limit.
>
> The world may really be as strange as some physicists say, but it does not flaunt this strangeness, evidently preferring to hide its magic– like Cinderella—in humble guise. The Cinderella effect itself is a subtle example of quantum weirdness: why does nature employ such extraordinary realities to keep up merely ordinary appearances? (56)

The Bottom Line

We live in the macro-world as well as in a microscopic world which enables us to deal with the empirical reality of our senses (what we see, hear, feel, smell, taste, etc.). In this world we are able to use Newton's laws of motion for the majority of the facets of life. With the beginning of the atomic age in 1900 and the nuclear age with the discovery of atoms and electrons we discovered the existence of the quantum world. That in turn led to a great many innovations based on quantum mechanics and yet we still do not fully understand that world. The facts and the mathematics of those facts have greatly enriched our world, yet the "theory" of atoms and electrons and all of the sub-atomic particles is still debated. In fact our understandings has led the experts to conclusions that seem contradictory and against our intuitions at the empirical level (the classic world of Newton). Yet as with all sciences, eventually it will be discovered.

In the meantime many people have jumped on the bandwagon and with minimal understanding have posited all sorts of untenable conclusions from Quantum Theory.

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The Questioners: Physicist and the Quantum Theory, by Barabara Lovett Cline (1965)

The Revolution in Physics: A Non-Mathematical Survey of Quanta (1953), Louis de Broglie (show that matter also could behave like waves).

Physics and Philosophy: The Revolution in Modern Science (1957), Werner Heisenberg

Science Theory and Man (1935), Erwin Schrodinger.

Notes

1. Actually there are smaller units than atoms, other "pieces" of reality—neutrinos, electrons, protons, neutron, quarks, etc.

2. Pascal Gambardella, Ph.D. writes, "People have seen atoms, see "The First Image Ever of a Hydrogen Atom's Orbital Structure" http://io9.com/the-first-image-ever-of-a-hydrogen-atoms-orbital-struc-509684901 and the associated paper" http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.110.213001." The authors of the paper took an image of a wave function. "Hydrogen Atoms under Magnification: Direct Observation of the Nodal Structure of Stark States." They developed a quantum microscope, which is "a device that uses photoionization microscopy to visualize atomic structures directly."

3. The uncertainty principle is a law of physics and a foundation of quantum mechanics. In his Lectures on Physics (with Leighton and Sands, 1965) (Volume 3: Quantum Mechanics, page 1-11) Feynman says:

> "The uncertainty principle "protects" quantum mechanics. Heisenberg recognized that if it were possible to measure the momentum and the position simultaneously with a greater accuracy, the quantum mechanics would collapse. So he proposed that it must be impossible. Then people sat down and tried to figure out ways of doing it, and nobody could figure out a way to measure the position and momentum of anything—a screen, an electron, a billiard ball, anything - with any greater accuracy. Quantum mechanics maintains its perilous but still correct existence."

Chapters 1 and 2 in this book are an excellent, non-mathematical description of quantum behavior. This volume is free to read online: http://feynmanlectures.caltech.edu/. Also look at 2.6 – Philosophical Implications.

4. Pascal quotes from which asks, "Is there a paradox?" and answers it as follows:

> "What is sometimes called the wave-particle paradox/ puzzle/ mystery arises usually if we try to picture light or electrons or other tiny things in terms of macroscopic, familiar objects. If we imagine light as

being like a water wave, it's impossible to picture how a photon is both dispersed enough to create an interference pattern and simultaneously localised enough to interact violently with a single electron. If we imagine light as being made of little particles, it's impossible to picture how one particle 'goes through' two slits and interferes with itself.

Light is not a water wave, and it's not a stream of little particles. Whenever we use one or other of these pictures (and they are very useful at times), we have to be aware that they are also, at times, seriously misleading. Further, the conditions under which one picture is helpful are usually those under which the other is misleading. Consequently, using both pictures simultaneously leads to apparent paradoxes. So it's good to remember that the paradox lies in the use of inappropriate, imagined, macroscopic pictures, and does not come out of the laws of physics.

I've been asked why this is so — why don't the laws of physics give a paradox. The answer has to do with the way science works. If two different scientific theories or ideas predict two different outcomes, then scientists would work very hard to perform that experiment. One or other (or even both) of the predictions would be found to be false, and that theory or idea would ultimately be either abandoned or else retained as a useful approximation for use only in some cases. So, for example, where Galilean and Einsteinien Relativity predict different answers, we recognise that Galilean Relativity is wrong in a fundamental sense. Nevertheless, we still use it as an approximation in most situations just because it makes calculations much easier. More about this in our volume on Relativity and more again when we come to quantum mechanics."

5. Rae's book is titled, *Quantum Physics: A Beginner's Guide,* (2005) but it is not a beginner's book, not at all. The title makes it sound like it would be a simple and easy book to read. I minored in mathematics (my father was a mathematician) and I can testify this is not a beginner's book. I followed it for awhile in this book, but after awhile I couldn't track the mathematics of quantum mechanics any further.

6. Pascal writes: "I would not say quantum theory is inconsistent. It is true when people can be confused and see paradoxes when they view it from their everyday frames of reference. From Wikipedia (https://en.wikipedia.org/wiki/Precision_tests_of_QED):

"Quantum electrodynamics (QED), a relativistic quantum field theory of electrodynamics, is among the most stringently tested theories in physics. The most precise and specific tests of QED consist of measurements of the electromagnetic fine structure constant, α, in various physical systems. Checking the consistency of such measurements tests the theory. Tests of a theory are normally carried out by comparing experimental results to theoretical predictions. In QED, there is some subtlety in this comparison, because theoretical predictions require as input an extremely precise value of α, which can only be obtained from another precision QED experiment. Because of this, the comparisons between theory and experiment are usually quoted as independent determinations of α. QED is then confirmed to the extent that these measurements of α from different physical sources agree with each other. The agreement found this way is to within ten parts in a billion (10−8), based on the comparison of the electron anomalous magnetic dipole moment and the Rydberg constant from atom recoil measurements as described below. This makes QED one of the most accurate physical theories constructed thus far."

7. Pascal has added that superfluity and superconductivity are two macro-level manifestations of quantum mechanics. See http://scitation.aip.org/content/aip/magazine/physicstoday/article/43/12/10.1063/1.881218. Quoting from that reference: "A diverse class of physical systems—including superconductors, superfluid helium, lasers and quasi-one-dimensional conductors—derive their unusual properties from the macroscopic occupation of a single quantum state."

Pascal Gambardella, Ph.D.'s background:

My first paper in physics was published in the Journal of Mathematical Physics: Exact results in quantum many-body systems of interacting particles in many dimensions with SU(1,2) as the dynamical group. It is a solution to the Schrodinger equation. That is where I started. Now I like to work on models that contain people or organizations.

Journal of Mathematical Physics (Impact Factor: 1.18). 05/1975; 16(5). DOI: 10.1063/1.522651

ABSTRACT: We consider a class of system of N interacting particles in any dimension—the potential includes a quadratic pair potential and an arbitrary translation-invariant position-dependent potential that is homogeneous of degree -2. The group SU(1,2) $(1^{-},1^{-})$ is the dynamical group for the Hamiltonian. We illustrate the significance of the Casimir operator in relation to the separation of variables method; obtain a series of eigenfunctions that transform under the unitary irreducible representations of SU(1,2) $(1^{-},1^{-})$ labeled by the ground state energy; indicate the structure of arbitrary eigenfunctions; and specify when the complete energy spectrum is linear. We treat N-body examples which include two- and three-body forces. For N identical particles in one dimension interacting with a quadratic pair potential and an inverse square pair potential, we exhibit a series of eigenfunctions characterized by four quantum numbers. These eigenfunctions reduce to the complete set of eigenfunctions for five particles. We indicate how a complete set of eigenfunctions for N particles are obtained.