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[Commentary] The Zeroth Law of Science

Josh Mitteldorf

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Abstract

The practice of science is based on the premise that our universe obeys laws. Behavior of identical systems is presumed to be identical, independent of time and spatial variables, independent of the observer. This is not only a fundamental principle that we take for granted, it is also a scientific hypothesis, testable empirically. Evidence for validity of the Zeroth Law of Science is mixed.

The practice of science is founded in the premise that the universe is knowable because there are regularities in the behavior of objects and systems that we encounter (Dilworth 1997). In this weak form, there can be no doubt that the "Zeroth Law of Science" is true. But since the nineteenth century, an assumption has grown up through all the sciences which is a much stronger form of the Zeroth Law.

The strong form of the Zeroth Law may be understood as a reaction against vitalism, which was the predominant worldview in all cultures of the world before the nineteenth century. In the vitalistic worldview, the forces controlling the world are life forces. Natural events such as storms, tides, and earthquakes were attributed to personal gods asserting their will.

There was solid reason to reject vitalism in its extreme form – certainly tides and earthquakes can be described more parsimoniously via physics rather than the denizens of Olympus or Svarga. But the "rationalist" revolution of nineteenth century Europe went to the opposite extreme. The hypothesis was put forward that even the behavior of living things could be explained in terms of physics and chemistry. After the first, small organic molecules were synthesized in a laboratory (urea in 1828), the possibility was considered that all life processes might be explained in terms of chemistry and physics. It was, at the time, a radical leap to deny the necessity of special laws to explain life. In the mechanical model of the late nineteenth century,

> *Everything in nature can be understood in terms of interaction among elementary particles (atoms) of different types. All atoms of a given type obey the same fixed laws, and the laws are the same everywhere and for all time.*

Within a few decades, this went from a bold land grab* by the scientists, to a litmus test for whether you really believe in science, to an assumption that everyone made, a kind of *synthetic a priori* that "must" be true for science to "work".

I call it the *Zeroth Law of Science*, but once it is stated explicitly, it becomes obvious that it is a statement about the way the world works, testable, as a good scientific hypothesis should be. We can ask, "Is it true?", and we can design experiments to try to falsify it. ("Falsification" is fundamental to the epistemology of experimental science; you can never prove a hypothesis, but you can try earnestly to prove it wrong, and if you fail repeatedly, the hypothesis starts to look good enough to call it a "theory".)

The Zeroth Law only lasted a few decades in this form before it was blatantly and shockingly falsified by quantum mechanics. The quantum world does not obey fixed laws, but behaves unpredictably. Place a piece of uranium next to a Geiger counter, and the timing of the clicks (that tell us that somewhere inside it an atom of uranium has turned to lead) appears not fixed, but completely random.

So the Zeroth Law was amended by the quantum gurus, Planck, Bohr, Schrödinger, Heisenberg, and Dirac:

> *The laws of physics at the most fundamental level are half completely fixed and determined, and half pure randomness. The fixed part is the same everywhere and for all time. The random part passes every mathematical test for randomness, and is in principle unpredictable, unrelated to anything, anywhere in the universe, at any time.*

Einstein protested that the universe could not be this ornery. "God doesn't play dice." Einstein wanted to restore the original Zeroth Law from the 19th Century. The common wisdom in science was that Einstein was wrong, and that remains the standard paradigm to this day.

Whether a successor theory to quantum mechanics will someday eliminate randomness from the laws of nature is unknown, but today no one doubts that the practice of science is compatible with an element of randomness. In the words of Richard Feynman,

> *"Philosophers have said that if the same circumstances don't always produce the same results, predictions are impossible and science will collapse. Here is a circumstance that produces different results: identical photons are coming down in the same direction to the same piece of glass. We cannot predict whether a given photon will arrive at A or B. All we can predict is that out of 100 photons that come down, an average of 4 will be reflected by the front surface. Does this mean that physics, a science of great exactitude, has been reduced to calculating only the probability of an event, and not predicting exactly what will happen? Yes. That's a retreat, but that's the way it is: Nature permits us to calculate only probabilities. Yet science has not collapsed." (Feynman 2006)*

Worse than the appearance of randomness in quantum mechanics was an intertwined role of the observer. This led James Jeans to famously remark, "The universe begins to look more like a great thought than a great machine." And it was the role of the observer that inspired John Wheeler (Wheeler 1994) to write about a reality that is co-created by participatory observers.

In conventional views of quantum mechanics, observers "collapse the wave function." Whether the participation of observers puts life, consciousness, and the force of will back into the laws of nature at a fundamental level depends upon interpretation. In alternative interpretations, the wave function of a small system is collapsed by “decoherence”, the inevitable result of interaction with a larger system whose detailed properties are not known. The Many Worlds Interpretation may be the most extreme expedient used to deny a role of the observer in fundamental physics.

My goal in this essay is to challenge the Zeroth Law, but not on abstract philosophical grounds, rather as a testable hypothesis that might be falsified empirically.

The Law as articulated above has two parts, and we might test each of them separately. The first part is that statistical predictions of quantum mechanics are the same everywhere and for all time. We might test this with macroscopic systems where the quantum randomness is predicted to average itself out of the picture. We would arrange to repeat a simple experiment and see if we can fully account for the quantitative differences in results from one experiment to the next. The second part states that probabilities derived from the quantum wave function contain all the information that can be known about a system. To test this, we might do the opposite — measure microscopic events at the level of the single quantum, trying to create patterns in experimental results that are predicted to be purely random.

Part I — Are the fixed laws really fixed?

In biology, this is very far from being true. I worked in a worm laboratory a few years ago, participating in statistical analysis of thousands of protein abundances. The first question I asked was about repeatability. The experiment was done twice as a ‘biological replicate’. One week later, same lab, same person doing the experiment, same equipment, averaging over hundreds of worms, all of which are genetically identical. But the results were far from identical. The correlation between Week 1 and Week 2 was only R=0.4. The results were more different than they were the same. People who were more experienced than me told me this is the way it is with data from a biology lab. It is routine procedure to perform the experiment several times, then average the results, though they are very different.

This is commonly explained by the fact that no two living things are the same, so it’s not really the same experimental condition — not at the level of atoms and molecules. Biology is a derived science. A better test would be to repeat a physics experiment. On the surface, everyone who does experiments in any science knows that the equipment is touchy, and it commonly takes several tries to “get it right”. It is routine to throw away many experimental trials for each one that we keep. This is explained as human error, and undoubtedly a great deal of it *is* human error, in too many diverse forms to catalogue. But were there some real issue with repeatability, it would be camouflaged by the human error all around, and we might never know.

Measurement of fundamental constants is an area where physicists are motivated to repeat experiments in labs around the world and attempt to identify all sources of experimental error and quantify them. I believe it is routine for more discrepancies to appear than can be accounted for with the catalogued uncertainties. Replicability in science is the subject of a robust literature (Ioannidis 2005, Bell, Hankison et al. 2009, Schmidt 2009, Nichols, Oli et al. 2021) and some authors include the physical sciences (Sciences, Policy et al. 2019). "More than 70% of researchers have tried and failed to reproduce another scientist's experiments, and more than half have failed to reproduce their own experiments." (Baker 2016) However, no article that I have been able to find seriously considers the possibility that irreproducibility may be a fact of nature, rather than a human foible or an artifact of our experimental protocols.

In physics, there is no shortage of examples where good science produces predictable results. Below is an example where things work pretty well. The bars in Fig. 1 represent 7 independent measures of a fundamental constant of nature called the Fine Structure Constant, α ~ 1/137. The error bars are supposed to be such that ⅔ of the time the right answer is within the error bars, and 95% of the time the right answer is within a span of two error bars. The graphs don't defy this prediction. The error bars overlap, even as they get narrower. No measurement is even two standard deviations away from any other.

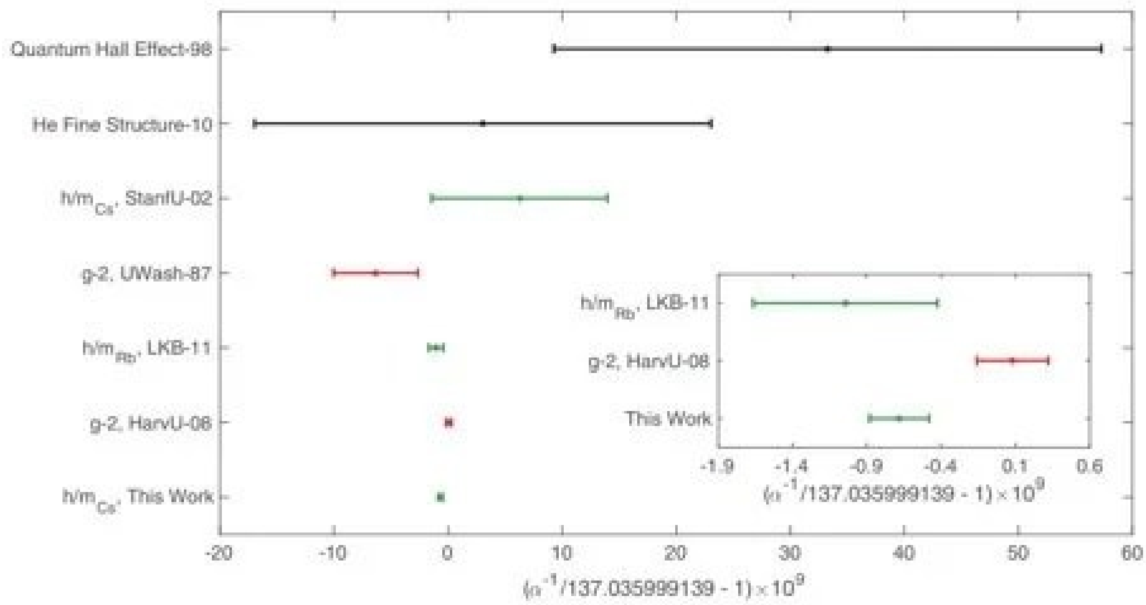

Figure 1. *Measurements of the fine structure constant (Source: Parker, Yu et al. 2018)*

Figure 2, in contrast, are measures of the gravitational constant.

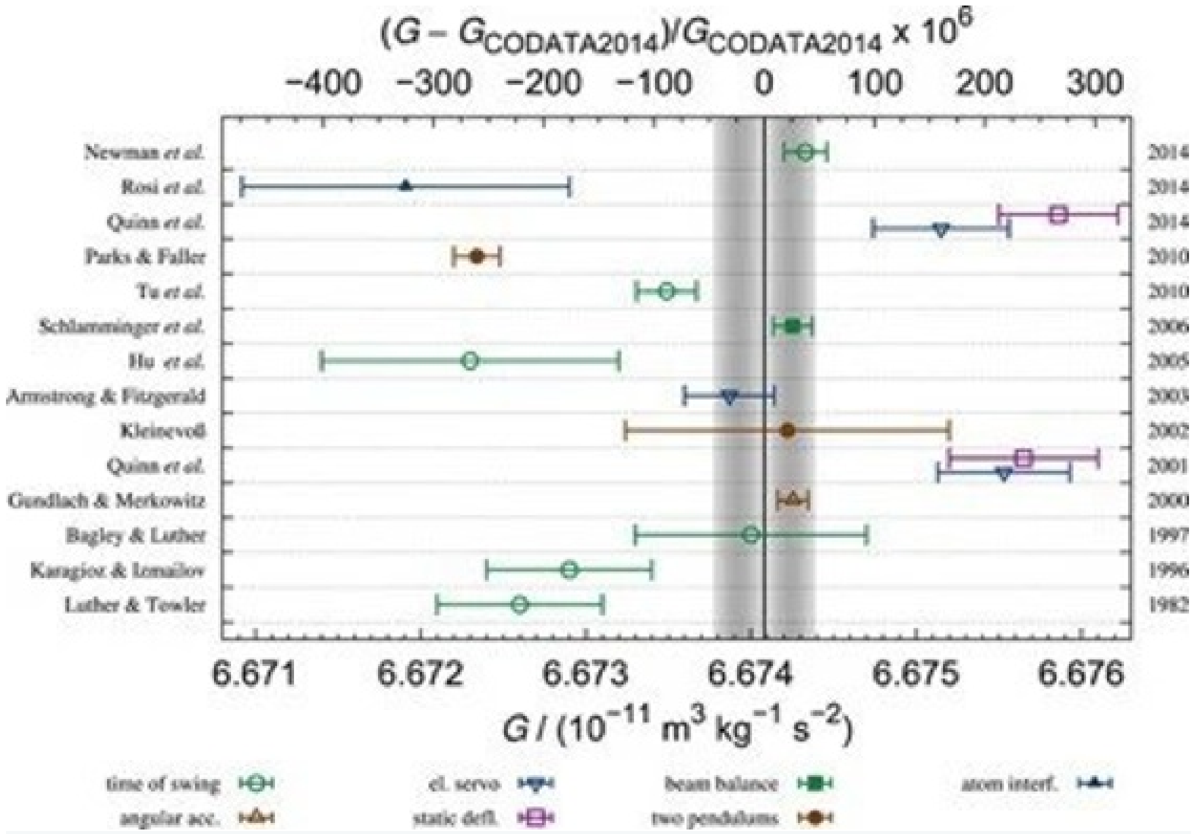

Figure 2. *(Source: Rothleitner and Schlamminger 2017)*

In the second diagram, the discrepancies are clearly *not* within expected limits. Some of the error bars don't overlap with others. There are 14 measurements, and we would expect 10 of them to include the accepted value within their error bars, but only 2 actually do. We would expect 13 of 14 to include the accepted value within two error bar lengths, but only 8 of 14 do. Clearly, there are sources of error here that are unaccounted for, but in the culture of today's science, no one would adduce this as evidence against the Zeroth Law. The conventional view is that experimenters are just too optimistic about their error bars. But this situation offers an opportunity to do further experimental trials, accounting more rigorously for possible errors. The Pioneer anomaly (Longo 2023, Lugo and Alarcón 2023, Stávek 2023) provides further motivation to apply the Zeroth Law to gravitation.

Outside academic science, a great number of anecdotes are reported which suggest exceptions to physical laws. These are routinely dismissed by mainstream scientists, who consider them so improbable as to be unworthy of the investment in time that would be needed to validate them. It is unclear whether the corpus of results from parapsychological research are better explained with new physical laws, or as powers of the mind to create exceptions to physical law.

Part II — Is Quantum Randomness really random?

Here, there are real experiments that have been done to attempt to answer the question directly, and there is solid evidence that the answer is, "no". From the 1970s through the 2000s, in the Princeton laboratory of Robert Jahn, experiments were performed with ordinary people trying to change the output of a quantum random event generator

(REG). The effect was very small, but overwhelmingly significant in the aggregate (Jahn, Dunne et al. 2007). Fig. 3 is a graph of Jahn's results:

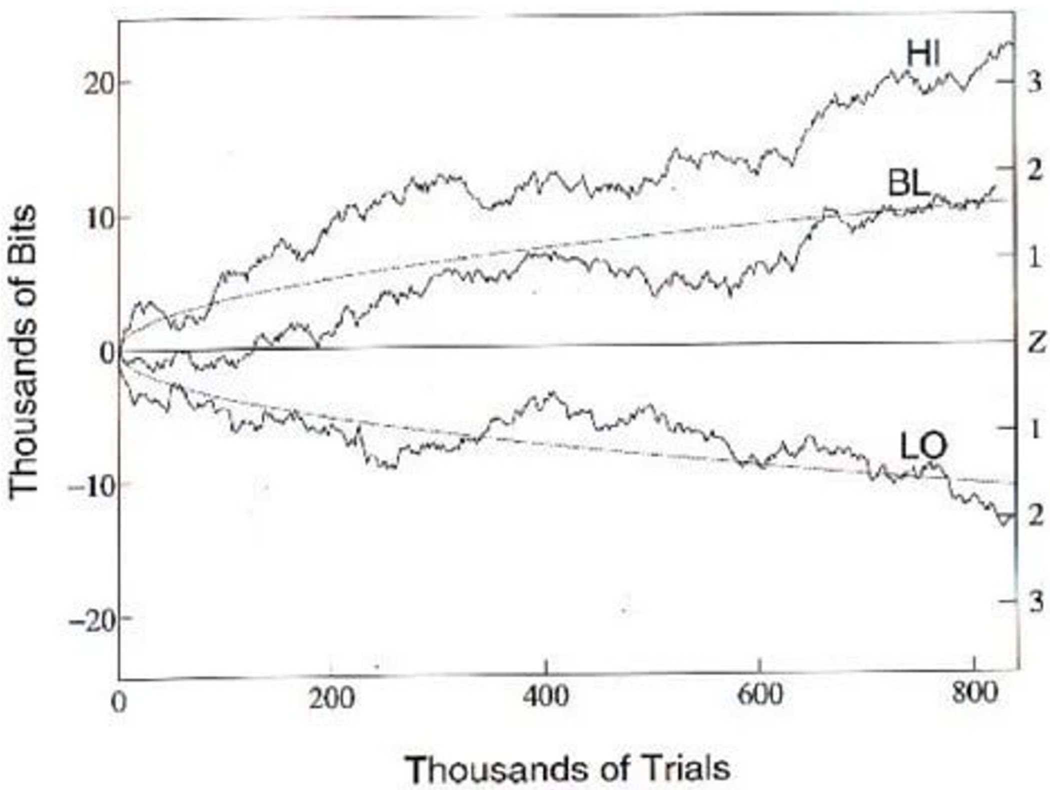

Figure 3. *Cumulative results from the experiment of Jahn and Dunne, effect of intention on a quantum random number generator.*

The top curve represents an average of random numbers when the human subject is "thinking high" and the bottom curve when the subject is "thinking low". The most pointed way to present this data is as the difference between the two, which should be close to zero in the long run, but clearly departs more and more from zero over time, reaching a difference of 5 standard deviations. The probability that this could occur by chance is less than one in a million.

Jahn was Dean of Engineering at Princeton and a prominent researcher in aerospace engineering until his credibility was attacked for daring to ask questions that are considered out-of-bounds by conventional science. The take-down of Robert Jahn represented a shameful triumph of Scientism over the true spirit and methodology of science.

Another of Jahn's experiments involved a big pinball machine mounted on the wall which dropped balls from the center, and let them bounce over an array of pegs, so they ended up usually in the center, but sometimes far to one side. The human subject would sit in front of the machine and "think right" or "think left" (Dunne, Nelson et al. 1989). Results are in Fig. 4.

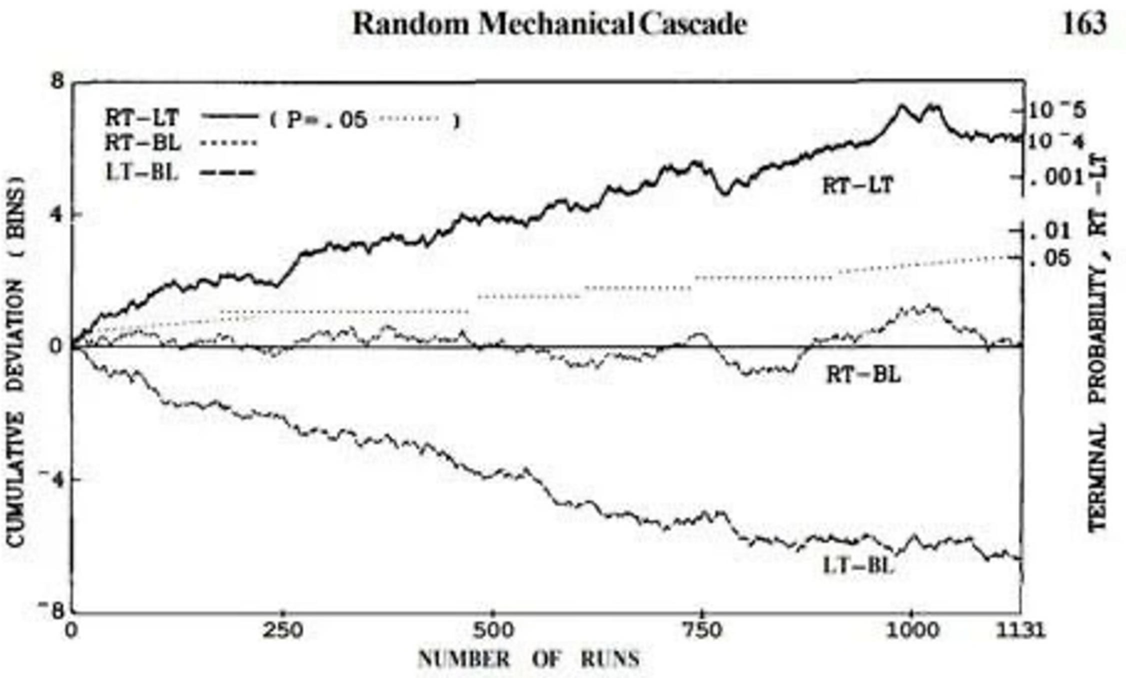

Figure 4. *Cumulative results from Jahn and Dunne, effect of conscious intent on distribution of balls falling througha Galton board.*

In this case, the system was macroscopic, but so arranged as to amplify the "butterfly effect". Very small differences in the first bounce can have macroscopic effects on the tenth bounce, and so it can be shown the system amplifies quantum randomness. The probability of the difference between the right and left curves occurring by chance is even smaller than the REG experiment, in the range of 1 in a billion.

Radin performed a different experiment based on the same idea of human intention influencing quantum events. Radin reports experimental results that are positive for people who have a meditation practice, but not significant for people who don't meditate (Radin, Michel et al. 2012). Since this account, more positive results have been collected.

More amusing than informative is the legend about Wolfgang Pauli, one of the geniuses who laid the foundation for quantum physics and in particular the relationship between theory of the atom and chemical properties of the elements and their atomic bonds. The legend is that whenever Pauli walked into the room, experimental apparatus would stop working for no identifiable reason. This came to be called the Pauli Effect (Pauli and Von Meyenn 2005).

Significance?

If the effect of human intention on quantum random events is so small that it has to be measured thousands of times to be sure we are seeing it, does it have any practical significance in our world? I would answer "yes" for three reasons.

First is a hypothesis that we have more influence when we care more. Human emotions and intention have a tiny effect on lab experiments, in which we have little stake for our lives and our destiny. But the positive results in principle leave open the possibility that we are profoundly (if unconsciously) influencing the events in our lives that mean most to us; and perhaps with meditation and focused intent we can consciously influence distant events. People who have thought more about this than I find evidence for a collective effect, in which many people meditating on the same intent can have dramatic effects.

Second, 90 years after quantum theory was first formulated, the physics community remains deeply divided over what it means. One school holds a place for consciousness in the fundamental workings of quantum physics. This is not currently the dominant interpretation, but it is the one advocated by Erwin Schrödinger himself, and it was attractive to several prominent physicists who followed him, especially de Broglie, Bohm and Wigner. The idea was expanded into three book-length treatments by Berkeley professor Henry Stapp. (Stapp and Stapp 2004, Stapp 2007, Stapp 2017) [Mindful Universe: Quantum Mechanics and the Participating Observer (2011), Mind, Matter and Quantum Mechanics (2013), Quantum Theory and Free Will (2017)] More accessible is my favorite book on the subject,Elemental Mind, by Nick Herbert (Herbert 1993).

Third, there is the link to quantum biology and the “hard problem” of metaphysics: What is the relationship between our conscious experience and activity of neurons in the brain? Quantum biology has firmly established a special role for quantum mechanics in some biological processes, including photosynthesis; beyond this, more radical proponents see quantum effects as essential to life. Johnjoe McFadden of Surrey University has put forth the hypothesis that consciousness is a driving force in evolution (McFadden 2002). Stuart Kauffman (Kauffman 2019), a pioneer in the mathematical physics of chaos theory, has collected evidence for quantum criticality in our brains. I’ll take a couple of paragraphs to summarize this idea.

Human-designed machines are engineered to perform reliably. If we run a computer program twice, we don't want it to output different answers. The system must behave reliably despite the fact that every transistor relies on quantum effects that are essentially stochastic. So electrical engineers make each transistor just large enough (many electrons involved with every switching event) such that quantum uncertainty *almost never* plays a role in the outcome. To make this quantitative: In today's microprocessors, each transistor is just a few hundred atoms across, so it contains perhaps a million atoms or less. The fact that numerical simulations run reliably means that the probability of a transistor being influenced by quantum randomness is much less than 1 in a trillion.

Contrast this with the way our brains work. Neurotransmitters are molecules that flip between two conformations, two very different shapes, dependent on their chemical and electrical environments. Kauffman has shown (Kauffman 2019) that most such molecules are “designed” (meaning “evolved”) to be *un* reliable, in the sense that they jump with maximal ease between the two conformations, and they exist in the brain in a “superposition state”. This is quantum jargon for saying that the atoms are in two places at once, their state is a mixture of the two conformations in a way that makes no sense to our intuitions that are attuned to macroscopic reality. The point is that electrical engineers determine to make each tiny component of a computer as reliable as possible, but nature seems to have gone out of her way to make our brains out of components that are as *un* reliable as possible. Kauffman interprets this to suggest that free will is a phenomenon that exists outside the realm of quantum wave functions (perhaps in a dualistic Cartesian or Platonic world), and that the brain is evolved to amplify the subtle quantum effects where our intent is capable of influence, and thus to allow our consciousness to shape our thoughts and (through neurons) control our muscular movements. This is also the premise of Stapp's books, mentioned above.

Technology

Machines work, by and large. We count on them as a matter of everyday experience. When we put a key in the ignition, we expect the car to start, and when we run a computer program twice, we don't expect to get different answers. But this is weak evidence for the Zeroth Law. Machines are engineered for a level of reliability that serves a specific market, and in critical applications, they have redundancies built in to assure fail-safe performance. The existence of so many high-tech devices that generally work is the source of an intuitive faith in the Zeroth Law, but if we ask more carefully about the meaning of their reliability, we can only conclude that the world is generally governed by physical laws that work with good precision and reliability *most of the time.*

Macroscopic miracles

“Miracles” by definition are exceptions to physical law, the quintessential counterexamples to the Zeroth Law of Science.

Miracles in the Bible and in stories of Sufis and Yogis and mystics of the East are abundant. It is difficult to verify any one of them, but the persistence of so many stories over so many centuries might be taken as more than wishful thinking by fallible humans. In his recent book Real Magic, Dean Radin {Radin, 2018| builds a case that some of these reports are credible. Joseph of Cupertino was a man who couldn’t stop himself from floating in the air (Grosso 2015). US intelligence services investigated human paranormal abilities for at least 17 years {Jacobsen, 2017}.

A concerted program to test the Zeroth Law

Science has, far and away, more explanatory power than any system of thought that mankind has ever devised. We can say this and still ask, Does science explain everything? Or does scientific law admit of exceptions? If we determine that there are exceptions, then we are moved to ask the next question, Can scientific methodology be expanded to encompass the exceptions? Or will the whole Scientific Project be subsumed in something larger and more broad-minded, in which experimental measurement and mathematical reasoning are two powerful ways of knowing about the world, but not the only ways. Closely linked to these is the question whether the fundamental laws of physics can be formulated in a way that integrates the free will of conscious participants as an element of the theory.

A scientific program to validate or to falsify (or to reformulate) the Zeroth Law is perfectly feasible. It would require modest resources, in the context of today's Big Science. It would be humbling and instructive, and would certainly invite a level of discussion that is overdue, and might prove extremely fertile.

In parapsychological and also psychology research, the experimenter effect is well-known (Rosenthal 1976). No matter how carefully he isolates himself and maintains objectivity, results depend on who is doing the experiment. In psychology and sociology and medicine, results vary glaringly enough that the experimenter effect is difficult to deny. But what about physics and chemistry experiments (Sheldrake 1998)? Does the person asking the question inevitably affect the answer? If the experimenter effect is universal, as I suspect, it alters the way we judge scientific truth, and it affects the claim of Science to be the pre-eminent tool for acquiring knowledge.

The Zeroth Law of Science is fundamental to our world view, not just as scientists but as people. It affects our concept of life and our place in the universe and what (if anything) we might expect after death. It impacts our tolerance for non-scientific views of the world, and it touches on questions about the limits of what we know now, and what we *can* know in the future. In this time when the world is so terrifyingly poised on the brink of eco-suicide or thermonuclear disaster or political or social chaos, we may feel that we need a miracle to carry us past the crisis to a saner world. In the words of Charles Eisenstein (Eisenstein 2013),

> *“A miracle is something that is impossible from one’s current understanding of reality and truth, but that becomes possible from a new understanding.”*

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* What I mean by a “land grab” is that Science was once one way of knowing the truth, but with this assertion, Science was saying it is the ***only*** way of knowing the truth, fundamentally more reliable than intuition or religion or judgments about others’ credibility, or received dicta from other authorities.

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