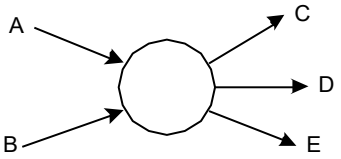
Comments with regard to *The Dancing Wu-Li Masters* PhL 11.24.06

Warning: there are facts and dates quoted below that come only from my memory, and I have not taken the time to check everything against web references, so I make no claim of complete accuracy in the following comments. Also, I have not thought seriously about this stuff for at least a quarter of a century.

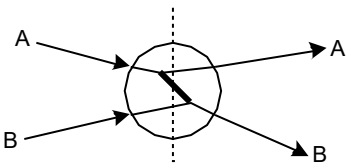
1. QED and S-Matrix Theory

When elementary particles collide with each other, they are deflected and often new particles are created just from the energy of the collision, the way heat might be generated in a head-on car crash. The goal of elementary particle theory has always been to predict what comes out and how it comes out when you send something in. Here is a picture showing a collision A+B $\rightarrow$ C+D+E (just an example)



In this picture, time flows to the right. Perhaps particles A and B have a head-on collision and out come A and B and some new particle E, so in this case we would have C = A and D = B. This is very typical of what happens "in the laboratory" meaning in a particle accelerator. The circle in the above picture is meant to signify the region of interaction of the particles.

In the 1940's a method was discovered for predicting "everything" regarding particle collisions, but only for a certain class of particles which includes electrons (called leptons). As long as A,B,C,D,E... were all charged leptons (or photons which are particles of light), the theory could correctly predict the result. Notice that the prediction must not only tell *what* comes out, but it must predict the speed and direction of every particle that comes out, as a function of the speed and direction and type of all incoming particles (at least in a probabilistic sense, see later). This successful theory was called QED and although the theory was developed by perhaps six famous people, the name Richard Feynman is usually associated with QED because he is the one who showed how to compute results using his Feynman Diagrams, which are shorthands for certain mathematical calculations. For example, here is the simplest Feynman diagram showing the "scattering" of two electrons coming in producing two electrons going out:



In this picture, the heavy bar represents a photon which exists only temporarily. At the time indicated by the dotted line, you actually have two electrons and one photon existing. The photon is "exchanged" between the two electrons, and that is how the electrons "interact" (more generally, that is how electrically charged particles interact, we are talking here about the "electromagnetic force"). In some sense, the electric charge of an electron causes it to have a probability of emitting a photon which can then be absorbed by the other electron, causing both electrons to be deflected. The above diagram and

others like it do in fact explain why two electrons "repel" each other (they both have negative electric charge), and the reason is that they interact by exchanging temporary "virtual" photons as shown above, even when the electrons are at rest. Why this exchange causes a repulsion is not intuitively obvious, however.

Feynman's QED theory was more or less finalized in 1949. There were certain technical math problems in the theory that have now been resolved (again, more or less). These problems relate to certain steps in the calculation of Feynman diagrams which appear to give infinite results. The repair of this problem is called "renormalization". The problem arises because the electron appears to be a collection of electric charge all jammed into a single point in space. If you were to try to create your own electron by compressing some "electric charge" together in this way, it would take an infinite amount of energy to do it. This is because the electric force gets larger and larger without limit as you push charges closer together. So it is somewhat a mystery how this charge is "contained" in the electron which really does appear to be a point particle, not spread out.

During the 1950's and 1960's people tried very hard to produce a theory like QED that would explain the *non*-electromagnetic interactions of small particles. In particular, they wanted to know how to understand the strong interaction of heavy particles ("hadrons"), such as protons and neutrons. This was of course of great interest because such interactions result in nasty things like atomic bombs. In all that time, no one could find a solid theory that explained strong interactions based on modification of the QED theory, and they became very frustrated.

A group of physicists decided to take a different approach which is now called S-Matrix Theory. Two leaders of this group were Geoff Chew, a Berkeley physics professor (my thesis adviser) and Henry Stapp (with whom I spoke on occasion), a researcher at the Lawrence Berkeley Lab in Berkeley (known earlier as the Radiation Lab). Both these people are mentioned in the Wu Li book. The idea of S-Matrix Theory was this: we don't really need to know the details of what happens inside the circle in the above pictures; all we want to know is what comes out and how it comes out. In the Wu Li book, this is described in the following language: we don't care about the dancers, we only care about the dance. If you make a list of all possible "inputs" to a collision, and another list of all the possible "outputs" (such as C + D + E in our first picture), you can describe any collision by a number (a probability, see later) which might be written $S_{input,\ output}$ where S stands for "scattering". This can be thought of as a matrix where the first index "input" labels the rows of the matrix, and "output" labels the columns -- hence the name S-matrix theory.

So how would you be able to calculate $S_{input,\ output}$? The idea was that this should be calculable from the many known constraints on physical processes. Three of these are : (1) conservation of momentum and energy; (2) conservation of probability (called "unitarity"); (3) various requirements of special relativity (called "analyticity") such as time reversal. This was a very radical theory in its time and had various buzzwords associated with it such as "nuclear democracy" (since all particles are on an equal footing) and "the bootstrap theory" (since the theory was supposed to define itself from all the constraints). Geoff Chew and his associates worked on this idea for all of the 1960's and into the early 1970's when I became Geoff's thesis student. It sounded like a very interesting theory to me and I learned a lot about it, investing large chunks of my time.

Unfortunately, in those same early 1970's people did in fact find a theory similar to QED which explained the strong interactions of the hadrons. This theory is now called QCD. Since I was half-way through getting my PhD degree when this theory was dramatically proven viable, it was too late to change course, and I was lucky to even finish the degree, since I was working in a "discredited" area. So in a sense, I started the race for a permanent physics job with a broken leg (more on this later).

Of course Geoff Chew and others might still claim that QCD is wrong and S-matrix theory is going to win eventually. Theirs is certainly a minority view right now, but may not always be so.

It is true that QCD has various technical problems (like the renormalization described above), and the theory is somewhat incomplete in that it does not let you compute "everything". But in its favor, almost every prediction that the QCD theory has made so far has been verified in the laboratory (to the extent the laboratory can do the experiment). In "science" (as opposed to "religion", say), you come up with a theory, it makes predictions, and they are either experimentally right or wrong. If they are right, the theory survives for the time being and is in some sense strengthened. If they are wrong, the theory is wrong, and you either have to modify it, or throw it out. The predictions of the theory must be testable by anyone, not just by the person who comes up with the theory. The Cold Fusion theory developed in Utah has been discredited because no one other than Stanley Pons and Martin Fleischmann could get the predicted experimental results. (This theory is undergoing modification all the time and certain workers still hold out hope for developing useful room-temperature fusion to generate electric power).

2. QCD and The Standard Model

QCD was firmly established around 1974, one of the main developers was Steven Weinberg. In that year, when I was at Berkeley, a new particle was discovered whose existence was predicted by QCD and it had all the right predicted properties. This particle was found at the same time in two different labs, one called it the PSI, the other called it the J. The particle turns out to be a hydrogen atom that, instead of being made of a proton and an electron, is made of a quark and an anti-quark. The quarks are the elementary particles of the QCD theory, and they interact in a manner similar to the electrons in QED. Instead of exchanging photons as in the second picture above, the quarks exchange particles called gluons. And instead of involving electric charge, the quark interactions involve a new kind of charge called "color charge" and color is the C in QCD, whereas electromagnetic is the E in QED. The QCD model is continuously being tested, but so far no one has found a testable prediction that is significantly wrong. It is now 2006, so this QCD theory has so far survived for 30+ years. Of course Newton's theory of mechanics survived much longer until it was overthrown by quantum mechanics.

A major problem in the development of QCD was this: (1) in QCD, quarks all have fractional electric charge (for example, 1/3 of an electron's charge); but, (2) no particle has ever been found (directly found, that is) which has a fractional electric charge. You can see why this was a strong argument against QCD.

It is now understood (inasmuch as theory and experiment agree on this point) that the reason for (2) above is that quarks cannot exist in isolation, but are "confined" to exist only in small groups of 2 or 3, and these small groups always have an integral electric charge when you add up the contributions of the members of the group.

Why then are quarks confined into small groups, whereas electrons are not so confined? The reason has to do with the behavior of the "force" implied by QCD versus QED. We all know that if we move electrically charged particles far apart, the force between them becomes very weak; in fact, the force "drops off" proportional to the inverse square of the separating distance. On the other hand, if we push two electric charges together, the force becomes stronger without limit as the separation goes to zero. In QCD, it turns out that the exact opposite is true. When quarks are very close together, the force between them is small, and they behave as little free point particles, and this has been confirmed by collision experiments (this behavior is called "asymptotic freedom"). But as quarks try to move farther apart, the force between them increases without limit. This is why you cannot pull apart the three quarks that make up the proton, for example. It turns out that the gluon particle is also confined.

Although QCD is now accepted by most physicists in the field, it still has major problems. One is that no one has been able to "solve" the equations of the model in a genuine sense, because the equations are

very messy. However, approximate solutions have given testable results which are always verified as being true in the lab. A similar comment can be made about QED, although its equations are not as complex.

By combining QED and QCD together, we have a theory which allows verifiable predictions to be made for interactions of electrons and photons as well as protons and neutrons. Many other short-lived particles like pions and kaons, as well as anti-particle forms of all known particles have been observed and all fit the theory when they interact. So far, then, the Electromagnetic (QED) and Strong (QCD) forces are being handled by the theory. Another obscure force called the Weak force has also been reasonably wedged into this theory, and weak interactions are also "calculable" and the calculations agree with experiment. The Weak force involves neutrinos as well as the recently discovered (after prediction by the theory) exchange particles like the photons and gluons, but these have the unglamorous names W and Z.

This combined model of QED + Weak + QCD is now called "The Standard Model". In this model, the "dancers" are the special particles like leptons and photons and gluons and quarks. Mathematically, each of these particles has something called a "field", somewhat like an electric field, and the framework of the theory is called "relativistic quantum field theory". This theory is correct from the point of view of special relativity because its predictions are correct even for particles going arbitrarily near the speed of light. And the theory is correct from a quantum mechanics point of view (meaning it works in probabilities, see below), and allows for the "creation" of new particles either permanently or as temporary intermediates, such as the photon in our second picture above.

The Wu Li book was written in 1979 when the Standard Model was still being firmed up, while its problems were being worked on, and before most of the events in the next section took place. It accepts QED as a valid theory for electrically charged particle interactions, but rejects QCD in favor of the S Matrix Theory as the correct theory of hadron interactions.

By the way, QED stands for quantum electro dynamics, and QCD for quantum chromo dynamics. The word *dynamics* refers to the mechanics of moving objects, in contrast to *statics* which refers to the mechanics of a static object, such as a ladder leaning against a house.

You can find a nice graphic which summarizes the Standard Model at this location: http://en.wikipedia.org/wiki/Standard_Model .

3. Gravity, GUTs and String Theory

The force of gravity -- the fourth force -- is *missing* from The Standard Model. People have worked very hard to make a quantum field theory of gravity, and to get this theory integrated into the Standard Model. All these attempts at making a Grand Unified Theory (GUT) have failed. In the gravity theory, the little exchanged particle (like the photon of QED or the gluon of QCD) has a name, even though it may not exist and has never been detected: the graviton. The idea is that all physical objects have a special kind of "mass charge" (really, just the mass itself) and by exchanging gravitons, you should be able to explain the gravitational interaction. This interaction, unlike that of the other forces, is always attractive, at least as we have observed it so far "locally". This may not be true on a cosmological scale.

I have never studied the quantum theory of gravity, so I don't really know why it is so intractable. I do know that the gravitational force between two small particles is awesomely smaller than the other three forces, although we are misled about this fact since we observe gravity always involving monstrous objects like stars, planets and moons. Since gravity is such a super weak force, no one has really been able to do any significant "lab" experiments to study the gravitational force in terms of particle interactions.

We know all about the classical limit of this theory when there are huge numbers of particles (planets), but we don't know the underlying microscopic quantum theory.

An early attempt at a GUT by my college teacher Sheldon Glashow had a major problem: it predicted that protons should decay into other particles at a rate much faster than is observed in the lab. As usual, when a theory makes wrong predictions, you have to give it up or modify it in some way.

Often gravity theories end up only being self-consistent if the number of spacetime dimensions is larger than 4 (3 space + 1 time). For example, one theory requires this number to be 11. Since 11 dimensions have not been observed in any experiment done by mankind, such a theory needs to be dismissed, unless it can be shown that the 11 - 4 = 7 extra dimensions are somehow "confined" like the quarks, but it is certainly unclear what that even means.

As early as the 1960's people were working on an alternate theory called "string theory" where the elementary particles are not little points like electrons and quarks, but are in fact extremely tiny hula hoops -- strings tied into loops. I think one motivation for string theory was the hope that strings might not have the renormalization problems discussed above which point particles have. Since all the charge is not forced to be at a single point, you don't get the infinities in the calculations. [I am just guessing about this since I know little about string theory.]

As the attempts to add gravity to the Standard Model kept failing, string theory became more popular, and now it is "all the rage" in a form called "superstring theory" which has something called "super symmetry". This theory is extremely heavy on the mathematics, is very complex, and has been studied by some people who are generally considered to be true geniuses by their fellow physicists. The theory has, however, several large difficulties. First, even though people have studied string theory for the last 35 years or so, no string theory has ever made a single prediction that is even testable (I believe this is a true statement, but it might be contested.) . Since there are no predictions, you cannot say the theory is right or wrong. Second, like the earlier gravity theory mentioned above, the string theories always end up with too many spacetime dimensions. An early string theory required 26 spacetime dimensions, while the current superstring theory requires 10 dimensions. As noted above, the universe we live in seems to have 4 spacetime dimensions. A lot of work has gone into the job of "explaining" these extra dimensions.

Nevertheless, string theory is wildly popular both with professionals and with the public. The public loves hearing about the strange goings in the "higher dimensions" and "parallel universes", as presented for example in a recent multi-part public TV series [http://www.pbs.org/wgbh/nova/elegant/] with lots of flashy computer graphics. You might like to take a look at the titles in the "Press section" of the following link which shows a very impressive publication list for a Harvard physics professor and string theorist Lisa Randall. [http://randall.physics.harvard.edu/CV.html#press]. This is, by the way, the kind of "CV" you want to have to stay "on the wagon", see below. She has recently written her version of the Wu Li book which I have not read, but which I imagine reviews lots of basic physics in layman terms [a bit like the Word document you are right now reading] and then describes the string theory efforts of the last decade. This book is titled *Warped Passages: Unraveling the Mysteries of the Universe's Hidden Dimensions.*

I recently read what I thought was an excellent 2006 book criticizing string theory called *Not Even Wrong* by Peter Woit. Although it purports to be for the layman, this book is really only readable by someone like me, and even then just barely. Woit, a combination physics/math person at Colombia, argues that string theory is neither right nor wrong. It is so useless and ill-defined that it is "not even wrong", a phrase used by a legendary physicist Wolfgang Pauli. The theory has 105 "freely adjustable parameters" which means you can probably make it explain anything you want with appropriate settings of the parameters. This is called the Alice's Restaurant Problem ("you can get anything you want at Alice's Restaurant. "). Even if you know all the "right" 105 parameter values, you still cannot calculate

anything because there is no plan for calculation like the Feynman diagrams of QED. Although it is called superstring "theory", Woit argues that it is not really a scientific theory at all, since it makes no testable predictions. Woit calls it the "hope of a theory", and feels it is now slowly moving into the religious realm and out of the scientific realm. The joke is that the theorists should apply for funding to Bush's department of Faith Based Initiatives. He argues that after a theory fails for many decades, perhaps it is time to start thinking about something different.

Why has string theory persisted for so long as "the only game in town"? One reason Woit says is faith that the leading geniuses like Ed Witten at Princeton will have a breakthrough. These people have had breakthroughs in other areas and might do it again. Another reason is more political. It is so hard to learn string theory that by the time you have invested 5 years of your young energetic life learning it, you don't want to admit failure, give that all up, and start into some new approach -- which will necessarily reduce your output of papers. The leaders of all the particle theory groups in the world are now mostly string theory people, and they tend to hire young postdoctoral PhD's who are doing string theory. For the last many years (including my time) the US has produced about 100 particle theory PhD's per year. After the long session of musical chairs (multiple 3-year postdocs, tenure *track* jobs, etc), there are about 10 permanent jobs for these 100 people, so on the average each year 90 have to fall off the wagon, something that I did after my first postdoc in Utah (where I was sponsored by Jim Ball and his NSF grant; Jim was also a thesis student of Geoff Chew). I was lucky to get *any* postdoctoral fellowship, and just by going to Utah I had already fallen off the wagon, since Utah is a far cry from Harvard, Princeton, Berkeley, Stanford, Oxford, and so on. I saw the writing on the wall and decided not to play the game (Woit came to the same personal decision). The competition for the few real jobs is very intense, one needs to write as many "papers" as possible to stay in consideration for a real job ("publish or perish"), and those papers had better be on superstring theory, because that is what the people looking to hire you are interested in. These same people in effect control the government grant money that goes to theory groups from DOE and NSF. This is the gist of Woit's book, and based on what I have seen, I think it might very well be exactly true.

Just to get the scale of things here, there are only about 500 permanent particle physics theory jobs in the US (professors), and at any time there are about 500 graduate students working on their 5-year particle theory PhD programs. The US particle theory budget is around $30M which is a drop in the bucket compared to the budget for all of physics research, which in turn is very small compared to the entire US natural sciences and engineering budgets. However, the subject of "particle theory" remains of great interest, since the whole hierarchy of physical science rests upon it: particles, atoms, molecules, non-living and living objects.

I should point out that there are many professors who work in *experimental* particle physics as opposed to particle *theory*. These experimentalists design, build and run the very complex and expensive particle accelerators which provide the tests on the theories. A new accelerator is coming on line in 2008 in Europe, and is known as LHC, the Large Hadron Collider. You now know exactly what that machine is going to do: crash strongly interaction particles (protons) into each other at very high speeds. Perhaps new discoveries from LHC experiments will provide a spark needed to move the theory world forward.

The Woit book points out that Einstein spent the entire last part of his life, several decades, trying to find a way to combine gravity with earlier theories. He was looking for a mainly non-quantum theory because he did not like the whole nature of quantum mechanics, of which he was in fact a co-discoverer thanks to his early papers. He never succeeded, although he was definitely a genius.

4. Quantum Mechanics

In Newtonian mechanics (called classical mechanics from our current day's perspective), you calculate the trajectory of a particle that is acted upon by a force. Think cannon ball. You can compute at each point in time where that ball will be. The trajectory might be in the form of three functions x(t), y(t), z(t) where t means time and x,y,z are the three position coordinates of the canon ball.

In quantum mechanics, there are no such trajectories. Instead, what you compute in quantum theory is something called a wavefunction which is usually written $\psi(x,y,z;t)$, meaning we have a function of 4 variables x,y,z and t. Ignoring a detail not important to our layman discussion, this function ψ describes the *probability* that a cannon ball is at location (x,y,z) at time t. If you integrate over all locations in space at any time t, the total probably that the cannon ball is somewhere is exactly "1".

One writes this fact as follows: $\int_{-\infty}^{\infty} \psi(x,y,z;t)\, dx\, dy\, dz = 1$. This mathematical fact is called "unitarity" in S-matrix theory, which was mentioned earlier.

So what you end up with is something like a trajectory, but instead of having a razor sharp curve that a particle follows, the trajectory is blurred out and is described by $\psi(x,y,z;t)$. For a large cannon ball, the function $\psi(x,y,z;t)$ really results in the classical trajectory, and this is an example of how the classical limit of quantum mechanics agrees with Newtonian mechanics. This is because a cannon ball is a large object. For a small particle, however, the wavefunction does not look at all like a parabolic trajectory. When one studies chemistry and studies the valence electrons of atoms, one always sees little blurry pictures called "the electron cloud" (sometimes called orbitals). This cloud is in fact a picture of the wavefunction $\psi(x,y,z;t)$ describing the probability distribution of an electron.

In his famous comment that "God does not play dice", Einstein expressed his extreme discomfort with a theory that could not predict things exactly and precisely. He knew that quantum mechanics was "right" in that its predictions always agreed with experiments, but he did not like it. Presumably he thought there was some more detailed theory that would be discovered that would allow exact predictions, not just predictions of probabilities. Most physicists, however, now think the probability idea is going to stay around for good and is just the way the universe works.

While thinking about Einstein, the reader should be reminded that his "special theory" describes the motion of objects at very high speeds, and says nothing can go faster than the speed of light. His "general theory" describes what is now called the classical theory of gravity, meaning that planets warp space and make it curved in some sense, and there are such things as black holes, etc.

It is important to point out that no experiment ever done by any human being has produced a result that conflicts with quantum theory, or with the special or general theories of relativity. If you could come up with such an experiment, you would be very famous. Remember: such an experiment has to be repeatable by other people.

5. Crackpots

Physics has always had its share of crackpots -- people who come up with wild and usually un-testable conjectures and theories that are tied in some way to *bona fide* theories. There is a whole spectrum of crackpots, ranging from those just a little off the beaten path to those way out in the tall weeds. Some of these people are well-meaning and their theories may even be correct, while others are not well-meaning and are simply seeking publicity to inflate their own egos. It is always possible of course that today's crackpot may be tomorrow's Nobel Prize winner, and history undoubtedly can supply some examples. Usually, however, even radical new ideas (such as the discovery of DNA and its significance) are presented and then tested fairly near the mainstream, if not directly in it.

Particle physics like any other field has its share of crackpots. You see papers talking about the "consciousness" of elementary particles, extra sensory perception via particles, similarities between certain field theory equations and writings on old Buddhist artifacts, comparison of S-matrix theory to Eastern philosophies, and so on. A common theme in the latter category is that the arrogant impetuous western philosophy takes a long time to come back full circle to what the ancient Buddhists already new so long ago. I once knew a guy Fritjov Capra who wrote a book *Tao of Physics* when I was at Berkeley (and which I read). He and others were very attracted to Geoff Chew and the Berkeley group because the genuine Berkeley professors lent credibility to their efforts.

In the context of our discussion above, Mr. Woit might think of Ms. Randall as being somewhat of a crackpot, writing whole books about extra dimensions, as if they really existed and were a proven fact. And in turn, Ms. Randall might think of Mr. Woit as being a crackpot inasmuch as he refuses to work in the mainstream field of superstring theory. One person's terrorist is another person's freedom fighter.

I think the Wu Li book falls into the *Tao of Physics* category. As I scanned the book, I saw lots of good physics topics being presented in layman's language, with the constant background thread of trying to tie physics ideas to Eastern philosophy. I felt the presentation is somewhat condescending to the layman reader, what with the cutesy chapter titles and all, but that is perhaps just a question of writing style. The Buddhism stuff just left me stone cold, however. Here is a review from Amazon that I think summarizes my thoughts about this book:

This book implies that you will get a startling revelation by reading it, but when all is said and done, it's basically a 314-page layman's introduction to quantum physics and relativity, with a few doses of "And that's just what Buddha was saying all along!" thrown in.

Here is the book in a nutshell: "From the time of Newton until about 1900, physicists thought that physics was a set of provable laws about predictable forces, such as gravity, operating on solid objects. However, a series of experiments around the turn of the last century, conducted by Michelson, Planck, Bohr, Einstein, and others, showed first that the behavior, and later even the nature, of light, of subatomic particles, and other fundamental elements of the physical world were not at all what we thought. The world we 'see' may seem solid and predictable, but at bottom, we are entitled to wonder whether 'matter' even exists at all in any permanent way, or is just a momentary meeting of forces that we call 'matter' as a convenience. Interestingly enough, this echoes some things said centuries ago by the Buddha and other eastern philosophers about the fundamental nature of reality."

There. If you read that, you've basically read the book, but mercifully without Zukav's "Oh, wow, it's just so...like WOW" tone. I have no idea whether the details are correct in his discussion of physics, though he claims his manuscript was checked and approved by experts, chapter by chapter. As a technical writer, I was rather surprised to see occasional lapses in copy editing, such as printing "even horizon" for "event horizon."

But the book actually amounts to less than what Zukav thinks it does. If you want to learn physics, you can go read a physics book. If you want to learn about eastern philosophy, you can read the Bhagavad Gita or the Tao Te Ching. But basically, Zukav's book amounts to saying something like, "Gosh, you know, they've found out that even the biggest ocean wave is just made up of drops of water! And even the smartest scientist can't tell you just which drop will be where, in that big ocean wave! So that proves that a tidal wave is just a construct of our rational minds!"

Uh huh. And meanwhile, we still have the tsunami. To the extent that this book contributes anything to knowledge, it really would have worked better as an article in "Harper's" or "The Atlantic." I've basically said all that was worthwhile in it in one paragraph, above, and Zukav didn't need to recite every last detail of particle physics to show that the Buddha knew that a mountain is only so many grains of dust.

At the same time I have to praise any book that successfully motivates "lay" readers to read about physics, and if the Buddhism hook works, fine. My friends refer to such hooks as making the subject more "touchy-feely" and thus less threatening. Without such books, many people would go cradle to grave without knowing anything whatsoever about Feynman diagrams, special relativity, and all these

great things that form testable scientific theories. Other topics such as Buddhism and art history are also very interesting, but they are not part of science and usually don't get mixed into science books.

6. Bell's Theorem

The Wu Li book mentions this subject which certainly is intriguing. My PhD office mate George Weissman (also mentioned in Wu Li) wrote his thesis on this subject, though I never read it. Bell's Theorem says that either quantum mechanics is wrong, or that particles can communicate with each other over arbitrarily large distances *instantaneously*, and in particular, they can communicate with each other "faster than the speed of light". So Bell's Theorem appears to invalidate either quantum mechanics or the theory of special relativity. I think you might find it very interesting to read the following proof of Bell's Theorem which is beautifully presented in a one web-page document with a few pictures and the entire math involved is that $5/9 > 1/2$.

http://www.ncsu.edu/felder-public/kenny/papers/bell.html

This is a wonderful example of what is meant by "a thought experiment" that Einstein liked to work with. In fact, he is one of three authors that discovered this paradox (Einstein, Podolsky and Rosen 1935). The conclusion seems to be that quantum mechanics is correct, that the particles do in fact communicate faster than the speed of light in some sense, but that you and I cannot create an apparatus that can piggy back on this fact so that *we* can communicate faster than the speed of light. I am not an expert in this subject, but merely throw out the above link as being very fascinating and understandable to the lay reader.

7. Richard Feynman [1918-1988]

Right this minute you can attend a layman's lecture on QED presented directly by Richard Feynman at this web location: http://www.vega.org.uk/video/subseries/8. When you have a little time, listen to the first 10 minutes of the first lecture on "photons" and you will understand what Feynman is all about.

As with all web links in my comments here, if they become defunct, you can always relocate the material with a quick web search.