Naked Woolly Dancers

A Book Review of a book by Gary Zukav,
"The Dancing Wu Li Masters, An Overview of the New Physics," Bantam New Age Books, New York, 1980.

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Foreword 2002a: Insights from a Visit to Fermilab

It was my privilege, in July 2002, to be invited to present one of the weekly Colloquium talks at Fermilab, a Department of Energy National laboratory dedicated to resolving the remaining mysteries in particle physics, and there are many. So what was the Colloquium about? A mixed bag of allusions to the science underlying the long-term safety evaluations done for a potential high-level nuclear-waste repository at Yucca Mountain, Nevada (it is what I do for a living). I wanted these scientists to be asured there was science underlying those evaluations. I worry and fret over that science and the calcualations that use it as a basis for judging how the system behaves up to 10,000, 100,000 and a million years into the future. Nice job, actually, very interesting. To me.

I also took the opportunity to tell these people they were my heroes. They were enaged in doing what adds to our humanity, looking for clues to explain to ourselves how the universe works. As you will find out if you keep reading, I was challenged at one point to read "The Dancing Wu-Li Masters" by Gary Zukav, because in some new Age discussion or other I had made a statement that violated what many New Agers know to be true: there is faster-than-light travel, it has been demonstrated by science; and all the subatomic particles we look for come into existence because we postulate them and look for them. They are created by the experiment and the experimenter's expectations. They don't exist otherwise. All is illusion. Etc.

The person that challenged me to read Zukav's book was a friend. Now that he knows how I feel about Zukavian physics we simply don't discuss it anymore. We don't discuss much of anything anymore. Of course he thinks I am a kook, way off base, etc., and I harbor similar thoughts about his continuing adamance that Zukav is right because his physics shows his own inner belief structure is corroborated by science.

So I read the book and it really, really infuriated me. The science was half correct and half outrageously incorrect, and I am not at all a physicist and probably judged incorrectness by completely wrong criteria. But I was sufficiently enraged that about 8 books and many articles later I wrote a lenghty (103 small pages) rebuttal, told Zukav about it in an email and invited his comments, heard nothing and posted it on my website with the title "Naked Woolly Dancers." A parody of the book's title. To my amazement its first page is one of the most popular pages on my website, thousands of hits! But only about a dozen people have gone to the rest of the pages.

You may not believe this, but it took me months to figure this out. It finally dawned on me when I saw a billboard in Las Vegas for "Exotic Dancers, Direct to

Your Room, Totally Nude." People were putting these types of words into their computers and searching the Internet for some word string containing "naked" and "dancers" and I bet their little hearts beat wildly when my suggestive title appeared in the list of Internet sites! Then they 'click,' and get words only, worse than that, they are words that have something to do with physics. Yuck! But no one, I hope, dies from having high hopes dashed!

One of the physicists at that laboratory was kind enough to take me to dinner and give me some pointers on what to expect in my address the next day, in terms of questions, and what may be of interest to this particular audience. When I expressed my enthusiasm at being here among people that are doing what I wished I could do, investigate the nature of matter and the universe, and how I had struggled to rebutt the Zukav book, she nodded her head and agreed that there certainly was a lot of bad science in that book. But imagine my delight when she told me that in my readings I should have run across a book by the Nobel laureate who ran Fermilab for many years until his retirement, Leon Lederman. Sheepishly I had to admit I did not run across this book. I didn't tell her this, but the reason I miised it is that I simply skipped over it when searching the Clark County, Nevada, library holdings on the topic of physics. It is a very good public library system, it actually has two copies of the book! But I am not perfect, obviously, since I somehow dismissed it in my searches [maybe the title threw me, not realizing it was a humorous title]. But now I have it, bought it at Fermilab, and have been devouring it ever since.

Lederman, as I am now almost done with his book, created a really fun read. It is about what they do at Fermilab, and about particle physics generally. It is called "The God Particle," his nickname for the Higgs boson, an energy field (particles and fields seem to be so intimately related that the 'Higgs field' and the 'Higgs boson' are both acceptable descriptors for what is now being sought). If it exists it will be found. If found it will complete the model of subatomic particles and forces that has been worked on for decades by thousands in the U.S. and, cooperatively, in many other countries. If it doesn't exist the model goes in the trash bin and the world starts over on trying to understand the universe at the subatomic level.

In the Lederman book he has a short section that takes on the Zukav book. I am in great company to be picking on Gary's attempt to rewrite physics to support the New Age's (and Buddhist and Muslim and Christian mysticism's) notions of reality=illusion. [Are the mystics wrong? No, they are just coming from a very different perspective is all, and are not speaking of physical reality being unreal as much as they are talking about the human soul's need to saty focused on its mission of rejoining the Divine Source and not getting trapped in materialism.

The idea that things do not really exist has been uttered by some mystic visionaries, and New Age gurus, but revelation is notoriously difficult to interpret, and any attempt to bring the inherently ineffable down into concrete langage and certain meanings is a violation of common sense. Creating an orthodox belief system out of the ephemeral insights obtained by sensing or intuiting the ineffable is dangerous. Any belief system that people understand and feel confort in creates defensiveness against challenges and leads to calls to curtail further experimental work that in a believer's mind seems expressly designed to challenge his or her cherished beliefs. That is where Zukav (and his scientist supporters) is: like a creation-scientist defending the faith by calling for an end to evolution research he (they) are calling for an end to particle-physics work. Why? Because their version of reality says there is no merit in looking further. All that will be seen from now on is what is anticipated by the experimenter and created by the experiment. To which all I can do is agree with what was said by a different physicist in a different context:

[Source: http://www.fnal.gov/pub/ferminews/Ferminews02-04-19.pdf] "Boston University theorist Ken Lane is frustrated that particle physics is a hard sell compared to, say, research on the human genome. "I don't get it," Lane said recently. "Particle physics is the most fascinating science that there is. And I'll tell you one thing: there was physics long before there was DNA, and long after there isn't any more DNA there will still be physics." Perhaps only a physicist would find that a comforting thought. While Lane's invidious comparison of physics and DNA may be faulted for a certain lack of political correctness, his frustration reflects a long-held view that particle physics has a unique place among the sciences, namely that when you get down to it, particle physics is the basis for them all."

You can see the context is very different, but it is exactly my thought on reading stuff by Zukav and his promoters that says the universe is not real, it is imagined by us. Excuse me? The universe was here long before we were and will be long after we are gone. And you can take 'we' as far as you want, to the immediate us, to humanity, or even to DNA in the extreme. There is a reality greater than us in which we developed. For us to then wake up into sentience and suggest we are its creators is the ultimate absurdity.

Lederman took Zukav on gently and in good humor. I was mean if not quite humorless. Lederman's book is a fun read. My diatribe is one you really have to want to read to get through it. If you have read Zukav and liked that book, but now you want to learn more about particle physics and what it is really about, I would heartily recommed you spend the 15 dollars and get Lederman's book. If you don't have 15 dollars order it through your local library and wait. If you do not wait well, and you can tolerate poor but impassioned writing, keep reading.

Foreword 2002b: Reading the Lederman Book "The God Particle"

These are some of my notes made while reading the book by Leon Lederman and Dick Teresi titled *The God Particle; If the Universe Is the Answer, What Is the Question?* (1994, Delta/Dell Publishing, New York).

Lederman and Teresi composed a delightful read. You can tell the tone of the book, lighthearted, on the first page where the Greek philosopher Democritus (circe 400 BC) is cited saying something as profoundly true today as it was then: "Nothing exists except atoms and empty space; everything else is opinion." Lederman and Teresi spend some time explaining that Democritus' atom is not the chemical atom, which can be divided into many subatomic particles. Democritus meant the indivisible atom, the elementary particles of which chemical atoms are made.

If one understands there is a good-natured rivalry, sometimes breaking into tension, between theorists and experimenters in particle physics, one can enjoy the jokes that Lederman, the experimenter, makes at the expense of his theorist colleagues. And there are many such jokes and jabs, all in fun from Lederman's perspective at least. But he does set the record straight, in a more serious vein, on page 13: "Physics in general progresses because of the interplay of these two divisions." And on page 14: "The interaction of theory and experiment is one of the joys of particle physics."

That same rivalry, in the hands of another author, Gary Zukav in his *The Dancing Wu-Li Masters* turns experimentalists into mere mechanics, and makes theorists into the only real physicists. Whoever told him that was not telling the whole story about how progress has been made in the science of particle physics, and will continue to be made.

Speaking of the Zukav version of physics, later in this book review I tell a long story about a thought-experiment, made into reality. The experiment shows Bohr was right in claiming that quantum theory provided a complete explanation for the rsults of all imaginable experiments, and Einstein was wrong in claiming there were unmeasurable but real properties that determined the outcomes of subatomic particle experiments. The experiment is also a cause-celebre for those looking for proof of the existence of faster than light travel.

Lederman covers this subject on his pages 186 through 188. Lederman explains the argument between Eisnstein, Podolski and Rosen (EPR) and their thought-experiment on the one side, and Bohr on the other. Einstein believe that quantum theory was incomplete, and that there were unknown variables that determined the outcomes of experiments, variables unknown and likely unknowable. A theorist named Bell wrote a theorem that placed the EPR type of experiment within reach of experimentalists, and one by the name of Aspect performed the experiment in 1982, in Paris. The experiment involved long-distance correlations between the properties of twin particles emating from a source at the same time, and showed Bohr was right, Einstein wrong, with respect to the issue of whether or not quantum theory explained observation in experiments. Bell talks of quantum theory, according to lederman, as being as "complete-as-can-be." Lederman says to the question whether or not this experiment by Aspect and interpretation by Bell ended the debate: "No way. It rages today." And he then suggests that "quantum spookiness" is still invoked in the theorizing that is being done on the origin of the universe. The universe at the time of the Big Bang's start had a subatomic dimension, according to Ledermans. But, as if throwing his hands up at that sppoky idea, he then says: "I'll stick to my accelerator research" . . . . where the ". . . road to the God Particle –or at least its beginning– is now very clear."

Lederman takes on the Zukav book and some others like it in a digression within his own book. He calls this digression an 'interlude,' and his Interlude B is on pp. 189 through 198 and is euphemistically called "The Dancing Moo-Shu Masters." [I seem to be in good company making fun of the title of Zukav's book!]

Lederman cites both *The Dancing Wu-Li Masters* by Gary Zukav and *The Tao of Physics* by Fritjof Capra as books that are the most prominent out of a larger number of books seeking to tie the spookiness of quantum physics to the spookiness in some ideas of Eastern Religions and the New Age. On page 190 Lederman states that: "There is some good physics writing in both of these books, which gives them a feeling of credibility. Unfortunately, the authors jump from solid, proven concepts in science to concepts that are outside of physics and to which the logical bridge is extremely shaky or nonexistent." He then shows (pp. 190-191) what he means by citing Zukav's treatment of the double-slit experiment by Thomas Young as a good physics-description followed by an incredible interpretation. Lederman contrasts Zukav's description of the photon as an intelligent, "organic" particle with his unqualified assertion that there are no such things as atoms physically, that none have ever been seen, and that they are but "hypothetical entities constructed to make experimental observations intelligible." Lederman says that in fact atoms can be seen, they are real. Asking how a photon knows whether either one or two slits are open is an irrelevant question, according to Lederman, and concluding that photons are intelligent . . . "is fun, perhaps even philosophical, but we have departed from science."

Lederman says that Fritjof Capra, in his book, is . . . "much cleverer, hedging his bets and his language, but essentially he's a non-believer. He insists that the 'simple mechanistic picture of building blocks' should be abandoned. Starting with a reasonable description of quantum physics, he constructs elaborate extensions, totally bereft of the understanding of how carefully experiment and theory are woven together and how much blood, sweat and tears go into each painful advance." (P. 191) But, Lederman continues, these two books are the best of the lot and . . ."constitute a relatively respectable middle ground between good science books and a lunatic fringe of fakes, charlatans, and crazies." (The phrase "damning with faint praise" comes to mind!)

The remainder of this "Interlude" is dedicated to showing that some of the confusion about the implications of quantum physics in the larger world is the fact that different laws of physics apply as good approximations of reality at different time and distance scales, and the laws of Newton still work even though Einstein suggested several corrections for explaining the early moments of the universe. At the subatomic scale still other laws and relationships apply. But what applies at one scale does not automatically apply at every other scale, neither does it negate what obviously works at those other scales.

The main method of exploring the subatomic universe is to perform experiments that accelerate particles toward each other so that their collision speed is near the square of the speed of light. According to the $E=mC^2$ formula of Einstein, this provides sufficient energy to change matter to energy. In the aftermath, the resulting energy may coalesce back into matter and/or radiate excess energy. The resulting matter may or may not be of the same type as was originally accelerated. These outcomes, however, do not mean that the experimenter created the resulting matter in his or her mind, and that it really does not exist. They are repeatable experiments using the same setup, and results concerning a specific particle associated with a specific energy range in the collision can also be, and often are, duplicated using different types of accelerated particles, giving an independent line of evidence for that specific particle's existence (even though it may take billions of collisions to create just a few, and they may be extremely short-lived).

Lederman, in his book, describes these types of experiments and their outcomes in a non-mathematical and delightfully easy to read style interspersed with good humor and wonderful historical insights. He celebrates the discovery of the first subatomic particle, one without a size attribute, a geometric point, a real enigma that has no doubt already paid for every research project to do with particle physics many times over since it came into general use: the electron. He walks through every subsequent discovery, introduces the Standard Model, created by an interplay between the math and thought of theorists and the findings of experimentalists, and gets to the book's title when explaining that there is a particle or two left to find, the 'top quark' and the 'Higgs boson,' carrier of the Higgs field that organizes and gives a context defining the mass of all matter, hence its whimsical description as the "God particle." Since the book's publication, the top quark has been seen, in 1995 at Fermilab and confirmed by others, and the race for the Higgs boson is on. And if it is not found? Time for new theories and models!

This quick description misses the high drama and hard work described on the pages of the book, and the genuine insight offered regarding such esoteric ideas a string and superstring theory. To understand where these new ideas are making contributions to perhaps someday finally folding gravity into quantum physics and completing understanding of matter the book needs to be read. His last chapter also describes the close reliance of astrophysics and particle physics on each others' work and theories. After all, the grand collisions of the accelerators are attempting to re-create what the universe must have been like very shortly after the Big Bang.

Lederman has some fun in every chapter but does an exceptional job in the last part of his last chapter where he does what others have done before when writing about science. He provides an "Obligatory God Ending" in imitation of these other works. He reviews several books and detects two approaches to writing this type of ending for a book: one puts man in his totally insignificant place as a temporary grease-stain in a mechanistic mindless universe; the other makes man the creator of all there is. He combines the two in a most satisfying way. To me it seemed a thoughtful yet hilarious last poke in the eye of the great ego of an archetypical astrophysics theorist like the ones who have been contaminated with Zukav-type beliefs (or who contaminated Zukav with their beliefs) in the human mind's defining and making the universe what it is. Then comes the revelation, one we as the reader see and understand, but it is likely unseen by the triple-Nobel endowed theorist whose colossal ego Lederman is taking a last good natured poke at.

But, am I going to steal lederman's last paragrpah in his book and serve it to you here? That would not be right, get the book My local library has 3 copies, yours should have one too.

So, was there anything in the Lederman-Teresi book that made me get off my high-horse and revise my nasty Zukav book review? I thought for a while there might be an instance where Zukav was right and I was wrong. The one thing in the Lederman book that surprised me and made me revisit the Zukav book review that I did some years ago was Lederman's treatment of matter in vacuum. On first reading it left me thinking I was back in Zukav's world! Well, all except for one word: "virtual."

I pick on Zukav mercilessly for suggesting something similar to what Lederman suggests on his page 278, which is that: . . . "so-called empty space can be awash with these ghostly objects: virtual photons, virtual electrons and positrons, quarks and anti-quarks, even (with oh god how small a probability) virtual golf balls and anti-golf balls. In this swirling, dynamic vacuum, a real particle's properties are modified . Fortunatlely for sanity and progress, the modifications are very small. Nevertheless, they are measurable, and once this was understood, life became a contest between increasingly precise measurements and ever more patient and determined theoretical calculations. For example, think about a real electron. Around the electron, because of its existence, there is a cloud of transient virtual photons. These notify all and sundry that an electron is present, but they also influence the electron's properties. What's more, a virtual photon can dissolve, very transiently, into an e^+ e^- pair (a positron and an electron). In the blink of a mosquito's eye, the pair is back together as a photon, but even this evanescent transformation influences the properties of our electron."

On his next page Lederman ties this theoretical idea to the existence of messenger particles that define fields that affect the properties of matter within their influence, and ends with this humorous observation: "Very abstract stuff, but the agreement between theory and experiment is sensational and indicates the power of the theory." A compliment for the work of theorists!

But is Lederman speaking of the vacuum of outer space with little to no energy, or the vacuum of an accelerator writhing with energy? I think his discussion on page 278 indicates the latter. After explaining that virtual particles do not move from point A to point B nor they they cause a click on a Geiger counter, he explains: "Messenger particles –force carriers– can be real particles, but more frequently they appear in the theory as virtual particles, so the two terms are often synonymous. It is virtual particles that carry the force message from particle to particle. If there is plenty of energy around, an electron cam emit a real photon, which produces a real click in a real Geiger counter. A virtual particle is a logical construct that stems from the permissiveness of quantum physics. According to quantum rules, particles can be created by borrowing the necessary energy. The duration of the loan is governed by Heisenberg's rules, which state that the borowed energy times the duration of the loan must be greater than Planck's constant divided by twice pi. . . . This means that the larger the amount of energy borrowed, the shorter the time the virtual particle can exist to enjoy it."

The point is that it takes energy to have "empty space awash with these ghostly objects," as Lederman put it. To me this suggests special circumstances, such as the vacuum in an accelerator, or perhaps at the fringe of a black hole where astrophysics suggests particles appear and disappear leaving signatures of detectable energy marking such boundaries.

So, this is the exception to the rule I found when reviewing books by which to judge the Zukav book. In my review of that book I denounced his idea that space's vacuum is a boiling cauldron of energy continually sliding into ephemeral matter and back into energy. Apparently this is the phenomenon that allows us to detect black holes where there is a massive amount of energy and a continual inpouring of particles. A natural accelerator?!

Introduction

I loved Gary Zukav's "The Seat of the Soul"[1] and liked his "Soul Stories."[2] So, with the added incentive of a friend's recommendation, I finally also read his "The Dancing Wu Li Masters,"[3] more than 20 years after its initial publication.

The few bones I had to pick with the book I loved (Seat of the Soul) and the book I liked (Soul Stories) were where I felt Zukav was departing from teaching me to see my own vision, and was, I felt, attempting to move me ever so slightly into seeing his vision. I am overly sensitive on this issue, I know, but it makes me feel that I am being proselyted, rather than being in a discussion (however one-sided it is in book form), and I simply don't like it.

I also did not like his taking a tiny intuitive insight, even if it was one I totally agreed with, and painting it all over the universe as an incontrovertible fact and as part of reality. I am more cautious. So in several instances I was uncomfortable with his grand interpretations of what, to me, were little nuggets of genuine insight, but of limited scope and interpretability.

When I got to "The Dancing Wu Li Masters" I saw that the book is filled with these same types of grandiose statements that are extrapolated universally from findings that belong to a very specific context, according to my reading. Where I would be more cautious and try to preserve context, Zukav would boldly generalize. And when it comes to the physics, I believe he was often wrong. But that is my opinion, and reading more on the subject shows me that some physicists would endorse Zukav's rewriting of what he learned from physicists, and others would not, to put it more mildly than it should be put.

Since it is more than twenty years later, if Zukav were to attempt this book now, I believe he would have a hard time. Most of his more astounding conclusions derive directly from a strict adherence to what is called the Copenhagen Interpretation of Quantum Mechanics in the book. It is an interpretation I, as a non-physicist, instinctively distrust. My further reading shows me that others, with recognized names in physics, see it as I do. But the majority of physicists,

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[1]Gary Zukav, "The Seat of the Soul," Fireside, New York, 1987.

[2]Gary Zukav, "Soul Stories," Simon & Schuster, New York, 2000.

[3]Gary Zukav, "The Dancing Wu Li Masters, An Overview of the New Physics," Bantam New Age Books, New York, 1980.

according to several sources (see Herbert[4] for one example) are accepting of the orthodox interpretation. Another view is that what Bohr revealed to the world from Copenhagen in 1913 is now known as the "old quantum theory." Lederman's book mentioned in the two updates for 2002 at the beginning of this review makes this observation on page 162 of *The God Particle, If the Universe is the Answer, What is the Question?"*

My point is that in my opinion almost all of Zukav's "new age" interpretations of physics, even the ones I agree have a basis in human experience, are tied to what are at least questionable interpretations (because they are being questioned, by physicists). Also, from my readings I gather that the tide is strongly shifting away from the orthodox interpretation as it is related and interpreted by Zukav. But that is my view, bolstered by readings from a small, selected reading list.

I feel I need to make a disclosure here. I confess that I was trained as, and work as, a scientist. Hence my instinctive cautionary approach where another may be instinctively bold.

All in all: I am glad I read the books in the sequence in which I did. Had I begun with *The Dancing Wu Li Masters*, I might not have read Zukav's later books which, all in all, are deeply insightful. They are insightful in ways I can, usually, fully appreciate and agree with from my own experience. I especially recommend his Seat of the Soul (see footnote 1) highly.

I have nothing whatever against mysticism and the visionary and intuitive approaches to obtaining knowledge. I have written positively on those topics myself. I just don't think they have much to do with the physics, new or old, described in Zukav's book.

Zukav and several others seem to insist that electromagnetic radiation has something to do with the inner life of a human being. Maybe so. But I think it is wrong to twist and turn physics to make it appear like it is dovetailing with the insights of mysticism. I think the view that is being taken of both physics and mysticism, in Zukav's book, is too limited, and the mystical experience is being interpreted in too materialistic a fashion if the waves and particles of the quantum world are seen as the media for the mystical experience.

In the ancillary reading I did to gain a broader perspective on Zukav's book, I was particularly taken by a statement by David Bohm, a physicist who cites Zukav's book, by the way, as approvingly as Zukav cited him in his The Dancing Wu-Li

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[4]Nick Herbert, "Quantum Reality, Beyond the New Physics," Anchor Press/Doubleday, Garden City, New York, 1985, pages 117-121.

Masters book:

> . . . the smallest distances that have thus far been probed in physics are of the order of 10^{-16} cm. On the other hand the shortest distance that could have meaning in present-day physics is of the order of 10^{-33} cm, the so-called Planck length, at which it is generally agreed that current concepts of space, time and matter would probably have to change radically. Between 10^{-16} and 10^{-33}, there is a factor of 10^{+17}, which is about the same as that between 10^{-16} and ordinary macroscopic distances (of the order of 10 cm). Between 10 cm and 10^{-16} cm lies a tremendous possibility for structure. Why should there not be a similar possibility between 10^{-16} cm and 10^{-33} cm, and perhaps even beyond even this? [5]

It seems to me that if one is looking for a physical explanation for para-psychic phenomena, that it could well lie in this completely undefined realm. It is a totally unknown part of our reality that, no doubt, conforms to laws as strange to quantum mechanics as the laws governing particle physics are to the laws of Newtonian, classical-world physics! But it is always easier to look where the light is (pun intended).

Now that you see the flavor of my writing, I'll guarantee that if you continue to read, the flavor stays the same: critical. So, proceed at your own risk.

But first one point of agreement.

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[5] David Bohm, "A new theory of the relationship of mind and matter," Reprinted from "Philosophical Psychology," Vol. 3, No. 2, 1990, pp. 271-286. Accessed on http://members.aol.com/%20mszlazak/BOHM.html on 8/9/2000.

A Place and Time of Agreement: The Eternal Here and Now

There is one place where I fully agreed with Zukav on the insight from physics being similar to, but not the same as, a basic mystical insight.

On page 154 Zukav writes:

> . . . Einstein's mathematics teacher, Hermann Minkowski, . . . was inspired by his most famous student's special theory of relativity. In 1908 Minkowski announced his vision this way:
>
> > Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.
>
> Minkowski's mathematical explorations of space and time were both revolutionary and fascinating. Out of them came a simple diagram of space-time showing the mathematical relationship of the past, present, and the future. Of the wealth of information contained in this diagram, the most striking is that all of the past and all of the future, for each individual, meet and forever meet, at one single point, *now*. Furthermore, the *now* of each individual is specifically located, and will never be found in any other place, than *here* (wherever the observer is at).
>
> Sixty-three years before Ram Dass's great book, *Be Here Now*, established the watchwords of the awareness movement, Hermann Minkowski proved that, in physical reality, no choice exists in the matter (pun?). Unfortunately for physicists, the realization is not always the experience. Nonetheless, after two-thousand years of use in the East, being here now, the beginning step in meditation, received the validation of western science via Minkowski's rigorous mathematical confirmation of it inspired by the general theory of relativity.

And though I really like and agree with this thought, I think overall the book is so keen on drawing validation for Eastern thought from physics that it distorts physics as it is in the process. Zukav may be right about many things, but physics is just not to the same place and time as he is. That is my opinion.

[By the way, if there is a [ ] in a citation it is my note. If there is a ( ) it is in the original.]

Now It Begins -- with A Little Whiney Whimper

On the back cover of my paperback copy of Gary Zukav's book "The Dancing Wu Li Masters, An Overview of the New Physics" there is a quote from a Martin Gardner which says "Zukav is such a skillful expositor, with such amiable style, that it is hard to imagine a layman who would not find his book enjoyable and informative."

I read the book and did indeed find it both enjoyable and informative. However, I also found it offensive in places, self-contradictory in places, and just plain wrong in some other places. I will explain at length:

Elitist Notions: Scientists and Technicians

I thought I was covered under the "layman" label used by Gardner on the back cover of my paperback. But maybe not.

I am no physicist, although I did take a year of college physics and a single course in nuclear physics in the late 60's and early 70's. I was surprised about how little in Zukav's book about quantum physics was really new to me, conceptually. Of course it reminded me of a lot of things I had forgotten. The Bell theorem of Zukav's final chapter, and its experimental evaluations and surprising interpretations, were the only things I was not at least somewhat aware of.

I make my living in the application of the geological sciences to an environmental problem. My employer says I am a Physical Scientist. I had no reason to doubt that classification since I use science in pursuit of a solution to a practical problem.

So imagine my surprise in reading this on Zukav's page 9:

> This brings us to a common misunderstanding. When most people say "scientist," they mean "technician." A technician is a highly trained person whose job it is to apply known techniques and principles. He deals with the known. A scientist is a person who seeks to know the true nature of physical reality. He deals with the unknown.

My first thought was to check the dictionary. It simply said a scientist was a person knowledgeable in one or more of the sciences. I was reassured. I could play golf all day, not do a lick of work, and still be a scientist.

When the point was repeated on page 10, I smelled a familiar rat:

> The fact is that most "scientists" are technicians. They are not interested in

> the essentially new. Their field of vision is relatively narrow; their energies are directed toward applying what is already known. Because their noses often are buried in the bark of a particular tree, it is difficult to speak meaningfully to them of forests.

The rat I smelled is the superiority complex of certain physical science types who have naught but disdain for the "soft" sciences dealing with life and other unexciting stuff. While working at Argonne National Laboratories near Chicago, in the environmental sciences, I would occasionally hear complaints from the reactor physics and nuclear chemistry types that the proliferation of us environmental types was degrading Argonne as a prestigious "hard science" center of competence.

To each their own prejudice. Maybe they were right, but who knows and who cares? If publicly funded science is not to some appreciable extent being applied to real-world health and safety problems, public agencies are not fulfilling their mandates to provide science in the public interest. Of course, improving the basic understanding of reality, as approached through physics, is also in the public interest, albeit in a less direct way. And if you have ever undergone a "PET Scan" (Positron-Electron Tomography) which involves ingesting a fluorinated glucose compund (same as your body makes) that is tagged with a positron (positively charged electron: anti-matter) and taken up all over the body. The positron is emitted over time and inevitably collides with an electron (matter), and the result is the annihilation of both into two gamma rays that a detector picks up. The technique gives the most intricate images yet of internal organs and allows diagnoses of diseases heretofore not captured by any other imaging techniques. The point is that while the 'technicians' of physics were working on proton/electron collisions to see what results when matter meets anti-matter, they had no idea it could lead to something as useful as the PET Scan. It pays to do science now and think about potential applications later, after you gain some understanding of what you are dealing with.

But, back to the difference between real scientists and mere technicians who bring us things like the PET scan. From my own experience of being disparaged as a "soft scientist" I felt I knew where this notion in Zukav's book was coming from, sciene's own elitists, and did not blame Zukav. It is an unfair and elitist notion that in a team addressing a problem in science, only the ones doing the theoretical thinking are real scientists. As Zukav points out, scientists facing complex problems work in teams, and the team member that knows how to make a detector is as important as the member who theoretically determines what should be detected. This is the reason that Nobel Prizes in Physics have gone to designers of detectors, to experimentalists, to mathematical modelers, as well as to theorists over the last twenty-five or so years! (See page 67 of a recent National Academy of Sciences book for names and details.[6])

I challenge anyone to find a tree-bark expert who would not know a lot about the forests that provide the environments for the specific trees being studied. Denigrating this field of genuine scientific endeavor by making this callous remark would only be done by a physical scientist that sincerely feels that unless there are differential equations aplenty, with more unknowns than equations, there is no science. It is a foolish, even childish prejudice reflected in this chapter.

This prejudice continues on page 15:

> Most of the physicists who went to work on Bohr's theory, applying it and further developing it, were *technicians*. Bohr himself, one of the founders of the new physics, was a *scientist*.
>
> This is not to say that technicians are not important. The technicians and scientists form a partnership. Bohr could not have formulated his theory without the wealth of spectroscopic data at his disposal. . . . Technicians are important members of the scientific community. However, since this book is about Wu Li Masters and not about technicians, we will use the word "physicist" from now on to mean those physicists who are also scientists, that is, those physicists (people) who are not confined by the "known."

This elitism is in stark contrast to the call to enlightenment at the end of the book, in my opinion. It is very much out of harmony with Zukav's hopeful near-final statement (p. 313):

> We are approaching the end of science. . . . The "end of science" means the coming of western civilization, in its own time and its own way, into the higher dimensions of human experience.

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[6]Commission on Physical Sciences, Mathematics, and Applications, "Elementary-Particle Physics: Revealing the Secrets of Energy and Matter," The National Academy of Sciences, Washington, DC, 1998. Accessed on http://www.nap.edu/books/0309060370/html/index.html on 8/25/2000.

Factions and Rivalries: “Old” Thought Gets a Nobel Prize!

Another place where disdain is shown, this time for the accomplishments of a fellow physicist, is in the discussion of the ‘discovery’ of the “quark.” The discoverer received a Nobel Prize in Physics for this work, but in Zukav’s book the disdain for this work is palpable (pp. 244-245):

> Theoretical physics, roughly speaking, has branched into two schools. One school follows the old way of thinking and the other school follows new ways of thinking. Physicists who follow the old way of thinking continue their search for the elementary building blocks of the universe in spite of the hall-of-mirrors predicament (page 192).
>
> For these physicists, the most likely candidate at present for the title of "building block of the universe" is the quark. A quark is a type of hypothetical particle theorized by Murray GellMann in 1964. . . .
>
> All known particles, the theory goes, are composed of various combinations of a few (twelve) different types of quarks. No one has found a quark yet but many are looking. It is an extraordinarily elusive particle (as many now-known particles were in the past) with some strange characteristics. . . . The great quark hunt could become very exciting in the future, but no matter what is discovered in the future, one thing about it already is certain: The discovery of quarks will open an entirely new area of research, namely, "What are *quarks* made of?"
>
> The physicists who follow the new ways of thinking are pursuing so many different approaches to understanding subatomic phenomena that it is not possible to present them all. Some of these physicists feel that space and time are all that there is. According to this theory, actors, action, and stage are all manifestations of an underlying four-dimensional geometry. Others (like David Finkelstein) are exploring processes which lie "beneath time," processes *from which* space and time, the very fabric of experiential reality, are derived. These theories, at the moment, are speculative. They cannot be "proven" (demonstrated mathematically).

The reference to page 192 is to a long discussion of the scientific revolution of quantum mechanics and how difficult it is for scientists in general to accept new theories. Apparently the Nobel Prize for Physics going to Gell-Mann for his discovery of the quark was a mistake, since he was following old thought!

Taking a lesson from the soft science of forestry: a healthy forest is one with old and new trees. So, physics is a healthy forest! New and old ideas abound!

Selected words from pages 192-194 show that the above reference to Gell-Mann’s work is meant to be as judgmental and mean-spirited as I made it appear through selective quoting:

> Old theories die hard. Much more is at stake than the theories themselves. To give up our privileged position at the center of the universe, as Copernicus asked, was an enormous psychological task. To accept that nature is fundamentally irrational (governed by chance), which is the essential statement of quantum mechanics, is a powerful blow to the intellect. Nonetheless, as new theories demonstrate superior utility, their adversaries, however reluctantly, have little choice but to accept them. In so doing, they must also grant a measure of recognition to the world views that accompany them.
>
> Today, particle accelerators, bubble chambers and computer printouts are giving birth to another world view. This world view is as different from the world view at the beginning of this century as the Copernican world view was from its predecessors. It calls upon us to relinquish many of our closely clutched ideas.
>
> In this world view there is no substance.
>
> The most common question we can ask about an object is, "What is it made of?" That question, however, "What is it made of?", is based upon an artificial mental structure that is much like a hall of mirrors. If we stand directly between two mirrors and look into one, we see our reflection, and, just behind ourselves, we see a crowd of "us"s, each looking at the back of the head in front of it, stretching backward as far as we can see. These reflections, all of them, are illusions. The only real thing in the whole setting is *us (we)*. . . .

So, Copernicus was wrong to suggest we were not at the center of the universe? Biting my tongue and continuing the quote:

> Physicists are people who have pursued tenaciously this endless series of questions. What they have found is startling. . . . The search for the ultimate stuff of the universe ends with the discovery that there *isn't any.*
>
> If there is any ultimate stuff of the universe, it is pure energy, but subatomic particles are not "made of" energy, they *are* energy. This is what Einstein theorized in 1905. Subatomic interactions, therefore, are interactions of energy with energy. At the subatomic level there is no longer a clear distinction between what is and what happens, between the actor and the action. At the subatomic level the dancer and the dance are one.
>
> According to particle physics, the world is fundamentally dancing energy; energy that is everywhere and incessantly assuming first this form and then that. What we have been calling matter (particles) constantly is

> being created, annihilated and created again. This happens as particles interact and it also happens, literally, out of nowhere.
>
> Where there was "nothing" there suddenly is "something," and then the something is gone again, often changing into something else before vanishing. In particle physics there is no distinction between empty, as in "empty space," and not-empty, or between something and not-something. The world of particle physics is a world of sparkling energy forever dancing with itself in the form of its particles as they twinkle in and out of existence, collide, transmute, and disappear again.
>
> The world view of particle physics is a picture of *chaos beneath order*. At the fundamental level is a confusion of continual creation, annihilation and transformation. Above this confusion, limiting the forms it can take, are a set of conservation laws (page 156). They do not specify what must happen, as ordinary laws of physics do, rather they specify what *cannot* happen. They are permissive laws. At the subatomic level, absolutely everything that is not forbidden by the conservation laws actually happens. . . .
>
> The old world view was a picture of order beneath chaos. It assumed that beneath the prolific confusion of detail that constitutes our daily experience lie systematic and rational laws which relate them one and all. This was Newton's great insight: The same laws which govern falling apples govern the motion of planets. There is still, of course much truth in this, but the world view of particle physics is essentially the opposite.

So, Murray Gell-Mann failed to believe in this ephemeral dance of no-things and pure energy and looked for ultimate building blocks, stable particles, where there should be none. He was a heretic! Shame on that old-think practitioner!

But we will visit with Murray Gell-Mann a bit later and get his opinion about some of the types of conclusions being drawn by Zukav.

Newton's Laws: Much Truth But Essentially Opposite?

The last line of the previous quote is an enigma, to me. So I went back to see what was actually said in several places about Newtonian physics in Zukav's book.

On page 19 is a common-sense statement:

> Newtonian physics still is applicable to the large-scale world, but it does not work in the subatomic realm. Quantum mechanics resulted from the study of the subatomic realm, that invisible universe underlying, embedded in, and forming the fabric of everything around us.

This thought continues on page 20:

> It was the study of elementary particles that brought physics nose to nose with the most devastating (to a physicist) discovery: *Newtonian physics does not work in the realm of the very small!* The impact of that earthshaking discovery still is reshaping our world view. Quantum mechanical experiments repeatedly produced results which the physics of Newton could neither predict nor explain. Yet, although Newton's physics could not account for phenomena in the microscopic realm, it continued to explain macroscopic phenomena very well (even though the macroscopic is made of the microscopic)! This was perhaps the most profound discovery of science.

So far, so good. I could agree wholeheartedly with these statements. And I was rather pleased with this somewhat related admission as well: in spite of the fact particle physicists do not believe in particles, they use the language of simpler concepts where it is acceptable even if inaccurate (p. 105):

> Although Schrodinger's wave mechanics became a pillar of today's quantum mechanics, the useful aspects of Bohr's model of subatomic phenomena still are used when the wave theory does not yield appropriate results. In such cases, physicists simply stop thinking in terms of standing waves and start thinking again in terms of particles. No one can say that they are not adaptable in this matter (wave).

The last line was a cute little pun, in case the context in this review makes this less clear than the original book-context.

But there are other statements in the book that suggest Newtonian physics is no longer useful. For example on page 66:

> By 1924, Planck's discovery of the quantum was producing seismic effects in physics. It enabled Einstein to discover the photon, which caused the wave-particle duality, which led to probability waves. The physics of Newton was a thing of the past.

That last line has a context, obviously, and is probably not meant to be a general truth for all scales of measurement. This is made very clear in the next citation (p. 113):

> We cannot apply Newton's laws of motion to an individual particle that does not have an initial location and momentum, which is exactly what the uncertainty principle shows us that we cannot determine. In other words, it is impossible, even in principle, ever to know enough about a particle in the subatomic realm to apply Newton's laws of motion which, for three centuries, were the basis of physics. *Newton's laws do not apply to the subatomic realm*. (Newton's *concepts* do not even apply in the subatomic realm).

Zukav has a footnote explaining, at this point, that, "strictly speaking, Newton's laws do not disappear totally in the subatomic realm: they remain valid as operator equations. Also, in some experiments involving subatomic particles Newton's laws may be taken as good approximations in the description of what is happening."

This brings up a point needing to be made. The physicists reviewing Zukav's book sometimes made suggestions that did not fit well into the flow of the text, and sometimes gave a contrary opinion. These were added in as footnotes.

So, are we safe to assume Newtonian physics rules the macro world, and quantum physics rules the micro world? As the page 113 footnote shows, it isn't as clearcut as all that. But the text calling on the footnote makes a different, more direct statement.

And in other places, the claim is made that quantum physics rules in both worlds. But to get to that point, we need to make our acquaintance with two large items of information and several smaller ones. The big items are the Great Machine that is the Newtonian universe, and the orthodox Copenhagen interpretation of quantum mechanics!

Liberation From the Great Machine?

On page 26 we meet the concept of a Newtonian universe being causal and deterministic, a Great Machine that fixes all of nature and makes us pawns and puppets in a game pre-determined at the Big Bang, the last probabilistic event of this universe.

The claim is that quantum mechanics freed us from the Great Machine and gave us free will. The Heisenberg uncertainty principle that says there are limits to what can be known assures free will, since the future is not predetermined but is continually being created through random-chance controlled processes.

To me, this assumes that Nature is as ignorant as we are (the uncertainty principle is as applicable to Nature as it is to us) and that the underlying order is chaotic. The difference between probability directing the course of nature (quantum mechanics is always right about the probabilities!), and chaos (not even a predictable probability directs this course) is missing from this argument.

It also fails to appreciate that Newton's laws still hold where they matter to macro-scale existence, and it really fails to appreciate that although nature at the macro-scale may be deterministic, we also model its processes probabilistically because of the inability to know everything. Examples from daily life are weather forecasts and the occurrence and potential effects of volcanic and seismic events.

Perhaps the Newtonian earth is deterministic and its destiny is fixed, but for the temporary human inhabitant of 100 years or less there is a lot of freedom of choice, irregardless of where the next meteor strikes, the next earthquake hits, or the next severe thunderstorm threatens. The greatest uncertainty of all in nature is in predicting future human behavior. Free will seems to exist, with or without quantum mechanics! The whole notion of a Great Machine is so abstract that it is irrelevant at best, in my opinion. I think it is simply spurious, but will allow Zukav to make his point because it leads to a second point: quantum mechanics rescues us from victim status under Newtonian physics and elevates us to creators!

Zukav's background discussion on the Great Machine is on page 26:

> The ability to predict the future based on a knowledge of the present and the laws of motion gave our ancestors a power they had never known. However, these concepts carry with them a very dispiriting logic. If the laws of nature determine the future of an event, then, given enough information, we could have predicted our present at some time in the past. . . . In short, if we are to accept the mechanistic determination of Newtonian physics--if the universe really is a great machine--then from the

> moment that the universe was set in motion, everything that was to happen in it was already determined. . . . Everything, from the beginning of time, has been predetermined, including our illusion of having a free will. The universe is a prerecorded tape playing itself out in the only way that it can. The status of men is immeasurably more dismal than it was before the advent of science. The Great Machine runs blindly on, and all things in it are but cogs.
>
> According to quantum mechanics, however, it is not possible, *even in principle*, to know enough about the present to make a complete prediction about the future. Even if we have the time and the determination, it is not possible. Even if we have the best possible measuring devices, it is not possible.

What follows is an introduction, of course, to the Heisenberg uncertainty principle which places an absolute limit on what can be known about any one subatomic particle, which has the following consequence:

> Quantum theory can predict the probability of a microscopic event with the same precision that Newtonian physics can predict the actual occurrence of a macroscopic event.

(We will follow this microscopic/macroscopic usage, popular in physics literature, although what can be seen with a microscope is definitely macroscopic compared with the context of subatomic physics.) The cited statement is true enough, but has anything at all changed on the macro scale where we live because it is true? If the great revolution is that order overlies chaos, order does not cease to exist in the overlying manifestation of reality.

Chaos is a false notion of course. Our ignorance forces the use of statistical approaches to deal with deterministic but complex phenomena on the macro-scale as well, meaning that they are "chaotic" [following Zukav's usage] in our experience, even though they really are deterministic but determined by so many variables at so many known and unknown locations as to be unknowable in a practical sense.

The same may be true on the micro-scale, according to those who do not believe in the Copenhagen interpretation of quantum mechanics. The Copenhagen interpretation says that there is no mechanistic understanding possible, only statistical predictions, not single event predictions, are possible.

Also, even if there were chaos beneath order, just because we discover that this is so does not deny the fact that there is order at the macro scale! To me, the incredible part of the discovery, as Zukav points out, was that these 'chaotic' particles underlie the order we can count on in our daily living experience. Newton's laws still work, a point repeatedly made by Zukav (except where he takes it back, which we will get to later), and rightly so.

But Zukav is not satisfied liberating us from the Great Machine. He is also declaring us creators of the universe!

Creators!

Zukav's creator theme is based very loosely on the Copenhagen interpretation that suggests that there are no particles, or properties of particles, in existence until they are observed (by instruments, sentient beings reading those instruments, or sentient entities observing in some other way). This means that the realities seen in an experiment are created by the experiment, hence the experimenter, or us. Zukav generalizes this to mean that in a very real sense we are the creators of the reality we experience!

This concept boggles my mind. It is a macro-scale interpretation, based on a micro-scale-phenomenon interpretation. And that interpretation, the Copenhagen interpretation, though considered orthodox dogma in physics for decades, is being questioned widely. It has been observed, for example, that the universe came into being and developed quite nicely into the present state to make it a habitable place for us newcomers. This has been pointed out by cosmologists and astrophysicists as at least a caution to be considered concerning the 'creator' hype.

Nevertheless, here is Zukav's creator-ship story, starting on pages 28-29:

> Quantum physicists ponder questions like, "Did a particle with momentum exist before we conducted an experiment to measure its momentum?"; "Did a particle with position exist before we conducted an experiment to measure its position?"; and "Did any particles exist at all before we thought about them and measured them?" "*Did we create the particles that we are experimenting with?*" Incredible as it sounds, this is a possibility that many physicists recognize.
>
> John Wheeler, a well-known physicist at Princeton, wrote:
>
> > May the universe in some strange sense be
> > "brought into being" by the participation of
> > those who participate? . . .
>
> The languages of eastern mystics and western physicists are becoming very similar.
>
> Newtonian physics and quantum mechanics are partners in a double irony. Newtonian physics is based upon the idea of laws that govern phenomena and the power inherent in understanding them, but it leads to impotence in the face of a Great Machine which is the universe. Quantum mechanics is based upon the idea of minimal knowledge of future phenomena (we are limited to knowing probabilities) but it leads to the possibility that our reality is what we choose to make it.

Of course, to me this discussion overlooks ideas explained elsewhere in this same book (pages 45-66) about subatomic particles being alive and instantaneously aware of changes everywhere in the universe. To me, if one accepts this thesis, it means that it is only we who are ignorant and restricted to probabilities. Perhaps Nature knows! And Nature acts deterministically, perhaps, even at the micro-scale, and the Great Machine rumbles on! But by adhering to the Copenhagen interpretation, as many physicists do, Zukav eliminates this possibility of a deterministic universe from consideration.

But I should control my doubt-filled self, and allow Zukav to explain the conceptual model for our creator status (p. 79):

> Without perception, the universe continues, via the Schrodinger equation, to generate an endless profusion of possibilities. The effect of perception, however, is immediate and dramatic. All of the wave function representing the observed system collapses, except one part, which actualizes into reality. No one knows what causes a particular possibility to actualize and the rest to vanish. The only law governing this phenomenon is statistical. In other words, it is up to chance.
>
> . . . If there were twenty-five possibilities in the wave function of the photon, the wave function of the measuring system, technician, and supervisor similarly would have twenty-five separate humps, until a perception is made and the wave function collapses. From photon to detectors to technician to supervisor we could continue until we include the entire universe. *Who is looking at the universe?* Put another way, *How is the universe being actualized?*
>
> The answer comes full circle. *We* are actualizing the universe. Since we are part of the universe, that makes the universe (and us) self-actualizing.
>
> This line of thought is similar to some aspects of Buddhist psychology. In addition, it could become one of many important contributions of physics to future models of consciousness.

(Schrodinger, by the way, as may be seen in the footnote 4 reference, was not one who believed in the Copenhagen interpretation.)

The line of thought in the above citation from Zukav also suggests that wave equations for complex systems are known, and have been solved. This was a positive impression I had while reading the book: they have come a long way since my college days when these equations could be exactly solved for a two-"particle" atom only. In fact, as Treiman[7] quipped in 1999, after dozens of pages of equations and discussion illustrating the wave equation and the energy eigenvalue

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[7] Sam Treiman, "The Odd Quantum," Princeton University Press, Princeton, New Jersey, 1999.

relations for a one-electron atom: (Treiman p. 162)

> The one-electron atom was easy. For many-electron atoms, exact analytic solutions of the energy eigenvalue equation are beyond reach. Indeed, with increasing numbers of electrons a precision all-out *numerical* attack becomes hopelessly demanding even for modern computers.

What perhaps is new is this, however:

> But the experts in this well-developed field have successfully devised various approximation procedures based on plausible physical models (which still require substantial globs of numerical computation).

Treiman's next sentence, to me, brings into question the acceptability of the Copenhagen interpretation, as it is explained in Zukav's book, even at this well-developed working level of physics:

> The virtue of modeling, if it is good modeling, is that it nourishes physical intuition and provides a useful basis for organizing, interpreting, and communicating numerical results.

There is apparently more to physics than getting exact solutions to wave equations and not questioning the nature of the underlying bases of outcomes as suggested by the Copenhagen interpretation of quantum mechanics. But, I should allow Zukav the last word on this creator topic (page 114):

> The tables have been turned. "The exact sciences" no longer study an objective reality that runs its course regardless of our interest in it or not, leaving us to fare as best we can while it goes its predetermined way. Science, at the level of subatomic events, is no longer "exact," the distinction between objective and subjective has vanished, and the portals through which the universe manifests itself are, as we once knew a long time ago, those impotent, passive witnesses to its unfolding, the "I"s, of which we, insignificant we, are examples. The Cogs in the Machine have become the Creators of the Universe.

A few paragraphs above, I noted that from a cosmological standpoint this creator-thesis gets little respect. An example is in the "Nothingness" book by Genz[8]. He indirectly addresses this creator question raised by Zukav (and others, of course).

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[8]Henning Genz, "Nothingness, The Science of Empty Space," translated by Karin Heusch, Helix/Perseus Books, Reading, Massachusetts, 1998.

At the end of the Genz book is the "Epilogue: Physics and Metaphysics" which is a mirror of the similarly titled Prologue. What makes this material relevant to this Zukav book discussion is the discussion of the contingent nature of the present universe that obeys a myriad of what are now called fundamental laws. The idea is that a different set of choices in the formation of a material universe out of the homogeneous particle soup after the Big Bang was possible (Genz's page 310):

> . . . creation did not stop with the Big Bang. In its immediate wake, the universe was structureless and homogeneous. Creation then continued. The formation of structures, the appearance of objects and of the laws that govern their specific behavior–none of this was predestined. Along with the structures, the laws might have turned out differently. Our universe and its laws are what we have called contingent. . . .

Where I am going with this is to Genz' next page (311) where he goes to some length to show that even a small variation in some constants in the fundamental laws would make life as we know it impossible. But the heart of the matter is answering the question "Whence the Quasi-Classical World?" (p. 312). Here Genz mentions the word-soup that Zukav and others are mired in (in my opinion). Genz recognizes that this is a general problem among physicists because (page 312):

> In trying to define the notions we just discussed, in approaching questions we can barely ask but are fundamentally unlikely to solve, the words we use lose their familiar meaning. We meddle with the meaning of words in order to describe new concepts; without them we would not know how to categorize ideas in the progress of physics--ideas that transcend the language created for familiar notions. In this sense, the epilogue to this book may serve as a prologue for the physics of the future.

Genz wraps up his book with questions. He says the universe, citing Hartle and Hawking (page 313):

> . . . started with an initial state in which space and time were indistinguishable. This was a purely quantum mechanical initial state. We might ask whether out of this state our essentially classical world had to develop as the universe grew large. We might even ask: Did the universe have to become large? Or is all this nothing but ballast--a consequence of nothing but the specific initial conditions of the universe that happens to be observable to us? And again: Is our universe just a bubble inside an all-encompassing superuniverse? If there are other such bubbles, are they all quasi-classical? A purely quantum mechanical universe would clearly be uninhabitable for creatures like humans. Can we ascribe the fact that we live in a quasi-classical universe to the fact that we are here to observe it?

> If the cosmological constant differed noticeably from its established range of values, life could not exist in the universe. Among the convoluted arguments that bring us to this conclusion, I will mention only this: A universe with a considerably larger cosmologic constant would have developed so rapidly that life would not have had time to develop.

The cosmological constant is the term for the energy of empty space in Einstein's general theory of relativity (see Genz, pages 292, 296, and 301-303 for a more complete discussion).

What this says to me (it is my turn to over-interpret) is that the idea that we actualize or create the universe is without merit. The universe had to be well established already, for us to come into being. And we live in a quasi-classical universe, we could not live in a quantum universe. So the idea that quantum properties of matter show we are creators of that matter is silly and without foundation, even if it is based on the Heisenberg uncertainty principle and the classic view of the Copenhagen interpretation.

Particles Are Not Real, Waves Aren't Either?

If nothing is real until it is actualized by us, and particles are just potentials on wave functions, then what is our daily reality made of? Self realized potentialities?

The theme of there being no particles until we perform an experiment to actualize them from their tendencies to be in their wave functions is related to the slit experiments with photons that show light is a wave phenomenon (while other experiemnts show it to be a particle phenomenon, suggesting it is both). On page 71 Zukav says:

> "Correlation" is a concept. Subatomic particles are correlations. If we weren't here to make them, there would not be any concepts, including the concept of "correlation." In short, if we weren't here to make them, there wouldn't be any particles!

And, apparently, the same goes for waves (page 73):

> A wave function is a mathematical fiction that represents all the possibilities that can happen to an observed system when it interacts with an observing system (a measuring device).

On page 80, a footnote similarly says:

> The wave function, since it is a tool for our understanding of nature, is something in our thoughts. It represents certain *specifications* of certain physical systems.

Zukav explains further on page 95:

> Since particle-like behavior and wave-like behavior are the only properties that we ascribe to light, and since these properties now are recognized to belong (if complementarity is correct) not to light itself, but to our interaction with light, then it appears that light has no properties independent of us! To say that something has no properties is the same as saying that it does not exist. The next step in this logic is inescapable. Without us, light does not exist.
>
> Transferring the properties that we actually ascribe to light to our interactions with light deprives light of an independent existence. Without us, or by implication, anything else to interact with, light does not exist. This remarkable conclusion is only half the story. The other half is that, in a similar manner, without light, or, by implication, anything else to interact with, *we do not exist*! As Bohr himself put it:

. . . an independent reality in the ordinary physical sense can be ascribed neither to the phenomena nor to the agencies of observation.

By "agencies of observation," he may have been referring to instruments, not people, but philosophically, complementarity leads to the conclusion that the world consists not of things, but of interactions. Properties belong to interactions, not to independently existing things, like "light." This is the way that Bohr solved the wave-particle duality of light. The philosophical implications of complementarity became even more pronounced with the discovery that the wave-particle duality is a characteristic of *everything*.

But these pronounced implications mean little, as Zukav acknowledges as he continues (page 98):

Theoretically, in fact, *everything* has a wavelength--baseballs, automobiles, and even people--although their wavelengths are so small that they are not noticeable.

So without our observation, there is no light, and without light there is no thing. Not even us. This leads one to wonder what came first, light or beings to actualize it?

But just in case we might overinterpret some of these notion (as, to me, Zukav already has), it is sobering, or reassuring, to much later read that the very atoms we are made of are not continually disintegrating and reforming. Zukav does explain, on page 243, that there are conservation laws that make electrons and protons, and thus the atoms of which we are made, stable.

So, are they real or not?

There Is No Physical World Either

On page 82, Zukav explains that according to the orthodox interpretation:

> The Copenhagen Interpretation of Quantum Mechanics does not go so far as to say what reality is "really like behind the scenes," but it does say that it is not like it appears. It says that what we perceive to be physical reality is actually our cognitive construction of it. This cognitive construction may appear to be substantive, but the Copenhagen Interpretation of Quantum Mechanics leads directly to the conclusion that the physical world itself is not.
>
> This claim at first appears so preposterous and remote from experience that our inclination is to discard it as the foolish product of cloistered individuals. However, there are several good reasons why we should not be so hasty. The first reason is that quantum mechanics is a logically consistent system. It is self-consistent and it also is consistent with all known experiments.
>
> Second, the experimental evidence itself is incompatible with our ordinary ideas about reality.
>
> Third, physicists are not the only people who view the world this way. They are only the newest members of a sizable group; most Hindus and Buddhists also hold similar views.
>
> Therefore, it is evident that even physicists who disdain metaphysics have difficulty avoiding it. Now we come to those physicists who have jumped feet first into describing "reality."

The discussion that follows this particular quote is on something called the Many Worlds interpretation of quantum mechanics, to which we will turn shortly. First, however, it is time to check a few more references to the unreal world to show this is a serious idea:

Page 114:

> The uncertainty principle . . . brings into question the very existence of an "objective" reality, as does complementarity and the concept of particles as correlations.

Page 155:

> The world of matter is a relative world, and an illusory one: illusory not in the sense that it does not exist, but illusory in the sense that we do not see it as it really is. The way it really is cannot be communicated

verbally, but in the attempt to talk around it, eastern literature speaks repeatedly of dancing energy and transient, impermanent forms. This is strikingly similar to the picture of the physical world emerging from high-energy particle physics.

The point about the ineffable insights of Eastern mysticism leading to a discourse similar to that seen at work among workers in the new physics is an interesting one, to me, since it may only mean that when humans face the unexplainable they reach into the same tool box of concepts to try to explain the inherently unexplainable anyway. Zukav makes this same point about common language limitations between physicists and mystics. On pages 260 through 262, for example, there is a lengthy discussion of the difficulty of explaining quantum mechanics. Zukav begins with these words:

> Quantum theory is not difficult to explain because it is complicated. Quantum theory is difficult to explain because the words we must use to communicate it are not adequate to explain quantum phenomena. This was well known and much discussed by the founders of quantum theory.

This thought is in close agreement with a statement cited above by Genz (see page 312 of the reference at footnote 8).

Zukav continues this thought, but in what is a very different way: physicists cope with the ineffable by using simpler concepts as if they are real, but knowing they are not (page 272):

> So much for the relationship between the "truth" of a scientific assertion and the nature of reality. There isn't any. Scientific "truth" has nothing to do with "the way that reality really is." A scientific theory is "true" if it is self-consistent and correctly correlates experience (predicts events). In short, when a scientist says a theory is true, he means that it correctly correlates experience and, therefore, it is useful. If we substitute the word "useful" whenever we encounter the word "true," physics appears in its proper perspective.

So, is the world unreal? Perhaps it is just that it is not as we perceive it to be. What a relief! Or is it?

Wave Functions Are So Real They Never Collapse But Create New Worlds!

On page 81, just one page after the wave function has been explained as a product of human thought that gives specifications about reality, and nothing more, the book says something that, to me, seems very different, invoking the Copenhagen interpretation:

> The wave function, strictly speaking, represents an observed system in a quantum mechanical experiment. In more general terms, it describes physical reality at the most fundamental level (the subatomic) that physicists have been able to probe. In fact, according to quantum mechanics, the wave function is a *complete* description of physical reality at that level. Most physicists believe that a description of the substructure underlying experience more complete than the wave function is not possible.

On page 83, another interpretation of quantum mechanics called the Many Worlds theory is explained in this context. This alternative interpretation:

> . . . claims that the wave function is a real thing, all of the possibilities that it represents are real, *and they all happen*. The orthodox interpretation of quantum mechanics is that only one of the possibilities contained in the wave function of an observed system actualizes, and the rest vanish. The Everett-Wheeler-Graham theory says that they *all* actualize, but in different worlds that coexist with ours!
>
> . . . According to the Everett-Wheeler-Graham theory, the development of the Schrodinger wave equation generates an endlessly proliferating number of *different branches of reality*! This theory is called, appropriately, the Many Worlds Interpretation of Quantum Mechanics.
>
> The technical advantage of the Many Worlds Interpretation is that it does not require an "external observer" to "collapse" one of the possibilities contained in a wave function into physical reality.

Zukav does not particularly endorse this theory, but does offer on page 84 that:

> . . . the Many Worlds description of the relationship between the various branches of physical reality sounds like a quantitative version of a mystical vision of unity.

I have mulled over this statement several times. I just don't get it. It is a qualitative version of eternal splitting of one world into non-communicating parallel worlds. There is nothing either quantitative or unifying about it! Oh well.

The problem of observers and just where wave functions really collapsed also vexed the famed physicist von Neumann. His treatment of wave functions in response to this struggle is characterized by Zukav as suggesting that (p. 258) "it is not quite a thing but it is more than an idea."

On page 259 this discussion continues by describing the two ways von Neumann attempted to understand wave functions, as either real or as a mathematical construct defying logic. The discussion reiterates that

> Most physicists, however, have adopted a third explanation of wave functions. They dismiss them as purely mathematical constructions, abstract fictions which represent nothing in the world of reality.

This suggests that "most physicists" would reject the Many Worlds Interpretation outright. Thank goodness.

But I jumped to the von Neumann discussion without finishing Zukav's complete description of the Many Worlds interpretation of quantum mechanics. I did that to show this was not something being taken too serious among physicists. But Zukav continues to explain Many Worlds on page 87:

> In short, classical physics says that there is one world, it is as it appears, and this is it. Quantum physics allows us to entertain the possibility that this is not so. The Copenhagen Interpretation of Quantum Mechanics eschews a description of what the world is "really like," but concludes that whatever it is like, it is not substantive in the usual sense. The Many Worlds Interpretation of Quantum Mechanics says that different editions of us live in many worlds simultaneously, an uncountable number of them, and all of them are real. There are even more interpretations of quantum mechanics, but all of them are weird in some way.
>
> Quantum physics is stranger than science fiction.

I can't find any fault with that!

Is There Gravity?

Zukav does a very nice job explaining the special and general theories of relativity. The explanation of the theory of general relativity by Einstein, on pages 170, and 186-187, includes some strong statements about there being no such thing as gravity in this theory. To wit on pages 186-187:

> One of the most profound by-products of the general theory of relativity is the discovery that gravitational "force," which we had so long taken to be a real and independently existing thing, is actually our mental creation. There is no such thing in the real world. The planets do not orbit the sun because the sun exerts an invisible gravitational force on them, they follow the paths that they do because those paths are the easiest way for them to traverse the terrain of the space-time continuum in which they find themselves.

Without any guidance for interpretation, however, later in the book gravity is again discussed, but in classical terms: On page 197 a footnote on the meanings of the terms in the $E=mc^2$ equation says about the letter m in that equation that it is: "defined by the fact that it is a source of the gravitational field." And on page 234, "Gravity is the long range force which holds together solar systems, galaxies, and universes." . . . "The particle associated with gravity is the graviton, whose properties have been theorized, but whose existence never has been confirmed." . . .

But, just 60 pages before this, when discussing the non-existence of gravity in accord with Einstein's vision of mass causing curvatures of the space-time continuum, Zukav exults:

> There is nothing but space-time and motion and they, in effect, are the same thing. Here is an exquisite presentation, in completely western terms, of the most fundamental aspect of Taoist and Buddhist philosophies.

In the chapter that follows the discussion of Einstein's massless and gravitationless visions of curved space, Zukav does warn the reader that old concepts and ideas die slowly. Hence the chapter talks all about particles, in the old way, and about gravity in the old way, not as the space-time continuum shaped by the presence of an object: the larger the presence, the deeper the impressions in, or the tighter the curvature of, the space-time continuum near the objects.

Objects? Well, it is a term of convenience. And that is how the chapter on "The Particle Zoo" explains its classical language and concepts on pages 201-2 (and again toward the end of the book on page 211):

Leptons, mesons, baryons, mass, charge, spin, and anti-particles are some of the concepts physicists use to categorize subatomic phenomena when they momentarily assume that subatomic particles are real objects that move through space and time. These concepts are useful, but only in a limited context. That context is when physicists, for convenience, pretend, as we all do, that dancers can exist apart from a dance.

The dance referred to is the $E=mc^2$ matter=energy dance. On page 195 Zukav indicates that the discussion of matter and energy interconversion is based on the use of high-energy devices such as particle accelerators:

> Physicists send subatomic particles smashing into each other as hard as they can. they use one particle to shatter another particle so that they can see what the remains are made of. . . .

On the next page, 196, Zukav explains that instead of seeing remains, however, new particles are seen:

> When the projectile strikes the target, both particles are destroyed at the point of impact. In their place, however, are created *new* particles, all of which are as "elementary" as the original particles and often as massive as the original particles! . . .

Zukav, on page 197, observes that it is in keeping with Einstein's special relativity that:

> *The new particles are created from the kinetic energy (energy of motion) of the projectile particle* in addition to the mass of the projectile particle and the mass of the target particle. . . .
>
> *Every subatomic interaction consists of the annihilation of the original particles and the creation of new subatomic particles*. The subatomic world is a continual dance of creation and annihilation, of mass changing to energy and energy to mass. Transient forms sparkle in and out of existence creating a never-ending, forever-newly-created reality.
>
> Mystics from both the East and the West who claim to have beheld "the face of God" speak in terms so similar to these that any psychologist who professes an interest in altered states of awareness scarcely can ignore this obvious bridge between the disciplines of physics and psychology.

This would certainly be stupendous if it were so. But the key statement: “The subatomic world is a continual dance of creation and annihilation, of mass changing to energy and energy to mass” is only true in two very specialized environments. Nothing nearly as exciting as this dance is going on in our bodies or our world at large. It may be too soon to have a lot of concepts cross this "obvious" bridge between physics and psychology.

And what are those two very special environments? Zukav has already mentioned accelerators and atom smashing devices. He also hints that in the vacuum of space there is much dancing of the sort alluded to.

Annihilation and Creation in Space?

On pages 239 through 241, Zukav has a fascinating discussion about the spontaneous creation of particles. It left me puzzled so I had to go and "read more."

Zukav is excited by the comparability of conceps between Mahayana Buddhism and the new physics. After citing some Buddhist sutras, Zukav suggests (239-240):

> The appearance of physical reality, according to Mahayana Buddhism, is based upon the interdependence of all things.
>
> Although this book is not about physics and Buddhism specifically, the similarities between the two, especially in the field of particle physics, are so striking and plentiful that a student of one necessarily must find value in the other.
>
> Now we come to the most psychedelic aspect of particle physics. Below is a Feynman diagram of a three-particle interaction. . . .
>
> In this diagram no world line [denoting previous existence] leads up to the interaction and no world line leads away from it. It just happens. It happens literally out of nowhere, for no apparent reason, and without any apparent cause. Where there was *no-thing*, suddenly, in a flash of spontaneous existence, there are three particles which vanish without a trace.
>
> This type of Feynman diagram is called a "vacuum diagram." That is because the interactions happen in a vacuum. . . .

[Note: a footnote here suggests a connection between "mystic knowing" and the "zero-point vacuum fluctuations of the dance of virtual particles in empty space."]

> In the subatomic realm, a vacuum obviously is *not* empty. . . .
>
> Vacuum diagrams are the serious product of a well-intentioned physical science. However, they are also wonderful reminders that we can create our "reality." . . .
>
> In any case, vacuum diagrams are representations of remarkable transformations of "something" into "nothing" and "nothing" into "something." These transformations occur continuously in the subatomic realm and are limited only by the uncertainty principle, the conservation laws, and probability. . . .

Just in case this leaves you with the impression that anything is possible in space in terms of the creation and annihilation of matter, the next few pages speak of the constraints provided by the laws of conservation and probability. Conservation laws, in fact, dictate (see. p. 243) that the lightest baryons and leptons cannot decay further, thereby making the basic building blocks of the macro-world, protons and electrons, stable in nature.

A previous discussion gives a solid hint about the reason for the spontaneous appearance of particles, it is a result of quantum field interactions (page 199):

> When two fields interact with each other they interact neither gradually nor at all their areas of contact. Rather, when two fields interact, they do it *instantaneously* and at a single point in space ("instantaneously and locally"). These instantaneous and local interactions make what we call particles. In fact, according to this theory, these instantaneous and local interactions *are* "particles." The continual creation and annihilation of particles at the subatomic level is the result of the continual interaction of different fields.
>
> This theory is called quantum field theory. Some major cornerstones of the theory were laid in 1928 by the English physicist, Paul Dirac. Quantum field theory has been highly successful in predicting new types of particles and in explaining existing particles in terms of field interactions.

The remainder of the page discusses some problems with the theory, explains that there may not be a particular field associated with each particle type after all, that the theory does incorporate relativity, in a limited way, and the next page (200) finally says quantum field theory is ad hoc:

> Quantum field theory is an *ad hoc* theory. That means that, like Bohr's famous specific-orbits-only model of the atom, quantum field theory is a practical but conceptually inconsistent scheme. Some parts don't fit together mathematically. It is a working model designed around the available data to give physicists a place to stand in the exploration of subatomic phenomena. The reason it has been around so long is that it works so well. (Some physicists think that it may work *too* well. They fear that the pragmatic success of quantum field theory impedes the development of a consistent theory.)

So the dance of the energies and particles is observed in accelerators, atom smashers, but does it really happen as described on page 241?: "These transformations occur continuously in the subatomic realm and are limited only by the uncertainty principle, the conservation laws, and probability". . . ?

Is the vacuum of space a boiling cauldron of continuous creation and annihilation?

Potentially, is probably the right word, if I read Henning Genz's "Nothingness" book (see footnote 8) correctly. But someone forgot to pay the power bill for space, there isn't enough energy there to pay for these short-lived ex-nihilo creation phantoms except in one type of place: the peripheries of black holes!

Genz has some fascinating things to say about space, its ubiquitous fields, and matter. An addition of energy to these fields will result in the creation ($E=mc^2$) of particles: "To make real particles out of the virtual ones that are part of the vacuum fluctuations, the only thing needed is energy." (p. 224, footnote 8)

However, Genz explains that this means a lot of energy, not available in the general vacuum of space that is at its lowest possible energy state. Energy is needed of the magnitude used to cause particle anti-particle collisions using the hugely energetic large electron-positron collider (LEP) at the CERN complex in Geneva.

The entire chapter in Genz's book called "Spontaneous Creation" is about this phenomenon, but only some summary remarks will be cited here. In the LEP, the electron and positron are collided at a very high energy in a vacuum (page 225):

> Electron and positron annihilate as a pair, in a particle-antiparticle collision. Their energy heats up the vacuum; when the hot vacuum decays, real particles emerge. The annihilation energy of electron and positron has, in the process, been used to realize the hidden faculties of the vacuum. . . . In passing through the intermediate state of an excited vacuum, it looks as though the electron and positron actually knew which virtual particles their annihilation might realize. But in fact, electrons and positrons in themselves are point like, and can be fully described in terms of a theory that knows neither muons nor quarks. So it is not the electron and the positron that "know" the possible final products of their interaction--it is the intermediate state, our vacuum, that has that knowledge.

This is fascinating in and of itself, but why does it matter? It addresses a cosmology problem as explained on pages 225-226:

> The same energy density that we reach today in electron-positron collisions pervaded the entire universe one ten-billionth of a second after the Big Bang. At that time the universe was the size of our solar system today, and its temperature was one million billion (or 10^{15}) degrees Celsius. All over space the same processes happened that we observe today in the electron-positron collisions we just described.

But is it only a "prehistorical" curiosity then, this creation of matter out of an excited vacuum? No, this phenomenon has also been used by Stephen Hawking, according to Genz, to explain why black holes have temperatures.

Since not even light can escape a black hole, how can it radiate temperature? The answer is that there are energy fluctuations in the vacuum surrounding a black hole, it is there that the vacuum creates virtual particles from the potential. The virtual particles made of the vacuum's fields become an actual particle-antiparticle pair, one of which falls into the black hole while the other is expelled, producing thermal radiation that allows the registering of a temperature.

This loss of a particle means a net loss of energy for the "isolated" system even though a particle is gained by the black hole in the process. The energy that created the particles comes from the black hole, and the electron that was created had a negative potential energy, so its absorption steals energy from the black hole. The positron sent into space is an obvious loss of energy to the system. (See pp. 252-253). The point is that black holes, because they do emit such thermal radiation from their environment, are slowly shrinking in size.

The chapter in which Genz discusses the implications of these types of processes is called "Let Nature Be As She May: Special Systems," and is quite fascinating all the way around.

So, Zukav was right, but in a limited way. He was not right in giving the impression that all of space, let alone our world or ourselves, was a boiling cauldron of particle creations and annihilations.

Science is Not Objective

The words in one of the above citations from Zukav, "the distinction between objective and subjective has vanished" leads to a side-bar in this discussion: there is no such thing as scientific objectivity (another consequence of the Copenhagen interpretation, of course, but not one I greatly disagree with). Zukav states on pages 30-31:

> The Great Machine is impersonal. In fact it was precisely this impersonality that inspired scientists to strive for "absolute objectivity."
>
> The concept of scientific objectivity rests upon the assumption of an external world which is "out there" as opposed to an "I" which is "in here." . . . The task of the scientist is to observe the "out there" as objectively as possible. . . .
>
> The new physics, quantum mechanics, tells us clearly that it is not possible to observe reality without changing it. . . .
>
> Some experiments show that light is wave-like. Other experiments show equally well that light is particle-like. If we want to demonstrate that light is a particle-like phenomenon or that light is a wave-like phenomenon, we only need to select the appropriate equipment.
>
> According to quantum mechanics there is no such thing as objectivity. We cannot eliminate ourselves from the picture. We are a part of nature, there is no way around the fact that nature is studying itself. Physics has become a branch of psychology, or perhaps the other way around.

Carl Jung the famed psychiatrist and his physicist friend Wolfgang Pauli are cited right here (in the Zukav book) on the connection between internal conflict and exterior circumstance, after which Zukav states:

> If these men are correct, then physics is the study of the structure of consciousness.

How the one, dealing with the macro-scale, follows from what I still feel is a questionable conclusions from experience with the micro-scale, is a mystery to me.

Regarding consciousness, it is true that there are several physicists, David Bohm and Henry Stapp in particular, who are pursuing the modeling of the mind using quantum mechanical insights. But neither of these two men are limiting themselves to the orthodox strictures of the Copenhagen interpretation! Neither one would, I believe, buy the idea that physics and psychology are branches of each other. Not yet, at least.

Zukav gets it right, however, in this paragraph where he says all of this applies to the micro-scale only. Speaking of the insight of one of the Copenhageners, Heisenberg, in particular his uncertainty principle, Zukav correctly says (page 112):

> This is the primary significance of the uncertainty principle. At the subatomic level, *we cannot observe something without changing it*. There is no such thing as the independent observer who can stand on the sidelines watching nature run its course without influencing it.

However, the observer's tendency to bias is well known even at the macro-scale. There has been enough experience accumulated to make this point even without this special case of investigator influence at the micro-scale. Of course Zukav's point is that at the smaller scale every measurement changes the object measured. And the point is correct.

But at the larger scales I suggest that common investigator biases do the same thing, but perhaps more subtly. For my soil chemistry research as well as my brine chemistry work, for my masters' and doctorate degrees respectively, a required reading before designing the necessary field and laboratory experiments was a little book I came to admire greatly for its breadth and insight, written by E. Bright Wilson in 1952.[9]. Within his section on the "Design of Experiments" is a subsection, pages 43-46, on "Psychological Bias." The section covers bias in the subject, bias in the experimenter, subconscious signaling, subliminal differences, and bias in instruments. The section suggests all of these factors are both real and important. There are usually ways to design experiments to minimize or eliminate these biases, and if there are not at least the would-be researcher is put on notice to look for opportunities for these types of biases, and is told to attempt to understand their potential impact. The point is that (p. 44): "Only the naive or dishonest claim that their own objectivity is a sufficient safeguard" [against biases]. And my point in bringing this up is that this has been a staple awareness at the macro-scale level for a long time. Perhaps this very basic awareness of potential biases made the point so immediately obvious to workers at the micro-scale, not the other way around.

To me, Zukav's objectivity discussion is closely tied in with the creator discussion, and in turn both are dependent on what I see as a dogma, an orthodox interpretation of quantum mechanics, coming from Bohr and Heisenberg and their Copenhagen fellow travelers while in Brussels in 1927.

---

[9]E. Bright Wilson, Jr., "An Introduction to Scientific Research," McGraw-Hill Book Company, Inc., New York, 1952.

I realize I have been poisoning your mind on the Copenhagen interpretation in the last few sections. So, I should let Zukav speak on the subject and explain why he follows (as does the author cited in reference 4) this famed and well defended Copenhagen interpretation of quantum mechanics.

The Copenhagen Interpretation: Scientific Orthodoxy?

On pages 37-38, Zukav begins to explain the Copenhagen interpretation of quantum mechanics:

> The Copenhagen Interpretation says, in effect, that it *does not matter* what quantum mechanics is about! The important thing is that it works in all possible experimental situations. This is one of the most important statements in the history of science. The Copenhagen Interpretation of Quantum Mechanics began a monumental reunion which was all but unnoticed at the time. The rational part of our psyche, typified by science, began to merge again with that other part of us which we had ignored since the 1700s, our irrational side. . . .
>
> The Copenhagen Interpretation does away with this idea of a one-to-one correspondence between reality and theory. This is another way of saying what we have said before. Quantum mechanics discards the laws governing individual events and states directly the laws concerning aggregations. It is very pragmatic.

On pages 40-1 Zukav continues this line of 'thought':

> The Copenhagen Interpretation was, in effect, a recognition of the limitations of left hemispheric thought, although the physicists at Brussels in 1927 could not have thought in those terms. It was also a *re-cognition* of those psychic aspects which long had been ignored in a rationalistic society. . . .
>
> The next time you are awed by something, let the feeling flow freely through you and do not try to "understand" it. You will find that you *do understand*, but in a way that you will not be able to put into words. You are perceiving intuitively through your right hemisphere. . . .
>
> Wu Li Masters perceive in both ways, the rational and the irrational, the assertive and the receptive, the masculine and the feminine. They reject neither one nor the other. They only dance.

It is perhaps irreverent to interrupt this dance, so I'll pick up the thread of this thought again on page 79, this time Zukav speaks plainly and without invoking visions of whirling Dervishes:

> The Copenhagen Interpretation of Quantum Mechanics says that it is unnecessary to "peer behind the scenes to see what is really happening" as long as quantum mechanics works (correlates experience correctly) in all possible experimental situations. It is not necessary how light can manifest itself as both particles and waves. It is enough to know that it does and to

> be able to use this phenomenon to predict probabilities. In other words, the wave and particle characteristics of light are unified by quantum mechanics, but at a price. There is no description of reality.

On page 39 Henry Stapp was cited describing the Copenhagen Interpretation in favorable terms such as "the new view" whose "theoretical structure did not extend down and anchor itself on fundamental microscopic space-time realities. Instead it turned back and anchored itself in the concrete sense realities that form the basis of social life. . . ."

On pages 302-304, Stapp is represented as explaining the implications of Bell's theorem (a theorem we will discuss at some length later), with a "no models" option for interpreting a certain experimental outcome that is not important to this discussion except that, according to the footnote on page 304, it is the preferred option for most physicists because they agree with the Copenhagen Interpretation.

Statements by Zukav explaining the Copenhagen Interpretation again leave no doubt about its superiority over other approaches (pages 303-304):

> The "no models" option in the diagram is, in effect, the Copenhagen Interpretation of Quantum Mechanics (page 37). In 1927, the most famous assemblage of physicists in history decided that it might not ever be possible to construct a model of reality, i.e., to explain the way things "really are behind the scenes." Despite the tidal wave of "knowledge" which has swept over us for forty years, the Fundamental Physics Group [at Lawrence Berkeley National Laboratory, whom Zukav is discussing Bell's theorem and other topics with] found it necessary, like the physicists at Copenhagen [actually they met in Brussels, as Zukav correctly says on page 40, but the group was dominated by Bohr and Heisenberg and others from Copenhagen] a half century before them, to acknowledge that it might not be possible to construct a model of reality. This acknowledgment is more than a recognition of the limitations of this theory or that theory. It is a recognition emerging throughout the West that *knowledge itself* is limited. Said another way, it is a recognition of the difference between knowledge and wisdom.

I find it proof that physics is alive and well as a science to see that, apparently since the Zukav book was written, Stapp has joined long-time heretics like Bohm and Einstein in seeking to overthrow what some perceive to be a yoke on physics thought. They resent the enforcement in thought and literature of the orthodox dogma of the Copenhagen interpretation: you can't know so don't bother to ask, and don't bother to perform experiments that ask. As soon as one seeks to look behind the scenes to feed one's understanding, as soon as one is no longer satisfied with predictions and correlations of observed data points, one becomes a Copenhagen-interpretation heretic.

Judging by my reading, there is a tide of dissatisfaction with this limiting idea. It served a purpose and allowed much practical work to get done uninterrupted by theorizings. But the time has come for some deeper understanding, is the sense I get from my readings. We will return to this theme later in this review. There I will provide several substantial citations from several physicists showing they have had to walk away from the strictures on thought, experiment and interpretation dictated by adherence to the Copenhagen interpretation.

There is a litany of points to be made regarding Zukav's treatment of a variety of notions all related to or implied by sub-interpretations or corollaries of the Copenhagen interpretation. These cover a range of topics such as time and consciousness; the living universe; matter-energy relations (and the vacuum of space); and finally there being nothing real in the universe.

All of this is based, according to Lederman's book, on 'the old quantum physics' of 1913, not 'the new physics'Zukav's book is claiming to describe. Lederman, in his Interlude B, suggests these fanciful ideas have litle to nothing to do with Niels Bohr's quantum theory, they are interpretations that lie outside science.

Thoughts on the Nature of Time and on Consciousness

Zukav discusses space and time on page 150:

> The Newtonian view of space and time is a *dynamic* picture. Events *develop* with the passage of time. Time is one-dimensional and *moves* (forward). The past, present, and future happen in that order. The special theory of relativity, however, says that it is preferable, and more useful, to think in terms of a *static*, non-moving picture of space and time. This is the space-time continuum. In this static picture, the space-time continuum, events do not develop, they just are. If we could view our reality in a four-dimensional way, we would see that everything that now seems to unfold before us with the passing of time, already exists *in toto*, painted, as it were, on the fabric of space-time. We would see all, the past, the present, and the future with one glance. Of course, this is only a mathematical propostion (isn't it?).

This time-space discussion resurfaces on pages 219-221 as part of a description of a Feynman diagram that is interpretable, using the ad-hoc quantum-field theory current at that time, as showing an electron moving forward in time, emitting two photons, and moving backward in time as a positron, until it absorbs two photons and moves forward in time as an electron, again. This interpretation becomes the basis for an expanded discussion of the Einstein space-time continuum principles allowing for time to be just another dimension, another axis along which movement can be postulated. The discussion does invoke the second law of thermodynamics, however, to explain why this time travel that may be postulated to explain an experiment, is not part of our experience as classical-world humans. The discussion also tells of an alternative interpretation not invoking a time reversal. Either interpretation is allowed.

Following this discussion, on page 222 Zukav properly caveats the following statement with a triple *if*:

> *If*, at the quantum level, the flow of time has no meaning, and *if* consciousness is fundamentally a similar process, and *if* we can become aware of these processes within ourselves, then it also is conceivable that we can experience timelessness.
>
> If we can experience the most fundamental functions of our psyche, and if they are quantum in nature, then it is possible that the ordinary conceptions of space and time might not apply to them at all (as they don't seem to apply in dreams). Such an experience would be difficult to describe rationally ("Infinity in a grain of sand/And eternity in an hour"), but it would be very real, indeed. For this reason, reports of time distortion

> and timelessness from gurus in the East and LSD trippers in the West ought not, perhaps, to be discarded peremptorily.

But now, in my opinion, he has placed into human experience what he previously said the second law of thermodynamics kept out of that macro-world experience. Also, it gets more confusing, to me, because both Einstein's relativity theories were macro-theories that are still not recognized or addressed in quantum mechanics. Zukav makes it seem the relativity and quantum theories are unified theories. Not really. According to David Lindley, in his book The End of Physics,[10] page 99: ". . . physicists know perfectly well that quantum mechanics and relativity have a basic incompatibility." (We will describe this incompatibility later in this review when discussing the Bell theorem work.)

Although I have myself experienced, from my very own frame of reference, time distortion (experience of apparent slowing of time and also of accelerating of time), these are very common experiences and I believe there is *nothing* in the physics being described here that either validates or legitimizes that perception-experience or explains it. To me this discussion thoroughly confuses macro-scale events stemming from an altered state of consciousness and a micro-scale interpretation of what is essentially a macro-scale relativity theory, tested largely through observations in space. I would not take time-distortion experiences as being evidence of physics principles, just as I would not take micro-scale physics principles as explanations for time distortion experiences.

But Zukav is generally correct in this discussion and properly caveats his discussions, although he teases with bold interpretations being possible, perhaps. I believe that the paper I read on this topic by Cramer[11], as part of this review, makes a convincing statement, in general factual agreement with Zukav's description: at the macro scale, thermodynamics rules, and there are convincing evidences for the forward movement of time. But at one particular point in the electromagnetic microscale there is some question as to time reversibility. From Cramer's paper:

> At the macroscopic level it is self-evident that the past and the future are not the same. We remember the past but not the future. We can send electromagnetic signals to the future but not to the past. Isolated systems

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[10]David Lindley, "The End of Physics, The Myth of a Unified Theory," Basic Books, New York, 1993.

[11]John G. Cramer, "Velocity Reversal and the Arrows of Time," Published in "Foundations of Physics," Volume 18, starting on page 1205, 1988. Accessed at http://mist.npl.washington.edu/npl/int_rep/VelRev/VelRev.html on 8/8/2000.

have low entropy in the past but gain entropy and become more disordered in the future. The universe was smaller and hotter in the past but will be larger and cooler in the future. The K°_{L} meson exhibits weak decay modes having matrix elements and transition probabilities that are larger for the decay process than for the equivalent time-reversed process. [Note: See below for an explanation of this enigmatic last sentence.]

The subjective arrow of time is the arrow most directly perceived by our consciousness. We remember the past but cannot change it; we have no direct knowledge of the future but view it, in part, as changeable by our actions and decisions. In the past, we were born and progressed through childhood to become adults. In the future, we will grow old and die. From the subjective point of view the past and future are so different that it is difficult to comprehend their near indistinguishability at the microscopic level.

The electromagnetic arrow of time is the arrow most difficult to perceive directly. An observer watching a movie showing an electromagnetic process would be unable to say whether the film was running backwards or forwards through the projector, because emission in the forward direction looks like absorption in the reverse direction. In quantum electrodynamics we can distinguish normal "retarded" electromagnetic waves and photons as having positive energy eigenvalues . . . while exotic "advanced" electromagnetic waves and photons would have negative energy eigenvalues . . . . The equations of electrodynamics treat these two species of radiation equivalently and quite evenhandedly. But empirically, it is clear that an electromagnetic time asymmetry exists. Atoms can spontaneously emit retarded photons and lose energy; they cannot spontaneously emit advanced photons and gain energy. If we pass an alternating current through an antenna we can produce retarded waves that travel into the future but not advanced waves that travel into the past. We can construct delay lines from which a signal emerges some time after it enters, but not "advance" lines from which a signal emerges before it enters.

The thermodynamic arrow of time is an arrow that is quite apparent after one has digested the concept of entropy, a measure of the disorder of the system. The second law of thermodynamics states that the entropy of an isolated system must always remain constant or increase with time. This natural law has an unusual status, in that it is not only confirmed by observation and experiment, but it has also been "proved" by Boltzmann in his famous "H-theorem.". . . . In any case, when we observe the manifest irreversibility of an egg being scrambled, a log burning, a automobile fender being crumpled, it is the thermodynamic arrow that is in operation.

> The cosmological arrow of time is an arrow that, from one point of view, is not at all apparent. It is based on the hard-won realization that the universe is expanding with time, that the universe was smaller in the past and will be larger in the future, that space itself is stretching with time. This is an observation that slowly emerged from decades of careful work by Hubble and other astronomers who studied the systematics of Doppler shifts of light from distant galaxies. But from another point of view, the cosmological time arrow is also "obvious." If the universe were not expanding, but rather had been static or contracting over a time period spanning many billions of years, then the night sky, as first pointed out by Obler, would now have the average temperature of the surface of a star. Life as we know it would be impossible. The cosmological time arrow creates the condition of thermodynamic disequilibrium that makes life possible and in a sense is a precondition for all of our observations.

Elsewhere in the paper Cramer explains:

> The kaon [a short-lived meson] arrow of time is the time arrow that was discovered most recently and that remains the most mysterious.

The paper then goes on to its actual purpose, which is to propose an experiment to evaluate this particle's apparent violation of parity rules in its decay that implies a violation of the "time reversal invariance" principle.

The “Living” Universe

One of the stranger chapters in Zukav’s book, but also one of the more provocative, is called "Living?" (pp. 45-66). Its premise is an interesting one, but its language, to me, confused the points being made. The subject is introduced on page 45:

> When we talk of physics as patterns of organic energy, the word that catches our attention is "organic." Organic means living. . . .

Right here at the start I became confused by the language. Organic and living are not synonyms at all, and physicists are probably using the word in the sense my 1974 Webster's gives: "characterized by the systematic arrangement of parts into a whole; systematic; pertaining to the structure of a thing" (etc). But what follows is a somewhat entertaining yet thoughtful discussion that suggests there is no clear line of demarcation as is usually assumed to exist between living and nonliving.

But let us accept the synonymity of organic and living for the sake of this discussion and allow Zukav to proceed, on page 48:

> . . . We cannot establish clearly that we are different from inorganic substances.

Again I have to pause. I suppose non-living in the usual sense is meant by the word inorganic, Zukav is not referring to the chemistry usage of the word, meaning it contains no carbon. Zukav continues:

> That means that, logically, we must admit that we may not be alive. Since this is absurd, the only alternative is to admit that "inanimate" objects may be living.
>
> The distinction between organic and inorganic is a conceptual prejudice. It becomes even harder to maintain as we advance into quantum mechanics. Something is organic, according to our definition, if it can respond to processed information. The astounding discovery awaiting newcomers to physics is that the evidence gathered in the development of quantum mechanics indicates that subatomic "particles" constantly appear to be making decisions! More than that, the decisions they seem to make are based on decisions made elsewhere. Subatomic particles seem to know *instantaneously* what decisions are made elsewhere, and elsewhere can be as far away as another galaxy! The key word is *instantaneously.* How can a subatomic particle over here know what decision another particle over there has made *at the same time the particle over there makes it?* All the evidence belies the fact that quantum particles are actually particles.

The mention of communication between particles across galaxies shocked me. I was determined to read the rest of the book at this point largely to find out what the basis, in physics, was for such a declaration.

If you were reading the book itself this latter point about particles not being particles would not be a surprise. A discussion of the strange nonlocal nature of particles, which have already been redefined as "a tendency to exist" or to "happen" was given on page 32.

Zukav continues the thought of this interesting citation:

> . . . these apparent particles are related with other particles in a dynamic and intimate way that coincides with our definition of organic.
>
> Some biologists believe that a single plant cell carries within it the capability to reproduce the entire plant. Similarly, the philosophical implications of quantum mechanics is that all of the things in our universe (including us) that exist independently are actually parts of one all-encompassing organic pattern, and that no parts of that pattern are ever really separate from it or from each other.

In order to prepare the reader for the shocking interpretation of some experimental results that will prove the theme of the chapter on the living universe, the dual wave-particle nature of subatomic matter is quite well explained by Zukav. Then, on pages 63 and 64, the simple single-slit (light shines through, no interference) and double-slit (light shines through, sets up interference pattern) experiment is described. When the second slit is covered up, the pattern becomes that of a single slit experiment.

This is trivial, unless you are surprised that it proves light is a wave (interference) as well as a particle (impact on photographic plate). The shocker, however, is that if we shoot one photon at a time, with the second slit open, it never falls on the photographic plate where a beam of light shining at both slits sets up interference patterns! The one photon knows that second slit is open. That is it! The proof of a type of consciousness being an attribute of the photon! Close that second slit and it will fall on those dark portions. That single electron knows when two slits are open even though it just goes through one!

Now, to me, this simply says that quantum mechanics has a valid point: a wave function is set up in all space and if and when a particle actualizes in that space, it will be defined by the nature of the wave function in which it is a potential "tendency to exist" or "happen" as described on page 32 of Zukav's book. The reason this experiment is such a mystery, in my not so humble opinion, is that the brains being applied to it are in classical, particle-bound, modes. Consider this set of observations, that I see as being the height of silliness, but --after all -- I am no physicist; they are found on pages 63 and 64:

> When we fired our photon and it went through the first slit, how did it "know" that it could go to an area that must be dark if the other slit were open? In other words, how did the photon know that the other slit was closed?
>
> > "The central mystery of quantum theory," wrote Henry Stapp, is 'How does information get around so quick?'" How does the particle know that there are two slits? How does the information about what is happening everywhere else get collected to determine what is likely to happen here?
>
> There is no definite answer to this question. Some physicists, like E. H. Walker, speculate that photons may be *conscious*!
>
> > Consciousness may be associated with all quantum mechanical processes . . . since everything that occurs is ultimately the result of one or more quantum mechanical events, the universe is "inhabited" by an almost unlimited number of rather discrete conscious, usually nonthinking entities that are responsible for the detailed working of the universe.

To me, reading these words made me think all the wonderful things I had just read about waves and actualizing particles was just pulling my leg, since obviously these interpreters were looking at a particle, a photon, as if it were a bullet being shot out of a gun! On pages 67 and 68 there is a pretty good discussion about the meaning of probability and randomness, suggesting the photon could have appeared anywhere. Wave functions with interference, of course, restrict where the photon is likely to be located should a photographic plate be placed in the likelier target area. So, it is not as random as that discussion in the next chapter would have it either. But "pure chance" is the answer on page 68, while on page 63 there was a conscious decision! The same photon in the same experiment is being discussed!

Frankly, the confused vocabulary aside, these four pages from 45 through 48 guaranteed I would read the book to its end, every word. I really wanted to know what physics experiments supported these intuitively attractive notions. Needless to say I was disappointed by the one example in this chapter, the single/double-slits experiment. Somehow it did not touch communication between particles across galaxies. But more was at least implicitly promised.

The citation Zukav made from the writings of Walker is interesting, to me, because it flatly contradicts Zukav's exclamation on the next page (64) that the "wave-particle duality was the end of the line for classical causality." Walker is saying something very deterministic and causal, in my opinion, very unlike that which should be coming from a Copenhagen-interpretation true-believer.

Zukav continues after the Walker cite with:

> Whether Walker is correct or not, it appears that if there really are photons (and the photoelectric effect "proves" that there are), then it also appears that the photons in the double-slit experiment somehow "know" whether or not both slits are open and that they act accordingly.

A footnote here says: "An explanation other than "knowing" might be synchronicity, Jung's acausal connecting principle." Synchronicity is a wonderful principle, verified by many in their daily experience, yet again I see no connection between a photon being a wave as well as a particle and that macro-scale phenomenon that brings to you what you need, usually in an emotional sense, from other people usually, or from finding information in one form or another and just when you really need it.

Zukav continues:

> This brings us back to where we started: Something is "organic" if it has the ability to process information and to act accordingly. We have little choice but to acknowledge that photons, which are energy, do appear to process information and to act accordingly, and that therefore, strange as it may sound, they seem to be organic. Since we are also organic, there is a possibility that by studying photons (and other energy quanta) we may learn something about us.

I kept reading, after this serious breach of my credulity, because the communication between particles across galaxies wasn't explained yet. Turns out it isn't discussed at all in the book!

Not explicitly, that is. But I believe I am supposed to think that the Bell-theorem experiments of the last chapter (meter-scale experiments using photons) are illustrating such effects because measurements are made across "space-like" intervals (as compared with "light-like" or "time-like"). To me this has nothing to do with galaxies and I feel I have been had by a false advertisement of proof of instant intergalactic communication on page 47. (I know, I know, I saw page 88 where a Doubting Thomas is illustrated from the New Testament. Guess that is me.)

We will soon get to that Bell-theorem-related discussion of instant communication across space-like intervals, with its accompanying suggestion of superluminal (faster than light) travel by information. Looking for the answer to what I felt to be a promise of a discussion of intergalactic particle communication (on page 47) kept me reading and kept me taking the notes that would lead to this rather complaining and whiney review.

But I can't resist citing Zukav one more time on this single-/double-slit experiment. He explains it again on page 77:

> According to classical physics, the light source emitted a real particle, a photon, and it traveled from the light source to the slit where detector two recorded it. Although we did not know its location while it was in transit, we could have determined it, if we had known how.
>
> According to quantum mechanics, this is not so. No real particle called a photon traveled between the light source and the screen. There was no photon until one actualized at slit two. Until then, there was only a wave function. In other words, until then, all that existed were tendencies for a photon to actualize either at slit one or at slit two.
>
> From the classical point of view, a real photon travels between the light source and the screen. The odds are 50-50 that it will go to slit one and 50-50 that it will go to slit two. From the point of view of quantum mechanics, there is no photon until a detector fires. There is only a developing potentiality in which a photon goes to slit one *and* to slit two. This is Heisenberg's "strange kind of physical reality just in the middle between possibility and reality."

I agree it is strange from a classical point of view, but here you have the explanation for the mystery of the photon who knew how many slits were open! It didn't know anything, it was just a potentiality in a stream of wave functions that collapsed as a photon materialized on the detector. End of mystery if you believe the Copenhagen interpretation. To think more about it is evidence of being trapped in particle-like classical modes of thinking, after all.

Bell's Theorem and Superluminal Travel

The crown jewel of Zukav's book is the work evaluating Bell's theorem. The interpretation from some physicists is that it proves superluminal, or faster than light, information exchange. One such physicist other than the ones cited by Zukav is Nick Herbert, who in his "Quantum Reality" book cited previously (footnote 4) said (on his page 121):

> Bell's theorem shows that all efforts to eliminate the superluminal character of these waves must fail. Bell proves (among other things) that it is impossible to construct a hidden-variable model which explains the facts without including something that goes faster than light.

Herbert makes it clear that he is not one of the heretics when it comes to the Copenhagen interpretation (same page):

> We acknowledge for the moment the neorealist point of view but will continue to explore visions of reality consistent with the orthodox ontology.

And there you have it! If you are orthodox, you see the work addressing Bell's inequality/theorem as Zukav does.

And just who are the unorthodox? Herbert lists among them (page 120):

> Louis de Broglie, Erwin Schrodinger, David Bohm, and John Stewart Bell, as well as many lesser lights.

What, the father of the Bell theorem a heretic? Yes, he was trying to prove, as the others named thought should be provable, that even the quantum world, if we just knew enough, can be explained in classical terms. Herbert calls this view "neorealist."

Herbert (same page) goes on to say that:

> Because of their belief that quantum randomness stems not from utter lawlessness but from hidden causes, these heretics from the orthodox view are sometimes called "hidden-variable" physicists. Their goal is to "complete" quantum theory by constructing a deeper theory which includes an explanation not only of its randomness but of what actually goes on in a measurement.

So now we know this: Bell was out to separate the hidden-variable theory from the quantum- mechanical (orthodox) theory. The former said particles and waves are real things and always exist, the latter says that waves are a useful construct and particles exist when we collapse the wave function. Since the reality to be seen should, by definition, be the same for both cases, it is very difficult to define a test to separate the one from the other. But Bell did it, and quantum-mechanics won! Or so the orthodox interpretation goes.

So, now we are prepared for Zukav's words on matters pertaining to the Bell theorem and its tests. We will begin with pages 256-257:

> The possibility that separate parts of reality (like you and I and tugboats) may be connected in ways which both our common experience and the laws of physics belie, has found its way into physics under the name of Bell's theorem. Bell's theorem and quantum logic take us to the farthest edges of theoretical physics. Many physicists have not even heard of them. . . . (Bell's theorem) tells us there is no such thing as "separate parts." All of the "parts" of the universe are connected in an intimate and immediate way previously claimed only by mystics and other scientifically objectionable people.

Zukav continues using this superlative vocabulary on page 282:

> Bell's theorem was reworked and refined . . . until it emerged in its present form. Its present form is dramatic, to say the least. . . . Some physicists are convinced it is the most important single work, perhaps, in the history of physics. One of the implications of Bell's theorem is that, at a deep and fundamental level, the "separate parts" of the universe are connected in an intimate and immediate way.
>
> In short, Bell's theorem and the enlightened experience of unity are very compatible.

Well, in this instance, if I believe as Zukav does, then there is a glimmer of convergence here between mysticism and physics. He continues on pages 296-297:

> Bell's theorem showed that either the statistical predictions of quantum theory or the principle of local causes is false. It did not say which one was false, but only that both of them cannot be true. When Clauser and Freedman [experimentalists testing the theorem] confirmed that the statistical predictions of quantum theory are correct, the startling conclusion was inescapable: The principle of local causes must be false! However, if the principle of local causes fails and, hence the world is not the way it appears to be, then what is the true nature of our world?

There are several mutually exclusive possibilities. The first possibility, which we have just discussed, is that, appearances to the contrary, there really may be no such thing as "separate parts" in our world (in the dialect of physics, "locality fails"). In that case, the idea that events are autonomous happenings is an illusion. . . . This possibility entails a faster-than-light communication of a type different than conventional physics can explain.

In this context of faster-than-light communication a footnote also suggests a possible connection with Jung's synchronicity concept, although since there is almost instant communication in the macro-world, this seems a bit of an unnecessary stretch to me. What is the difference between instantaneous and the few seconds it takes messages to be broadcast by modern satellite-linked communications technology?

In this picture, what happens here is intimately and immediately connected to what happens elsewhere in the universe, which, in turn, is intimately and immediately connected to what happens elsewhere in the universe, and so on, simply because the "separate parts" of the universe are not separate parts.

"Parts," wrote David Bohm:

. . . "are seen to be in immediate connection, in which their dynamical relationships depend, in an irreducible way, on the state of the whole system (and, indeed, on that of broader systems in which they are contained, extending ultimately and in principle to the entire universe). Thus, one is led to a new notion of *unbroken wholeness* which denies the classical idea of analyzability of the world into separately and independently existent parts" . . . .

We will return to Bohm's views later, since he is a heretic, but we must allow Zukav to finish his thought (page 287):

The fastest communication signal is an electromagnetic wave, like a light wave or a radio wave. These travel at approximately 186,000 miles per second. Almost all of physics rests upon the assumption that *nothing in the universe can travel faster that the speed of light.*

Next, the Einstein-Podolsky-Rosen (EPR) thought experiment, generated to prove that quantum mechanics was an incomplete theory by Einstein and coworkers, heretics, is explained. It shook Bohr, a father of the orthodox Copenhagen interpretation, to the extent that he was forced to agonizedly agree, to an extent, with Einstein. Later experimentation showed Bohr was more correct than Einstein, however.

EPR involved two identical particles coming from a source and moving away from each other. Since they are twinned, changing one particle's spin properties with a magnetic device at one side, according to agreed-on principles, would change its twin, which has for some time already been moving in the opposite direction at the speed of light. Since quantum mechanics could not explain such a result, it was incomplete. In Zukav's book, Einstein is quoted as giving the key, one totally unacceptable to Einstein, to a possible solution of the conundrum (p. 289):

> "One can escape from this conclusion {that quantum theory is incomplete: Zukav} only by either assuming that the measurement of S_1 ((telepathically)) changes the real situation of S_2 or by denying independent real situations as such to things that are spatially separated from each other. Both alternatives appear to me entirely unacceptable."

Zukav suggests in response that Einstein was just stuck in old ways of thinking and thus wrong (p. 290):

> Although these alternatives were unacceptable to Einstein, they are being considered by physicists today. Few physicists believe in telepathy, but some physicists do believe either that at a deep and fundamental level there is no such thing as "independent and real situations" of things hat have interacted in the past but which are spatially separated from each other, or that changing the measuring device in area A *does* change "the real factual situation" in area B.
>
> This brings us to Bell's theorem.
>
> Bell's theorem is a mathematical proof. What it "proves" is that if statistical predictions of quantum theory are correct, then some of our commonsense ideas about the world are profoundly mistaken. . . .
>
> This is quite a conclusion because *the statistical predictions of quantum mechanics are always correct.* Quantum mechanics is *the* theory. It has explained everything from subatomic particles to transistors to stellar energy. It never has failed. It has no competition.
>
> Quantum physicists realized in the 1920s that our commonsense ideas were inadequate for describing subatomic particles (pages 20, 260). Bell's theorem shows that commonsense ideas are inadequate even to describe macroscopic events, events of the everyday world!
>
> As Henry Stapp wrote:
>
> > "The important thing about Bell's theorem is that it puts the dilemma posed by quantum phenomena clearly into the realm of macroscopic phenomena . . . {it} shows that our ordinary ideas about the world are somehow profoundly

deficient at the macroscopic level."

> Bell's theorem has been reformulated in several ways since Bell published the original version in 1964. No matter how it is formulated, it projects the "irrational" aspects of subatomic phenomena squarely into the macroscopic domain. It says that not only do events in the realm of the very small behave in ways which are utterly different from our commonsense view of the world, but also that events in the world at large, the world of freeways and sports cars, behave in ways which are utterly different from our commonsense view of them. This incredible statement cannot be dismissed as fantasy because it is based upon the awesome and proven accuracy of the quantum theory itself.

These paragraphs were cited at length because of the central importance of the claim being made here: that the experiments addressing the Bell inequality show that subatomic behavior spills into the macro-scale domain where humans live. Indeed, it has been shown there are classical systems that also violate Bell's inequality. But there are also serious questions of experimental setup and especially interpretation. We will take a look at those questions after we hear Zukav out on superluminal matters (another pun attempt).

On page 298 Zukav observes:

> Superluminal quantum connectedness seems to be, on the surface at least, a possible explanation for some types of psychic phenomena. Telepathy, for example, often appears to happen instantaneously, if not faster. Psychic phenomena have been held in disdain by physicists since the days of Newton. In fact, most physicists do not even believe that they exist.
>
> In this sense, Bell's theorem could be the Trojan horse in the physicist's camp; first, because it proves that quantum theory requires connections that appear to resemble telepathic communication, and second, it provides the mathematical framework through which serious physicists (all physicists are serious) could find themselves discussing types of phenomena which, ironically, they do not believe exist.

No doubt when this much is riding on this proof of superluminal communication, it is no great wonder that the discussion of alternative, unorthodox interpretations is quite unpalatable (snippets from pages 299-301):

> The failure of the princple of local causes does not necessarily mean that superluminal connections actually exist. There are other ways to explain the failure of the principle of local causes. For example, the principle of local causes--that what happens in one area does not depend

> upon variables subject to the control of an experimenter in a distant space-like separated area--is based on two tacit assumptions which are so obvious they are easy to overlook. . . . These two assumptions--that we choose how to perform our experiment and that each of our choices, including those that we did not select, produces or would have produced definite results--is what Stapp calls "contrafactual definiteness."
>
> . . . Since Bell's theorem shows that, assuming the validity of quantum theory, the principle of local causes is incorrect, and, if we do not want to accept the existence of superluminal connections ("the failure of locality") as the reason for the failure of the principle of local causes, then we are forced to confront the possibility that our assumptions about contrafactual definiteness are incorrect ("contrafactual definiteness fails"). Since contrafactual definiteness has two parts, there are two ways in which contrafactual definiteness could fail.
>
> The first possibility is that free will is an illusion ("contrafactualness fails").

This discussion is a long one and ends up finally invoking the specter of the Great Machine which has already been demolished in the book as a direct consequence of quantum mechanics. After offering the Great Machine as one alternative, Zukav continues to define the second altrnative:

> . . . Contrafactual definiteness also fails if the "definiteness" assumption in it fails. In this case, we do have a choice in the way we perform our experiments, but "what would have happened if . . ." does not produce any definite results. This alternative is just as strange as it sounds. It is also just what comes out of the Many Worlds Interpretation of Quantum Mechanics (p. 83). According to the Many Worlds theory, whenever a choice is made in the universe between one possible event and another, the universe splits into different branches.

Given these ponderous alternatives, either the Great Machine of Many Worlds, assuming the violation of general relativity's law on the maximum speed of a particle or a wave seems trivial! *In other words, to not accept superluminal communication on the basis of these Bell theorem experimental results is unthinkable.* Herbert would agree (see his page 121, footnote 4).

So would Chiao, Kwiat and Steinberg[12]. They went one better than the others and performed experiments on twin photons where they inserted two interferometers into their detector setup that provided a dual-possibility for course alteration

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[12]Raymond Y. Chiao, Paul G. Kwiat, and Aephraim M. Steinberg, "Faster than Light?", Scientific American August 1993, pp. 52-60.

(straight or right with a 50/50 chance twice). The idea was to give each of the twin photons two chances to either turn right or go straight, first; for those turning right there was a second chocie to turn right or go straight; for those initially choosing staright there was a second chouce to turn left or go straight. Those intially turning right were turned back by mirrors that could be moved, making the path length different. The physicist trio found that with a very high corellation, the photons on the one side of the experiment did what the photons on the other side of the experiment did. Adjusting the path length by moving the mirror could get them to do the opposite from its twin, however, and as the authors put it "each one knows instantly (nonlocally) what its twin has done and behaves acordingly."

The authors explain some of the variations run and the analyses of their data. They explain that the 90% interference (the Bell-inequality hidden-variable maximum would be 71%) rate suggested by interference fringes of alternating light and dark areas (like the two-slit experiments) prove the hidden variable theory is wrong. To interfere with each other they must take the same path or they would not arrive at exactly the same time. These authors conclude:

> If certain reasonable supplementary assumptions are made, one can conclude from these data that the intuitive, local, realistic picture suggested by Einstein and his cohorts is wrong: it is impossible to explain the observed results without acknowledging that the outcome of a measurement on the one side depends nonlocally on the result of a measurement on the other side.

So these authors believe there has been instantaneous information exchange over a distance, but maintain that this does not violate the basic premise of relativity "because there is no way to use the correlations between particles to send a signal faster than light." Einstein, as we will see shortly (two pages down), was unimpressed with this technicality. To him this was a violation of the basic premise of relativity.

Chiao, Kwiat and Steinberg also conclude that

> Although in our experiments the photons were separated by only a few feet, quantum mechanics predicts that the correlations would have been observed no matter how far apart the two interferometers were.
>
> Somehow nature has been clever enough to avoid any contradiction with the notion of causality. For in no way is it possible to use any of the above effects to send signals fater than the speed of light. The tenuous coexistence of relativity, which is local, and quantum mechanics, which is nonlocal, has weathered yet another storm.

Research on the potential use of this phenomenon in quantum cryptography is mentioned by these authors.

So am I convinced? No. This experiment is too complex for me. The fact that by spacing out the interferometers they could predictable switch from a high positive correlation to a high negative correlation, but nevertheless a high correlation, is fishy to me. It should have resulted in a loss of correlation, according to me, so I suspect something systematic is being overlooked. In the text on their interpretation of the interference data they stated that they needed to assume two emission times at the source for each photon, otherwise the arrival of two photons at the same time after traveling different path lengths could not be explained. They say in explanation:

> Classically, of course, this possibility is absurd. But in our experiments the observation of interference fringes implies that each of the twin photons possessed two indistinguishable times of emission from the crystal. Each photon has two birthdays.

I would suspect something in the physics at work in the experiment is not being understood before I would buy into twin emission times. What is more likely is that emission times are imprecisely known, and the data fits a poorly described distribution that is bimodal rather than the assumed bell-shape (see earlier part of this same article on quantum tunneling of photons, with arrival of photons tunneled through a barrier and their air-only twins at the same time! This is explained in terms of reshaped statistical distrubtions. Two birthdays could have been assumed in these experiments as well. I am more than ever, looking at these outcomes, of the opinion that Einstein et al. were right, there is a correlation of properties at birth that explains correlations of similar behavior in an interferometer pair or a polarity filtering device.

In addition to Herbert, and the trio of Chiao, Kwiat and Steinberg, several others agree with the nonlocal, superluminal interpretation too, obviously, since Zukav cites them at length. I am referring to David Bohm and Henry Stapp. We will return to them later. Not to establish their support of a Zukav-like interpretation, I concede readily that they support the interpretation as it is given by Zukav. But both of them are thorough heretics! Bohm has been since the 1950's. Stapp became one recently, judging by the latest additions to his web site.

We will visit with these heretics shortly. But first it needs to be explained that there are other views of Bell's theorem among physicists. Some physicists, in fact, think it has no bearing at all on the very issues for which it is being used as scientific proof.

Other Interpretations of the Bell Theorem and Its Experiments

Of the sources I consulted that disagreed with Zukav's notions, there were several that stood out. One gave the best plain language description of the problem and put the reasons for disagreeing with Zukav-like interpretations in clear language.. One gave the most thorough treatment of the problem. And one gave the most vehement attack on the Zukav-like interpretations. And then there were several others that were somewhere in between.

The Clearest Plain Language Explanation of the Problem

I'll start with the clearest plain-language description of the problem, one by David Lindley, in a book called The End of Physics (previously cited, see footnote 10). Lindley calls into question the orthodox interpreation as not dealing with a very fundamental contradiction between it and general relativity. This does not directly address the Zukav-like interpretations, but it does say that the fundamental assumptions that lead to such interpretations were not believed by Einstein, and for good reason.

As Lindley explains on his pages 78 and 91, special relativity's fundamental rule is that the speed of light is the ultimate speed in the universe, and general relativity was invented to take care of gravity's apparent contradiction of that rule. Gravity seemed to represent an instantaneous action at a distance. General relativity put it in its proper place and removed the last vestige of this need for inexplicable instantaneous action of one object on a distant object. And quantum mechanics blithely brought action at a distance right back into physics after Einstein spent a chunk of his life removing it. No wonder he was upset!

At the end of his discussion, Lindley fumes against the Copenhagen interpretation. The way he explains Einstein's reaction to some of the assumptions of the orthodox interpretation let me know I was thinking the same thoughts as Einstein. Wrong thoughts, perhaps, but I am in good company!

What follows now is a long citation, from Lindley's chapter called "The Last Contradiction." We will pick up where Lindley characterizes Einstein's rebellion against the orthodox interpretation of quantum mechanics (material taken from pages 93-97 of footnote 10):

> Einstein wanted to believe that probability entered into quantum mechanics because we didn't know everything there was to know about the subatomic world. In his later decades, Einstein inveighed against quantum mechanics and spent fruitless years trying to remove probability from it. He did not succeed, but his efforts left behind an example of how quantum mechanics

seems to contradict not just common sense but his sacred principle of causality. This is the famous Einstein—Podolsky—Rosen paradox of 1935, so familiar to physics students that it is known simply as EPR. In its original form, the EPR paradox was hard to imagine and would have been even harder to test experimentally, but in 1951 the Princeton physicist David Bohm came up with a much more accessible version. Bohm's formulation makes use of the quantum-mechanical property called spin, which many elementary particles possess and which can be thought of, for our purposes, as spin in the familiar sense except that it is quantized. . . .

The idea of electron spin was devised in 1925 to explain the curious fact that when atoms were placed in a strong magnetic field certain spectral lines split into two . . . . The basic assertion made by the inventors of spin was this: an electron placed in a magnetic field tends to orient itself in such a way that its spin arrow is parallel to the direction defined by the magnetic lines of force. At about the same time, Wolfgang Pauli came up with his famous exclusion principle, which declares that no two electrons in an atom can occupy exactly the same quantum-mechanical state. . . . But now spin had to be taken into account. Two electrons can occupy the same orbit, as long as their spins are pointing in opposite directions; if their spin directions were the same, they would be in the same state exactly, which Pauli forbids. . . .

. . . Before long, the reality of electron spin was experimentally established: an electron beam, presumably containing initially random spins, will split fifty-fifty into two beams when it passes through a magnetic field. Half the electrons will be "spin-up" with respect to the field, and the other half "spin-down." . . .

If the application of a magnetic field to a beam of electrons is thought of as a means of measuring electron spin, then it is only the act of measurement itself that forces the electrons to choose between spin-up and spin-down—or between spin-left and spin-right, if the magnetic field is placed the other way. One might think that the electron spins in a beam of electrons are, in the absence of a magnetic field, pointing every which way, at random, but a better statement of the idea is that each electron in an unmagnetized volume of space has a wholly uncertain (in the sense of the uncertainty principle) spin direction. It is not that the spin is pointing in a certain direction of which we are ignorant, rather that the spin direction itself is undefined. Only when a magnetic field is applied is the spin forced to align in a particular way, and only at that moment is the undetermined spin transformed into a measurable quantity.

This is the kind of thinking that Einstein found repellent, and the paradox he devised with his two young Princeton associates Boris Podolsky and Nathan Rosen is addressed to precisely this point. Imagine a pair of electrons whose spins add up to zero; quantum-mechanically, spin is an absolutely conserved quantity, and if the total spin of the two electrons is zero at the outset, it must remain zero at all times. Now imagine that these two electrons are made to travel in opposite directions away from the device that created them. At some distance, a physicist uses a magnetic field to measure the spin of one of them. According to the rules of quantum mechanics, the electron-spin direction is determined only when the measurement is made, and if a vertical magnetic field is applied, the electron will be found to be either spin-up or spin-down.

> So far, so good, but the paradox arises when we recall that the spin of the two electrons must add up to zero: at the moment when the physicist measures one electron, and forces it to choose between up and down, the other electron, by now a thousand miles away, is suddenly forced to be down or up—the opposite of what the first electron chose. And if things are to work out correctly, the second electron must be forced to adopt one state or the other at exactly the moment the first electron is measured. . . .
>
> In the EPR experiment, quantum mechanics seems to have acquired something analogous to the old classical idea of action at a distance, in that a measurement made at one place has had an instantaneous consequence somewhere else. It is important to realize that this is not, at least in any obvious way, the key to a means of instantaneous communication: . . . there is no practical way of sending a pre-determined instruction this way.
>
> The EPR experiment cannot be used, therefore, to transmit any information faster than the speed of light, and in that sense does not contradict the letter of the law of relativity. But to Einstein it contradicted the spirit of the law. He felt that the EPR "paradox" demonstrated the unsatisfactory nature of the foundations of quantum mechanics, he referred to this aspect of the new theory as "spooky action at a distance," and he did not want to see reintroduced into physics what he had striven so hard to banish.
>
> As far as Einstein was concerned, the EPR experiment demonstrated a flaw in quantum mechanics. Despite Bohr, Heisenberg, and all the other members of the Copenhagen gang, who declared that nothing in quantum mechanics was real until it was measured, Einstein interpreted the EPR experiment to mean that there must be some secret way in which the electron spin was fixed, but concealed, at the outset. Einstein's preference was for what has become known as the "hidden variable" version of quantum mechanics, in which unpredictability and uncertainty represent, as in classical physics, nothing more remarkable than our ignorance of the "true" state of the electron.

Note, this was exactly my interpretation while reading Zukav! Einstein, Lindley, Bell and I see this one the same way: if a source is excited to release a particle-pair but itself remains stationary, quantum mechanics' conservation laws say that the two particles are twins, they go in opposite directions and have spin characteristics that complement each other and add to zero. In case of photons, they are polarized at the same angle but with opposite spin along that same angle. So a detector sees the same polarity at both sides, or in the case of a particle the spin is opposite in the same dimension. So what is the big deal? The source did this to both particles to conserve its own state! But then comes the orthodox view: there is no particle, and certainly no such attribute as spin or polarity until a particle is created from its potential wave by a detector. OK fine, so all of these attributes, conserving the necessary properties, were built into the wave function created by the source! It is still the source who created the balanced wave function to conserve its own momentum! I just don't get it.

But back to Lindley (on page 97 now):

> This can easily seem an issue more of metaphysics than of physics. Any hidden-variable theory of quantum mechanics, if it is to work properly, must give exactly the same results that ordinary quantum mechanics provides, and to argue whether a quantity such as electron spin is genuinely indeterminate (Bohr) or determined but inaccessible (Einstein) seems pointless. . . . But in 1960, the Irish physicist John Bell came to the surprising conclusion that there was a practical way to tell the difference between the standard interpretation of quantum mechanics, in which the electron's spin was truly undetermined until the moment of measurement, and Einstein's hidden-variable idea, in which the spin was determined at the moment the two electrons were made, and merely revealed by the measurement. Bell showed that in slightly more complicated EPR-type experiments, the statistics of repeated measurements would come out differently in the two theories. Bell's result was not particularly difficult to follow, and was surprising only because no one until then had fully thought through the implications of a hidden-variable theory. . . .
>
> Bell's result brought an air of physical reality into previously metaphysical discussions of the EPR experiment, but for technical reasons it was some years before anyone was able to devise an experiment that would actually test quantum mechanics in the way Bell prescribed. Finally, in 1982, Alain Aspect and his group at the University of Paris put together just such an experiment and got the result that many expected: the standard interpretation of quantum mechanics was correct and the hidden-variable idea was not. (Many theoretical physicists claimed to be unimpressed by Aspect's work, since it merely confirmed what everyone already knew; physicists, like the rest of us, have infallible hindsight).
>
> Some thirty years after Einstein's death in 1955, his fond hope that quantum mechanics would turn out to be fundamentally mistaken was overturned, at least for the moment. The standard interpretation of

> quantum mechanics works fine, and the truly indeterminate nature of unmeasured physical properties has to be accepted at face value. The way to understand quantum mechanics, if it can be understood at all, is to concern oneself only with what is measured in a specific experiment, and to ignore resolutely all else. Some sort of "spooky action at a distance" may or may not be at work in Aspect's experiment, but it does no good to worry about the matter; quantum mechanics gets the answer right, and never mind how.

If the preceding paragraph seems like it may be read as a sarcastic statement, the next few pages make this very clear (98-100):

> As the physicist-turned-Anglican-Priest John Polkinghorne has observed, this is a curious attitude to take. The normal rule in physics, more so than in any other kind of science, is never to stop asking questions. . . . by tradition the physicist, having found one level of order in nature, invariably wants to know, like the archaeologist digging down into the remains of Troy, whether there is another, more primitive layer underneath. Except in the case of quantum mechanics, apparently: physicists continue to find quantum mechanics baffling . . . but they are supposed to live with their bafflement by refusing to ask questions that would cause trouble. It does no good, therefore, to ask what is the nature of the spooky action at a distance in an EPR experiment; the results come out as they should, and that is enough. . . .
>
> This attitude is all the more curious in that physicists know perfectly well that quantum mechanics and relativity have a basic incompatibility. General relativity relies on the old-fashioned classical notion of particles idealized as mathematical points moving along trajectories idealized as mathematical lines, but quantum mechanics forbids such thinking and insists that we think about particles and their trajectories (if we think about them at all, which perhaps we should not) as probabilities only: a particle has a certain chance of being in this region of space, and a certain chance of moving off in this direction. It is universally accepted that, in this respect, relativity is deficient and must be brought up to par with quantum theory. A quantum theory of gravity is needed precisely because general relativity uses a classical notion of objective reality that was banished long ago by quantum mechanics. But from Einstein's point of view there is also the problem that while relativity fully and completely upholds the principle of causality, in quantum mechanics there appears to be some pale remnant of the old classical bugbear of action at a distance. . . . Alain Aspect's experiments prove that Einstein's invocation of some sort of hidden-variable theory will not work, but the problem that so agitated Einstein has not been entirely beaten down.

> The contradictions between relativity and quantum mechanics constitute the single great question in fundamental physics today, and form the profoundest motivation for seeking a "theory of everything," but the common attitude seems to be that something must be done to general relativity to take account of the quantum uncertainty in all things. The idea of altering some part of quantum mechanics to get rid of spooky action at a distance is declared off-limits by order of the standard interpretation of quantum mechanics, which specifically forbids questions that probe beneath the surface: what you measure is all there is. It is a novelty indeed in physics that a theory should contain a stricture telling the physicist that it is no use trying to dig beneath the surface, especially when that theory, quantum mechanics, is known to be inconsistent with another fundamental theory, general relativity.

With this plain language explanation behind us, we are ready to move to the most vehement protest of Zukav-like interpretations.

The Most Vehement Protest Against Zukav-like Interpretations

If you will recall, near the beginning of this review we cited language critical of the inventor/discoverer of quarks. It accused him of being stuck in old style thought and strongly hinted that his work was a waste of time. Now I will cite Murray Gell-Mann,[13] the Nobel Prize winner who was being criticized. He weighs in quite strongly against Zukav-like interpretations, but never directly cites Zukav.

Gell-Mann observed on his pages 167-168 that:

> When we look at what can really happen with significant probability, we find that many phenomena that were impossible in classical physics are still effectively impossible in quantum mechanics. However, public understanding of this has been hampered in recent years by a rash of misleading references in books and articles to some elegant work done by the late John Bell and to the results of a related experiment. Some accounts of the experiment, which involves two photons moving in opposite directions, have given readers the false impression that measuring the properties of one photon instantaneously affects the other. Then the conclusion has been drawn that quantum mechanics permits faster-than-light communication, and even that claimed "paranormal" phenomena like precognition are thereby made respectable! How can this have happened?

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[13]Murray Gell-Mann, "The Quark and the Jaguar, Adventures in the Simple and the Complex," W. H. Freeman Company, New York 1994.

On his pages 172-173, Gell-Mann reviews the history of the EPR experiments pretty much as Zukav has done, but then says about the outcome of the experiments that:

> The result was eagerly awaited, although virtually all physicists were betting on the correctness of quantum mechanics, which was, in fact, vindicated by the outcome. One might have expected that interested people all over the world would heave a sigh of relief at hearing the news and then get on with their lives. Instead, a wave of reports began to spread alleging that quantum mechanics had been shown to have weird and disturbing properties. Of course, it was the same old quantum mechanics. Nothing was new except its confirmation and the subsequent flurry of flapdoodle.
>
> The principal distortion disseminated in the news media and in various books is the implication, or even the explicit claim, that measuring the polarization, circular or plane, of one of the photons somehow affects the other photon. In fact, the measurement does not cause any physical effect to propagate from one photon to the other. Then what does happen? If, on a particular branch of history, the plane polarization of one photon is measured and thereby specified with certainty, then on the same branch of history the plane polarization of the other photon is also specified with certainty. On a different branch of history the circular polarization of one of the photons may be measured, in which case the circular polarization of both photons is specified with certainty. On each branch, the situation is like that of Bertlmann's socks, described by John Bell in one of his papers. Bertlmann is a mathematician who always wears one pink and one green sock. If you see just one of his feet and spot a green sock, you know immediately that his other foot sports a pink sock. Yet no signal is propagated from one foot to the other. Likewise no signal passes from one photon to the other in the experiment that confirms quantum mechanics. No action at a distance takes place.
>
> The false report that measuring one of the photons immediately affects the other leads to all sorts of unfortunate conclusions. First of all, the alleged effect, being instantaneous, would violate the requirement of relativity theory that no signal--no physical effect--can travel faster than the speed of light. If a signal were to do so, it would appear to observers in some states of motion that the signal was traveling backwards in time. . . .
>
> Next, certain writers have claimed acceptability in quantum mechanics for alleged "paranormal" phenomena like precognition, in which the results of chance processes are supposed to be known in advance to "psychic"

> individuals. Needless to say, such phenomena would be just as upsetting in quantum mechanics as in classical physics; if genuine, they would require a complete revamping of the laws of nature as we know them..

Gell-Mann makes it clear there is no basis for the hype, in other words. Like Einstein (and me), he sees that it is the source (like Bertlmann putting on his socks), in obedience to the Pauli exclusion principle. The two are never alike, the two are opposite, if you discover the spin (color) of the one you know the other. No mystery. End of story. But, extremely heretical!

The Most Detailed Critical Treatment of the Zukav-like Interpretations

A very thorough discussion of the Bell-theorem work is given by Thomas Brody in his The Philosophy Behind Physics[14]. Three chapters of this book are devoted to this topic, in part because the Bell theorem and the outcomes of experiments testing it have been so misused, according to Brody.

Superluminal information transfer, parapsychology, and attacks on Einstein's notions of realities are some of the misuses cited by Brody (p. 205). What follows in his first chapter on the topic is five derivations of Bell's inequality, one by Bell and four by others who began from different starting points but came to exactly the same inequality. One of these, by Wigner, was used in Treiman's (see footnote 7) critical discussion of the Bell inequality issue (not repeated here).

The striking thing about these derivations by others is that they do not use hidden variable hypotheses, and only one of them makes locality assumptions like Bell did. This is quite astounding because this means the results of the experiments do not have anything to do with either locality or hidden variables, as Brody shows at great length in his Chapter 16, (pages 205- 222).

The one thing necessary to each derivation, according to Brody (p. 205) is a joint-measurability assumption or the assumption that there is a joint probability distribution for multiple spin projections for the same particle. The bottom line (p. 220) is that it is well known that one cannot determine multiple spin states on the same particle. Simple. Hence the experiments fail and obey quantum mechanical statistical predictions.

On page 223, Brody begins his second chapter on the Bell inequality. He explains that the real reason for the experimental violation of Bell's inequality involves the

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[14]Thomas Brody, "The Philosophy Behind Physics," (Luis de Pena and Peter Hodgson, Eds.) Springer-Verlag, Heidelberg, 1993.

failure of another assumption: "that it is possible to measure the quantity under study (spin projection or photon polarization) of a single particle in more than one direction without mutual interference."

This second chapter addresses Bell's locality condition, otherwise known as "the causality rule, derived from relativity theory, that causal connections cannot be propagated at speeds greater than light." (p. 223) The remainder of the chapter (pp. 224-230) is devoted to showing there are serious errors and inconsistencies in the mathematics of the Bell treatment of locality, as well as the Stapp version of that treatment. A third treatment he dismisses out of hand as being a restatement of the joint measurability assumption.

The final point is that because of these inconsistencies, the conclusions about locality based on the interpretation of the Bell inequality experiments are wrong (p. 229):

> It may be concluded that the three locality conditions here (1) differ among each other significantly, and (2) do not agree with what locality means in other parts of physics. Therefore (3) they do not bear the weight of the interpretation commonly placed on them; . . . the violation of the inequality by quantum systems could not be used to conclude anything concerning locality in its proper meaning.

The final chapter on the topic recapitulates the four derivations of Bell's inequality that do not require hidden variables, and recapitulates something mentioned in the previous chapter also, that there are classical, non-quantum mechanical cases that also violate the inequality. The chapter is a recapitulation, and it begins with a statement that seems pretty definitive, given the proofs and examples that follow (pages 231-232):

> It is almost half a century since the great quantum debate began, sparked off by Einstein, Podolsky and Rosen (1935) on one side and Bohr (1953) on the other. In that long time only one new element has been introduced, the inequality derived by Bell (1965). That this inequality is violated by quantum mechanics both theoretically and experimentally . . . has been held by many to presage the definitive defeat of the Einsteinian realist position in this debate. The argument is this: The Bell inequality rests on nothing but the two assumptions that hidden-variable extensions of quantum mechanics are possible and that two systems that have been in contact can move far enough apart for all interactions between them to be negligible; this last is the locality assumption. If the inequality is violated by quantum mechanics, then one or both assumptions must be false (unless we wish to reject quantum mechanics). Ruling out the hidden variables goes a long way to

> making it impossible to develop theories that go beyond quantum mechanics. Eliminating locality is even more serious: if the universe is too strongly non-local, we could not isolate a part of it and study it in relative independence of the remainder, so that essentially the scientific endeavour has been shown to be senseless. Even without this drastic conclusion, we might have to accept some at present unknown interaction, presumably propagated at speeds exceeding that of light, in order to explain the abnormally high correlations exhibited by quantum mechanics for systems separated by a space-like interval. This idea has been the source of much facile speculation, even spilling over into the popular press, concerning the supposed parapsychological consequences of modern physics; but even among the more responsible members of the physics community doubts have arisen. We are in fact living in a situation that Einstein had foreseen many years ago (Einstein 1948).
>
> But I hope to show that the outlook is not so bleak. I shall argue, firstly, that there are derivations of the Bell inequality that do not depend on the notions of hidden variables or locality; thus its violation has little to do with them and in particular does not imply that we have to abandon them. But then why does quantum mechanics violate it? I propose to show that all the derivations use a further assumption which has not so far been spelt out, namely that two different variables (e.g. the spin projections in two different directions) can be measured on the same particle without mutual interference. This is, of course, not the case for many quantum variables, and that their correlations should not satisfy the Bell inequality is thus not particularly mysterious. Now if this sort of explanation holds true, similar situations should arise in classical physics; I therefore exhibit some classical models that violate the Bell inequality.
>
> The conclusion from these arguments is then that Bell's inequality, so far from representing the final history of Bohr's side in the debate, turns out to be irrelevant to the problem.

The limitations on the measurement of two aspects of spin on the same particle is also mentioned by Treiman (pp. 181-184 of the reference at footnote 7) in the context of the EPR problem. After explaining that there" is no quantum state for which all three, or indeed any two, spin components can be known, simultaneously." Said more simply, Treiman offers that "the EPR notion of physical reality is too demanding for the quantum world that we actually inhabit." Treiman notes that the EPR enigma did inject the idea of locality into the picture and suggests that the genius of Bell's idea was to use twin particles so that the measurement made on the one and the measurement made on the other could specify two components of spin, something impossible on one particle as necessary to address the EPR paradox. But Brody claims to show that even in the Bell experiments there was an implicit assumption that two aspects of spin were measurable on the same particle.

Treiman (p. 185, footnote 7) notes that to

> . . .get around the EPR paradox we have to accept that the spin components in two (or more) different directions cannot be *known* simultaneously--the measurements disturb one another. But for a system of two spinning particles far apart, Bell assumes along with EPR that a measurement of a spin component of particle *A* cannot influence the outcome of a measurement of the same or any other spin component of particle *B*, provided the two measurements occur close enough in time so that a light signal could not have passed from one location to the other. As we have already said in connection with the EPR paradox, this *locality* hypothesis has the following consequence. For a system of two spins in the singlet state, a measurement on particle *A* of its spin projection along some particular direction automatically fixes the value of the spin along the same direction for the distant particle *B*. The spin projection of *B* is necessarily equal and opposite to that of *A*.

On page 286 of his book, Treiman similarly observes:

> . . . Without any mutual interference, we can experimentally determine the spin projections of *B* along any two of these (three in Bell's theorem) directions. We do this by performing one measurement directly on *B*, the other on the distant particle *A*.

So Treiman does not see the problem that Brody sees, even though he is aware of the inability to measure two components of spin on the same particle. Brody is not disagreeing that it is possible to measure two aspects of spin using two particles as in the photon experiment, he is not disagreeing with Treiman, in other words. But he alleges that these measurements do not provide sufficient information because there are actually four variables, not two (pp. 234-236), for two particles! He explains the correlation assumptions involved in making this problem appear tractable when only two of the four can in fact be measured, on two separate particles. But Brody's point is that this makes half the analysis of the experiment based on fact, and the complementary half based on assumed correlations that must meet the condition that "the dichomatic variables possess a joint probability distribution and can therefore be measured without disturbing each other." (p. 236). This rather densely worded statement is an amended version of a simpler statement that said that the four variables associate pairwise (p. 234), and this is an assumption without which none of the derivations of Bell's inequality can be made.

So, what is the actual problem then? Brody sees no problem measuring the two aspects that are measured, but the problem is that (page 236):

> The violation of the inequality . . . by quantum mechanics is now trivially explained, for of course neither in the spin cases originally envisaged by Bell nor in the photon-cascade experiments studied later do the variables satisfy [the joint probability distribution requirement cited above]; we may measure *a* and *b* on a particle pair; we can even deduce a value *b′* provided the angle *B′* coincided with *A*, and similarly for *a′*; but these angles never violate the inequality, and we cannot determine all four projections (or polarizations) for arbitrary angles.

In other words, (page 220):

> . . . the Bell inequality places a restriction on the correlation coefficients, and coefficients that vary unrestrictedly may violate it. Once this is realized, it is obvious that it is not the violation but the satisfaction of the inequality that could be thought to need transmitting further information between the *A* and the *B* measurements of the setup. . . . This is precisely the opposite of what is claimed in order to argue for the superluminal transmission of information. . . such arguments are therefore suspect from the outset.

Finally, Brody's showing that there are non-quantum systems that violate the same inequality seems quite convincing. It goes without saying that classical (non-quantum) systems are known to not transfer information superluminally! Brody discusses these classical cases on pages 217-218, and 236-237. I do not pretend to understand every part of his arguments here, but if he is correct, Bell's inequality is irrelevant to the purpose for which it is being used in Zukav's book. Or, as Zukav might say it, the world is a spookier place than experience suggests.

Believing-Heretic Soup

But what about Bohm and Stapp, physicists cited by Zukav to make his case for superluminal transfer of information?

David Bohm and de Broglie (and others)

David Bohm was cited in Zukav's book as the author of the "implicate order," another interpretation of quantum mechanics. Being another interpretation, it is heresy in view of the Copenhagen interpretation.

On pages 45-48, Zukav suggested a fabric of relatedness between all parts of the universe, which is a loosely worded version of Bohm's implicate order. Zukav's relatedness idea certainly looks behind the scenes in search for a reality not readily offered up through following the Copenhagen Interpretation.

David Bohm's implicate order is another interpretation of quantum mechanics, and is reviewed by Zukav over the course of five pages (305-310). Zukav does not mention that Bohm is a heretic in terms of his having thrown over the Copenhagen interpretation. Zukav only declares Bohm's ideas to be compatible with the interpretation of Bell's theorem as showing an interconnectedness between particles in the universe. After the review of Bohm's (in my view) rather deterministic and causal theory, Zukav observes with obvious enthusiasm (310):

> If Bohm's physics, or one similar to it, should become the main thrust of physics in the future, the dances of East and West could blend in exquisite harmony. Physics curricula of the twenty-first century could include classes in meditation.

It is worthwhile to cite Bohm's own view of his theory. It will not contradict Zukav, he cites him correctly and in turn Bohm cites Zukav with obvious approval (see footnote 5). But to me it was important to see that Bohm's interpretation is a theory of a causal universe. However, a causal universe was done away with by quantum mechanics, according to Zukav's page 113 where he said:

> The whole idea of a causal universe is undermined by the uncertainty principle.

And according to page 64, where he declared:

> The wave-particle duality was the end of the line for classical causality.

But in addition to Bohm, we will also cite another pioneer of the new physics, Louis de Broglie, to put Bohm into a context of deep causal thought. And for interest, we will also throw in words along the same lines from a few of their modern counterparts. de Broglie's death preceded the Bell theorem work. But Bohm and the others cited below were familiar with it, and approved of Zukav-like interpretations. But what they have in common is that all are heretics with respect to the Copenhagen interpretation on which the Zukav-like interpretations depend! Among the others cited here are Treiman (footnote 7), Cramer (footnote 11), and Stapp (yet to be cited).

So what did a colleague of Bohm, and fellow pioneer of the new physics have to say about the orthodox, interpretation? Louis de Broglie[15] was an adherent for over 25 years , after attempting another interpretation at the beginning of his career. He was sympathetic to Einstein's complaint as evidenced by his words on his pages 230-231:

> . . . a corpuscle passing through a hole impacts a hemispherical screen behind it at some point. When it registers on the film on that hemisphere, all other probabilities of trajectories causing an impact elsewhere on the film vanish. This is a straightforward explanation, but it is not at all that which a purely probabilistic interpretation would give. According to the latter, before the photographic impression, the corpuscle is potentially present in all points of the region behind the screen with a [known] probability . . . . As soon as a photographic impression is made . . . the corpuscle is localized, is condensed one might say, . . . and *instantly* the probability of its being at any other point of the film falls to zero. Now, Einstein said, such an interpretation is incompatible with all our ideas about space and time (even in their relativistic space-time form) and with the idea of a propagation of physical actions in space with a finite velocity And it is insufficient to say that our concepts of space and time drawn from macroscopic experience could be in error on the atomic level: actually, the film does have macroscopic dimensions (it might have a surface of a square meter) and here it would be a question of the insufficiency of our notions of space and time *even* on the macroscopic level, and this seems really difficult to believe. To this objection of Einstein, to which as far as I know no one has given a satisfactory answer, other facts have subsequently been added by Schrodinger and again by Einstein relating to phenomena of interaction. I can not outline these arguments here, I shall only say that like Einstein's objection of 1927, they lead to paradoxical conclusions, in particular to a doubt, even on the macroscopic level, of our former notions of space and time.

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[15]Louis de Broglie, "The Revolution in Physics, A Non-mathematical Survey of Quanta," The Noonday Press, New York, 1953, Trans. Ralph W. Niemeyer.

On pages 236 and 237, de Broglie confesses that after a quarter century of being orthodox and probabilistic, he agrees with Einstein now, in part thanks to some work by David Bohm that shows promise. How does de Broglie answer those who would accuse him of being inconsistent? With a quip, but also more seriously on pages 237-238:

> The history of science shows that the progress of science has constantly been hampered by the tyrannical influence of certain conceptions that finally came to be considered as dogma. For this reason, it is proper to submit periodically to a very searching examination, principles that we have come to assume without any more discussion. For a quarter of a century the purely probabilistic interpretation of wave mechanics has certainly been of service to physicists because it has kept them from being overwhelmed by the study of the very arduous problems which are as difficult to solve as are those that the conception of the double solution poses, and thus has permitted them to advance steadily in the direction of applications, which have been numerous and fruitful.

The "double solution" would be de Broglie's characterization of a deterministic particle physics that would provide the mechanistic underpinnings of the statistical approach. It would identify the hidden variables that produce the results statistically predicted. The hidden variable theory has subsequently been shown to be at odds with quantum theory, and has been largely abandoned. Until recently, that is.

These sentiments by de Broglie reminded me of Genz's (see footnote 8) discussion of the nature of the vacuum and how it was a good thing to have been ignorant for some time (Genz's p. 315):

> As the science of physics developed, a fundamentally faulty notion--like that of empty space--often proved to be more fruitful than the correct one would have been at the time. A mistaken notion often opens the way to understanding at a time when a correct statement--such as *there cannot be truly empty space*--could not have been understood. . .

de Broglie declares that even

> . . . the partisans of the purely probabilistic interpretation themselves are searching, without much success it would seem, to introduce new concepts which are even more abstract and further removed from classical images. . . . Without denying the interest of these endeavors, it might be asked if it is not rather toward a return to the clarity of spatio-temporal representations that we must direct ourselves. In any case it is certainly of use to take up

> again the very difficult problem of an interpretation of wave mechanics in order to see if what is now orthodox is really the only one that can be adopted.

de Broglie was wrong in assuming there was a spatio-temporal explanation for quantum mechanics. But he was right when he challenged those who wish to enforce any sort of orthodoxy or dogma in science. It stifles the development of new understanding to say that this or that endeavor is useless because we know all there is to know on the topic already. Don't look for quarks, it is a waste! But at the same time Everett's many worlds hypothesis gets some noncommittal respect?

Most of the sources I consulted think "Many Worlds" is an interesting but unprovable, untestable aside. To wit: a modern book, by physicist Sam Treiman (see footnote 7). Treiman tackles the same issue we have just seen de Broglie awash in, and says (on his page 189) that in quantum mechanics:

> . . . the future is intrinsically statistical, with probabilities governed by the equations of quantum mechanics. The trouble is that this way of looking at the situation seems something of a cop-out. In effect, it abandons the idea of *explaining* how facts come about, taking as the main function of science merely to correlate them. When a fact in fact happens, the quantum mechanical wave function is simply declared to have collapsed; after all, it is only a correlational tool! and that's that. The more orthodox *Copenhagen interpretation* places the emergence of the fact at the point where it is first registered by a "classical" measuring instrument; that is, by a "large" apparatus in good working order. As a practical matter, this is in some sense undoubtedly the case. The meter readings are facts. But it has never been clear within the Copenhagen view how the meter makes its selection when there are multiple choices to be made. We may also recall here the notion, mentioned earlier, that facts emerge only when registered in the consciousness of sentient beings, the ultimate measuring instruments! But having recalled it, there seems nothing much more to say.
>
> Finally, we may briefly mention the so-called *many-worlds* interpretation of quantum mechanics. Proposed in 1957 by Hugh Everett III, it confronts the selection conundrum in a most audacious manner. Whenever there is a choice to be made among alternative outcomes of a measurement, the world splits into many worlds, all the possible outcomes emerging, one in each of the newly created worlds! This has been going on for a long time, of course, so there is a vast proliferation of worlds out there living side by side. But they are totally out of contact with one another. It's hard to know what to make of such an interpretation of quantum mechanics. As with the consciousness hypothesis, it cannot be falsified or built on. But it is undoubtedly amusing to contemplate. Each

of us has clones all over the place, but we never meet.

And what does this astute gentleman say about the Bell hypothesis and its experiments? Pages 184-190 have an elaborate discussion of its basis and the meaning of the experiments. Bell, like de Broglie, but with "a more decisive insight and with a stunning result" was working on determining if there were hidden variables, a hidden set of classical realities that underpinned quantum mechanics. Treiman (footnote 7) cites Bell on his page 184:

> “To know the quantum mechanical state of a system implies, in general, only statistical restrictions on the results of measurements. It seems interesting to ask if this statistical element can be thought of as arising, as in classical statistical mechanics, because the states in question are averages over better defined states for which, individually, the states would be quite determined.”

The bottom line? On Treiman’s page 187:

> On the experimental front, tests of Bell's inequality have been carried out not just with material particles (protons) but also with photons, whose states of polarization are like the states of spin. The experiments are difficult and have a history of ups and downs, but by now quantum mechanics has safely emerged the winner.
>
> As said, hidden variables, in addition to all the other hurdles they face, are shown to be incompatible with quantum mechanics--unless one is prepared to relax the general conditions, notably locality, that go into the Bell theorem. In the 1950's David Bohm in fact succeeded in constructing an internally consistent hidden variable theory for nonrelativistic particles; but it is highly nonlocal, and in any case, rather forced.

The latter statement may be correlated with the last item in de Broglie's "Chronology of Important Events" (de Broglie’s page 302): - "1952-Revival of the deterministic interpretation of quantum processes (de Broglie, Bohm).”

Treiman’s treatment of Bell's inequality used a Wigner's variation of it, based on probabilities rather than Bell's averages. This variation was one of the alternate derivations discussed by Brody (see footnote 14), and has been described in general terms above. Treiman is a believer in the Bell-experiment interpretation that says there are no hidden variables. But he is a fiery heretic when it comes to the Copenhagen interpreatation!

de Broglie (as cited above) was a pioneer of the new physics who set about making the quantum mechanical understanding deterministic again. He worked on this reinterpretation with David Bohm. Bohm came up with his implicate order interpretation. It may be expected that this implicate order is the new and improved version of what he and de Broglie were working on thirty years before.

In fact the Bohm concept has changed from that original effort at trying to uncover hidden variables, and now makes a very attractive statement, well worth reading. One can readily see why Zukav would like it. It is readily available in an article on the Internet (see footnote 5).

Bohm in this newer article writes using words that would directly appeal to Zukav:

> Because the implicate order is not static but basically dynamic in nature, in a constant process of change and development, I called its most general form the holomovement. All things found in the unfolded, explicate order emerge from the holomovement in which they are enfolded as potentialities and ultimately they fall back into it. They endure only for some time, and while they last, their existence is sustained in a constant process of unfoldment and re-enfoldment, which gives rise to their relative stability and independent forms in the explicate order.

Bohm later brings the mind into the discussion:

> It takes only a little reflection to see that a similar sort of description will apply even more directly and obviously to the mind, with its constant flow of evanescent thoughts, feelings, desires, and impulses, which flow into and out of each other, and which, in a certain sense, enfold each other (as, for example, we may say one thought is implicit in another, noting that this word literally means 'enfolded'). Or to put it differently, the general implicate process of ordering is common both to mind and to matter. This means that ultimately mind and matter are at least closely analogous and not nearly so different as they appear on superficial examination. Therefore it seems reasonable to go further and suggest that the implicate order may serve as a means of expressing consistently the actual relationship between mind and matter, without introducing something like the Cartesian duality between them.

Bohm does plant a caution:

> . . . the implicate order is still largely a general framework of thought within which we may reasonably hope to develop a more detailed content that would make possible progress toward removing the gulf between mind and matter.

The basic problem seems to be that:

> . . . what is missing is a clear understanding of just how mental and material sides are to be related.

The paper then goes into explaining Bohm's 1952 causal interpretation of the quantum theory, as modified by coworkers and successors. This is the interpretation that threw de Broglie off the orthodox bandwagon (see below for de Broglie's words on the topic). But it has been modified, and the Zukav book is given as a reference to read more about it!

Some of the modifications of these causal interpretations, the paper later declares, are based on the latest findings of quantum mechanics! Bohm here, among other things, reiterates the importance of the Bell inequality work:

> . . . there is a strange new property of non-locality. That is to say, under certain conditions, particles that are at macroscopic orders of distance from each other appear to be able, in some sense, to affect each other, even though there is no known means by which they could be connected. Indeed if we were to assume any kind of force whatsoever (perhaps as yet unknown) to explain this connection, then the well-known Bell's theorem gives a precise and general criterion for deciding whether the connection is local, i.e. one brought about by the forces that act when the systems are not in contact (Bell, 1966). It can be shown that the quantum theory implies that Bell's criterion is violated, and this implication is confirmed by the actual experiments. Therefore, it follows that if there are such forces, they must act non-locally. Such non-local interactions are basically foreign to the general conceptual scheme of classical (Newtonian) physics, as it has been known over the past few centuries (which states that interactions are either in contact or carried by locally acting fields that propagate continuously through space).

Bohm continues with a discussion that this effect, together with the phenomena of wave-particle duality and quanta, leads to a notion of "quantum wholeness" which

> . . . means that in observation carried out to a quantum theoretical level of accuracy, the observing apparatus and the observed system cannot be regarded as separate. Rather, each participates in the other to such an extent that it is not possible to attribute the observed result of their interaction unambiguously to the observed system alone.

Heisenberg and then Bohr are cited pronouncing that statistical prediction, not understanding, is possible.

But Bohm takes exception to this:

> . . . Bohr's insistence that this wholeness cannot be understood through any concepts whatsoever, however new they may be, implies that further progress in this field depends mainly on the development of new sets of mathematical equations without any real intuitive or physical insight as to what they mean apart from the experimental results that they may predict. On the other hand, I have always felt that mathematics and intuitive insight go hand in hand. To restrict oneself to only one of these is like tying one hand behind one's back and working only with the other hand, I have always felt that mathematics and intuitive insight go hand in hand. To restrict oneself to only one of these is like tying one hand behind one's back and working only with the other. Of course, to do this is a significant restriction in physics, but evidently it is even more significant restriction in studying in mind, where intuitive insight must itself be a primary factor.

Thus, the man still declares himself a heretic with respect to the orthodox Copenhagen interpretation, after almost forty years! What follows then is an exposition of his causal interpretation of quantum mechanics which, he claims,

> . . . is able. . . to provide a basis for a non-dualistic theory of the relationship of mind and matter.

In explaining his causal interpretation, the slit experiments with which Zukav tantalizes his readers at the start with a promise of action at a distance, as well as the Bell inequality work, are cited again as proof of their being a "notion of active information," active throughout all space at the quantum level,

> . . . but actually active only where the particle is. I do not wish to cast any aspersions onto this very finely thought out concept, illustrated by such things as radio waves which are activated only where there is a receiver, etc.

But one thing in his description did grab my attention in a very positive way, and I cited this at the start of this review (at footnote 5) where I noted that below the subatomic world under current examination lie seventeen more orders of magnitude of fundamentally unexplorable space, where there is, no doubt, structure. This notion is important to Bohm's theorizings on the nature of mind.

Bohm mentions at the end of the paragraph I cited at footnote 5 that:

> It is interesting in this connection to note that even the current string theories of physics lead to the possibility of very complex structures at

> distances as short as 10^{-33} cm.

We will return to string theories in the Epilogue.

Bohm's discussion of the implications for the mind's processes being part of the overall processes known from quantum theory are very attractive, eliminating the need for a dichotomy between the mind and the body, for example, because

> . . . that which we experience as mind, in its movement through various levels of subtlety, will, in a natural way ultimately move the body by reaching the level of the quantum potential and of the 'dance' of the particles. There is no unbridgeable gap of barriers between any of these levels. Rather, at each stage some kind of information is the bridge.

This further implies some

> . . . rudimentary mind-like quality is present even at the level of particle physics, and that as we go to subtler levels, this mind-like quality becomes stronger and more developed. Each kind and level of mind may have a relative autonomy and stability. One may then describe the essential mode of relationship of all these as participation, recalling that this word has two basic meanings, to partake of, and to take part in. Through enfoldment, each relatively autonomous kind and level of mind to one degree or another partakes of the whole. Through this it partakes of all the others in its 'gathering' of information. And through the activity of this information, it similarly takes part in the whole and in every part. . . . . For the human being, all of this implies a thoroughgoing wholeness, in which mental and physical sides participate very closely in each other. Likewise, intellect, emotion, and the whole state of the body are in a similar flux of fundamental participation. Thus there is no real division between mind and matter, psyche and soma. . . . What may be suggested further is that such participation goes on to a greater collective mind, and perhaps ultimately to some yet more comprehensive mind in principle capable of going indefinitely beyond even the human species as a whole. (This may be compared to some of Jung's (1981. . .) notions.)

These are Jung's notions concerning a collective unconscious, of course.

This discussion by Bohm has brought us far afield, and what an interesting field it is! One can readily see the reason for the affinity between Zukav and Bohm.

But if the Bell-theorem work is not to be interpreted in accord with the

Copenhagen interpretation, as being particle-less and property-less until detected, as it were, what of Bohm's implicit order? I think it has very little effect. It is still possible to postulate non-local information dispersed throughout all space, including that seventeen orders of magnitude that physics knows nothing of, and that could be as unexpectedly different from the higher seventeen orders of magnitude as quantum physics is from classical physics.

Bohm (and de Broglie earlier) were not the only ones dissatisfied with the Copenhagen interpretation's suggestion that there was no structure. A more recent theoretical physics interpretation, the transactional interpretation, is described by its author, John Cramer[16]. Cramer explains, surprisingly to me, given what I had read from him previously as cited above (footnote 11), that

> . . . the intrinsic nonlocality of quantum mechanics has been demonstrated by the experimental tests of Bell's theorem. It has been experimentally demonstrated that nature arranges the correlations between the polarization of the two photons by some faster-than-light mechanism that violates Einstein's intimations about the intrinsic locality of all natural processes. What Einstein called "spooky actions at a distance" are an important part of how the wave nature works at the quantum level. Einstein's faster-than-light spooks cannot be ignored.

But Cramer, as did Bohm, found fault with the harness on thought implied by the Copenhagen interpretation of Heisenberg and Bohr, and suggests he has developed a "more objective interpretation of the quantum mechanics formalism," the *"transactional interpretation*" proposed in 1986 (see http://www.npl.washington.edu/ti for a reprint). In Cramer's words, the

> . . . transactional interpretation, a leading alternative to the Copenhagen interpretation, uses an explicitly nonlocal transaction model to account for quantum events. This model describes any quantum event as a space-time "handshake"executed through an exchange of retarded waves . . . and advanced waves . . . as symbolized in the quantum formalism.

The physics are described, and a place for criticism is admitted by Cramer:

> To accept the Copenhagen interpretation one must accept the intrinsic

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[16] John G. Cramer, "Quantum Nonlocality and the Possibility of Superluminal Effects," Published in the Proceedings of the NASA Breakthrough Propulsion Physics Workshop, Cleveland, OH, August 12-14, 1997, and found on Cramer's web page on 8/8/2000 at http://www.npl.washington.edu/npl/int_rep/qm_nl.html

> positivism of the approach and its interpretation of solutions of a simple second-order differential equation combining momentum, mass, and energy as a mathematical description of the knowledge of an observer. Similarly, to accept the transactional interpretation it is necessary to accept the use of advanced solutions of wave equations for retroactive confirmation of quantum event transactions, which smacks of backwards causality. No interpretation of quantum mechanics comes without conceptual baggage that some find unacceptable.

Cramer suggests his postulate requires correlations between measurement outcomes to be enforced

> . . . not across a spacelike interval, but across . . . lightlike intervals (if the EPR experiment uses photons). Therefore, the nonlocality of quantum mechanics is readily accounted for by the transactional interpretation.

Finally, Cramer argues that

> At minimum it should be clear that the transactional interpretation is not a clumsy appendage gratuitously grafted onto the formalism of quantum mechanics but rather a description which, after one learns the key to the language, is found to be graphically represented within the quantum wave mechanics formalism itself.

The bottom line question implied by the paper's title is that no, a faster than light or backwards in time telephone are not possible. But this is agreed to by all, even proponents of superluminal information exchange between elementary particles.

So, even if there is a possibility that the EPR and Bell experiments do need some faster than light action, there is a framework that could accommodate such a need already within the formalism of quantum mechanics, but it requires the loosening up of the orthodoxy of the Copenhagen interpretation and the use of the transactional interpretation. I believe this shows physics to be healthy, intellectually, and that de Broglie has nothing to worry about, wherever "he" is now, in terms of a dark age being imposed by the Copenhagen interpretation anytime soon! Physics is definitely looking to the light!

The Last Step in the Discussion: Stapp!

On his website, Henry Stapp[17] has just made available his very latest work on the

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[17]Henry Stapp, "From Quantum Nonlocality to Mind-Brain Interaction" Lawrence Berkeley National Laboratory report number,

subject of nonlocality. The Abstract of the paper/report is worth citing in full, because it is so vehemently, and surprisingly given the 20-year old Zukav citations, against the orthodox Copenhagen interpretation:

> Orthodox Copenhagen quantum theory renounces the quest to understand the reality in which we are imbedded, and settles for practical rules that describe connections between our observations. However, an examination of certain nonlocal features of quantum theory suggests that the perceived need for this renunciation was due to the uncritical importation from classical physics of a crippling metaphysical prejudice, and that rejection of that prejudice opens the way to a dynamical theory of the interaction between mind and brain that has significant explanatory power.

It can be seen that nonlocality is central to Stapp's work on understanding the relationship of mind and brain. It can also be seen that he has shifted from being a Copenhagen interpretation apologist to a heretic!

In an earlier paper[18] we find Stapp saying:

> Quantum mechanics, as formulated by Niels Bohr and his colleagues, is predicated on the fact that our experiences of the physical world---our immediate phenomenal knowledge of it---can be described in the language of classical mechanics, considered as an extension of ordinary every-day language. Quantum dynamics itself, in the von Neumann/Wigner form, entails that in many situations classical mechanics can provide a very accurate approximation. Thus quantum theory is a unified and seamless theory that accurately describes the quantum features of nature, but also justifies the use of classical concepts in situations where those concepts are applicable.

At the very end of this same paper the praise for the Copenhagen interpretation is even thicker:

> . . . quantum theory is basically a pragmatic theory . . . : it is a way of making progress toward some practically useful understanding of nature without knowing how everything really works at the fundamental level.

LBNL-44712, upload date 1 August 2000. (Located under title vnr.txt at http://www-physics.lbl.gov/~stapp/ accessed on 15 August 2000)

[18]Henry Stapp, "Science of Consciousness and The Hard Problem," based on a Plenary Talk at the Conference Toward A Science of Consciousness 1996, University of Arizona, Tucson, April 8-13, 1996 (accessed 8/9/2000 at http://www-physics.lbl.gov/~stapp/38621.txt)

> This is perhaps a humbling admission for science. But the fact is that we still have a long way to go. The creators of quantum theory did provide us, however, with a rational theoretical framework that allows progress to be made.

In this particular paper I found no mention of the necessity of assuming nonlocality. In another paper of about the same time, however, the need for assuming nonlocality in understanding the mind is mentioned, so perhaps it was Stapp's thoughtfulness that had him not go into that level of detail for the primarily non-physicist, or even non-physical scientist, audience expected at this conference.

By contrast, in another 1996 paper undoubtedly written for fellow physicists[19], nonlocality is barely mentioned, but the context in which it is mentioned is interesting, I think:

> Within the contemporary framework of quantum theory that I have been adhering to . . . [Note: in his discussion of consciousness and quantum theory] there remains, in the end, an element of 'pure chance' that selects one of the templates for action 'randomly'. Whether this occurrence of pure chance is a permanent feature of basic physical theory, or merely a temporary excursion, no one knows. In my own opinion this occurrence of pure chance is a reflection of our state of ignorance regarding the true cause, which must in any case be nonlocal, and hence both difficult to study and quite unlike the local causes that science has dealt with up until now. In another place . . . I have described in more detail the technicalities of the actualization process, and also the possibility of replacing the element of pure chance by a nonlocal causal process that makes the felt psychological subjective 'I', as it is represented within the quantum-theoretic description, rather than pure chance, the source of the decisions between one's alternative possible courses of action.

So in order to liken the mind to a quantum system obeying the orthodox concepts there must be a random chance involved in human decision making. But since this is contrary to the human perception of its own experience, a nonlocal causal factor needs to be defined. The 'I' is that perceiver of its own experience, and a nonlocal cause must be postulated because the 'I' is experienced, hence it exists!

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[19]Henry Stapp, "The Hard Problem; A Quantum Approach," Lawrence Berkeley National Laboratory report number LBL-37163, February 1996 (accessed 8/9/20000 at http://www-physics.lbl.gov/~stapp/37163new.txt)

In another paper[20] the discussion of nonlocality was also low key. In this one there is a short discussion in an appendix done at the request of a referee (an expert reviewer for a journal). It mentions the collapse of all wave functions when a result is measured (Einstein's problem with quantum mechanics) and it mentions the Bell theorem experiments, with references to Stapp's own work, without elaboration, as proofs of nonlocality. It also brings in a third example related to the brain's function, but unlike the above 'I' postulate, all it attempts to convey is that the mind is a special case of the collapse of wave functions when a thought is selected from among a host of possibilities.

Having read these three papers, I was totally shocked by the paper with which I began this section on Stapp. It flails out at the restrictions of the Copenhagen interpreation, and then it bubbles with enthusiasm for new Bell-inequality experiments! To wit, the paper begins thus:

> "Nonlocality gets more real". This is the provocative title of a recent report in Physics today [Note: issue of December 1998, p. 9]. Three experiments are cited. All three confirm to high accuracy the predictions of quantum theory in experiments that suggest the occurrence of an instantaneous action over a large distance. The most spectacular of the three experiments begins with the production of pairs of photons in a lab in downtown Geneva. For some of these pairs, one member is sent by optical fiber to the village of Bellevue, while the other is sent to the town of Bernex.
>
> The two towns lie more than 10 kilometers apart. Experiments on the arriving photons are performed in both villages at essentially the same time. What is found is this: The observed connections between the outcomes of these experiments defy explanation in terms of ordinary ideas about the nature of the physical world *on the scale of directly observable objects*. This conclusion is announced in the opening sentence of the Physical-Review-Letters report [Note: W. Tittle, J. Brendel, H. Zbinden, and N. Gisin, Phys. Rev. Lett. *81*,3563(1998)] that describes the experiment: `"Quantum theory is nonlocal".

As if it is important to the credibility of the nonlocal argument, Stapp reports that there is a practical application for this work:

> This observed effect is not just an academic matter. A possible application

[20]Henry Stapp, "Why Classical Mechanics Cannot Naturally Accommodate Consciousness but Quantum Mechanics Can," in "Psyche, An Interdisciplinary Journal of Research on Consciousness," 2(5), 1995 (accessed 9 August 2000 at http://psyche.cs.monash.edu.au/v2/psyche-2-05-stapp.html)

> of interest to the Swiss is this: The effect can be used in principle to transfer banking records over large distances in a secure way . . . .

So the purpose of the work is to create a photon-pair-based quantum cryptography capability, described as the subject of serious research using EPR phenomena in Murray Gell-Mann's afore- cited book (see pages173-175 of footnote 13). But recall that Gell-Mann describes the superluminal information transfer effect commonly associated with the EPR-type experiments as an unfortunate conclusion and as flapdoodle. I would tend to agree, and whether the observed phenomenon is created by the source, as I think, or by spooky actions at a distance, is no doubt irrelevant to the banking industry trying to create a cryptographic technology that is truly unbreakable.

What follows in this, Stapp's latest article is a similar discussion, except bolder, of what has appeared in previous papers. But what is new, in my perception at least, is the attack on the theory of relativity that Stapp makes here as part of his attack on the orthodox view:

> Yet how could the renowned scientists who created Copenhagen quantum theory ever believe, and sway most other physicists into believing, that a complete science could leave out the physical world? It is undeniable that we can never know for sure that a proposed theory of the world around us is really true. But that is not a sufficient reason to renounce, as a matter of principle, the attempt to form at least a coherent idea of what the world could be like, and rules by which it works. Clearly some extraordinarily powerful consideration was in play.
>
> That powerful consideration was a basic idea about the nature of physical causation that had been injected into physics by Einstein's theory of relativity. That idea was not working!

This is really a strange statement, given the fact that Bohr and Einstein never did agree with the implications of each other's theories for their own, leaving us with what Lindley says is "The Last Contradiction" (see footnote 10, pages 91-100 and the discussion above).

What follows in Stapp's new paper (see footnote 17) is a most interesting history of physics and its movement toward the present state in which it finds itself now confronted with experiments that suggest the impossible, faster than light information exchange! Picking up the story at this point is illuminating:

> von Neumann's objective theory immediately accounts for the faster-than-light transfer of information that seems to be entailed by the

> nonlocality experiments: the outcome that appears first, in the cited experiment, occurs in one or the other of the two Swiss villages. According to the theory, this earlier event has an immediate effect on the evolving state of the universe, and this change has an immediate effect on the *propensities* for the various possible outcomes of the measurement performed slightly later in the other village.
>
> This feature---that there is some sort of objective instantaneous transfer of information---conflicts with the spirit of the theory of relativity. However, this quantum effect is of a subtle kind: it acts neither on matter, nor on locally conserved energy-momentum, nor on anything else that exists in the classical conception of the physical world that the theory of relativity was originally designed to cover. It acts on a mathematical structure that represents, rather, *information and propensity*.
>
> The theory of relativity was originally formulated within classical physical theory. This is a deterministic theory: the entire history of the universe is completely determined by how things started out. Hence all of history can be conceived to be laid out in a four-dimensional spacetime. The idea of ``becoming'', or of the gradual unfolding of reality, has no natural place in this deterministic conception of the universe.

Stapp is here reiterating Lindley's discussion (footnote 10, page 99). The following sections of the Stapp paper go into great detail regarding von Neumann's interpretation of quantum mechanics. But the part of the discussion I am interested in is the subject of nonlocality, is it real or is it not real? Stapp begins to address this exact issue thus:

> I began this article with the quote from Physics Today: ``Nonlocality gets more real.'' The article described experiments whose outcomes were interpreted as empirical evidence that nature was nonlocal, in some sense. But do nonlocality experiments of this kind provide any real evidence that information is actually transferred over spacelike intervals? . . .
>
> The evidence is very strong that the predictions of quantum theory are valid in these experiments involving pairs of measurements performed at essentially the same time in regions lying far apart. But the question is this: Does the fact that the predictions of quantum theory are correct in experiments of this kind actually show that information must be transferred instantaneously, in some (Lorentz) frame of reference?
>
> The usual arguments that connect these experiments to nonlocal action stem from the work of John Bell . . . .

> Orthodox quantum theory can give a simple answer: the *assumption* about outcomes of unperformed measurements is wrong: it directly contradicts quantum philosophy! This allows one to retain Einstein's reasonable-sounding assumption that physical reality in one place cannot be influenced by what a faraway experimenter freely chooses to do at the same instant. But then Bell's argument does not entail, or suggest, the existence of faster-than-light influences.
>
> Bell, and others who followed his "hidden-variable" approach, later used assumptions that appear weaker than this original one. However, these later assumptions are essentially the same as the earlier one: they turn out to entail . . . the possibility of defining numbers that could specify, simultaneously, the values that all the relevant unperformed measurements would reveal if they were to be performed. But, as just mentioned, one of the basic precepts of quantum philosophy is that such numbers do not exist. . . .

Stapp reviews the Einstein-Bohr controversy and its basis, and then states:

> I shall pursue here a strategy similar to that of Einstein and his colleagues, and will be led to a conclusion similar to Bohr's, namely the failure of Einstein's assumption that physical reality cannot be influenced from afar.
>
> Values of unperformed measurements can be brought into the theoretical analysis by combining two ideas that are embraced by Copenhagen philosophy. The first of these is the freedom of experimenters to choose which measurements they will perform. . . .
>
> This assumption is important for Bohr's notion of complementarity: some information about all the possible choices is simultaneously present in the quantum state, and Bohr wanted to provide the possibility that any one of the mutually exclusive alternatives might be pertinent. Whichever choice the experimenter eventually makes, the associated set of predictions is assumed to hold.
>
> The second idea is the condition of no backward-in-time causation. According to quantum thinking, experimenters are to be considered free to choose which measurement they will perform. Moreover, if an outcome of a measurement appears to an observer at a time earlier than some time *T*, then this outcome can be considered to be fixed and settled at that time *T*, independently of which experiment will be *freely chosen* and performed by another experimenter at a time later than *T*: the later choice is allowed go either way without disturbing the outcome that has already appeared to

> observers at an earlier time.
>
> I shall make the weak assumption that this no-backward-in-time-influence condition holds for *at least one* coordinate system (x,y,z,t).
>
> These two conditions are, I believe, completely compatible with quantum thinking, and are a normal part of orthodox quantum thinking. They contradict no quantum precept or combination of quantum predictions. They, by themselves, lead to no contradiction. But they do introduce into the theoretical framework a very limited notion of a result of an unperformed measurement, namely the result of a measurement actually performed at an earlier time *T*, independently of which measurement will actually be performed *later* by some faraway experimenter. This early outcome exists, in the theory, for two alternative choices by the experimenter in the later region, even though only one of the two later options can be realized. This small opening provides the needed logical toe-hold.

Stapp then describes an experiment that sounds like the one just conducted in Switzerland:

> . . . two regions are situated far apart in space relative to their extensions in time, so that no point in either region can be reached from any point in the other without moving either faster than the speed of light or backward in time. . . .
>
> In each region an experimenter freely chooses between two possible experiments. Each experiment will, if chosen, be performed within that region, and its outcome will appear to observers within that region. Thus neither choice can affect anything located in the other region without there being some influence that acts faster than the speed of light or backward in time.

Stapp frankly loses me in some of his details describing the experiment and the decisions made and the results expected. To me if we just ignore orthodox quantum dogma, the source determines the nature of the twin-particles and the observers can turn their devices any way they want and will see that at one device the outcome is the same as at the other, except for the opposite direction of spin along the same orientation in obedience to the need for conservation of momentum between the twin particles. But Stapp’s triumphant bottom line, with reference to an experiment with the detectors in two widely separated regions named R and L, is this:

> Any theoretical model that is compatible with the premises of the argument would have to maintain these theoretical constraints on nature's choices in region L, and hence enforce the nontrivial dependence of these constraints on the free choice made in region R. But this dependence cannot be upheld without the information about the free choice made in region R getting to region L: *some sort of faster-than-light transfer of information is required.*

Stapp then bridges back to the "objective interpretation of von Neumann's formulation of quantum theory that is being developed here" . . . and under the subheading "The Physical World as Information" continues to explain that:

> von Neumann quantum theory is designed to yield all the predictions of Copenhagen quantum theory. It must therefore encompass the increments of knowledge that Copenhagen quantum theory makes predictions about. Von Neumann's theory is, in fact, essentially a theory of the interaction of these subjective realities with an evolving objective physical universe.
>
> The evolution of the physical universe involves three related processes. The first is the deterministic evolution of the state of the physical universe. It is controlled by the Schroedinger equation of relativistic quantum field theory. This process is a local dynamical process, with all the causal connections arising solely from interactions between neighboring localized microscopic elements. However, this local process holds only during the intervals between quantum events.
>
> Each of these quantum events involves two other processes. The first is a choice of a Yes-No question by the mind-brain system. The second of these two processes is a choice by Nature of an answer, either Yes or No, to this question. This second choice is partially free: it is a random choice, subject to the statistical rules of quantum theory. The first choice is the analog in von Neumann theory of an essential process in Copenhagen quantum theory, namely the free choice made by the experimenter as to which aspect of nature is going to be probed. This choice of which aspect of nature is going to be probed, i.e., of which specific question is going to be put to nature, is an essential element of quantum theory: the quantum statistical rules cannot be applied until, and unless, some specific question is first selected.
>
> In Copenhagen quantum theory this choice is made by an experimenter, and this experimenter lies outside the system governed by the quantum rules. This feature of Copenhagen quantum theory is not altered in the transition to von Neumann quantum theory: choice *by a person* of which question will be put to nature is not controlled by any rules that are known

> or understood within contemporary physics. This choice on the part of the mind-brain system that constitutes the person, is, in this specific sense, a free choice: it is not governed by the physical laws, as they are currently understood. Only Yes-No questions are permitted: all other possibilities can be reduced to these. Thus each answer, Yes or No, injects one ``bit'' of information into the quantum universe. These bits of information are stored in the evolving objective quantum state of the universe, which is just a compendium of these bits of information. The quantum state of the universe is therefore an informational structure. But this stored compendium of bits of information has causal power: it specifies the propensities (objective tendencies) that are associated with the alternative possible answers to the next question put to Nature.
>
> Once the physical world is understood in this way, as a stored compendium of locally efficacious bits of information, the instantaneous transfers of information along the preferred surfaces "now" can be understood to be changes, not in personal human knowledge, but in a state of objective information. This state has causal efficacy: it specifies propensities for the various alternative possible outcomes of any possible probing question that any person might ask. Thus the structure of the state can be studied by measuring the observed relative frequencies of the outcomes of actually performed probings.

Thus, Stapp has rationalized the faster than light transfer of information from region L to R or vice versa into a change in the sky above them both: the universe is a vast information storage device that both human minds and subatomic particles are attuned to. This shows an interaction between the human mind making a choice, and the structure of the universe's information system that can influence a specific particle in a place separated by time and space from the twin particle for which a decision has been made. This leads to suggestions of an association, a causal one, between the human mind and the quantum structure of the universe. Hence, the rest of the paper is on the mind and a comparison of its mode of operation with quantum theory, and Stapp needs nonlocality and superluminality for the development of his theories of mind.

My take on all of this? I still don't believe the Bell-inequality experiments are being rightly interpreted. I side with Bell: the mathematician choosing to put on two different color socks is the explanation. If the twin photons obey the rules of their origination from a stationary source under the conservation of mass, momentum and energy principles of quantum mechanics, then the experiments come out exactly as they should and determine what the observer observes after choosing to observe a particular aspect. The idea that facts do not exist until they have been sought by a sentient being placing a detector in the path of a potential is an overstatement and limited to very special cases, I expect.

But we should not be as the orthodox and try to dissuade Stapp from his theorizing. From the cited papers I gather that his theories are finding application in the field of quantum computing. His reconciliation of the disparate ideas of Einstein and Bohr by assuming an information structure beneath both relativity and quantum mechanics is unorthodox, but appealing! In fact, it has the same flavor and appeal as does Bohm's wholeness in an implicit order concept! (Stapp, in fact, cites Bohm with approval.)

<u>*Is There A Cosmological Problem Quantum Mechanics Is Inadequate to Address?*</u>

Oh, did I say Stapp was the last step? Sorry, but there is one more author I read on this topic whom I want to very briefly cite. Not because he brings anything really new into the discussion of Bell-theorem work, but because he suggests quantum mechanics is inadequate to the needs of understanding quantum cosmology! To wit:

Steven Weinberg earned the 1979 Nobel Prize for Physics for work unifying two fundamental forces of nature. He has written two books, in one of which he touches delicately on the Bell theorem issue, but then goes off into a lament that sends us into wondering about the cosmos.

Weinberg[21] describes and laments a doldrum in theoretical physics because of the success of quantum theory. The next frontier lies in the nature of elementary particles, the study of which requires new instruments with much higher energies than currently available (his page 4) like the Super Conducting Super Collider (cancelled), or the European Large Hadron Collider.

In a chapter entitled Quantum Mechanics and Its Discontents, the two sides of the EPR experiment are discussed using two fictitious characters who argue the realist as well as the positivist sides of the interpretational debate over this thought-experiment using electrons. The positivist character declares that the measurement of the spin of the one electron in the experiment causes an instantaneous change in the wave function defining both electrons, calling into question the reality of wave functions (page 80). The realist character argues that there could be other explanations, and a working physicist is too busy to worry about the reasons for an observation that does not violate quantum mechanics, they are too busy using wave functions in practical applications.

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[21]Steven Weinberg, "Dreams of A Final Theory," Pantheon Books, New York, 1992.

As part of this discourse, he says to his positivist debater that (page 81):

> While you were at it, you might have mentioned John Bell has come up with even weirder consequences of quantum mechanics involving atomic spins, and experimental physicists have demonstrated that the spins in atomic systems really do behave in the way expected from quantum mechanics, but that is just the way the world is.

The author next goes into some detail on the enigmas introduced by the Copenhagen interpretation, with respect to the relationship of the observer to the outcome of the experiment. It is a complex problem, with some physicists subscribing to the many world theory as one out to the question of what we make of the fact that the universe of small particles is fundamentally describable only as a statistical thing, even though the suspicion is that if we only knew more we would see that it is actually deterministic.

Weinberg continues this mildly heretical discourse by suggesting that efforts to define the deterministic nature of small particle interactions may prove fruitful in the future, but since the statistical approach of quantum mechanics is so successful, it makes no practical difference to the practical applications of physics.. On pages 84 and 85 is the conclusion to some of this dialogue:

> So irrelevant is the philosophy of quantum mechanics to its use, that one begins to suspect that all the deep questions about the meaning of measurement are really empty, forced on us by our language, a language that evolved in a world governed very nearly by classical physics. But I admit to some discomfort in working all my life in a theoretical framework that no one fully understands. And we really do need to understand quantum mechanics better in quantum cosmology, the application of quantum mechanics to the whole universe, where no outside observer is even imaginable. The universe is much too large now for quantum mechanics to make much difference, but according to the big-bang theory there was a time in the past when the particles were so close together that quantum effects must have been important. No one today knows even the rules for applying quantum mechanics in this context.

This brings us to quantum cosmology, elsewhere called particle cosmology. We will briefly visit this topic in the Epilogue below.

Epilogue: So, Is There Superluminal Information-Travel or Not?

I think the case has not been made in a convincing way. There seem to be alternative explanations, and relativity seems to be around to stay and it requires a maximum speed in the universe. There is little more I can say, after hammering on the topic for so many pages. But a natural question I had to ask was: "What has been done in physics over the decades since the Zukav book?" And the corollary to the question, of course, is: "And what have the last decades in physics shown us about the nature of reality?"

Somewhat to my surprise, it appears that great strides have been made in particle physics! The very endeavor not particularly favored for further exploration in the Zukav book, judging by his treatment of the search for the quark! This progress is a pleasant surprise, because I believe the existence of numerous subatomic particles, with finding them usually preceded by theoretical predictions of their existence and character, has moved us intellectually very far from the "there are no particles" wavelength (pun intended)!

Particle-Physics/Particle Cosmology: The Physics of the Future?

So, would I change my mind if the photon pairs were detected as predicted, galaxies apart, as Zukav promised on page 47, instead of just a few Swiss villages apart? Nope. I'd say the results will be the same: Of course! *It's the source!*

A very recent article in Nature[22] giving results of the international Boomerang project looking at the photons from the Big Bang in space, makes it obvious that photon wave functions go on forever if matter does not collapse them and absorb their little massless particles! Forever? Yes. After the Big Bang, photon wave functions were sent out in massive quantity in all directions, and even these many billions of years later we still detect them, moving away so fast that their red-shift makes them seem like microwave signals to us now!

In fact, according to my reading of the very latest in this fascinating field of enquiry, it is the perturbations in that microwave background at the edge of our universe that yield cosmologists an estimate of the quantity of dark mass (first postulated by Einstein in 1917) in space! Results are also showing the universe (space-time) is flat, not curved, suggesting the expansion of the universe will continue forever. I suggest reading the article for yourself (and browsing the website in footnote 22), since this type of evidence for the future of the universe is totally new to me and definitely out of my league. But the germane point for me was in terms of using this experiment's information for setting a context on the distance factor in twinned-photon experiments: what are a few villages, or galaxies, compared to 15 billion years of moving away at the speed of light?

The Boomerang project is one of several attempts to measure cosmic microwave background radiation, and the aim of these studies, according to the Lawrence Berkeley National Laboratory's Paul Preuss[23] is to determine fundamental cosmic parameters related to

> . . . the state of the universe some 300,000 years after the Big Bang, when the universe cooled enough for protons and electrons to form hydrogen

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[22]P. de Bernardis and 35 co-authors, "A Flat Universe from High-Resolution Maps of the Cosmic Microwave Background Radiation," Nature, v404, p955, 2000, as accessed through http://oberon.roma1.infn.it/boomerang/

[23]Paul Preuss, "Strong Evidence for Flat Universe Reported by BOOMERANG Project, a five page description dated April 26, 2000, posted on http://www.lbl.gov/Science-Articles/Archive/boomerang-flat.html accessed on 8/28/2000.

> atoms. At that moment, photons were freed from what had been a hot primordial soup of subatomic particles. Ever since that time these energetic photons have been traveling through space, their wavelength now stretched to microwave scale and their frequency reduced to the equivalent of radiation from a black body at only 2.73 degrees Kelvin.

It is no coincidence that at the same time that cosmologists are studying the aftermath of this primordial soup, physicists are trying to recreate that same soup in accelerators using heavy ions like lead or gold colliding with both particles moving toward each other at near the speed of light. Quark-gluon plasma is the objective of these collisions, and it is the natural next step in the march of particle-physics.

A Final Word: String Theory and Progress in Particle Physics

String Theory

In a cite above, Bohm mentioned "string theories." In the National Academy of Sciences book cited in footnote 6, it says this about string theories (pages 50-51):

> . . . Einstein's theory of gravity is remarkably successful at low energies, yet it gives rise to deep problems and inconsistencies at high energy. These problems suggest that it must be replaced by a more fundamental theory, reinforcing the view that new physics will appear close to the Planck length that might unify all the forces of nature, including gravity. Fortunately, there exists a theory that appears to have the potential of achieving these goals—string theory.

String theory is explained:

> What is string theory? String theory says that if we could look at a quark with a microscope that can resolve distances of 10^{-33} cm, we would not see smaller subobjects, but rather a quark would look to us like a little closed string.
>
> String theory is a natural generalization of previous theories of particles but represents a radical departure from the tradition initiated by Thales of Miletus. In uncovering string theory about 25 years ago, physicists set out on a path whose end we can still barely conceive, one that has led to a trail of theoretical surprises—including supersymmetry—without obvious historical parallel.
>
> String theory not only eliminates the contradiction between gravity and quantum mechanics but in a sense explains why just this combination exists in nature. String theory also automatically generates all of the ingredients that seem to be needed as building blocks of the Standard Model. In these and other ways, string theory provides potential answers to many of the puzzles posed by the Standard Model.
>
> Two major revolutions in physics have already occurred in this century: relativity and quantum mechanics. These were associated with two of the three really basic parameters of physics: the velocity of light and Planck's quantum of action. Both revolutions involved major conceptual changes in the framework of physical thought. In each case, the new theory was totally different from the old in its basic tools and concepts, but it reduced approximately to the old one when the appropriate parameter could be considered small.
>
> The last parameter of this sort is Newton's gravitational constant. A

third revolution appears to be likely, and string theory—which reduces to more familiar theories at large distances—may be the key. Perhaps this third revolution will lead to a final theory or perhaps only to a next theory that will lead to new questions.

The present state of theoretical physics is reminiscent of the days of confusion that preceded the birth of quantum theory in the mid-1920s, when it was clear that a new theory was coming but not at all clear what this theory was. In the present case, a whole host of theoretical insights clearly point toward a basic change in all of the concepts of space and time. One should not underestimate the likely scope of this change.

String theory is now in the midst of intense theoretical development. Although it appears to have the potential of reproducing the Standard Model and explaining its structure and parameters, the understanding is too primitive to be able to make complete predictions about details of the Standard Model; however, the main qualitative properties of the Standard Model have been derived from string theory in a strikingly elegant way. Moreover, string theory requires the existence of both quantum mechanics and gravity, whereas previous theories in physics make it impossible to have both together; other general predictions of string theory are gauge invariance, which has been seen to be the bread and butter of the Standard Model, and supersymmetry, which is one of the main targets in the worldwide enterprise of particle physics. Many deep problems remain to be solved before the theory can be compared directly with experiment. Nonetheless string theory is testable by experiment. It would be easy for new experimental discoveries that did not fit into a straightforward extrapolation of the Standard Model to provide evidence that string theory is the wrong theory to follow. Conversely, the discovery of supersymmetry would be an important validation for string theory. In addition, this discovery would provide invaluable clues as to the mechanism of supersymmetry breaking that could help in unraveling the predictions of string theory.

Thus, we have the beginnings of a new theory of fundamental physics— string theory—whose full elucidation could be as revolutionary as the discovery of quantum mechanics or relativity.

And just what is this “Standard Model” that the Academy authors referred to repeatedly? It is the great success story that is pushing particle physics into the soup. The quark-gluon soup of the primordial universe, that is:

The Standard Model: Progress in Particle Physics

It is fitting to let the National Academy of Sciences (see footnote 6 or the footnote below for the exact page being cited here[24]) have almost the last work in this review.

> Over the past 25 years, particle physics has undergone a period of spectacular development. This period began with a wealth of interesting phenomena and a patchwork quilt of theoretical ideas, each of which explained some part of the data. All of the available experimental data that have been collected are now well described by a theory called the Standard Model, which has been verified experimentally to great precision in an extraordinarily diverse set of measurements. It has proven to be frustratingly accurate. Every experimental result so far either has agreed with the Standard Model prediction or has turned out to be wrong! Some experiments made startling new discoveries, which helped to develop the model, and others made measurements of unprecedented precision in order to test it. . . .
>
> Since 1972, high-energy physics has advanced to the stage at which almost the entire Standard Model has been established. Three lepton generations, all six quarks, and the gauge bosons for strong, electromagnetic, and weak interactions have all been observed. All of the fundamental particles have been seen, except the Higgs boson or whatever takes its place.

The Executive Summary for the Academy's book is available for viewing and printing on another web location[25] and its opening statement ties particle physics and cosmology nicely together:

> How is it our universe came to be so rich and varied? Why are there stars, light, planets, and a hundred different atoms that can be combined into countless molecules? Elementary-particle physicists seek answers to these questions by studying subatomic particles and forces. Although these investigations require sophisticated instruments to reveal phenomena far smaller and more energetic than we are aware of in daily life, the deep connection between the two realms inspires researchers in elementary-

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[24]Elementary-Particle Physics: Revealing the Secrets of Energy and Matter (1998) The National Academy of Sciences, Washington, DC, accessed on 8/23/200 at http://books.nap.edu/books/0309060370/html/66.html

[25]Executive Summary begins on page 10 of the book referenced in previous footnote, and is also to be found in a more printer-friendly form at http://stills.nap.edu/html/particle/

particle physics and lends added significance to their investigations, In fact, the properties and interactions of the elementary particles have much to say about the properties of the world around us.

You need to read this book for yourself to get the details, but let me whet your appetite for more information by calling to your attention the very, very latest accomplishment in this area of investigation: the first runs at the Relativistic Heavy Ion Collider (RHIC)[26] smashing gold ions together with both accelerated to near relativistic speed.

The purpose? To recreate the very type of quark-gluon plasma from which project Boomerang's microwave background radiation originated! The second website mentioned in footnote 26 gives an excellent description of the two scientific aims of this work. In addition to understanding that primordial plasma from the outflow of newly created particles predicted by the Standard Model, the machinery will also address the nature of proton spin by studying the spin of quarks and gluons, and perhaps their movement inside the proton.

This is all very interesting (to me), of course, but in the context of this book review what it is really telling me is that physics is alive and well and soaring freely, free from the tether of the Copenhagen interpretation. Finally, all of this knowledge about particles and the forces that define their combinations makes it very plain, to me, that particles and their attributes exist. All the nonsense that the Copenhagen interpretation led to when it was used to put on blinders in interpreting some experiments with twinned particles is soon to be sen as a curious artifact of the last century, I predict, no matter how far the Swiss detectors become separated in the current set of quantum-cryptography experiments.

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[26]News Release, June 13, 2000, Relativistic Heavy Ion Collider (RHIC) Begins Smashing Atoms, Brookhaven National Laboratory, at http://www.pubaf.bnl.gov/pr/bnlpr060800.html which gives links to other sites and has an excellent science-explanatory website at http://www.rhic.bnl.gov/html2/rhicphysics.html